Massachusetts Department of Fish and Game

In-Lieu Fee Program

Eelgrass Restoration Project (IL01) 2023 Final Report

Implemented by the Division of Marine Fisheries

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Project Overview

The Massachusetts In-Lieu Fee Program (ILFP) funded The Massachusetts Division of Marine Fisheries (DMF) to restore and monitor ½ acre (2,023 m^2) of eelgrass in the North sub-area of the Coastal Service Area under the Corps General Permit number NAE-2017-00754. This report summarizes the restoration status as of calendar year 2023, the seventh and final year of the project.

Following an internal site selection process, DMF chose a ½ acre site at Middle Ground in Salem Sound (Figure 1). In 2017, DMF planted eelgrass along three transects within each ¼ acre (1,012 m2) area (Figure 2). To mitigate for seasonal effects (storms, algae blooms, crabs), the restoration effort was split over two seasons, the West ¼ acre set (MGW) was planted in April and May 2017, while the East ¼ acre set (MGE) was planted in the end of August and September 2017. An additional ¼ acre set (MGS) was planted directly South of MGW in May 2018 after poor success was recorded at MGE (Figure 2). Additionally, five plots missing from MGW were replaced in May 2018, serving to augment the MGW set (Figure 2). All planted plots were monitored annually through 2023. This report summarizes all monitoring for the planted plots at MGW, MGS, and MGE.

Methods

Transplanting

In 2017, DMF collected approximately 10,800 eelgrass shoots from harvest sites in Lynn (Broad Sound), Nahant (Nahant Cove), Salem (Aquavitae), Beverly (West Beach) and Gloucester (Niles Beach) to complete a combined ½ acre restoration effort (Figure 1). At each harvest site, divers gathered eelgrass shoots by hand in a dispersed manner so that no more than 10% were collected from any square-meter area. Coordinates were recorded and plotted to ensure that the same area and heading were not overharvested. This low impact collection method has been shown to have no measurable impact on donor sites in this region (Leschen et al. 2010).

Collected plants were stored in seawater for no more than 48 hours before being woven onto burlap discs. This method involved weaving ten eelgrass shoots by their rhizomes into a 20 cm diameter, circular burlap disc or planting unit. Each planting unit was buried approximately 3-5 cm in the sediment. The burlap disc planting method is further described in the 2017 Annual report (https://www.mass.gov/doc/eelgrass-2017-annual-report/download).

At the ½ acre restoration site, DMF arranged plantings in two sets of 5,400 transplanted eelgrass shoots (Figure 2). In each set, eelgrass shoots were planted along three transects, each containing six evenly spaced three-meter by four-meter plots of six planted 1 m^2 squares, for a total of 108 planted squares per set (Figure 2). Each square was planted at a density of 50 shoots/m^2. To mitigate for seasonal effects (storms, algae blooms, crabs), the restoration effort was split over spring and fall seasons. The West ¼ acre set (MGW) was planted in April and May 2017, and the East ¼ acre set (MGE) was planted in the end of August and September 2017.

In May 2018, a third ¼ acre set (MGS) and five replacement plots at the MGW set were planted at the restoration site to supplement the restoration after poor survival over the previous winter (Figure 2). Between 1,800-3,300 shoots were collected from the three most promising donor beds, Nahant, Gloucester, and Salem, and transplanted following the methods described above.

Restoration diver monitoring

Divers monitored the restoration sets 1-month following transplanting and then annually or semi-annually during the peak eelgrass growing season (i.e., May-August) through 2023. Divers visited each plot of six 1m^2 squares planted with eelgrass in 2017 or 2018. To assess eelgrass persistence, divers recorded the presence or absence of eelgrass at all six planted squares within a plot. To assess eelgrass expansion, divers measured the distance of continuous eelgrass (defined as no more than 0.5m to the next nearest shoot) along headings parallel and perpendicular to the transect and starting from planted squares selected within one year of planting. At each plot, divers also measured plant morphometrics (shoot density, canopy height, and percent cover) linked with eelgrass ecosystem functions in 1m^2 quadrats haphazardly distributed within eelgrass. Finally, divers made general observations and took video and still pictures.

Restoration side scan monitoring

On August 23, 2023, DMF staff conducted a side scan sonar survey of the restoration site to estimate the area of restored eelgrass. The survey was performed using a GPS integrated Humminbird Helix 9 (698SI 455Hz) side scan sonar and 83/200 kHz dual beam downward-looking bathymetric sonar rigged to a 20' Maritime Skiff moving 2-4 kts. Sonar transects were collected parallel to the planted transects and overlapped to achieve at least 150% coverage. Side scan sonar imagery was processed for water column removal, slant range, and beam angle corrections with SonarTRX Pro and then exported as GeoTiff mosaics to ArcGIS Pro (v3.0.0). Side scan sonar panels were georeferenced using markers with clear and distinctive signatures in the imagery (lobster pots) dropped at known locations around the restoration. The clearest side scan panels were then manually stitched together into a mosaic and eelgrass extents, characterized by a distinctive cloud like pattern, were estimated at scales between 1:200 and 1:500 (Figure 3, Greene et al. 2018).

Reference sites diver monitoring

Divers monitored three reference sites (i.e., local, representative natural eelgrass meadows; Figure 1) during the peak eelgrass growing season (i.e., May-August) located off the coast of Beverly (West Beach), adjacent to Middle Ground in Salem (Aquavitae), and off the coast of Marblehead (Peach's Point). Each year DMF measured eelgrass characteristics (shoot density, canopy height, and percent cover) linked with eelgrass ecosystem functions (Fonseca et al. 1990, Peterson et al. 2004, McCloskey and Unsworth 2015). Specifically, divers measured eelgrass at twelve ¼ m^2 quadrats randomly distributed along a 50m transect at each reference site following the SeagrassNet protocol (https://www.seagrassnet.org/global-monitoring/).

