Sedimentation

The sedimentation plates in Te Awarua-o-Porirua Harbour were measured on 20-21 January 2019 with results summarised in Table 1 and Figs 1, 2 and 3.

Figure 1a shows a steady increase in sediment at the Onepoto intertidal sites from the start of the baseline which is attributable largely to the deposition of coarse sediment on the Porirua Stream delta and the movement of sand across the tidally swept site Por A. There has been little net change in intertidal deposition in the Pauatahanui Arm (Fig. 1b).

Fig. 1c shows a net decrease in subtidal sedimentation in the Onepoto Arm with temporal and spatial changes, the most significant being a large loss of mud from the estuary between January 2014 and January 2015.

Fig. 1d shows a net increase in subtidal sedimentation for the Pauatahanui Arm (+6mm/yr over the past 6 years, Table 1). This likely underestimates the actual sedimentation rate because two of the five monitoring plates could not be relocated in January 2019 (P7 Kakaho and P10 Duck Creek), due in a large part to the deep muds overlying the sites. Field observations suggest that muds deposited since 2014-2015 are building up and being retained at these sites.

Figs 2 & 3 present site-specific data of annual changes over sediment plates (intertidal sites with multiple plates are presented as means ±SE), with trendlines added to each plot as a tentative guide to the overall pattern of change, and a rolling mean where more than 5 years of data have been collected.

The plots illustrate substantial within-site variability between years particularly at sites located on stream deltas or areas with strong tidal flows (Por A, Aotea, Duck Creek, Kakaho). The greatest subtidal variation is evident at sites adjacent to where intertidal sediment deposition events have been observed (e.g. Titahi, Onepoto, Kakaho, Horokiri).

Table 2 and Fig. 4 show the position along transect lines between buried subtidal plates and the shoreline where firm sands transition to soft muds. In 2013 soft mud areas ended ~5m shoreward from each subtidal plate. Since then soft mud has extended shoreward along the transect lines, with a large increase in the shallow subtidal area covered by mud.

Table 1. Mean change of sediment depth above buried plates (2008-2019), and cumulative mean annual change since baseline in Te Awarua-o-Porirua Harbour.

Site		No	Name	Calendar Year Baseline Commenced	Change in mean sediment depth (mm/yr)											Mean Annual Sedimentation since baseline (mm/yr)	
					2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019		
Onepoto Arm	Intertidal	O1	Por A (FS)	2008	0.8	2.3	-4.5	-0.3	14.3	-4.3	1.5	0.5	-1.5	12.0	-0.8	1.8	
		O2	Aotea	2012					12.3	-0.3	2.3	7.8	1.5	-0.3	6.5	4.3	+2.9
		O3	Por B (FS)	2008	7.0	0.5	2.0	0.3	4.3	1.8	2.3	5.0	5.3	1.3	2.4	2.5	
	Subtidal	OS6	Titahi	2013						0.0	-11.0	-16.0	32.0	43.0	3	8.5	
		OS7	Onepoto	2013						-6.0	-92.0	-2.0	7.0	0	NM	-	-0.5
		OS8	Papakowhai	2013						-8.0	-77.0	10.0	24.0	-2	2	-8.5	
		OS9	Te Onepoto	2008	-2.5	-2.5	0	3.0	-14.0	0.0	4.0	7.0	-3.0	1.0	-9.0	-1.5	
Pauatahanui Arm	Intertidal	P6	Boatsheds	2008		0.5	-0.8	0.3	3.5	-2.0	-3.0	-3.5	-4.5	6.3	4.0	0.2	
		P7	Kakaho	2008					9.3	-4.0	-2.0	-5.8	17.8	-7.0	2.0	1.5	
		P8	Horokiri	2009					2.0	-2.5	1.3	0	-7.0	7.3	1.3	0.3	+0.8
		P9	Paua B (FS)	2008	2.3	3.8	0.3	-5.3	-0.8	4.5	-2.5	-5.0	0.3	-1.8	0.5	-0.3	
		P10	Duck Creek	2012					-3.0	14.8	-5.5	1.8	1.0	4.0	2.0	2.1	
	Subtidal	PS1	Kakaho	2013						6.6	2.0	8.0	64.0	-6.0	NM	-	
		PS2	Horokiri	2013						26.4	18.0	10.0	54.0	-16.0	0	15.4	
		PS3	Duck Creek	2013						8.0	-12.0	NM	90.0	10.0	NM	-	+6.1
		PS4	Bradeys Bay	2013						11.0	-4.0	-5.0	12.0	5.0	-1.0	3.0	
		PS5	Browns Bay	2013						9.2	-10.0	-2.0	13.0	-10.0	-1.0	-0.1	

NM = Not Measured (plate unable to be relocated).

