CHAPTER 4: Results

4.1 Eelgrass Transplants

4.1.1 Survivorship

Total Survivorship

The total survivorship of eelgrass shoots in the Squamish Estuary pilot transplant project was 13.9% (Table 4.1). Survivorship numbers were determined based on change in numbers of healthy shoots from the August 2004 transplant to the final monitoring date reported (January 2004). The total number of eelgrass shoots surviving at the Cattermole Slough (CAT) site was greater (20.8 +/- 9.8%) than those of the Stawamus Estuary site (5.3 +/- 9.2 %).

Table 4.1 Squamish Estuary transplant site eelgrass shoot survivorship

Transplant Site	Total Shoots Transplanted (July 30)	August 27 (# shoots)	August Survivorship	December 12 (# shoots)	December Survivorship	January 10 (# shoots)	January Survivorship
CAT 1	125	10	8.0%	18	14.4%	17	13.6%
CAT 2	125	56	44.8%	25	20.0%	21	16.8%
CAT 3	125	23	18.4%	25	20.0%	40	32.0%
STA 1	100	11	11.0%	16	16.0%	16	16.0%
STA 2	100	29	29.0%	None Found	0.0%	None Found	0.0%
STA 3	100	None Found	0.0%	None Found	0.0%	None Found	0.0%
CAT total	*375*	*89*	*23.7%*	*68*	*18.1%*	*78*	*20.8%*
STA total	*300*	*40*	*13.3%*	*16*	*5.3%*	*16*	*5.3%*
All sites total	**675**	**129**	**19.1%**	**84**	**12.4%**	**94**	**13.9%**

Spatial and Temporal Comparison of Transplant Sites

Comparing the mean number of surviving plants per site (t-test) yielded no significant difference ($p > 0.05$) between the CAT and STA sites for both the first (August) and last day (January) monitored (Table 4.2). Both sites showed a significant decrease in shoot number from the transplant date to the first date monitored in August, with no significant decrease between subsequent monitoring dates (Figure 4.1). While mean survivorship did not vary significantly between treatment sites, it is important to note that in both sub-sites STA 2 and STA 3, no surviving shoots were found on the last date monitored (Table 4.1).

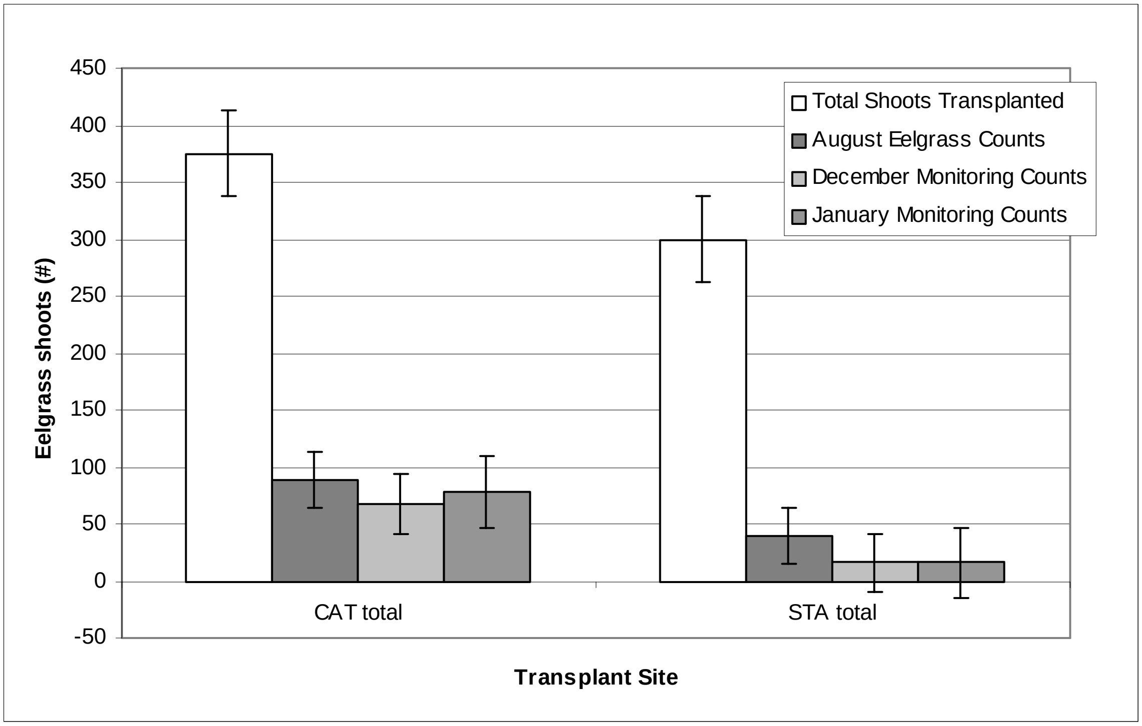

Figure 4.1 Number of eelgrass shoots planted and counted during monitoring

Table 4.2 T-test for spatial, site differences in eelgrass survivorship

	CAT Mean	STA Mean	t-value	df	p
August Survivorship	23.7%	13.3%	0.75	4	0.49
January Survivorship	20.8%	5.3%	1.99	4	0.12

4.1.2 Leaf Length

Samples of eelgrass leaf lengths showed a temporal shift from a pre-transplant distribution (Figure 4.2) skewed towards longer leaves to a January distribution (Figure

4.3), skewed towards smaller leaf lengths. No significant difference in leaf length was found between the sites (Table 4.3) on the final monitoring date. It was also qualitatively observed that the surviving blades appeared green, and without an epiphyte load. If the leaf appeared black, brown or opaque it was qualified as dead, and was not measured.

