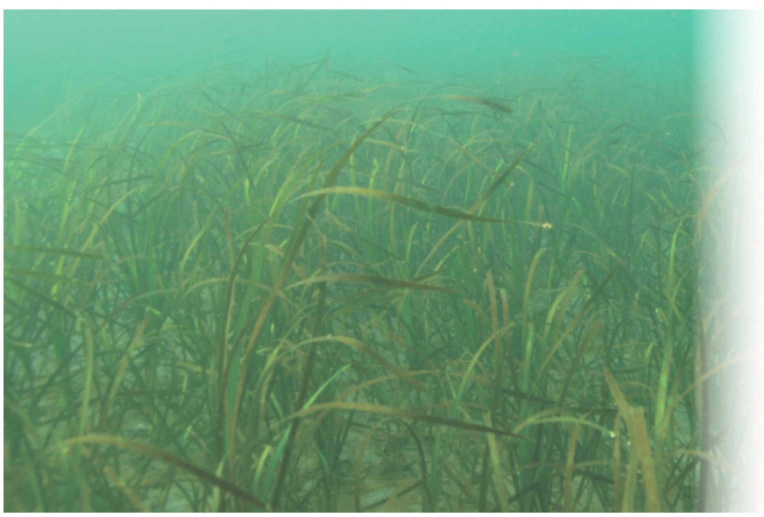

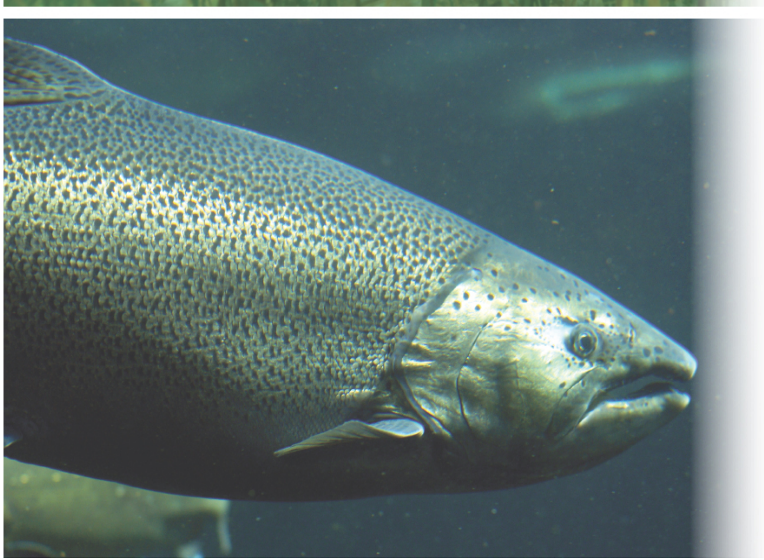

Restoration and Monitoring Report Eelgrass (*Zostera marina*) Restoration in Puget Sound, WA

Prepared for

The Environmental Protection Agency, the Washington State Department of Fish and Wildlife and Washington State Department of Natural Resources

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Prepared by

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Acknowledgements

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Restoration and Monitoring Report

Eelgrass (*Zostera marina*) Restoration in Puget Sound, WA

1.0 INTRODUCTION

The Washington State Department of Natural Resources (DNR) is steward of 2.6 million acres of state-owned aquatic land. The Aquatic Resources Division of DNR manages these aquatic lands for the benefit of current and future citizens of Washington State. DNR's stewardship responsibilities include protection of native seagrasses, an important nearshore habitat in greater Puget Sound. As part of that responsibility, DNR has sought to achieve measurable increases in Puget Sound eelgrass, *Zostera marina L.*, area by strategically targeting eelgrass plantings at sites that have a strong likelihood for restoration success.

Seagrass restoration is challenging and not always successful. A review of 17 projects in the Pacific Northwest, from San Francisco to British Columbia, found eelgrass survived and persisted in 65% (11 projects) (Thom 1990). The cause for failed seagrass transplant efforts can range from site selection and methods, to unforeseen natural events (e.g., algae blooms, storms, turbidity) (Thom 1990, Thom et al. 2014).

Recent eelgrass restoration efforts in Puget Sound have focused on improving site selection to optimize transplant success (Thom et al. 2014). Sites with a high probability of restoration success have been identified through an eelgrass transplant suitability model developed to address the Puget Sound Partnership's "20% More Eelgrass by 2020" goal (Thom et al. 2014). The site selection tool integrated a hydrodynamic model and an eelgrass biomass model along with spatially explicit predictive habitat variables and potential stressors to identify suitable restoration sites throughout greater Puget Sound. Model outputs were filtered with known eelgrass distribution data and stakeholder input to further refine locations of potential restoration sites. The eelgrass restoration site suitability model was tested at five locations throughout Puget Sound; a small fraction of the potential 4,492 hectares of habitat identified by the model as suitable for restoration. There have been additional eelgrass restoration projects implemented based on the site suitability model output (Aston et al. 2015, Vavrinec and Borde 2015). These eelgrass restoration efforts help verify model performance and provide additional nearshore data to include in future model iterations.

The goal of this project was to restore eelgrass at sites throughout greater Puget Sound. In addition to eelgrass transplantation, other project goals were to investigate effects of harvest on donor sites, potential changes in ocean acidification by restored eelgrass beds, and performance of eelgrass transplant survival over time.

Specific objectives of the project were to:

- Select sites based on the results of the "20% More Eelgrass by 2020" project to conduct eelgrass transplants throughout Puget Sound.
- Transplant eelgrass at ten (10) test-transplant sites with a total of 7,800 eelgrass shoots transplanted
- Monitor restoration performance at test-transplant sites to identify eight (8) suitable large-scale transplant sites
- Transplant eelgrass at eight (8) large-scale sites with a total of 162,080 eelgrass shoots transplanted
- Monitor eelgrass shoot survival (density) and natural expansion (distribution) over regular intervals of time at test-transplant and large-scale transplant sites
- Monitor eelgrass shoot density at donor sites over regular intervals of time to track the recovery of the donor beds.
- Analyze autonomous sensor data to determine the effect eelgrass transplants have on water quality

2.0 RESTORATION METHODS

DNR established requirements for the donor, large-scale, and test-transplant sites at which the restoration work was conducted. Across site types, all work was conducted on state-owned aquatic lands deeper than -1.5 m, relative to mean lower low water (MLLW). Candidate donor, large-scale, and test-transplant sites were identified using the model output data from Pacific Northwest National Laboratory (Thom et al. 2014), data from DNR's Submerged Vegetation Monitoring Program, and assessments based on site visits. In February 2016, a draft list of candidate sites was presented to DNR for initial review and feedback. After discussion and preliminary field assessments, these sites were finalized and presented in a subsequent memo as a supplement to the Restoration Plan (Appendix A).

Initially DNR established that restoration must occur at a minimum of 10 test sites and 8 large-scale sites and that eelgrass shoots for these efforts will be harvested from a minimum of 5 healthy donor beds. However, due to the conditions encountered in the field during 2017 (i.e., *Ulva* accumulation at large-scale sites) we modified the restoration requirements to 15 test-transplant, 7 large-scale, and 3 donor sites as depicted below in Figure 1 and described in Sections 2.1 and 2.2.

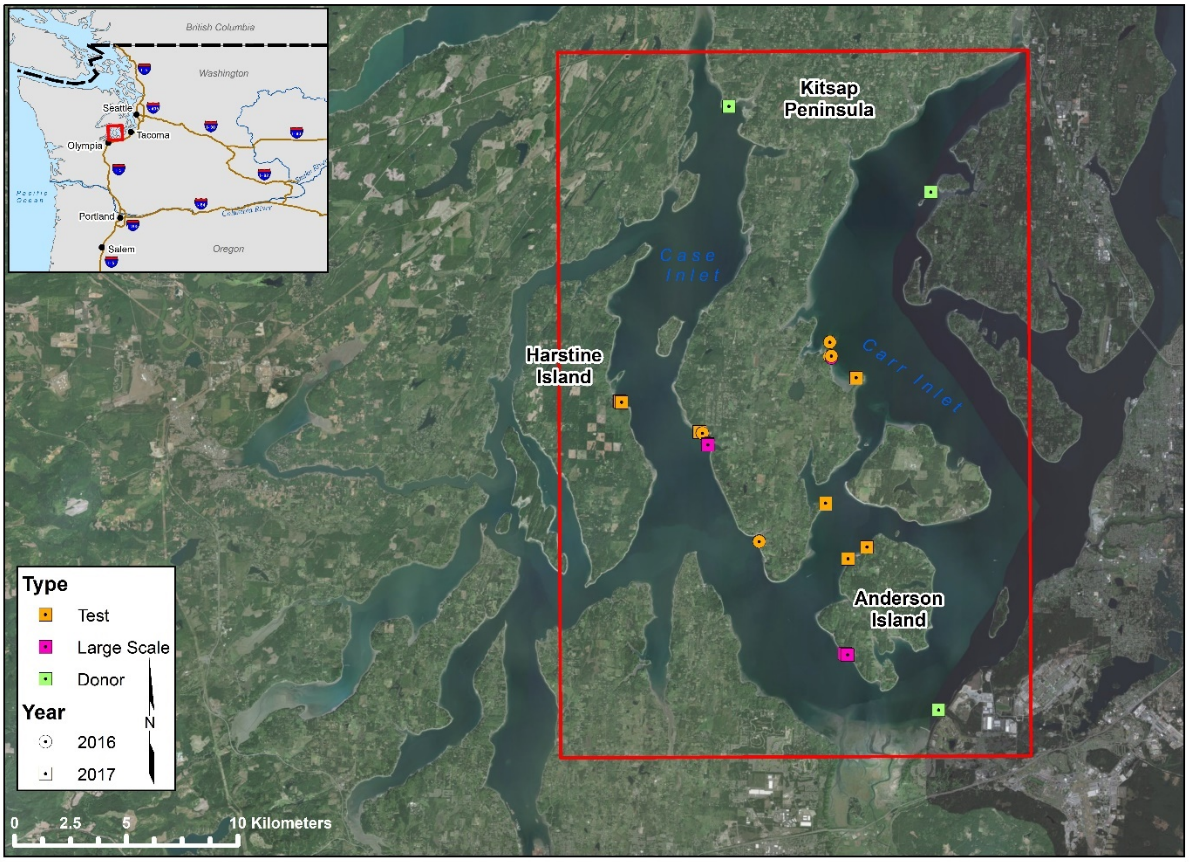


Figure 1. Map of donor, test, and large-scale transplant locations. Some locations have more than one test and large-scale transplant site.

2.1 Donor Site Selection and Delineation

Suitable donor sites were identified during discussions prior to the field season. A number of donor sites were identified but only a few were used for eelgrass restoration donor stock (Table 1 and Figure 2).

Table 1. Donor Sites. The location of each donor site and an estimate of eelgrass harvested at each site for 2016 and 2017. N/A = no eelgrass shoots were harvested from DuPont Wharf in 2016.

DONOR SITE	LATITUDE	LONGITUDE	EELGRASS HARVESTED	
			2016	2017
Cutts Island	47.325325813°N	122.681939252°W	21,630	19,778
Rocky Bay	47.357408162°N	122.802893458°W	25,360	103,333
DuPont Wharf	47.117162715°N	122.669118414°W	N/A	11,245

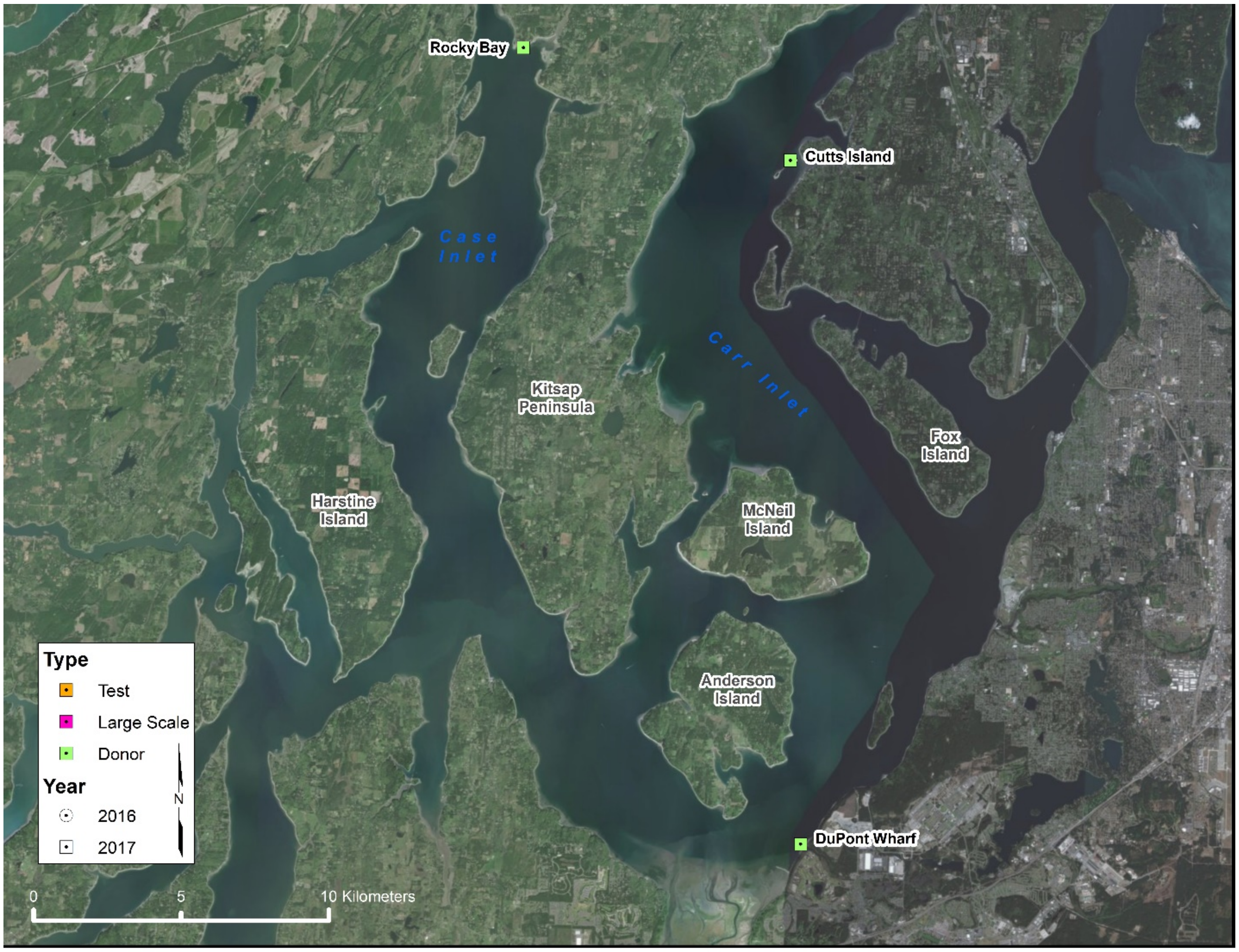


Figure 2. Map of donor sites.

Donor sites were selected through a combination of data review and field verification. Information on candidate sites were researched through DNR's Marine Vegetation Atlas, DNR's eelgrass monitoring data, and local knowledge. After donor sites were initially selected by screening available documentation, top candidates were field verified for areal coverage, bed persistence (see DNR's Submerged Vegetation Monitoring Program data), and dive conditions at the site. At sites that met the necessary criteria and had favorable conditions for diving, two divers deployed a tape between the shallow harvest limit (-1.5 m, MLLW) and the deep edge, perpendicular to shore. Divers then permanently marked the center of the bed along the tape and denoted it with a "C" (Figures 3 and 4, Appendix A: Restoration Plan).

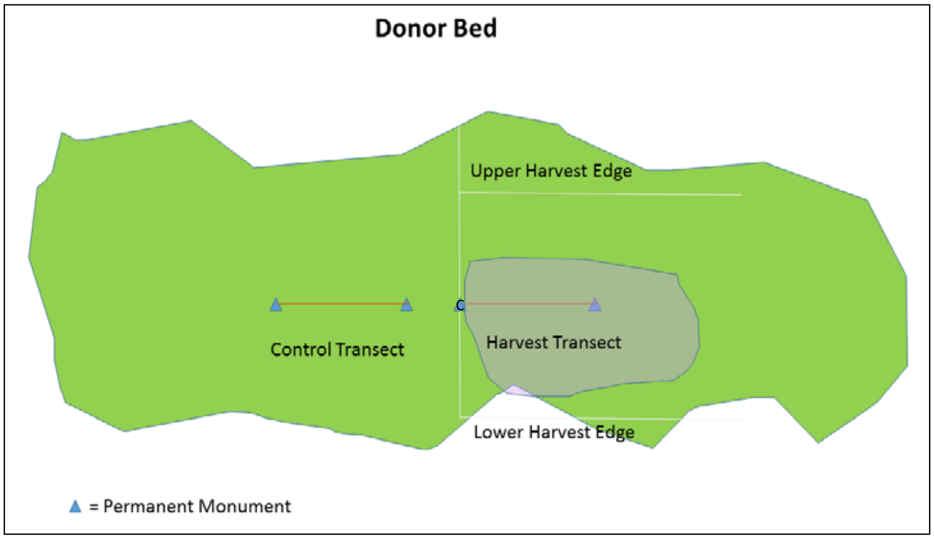


Figure 3. Donor beds consisted of a control transect to track natural variability and a harvest transect. Eelgrass harvest, bounded by the upper and lower harvest edge, occurred along the harvest transect.

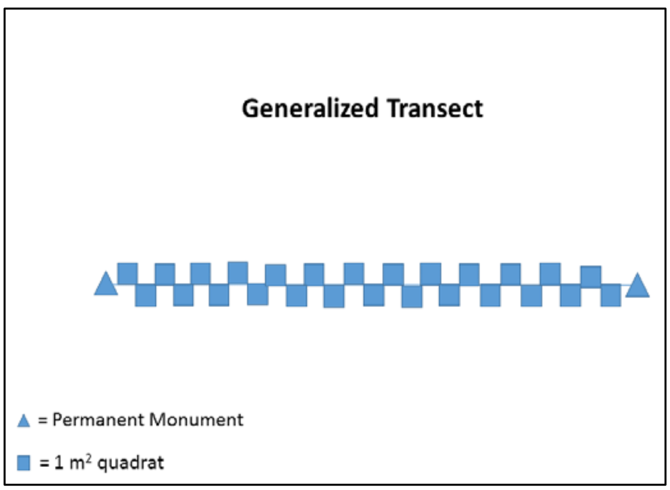


Figure 4. Example of checkerboard harvesting between helical anchors

From this center point, divers laid a 26-meter transect line parallel to shore and marked the end (opposite the permanent center point) with another permanent marker. This served as the permanent monitoring transect that was revisited throughout monitoring efforts for this project. A second 26- meter transect (control transect) was set within the same donor bed but offset from the center marker of the donor harvest transect by a 3-meter buffer and heading in the opposite direction. Divers verified that the depth and density of eelgrass along the control transect is similar to the donor harvest transect before placing the helical anchors and PVC post to demarcate each end of the transect.

To facilitate repeat monitoring, coordinates for each marker were recorded using a survey-grade Global Positioning System (GPS) with a horizontal accuracy of less than 1 meter. Horizontal coordinates are referenced to DNR's preferred standard of "NAD 1983 HARN State Plane Washington South FIPS 4602 Feet" (Table 1).

At two of the donor sites, Rocky Bay and Cutts Island, helical anchors delineated a harvest area and control area within the eelgrass bed. Eelgrass around the control transect was not harvested to track natural variability within the donor site, while eelgrass adjacent to the harvest transect, bounded by the upper and lower harvest edge, was harvested for the test and large-scale transplants. Detailed maps of each donor site are in Appendix B: Site Maps.

2.2 Test-Transplant Site Selection and Delineation

Test-transplant sites were selected based on multiple parameters that factor into habitat suitability and restoration potential. Habitat suitability maps from the Eelgrass Restoration Site Prioritization Geodatabase take substrate, stressors (i.e., overwater structures and armoring), water quality, current and historical extent of eelgrass, and stakeholder input into account to determine where eelgrass is likely restorable (Thom et al 2014). The eelgrass transplant suitability model identified over 4,492 hectares of potential eelgrass restoration habitat throughout Puget Sound (Thom et al. 2014). Candidate test-transplant sites for this project were selected based on output from the eelgrass transplant suitability model. To optimize recovery potential test sites must support a minimum area (12 - 150 m^2) for six eelgrass test plots, and preference was given to areas with potential to support a large-scale transplant site (160 - 2,025 m^2) and natural expansion. Site visits assessed transplant area potential and substrate and ensured eelgrass restoration would not conflict with permitted activities in the area.

During each site visit, suitable areas within each site were delineated using helical anchors and spatial coordinates (e.g., latitude and longitude) for each anchor were recorded (Table 2 and Figure 5). Eelgrass was test transplanted within the boundaries of the helical anchors.

Table 2. Test-Transplant Sites. Site name, year eelgrass was test transplanted and coordinates for helical anchor sub-location.

SITE #	SITE NAME	YEAR	SUB-LOCATION	LATITUDE	LONGITUDE
1	Delano Beach	2016	N	47.25804	-122.73927
			S	47.25828	-122.73809
2	Joemma Beach State Park North	2016	N	47.22589	-122.81332
			S	47.22580	-122.81301
3	Joemma Beach State Park North 1	2017	N	47.22627	-122.81467
			S	47.22623	-122.81460
4	Joemma Beach State Park North 2	2017	N	47.22632	-122.81497
			S	47.22627	-122.81483
5	Taylor Bay	2016	N	47.18309	-122.77779
			S	47.18286	-122.77778
6	Penrose State Park	2016	N	47.26407	-122.73926
			S	47.26387	-122.73926
7	McDermott Point 1	2017	N	47.19868	-122.73923
			S	47.19862	-122.73927
8	McDermott Point 2	2017	N	47.19903	-122.73913
			S	47.19898	-122.73917
9	Anderson Island West 1	2017	N	47.18186	-122.71403
			S	47.18183	-122.71405
10	Anderson Island West 2	2017	N	47.17693	-122.72505
			S	47.17690	-122.72510
11	South Head 1	2017	N	47.24985	-122.72317
12	South Head 2		S	47.24963	-122.72338
13	Fudge Point 1	2017	N	47.23726	-122.86145
			S	47.23725	-122.86138
14	Fudge Point 2	2017	N	47.23774	-122.86269
			S	47.23766	-122.86240
15	Fudge Point 3	2017	N	47.23726	-122.86145

Figure 5. Map of test-transplant locations. Some locations have more than one test-transplant site.

2.3 Large-Scale Site Selection and Delineation

Initially large-scale sites were required to be large enough to support a minimum of 2,025 m^2 of eelgrass restoration area. However, the large-scale sites could be subdivided into smaller areas as long as the sum of the smaller areas was a minimum of 2,025 m^2, and that a minimum of 20,260 eelgrass shoots were planted at a minimum density of 20 shoots m^{-2}. Large-scale sites were selected based solely on the success of a test-transplant site that persisted for a minimum of 6 months. To improve transplant success, the size of the large-scale transplant sites was modified as long as a minimum of 20,260 eelgrass shoots were planted. These adjustment allowed for smaller areas with higher shoot density to be planted.

Large-scale transplant sites were delineated using helical anchors and spatial coordinates (e.g., latitude and longitude) for each anchors were recorded (Table 3 and Figure 6). Eelgrass was planted within the boundaries of the helical anchors.

Table 3. Large-Scale Transplant Sites. Site name, year eelgrass was transplanted and coordinates for helical anchor sub-location (transplant corners). Note: Anderson Island South 1 & 2 only have shallow corner markers.

SITE #	SITE NAME	YEAR	SUB-LOCATION	LATITUDE	LONGITUDE
1	Delano Beach	2016	SE	47.25753	-122.73820
			SW	47.25754	-122.73814
			NE	47.25784	-122.73817
			NW	47.25784	-122.73824
2	Joemma Beach State Park 1	2016	SE	47.22180	-122.80988
			SW	47.22174	-122.80997
			NE	47.22199	-122.80993
			NW	47.22197	-122.81002
3	Joemma Beach State Park 2	2017	SE	47.22145	-122.80969
			SW	47.22141	-122.80973
			NE	47.22151	-122.80975
			NW	47.22146	-122.80984
4	Joemma Beach State Park 3	2017	SE	47.22132	-122.80962
			SW	47.22128	-122.80979
			NE	47.22142	-122.80965
			NW	47.22141	-122.80973
5	Joemma Beach State Park 4	2017	SE	47.22115	-122.80956
			SW	47.22112	-122.80964
			NE	47.22123	-122.80963
			NW	47.22128	-122.80979
6	Anderson Island South 1	2017	E	47.13892	-122.72556
			W	47.13875	-122.72511
7	Anderson Island South 2	2017	E	47.13844	-122.72417
			W	47.13825	-122.72369

Figure 6. Map of large-scale transplant locations. Some locations have more than one large-scale transplant site.

2.4 Transplant Methods

As the project progressed the team modified the transplant approach to favor more efficient and cost-effective methods. The 2016 transplant effort used the Burlap Strip Method, and the 2017 effort used the Bare-root Method, described below.

2.4.1 Burlap Strip Method (2016 Planting)

The Burlap Strip Method is a modification of the Tortilla Method (Pickerell et al. 2012). The Tortilla Method used circular patches of burlap with eelgrass shoots woven through holes in the burlap; the strip method substituted the circular patch with a rectangular strip of burlap. After eelgrass was harvested from donor sites, it was transported in coolers filled with sea water to staging areas where strips of burlap were prepped with eelgrass.

The initial 2016 test-transplant sites at Penrose State Park, Delano Beach, Taylor Bay and Joemma Beach State Park were planted at a density of 20 shoots m^{-2} – four (4), 12 cm by 45 cm strips of burlap with 5 eelgrass shoots in each. At each test-transplant site, two helical anchors were installed approximately 25 m apart to demarcate the shallow edge of a suitable test-transplant site (Table 2). Test-transplant plots (5 x 5 m) were planted at the first helical anchor (0 m) and at 10 and 20 meters thereafter (Figure 7). Divers planted each plot in a checkerboard pattern that established 13 m^2 of planted area at a shoot density of 20 shoots m^{-2} (260 shoots $plot^{-1}$, 780 shoots test $site^{-1}$) (Figure 7).

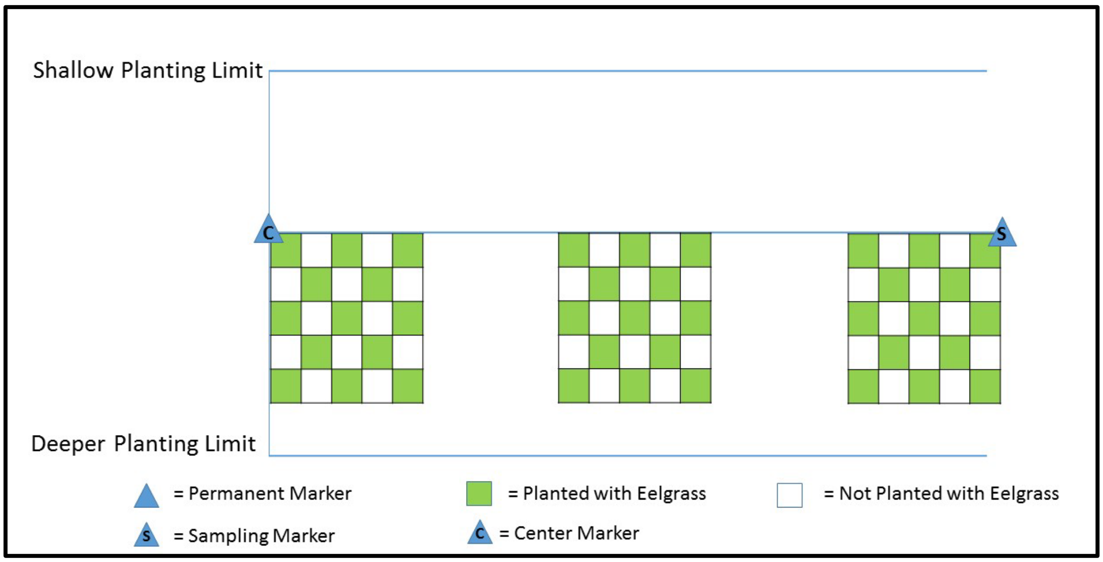


Figure 7. 2016 test-transplant site planting schematic. Divers planted 13 m^2 of each test plot with 20 shoots m^{-2} (260 shoots $plot^{-1}$, 780 shoots test $site^{-1}$).

