PNNL-15678-3

Pacific Northwest National Laboratory
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Third Annual Report: 2006 Pre-Construction Eelgrass Monitoring and Propagation for King County Outfall Mitigation

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February 2007

Prepared for
King County Department of Natural Resources and Parks
Wastewater Treatment Division, Brightwater Project
Under a Related Services Agreement
With the U.S. Department of Energy
Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

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Executive Summary

King County proposes to build a new sewer outfall discharging to Puget Sound near Point Wells, Washington. Construction is scheduled for 2008. The Point Wells site was selected to minimize effects on the nearshore marine environment, but unavoidable impacts to eelgrass (*Zostera marina*) beds are anticipated during construction. To mitigate for these impacts and prepare for post-construction restoration, King County began implementing a multi-year eelgrass monitoring and restoration program in 2004, with the primary goal of returning intertidal and shallow subtidal habitat and eelgrass to pre-construction conditions. Major program elements are a) pre-construction monitoring, i.e., documenting initial eelgrass conditions and degree of fluctuation over 5 years prior to construction, b) eelgrass transplanting, including harvesting, offsite propagating and stockpiling of local plants, and post-construction planting, and c) post-construction monitoring. The program is detailed in the *Eelgrass Restoration and Biological Resources Implementation Workplan* (King County 2006).

This report describes calendar year 2006 pre-construction activities conducted by Pacific Northwest National Laboratory (PNNL) in support of King County. Activities included continued propagation of eelgrass shoots and monitoring of the experimental harvest plots in the marine outfall corridor area to evaluate recovery rates relative to harvest rates. Approximately 1500 additional shoots were harvested from the marine outfall corridor in August 2006 to supplement the plants in the propagation tank at the PNNL Marine Sciences Laboratory in Sequim, Washington, bringing the total number of shoots to 4732. Eelgrass densities were monitored in the five experimental harvest plots established in the marine outfall corridor. Changes in eelgrass density were evaluated in year-to-year comparisons with initial harvest rates. Net eelgrass density decreased from 2004 post-harvest to 2006 in all plots, despite density increases observed in 2005 in some plots and at some harvest rates. Eelgrass densities within individual subplots were highly variable from year to year, and the change in density in any interannual period did not correlate to the initial 2004 harvest rate. Continued monitoring should help project managers determine an optimum harvest rate that supports rapid recovery of donor eelgrass beds.

Contents

Figures

Tables

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1.0 Introduction

King County's Wastewater Treatment Division is planning to construct the Brightwater sewer outfall, which will discharge into Puget Sound near the King-Snohomish County line just south of Point Wells, Washington. The site was chosen to minimize impacts to the nearshore marine environment: the shallow nearshore zone is narrower, and biological resources such as eelgrass are less abundant than at other potential sites. However, native eelgrass (*Zostera marina*) is present on the proposed outfall alignment, and King County is implementing a mitigation program to monitor and restore eelgrass beds that will be unavoidably disturbed by construction.

This report is the third in a series of annual reports on pre-construction activities conducted by the Pacific Northwest National Laboratory (PNNL) for the King County Brightwater Outfall eelgrass and biological resource mitigation program. Work related to this program is described in a *Draft Eelgrass Restoration and Monitoring Plan* (King County 2004), which was refined and further detailed in the *Eelgrass Restoration and Biological Resources Implementation Workplan* (King County 2006). PNNL tasks include the pre-construction mapping that was completed in 2004 (Woodruff et al. 2006a), subsequent monitoring of eelgrass beds in the outfall survey area in 2005, and eelgrass stockpiling and propagation for post-construction restoration (Woodruff et al. 2006b)

The Brightwater outfall survey area encompasses the Outfall (Eelgrass) Study Area, Marine Outfall Corridor, Eelgrass Reference Area, and the Eelgrass Reference Corridor. An Eelgrass Donor Site has been identified as a contingency in the event the harvest and propagation effort described below fails to provide sufficient eelgrass for transplanting. These areas are depicted in Figure 1. The Outfall Study Area extends 210 feet both north and south of the outfall pipeline alignment centerline, between 0 ft mean lower low water (MLLW) and -25 ft MLLW, which is the zone in which eelgrass and associated macroalgae grow. Within the Outfall Study Area is the Marine Outfall Corridor, a narrow zone (20 ft wide) centered on the outfall pipeline alignment that includes 4 ft on either side of the 12-ft-wide sheeted trench. In 2006, only the Marine Outfall Corridor was surveyed for eelgrass.

In accordance with the restoration and monitoring plan, PNNL harvested just over 300 eelgrass shoots from the Marine Outfall Corridor in 2004 to begin offsite propagation of plants for post-construction restoration (Woodruff et al. 2006a). This approach to restoration eliminates the need to remove plants from eelgrass meadows that would otherwise be undisturbed, while ensuring that the resident population is restored at the site. To determine the optimum harvest range at which eelgrass will best recover, study plots were established within the Marine Outfall Corridor area from which a designated percentage of eelgrass shoots were removed (i.e., 0%, 5%, 10%, 25%, 50%, and 100%). Documentation of 2005 eelgrass propagation and monitoring activities, along with eelgrass recovery rates were reported in Woodruff et al. 2006b. Eelgrass propagation activities and progress during 2006 are detailed in Section 2 of this report. Documentation of monitoring activities and eelgrass recovery rates are provided in Section 3.