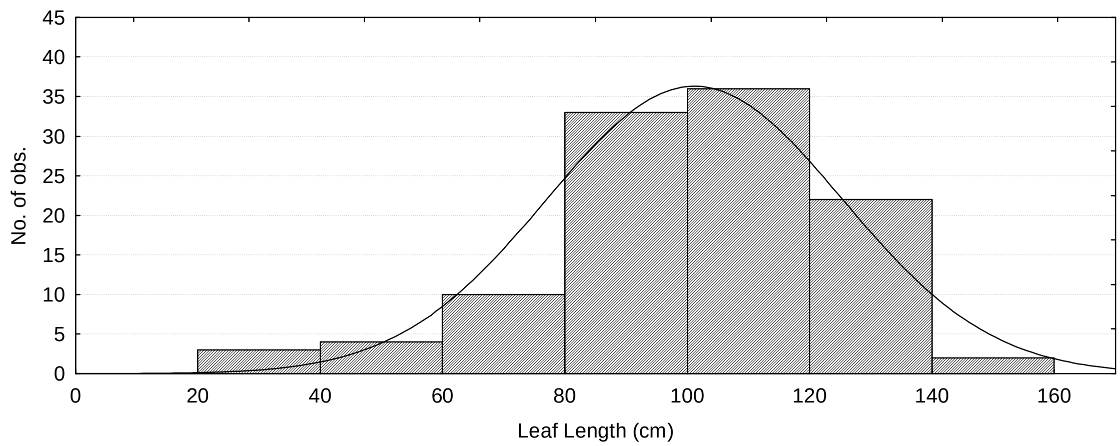

Figure 4.2 Pre-transplant frequency distribution of eelgrass blade lengths (all sites). Solid line is the expected normal distribution.

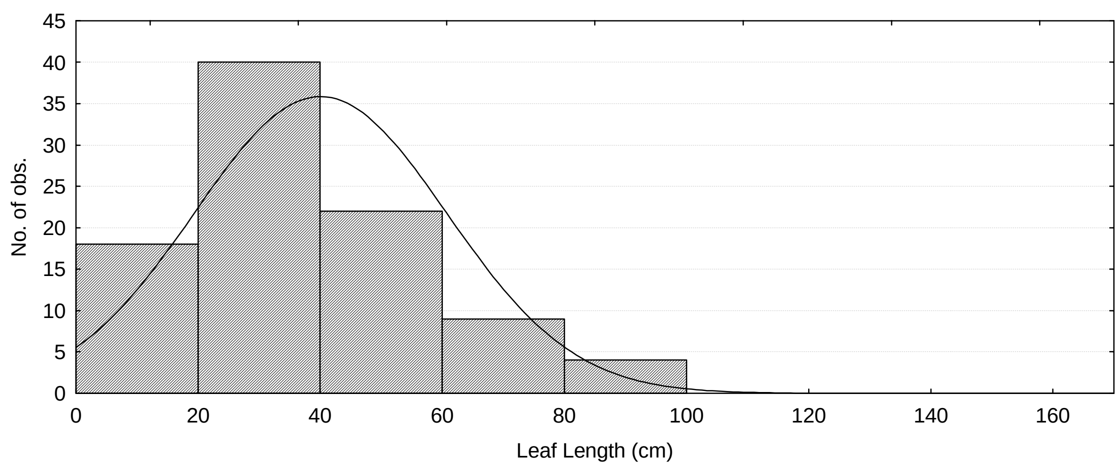

Figure 4.3 Post-transplant (January monitoring) distribution of blade lengths (all sites). Solid line is the expected normal distribution.

Table 4.3 Independent t-test of blade lengths at each site (January monitoring)

	Mean	St. Dev.	N	t-value	df	p
CAT (square root transformed)	6.12	1.66	80	0.15	91	0.88
STA (square root transformed)	6.04	1.71	13			

4.2 Water Column Variables

The variables monitored are representative of those known to be related to eelgrass growth and development in the Pacific Northwest (Table 4.4).