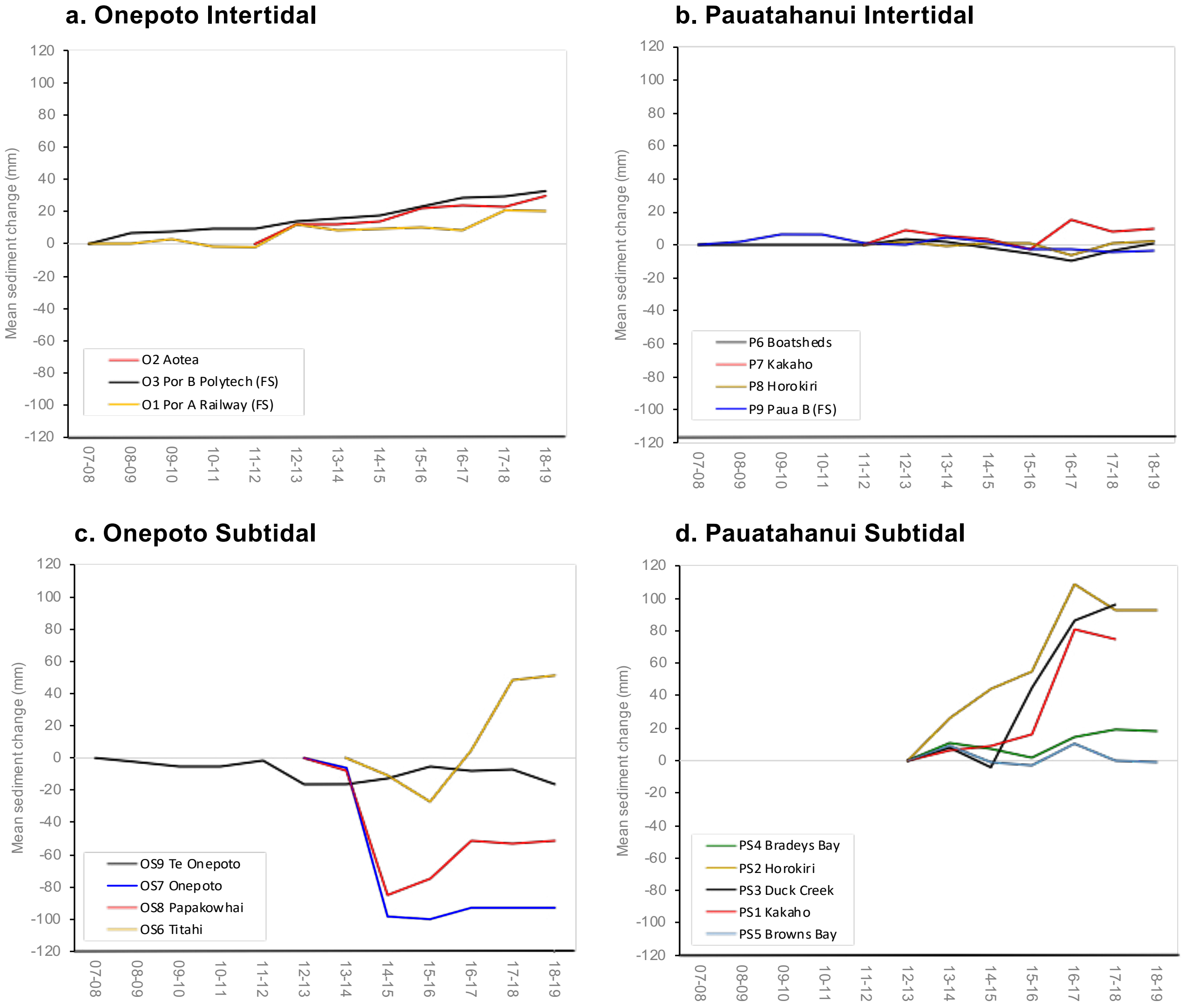


Fig. 1. Cumulative change in mean sediment level over buried plates at individual monitoring sites in Te Awarua-o-Porirua Harbour.

Between January 2018 and January 2019 there were increases in the horizontal extent of mud in the Pauatahanui Arm at Duck Creek and Browns Bay, and reductions at Kakaho, Horokiri and Bradeys Bay. In the Onepoto at Titahi, there was a reduction in mud extent.

Compared to the 2013 baseline, Bradeys Bay shows no net change, but the other sites show the cover of mud has extended horizontally towards the shoreline by between 10m and 75m.

Sediment grain size

Grain size monitoring results (Table 3) show that in 2019, as in previous years, sands dominate intertidal sediments (82%-95%) with mud contents ranging from 5%-15% and relatively little difference between the two arms. Subtidal sites fall in two general types, those dominated by sands (73-90% sand) and those dominated by muds (61-86% mud). The lowest subtidal mud contents were recorded from the relatively well-flushed sites at Papakowhai, Te Onepoto, and Onepoto. Bradeys Bay also had a relatively low mud content. The highest mud contents were in the deeper settlement basin areas with four of the five muddiest subtidal sites are located in the Pauatahanui Arm.

Figs 5 and 6 plot, respectively, the intertidal and subtidal mud contents at each site, and show changes in mud content over time. There is a general trend of increasing mud content at all sites since the start of the baseline. Fig. 6b also highlights a significant increase in the intertidal mud content of sediments following the large deposition event at Horokiri in 2016, followed by a subsequent reduction in mud from 2017-2019.

