Friends of Semiahmoo Bay Society

Marine Conservation Initiative

Zostera marina (Eelgrass) Mapping and Monitoring:

A Synthesis of Monitoring Results 2004 to 2007

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WHITE ROCK AND SURREY NATURALISTS

Vancity

VANCOUVER FOUNDATION

COMMUNITY MAPPING NETWORK

Fisheries and Oceans Canada   Pêches et Océans Canada

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Executive Summary

This report is one of a series of reports analyzing data from the Friends of Semiahmoo Bay Society eelgrass (*Zostera marina)* mapping and monitoring project. This report is a synthesis of yearly data sets collected to monitor the eelgrass beds in Semiahmoo Bay from 2003 – 2007.

Data collected of vegetative eelgrass growth parameters (shoot density, reproductive shoot density, blade width and blade length) reveal that since 2005, growth conditions within the White Rock Pier area are improving as average shoot and reproductive shoot densities are increasing. Across Semiahmoo Bay, most eelgrass growth parameters are higher than those found at the White Rock Pier and are maintaining at constant levels. Average values of eelgrass parameters at the White Rock Pier appear to be within the natural range of variation seen across Semiahmoo Bay. Comparisons of the position of the shoreward edge of eelgrass bed reveal that there was no significant movement (shoreward or seaward) of the edge among years (2003, 2004, 2005, 2006 and 2007); and, concurrently, change in bed area size. The distance between shoreward edges among these years also was not significantly different. Intertidal depths of the shoreward edge also did not differ among years.

While the data showed that from 2003-2007 conditions throughout Semiahmoo Bay showed some within sector variation, overall eelgrass growth parameters and shoreward edge distribution are remaining constant. This does not imply that water quality throughout Semiahmoo Bay is allowing for the optimal growth of eelgrass only that conditions have not statistically varied from 2003-2007. It would be advantageous to partner with relevant agencies to gain data on water quality relevant to eelgrass growth. Having data on these stressors to growth would provide a more quantitative approach to interpretation of the monitoring data.

Introduction

> "Seagrasses are among the most productive ecosystems in the world and perform a number of irreplaceable ecological functions which range from chemical cycling and physical modification of the water column and sediments to providing food and shelter for commercial, recreational as well as ecologically important organisms."

Thayer et al 1997.

Seagrasses evolved from terrestrial plants and are flowering plants rooted in marine sediments. Limited to maximum depths of 15-20 metres, *Zostera marina* is extremely sensitive to degradation of water quality parameters, and its decline has been strongly linked to both natural and human caused disturbance. Reduction in eelgrass cover has impacts on the nearshore marine community, including: changes in migration of water fowl, reduction in population sizes of marine fishes; increased erosion of shorelines; and impacts to coastal fishing economies.

Monitoring for natural variation and trends in *Zostera marina* abundance and extent is important to understand the quality of eelgrass environments. Measuring growth parameters can provide information on the quality of the marine environment. In general, growth parameters such as shoot density, blade length and blade width (within a particular zone of eelgrass) decrease with deteriorating water quality and can signal environmental changes (Berry *et al* 2003).

The goals of the Semiahmoo Bay Eelgrass Mapping and Monitoring Project are to monitor vegetative parameters that are established indicators of eelgrass extent and quality by:

1. designing a monitoring program to provide baseline information on temporal trends in *Zostera marina* abundance and extent in Semiahmoo Bay by:
   i) measuring shoot abundance and leaf area indices
   ii) and mapping of plant extent and depth
2. monitoring a high impact site (White Rock Pier) for changes over time
3. providing baseline information on the variability of eelgrass growth parameters over time.

Methods – Vegetative Parameters

In the first years of eelgrass mapping and monitoring (2002-2005), the Friends of Semiahmoo Bay Society collected data throughout the bay as well as at the high impact area of the White Rock Pier. In order to apply a statistical methodology to the monitoring program, an experimental approach was used in 2006 and 2007. Permanent control sectors of Semiahmoo Bay were chosen to allow for and make easier replicate sampling within portions of the bay that were within the resources of the Society. The established sectors were chosen to overlap with yearly Shorekeepers' habitat and invertebrate sampling as well as to represent eelgrass parameters along the entire stretch of Semiahmoo Bay, White Rock and Surrey, BC (Figure 1). The majority of the vegetative results presented in this report will focus on the data obtained since the adoption of the sector design. Eelgrass growth data measurements obtain in 2004 are incorporated within the data on growth characteristics and 2003 mapping data are used to describe the position of the shoreward edge of the eelgrass bed.

<u>Vegetative Characteristics:</u>

Measures of vegetative parameters followed the protocols established for eelgrass mapping and monitoring in British Columbia (Cynthia Durance, Precision Identification Biological Consultants, Dec. 2002). Vegetative parameters measured (blade length, width, shoot density, leaf area index) are standard parameters used to document *Zostera marina* quality (Berry *et al* 2003). All vegetative data were collected in the summer between June-August of each year.

<u>Statistical Analysis:</u>

<u>Monitoring Eelgrass Quality of Semiahmoo Bay and the White Rock Pier Impact Area</u>

2004 Data to describe conditions of Semiahmoo Bay for 2004 are represented by one random location and data exists for the White Rock Pier impact area. While the data for 2004 are not sufficient for statistical analyses, the summary statistical parameters (averages, standard error, and 95% confidence levels) are described.

2005 Temporal trends in vegetative characteristics in 2005 were measured by pooling results of control random sampling sites of the eastern portion of Semiahmoo Bay, east of the White Rock Pier, and then used to compare vegetative parameters collected in 2005 within the White Rock Pier area.

2006-2007 Temporal trends in vegetative characteristics were measured by pooling results of all four permanent control sectors for 2006 and 2007 to describe trends or differences between years. The sectors (or control sectors) were then used to compare trends within the White Rock Pier site.

Monitoring for Trends of Eelgrass Variability-Within Controls

Trends of variability of eelgrass characteristics were measured by calculating the variability within each of the four control sectors for 2006 and 2007 and the White Rock Pier.

Data sets were tested for normality and where applicable transformed. Following these procedures, most of the data sets still displayed non-parametric distributions, and analyses utilized non-parametric tests. Both median and average parameters will be discussed. JMP software was used for data analyses and Excel software used for data display.

Sector Design:

The four-eelgrass sectors are described as: Coldicutt Ravine, West Beach Boat Ramp, The Bear, and the Boundary Marker. Coldicutt Ravine and the West Beach Boat Ramp are on the western side of Semiahmoo Bay. The Bear and the Boundary Marker are found on the eastern side of Semiahmoo Bay.

White Rock Pier Impact Area:

Eelgrass data were collected on both the west and east side of the Pier behind the rock jetty. The western and eastern transect data were combined for analysis.

Results

Vegetative Characteristics – Temporal Analysis ***2005, 2006 and 2007***

Summary statistics (averages, medians and measures of variation) of vegetative shoot density, reproductive shoot density, blade length, blade width, and leaf area index (LAI) for the 2004 data, pooled random control samples and the White Rock Pier area from 2004 and 2005 are given in Table 1**.** Summary statistics for data collected at the control sectors and the White Rock Pier in 2006-2007 are included in Table 2.