Table 4.4 Physical characteristics of areas where eelgrass occurs along the North Pacific coast (adapted from Thom, 1990). (a) Dennison, 1987, (b) Phillips, 1984, (c) Thom, 1990, (d) Ohrel and Register, 1995, (e) Hemminga and Duarte, 2000

Variable	Range	Optimal	Squamish Measurement
Irradiance	11% surface irradiance or 0.95 x mean annual Secchi depth (m) (compensation depth) (a)	Unknown	Average Secchi depth: 0.63 m Compensation depth: 0.60 m
Growing Depth	1.8 m above MLLW to 30 m deep (b)	MLLW to - 6.6 m MLLW (c)	Range: + 0.5 m to - 0.5 m MLLW Average: 0 m MLLW
Surface conditions	Waves to stagnant water (b)	Small and infrequent wave action, gentle currents to 3.5 knots (b)	Moderate to no wave action
Temperature	-6 °C - 40.5 °C (b)	10°C - 20°C (b)	Range: 4.1 - 19.4 °C Average: 12.3 °C
Salinity	0 ppt - 42 ppt (b)	10 ppt - 30 ppt (b)	Range: 0.4 ppt - 29.1 ppt Average: 9.2 ppt
Dissolved Oxygen	> 5 mg/L (d)	Unknown	Range: 5.49 – 9.95 mg/L Average: 8.03 mg/L
Substrate	Pure firm sand to pure soft mud (b) <6% dry weight (DW) sediment organics (e)	Mixed sand and mud (b) Optimal organic content unknown	Mixed sand-mud size class dominant Range: 0.9% - 27.95% DW Average: 9.8% DW

4.2.2 Spatial and Temporal Variability of Water Quality Variables

Spatial differences between CAT and STA transplant sites, and temporal differences between the water quality monitoring dates were analyzed based on results of RM ANOVA. Significant changes ($p < 0.05$) over time were found for all of the variables except dissolved oxygen (Table 4.5).

Salinity measurements were the only variables that showed a significant spatial difference between CAT and STA. For both of these measurements, CAT had higher values than STA. Significant interactions between site and date indicated that salinity and conductivity had different temporal patterns at each site. The same results were also obtained using MANOVA tests of these data, which further supports the results from the RM ANOVA analysis. Since one of the primary components of this pilot project was to gather baseline information on the physical variables important to eelgrass growth and survival in the Squamish Estuary, the raw data from each monitoring dates are included in Appendix B.

Table 4.5 RM ANOVA tests for spatial (site) and temporal (date) differences for monitored water-column variables (* - significant at $\alpha < 0.05$)

Dependent Variable	Independent Variable	MS Between	df	MS Within	df	F	p-value
Secchi Depth	Site	27.2	1	112.9	3	0.24	0.66
	Date	7251.6	5	133.0	15	54.51	0.00*
	Site x Date	216.9	5	133.0	15	1.63	0.21
Temperature	Site	3.42	1	19.43	5	0.18	0.70
	Date	59.81	5	14.18	15	4.22	0.01*
	Site x Date	17.03	5	14.18	15	1.20	0.36
Salinity	Site	9.44	1	0.27	3	34.56	0.01*
	Date	466.47	5	0.32	15	1451.8	0.00*
	Site x Date	3.92	5	0.32	15	12.20	0.00*
Dissolved Oxygen	Site	0.87	1	0.69	3	1.27	0.34
	Date	1.09	3	0.83	9	1.31	0.33
	Site x Date	2.05	3	0.83	9	2.47	0.13

Surface Conditions

Surface conditions varied slightly between the different monitoring dates and stations, but were, on average, relatively calm, from small waves to ripples (Table 4.6).

Table 4.6 Spatial and temporal variation of surface conditions at water quality monitoring stations based on the Beaufort Scale (McKnight and Hess, 2002).

Surface Condition Scale (based on the Beaufort Scale)	
0	Completely flat, no wind
1	Very small ripples, very light breeze (1 -3 knots)
2	Small, choppy wavelets, light breeze to gentle wind (4-6 knots)
3	Large wavelets, crests beginning to break, winds gentle to moderate (7- 10 knots)
4	Small waves, becoming larger, whitecaps, winds moderate (11-16 knots)
5	Moderate waves, whitecaps frequent, winds getting strong (17 – 21 knots)
6	Large waves begin to form, whitecaps extensive winds strong (22-27 knots)
7	Sea heaps up, breaking waves, near gale force winds (28-33 knots)
8	Moderately high waves of greater length, gale force winds (34-40 knots)
9	High waves, spray, severe gale force winds (41-47 knots)
10	Very high waves with long-hanging crests, storm force winds (48-55 knots)
11	Exceptionally high waves, violent storm (65-63 knots)
12	Hurricane (64-71 knots)

Date	Time	Tidal Height	CAT 1	CAT 2	CAT 3	STA 1	STA 2
Jul-15	11:45 - 1:30	FLOW: 1-2 m	4	4	4	4	4
Jul-26	9:20 - 11:03	FLOW: 1.8 - 2.6	2	2	2	3	3
Aug-08	11:30 - 2:28	FLOW: 3.2 -3.7	2	1	1	2	2
Aug-27	11:55 - 1:43	FLOW: 1.2-2.8	2	2	2	2	2
Sep-14	11:22 -12:43	EBB/FLOW: 1.3 - 1.45	2	2	2	2	2
Dec-12	20:30 - 21:38	EBB: 1.3 - 2.0	1	1	1	1	1
Jan-10	20:42 - 21:52	EBB: 0.9 - 2.0	2	2	2	2	2

Secchi Depth

Secchi depth values varied throughout the monitoring period (Figure 4.4). A large increase in average Secchi depth occurred on August 8th and January 10th 2005 at both transplant sites. Both winter monitoring dates were recorded at night with a flashlight.