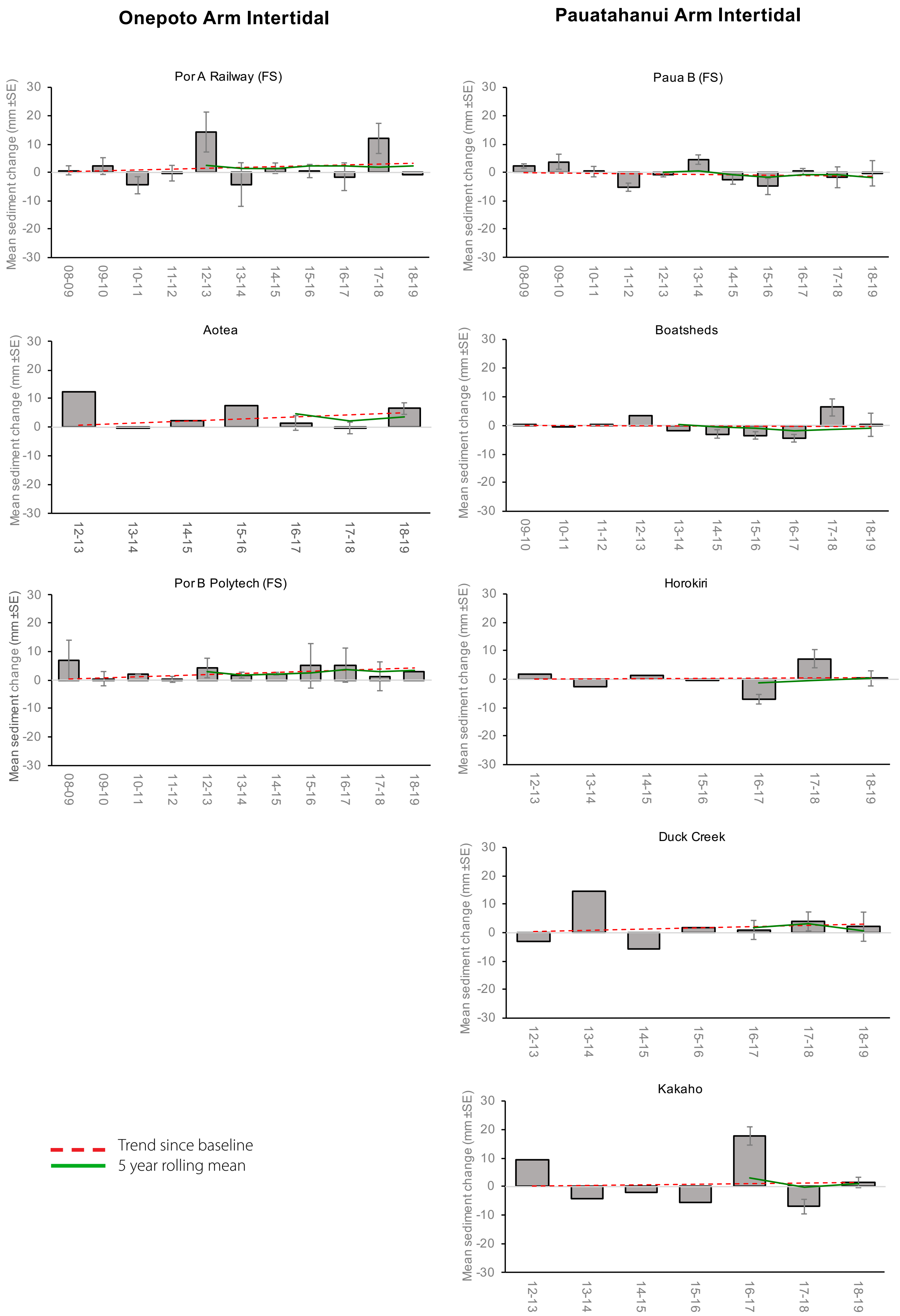


Fig. 2. Mean change in intertidal sediment height (mm/yr ±SE) over buried plates at individual monitoring sites in Te Awarua-o-Porirua Harbour.