Within Pooled Control Sectors – 2005 -2007.

In summary, 2005-2007 trends of average shoot densities remained constant in control sectors (Figure 2). Average reproductive shoot densities increased in control sectors (Figure 3). Trends of average blade length appear to decrease in control sectors while blade width remains constant (Figures 4 and 5). Leaf area indices were highest in 2005 but remained constant from 2006 to 2007 (Figure 6). Overall, these results may indicate that growth parameters (and perhaps environmental conditions) from 2005 to 2007 across Semiahmoo Bay did not vary. The 2005 control sector is very different from the 2006 and 2007 control sectors. As a result, differences between the 2005 and 2006-2007 parameters are to be expected. Results of statistical tests between 2006 and 2007 control sectors are provided below.

There was no statistical difference between median shoot densities of the 2006 and 2007 control sectors (Wilcoxon one-way test, $X^2_{1(0.05)} = 2.04$, $p < 0.15$)(Table 2).

Median reproductive shoot density of the control sector area was significantly higher in 2007 relative to 2006 (Wilcoxon; $X^2_{1(0.05)} = 22.03$, $p < 0.001$)(Table 2). Median blade length was statistically significantly higher in 2006 relative to 2007 for the control sector (Wilcoxon; $X^2_{1(0.05)} = 6.9$, $p = 0.008$)(Table 2). There was no statistical difference between median blade width of the 2006 and 2007 control sectors (Wilcoxon $X^2_{1(0.05)} = 0.002$, $p = 0.97$)(Table 2). Statistical tests of LAI differences are not possible.

<u>Within White Rock Pier Area</u>

Trends of average shoot densities increased at the White Rock Pier area (Figure 2). Trends of average reproductive shoot densities increased at the White Rock Pier area (Figure 3). Trends of average blade length remains constant at the White Rock Pier area while blade width remains constant (Figures 4 and 5). Leaf area indices increased from 2005 to 2007 (Figure 6). These trends of increasing growth parameters, may indicate improving environmental conditions at the White Rock Pier site. Results of statistical tests are provided below.

White Rock Pier area shoot densities were significantly higher in 2007 than 2006 (Wilcoxon one-way test, $X^2_{1(0.05)} = 26.8$, $p < 0.0001$)(Table 2). Median reproductive shoot density of the Pier area was significantly higher in 2007 relative to 2006 (Wilcoxon; $X^2_{1(0.05)} = 8.3$, $p = 0.004$) (Table 2). Median blade length was significantly higher in 2006 relative to 2007 for the White Rock Pier area (Wilcoxon; $X^2_{1(0.05)} = 13.5$, $p = 0.0002$)(Table 2). There was no statistical difference between median blade width of the 2006 and 2007 Pier area (Wilcoxon; $X^2_{1(0.05)} = 0.11$, $p = 0.74$) (Table 2).

<u>Control Sectors v. White Rock Pier</u>

For 2005, in statistical comparisons of the median values of eelgrass shoot density, blade length and blade width, values were higher at the random control sites relative to the White Rock Pier (Wilcoxon; $X^2_{1(0.05)} = 74.05$, $p < 0.0001$ Wilcoxon; $X^2_{1(0.05)} = 12.3$, $p = 0.0005$; Wilcoxon; $X^2_{1(0.05)} = 9.3$, $p = 0.002$; respectively) (Figures 2, 4, and 5; Table 2). The median reproductive shoot density was statistically higher at the 2005 Pier site relative to the 2005 random control sites (Wilcoxon; $X^2_{1(0.05)} = 16.6$, $p = 0.0001$) (Figure 3, Table 2). Leaf area indices for the control sites and the White Rock Pier were 4159 cm^2/m^2 and 1047 cm^2/m^2 respectively (Figure 6, Table 2). Values for both the random control area and the White Rock Pier are within the natural variability of eelgrass growth parameters across Semiahmoo Bay (Table 3).

Overall, there were no differences between average shoot and reproductive shoot densities at the control sectors and the White Rock Pier area in 2006 and 2007 (Figures 2 and 3; Table 2). In 2006 and 2007, blade lengths and blade widths were significantly higher at the Pier area relative to the control sectors and consequently LAI is higher for both years at the Pier area (Figures 4, 5 and 6; Table 2). Results of statistical tests are described below.

For 2006 and 2007, there were no significant differences between shoot densities of the control sector relative to Pier shoot densities (2006; Wilcoxon one-way test, $X^2_{1(0.05)} = 0.007$, $p < 0.93$; 2007; Wilcoxon one-way test, $X^2_{1(0.05)} = 3.4$, $p < 0.07$) (Figure 2, Table 2).

There were no significant differences between the 2006 and 2007 reproductive shoot densities of the control sector relative to Pier reproductive shoot densities (2006 Wilcoxon; $X^2_{1(0.05)} = 2.8$, p=0.10; 2007 Wilcoxon, $X^2_{1(0.05)} = 1.2$, p =0.28)
(Figure 3, Table 2).

Median blade length in 2006 and 2007 was statistically significantly higher in the Pier area than in the control sector (2006 Wilcoxon; $X^2_{1(0.05)} = 15$, $p = 0.00001$; 2007 Wilcoxon $X^2_{1(0.05)} = 4.8$, $p = 0.03$) (Figure 4, Table 2).

Median blade width in 2006 and 2007 was statistically significantly higher in the Pier area than in the control sector (2006 Wilcoxon $X^2_{1(0.05)} = 12.5$, $p = 0.00004$; 2007 Wilcoxon $X^2_{1(0.05)} = 9.1$, $p = 0.0016$)(Figure 5, Table 2).

Leaf Area Indices for the control sector and the White Rock Pier area were of similar magnitudes: 2332 (m^2/cm^2) (2006), 1803 (m^2/cm^2)(2007), 2339 (m^2/cm^2) (2006), and 2789 (m^2/cm^2) (2007) respectively (Figure 6, Table 2).

Vegetative Characteristics: Trends in Variation within sectors (2006 and 2007) and the Pier Area

These analyses provide a background to the natural variability across areas of Semiahmoo Bay. Summary statistics of average and median vegetative shoot density, reproductive shoot density, blade length, blade width and leaf area index (LAI) 2005-2007 within each sector and the White Rock Pier area 2006-2007 are provided in Table 3.

Within sectors, these eelgrass growth parameters varied between years examined (Figures 7, 8, 9, and 10, Table 3). Some of these differences were statistically significant (Table 3). Eelgrass growth parameters for 2006-2007 fluctuate yearly within sectors and among sectors. Across parameters, average values within the White Rock Pier area varied within the ranges of values measured within control sectors. For example, at control sectors, average shoot densities (shoots/m^2) ranged from 22.1-255 and the averages at the White Rock Pier were 46.6-146.2 (Table 3). This indicates, that overall, variation among years within the White Rock Pier area are within the natural range of eelgrass parameter variability across all of Semiahmoo Bay.

