Repeat Monitoring of Seagrass Beds for Project Next Generation: Autumn 2015

Prepared by

Ryder Consulting

May 2015

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Cover Photo: Seagrass beds off West Harwood, Otago Harbour – Brian Stewart

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Executive Summary

Port Otago Ltd has been granted consents to carry out dredging and disposal work that will deepen the approaches to Port Chalmers. Conditions of the consent stipulate that environmental monitoring of seagrass beds be carried out before work commences. Seagrass beds are recognised as being ecologically significant in providing nursery grounds for a wide variety of intertidal invertebrates and fish, and as feeding areas for birds and fish. Seagrass beds were surveyed in winter 2013, spring 2013, summer of 2013/2014 and autumn 2014 by Ryder Consulting Ltd. This report presents the findings of the forth (autumn) and final baseline survey.

There has been no significant increase in the mean length of *Zostera* blades since the previous autumn survey at all three monitored sites (Papanui Inlet – control; West Harwood and North Harwood – potential impact).

For other parameters measured there have been significant changes to shoot density and percentage cover with season but not for site. For biomass the converse is true, with the biomass of plants at West Harwood being significantly greater than biomass at other sites, irrespective of season. Both blade length and percentage cover show significant differences for site/season interaction.

All other parameters, including substrate composition and thickness of the RDL, show no significant changes.

Bearing in mind there had been no major capital works dredging carried out prior to this latest survey, nor any major incremental dredging, any changes must be put down to natural variability. Such variability needs to be considered when analysing results obtained after dredging does commence.

The survey will be repeated after capital works dredging has commenced.

1 Introduction

The approaches to Port Chalmers are considered to be inadequate to accommodate the passage of large container vessels that may visit the port in future years (Plunket 2011). To address this concern Port Otago Ltd (POL) applied for and has been granted consents enabling dredging of the channel between Port Chalmers and the entrance to Otago Harbour at Taiaroa Head. Dredging will ultimately result in the disposal of up to 7.2 million cubic metres of dredged material at a site known as A0, some 6.3 km north-east of Taiaroa Head. It is proposed that the dredging will be carried out at two intensities; incremental capital works dredging (ICW), which is relatively small scale, and major capital works dredging (MCW), which is at a larger scale.

As part of the resource consent application process POL engaged various consultants to carry out a raft of investigations, including comprehensive assessments of the ecology of the lower Otago Harbour (e.g. James *et al*. 2007, Paavo and Probert 2005, Paavo *et al.* 2008, Paavo 2009).

A condition of the resource consent granted to carry out the proposed dredging work specifies that POL must carry out appropriate biological monitoring of seagrass beds to gauge any effects that might be attributable to the works. The surveys were to occur quarterly for a period of one year. Should significant adverse effects be found once dredging commences modifications may be made to the dredging regime to mitigate effects, if necessary.

Seagrass (*Zostera muelleri* subsp. *capricorni*) beds, are considered important due to their significance as vital shelter, feeding, spawning and nursery habitat for a number of epifaunal species and fish (Reed and Hovel 2006, Mills 2006).

POL has engaged Ryder Consulting Ltd (RCL) to carry out quarterly baseline monitoring of seagrass beds within Otago Harbour and at a control site in Papanui Inlet. Port Otago Ltd anticipates commencing capital works dergdging in June of 2015. With this in mind it was decided that the seagrass monitoring should be updated with a further survey before dredging started.

The following report presents the findings of the fifth (autumn) baseline survey carried out by RCL and compares them with the findings presented for the previous four surveys commissioned by POL.

2 Methods

On each occasion four randomly placed transects across the seagrass beds at Harwood were surveyed. Transects were in pairs (nested) according to location (i.e. West Harwood and North Harwood). Harwood was selected as a suitable site as it is a possible impact site where, due to lower tidal current speeds, fine sediments generated from the dredging operation may settle out and affect the habitat (Figure 2.1). Two additional transects were surveyed at Papanui Inlet as a control site (Figure 2.2).

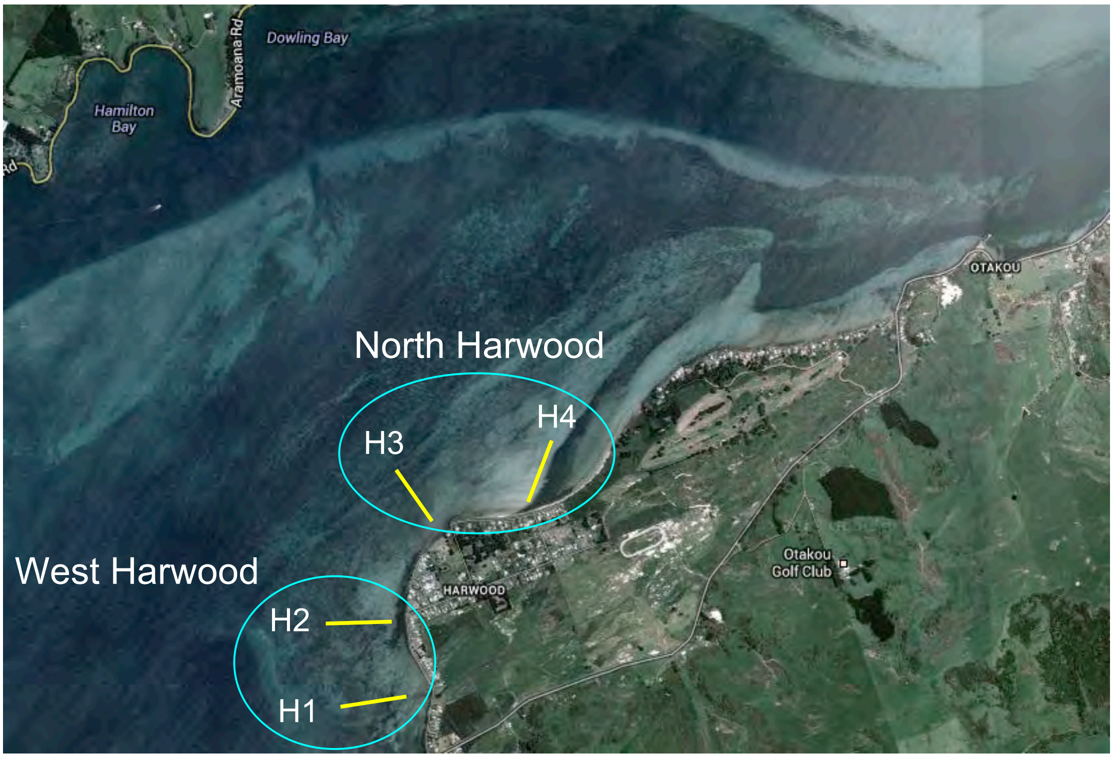

Figure 2.1 *Location of transects across seagrass beds off Harwood, Otago Harbour.*

