Merepoint Boat Launch Facility Eelgrass Mitigation Measures: 2012 Monitoring Report

Prepared for

Department of Inland Fisheries and Wildlife
284 State Street
Augusta, ME 04333-0041

207-287-8000

by

MER Assessment Corporation
14 Industrial Parkway
Brunswick, Maine 04011
207-798-7935 (V)
207-729-4706 (F)
207-751-3696 (C)

16 November 2012

Acknowledgement

Aerial photography and assistance with geo-referencing of the aerial photographs was provided by John Sowles, Yarmouth, Maine and Jennifer Austin, GISP of Kleinschmidt, Pittsfield, Maine.

Contents

List of Figures

List of Tables

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 April 13, 2007 to construct and install a boat launch 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 launch 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. This report summarizes the results of: 1) continuing monitoring of the eelgrass scars at 3 removed moorings and at 3 helical replacement moorings; 2) recovery of eelgrass habitat at Simpsons Point landing following closure of the launch ramp to motorized vessels; and 3) underwater diver video monitoring at the Merepoint Boat Launch Facility.

MER Assessment Corporation (MER) conducted detailed *in situ* measurements and video documentation of the 6 mooring scars on August 8 and 9, 2012. Although delineation of some of the scars was straightforward, efforts to accurately delineate certain mooring scars were again, as in prior years, made difficult due to several factors, including eelgrass patchiness, proximity of adjacent boats on moorings, apparent loss of eelgrass between adjacent moorings, and thinning of eelgrass resulting in poor definition of habitat boundaries. This resulted in some scars showing expansion despite the moorings having been removed and no boat being present. Mooring scar MER 16 shows significant expansion due to the apparent loss of eelgrass between adjacent scars; this is clearly an anomaly since the mooring at MER 16 was removed in 2008. If the MER 16 scar is assumed to have no recovery or is eliminated for purposes of calculation, the percent reduction in scar is 4% of the original scar area (6,250 ft^2) and 5% of the desired recovery area of 5,400 ft^2. These results continue to indicate that recovery is slow.

Aerial photography of the Simpsons Point area was conducted on August 6, 2012. Video recording and delineation of the eelgrass meadow at Simpsons Point was conducted on August 15 and 20, 2012 using the same methods as used in 2008 and 2011. Specifically, a SCUBA diver video recorded transects set within the eelgrass meadow to document eelgrass condition and locate the upper eelgrass boundary based on GPS coordinates. As in previous years, these efforts were confounded by poor visibility caused by the naturally turbid conditions encountered in the upper bay area and the sparseness and increased patchiness of eelgrass within the area that made clear delineation very difficult. Delineation based on video recordings indicates that the upper boundary of the eelgrass habitat in the vicinity of the landing has receded between 12 and 17 meters since 2008.

The reduced shoot density and increase in barren area between eelgrass patches is not restricted to the boundary areas but was observed throughout the survey area. These observations corroborate the aerial photography of the area of August 6, 2012 which continues to show thinning of the eelgrass and expansion of barren areas within the meadow seen in 2011 compared to conditions seen in 2008.

The slow rate of recovery, and in some cases expansion, of the scars seen in 2011 and again in 2012 at the mooring sites selected in 2008 for mooring removal or replacement is clearly unrelated to physical disturbance. Similarly, the general thinning and decline of the eelgrass at Simpsons Point since 2008 is unrelated to boat activity in the area since the Simpsons Point landing has been blocked to motorized vessels since 2008. Although several factors, including elevated turbidity and temperature, may be contributing to the lack of recovery and general decline of eelgrass in the area, the increased incidence of the invasive orange-sheathed tunicate, *Botrylloides violaceus*, found attached to, and in some cases encrusting, eelgrass blades is likely an important cause.

In Maquoit Bay at MER 11, a helix replacement mooring, some incidence of the orange tunicate is evident, although the eelgrass is in generally healthy condition. However, at mooring scar MER 5, another helix replacement located in Merepoint Bay just north of the Merepoint Boat Launch Facility and just south of Paul's Marina, the infestation by *Botrylloides violaceus* is heavy and the condition of the eelgrass is generally poor in comparison to that observed in Maquoit Bay. All of the other monitored scars are also located in Merepoint Bay around Paul's Marina and show similar, and in some cases worse, eelgrass condition. Review of the video recordings taken at Simpsons Point shows that the tunicate is also present there throughout the meadow but appears to become less dense towards the middle of the meadow.

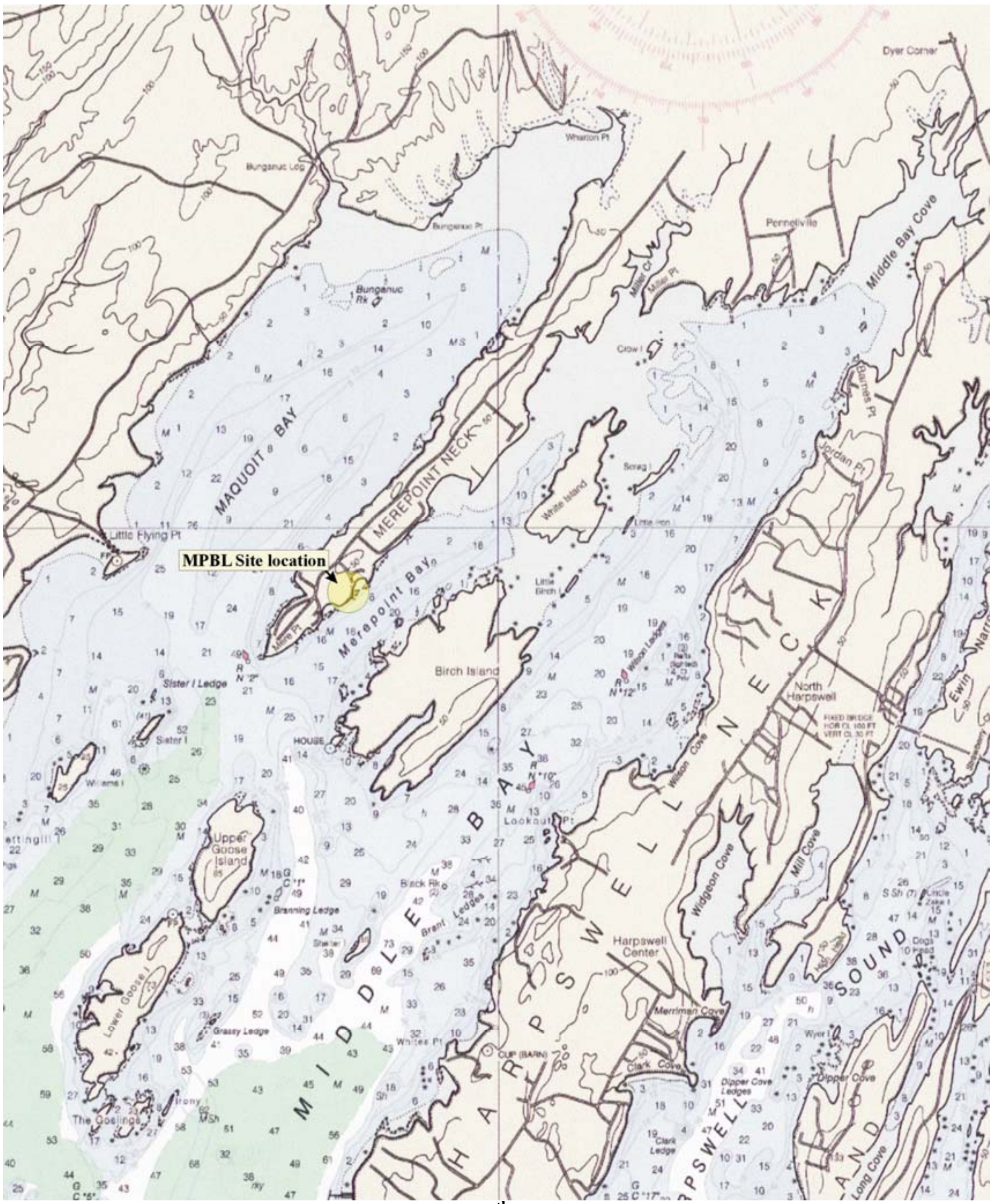
These results indicate that the eelgrass habitat recovery rate will take longer than the initially estimated 5 years to achieve 80% recovery. Although several causes may play a role in this, the apparent recent expansion of infestation by the invasive tunicate *Botrylloides violaceus* is the suspected likely cause. In view of this, the need for additional remedial measures by IF&W does not seem warranted.

As previously reported, much of the difficulty encountered with the 2012 survey, as in the 2011 survey, was related to the difficulty in determining the eelgrass boundary in patchy and sparse conditions. The development of a clear and measurable definition of an eelgrass boundary in such conditions is needed.

Introduction

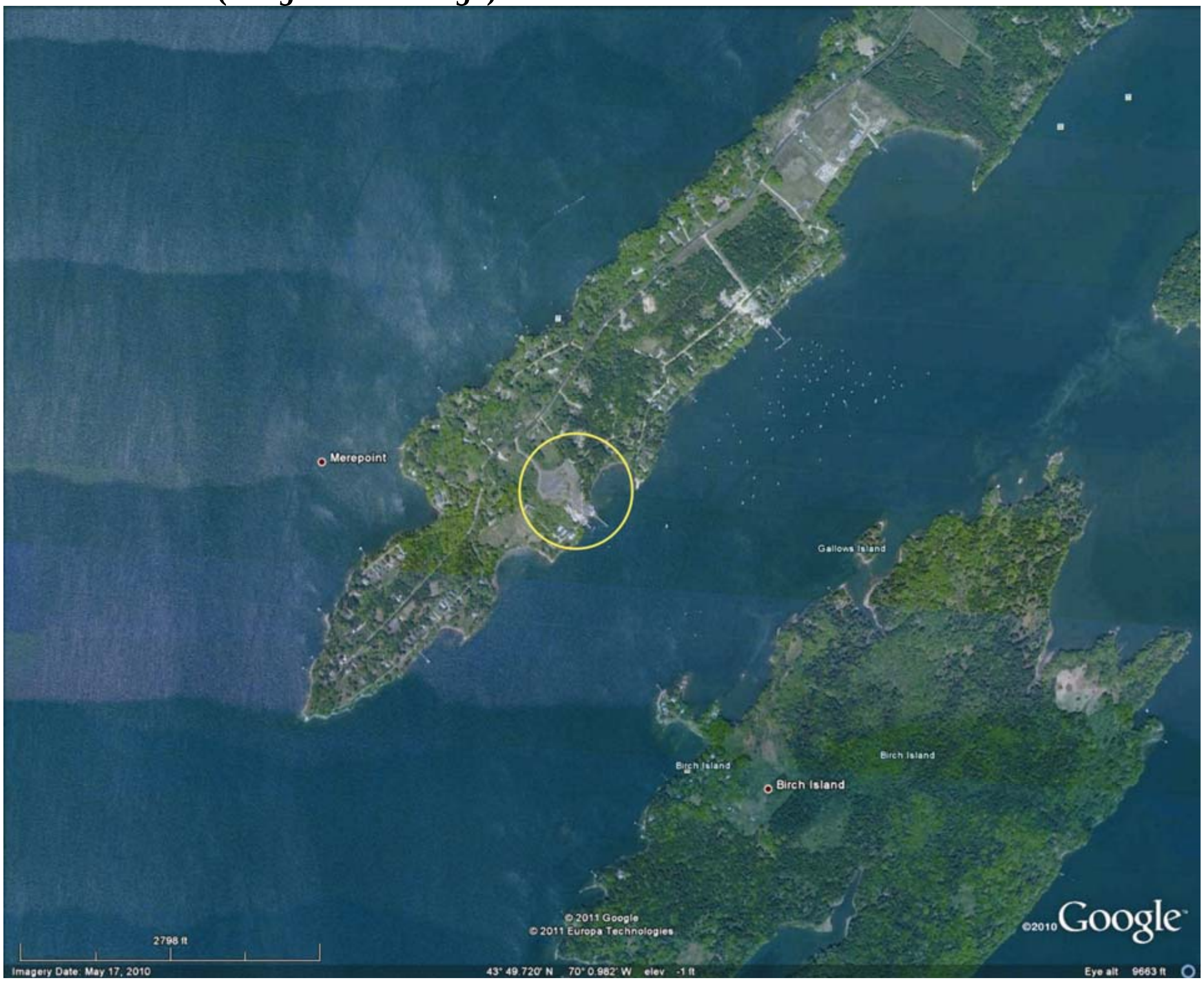
The Maine Department of Inland Fisheries and Wildlife (IF&W) was issued a permit approval for the development and installation of the Merepoint Boat Launch (MPBL) facility at Merepoint, Brunswick, Maine on April 13, 2007. The location of the MPBL is shown in Figures 1 and 2, below.