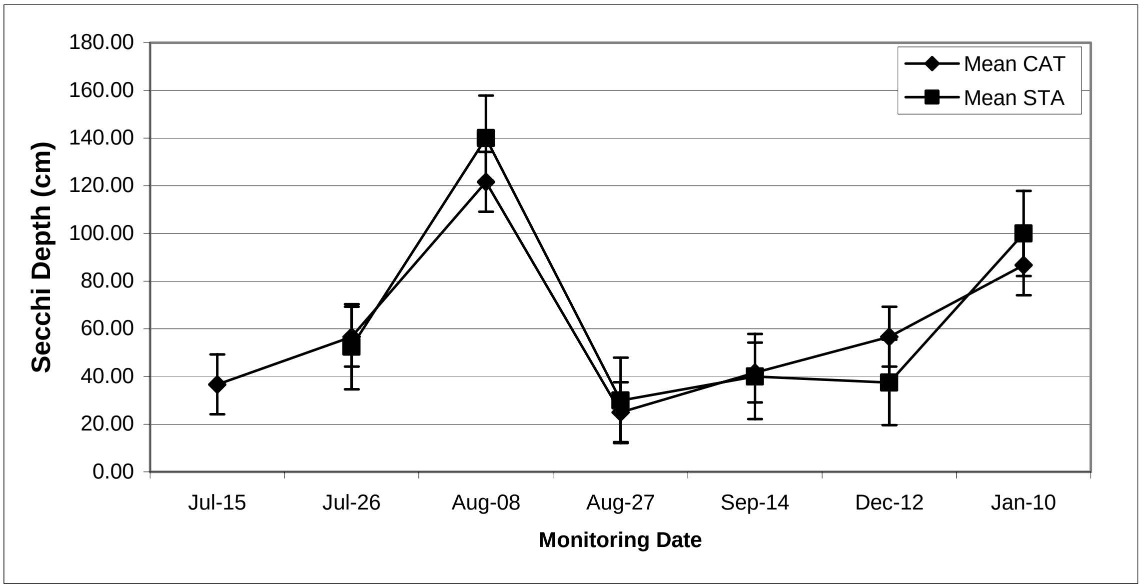

Figure 4.4 Spatial and temporal variation of average Secchi depths (+/- SE) at water quality monitoring stations

Temperature

Temperature values of the water column decreased from summer to winter months (Figure. 4.5).

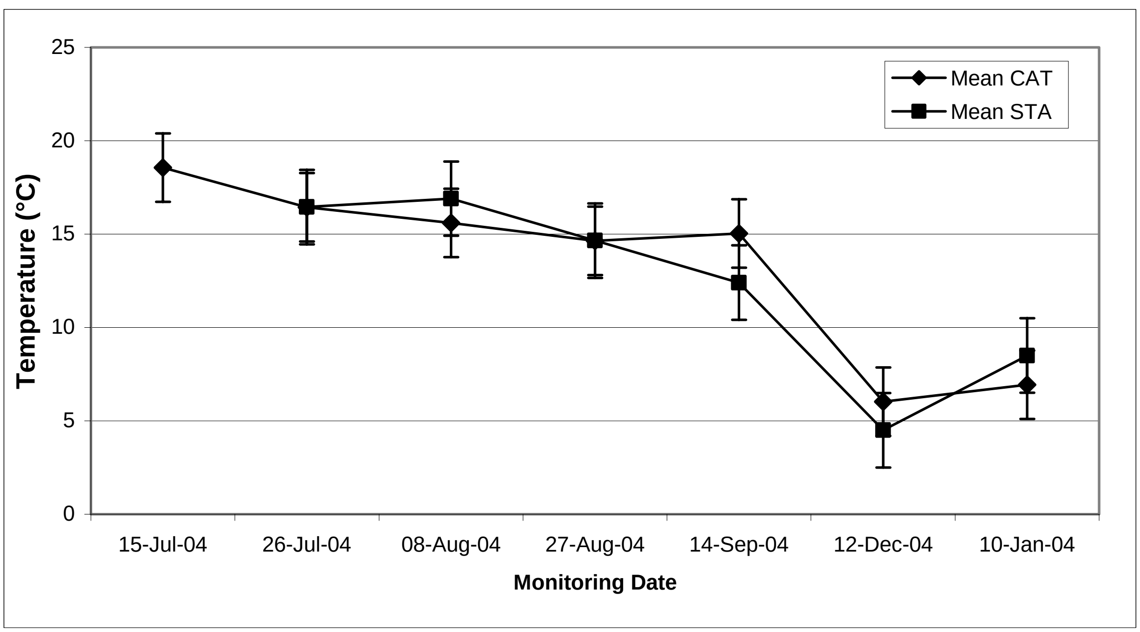

Figure 4.5 Spatial and temporal variation of average temperature (+/- SE) at water quality monitoring stations

Salinity

Measurements of salinity showed peaks on August 8th, 2004 and January10, 2005 (Figure 4.6).