Methods – *Zostera marina* Shoreward Edge Analysis

Eelgrass bed Characteristics:

Z. marina shoreline mapping data (2003 – 2007) together with minimum depth data are used to describe eelgrass bed extent. Intertidal eelgrass bed depths were determined using standard tide tables for the area.

Comparisons of the extent and position of the intertidal shoreward edges were performed using three methods:

1. by qualitatively assessing the position of each yearly shoreline edge map
2. by quantitatively assessing the distance between each yearly shoreline edge map using the GIS distance tool on the Community Mapping Network (CMN) Eelgrass Atlas. Ten sets of random data points were generated among years (2003 v 2004; 2003 v 2005; 2003 v 2006; 2003 v 2007; 2004 v 2005; 2004 v 2006; 2004 v 2007; 2005 v 2006; 2005 v 2007; and 2006 v 2007). Within each of the four Semiahmoo Bay monitoring control sectors as well as the White Rock Pier, random data points were chosen by selecting GPS points along shoreline areas where delineation of the intertidal eelgrass bed was clear to all surveyors (2003 – 2007); then separate points were chosen every 50 metres apart that were in a perpendicular line relative to each other. If sectors were excessively large, data points were measured every 100 or 250 metres. Areas that were avoided for random data point selection were where the eelgrass bed edge was difficult to distinguish and differences between surveyor's interpretation were evident (these areas were evident from surveyor's notes as well as the maps themselves). The data sets of most value are those where the same surveyor completed the mapping (2005-2007). The general error of handheld Garmin 12XL and 12CX units was determined, from surveyors' notes, to be 4 metres. The distances were corrected by subtracting 4 metres from each generated data point.

After GPS deviation correction, the data were assessed using ANOVA (as variances among groups were equal and the data followed a normal distribution).

3. by quantitatively assessing any difference between the position of yearly shoreward maps using three ordinal categories and Chi Square analysis: 1=shoreward position relative to successive year; 2=seaward position; and 3=overlapping shoreward map.

Comparison of intertidal depth distribution was made by reviewing all of the tide height data from 2004 to 2007 within each control sector and the White Rock Pier.

Results: *Zostera marina* Shoreward Edge Analysis

Qualitatively it appeared that in areas where the shoreline edge is distinctive, most often, the 2003 data set is seaward to 2004-2006 in the Coldicutt Ravine, West Beach Boat Ramp sectors (there is no 2003 data in the Bear and Boundary Marker control sectors). Secondly, it appeared that the 2003 data set most often overlapped with the 2005 and 2006 data in the West Beach Boat Ramp control sector. Thirdly it appeared that the 2003, 2004, 2005 and 2006 data sets overlapped in the West Beach Boat Ramp. In the Coldicutt Ravine, West Beach Boat Ramp, Bear and Pier Sectors, it appeared that the 2005 and 2006 data sets overlapped. In the Pier sector the 2004 and 2005 data sets appear to overlap mostly on the western side; and on the eastern side (no data exists on the eastern side for 2004), 2005 is mostly shoreward of 2003 and 2004. Due to this variation, it is important to note that surveyors for 2003, 2004, and 2005/2006/2007 were different. Testing this qualitative data is important to gain a better understanding of the extent of the shoreward edge throughout Semiahmoo Bay.

ANOVA analysis revealed no difference between either the measured distances among all years (p=0.99) and across all Semiahmoo Bay sectors or when only groups involving 2003 data were analyzed. Within each individual sector among years, the distance between shoreward edges were not statistically significant (Coldicutt Ravine, ANOVA F=3.68, p=0.67; ANOVA West Beach Boat Ramp F=2.6, p=0.94; and ANOVA White Rock Pier F=2.54, p=0.78)(Figure 11, Table 4). These results indicate that the shoreward edge is not changing over time across the entire area of the Bay and within sectors.

When accessing the shoreward position of maps among years, Chi Square analysis ($\mathcal{X}^2$) revealed no differences between the number of times data points were shoreward, seaward or overlapped among years within Coldicutt Ravine Sector ($\mathcal{X}^2_{(4,0.05)}$, 7.21, p=0.12), within West Beach Boat Ramp Sector ($\mathcal{X}^2_{(4,0.05)}$, 6.3, p=0.18). When only year groups involving 2003 were compared the results were not statistically different. These results are informative as although the maps appear to have deviations (shoreward and seaward) among years over a large number of randomly selected points the position of the shoreward extent of eelgrass does not change to the degree that can be detected by statistical methods. Overall, there are no qualitative or statistically significant differences among the shoreward maps from 2003 – 2007.

With respect to intertidal depth data, there was no difference in the depth of the intertidal edge of *Zostera marina* within each control sector and within the White Rock Pier.

Tables and Figures

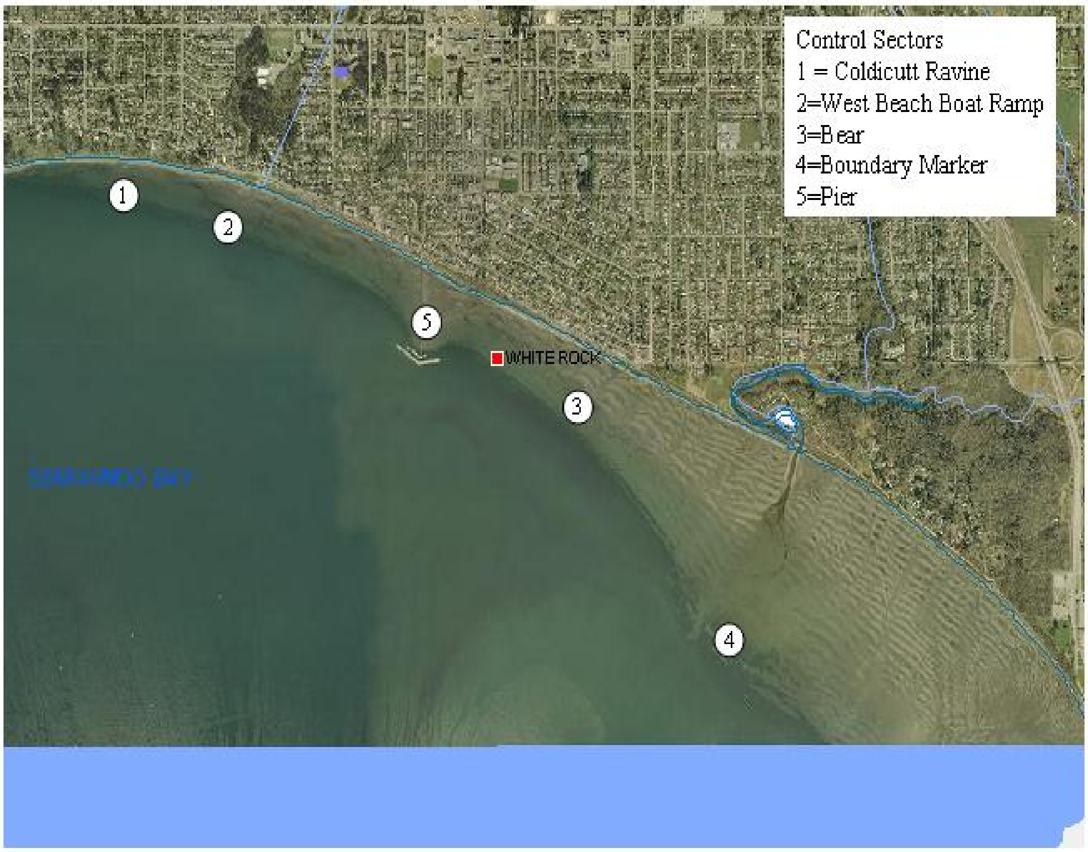

Figure 1: Map of Eelgrass Monitoring Control Sectors and the White Rock Pier area.