Figure 1. Location of Merepoint Boat Launch Facility, Merepoint, Brunswick, Maine



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

Figure 2. Completed Merepoint Boat Launch 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 launch 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 March 18, 2011.

This report summarizes the results of continuing fieldwork performed in August 2012, based on the methods developed in 2007 and 2008, and used in 2011 to verify: 1) recovery of eelgrass habitat in the vicinity of individual removed or helix-replaced moorings; 2) recovery of eelgrass habitat in the Simpsons Point boat ramp area following closure to motorized vessels in 2008; and 3) underwater diver video monitoring at the Merepoint Boat Launch Facility.

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

Mooring scar measurements were made on August 8-9, 2012 around the six (6) moorings selected in 2008 for removal and either relocation of the mooring or replacement of the traditional mushroom/block-chain mooring with an embedment helix mooring. The location of the six moorings is shown in Figure 3.

Figure 3. Location of the six (6) moorings selected in 2008 (*Google Earth image*)

Detailed *in situ* measurements of the "scar" area around each mooring were made by a SCUBA diver using the same method developed in 2008 and used again in 2011 (MER, 2011a; 2011b). 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 measuring tape to the permanent or temporary (MER-placed based on GPS coordinates) mooring, stretching the tape to the first evidence of eelgrass boundary, and reading the distance; where no mooring exists, a red-tipped section of 1¼ in. PVC pipe was driven into the bottom to mark the center. Each segment was 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 reported in 2011, measurement of certain scars was relatively straightforward where eelgrass boundaries encircling the scar are clearly defined; however, measurement of the scar area associated with other moorings was again rendered difficult to measure where eelgrass boundaries are poorly defined due to patchy and/or sporadic eelgrass, particularly in the cases of former mooring locations MER 15, MER 16 and MER17. These moorings are in shallow water and in close proximity to the service floats and access thoroughfare of Paul's Marina (Figure 4); these moorings are also in close proximity of adjacent moorings and boats (see Figure 5).

Figure 4. Thoroughfare between MER 15 and float

Figure 5. Proximity of boat to MER 16

As in all previous monitoring efforts, the area of eight triangles (each with side lengths A, B and C and semi-perimeter "s") was calculated using the equation:

$$\textbf{Area} = (s \cdot (s\text{-}A) \cdot (s\text{-}B) \cdot (s\text{-}C))^{-2}$$

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

The individual areas of all eight triangles defining a scar were summed to yield the full scar area.

A comparison of the 2008, 2011 and 2012 estimated area for each measured mooring scar based on distance from the center of the scar to a defined eelgrass boundary is shown in Table 1; the area calculations for the 2012 scars are included as Appendix I. The % Scar reduction represents change between the 2008 baseline calculated area and the area calculated for 2012; the 2011 calculated areas are presented for comparison of change over time. Calculations for the 2008 baseline and 2011 monitoring event scar areas are included as Appendix II; graphic comparisons of the 2008 and 2012 scar areas are included in Appendix III.

Table 1. Comparison of the 2008, 2011 and 2012 estimated area for each measured mooring scar based on distance from center to the defined eelgrass boundary

MER Mooring #	Owner	Coordinates		2008 Post-replacement Measured scar area (ft^2)	2011 Monitoring Measured scar area (ft^2)	2012 Monitoring Measured scar area (ft^2)	% Scar reduction
		Lat. (N)	Long. (W)				
MER 5	Jim Dodd	43.82996º	70.01324º	390	99	284	27%
MER 15	Doc Higgins	43.83242º	70.00957º	1193	1305	1259	-6%
MER 17	Morin	43.83255º	70.00935º	1633	1604	1437	12%
MER 16	David Bean	43.83225º	70.00981º	1202	1529	3602	-200%
MER 11	Sean White	43.82995º	70.02439º	1070	980	1162	-9%
MER 18	Bill Moore	43.83284º	70.00643º	762	541	650	15%
				6250	6069	8394	-34%

Although some patchy growth appears to be occurring within some of the scars, in most cases the scars show little to moderate reduction in area and in some cases enlargement of the area, particularly in the case of MER 16, yielding a net expansion of scar area of approximately 34%. It is important to note, however, that during measurement of the southeastern leg of scar MER 16, it was discovered that the scar from an adjacent, actively-used mooring (shown in Figure 6) seems to have merged with MER 16. The patchy, poorly-defined eelgrass boundaries in this area make it impossible to separate the scars of the active mooring from that of MER 16. Similar patchy, poorly-defined boundaries occurred along the eastern, southwestern and western legs (see Appendix III). Consequently, inclusion of the MER 16 scar confounds calculation of total scar area resulting in a net loss of eelgrass. To correct this, if the MER 16 scar is assumed to have no recovery or is eliminated for purposes of calculation, the percent reduction in scar is 4% of original area (6,250 ft^2) and 5% of the desired recovery area of 5,400 ft^2.

Mooring scar MER 5 had been measured at 99 ft^2 in 2011 suggesting substantial recovery of eelgrass within the scar, but it was noted that this might be attributable to location discrepancies between the GPS coordinates for the mooring used by MER in 2011 and the actual helix position. In 2012 the actual helix position was used since the helix was reportedly installed in the previous mooring location. Scar measurements for MER 5 in 2012 yield a similar configuration as those of the 2008 baseline, albeit shorter, and the calculated scar area shows a 27% reduction in scar area; it is interesting to note that mooring MER 5 is in very shallow water which might explain the level of recovery observed.

Scars were generally found to be devoid of eelgrass with the exception of occasional individual shoots and patches; the exposed bottom is generally covered by a layer of brown epilithic diatoms and some eelgrass detritus. Eelgrass at the scar boundary and elsewhere in the surrounding area was found to be encrusted to varying extents with the invasive tunicates, *Botrylloides violaceus*, including the violet and/or orange variant, and the pancake tunicate, *Didemnum vexillum*. The possible implications of the occurrence of these tunicates are discussed later.

Figure 6. Diver crossing through mooring scar adjacent to scar MER 16

Eelgrass habitat recovery in the vicinity of Simpsons Point landing area

Video recordings within the area west of the stone pier adjacent to the Simpsons Point boat landing were made on August 15 and 20, 2012 following the same method and transect start and end points used in 2008 and 2011. DVD copies of the videos accompany this report.

Diver survey and video recording

Transect lines used for the video recording in 2012 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 7.

Figure 7. Video survey transect lines

To adequately cover the eelgrass meadow in the vicinity of the Simpsons Point landing and remnant stone pier, one 100m (330 ft) transect line and one 60m (200 ft) transect line were clipped together using stainless steel snap clips to form 160m (530 ft) transect lines; these were anchored with a 20 lb. mushroom anchor at the start and a yellow-painted window weight at the end. Transects were set parallel to shore (perpendicular to the remnant stone pier) at various distances from the low water mark to cover the study area (T1, T2, T3 and T4); one transect was recorded along the western side of the stone pier (T5). Transects were also set perpendicular to the shore to capture the upper boundary of the eelgrass habitat (T6, T7 and T8). GPS coordinates for the start and end of all 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 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)	43.85057º	69.97344º	43.85007º	69.97523º	154	505	249
Transect 2 (T2)	43.85087º	69.97336º	43.85048º	69.97527º	159	522	254
Transect 3 (T3)	43.85116º	69.97339º	43.85073º	69.97528º	159	522	253
Transect 4 (T4)	43.85140º	69.97343º	43.85098º	69.97535º	161	528	253
Transect 5 (T5)	43.85127º	69.97346º	43.85073º	69.97337º	60	197	173
Transect 6 (T6)	43.85136º	69.97369º	43.85070º	69.97375º	74	243	183
Transect 7 (T7)	43.85147º	69.97386º	43.85097º	69.97400º	57	187	191
Transect 8 (T8)	43.85156º	69.97411º	43.85103º	69.97431º	60	197	195

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.

The video recordings were reviewed to establish points along the transects where the eelgrass habitat began and/or ended, as well as to detect any obvious changes in the eelgrass since the previous recordings of 2008 and 2011. At the upper, shoreside boundary of the eelgrass bed, where practical, geographic positions for the start and end of eelgrass were calculated based on the start and end points for the transects, the distance along the transect at which eelgrass either started or ended (based on swim direction and rate), and the course direction (True) of the dive. These data were used as input to POSAID (ver. 2.1) to calculate the latitude and longitude of the geographic points.

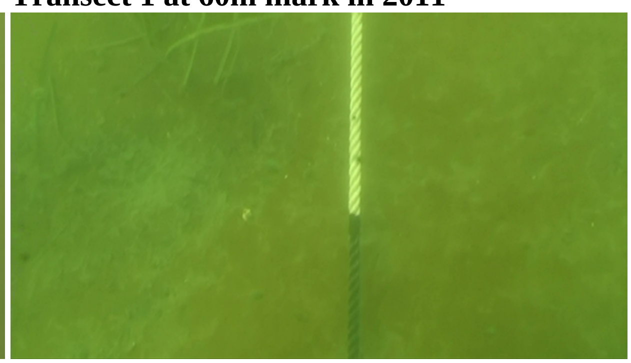
Water clarity during the 2012 video survey was generally poor, although better in the deeper areas, but very poor in the nearshore area. As previously reported, this is due to the very soft surface sediments in the vicinity of Simpsons Point that are subject to easy disturbance resulting in elevated turbidity that quickly reduces visibility to near zero at the start of the transect, particularly in the shallowest areas nearshore. Several swimmers were seen in the shallow, nearshore area on both survey dates and their activity may have contributed to the increased turbidity.