Success Criteria (performance standards)

DMF evaluated restoration success by assessing the persistence, expansion, and quality of the ecosystem services of the restored eelgrass meadow over five years. Restoration targets are defined as the persistence of the desired eelgrass acreage of ½ acre at the restoration site with

ecosystem services similar to local representative natural eelgrass meadows. These targets should all be met or the mitigation will not have successfully replaced the lost habitat (Evans and Short 2005).

To determine if persistence and acreage targets are met, DMF estimated survival and acreage of the restored eelgrass (see methods above).

To determine if restored eelgrass provides ecosystem services similar to nearby natural eelgrass meadows DMF compared the plant morphometrics of the restored eelgrass to natural meadows using the method described in Short et al. (2000). Specifically, DMF calculated success criteria (SC) and success ratio (SR) using the following equations:

SC = 100*reference site mean-1 Standard Deviation (SD)/ Reference site mean

SR =100* Restoration site mean/Reference site mean

The success criteria (SC) is calculated based on each reference site's mean and standard deviation (SD). Specifically, the threshold for success (the SC) is within one SD of the mean of the reference site. The success ratio is the proportion of the mean at the restoration site compared to the mean at the reference site. The success ratio approaches 100 as the restoration site mean gets closer to the reference site mean and when the SR reaches the SC, that parameter is deemed a success.

Between our monitoring on June 28th, 2021 and July 5th, 2022, the natural eelgrass meadow at our Peach's Point reference site experienced a catastrophic die-back (Figures 5-7). The site remained bare through monitoring in 2023. DMF has excluded the Peach's Point reference site from consideration in the success criteria results reported below because the site was bare at the final monitoring time points and thus no longer representative of a local eelgrass meadow.

Results

Eelgrass Survival

In July 2023, eelgrass was observed growing at 52% of planted squares across the entirety of the restoration site. Specifically, eelgrass was present in 68% of planted squares at the MGW restoration set, 64% of planted squares at the MGS restoration set, and 23% of planted squares at the MGE restoration set (Figure 2).

Eelgrass Acreage

In July 2023, divers estimated 602 m^2 or slightly more than 1/7 of an acre of restored eelgrass across the entirety of the ¾ acre restoration site. Side scan sonar surveys conducted in August of 2023 detected 660 m^2 or just under 1/6 of an acre of restored eelgrass across the restoration site (Figure 3A-B).

Observations by divers and from side scan sonar surveys both demonstrate that, by the summer of 2023, surviving eelgrass from the planted squares had coalesced at many of the plots (Figures 3A-B and 4). Encouragingly, eelgrass planted in 2017 at the MGW set and in 2018 at the MGS set not only coalesced within the initial 12 m^2 plot planting area, but on average expanded 10 m^2 as well (Figure 4). In some cases, plots were even observed beginning to merge with each other (Figure 3A-B). However, little change in eelgrass plot area (< 2 m^2) has occurred over the past two years at the plots planted at the MGW set in 2017 or over the past year at the plots planted at the MGS set in 2018 (Figure 4). The planted squares had also coalesced at the MGW set planted in 2018 and at the MGE set in 2017 (Figures 3A-B and 4). However, these plots had not expanded beyond the initial planting area by July 2023 (Figure 4). Notably, the average area of the plots planted in the Spring of 2018 at the MGW set was less than half the area estimated the previous year (Figure 4).

Quality of Eelgrass Ecosystem Services

Eelgrass density- In July 2023, the density of all restored eelgrass exceeded the density success criteria calculated from both reference sites (Table 1, Figure 5). Restored eelgrass density ranged from 135 to 197 shoots m^{-2} (Figure 5). Eelgrass density at the MGW and MGS restoration sets had declined from peak densities between 300 and 600 shoots m^{-2} observed over the previous two years (Figure 5).

Eelgrass canopy height- In July 2023, the canopy height of all restored eelgrass exceeded the canopy height success criteria calculated from the Aquavitae reference site, but none of the restored eelgrass met the canopy height success criteria calculated from the West Beach reference site (Table 1, Figure 6). Average restored eelgrass canopy height ranged between 50 and 75 cm among the restoration sets (Figure 6). Restored eelgrass canopy height in 2023 was less than the maximum canopy heights between 80 and 90 cm observed at the various restoration sets between 2020 and 2022 (Figure 6).

Eelgrass percent cover- In July 2023, the percent cover of all restored eelgrass exceeded the percent cover success criteria calculated from the Aquavitae reference site (Table 1, Figure 7). Eelgrass restored at the MGS restoration set also exceeded the percent cover success criteria calculated from the West Beach reference site (Table 1, Figure 7). The percent cover of the restored eelgrass from the other restoration sets did not meet the percent cover success criteria calculated from the West Beach reference site (Table 1, Figure 7). Restored eelgrass percent cover ranged from 25 to 65% among the restoration sets (Figure 7). Similar to eelgrass density, eelgrass percent cover at the MGW and MGS restoration sets had declined from peak coverage between 70 and 85% over the previous two years (Figure 7).

Qualitatively, divers have observed numerous fish, crustacean, and mollusk species utilizing the restored eelgrass habitat at the restoration site (Figure 8).

Credit Release

So far, USACE has released 0.375 wetland mitigation M1AB credits for this project. The total potential mitigation credits for this project is 0.5 wetland credits (https://ribits.ops.usace.army.mil/ords/f?p=107:10:::::P10_BANK_ID:4471).

The ILF contribution of $214,832.24 represents about 80% of the total project cost of $267,087.92. Therefore, the ILF contribution is valued at 80% of the total potential mitigation credits for the project, or 0.402 wetland credits. At this time, we request the release of the final 7% of credits (0.027) for 2022 and 2023 monitoring to include the sixth year of monitoring for MGW and MGE and the fifth year of monitoring for MGS.

Summary and Conclusions

MA DMF has successfully completed the 2023 seasonal monitoring of eelgrass at the Middle Ground ILF restoration site in Salem Sound.

The goal of the project is the restoration of ½ acre of eelgrass after five years. Success is determined by the persistence, expansion, and quality of the ecosystem services of the restored eelgrass.