In June and July 2016, the shoot density for the large-scale transplant efforts at Delano Beach and Joemma Beach State Park increased to approximately 60-126 shoots m^{-2} to better mimic natural densities. To achieve the higher shoot density, six (6) burlap strips were planted per square meter with 21 shoots woven into each strip, or "Planting Unit (PU)" (Photograph 1). When transplanting the PUs, divers used a 5- by 1-meter grid to guide the eelgrass transplant effort. The grid was oriented along the shallow edge of the site and flipped down slope towards the deep edge 7 times for a total of a 5 m by 8 m area planted. After transplanting the 5 m by 8 m swath, the grid was re-positioned at the shallow edge adjacent to the previously planted swath. Transplanting commenced until the divers planted 20 m alongshore or the equivalent of four, 5 m wide, swaths (Figure 8). Each PU was planted in an approximately 12 cm by 45 cm trench dug by divers. PUs were staked in place using two 30 cm (12 in) staples, and sand was backfilled on top.

Photograph 1. Crew member pulling shoots through a burlap strip to create a planting unit.

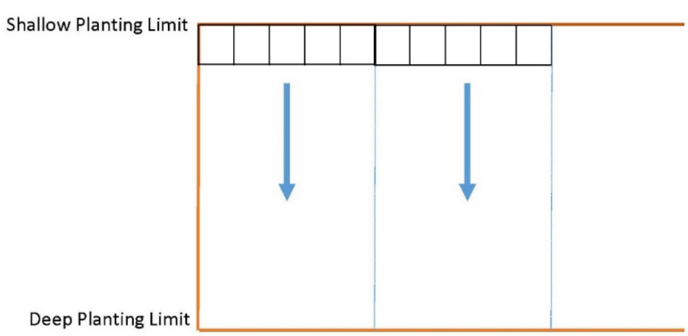


Figure 8 . Schematic of large-scale planting by divers using 5 by 1 m grid. The grid was flipped 7 times to plant a 5 by 8 m swath. The grid was re-positioned at the shallow edge and planting repeated until the 8 x 20 m area was transplanted.

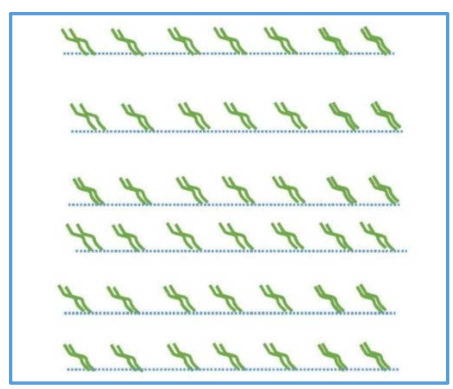


Figure 9. Example of planted 1 m^2 quad with 6 PU's (strips of burlap with eelgrass).

2.4.2 Bare-root Method (2017 Planting)

The bare-root seagrass transplant method is a technique that uses whole seagrass plants or shoots with intact rhizome and roots but without any sediment from donor sites (Davis and Short 1997). Individual shoots or groups of shoots are planted at restoration sites by inserting the rhizome just below the sediment surface and relying on the cohesiveness and weight of the overlying sediment to hold the plants in place. Practitioners have also used various anchoring systems to hold plants in place such as metal bars (Phillips 1990, this project), landscape staples (Derrenbacker and Lewis 1982, Fonseca et al. 1982), bamboo staples (Davis and Short 1997) and popsicle-sticks (Merkel 1988). Another methods that incorporates the concept of the bare-root method but eliminates the use of divers is the TERFS method – Transplanting Eelgrass Remotely with Frames System (Fonseca et al. 1998, Kopp and Short 2001, Short et al. 2002).

Eelgrass at 11 of the test-transplant sites and 5 of the large-scale sites were planted using variations of the bare-root method. Groups of shoots (turfs) were anchored with metal landscape staples at 10 test-transplants sites and the 5 large-scale sites (Derrenbacker and Lewis 1982, Fonseca et al. 1982, Fonseca et al. 1998). At the last test-transplant site, bare-root eelgrass plants were attached to 5, 50 cm lengths of rebar using hemp cord. Tying multiple eelgrass shoots to rebar or planting small turfs (clumps of 5-15 shoots) varied from the Horizontal Rhizome Method (Davis and Short 1997) in that more than two eelgrass shoots (i.e., a group of shoots or turf) were anchored for each planting unit. With the exception of Fudge Point 3 test-transplant site, all the 2017 test-transplant sites and large-scale transplant sites used the eelgrass turf method (referred to as 'turf'). Divers stapled down the turf with 30 cm (12 in) staples to hold the shoots in place.

2.4.2.1 Weighing and Enumerating Shoots (2017 Planting)

For the 2017 field season, divers harvested eelgrass in small mats (approx. 10 x 10 cm) with intact rhizome structure. These mats of harvested eelgrass were kept in catch bags and the sediment was carefully removed from each mat. Full catch bags were brought up to the support vessel and contents were transferred to laundry bags and carefully dunked in seawater to wash away any remaining sediment. Each laundry bag of eelgrass was drained of water for 5 minutes. After draining, each bag was weighed and subsampled to provide a conversion factor for weight and shoot counts. A subsample consisted of weighing and counting the number of shoots in a mat; the weight and tally were recorded with its corresponding laundry bag number and the subsample was returned to the original laundry bag (see supplemental data <2017_Zm_RestorationMonitoring_data.xlsx>). Each bag was returned to cool water immediately after subsample data was collected. A spreadsheet was used for each harvest bed to generate a linear regression between eelgrass weight and shoot count while accounting for differences in eelgrass morphology per donor site. Each subsample from each laundry bag provided a data point to factor into the conversion to extrapolate the total shoot weight estimated to give the number of shoots needed. A 10% buffer was added to the weight of any conversion calculations to ensure divers err on the side of having adequate eelgrass to account for potential damage and loss during harvest and transplanting. All harvested eelgrass was replanted in another location to meet the minimum requirements of 780 shoots per test site (minimum of 260 shoots test plot^{-1}, 3 plots per site) and 20,260 shoots per large-scale site.

2.4.2.2 Transplanting Method

Using the weight-to-shoot count conversion factor, crew members calculated the weight of eelgrass needed for a specific area based on proposed planting densities. Thus, if a test-transplant plot required 260 eelgrass shoots, the weight equating to this number of eelgrass shoots was calculated using the conversion factor from the enumeration method. A dive team was then provided a bag with the necessary weight of eelgrass calculated, plus a 10% buffer, to approximate the designated planting density. Divers loosened the sediment with a gardening hand fork/trowel and gently placed each turf of eelgrass in and secured the plants to the sediment with a staple. The same checkerboard pattern from the burlap method was used for planting (Figure 7). The slightly different planting methods used across sites is summarized in Table 4 and Table 5.

Two test plot configurations were used at 2017 sites:

1. Plots were 5 m x 5 m, planted as a checkerboard pattern.
2. Plots were 1 m x 2 m, planted evenly across all squares with no empty squares.

Table 4. Summary of Test-Transplant Sites, methods used, and quantity and size of test-transplant plots.

SITE	YEAR	METHOD	PLOT QUANTITY	PLOT SIZE	EFFECTIVE AREA PLANTED
Delano Beach	2016	burlap	3	5 x 5 m	13 m^2 plot^{-1}
Joemma Beach State Park North	2016	burlap			
Taylor Bay	2016	burlap			
Penrose State Park	2016	burlap			
Joemma Beach State Park North 1	2017	turf	3	5 x 5 m	13 m^2 plot^{-1}
Joemma Beach State Park North 2	2017	turf			
McDermott Point 1	2017	turf	3	5 x 5 m	13 m^2 plot^{-1}
McDermott Point 2	2017	turf			
Anderson Island West 1	2017	turf	1	1 x 2 m	2 m^2 plot^{-1}
Anderson Island West 2	2017	turf			
South Head 1	2017	turf			
South Head 2	2017	turf			
Fudge Point 1	2017	turf			
Fudge Point 2	2017	turf			
Fudge Point 3	2017	rebar	1	0.5 x 0.5 m	0.25 m^2 plot^{-1}

Table 5. Large-scale Transplant Site Names, year planted and site dimension. Site dimension is less than effective area planted with eelgrass.

SITE NAME	YEAR	METHOD	SITE DIMENSIONS
Delano Beach	2016	burlap	5 x 35 m
Joemma Beach State Park 1	2016	burlap	
Joemma Beach State Park 2	2017	turf	8 x 20 m
Joemma Beach State Park 3	2017	turf	
Joemma Beach State Park 4	2017	turf	8 x 20 m
Anderson Island South 1	2017	turf	4 x 40 m
Anderson Island South 2	2017	turf	

3.0 EELGRASS RESTORATION

3.1 Test Plots

A goal of the project was to transplant eelgrass at 10 test-transplant sites for a total of 7,800 eelgrass shoots planted. Sites with evidence of test-transplant success 6 months to a year after planting were considered for large-scale transplanting. In some cases, successful test-transplant sites from other eelgrass restoration projects were used to indicate a suitable site for large-scale restoration. For example, successful eelgrass test-transplant sites at Delano Beach and Joemma Beach State Park were used to support the 2016 and 2017 large-scale transplants at these sites (Aston et al. 2015, Thom et al. 2014).

Although the project originally set out to plant 10 test-transplant sites, there was a need after the first year for more test sites to identify additional large-scale sites. Therefore, in 2017 one large-scale transplant site was replaced with five test-transplant sites. The exchange increased the number of test-transplant sites from the scheduled 10 to 15. The change also increased the opportunity to identify suitable large-scale transplant sites for future efforts. One additional test-transplant site at Fudge Point was planted using rebar in place of burlap or staples as a pilot study to compare methods. Table 6 summarizes the test plot transplant effort for the 2016 and 2017. Over the course of the 2 -year project, the number of shoots transplanted in test plots totaled 13,597 shoots, exceeding the project goal by 2,677 shoots (Table 6).

Table 6. Test-Transplant Site Summary.

TEST SITE	TRANSPLANT DATE	METHOD	SITE AREA	AREA PLANTED	SHOOT DENSITY (shoots m^{-2})	SHOOTS PLANTED
Delano Beach	2016/04/21	burlap	75	39	20	780
Joemma Beach State Park North	2016/05/18	burlap	75	39	20	780
Taylor Bay	2016/05/19	burlap	75	39	20	780
Penrose State Park	2016/05/20	burlap	75	39	20	780
					TOTAL 2016	**3,120**
					Objective	**3,120**
					Variance (± shoots)	**0**
Joemma Beach State Park North 1[1]	2017/05/04	turf	75	39	27	1,042
Joemma Beach State Park South 2[1]	2017/05/04	turf	75	39	27	1,052
McDermott Point North[1]	2017/05/05	turf	75	39	25	994
McDermott Point South[1]	2017/05/05	turf	75	39	26	998
Anderson Island West 1[2]	2017/05/05	turf	10	6	145	869
Anderson Island West 2[2]	2017/05/05	turf	10	6	145	869
South Head 1	2017/07/16	turf	10	6	195	1,172
South Head 2	2017/07/16	turf	10	6	169	1,015
Fudge Point 1	2017/07/19	turf	10	6	193	1,160
Fudge Point 2	2017/07/19	turf	10	6	176	1,056
Fudge Point 3	2017/07/19	rebar	1	1	250	250
					TOTAL 2017	**10,477**
					Objective	**7,800**
					Variance (± shoots)	**2,677**
					GRAND TOTAL	**13,597**
					Objective	**10,920**
					Variance (± shoots)	**2,677**

[1] = Planting configuration 1; 5m x 5m, planted as a checkerboard pattern starting in the top left.
[2] = Planting configuration 2; 1m x 2m, planted evenly across entire area

Photograph 2. Eelgrass test-transplants at Joemma Beach State Park using the burlap strip method (2016)

3.2 Large-Scale Sites

The project originally scheduled to plant eight (8) large-scale transplant sites with a minimum of 20,260 shoots at each site (grand total: 162,080 shoots). Prior to the 2017 field season the goal for eight large-scale transplant sites was reduced by one and replaced with the addition of 5 test-transplant sites. The change was made because the project did not have any suitable areas for large-scale transplanting and more test-transplant sites would increase the probability for future work. Table 7 summarizes the large-scale site effort for 2016 and 2017. After the large-scale transplant site count adjustment, the estimated number of shoots planted over the two-year project totaled 155,092 shoots, exceeding the updated project goal (141,820 shoots) by 13,272 shoots.

Table 7. Large-Scale Site Summary

LARGE-SCALE SITE	TRANSPLANT DATE	METHOD	AREA PLANTED	SHOOT DENSITY (shoots m^{-2})	SHOOTS PLANTED
Delano Beach	2016/06/19	burlap	210	99	20,850
Joemma Beach State Park 1	2016/07/28	burlap	161	126	21,460
				TOTAL 2016	**42,310**
				Objective	**40,520**
				Variance (± shoots)	**+1,790**
Joemma Beach State Park 2	2017/05/07	turf	160	104	16,570
Joemma Beach State Park 3	2017/05/19	turf	160	160	24,734
Joemma Beach State Park 4	2017/05/22	turf	160	163	26,149
Anderson Island South 1	2017/06/02	turf	160	132	20,500
Anderson Island South 2	2017/06/04	turf	160	155	24,830
				TOTAL 2017	**112,782**
				Objective	**101,300**
				Variance (± shoots)	**+11,482**
				GRAND TOTAL (2016 + 2017)	**155,092**
				Objective	**141,820**
				Variance (± shoots)	**+13,272**

3.2.1 Delano Beach

A large-scale site was planted at Delano Beach in 2016. A second large-scale site was planned for 2017 but an overabundance of *Ulva* during the scheduled transplanting in May forced the project to substitute a second large-scale transplant site at Joemma Beach State Park, south of the 2016 Joemma Beach State Park 1 site. Eelgrass from the DuPont Wharf donor site was used to plant half of the Joemma Beach State Park 2 large-scale site. The other half was planted with eelgrass from the Rocky Bay donor site (Figure 2).

3.2.2 Joemma Beach State Park

In 2016, a large-scale eelgrass transplant site was planted at Joemma Beach State Park 1, while an additional 3 large-scale transplant sites were planted in 2017. The eelgrass transplanted at Joemma Beach State Park 1 was from the Rocky Bay donor site. In 2017, the eelgrass transplanted at Joemma Beach State Park 2 was a mix of plants from DuPont Wharf and Rocky Bay donor sites, and the eelgrass for the remaining two sites (Joemma Beach State Park 3 & 4) came from Cutts Island and Rocky Bay donor sites (Figure 2). The concentrated focus of large-scale sites established at Joemma Beach State Park was due to the success observed in previous test and large-scale transplant efforts.

3.2.3 Anderson Island, South

In 2017, two large-scale transplant sites were planted at South Anderson Island. Each site, Anderson Island South 1 and Anderson Island South 2 was 4 x 40 m. Divers transplanted small turfs of eelgrass (~10-15 shoots), harvested from the Rocky Bay donor site (Figure 2), in every square meter.

4.0 EELGRASS MONITORING

4.1 Donor Sites

4.1.1 DuPont Wharf

Approximately 11,245 shoots were harvested from DuPont Wharf in May 2017. The Dupont Wharf donor site was removed from future harvest, therefore no post-harvest counts were taken after the May 2017 harvest effort (Table 8).

Table 8. 2017 Donor Site Shoot Density. Average shoot density (± se) from 26 - 0.25 m^2 quadrats sampled in May and July 2017 along the control transect and the harvest transect. The harvest transect was measured the same day post-harvest. Post-harvest monitoring did not occur at DuPont Wharf.

	CONTROL average (±se)	PRE-HARVEST average (±se)	POST-HARVEST average (±se)
May 2017			
Cutts Island	25.3 (3.1)	25 (2.7)	21.0 (2.3)
DuPont Wharf	21.2 (1.4)	12 (1.3)	
Rocky Bay	44.8 (3.9)	116 (8.3)	68 (6.8)
July 2017			
Cutts Island	16.2 (2.4	22.3 (3.6)	18.5 (2.4)
Rocky Bay	99.5 (5.5)	70.8 (3.3)	52.8 (3.1)

4.1.2 Rocky Bay

In early May 2017, pre-harvest eelgrass counts were measured at the Rocky Bay donor site. On the same day after harvesting eelgrass for transplanting, post-harvest conditions were measured. There were statistically significant differences between the pre-harvest eelgrass counts and post-harvest counts along the harvest transect (p<0.0001); as expected shoot counts decreased post-harvest. There was also a statistically significant difference between the control counts and both the pre- and post-harvest counts (p <0.0001 and p=0.004, respectively). Both the pre- and post-harvest sites have more eelgrass in sum and in average than the control transect in May 2017 (Table 8). However, in the July 2017 monitoring event, roughly 10 weeks (70 days) after harvest, the control counts were significantly higher than the pre- and post- harvest counts (p<0.0001 and p<0.0001, respectively). It was calculated using the weight-to-shoot count conversion factor (Section 2.4.2.1) that 128,693 shoots were harvested from Rocky Bay over the course of the 2 -year project. In 2016, 25,360 shoots were harvested and transplanted at Joemma Beach State Park, and Taylor Bay. In 2017, 103,333 shoots were harvested from Rocky Bay and all were transplanted at Joemma Beach State Park 2, 3 and 4, Anderson Island South 1 and 2, and the Fudge Point test-transplant sites 1, 2 and 3.

4.1.3 Cutts Island

A total of 41,408 shoots were harvested from Cutts Island donor site. In 2016, 21,630 shoots were harvested and planted at Delano Beach and Penrose State Park. In 2017, an additional 19,778 shoots were harvested and planted at the following test-transplant sites: South Head 1 and 2, McDermott Point 1 and 2, Anderson Island West 1 and 2, and Joemma Beach State Park North 1 and 2. Cutts Island donor site showed no significant change in shoot count between pre- and post-harvest from the May 2017 and July 2017 harvest activities (p=0.25 and 0.37, respectively).

Cutts Island had an abundance of ghost shrimp burrows present and a sand spit at the site appeared to shift eastwardly between 2016 and 2017. Measurements from monitoring anchors at the Cutts Island donor site show the eelgrass bed is moving with the sand spit. Overall, the monitoring data show the donor bed recovered from the 2016 eelgrass harvest (Table 8).

4.2 Test Plots

Eelgrass test-transplant site monitoring occurred in reference to the permanent corner markets established during the initial planting. Divers located the permanent markers at each test plot within each site and counted all shoots within the planted area (Table 9). Typically, quantitative monitoring occurred at 6 – 12 months post transplanting to allow eelgrass to establish itself and to minimize excessive costs related to frequent monitoring. However, all of the test-transplant sites planted in May 2017 were monitored in July 2017 to determine transplant status prior to winter and in anticipation of funding limitations for future monitoring efforts.

Table 9. Test-Transplant Plot Monitoring Results. Total eelgrass shoot counts measured in July 2017 at 10 of the 15 test-transplant sites. Eelgrass transplanted at South Head 1 & 2 and Fudge Point 1, 2 & 3 on July 16 and July 19, 2017 respectively, were not monitored.

Site Name	Year	Sub-Location	Date Monitored	Plot #	Total Shoot Count
Delano Beach	2016	N	2017/07/17		1
	2016	S			
Joemma Beach State Park North	2016	N	2017/07/18		527
		S			
Joemma Beach State Park North 1	2017	N	2017/07/18		265
		S			
Joemma Beach State Park North 2	2017	N	2017/07/18		468
		S			
Taylor Bay	2016	N	2017/07/18		0
		S			
Penrose State Park	2016	N	2017/07/17		4
		S			
McDermott Point 1	2017	N	2017/07/17		0
		S			
McDermott Point 2	2017	N	2017/07/17		0
		S			
Anderson Island West 1	2017	N	2017/07/17	1	55
				2	132
				3	48
Anderson Island West 2	2017	S	2017/07/17	1	6
				2	52
				3	11

4.2.1 Delano Beach

The Delano South 2016 site had muddy, anoxic sediment which likely lead to the total loss of eelgrass at the site. Delano North 2016 had only 1 eelgrass shoot; sediment disturbance and liquefied geoduck harvest holes were evident throughout the area. It is likely that the planting occurred too shallow for plant survival particularly considering the accessibility to recreational geoduck harvesters.

A subsequent visit in mid May 2017 determined the site unsuitable due to excessive green algae (ulvoids). The presence of excess algae at the site was confirmed in late May and subsequently all helical corner anchors were removed.

In July 2017, two additional test-transplant sites were planted on the east side of Delano Beach: South Head 1 and 2. A qualitative assessment was performed one week after transplanting and confirmed that eelgrass was still present.

4.2.2 McDermott Point

The two McDermott Point Sites (1 and 2) were planted in May 2017 and monitored in July 2017. No eelgrass was present during the July monitoring effort and the loss could be attributed to an abundance of *Ulva* observed at the site during monitoring. All gear was removed from the area and the site was determined to be unsuitable.

4.2.3 Anderson Island West

The two Anderson Island West sites (1 and 2) were also planted in early May 2017 and monitored in July. Monitoring observed eelgrass under a thick layer of *Ulva*; a census of the surviving eelgrass was conducted. Approximately 20% of the transplanted eelgrass had survived to the monitoring date in July 2017 (Table 10).

Table 10. Anderson Island West 1 (North) and 2 (South) eelgrass test site monitoring data. Both sites were planted in May 2017 and monitored in July 2017.

Site	Sub-location	Plot	Planted (5 May 2017)*	Monitored (17 July 2017)*	% Survival
Anderson Island West 1	N	1	289	55	19
		2	289	132	46
		3	289	48	17
Anderson Island West 2	S	1	289	6	2
		2	289	52	18
		3	289	11	4
TOTAL			1,734	304	18

*Both North and South were planted in May 2017 and monitored in July 2017.

4.2.4 Penrose State Park

Eelgrass test plots were planted at Penrose State Park in May 2016. A qualitative assessment using remote video in June 2016 determined eelgrass was present. During the 2017 monitoring event at the Penrose site, only 4 shoots were found and all were dying; likely due to a thick layer of *Ulva*. After the monitoring event, all gear was removed from the area and the site was determined to be unsuitable.

4.2.5 Taylor Bay

Eelgrass test plots were planted in Taylor Bay in May 2016. A qualitative monitoring effort at test-transplant sites was conducted in July 2016. There were few eelgrass shoots remaining and plants appeared distressed; the site had silty sediment, a high amount of organics, and drift macroalgae. A quantitative monitoring effort was completed in July 2017 and no eelgrass was found; a 2-foot-thick layer of *Ulva* blanketed the transplant area. After no eelgrass was found, all gear was removed from the area.

4.2.6 Joemma Beach State Park

Transplants at Joemma Beach State Park North (2016) did not appear healthy enough to justify a large-scale transplant but the transplanting was not considered unsuccessful. Joemma Beach State Park North (2016) had evidence of tampering and liquefied geoduck harvest holes throughout the area. There was also evidence of drift *Ulva* accumulating on the staples used to hold the burlap strips in place (Photograph 3). To further explore the transplant potential at Joemma Beach State Park North (2016), two additional test-transplant sites were completed in May 2017 (Table 11). All test-transplant sites at Joemma Beach State Park North were monitored in July 2017. Survival at the three sites ranged from 25-44% with an overall average of 34%.

Photograph 3. Visible sod stake accumulating drift algae at Joemma Beach State Park North (2016)

Table 11. Joemma Beach State Park eelgrass test site monitoring data.

SITE NAME	YEAR	PLANTED (18 May 2016, 4 May 2017)	MONITORED (18 July 2017)	% SURVIVAL
Joemma Beach State Park North	2016	1,560	527	34
Joemma Beach State Park North 1	2017	1,042	265	25
Joemma Beach State Park North 2	2017	1,052	468	44
TOTAL		3,654	1,260	34

4.2.7 Fudge Point

The Fudge Point sites (1, and 2) and the rebar plot (3) established in 2017 appear to be surviving post-harvest. Five days after planting, eelgrass was confirmed to still be present. The Fudge Point test-transplants were not quantitatively monitored for post-harvest counts beyond the July 24, 2017 qualitative assessment.

4.2.8 Summary

No additional area was identified as suitable for a large-scale transplant in 2017. Transplant success and performance of test-transplant sites from 2016 does not support a large-scale effort at Taylor Bay, Penrose State Park, and Delano Beach. However, further monitoring of 2017 test- and large-scale transplant sites will gauge success of all eelgrass transplants and to identify potential sites for future efforts.

4.3 Large-Scale Sites

Due to the timing of 2017 large-scale eelgrass transplant efforts a comprehensive monitoring was not performed. Monitoring of the 2017 large-scale sites will be conducted in 2018 to determine transplant success. Table 12 summarizes shoot density from a few samples measured at the large-scale Joemma Beach State Park 3 (2017) and Delano Beach (2016) sites in July 2017.

Table 12. Large-Scale Monitoring Results. Eelgrass shoot density (shoots m^{-2} ± se) measured at two large-scale eelgrass transplant sites in July 2017.

Site Name	Year Planted	Date Monitored	Density [shoots m^{-2} (±se)]
Joemma Beach State Park 3	2017	2017/07/18	37.4 (3.8)
Delano Beach	2016	2017/07/17	0

4.3.1 Joemma Beach State Park

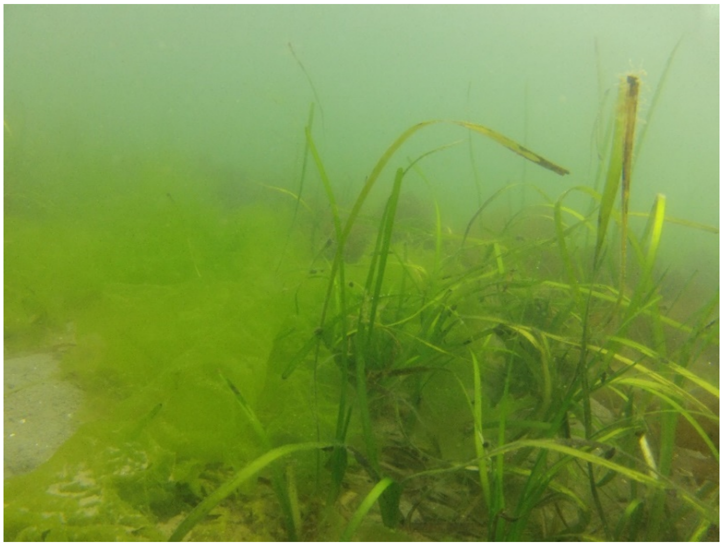
A quantitative survey of the Joemma Beach State Park 1 (2016) large-scale transplant was completed on June 27, 2017. Thirty-two (32) random 0.25 m^2 quadrats were sampled throughout the 160 m^2 transplant area. Average shoot density was 674 ± 34 shoots m^{-2} compared to the original transplant density of 504 shoots m^{-2}. There was no evidence of eelgrass growing outside the original 160 m^2 transplant area but it was clear the eelgrass was expanding and the transplanted rows of plants were coalescing through vegetative growth (Photograph 4).

Photograph 4. Large-scale eelgrass transplant site at Joemma Beach State Park 1 planted in 2016. Original transplant shoot density was 504 shoots m^{-2} and measured shoot density in 2017 was 674 ± 34 shoots m^{-2}.

4.3.2 Delano Beach

A qualitative monitoring effort at the Delano Beach (2016) large-scale eelgrass transplant site was conducted on July 19, 2016. The transplants were present with some evidence of disturbance to the burlap strips and the presence of filamentous algae (Photographs 5 and 6). At the time, the disturbance to the burlap strip planting units and the presence of algae did not suggest major factors that would inhibit transplant success as observed in 2017. In April 2017, the Delano Beach (2016) large-scale site was re-visited to determine presence of eelgrass that would support efforts to establish two more large-scale sites for transplanting in 2017. A qualitative assessment in April 2017 found sparse eelgrass and very little presence of algae, typical of early spring conditions. Two additional sites were established for transplanting later in 2017.