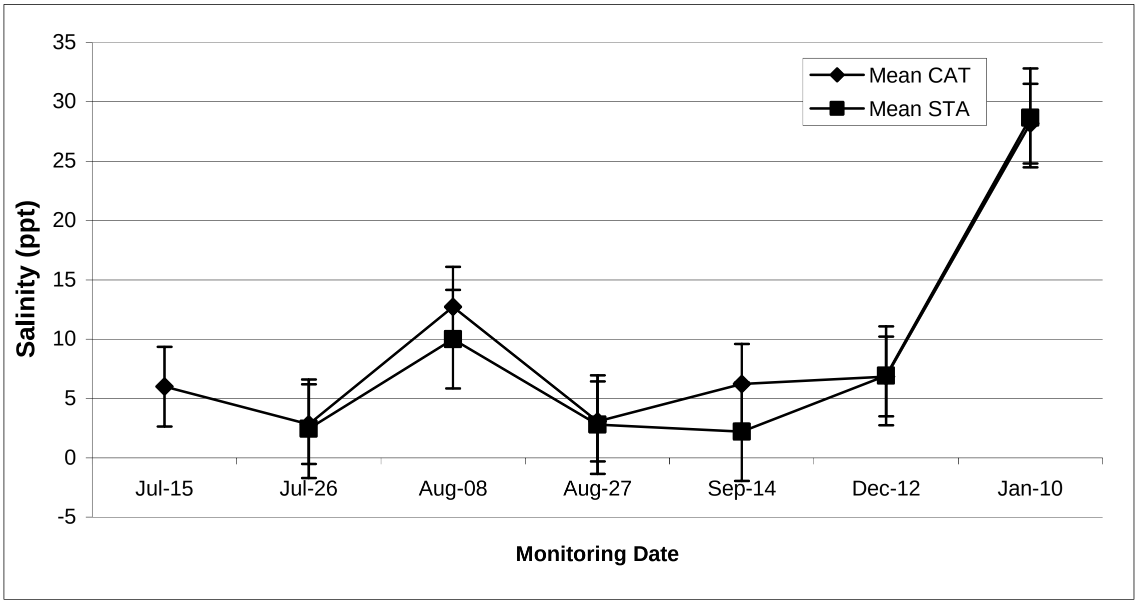

Figure 4.6 Spatial and temporal variation of average salinities (+/- SE) at water quality monitoring stations

Dissolved Oxygen

Concentrations of dissolved oxygen did not fluctuate widely throughout the monitoring period (Figure 4.8, Table 4.5).

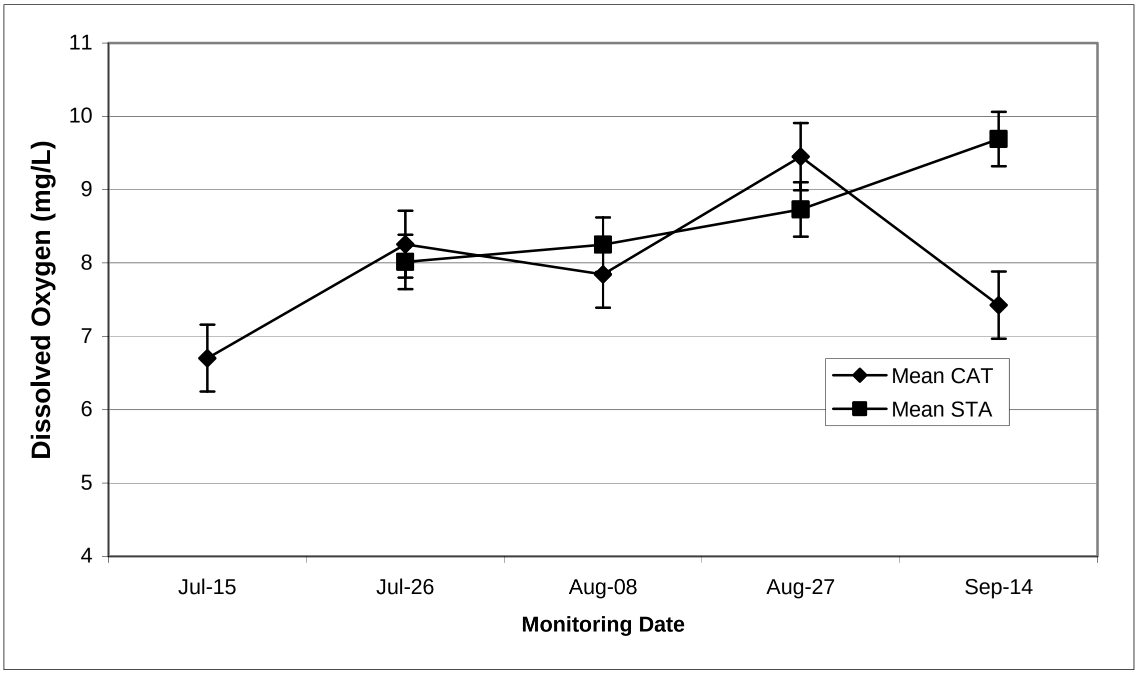

Figure 4.7 Spatial and temporal variation of dissolved oxygen (+/- SE) at water quality monitoring stations