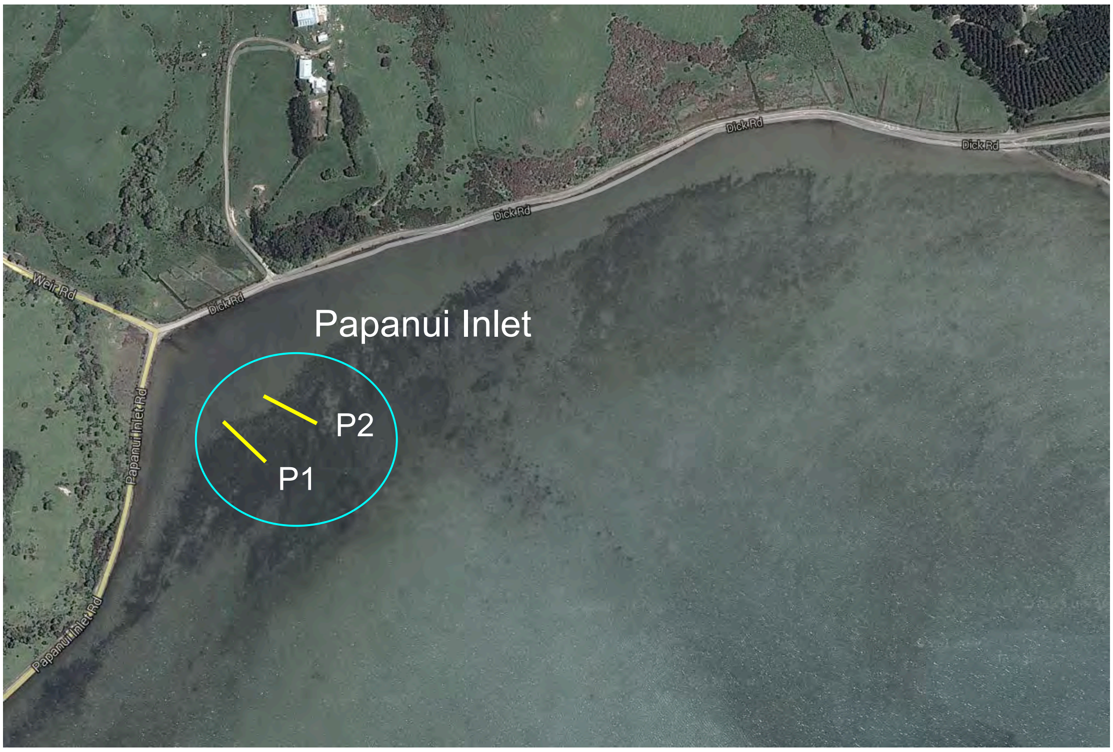

Figure 2.2 *Seagrass bed transect locations at Papanui Inlet.*

Being outside the Harbour, Papanui Inlet is not an ideal control site. However, it is believed to be the best control site available within reasonable travelling distance as it has a similar low-current regime to the Harwood site and will be affected by weather events that may also affect the Harbour at Harwood. It may be best thought of as a "reference" site.

Each transect was 100 m long with a 1m^2 quadrat photographed at 20 m intervals. At each quadrat a randomly located 75 mm diameter core was taken to a depth that ensured collection of *Zostera* plant stems and root systems (i.e. 200 mm). Cores were labelled and returned to the laboratory where they were rinsed using a 1 mm sieve to separate plant material from substrate.

It was assumed that only the parts of *Zostera* plants that appeared above the substrate contained chlorophyll and, as such, individual *Zostera* blades were measured from the point at which they became distinctly green (Figure 2.3). Shoots were counted as a 'set' of blades obviously grouped together, regardless of whether or not they arose on the same stolon (Figure 2.4) and shoots per square metre calculated.

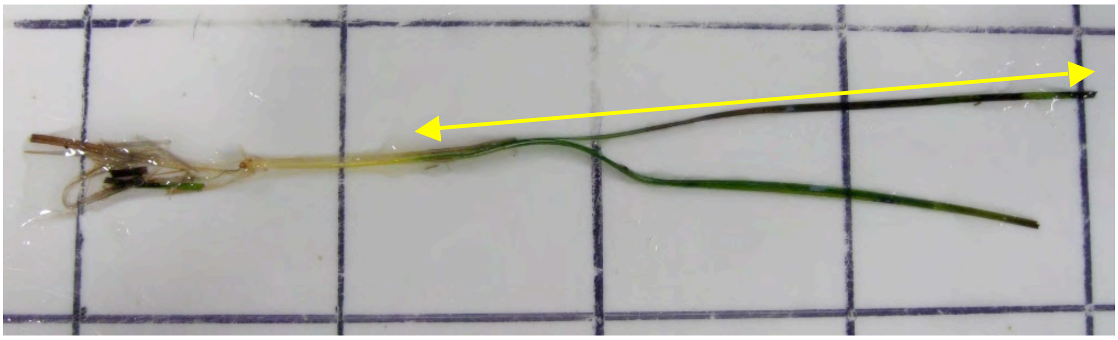

Figure 2.3 Zostera *blade length measured as length of yellow arrow.*

Finally all *Zostera* plant material, including blades, stolons and root system was gently squeezed to remove excess water and weighed to give biomass per core, from which biomass per square metre was calculated.

Percentage cover was calculated for each quadrat using a methods similar to the "Dots on Rocks" technique, in which fifty randomly placed dots are overlain on each image and whether or not seagrass blades are present under the dot is recorded (e.g. Figure 2.5).

