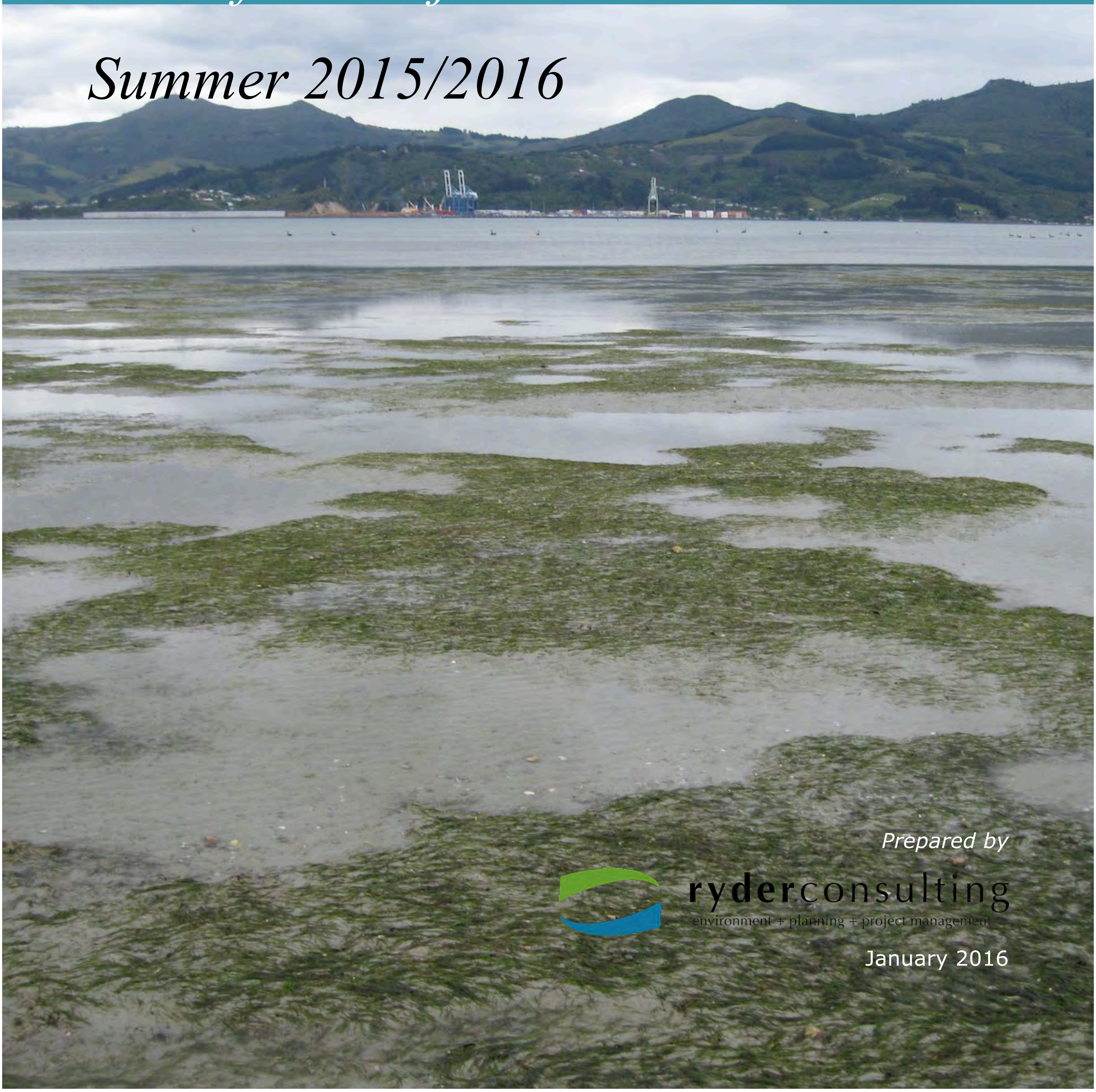
Repeat Monitoring of Seagrass Beds for Project Next Generation

Summer 2015/2016



Prepared by

ryderconsulting

environment + planning + project management

January 2016

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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, autumn 2014, autumn 2015, and summer 2015/2016 by Ryder Consulting Ltd. This report presents the findings of the seventh (summer 2015/2016) survey, which was conducted after the commencement of capital works dredging.

There has been a significant decrease in percentage cover of *Zostera* since autumn 2015 at all three monitored sites (Papanui Inlet – control; West Harwood and North Harwood – potential impact). This is not unexpected, as growth is known to vary with season.

For other parameters measured there have been significant changes to blade length, shoot density and biomass with season. However, blade length has not varied significantly with site.

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

The observation that changes were common to both impact and control sites and a lack of very fine sediment at the impact sites suggests that changes are likely due to natural variability, mainly with the seasons. Such variability needs to be considered when analysing results obtained after dredging does commence.

The survey will be repeated in autumn 2016.

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 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 commenced capital works dredging in March of 2015. With this in mind the seagrass monitoring was updated with a further survey being carried out in autumn 2015 and this latest survey carried out in the summer of 2015/2016.

The following report presents the findings of the seventh survey, and 2nd summer survey carried out by RCL and compares them with the findings presented for the previous six 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.*

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.

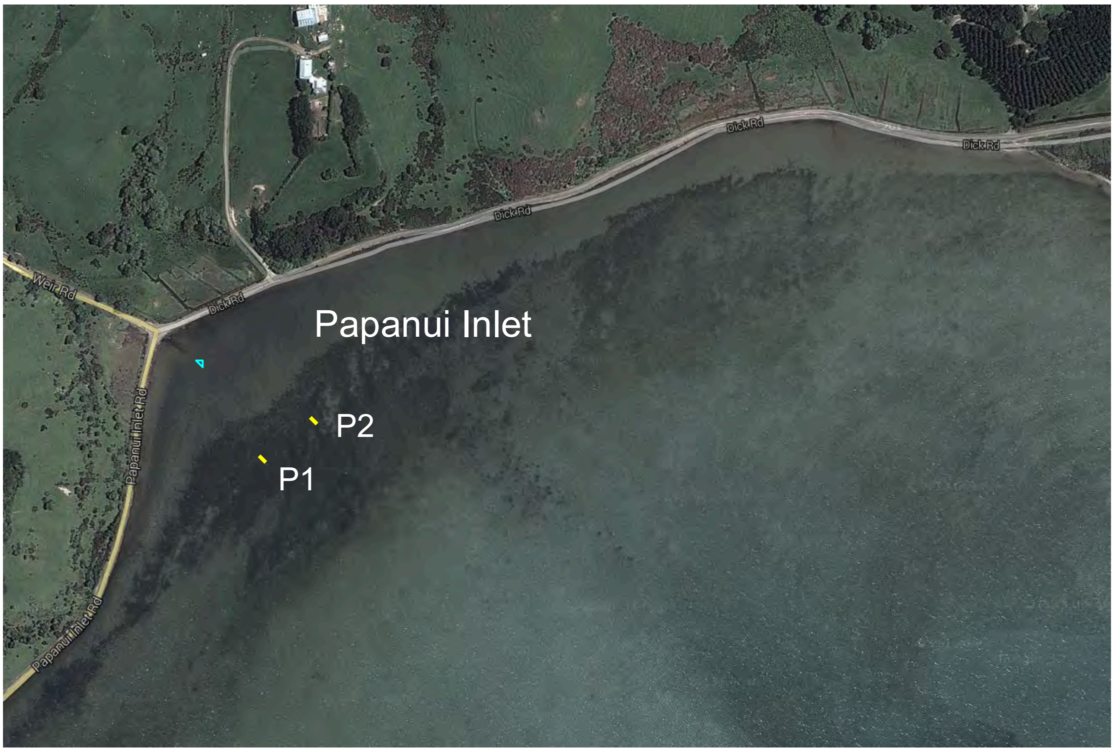


Figure 2.2 *Seagrass bed transect locations at Papanui Inlet.*

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.

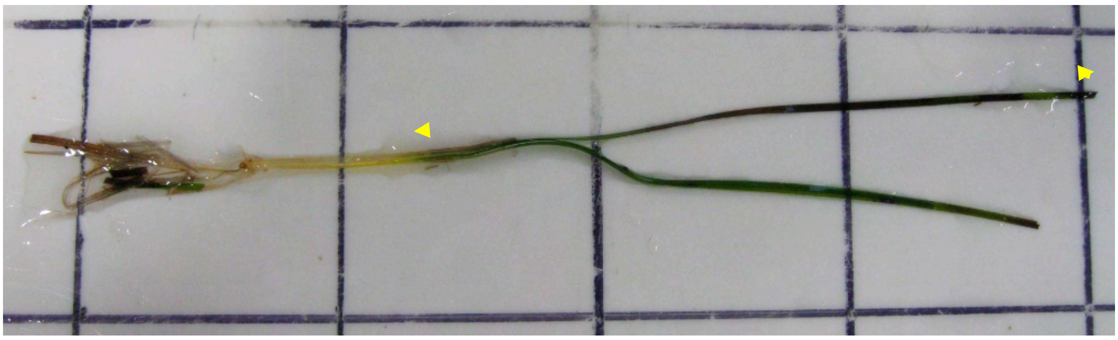


Figure 2.3 Zostera *blade length measured as length of yellow arrow.*

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).

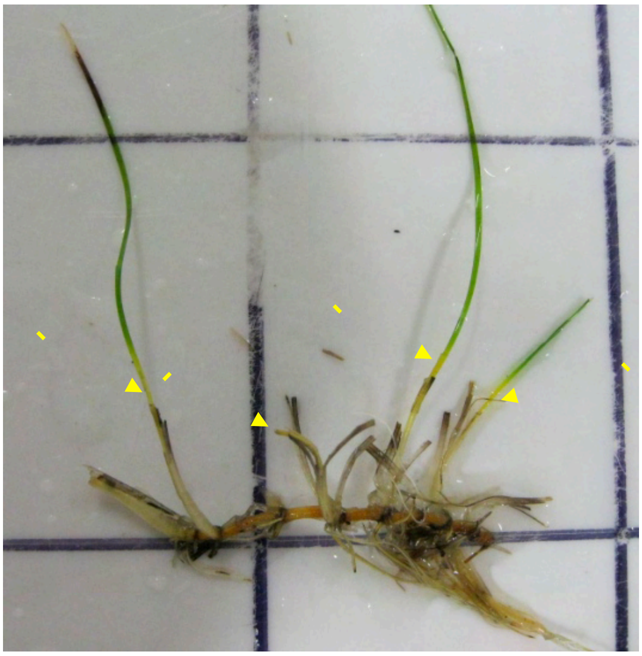


Figure 2.4 *Four* Zostera *'shoots' (arrows) arising from a single stolon.*

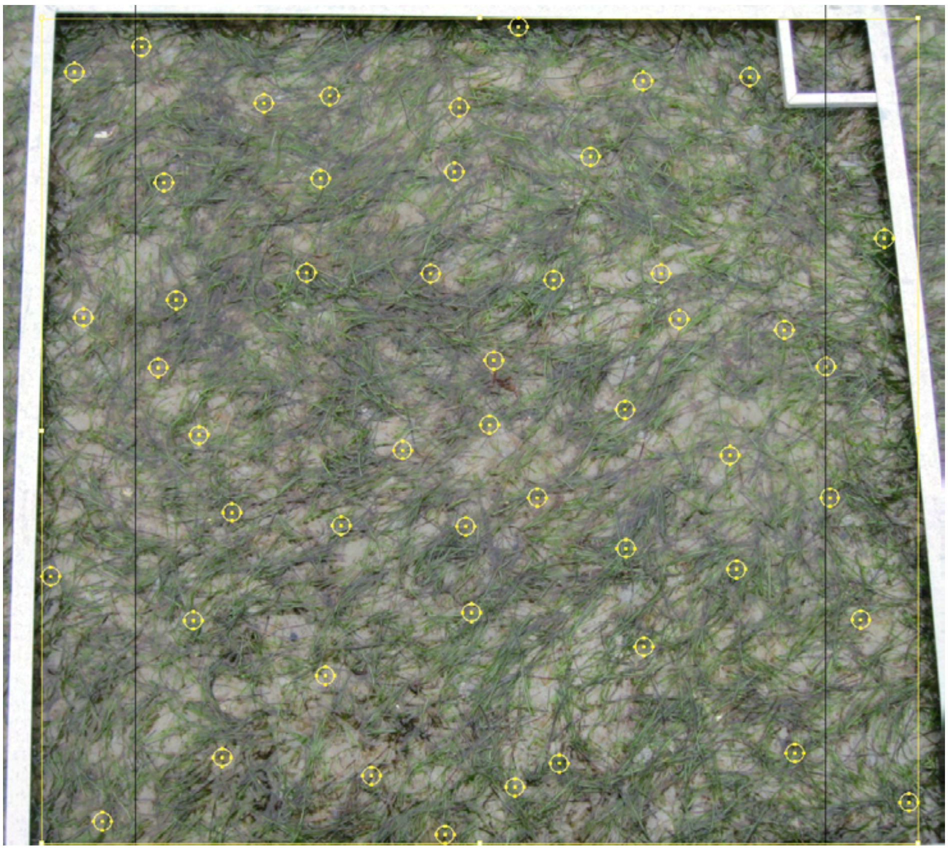


Figure 2.5 *Random points used to determine percentage cover for a quadrat.*

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 photography.*

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 15th December 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.

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

Site						
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

As in the autumn and spring of 2015 cover by seagrass was generally moderately high along transects at West Harwood and less so at Papanui Inlet, with relatively few quadrats falling on sparsely vegetated areas (Table 3.2, Figure 3.1). Cover at North Harwood was higher than in the spring 2015 survey, but lower than it was at the previous summer survey in 2013/2014, despite both surveys being carried out in the first half of December (Figure 3.1). As observed previously (Stewart 2013, 2014, 2015), there were frequent patches of bare sand scattered throughout the seagrass beds, but with just four such patches (i.e. percentage cover <5%) occurring on transects this round (Table 3.2).

Percentage cover of *Zostera* varies from season to season and among sites (Figure 3.1). When percentage cover is analysed using two-way analysis of variance (ANOVA) there is a significant difference in cover among transects from season to season and among sites (Table 3.5). The interaction between site and season is, however, not significant (Table 3.2).

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

Site	% cover
P1A	1
P1B	28
P1C	2
P1D	3
P1E	96
P1F	82
P2A	6
P2B	66
P2P	100
P2D	17
P2E	50
P2F	72
HW1A	56
HW1B	96
HW1C	11
HW1D	92
HW1E	74
HW1F	95
HW2A	46
HW2B	27
HW2C	68
HW2D	98
HW2E	90
HW2F	90
HN3A	78
HN3B	92
HN3C	8
HN3D	60
HN3E	90
HN3F	16
HN4A	99
HN4B	92
HN4C	8
HN4D	0
HN4E	39
HN4F	73

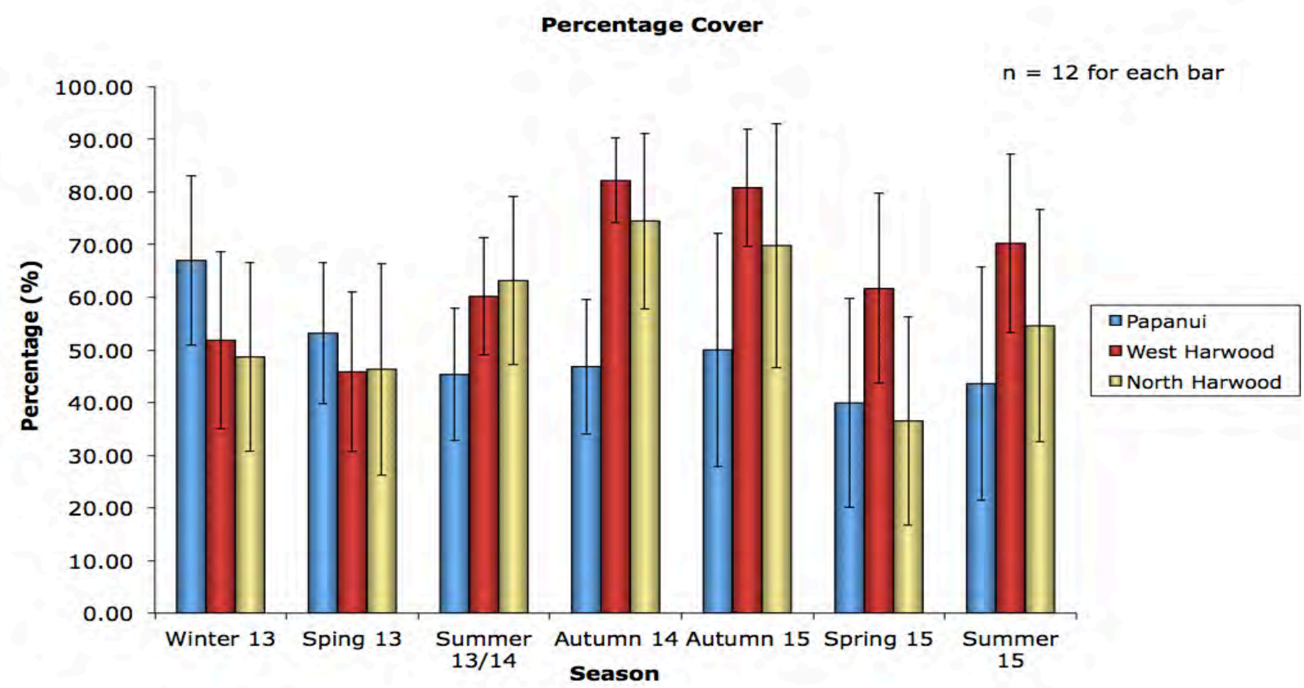


Figure 3.1 *Mean* Zostera *percentage cover along nested transects at survey sites in Otago Harbour through seven surveys. Error bars are +/- two standard errors.*

Figure 3.2 Zostera *bed at North Harwood showing patchy nature of cover.*

Table 3.2 *Results for 2-way ANOVA testing effect of season and site with respect to percentage cover.*

	$F_{1,251}$	p
Season	2.760	0.013
Site	5.502	0.005
Season/Site Interaction	1.677	0.073

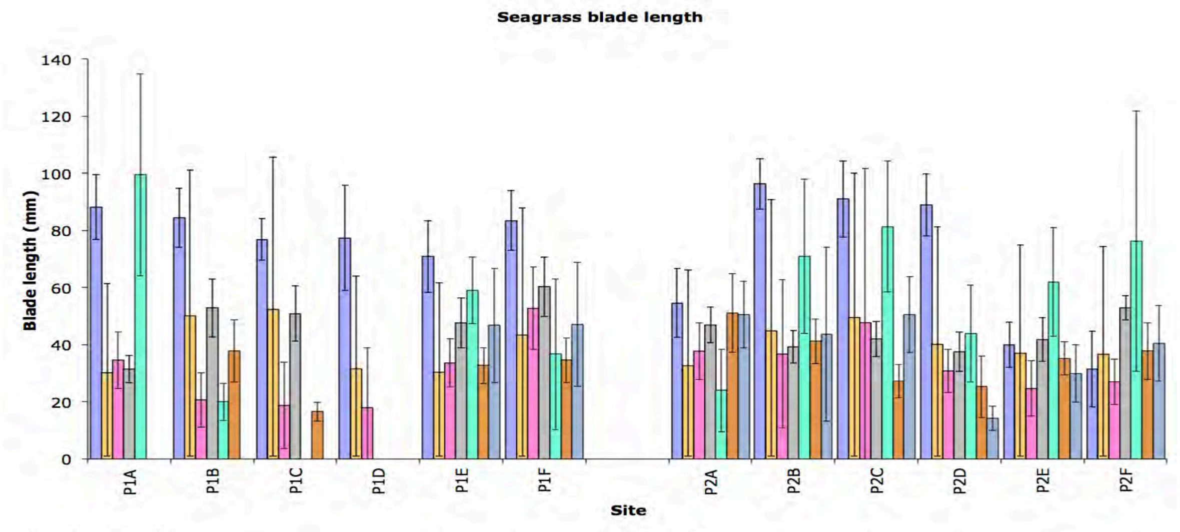
Blade length was once again variable among transects and also along the length of each transect (Figure 3.3).

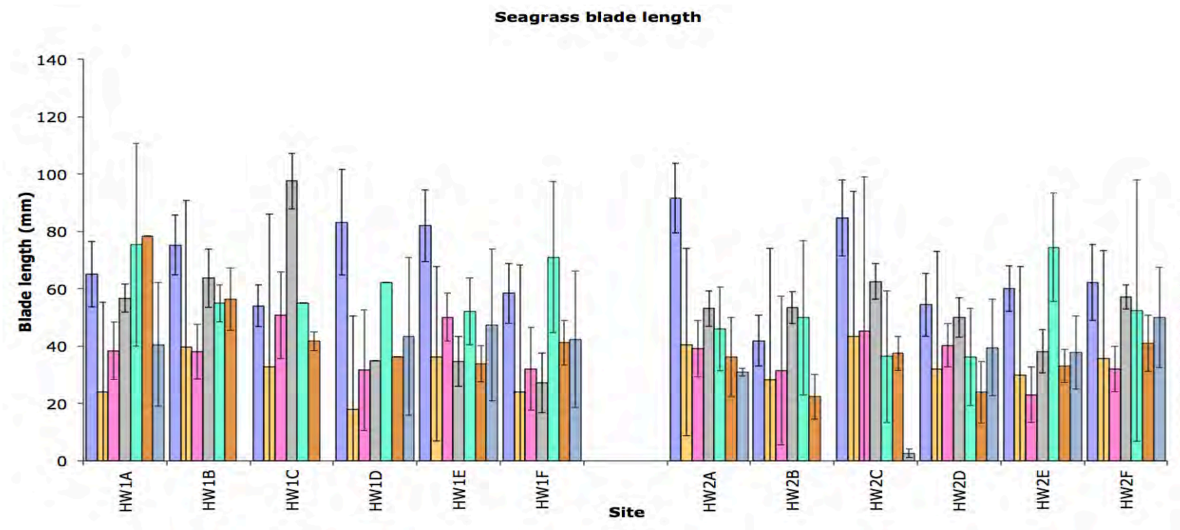
The greatest mean blade length was observed along Transect 1, West Harwood (HW1). This is the same as the spring 2015 survey, but differs from the previous three surveys when longest blade length occurred at HN4. Next mean longest mean blade length was along West Harwood Transect 2 (HW2). Apart from quadrats where there was no cover at all, the shortest overall blade lengths were found along Papanui Inlet Transect 1 (Figure 3.3).

Overall, however, *Zostera* blade length was not significantly different among sites at the summer 2015/2016 survey ($F_{2,,32}$ = 0.211; p = 0.811) (Figure 3.4).

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 not significant (Table 3.4). Note that p values of less than 0.05

indicate significant differences.





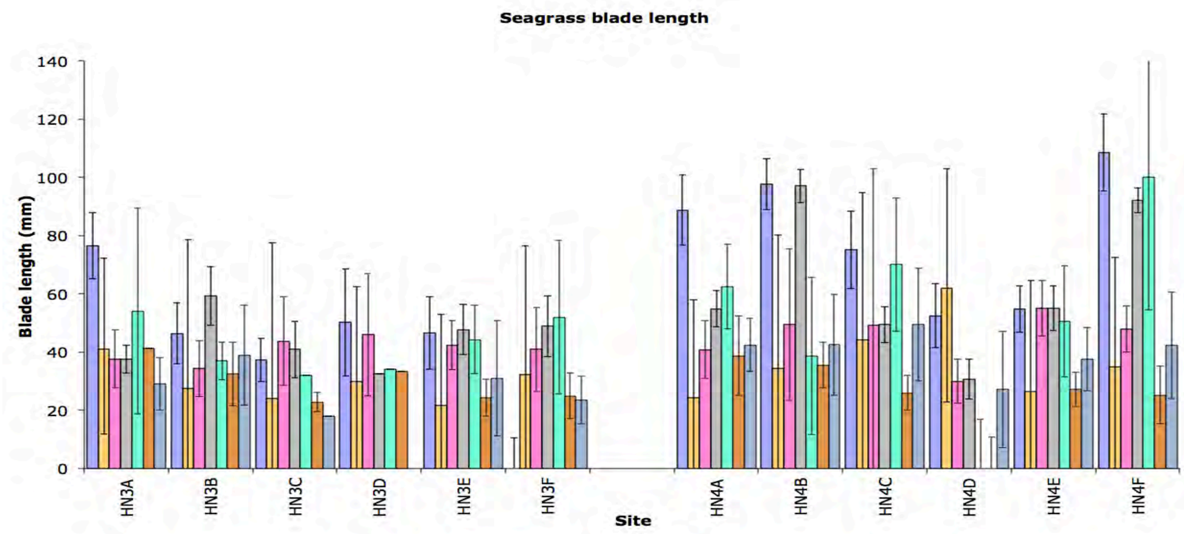


Figure 3.3 Zostera *mean blade lengths in quadrats at (top) Papanui Inlet (P), (middle) West Harwood (HW), and (bottom) North Harwood (HN) in winter 2013 (purple), spring 2013 (orange), summer2013/14 (pink), autumn 2014 (grey), autumn 2015*

(green), spring 2015 (orange) and summer 2015/2016 (blue). Error bars are +/- two standard errors.

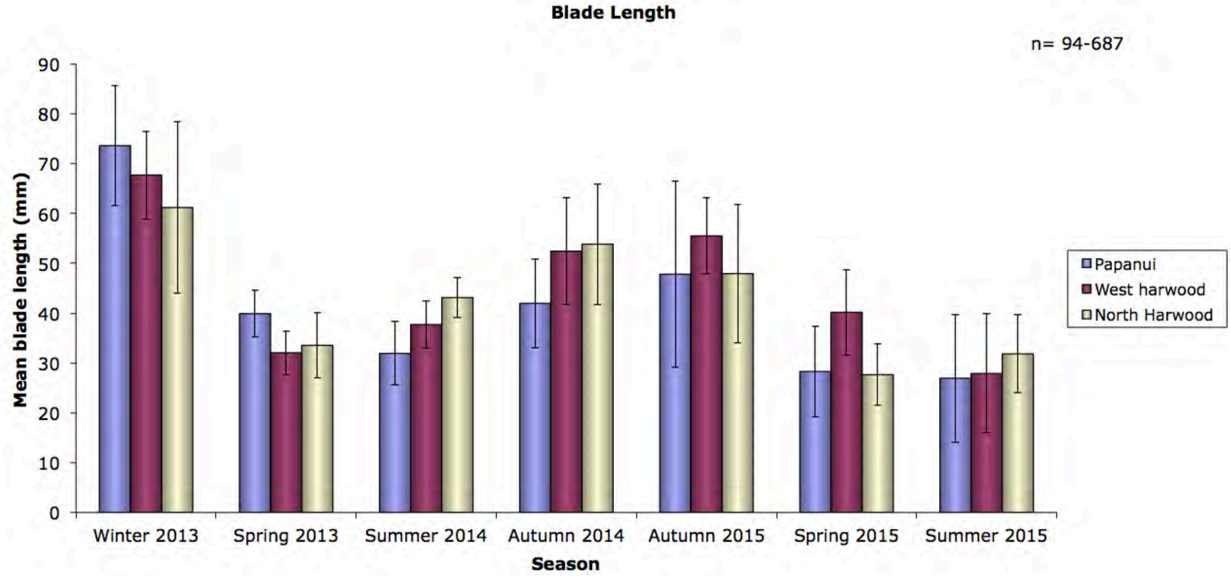


Figure 3.4 *Mean* Zostera *blade length along nested transects at survey sites in Otago Harbour through seven surveys. Error bars are +/- two standard errors.*

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

	$F_{1,251}$	p
Season	27.269	<0.001
Site	0.793	0.477
Season/Site Interaction	1.191	0.290

Unlike in the spring survey, the density of *Zostera* shoots showed no significant differences this round for site or season/site interaction (Figure 3.5; Table 3.4). Density appears highest at North Harwood and lowest at Papanui Inlet. There is, however, a significant difference for density with season (Table 3.4).

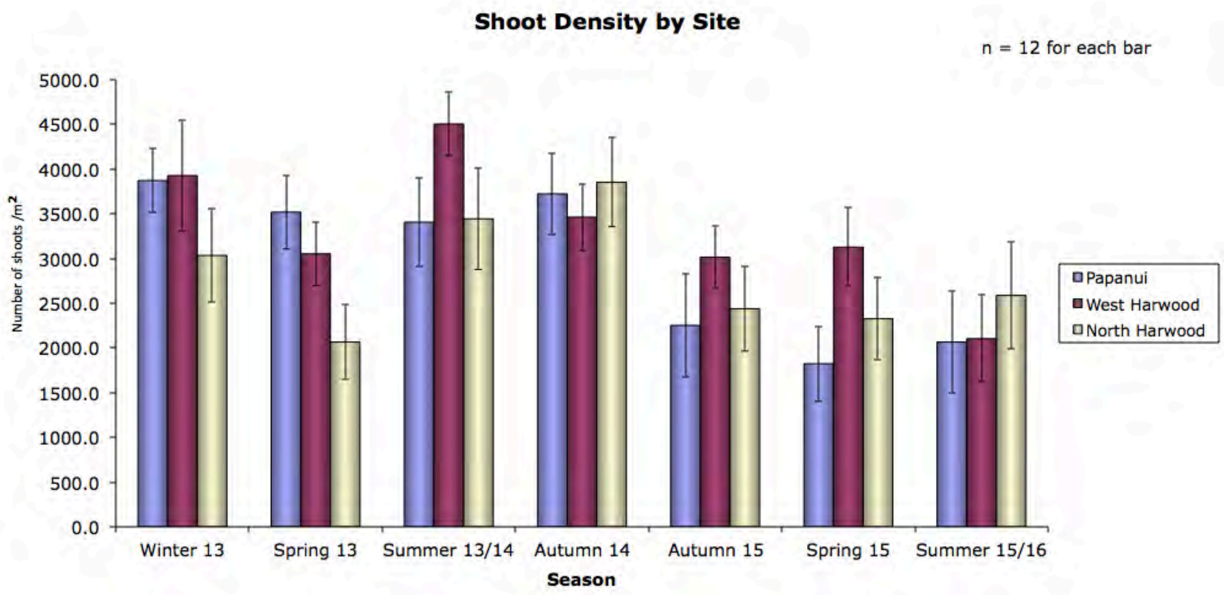


Figure 3.5 *Mean* Zostera *shoot density along nested transects at survey sites in Otago Harbour through seven seasons. Error bars are +/- two standard errors.*

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

	$F_{1,251}$	p
Season	5.624	<0.001
Site	2.018	0.135
Season/Site Interaction	1.072	0.368

Biomass in spring 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, although North Harwood has the highest biomass this round rather than West Harwood (Figure 3.5). Biomass at particular sites appears to change relatively little from season to season at (Figure 3.6). However, when tested using two-way ANOVA there is a significant difference in biomass among seasons and among sites (Table 3.5). For season/site interaction there is also a significant difference in biomass (Table 3.5). This result differs from previous surveys when no significant season/site interaction was observed.

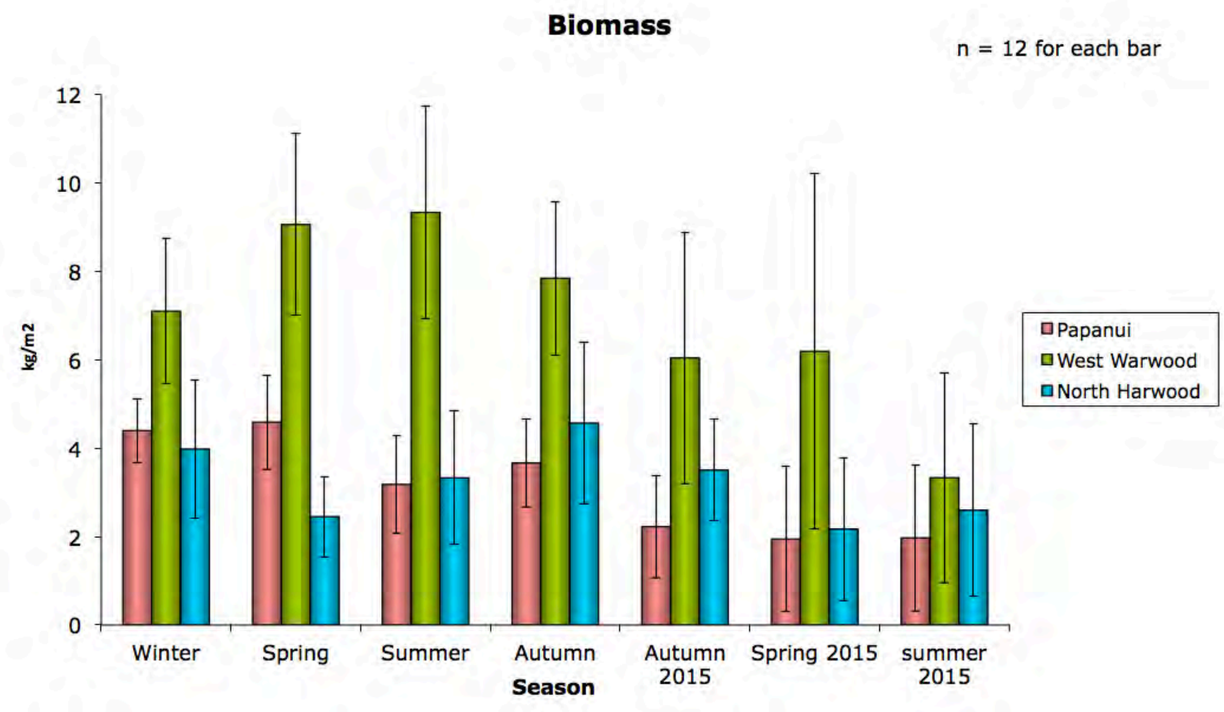


Figure 3.6 *Mean* Zostera *biomass along nested transects at survey sites in Otago Harbour through one year. Error bars are +/- two standard errors.*

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

	$F_{1,251}$	p
Season	6.147	<0.001
Site	55.541	<0.001
Season/Site Interaction	2.081	0.0188

Examination of cores taken at each transect revealed that the redox discontinuity layer (RDL) is moderately well defined at both transects in Papanui Inlet, and of a similar depth to that observed in autumn 2015 and spring 2015 (Appendix 2). At West Harwood, the RDL is ill defined at Transect HW1 and slightly more defined at HW2, as it was in spring (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 ~50 mm to >200 mm depth. Overall, the RDL is reasonably consistent from season to season (Appendix 2).

Substrate composition was also 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 relatively similar. However, as in autumn this year, at the Papanui transects there is a higher percentage of grains in the <63 - >63 µm size range (Figure 3.9).

	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
P1 (spring 15)	4.67	4.33	23.04	59.41	7.31	1.25
P1 (summer 15)	2.47	2.34	13.34	76.00	3.50	2.35
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 (spring 15)	2.18	4.61	80.01	6.41	5.92	0.87
P2 (autumn 15)	2.47	3.22	33.07	56.82	4.03	0.40
P2 (summer15)	4.91	3.30	17.36	71.74	1.94	0.75
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)	0.03	0.06	4.27	88.90	4.45	2.28
H1 (spring 15)	0.15	0.44	62.37	32.58	3.29	1.17
H1 (summer 15)	0.79	0.55	25.43	64.77	6.32	2.15
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
H2 (spring 15)	0.04	0.05	3.09	91.80	2.49	2.53
H2 (summer 15)	0.06	0.06	9.46	86.19	2.06	2.16
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
H3 (spring 15)	0.03	0.04	3.54	91.44	3.22	1.73
H3 (summer 15)	0.05	0.05	6.34	89.89	2.64	1.03
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
H4 (spring 15)	0.94	0.82	4.37	91.20	1.85	0.82
H4 (summer 15)	0.79	0.72	7.95	88.43	1.75	0.37

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

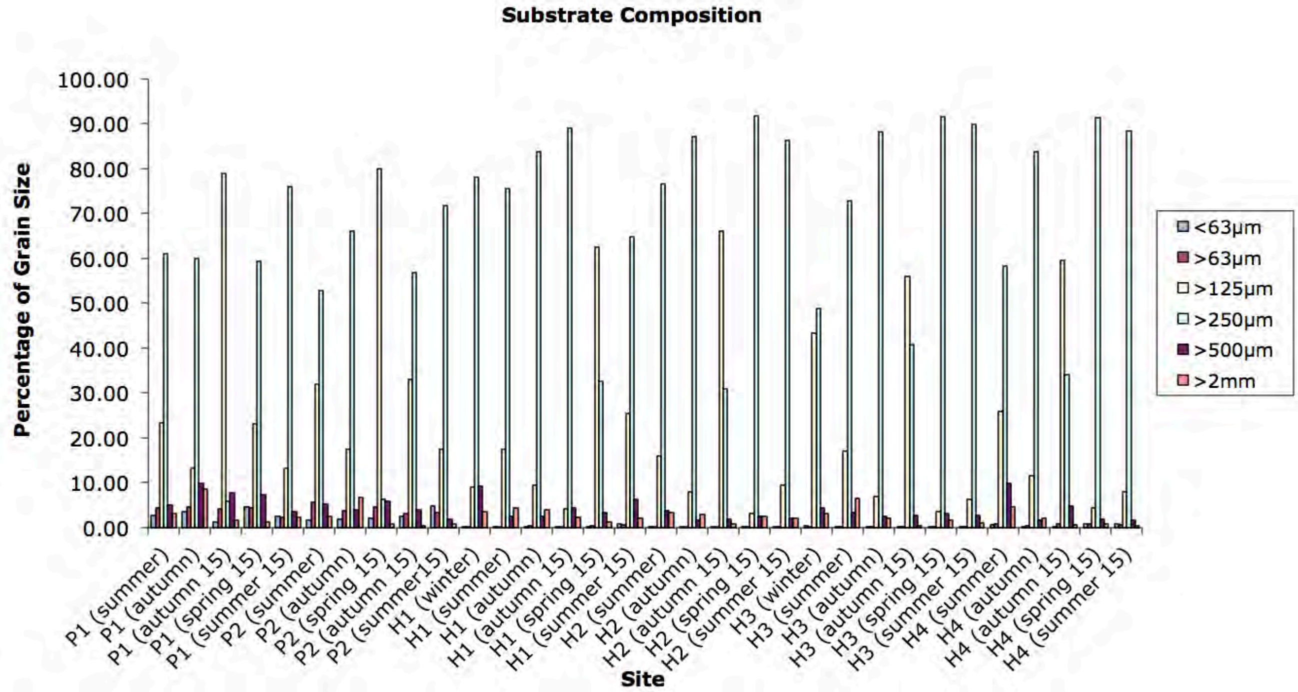


Figure 3.7 *Composition of substrate at each transect through the seasons. P = Papanui; H = Harwood.*

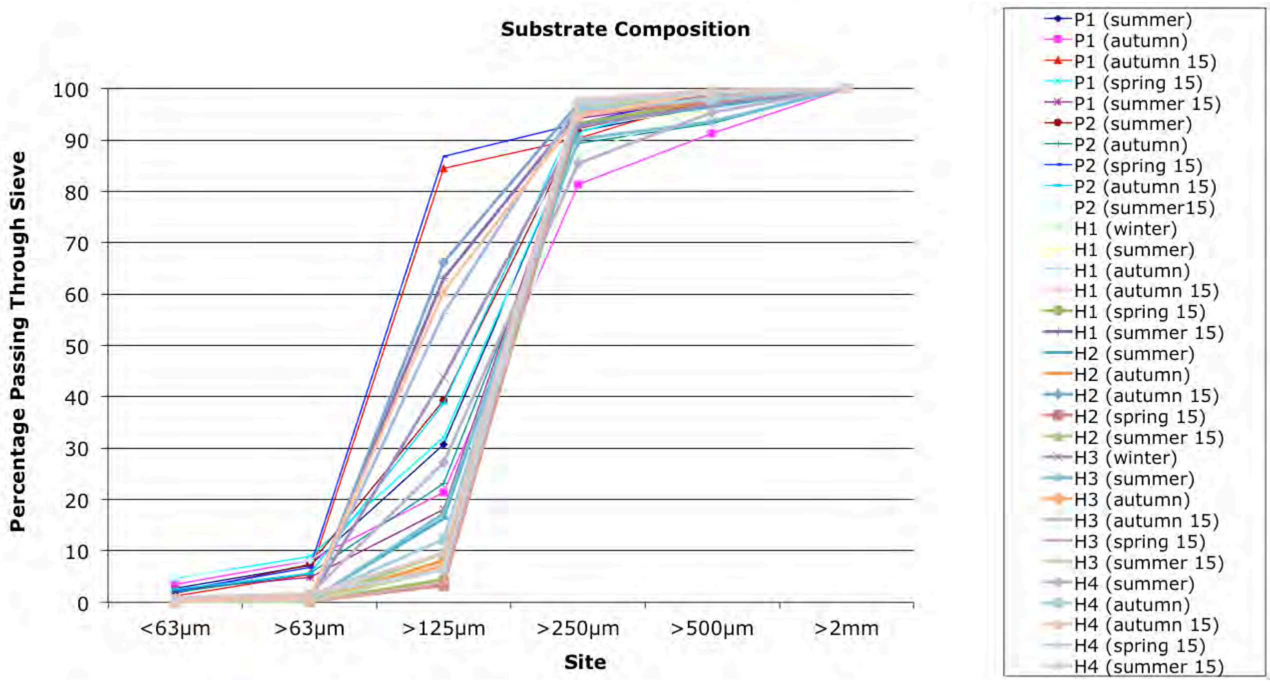


Figure 3.8 *Composition of substrate at each transect expressed as percentage of grains passing through specific mesh sizes.*

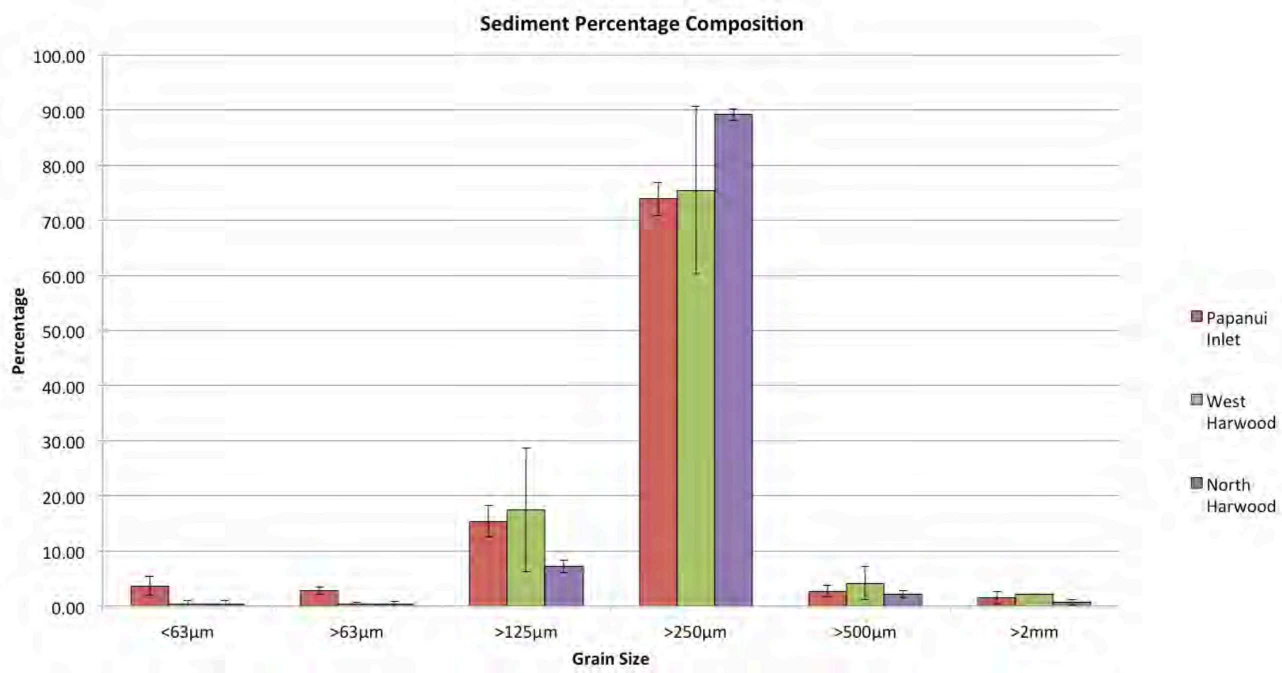


Figure 3.9 *Composition of substrate among sites. Error bars are +/- standard error.*

Substrate composition is also quite consistent among treatment and control sites (Figure 3.10), with there being no significant difference when results are examined using one-way analysis of variance ($F_{1,35} = 0.001$; $p = 0.974$).

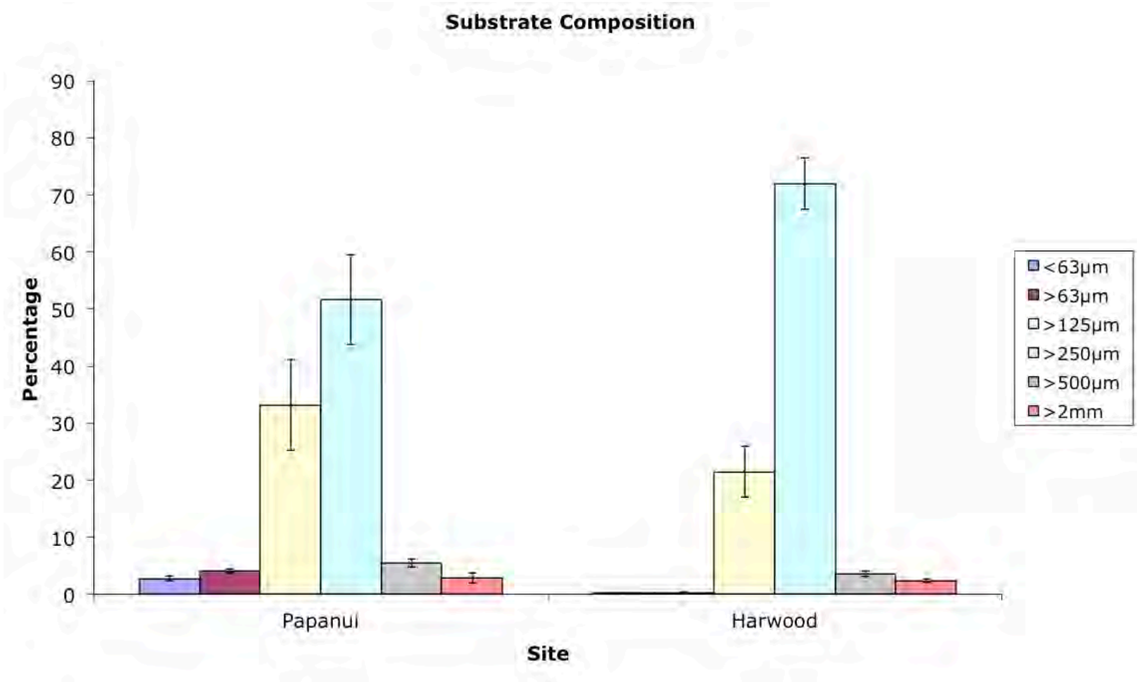


Figure 3.10 *Mean composition of substrate among control (Papanui) and treatment (Harwood) sites. Error bars are +/- standard error.*

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). It is worthwhile noting that very fine sediments (i.e. 125 μm or less) make up a very small percentage of the substrate at sites within Otago Harbour.

Areas that were originally aerial photographed on 28 July 2013 were re-photographed on 3 February 2014, on 16 May 2014, on 14 September 2015, and most recently on 21st December 2015. Actual spatial area covered by seagrass beds has varied little through the seasons for both Papanui Inlet and Harwood (Figures 3.11 and 3.12). However, there appears to have been a marked reduction in overall seagrass density during spring and summer for both sites (Figures 3.11 and 3.12). This is borne out by actual measurement with shoot density, percentage cover and blade length all showing significant differences with season for this round of monitoring.

Seagrass beds at Waipuna Bay and Poo Corner were photographed at the same time as Papanui Inlet and North Harwood beds (Figures 3.13 and 3.14). They too, appear to show a marked reduction in density of seagrass cover in spring and summer. 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.

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

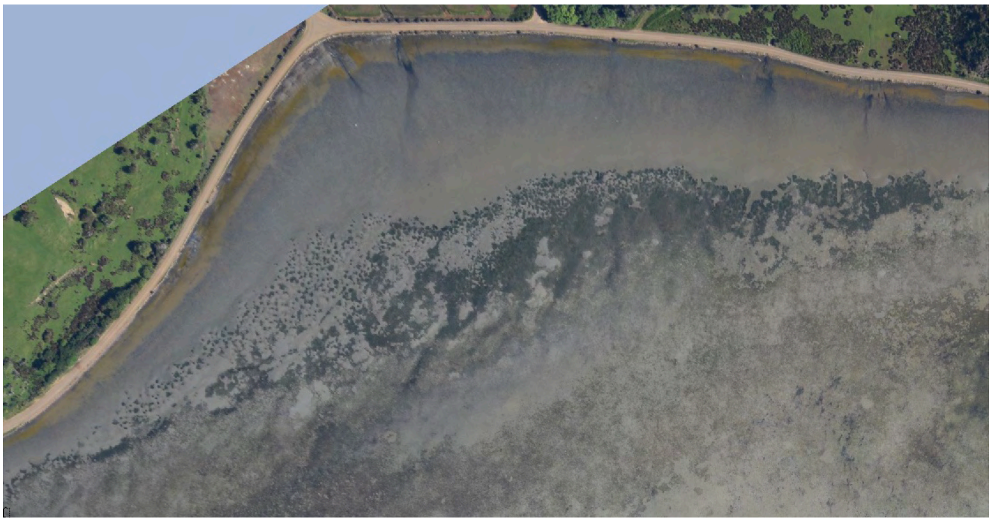


Figure 3.11 cont'd *Aerial photographs of seagrass study area, Papanui Inlet. Top = spring 2015; bottom = summer 2015.*

Figure 3.12 *Aerial photographs of seagrass study area, Harwood: winter 2013*

Figure 3.12 cont'd *Aerial photographs, Harwood. Top = summer 2013-2014; middle = autumn 2014; 2nd bottom = spring 2015; bottom = summer 2015.*

Figure 3.13 *Aerial photograph of additional seagrass area, Waipuna Bay. Top = autumn 2014; middle = spring 2015; bottom = summer 2015.*

Figure 3.14 *Aerial photograph of additional seagrass area, Poo Corner. Top = autumn 2014; middle = spring 2015; bottom = summer 2015.*

4. Discussion

There has been a significant decrease in the mean length of *Zostera* blades since the autumn 2015 survey. However, this has occurred at the Papanui Inlet sites and at both the Harwood sites and is not entirely unexpected. 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 beginning of summer and it was expected that blade length would have decreased through the cooler winter months and will likely increase as summer progresses. *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. It should be noted, however, that the overall reduction in *Zostera* cover this summer is apparently greater than in the summer of 2014.

For other parameters measured there have been significant changes to shoot density with season but not for site. For biomass the converse is true, with the biomass of plants at Harwood being significantly greater than biomass at Papanui sites, irrespective of season. Both blade length and percentage cover show significant differences for site but not for site/season interaction. Substrate composition and thickness of the RDL show no significant changes.

This summer survey is the third to have been carried out since capital works dredging has commenced.

Bearing in mind there has been major capital works dredging carried out prior to this latest survey and the spring survey, the observation that changes in seagrass cover are echoed at the control site (Papanui Inlet) would suggest that changes are likely due to natural variability.

5. References

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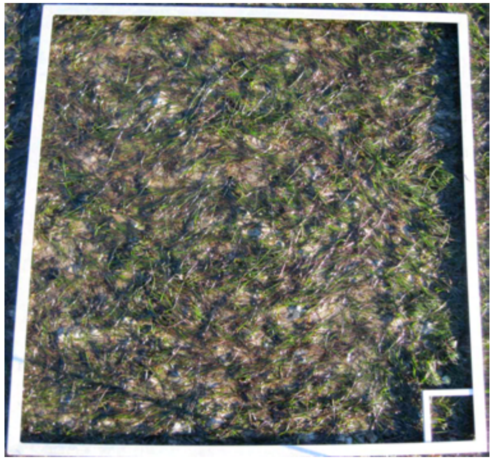
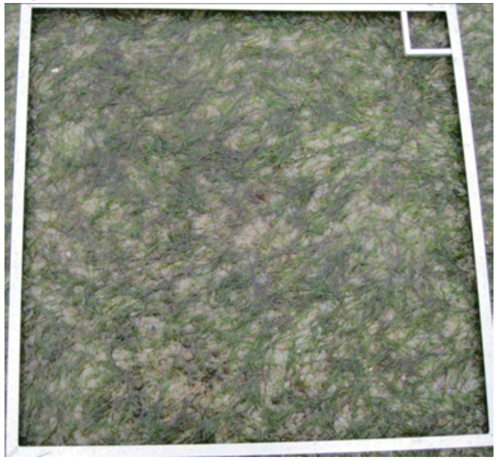
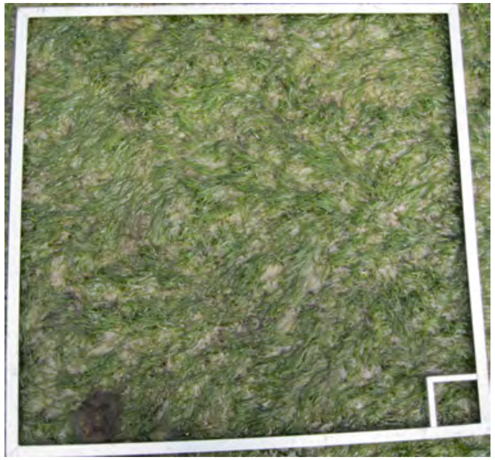
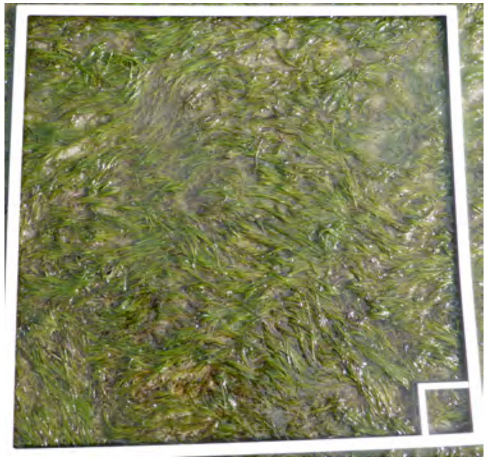
Appendix 1 – Example Seagrass Quadrats

West Harwood: Transect H1 (Quadrats are 1 m x 1 m.

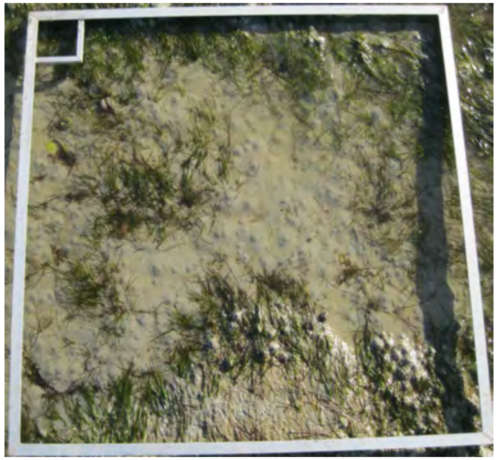

Quadrat A, July 2013

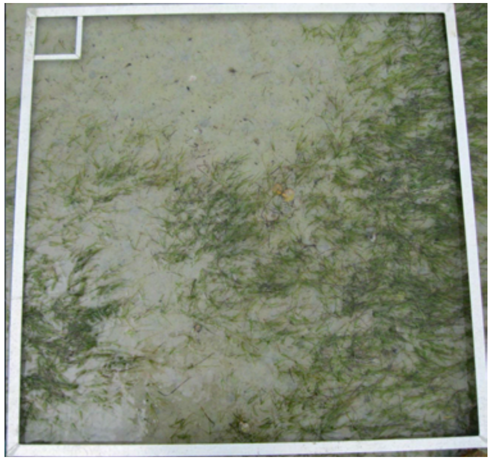

Quadrat A, October 2013


Quadrat A, December 2013

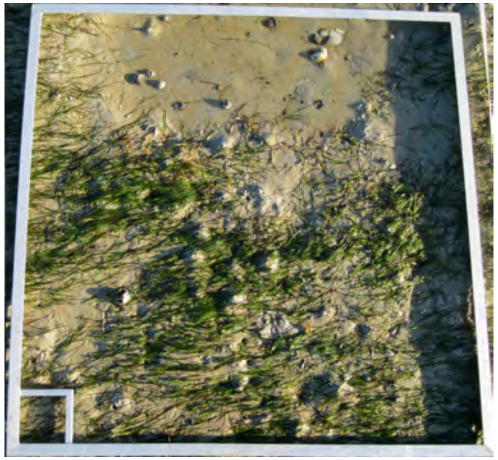

Quadrat A, March 2014


Quadrat A, April 2015

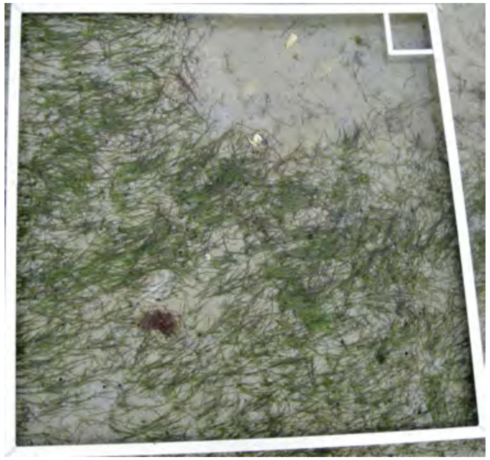

Quadrat A, September 2015


Quadrat A, December 2015

North Harwood: Transect H3



Quadrat D, July 2013



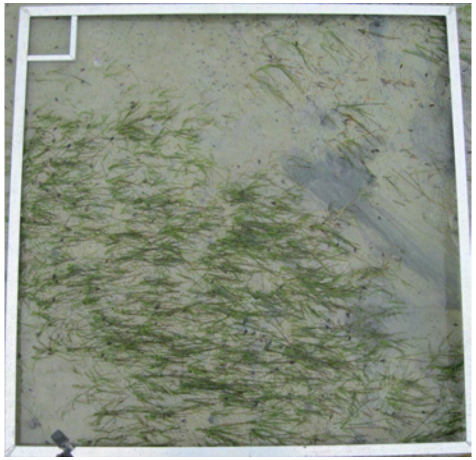
Quadrat D, October 2013

Quadrat D, December 2013

Quadrat D, March 2013

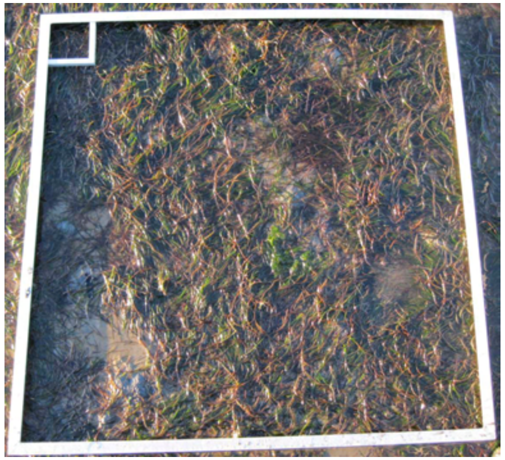
Quadrat D, April 2015

Quadrat D, September 2015



Quadrat D, December 2015

Papanui Inlet: Transect P1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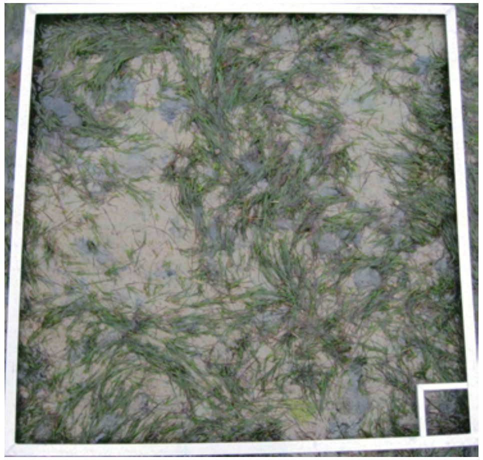
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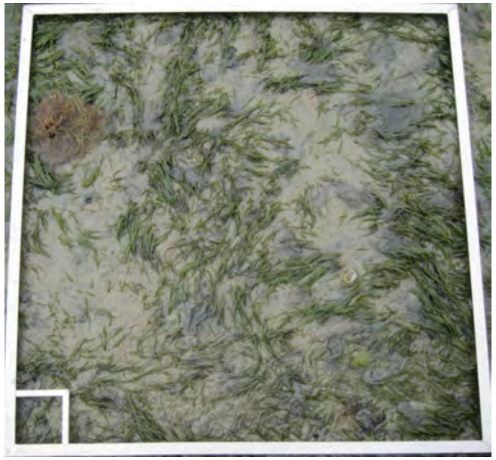
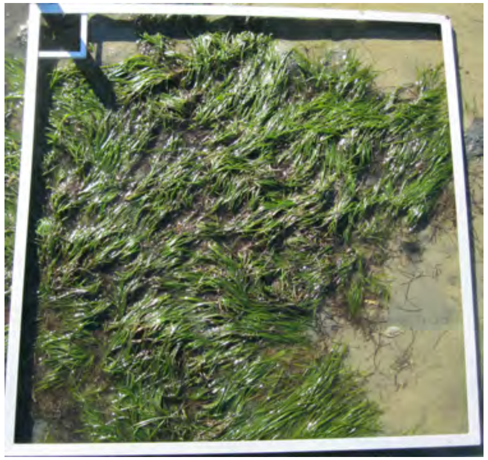
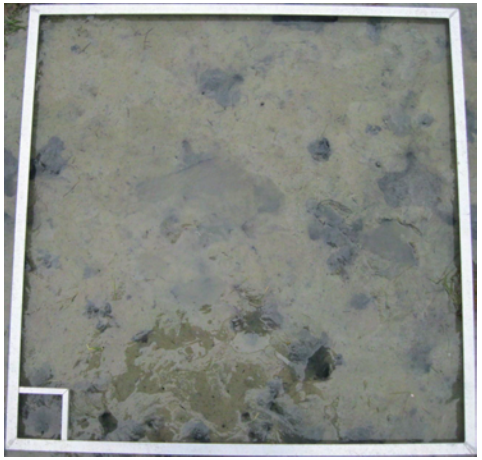

Quadrat A, December 2013


Quadrat A, March 2014


Quadrat A, April 2015


Quadrat A, September 2015


Quadrat A, December 2015

Appendix 2 – Cores

P1 (summer)

P1 (autumn 2014)

P1 (autumn 2015)

P1 (spring 2015)

P1 (summer 2015)

P2 (summer)

P2 (autumn 2014)

P2 (autumn 2015)

P2 (spring 2015)

P2 (summer 2015)


HW1 (winter)


HW1 (summer)


HW1 (autumn 2014)


HW1 (autumn 2015)


HW1 (spring 2015)


HW1 (summer 2015)


HW2 (summer)


HW2 (autumn 2014)


HW2 (autumn 2015)


HW2 (spring 2015)


HW2 (summer 2015)


HN1 (winter)


HN1 (summer)

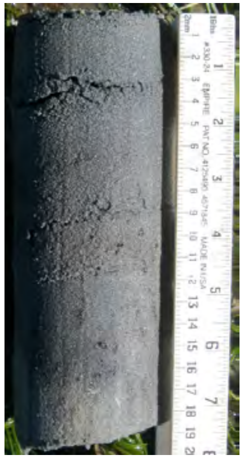

HN1(autumn 2014)


HN1 (autumn 2015)


HN1 (spring 2015)


HN1 (summer 2015)


HN2 (summer)


HN2 (autumn 2014)


HN2 (autumn 2015)


HN2 (spring 2015)


HN2 (summer 2015)