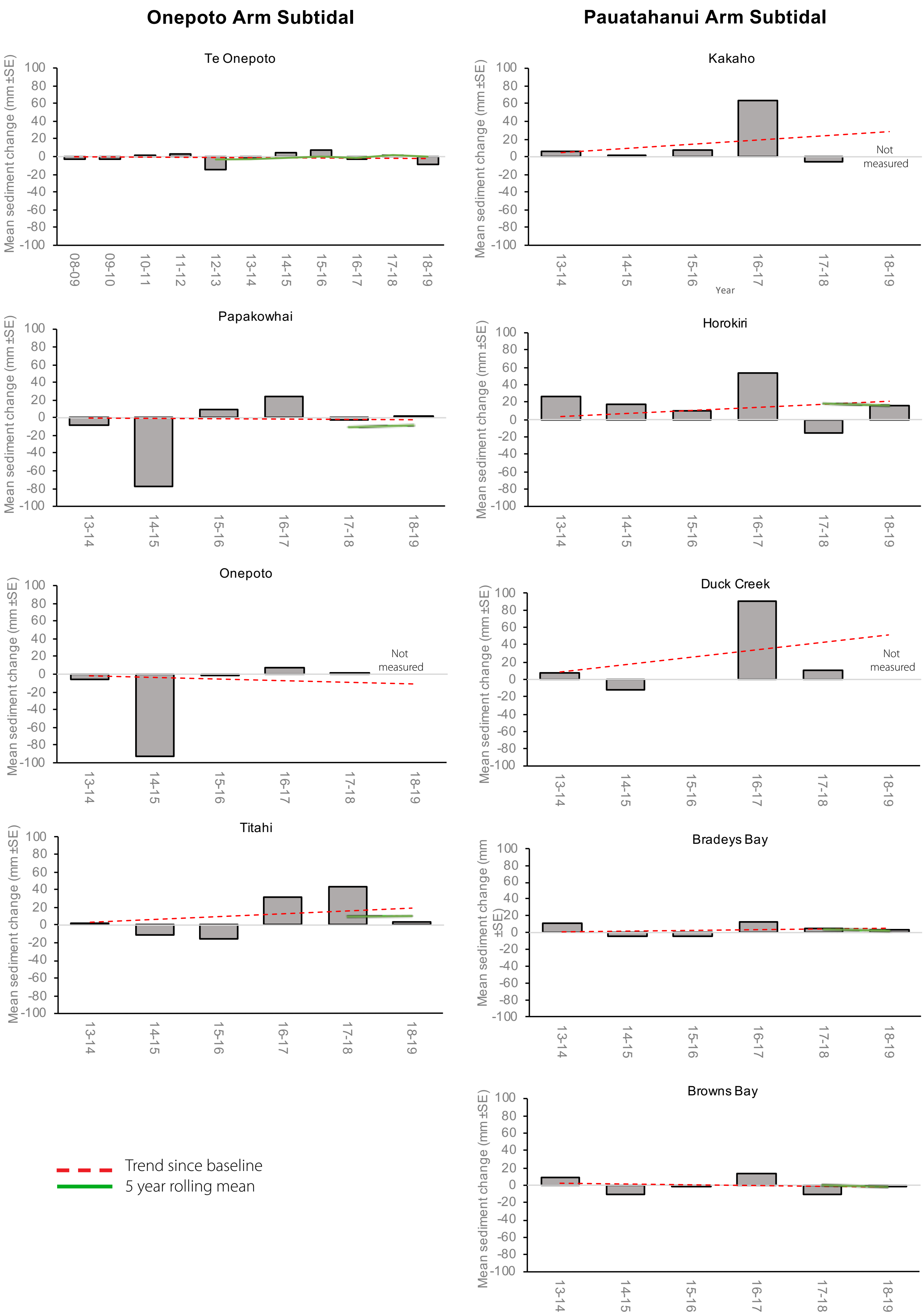


Fig. 3. Mean change in subtidal sediment height over buried plates at individual monitoring sites in Te Awarua-o-Porirua Harbour.