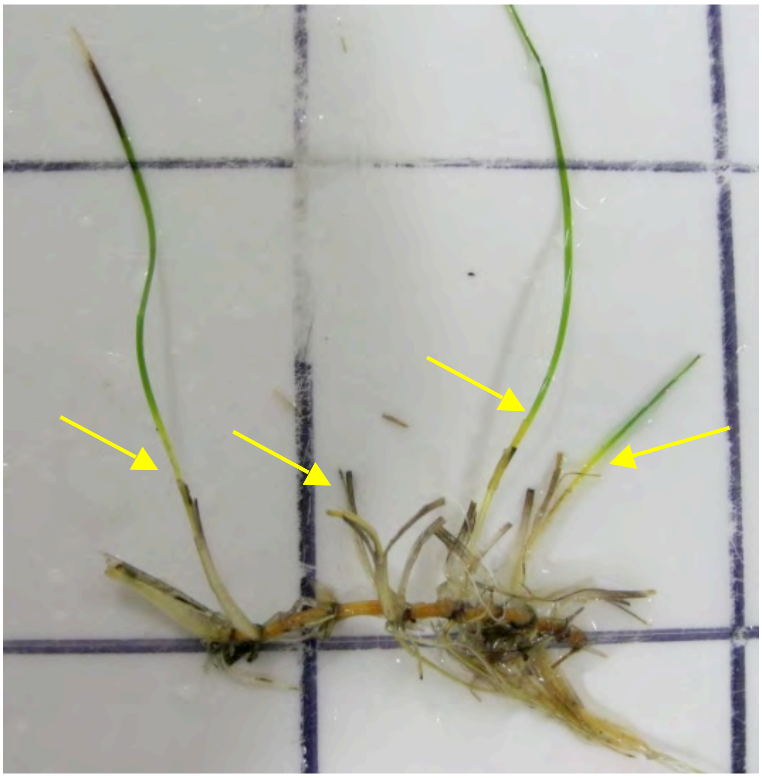

Figure 2.4 *Four* Zostera *'shoots' (arrows) arising from a single stolon.*

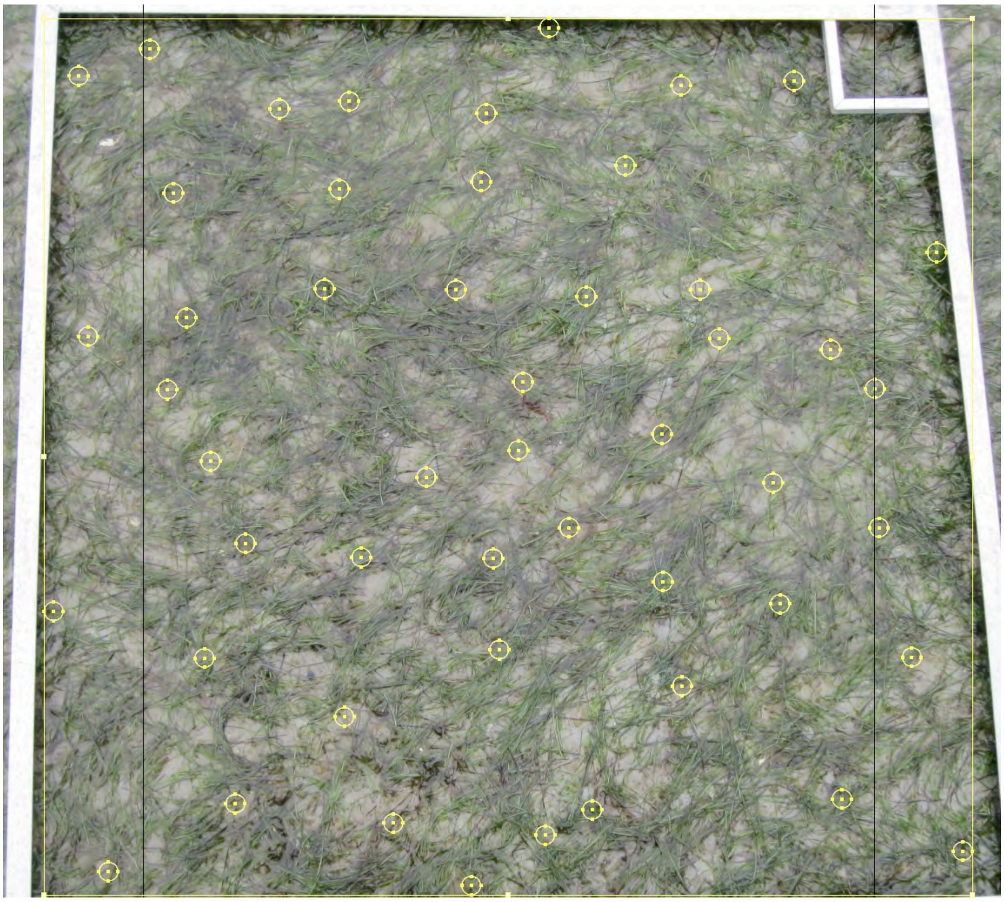

Figure 2.5 *Random points used to determine percentage cover for a quadrat.*

Aerial photographs were taken as near as possible to the time of each survey to allow comparison or areal extend of the seagrass beds and note any obvious changes (Figure 2.6). During discussions with the Technical Group in early 2014 it was suggested that additional seagrass beds be photographed and digitised to allow greater resolution of possible changes to beds within the harbour that may be affected by dredging activities. Following investigation, suitable sites were selected at Waipuna Bay and Poo Corner (Figure 2.6). These sites were selected due to their being within close proximity of any channel dredging operations and because each is a discrete, well established bed with easily defined boundaries that will provide ready comparisons with future surveys.

Figure 2.6 *Locations of seagrass beds subject to aerial photograpy.*

To gauge impacts on substrate, a single core was taken at the seaward end of each transect and photographed for determination of the depth of the redox discontinuity layer (RDL). A subsample was then removed from the top 20 mm of each core and returned to the laboratory for particle size analysis.

3. Results

Seagrass beds were visited at low tide on 23rd April 2015. GPS co-ordinates (NZMG) for all transects and quadrat locations are presented in Table 3.1. Examples of photographs of individual quadrats assessed are presented in Appendix 1.

As in the Autumn of 2014 cover by seagrass was generally moderately high along transects at Harwood but less so at Papanui Inlet, with relatively few quadrats falling on sparsely vegetated areas (Table 3.2, Figure 3.1). As in previous surveys however (Stewart 2013, 2014), there were frequent patches of bare sand scattered throughout the seagrass beds, with three such patches occurring on transects (Figure 3.1).

Table 3.1 *GPS locations of seagrass assessment sites. Co-ordinates are expressed as NZMG.*

Harwood	Transect 1					
	QA	QB	QC	QD	QE	QF
	E2328600	E2328580	E2328559	E2328540	E2328521	E2328502
	N5484829	N5484836	N5484841	N5484845	N5484848	N5484855
	Transect 2					
	QA	QB	QC	QD	QE	QF
	E2328577	E2328558	E2328540	E2328521	E2328502	E2328480
	N5485157	N5485162	N5485167	N5485170	N5485175	N5485179
	Transect 3					
	QA	QB	QC	QD	QE	QF
	E2328630	E2328613	E2328596	E2328580	E2328562	E2328545
	N5485474	N5485483	N5485494	N5485506	N5485517	N5485528
	Transect 4					
	QA	QB	QC	QD	QE	QF
	E2329367	E2329374	E2329382	E2329389	E2329397	E2329406
	N5485828	N5485843	N5485864	N5485881	N5485899	N5485920
Papanui Inlet	Control 1					
	QA	QB	QC	QD	QE	QF
	E2330260	E2330267	E2330278	E2330291	E2330304	E2330315
	N5482688	N5482671	N5482658	N5482640	N5482627	N5482606
	Control 2					
	QA	QB	QC	QD	QE	QF
	E2330278	E2330296	E2330312	E2330330	E2330347	E2330365
	N5482708	N5482700	N5482690	N5482680	N5482673	N5482663

Table 3.2 *Seagrass cover (%) for each quadrat at Papnui Inlet (P),West Harwood (HW), an North Harwood (HN).*

Quadrat	% cover
P1a	82
P1b	4
P1c	0
P1d	0
P1e	96
P1f	68
P2a	14
P2b	62
P2c	92
P2d	32
P2e	54
P2f	96
HW1a	68
HW1b	98
HW1c	76
HW1d	60
HW1e	62
HW1f	92
HW2a	88
HW2b	40
HW2c	98
HW2d	100
HW2e	92
HW2f	96
HN3a	90
HN3b	84
HN3c	8
HN3d	86
HN3e	72
HN3f	6
HN4a	98
HN4b	94
HN4c	100
HN4d	0
HN4e	100
HN4f	100

Figure 3.1 Zostera *bed at West Harwood showing patchy nature of cover.*

Blade length was once again variable among transects and also along the length of each transect (Figure 3.2).

The greatest mean blade length was observed along Transect 4, North Harwood (HW4), the same as it was in the previous two surveys, with next mean longest being along Transect 1 at Papanui (P2). Aaprt from quadrats where there was no cover at all, the shortest overall blade lengths were found along the Papanui Inlet transects (Figure 3.3).

Overall, however, *Zostera* blade length was not significantly different among sites at the autumn 2015 survey ($F_{2,,33} = 0.389$; $p = 0.680$) (Figure 3.2).

When blade length at the different sites is analysed through time (i.e. from season to season) season using 2-way ANOVA, we find that there is a significant difference in blade length with season, but not for site (Figure 3.3, Table 3.3). The interaction between site and season is also significant (Table 3.3). Note that p values of less than 0.05 indicate significant differences.

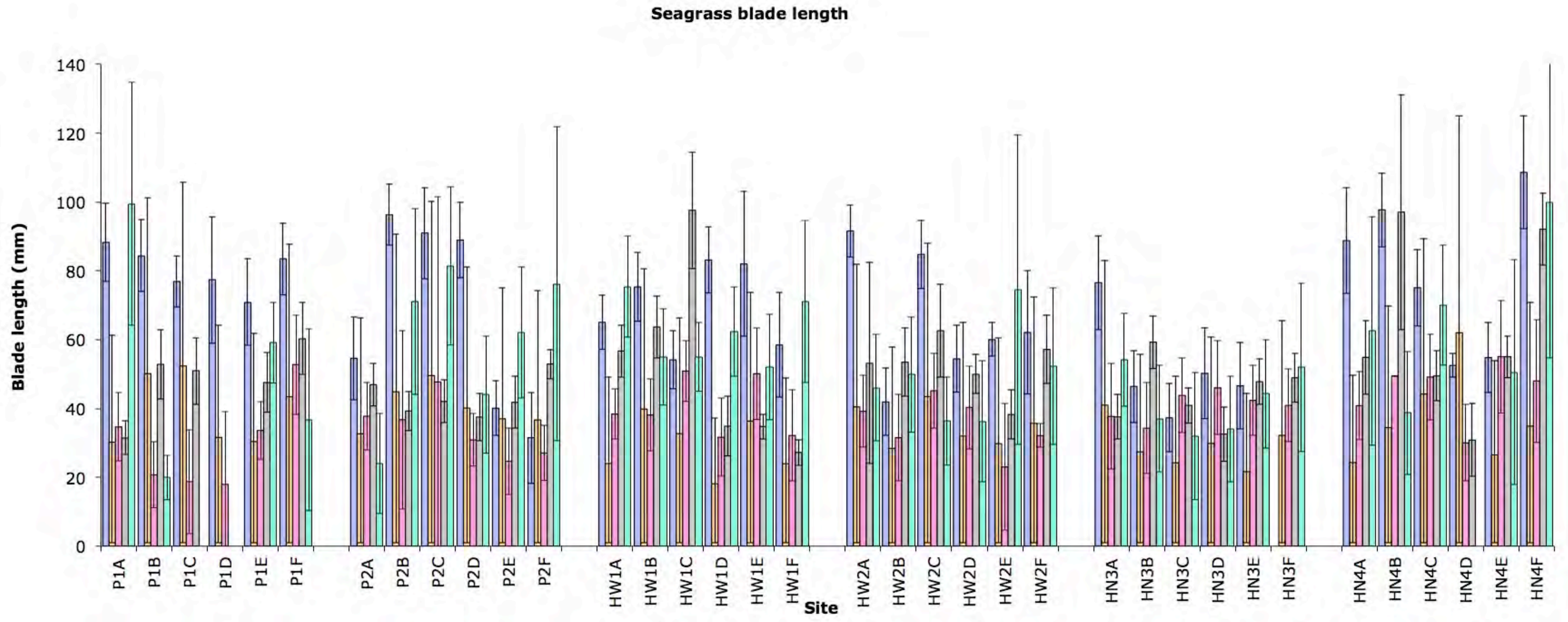

Figure 3.2 Zostera *mean blade lengths in quadrats at Papanui Inlet (P), West Harwood (HW), and North Harwood (HN) in winter 2013 (purple), spring 2013 (orange), summer2013/14 (pink), autumn 2014 (grey) and autumn 2015 (green). Error bars are +/- two standard errors.*

