Coastal Water Quality and Ecology monitoring programme

Annual data report, 2017/18

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Contents

1. Introduction

This report summarises the key results of water quality, sediment quality, ecological health and habitat monitoring undertaken in the Wellington Region's near-shore coastal environment for the period 1 July 2017 to 30 June 2018. Note that the suitability of coastal waters for contact recreation purposes is assessed separately under Greater Wellington Regional Council's (GWRC) recreational water quality monitoring programme; see Brasell & Conwell (2018) for the 2017/18 results.

2. Overview of coastal monitoring programme

Coastal monitoring in the Wellington Region began around 25 years ago, with a focus on microbiological water quality – a reflection of the high usage of much of the region's coastline for contact recreation such as swimming and surfing. Periodic assessments of contaminants in shellfish flesh commenced in 1997, with the last assessment undertaken at 20 sites in 2006 (see Milne 2006). In 2004, monitoring expanded into coastal ecology and sediment quality, with a key focus being the effects of urban stormwater on our coastal harbour environments. In addition, between 2004 and 2008 broad scale surveys of the region's coastal habitats were carried out, with detailed sediment and ecological assessments undertaken at representative intertidal locations of selected estuaries and sandy beaches. The information gained from these surveys was combined with ecological vulnerability assessments to identify priorities for a long-term monitoring programme that would enable GWRC to fulfil State of the Environment (SoE) monitoring obligations with respect to coastal ecosystems.

More recently, a focus on the feasibility of other tools as proxies for near shore coastal water quality has seen the development of a pilot microbial water quality forecast tool (Porirua Harbour), as well as deployment of telemetered instruments for near shore coastal biophysico-chemical monitoring (Wellington Harbour).

2.1 Monitoring objectives

The aims of GWRC's coastal monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in near-shore coastal waters;
2. Contribute to our understanding of coastal biodiversity in the Wellington Region;
3. Determine the suitability of coastal waters for designated uses;
4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality or ecosystem health is desired; and
5. Provide information required to determine the effectiveness of regional plans and policies.

2.2 Monitoring sites and frequency

The core coastal ecological monitoring sites are located in Porirua and Wellington harbours, and the Waikanae and Hutt estuaries, (Figure 2.1).

In addition, habitat mapping of key substrate and habitat types is carried out at selected sites approximately every five years. In the past, habitat mapping has been limited to the intertidal areas of estuaries but, in early 2014, habitat mapping was extended to the subtidal areas of Te Awarua-o-Porirua Harbour (Porirua Harbour).

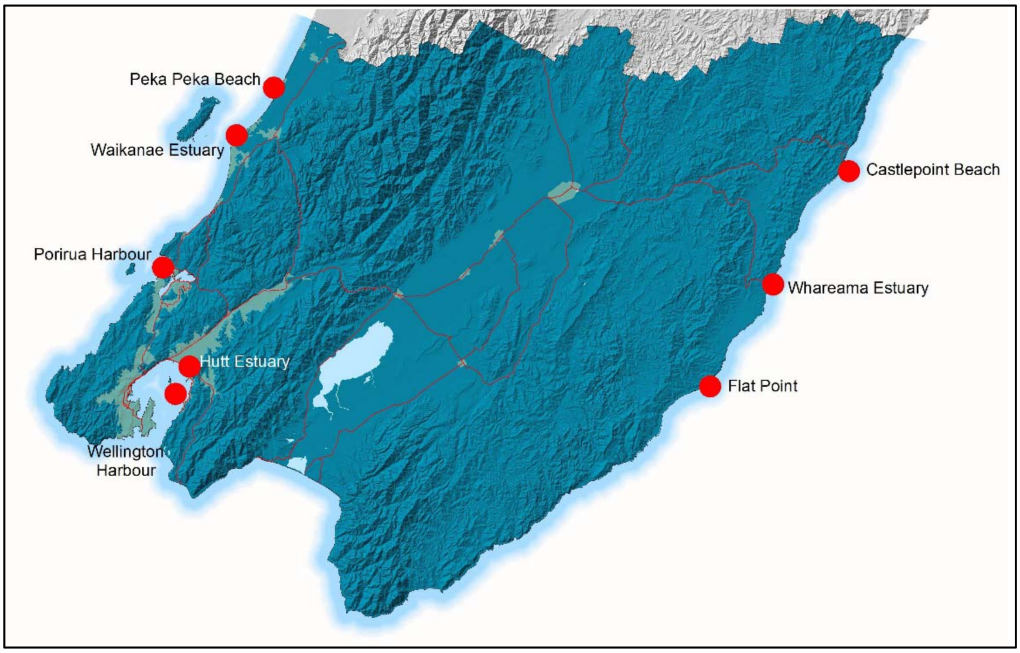

Figure 2.1: Map of the current core estuary, harbour, beach and rocky shore ecological monitoring sites in the Wellington region as at 30 June 2018

Monitoring frequency varies across the sites, depending on the nature of the receiving environment, the purpose of monitoring and what the results indicate. The general approach is to monitor beach, estuary and rocky shore sites annually for three years to establish a baseline, with monitoring then reducing to five-yearly intervals unless specific issues have been identified that warrant more frequent monitoring (eg, persistent macroalgal growth in Hutt Estuary). In contrast, subtidal monitoring in Porirua Harbour and Wellington Harbour is undertaken approximately every five years. See Oliver and Milne (2012) for more information.

2.2.1 Sites monitored during 2017/18

Coastal monitoring and reporting undertaken over the period 1 July 2017 to 30 June 2018 included:

- Annual monitoring of macroalgal cover and biomass, and sedimentation rates in Porirua Harbour; Waikanae and Hutt estuaries (Section 3);
- Baseline assessment and characterisation of three rocky shores in Wellington Harbour; Makara, Scorching Bay and Baring Head (Section 4);
- Baseline assessment and characterisation of three beaches in Wellington Harbour; Petone Beach, Lyall Bay and Owhiro Bay (Section 5);
- Biophysical monitoring of temperature, conductivity, turbidity and chlorophyll-*a* continuously across a range of depths at a mooring in Wellington Harbour (Section 6);
- Validation and performance assessment of a microbial water quality forecast tool for Porirua Harbour to predict when water quality conditions are suitable for swimming (Section 7); and

- Assessment and interpretation of emerging organic contaminants in the subtidal sediments of Wellington Harbour sampled in 2016 (Section 8).

2.3 Monitoring variables

The basic approach to monitoring coastal water quality and the ecological condition of the region's estuaries, beaches, rocky shores, and harbours is outlined in each of the following sections and underlying technical reports, with selected methods summarised in Appendix 2.

3. Estuary condition

In January 2018, Salt Ecology carried out surveys of the Waikanae and Hutt estuaries and Porirua Harbour (Onepoto and Pauatahanui Arms). The surveys are documented in full in Stevens (2018b, 2018d, 2018e), and the key findings are summarised in Table 3.1

3.1 Annual monitoring indicators

In broad terms the surveys of Porirua Harbour and the Waikanae estuaries included measurements of sedimentation over buried plates (Figure 3.1), apparent Redox Potential Discontinuity (aRPD)[1] depth, and mud content. Measures of macroalgal biomass and cover were also carried out in the Hutt Estuary, as a proxy for eutrophication risk (Figure 3.2). These are the fine and broad scale indicators selected for ongoing annual monitoring, following detailed baseline surveys between 2008 and 2012. Table 3.1 presents the results of these assessments. Note that the mean annual sedimentation rates are for the January 2017 to January 2018 period.

(Source: Stevens 2018e)

Figure 3.1: Sedimentation plate monitoring in the Waikanae Estuary, January 2018

It is important to note that the method for assessing the macroalgae condition changed in 2014/15 from simple percentage cover (density) estimates used in previous years, to an Ecological Quality Rating (EQR) for macroalgae. Refer to Stevens & O'Neill-Stevens (2017) for more detail. This rating is intended to provide an early warning of increasing or excessive algal growth and triggers annual macroalgal monitoring when the EQR is <0.4.

[1] The aRPD provides a measure of the depth of oxygenated sediment.

Table 3.1: Sedimentation and eutrophication indicator results for estuaries monitored in early 2018. Porirua Harbour cells shaded in light blue and dark blue equate to intertidal and subtidal sites, respectively.

		Sedimentation					Eutrophication	
		Sedimentation rate (Jan 2017 – Jan 2018)	**Mean sedimentation rate (mm/yr) for the last 5 years ↑↓ change from previous mean[1]**	**No. of years measured**	**RPD (cm)**	**Mean mud content (%)**	**Ecological Quality Rating (EQR) for macroalgae**	**Quality status**
Waikanae Estuary		-27	9.7↓	8	2.7	27.4	Not assessed	
Hutt Estuary		Not assessed	1.64↑[2]	7	-	-	0.59	Moderate
Porirua Harbour								
Onepoto Arm	1	12	1.64↑	10	4	10	Not assessed	Moderate (2017)
	2	-0.3	2.2↓	6	3	13		
	3	1.3	3.14↓	10	2	10		
	S6	43	12.8↑	5	0.5	50		
	S7	0	-18.6↑	5	3	10		
	S8	-2.0	-13.8↑	5	5	15		
	S9	1.0	1.8↓	10	3	8		
Pauatahanui Arm	6	6.3	-1.34↑	9	3	11		
	7	-7.0	-0.2↓	6	2	15		
	8	7.3	-1.8↓	6	1	6		
	9	-1.8	-0.9	10	1	9		
	10	4.0	3.22↑	6	2	3		
	11	-	-7.75	4	3	10		
	S1	-6.0	14.92↓	5	1	84		
	S2	-16	18.5↓	5	1	65		
	S3	10	24↓	5	1	65		
	S4	5.0	3.8↑	5	1	26		
	S5	-10	0.04↓	5	1	64		

[1] Note this is a 5-year rolling mean of sedimentation rate rather than the mean sedimentation rate for all years as reported in previous annual data reports
[2] Five year mean sedimentation rate for the period 2013-2017

(Source: Stevens 2018b)

Figure 3.2: High biomass growth of the green alga, Ulva, growing near the Waione Street Bridge in the Hutt Estuary, January 2018

4. Rocky reef condition

In January 2018, Salt Ecology carried out baseline assessment and characterisation of three rocky shores; Scorching Bay, Makara and Baring Head. These semi-quantitative surveys provided a cursory overview of rocky shore biota across three shore heights. The surveys will be used to establish a baseline understanding of rocky shore condition against which future changes related to sea level rise, temperature change, ocean acidification, invasive species and, to a lesser extent, over-collection of living resources, can be measured. The surveys are documented in full in Stevens (2018c), and summarised in a coastal vulnerability report prepared for the Whaitua Te Whanganui-a-Tara committee (Stevens, 2018f).

The key measurements carried out at all three sites were based on the UK-MarClim project (MNCR 1990) and included assessments of plant and animal diversity and abundance within representative supralittoral and eulittoral zones and within permanent quadrats (at Scorching Bay only) (Figure 4.1). The percent cover and counts were then rated using SACFOR[2] percentage cover and density scales (see Table 4.1 for an example of how the SACFOR ratings are applied (MNCR 1990)). The risks from pathogens, sedimentation, eutrophication and toxins are considered low so were not assessed.

Overall the range of taxa recorded at all three sites were typical of healthy rocky shores across the range of tidal heights and wave exposures, and the SACFOR method has enabled ease of sampling across a range of tidal states and conditions. There will, however, be a review of the rocky shore monitoring method ahead of the next sampling season, with a view to aligning the methodology with that carried out in other regions and by other agencies, such as the Department of Conservation.

[2] S=Super abundant, A=Abundant, C=Common, F=Frequent, O=Occasional, R=Rare

(Source: Stevens 2018c)

Figure 4.1: Typical low shore assemblage of seaweeds and Coralline turf at Makara, January 2018

Table 4.1: Example of the output from rocky shore monitoring summarising raw quadrat counts, and SACFOR rating of invertebrates and macroalgal present at low shore quadrats, Makara 2018

(Source: Stevens 2018c)

MAKARA

Group	Scientific name	Common Name	Unit	Class	Quadrat	SACFOR
a. High shore						
Barnacles	*Chamaesipho brunnea*	Brown surf barnacle	%	i	20	C
Bivalves	*Mytilus galloprovincialis*	Blue mussel	%	ii	1	R
Red Algae	*Pyropia* sp.	*Porphyra*, Karengo, Nori	%	ii	1	R
Topshells	*Austrolittorina antipodum*	Blue banded periwinkle	#	i	175	C
Topshells	*Austrolittorina cincta*	Brown periwinkle	#	i	1	O
Other	na	Bare Rock	%	i	80	S
b. Mid-low shore						
Anemones	*Actinia tenebrosa*	Red waratah	#	ii	1	F
Barnacles	*Chamaesipho columna*	Column barnacles	%	i	15	F
Barnacles	*Chamaesipho brunnea*	Brown surf barnacle	%	i	5	O
Brown Algae	*Ralfsia* spp.	Tar spot/Brown crust	%	ii	10	F
Green Algae	*Codium convolutum*	Encrusting velvet	%	i	1	R
Limpets	*Cellana ornata*	Ornate limpet	#	ii	8	C
Limpets	*Cellana denticulata*	Denticulate limpet	#	ii	1	F
Red Algae	*Corallina* spp.	Pink paint	%	i	1	R
Topshells	*Austrolittorina antipodum*	Blue banded periwinkle	#	i	100	C
Topshells	*Risellopsis varia*	Periwinkle	#	i	1	O
Topshells	*Diloma aethiops*	Grooved topshell	#	ii	2	F
Other	na	Bare Rock	%	i	70	A

5. Beach condition

In January 2018, Salt Ecology carried out surveys of the Petone, Lyall Bay, and Owhiro Bay beaches. The focus of these surveys was to characterise the biota, and to assess the general condition, or health, of these sand and gravel beaches. The surveys are documented in full in Stevens (2018a), and summarised in a coastal vulnerability report prepared for the Whaitua Te Whanganui-a-Tara committee (Stevens, 2018f).

The survey approach was based on Aerts et al (2004) and involved measuring beach profile, and collecting sediment cores for analyses of invertebrate fauna across a range of tidal heights, extending from the upper beach to the lower intertidal. Sampling at Lyall and Owhiro Bays consisted of single composite samples at six sites intertidal sites and one subtidal site. At Petone Beach (Figure 5.1), sampling was more comprehensive and included three samples at each of 12 sites along two transects.

(Source: Salt Ecology)

Figure 5.1: Petone Beach – gentle beach gradient with fine sands, January 2018

(Source: Stevens 2018a)

Figure 5.2: Sorting invertebrates from a beach sediment sample, January 2018

Overall, across the range of intertidal zones and wave exposures, the beach infauna was relatively species poor, and low in abundance, with the exception of areas with beach-cast seaweed which support good numbers of sand hoppers. This is typical of semi-exposed sandy beaches, however, and when considered with other indicators or beach health, the three beaches monitored were deemed to be in good or very good condition.

6. Wellington Harbour water quality monitoring programme

6.1 Background

The use of real-time telemetered water quality instruments is one tool for monitoring biophysical properties of water. Coupled with discrete water quality sampling, this information can be used to build a baseline picture of water quality, as well as validate existing models for a range of purposes.

NIWA and GWRC have been collaborating on environmental monitoring of Wellington Harbour since 2016, stemming from the overlapping interests between the organisations. For GWRC, this includes a need to have water quality data for Wellington Harbour to be able to assess changes or impacts from the surrounding catchments.

Following the successful deployment of a 'proof of concept' interim buoy (see Elliot (2016) for full details), a high-spec real-time coastal monitoring buoy, WRIBO (Wellington Region Integrated Buoy Observation) was deployed on 10 July 2017 (Figure 6.1). Discrete monthly water quality sampling aligned with the instrument package commenced in August 2017.

6.2 Deployment and monitoring

The WRIBO mooring (Axys Technologies Watchman 500) was deployed from NIWA's RV Tangaroa on 10 July 2017, approximately 2 km south-east of Matiu/Sommes Island (Figure 6.2, Appendix 1). A summary of the array of atmospheric, surface and subsurface instrumentation is listed in Table 6.1.

(Source: NIWA)

Figure 6.1: Wellington Region Integrate Buoy Observations mooring (WRIBO)

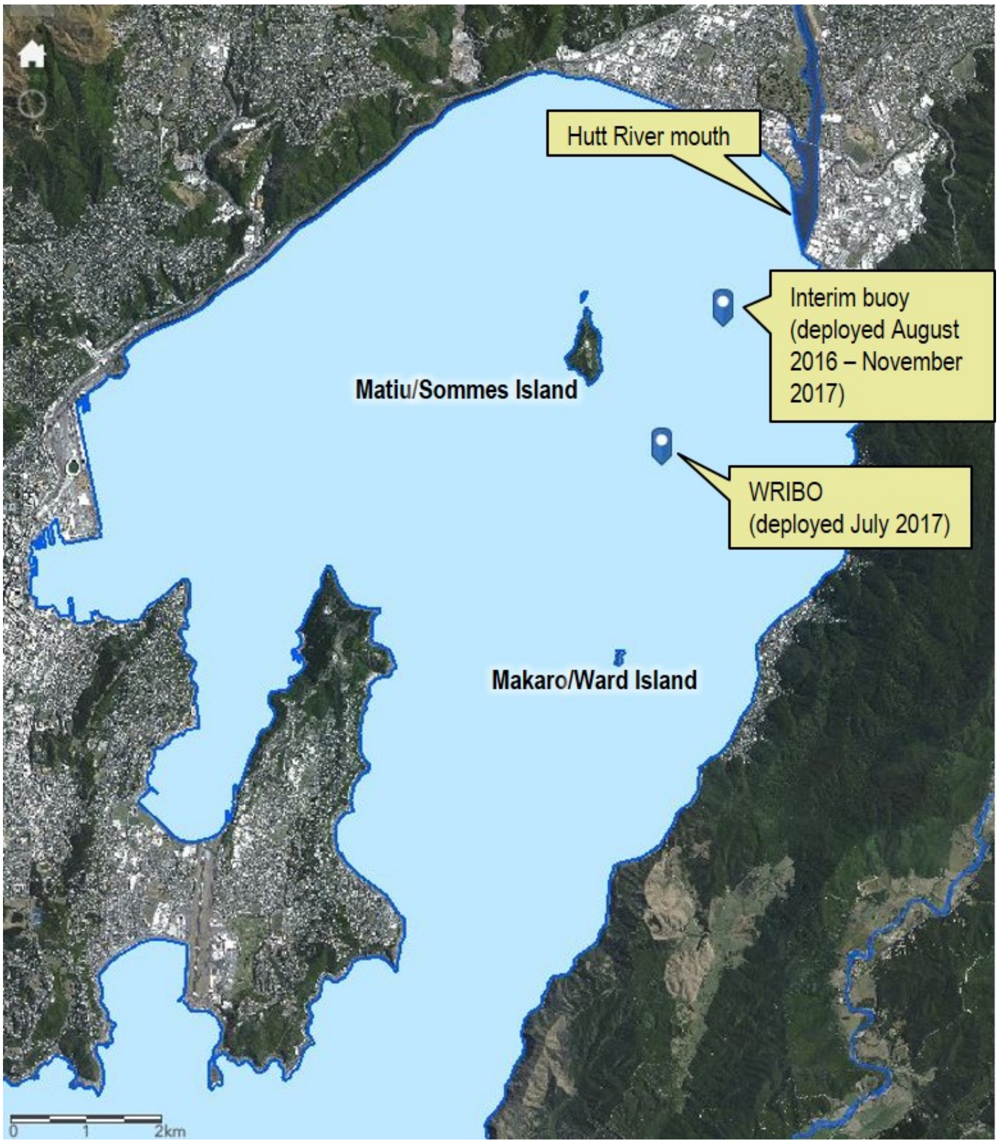

Figure 6.2: Location of the Wellington Region Integrate Buoy Observations mooring (WRIBO) deployed 2 km SE Matiu/Sommes Island 10 July 2017. Location of the interim buoy (deployed August 2016 to September 2017) is also shown.

Table 6.1: Summary of instrument array on Wellington Harbour Integrated Buoy Observations (WRIBO) (from O'Callaghan et al. 2018)

Instrument Manufacturer	Parameter	Sampling interval (mins)	Sampling duration (mins)	Water depth (m)
Rotronic MP 101A	Air temperature and relative humidity	600	600	surface
Gill Windsonic	Wind speed and direction	600	600	surface
Li COR Li-200R	Solar Radiation	600	600	surface
RM Young 61302	Barometric pressure	600	600	surface
Triaxys G3 wave sensor	Directional Waves	1800	1200	WRIBO hull
Seabird Water Quality Monitor (SBE WQM)	Conductivity, temperature, pressure, DO, turbidity, chlorophyll-fluorescence	600	60	1m WRIBO moon pool
Nortek ADCP (400kHZ)	Current speed and direction	600	300	1m WRIBO moon pool
Seabird (SBE) 37 with ODO	Conductivity, temperature, pressure, DO	600	60	5, 10 (18 not yet deployed)
SeaFET	pH	600	60	5
Wetlabs BBFl2B Ecotriplet	Chlorophyll-fluorescence, coloured dissolved organic matter (CDOM) and backscatter at 650 nm	600	60	5 (18 not yet deployed)

A discrete water sampling programme to support the calibration and performance of instruments commenced in August 2017 at the deployment site. Sampling is carried out monthly, but is dependent on GWRC Harbour Department staff availability and weather conditions.

Water samples are collected using a hand held van Dorn grab (3L) deployed to selected depths corresponding to the depth of moored instrument. Water samples were decanted into standard laboratory supplied bottles. As far as possible, all sample handling was in accordance with protocols set out in Part 4 of the draft National Environmental Monitoring Standards for Water Quality (NEMS 2017). The suite of physico-chemical variables and analytical methods are listed in Appendix 2.

In addition, water sampling for SeaFET pH data validation commenced in September 2018 following the deployment of the SeaFET pH sensor at 5m water depth; this data will contribute to the New Zealand Ocean Acidification Observation Network (NZOA-ON). Sampling follows protocols set out by the NZOA-ON research leads from NIWA and Department of Chemistry, Otago University. Water samples for the NZOA-ON are being preserved and held at GWRC until required for full analysis and reporting (scheduled for 2019).

6.3 Key findings

NIWA summarised the performance of the interim buoy in a preliminary report covering the deployment period from 31 August 2016 – 8 November 2016 (see Elliot 2016 for full details). Further analysis and interpretation for both the interim buoy (for the period September 2016 to September 2017), as well as the real time buoy (August 2017 to July 2018) are set out in O'Callaghan et al. (2018).

Figure 6.3 displays a time series of key data from instruments on WRIBO. As with the interim buoy, significant weather events and the influence of the Hutt River are being picked up by the surface instrument arrays. Changes in surface temperature, salinity, turbidity and chlorophyll-a indicated surface water parameters changed in response to local weather events such as rainfall, as well as tracking with seasonal temperature increases during the summer months.

The increase in water temperature is evident across the annual data summary (Fig 6.3b) – with an average increase of around 14°C between winter and summer months. During relatively drier months (November – February), when rainfall was typically less than 10 mm, the surface salinity was high at approximately 34 psu (Figure 6.3c). During periods of high rainfall, the surface salinity decreased. Over 20% of the days in June 2018 experienced rainfall over 10 mm, and the surface salinity during this period was often 20 psu. Below the surface, salinity was a constant 34 psu.

Surface concentrations of cholorophyll-*a* generally increased following high rainfall periods and an associated increase in freshwater flowing from the Hutt River to the harbour. These high rainfall events also led to a corresponding supersaturation of dissolved oxygen.

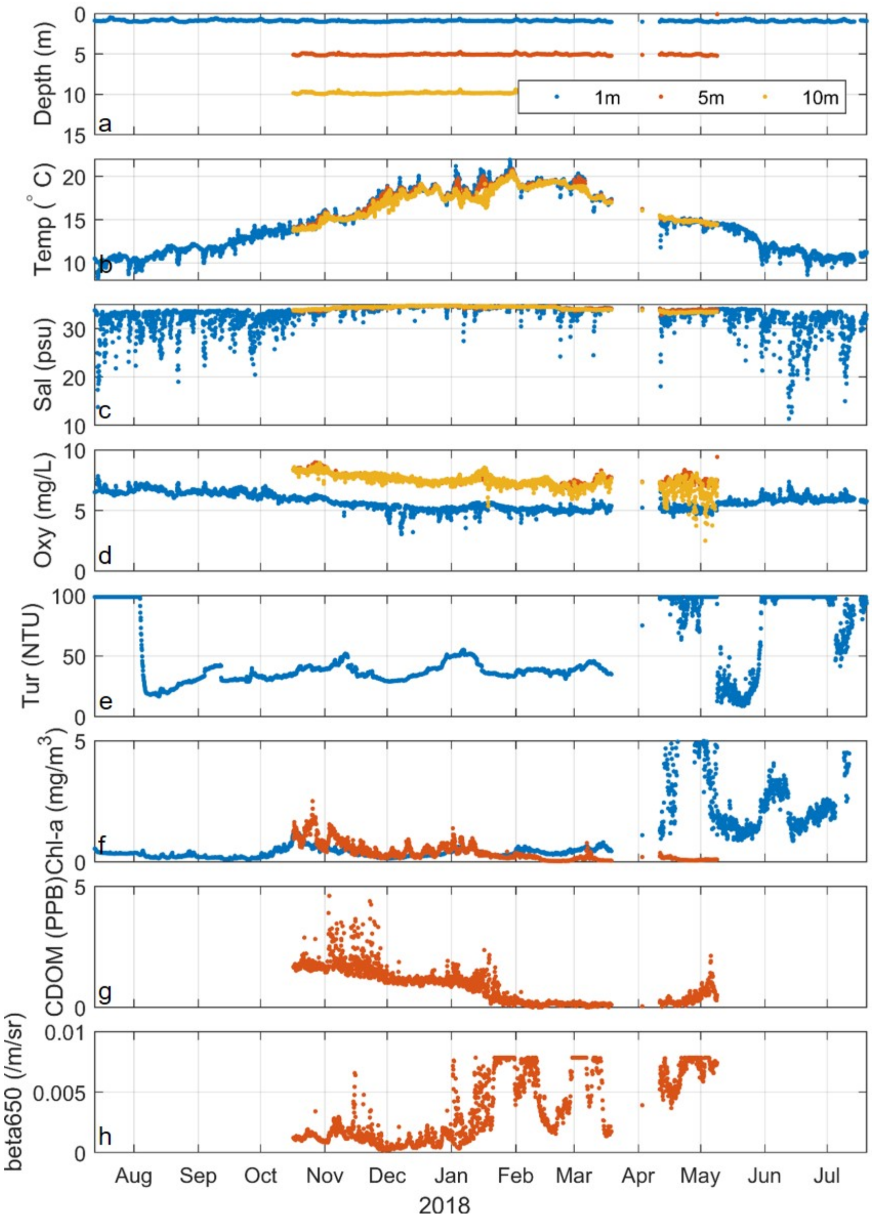

Figure 6.3: Time series from instruments on Wellington Region Integrated Buoy Observations (WRIBO): (a) instrument depth, (b) temperature, (c) salinity, (d) dissolved oxygen concentration, (e) turbidity, (f) chlorophyll-s, (g) CDOM and (h) backscatter. From O'Callaghan et al. (2018).

6.3.1 Discrete water sampling

Discrete water sampling was carried out adjacent to the mooring array every month from September 2017 to the present. In-situ samples for salinity, chlorophyll-*a* and turbidity (and other parameters listed in Appendix 2) were collected at depths of 1, 5, 10 and 18 m. Comparison of discrete samples and time series observations from depths with relevant sensors was undertaken by NIWA to provide an additional evaluation of data quality (see O'Callaghan et al. 2018 for further details).

7. Porirua Harbour microbial forecast model

7.1 Background

In 2015 a water quality forecast with a focus on enterococci contamination was developed for Porirua Harbour, building on previous investigations of hydrodynamics and faecal contamination in the harbour. This was initially set up as an action under the Te Awarua-o-Porirua Harbour Strategy and Action Plan, and was prompted by successive years of poor recreational water quality in the harbour.

The development of the three day forecast was intended to address the limitations of the traditional approach to monitoring recreational water quality (for full discussion refer to Milne et al. 2017). The approach is also fully operational as part of the Auckland Council ‘Safeswim’ programme. For further context of the range of available options, including this approach of mechanistic ‘white box’ modelling, refer also to the review undertaken by Puhoi Stour Ltd. for GWRC (Neale 2018).

The Porirua forecast has been running since January 2016, and the full details of the assumptions, updates and performance of the forecast in the third year are available in the technical annual quality status report (Tuckey 2018).

A screen display of the seven sites for which the forecast is available is shown in Figure 7.1.

Figure 7.1: Representative map display of seven water quality forecast sites in Porirua Harbour

Following the 2016/17 performance report recommendations, several updates to the Global Forecast System (GFS) forecast were implemented (September 2017):

- Onepoto and Takapuwahia Stream inflows were incorporated, with flow derived by scaling the observed Porirua Stream flow (for the Onepoto Stream),and by a ratio of mean flows based on previous studies (for the Takapuwahia Stream),

- The assumed concentrations of enterococci for inflows to the Onepoto Arm (Porirua, Kenepuru, Onepoto, Takapuwahia Stream) were calculated based on the preceeding 12 h rainfall categories (>1 mm or <1 mm),

- Takapuwahia Stream source contamination was adjusted according to wind direction and its influence on sediment resuspension.

For the Rowing Club, Waka Ama Launch and South Beach locations, predictions from the forecast were re-run with several modifications (see Tuckey 2018 for full details):

- Adjustment to the wind speed, stream inflow and enterococci concentration for the Takapuwahia Stream

- The assumed enterococci concentration for Taupo Stream inflo was re-calculated based on preceeding 12 h rainfall scaled to categories <1 mm and > 1 mm

- Forecast data was extracted from the actual surveillance sample location (rather than constant sub-tidal location).

7.2 Field sampling and model validation

Data for model validation was sourced from the routine recreational water quality surveillance sampling programme conducted between 1 December 2017 and 31 March 2018. No additional sampling was carried out during 2017/18 due to time and budget constraints, as well as uncertainty regarding the future of the forecast tool development.

For routine sampling, the sample procedures were undertaken according to standard protocols outlined in MfE/MoH (2003) guidelines, and Brasell and Conwell (2018). Laboratory methods for freshwater and marine samples are listed in Appendix 2.

The performance of the model set-up is based on the comparison of the observed data against the predictions. For simplicity and comparison against scenarios, only the frequency of exceedance of the red/action trigger of 280 cfu/100 mL (MfE/MoH 2003) was compared as per Table 7.1.

Table 7.1: Comparison of model performance (number of predicted alerts) compared with routine observations (number of observed alerts).

		Predicted	
		No alert	Alert
Observed	No alert	Match	False negative
	Alert	False Positive	Match

The optimal performance of the model would be to have 100% agreement between the two green squares in Figure 7.1 (ie, matching number of observed versus predicted). A ‘false positive’ is undesirable, and indicates an observed alert (>280 cfu/100 mL) has not been predicted by the forecast. Some ‘false negatives’ (alert is predicted where none was observed) can be considered acceptable (i.e. overly precautionary).

7.3 Key findings

A summary of the results from the 2017/18 annual quality status report are presented in Table 7.2.

Table 7.2: Model performance compared with routine observations. Comparison (as % of total observations) of alert mode (>280 cfu/100mL) for observed and model forecast concentrations of enterococci at routine recreational monitoring sites in Porirua Harbour 2017/18

			Predicted			
			2016/17 model		2017/18 Updated model	
			No Alert	Alert	No Alert	Alert
Observed	Rowing Club	No Alert	75	6	67	11
		Alert	3	16	3	19
	Waka Ama	No Alert	71	5	48	22
		Alert	24	0	8	22
	Sth Beach	No Alert	78	0	79	2
		Alert	22	0	12	7
	Water Ski*	No Alert	100	0	na	na
		Alert	0	0	na	na

*Performance of the updated forecast at Water Ski Club site was not undertaken as there was no change in the model set up that influenced forecasted contamination.

Although there was no event based data against which to assess the model, for the available sites the percentage of matches between observed and predicted alert levels generally demonstrated that the model performed well across routinely monitored sites.

The model was shown to perform well at both the Rowing Club and Water Ski Club site – false positive alerts were minimised (with zero at the Water Ski site). There was no change in the false positive percentage at the rowing Club with the updated model compared to the 2016/17 model (Table 7.2), but slight increase in the false negative (i.e overly precautious). The updated model performed slightly better at South Beach, with an increase from 78% to 86% matches between the observed and predicted alerts levels (Table 7.2). The updated model was needed to improve the percentage of prediction (and to decrease the false positive alerts) at the Waka Ama site.

The forecast will be put on hold in 2018/19 pending further discussions and recommendations about funding and alignment with other work programmes.

8. Wellington Harbour subtidal sediment emerging organic contaminant assessment

8.1 Background

In 2016, GWRC carried out the third survey of subtidal sediment quality and invertebrate community health in Wellington Harbour. The focus of these surveys has been the accumulation of stormwater contaminants and for the first time sediment samples were collected from 10 sites and analysed for emerging organic contaminants (EOCs).

The EOCs analysed in the sediment samples were selected from the core list of Tier 1 EOCs recommended for monitoring in sediment in New Zealand in the 2016 review report on EOCs prepared by Stewart et al (2016) (see Appendix 2.8 for analytical summary table). The methods and results of the analysis of EOCs in the subtidal sediment samples from Wellington Harbour are reported in full in Olsen et al (2017); results are summarised in Table 8.1. Full interpretation of results is provided in Northcott (2018).

8.2 Key findings

Overall there was an absence of many compounds from the Tier 1 suite; compounds were not detected above their respective method detection limits (LOR, limit of reporting). These included most of the flame retardants, plasticisers, perfluorinated compounds (PFAS), musk fragrances, the herbicide glyphosate, and pharmaceuticals compounds.

The EOCs that were more prevalent, or detected in 5 or more of the ten analysed subtidal sediment samples, were the flame retardant (TCPP), plasticisers (butylbenzyl phthalate, bisphenol-A), a surfactant (technical nonylphenol), the pyrethroid insecticide bifenthrin, a steroid estrogen (estrone), personal care products (triclosan, methyl-paraben) and the anti-corrosive compound benzotriazole. Except for estrone, these EOCs are all high production volume chemicals that are common components in a wide range of domestic and industrial products and household chattels.

There are limited environmental quality guideline criteria against which results can be benchmarked. However, for the EOCs for which international criteria are available, the concentrations for all but one (tricolan) were at least one order of magnitude lower than their respective guideline value (see Northcott (2018) for details).

There is also very limited data on residues of EOCs in New Zealand marine sediments to compare against that obtained from the analysis of the Wellington Harbour subtidal sediments. However of the available information, results for Wellington Harbour sediments were well below those reported in Auckland and overseas (see Northcott 2018 for full discussion).

Table 8.1: Concentration of EOCs analysed in sediments of Wellington Harbour in µg/kg dry weight sediment

Class	Representative EOC	WH-1	WH-2	WH-3	WH-4	WH-7	WH-10	WH-15	AQ-1	AQ-2	LB-1	Field blank	LOR[A] (µg/kg)
Flame retardants	BDE[B] 47	N.D[C]	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.1
	BDE 99	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.1
	BDE 209	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	1
	TDCP[D]	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	1
	TPP[E]	2.18	N.D	3.67	N.D	N.D	N.D	1.36	N.D	N.D	2.67	N.D	1
	TCPP[F]	12.1	N.D	1.69	10.7	4.04	N.D	N.D	N.D	2.22	13.6	N.D	1
Plasticisers	DEHPAE[G]	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	20
	BBPAE[H]	30.4	19.7	31.6	27.9	20.8	25.1	8.33	20.5	16.1	40.4	N.D	10
	Bisphenol-A	0.57	N.D	1.52	N.D	N.D	N.D	N.D	0.84	0.64	4.76	N.D	0.5
Surfactants	4-n-Nonylphenol	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.1
	Tech-NP EQs[I]	21.5	18.5	54.1	42.3	38.2	74.2	83.8	73.9	90.3	96.2	N.D	10
PFAS[J]	Numerous	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	1.0
Polycyclic musk fragrances	Galaxolide	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	3.0
	Tonalide	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	1.0
Herbicide	Glyphosate/AMPA	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	20/20
Pyrethroid insecticides	Bifenthrin	0.76	0.31	0.36	0.16	0.31	0.78	0.62	0.30	0.91	0.64	N.D	0.1
	cis-permethrin	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.43	N.D	N.D	0.4
	trans-permethrin	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.1
Pharmaceuticals	Acetaminophen	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.1
	Carbamazepine	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.5
	Diclofenac	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.5
	Ibuprofen	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.5
Steroid estrogen	Estrone	1.30	1.37	2.82	1.22	1.27	2.06	2.85	1.86	1.28	1.53	N.D	0.05
Personal care product	Triclosan	0.20	0.17	N.D	0.63	0.37	0.26	N.D	0.51	0.16	1.30	N.D	0.1
	Methyl-Triclosan	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	2.08	N.D	0.1
Preservative	Methyl-Paraben	0.44	0.32	2.31	0.53	0.45	0.29	1.64	0.76	0.34	0.53	N.D	0.1
Anti-corrosive	Benzotriazole	6.53	8.20	8.17	1.63	10.7	2.48	N.D	2.99	6.78	4.98	N.D	1.0

[A] LOR = Limit of reporting, [B] brominated diphenyl ether, [C] N.D = not detected above the LOR, [D] TDCP = Tris-(2-chloro-1-(chloromethyl)ethyl)phosphate, [E] TPP = Triphenylphosphate, [F] TCPP = Tris-(1-chloro-2-propyl)phosphate, [G] Diethylhexylphthalate acid ester, [H] Butylbenzylphthalate acid ester, [I] Sum of the eleven highest response peaks in a technical mixture of branched nonylphenol isomer, [J] Perfluorinated alkyl substances, sum of 23 individual compounds as listed in Appendix 1, highest response peaks in a technical mixture of branched nonylphenol isomer.

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Appendix 1: Monitoring sites

Table A1.1: Wellington Harbour subtidal sediment quality monitoring sites, 2016. Sites at which emerging contaminants were collected are highlighted in bold.

Site	Location / Sample collection	NZTM co-ordinates	
		Easting	Northing
WH1	**Southern Evans Bay** / *R, EC*	**1751530**	**5425348**
WH1B	*B*	1751492	5425333
WH2	**Northern Evans Bay** / *R, EC*	**1751710**	**5427288**
WH2B	*B*	1751744	5427271
WH3	**Lambton Basin entrance** / *R, EC, BR*	**1750056**	**5428340**
WH3B	*B*	1750055	5428303
WH4	**~ 0.7 km NW of Point Jerningham** / *R, EC*	**1750763**	**5428789**
WH4B	*B*	1750775	5428760
WH5	~ 1.2 km NNE of Point Jerningham / *R*	1751748	5429138
WH5B	*B*	1751743	5429104
WH7	**≈ 1.5 km N of Point Halswell** / *R, EC*	**1753581**	**5429932**
WH7B	*B*	1753604	5429907
WH9	~ 1.5 km SSE of Ngauranga Stream mouth / *R*	1751921	5430708
WH9B	*B*	1751975	5430747
WH10	**~ 0.5 km SSE of Ngauranga Stream mouth** / *R, EC*	**1752012**	**5431724**
WH10B	*B*	1752008	5431740
WH13	~ 1.25 km S of Petone Wharf / *R*	1756023	5433121
WH13B	*B*	1756061	5433126
WH15	**~ 1.1 km SW of Seaview (Hutt River mouth)** / *R, EC*	**1758160**	**5431778**
WH15B	*B*	1758176	5431750
WH17	~ 1.6 km NNW of Makaro/Ward Island	1756770	5428847
WH17B	*R, BR*	1756793	5428858
WH18	~1.75 km WSW of Seaview (Hutt River mouth) / *R*	1757450	5432426
WH18B	*B*	1757460	5432435
EB2	Evans Bay , Western side / *R*	1750896	5425520
EB2B	*B*	1751283	5425517
LB1	**Lambton Harbour ~ 250 m from shore (FK Park)** / *R, EC*	**1749263**	**5427887**
LB1B	*B*	1749262	5427872
LB2	Lambton Harbour ~ 500 m from shore (FK Park) / *R*	1749576	5427939
LB2B	*B*	1749541	5427940
AQ1	**~ 0.5 km ENE of Aotea Quay east** / *R, EC*	**1750317**	**5429346**
AQ1B	*B*	1750331	5429374
AQ2	**~ 0.5 km ENE of Aotea Quay west** / *R, EC*	**1750125**	**5430214**
AQ2B	*B*	1750133	5430254

R: routine sediment chemistry, B: benthic fauna collection area, *EC*: emerging contaminant sediment collection, *BR*: bulk reference sediment sample collection

Table A1.2: Wellington Harbour interim and real-time buoy mooring sites

Site	NZTM	
	Easting	Northing
Interim buoy SW of the Hutt River mouth (18 m depth)	1758074	5431236
WRIBO, SE of Matiu-Sommes (20 m depth)	1757265	5429427.95

Table A1.3: Porirua Harbour microbial water quality forecast sites

Site	NZTM	
	Easting	Northing
South Beach at Plimmerton*	1756810	5449874
Pauatahanui Inlet at Water Ski Club*	1758074	5449593
Pauatahanui Inlet at Browns Bay	1757989	5447780
Pauatahanui Inlet at Ivey Bay	1757356	5447977
Pauatahanui Inlet at Shellfish Collection Site	1756697	5447910
Porirua Harbour at Rowing Club*	1754891	5446947
Porirua Harbour at Waka Ama (Wi Neera Drive)*	1754485	5445706

* Sites monitored under the Recreational Water Quality Monitoring Programme

Appendix 2: Monitoring variables and methods

Microbiological water quality for Porirua Harbour microbial water quality field sampling

Results of weekly surveillance monitoring under the recreational water quality monitoring programme were used to validate the Porirua Harbour microbial water quality model assumptions. All sampling was undertaken in accordance with the 2003[4] Ministry for the Environment (MfE) and the Ministry of Health (MoH) microbiological water quality guidelines for marine and freshwater recreational areas (Mfe/MoH 2003). For routine water samples collected from coastal waters, these were generally sampled weekly during the summer bathing season (1 December to 31 March inclusive) and fortnightly at selected sites. The recommended indicator for coastal water is enterococci (with faecal coliforms the preferred indicator for shellfish gathering waters). Refer to Brasell and Cowell (2018) for full details of GWRC's microbiological water quality monitoring methods, site details, and results of the routine bathing water monitoring.

[4] The guidelines were published in June 2002 and updated in June 2003.

Table A2.1: Summary of discrete water quality sampling physico-chemical measured at the Wellington harbour mooring array (WRIBO)

Variable	Unit	Detection Limit	Method	Source
Field measurements				
Dissolved oxygen	ppm	0.1	CTD	Field
Dissolved oxygen saturation	% sat	0.01	CTD	Field
Temperature	^{o}C	0.1	CTD	Field
Conductivity	mS/m	0.1	CTD	Field
Laboratory measurements				
Salinity	-	0.01	APHA (2012) 2520 B	Lab
pH	pH units	0.01	APHA 4500-H^{+}	Lab
Suspended sediment conc.	mg/L	10.0	ASTM D3977-97 (modified)	Lab
Turbidity	NTU	0.1	APHA (2012) 2130 B (modified)	Lab
VSS	mg/L	3.0	APHA 2540 E GF/C 1.2 µm	Lab
Chlorophyll-*a*	mg/L	0.0006	APHA (2012) 10200 H (modified)	Lab
Nitrate nitrogen (NO3)	mg/L	0.002	Calculation (NNN - NO2)	Lab
Nitrite nitrogen (NO2)	mg/L	0.002	APHA (2012) 4500-NO2 B (modified)	Lab
Ammoniacal nitrogen (NH4-N)	mg/L	0.005	APHA (2012) 4500-NH3 G (modified)	Lab
Total kjeldahl nitrogen (TKN)	mg N /L	0.02	APHA (2012) 4500-org A, D Modified	Lab
Total nitrogen (TN)	mg N /L	0.02	APHA (2012) 4500-P J, 4500-NO3 F (modified)	Lab
Soluble reactive phosphorus	mg/L	0.0006	APHA (2012) 4500-P B, F Mod	Lab
Total phosphorus	mg/L	0.005	APHA (2012) 4500-P B,J (modified)	Lab

Table A2.2: Summary of selected classes and representative individual emerging organic contaminants analysed in Wellington Harbour sediment samples

Class	Representative EOC	Estimated LOR[A] (ug/kg)
Flame retardants	BDE[B] 47	0.01-1.0
	BDE 99	0.01-1.0
	BDE 209	0.01-1.0
	TDCP[C]	1.0-20
	TPP[D]	1.0-20
	TCPP[E]	1.0-20
Plasticisers	Diethylhexyl phthalate	50-100
	Butylbenzyl phthalate	1.0-20
	Bisphenol-A	1.0-20
Surfactants	4-n-Nonylphenol	0.1-10
	Technical nonylphenol equivalents[F]	0.1-10
Perfluorinated Compounds[G]	Various	1.0
Musk fragrances	Galaxolide	0.1-10
	Tonalide	0.1-10
Herbicides	Glyphosate, AMPA	20/20
Pyrethroid insecticides	Bifenthrin	0.10
	Permethrin[H]	0.20
Pharmaceuticals[I]	Acetaminophen	0.1-1.0
	Carbamazepine	0.1-1.0
	Diclofenac	0.1-1.0
	Ibuprofen	0.1-1.0
Steroid estrogen	Estrone	0.01 - 10
Personal care product	Triclosan[J]	0.05-5.0
	Methyl-Triclosan	0.05-5.0
Preservative	Methyl-Paraben	0.1-10
Anti-corrosive	Benzotriazole	0.1-10

[A] Limit of reporting, [B] brominated diphenyl ether, [C] TDCP = Tris-(2-chloro-1-(chloromethyl)ethyl)phosphate, [D] TPP = Triphenylphosphate, [E] TCPP = Tris-(1-chloro-2-propyl)phosphate, [F] Sum of the eleven highest response peaks in a technical mixture of branched nonylphenol isomers, , [G] see Appendix 1 in Northcott (2018) for full list of PFAS chemicals, [H] cis- and trans- isomers, [I] all non-steroidal anti-inflammatory drugs (NSAIDs), [J] Phenolic antimicrobial chemical.