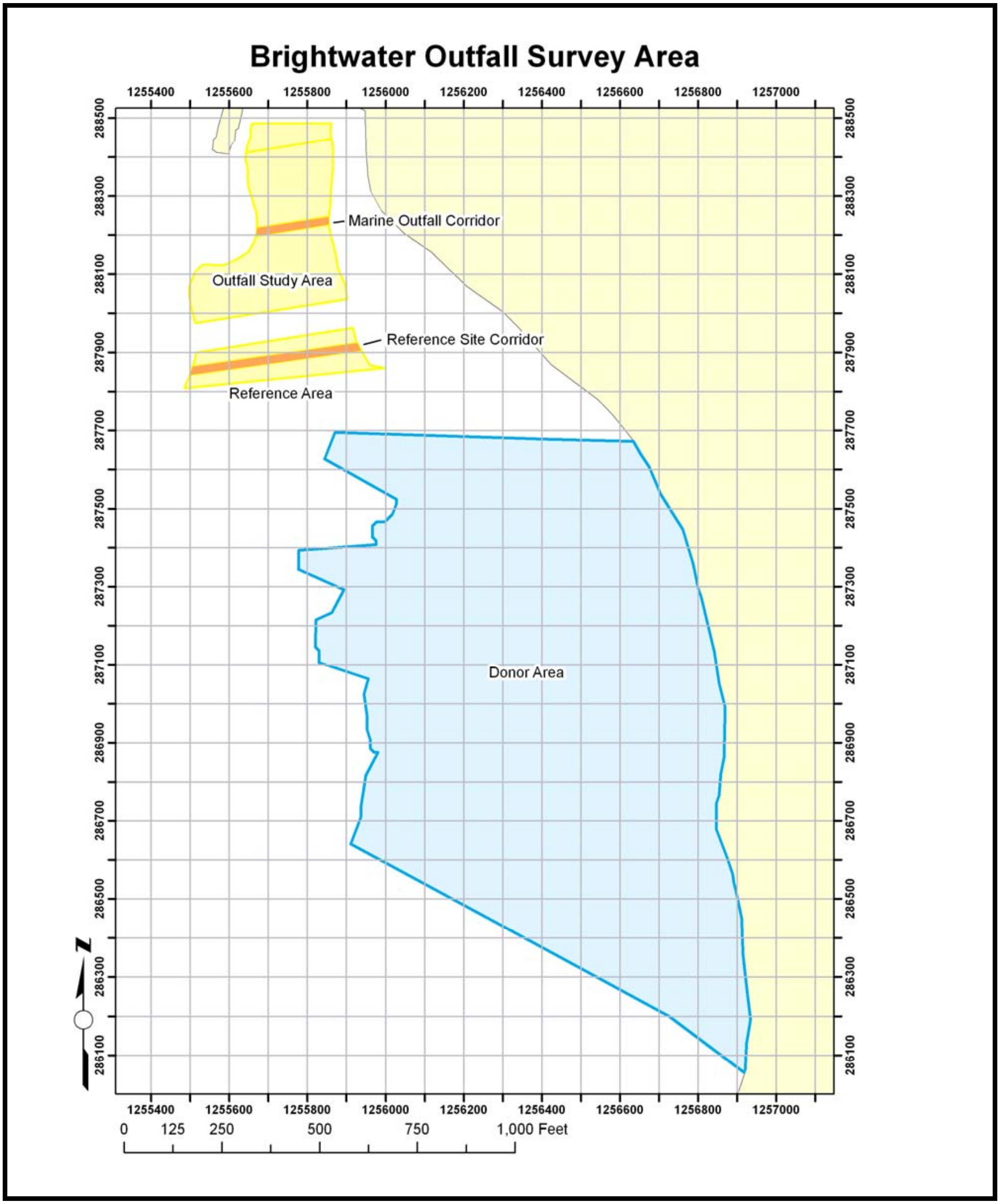

Figure 1. Brightwater Outfall Survey Area

2.0 Eelgrass Stockpile and Propagation

For the eelgrass stockpile and propagation task, a population of eelgrass from the Marine Outfall Corridor was removed in 2004, when divers selectively and systematically harvested 305 eelgrass shoots using a "bare-root method" (Woodruff et al. 2006a). The harvested shoots were transported to the PNNL Marine Sciences Laboratory in Sequim, Washington, where they were planted in outdoor tanks containing sand and supplied with continuously flowing ambient, unfiltered seawater. A variety of techniques were used to increase the eelgrass population in the tanks to supply the maximum number of plants for post-construction restoration planting. Propagation of plants from the site eliminates the need to disturb a natural eelgrass bed for the purpose of transplanting to another location; it also ensures that the same genetic population is restored to the site.

Stockpile and propagation activities conducted in 2005 involved maintenance and monitoring of eelgrass in the propagation tanks at the Marine Sciences Laboratory. Planned supplementation of the stockpiled eelgrass population with flowering shoots collected from the construction area did not occur because of the lack of flowering shoots at the site in August 2005 (Woodruff et al. 2006b).

Stockpile and propagation activities planned for 2006 included supplementation of the stockpiled eelgrass population with a minimum of 1000 shoots and additional flowering shoots collected from the Marine Outfall Corridor, and maintenance and monitoring of eelgrass in the propagation tanks at the Marine Sciences Laboratory. Shoots harvested in 2006 were collected from areas outside the monitoring plots established in 2004 so as not to affect assessments of eelgrass recovery rates (Section 3).

2.1 Eelgrass Stockpile and Propagation Methods

PNNL divers surveyed the Marine Outfall Study Area and Marine Outfall Corridor on August 1, 2006. Divers located markers delineating the previously harvested areas, and harvested 1500 shoots from the Marine Outfall Study Area outside the experimental harvest plots (Section 3). The shoots were transported in coolers to the Marine Sciences Laboratory and planted in the outdoor tanks alongside the previously planted and propagated eelgrass from the Marine Outfall Corridor. Because very few flowering shoots were observed anywhere in the Marine Outfall Study Area, none were harvested for propagation purposes.

In 2006, maintenance and monitoring of the eelgrass propagation tanks continued. These tasks involved occasional removal of excess macroalgae and invertebrates and shoot counts to track progress toward the target adult plant abundance needed for post-construction restoration.

2.2 Eelgrass Stockpile and Propagation Results

Initially, 305 eelgrass shoots were collected from the Marine Outfall Corridor and transplanted to the Marine Sciences Laboratory propagation tanks in October 2004. The first annual shoot count was performed in November 2004, after the shoots had acclimated to the tanks for 1 month. In that 1-month period, the eelgrass stockpile population experienced a 36% decline; only 195 shoots were counted. The second annual count was conducted in September 2005. The number of shoots had rebounded to 397, a 30% increase in shoots from the initial October 2004 planting, and a 104% increase in shoots since

November 2004. The third annual count was conducted in August 2006 prior to the collection of additional shoots. The number of shoots had increased to 3232, a 960% increase in shoots from the initial 2004 planting and a 714% increase in shoots since September 2005. The increase in additional shoots was a result of vegetative reproduction in the propagation tanks. The primary reproduction mechanism for *Z. marina* in the Pacific Northwest is through growth of underground stems (rhizomes), which produce roots below ground and progressively send shoots upward. Following field collections from the Marine Outfall Corridor in 2006, PNNL staff added a total of 1500 shoots to the outdoor tank. Thus, the total number of shoots in the outdoor tank in August 2006 was 4732 shoots. To accommodate the expected eelgrass reproduction, all 4732 shoots were transplanted in September 2006 from their smaller 6.1-m diameter tank to a larger 9.1-m diameter propagation tank. The health of the plants appeared to be quite good after the move, with minimal loss anticipated. All shoots in the large propagation tank will be counted in summer 2007 during the growing season.

2.3 Eelgrass Stockpile and Propagation: Future Activity

Maintenance and monitoring of the propagation tank, including the annual count of eelgrass shoots, will continue in 2007. No additional harvesting of shoots from the Marine Outfall Corridor or any other form of supplementation of the shoots in the propagation tank is planned for 2007. All shoots from the Marine Outfall Corridor may be harvested immediately prior to construction trenching between 0 and -30 ft MLLW in 2008.

3.0 Eelgrass Monitoring in Experimental Harvest Plots

A common uncertainty with many eelgrass restoration projects is the effect of removal of eelgrass from donor meadows. Harvest levels have typically been restricted to 10% or less of the total abundance to minimize effects; however, there are no published studies or quantitative data to support anecdotal observations that harvest has a small, short-term effect on eelgrass density. The *Eelgrass Restoration and Biological Resources Implementation Workplan* (King County 2006) detailed a pre- and post-harvest experimental monitoring plan to provide quantitative data on eelgrass recovery rates after shoot harvest.

As part of the experimental design, eelgrass shoot density was determined in semi-permanent experimental plots established in the Marine Outfall Corridor prior to the 2004 eelgrass harvest (Woodruff et al. 2006a). Eelgrass density in these plots was monitored in 2005 (Woodruff et al. 2006b) and 2006 (this report), and will be monitored once more prior to construction in 2008 to assess post-harvest recovery rates. Monitoring and data analysis methods are provided below in Section 3.1; 2006 results are presented and compared with prior years' data in Section 3.2. In 2006, eelgrass monitoring focused on the experimental harvest plots established in 2004 for changes in eelgrass shoot density (recovery) 2 years after initial harvest.

3.1 Eelgrass Harvest Plot Design and Monitoring Methods

In 2004, eelgrass was harvested for propagation at different rates from experimental plots described in Woodruff et al. 2006a, and summarized here. Five plots were established as semi-permanent 2-m^2 (1- x 2-m) rectangular plots, located in eelgrass patches inside the Marine Outfall Corridor. Each 2-m^2 plot was divided into eight 0.25-m^2 treatment subplots or cells. Each rectangular plot had 2 subplots of 100% harvest located on one end of the rectangle (to minimize potential effects of 100% harvest on adjacent cells), and two subplots of 0% harvest placed randomly within the six remaining cells. The four remaining subplots were randomly assigned to be one of either 5%, 10%, 25%, or 50% harvest. The plot locations and experimental harvest rates for each subplot are shown in Figure 2.