Two of the ¼ acre restoration sets of eelgrass, MGW and MGS, continue to show eelgrass survival greater than 50%. Eelgrass is present at the third ¼ acre set, MGE, however, considerably less eelgrass persists. Eelgrass area appears to have largely stabilized at nearly 1/6 of an acre distributed throughout the ¾ acre restoration site. Interestingly, the few plots where DMF observed declines in eelgrass area over the past year were mostly from the MGW supplementary plantings where DMF had re-planted eelgrass in 2018 following the loss of initial plantings over the winter of 2017/2018. DMF believes these losses were most likely due to uprooting during severe storms. Further, the repeated losses at these plots suggest that some environmental component at these specific locations within the restoration site may be increasing eelgrass vulnerability to damage from storms. This supposition is further supported by the patchy distribution of eelgrass at the nearby natural meadow, Aquavitae, where some locations within the meadow remain bare despite being surrounded by eelgrass. DMF believes the patchiness of the nearby natural meadow also suggests eelgrass may never expand across the entirety of the restoration site, instead remaining in the current patchy distribution.

The quality of the ecosystem services provided by the restored eelgrass as estimated by the eelgrass density, canopy height, and percent cover, exceeded all the success criteria determined from the reference eelgrass meadow at Aquavitae in 2023, but not the reference meadow at West Beach in 2023. Specifically, eelgrass canopy height and percent cover did not meet the success criteria determined from the West Beach reference meadow. This discrepancy is most likely the result of differences in the influence of storms on the West Beach reference meadows compared to the Aquavitae reference meadow and the restoration site. Specifically, both the restoration site and the adjacent Aquavitae reference meadow have similarly high exposure to the open ocean and likely experience similarly rough conditions during severe winter storms (Figure 1). In contrast, the natural eelgrass meadow at West Beach, located in the lee of Great Misery Island, is well protected from the open ocean and the effects of most storms (Figure 1). In addition, longer eelgrass leaves likely experience stronger hydrodynamic forces from the waves and currents generated by severe storms and may also be more likely to become entangled with drift algae and other marine debris suspended by severe storms, also increasing their drag. Thus at locations with greater exposure, such as the restoration site and the Aquavitae reference meadow, longer eelgrass leaves may be more likely to be ripped from shoots, leading to the shorter canopy heights DMF observed at these exposed sites. Further, because percent cover is influenced by the density of shoots as well as their size, it follows that the smaller eelgrass at the Aquavitae reference and restoration sites would also have lower percent cover than the larger, but similarly dense, eelgrass at West Beach. In sum, these results highlight

the importance of choosing reference meadows with similar conditions to the restoration site when assessing restoration success. DMF posits that the Aquavitae reference site provides a more appropriate benchmark for assessing the success of the restoration site than the West Beach reference site and, by meeting the success criteria calculated from the Aquavitae reference site in 2023, the restoration site is likely providing ecosystem services akin to natural eelgrass meadows growing under similar conditions in the region. Further, the MGW and MGS restoration sets consistently exceeded all restoration success criteria calculated from the Aquavitae references site from as far back as 2020 suggesting our assessment of the restoration performance is robust to natural interannual variation in eelgrass habitat quality in the region.

CY2023 Budget Update

The final project expenditures and match are outlined in Tables 2 and 3. Project expenses for 2023 amounted to $32,921.03 and the cumulative expenditures from 2017-2023 are $214,832.24. MA DMF also provided a total of $52,195.22 in match to this project.

Acknowledgements

Thanks to all who worked on this project from the initial planning and permitting to the field work, data analysis, account management, and report preparation. Our project team includes Mark Rousseau, Forest Schenck, Kate Frew, and Iris Seto, with help from Kevin Creighton, Alex Boeri, and Vin Malkoski of DMF; Tay Evans of MassDEP; Jill Carr of Massachusetts Bays National Estuary Partnership; Randall Hughes, Cori Carlston, Gwendolyn McManus, Rachel Spadafore, Mallarie Yeager, and Lauren Puishys of Northeastern University; and Phil Colarusso of EPA. Thanks also to Josh Helms of the Army Corps of Engineers for coordinating the funding and permitting for this project and to Aisling O'Shea and Elisabeth Cianciola of the DFG ILF Program.