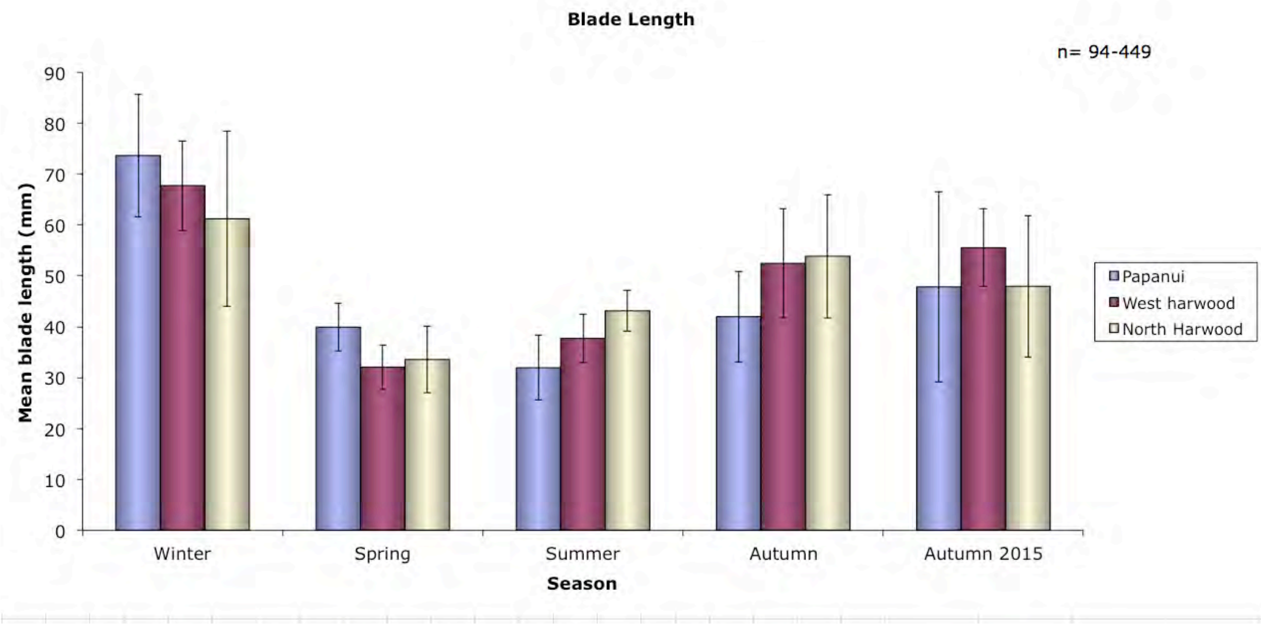

Figure 3.3 *Mean* Zostera *blade length along nested transects at survey sites in Otago Harbour through five surveys. Error bars are +/- two standard errors.*

Table 3.3 *Results for 2-way ANOVA testing effect of season and site with respect to blade length.*

	$F_{1,165}$	p
Season	13.81	<0.001
Site	0.146	0.866
Season/Site Interaction	1.327	<0.001

As in the winter, spring and summer surveys, the density of *Zostera* shoots was reasonably consistent among transects at all three sites (Figure 3.4). Density appears very slightly higher at West Harwood but the difference is not significant. Neither is there a significant difference for density with site (Table 3.4). There is, however, a significant difference for season this year and for season/site interaction (Table 3.4).

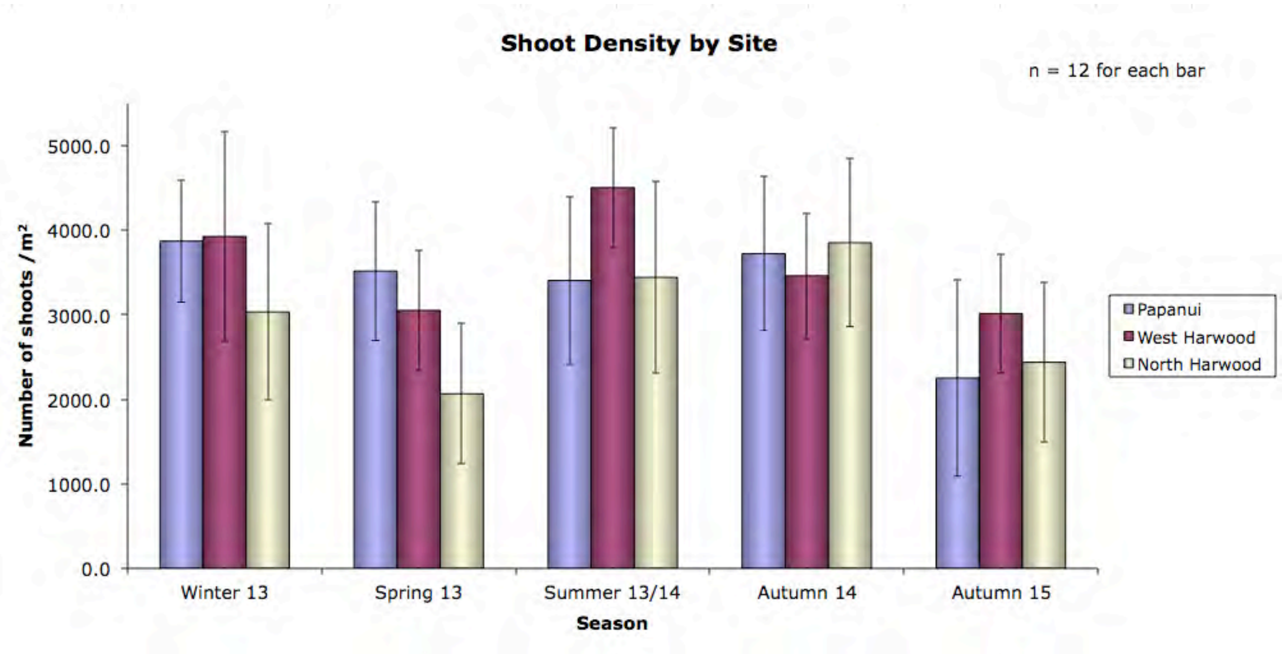

Figure 3.4 *Mean* Zostera *shoot density along nested transects at survey sites in Otago Harbour through one year. Error bars are +/- two standard errors.*

Table 3.4 *Results for 2-way ANOVA testing effect of season and site with respect to shoot density.*

	$F_{1,165}$	p
Season	13.81	0.045
Site	0.146	0.169
Season/Site Interaction	1.327	<0.001

Percentage cover of *Zostera* varies from season to season but less so among sites (Figure 3.5). When percentage cover is analysed using to-way analysis of variance (ANOVA) there is no significant difference in cover among transects from season to season or among sites (Table 3.5). However, the interaction between site and season is significant (Table 3.5).