3.1.1 Field Survey Methods

The 2006 eelgrass monitoring of the experimental harvest plots was conducted by PNNL's scientific dive team on August 1, 2006. Divers located all of the location markers associated with the five previously established plots and counted eelgrass shoots in each of these plots and subplots. The plot markers had not been disturbed, in contrast to 2005 when most of the markers for Plots 1, 3, and 4 were missing and had to be resurveyed (Woodruff et al. 2006b). Underwater photographs and video footage of the eelgrass within the Marine Outfall Corridor Area were recorded. In general, the Marine Outfall Corridor was still very sparsely populated with eelgrass, but did not appear to have changed noticeably since the previous survey in 2005. The presence of drift eelgrass (i.e., not attached) was confirmed in the deep end of the corridor, as it was in 2005. This eelgrass wrack was tangled and drifting down slope.

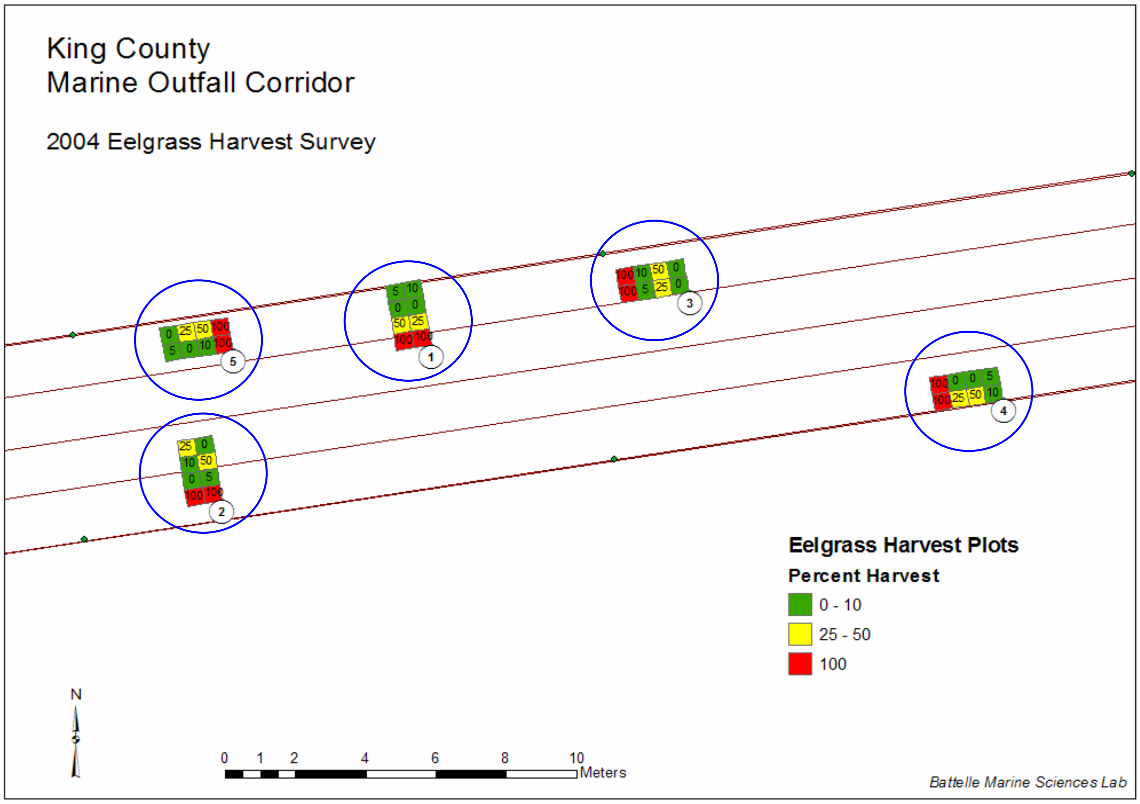

Figure 2. Site Map Indicating Experimental Harvest Plot Locations and the Percentage of Eelgrass Shoots Originally Harvested in 2004

3.1.2 Data Analysis

Annual monitoring data for eelgrass density in the five 2-m^2 experimental harvest plots (each containing eight 0.25-m^2 subplots) were compared with the 2004 data for post-harvest eelgrass density. The interannual differences between plots overall and within individual subplots were calculated. Statistical analyses were conducted to assess the effect of initial harvest rate on eelgrass abundance (expressed as proportion of change in density), and to assess whether eelgrass density in an individual subplot was affected by the harvest rate in adjacent subplots ("neighbor effect"). These analyses were conducted for the periods 2004 to 2005, 2005 to 2006, and net change from 2004 to 2006.

The correlation between harvest rate and change in density between years was calculated for each individual subplot, and then for the total of adjoining subplots ("neighbors"). The total adjoining subplots were considered because it was hypothesized that the harvest rate of neighboring subplots could influence the recovery rate of remaining shoots in an additive manner. An individual 0.25-m^2 subplot on either end of the whole 2-m^2 plot has three adjacent subplots, and therefore lies in a "neighborhood" of four adjoining subplots; an individual subplot in the middle of the plot lies in a "neighborhood" of six adjoining subplots (i.e., it has five adjacent subplots). The "neighbor effect" is essentially the average harvest rate of the "neighborhood" of the four or six adjoining subplots. The nonparametric Kruskal-Wallis test was used to compare median change in density between years and harvest rates for individual subplots and adjoining subplots.

Because a number of experimental plot markers were missing in 2005 and needed to be resurveyed, there is more uncertainty associated with the 2004 to 2005 and net 2004 to 2006 eelgrass density changes than with the current 2005 to 2006 density changes. This uncertainty was addressed by analyzing data for Plots 2 and 5 separately, because their locations had been maintained through time (few plot markers missing in 2005).

3.2 Experimental Harvest Plot Monitoring Results

Figure 3 through Figure 7 are representative photographs of the vegetative cover and bottom substrate of each plot. Plots 3 and 4 are in the -1 to -5 ft MLLW depth range; Plots 1, 2, and 5 lie in the -5 to -10 ft MLLW depth range. Substrate at the shallowest Plot 4 (Figure 6) is notably coarser than that at the other plots (e.g., Figures 3 through 5). Where present in a photograph, the white square covers 0.25 m^2.

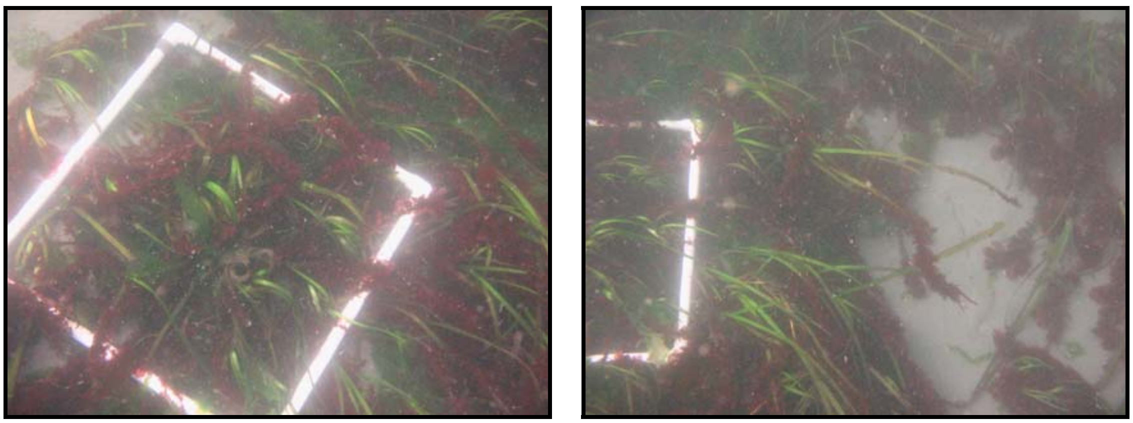

Figure 3. Representative Photographs of the Vegetation and Substrate Found in Plot 1, August 2006