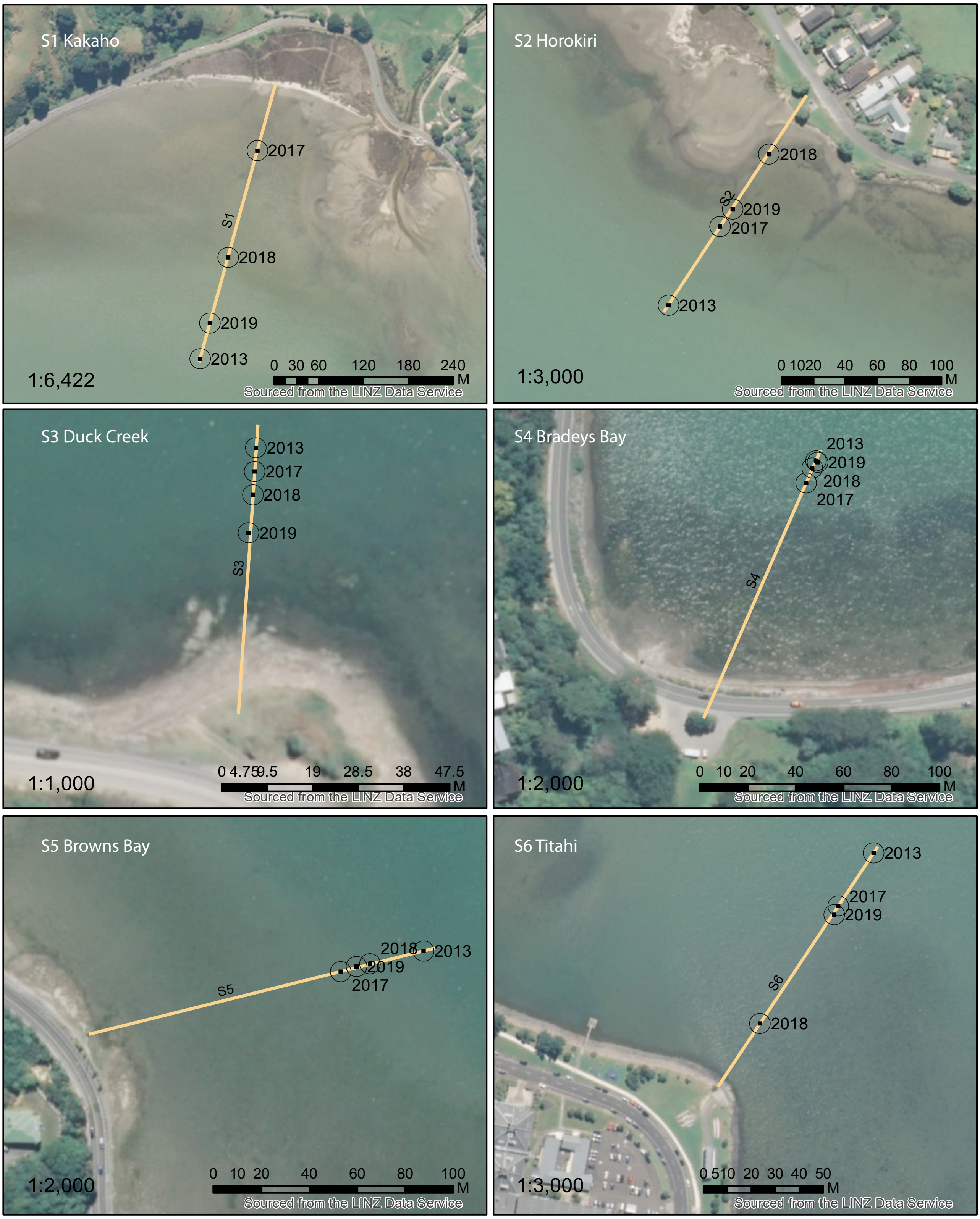


Fig. 4. Transects showing the distance from subtidal plates to the boundary between soft mud and firm sand dominated substrates (2013, 2017, 2018 and 2019).

Table 2. Distance from subtidal plates to the soft mud boundary at sites S1-S6, 2013-2019.

Site	Subtidal Site No.	Distance from subtidal plate to edge of soft mud (m) 2013	2017	2018	2019	Change from baseline (m) 2013-2019
Kakaho	PS1	5	300	150	55	50
Horokiri	PS2	5	65	120	80	75
Duck Creek	PS3	5	10	15	23	18
Bradeys Bay	PS4	5	15	8	5	0
Browns Bay	PS5	5	40	28	35	30
Titahi	OS6	5	45	135	52	47

SYNTHESIS

The mean annual intertidal sedimentation rate across all sites and over all years of monitoring shows a net increase of intertidal sediment of +2.9mm/yr in the Onepoto Arm and +0.8mm/yr in the Pauatahanui Arm (Table 1).

Subtidal sites in the Onepoto Arm show a net decrease in subtidal sedimentation of -0.5mm/yr over the past 6 years (Table 1), although the most recent data indicate sediment accrual is continuing and the small net decrease is almost exclusively an artifact of the baseline monitoring commencing shortly after a significant deposition event in the Onepoto Arm.

Subtidal sites in the Pauatahanui Arm show a net increase in subtidal sedimentation of 6.1mm/yr over the past 6 years. There is also a trend of increasing mud content and an expanding spatial boundary of soft mud compared to baseline measurements.

Because sites OS7 (Onepoto), PS1 (Kakaho) and PS3 (Duck Creek) could not be relocated in January 2019, the level of confidence associated with the current results is reduced compared to previous years.

The expansion of subtidal soft mud towards the intertidal boundary, the cumulative increase in sediment deposition and mud content, and the often

Table 3. Sediment grain size and RPD depth results, Te Awarua-o-Porirua Harbour, January 2019.

Site		No	Name	Mean aRPD depth (mm)	Site Mean % Gravel g/100g dry weight	% Sand g/100g dry weight	% Mud g/100g dry weight
Onepoto Arm	Intertidal	O1	Por A Railway (FS)	11	1.1	91.9	7.0
		O2	Aotea	12	1.0	84.5	14.6
		O3	Por B Polytech (FS)	10	1.7	83.3	14.9
	Subtidal	OS6	Titahi	15	0.2	29.9	69.9
		OS7	Onepoto	10	0.9	89.7	9.4
		OS8	Papakowhai	10	< 0.1	86.3	13.7
		OS9	Te Onepoto	10	1.7	87.0	11.3
Pauatahanui Arm	Intertidal	P5	Paua A (FS)	10	5.0	86.4	8.6
		P6	Boatsheds	11	1.9	84.4	13.7
		P7	Kakaho	8	1.2	85.2	14.0
		P8	Horokiri	8	1.2	89.8	9.0
		P9	Paua B (FS)	7	3.3	89.7	7.0
		P10	Duck Creek	5	< 0.1	95.3	4.7
		P11	Browns Bay	10	3.8	82.2	14.0
	Subtidal	PS1	Kakaho	5	0.2	13.8	86.1
		PS2	Horokiri	5	0.3	27.3	72.4
		PS3	Duck Creek	5	2.7	36.4	61.0
		PS4	Bradeys Bay	5	0.3	73.4	26.3
		PS5	Browns Bay	5	1.1	30.0	68.9

Note: Grain size and aRPD are based on a single composite sample comprising 4 sub-samples collected from each site.