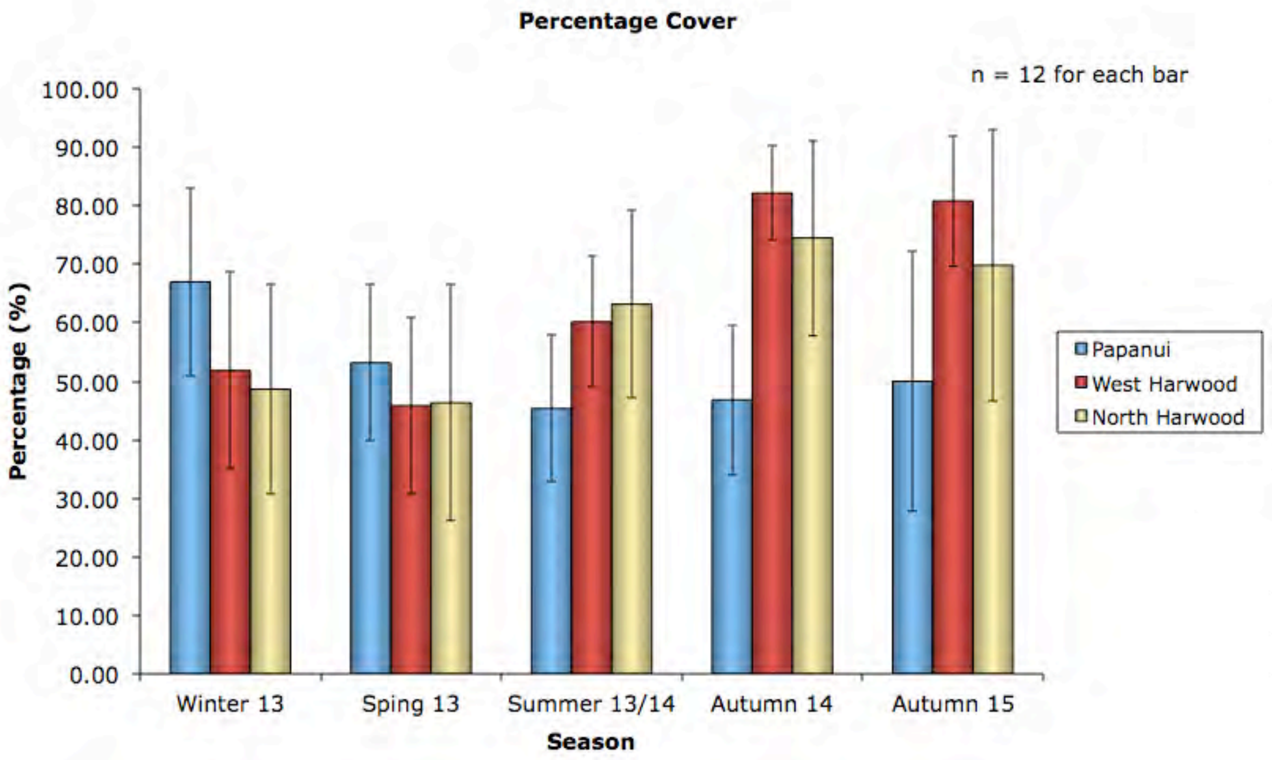

Figure 3.5 *Mean* Zostera *percentage cover along nested transects at survey sites in Otago Harbour through five surveys. Error bars are +/- two standard errors.*

Table 3.5 *Results for 2-way ANOVA testing effect of season and site with respect to percentage cover.*

	$F_{1,165}$	p
Season	1.315	0.343
Site	1.165	0.359
Season/Site Interaction	2.377	<0.001

Biomass in autumn was greatest along West Harwood transects, a result that has been consistent since surveys began (Figure 3.6). Once again the highest biomass is generally closely associated with the highest shoot density (Figure 3.4). Biomass at particular sites appears to change relatively little from season to season at (Figure 3.6). When tested using two-way ANOVA there is a significant difference in biomass among sites and for season/site interaction, but there is no significant difference in biomass from season to season (Table 3.6).

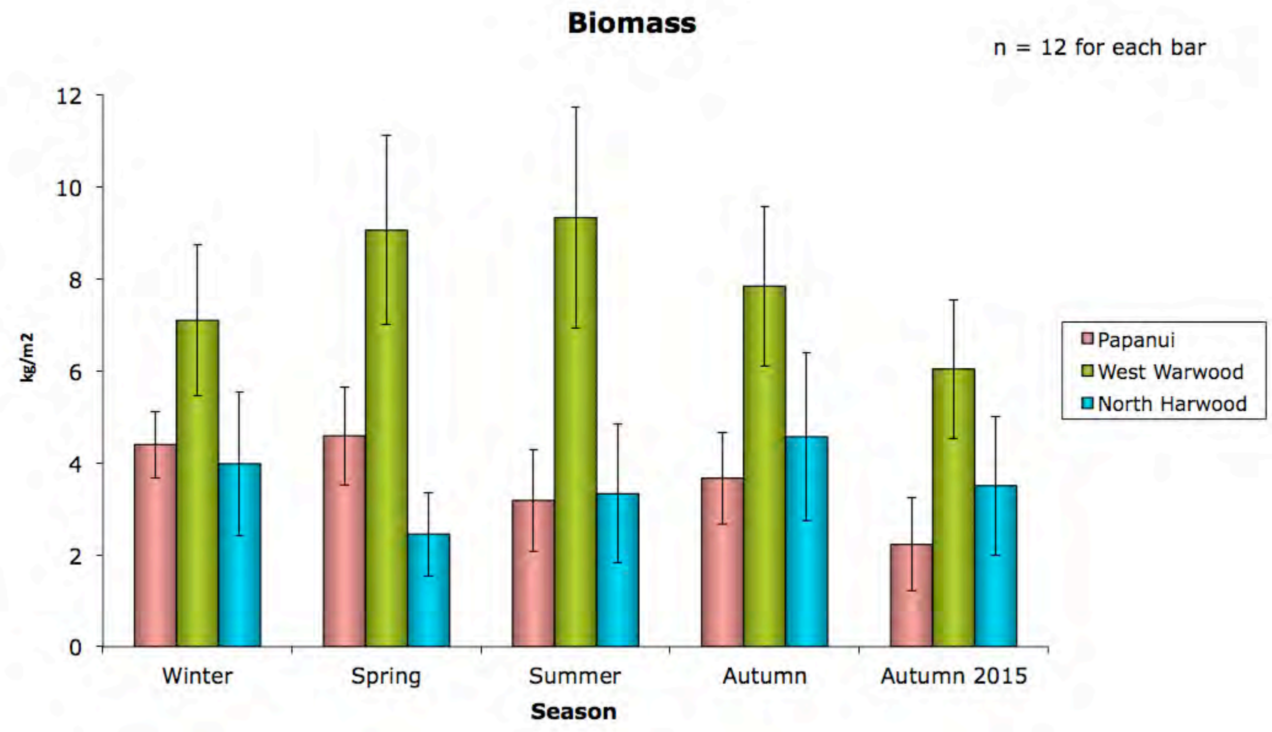

Figure 3.6 *Mean* Zostera *biomass along nested transects at survey sites in Otago Harbour through one year. Error bars are +/- two standard errors.*

Table 3.6 *Results for 2-way ANOVA testing effect of season and site with respect to biomass.*

	$F_{1,165}$	p
Season	1.01	0.458
Site	26.98	<0.001
Season/Site Interaction	1.99	<0.001

Examination of cores taken at each transect revealed that the redox discontinuity layer (RDL) is moderately well defined at both transects in Papanui Inlet, but somewhat less deep than last autumn (Appendix 2). At West Harwood, the RDL is ill defined at both Transects HW1 and HW2 this year (Appendix 2). At North Harwood on Transect HN1 the RDL is moderately well defined, while at Transect HN2 there is an ill-defined anoxic layer extending from 0 mm to ~180 mm depth. Overall, the RDL is reasonably consistent from season to season (Appendix 2).

Substrate composition was reasonably consistent across transects (Table 3.6, Figures 3.7 and 3.8). Only two cores were collected from the seagrass beds during the initial baseline survey. Composition at Harwood Transects is very similar from, but at the papanui Transects this year there is a much higher percentage of grains in the 125-250 μm size range (Figure 3.8).