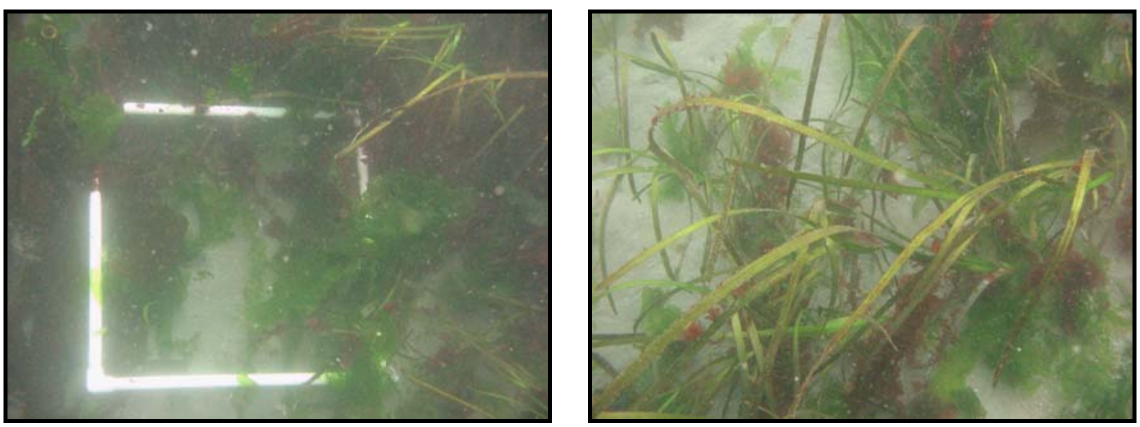

Figure 4. Representative Photographs of the Vegetation and Substrate Found in Plot 2, August 2006

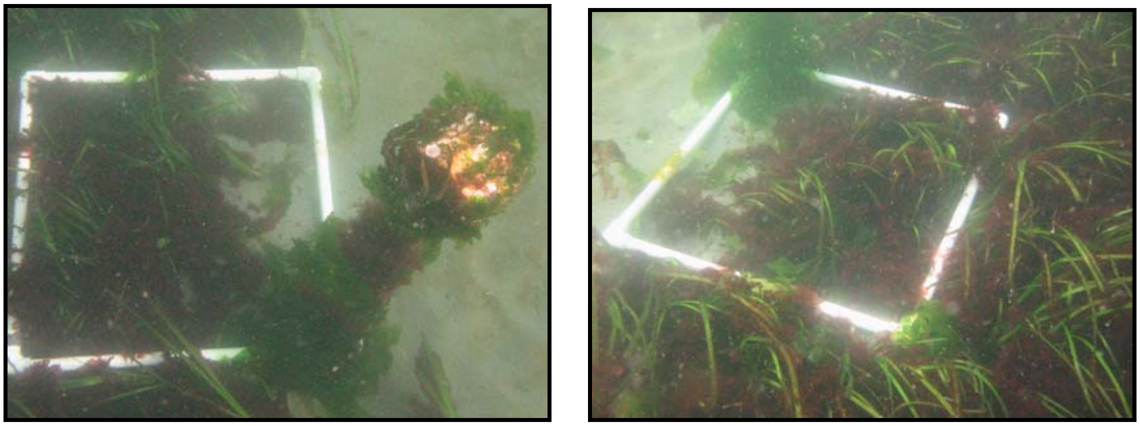

Figure 5. Representative Photographs of the Vegetation and Substrate Found in Plot 3, August 2006

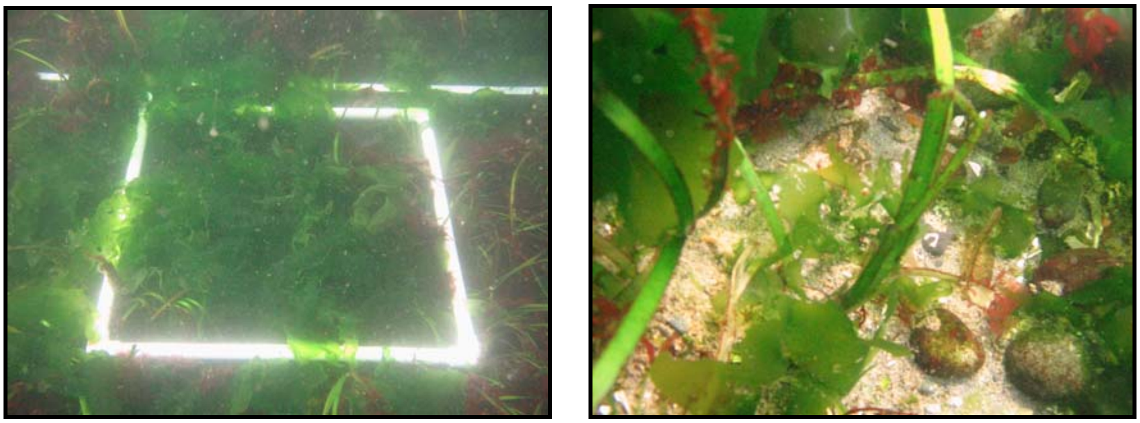

Figure 6. Representative Photographs of the Vegetation and Substrate Found in Plot 4, August 2006

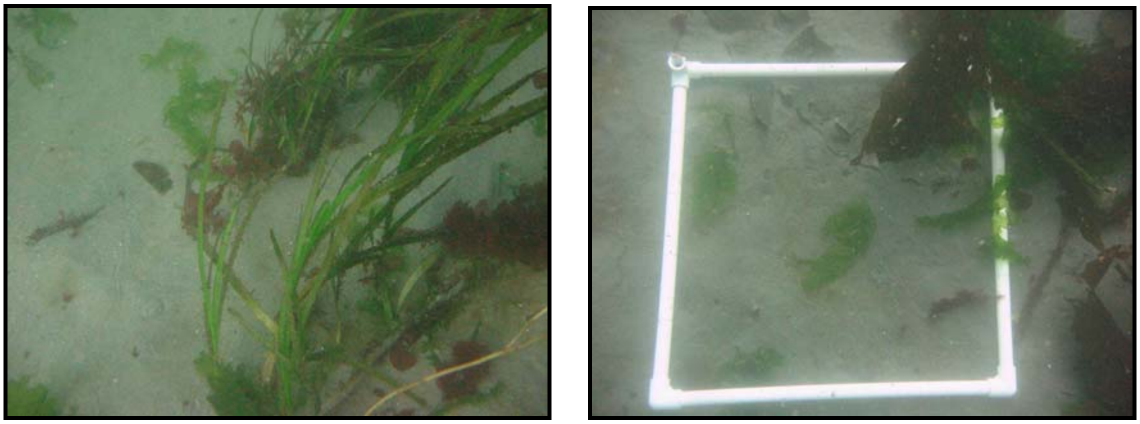

Figure 7. Representative Photographs of the Vegetation and Substrate Found in Plot 5, August 2006

Monitoring results since 2004 in the five experimental harvest plots located in the Marine Outfall Corridor are tabulated in Appendix A. Figures 8 through 13 depict the harvest rate, pre-harvest density, and post-harvest eelgrass densities for each of the subplots in their relative positions within each plot. For descriptive purposes, the maximum number of eelgrass shoots counted in a single subplot (67 in 2005) was divided into thirds to establish a gradient scale indicating low (0-22 shoots per 0.25 m^2), moderate (12-44 shoots per 0.25 m^2), and high (45-67 shoots per 0.25 m^2) densities of shoots for the Marine Outfall Corridor experimental harvest plots (Figure 8). The number of eelgrass shoots counted in each subplot prior to harvest in 2004, after harvest in 2004, and again in 2005 and 2006, are presented graphically in Figures 9 through 13.