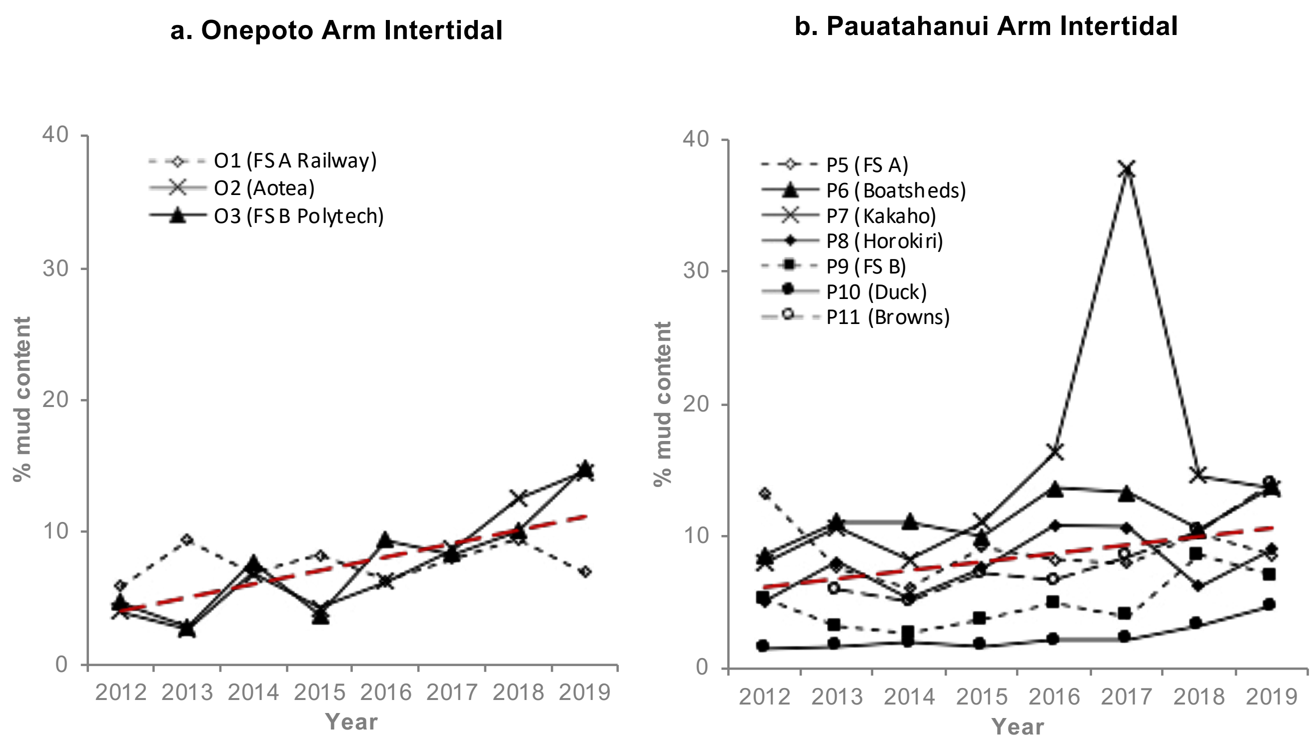


Fig. 5. Change and trend in mean sediment mud content for intertidal sites in the Pauatahanui and Onepoto arms of Te Awarua-o-Porirua Harbour.