Table 3.6 *Percentage composition of particle sizes of substrate at each transect through the seasons. P = Papanui; H = Harwood.*

	Percentage Composition					
Site	<63µm	>63µm	>125µm	>250µm	>500µm	>2mm
P1 (summer)	2.71	4.48	23.45	61.03	5.09	3.23
P1 (autumn)	3.48	4.67	13.28	59.91	9.95	8.71
P1 (autumn 15)	1.22	4.21	78.94	5.99	7.87	1.77
P2 (summer)	1.67	5.72	31.88	52.88	5.31	2.54
P2 (autumn)	1.87	3.84	17.49	66.05	3.96	6.79
P2 (autumn 15)	2.18	4.61	80.01	6.41	5.92	0.87
H1 (winter)	0.06	0.06	9.08	78.07	9.20	3.53
H1 (summer)	0.12	0.04	17.43	75.52	2.53	4.37
H1 (autumn)	0.16	0.32	9.37	83.63	2.61	3.92
H1 (autumn 15)	0.15	0.44	62.37	32.58	3.29	1.17
H2 (summer)	0.04	0.31	15.90	76.55	3.72	3.47
H2 (autumn)	0.07	0.06	7.99	87.19	1.72	2.97
H2 (autumn 15)	0.07	0.13	65.99	30.98	1.95	0.87
H3 (winter)	0.48	0.06	43.26	48.75	4.32	3.14
H3 (summer)	0.11	0.14	17.00	72.89	3.44	6.42
H3 (autumn)	0.04	0.20	6.92	88.16	2.50	2.18
H3 (autumn 15)	0.07	0.22	55.97	40.71	2.65	0.37
H4 (summer)	0.66	0.79	25.82	58.24	9.90	4.60
H4 (autumn)	0.25	0.52	11.54	83.72	1.78	2.18
H4 (autumn 15)	0.17	0.81	59.43	34.17	4.77	0.64

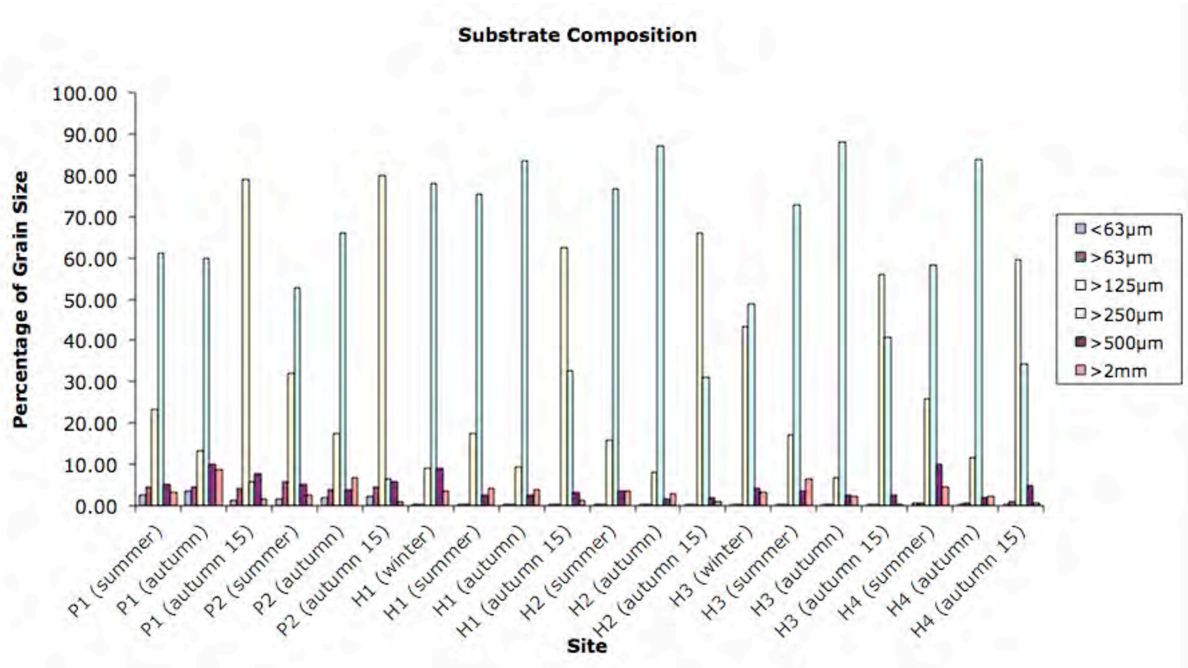

Figure 3.7 *Composition of substrate at each transect through the seasons. P = Papanui; H = Harwood.*

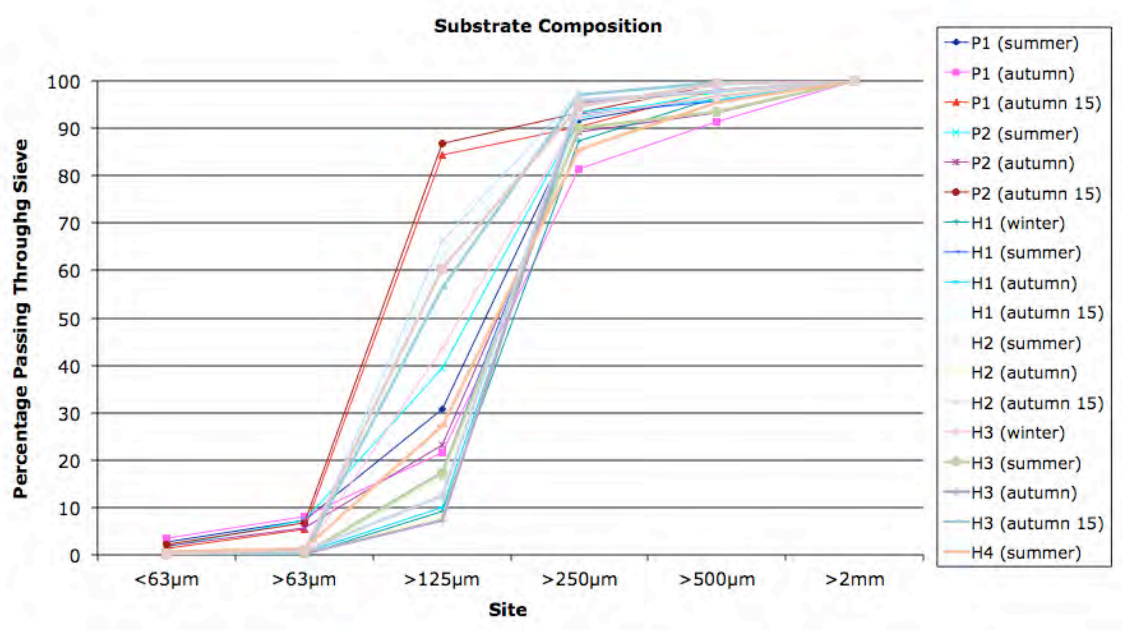

Figure 3.8 *Composition of substrate at each transect expressed as percentage of grains passing through specific mesh sizes.*

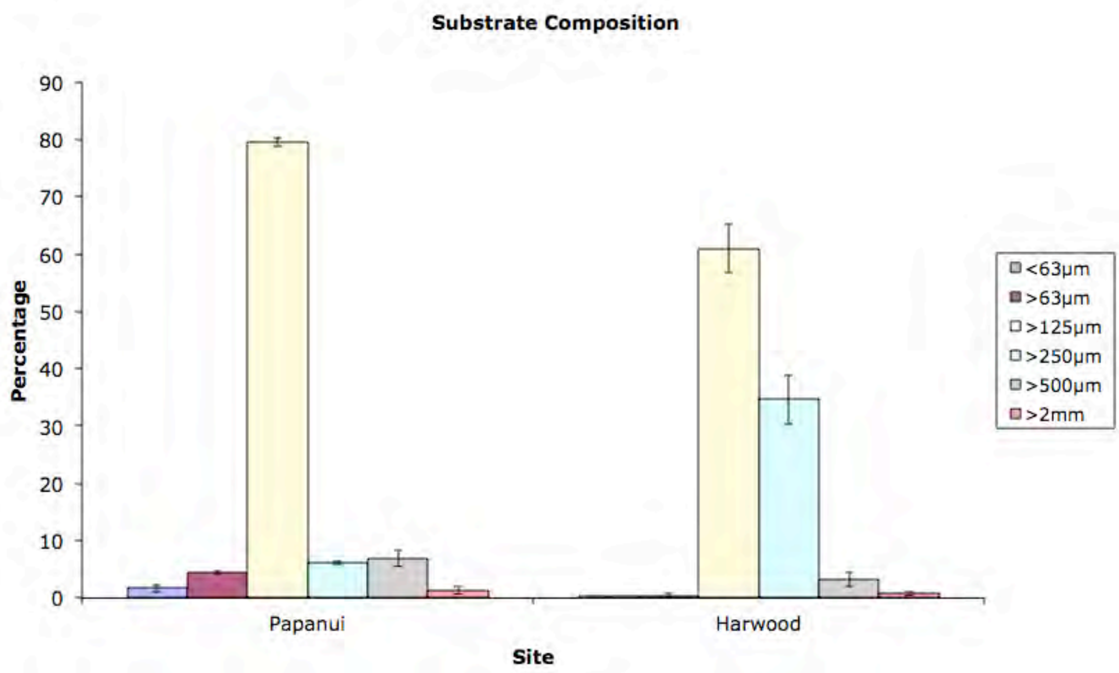

Figure 3.9 *Mean composition of substrate at each site. Error bars are +/- standard error.*

Substrate composition is also quite consistent among treatment and control sites (Figure 3.9), with there being no significant difference when results are examined using one-way

analysis of variance ($F_{1,34} = 0.005$; $p = 0.943$).