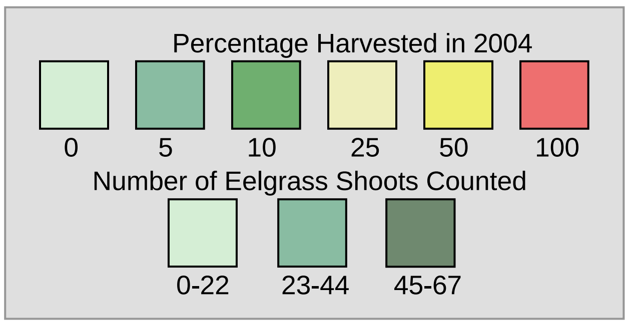

Figure 8. Legend Indicating Color Codes Used in Figures 9 through 13 to Indicate the Percentage of Eelgrass Harvested Per Subplot in 2004, and the Relative Number of Shoots Counted within Each Subplot in Subsequent Years

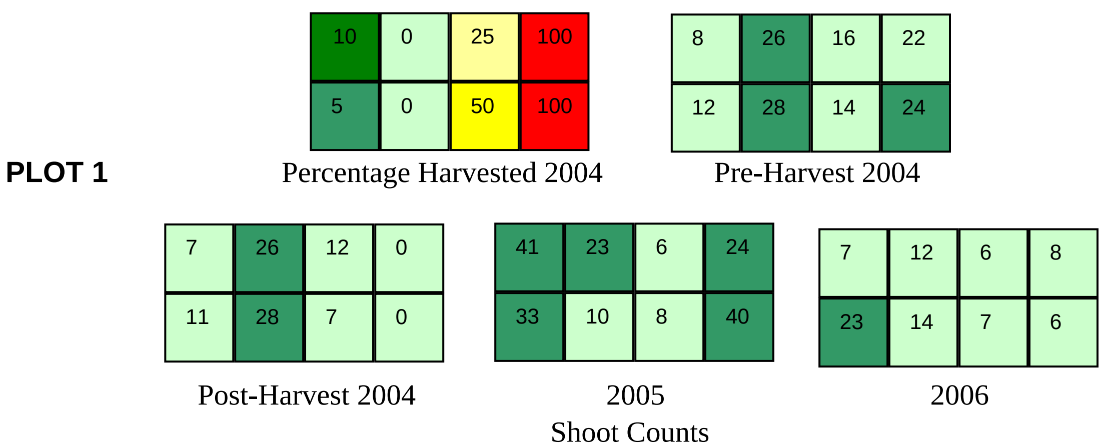

Figure 9. Shoot Counts for Plot 1

PLOT 2

Percentage Harvested 2004

0	50	5	100
25	10	0	100

Pre-Harvest 2004

14	28	18	18
10	26	12	9

Post-Harvest 2004

14	14	17	0
7	23	12	0

2005

19	15	12	1
11	11	1	3

2006

8	0	15	8
0	8	15	8

Shoot Counts

Figure 10. Shoot Counts for Plot 2

PLOT 3

Percentage Harvested 2004

100	10	50	0
100	5	25	0

Pre-Harvest 2004

32	38	10	54
8	7	42	40

Post-Harvest 2004

0	34	5	54
0	7	32	40

2005

15	67	54	37
33	49	15	38

2006

28	17	2	21
27	11	26	31

Shoot Counts

Figure 11. Shoot Counts for Plot 3

PLOT 4

Percentage Harvested 2004

100	0	0	5
100	25	50	10

Pre-Harvest 2004

48	50	48	43
9	44	62	28

Post-Harvest 2004

0	50	48	41
0	33	31	25

2005

4	32	61	32
17	25	7	23

2006

12	11	31	27
42	33	27	7

Shoot Counts

Figure 12. Shoot Counts for Plot 4

PLOT 5

Percentage Harvested 2004

0	25	50	100
5	0	10	100

Pre-Harvest 2004

9	10	10	17
18	13	17	8

Post-Harvest 2004

9	8	5	0
17	13	15	0

2005

1	19	12	0
1	13	0	0

2006

3	2	1	0
6	6	1	0

Shoot Counts

Figure 13. Shoot Counts for Plot 5

Mean eelgrass density in each experimental harvest plot varied over time (Figure 14). Results from 2004 to 2005 were mixed, with some plot densities increasing substantially (Plots 1 and 3) and the rest decreasing slightly. Every plot showed a decrease in shoot counts between 2005 and 2006, ranging from a 6% decline in Plot 4 to a 59% decline in Plot 5 (Figure 14). The decline in Plot 5 is somewhat magnified because its initial eelgrass density was lower (Figure 13), and differences in low numbers are proportionally larger than differences between high numbers.

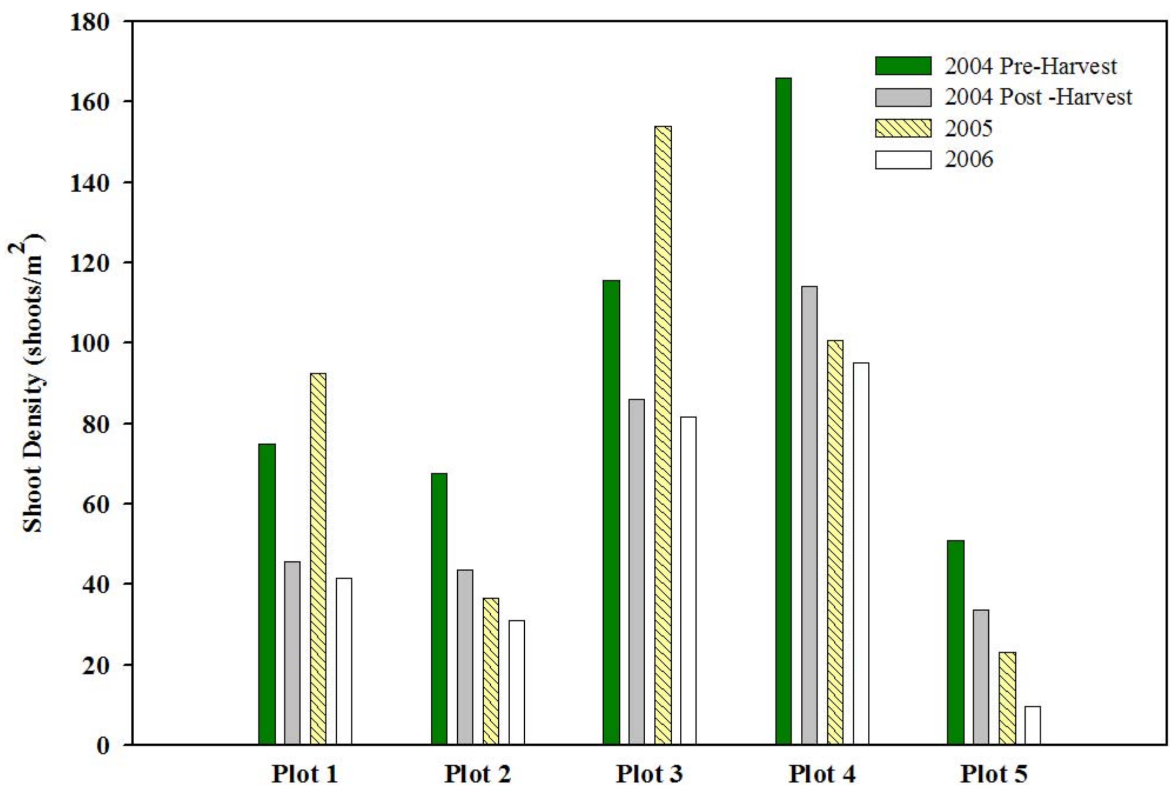

Figure 14. Mean Pre-harvest and Post-harvest Eelgrass Densities by Plot

The main focus of this study was to examine changes in eelgrass density relative to the rate of harvest. As noted earlier, harvest rates from eelgrass donor sites are typically kept to 10% or less to minimize effects on the donor meadow. The experimental harvest plot and subplot data were further analyzed to examine the interannual changes between subplots harvested at six different harvest levels: 0% (control), 5%, 10%, 25%, 50%, and 100% harvest. Mean pre- and post-harvest eelgrass densities by target harvest rate are provided in Figure 15. The total number of shoots in the control plots (0 % harvested) in 2005 and 2006 declined from 235 to 124, a 47% reduction. There was a decrease in shoot density in all but the 25% and 100% harvested plots, which increased by 9% and 7%, respectively (Figure 15). The declines in shoot density in 0%, 5%, 10%, and 50% harvested plots from 2005 to 2006 ranged from 41% to 68%.

Change in eelgrass density was further examined statistically to determine the effects of initial harvest rate on each subplot alone, followed by the "neighbor effect" analysis to determine whether change in density in an individual subplot was affected by adjacent subplots. Results of these analyses are provided in Table 1.

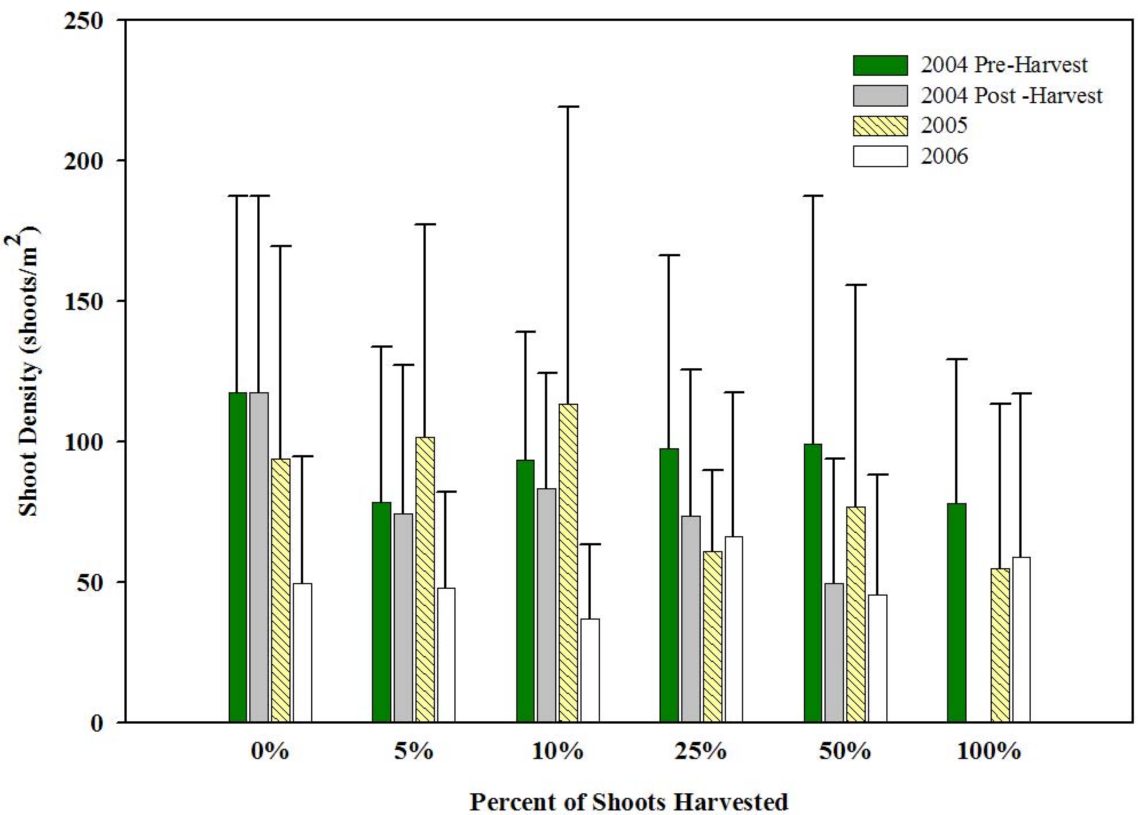

Figure 15. Mean Eelgrass Densities Before and After Harvest (bars indicate 1 standard deviation; n = 10 for 0% and 100% harvest rates; n = 5 for 5%, 10%, 25%, and 50% harvest rates)

Table 1. Correlation of Proportion of Change in Eelgrass Density with Initial Harvest Rate and Neighbor Effect

Number of Subplots in Neighborhood	Actual 2004 Harvest Rate	Neighbor Effect[a]	Proportion Change		
			2004-2005	**2005-2006**	**2004-2006**
4	0.000	0.060	-0.800	1.000	-0.600
4	0.000	0.103	-0.309	-0.421	-0.600
4	0.000	0.103	-0.049	-0.179	-0.220
4	0.000	0.256	0.333	-0.550	-0.400
4	0.047	0.199	-0.214	-0.152	-0.333
4	0.056	0.060	-0.889	2.500	-0.611
4	0.083	0.027	1.833	-0.735	-0.250
4	0.107	0.199	-0.077	-0.667	-0.692
4	0.125	0.027	4.250	-0.833	-0.125
4	0.300	0.256	0.500	-0.250	0.125
4	1.000	0.450	4.000	1.600	12.000
4	1.000	0.450	17.000	1.389	42.000
4	1.000	0.491	3.000	1.250	8.000
4	1.000	0.491	1.000	-0.500	0.000
4	1.000	0.518	15.000	0.813	28.000
4	1.000	0.518	33.000	-0.176	27.000
4	1.000	0.615	0.000	0.000	0.000
4	1.000	0.615	0.000	0.000	0.000
4	1.000	0.750	40.000	-0.805	7.000
4	1.000	0.750	24.000	-0.040	23.000
Correlation with Harvest Rate			**0.56**	0.19	0.61
Correlation with Neighbor Effect			**0.62**	0.01	0.49
6	0.000	0.125	-0.621	-0.364	-0.759
6	0.000	0.125	-0.111	-0.667	-0.704
6	0.000	0.130	0.000	-0.500	-0.500
6	0.000	0.171	0.265	-0.484	-0.347
6	0.000	0.379	-0.353	-0.636	-0.765
6	0.000	0.405	-0.846	-0.500	-0.923
6	0.000	0.431	5.250	-0.760	0.500
6	0.056	0.405	-0.278	-0.308	-0.500
6	0.105	0.431	0.943	-0.735	-0.486
6	0.115	0.194	-0.500	0.333	-0.333
6	0.118	0.453	-0.938	1.000	-0.875
6	0.200	0.130	1.222	-0.850	-0.667
6	0.238	0.099	-0.515	0.688	-0.182
6	0.250	0.379	-0.235	0.308	0.000
6	0.250	0.438	-0.462	1.143	0.154
6	0.500	0.099	8.167	-0.945	-0.500
6	0.500	0.171	-0.750	2.500	-0.125
6	0.500	0.194	0.067	0.000	0.067
6	0.500	0.438	0.125	0.444	0.625
6	0.500	0.453	1.167	-0.846	-0.667
Correlation with Harvest Rate			**0.24**	0.36	0.40
Correlation with Neighbor Effect			**-0.11**	0.03	0.18

a. Neighbor effect is average harvest rate of the "neighborhood" of adjoining subplots.

The results presented in Figure 15 show that post-harvest eelgrass densities at every harvest rate were highly variable. Table 1 and Figure 16 show that growth, expressed as the proportion of change in eelgrass density, in each monitoring interval was variable as well. As described in Section 3.1.2, the "neighbor effect" was evaluated by comparing a subplot harvest rate with the average harvest rate for that subplot plus its adjoining neighbors. Correlations between proportion change in density and harvest rates were greater for subplots on the ends of the rectangular plot (neighborhood of four subplots) in the 2004 to 2005 period (r = 0.56) and net 2004 to 2006 period (r = 0.61) than they were for subplots in the middle of the rectangular plot (neighborhood of six subplots) (r = 0.24 and 0.36 for 2004 to 2005 and net 2004 to 2006, respectively) (Table 1). However, these correlations appear to be driven by the high positive change in the 100% harvest subplots. Proportion change in eelgrass density was not significantly correlated with harvest rate in the 2005 to 2006 period (r = 0.25).

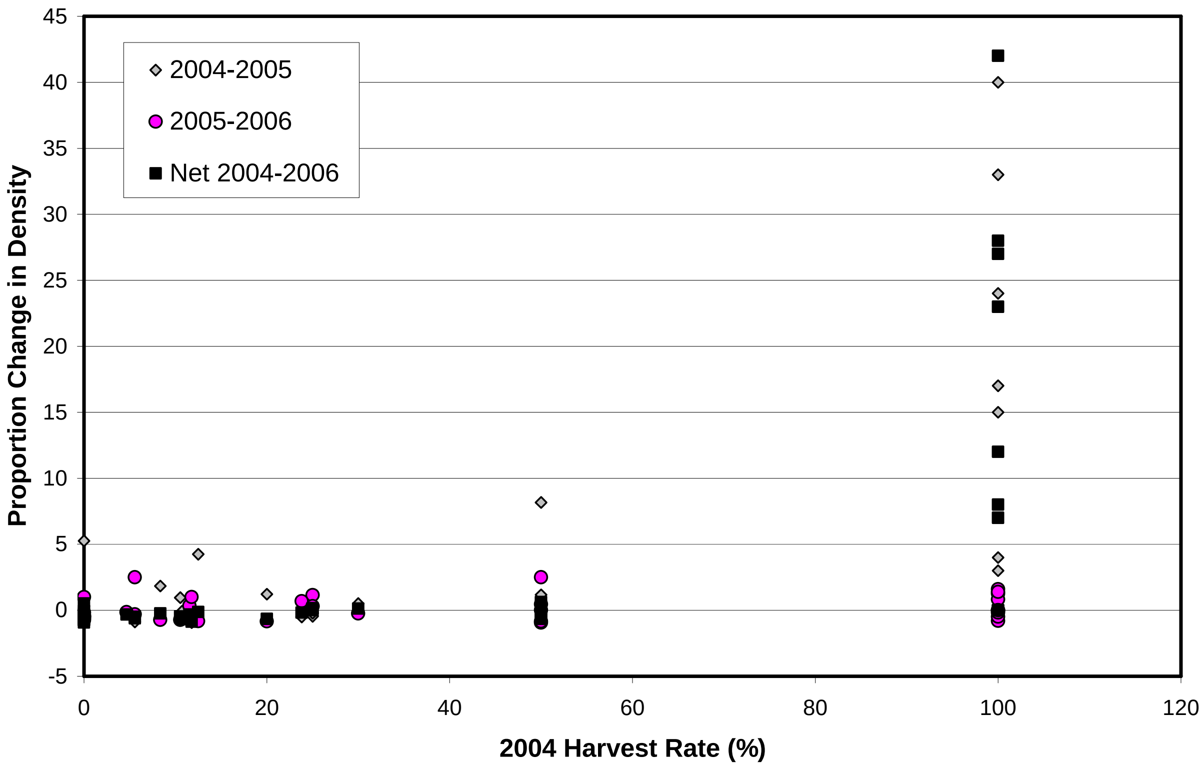

Figure 16. Proportion Change of Eelgrass Density as a Function of Harvest Rate in 2004-2005, 2005-2006, and Net 2004-2006 Interannual Periods

Change in eelgrass density was consistently higher in 100% harvest subplots than in subplots at other harvest rates (Figure 16). This relationship was expected because the difference is calculated from the 2004 post-harvest count, which was always 0 shoots in subplots that were 100% harvested. Because change in eelgrass density in the 100% harvest subplot completely overshadows changes at other harvest rates, the data were further analyzed in year-to-year pair-wise comparisons at each harvest rate. For those subplots that had 0% harvest, there was no difference in the proportional change in eelgrass density in any interannual period. This held true whether the 0% subplot was one of four adjoining subplots or one of six adjoining subplots (Kruskal-Wallis; p = 0.30). A regression of growth from the 0% harvested subplots as a function of the neighboring subplots harvest levels was not significant (p = 0.90). For the

5%, 10%, 25%, and 50% harvest rates, there was also no consistent relationship between the 2004 harvest rate and the proportional change in eelgrass density for any of the pair-wise years. Further, the Kruskal-Wallis test failed to detect any significant differences between median change in density of each harvest rate ($p > 0.3$ for each pair-wise comparison). The results show consistent variability between harvest rates and interannual periods, demonstrated by the average rank of growth for each interannual period against 2004 harvest rate (Figure 17).

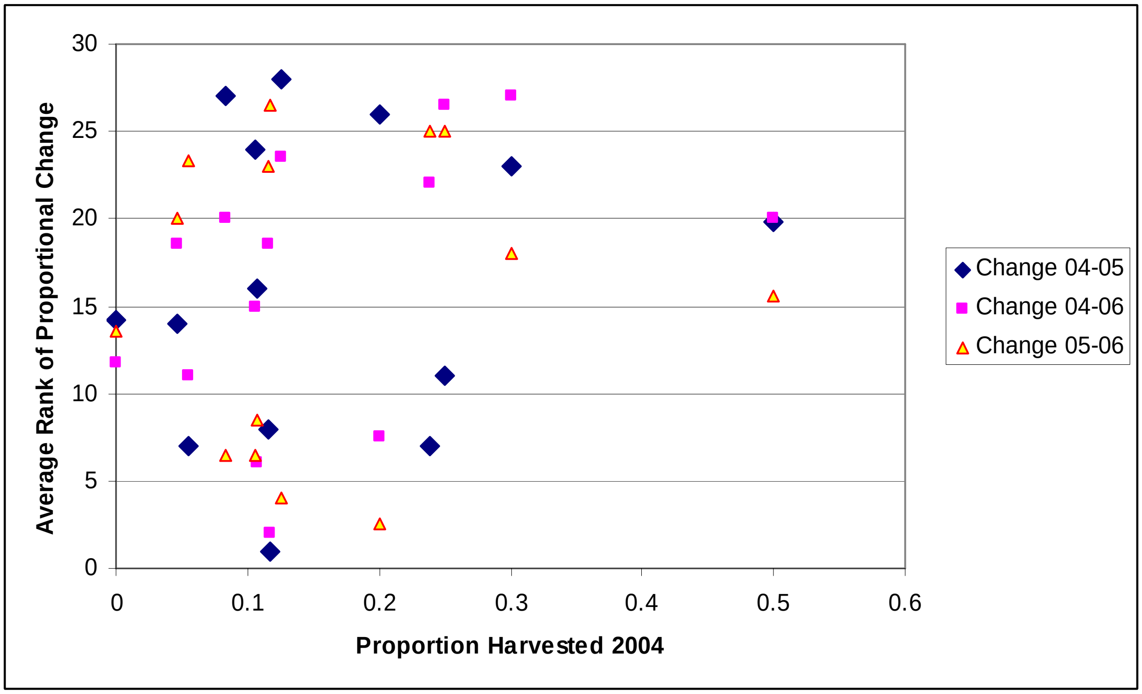

Figure 17. Average Rank of Proportional Change as a Function of 2004 Harvest Rate (ignoring 100% harvest)

As described in Section 3.1.2, a number of experimental plot markers were missing in 2005 and needed to be resurveyed. Therefore, there is greater uncertainty associated with the 2004 to 2005 and net 2004 to 2006 eelgrass density changes than with the current 2005 to 2006 density changes. This concern was addressed by repeating the year-to-year pair-wise comparison analysis and the rank of interannual growth versus harvest rate analysis (for 0% to 50% harvest) using only data for locations that had been maintained through time (Plots 2 and 5). The analysis of Plots 2 and 5 alone (Figure 18) showed the same level of variability in change over time as observed when all plots were analyzed together (Figure 15). Therefore, the uncertainty about plot locations does not influence the overall conclusions.

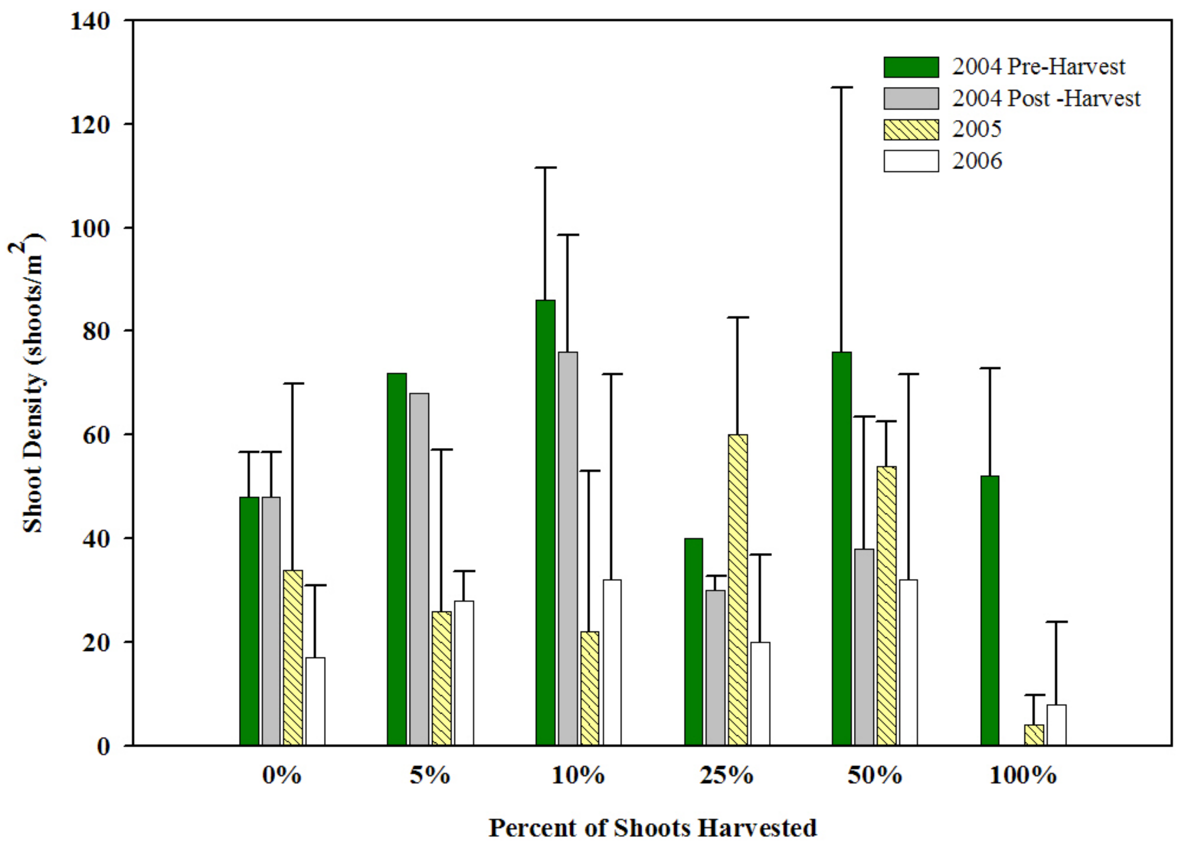

Figure 18. Mean Eelgrass Densities Before and After Harvest in Plots 2 and 5 Only (bars indicate 1 standard deviation; n = 4 for 0% and 100% harvest rates; n = 2 for 5%, 10%, 25%, and 50% harvest rates)

In summary, there was a net decrease in eelgrass density from 2004 post-harvest to 2006 in all plots, despite density increases observed in 2005 in some plots and at some harvest rates. Eelgrass densities within individual subplots were highly variable from year to year, and the change in density in any interannual period was not related to initial 2004 harvest rate. There appeared to be some effect of adjacent subplots on individual subplots located on the ends of the rectangular 2-m^2 plot, but this was highly influenced by the much higher density increases observed in the 100% harvest subplots, which were always located on one end of the rectangle (e.g., Figure 9).

3.3 Eelgrass Experimental Harvest Plots: Future Activity

The experimental harvest plots established in 2004 and monitored in 2005 and 2006 will again be monitored for eelgrass shoot density in 2008. An annual report will be prepared that incorporates current monitoring data in the analyses described in this report.

4.0 References

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APPENDIX A

Experimental Harvest Plot Data

Table A- 1. Eelgrass Monitoring Results in the Experimental Harvest Plots

Plot	Sub-plot	Target 2004 Harvest Rate (%)	2004 Pre-harvest Density (shoots per 0.25 m^2)	Number of Shoots Harvested in 2004	Actual 2004 Harvest Rate (%)	Eelgrass Density (shoots per 0.25 m^2) 2004 Post-harvest	2005	2006
Plot 1	11	5	12	1	8.3	11	33	8
Plot 1	12	10	8	1	12.5	7	41	6
Plot 1	13	0	28	0	0.0	28	10	6
Plot 1	14	0	26	0	0.0	26	23	7
Plot 1	15	50	14	7	50.0	7	8	12
Plot 1	16	25	16	4	25.0	12	6	14
Plot 1	17	100	24	24	100	0	40	7
Plot 1	18	100	22	22	100	0	24	23
Plot 2	21	25	10	3	30.0	7	11	8
Plot 2	22	0	14	0	0.0	14	19	8
Plot 2	23	10	26	3	11.5	23	11	15
Plot 2	24	50	28	14	50.0	14	15	15
Plot 2	25	0	12	0	0.0	12	1	0
Plot 2	26	5	18	1	5.6	17	12	8
Plot 2	27	100	9	9	100	0	3	8
Plot 2	28	100	18	18	100	0	1	0
Plot 3	31	100	32	32	100	0	15	28
Plot 3	32	10	38	4	10.5	34	67	17
Plot 3	33	50	10	5	50.0	5	54	2
Plot 3	34	0	54	0	0.0	54	37	21
Plot 3	35	100	8	8	100	0	33	27
Plot 3	36	5	7	0	0.0	7	49	11
Plot 3	37	25	42	10	23.8	32	15	26
Plot 3	38	0	40	0	0.0	40	38	31
Plot 4	41	100	48	48	100	0	4	12
Plot 4	42	0	50	0	0.0	50	32	11
Plot 4	43	0	48	0	0.0	48	61	31
Plot 4	44	5	43	2	4.7	41	32	27
Plot 4	45	100	9	9	100	0	17	42
Plot 4	46	25	44	11	25.0	33	25	33
Plot 4	47	50	62	31	50.0	31	7	27
Plot 4	48	10	28	3	10.7	25	23	7
Plot 5	51	0	9	0	0.0	9	1	3
Plot 5	52	25	10	2	20.0	8	19	2
Plot 5	53	50	10	5	50.0	5	12	1
Plot 5	54	100	17	17	100	0	0	0
Plot 5	55	5	18	1	5.6	17	1	6
Plot 5	56	0	13	0	0.0	13	13	6
Plot 5	57	10	17	2	11.8	15	0	1
Plot 5	58	100	8	8	100	0	0	0

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