Photograph 5. Delano Beach 2016 large-scale eelgrass transplant site with evidence of disturbance to the burlap strip planting unit. Photograph taken in July 2016, one month after transplanting.



Photograph 6. Delano Beach 2016 large-scale eelgrass transplant site with evidence of green algae (ulvoids). Photograph taken in July 2016, one month after transplanting.

In July 2017, the dive team planned to transplant eelgrass in two new sites at Delano Beach but were hindered by an abundance of green algae (ulvoids). In addition, no eelgrass was found by divers during a qualitative survey of the 2016 Delano Beach large-scale transplant site in July 2017. In the end, the two 2017 large-scale sites were abandoned and the Delano Beach (2016) large-scale site was considered not successful (i.e., 0 shoot density) (Table 12).

5.0 WATER QUALITY MONITORING

An additional element to eelgrass restoration is the effect primary producers have on nearshore marine water chemistry. Studies have demonstrated the ability of seagrass to absorb excess CO_2 in marine systems buffering water column pH (Marbà et al. 2006, Unsworth et al 2012, Hendricks et al. 2014). The physiological processes related to photosynthesis enable eelgrass to make these changes to nearshore waters that support its productivity as CO_2 levels increase (Zimmerman et al. 2015). In an effort to document the effect of eelgrass restoration projects on water quality, a suite of sensors were deployed in eelgrass and adjacent unvegetated areas at Joemma Beach State Park and Delano Beach. The objective of the sensor deployment was to track water quality parameters between the vegetated, eelgrass habitat and unvegetated, bare sediment habitat.

The deployed sensors measured pH, temperature, conductivity and temperature, and Photosynthetically Active Radiation (PAR) over two deployment periods from May to late August 2017 (Gaeckle 2017; see supplemental data <Zm_RestorationMonitoring_data.xlsx>). A handheld temperature and conductivity sensor, CastAway-CTD (SonTek), was used to collect point measurements adjacent to the sensor deployments on August 20, 2017, the day all sensors were retrieved from the field.

5.1 Water temperature

Water temperature sensors (Onset HOBO TidBit v2) were deployed in eelgrass and an unvegetated area at both Joemma Beach State Park and Delano Beach from May 1 through August 19, 2017. Sensors were deployed at approximately the same depth (±0.2 m) and were programmed to record water temperature every 10 minutes. Water temperatures throughout the deployment ranged from a minimum of 9.5 °C to a maximum of 17.2 °C (Table 13).

Table 13. Daily average water temperatures (°C) measured in the eelgrass and unvegetated locations at Joemma Beach State Park and Delano Beach eelgrass transplant sites. Temperature was measured using HOBO Tidbit v2 Temp Loggers (Gaeckle 2017).

	Joemma Beach State Park		Delano Beach	
	Eelgrass	Unvegetated	Eelgrass	Unvegetated
Maximum (°C)	15.6	15.5	17.2	16.9
Minimum (°C)	9.7	9.6	9.5	9.5
Average (± se)	13.0 (0.2)	13.0 (0.2)	13.4 (0.2)	13.4 (0.2)

The maximum measured water temperature of 26.94 °C was measured in eelgrass at Delano Beach at 12:50 PM on June 24, whereas a recording of 24.68 °C was recorded at 1:50 PM on June 25 in unvegetated habitat at Delano Beach. At Joemma Beach State Park, the highest recorded temperature was 26.72 °C and 24.97 °C in eelgrass and unvegetated habitat, respectively, measured at 2:00 PM on July 22.

The recorded water temperatures at Delano Beach increased steadily over the deployment until the peak daily average observed during the July 23 low tide series (Table 13, Figure 10). The daily average temperature decreased 2.4 °C between July 22 and Aug 19 when the last day of valid data was recorded (Figure 10).

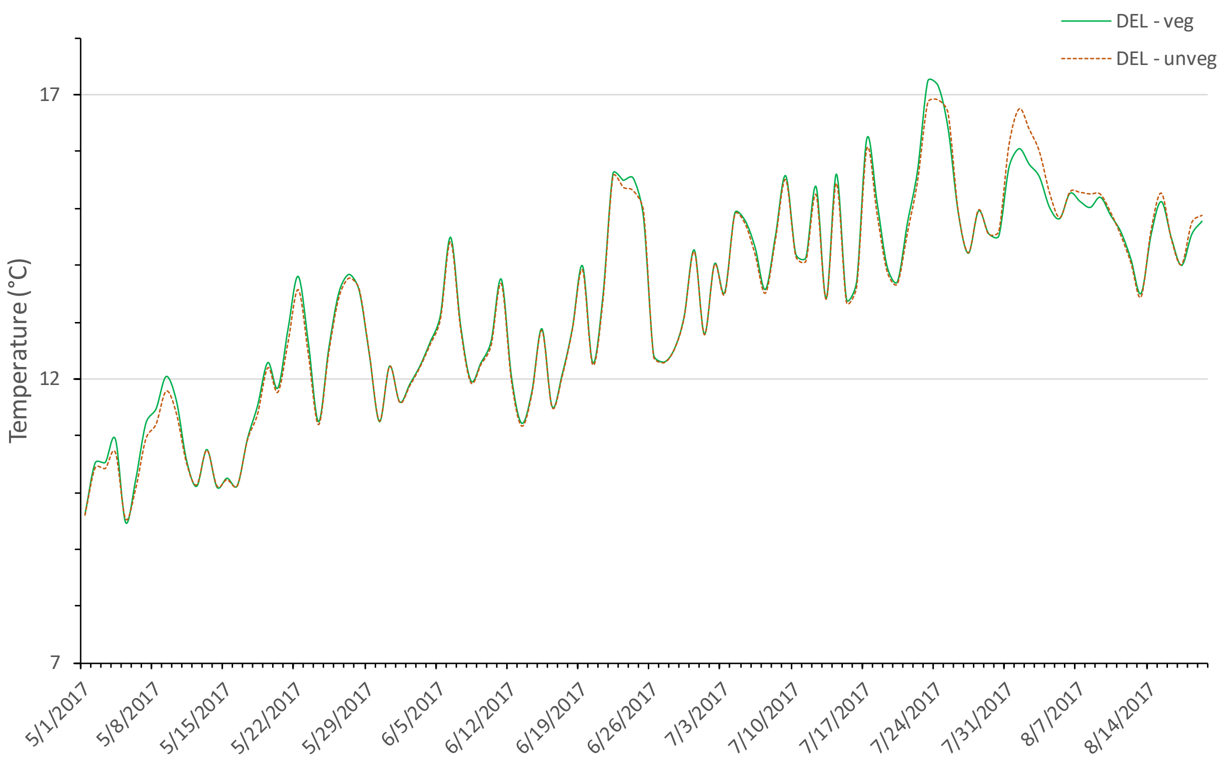


Figure 10. Average water temperature (°C) measured in eelgrass (DEL-veg) and an unvegetated area (DEL-unveg) at Delano Beach. Temperatures were measured using HOBO Tidbit v2 Temperature Loggers (Gaeckle 2017).

At Joemma Beach State Park, daily average water temperatures increased steadily between May 1 and August 19 (Figure 11). The peak daily average temperature was measured on August 16, three days prior to the last valid day of data were collected.

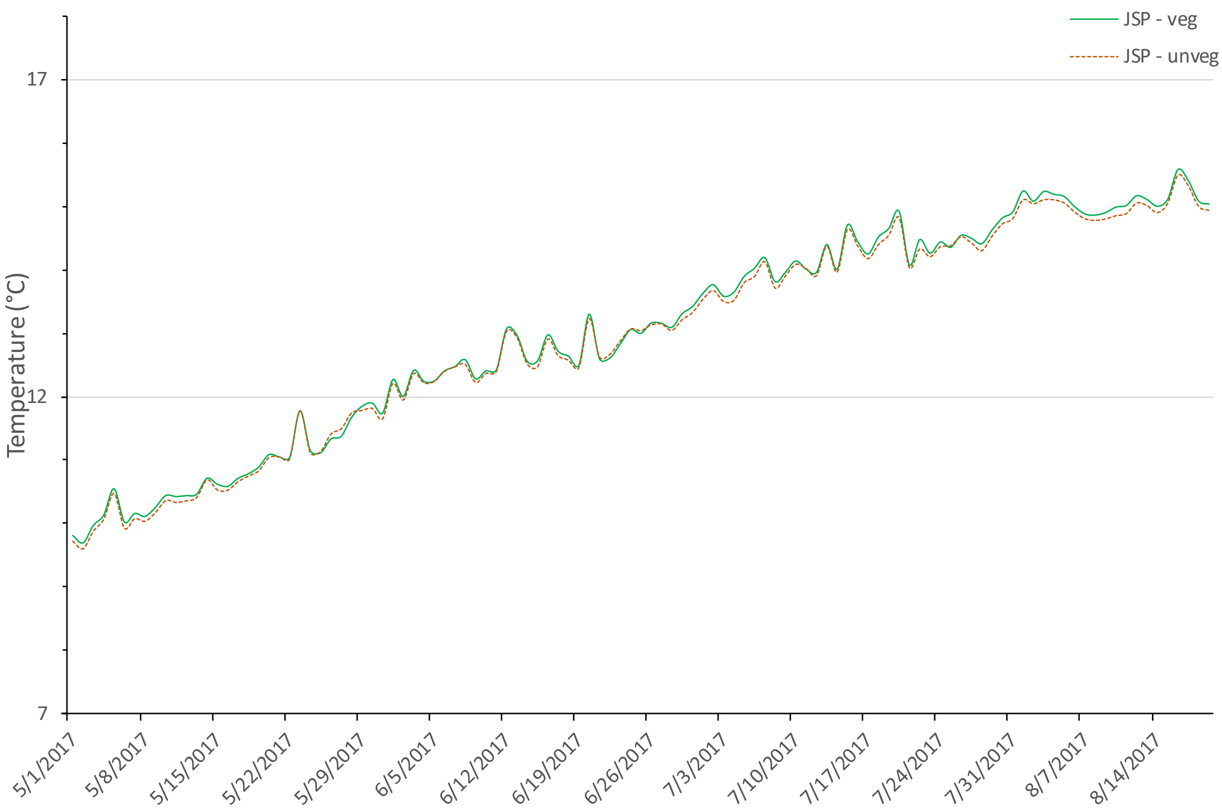


Figure 11. Average water temperature (°C) measured in eelgrass (JSP-veg) and an unvegetated area (JSP-unveg) at Joemma Beach State Park. Temperatures were measured using HOBO Tidbit v2 Temperature Loggers (Gaeckle 2017).

Nearshore water temperature likely varied between these two eelgrass restoration sites because of the location of each site in South Puget Sound and the proximity each site is to the larger and cooler water mass north of the Tacoma Narrows. Daily average temperatures observed at Delano Beach were more variable with daily changes in temperature of a degree or two during spring low tides series (Figure 10). There was no noticeable difference in water temperature between the eelgrass and unvegetated areas at each site.

Overall, the temperatures observed were not in excess of the maximum observed temperatures measured on large eelgrass flat sites in coastal bays along the Washington and Oregon coasts (Thom et al. 2003b). However, the observed maximum temperatures were in excess of optimal temperatures for eelgrass productivity (7-13 °C) in Washington (Thom et al. 2005, 2008). Periodic exposure to high temperatures should not affect eelgrass productivity, but long-term and more frequent temperatures events may likely cause adverse implications to its survival (Ehlers et al. 2008).

5.2 pH

At both Delano Beach and Joemma Beach State Park, Durafet-based pH sensors were deployed at three different eelgrass restoration sites from May 1 through July 21, 2017 and again from July 24 through August 19, 2017. The Durafet-based pH sensors was deployed horizontally in the water column, approximately 15 cm off the sediment surface in both unvegetated habitats and eelgrass habitat. The Durafet-based pH sensor was selected because it exhibits stability better than 0.005 pH units over periods of weeks to months, with short-term precision of ± 0.0005 pH units (Martz et al. 2010). The three sites included: Delano HC - the large-scale restoration Delano Beach 2016 site, Joemma HC - the large-scale Joemma Beach State Park 1 site planted in 2016, and Joemma PNNL - a test plot planted in 2013 at Joemma Beach State Park as part of the original eelgrass transplant site suitability model (Thom et al. 2014). At each site, pH sensors were deployed in restored eelgrass and in bare sediment approximately 5-10 m from the eelgrass.

There were sensor glitches that required data to be clipped. For each deployment period (May-July, and July-August), average daily pH data are presented for each of the three different eelgrass transplant sites for the deployment period dates where the sensors functioned properly (Figures 12, 13, 14 & 16, 17, and 18) and a comparison of day – night pH values across habitat types are presented for dates when all pH sensors were functioning properly (Figures 15 & 19).

5.2.1 May – July Deployment

The first pH sensor deployment extended from May 1 through July 21, 2017, however, some sensors did not function properly to utilize all the data. At Delano Beach, the pH sensor in eelgrass was deployed in the 2016 large-scale eelgrass transplant site while the other sensor was deployed in bare sediment approximately 5 m outside the site. At the time of deployment, there was only a small amount of eelgrass at the site. Even so, the observed average daily pH was consistently higher in the eelgrass bed relative to the bare substrate (Figure 12).

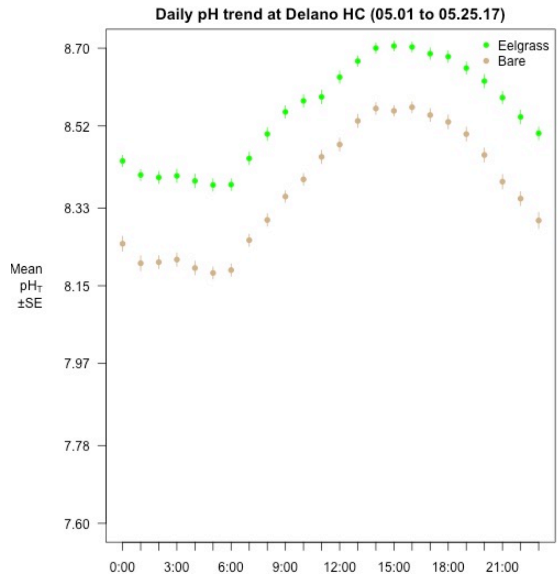


Figure 12. Mean (± se) hourly pH averaged for the period from May 1-25, 2017, at Delano Beach 2016. The sensors were deployed in eelgrass at the Delano Beach 2016 large-scale eelgrass transplant site and in an adjacent bare substrate.

The average hourly pH for each deployment period at the two sites at Joemma Beach State Park was inconsistent with expected trends, with more acidic values (lower pH) related to the eelgrass habitat compared to the bare substrate (Figures 13 & 14). In addition, the average daily pH values in eelgrass and bare substrate at Joemma HC and Joemma PNNL were lower than observed values at Delano HC (Figure 12).

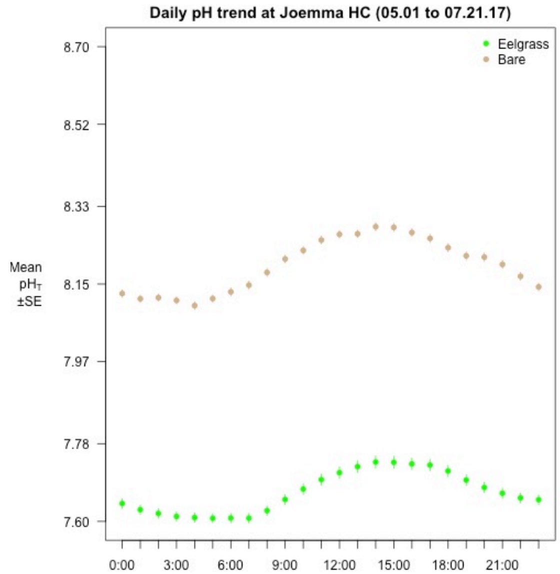


Figure 13. Mean (± se) hourly pH averaged for the period from May 1-July 21, 2017, at Joemma Beach State Park 1. The sensors were deployed in eelgrass at the Joemma Beach State Park 1 large-scale eelgrass transplant site and in an adjacent bare substrate.

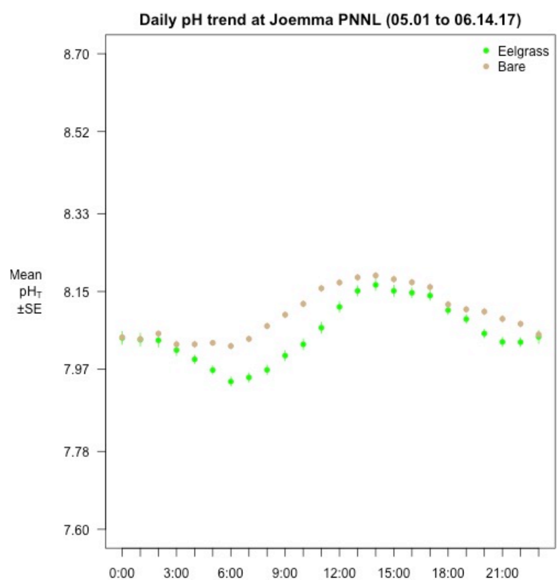


Figure 14. Mean (± se) hourly pH averaged for the period from May 1 – June 14, 2017, at Joemma PNNL (Joemma Beach State Park 2013 test-transplant site). The sensors were deployed in eelgrass at the Joemma Beach State Park (PNNL 2015 large-scale transplant site) and in an adjacent bare substrate. The restored eelgrass bed was transplanted in 2013 (Thom et al. 2014).

Overall, the average pH values across eelgrass and bare habitat types during periods of photosynthesis (daylight, 4-6 PM) and respiration (nighttime, 3-5 AM) were not significantly different at Delano HC (Delano Beach 2016) and Joemma PNNL (Figure 15). There was a significant difference in average pH observed between the eelgrass and bare habitat types during the day and night at Joemma HC (Joemma Beach State Park 1, Figure 15).

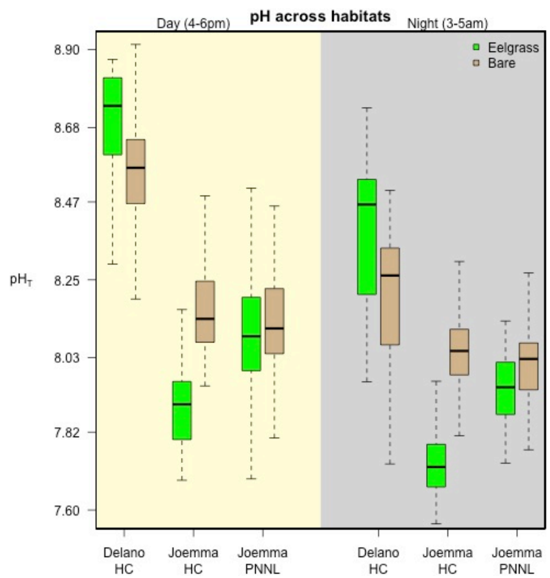


Figure 15. pH across eelgrass and bare habitat from May 1-25, 2017, at three eelgrass restoration sites (Delano HC, Joemma HC, and Joemma PNNL) during periods of photosynthesis (Day 4-6 PM) and respiration (Night 3-5 AM). Delano HC (Delano Beach 2016) and Joemma HC (Joemma Beach State Park 1) were planted in 2016 as part of this project, and Joemma PNNL was planted in 2013 (Thom et al. 2014).

5.2.2 July – August Deployment

The second pH sensor deployment extended from July 24 through August 19, 2017, and all sensors functioned properly. The average hourly pH for each deployment period at Delano HC, Joemma HC and Joemma PNNL in eelgrass and bare habitat types was consistent with expected values with the observed pH values in eelgrass were consistently higher than in bare habitats (Figures 16, 17, & 18).

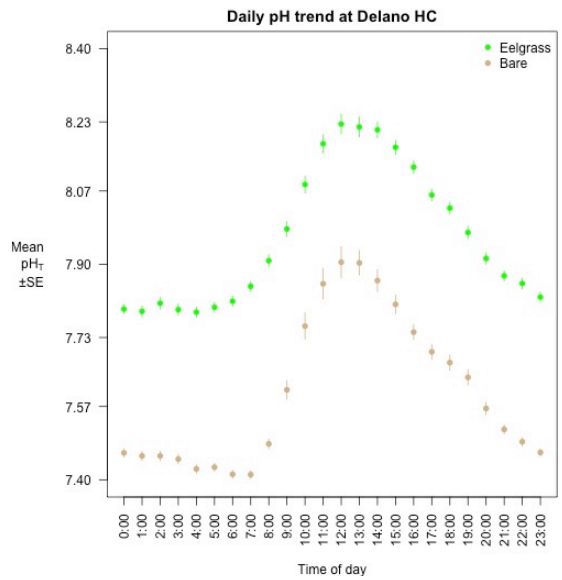


Figure 16. Mean (± se) hourly pH averaged for the period from July 24 – August 19, 2017, at Delano HC (Delano Beach 2016) large-scale transplant site. The sensors were deployed in eelgrass at the Delano Beach 2016 large-scale transplant site and in an adjacent bare substrate.

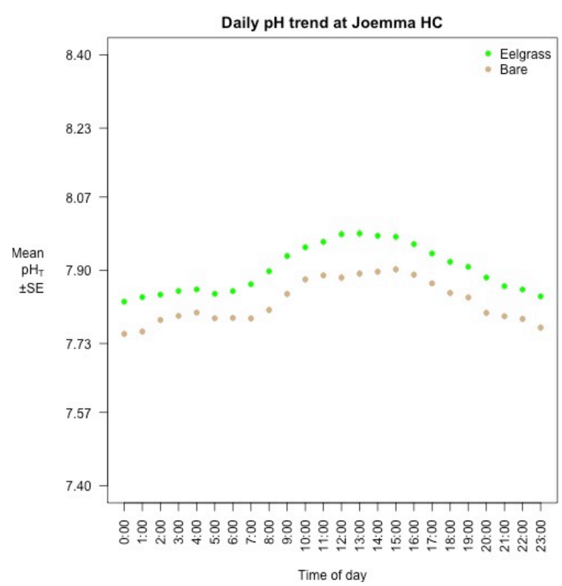


Figure 17. Mean (± se) hourly pH averaged for the period from July 24 – August 19, 2017, at Joemma HC (Joemma Beach State Park 1 large-scale transplant site). The sensors were deployed in eelgrass at the Joemma Beach State Park 1 large-scale transplant site and in an adjacent bare substrate.

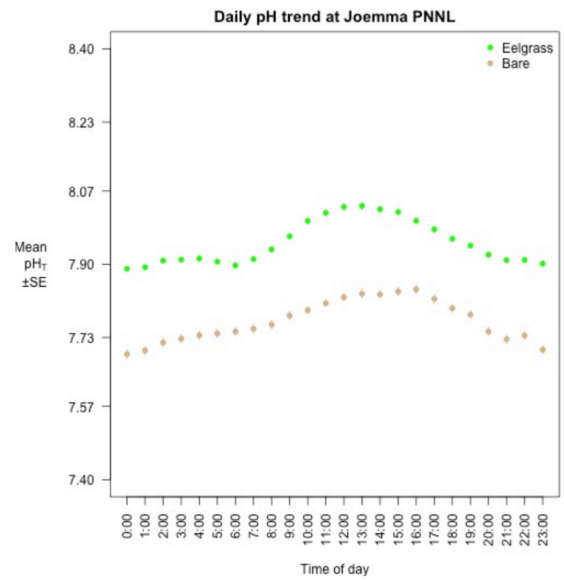


Figure 18. Mean (± se) hourly pH average for the period from July 24 – August 19, 2017, at Joemma PNNL (Joemma Beach State Park 2013 test-transplant site). The sensors were deployed in eelgrass at the Joemma Beach State Park 2013 test-transplant site and in an adjacent bare substrate.

The average pH values across eelgrass and bare habitat types during periods of photosynthesis (daylight, 4-6 PM) and respiration (nighttime, 3-5 AM) were not significantly different at Joemma HC (Joemma Beach State Park 1) and Joemma PNNL (Figure 19). There was a significant difference in average pH observed between the eelgrass and bare habitat types during the day and night at Delano HC (Delano Beach 2016, Figure 19).

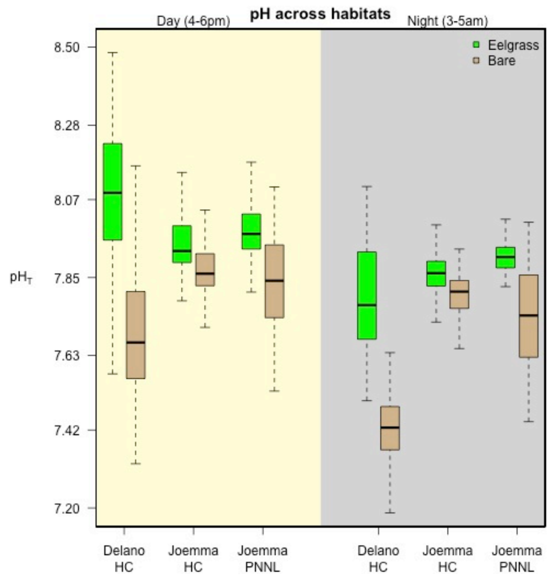


Figure 19. pH across eelgrass and bare habitat from July 24 through August 19 at three eelgrass restoration sites (Delano HC, Joemma HC, and Joemma PNNL) during periods of photosynthesis (Day 4-6 PM) and respiration (Night 3-5 AM). Delano HC (Delano Beach 2016) and Joemma HC (Joemma Beach State Park 1) were planted in 2016 as part of this project, and Joemma PNNL was planted in 2013 (Thom et al. 2014).

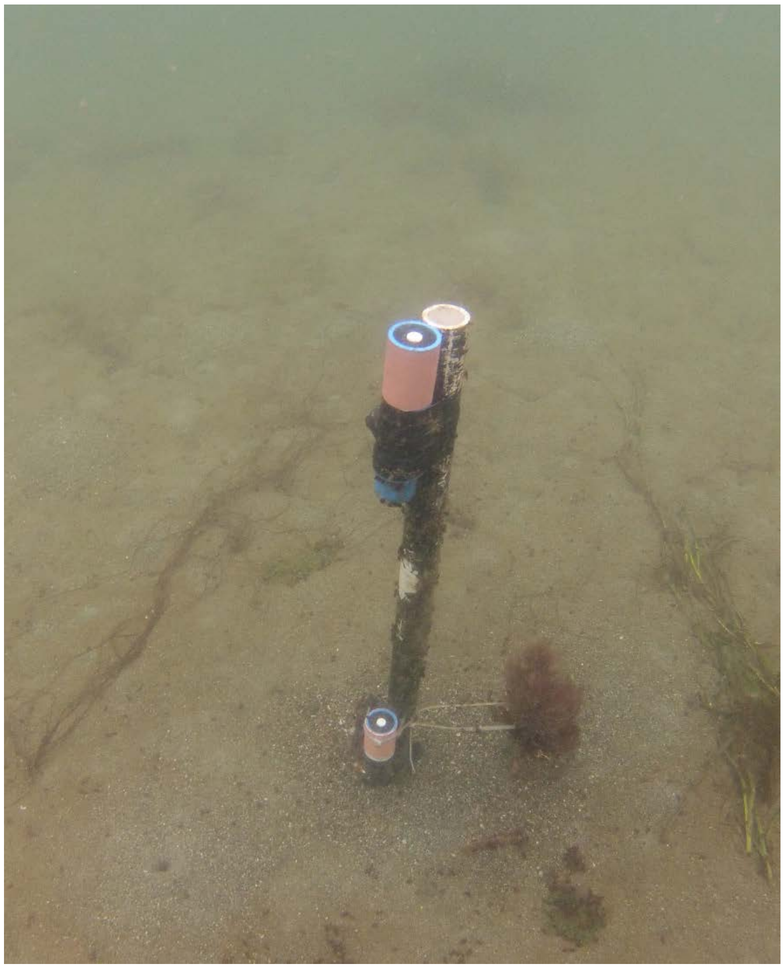
Preliminary results suggest that eelgrass beds may influence local water chemistry due to high amounts of photosynthesis (Figures 12, 16, 17 & 18), but the results were not consistent across the sites during the May through July sampling (Figures 13 & 14). Surprisingly, the site with the greatest observed difference in pH between habitat types during both periods of photosynthesis and respiration was Delano HC (Delano Beach 2016), a site that had very little eelgrass at the beginning of the deployment and none at the end (see section 4.3.2). It is possible that a green algae bloom around the pH sensor deployed in eelgrass at this site triggered a response in pH similar to the presence of eelgrass (Van Alstyne et al. 2015). To improve data quality, minimize lost data due to sensors malfunctioning and improve data uncertainty, future deployments should consist of multiple sensors at the each site with routine cleaning. The addition of dissolved oxygen (DO) sensors could provide a proxy for photosynthesis in the eelgrass compared to bare substrate.

5.3 Photosynthetic Available Radiation (PAR)

Sensors that measured Photosynthetic Active Radiation (PAR), spectral range of light from 400-700 nanometers that is available to photosynthetic organisms, were deployed in eelgrass at Joemma Beach State Park and Delano Beach. Each sensor deployment included two Odyssey sensors (Dataflow Systems, Ltd.), attached to a PVC pole, 50 cm apart to measure PAR at the bottom and at the top of the canopy. The PAR sensors at Joemma Beach State Park were set at the deep edge, -1.6 m (MLLW), of a 2013 eelgrass test-transplant site (Thom et al. 2014). The bottom sensor was just above the sediment surface (+15 cm), while the top sensor was 50 cm higher (65 cm from the sediment surface) (Photograph 7). Sensors were programmed to record PAR every 15 minutes and data were presented as total PAR recorded for each day (24 hour period). The water attenuation was calculated from the difference in PAR measurements between the top and the bottom sensors.

The PAR sensors at Delano Beach were set at a depth of -1.4 m (MLLW) in a 2015 test-transplant site (47.2550 N, -122.7371 W; Aston et al. 2015). The 2015 test-transplant site was a preferred location for the PAR sensors because, 1) the site was slightly deeper than the 2016 large-scale transplant site and, 2) the transplanted eelgrass, planted in February 2015, had persisted for the last two growing seasons (2015 and 2016), suggesting the site may be more suitable than the 2016 large-scale transplant site at Delano Beach (see section 4.3.2). The PAR sensors at Delano Beach were deployed similar to the sensors at Joemma Beach State Park with the lower sensor 15 cm off the bottom and the top sensor 65 cm from the sediment surface, or 50 cm above the lower sensor.

Due to the shallow location of these sensors there were a number of days during the spring low tides when the top sensor at both sites was exposed to air (Table 13). Since the eelgrass at the sensor locations was always submerged, data collected from sensors exposed to air were removed from the analysis as the measured PAR was not a true representation of what the plants experienced.



Photograph 7. Phytosynthetically Active Radiation (PAR) sensors at the deep edge (-1.6 m, MLLW) of eelgrass transplants at Joemma Beach State Park. Sensors were positioned at 15 cm and 65 cm above the surface of the sediment to capture PAR at the bottom and top of the eelgrass. Each sensor was wrapped with copper tape to inhibit fouling and extend the data collection period.

Table 14. Dates Photosynthetically Active Radiation (PAR) data collected by the top sensors were omitted because the sensor was exposed to air during extreme low spring tides. Data collected from sensors exposed to air is not a true representation of the PAR plants received on these dates.

MONTH	DATES	LOW TIDE RANGE (m, MLLW)
May	25, 26, 27, 28, 29	-0.84 to -1.16
June	22, 23, 24, 25, 26	-0.80 to -1.22
July	21, 22, 23, 24	-0.81 to -1.03

5.2.3 Delano Beach

The total daily PAR measured from May 30 – July 21, 2017, at the 2015 eelgrass test-transplant site (Aston et al. 2015) at Delano Beach ranged between 2.0 – 19.8 mol m^{-2} d^{-1} at the bottom sensor and 3.3 – 23.5 mol m^{-2} d^{-1} at the top sensor (Figure 20). The total PAR measured at the bottom sensors was 10.33 ± 0.66 mol m^{-2} d^{-1} (± se) and 14.03 ± 0.78 mol m^{-2} d^{-1} (± se) at the top sensor for the same time period. The calculated light attenuation coefficient (K_d m^{-1}), amount of light reduction relative to depth of water column, ranged between 0.2 – 4.2 K_d m^{-1}, with an average of 0.95 ± 0.09 K_d m^{-1} (± se) for the period between May 30 and July 21 (Figure 21).

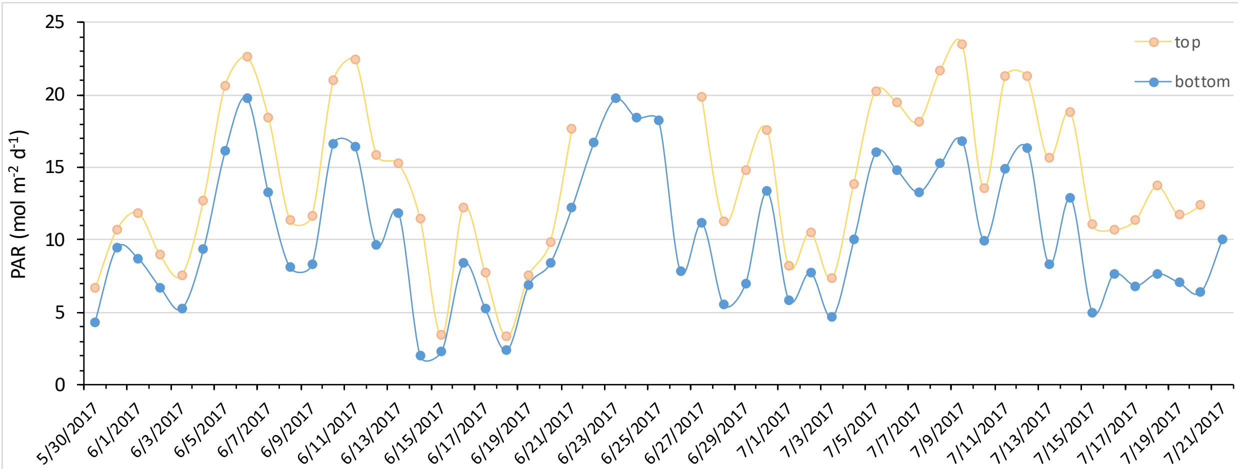


Figure 20. Total daily Photosynthetically Active Radiation (PAR) measured 15 cm (bottom) and 65 cm above the sediment surface between May 30 to July 21, 2017, at a 2015 eelgrass test-transplant plot at Delano Beach. Data was omitted from the top sensor on June 22 – 26 and July 21 as the sensor was exposed to air.

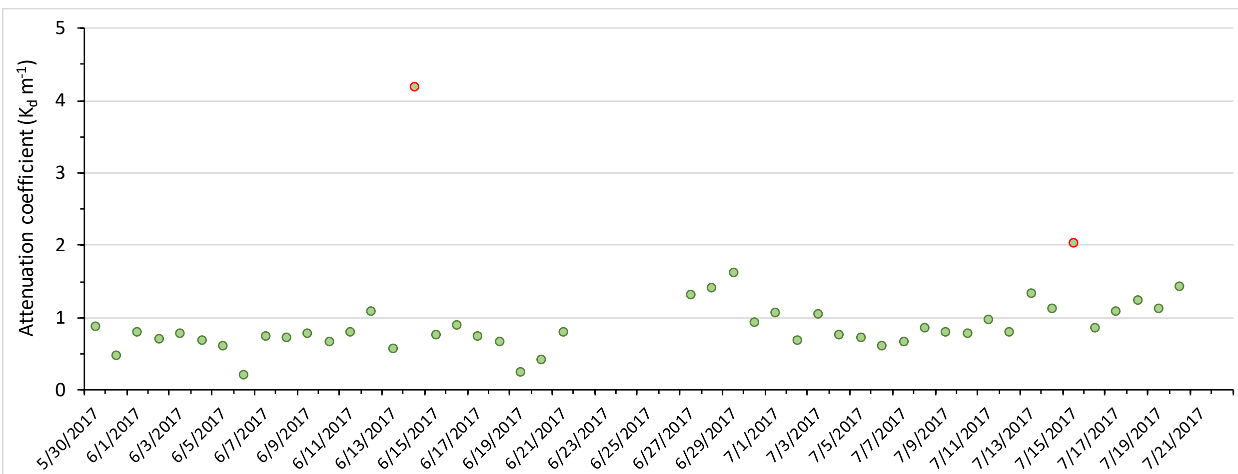


Figure 21. Attenuation coefficient (K_d m^{-1}) calculated from PAR measurements from a 2015 eelgrass test-transplant plot at Delano Beach. Data was omitted from the top sensor on June 22 – 26 and July 21 as the sensor was exposed to air. The two data points (6/14/2017 & 7/15/2017) outlined in red indicate outlier data likely from a fouled bottom PAR sensor (see Photograph 8).

With the exception of three days (6/14, 6/15 & 6/18) PAR values measured at the bottom sensor were all in excess of 3 mol m^{-2} d^{-1}, well above the minimum light requirements for eelgrass in Puget Sound (Thom et al. 2003a). Measured PAR on June 14, 2017, was 1.97 mol m^{-2} d^{-1} and caused the calculated light attenuation to be in excess of 4 K_d m^{-1}. Considering most PAR values for both sensors were above 5 mol m^{-2}

d^{-1} and attenuation was typically below 1.0 K_d m^{-1} suggests the bottom sensor was likely fouled by algae on this date and possibly the other dates when PAR values dropped and attenuation increased.

The PAR sensors at Delano Beach were swapped on July 24, 2017, and retrieved on August 20, 2017. The daily PAR measured from July 25 – August 19 ranged between 3.3– 15.2 mol m^{-2} d^{-1} at the bottom sensor (Figure 22). The top sensor failed to record any data. The average PAR measured at the bottom sensors was 7.10 ± 0.58 (± se) for this deployment. Since there were no data from the top sensor a light attenuation coefficient could not be calculated.

Overall, the measured PAR during the second deployment at the bottom sensor at Delano Beach exceeded the minimum required light (3 mol m^{-2} d^{-1}) necessary for eelgrass to persist at a site (Thom et al. 2003a). Considering these values were from the bottom sensor, PAR values measured on the top sensor would likely have been higher. The PAR also appeared to decline over the course of the second sample period from July through August. This pattern could be a result of the changing seasons from summer to fall and possibly due to additional fouling by late summer algae blooms (Photograph 8).

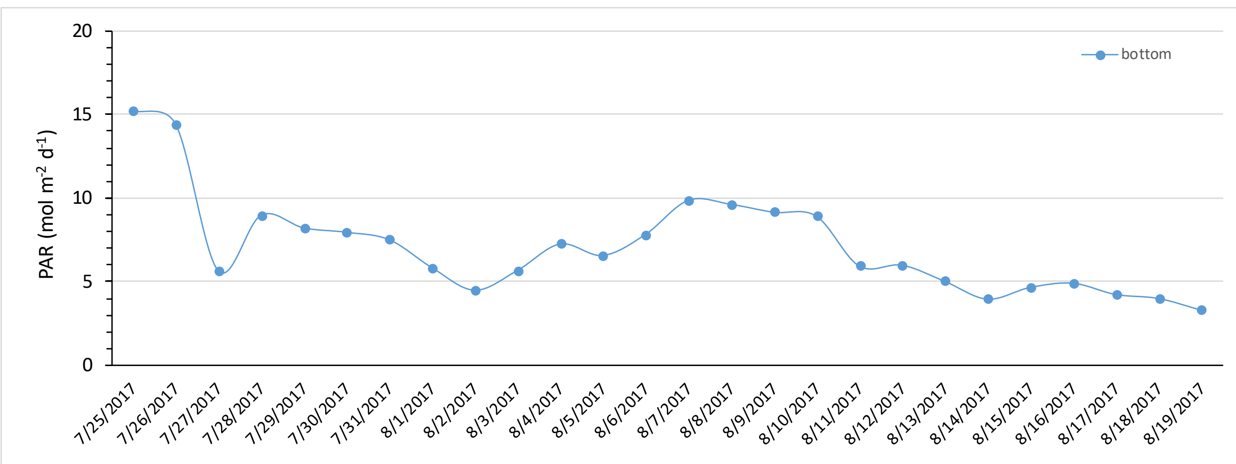


Figure 22. Photosynthetically Active Radiation (PAR) measured 15 cm (bottom) above the sediment surface between July 25 to August 19, 2017, at a 2015 eelgrass test-transplant plot at Delano Beach. The top sensor failed to record data over this time period.

Photograph 8. Photographs of the PAR sensors that show the bottom sensor fouled by green algae (ulvoids). The low PAR values recorded when a sensor was fouled creates an unrealistically high attenuation value ($K_d > 5$).

5.2.4 Joemma Beach State Park

The daily PAR measured from May 30 – July 21, 2017, at the 2013 eelgrass test-transplant site (Thom et al. 2014) at Joemma Beach State Park ranged between 0.1 – 18.9 mol m^{-2} d^{-1} at the bottom sensor and 2.5 – 23.2 mol m^{-2} d^{-1} at the top sensor (Figure 23). The average PAR measured at the bottom sensors was 6.67 ± 0.66 mol m^{-2} d^{-1} (± se) and 12.82 ± 0.75 mol m^{-2} d^{-1} (± se) at the top sensor for the same time period. The calculated light attenuation coefficient ranged between 0.9 – 10.8 K_d m^{-1}, with an average of 2.68 ± 0.36 K_d m^{-1} (± se) for the period between May 30 and July 21 (Figure 24).

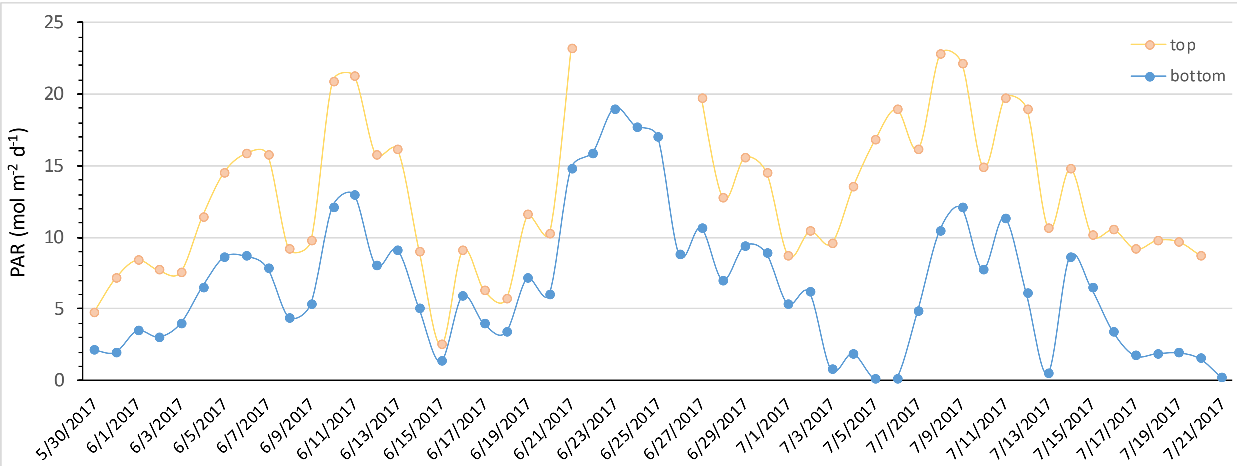


Figure 23. Photosynthetically Active Radiation (PAR) measured 15 cm (bottom) and 65 cm above the sediment surface between May 30 to July 21, 2017, at a 2013 eelgrass test-transplant plot at Joemma Beach State Park. Data was omitted from the top sensor on June 22 – 26 and July 21 as the sensor was exposed to air.

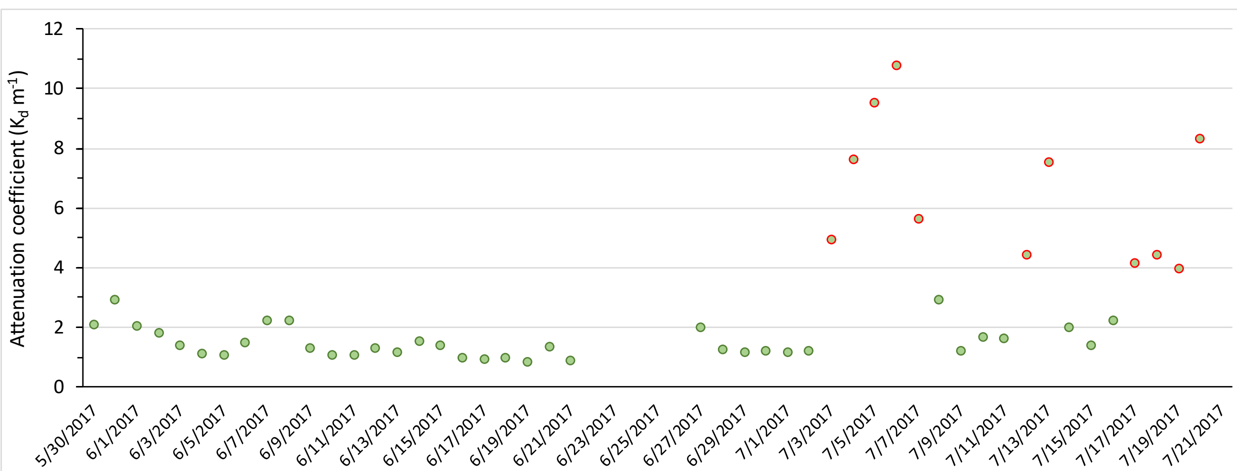


Figure 24. Attenuation coefficient (K_d m^{-1}) calculated from PAR measurements from a 2013 eelgrass test-transplant plot at Joemma Beach State Park. Data was omitted from the top sensor on June 22 – 26 and July 21 as the sensor was exposed to air. Eleven (11) data points (7/3-7/7, 7/12-7/13 & 7/17-7/20) outlined in red indicate outlier data likely from a fouled bottom PAR sensor (see Photograph 8).

The daily average PAR from May through July was in excess of the minimum require PAR (3 mol m^{-2} d^{-1}) necessary for eelgrass persistence in the region (Thom et al. 2003a), however, there were as many as 13 days during this period where measured PAR at the bottom sensor was below the minimum requirement. High light attenuation values (K_d m^{-1}) from July 3 through July 20, coincided with 11 days of low PAR (< 3 mol m^{-2} d^{-1}) values and is likely a result the bottom sensor fouled with algae (Photograph 8). With the exception of the last two weeks of sensor deployment (July 3 - July 20), light attenuation was typically below 2 K_d m^{-1}, with most values closer to 1 K_d m^{-1}. The light attenuation coefficient values (K_d m^{-1}) observed are within the range of values calculated in other eelgrass meadows throughout its range (Dennison et al. 1993).

The PAR sensors at Joemma Beach State Park were swapped on July 22, 2017, and retrieved on August 20, 2017. The bottom sensor only recorded data through July 31, 2017, while the top sensor recorded over the entire sampling period from July 25 through August 19. The daily PAR measured from July 25 – 30, at the bottom sensor ranged between 2.3– 18.4 mol m^{-2} d^{-1} with a daily average of 9.52 ± 2.44 (± se) (Figure 25). The PAR recorded at the top sensor from July 25 through August 19, ranged from 5.9– 27.9 mol m^{-2} d^{-1} with a daily average of 10.82 ± 0.95 (± se) (Figure 26).

For the seven (7) days the bottom sensor recorded data during the second deployment at Joemma Beach State Park, PAR values were in excess of the minimum light requirements (3 mol m^{-2} d^{-1}). On last day (July 31), the average daily PAR was 2.3 mol m^{-2} d^{-1}, however, this low reading could be an anomalous reading due to a faulty sensor. Prior to July 31, the bottom sensor recorded PAR measurements from as early as 5:30 AM through 9:15 PM. This period of light was also observed in the data recorded on the top PAR sensor. However, after July 31, the bottom sensor failed to record consistently beyond 11:00 AM.

The PAR values recorded at the top sensor from July 25 through August 19 at Joemma Beach State Park were consistently in excess of 5 mol m^{-2} d^{-1} (Figure 25). Due to the faulty bottom PAR sensor, only 7 days of light attenuation could be calculated from July 25 – 31 (Figure 26). The minimum light attenuation was 0.93 K_d m^{-1} and the highest was 3.61 K_d m^{-1}. The average K_d m^{-1} was 2.05 ± 0.44 K_d m^{-1} (± se). Only three (3) light attenuation values fall within the range of attenuation values calculated for eelgrass elsewhere in its range (Dennison et al. 1993), raising more uncertainty with the measured PAR values from the bottom sensor.

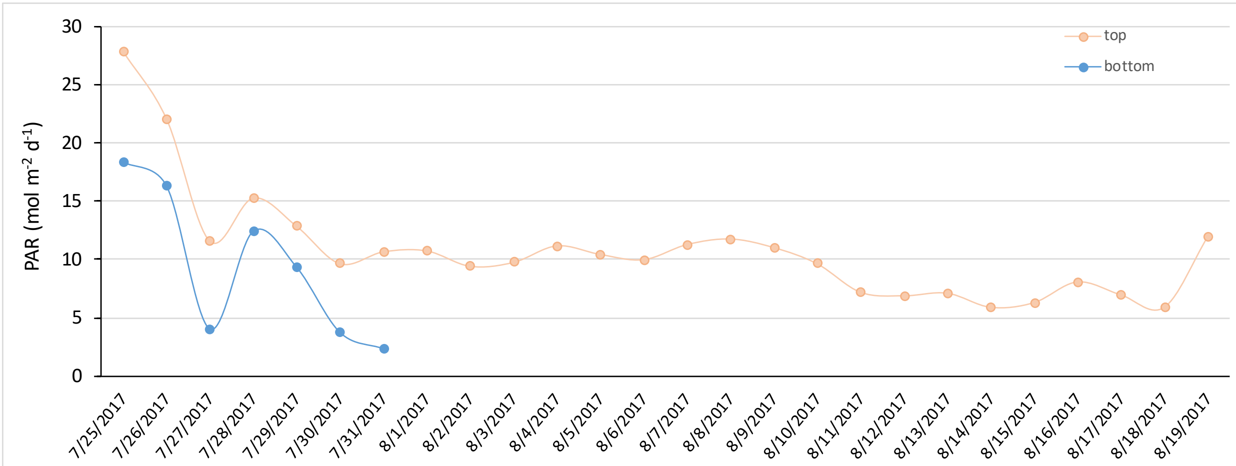


Figure 25. Photosynthetically Active Radiation (PAR) measured 15 cm (bottom) above the sediment surface between July 25 to August 19, 2017, at an eelgrass test-transplant plot at Joemma Beach State Park. The bottom sensor failed to record data consistently after July 31, 2017, therefore, these data are not presented.

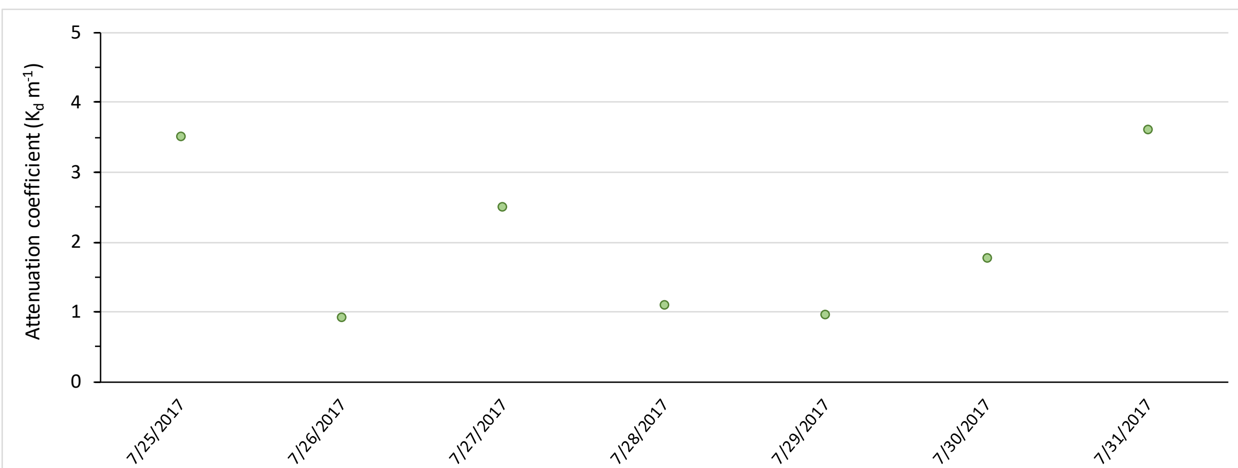


Figure 26. Attenuation coefficient (K_d m^{-1}) calculated from PAR measurements from an eelgrass test-transplant plot at Joemma Beach State Park from July 25 – 31, 2017. The bottom sensor failed to record data consistently after July 31, 2017, therefore, an attenuation coefficient could not be calculated beyond this date.

6.0 DISCUSSION

Overall, the goals of the project, after minor adjustments, were to transplant 14 test- and seven large-scale transplant sites. To meet these goals 168,014 shoots needed to be harvested which is equivalent to the number of shoots slated to be transplanted (152,740 shoots) plus a 10% buffer (15,274 shoots) for any unexpected loss during the transplant process. The total number of shoots harvested exceeded the goal by 13,333 shoots for an estimated 181,347 shoots harvested. The total number of shoots transplanted over the two year project was 168,689 shoots (test-transplants = 13,597 shoots, large-scale = 155,092 shoots), 12,658 shoots less than the total harvested shoots (Tables 15 and 16). The total number of shoots transplanted represented here is likely an underestimate, as every shoot that was harvested was transplanted per protocol. It is likely that the weight-to-shoot conversion method implemented in 2017 underestimated the number of shoots for the corresponding bag weight due to morphological differences between each shoot. Furthermore, excess shoots remaining from each site were transplanted to a location just outside the transplant site boundary to not waste eelgrass shoots and were therefore under-represented by final counts for each site. In the end, the amount of shoots transplanted relative to shoots harvested reduced the 10% buffer for unexpected loss to 7.5%, an indication that transplant efforts focused on efficiency.

Table 15. Summary of Shoots Transplanted Per Site Type

	LARGE-SCALE	TEST	HARVEST
Total 2016	42,310	3,120	46,990
Objective	40,520	3,120	45,980
Variance (+/-) shoots	+1,790	0	+1,010
Total 2017	112,782	10,477	134,357
Objective	101,300	7,800	109,100
Variance (+/-) shoots	+11,482	+2,677	+25,257
GRAND TOTAL	155,092	13,597	181,347
Objective	141,820	10,920	168,014
Variance (+/-) shoots	+13,272	+2,677	+13,333

Table 16. Summary of Shoots Planted and Density for 2016 and 2017

Year	Site	Estimated shoots	Area Planted (m^2)	Estimated Shoot Density (shoots/m^2)
2016	Test plots	3,120	156	20
	Large-scale plots	42,310	371	112
2017	Test plots	10,477	193	125*
	Large-scale plots	112,782	800	143
Grand Total	Test plots	13,597	349	66.5
	Large-scale plots	155,092	1,171	127

*This lower number is due to using the previous 5mx5m method.

6.1 Future Research

The test- and large-scale transplant sites with evidence of eelgrass present during the July 2017 monitoring event will be re-visited in the 2018 field season to determine overwinter survival. These sites will be monitored for shoot density and total eelgrass area. The increase in shoot density measured after one year at Joemma Beach State Park 1 was encouraging (see Section 4.3.1). Although area assessments at the large-scale sites may prove a challenge as bare spaces in the original planting footprint fill in, monitoring should be possible with enough detail. Techniques for monitoring the coalescence of bare space may require some modification; future efforts may be benefitted by unmanned aerial vehicle (e.g., UAV, drone) investigation.

Monitoring efforts should also include donor sites to assess their recovery after harvest and to determine any long-term impacts to the site. If restoration is to continue, more donor sites may need to be identified to minimize the impact on current sites. During the 2017 field season, the Vaughn Bay eelgrass bed was inspected as a possible donor site and determined to be a potential future donor bed. The eelgrass plants at Vaughn Bay site appears to be larger than Rocky Bay but smaller than the shoots at DuPont Wharf and would be suitable for transplant in test sites and potentially large-scale sites. At some point in the future it may even be worthwhile to consider using successful transplant sites as donor sites for test plots. Joemma Beach State Park may support a resilient eelgrass population that can tolerate small scale harvest to test-transplant elsewhere. However, a criteria for using a recently restored site as a donor bed would need to be developed prior to any action.

The water quality monitoring results were mixed. As expected, temperature increased over the course of the growing season and there was adequate daily PAR to support eelgrass at the sites where it was measured. The pH results were inconclusive; sensors failed to collect data and some results were opposite predicted patterns. To improve pH monitoring in the future multiple sensors will be deployed in each location to provide a comparison between sensors to validate data quality. Multiple pH sensors at a site may also help parse out confounding factors such as the effects of tidal exchange, benthic macroalgae and any calibration issues between sensors. In addition, analysis of water samples to field calibrate sensors is recommended but requires special care due to the chemicals involved. Comparison of data from water samples and the sensors would greatly improve post-deployment calibration and results.

Finally, to optimize transplant success, more test-transplant plots should be planted using modifications of the burlap strip and staple methods. A quick and efficient method with minimal handling of eelgrass shoots that securely affixes plants to the sediment helps maximize survival of transplants.

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APPENDIX A
RESTORATION PLAN & SUPPLEMENT

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Restoration Plan and Timeline

Puget Sound Eelgrass (*Zostera marina*) Restoration and Monitoring

Prepared for

Washington State Department of Natural Resources

April 29, 2016
1205905

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Restoration Plan and Timeline

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Prepared for

Washington State Department of Natural Resources

April 29, 2016
1205905

Prepared by

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Puget Sound Eelgrass (*Zostera marina*) Restoration and Performance Monitoring

INTRODUCTION AND SCOPE

Hart Crowser's Team has been selected to help the Washington State Department of Natural Resources (DNR) restore *Zostera marina* (eelgrass) to help support target outcomes of the "20% More Eelgrass by 2020" project. The restoration will be conducted at select large-scale and test sites throughout Puget Sound chosen for their strong probability for transplant success of eelgrass shoots from healthy donor beds. This project includes monitoring the recovery of eelgrass at donor sites following harvest activities and the success of the eelgrass plantings within the test and large-scale restoration sites. Hart Crowser will test water quality using sensors provided by DNR in areas with transplanted eelgrass and in areas without eelgrass at the donor, large-scale, and test sites.

This document provides our team's approach to restoration and monitoring and includes a draft schedule for this work.

RESTORATION SITE CRITERIA

DNR has established requirements for the donor, large-scale, and test sites at which the restoration work will be conducted. Across site types, all work must be conducted on state-owned aquatic lands deeper than –1.4 m, relative to mean lower low water (MLLW). Identified test sites must be large enough to support three eelgrass test plots and large-scale sites must be large enough to support a minimum of 2,025 square meters (m^2) of eelgrass restoration area. Large-scale sites can be subdivided into smaller areas as long as the sum of the smaller areas is a minimum of 2,025 m^2, and that a minimum of 20,260 eelgrass shoots are planted at a minimum density of 20 shoots per meter (m).

DNR has established that restoration must occur at a minimum of 10 test sites and 8 large-scale sites, and that shoots for these efforts will be harvested from a minimum of 5 healthy donor beds.

We have already identified candidate donor, large-scale, and test sites using the model output data from Pacific Northwest National Laboratory, data from DNR's Submerged Vegetation Monitoring Program, and our local knowledge. On February 17, 2016, we presented a draft list of candidate sites to DNR for initial review and feedback. After discussion and preliminary field assessments, these sites will be finalized and presented in a subsequent memo as a supplement to this plan.

FIELD PROCEDURES

Donor Site

Site Setup

Donor sites will be selected through a combination of data review and field verification. Information on candidate sites will be researched through the Marine Vegetation Atlas, DNR's eelgrass monitoring data, and local knowledge. Once donor sites are initially selected by screening available documentation, top candidates will be field verified for areal coverage, health of the bed, and dive conditions at the site. Field verification will be largely done through video survey to confirm the general size of the bed and to identify the shallow and deep edges of the bed (Figure 1). If the bed meets the necessary criteria for size and density and the dive conditions are favorable, two divers will deploy a tape between the shallow harvest limit (–1.4 m) and the deep edge, perpendicular to shore. Divers will then mark the center of the bed along that tape.

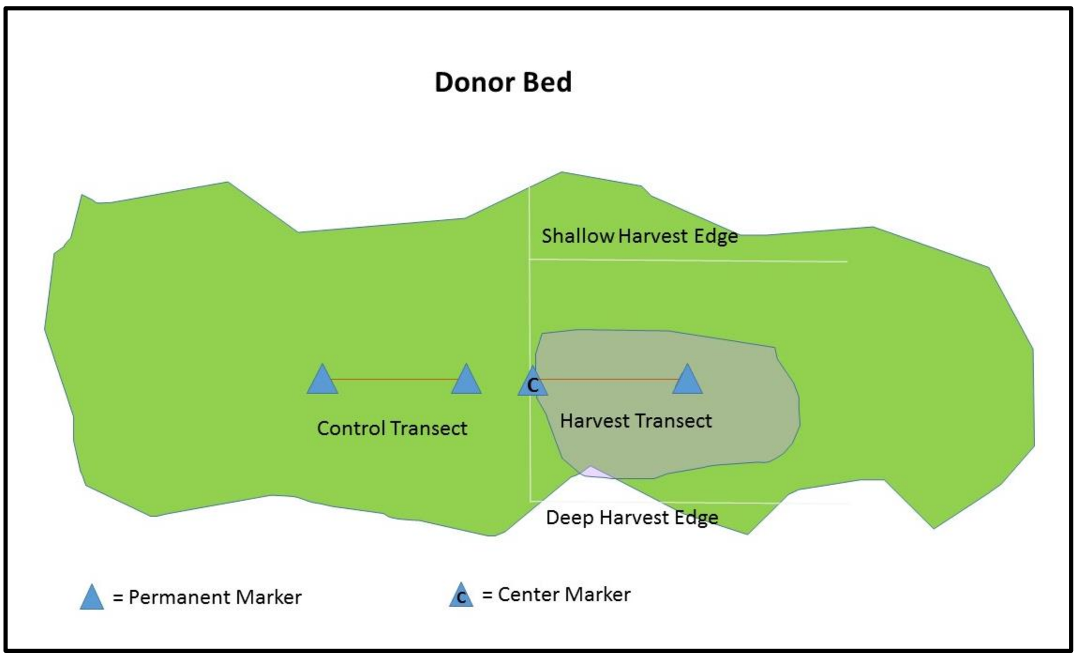

Figure 1 – Donor bed setup

This center point will be permanently marked (denoted with a "C" on Figure 1). From this center point divers will lay a 26-meter transect line parallel to shore and then mark the end (opposite the permanent center point) with another permanent marker. This will serve as the permanent monitoring transect that we will revisit during our monitoring efforts for this project. A second 26-meter transect will be set within the same donor bed but offset from the center marker of the donor harvest transect by a 3-meter buffer and heading in the opposite direction. This will serve as a control. Divers will verify that the depth and density of grass along the control transect is similar to that along the donor harvest transect before placing the permanent monuments at each end. The donor site monitoring transects are illustrated in Figure 1.

The markers will consist of small helical anchors and PVC posts that divers will install into the substrate (WDFW 2015). To facilitate repeat monitoring, coordinates for each marker will be recorded using a survey-grade Global Positioning System (GPS) with a horizontal accuracy of less than 1 meter. Horizontal coordinates will be referenced to DNR's preferred standard of "NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet."

Transect Sampling

Eelgrass density will be determined within each plot before harvesting to provide a baseline for average shoot density, spatial variability in shoot density, and to help inform how many shoots may be available for harvest. A team of two divers, each with a 1-m^2 quadrat, will count shoots in an offset pattern along each 26-meter transect line, beginning with the first quadrat (Quadrat 1) placed downslope of the transect tape on the deeper harvest edge (Figure 1) at the sampling monument furthest from the center marker (Figure 2). Quadrat 2 will be placed 1 meter away from the sampling monument, but upslope of the transect line. Quadrats 3–26 will be placed on alternating sides of the transect tape according to this pattern. To be consistent, shoots will always be counted beginning with Quadrat 1. The two-person dive team will then survey each of the 26 quads. Each diver (one upslope and one downslope from the transect line) will count 13 quads along the transect line. This practice will be identically repeated along the control transect and in subsequent survey efforts over time.

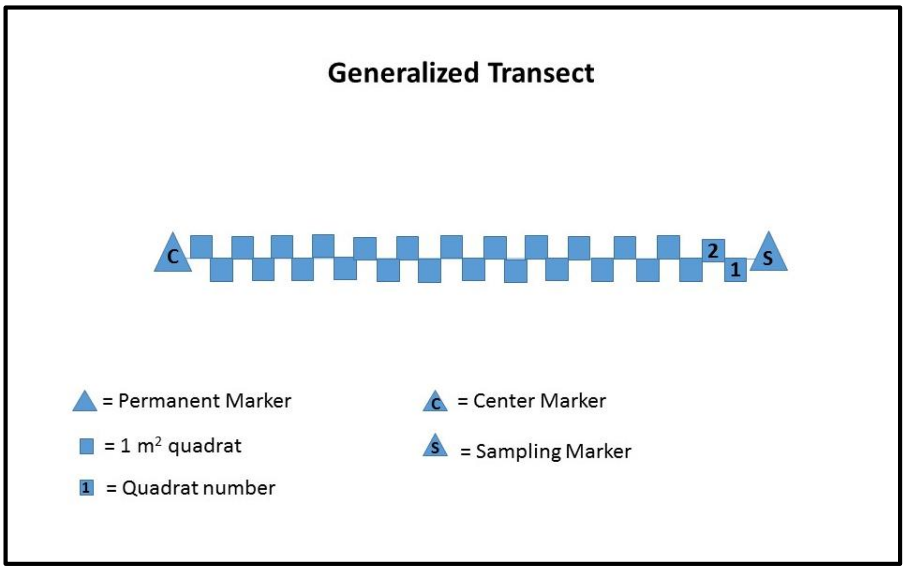

Figure 2 – Generalized monitoring transect placed within harvest portion of donor bed and in control area

Large-scale Transplant Effort

Harvesting Eelgrass

Once the pre-harvest data have been collected along the 26-meter transects in the donor bed as described above, the divers will begin to harvest shoots at a predetermined density along a narrow depth range. The divers will harvest shoots by hand or with light tools (depending on substrate) in order to minimize damage to the plants. These harvested shoots will ideally be bundled in clusters of

100 with a rubber band and then placed in a dive bag. If this bundling cannot be done efficiently, divers will fill the bags with harvested shoots and a processing crew will sort and bundle them on shore. Harvested plant bundles will be deposited into larger, permeable laundry bags when brought to the surface and handed off to a kayak support vessel. The kayaker will take the filled laundry bags to the shore where they will be processed by a designated processing crew.

Processing Eelgrass

All eelgrass processing will be done on shore by taking the diver-filled laundry bags from the kayaker and emptying them into a shaded shallow container of sea water (e.g., a kiddy pool). The bundled shoots will first be trimmed to length and then separated into individual plants. Once separated, the shoots will be "woven" into pre-cut strips of burlap to create discrete planting units. These planting units will have five to ten eelgrass shoots per burlap strip depending on the site they are destined for. These assembled burlap strips will be collected onto a "key ring" so that multiple planting units can be handled with minimal damage. Once a "key ring" is completely loaded with planting units, it will be placed back into a laundry bag, or "purse," which the shore crew will hand off to the kayaker so that it can be stored on a floating buoy system (Figure 3). Processed eelgrass purses will continue to be added to the buoy system until all harvested eelgrass has been processed. We estimate that approximately six purses will fit along each buoy system.

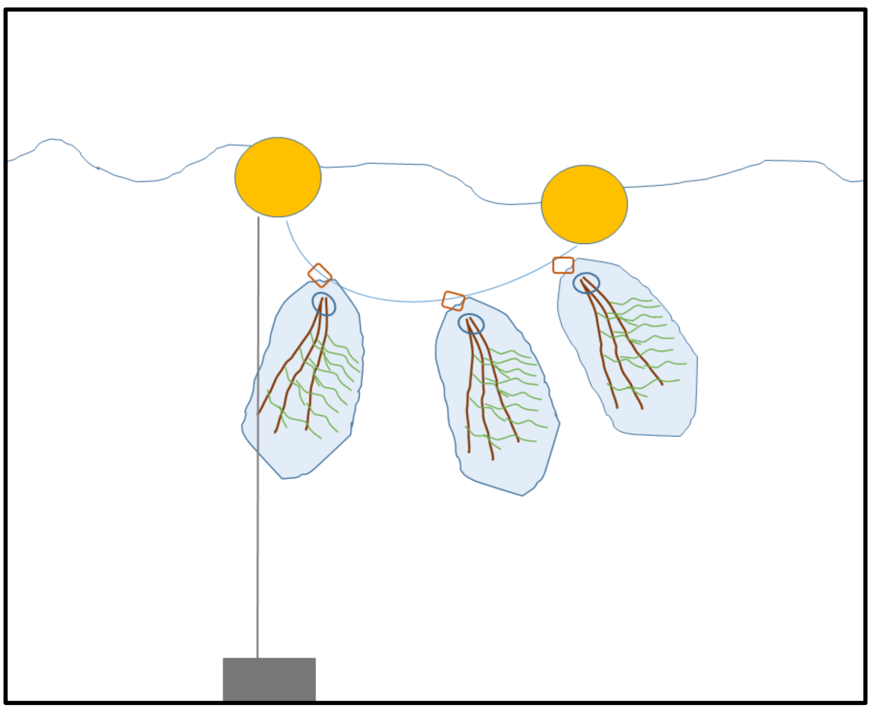

Figure 3 – Buoy system with attached purses and planting units

Transport and Transplanting Eelgrass

Once processing is complete at the donor site, the buoy system (with attached purses) will be pulled out of the water using the A-frame aboard the vessel. Each individual buoy system will be deposited into a large tote, filled with fresh seawater. These buoy systems can be transported up to six at a time aboard the boat.

Once at the large-scale planting site, the buoy systems will be lifted out of the totes and deployed within the planting area. After unloading the harvested eelgrass, we will locate the minimum and maximum planting depths via diver or video. Transplant sites will be matched with suitable donor sites so that eelgrass is planted along a similar depth range. Transplanting depths will be to the shallow limit of the bed to 20 percent of the deep edge of the donor bed. Teams of two divers will use a 2-m by 3-m PVC grid "jig" as a guide to plant the eelgrass. Beginning on the established deeper edge of the bed, divers will set the jig and install stakes within the inside of each corner and the outside of each corner on the right side as shown in Figure 4. Once the jig is set, kayakers will give each diver a "purse" (permeable laundry bag filled with processed eelgrass; see Figure 3). The divers will begin to install the PU's by fixing the eelgrass woven strips to the substrate with garden stables. Divers will plant within each square of the jig to achieve a density of 20 shoots/m^2. Once the divers are finished planting within the jig, the jig will be moved up slope, guided by the stakes left in place. Once the jig reaches the shallow planting limit, the jig will be moved to the deeper planting limit of the adjacent column, guided by stakes left in place from the previous columns (Figure 5).

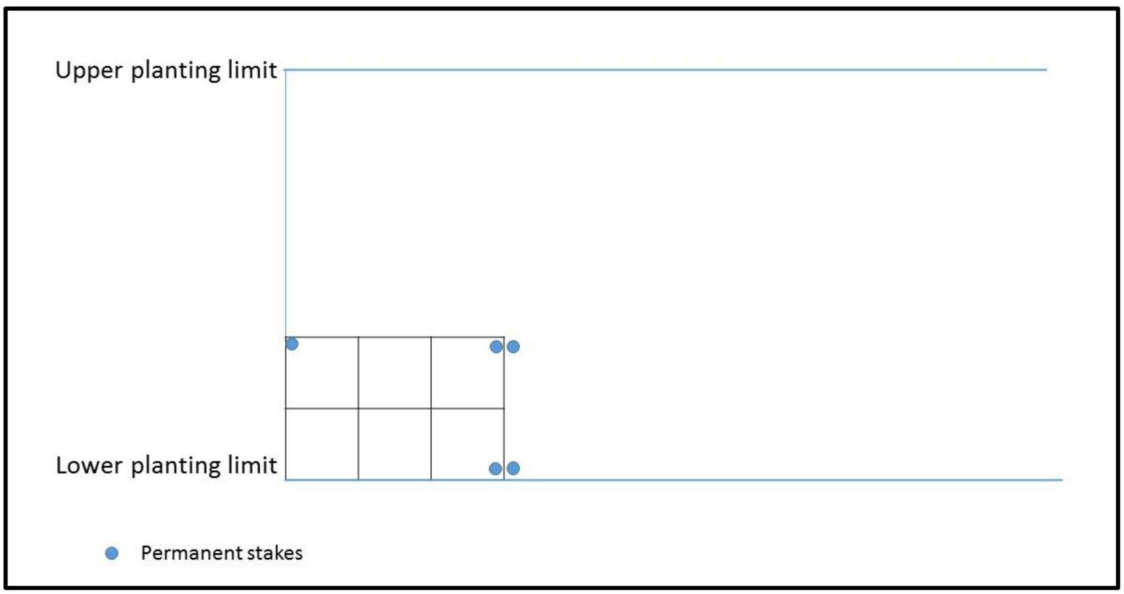

Figure 4 – Transplanting schematic for the initial swath

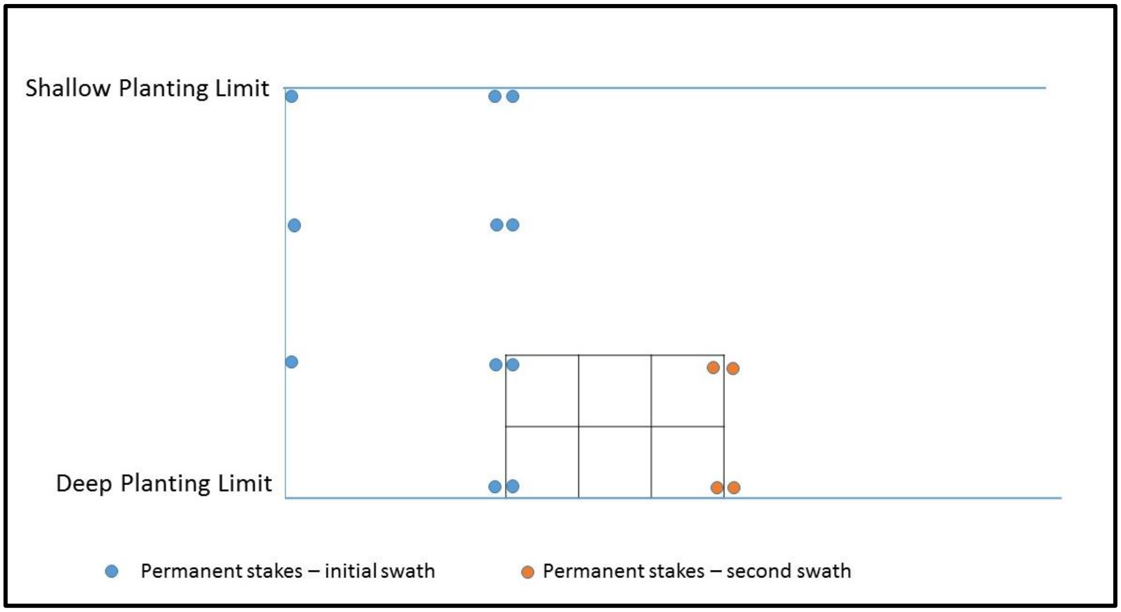

Figure 5 – Transplanting schematic for the second swath

Using stakes left from the previous column will ensure that the bed is planted evenly and consistently. Divers finishing a "purse" will come to the surface for another one so that swimming is minimized. Once the area is completely transplanted, a survey transect will be installed using permanent markers, as previously described for the donor beds (Figures 1 and 2). This will allow for a consistent, repeatable survey methodology for all beds. DNR has established that each large-scale site will have a minimum area of 2,025 m^2 and a planting density of 20 shoots per square meter, for a total of 20,260 shoots at each large-scale site.

Test Site Transplanting Effort

Eelgrass will be harvested, transported, and staged according to the same methodology for the large-scale transplanting sites described above. The difference at test sites is in how the eelgrass will be planted and subsequently monitored. Within each test site will be three test plots and each test plot will be 25 m^2. These test plots will be established along the center transect line with 6 meters of separation between each. Transplant efforts at a test site will begin with the divers establishing a center transect line at a depth similar to that of the plants harvested from within the donor bed (harvest transect line depth). From there, the divers will transplant using the 2-m by 3-m jig to create the checkerboard pattern shown in Figure 6. The jig allows for the planting of two rows and will be flipped a total of 2.5 times from deep to shallow to establish the first swath. To complete the test plot planting area, the jig will then be placed at the same deep edge as the initial swath, to complete a second swath. During the second swath, only two of the three columns of the jig will be used so that only two more columns will be added to the initial swath by flipping the jig 2.5 times from deep to shallow. These test plots will either all be planted upslope or downslope of the transect line, depending on conditions at the test site. Figure 6 illustrates a scenario where all test plots are below the center transect line. DNR has established criteria that 780 shoots will be planted at each test site;

therefore each of the three test plots will require 260 shoots. To achieve this total within the required checkerboard pattern, shoots will be planted at a density of 20 shoots per meter.

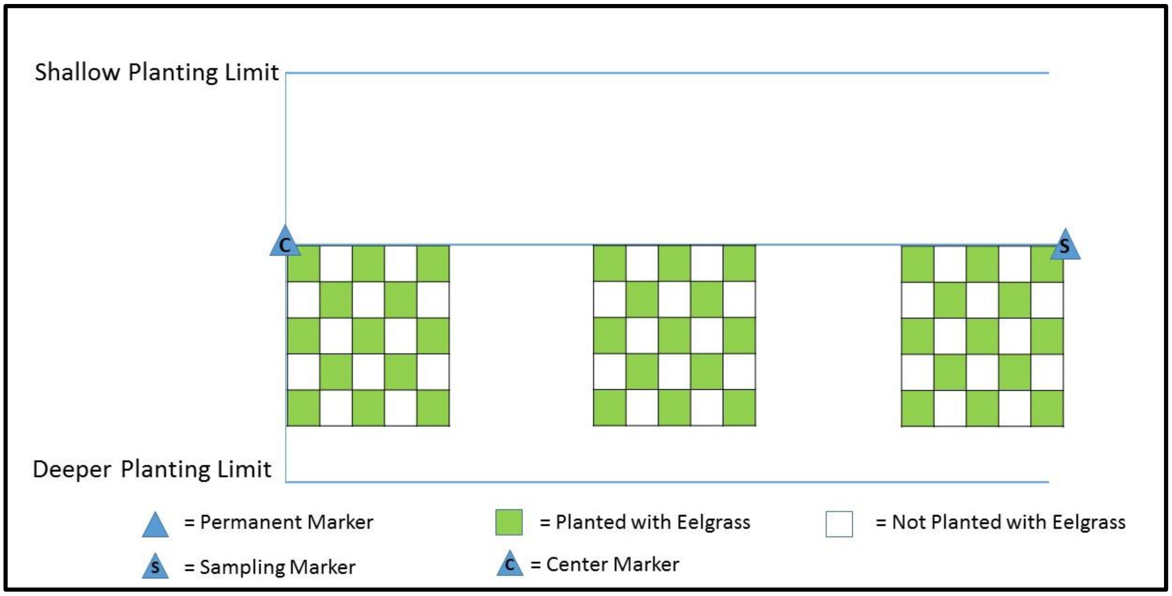

Figure 6 – Example test site planting schematic

RESTORATION MONITORING

Donor Sites

Donor sites will be monitored to quantify the recovery rates within each bed. The recovery of these sites depends on the resilience of the bed and the specific environmental conditions within that area. As described above and shown in Figures 1 and 2, two 26-meter transects will be permanently installed within the donor bed, one within the harvest area and a second adjacent to the harvest area to serve as a control transect. Monitoring will be conducted along each of these 26-meter transects by a team of two divers, each with a 1-m^2 quadrat. Eelgrass shoots will be counted in an offset pattern beginning at the sampling monument furthest from the center monument. To be consistent, shoots will always be counted beginning with Quadrat 1, downslope of the transect tape on the deeper harvest edge (see Figure 2). From there, each diver will count 13 quads so that a total of 26 density counts are collected along the transect line.

Large-scale Sites

Since large-scale sites were transplanted at a density of 20 shoots/m^2, we can employ the same monitoring methodology established for the donor sites. Large-scale sites will be monitored using methods nearly identical to those described for the donor site. Large-scale sites will not have a control transect, however, and density counts will be measured to assess the success and survival of transplants. These density counts will be collected along the 26-meter center transect line by a pair of divers, each with a 1-m^2 quad, to count in an offset pattern beginning at the sampling monument furthest from the center monument. To be consistent, shoots will always be counted beginning with

Quadrat 1, downslope of the transect tape on the deeper harvest edge (see Figure 2). From there, each diver will count 13 quads so that a total of 26 density counts are collected along the transect line.

Test Sites

Test sites will be monitored using the permanent transect established during the initial planting (Figure 6). Divers will match the corner of the 2-m by 3-m jig with the marker to count all shoots within the quad and flip once away from the center line to count the last row. This will be repeated at the remaining two test plots within the test site so that all shoots at an individual test site are counted. The divers will also make qualitative notes on the location and density of shoots that have recruited outside of the originally planted area.

WATER QUALITY MONITORING

DNR will provide the Hart Crowser team with pre-calibrated water quality instruments (e.g., PAR, temperature, and pH sensors), equipment necessary for deployment, and instructions on deployment procedures. These water quality instruments will be placed at locations identified by DNR along the transect(s) at each site. Water quality instruments will be deployed and serviced (i.e., cleaned, swapped) every three to six months during eelgrass transplant monitoring events. Hart Crowser will collect water samples at the pH sensors during sensor retrieval to compare the sensor pH reading with the actual pH of the water. These water samples will be fixed on land (not aboard vessel) using approximately 50 microliters (µl) of mercuric chloride ($HgCl_2$) provided by DNR or by dispensing the collected water sample into pre-fixed sample bottles containing approximately 50 µl of mercuric chloride. DNR will retrieve collected water quality instruments and samples at the end of each field event when the Hart Crowser team is demobilizing. Water quality monitoring data from the instruments will be downloaded and reviewed by DNR and then provided to the Hart Crowser team in Excel spreadsheet or Access database format for use in the Final Report. DNR will process the collected water samples, review the data, and then provide the data to Hart Crowser for use in the final report.

SCHEDULE

The 2016 field schedule will begin in April, when we will start site assessments to identify all donor sites. Our plan for the first season is to identify, set up, and harvest from at least three donor sites and to transplant at ideally seven of the 10 test sites and four of the eight large-scale sites. In-water work will stop in October. Sites not planted during 2016 will be transplanted as early in the field season as possible, ideally at the beginning of May 2017. In addition, the 2016 sites will be monitored in April, July, and October 2017 to evaluate the recovery at the donor sites and the success of the transplants at the large-scale and test sites.

We will complete a draft report by the end of October 2017; DNR will then review the report and provide comments. We will finalize the report by the contract end date of November 30, 2017. This report will summarize the completed work, indicating recovery and survival trajectories of the eelgrass at donor sites, eelgrass growth and survival at the restoration sites, and an analysis of effectiveness of the planting design used at the test sites. Statistical analysis of the data will be conducted as appropriate, and the report will include maps containing spatially explicit visualization of the shoot density, eelgrass distribution, and water quality results. The report will also include the results of the water quality monitoring data.

PROJECT PERSONNEL AND RESPONSIBILITIES

Key staff members for the work are listed below with their project roles:

- **Jeff Barrett, PhD,** Natural Resource Business Unit Manager at Hart Crowser, will be the Principal in Charge for contracting matters with DNR, and as the senior internal reviewer responsible for all work conducted under the contract.
- **Jason Stutes, PhD,** Marine Ecologist at Hart Crowser, will be the Project Manager. He will manage all office work (project planning and reporting) and assist with managing field efforts.
- **Emily Duncanson,** Environmental Scientist at Hart Crowser, will be the Field Operations Manager, managing field operations and assisting Jason with office work as needed.
- **Amy Leitman, MS,** Marine Biologist and Scientific Diver, Owner of Marine Surveys & Assessments, will assist with transplanting efforts, eelgrass surveys, and water-quality probe deployment.
- **Nam Siu, MS,** Marine Biologist and Scientific Diver at Marine Surveys & Assessments, will implement transplanting efforts, eelgrass surveys, and water-quality probe deployment.
- **Eric Parker,** Vessel and Video Owner/Operator of Research Support Services, will lead all boat and diving operations, managing any staff that assist in boat operation or diving-related surveys.
- **Chris Fairbanks, MS**, Marine Biologist and Scientific Diver at Research Support Services, will assist with transplanting efforts, eelgrass surveys, and water-quality probe deployment.

REFERENCES

WDFW 2015. Hydraulic Project Approval, Eelgrass (*Zostera marina* L.) restoration in Puget Sound. Issued by Washington Department of Fish & Wildlife, Olympia, WA. Application ID: 456.

R:\NOTEBOOKS\1205905_DNR Eelgrass Restoration and Monitoring\Deliverables\Reports\Restoration Plan\20160429\DNR Eelgrass Restoration_Plan_201600429.docx

Supplement to -

Restoration Plan and Timeline

Puget Sound Eelgrass (*Zostera marina*) Restoration and Monitoring

Proposed Restoration Sites

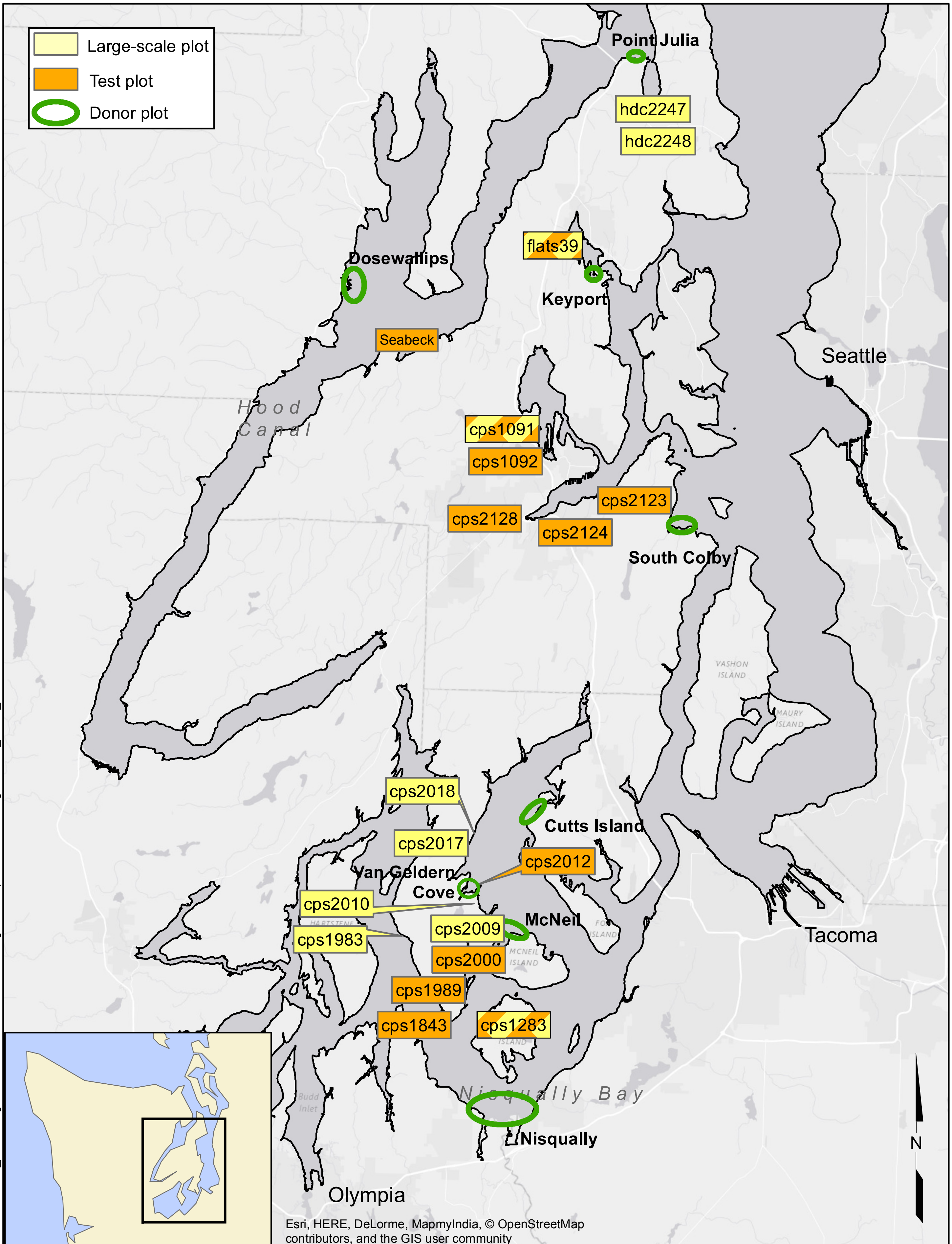

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Figure 3

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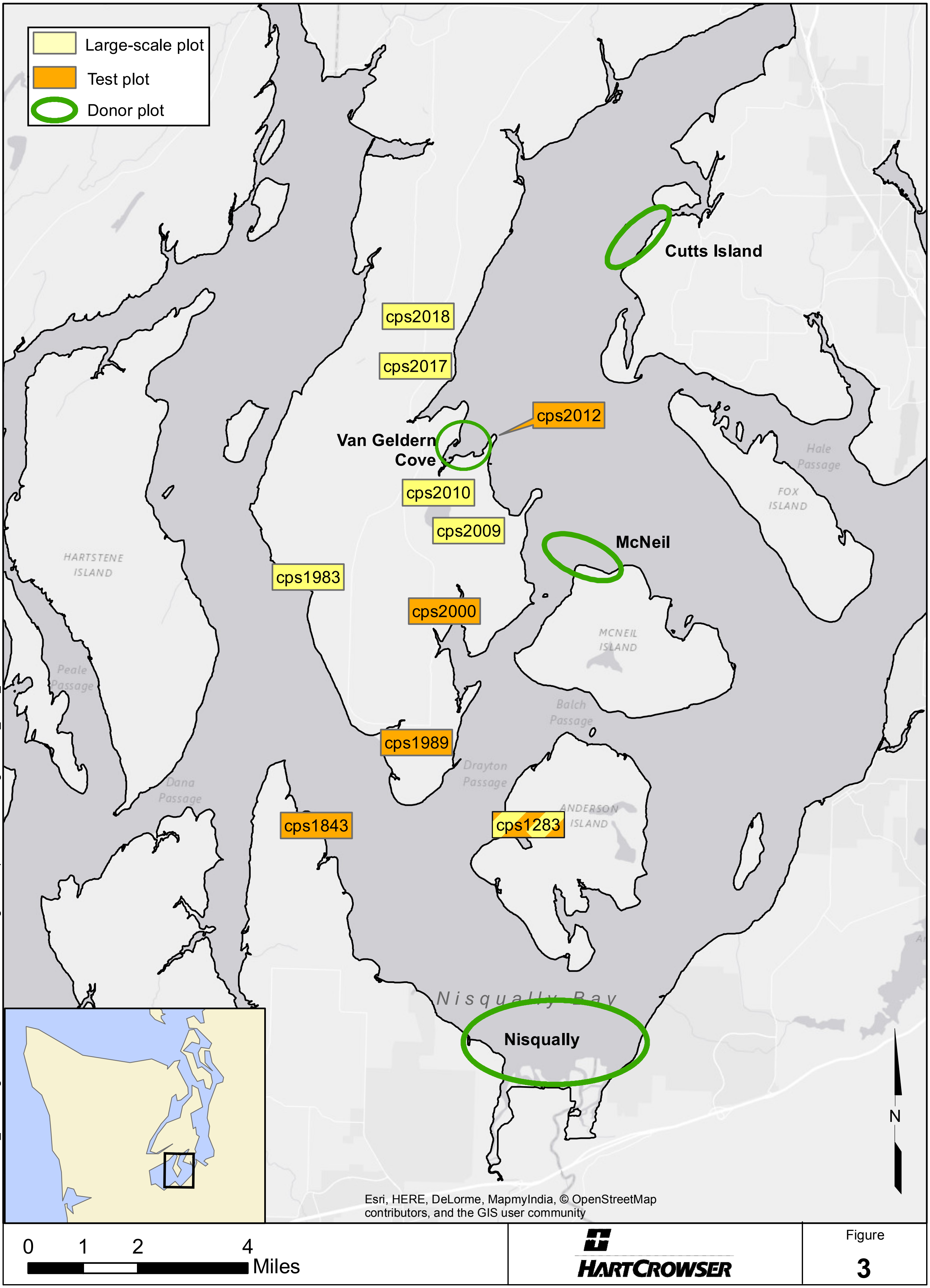

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Figure

3

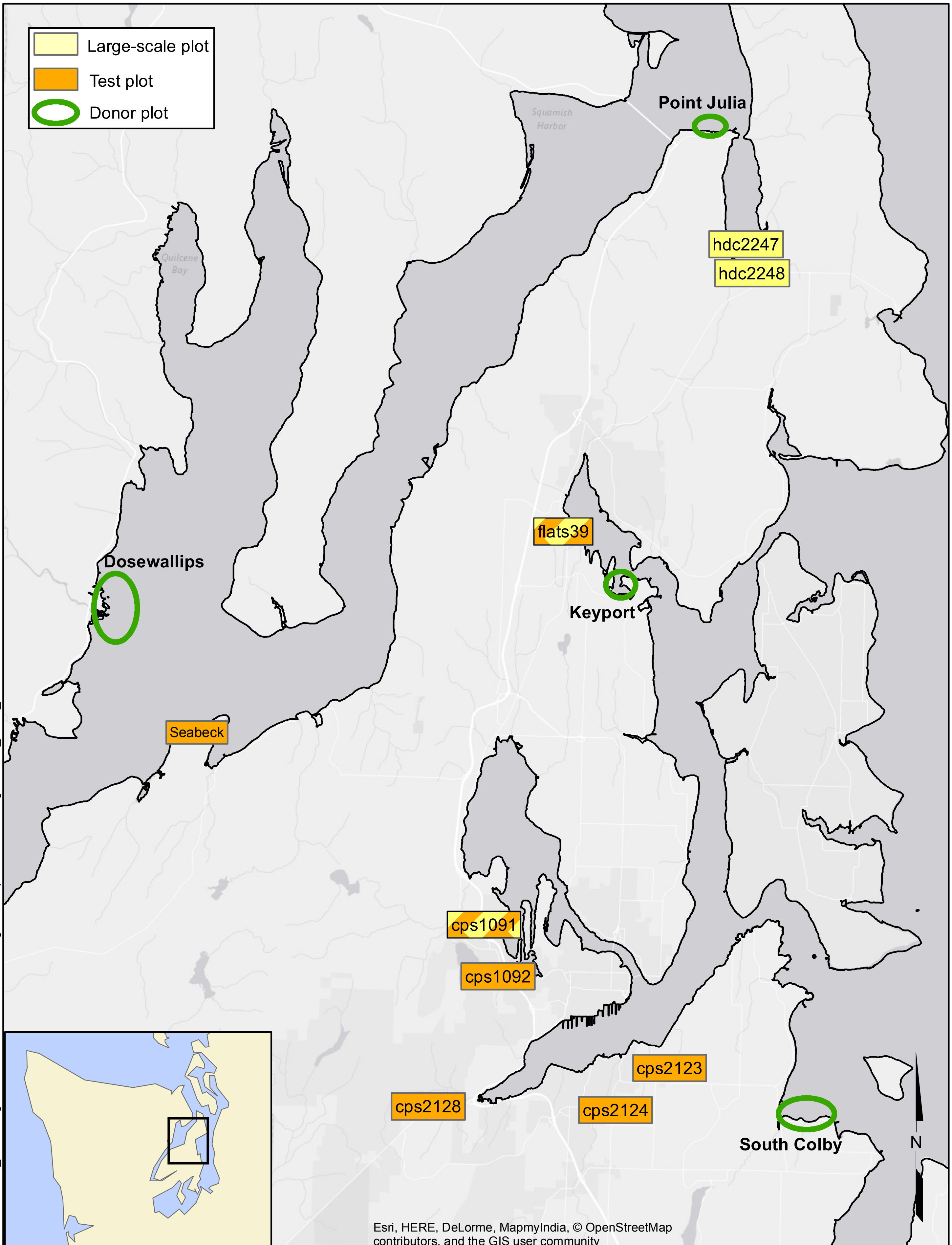

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Figure 3

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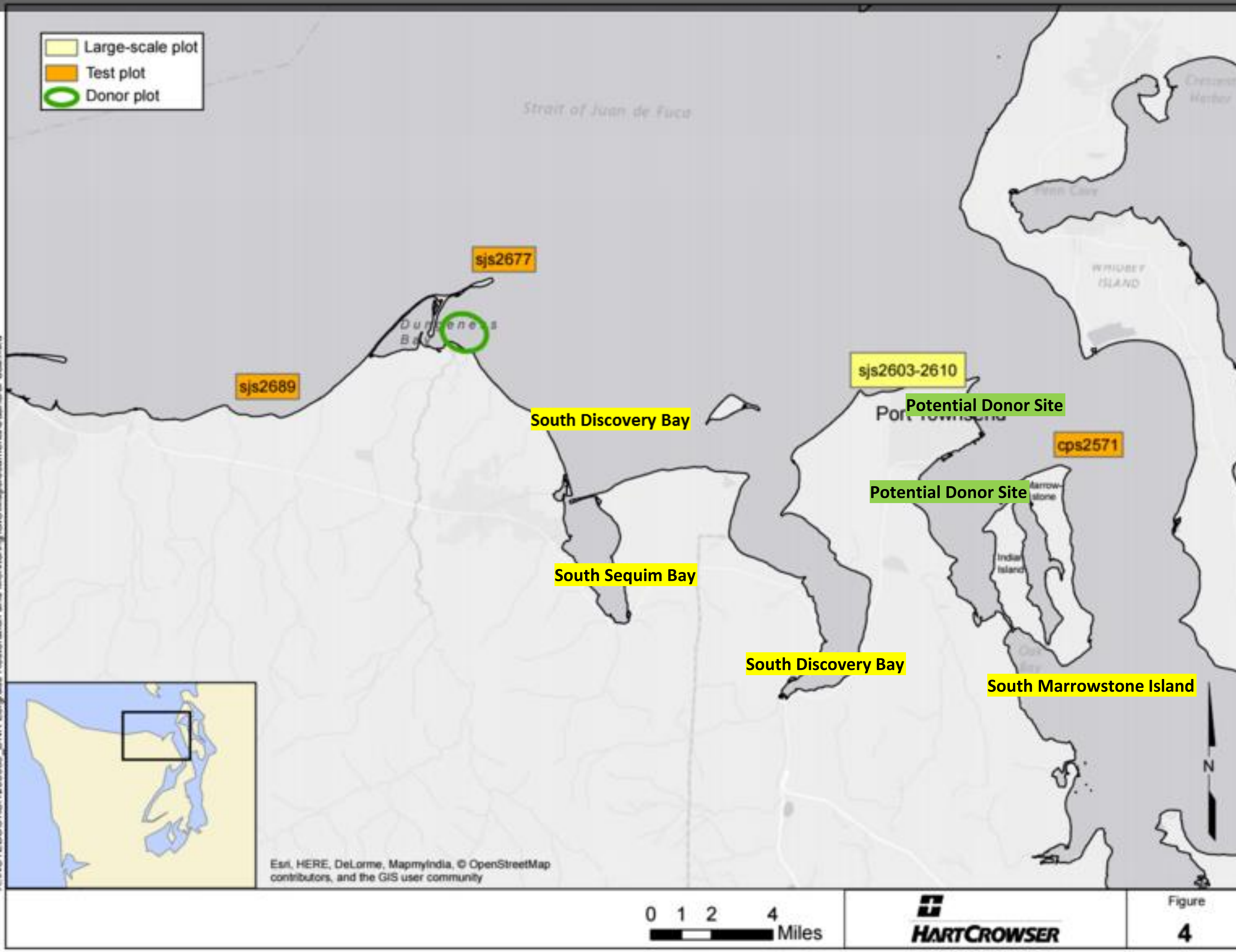

Large-scale plot
Test plot
Donor plot
Strait of Juan de Fuca
sjs2677
sjs2689
South Discovery Bay
sjs2603-2610
Potential Donor Site
cps2571
Potential Donor Site
South Sequim Bay
South Discovery Bay
South Marrowstone Island
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Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
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Figure 4

APPENDIX B
SITE MAPS

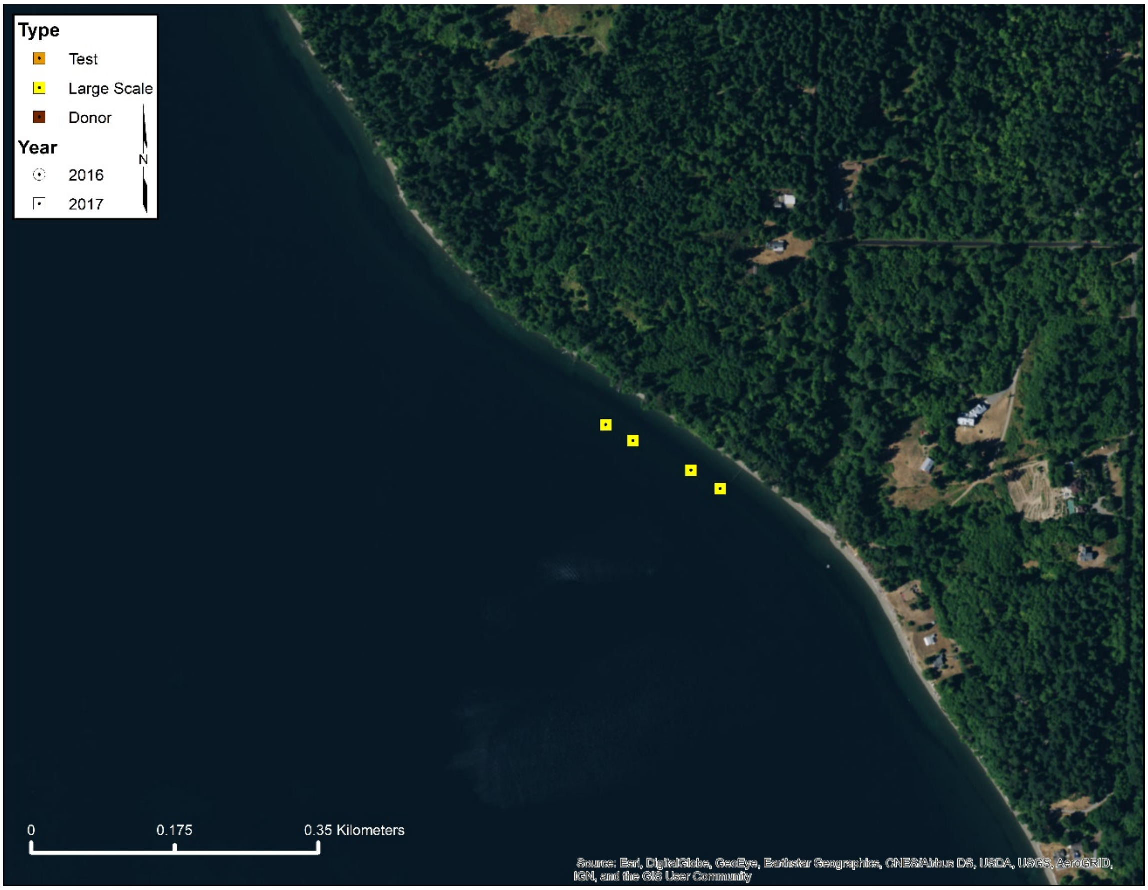

Figure B-1 – Anderson Island South Large-Scale Transplant Sites

Figure B-2 – Anderson Island West 1 (north) and 2 (south) Test-Transplant Sites

Figure B-3 – Cutts Island Harvest Site

Figure B-4 –Delano Beach 2016 Test- and Large-Scale Transplant Sites

Figure B-5 – DuPont Wharf Donor site

Figure B-6 – Fudge Point Test-Transplant Sites

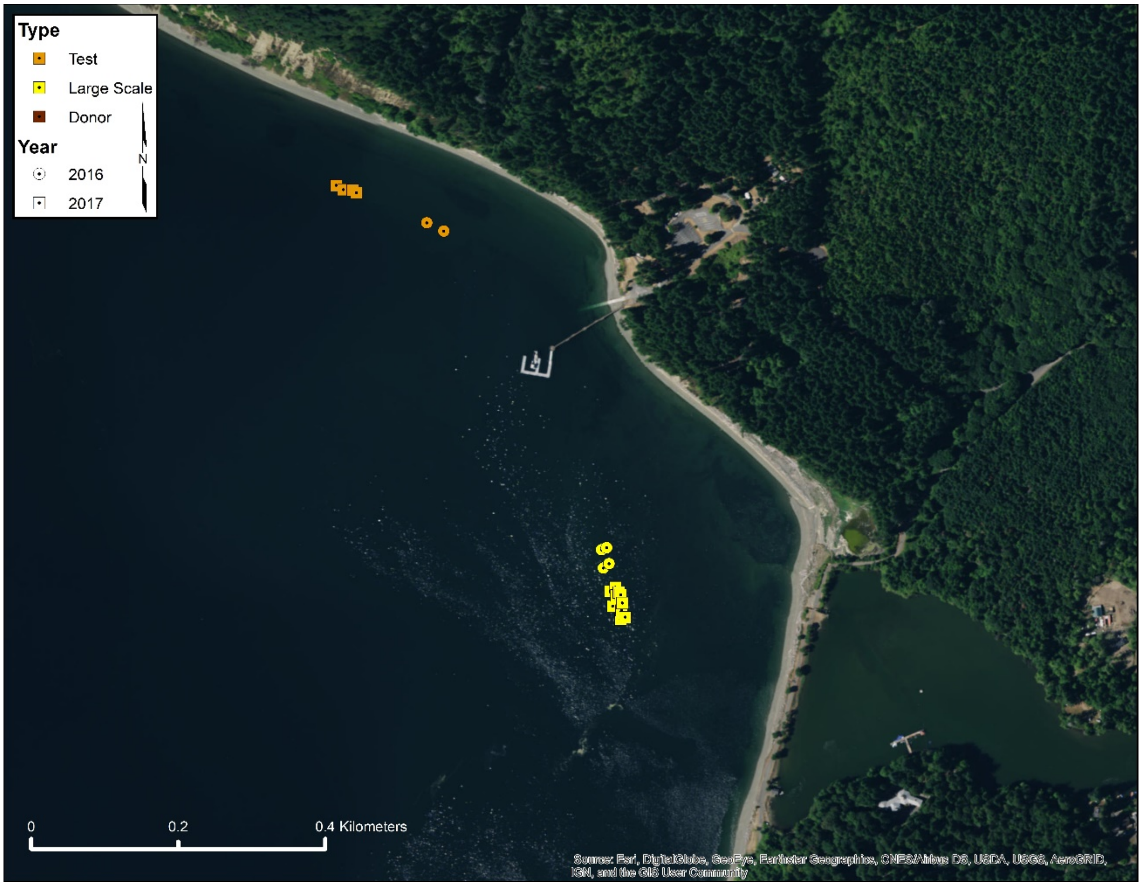

Figure B-7 – Joemma Beach State Park Test- and Large-Scale Transplant Sites

Figure B-8 – McDermott Point 1 (north) and 2 (south) Test-Transplant Sites

Figure B-9 – Penrose State Park Test-Transplant Site

Figure B-10 – Rocky Bay Donor Site

Figure B-11 – South Head Test-Transplant Site

Figure B-12 – Taylor Bay Test-Transplant Sites

APPENDIX C
FIELD NOTES - 2016

MEMORANDUM

DATE: June 2, 2016

TO: Jeff Gaeckle, Washington State Department of Natural Resources

FROM: Emily Duncanson, Hart Crowser
Jason Stutes, Hart Crowser

RE: **SC 16-17: Summary of April 2016 Field Event, Key Peninsula**
1205905

CC: **Amy Leitman, Marine Surveys & Assessments**
Nam Siu, Marine Surveys & Assessments
Eric Parker, Research Support Services

This memo summarizes the field work completed from April 18 to 21, 2016.

Task 4: Monitoring Effort

Numerous Locations

On April 18, 2016, Hart Crowser and RSS reviewed numerous sites using the Sea-All to begin identifying test site locations. The notes are as follows:

- cps1283 – silty sand, possible test plot
- South side of Anderson – eelgrass present
- Thompson Cove – Lots of eelgrass however since previous PNNL work used this as a donor so this is not a donor option.
- cps1843 – substrate doesn't look suitable, bulkheads and other concerns
- cps1983 (Joemma State Park) - good substrate within large area, found PNNL grass potentially, lots of small gastropods. Identified that there was enough space for a large planting within this area.
- cps1989 (Taylor Bay) – Noted quite a bit of shoreline development but areas without modified uplands with suitable substrate. This site should be considered a potential test site.
- cps2000 – Lots of bulkheaded shoreline and deemed unsuitable.
- McNeil Island (south side) – Looked near the white house (caretaker's house) along the shoreline and there was an appreciable amount of grass, but not enough for a donor bed. However this grass is located too close to the island to be harvested.

- Kopachuck State Park – Grass present and likely enough for a donor bed.
- Cutts Island – Good donor bed, lots of grass present at the proper depth.
- cps2009 (Delano Bay) – Very shallow and flat, no grass was found during the video survey however suitable substrate was found that could be a potential test site.

Penrose Point State Park

On April 19, 2016, the Team reviewed the potential to use the Penrose Point State Park site (cps2012) as a test site. Some existing eelgrass was found, although it was shallower than other grass in the south Puget Sound area. Some of the eelgrass was potentially mixed with *Zostera japonica*. The substrate was of good quality at locations deeper than the existing eelgrass. However, after discussions with Gaeckle, the Team decided to remove the Penrose site from consideration as a test site due to the existing eelgrass and prior modifications in the area.

Von Geldern Cove

On April 19, 2016 the Team reviewed potential test sites at Von Geldern Cove (cps2017 and cps2018). At site cps2017, the substrate quality was decent, but a lot of macroalgae was observed. At site cps2018, good water and substrate quality were observed between the shallow and deep edges of the potential eelgrass zone. This site was also less steep than cps2017. During a second visit on April 21, 2016, divers observed macroalgae in higher amounts than observed at Taylor Bay or Joemma State Park sites. This could be a potential site but there are concerns about smothering by ulva and other macroalgae.

Delano Bay

The Team reviewed potential test sites at Delano Bay on April 19, 2016. Initially, a site along the southeast portion of the Bay was identified as having good quality substrate within the appropriate depth contours for transplanting. However, during the transplanting efforts on April 20, 2016, it was discovered that this was only the case for the first few inches of substrate. Below this, the substrate was too hard for transplanting. A site with more suitable substrate was found on the northwest portion of the Bay and this was used as the test site, instead.

Joemma State Park

The Team reviewed potential test sites at Joemma State Park (cps1983) on April 21, 2016. North of the mooring buoys, the divers found the substrate to be good quality. A large sand dollar bed was observed, but this was above the upper depth contour for eelgrass transplants. The Team decided to include this as a test site.

Taylor Bay

The Team reviewed potential test sites at Taylor Bay (cps1989) on April 21, 2016. The divers found the substrate to be of good quality within the appropriate depth contours for eelgrass transplants. Sand dollars were also found, but again, at depths shallower than appropriate for eelgrass planting. The Team decided to include this as a test site.

Task 3: Transplant Effort

Transplanting began on April 19, 2016 with setting up the donor site at Cutts Island by delineating eelgrass at the site and setting up the donor and harvest transects within the bed. Harvesting was done after pre-harvest counts were taken along both the harvest and control transects at Cutts Island (Photograph 1).

Photograph 1. Cutts Island Donor Site

The coordinates provided here are for the permanent markers positioned at each end of both the Control Transect and the Harvest Transect established at Cutts Island as shown in Figure 1.

Cutts Island Control 1

47°19′ 31.15897″ N
122°40′ 54.98138″ W

Cutts Island Control 2

47° 19′ 30.59403″ N
122° 40′ 56.03639″ W

Cutts Island Harvest 1

47° 19′ 31.17291″ N
122° 40′ 54.12544″ W

Cutts Island Harvest 2

47° 19′ 31.72297″
122° 40′ 54.12544″

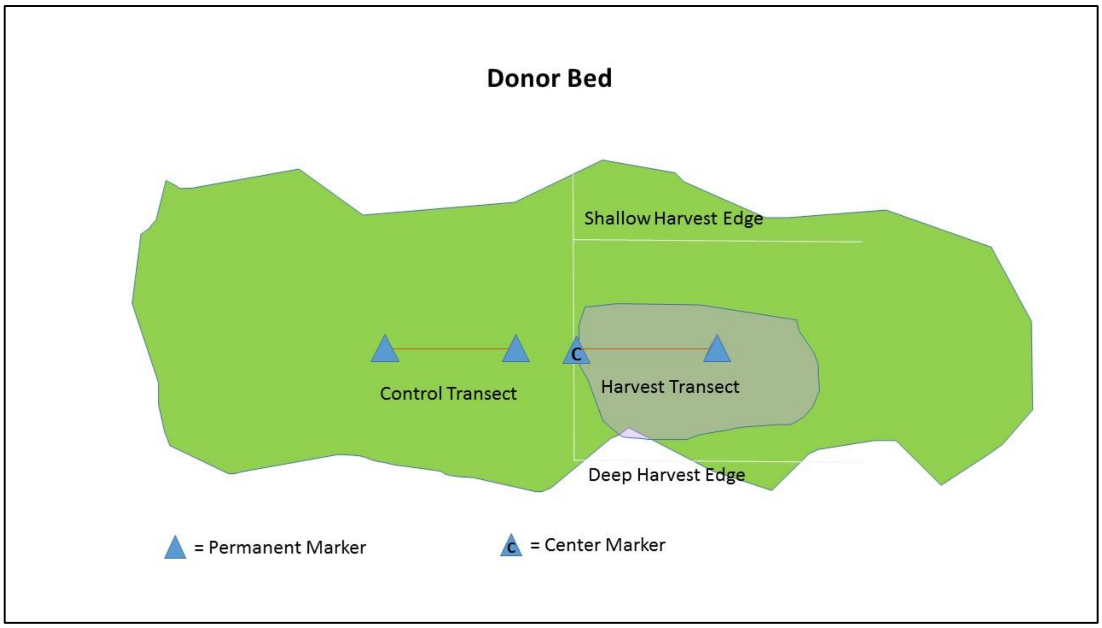

Figure 1. Example donor bed schematic

Delano Bay

We established a test site on the west end of Delano Bay near cps2011. Planting at the site occurred on April 21, 2016; methodology is described below and illustrated in Figure 2.

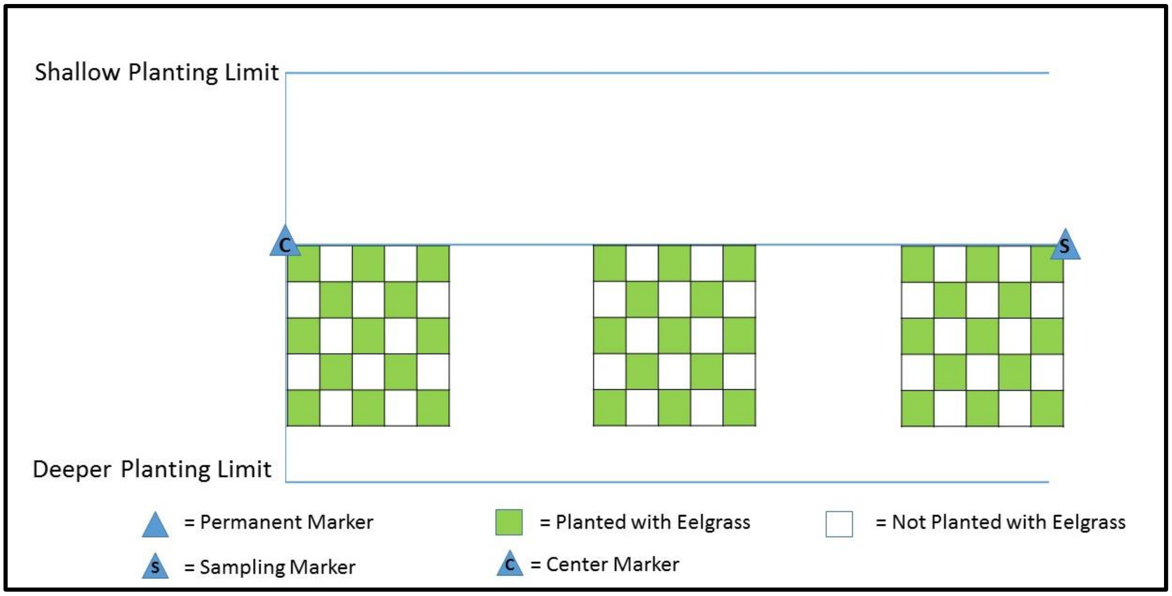

Figure 2. Example test site planting schematic

At each test site, there are three 5 by 5 meter test plots where eelgrass was planted in a checkboard pattern along a transect as shown above. Each test plot was separated by 5 meters. This transect was established at a depth of approximately -2 meters MLLW. Within each planted square, shown in green above, eelgrass was planted at a density of 20 shoots/meter by placing 4 planting units (PUs) each holding 5 shoots. Planting units consist of a 5 by 18 inch burlap strip where the 5 shoots were woven (shoot and rhizome on same side). See Photograph 1 for more detail. The total number of PUs installed at each test site was 156 PUs for a total of 780 shoots per test site.

Photograph 1. Creation of a planting unit by weaving eelgrass shoot into burlap strip

The coordinates provided here are for each end of the Delano Bay test site transect as shown in Figure 2.

Delano Bay W T1

47° 15′ 28.94527″ N
122° 44′ 17.37676″ W

Delano Bay W T2

47° 15′ 29.80688″ N
122° 44′ 17.14128″ W

HARTCROWSER

MEMORANDUM

DATE: May 26, 2016

TO: Jeff Gaeckle, Washington State Department of Natural Resources

FROM: Emily Duncanson, Hart Crowser
Jason Stutes, Hart Crowser

RE: **SC 16-17: Summary of May 2016 Field Event, Key Peninsula**
1205905

CC: **Amy Leitman, Marine Surveys & Assessments**
Nam Siu, Marine Surveys & Assessments
Eric Parker, Research Support Services

This memo summarizes the field work completed from May 16 to 20, 2016.

Task 4: Monitoring Effort

Delano Bay

On May 16, 2016, Emily Duncanson and Jason Stutes with Hart Crowser and Eric Parker and Chris Fairbanks (diver) with Research Support Services (RSS) surveyed the recently planted eelgrass at Delano (April 2016) where 780 shoots were planted at the test site among three test plots. The plants looked decent with approximately 27 percent of planting units observed being qualified as disturbed, meaning that some edge of the burlap was visible or slightly modified. Plants were confirmed to have been planted too shallow at -1.25 m MLLW.

The next site reviewed was the PNNL Delano Transplant Site. Chris Fairbanks (Chris) collected density data of the planted grass and found approximately the same number of shoots that were planted (800 shoots) in 2015. Plants overall looked healthy with new growth and reproductive shoots noted. The density estimate for the planted area is 48.5 shoots/m^2 which is the average of two 1-m^2 quadrat counts within the planted area.

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Joemma State Park

We then headed to Joemma to assess the PNNL North Transplant Site. We were able to locate Transects 0, 1, 2, and 3 and collected density counts along them. Chris relayed that the plants were stiff and looked like "old fettucine" and from the live video we saw that nearly all shoots were very weighed down by a small gastropod and laying on the seafloor. No new growth was noted in contrast to the transplants found at Delano. We were not able to locate Transect 4. Average density over all sampled plots where eelgrass was present was 8.8 shoots/m^2. Several plots were noted with no eelgrass present and sediment staples visible. Density was measured by locating the helical at the end of each transect and counts were collected by locating eelgrass patches along the transect and counting all shoots within the meter squared quadrat.

Task 3: Transplant Effort

Transplanting began on May 17, 2016 with setting up the donor site at Rocky Bay by delineating eelgrass at the site and setting up the donor and harvest transects within the bed. Harvesting was done after pre-harvest counts were taken along both the harvest and control transects at Rocky Bay.

The coordinates provided here are for the permanent markers positioned at each end of both the Control Transect and the Harvest Transect established at Rocky Bay as shown in Figure 1.

Rocky Bay Control 1

47°21'26.59751

122°48'07.86830

Rocky Bay Control 2

47°21'26.67122

122°48'09.06407

Rocky Bay Harvest 1

47°21'26.66938

122°48'10.41645

Rocky Bay Harvest 2

47°21'26.67028

122°48'09.21776

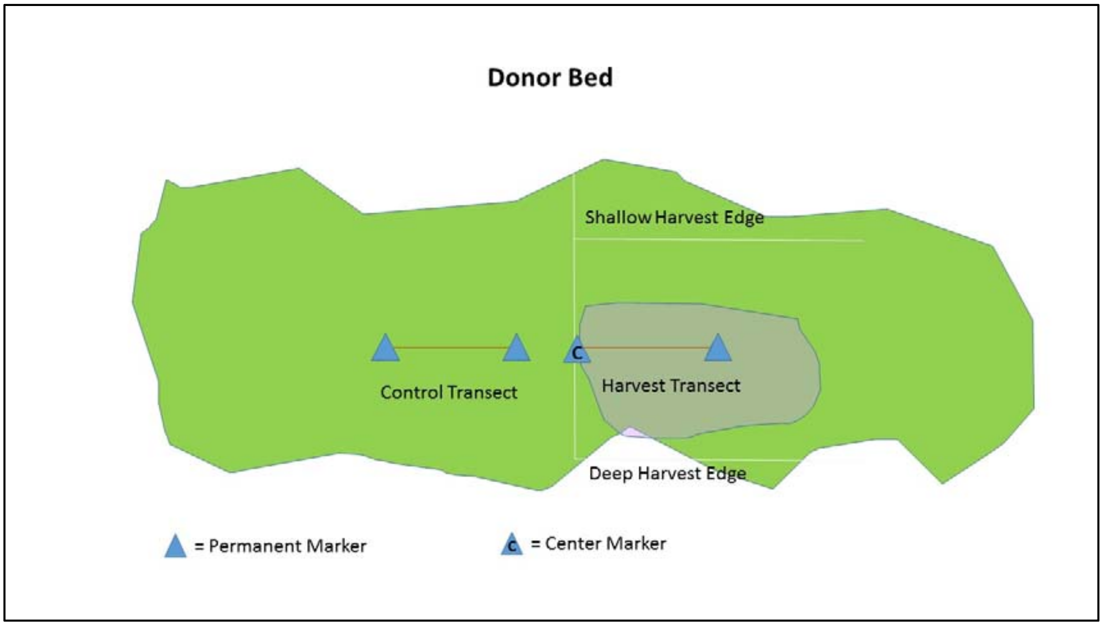

Figure 1. Example donor bed schematic

Planting at three test transplant sites began on May 18 to at the north end of Joemma State Park (CPS 1983), then we planted at Taylor Bay (CPS 1989), and finished up on May 20, 2016 with Penrose State Park (CPS 2012).

Joemma State Park

We established a test site north of the mooring buoys on the north end of Joemma State Park. Planting methodology is illustrated in Figure 2.

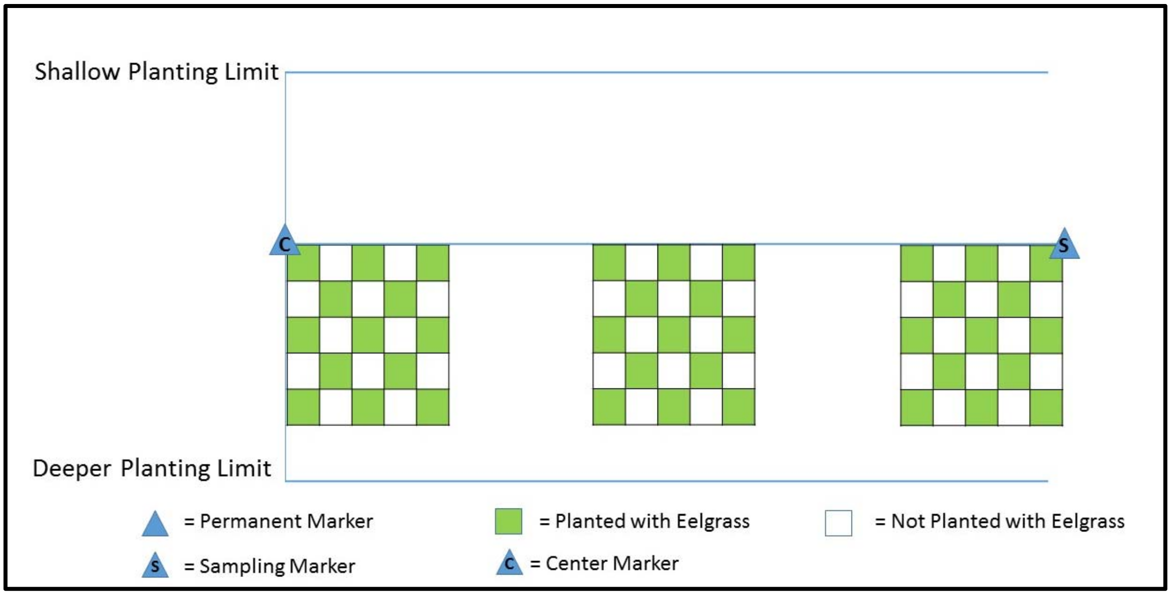

Figure 2. Example test site planting schematic

At each test site, there are three 5 by 5 meter test plots where eelgrass was planted in a checkboard pattern along a transect as shown above. Each test plot was separated by 5 meters. This transect was established at a depth of approximately -2 meters MLLW. Within in each planted square, shown in green above, eelgrass was planted at density of 20 shoots/meter density by placing 4 planting units (PUs) each holding 5 shoots. Planting units consist of a 5 by 18 inch burlap strip where the 5 shoots were woven (shoot and rhizome on same side). See Photograph 1 for more detail. The total number of PUs installed at each test plot was 156 PUs for a total of 780 shoots per test site. Each PU was anchored at either end using biodegradable stakes that had an anchoring barb at the end for a total of 312 stakes. The plants were reviewed the next morning (May 18, 2016) before planting at the second test site. Divers found that about 62 stakes (approximately 20 percent) had either popped out completely or partially. Since they are barbed there was concern that once they pop out they would rip out the whole strip so we decided it might be worth modifying the anchoring method at the next site.


Photograph 1. Creation of a planting unit by weaving eelgrass shoot into burlap strip

The coordinates provided here are for each end of the Joemma State Park test site transect as shown in Figure 1.

Joemma Test North

47°13’33.21787
122°48’47.95222

Joemma Test South

47°13’32.86947
122°48’46.84585

Taylor Bay

Transplant effort at Taylor Bay followed the same methodology as described above for Joemma. The test site was established at south end of Taylor Bay. Substrate was reportedly more flocculent than Joemma, with some ulva but none enough to cause concern. Graceful crabs in some cases were aggressive and began disturbing plants and burlap after placement. We modified the anchoring method at Taylor Bay with Plot 1 and Plot 2 using stakes and Plot 3 using sod staples. Divers said that staples were easier and faster to install when compared to the barbed stake and noted that the 12-inch long, rusted sod staples seemed very solidly anchored.

The coordinates provided here are for each end of the Taylor Bay Test Site transect as shown in Figure 1.

Taylor Bay North

47°10’59.12601
122°46’40.05838

Taylor Bay South

47°10’58.29628
122°46’40.01636

Penrose State Park

Transplant effort at Penrose State Park followed the same methodology as described above for Joemma and Taylor bay. We established a test site along the NE shore of Penrose State Park. Prior to planting at this site, we decided to modify the burlap to only have one hole so the plants were more up and down. See Photograph 2 for more detail.

Photograph 2. Modified installation of eelgrass within burlap – no weave

The decision to go to one hole installation was made after observing how this improved the location of the meristem in relation to the burlap and that the shoots have advantage of being immediately more upright. There were concerns about shoots slipping out of the burlap in transport without being weaved, but divers assessed as they planted and found no loss in shoots. Also stored a test PU with this method off the side of the boat all day and all shoots were still within the burlap after 5 hours. As was done at Joemma, and Taylor, PUs at Penrose were anchored on each end with barbed stakes.

The coordinates provided here are for each end of the Penrose State Park Test Site transect as shown in Figure 1.

Penrose Test North

47°15’50.64106
122°44’21.33287

Penrose Test South

47°15’49.92018
122°44’21.33287

MEMORANDUM

DATE: July 1, 2016

TO: Jeff Gaeckle, Washington State Department of Natural Resources

FROM: Emily Duncanson, Hart Crowser
Jason Stutes, Hart Crowser

RE: **SC 16-17: Summary of June 2016 Field Event, Key Peninsula**
1205905

CC: **Amy Leitman, Marine Surveys & Assessments**
Nam Siu, Marine Surveys & Assessments
Eric Parker, Research Support Services

This memo summarizes the field work completed from June 12 to 19, 2016.

Task 4: Monitoring Effort

Taylor Bay

On **June 12, 2016**, Jason Stutes with Hart Crowser and Eric Parker and Chris Fairbanks (diver) with Research Support Services (RSS) surveyed the recently planted eelgrass at Taylor Bay (May 2016) where 780 shoots were planted at the test site among three test plots. No divers got in the water for survey at this site. Review of this site was done entirely with the SeaAll video system.

Generally, very little burlap was exposed throughout the transplant area. The eelgrass planted at Taylor Bay was woven into the burlap and video of the area indicated that the grass was not erect. It was at this site that we experimented with both barbed biodegradable stakes and metal staples as a means to anchor the burlap strips. It appears from the video footage that the metal staples are superior to the stakes, with several stakes exposed within the transplant area. There was some algae wrack that had accumulated but was minimal at the time of the survey.

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Penrose State Park

On the same day, the crew surveyed the recently planted eelgrass at Penrose State Park (May 2016) where 780 shoots were planted at the test site among three test plots. No divers got in the water for survey at this site. Review of this site was done entirely with the SeaAll video system.

This eelgrass was planted using a single hole method (previous efforts had used a double hole) and with the biodegradable barbed stake. From the video assessment, the grass looks like it's in good condition and comparatively better looking and more erect than Taylor with less gastropods present on the blades. There was more macroalgae present at this site than compared to Taylor which could be a concern if this condition is persistent or escalates.

Task 3: Transplant Effort

June 12, 2016 - Transplanting began after test site inspection later in the day where divers collected shoot density data from the control transect located at Cutts Island.

June 13, 2016 - Work continued at Cutts Island on the following day with the crew heading back to finish the pre-harvest assessment of donor bed, where divers collected density data along the harvest transect at the donor site. Following these counts, two teams of two divers began to harvest randomly and evenly within the harvest transect area. Weather turned for the worse in the early afternoon and we concluded dive operations as a safety precaution. The crew headed back to Penrose where we began to process eelgrass for planting the following day. Crew used fid apparatus (Photograph 1) to insert an average of 10 shoots of eelgrass into each burlap strips cut into 4 by 20-inch strips to create a planting unit (PU). Once a PU was assembled, it was stored in a temperature monitored tub on a keyring (Photograph 2). Once the keyring had 30 PU's, it was placed into a laundry bag and held off the dock for longer term storage until planting.

Photograph 1. Single hole with single eelgrass shoot

Photograph 2. Post processed eelgrass being stored temporarily

June 14 through 16, 2016 – A second boat from RSS (Sled) was added to the effort and departed with the Dow to set the planting area by marking corners for divers to set tapes on (Photograph 3). We were conservative when marking depth and applied a “safety factor” of about -0.12 meter MLLW to -0.15 meter MLLW to ensure proper planting elevation on state owned aquatic lands. While the tape was being set, the team on shore began processing harvested eelgrass. The Sled remained on site to begin dive operations with processed eelgrass and the Dow returned to dock to help process and transport PU’s.

Photograph 3. Sled and Dow at Delano getting set up.

After transect tapes were set along transplant area edges, divers used a 5 by 1 meter grid to install the eelgrass. They set the grid along the shallow edge and installed **six** PU’s within each cell as shown in Figures 1 and 2. Divers dug a trench, placed the PU within the trench, staked the strip using a 12” staple and buried.

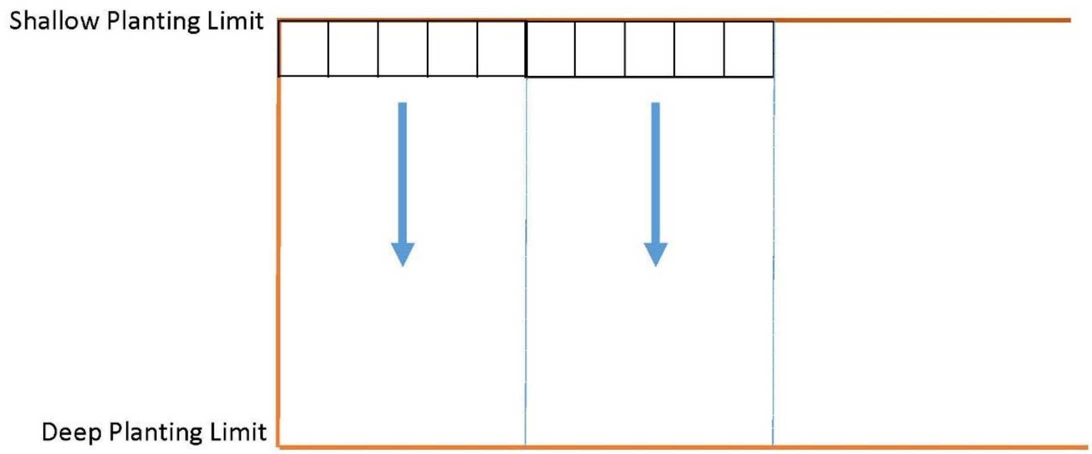

Figure 1. Schematic of large scale planting by divers using 5 by 1 meter grid

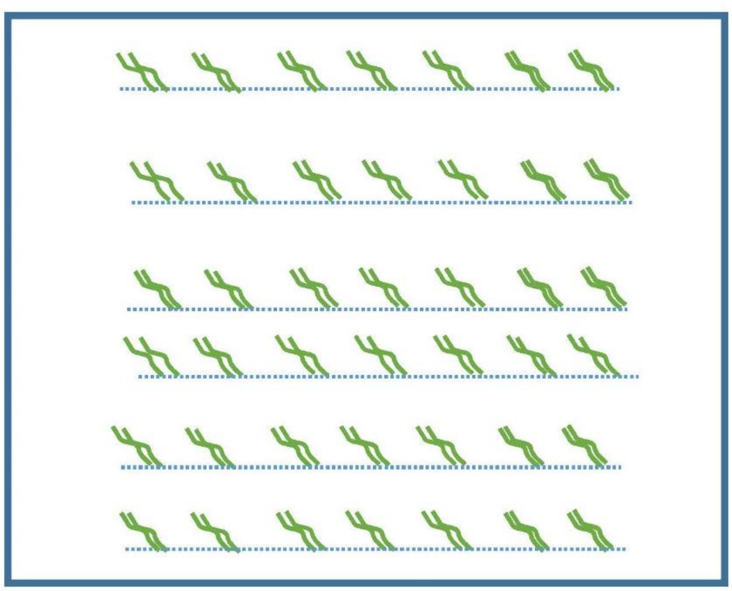

Figure 2. Example of planted 1 meter quad with 6 PU's (strips of burlap with eelgrass)

COLUMN 7					COLUMN 6					COLUMN 5					COLUMN 4					COLUMN 3					COLUMN 2					COLUMN 1					
CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	CELL 1	CELL 2	CELL 3	CELL 4	CELL 5	
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	ROW 1
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	ROW 2
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	ROW 3
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	ROW 4
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	ROW 5
126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	126	60	60	60	60	60	60	60	60	60	60	ROW 6

Figure 3. Delano planting schematic showing the shoot density within each cell

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June 15, 2016 through June 17, 2016 – Team did a combination of planting, processing and harvesting of more eelgrass. We realized after planting three columns, that we could increase the planting density with likely no serious biological reprocussions. We had been installing plants at a density of 60 shoots per meter, and made the decision to increase the number to 126 shoots per meter, which approximates natural density. To accomplish this we increased the number of shoots per hole within the burlap to 3 so that the total number of shoots per strip was 21. This had the added bonus of increasing efficiency of processing eelgrass into PU's which is often the rate limiting step. This shift in density is illustrated in Figure 3. The light green color represents the intial density of 60 shoots per m^2 and the darker green represents the increased density of 126 shoots per m^2.

June 17, 2016 – In addition to processing and planting eelgrass as detailed above, the dive team collected post harvest density data along the harvest transect at Cutts Island.

June 18 and 19, 2016 – Team continued to process and plant and finished up at 15:00 on the 19th and headed back to the dock to demobilize from the site. Final number of shoots installed within the Delano planting area was 20,850 eelgrass shoots. Final total area of planting at Delano was 6 meters by 35 meters totaling a $210m^2$. Figure 4 indicates the location of the large scale planting in relation to the Delano test site and its orientation and proximity to shore within Delano Bay.

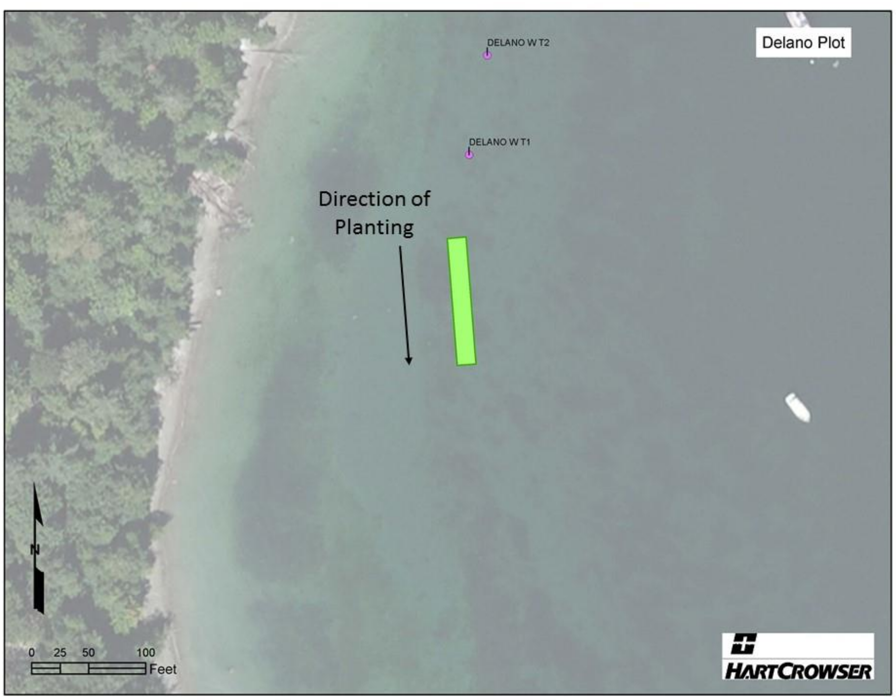

Figure 4. Delano Large Scale Planting Area (note: Delano Test Site shown to the north)

The final coordinates of the Delano planting area are:

Delano SE: 47.257533, -122.738204

Delano SW: 47.257537, -122.738138

Delano NE: 47.257842, -122.738172

Delano NW: 47.25783897, -122.738238

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MEMORANDUM

DATE: August 5, 2016

TO: Jeff Gaeckle, Washington State Department of Natural Resources

FROM: Emily Duncanson, Hart Crowser
Jason Stutes, Hart Crowser

RE: **SC 16-17: Summary of July 2016 Field Event, Key Peninsula**
1205905

CC: **Amy Leitman, Marine Surveys & Assessments**
Nam Siu, Marine Surveys & Assessments
Eric Parker, Research Support Services

This memo summarizes the field work completed on July 6 and from July 24 through 28, 2016.

Task 4: Monitoring Effort

Joemma Beach

On **July 6, 2016**, DNR and Hart Crowser surveyed the recently planted eelgrass test plot at Joemma Beach (May 2016) where 780 shoots were planted at the test site among three test plots. DNR's Jeff Gaeckle and Bart Christiaen snorkeled the area as part of the review.

Generally, the transplants were intact and appeared in good health. There were some sod stakes within the planting area that had popped up and were accumulating large drift macroalgae which has the potential to cover/smother the adjacent grass. Small gastropods noted in other surveys at Joemma were present on the shoots throughout the site and in some cases occurred at densities that weighed down the shoots.

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Photograph 1. Visible sod stake accumulating drift algae

Photograph 2. Transplanted eelgrass shoots with small gastropods

Photograph 3. Accumulated drift algae within planting area

Taylor Bay

On the same day, the Hart Crowser and DNR surveyed the recently planted eelgrass at Taylor Bay (May 2016) where 780 shoots were planted at the test site among three test plots. Jeff Gaeckle snorkel surveyed the area.

The sediments at this site were silty with high amounts of organics which contributed to poor visibility. Jeff was able to locate both of the helical anchors at each end of the transplant area and saw that the transplants along the transect seems to be struggling. There were low numbers of shoots observed and the plants that he was able to locate appeared distressed. He noted that this area seems to be an depositional in nature with drift macroalgae noted through the area.

Task 3: Transplant Effort (Large)

July 6, 2016 – Hart Crowser and DNR installed 4 helical anchors to the south of the PNNL transplant area to designate the new large transplant area for the upcoming planting.

July 24, 2016 – Began field week by traveling north to Rocky Bay to collect pre-harvest eelgrass density counts along previously established control and harvest transects within the donor bed at Rocky Bay. Following these counts, two teams of two divers began to harvest randomly and evenly within the harvest transect area. All eelgrass that was harvested was transported back to Joemma in a tub filled with fresh seawater and upon arrival at Joemma was suspended off the boat at the floating dock.

July 25, 2016 - Crew spent the first few hours of the morning setting up for processing and also created an additional 5 fid apparatus (Photograph 4) to insert an average of 21 shoots of eelgrass into each burlap strip (4 by 20-inch) to create a single planting unit (PU).

Once a PU was assembled, it was stored in a temperature monitored tub on a keyring. Once the keyring had 30 PU's, it was placed into a laundry bag and held off the dock for longer term storage until planting.

A group of 16 high school students arrived around 9:30 to assist with processing for a few hours (Photographs 4 and 5). They were extremely hard working and excited to participate in the project.

Photographs 4 and 5. High schoolers helping process eelgrass

Once we had processed about 120 PU's, two divers were dispatched to transplant area at Joemma to begin planting. They began by running out transect tapes along the deep and shallow edge to guide the planting grid. The divers used a 5- by 1-meter grid to install the eelgrass. After setting the transect tape, the divers placed the grid along the shallow edge and installed six PU's within each cell as shown in Figures 1 and 2. Divers dug a trench, placed the PU within the trench, staked the strip using two 12" staples, and backfilled the trench. The grid was flipped 8 times to reach the deep edge, making the width of the bed 8 meters or approximately 26 feet. We referred to this as a swath or column of installed eelgrass.

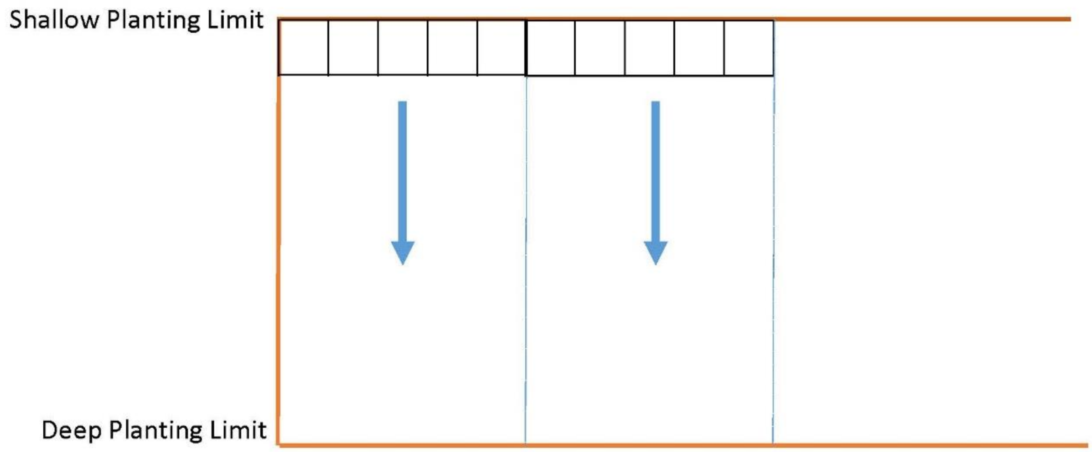

Figure 1. Schematic of large scale planting by divers using 5 by 1 meter grid

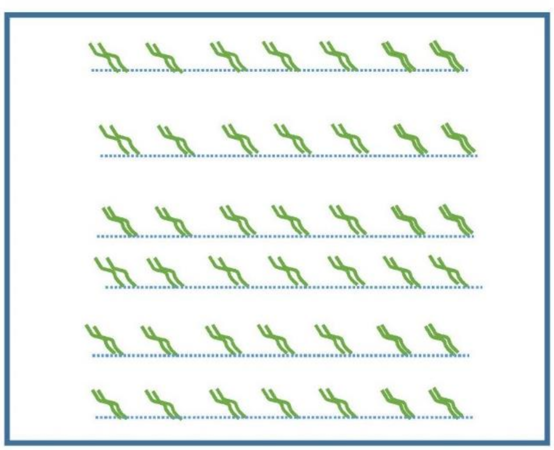

Figure 2. Example of planted 1-meter quad with 6 PU's (strips of burlap with eelgrass)

We tracked the progress of the plantings throughout the week by marking up the schematic shown in Figure 3.

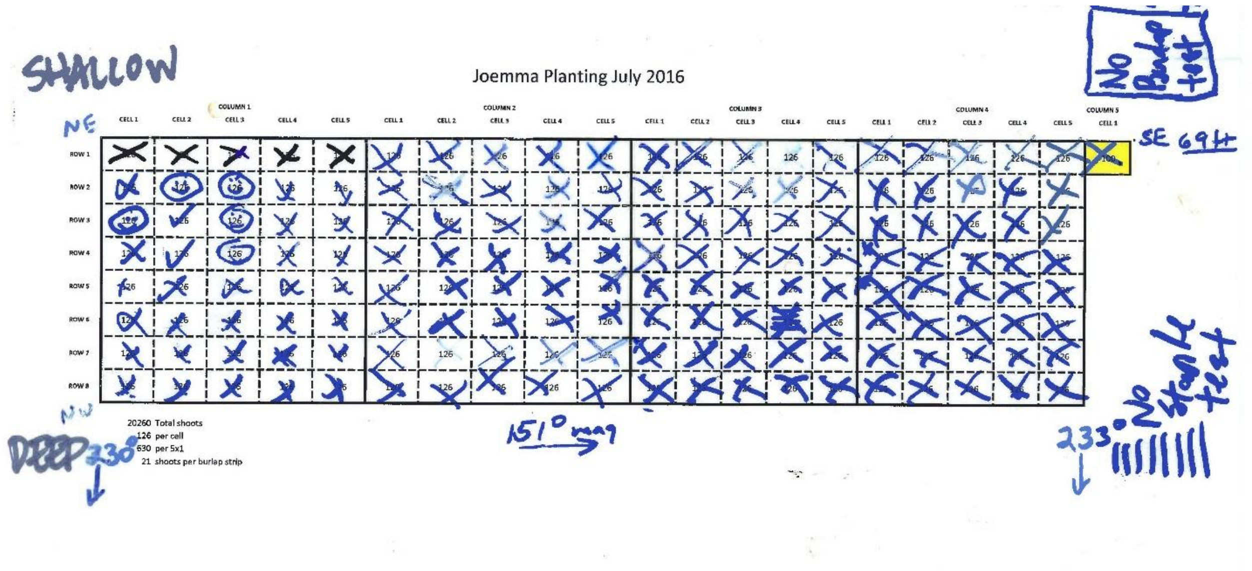

Figure 3. Schematic of Joemma planting used to keep track of plants installed

June 26, 2016 through June 27, 2016 – Team did a combination of planting, processing and harvesting of more eelgrass. The planting went very smoothly for the divers as a result of great visibility and easy substrate for digging. There were additional volunteers on June 26 and June 27 that helped boost processing efforts so that divers could be underwater longer.

June 28, 2016 – One team continued to process and plant the remaining shoots necessary to meet the 20,260 shoot requirement. There was additional eelgrass at the end of processing beyond what was needed to meet the requirement. The additional eelgrass was in the form of unprocessed eelgrass (as harvested) and processed eelgrass mounted on burlap. As marked on Figure 3, the unprocessed eelgrass was installed just outside the SE corner of the transplant area. The diver planted the extra mats of eelgrass into the substrate without burlap or staples. The additional processed eelgrass with the burlap was planted just outside the southwest corner of the planting area and was planted similarly to those within the planting area but was not staked. The approximate number of shoots between both of these areas is 1,200 shoots. The other team went to Rocky Bay to conduct post-harvest transect counts. Both teams were demobilized by 15:00.

The final planted area of the Joemma transplant is 160 m^2. The final coordinates of the Joemma planting area are:

Joemma SE: 47°13’18.47099, 122°48’35.55674

Joemma SW: 47°13’18.27130, 122°48’35.90835

Joemma NE: 47°13’19.1712, 122°48’35.7444

Joemma NW: 47°13’19.07561, 122° 48’36.06807

APPENDIX D
FIELD NOTES – 2017

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DNR Eelgrass Restoration Project May 3rd - 8th 2017 Field Effort Summary

Wednesday May 3rd

- Arrived at Rocky Bay harvest site to collect eelgrass for transplantation test plot locations.
- Performed monitoring counts at Rocky Bay harvest site.

Count #	Control	Pre-harvest	Post-harvest	Count #	Control	Pre-harvest	Post-harvest
1	31	92	107	**14**	48	156	21
2	0	122	3	**15**	52	127	148
3	34	112	75	**16**	33	164	42
4	53	148	51	**17**	58	118	55
5	47	123	97	**18**	79	161	35
6	38	33	55	**19**	0	102	74
7	55	115	92	**20**	0	99	22
8	61	200	41	**21**	62	104	56
9	57	101	133	**22**	56	181	63
10	42	130	73	**23**	60	92	64
11	35	87	93	**24**	59	29	42
12	56	44	64	**25**	42	106	98
13	53	96	118	**26**	55	59	54

- Subsample weights and counts

Sub-count	Weight (kg)	Count	Shoots/kg
1	0.05	45	900
1	0.1	78	780
1	0.1	65	650
1	0.1	80	800
	Average Weight (kg)	Average Count	Average Shoots/kg
	0.0875	67	782

- Harvested 8.585 kg of eelgrass equating to 6713 shoots.

Thursday May 4th – Friday May 5th

- Harvested Rocky Bay eelgrass was transplanted to 3 test plot sites.
- Sites contain 3 plots, at 0m, 5m, and 10m along the baseline.
- Two test plot configurations were used.
  1. Plots were 5m x 5m, planted as a checker board pattern starting in the top left.
  2. Plots were 1m x 2m, planted evenly across all squares with no empty squares.
- Sites that used test plot configuration #1
  - Joemma North 2017 test plot site
  - Joemma South 2017 test plot site
  - McDermott Point North 2017 test plot site
  - McDermott Point South 2017 test plot site
- Sites that used test plot configuration #2
  - West Anderson Island North 2017 test plot site
  - West Anderson Island South 2017 test plot site

Site Name	Baseline Location (m)	Bag Weight (g)	Est. Shoot Count
Joemma North	0	455	355
Joemma North	5	426	333
Joemma North	10	450	351
Joemma South	0	450	351
Joemma South	5	450	351
Joemma South	10	445	347
McDermott Point North	0	415	324
McDermott Point North	5	435	340
McDermott Point North	10	420	328
McDermott Point South	0	425	332
McDermott Point South	5	430	336
McDermott Point South	10	420	328
West Anderson Island North	0	370	289
West Anderson Island North	5	370	289
West Anderson Island North	10	370	289
West Anderson Island South	0	370	289
West Anderson Island South	5	370	289
West Anderson Island South	10	370	289

Saturday May 6th

- After completing the test plots, it was decided to start a large-scale planting at Joemma.
- Eelgrass was collected and monitoring counts were performed at the Cutts Island harvest site.

Count #	Control	Pre-harvest	Post-harvest	Count #	Control	Pre-harvest	Post-harvest
1	12	0	1	**14**	21	23	3
2	7	20	18	**15**	27	15	14
3	28	20	15	**16**	38	49	7
4	13	6	7	**17**	37	42	21
5	15	12	13	**18**	44	40	28
6	20	18	10	**19**	3	31	35
7	18	37	22	**20**	82	18	42
8	26	43	28	**21**	23	32	32
9	14	35	24	**22**	19	18	20
10	31	14	27	**23**	20	38	42
11	29	26	19	**24**	30	21	22
12	4	0	11	**25**	41	44	37
13	24	14	15	**26**	32	37	34

- It was noted that there were large numbers of ghost shrimp burrows present at this site.
- Sandbar is very dynamic and the spit is moving East.
- Eelgrass bed has shifted East with sand spit.
- Subsample counting of collected grass to calculate shoots/weight ratio.

Sub-count	Weight (kg)	Count	Shoots/kg
1	0.1	27	270
1	0.2	50	250
1	0.2	51	255
1	0.1	19	190
2	0.125	26	208
2	0.110	34	309
2	0.205	72	351
2	0.265	60	226
3	0.1	36	360
3	0.1	42	420
3	0.1	36	360
3	0.1	50	500
4	0.1	34	340
4	0.1	33	330
4	0.1	35	350
4	0.1	37	370
	Average Weight (kg)	Average Count	Average Count/kg
	0.132	40	318

- A total of 55.3 kg was collected, equating to 17,585 shoots.

Sunday May 7th - 8th

- All eelgrass harvested from Cutts Island was planted at Joemma large-scale planting site.
- New 2017 large-scale planting configuration was used for this effort.
- Bags were weighed for each row of planting.

Bag #	Weight (kg)	Bag #	Weight (kg)	Bag #	Weight (kg)	Bag #	Weight (kg)
1	1.625	9	1.635	**17**	1.625	25	1.620
2	1.620	10	1.630	**18**	1.635	26	1.625
3	1.620	11	1.635	**19**	1.630	27	1.635
4	1.615	12	1.630	**20**	1.640	28	1.635
5	1.630	13	1.625	**21**	1.625	29	1.625
6	1.625	14	1.620	**22**	1.630	30	1.625
7	1.620	15	1.625	**23**	1.625	31	1.625
8	1.645	16	1.630	**24**	1.635	32	1.625

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DNR Eelgrass Restoration Project May 17th - 23rd 2017 Field Effort Summary

Wednesday May 17th – Thursday May 18th

- Collection site was at DuPont Wharf.
- Performed monitoring counts at DuPont harvest site.

Count #	Control	Pre-harvest	Post-harvest*	Count #	Control	Pre-harvest	Post-harvest*
1	23	0	N/A	**14**	14	12	N/A
2	24	12	N/A	**15**	20	20	N/A
3	21	2	N/A	**16**	15	11	N/A
4	28	4	N/A	**17**	17	19	N/A
5	26	12	N/A	**18**	7	12	N/A
6	21	6	N/A	**19**	7	24	N/A
7	30	0	N/A	**20**	18	12	N/A
8	21	9	N/A	**21**	32	22	N/A
9	29	17	N/A	**22**	15	12	N/A
10	19	8	N/A	**23**	36	20	N/A
11	24	16	N/A	**24**	14	10	N/A
12	24	14	N/A	**25**	22	16	N/A
13	29	22	N/A	**26**	14	13	N/A

* NOTE: No post-harvest counts because site was abandoned as a harvest location due to contaminates in water and sediment.

- Subsample weights and counts

Sub-count	Weight (kg)	Count	Shoots/kg
1	0.1	15	150
2	0.1	19	190
3	0.1	16	160
4	0.1	25	250
5	0.1	25	250
6	0.1	22	225
7	0.1	28	280
8	0.1	25	250
9	0.1	29	290
10	0.1	34	340
11	0.1	36	360
	Average Weight (kg)	Average Count	Average Count/kg
	0.1	25	250

- Harvested 45.145 kg of eelgrass equating to 11,286 shoots

- After completion of harvesting, team traveled to Delano to plant a large-scale. However, due to overwhelming algal cover at Delano, this site was abandoned and it was decided to plant at Joemma instead.

Friday May 19th

- Added base line at Joemma to create new large-scale site.
- Surveyed previously planted sites, looked very good.
- New site located 1m South of early May South site.
- Dupont eelgrass was used to plant ~ half of the large-scale site.

Bag #	Weight (kg)	Bag #	Weight (k
1	2.61	**9**	2.61
2	2.62	**10**	2.58
3	2.60	**11**	2.58
4	2.61	**12**	2.63
5	2.58	**13**	2.58
6	2.62	**14**	2.58
7	2.57	**15**	1.78
8	2.59		

Saturday May 20th

- Team traveled to Rocky Bay to harvest for 2nd half of Joemma large-scale.
- No monitoring counts were done at this point, as it was suggested we collect outside of the monitoring area. We collected to the right and left of the established monitoring area.

Sub-count	Weight (kg)	Count	Shoots/kg
1	0.105	143	1362
2	0.110	114	1036
3	0.100	100	1000
4	0.105	90	857
5	0.105	95	904
6	0.125	121	968
7	0.135	142	1052
8	0.105	120	1143
9	0.105	96	914
10	0.105	103	980
11	0.110	121	1100
12	0.115	108	939
	Average Weight (kg)	Average Count	Average Count/kg
	0.110	112	1021

- A total of 15.6 kg were harvested, equating to 15,927 shoots.
- The rest of the day was spent alliquoting and planting the 2nd half of the Joemma large-scale.

Sunday May 21st

- Team once again traveled to Rocky Bay to harvest eelgrass. This time for the 2nd large-scale of this effort (3rd large-scale for 2017).
- Same shoot/weight ratio was used, 1021 shoots/kg.
- A total of 25.9 kg were collected, equating to 26,443 shoots.

Monday May 22nd Tuesday May 23rd

- Planted 3rd large-scale at Joemma 2017.
- Tuesday was a half day, ending at ~ noon.

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DNR Eelgrass Restoration Project June 1st – June 4th 2017 Field Effort Summary

Thursday June 1st

- Arrived at Rocky Bay harvest site to collect eelgrass for transplantation to large-scale at South Anderson Island.
- Collection was outside of established donor bed, so monitoring counts were not required.
- Subsample weights and counts

Sub-count	Weight (kg)	Count	Shoots/kg
1	0.105	78	740
2	0.115	76	660
3	0.105	92	876
4	0.105	96	914
5	0.135	79	585
6	0.115	95	826
7	0.110	97	881
8	0.105	99	942
9	0.135	102	755
10	0.145	120	827
11	0.100	87	870
12	0.125	95	760
	Average Weight (kg)	Average Count	Average Count/kg
	0.117	93	803

- Harvested a total of 29.7 kg of eelgrass, equating to 23,849 shoots.

- Alliquoted into bags for planting.

Bag #	Weight (kg)	Bag #	Weight (kg)
1	0.810	**9**	0.835
2	0.805	**10**	0.840
3	0.805	**11**	0.835
4	0.805	**12**	0.840
5	0.830	**13**	0.840
6	0.810	**14**	0.810
7	0.830	**15**	0.840
8	0.840	**16**	0.845

Friday June 2nd

- Traveled to South Anderson Island to plant large-scale.
- Planted 1st half of site.
- Alliquoted 2nd half of eelgrass.

Bag #	Weight (kg)	Bag #	Weight (kg)
1	0.835	**9**	0.815
2	0.825	**10**	0.805
3	0.840	**11**	0.810
4	0.830	**12**	0.810
5	0.810	**13**	0.810
6	0.825	**14**	0.35
7	0.805		
8	0.805		

- Didn't have enough eel grass to finish large-scale, so took note of end point and picked-up later.

Saturday June 3rd

- Checked out Vaughn Bay eelgrass bed as possible donor site. Bed looked good, could be a donor bed in the future.
- The team then continued onto Rocky Bay to harvest eelgrass to finish the 1st large-scale at South Anderson Island and the 2nd large-scale at South Anderson Island.
- A shoot/weight ratio of 803 shoots/kg was used.
- A total of 35 kg of eelgrass was collected, equating to 28,105 shoots.
- Eelgrass was alliquoted into bags for planting.

Bag #	Weight (kg)	Bag #	Weight (kg)	Bag #	Weight (kg)	Bag #	Weight (kg)
1	0.820	**9**	0.825	**17**	1.030	**25**	1.045
2	0.805	**10**	0.840	**18**	1.005	**26**	1.045
3	0.805	**11**	0.830	**19**	1.080	**27**	1.090
4	0.805	**12**	0.830	**20**	1.050	**28**	1.085
5	0.830	**13**	0.820	**21**	1.070	**29**	1.175
6	0.820	**14**	0.815	**22**	1.090	**30**	1.165
7	0.835	**15**	0.815	**23**	1.030	**31**	1.000
8	0.835	**16**	1.050	**24**	1.070	**32**	1.045

Sunday June 4th

- Finished 1st South Anderson Island large-scale.
- Started and completed 2nd South Anderson Island large-scale plot.

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MARINE SURVEYS & ASSESSMENTS

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DNR Eelgrass Restoration Project July 16th to 19th 2017 Field Effort Summary

Sunday July 16th

- Arrived at Cutts Island to harvest eelgrass for transplanting at South Head location.
- Performed monitoring counts at Cutts Island Harvest Site

Count #	Control	Pre-harvest	Post-harvest	Count #	Control	Pre-harvest	Post-harvest
1	1	4	2	**14**	5	5	5
2	6	17	14	**15**	21	19	9
3	7	23	7	**16**	17	15	26
4	3	0	0	**17**	26	7	20
5	5	0	5	**18**	13	41	39
6	7	5	10	**19**	22	29	32
7	31	27	23	**20**	14	22	24
8	11	26	22	**21**	37	46	46
9	23	44	34	**22**	13	23	18
10	0	11	16	**23**	42	64	28
11	8	6	4	**24**	34	25	9
12	8	9	7	**25**	34	68	31
13	6	16	25	**26**	27	28	24

- Harvested 7.03 kg of eelgrass equating to 2100 shoots (1.03kg = 300 shoots)
    - Subsample weights and counts

Weight	Count
0.110 kg	27
0.090kg	29
0.110kg	28
0.085kg	32
0.120kg	34
Average Weight	**Average Count**
0.103kg	30

- Transplanted harvested Cutts Is. eelgrass to South Head North and South Sites
    - South Head North Site received the following amounts in three 2m^2 (1m x 2m) plots along the 10m baseline at 0m, 5m, and 10m
        - 358 shoots, 336 shoots, and 495 shoots respectively
    - South Head South Site received the following amounts in three 2m^2 (1m x 2m) plots along the 10m baseline at 0m, 5m, and 10m
        - 342 shoots, 340 shoots, and 348 shoots respectively

Monday July 17th

- Team moved to east side of Key Peninsula to monitor large scale and test sites there.
- Delano Large Scale (2016)
  - No trace of the site found. Divers surveyed 300 ft in all directions of the two GPS coordinates.
  - Evidence of tampering observed. Liquefy geoduck harvest holes throughout area. Looks like Ulva had been moved aside.
- Delano Test Site (2016)
  - Same as above, except one dying eelgrass shoot found.
- Another Delano Site (2016, furthest south coordinates)
  - Nothing found, we believe this is the one that was canceled in 2016 due to muddy anoxic sediment
- McDermott North Test Site (2017)
  - Nothing left, site covered in thick ulva, ground tackle recovered.
- McDermott South Test Site (2017)
  - Nothing left, site covered in thick ulva, ground tackle recovered.
- West Anderson Island North Test Site (2017)
  - Eelgrass dying, site covered in thick ulva, total census of surviving eelgrass taken.
    - Plot 1 had 55 shoots
    - Plot 2 had 132 shoots
    - Plot 3 had 48 shoots
  - Photos and videos taken.
- West Anderson Island South Test Site (2017)
  - Eelgrass dying, site covered in thick ulva, total census of surviving eelgrass taken.
    - Plot 1 had 6 shoots
    - Plot 2 had 52 shoots
    - Plot 3 had 11 shoots
  - Photos and videos taken.
- Penrose Test Site (2016)
  - Only four dying eelgrass shoots found, recovered lots of “biodegradable” potato stakes, site covered in thick ulva, ground tackle recovered.

Tuesday July 18th

- Team moved to west side of Key Peninsula to monitor test sites there.
- Taylor Bay Test Site (2016)
  - Nothing left, site covered in thick ulva, ground tackle recovered.
- Joemma Test Site (2016)
  - Evidence of tampering observed. Liquefy geoduck harvest holes throughout area. Recovered lots of "biodegradable" potato stakes.
  - Eelgrass dying due to ulva, total census taken.
  - Total = 527 shoots
- Joemma Test Site North (2017)
  - Eelgrass surviving, total census taken.
  - Total = 265 shoots
- Joemma Test Site South (2017)
  - Eelgrass surviving, total census taken.
  - Total = 468 shoots

- Team traveled to Rocky Bay to harvest eelgrass for transplanting at Fudge Point location.
- Performed monitoring counts at Rocky Bay Harvest Site

Count #	Control	Pre-harvest	Post-harvest	Count #	Control	Pre-harvest	Post-harvest
1	87	63	45	**14**	81	78	53
2	10	54	62	**15**	106	86	62
3	104	74	57	**16**	82	95	51
4	116	81	79	**17**	88	56	24
5	78	65	63	**18**	103	84	49
6	118	70	64	**19**	109	61	19
7	89	87	41	**20**	107	102	65
8	102	76	70	**21**	97	68	42
9	98	36	32	**22**	174	85	68
10	105	55	45	**23**	73	72	58
11	125	73	48	**24**	123	85	84
12	96	83	56	**25**	108	68	61
13	131	52	46	**26**	78	33	30

  - Harvested 502 kg of eelgrass equating to 2995 shoots (1kg = 580 shoots)
    - Subsample weights and counts

82Weight	Count
0.105kg	58
0.090kg	36
0.095kg	71
0.100kg	58
0.110kg	65
Average Weight	**Average Count**
0.100kg	58

Wednesday July 19th

- Transplanted Rocky Bay eelgrass to Fudge Point.
- 1kg or approximately 580 shoots given to Jeff (DNR) for testing rebar method. Five rebars with shoots tied on were set just outside and to the south of the Fudge Point North Test Site. Photos taken.

    - Fudge Point North Site received the following amounts in three $2m^2$ (1m x 2m) plots along the 10m baseline at 0m, 5m, and 10m
        - 389 shoots, 389 shoots, and 386 shoots respectively
    - Fudge Point South Site received the following amounts in three $2m^2$ (1m x 2m) plots along the 10m baseline at 0m, 5m, and 10m
        - 392 shoots, 386 shoots, and 282 shoots respectively
        - We found that the baseline was 20m long so we moved the southern anchor and made the line 10m and retook the GPS coordinates.