4.3 Sediment Characteristics

4.3.1 Particle Size

Substrate samples were classified into 3 primary particle size classes: gravel, sand and mud (a mixture of silt and clay size classes). The sand class composed the largest percentage with averages of 64 +/- 10% (CAT) and 67 +/- 6% (STA) of the samples, and the smallest size class was mud with average compositions of 9% at both sites. The sand and mud classes were pooled in order to determine the composition of the optimal sand-mud medium for eelgrass (74 +/- 13% CAT and 76 +/- 9% STA). Average gravel composition was 27 +/- 13% (CAT) and 24 +/- 9% (STA). A significant difference between sand-mud and gravel was found between the average values for these size classes at both the site and sub-site level (dependent t-test, p = 0.00). No significant difference between the average mean values for the different size classes was found between the two sites (Figure 4.9 and Table 4.7).

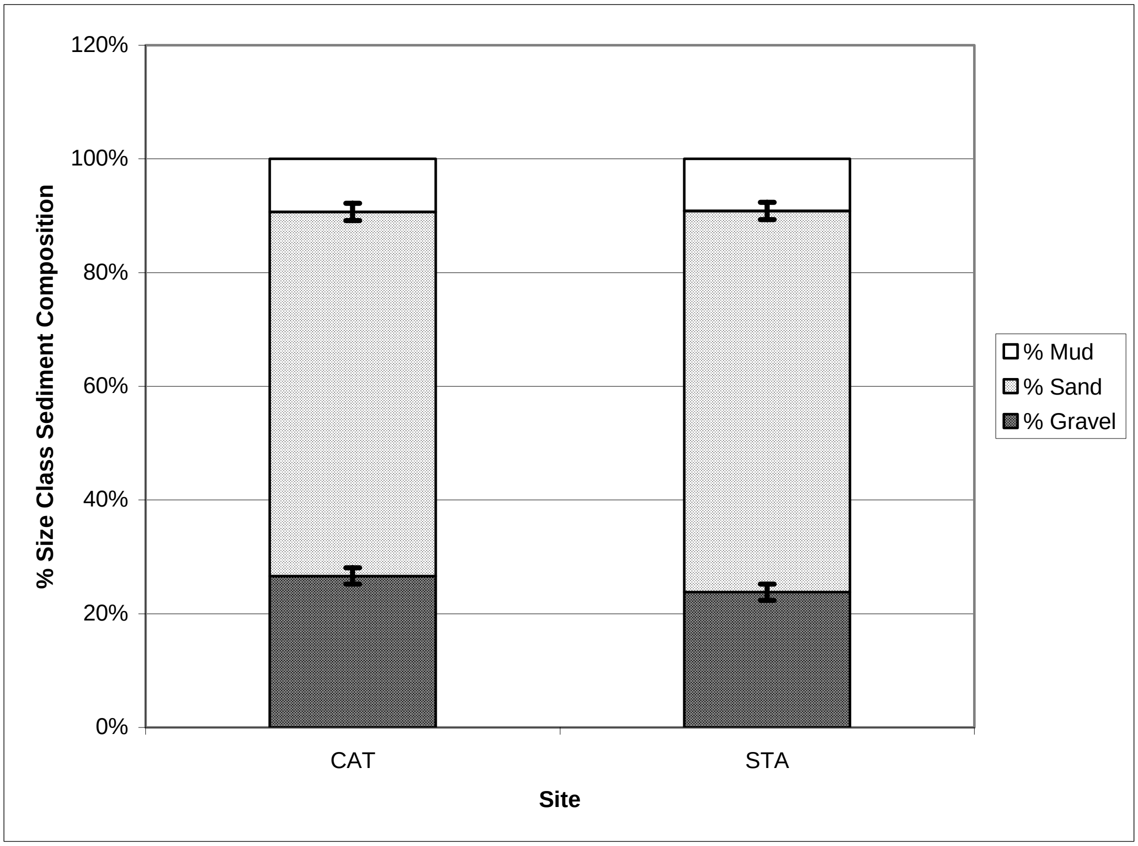

Figure 4.8 Between site difference in substrate size class composition

4.3.2 Organic Content

There was no significant difference (Table 4.7) between sites with respect to mean organic matter content per sample, for both total organic content (CAT: 8.64 +/- 10.16% DW, STA: 11.09 +/- 8.55% DW) and organic content per individual substrate class (gravel, sand and mud) (Figure 4.10 and Table 4.7). The greatest average percentage organic content per sample was found in the gravel class at CAT 1 (11.40 +/- 6.57% DW) and STA 1 (11.04 +/- 8.69% DW). The largest values of organic content in the sand class were found at these same sites, CAT 1 (9.56 +/- 11.10% DW) and STA 1 (6.02 +/- 2.34% DW). No significant differences (dependent t-test, $p > 0.05$) were found between the average organic content per gravel and sand size classes at either site. The smallest size class, mud, also had the lowest levels of organic matter, with average values for CAT of 0.37 +/- 0.39% DW and STA of 0.71 +/- 0.44% DW. This represented less than 7% of the average total organic content at both sites.

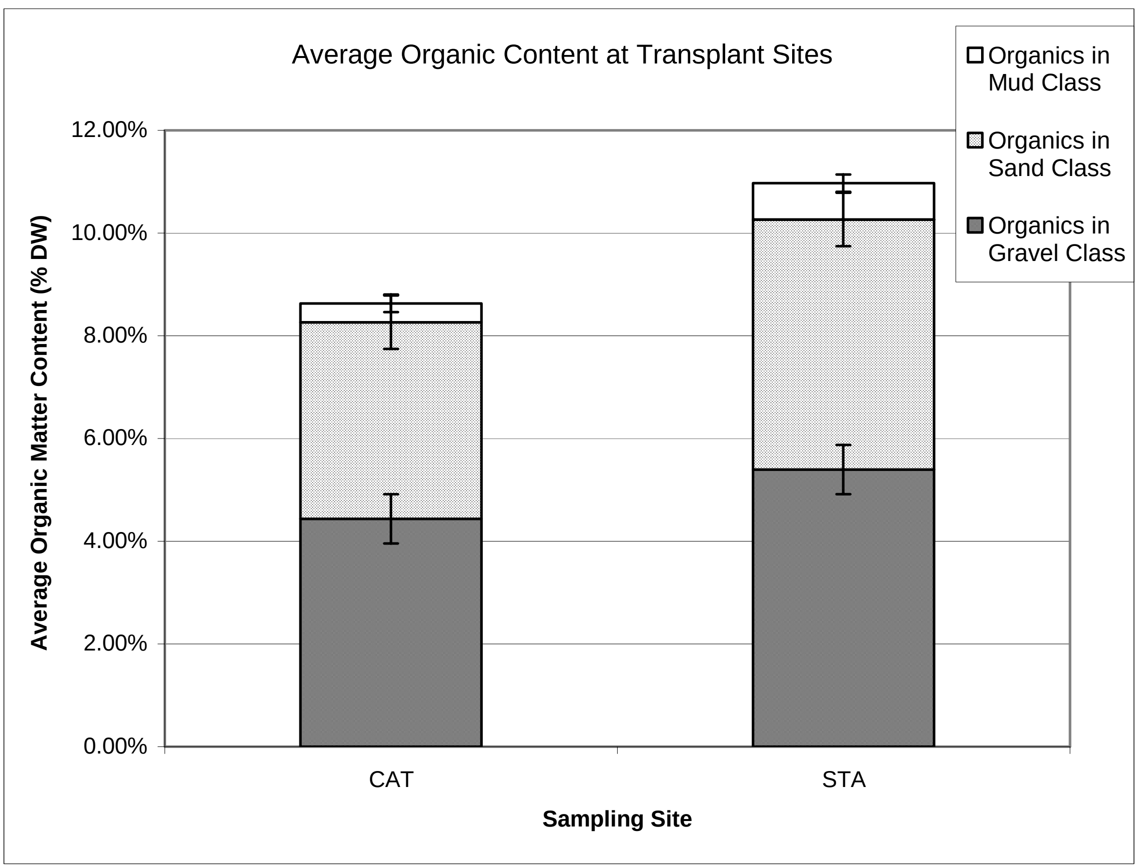

Figure 4.9 Between site difference in organic content (by size class)

While no significant difference in organic content (% DW) was found between the sites, significant difference as the sub-site level did exist for total organic content, as well as organic content in the gravel size class (Table 4.7). Sub-site means were compared with a Tukey test, which found the largest significant difference in total organic content within the STA sites (i.e., between STA 1 and STA 2, STA1 and STA 3) (Figure 4.11).