In 2011 we reported a substantial thinning of the eelgrass and increase in patchiness between 2008 and 2011. The 2012 video survey shows a continuation of the thinning and patchiness of the meadow within the area, particularly at the eastern end of Transects 1 through 4, adjacent to the stone pier, and at the western end. Eelgrass was generally lush and dense in 2008 with relatively few interruptions or gaps and blades were long, at times entangling the diver. In both 2011 and 2012 eelgrass density appeared substantially thinner with patches of eelgrass separated by large gaps, some gaps extending for several meters and often covered by a layer of brown epilithic diatom growth, eelgrass detritus and snails, likely *Nassarius obsoletus*. The increased level of thinning and patchiness observed in 2012 was most obvious at the periphery of the meadow and in the outer, deeper sections although these were seen throughout the entire meadow area covered by the survey; the densest areas of eelgrass were seen in the center and shallower areas of the meadow. These observations corroborate the aerial photo images that show similar changes (see Aerial Photography section).

Still capture images taken from the videos at the 60m mark (this distance chosen arbitrarily) from the video recordings of Transects 1, 2, 3, and 4 of 2012, 2011 and 2008 are shown side-by-side in the series below for comparative purposes.

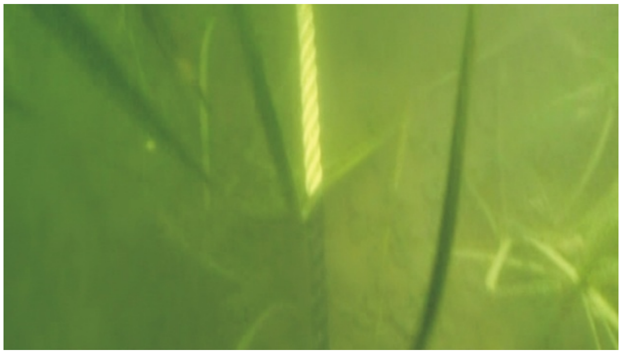
Transect 1 at 60m mark in 2012

Transect 1 at 60m mark in 2011

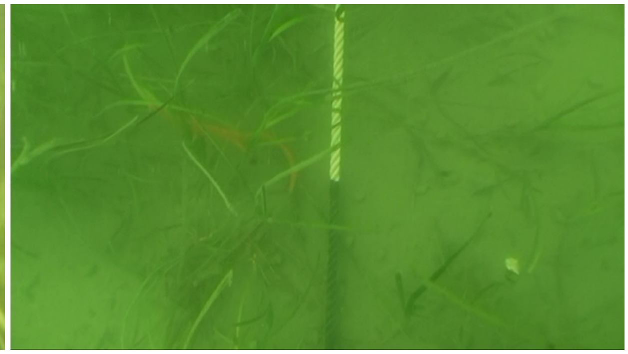


Transect 1 at 60m mark in 2008

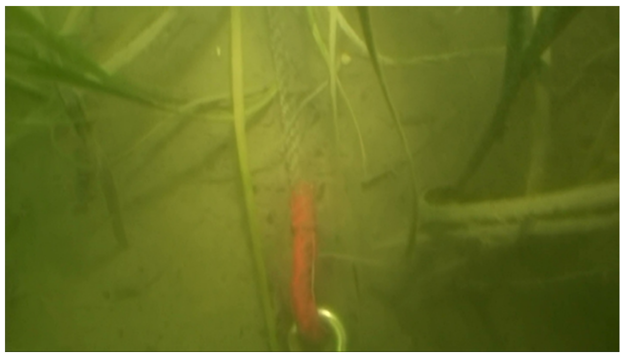
Transect 2 at 60m mark in 2012



Transect 2 at 60m mark in 2011

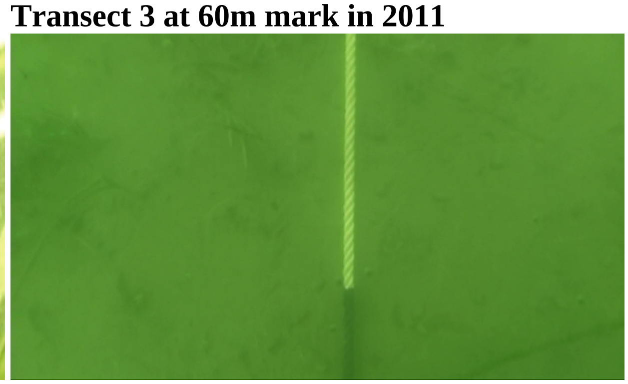


Transect 2 at 60m mark in 2008



Transect 3 at 60m mark in 2012

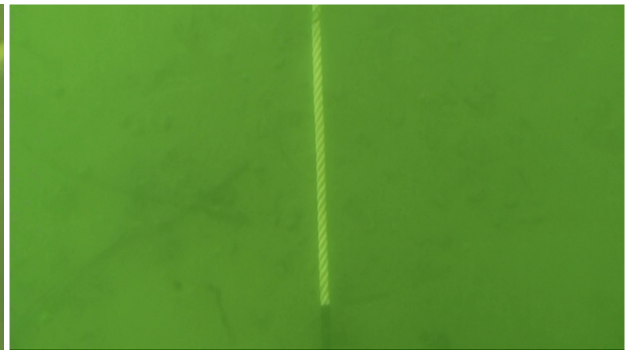
Transect 3 at 60m mark in 2011



Transect 3 at 60m mark in 2008

Transect 4 at 60m mark in 2012

Transect 4 at 60m mark in 2011

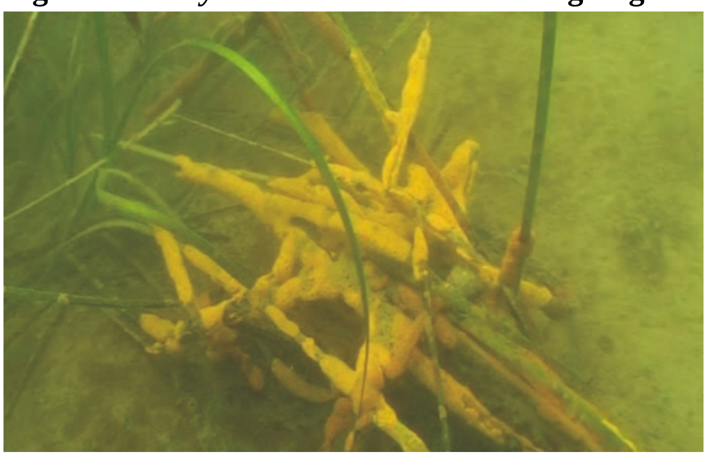


Transect 4 at 60m mark in 2008

During the video recording in 2008 and 2012 the camera was carried somewhat closer to the bottom than during the 2011 recordings. Nevertheless, the 2008 images consistently show eelgrass while in 2011 only Transect 2 shows any substantive eelgrass, and in 2012 only Transects 2 and 3 show any substantive eelgrass; the images from the other transects show only a few plants or none at all.

As observed elsewhere during the mooring scar survey, the incidence of the invasive tunicate, *Botrylloides violaceus*, shown in Figure 8 below, was substantially greater in 2012 at Simpsons Point than previously observed. The potential implications of this are discussed later.

Figure 8. *Botrylloides violaceus* encrusting eelgrass



As on all previous occasions the delineation of the upper boundary of the eelgrass in the shallows was complicated, first, by elevated turbidity that limited the field of view and second, by the sparse nature of the eelgrass. Video delineation of the upper boundary was based on first observation of significant eelgrass (not isolated shoots) on the video recordings of Transect 6, 7, and 8; these points are listed in Table 3 and are very similar to those recorded in 2011.

Table 3. GPS coordinates for the video delineation of the upper eelgrass boundary

Location	Lat. (N)	Long. (W)
T6	43.85117º	69.97371º
T7	43.85129º	69.97390º
T8	43.85139º	69.97417º

Using the same procedure as used in 2008 and 2011, GPS coordinates were also recorded for individual diver-set points to define the upper eelgrass meadow edge by having the diver mark the edge of the meadow at intervals using pins with attached small buoys; the interval distance between points was reduced in 2012 resulting in a substantially larger number of points. Coordinates were collected by placing the boat directly over the point and recording the latitude and longitude; these are listed in Table 4 and are shown in the geo-referenced aerial photo shown in Figure 10.

Table 4. GPS coordinates for the diver delineation of the eelgrass meadow edge

Lat. (N)	Long. (W)
43.851444º	69.974583º
43.851472º	69.974556º
43.851472º	69.974528º
43.851472º	69.974500º
43.851389º	69.974500º
43.851417º	69.974500º
43.851389º	69.974472º
43.851389º	69.974444º
43.851417º	69.974417º
43.851472º	69.974417º
43.851444º	69.974361º
43.851389º	69.974333º
43.851389º	69.974306º
43.851389º	69.974278º
43.851417º	69.974250º
43.851389º	69.974194º
43.851389º	69.974167º
43.851389º	69.974139º
43.851333º	69.974111º
43.851333º	69.974056º
43.851361º	69.974056º

Table 4. GPS coordinates for the diver delineation of the eelgrass meadow edge (Continued)

Lat. (N)	Long. (W)
43.851333°	69.973972°
43.851333°	69.973944°
43.851278°	69.973889°
43.851278°	69.973833°
43.851306°	69.973806°
43.851278°	69.973806°
43.851278°	69.973875°
43.851250°	69.973875°
43.851167°	69.973875°
43.851167°	69.973722°
43.851167°	69.973667°
43.851111°	69.973583°
43.851083°	69.973556°
43.851083°	69.973528°
43.851028°	69.973500°
43.850889°	69.973500°

****

Intentionally blank

Aerial photography

Aerial photos were taken of the Simpsons Point landing area between 0735 and 0805 on August 4, 2012 with low water of -0.8 feet at 0718, and on August 6, 2012 at 0818 with low tide of 0.0 feet at 0845. Conditions during flight were clear with little or no wind. A slight vibration caused a slight blurring of the August 4, 2012 photos and the August 6, 2012 photo was therefore selected for use.

The 2012 aerial photo and those previously taken in 2007 through 2011 are shown in the figures below for comparative purposes. Figure 9 shows an aerial photo taken August 6, 2012 of the broader Simpsons Point landing area. Figure 10 shows a geo-referenced detail of the photo taken August 6, 2012 of the Simpson Point landing area and includes the geo-referenced video transects and upper eelgrass boundary delineation. Figure 11 shows the August 31, 2011 aerial photo of the area and includes the geo-referenced video transects, upper eelgrass boundary based on the video review, and the boundary of the eelgrass meadow based on the diver delineation GPS points. Figure 12 shows the September 2008 aerial photo of the same area along with the geo-referenced video transects and diver-delineated upper boundary of the eelgrass for that year. Figure 13 shows the same area in 2007 prior to the closing of the boat landing to motorized vessels.

Comparison of these photos clearly shows a decline in the density of eelgrass within the area over the time period 2007 through 2012; these aerial observations are corroborated by the video recordings over the period 2008 through 2012. The most obvious change is in the apparent decrease in eelgrass density and the expansion of barren sediment areas between the eelgrass patches. Although barren areas existed within the meadow in 2008, these were generally small however, over the period these have increased in number as well as size.

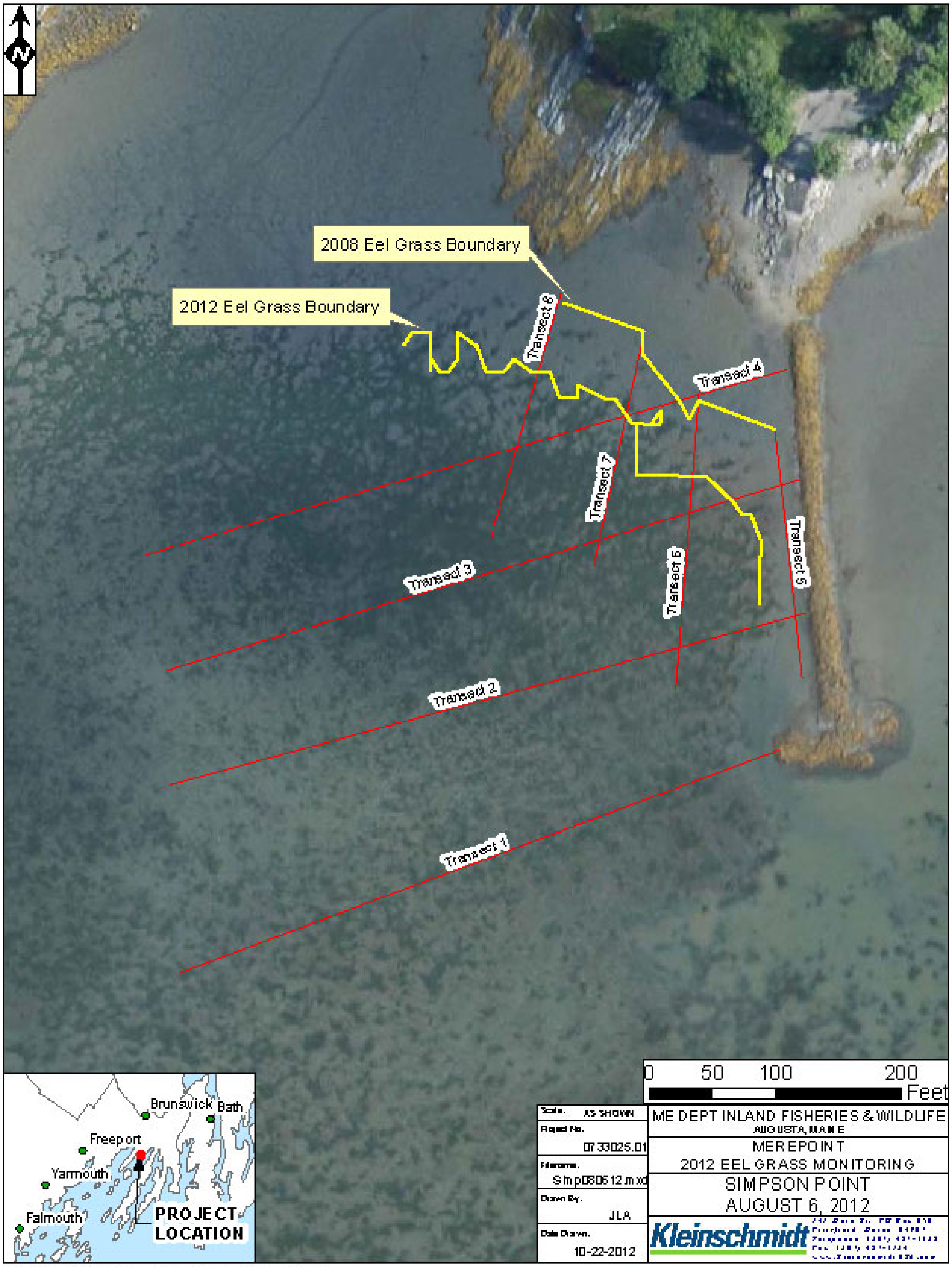
Figure 14 is a screenshot image of low tide photography taken by DeLorme in 2003 and available on the Maine office of GIS website at:
http://megiswebmaps.maine.gov/orthoviewer/default.aspx. The DeLorme photo appears color-enhanced to highlight the vegetation; however, the photo clearly shows the extent and density of the eelgrass coverage in that year, both to the east and west of the old stone pier, and serves to highlight the extent to which eelgrass in the area has declined over time.

****

Intentionally blank

Figure 9. August 6, 2012 aerial photo of Simpsons Point landing area

Figure 10. Geo-referenced aerial photo of Simpsons Point landing area of August 6, 2012 aerial photo showing dive transects and upper eelgrass boundary delineation of 2011 and 2008.



Aerial photography collected by John Sowles, 2012
Eel grass boundary location delinated by M E R Assessment, Inc. on August 20, 2012.

Figure 11. August 31, 2011 aerial photo of Simpsons Point landing area with video transects and eelgrass upper boundary delineations 2011 (light green) and 2008 (yellow) and 2011 diver-defined edge of meadow (purple)

Source: John Sowles/Google Earth

Figure 12. 2008 aerial photo of Simpsons Point landing area with video transects and eelgrass upper boundary delineation

Source: John Sowles/Google Earth

Figure 13. 2007 aerial photo of Simpsons Point landing area prior to boat landing closure

Source: John Sowles/Google Earth

Figure 14. DeLorme photo of Simpsons Point landing area in 2003

Source: Maine Office of GIS

Eelgrass monitoring at Merepoint Boat Launch Facility

Four video recordings were made on August 9, 2012 at the Merepoint Boat Launch Facility, two 60m transects having been recorded parallel to the float system on both the north and south sides beginning at the discernible end of the concrete ramps and extending approximately 30m to 35m beyond the end of the floats, using the same methods and equipment described above. GPS coordinates for the start and end of each transect are listed in Table 5, below.

Table 5. GPS coordinates for the video transects recorded at Merepoint Boat Launch Facility

	Start		End	
Location	Lat. (N)	Long. (W)	Lat. (N)	Long. (W)
V1	43.82798º	70.01639º	43.82765º	70.01577º
V2	43.82795º	70.01638º	43.82756º	70.01580º
V3	43.82793º	70.01646º	43.82756º	70.01589º
V4	43.82790º	70.01647º	43.82755º	70.01591º

Eelgrass detritus was found covering the bottom from the end of the ramps to several meters out along the transects. The bottom beyond the end of the detritus covered bottom was generally barren with epilithic diatom growth on the surface. Little or no eelgrass was recorded along each of the transects; observed eelgrass was in the form of individual plants with one to few shoots. Some individual upright blades on the video appear to be attached shoots, but are actually separated blades. Other organisms observed include sea stars, *Asterias* sp., green crabs, *Carcinus maenas*, rock crab, *Cancer irroratus*, hermit crabs, likely *Pagurus longicarpus*; and the invasive tunicate, *Botrylloides violaceus*, was seen encrusted on the eelgrass detritus.

Discussion

Patchy, ill-defined boundaries around the mooring scars rendered scar measurements difficult, particularly in the case of the scar at MER 16. Including scar MER 16 in the scar measurements, the 2012 survey indicates a net loss of 2,144 ft^2 of eelgrass habitat or 34% additional loss of habitat since 2008. However, the enlarged scar at MER 16 is clearly an anomaly and omitting it from the calculations, thus assuming no recovery of the scar, yields a net recovery of 256 ft^2 or 4% of the original scarred area. The 2012 results indicate that recovery is slow, as previously found by others working on scar recoveries in the area (Neckles *et al*., 2005). In both 2012 and 2011, although actual mooring occupancy is unclear, none of the moorings surveyed were occupied at the time of the survey and in three cases the moorings no longer exist. Therefore, where expansion of the scar areas occurs, it is unlikely attributable to mooring effects and it again appears that some other factor, or factors, are contributing to the continued thinning and loss of eelgrass around the scars and the broader area.

Eelgrass in the vicinity of the Simpsons Point landing has declined significantly since the 2008 baseline in extent, density, and overall health of the meadow. The Simpsons Point landing has been blocked to motorized boats since 2008 to avoid any negative impacts to eelgrass associated with the launching, hauling and operation of such boats. Given the cessation of motorized boat traffic, the general thinning of the eelgrass and increased barren areas between clusters within the meadow at Simpsons Point, as revealed by the underwater video and aerial photography in both 2011 and 2012, appear unrelated to boat activity and are likely also related to some other factor, or factors.

Changes in density and distribution within eelgrass beds are not uncommon; declines are related to both natural and anthropogenic causes. Common causes of declines in eelgrass habitat are physical disturbance that results in damage or uprooting of plants, including those related to storms, moorings and dredging and 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, and waste water treatment effluents; and natural factors including disease (wasting), grazing, and self-poisoning (Robertson, 1984; Frederiksen *et al*., 2004). Costello and Kenworthy (2009) have reported widespread declines of eelgrass habitat in Massachusetts. Orth *et al*. (2006) discuss the broader impacts to sea grasses related to global climate change, including rising sea surface temperature.

Several of these common causes of decline are unlikely to be causal effects in the minimal recovery of mooring scar area and the decline of the eelgrass meadow at Simpsons Point. In the case of the moorings, the moorings have either been completely removed or replaced with more "eelgrass-friendly" helical anchors, thus removing the physical disturbance to the bottom. As noted in the 2011 report, the shading effect of a boat occupying a mooring might cause sufficient shading to reduce eelgrass growth and density within the immediate area of the mooring. However, in the case of the moorings surveyed here, in three cases the moorings have been removed and in the other three cases the moorings have been found unoccupied at the time of the surveys. It therefore seems reasonable to assume that shading is not a new major contributor to decline, particularly where no mooring exists.

With regard to elevated nutrients, no waste water treatment facility exists in the area and, as pointed out in the 2011 report, the Town of Brunswick enacted ordinances in the early 1990s to control excessive transport of nutrients into its coastal waters. It therefore seems unlikely that local nutrient loading, leading to excessive epiphyte growth, is involved. However, although growth of epiphytes does not appear to be problematic, the recent increase in the level of infestation and encrustation of eelgrass by the invasive tunicate *Botrylloides violaceus* may prove to be an important factor driving the general decline of eelgrass within the area.

The occurrence and effects of invasive tunicate encrustation on eelgrass have been reported by Carman *et al*. (2009; 2010) working on Martha's Vineyard, Massachusetts and Block Island, Rhode Island and Wong, *et al.* (2012) working in Nova Scotia. *B. violaceus* was observed in both studies along with other invasive tunicate species, including the cream-colored pancake batter tunicate, *Didemnum vexillum* (Carman *et al*., 2010). Wong *et al* (2010) found that even minimal amounts of tunicate growth can substantially affect light attenuation by eelgrass blades; at high biomass of tunicate (>0.5 dry mg/cm^2) attenuation can reach 85-95% of incident light reaching the blade. This attenuation of light reaching the blades results in reduced photosynthesis and growth and in physical effects likely resulting in blades breaking away, eventually leading to reduced number of leaves per shoot, shoot length and shoot density within the bed. Additionally, the breaking away of blades carrying encrusted tunicates can serve as a transport mechanism to infest other areas. Indeed, during the mooring scar survey, rafts of floating eelgrass were observed with a high percentage of the blades carrying at least some level of tunicate (see Figure 15). Some of the blades are clearly encrusted. Careful examination of this photo reveals that most of the blades are carrying some level of tunicate colonies. Infestation of eelgrass by *B. violaceus* has also been reported elsewhere in Casco Bay including the mouth of the Royal River (Steve Walker, Department of Inland Fisheries and Wildlife/Brunswick resident, pers. comm.).

Figure 15. Rafting of broken eelgrass blades carrying *Botrylloides violaceus*

Elevated turbidity appears to be a normal condition in the Simpsons Point area based on observations in 2008, 2011 and 2012. The soft sediments are easily disturbed and even small wind-generated waves can stir up the sediment, particularly in the shallower areas. The decline in eelgrass density within the bed, however, may lead to yet greater turbidity in the area as the sediment-stabilizing effect of eelgrass declines. Additionally, although motorized boat traffic has been eliminated from the landing, non-motorized boating activity and swimming does occur. During the diver video surveys in 2011 and 2012, swimmers and kayakers were observed in the area and using the landing. These activities were generally restricted to the nearshore area and are unlikely contributing to the larger area eelgrass decline; however, this activity may be contributing to some recession of eelgrass at the upper, nearshore boundary, since footprints along the bottom within the upper boundary of the eelgrass were reported by the diver.

Water temperature may also play a role, either directly or indirectly, in eelgrass decline in the area. Warmer than normal sea surface temperatures were recorded by MER early in the spring of 2012 and Friends of Casco Bay have reported similar trends within the Bay (pers. comm.). Additionally, in 2012 the NOAA Northeast Fisheries Science Center reported the warmest sea surface temperatures ever recorded for the Northeast Continental Shelf (NOAA, 2012).

Since the cause of the slow recovery of the mooring scars and the general decline of the eelgrass meadow at Simpsons Point appear to be related, at least in part, to the tunicate infestation, the need for additional remedial measures by IF&W does not seem warranted. In our 2011 report we suggested that colonization of the scars might be accelerated by efforts to increase seed propagation within the scar area (Pickerell *et al.*, 2005) or transplanting eelgrass shoots into the scars (Short, 2002). However, in view of the continued lack of recovery within the mooring scar areas and the decline of eelgrass in the vicinity of Simpsons Point resulting from causes apparently beyond immediate control, such efforts would likely prove futile and therefore are probably not advisable until the causes of decline are more definitively identified and better understood.

Finally, as previously noted in our 2011 report, most of the difficulties encountered with the 2012 survey were again related to the difficulty in determining the eelgrass boundary where patchy and sparse eelgrass result in an ill-defined eelgrass boundary leading to increasingly subjective determinations of such boundaries. We therefore reiterate the importance of developing a clear and measurable definition of an eelgrass boundary in such conditions since such a definition is critical to properly quantifying area.

Conclusions and recommendations

The results of the mooring scar measurement work indicate that the eelgrass habitat recovery rate will take longer than the initially estimated 5 years to achieve 80% recovery. The rate of recovery is slow in nearly all cases, and although several causes may play a role in this, the apparent recent expansion of infestation by the invasive tunicate *Botrylloides violaceus* is likely suspect cause.

Thinning and general decline of the eelgrass within the immediate vicinity of the Simpsons Point landing appears to be continuing and the upper boundary of the eelgrass meadow remains receded from the 2008 boundary. Although increases and decreases in eelgrass density and distribution occur periodically as a result of natural and anthropogenic causes, the observed decline in eelgrass is clearly unrelated to motorized boat traffic since the landing has been blocked to motor vessel launching since September 2008. Similar to the lack of recovery of the mooring scars, the decline of eelgrass at Simpsons Point is probably the result of a combination of causes, but the infestation by the invasive tunicate *B. violaceus* is likely an important cause.

Although, as suggested in the 2011 report, measures are available that might enhance the rate of recovery, in view of the limited recovery observed within the mooring scar areas over the past four years and the apparent continuing decline of eelgrass in the vicinity of Simpsons Point, implementation of such efforts would likely prove futile and therefore not advisable.

Aerial photography proved very useful in providing a broader view of conditions surrounding Simpsons Point, offering a comparison of changes in those conditions between 2008, 2011 and 2012; its continued use to provide a broader context for changing conditions around the Simpsons Point landing should be considered.

Finally, as reported for the 2011 survey, most of the difficulties encountered with the 2012 survey were related to the difficulty in determining the eelgrass boundary where eelgrass is patchy and sparse, particularly when compounded by turbid conditions and reduced visibility. Therefore, the need remains for the development of a clear and measurable definition of an eelgrass boundary in such conditions, particularly where quantifying area.

References

Carman M.R. and D.W. Grunden, 2010. First occurrence of the invasive tunicate *Didemnum vexillum* in eelgrass habitat. Aquatic Invasions (2010) Volume 5, Issue 1: 23-29. *Proceedings of the 16th International Conference on Aquatic Invasive Species (19-23 April 2009, Montreal, Canada)*

Carman M.R. and K.E. Hoagland, E. Green-Beach and D.W. Grunden, 2009. Tunicate faunas of two North Atlantic-New England islands: Martha's Vineyard, Massachusetts and Block Island, Rhode Island. Aquatic Invasions (2009) Volume 4, Issue 1: 65-70. *Proceedings of the 2nd International Invasive Sea Squirt Conference (October 2-4, 2007, Prince Edward Island, Canada)*

Costello, C.T. and W.J. Kenworthy, 2011. Twelve-Year Mapping and Change Analysis of Eelgrass (Zostera marina) Areal Abundance in Massachusetts (USA) Identifies Statewide Declines. Estuaries and Coasts, Volume 34, Issue 2: 232-242.

MER, 2011a. Merepoint Boat Launch Facility Eelgrass Mitigation Measures: Detailed Methods and Results Report. Report prepared for the Maine Department of Inland Fisheries and Wildlife, March, 2011, 51pp.

MER, 2011b. Merepoint Boat Launch Facility Eelgrass Mitigation Measures: 2011 Monitoring Report. Report prepared for the Maine Department of Inland Fisheries and Wildlife, December, 2011, 27pp.

Neckles, H.A., F.T. Short, S. Barker, and B.S. Kopp, 2005. Disturbance of eelgrass *Zostera marina* by commercial mussel *Mytilus edulis* harvesting in Maine: dragging impacts and habitat recovery. Mar. Ecol. Prog. Ser. 285: 57-73.

NOAA, 2012. http://www.nefsc.noaa.gov/press_release/2012/SciSpot/SS1209/

Orth R.J., T.J. B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourquerean, K.L. Heck, JR., A. R. Hughes, G.A. Kendrick, W. J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott, and S.L. Williams, (2006). A Global Crisis for Seagrass Ecosystems, BioScience, Vol. 56 No. 12, 987-996.

Pickerell, C.H., S. Schott, Sandy Wyllie-Echeverria, 2005. Buoy deployed seeding: Demonstration of a new eelgrass (*Zostera marina* L.) planting method. Ecol. Eng. 25:

Robertson AI, Mann KH, 1984. Disturbance by ice and life-history adaptations of the seagrass *Zostera marina*. Mar Biol 80:131–141

Short, F.T., C.A. Short, and C.L. Burdick-Whitney, 2002. A Manual for Community-Based Eelgrass Restoration. Jackson Estuarine Laboratory, University of New Hampshire, Durham, New Hampshire, 56pp.

Wong, M.C. and B. Vercaemer, 2009. Effects of invasive colonial tunicates and a native sponge on the growth, survival, and light attenuation of eelgrass (*Zostera marina*). Aquatic Invasions (2012) Volume 7, Issue 3: 315–326

Appendix I

2012 detailed calculations of the 2008 selected mooring scars area based on the eight *in situ* radii measurement method

2012 Scar area calculation based on two known side lengths and 45° angle at center

MER 11	Sean White MQ156				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	5.0	22.5	19.3	23.4	39.8
2	22.5	18.5	16.1	28.6	147.2
3	18.5	18.0	14.0	25.2	117.7
4	18.0	35.0	25.7	39.3	222.7
5	35.0	32.0	25.8	46.4	395.9
6	32.0	14.0	24.2	35.1	158.4
7	14.0	12.0	10.1	18.1	59.4
8	12.0	5.0	9.2	13.1	21.2
Mean r	19.6				**1162**
Mean r area	**1210**				

MER 18	Bill Moore MP001				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	11.0	14.5	10.3	17.9	56.4
2	14.5	12.0	10.4	18.4	61.5
3	12.0	12.5	9.4	16.9	53.0
4	12.5	20.5	14.6	23.8	90.6
5	20.5	22.5	16.6	29.8	163.1
6	22.5	18.0	16.0	28.3	143.2
7	18.0	8.0	13.6	19.8	50.9
8	8.0	11.0	7.8	13.4	31.1
Mean r	14.9				**650**
Mean r area	**695**				

MER 5	Jim Dodd M55/MP030				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	12.0	15.0	10.7	18.8	63.6
2	15.0	5.0	12.0	16.0	26.5
3	5.0	8.0	5.7	9.3	14.1
4	8.0	9.0	6.6	11.8	25.5
5	9.0	16.0	11.5	18.3	50.9
6	16.0	10.0	11.4	18.7	56.6
7	10.0	6.0	7.2	11.6	21.2
8	6.0	12.0	8.8	13.4	25.5
Mean r	10.1				**284**
Mean r area	**322**				

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

MER 15	Doc Higgins M14/MPxxx				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	10.0	34.0	27.8	35.9	120.2
2	34.0	36.0	26.8	48.4	432.7
3	36.0	20.0	26.0	41.0	254.5
4	20.0	22.0	16.2	29.1	155.6
5	22.0	18.0	15.7	27.9	140.0
6	18.0	10.0	13.0	20.5	63.6
7	10.0	13.0	9.2	16.1	46.0
8	13.0	10.0	9.2	16.1	46.0
Mean r	20.4				**1259**
Mean r area	**1304**				

MER 17	Morin M13/MPxxx				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	20.0	33.0	23.6	38.3	233.3
2	33.0	25.0	23.4	40.7	291.7
3	25.0	19.0	17.7	30.9	167.9
4	19.0	16.0	13.7	24.3	107.5
5	16.0	22.0	15.6	26.8	124.4
6	22.0	25.0	18.2	32.6	194.4
7	25.0	20.0	17.8	31.4	176.8
8	20.0	20.0	15.3	27.7	141.4
Mean r	22.5				**1437**
Mean r area	**1590**				

MER 16	David Bean M25/MPxxx				
Triangle	**A**	**B**	***C***	**s**	**Area**
1	16.0	12.0	11.3	19.7	67.9
2	12.0	42.0	34.6	44.3	178.2
3	42.0	82.0	60.1	92.1	1217.5
4	82.0	12.0	74.0	84.0	347.9
5	12.0	86.0	78.0	88.0	364.8
6	86.0	36.0	65.7	93.8	1094.5
7	36.0	18.0	26.5	40.3	229.1
8	18.0	16.0	13.1	23.6	101.8
Mean r	38.0				**3602**
Mean r area	**4536**				

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 — Pre-estimate: **1353**

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 — Pre-estimate: **731**

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**				

MER 5 Jim Dodd M55/MP030 — Pre-estimate: **434**

Triangle	A	B	C	s	Area
1	10.5	18.0	12.9	20.7	66.8
2	18.0	9.5	13.1	20.3	60.5
3	9.5	14.5	10.3	17.1	48.7
4	14.5	10.0	10.3	17.4	51.3
5	10.0	17.0	12.2	19.6	60.1
6	17.0	9.5	12.3	19.4	57.1
7	9.5	6.5	6.7	11.4	21.8
8	6.5	10.5	7.5	12.2	24.1
Mean r	11.9				**390** Post-estimate
Mean r area	**448**				

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

MER 15	Doc Higgins M14/MPxxx						Pre-estimate
Triangle	A	B	C	s	Area		1134
1	11.5	33.0	26.2	35.3	134.2		
2	33.0	31.0	24.6	44.3	361.7		
3	31.0	20.0	22.0	36.5	219.2		
4	20.0	22.0	16.2	29.1	155.6		
5	22.0	17.5	15.7	27.6	136.1		
6	17.5	15.0	12.6	22.6	92.8		
7	15.0	10.0	10.6	17.8	53.0		
8	10.0	11.5	8.3	14.9	40.7		
Mean r	20.0				1193	Post-estimate	
Mean r area	1257						

MER 17	Morin M13/MPxxx						Pre-estimate
Triangle	A	B	C	s	Area		1336
1	19.5	30.5	21.7	35.8	210.3		
2	30.5	20.0	21.6	36.1	215.6		
3	20.0	32.0	22.8	37.4	226.3		
4	32.0	22.0	22.6	38.3	248.9		
5	22.0	27.5	19.6	34.6	213.9		
6	27.5	26.0	20.5	37.0	252.8		
7	26.0	16.5	18.5	30.5	151.7		
8	16.5	19.5	14.1	25.0	113.7		
Mean r	24.3				1633	Post-estimate	
Mean r area	1847						

MER 16	David Bean M25/MPxxx						Pre-estimate
Triangle	A	B	C	s	Area		672
1	18.0	33.5	24.4	37.9	213.2		
2	33.5	20.5	23.9	38.9	242.8		
3	20.5	30.5	21.6	36.3	221.0		
4	30.5	10.5	24.2	32.6	113.2		
5	10.5	24.5	18.6	26.8	90.9		
6	24.5	14.5	17.6	28.3	125.6		
7	14.5	17.0	12.3	21.9	87.1		
8	17.0	18.0	13.4	24.2	108.2		
Mean r	21.1				1202	Post-estimate	
Mean r area	1402						

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

2011 Full

MER 5	Jim Dodd M55/MP030					Helix	
Triangle	A	B	C	s	Area		
1	0.0	0.0	0.0	0.0	0.0		
2	0.0	0.0	0.0	0.0	0.0		
3	0.0	0.0	0.0	0.0	0.0		
4	0.0	10.0	10.0	10.0	0.0		
5	10.0	28.0	22.1	30.0	99.0		
6	28.0	0.0	28.0	28.0	0.0		
7	0.0	0.0	0.0	0.0	0.0		
8	0.0	0.0	0.0	0.0	0.0		
Mean r	4.8				**99**	**2011 estimate**	390
Mean r area	**71**						**75%**

MER 15	Doc Higgins M14/MPxxx					Removed	
Triangle	A	B	C	s	Area		
1	9.0	38.0	32.3	39.6	120.9		
2	38.0	41.0	30.4	54.7	550.8		
3	41.0	26.0	29.1	48.1	376.9		
4	26.0	20.0	18.5	32.2	183.8		
5	20.0	6.5	16.1	21.3	46.0		
6	6.5	5.0	4.6	8.1	11.5		
7	5.0	3.0	3.6	5.8	5.3		
8	3.0	9.0	7.2	9.6	9.5		
Mean r	18.6				**1305**	**2011 estimate**	1193
Mean r area	**1082**						**-9%**

MER 17	Morin M13/MPxxx				Removed		
Triangle	A	B	C	s	Area		
1	22.5	42.0	30.6	47.5	334.1		
2	42.0	33.0	29.9	52.4	490.0		
3	33.0	16.0	24.5	36.7	186.7		
4	16.0	30.5	22.3	34.4	172.5		
5	30.5	16.5	22.2	34.6	177.9		
6	16.5	16.0	12.4	22.5	93.3		
7	16.0	11.0	11.3	19.2	62.2		
8	11.0	22.5	16.6	25.1	87.5		
Mean r	23.4				**1604**	**2011 estimate**	1633
Mean r area	**1726**						**2%**

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

2011 Full

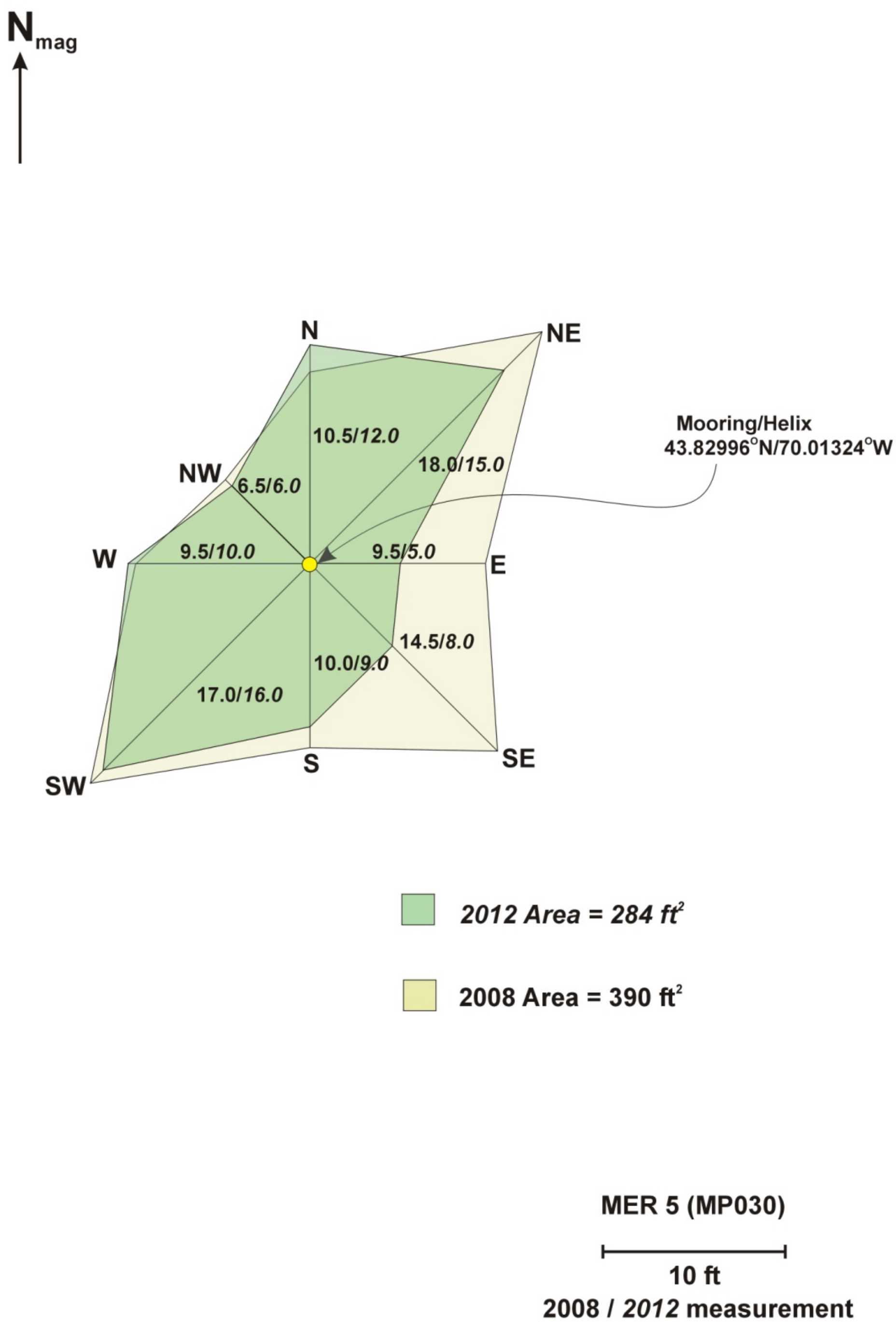
MER 16	David Bean M25/MPxxx					Removed	
Triangle	A	B	C	s	Area		
1	12.0	16.0	11.3	19.7	67.9		
2	16.0	7.0	12.1	17.6	39.6		
3	7.0	11.0	7.8	12.9	27.2		
4	11.0	9.0	7.9	13.9	35.0		
5	9.0	83.0	76.9	84.4	264.1		
6	83.0	34.0	63.7	90.3	997.6		
7	34.0	6.0	30.1	35.0	72.1		
8	6.0	12.0	8.8	13.4	25.5		
Mean r	22.3				1529	2011 estimate	1202
Mean r area	1555						-27%

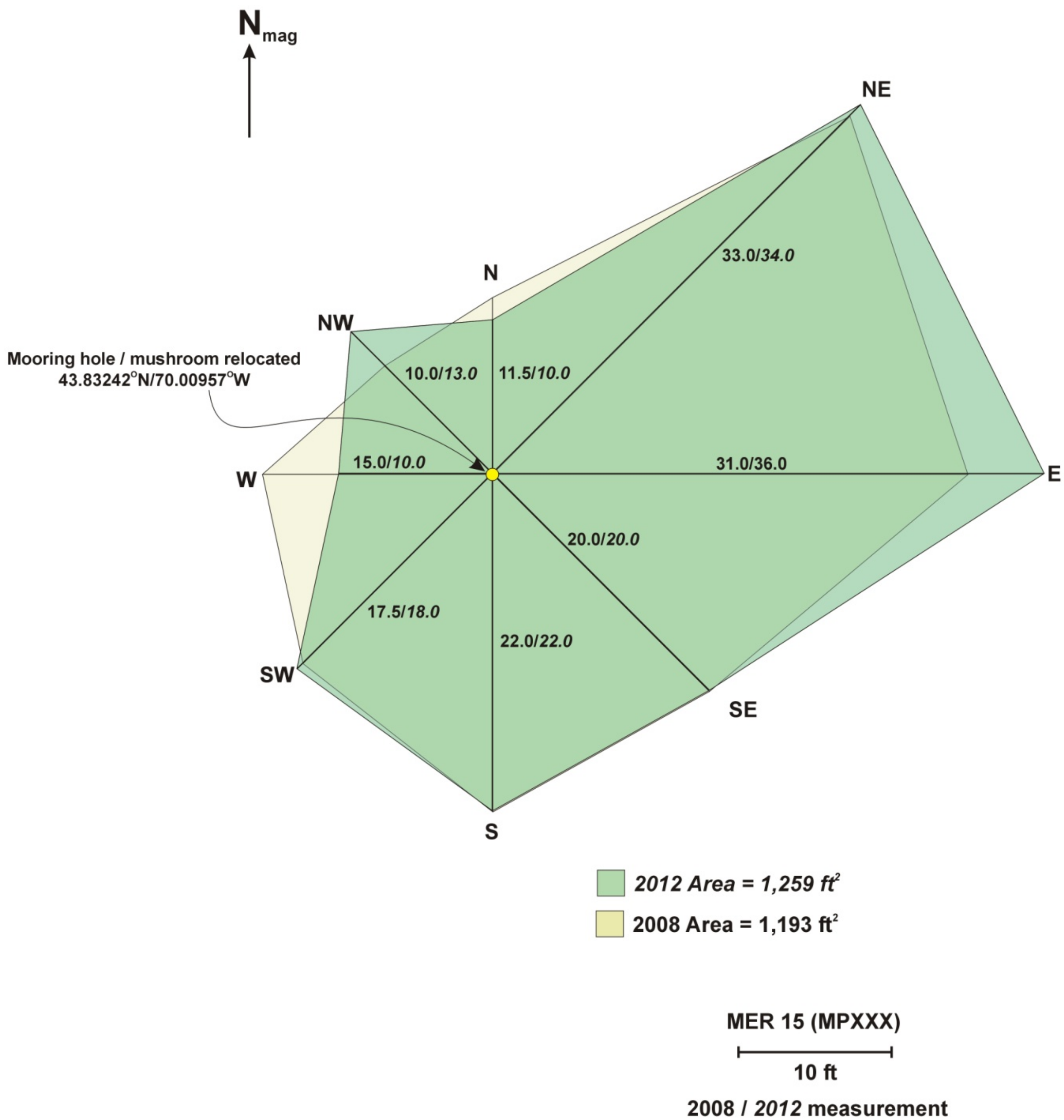
MER 11	Sean White MQ156					Helix	
Triangle	A	B	C	s	Area		
1	6.0	22.0	18.3	23.1	46.7		
2	22.0	16.5	15.6	27.0	128.3		
3	16.5	18.0	13.3	23.9	105.0		
4	18.0	32.5	23.5	37.0	206.8		
5	32.5	26.5	23.2	41.1	304.5		
6	26.5	13.0	19.6	29.5	121.8		
7	13.0	10.0	9.2	16.1	46.0		
8	10.0	6.0	7.2	11.6	21.2		
Mean r	18.1				980	2011 estimate	1070
Mean r area	1025						8%

MER 18	Bill Moore MP001				Helix		
Triangle	A	B	C	s	Area		
1	11.0	12.0	8.8	15.9	46.7		
2	12.0	10.0	8.6	15.3	42.4		
3	10.0	12.0	8.6	15.3	42.4		
4	12.0	23.5	17.2	26.4	99.7		
5	23.5	16.0	16.6	28.1	132.9		
6	16.0	16.0	12.2	22.1	90.5		
7	16.0	9.0	11.5	18.3	50.9		
8	9.0	11.0	7.9	13.9	35.0		
Mean r	13.7				541	2011 estimate	762
Mean r area	589						29%

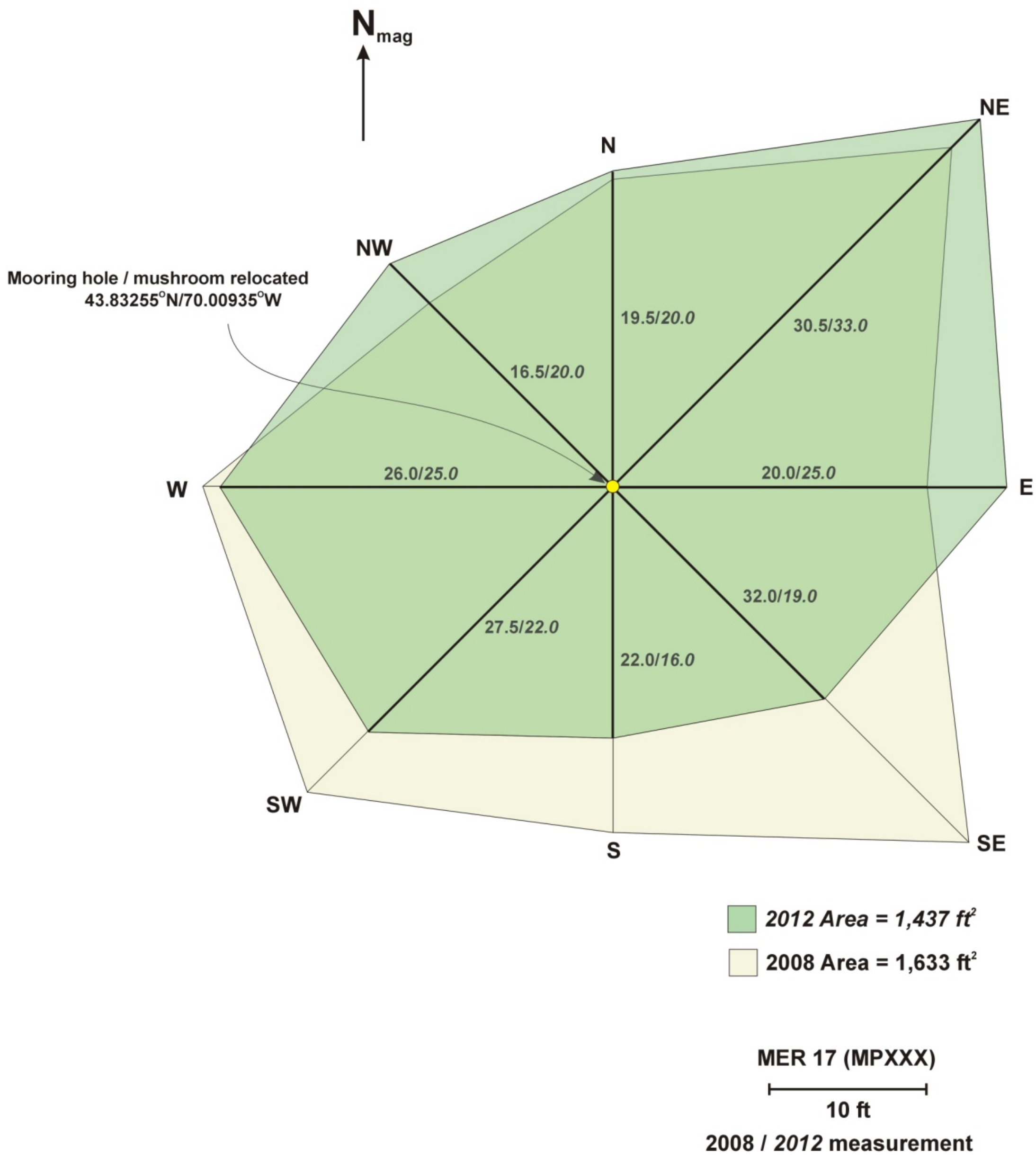
Appendix III

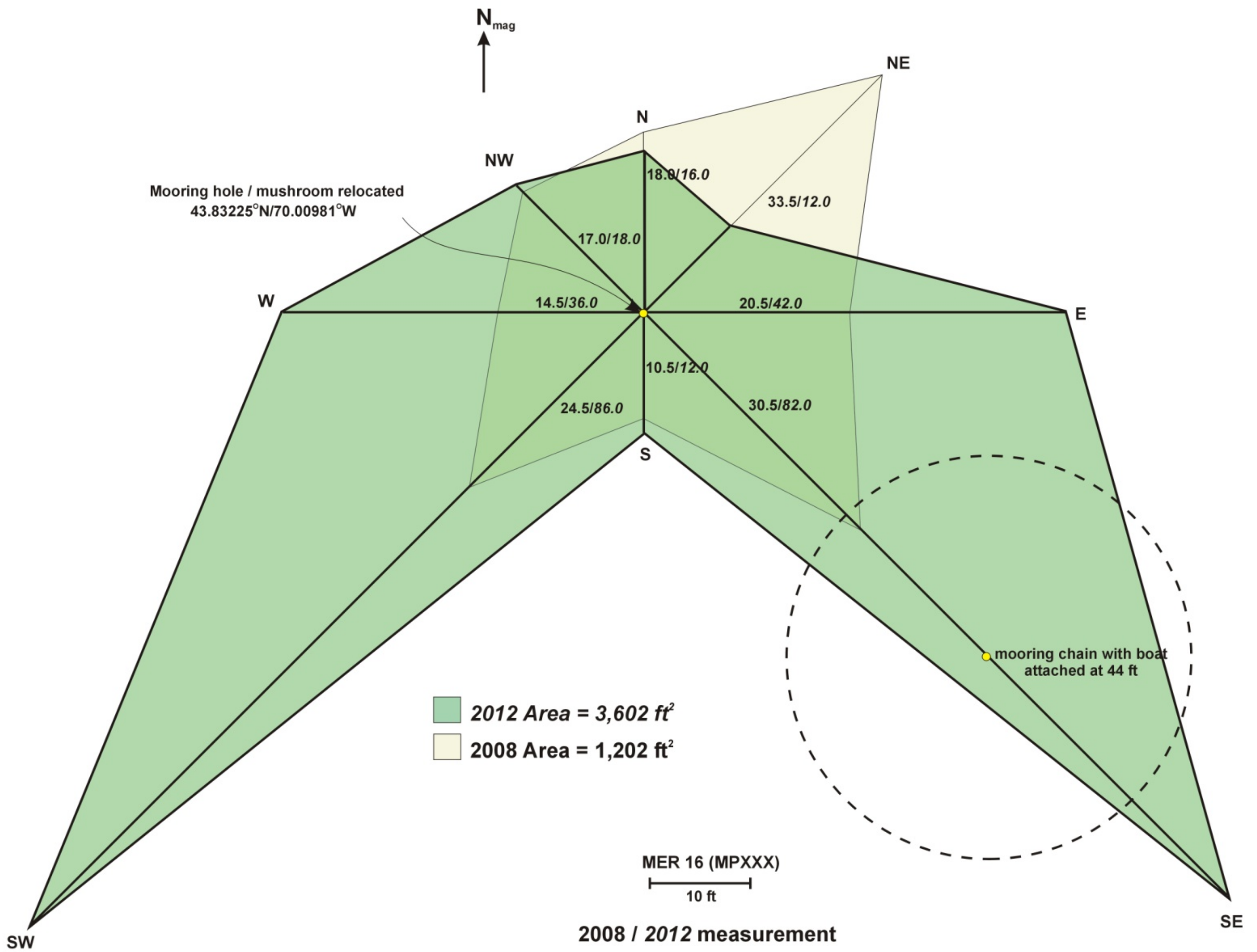
Graphic representations showing 2008 and 2012 mooring scars area based on eight *in situ* radii measurements