It must be appreciated that sediment characteristics observed during these surveys likely bear no relationship to season, but rather are the result of physical disturbances within the harbour (i.e. wind/wave events that disturb and redistribute sediment and heavy rainfall events that result in flooding and the influx of significant amounts of sediment).

Areas that were originally aerial photographed on 28 July 2013 were re-photographed on 3 February 2014 and again on 16 May 2014. Actual spatial area covered by seagrass varied very little from winter to summer for both Papanui Inlet and Harwood. However, there appears to have been a reduction in overall seagrass density from summer to autumn at Papanui while the converse is true for Harwood (Figures 3.10 and 3.11). This is not borne out by actual measurement of shoot density, but is reflected by significant differences in percentage cover and blade length with season and site.

Seagrass beds at Waipuna Bay and Poo Corner were photographed at the same time as Papanui Inlet and North Harwood beds (Figures 3.12 and 3.13). All original photographs are of high resolution and are able to be inserted into GIS software to allow measurement of changes in areal extent of the seagrass beds.

Unfortunately weather conditions did not permit photography of the seagrass beds in autumn 2015.

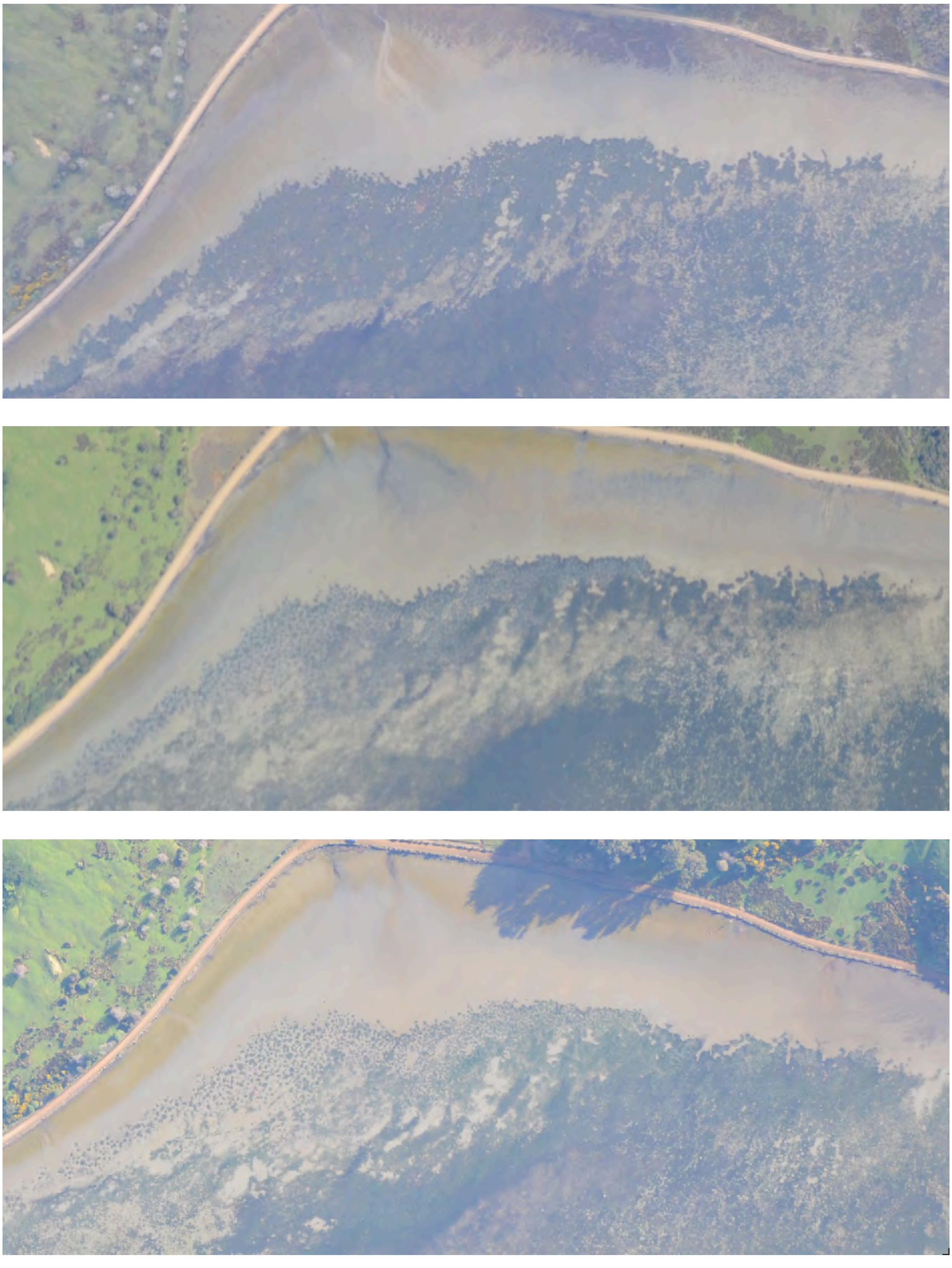

Figure 3.10 *Aerial photographs of seagrass study area, Papanui Inlet. Top = winter 2013, middle = summer 2013-2014, bottom = autumn 2014.*

Figure 3.11 *Aerial photographs of seagrass study area, Harwood. Top = winter 2013, middle = summer 2013-2014, bottom = autumn 2014.*

Figure 3.12 *Aerial photograph of additional seagrass area, Waipuna Bay. Autumn 2014.*

Figure 3.13 *Aerial photograph of additional seagrass area, Poo Corner. Autumn 2014.*

3. Discussion

There has been no significant increase in the mean length of *Zostera* blades since the previous autumn survey. Ismail (2001) found that cover by *Zostera* can change markedly with season due largely to growth parameters (biomass, leaf length, leaf area) being typically higher in summer and lower in winter. Further, Ismail (2001)

found that mean leaf growth rate was much higher during the summer season. This latest survey was conducted at the middle of autumn and it was expected that blade length would have increased through the warmer months. *Zostera* is a perennial plant and the change in blade length is largely the result of die-back during late winter and spring and regrowth in summer/autumn.

For other parameters measured there has been a significant change for shoot density with season, but there have been no significant changes to percentage cover with season or for site. The biomass of plants at West Harwood is significantly greater than biomass at other sites, irrespective of season. Both blade length and percentage cover show significant differences for site/season interaction.

All other parameters, including substrate composition and thickness of the RDL, show no significant changes.

Bearing in mind there had been no major capital works dredging or major incremental dredging carried out prior to this latest survey, any changes must be put down to natural variability. Such variability needs to be considered when analysing results obtained after dredging does commence.

The survey will be repeated after capital works dredging has commenced.

4. References

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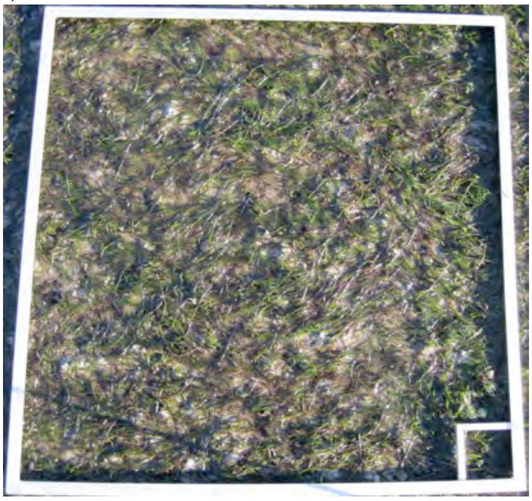
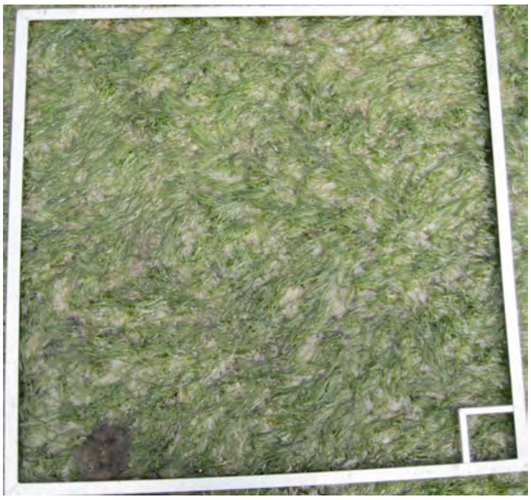
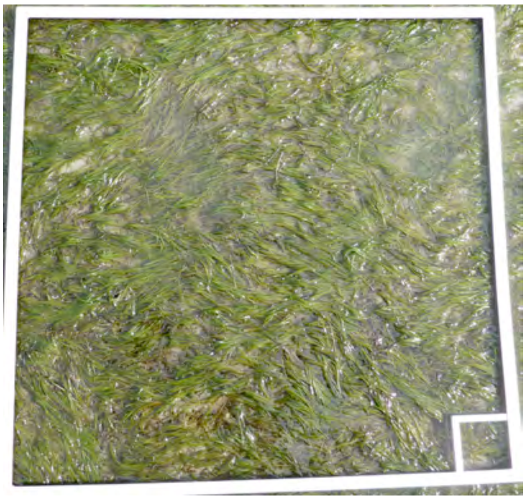
Appendix 1 – Example Seagrass Quadrats

West Harwood: Transect H1 (Quadrats are 1 m x 1 m. Small square is 10 cm x 10 cm)


Quadrat A, July 2013

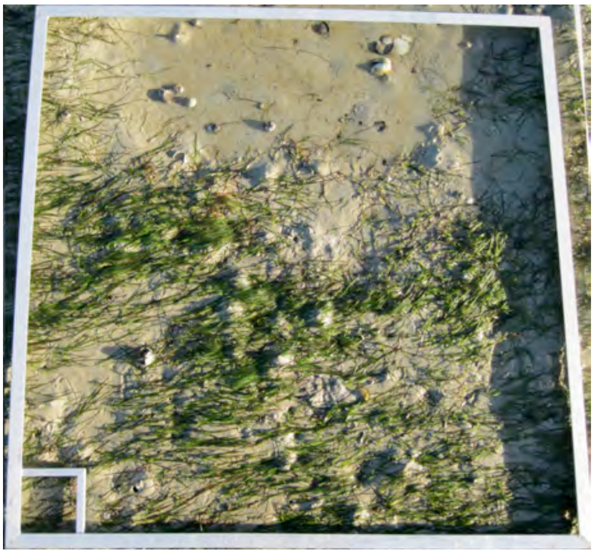

Quadrat A, October 2013

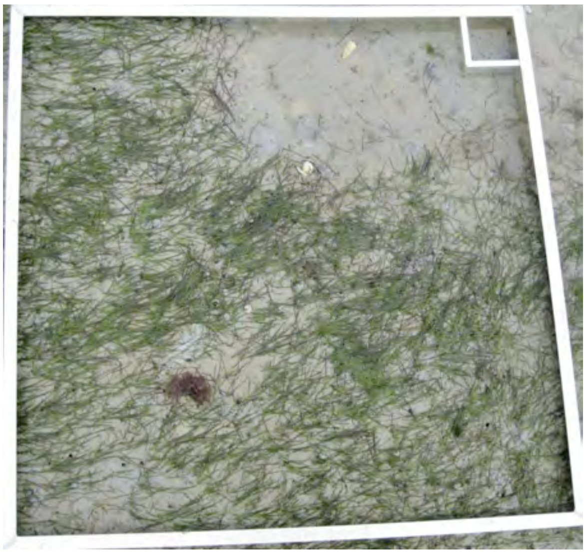

Quadrat A, December 2013


Quadrat A, March 2014


Quadrat A, April 2015

North Harwood: Transect H3


Quadrat D, July 2013

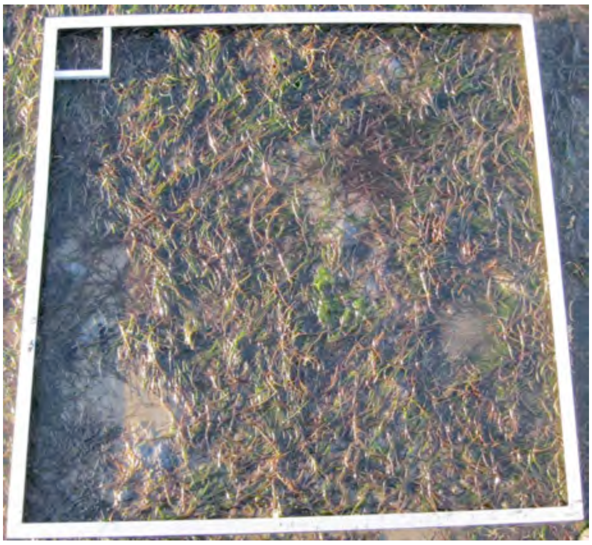

Quadrat D, October 2013

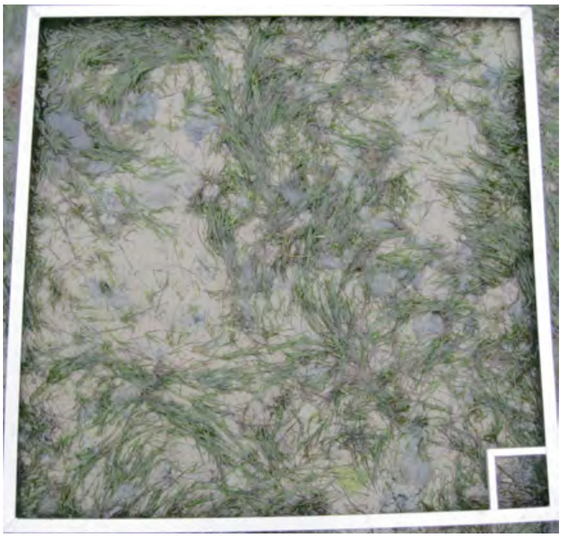

Quadrat D, December 2013

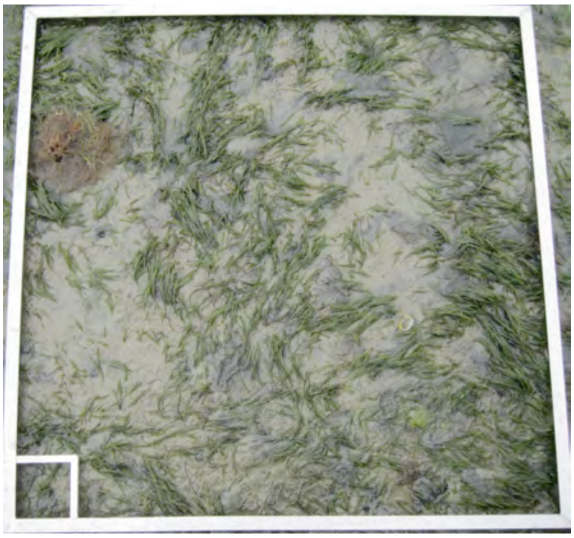

Quadrat D, March 2014


Quadrat D, April 2015

Papanui Inlet: Transect P1


Quadrat A, July 2013


Quadrat A, October 2013


Quadrat A, December 2013


Quadrat A, March 2014


Quadrat A, April 2015

Appendix 2 – Cores


P1 (summer)


P1 (autumn 2014)


P1 (autumn 2015)


P2 (summer)


P2 (autumn 2014)


P2 (autumn 2015)


HW1 (winter)


HW1 (summer)


HW1 (autumn 2014)


HW1 (autumn 2015)


HW2 (summer)


HW2 (autumn 2014)


HW2 (autumn 2015)


HN1 (winter)


HN1 (summer)


HN1(autumn 2014)


HN1 (autumn 2015)


HN2 (summer)


HN2 (autumn 2014)


HN2 (autumn 2015)