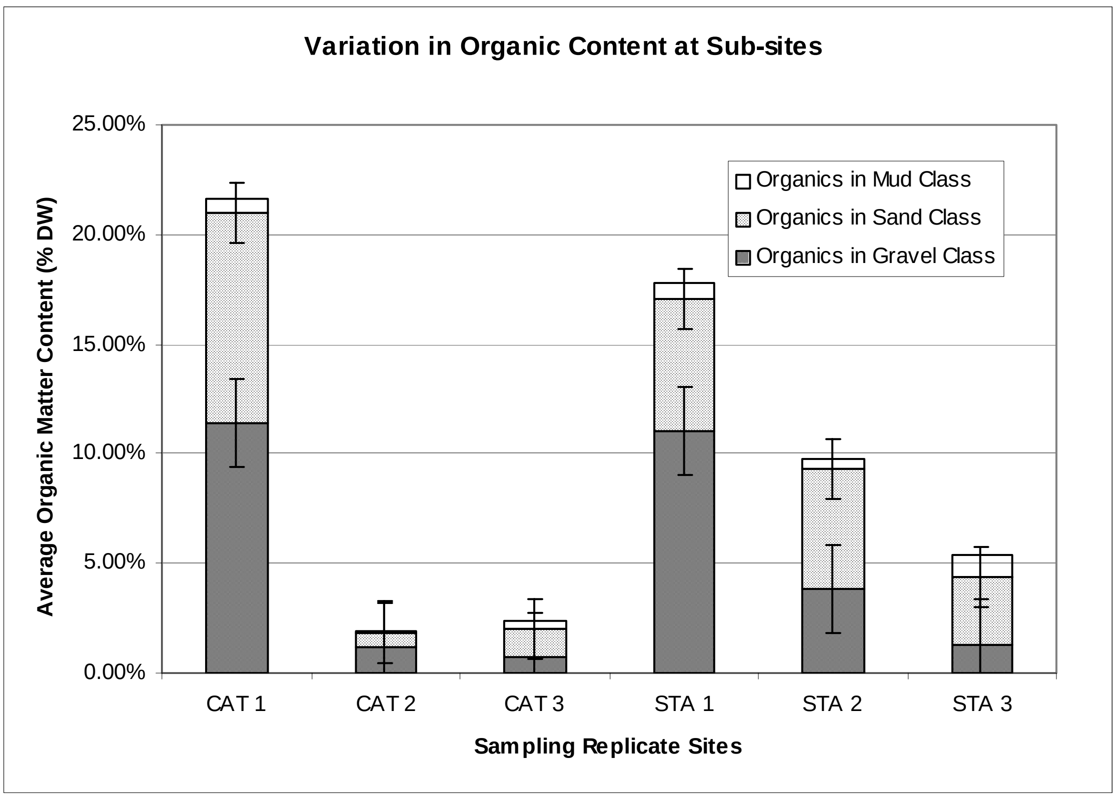

Figure 4.10 Sub-site differences in organic content (% DW size class)

Table 4.7 ANOVA's of spatial variability of particle size classes and organic content. Nested sub-sites CAT 1, 2, 3 in CAT site, and sub-sites STA 1, 2, 3 in STA site (* - significant at $\alpha < 0.05$)

ANOVA	Factor tested	MS Between	df	MS Within	df	F	p-level
Independent Variable: **% Gravel**	Site Sub-site	0.00 0.04	1 4	0.02 0.02	12 12	0.16 1.65	0.70 0.23
Independent Variable: **% Sand**	Site Sub-site	0.00 0.02	1 4	0.02 0.02	12 12	0.18 0.94	0.68 0.47
Independent Variable: **% Mud**	Site Sub-site	0.00 0.01	1 4	0.01 0.01	12 12	0.00 1.22	0.97 0.35
Independent Variable: **% Sand-Mud**	Site Sub-site	0.00 0.04	1 4	0.02 0.02	12 12	0.16 1.65	0.70 0.23
Independent Variable: **Gravel Organic Content (% DW)** (arcsine transformed)	Site Sub-site	0.00 0.02	1 4	0.00 0.00	12 12	0.01 4.89	0.43 0.01*
Independent Variable: **Sand Organic Content (% DW)** (arcsine transformed)	Site Sub-site	0.00 0.00	1 4	0.00 0.00	12 12	1.90 2.29	0.19 0.12
Independent Variable: **Mud Organic Content (% DW)** (arcsine transformed)	Site Sub-site	0.00 0.00	1 4	0.00 0.00	12 12	4.47 1.56	0.06 0.25
Independent Variable: **Organic Content (% DW)** (arcsine transformed)	Site Sub-site	0.00 0.02	1 4	0.00 0.00	12 12	2.37 8.72	0.15 0.00*

4.4 Eelgrass Mapping & Videography

During all of the low tide reconnaissance trips (May and June 2004) to the estuary, no patches or beds of eelgrass plants were documented. However, in the upper, freshwater dominated reaches of the estuary, another brackish lower salinity seagrass, *Ruppia maritima* was found. The first underwater videography excursion (August 28, 2004) in lower Howe Sound (Porteau Cove and Minati Bay) documented zero eelgrass plants, and was shortened due to faulty videography equipment. The second videography expedition (January 6, 2005) within the Squamish harbour and Howe Sound also found no new un-documented eelgrass plants, but was able to relocate those planted at STA 1.

4.5 Summary

This chapter has presented the results from the analysis of the Squamish Estuary pilot eelgrass project. Results include spatial and temporal variability of survivorship numbers, blade length, water-column variables, substrate qualities and eelgrass mapping. These results, and their spatial and temporal trends are discussed in Chapter 5, followed by recommendations and overview of the project as a whole presented in Chapter 6.