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Figures

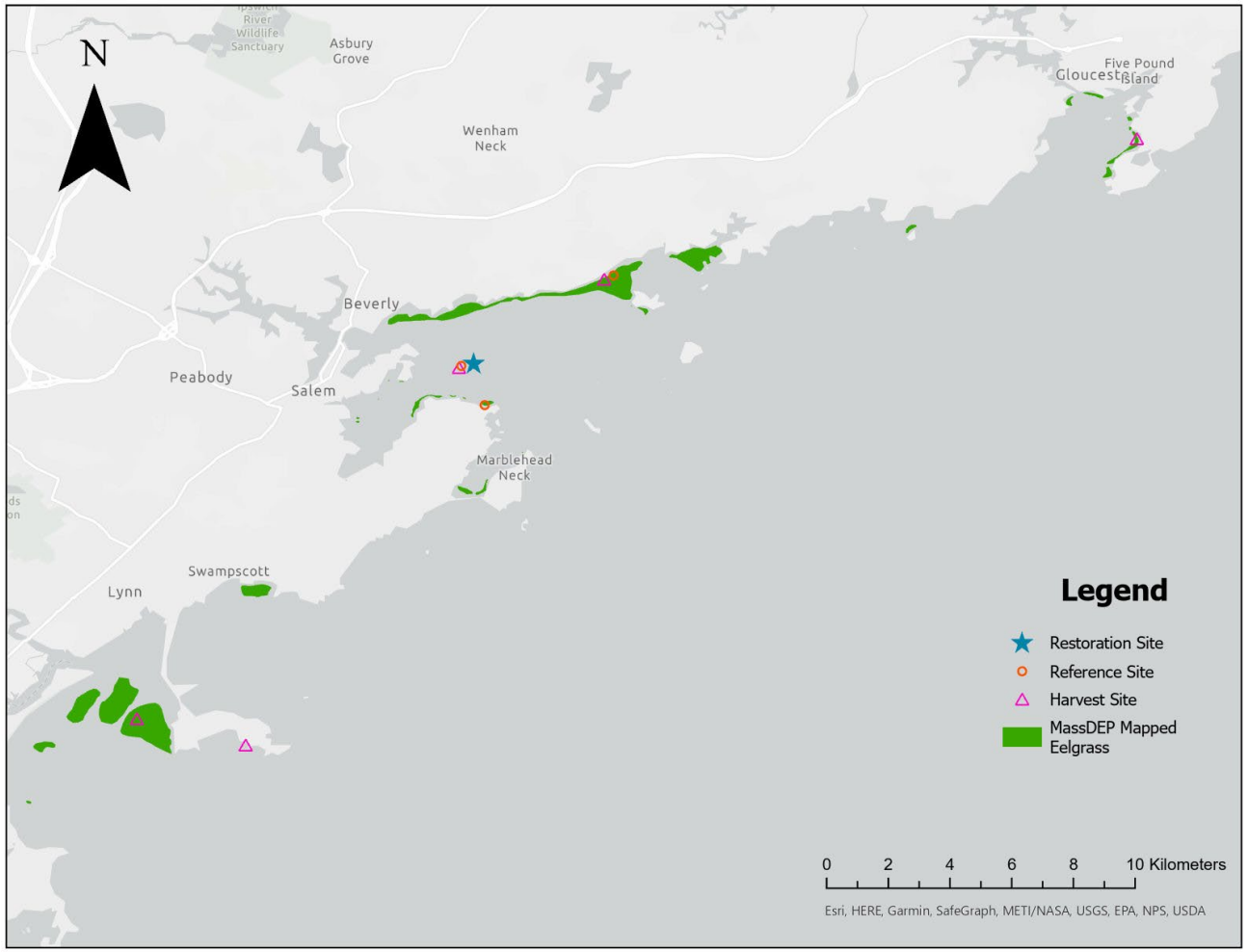

Figure 1. Map of Massachusetts north shore including restoration site, harvest sites, reference sites and eelgrass habitat mapped by MassDEP.

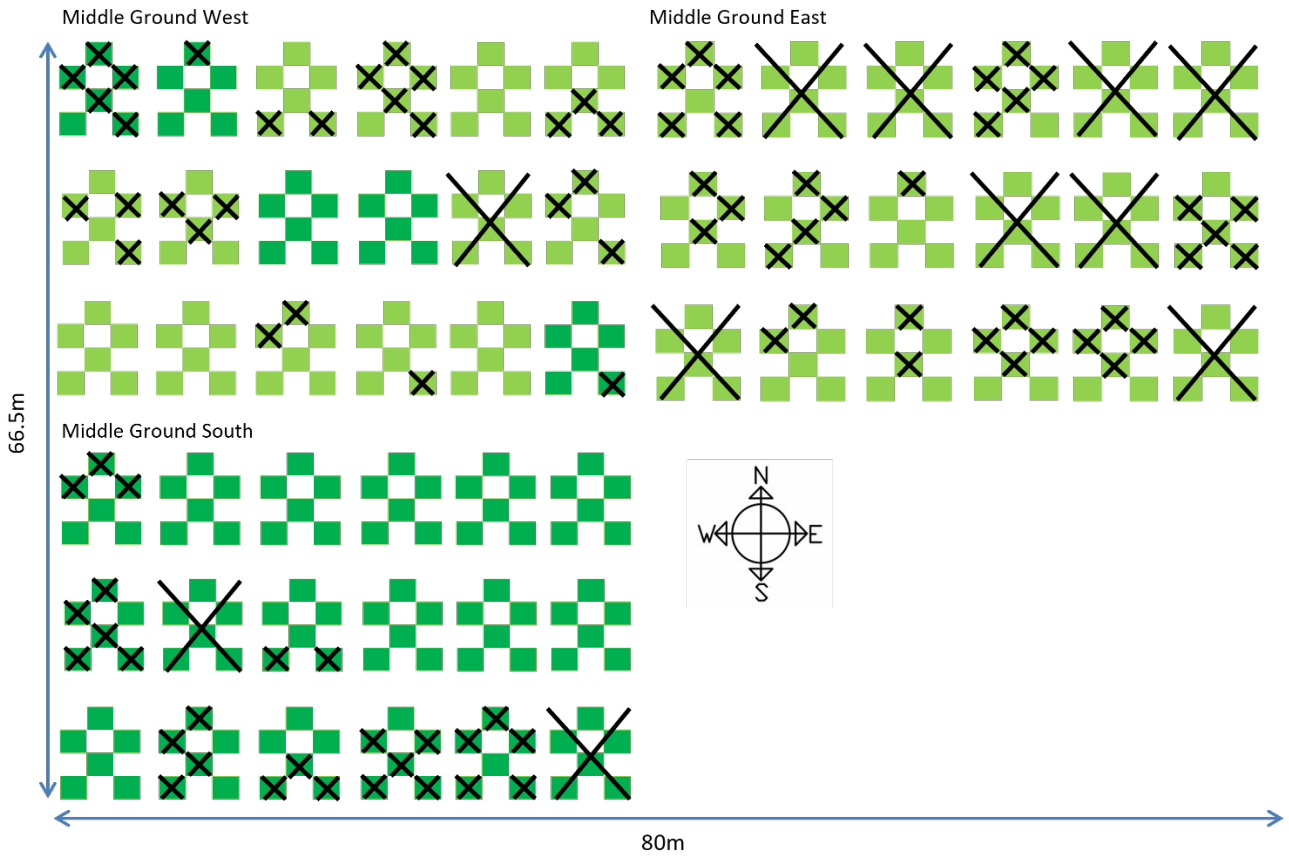

Figure 2. Middle Ground restoration site layout. Each set of three transects spans approximately ¼ acre and includes 18 plots each in a checkerboard pattern of 6 planted 1 m^2 squares (50 shoots m^{-2}) for a total of 5,400 planted shoots over ¾ acre. Light green squares indicate 2017 plantings. Dark green squares indicate supplemental plantings in 2018. X indicates no eelgrass present in 2023.