Table 1: Summary Statistics of Vegetative Characteristics of 2004 Transects, 2005 Pooled Control Sectors and 2005 White Rock Pier.

Shoot Density (m2)	West Semiahmoo Bay 2004	White Rock Pier 2004	Random Control Sites 2005	White Rock Pier 2005
Median	24	68	108	0
Average	25.3	109.2	128.8(*)	46.6
STDV	15.2	96.3	128.2	98
SE on mean	2.8	14.1	15	6.7
95% CI	19.7-31	80.9-137.5	99-159	33.5-59.7
80% CI	21.7-29	90.9-127.5	109-148	38-55.1
N=sample size	30	47	73	216
LAI	724	3120	4159	1047
*denotes statistically significantly different (SD)				

Reproductive Shoot Density (m2)	West Semiahmoo Bay 2004	White Rock Pier 2004	Random Control sites 2005	White Rock Pier 2005
Median	no data	no data	0	0
Average			2.3(*)	0.1
STDV			8.4	1
SE on mean			1	0.07
95% CI			0.3-4.2	-0.02-0.25
80% CI			1-3.5	0.02-0.2
N=sample size			73	216

Table 1 continued: Summary Statistics of Vegetative Characteristics of 2004 Transects, 2005 Pooled Control Sectors, and 2005 White Rock Pier.

Average Blade Length (cm)	West Semiahmoo Bay 2004	White Rock Pier 2004	Random Control Sites 2005	White Rock Pier 2005
Median	61	58.4	52	46
Average	59.6	58.3	62.1(*)	46.8
STDV	19.6	24	31.5	13.7
SE on mean	3.7	2.9	2.4	1.21
95% CI	52.1-67.2	52.6-64	57.4-66.9	44.4-49.2
80% CI	54.8-64.5	54.6-62	59-65.3	45.2-48.4
N=sample size	28	70	169	128

Average Blade width (mm)	West Semiahmoo Bay 2004	White Rock Pier 2004	Random Control sites 2005	White Rock Pier 2005
Median	5	5	5	5
Average	4.8	4.9	5.2(*)	4.8
STDV	1.4	1.2	1.2	1.1
SE on mean	0.3	0.15	0.09	0.09
95% CI	4.3-5.4	4.6-5.2	5-5.4	4.6-5.0
80% CI	4.5-5.2	4.8-5.2	5.1-5.3	4.7-4.9
N=sample size	28	70	169	139

LAI	West Semiahmoo Bay 2004	White Rock Pier 2004	Control Sites 2005	White Rock Pier 2005
	724	3120	4159	1304

Summary	Average Shoot Density (m2)	Average Reproductive Shoot Density (m2)	Average Blade Length (cm)	Average Blade Width (mm)	LAI
2004 West Semiahmoo Bay	25.3	no data	59.6	4.8	724
2004 White Rock pier	109.2	no data	58.3	4.9	3120
2005 Random Control Sites	128.8	2.3	62.1	5.2	4159
2005 White Rock Pier	46.6	0.1	46.8	4.8	1047

Table 2: Summary Statistics of Vegetative Characteristics 2006-2007 of Control Sectors and White Rock Pier.

Shoot Density (m2)	Control Sector 2006	Control Sector 2007	White Rock Pier 2006	White Rock Pier 2007
Median	68	112	80	128
Average	119.4	126.1	78.8(*)	146.2
STDV	121.9	98.5	44.4	78
SE on mean	10.8	9	6.5	11
95% CI	98.1-140.7	108.3-143.9	65.8-91.8	124.1-168.4
80% CI	105.5-133.3	114.5-137.7	70.4-87.2	131.9-160.6
N=sample size	128	120	47	50
(*) denotes statistically different at p=0.05				

Reproductive Shoot Density (m2)	Control Sector 2006	Control Sector 2007	White Rock Pier 2006	White Rock Pier 2007
Median	0	4	0	8
Average	4.3(*)	7.3(*)	2.9	6.4
STDV	10.4	11.3	4.5	6.5
SE on mean	0.9	1	0.7	0.9
95% CI	2.5-6.1	5.0-9.1	1.6-4.2	4.6-8.2
80% CI	3.1-5.5	5.7-8.4	2.0-3.7	5.2-7.6
N=sample size	128	120	47	50
(*) denotes statistically different at p=0.05				

Table 2 continued: Summary Statistics of Vegetative Characteristics 2006-2007 Control Sectors and White Rock Pier.

Average Blade Length (cm)	Control Sector 2006	Control Sector 2007	White Rock Pier 2006	White Rock Pier 2007
Median	40	32.5	56	36
Average	43.4	36.1	56.6	43.2
STDV	20.6	15.1	18.7	18
SE on mean	1.9	1.4	2.7	2.7
95% CI	39.5-47.3	33.3-38.9	51.1-62.1	37.8-48.6
80% CI	40.8-45.9	34.3-37.9	53.1-60.2	39.8-46.7
Range				
N=sample size	113	110	47	45

Average Blade width (mm)	Control Sector 2006	Control Sector 2007	White Rock Pier 2006	White Rock Pier 2007
Median	5	4	5	5
Average	4.5	4.4	5.3	5.2
STDV	1.4	1.5	1.08	1.1
SE on mean	0.13	0.14	0.16	0.17
95% CI	4.2-4.7	4.2-4.7	5-5.6	4.9-5.5
80% CI	4.3-4.6	4.3-4.6	5.1-5.5	5.0-5.4
Range				
N=sample size	113	110	47	45

Summary	Average Shoot Density (m2)	Average Reproductive Shoot Density (m2)	Average Blade Length (cm)	Average Blade Width (mm)	LAI
Control Sector 2006	119.4	4.3	43.4	4.5	2332
Control Sector 2007	126.1	7.3	32.5	4.4	1803
White Rock Pier 2006	78.8	2.9	56	5.3	2339
White Rock Pier 2007	146.2	6.4	36	5.3	2789

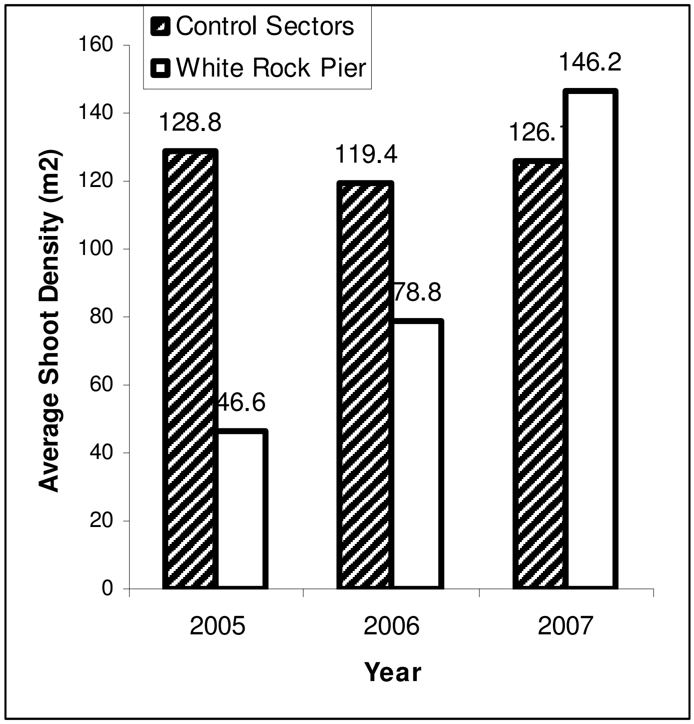

Figure 2: Average Shoot Density (m^2) from 2005 to 2007of Pooled Control Sectors and The White Rock Pier

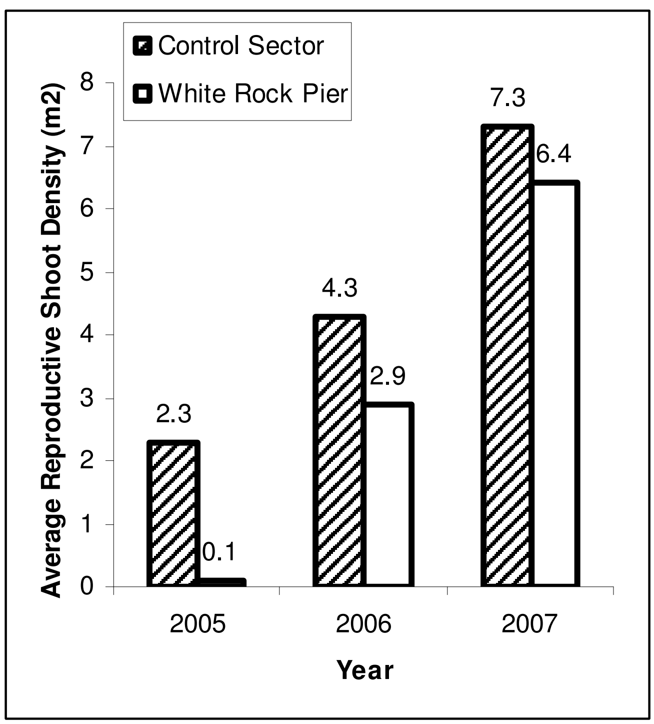

Figure 3: Average Reproductive Shoot Density (m^2) from 2005 to 2007 of Pooled Control Sectors and The White Rock Pier

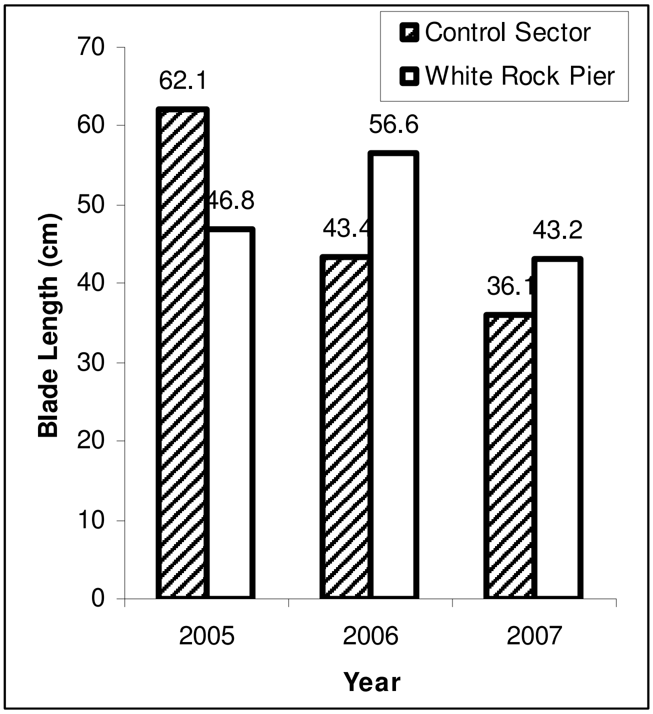

Figure 4: Average Blade Length (cm) from 2005 to 2007 of Pooled Control Sectors and the White Rock Pier.

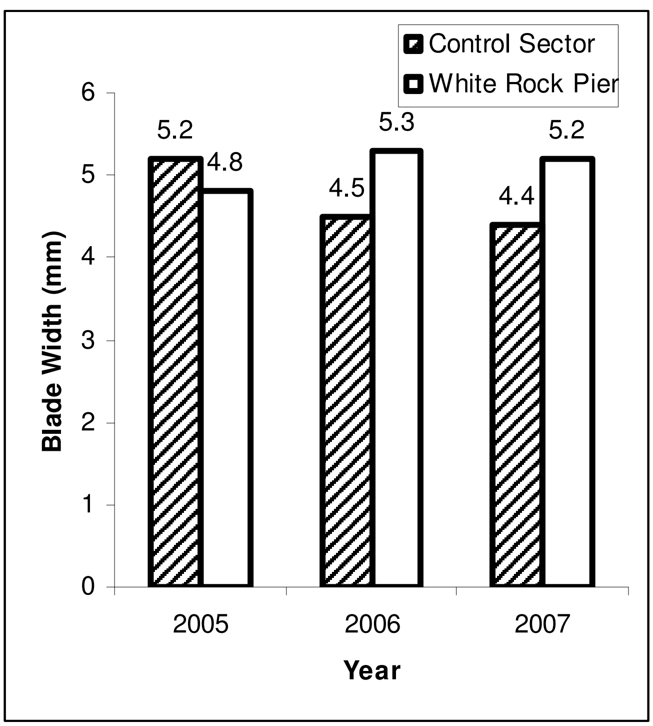

Figure 5: Average Blade Width (mm) from 2005 to 2007 of Pooled Control Sectors and the White Rock Pier.

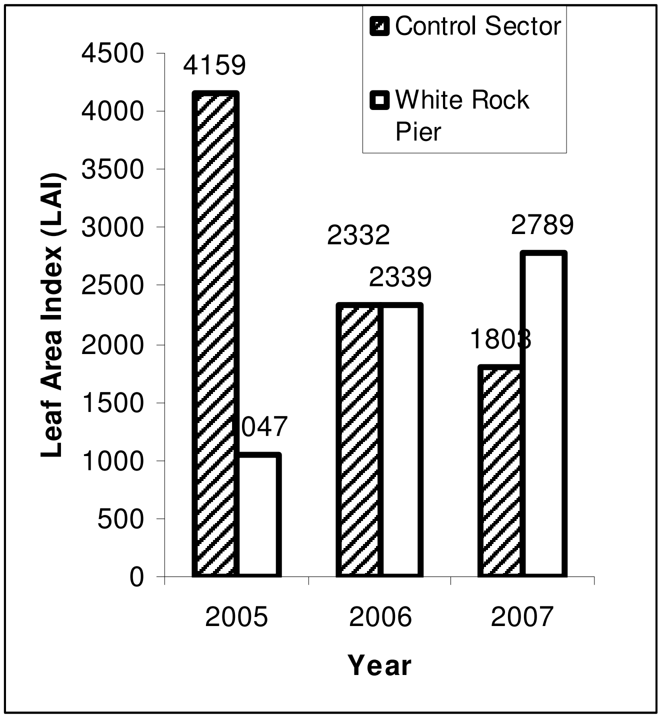

Figure 6: Leaf Area Index (cm^2/m^2) from 2005 to 2007 of Pooled Control Sectors and the White Rock Pier.

Table 3: Summary Statistics of Vegetative Characteristics Within control sectors and the White Rock Pier.

Shoot Density (m^2)	Coldicutt Ravine 2006	Coldicutt Ravine 2007	West Beach Boat Ramp 2006	West Beach Boat Ramp 2007	Bear 2005	Bear 2006	Bear 2007	Boundary Marker 2006	Boundary Marker 2007
Median	56	106	12	32	52	236	124	216	186
Average	54.5	116.4(*)	22.1	49.2	52.3(*)	255(*)	135.1(*)	171.6	203.6
STDV	37	60.1	33.8	68.2	33.4	84.9	102.7	130.6	92.2
SE on mean	6.5	11	5.9	12.5	7.3	17.3	18.8	20.9	16.8
95% CI	41.2-67.8	94-139	10.1-34	23.7-75	37.6-68	219-291	96.7-173.4	129-214	169-238
80% CI	46-63	102-131	14.4-29.8	32.9-65.5	43.1-62.4	232-278	110.5-159.6	144-199	182-226
N=sample size	32	30	33	30	21	24	30	39	30
LAI	1298	2733	494	977	916	7069	1914	1599	2634
Test: T-test, Wilcoxon, Kruskal-Wallis	(t-4.9, p=0.001)		not SD		K-W=41.8, p-0.0001			not SD	
* denotes significantly different(SD) between years									

Table 3 continued: Summary Statistics of Vegetative Characteristics of Within control sectors and the White Rock Pier.

Reproductive Shoot Density (m^2)	Coldicutt Ravine 2006	Coldicutt Ravine 2007	West Beach Boat Ramp 2006	West Beach Boat Ramp 2007	Bear 2005	Bear 2006	Bear 2007	Boundary Marker 2006	Boundary Marker 2007
Median	0	8	0	0	0	8	4	0	4
Average	0.4	10.3(*)	0.12	2.7	0	16.3	9.7	3.7	5.5(*)
STDV	1.2	12.6	0.7	7.5	0	17.7	15.7	6.9	5.2
SE on mean	0.2	2.3	0.12	1.4	0	3.6	2.9	1.1	1
95% CI	-0.05-0.8	5.6-15	=0.12-0.37	-0.11-5.5	0	8.8-23.8	3.9-15.6	1.5-6.0	3.5-7.4
80% CI	0.1-0.65	7.3-13.3	-0.04-0.28	0.9-4.5	0	11.6=21.1	6-13.5	2.3-5.1	4.2-6.7
N=sample size	32	30	33	30	24	24	30	39	30
Test: T-test or Wilcoxon	W=30.2, p=0.0001		not SD		K-W=21.2, p=0.0001			W=6.2, p=0.01	
* denotes significantly different (SD) between years									

Table 3 continued: Summary Statistics of Vegetative Characteristics of Within control sectors and the White Rock Pier.

Average Blade Length (cm)	Coldicutt Ravine 2006	Coldicutt Ravine 2007	West Beach Boat Ramp 2006	West Beach Boat Ramp 2007	Bear 2005	Bear 2006	Bear 2007	Boundary Marker 2006	Boundary Marker 2007
Median	50	43	42	39	40	63	31	27	30
Average	49.6	44.3	43	38.2	39.8	63(*)	32.2	27.4	30.8
STDV	15.4	15.7	12.9	18.7	9.3	21.7	13.6	13.2	8.3
SE on mean	2.9	3	2.7	3.9	1.5	4.4	2.5	2.1	1.5
95% CI	43.7-55.4	38.2-50.3	37.3-48.7	30.1-46.3	36.7-43	53.8-72.1	27-37.3	23.1-31.7	27.6-33.9
80% CI	45.9-53.3	40.4-48.1	39.4-46.7	33-43.3	37.8-41.9	57.1-68.8	28.8-35.5	24.6-30.3	28.8-32.7
N=sample size	29	28	22	23	36	24	29	39	30
Ttest: T-test or Wilcoxon	not SD		not SD		K-W=32.8, p=0.0001			not SD	
*denotes significantly different (SD) between years									

Table 3 continued: Summary Statistics of Vegetative Characteristics of Within control sectors and the White Rock Pier.

Average Blade width (mm)	Coldicutt Ravine 2006	Coldicutt Ravine 2007	West Beach Boat Ramp 2006	West Beach Boat Ramp 2007	Bear 2005	Bear 2006	Bear 2007	Boundary Marker 2006	Boundary Marker 2007
Median	5	5	5	3	4.5	5	5	3	4
Average	4.8	5.3	5.2(*)	3.15	4.4(*)	5.1	4.9	3.4	4.2(*)
STDV	1.2	1.2	1.4	1.6	1	0.8	1.3	1.1	0.8
SE on mean	0.23	0.22	0.3	0.3	0.2	0.2	0.24	0.2	0.2
95% CI	4.3-5.2	4.8-5.7	4.6-5.9	2.5-3.9	4.03-4.7	4.7-5.4	4.4-5.4	3.1-3.8	3.9-4.5
80% CI	4.5-5.1	5.0-5.6	4.8-5.6	2.7-3.6	4.2-4.6	4.9-5.3	4.6-5.2	3.2-3.6	3.4-4.4
N=sample size	29	28	22	23	36	23	29	39	30
Ttest: T-test or Wilcoxon	not SD		W=15.4, p=0.0001		K-W=8.3, p=0.02			W=8.9, p=0.003	
*denotes significantly different (SD) between years									

Summary	Average Shoot Density (m2)	Average Reproductive Shoot Density (m2)	Average Blade Length (cm)	Average Blade Width (mm)	LAI
Coldicutt R 06	54.5	0.4	50	4.8	1298
Coldicutt R 07	116.4	10.3	44.3	5.3	2733
West Beach Boat Ramp 06	22.1	0.12	43	5.2	494
West Beach Boat Ramp 07	49.2	2.7	38.2	3.15	977
Bear 05	52.3	0	39.8	4.4	916
Bear 06	255	16.3	63	5.1	7069
Bear 07	135.1	9.7	32.2	4.9	1914
Boundary Marker 06	171.6	3.7	27.4	3.4	1599
Boundary Marker 07	203.6	5.5	30.8	4.2	2634

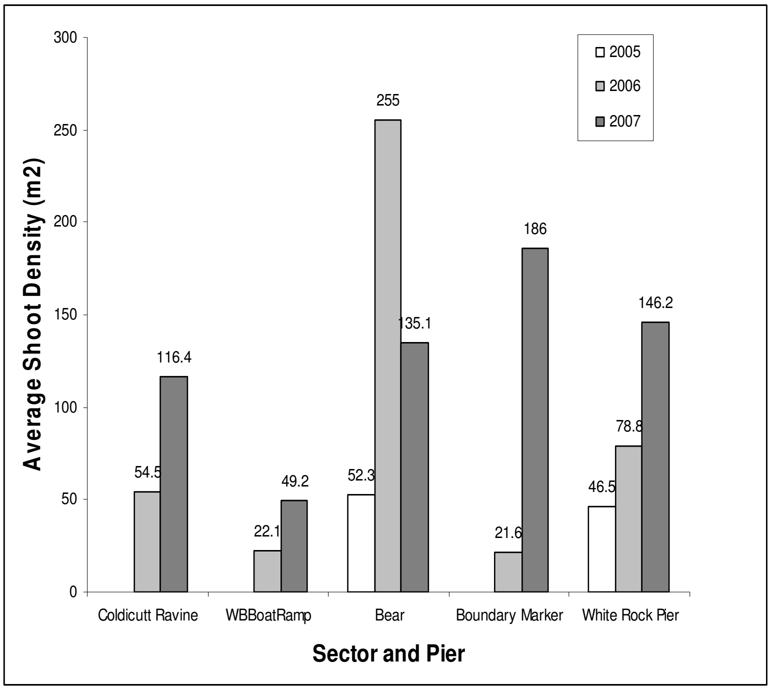

Figure 7: Average Shoot Densities (m^2) within Control Sectors and the White Rock Pier 2005-2007.

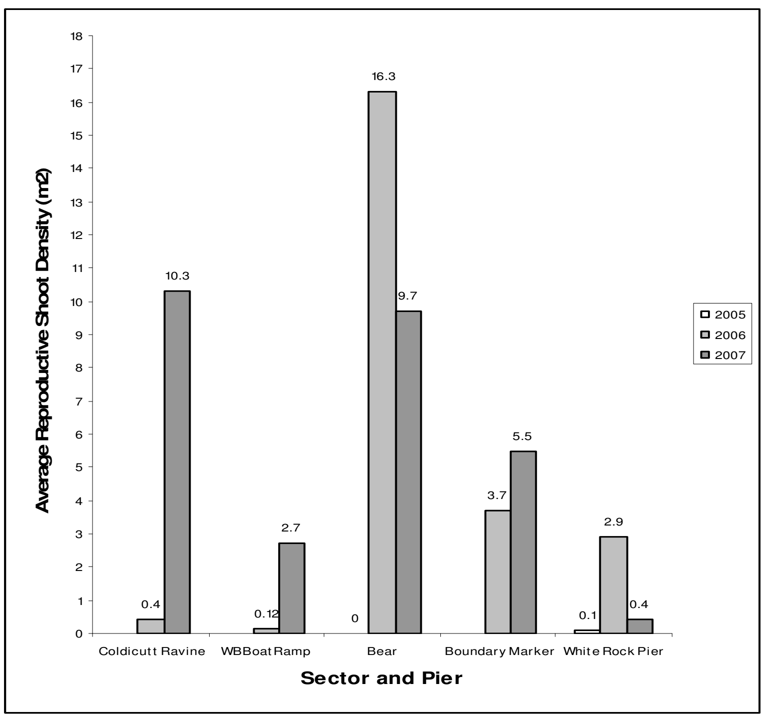

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Figure 8: Average Reproductive Shoot Densities (m^2) within Control Sectors and the White Rock Pier 2005-2007.

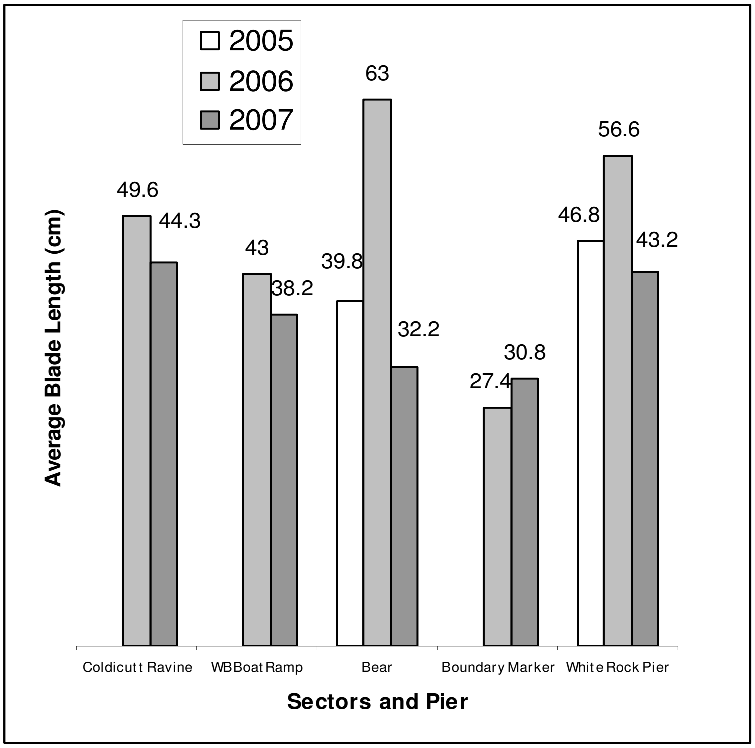

Figure 9: Average Blade length (cm) within Control Sectors and the White Rock Pier 2005 – 2007.

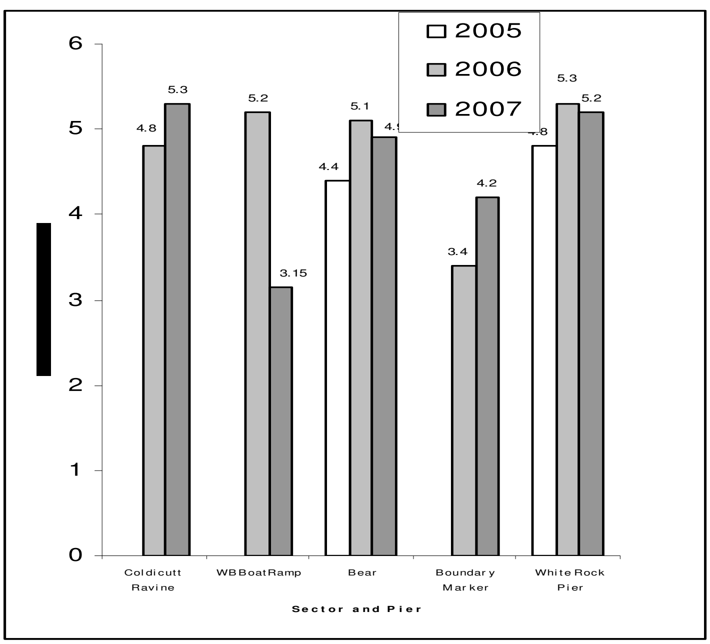

Figure 10: Average Blade Width (mm) within Control Sectors and the White Rock Pier 2005-2007

Table 4: Summary statistics of corrected data point. Average distances between shoreward edges were not statistically different (ANOVA, $F_{(4, 0.05)}$=0.09, p=0.99; K-W, $X^2_{(4, 0.05)}$, 1.79, p=0.78).

Group	Sample Size	Average (m)	Std Error	Lower 95%	Upper 95%
1	15	7.11	2.50	2.14	12.08
2	30	7.68	1.77	4.17	11.19
3	20	6.93	2.17	2.63	11.23
4	15	6.46	2.50	1.50	11.43
6	25	6.23	1.94	2.38	10.08

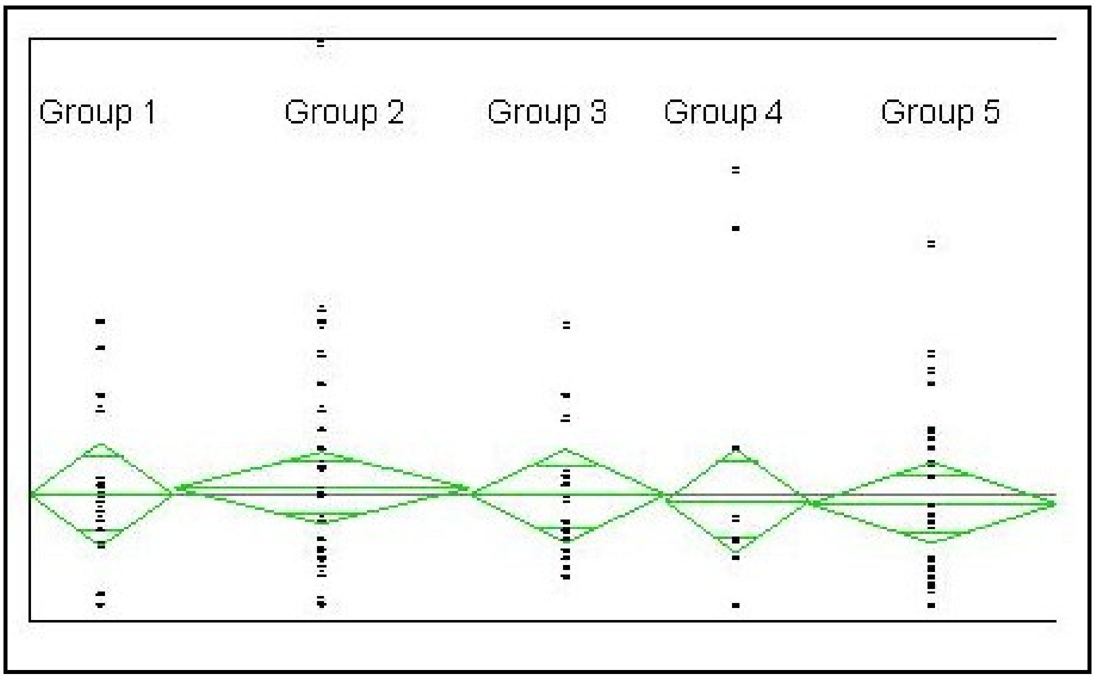

Figure 11: Average corrected distances (metres) between yearly shoreward edges (data groups by year). Averages are given in Table 4. Averages are not statistically different among years.

Discussion

Control Sectors relative to the White Rock Pier Monitoring Area

All vegetative parameters are important to consider when accessing eelgrass bed quality. As there are only two years' of data in the experimental design, further years of baseline sampling are important to monitor bed health. Overall, it appears that conditions across Semiahmoo Bay control sectors are remaining constant, while conditions for eelgrass growth near the White Rock Pier are improving.

It is important to consider if the data across years indicates a trend of increasing or decreasing parameters. For example, a clear example is at the White Rock Pier where a clear trend of increasing shoot density is seen (2005 to 2007) until it is the same as the average shoot density across control sectors for 2006-2007; and shoot density measured at control sectors does not vary between 2006 and 2007 (Figure 2). As eelgrass growth parameters such as blade length, width and shoot density generally decline with decreased water quality parameters (Berry *et al* 2003). These results are important as they may indicate conditions for eelgrass growth within the area of the White Rock Pier are improving and conditions across Semiahmoo Bay remaining constant (Figures 2, 3, 4, and 5; Tables 1 and 2). This is also consistent with the data concerning the stability of the shoreward edge from 2003-2007. Average reproductive shoot density appears to be increasing in both control sectors and at the White Rock Pier. Monitoring reproductive shoot density is an important parameter as this parameter can vary with environmental differences. It will be important to partner with other agencies to gain data on environmental differences and data on environmental stressors.

2005 Random Control Areas

In 2005, vegetative parameters were generally higher in the random control sectors than at the Pier. In 2006 and 2007, the results were quite different with there being only statistically difference of blade length and width. The control area of 2005 is not the same as that designed for 2006 and 2007. Until 2006, there was no experimental design allowing appropriate sample sizes and replicates for statistically assessing natural variation across Semiahmoo Bay. Results for 2006 and 2007 may be a result of improved statistical design (increased sample size and representation across all of Semiahmoo Bay). Due to the improved statistical design of 2006 and 2007, the comparative analysis of the 2005 random control sector versus the White Rock Pier area is likely unreliable. However, if this is not the case, variation in vegetative growth is normal and the totality of results is important to consider. It may be, then that in 2005 growth characteristics at the Pier were lower than at the sites across the eastern side of Semiahmoo Bay.

Within Sector Variability – 2006-2007

These analyses provide a background to the natural variability across areas of Semiahmoo Bay. Judging whether or not eelgrass parameters are changing across Semiahmoo Bay or at the White Rock Pier area relies on measures of the natural variability within the eelgrass bed. Without data on stressors (environmental changes) to the eelgrass bed, interpretation of these data can only be qualitative.

Also, overall growth parameters within control areas fluctuate between years as would be expected when examining individual transect lines. Overall, changes in eelgrass parameters at the White Rock Pier are within the natural variability across Semiahmoo Bay.

Shoreward Edge 2003-2007

Using a variety of tests, it appears that the shoreward edge and intertidal depth distribution of the eelgrass bed in Semiahmoo Bay is remaining constant. These results are consistent with eelgrass growth parameters measured in control sectors from 2006-2007.

Future monitoring of eelgrass beds in Semiahmoo Bay should follow the sector design implemented. The data provided to date are important to monitoring the marine health of Boundary Bay. Further years of baseline data will greatly assist in continuing this valuable monitoring program. While the data showed that from 2003-2007 conditions throughout Semiahmoo Bay showed some within sector variation, overall eelgrass growth parameters and shoreward edge distribution are remaining constant. This does not imply that water quality throughout Semiahmoo Bay is allowing for the optimal growth of eelgrass only that conditions have not statistically varied from 2003-2007. It would be advantageous to partner with relevant agencies to gain data on water quality relevant to eelgrass growth. Having data on these stressors to growth would provide a more quantitative approach to interpretation of the monitoring data.

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