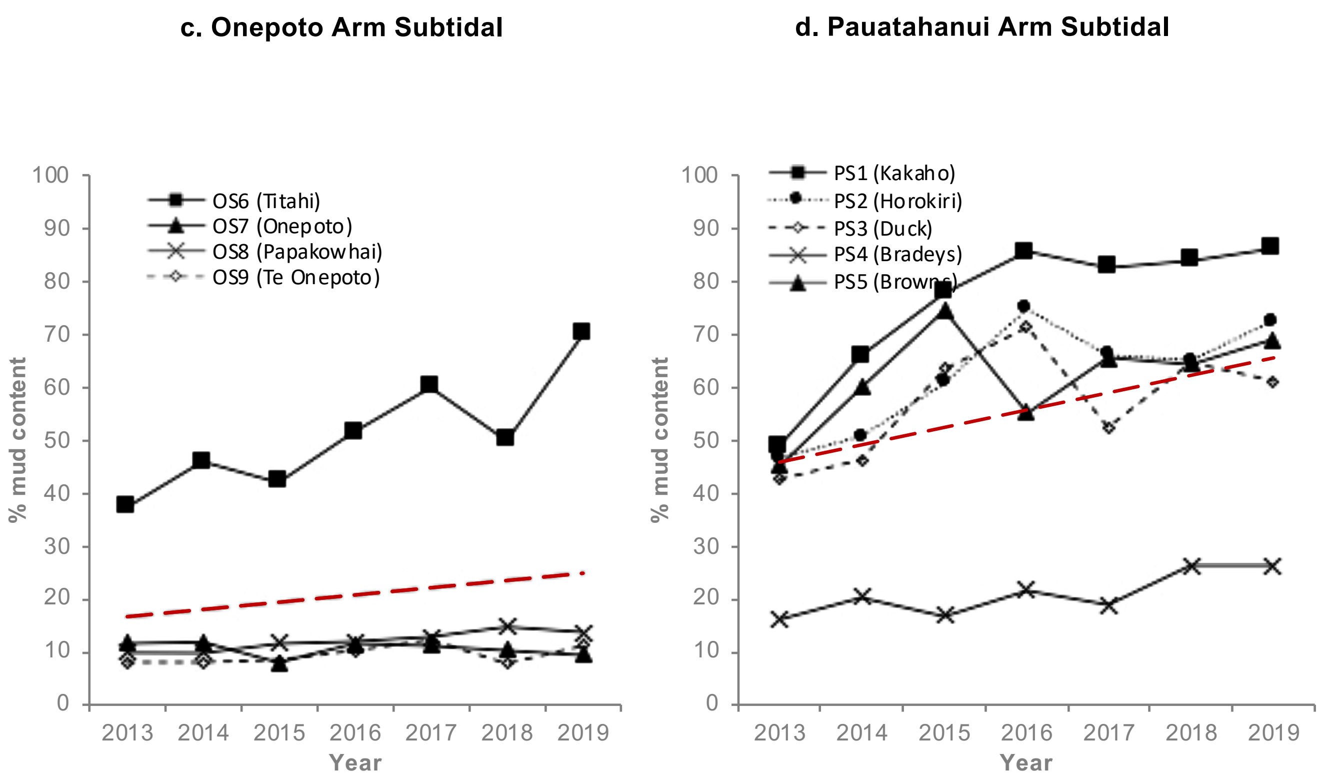


Fig. 6. Change and trend in mean sediment mud content for subtidal sites in the Pauatahanui and Onepoto arms of Te Awarua-o-Porirua Harbour.

very high measured annual deposition particularly at subtidal sites S1, S2, S3 and S6 (Kakaho, Horokiri, Duck Creek and Titahi) highlight recent infilling of the subtidal basins (the primary deposition zones in the estuary).

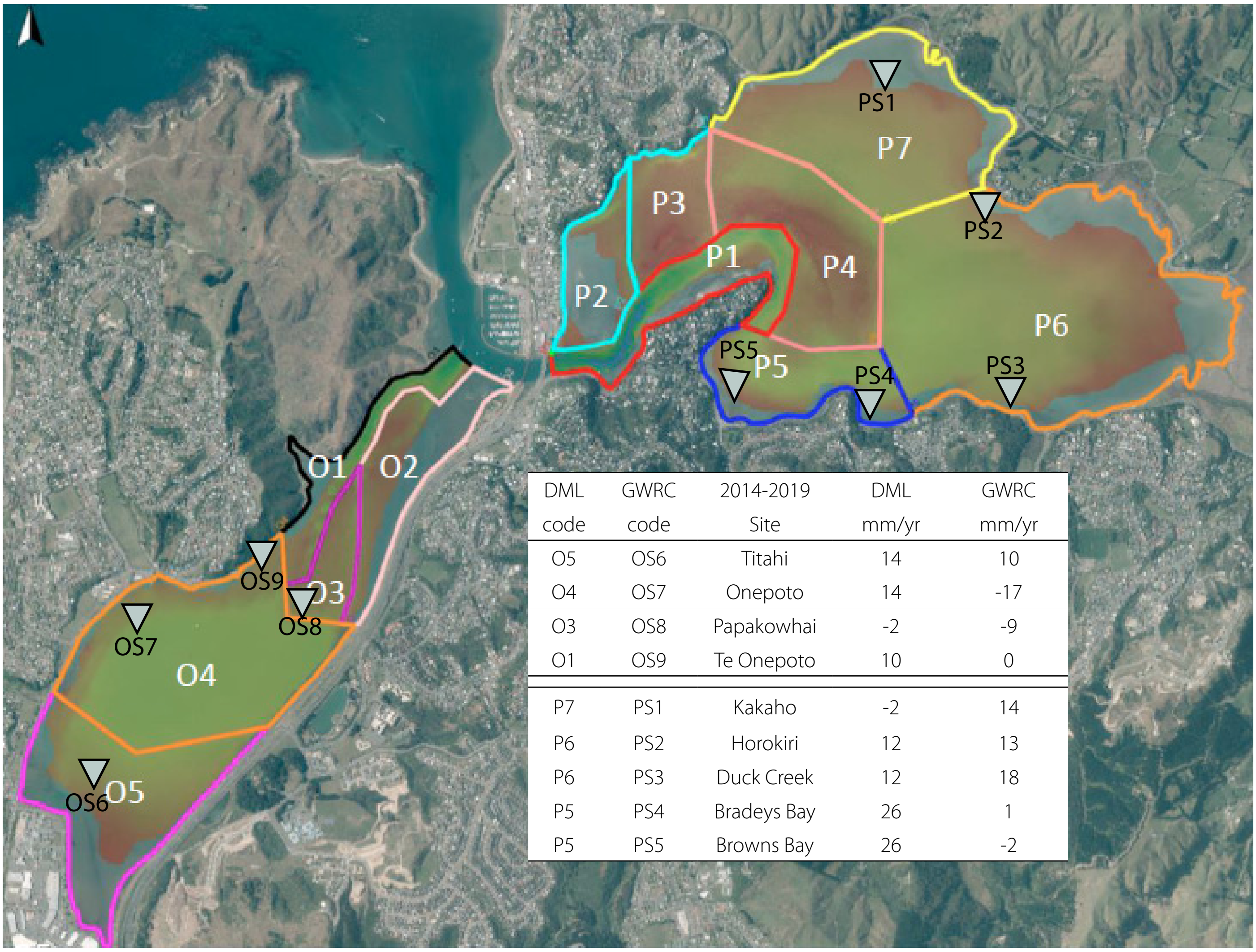
Mean subtidal sedimentation rates (mm/yr) for the past 5 years (2014-2019) are summarised in Fig. 7 for the GWRC sediment plate sites and the DML bathymetry summary zones. There is an offset of ~6 months between the measurement periods of the surveys which may affect the results, and the positioning of the subtidal sediment plate sites at the margins of where the hydrodynamic survey coverage extends, limits how representative the existing sediment plates are of the wider subtidal area. Notwithstanding, the DML surveys suggest the estuary is infilling more rapidly than indicated by the existing sediment plate sites.