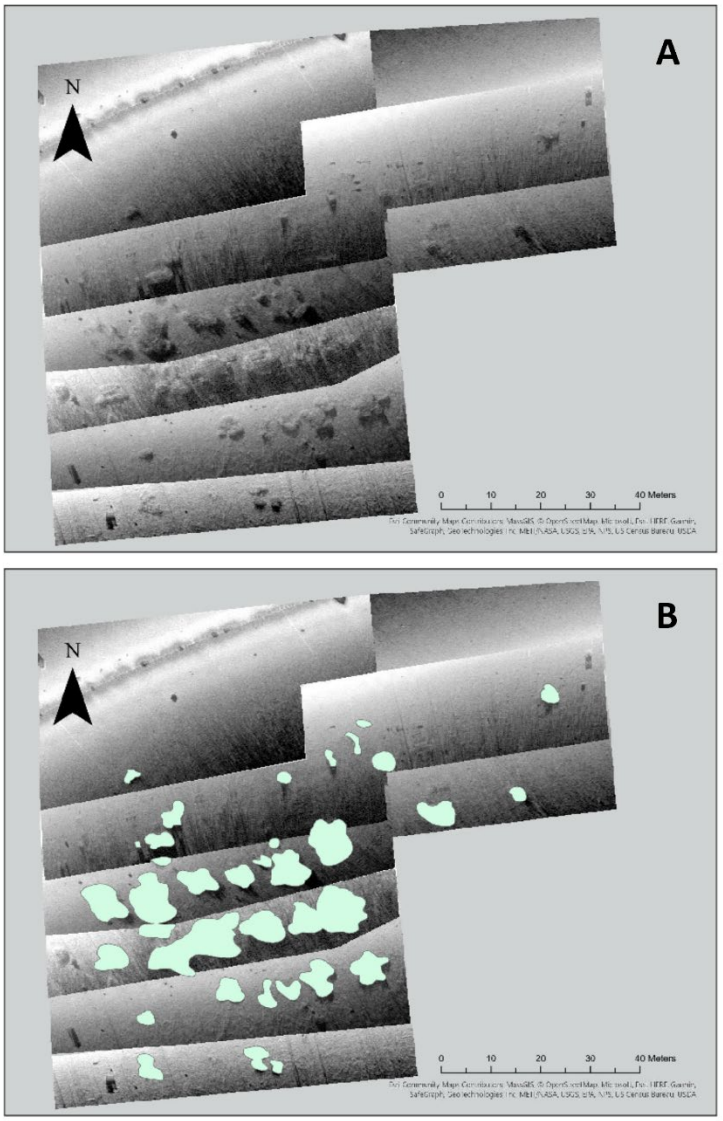

Figure 3. Eelgrass restoration site side scan sonar imagery. (A) Mosaic of processed and georeferenced panels of the restoration site from the side scan sonar survey conducted in August 2023. (B) Eelgrass areas in green delineated based on the distinctive visual signature of eelgrass in the side scan sonar imagery.

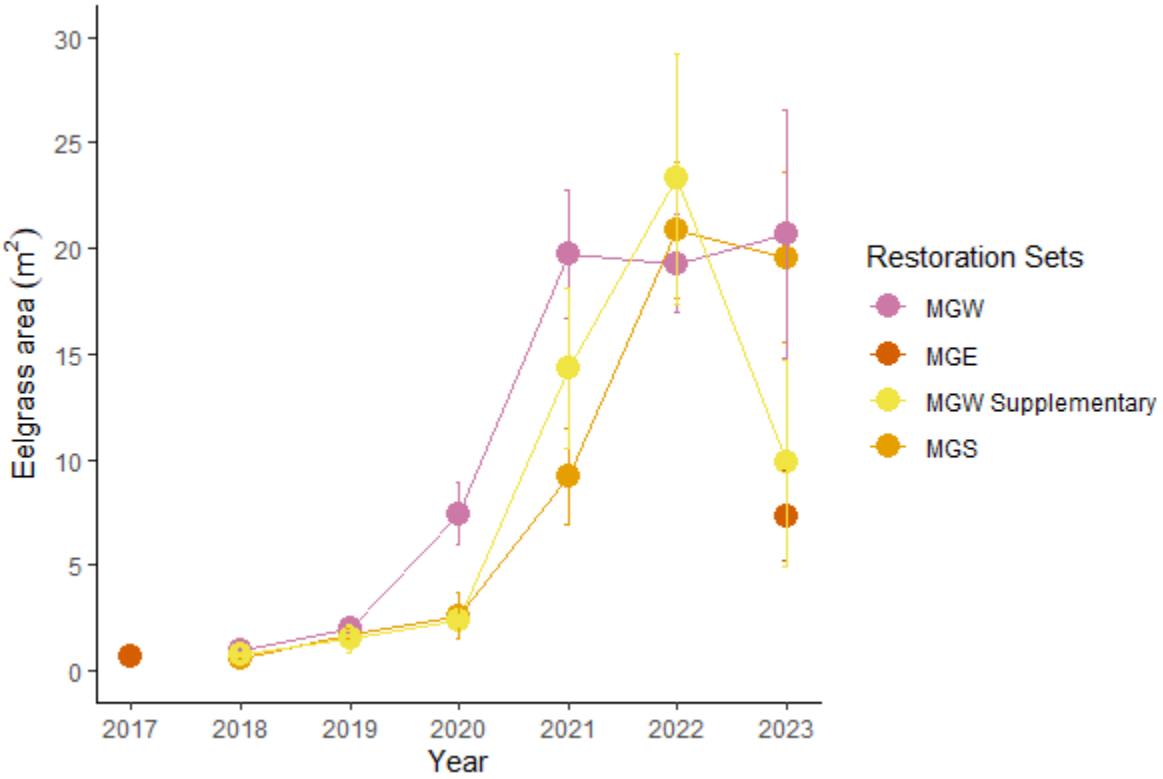

Figure 4. Area of plots vegetated with eelgrass over the years since planting estimated by divers. Restoration set means ± standard errors are represented by filled circles and error bars.

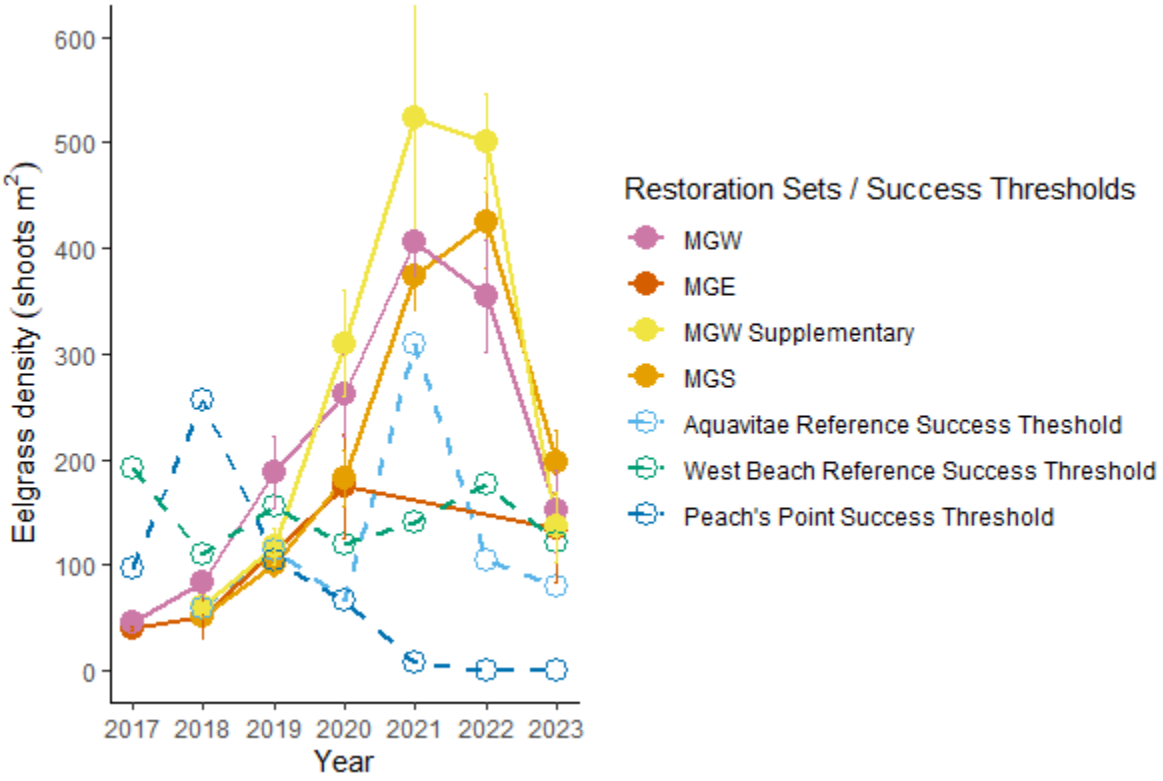

Figure 5. Eelgrass density over time at the restoration sets and density success thresholds calculated from the three reference sites. Restoration set means ± standard errors are represented by filled circles and error bars. Reference site success thresholds represented by open circles.

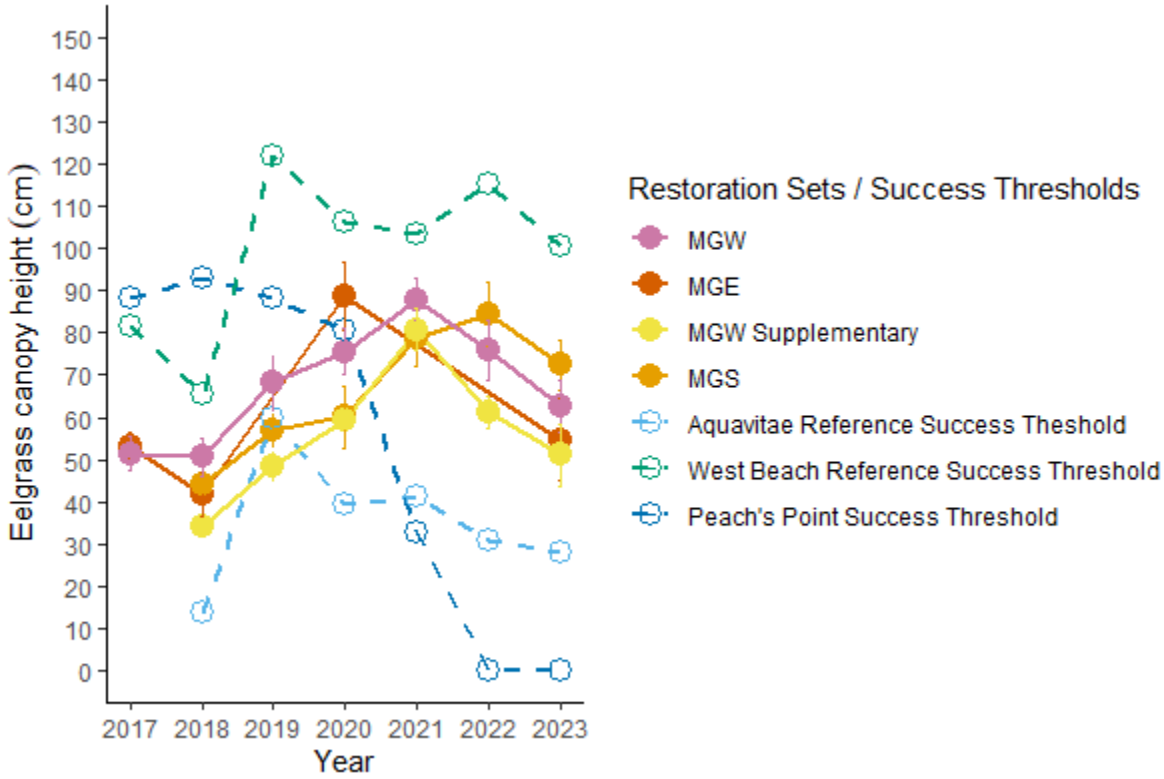

Figure 6. Eelgrass canopy height over time at the restoration sets and canopy height success thresholds calculated from the three reference sites. Restoration set means ± standard errors are represented by filled circles and error bars. Reference site success thresholds represented by open circles.

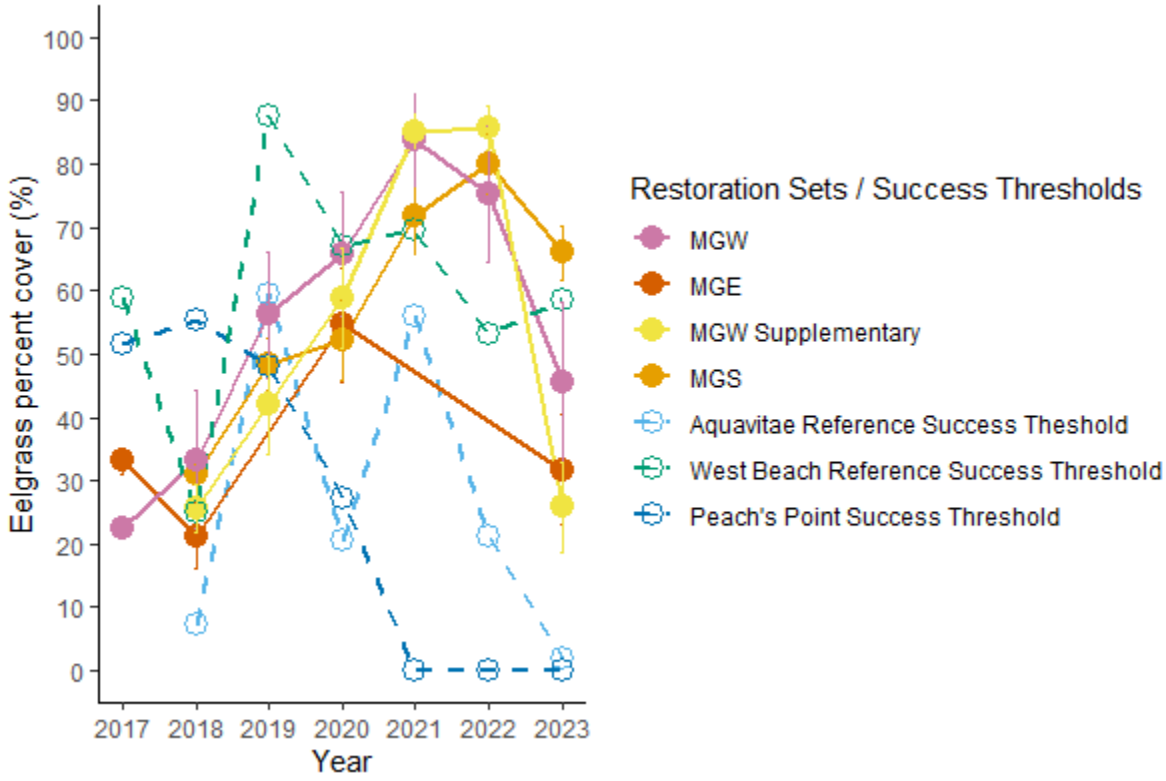

Figure 7. Eelgrass percent cover over time at the restoration sets and percent cover success thresholds calculated from the two reference sites. Restoration set means ± standard errors are represented by filled circles and error bars. Reference site success thresholds represented by open circles.

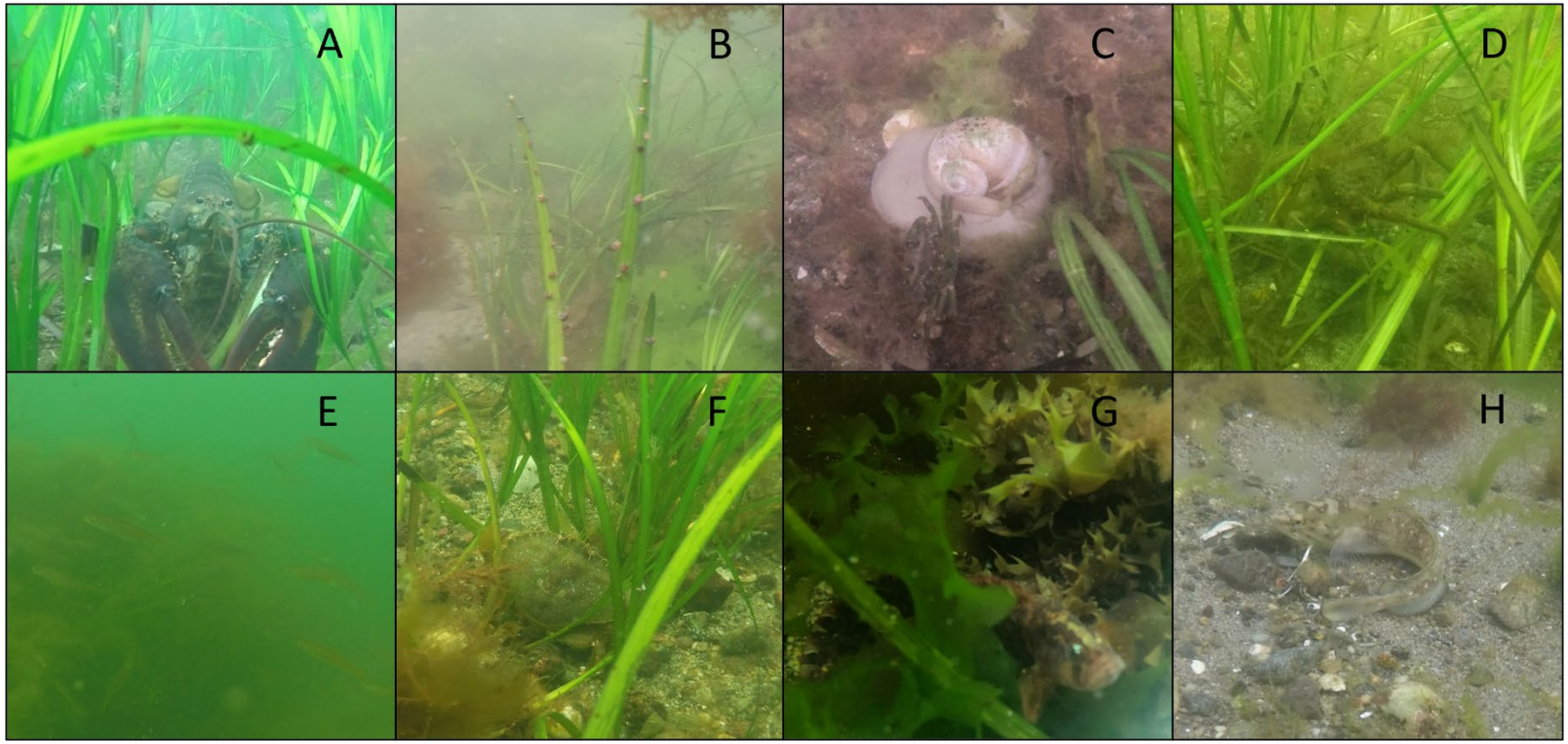

Figure 8. Photographs of fin fish, crustacean, and mollusk species observed utilizing the eelgrass habitat at the restoration site. (A) American lobster (*Homarus americanus*); (B) banded chink shell (*Lacuna vincta*); (C) northern moon snail (*Euspira heros*) and European green crab (*Carcinus maenas*); (D) common spider crab (*Libinia emarginata*); (E) juvenile Atlantic pollock (*Pollachius virens*); (F) Atlantic rock crab (*Cancer irroratus*); (G) rock gunnel (*Pholis gunnellus*); (H) juvenile spotted hake (*Urophycis regia*).

Tables

Table 1. Success criteria for the three eelgrass morphometrics calculated from the Aquavitae and West Beach reference sites and corresponding success ratios for each of the four eelgrass restoration sets. Green boxes indicate the success ratio meets or exceeds the success criteria and red boxes indicate the success ratio does not meet the success criteria.

Site	Response	Success Criteria (Aquavitae / West Beach)		Success Ratio (Aquavitae / West Beach)	
MGW Restoration Set	Eelgrass density	31	62	59	78
	Eelgrass canopy height	66	91	149	57
	Eelgrass percent cover	5	81	119	63
MGE Restoration Set	Eelgrass density	31	62	53	69
	Eelgrass canopy height	66	91	130	49
	Eelgrass percent cover	5	81	83	44
MGW Supplementary Restoration Set	Eelgrass density	31	62	53	70
	Eelgrass canopy height	66	91	122	46
	Eelgrass percent cover	5	81	68	36
MGS Restoration Set	Eelgrass density	31	62	77	101
	Eelgrass canopy height	66	91	172	65
	Eelgrass percent cover	5	81	173	91

Table 2. Budget

Line Item	Approved 5-Year Budget	CY2017 Expenses	CY2018 Expenses	CY2019 Expenses	CY2020 Expenses	CY2021 Expenses	CY2022 Expenses	CY2023 Expenses	Cumulative Charges	Remaining Balance
SCUBA Air fills	$11,556	$367.50	$2,443.00	$1,034.00	$90.00	$973.00	$0.00	$990.00	$5,897.50	$5,658.50
Field Supplies	$3,200	$552.80	$476.00	$1,339.00	$497.04	$386.00	$267.29	$0.00	$3,518.13	($318.13)
Licor Sensors	$560	$912.76	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$912.76	($352.76)
Boat Fuel& Maintenance	$26,750	$683.06	$6,090.46	$3,256.69	$3,955.00	$163.09	$3,980.84	$6,940.06	$25,069.20	$1,680.80
Dive Gear	$5,000	$304.59	$1,085.00	$1,651.00	$876.70	$562.46	$2,017.00	$4,086.00	$10,582.75	($5,582.75)
Hummingbird Software	$1,200	$0.00	$1,200.00	$0.00	$0.00	$0.00	$0.00	$0.00	$1,200.00	$0.00
Lab Work	$10,000	$0.00	$3,192.66	$0.00	$0.00	$0.00	$0.00	$0.00	$3,192.66	$6,807.34
Field & Analytical Support	$8,300	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$8,761.00	$8,761.00	($461.00)
Permitting	$880	$656.62	$0.00	$0.00	$0.00	$0.00	$85.00	$11.51	$753.13	$126.87
subtotal non-payroll	$67,446	$3,477.33	$14,487.12	$7,280.69	$5,418.74	$2,084.55	$6,350.13	$20,788.57	$59,887.13	$7,558.87
subtotal payroll	$194,646	$45,226.00	$43,022.00	$37,993.00	$9,826.00	$4,903.86	$1,841.79	$12,132.46	$154,945.11	$39,700.89
TOTAL	**$262,092**	**$48,703.33**	**$57,509.12**	**$45,273.69**	**$15,244.74**	**$6,988.41**	**$8,191.92**	**$32,921.03**	**$214,832.24**	**$47,259.76**

Table 3. Match

MA DMF Match	2017	2018	2019	2020	2021	2022	2023	Cumulative Match
Personnel	$7,156.46	$7,156.46	$7,156.46	$7,156.46	$7,156.46	$7,156.46	$8,156.46	$51,095.22
Acoustic mapping	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$800.00	$800.00
Equipment	$300.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$300.00
Total Match	**$7,456.46**	**$7,156.46**	**$7,156.46**	**$7,156.46**	**$7,156.46**	**$7,156.46**	**$8,956.46**	**$52,195.22**