N mag
N
NE
NW
W
E
SW
S
SE
10.5/12.0
18.0/15.0
6.5/6.0
9.5/10.0
9.5/5.0
14.5/8.0
10.0/9.0
17.0/16.0
Mooring/Helix
43.82996°N/70.01324°W
2012 Area = 284 ft²
2008 Area = 390 ft²
MER 5 (MP030)
10 ft
2008 / 2012 measurement

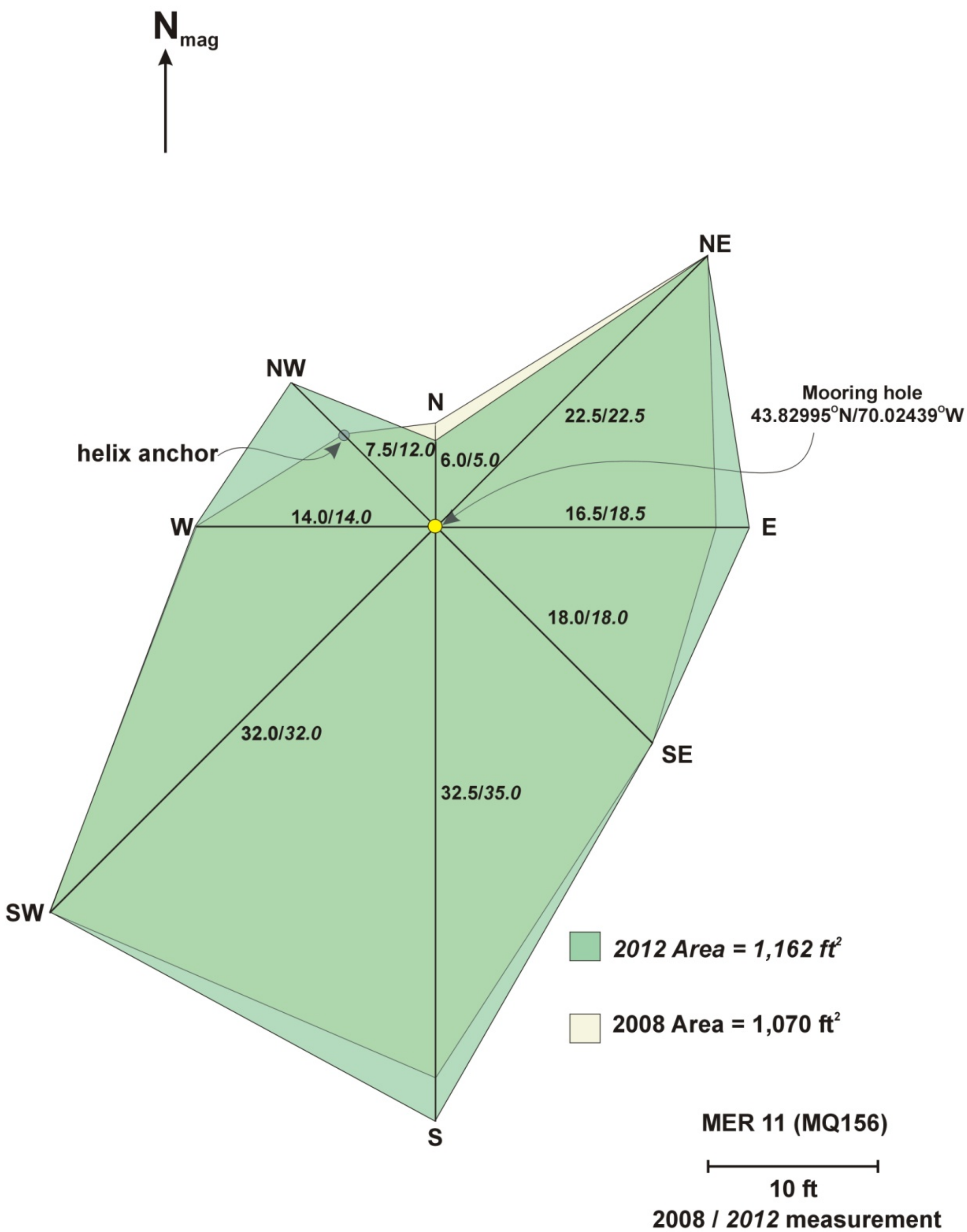


Nmag
NE
N
NW
Mooring hole / mushroom relocated
43.83242°N/70.00957°W
33.0/*34.0*
10.0/*13.0*
11.5/*10.0*
15.0/*10.0*
31.0/36.0
W
E
20.0/*20.0*
17.5/*18.0*
22.0/*22.0*
SW
SE
S
2012 Area = 1,259 ft²
2008 Area = 1,193 ft²
MER 15 (MPXXX)
10 ft
2008 / *2012* measurement

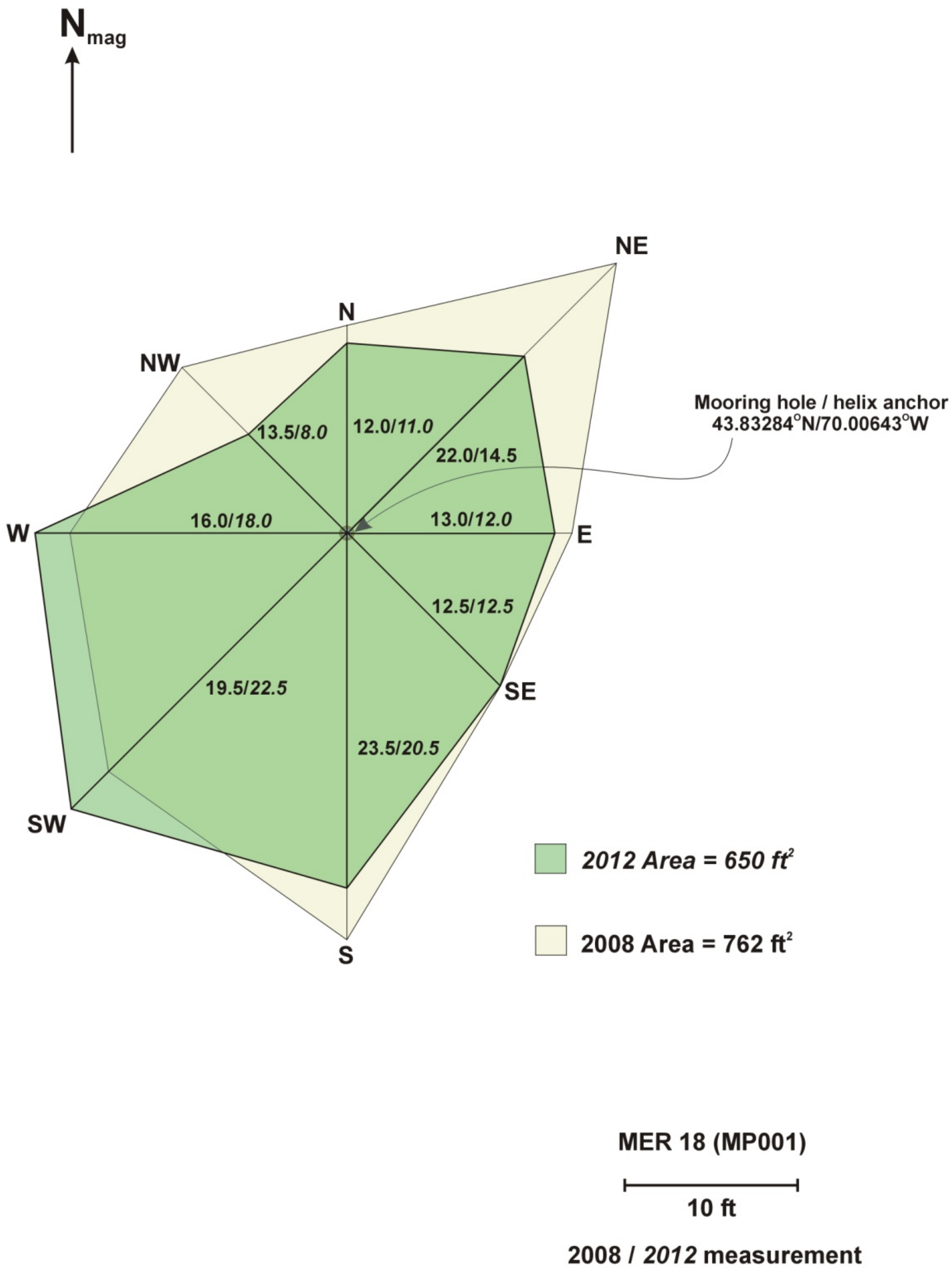

Nmag
N
NE
NW
Mooring hole / mushroom relocated
43.83255°N/70.00935°W
19.5/20.0
30.5/33.0
16.5/20.0
W
26.0/25.0
20.0/25.0
E
32.0/19.0
27.5/22.0
22.0/16.0
SW
S
SE
2012 Area = 1,437 ft²
2008 Area = 1,633 ft²
MER 17 (MPXXX)
10 ft
2008 / 2012 measurement



Nmag
NE
N
NW
Mooring hole / mushroom relocated
43.83225°N/70.00981°W
18.0/16.0
33.5/12.0
17.0/18.0
W
14.5/36.0
20.5/42.0
E
10.5/12.0
24.5/86.0
30.5/82.0
S
mooring chain with boat attached at 44 ft
2012 Area = 3,602 ft²
2008 Area = 1,202 ft²
MER 16 (MPXXX)
10 ft
2008 / 2012 measurement
SW
SE



Nmag
NE
NW
N
Mooring hole
43.82995°N/70.02439°W
22.5/22.5
helix anchor
7.5/12.0
6.0/5.0
W
14.0/14.0
16.5/18.5
E
18.0/18.0
32.0/32.0
SE
32.5/35.0
SW
2012 Area = 1,162 ft²
2008 Area = 1,070 ft²
S
MER 11 (MQ156)
10 ft
2008 / 2012 measurement


N mag
NE
N
NW
W
E
SE
SW
S
13.5/*8.0*
12.0/*11.0*
22.0/14.5
16.0/*18.0*
13.0/*12.0*
12.5/*12.5*
19.5/*22.5*
23.5/*20.5*
Mooring hole / helix anchor
43.83284°N/70.00643°W
2012 Area = 650 ft²
2008 Area = 762 ft²
MER 18 (MP001)
10 ft
2008 / *2012* measurement