RECOMMENDATIONS

Annually monitor sedimentation rate, aRPD depth and grain size at the existing intertidal and shallow subtidal sites.

Because it has become increasingly difficult to relocate the subtidal plates using the current methods, it is recommended that metal markers be installed at each site to enable relocation with a metal detector.

If sediment plate measurements are to be used to validate the bathymetry survey results, sediment plates need to be established in subtidal basin areas with an increased level of replication.



DML code	GWRC code	2014-2019 Site	DML mm/yr	GWRC mm/yr
O5	OS6	Titahi	14	10
O4	OS7	Onepoto	14	-17
O3	OS8	Papakowhai	-2	-9
O1	OS9	Te Onepoto	10	0
P7	PS1	Kakaho	-2	14
P6	PS2	Horokiri	12	13
P6	PS3	Duck Creek	12	18
P5	PS4	Bradeys Bay	26	1
P5	PS5	Browns Bay	26	-2

Figure 7. Comparison of sedimentation rates (mm/yr) for the 2014-2019 period calculated for DML boundaries, and related GWRC sediment plates sites. Note there is a ~6 month offset in the two monitoring data sets.

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Certificate of Analysis

SPv1

Client:	Salt Ecology Limited	**Lab No:**	2113562
Contact:	Leigh Stevens C/- Salt Ecology Limited 21 Mount Vernon Place Washington Valley Nelson 7010	**Date Received:**	24-Jan-2019
		Date Reported:	27-Feb-2019
		Quote No:	96904
		Order No:	
		Client Reference:	GRWC-Porirua Harbour
		Submitted By:	Leigh Stevens

Sample Type: Sediment

Sample Name:		1 Por A Railway 20-Jan-2019	2 Aotea 20-Jan-2019	3 Por B Polytech 20-Jan-2019	5 Paua FS A 20-Jan-2019	6 Boatsheds 20-Jan-2019
Lab Number:		2113562.1	2113562.2	2113562.3	2113562.4	2113562.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	74	78	78	76	76
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	1.1	1.0	1.7	5.0	1.9
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	91.9	84.5	83.3	86.4	84.4
Fraction < 63 µm*	g/100g dry wt	7.0	14.6	14.9	8.6	13.7

Sample Name:		7 Kakaho 20-Jan-2019	8 Horokiri 20-Jan-2019	9 Paua FS B 20-Jan-2019	10 Duck Creek 20-Jan-2019	11 Browns Bay 20-Jan-2019
Lab Number:		2113562.6	2113562.7	2113562.8	2113562.9	2113562.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	80	80	79	78	82
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	1.2	1.2	3.3	< 0.1	3.8
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	85.2	89.8	89.7	95.3	82.2
Fraction < 63 µm*	g/100g dry wt	13.6	9.0	7.0	4.7	14.0

Sample Name:		S1 Kakaho 20-Jan-2019	S2 Horokiri 20-Jan-2019	S3 Duck Creek 20-Jan-2019	S4 Bradeys Bay 20-Jan-2019	S5 Browns Bay 20-Jan-2019
Lab Number:		2113562.11	2113562.12	2113562.13	2113562.14	2113562.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	66	59	64	73	68
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	0.2	0.3	2.7	0.3	1.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	13.8	27.3	36.4	73.4	30.0
Fraction < 63 µm*	g/100g dry wt	86.1	72.4	61.0	26.3	68.9

Sample Name:		S6 Titaki 20-Jan-2019	S7 Onepoto 20-Jan-2019	S8 Papakowhai 20-Jan-2019	S9 To Onepoto 20-Jan-2019	
Lab Number:		2113562.16	2113562.17	2113562.18	2113562.19	
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	55	78	70	80	-
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	0.2	0.9	< 0.1	1.7	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	29.9	89.7	86.3	87.0	-
Fraction < 63 µm*	g/100g dry wt	69.9	9.4	13.7	11.3	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-19
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-19
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-19
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-19

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental