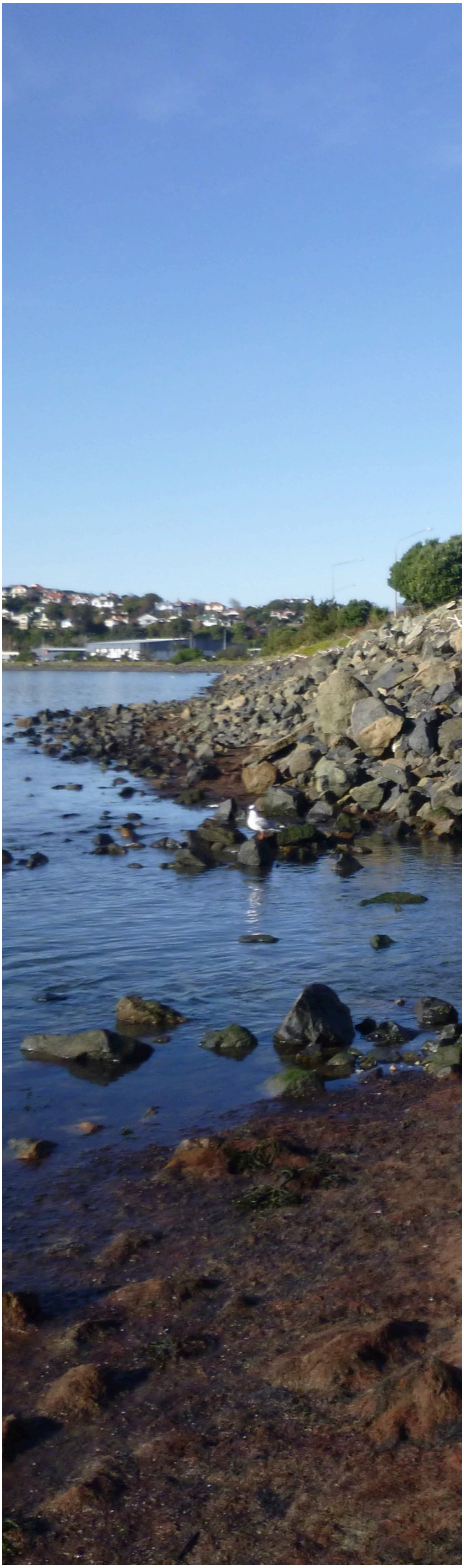

Dunedin City Council

Stormwater Monitoring

July 2018 – June 2019

ryder

Dunedin City Council

Stormwater Monitoring

July 2018 to June 2019

Prepared for Dunedin City Council

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Executive Summary

Dunedin City Council operates the Dunedin stormwater system. Monitoring of stormwater and the receiving environments is required by Otago Regional Council resource consents (RM11.313.01 - RM11.313.10). Between July 2018 and June 2019, required monitoring included stormwater quality during dry and wet weather conditions, harbour water quality during dry and wet weather conditions, harbour sediments, and harbour biological communities.

Dry weather sampling of stormwater found variable levels of faecal contamination. However, there were no outfalls with consistently high results and therefore no outfalls require immediate further investigation.

Automated sampling of stormwater during rainfall events in the Mason Street catchment found variable contaminant concentrations between and during each rain event, with similar concentrations to those found in previous monitoring of other catchments.

Harbour water quality sampling during dry weather found high copper concentrations at all sites, but the source of the copper is unlikely to be a single or point source discharge. Comparisons of harbour water with dry weather discharges from stormwater outfalls indicate contamination of the harbour water can be influenced by dry weather discharges, but sources other than stormwater, such as surface runoff, are also important contributors of contaminants to the harbour.

Harbour sediment contaminant concentrations were low in 2019 and well below the resource consent trigger levels. PAH concentrations, in particular, at some sites were much lower in 2019 than in previous results. Reductions in contaminant inputs to the harbour in recent years have contributed to a decline in contaminant concentrations in harbour sediments.

Harbour biological communities were similar to those found in previous surveys, with low diversity but high variability between sites. There were no obvious differences in communities between sites adjacent to stormwater outfalls and sites without any stormwater inputs.

1. Introduction

Dunedin City Council (DCC) operates the Dunedin stormwater system which comprises a network of gutters, open channels, pipes, mud tanks, and outfalls. The principal coastal receiving water environments for Dunedin's reticulated stormwater are the upper basin of Otago Harbour, Port Chalmers, and, on the open coast, Second Beach and St. Clair Beach. Otago Regional Council (ORC) resource consents (RM11.313.01 - RM11.313.10) authorise the discharge of stormwater from ten stormwater catchments to these receiving environments (Figure 1). Conditions of the consents require monitoring of stormwater quality during dry and wet weather conditions, harbour water quality during dry and wet weather conditions, harbour sediments, and, on a biennial basis, harbour biological communities.

DCC engaged Ryder Environmental to undertake the required monitoring in 2018-19. This report summarises the monitoring undertaken between July 2018 and June 2019.

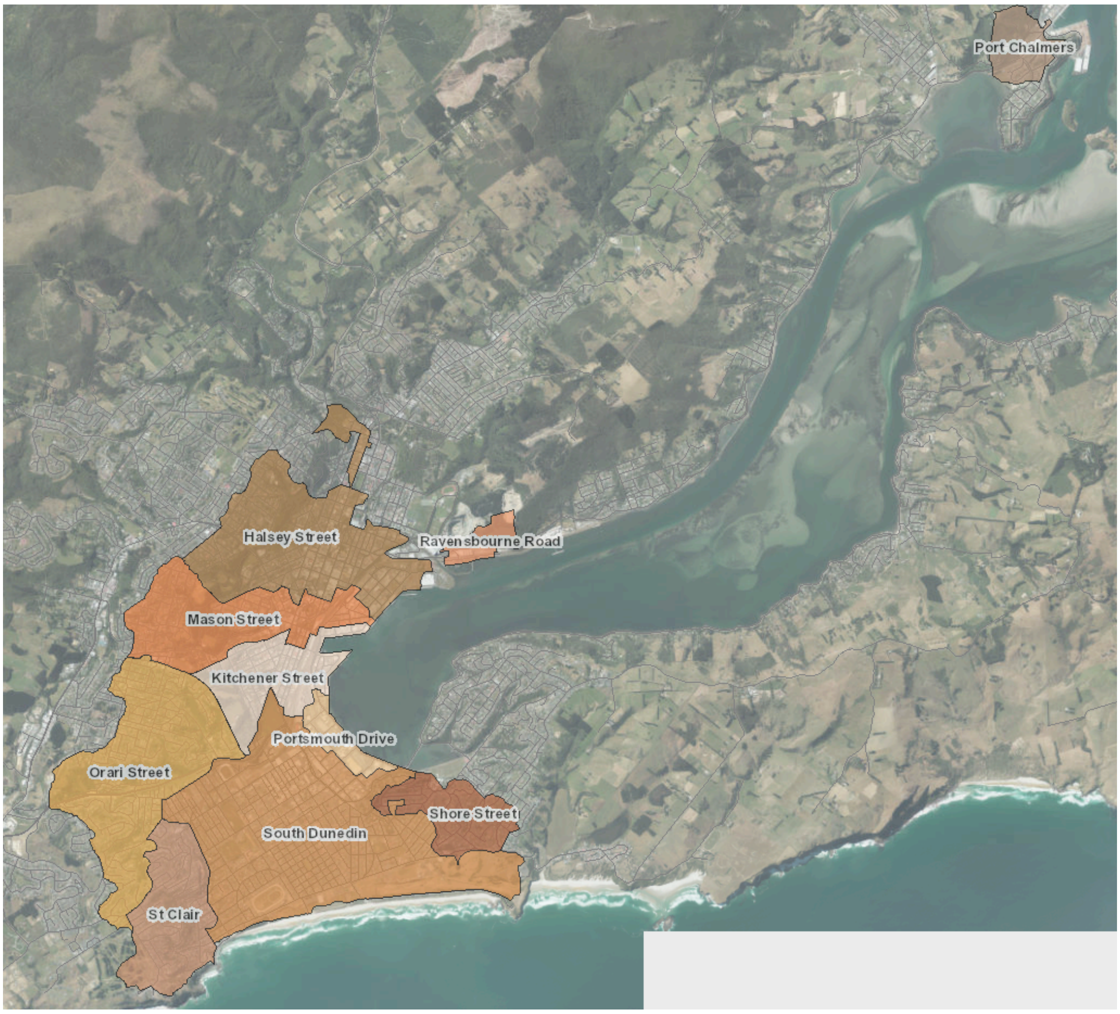


Figure 1. Dunedin stormwater catchments. From DCC webpage.

2. Methods

2.1 Stormwater outfalls

Monitoring of stormwater quality is required at 14 larger outfalls and many smaller outfalls where Dunedin's stormwater discharges to receiving environments (Figure 2). Many of Dunedin's outfalls have long histories dating back to the early settlement of the city. A number of the outfalls do not have outfall structures or are inaccessible for sampling. It is therefore neither practical nor possible to sample all 33 outfalls at the discharge point to the receiving environment. However, access at many sites is available via manholes a short distance upstream from the outfall.

2.2 Stormwater – Dry weather

Dry weather sampling is required at stormwater outfalls (Figure 2) at low tide (to avoid seawater contamination) during dry weather that includes an antecedent dry period of at least 72 hours. Samples are collected for laboratory analysis (Eurofins) for *Escherichia coli* (*E. coli*), which is a type of bacteria commonly found in the guts of warm-blooded mammals (including people) and birds, and is used as an indicator of faecal contamination in freshwater. The indicator bacteria themselves do not pose a significant risk to human health, but rather indicate the likely presence of faecal material which contains disease-causing pathogens. Sources of *E. coli* bacteria include untreated wastewater and faecal deposition by birds and other animals (e.g., dogs). Samples are also collected and analysed on site for fluorescent whitening agents (FWAs) using an *AquaFluor* Handheld Fluorometer/Turbidimeter. FWAs are used in laundry detergents and, as household plumbing mixes effluent from toilets with washing machine 'grey water', FWAs are usually associated with human faecal contamination and indicate possible wastewater infiltration to the stormwater system (Petch 1996, Gilpin *et al.* 2004). Dry weather sampling allows the determination of background contaminant levels entering the receiving environments via stormwater outfalls, and can indicate possible cross-connections between stormwater and wastewater systems. Where human wastewater is present, both elevated *E. coli* concentrations and FWA levels are expected. At some outfalls where indicators of human wastewater have not been detected or there is generally no flow, sampling is only required six-monthly, while sampling at other outfalls is required monthly (when all conditions for sampling are met) (see Appendix One).

2.3 Stormwater – Wet weather

Wet weather sampling is required at ten major stormwater outfalls at low tide within one hour of the commencement of a rain event (more than 2.5 mm of rain), following an antecedent dry period of at least 72 hours. Sampling under these conditions is undertaken in an endeavour to sample the first flush, which is likely to contain the highest concentration of contaminants. Samples are collected for laboratory analysis (Eurofins) for arsenic, cadmium, chromium, copper, nickel, lead, zinc, oil and grease, suspended solids, pH, polycyclic aromatic hydrocarbons (PAH), and *E. coli* (the freshwater faecal indicator bacteria).

Figure 2. Dunedin stormwater outfalls. Monthly dry weather sampling sites (blue circles) and six-monthly dry weather sites (green circles). See Appendix One for outfall information. Aerial photo from Google Earth.

Figure 2 continued. Dunedin stormwater outfalls. Monthly dry weather sampling sites (blue circles) and six-monthly dry weather sites (green circles). See Appendix One for outfall information. Aerial photo from Google Earth.

2.4 Automated sampler – Wet weather

The ISCO automated sampler is used to target specific stormwater outfalls during wet weather and is located within stormwater catchments as required by the resource consent. Since February 2018, the automated sampler has been located near Toitu Museum, approximately 600 m up-pipe of the Mason Street stormwater outfall (Figure

3). The automated sampler has been programmed to collect samples over the first two-hour period of a rain event (more than 2.5 mm of rain) that coincides with low tide, following an antecedent dry period of at least 72 hours. When the automated sampler is triggered successfully under the correct conditions, samples are collected for laboratory analysis (Eurofins) for arsenic, cadmium, chromium, copper, nickel, lead, zinc, oil and grease, suspended solids, pH, polycyclic aromatic hydrocarbons (PAH), and *E. coli* (the freshwater faecal indicator bacteria).

Figure 3. The location of the ISCO automated sampler, near Toitu, sampling the Mason Street catchment. Mason Street stormwater outfall indicated by green circle. Aerial photo from Google Earth.

2.5 Harbour water

Monitoring of harbour water quality is required at six sites in the upper harbour (Figure 4). Sampling of harbour water quality is required on four occasions, targeting two rainfall events and two dry periods. Sampling for a rainfall event is required within three hours of the commencement of a rain event (more than 2 mm of rain) following an antecedent dry period of at least 72 hours, while sampling for a dry period is following an antecedent dry period of at least 72 hours. Samples are to be collected at mid-flood tide and mid-ebb tide on each occasion. Dry weather sampling allows the determination of background contaminant levels in harbour water, while wet weather sampling assesses the contribution of contaminants from stormwater inputs into the harbour. Ebb tides (outgoing tides) are likely to move contaminants down harbour while flood tides (incoming tides) may lead to higher concentrations of contaminants in the upper harbour. It must be noted, however, that inputs from the Water of Leith can complicate contaminant levels, especially during flood tides. Samples are collected for laboratory analysis (Eurofins) for cadmium, copper, lead, zinc, and enterococci. Enterococci is a type of bacteria commonly found in the guts of warm-blooded mammals (including people) and birds, and is used as an indicator of faecal contamination in marine water; enterococci have been identified as having the best relationship with health effects in marine waters (Ministry for the Environment 2003). The indicator bacteria themselves do not pose a significant risk to human health, instead they indicate the presence of faecal material which contains disease-causing pathogens. Sources of enterococci bacteria include untreated wastewater and faecal deposition by birds and other animals (e.g., dogs).

2.6 Harbour sediment

Monitoring of harbour sediment quality is required at four sites in the upper harbour (Figure 4). Sediments are a potential source and sink for dissolved contaminants, and assessing sediment quality can identify where contaminant concentrations could result in adverse effects on ecological communities. Sampling of harbour sediment quality involves the collection of the uppermost 20 mm of sediment. At the Orari Street and Shore Street sites, samples are collected directly from the substrate by scraping the top 20 mm into a collection jar. At the Halsey Street and Kitchener Street sites, sampling is required in deep water (approximately 3-7 m deep) and sediment is subsequently collected using a petit ponar grab with a subsample obtained from the uppermost 20 mm of the contents of the grab. Samples are collected for laboratory analysis (Eurofins) for arsenic, cadmium, chromium, copper, nickel, mercury, lead, zinc, weak acid extractable copper, total petroleum hydrocarbons (TPH), organochlorine pesticides, and polycyclic aromatic hydrocarbons (PAH).

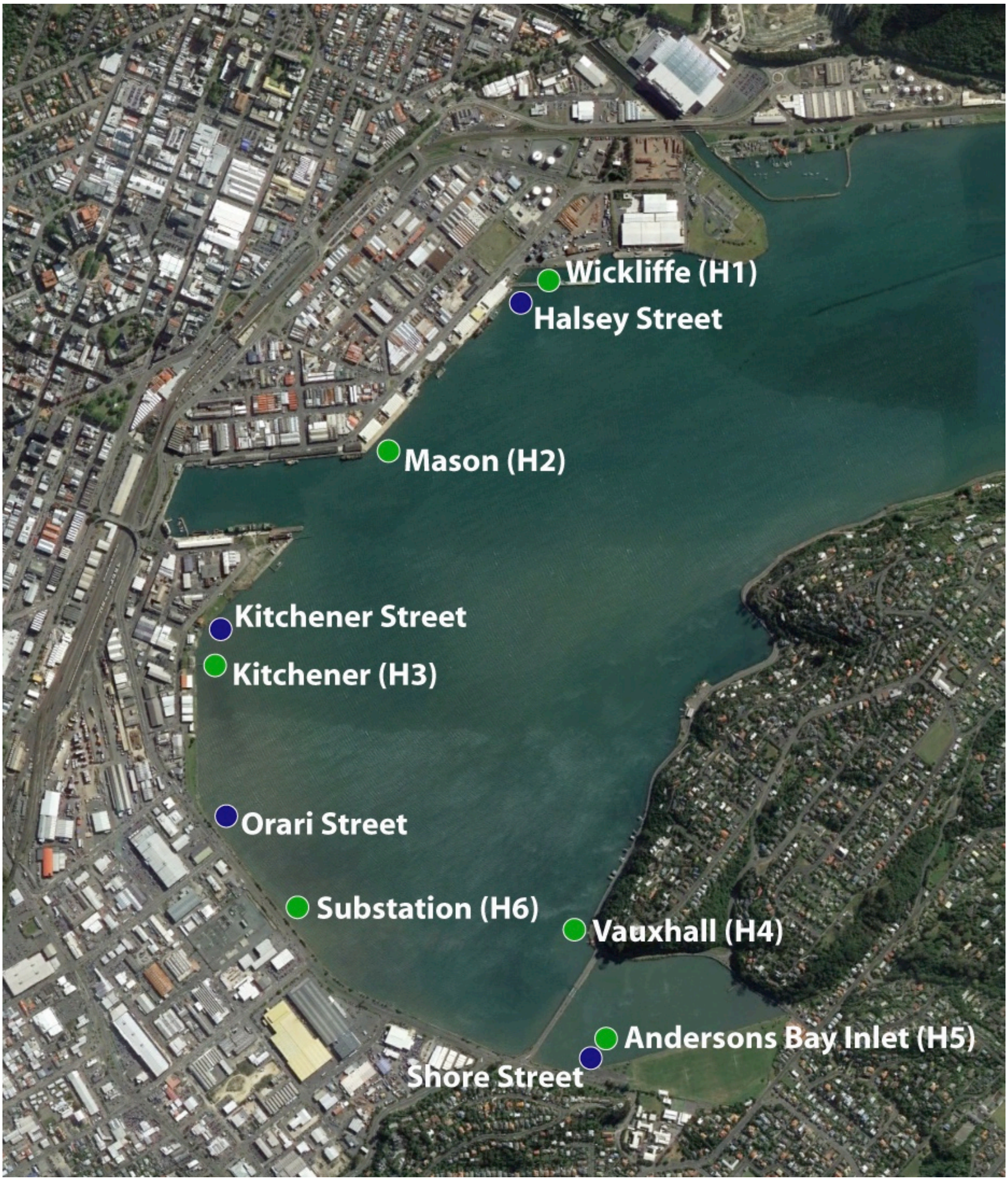


Figure 4. Otago Harbour water quality sampling sites (green circles) and sediment sampling sites (blue circles). Aerial photo from Google Earth.

2.7 Harbour biological

Sampling the biological communities of Otago Harbour sites is required at two yearly intervals. Biological monitoring is required at five sites in Otago Harbour (Figure 5). The Kitchener Street, Orari Street and Portobello Road sites are located near stormwater outfalls, while the Burkes and Macandrew Bay sites are not directly impacted by stormwater outfalls and are therefore considered control sites.

Biological sampling has two components: sampling the epifauna, infauna, and macroflora at five sites (including two control sites), and sampling the flesh of cockles (*Austrovenus stutchburyi*) at three sites.

Epifauna, infauna, and macroflora

Epifauna, infauna, and macroflora sampling is required at five sites. At the Kitchener Street, Orari Street, and Portobello Road sites, sampling was undertaken at the waters edge at low tide in three areas (0-5 m from the stormwater outfall, 5-20 m from the outfall, and >50 m from the outfall). Due to the absence of stormwater outfalls at the Burkes and Macandrew Bay control sites, sampling was undertaken at three random areas along the waters edge at low tide. At each area, the percentage cover of macroflora was estimated within three 1 m^2 quadrats, epifauna was identified and counted within five 0.25 m^2 quadrats, and infauna samples were collected in three sediment cores (85 mm diameter cores to a depth of 200 mm). Sediment cores were sieved in the field using a 500 µm mesh sieve and all retained organisms were returned to the laboratory (Ryder Environmental) for identification and enumeration.

Cockles

As shellfish are filter feeders and filter particles out of the water, they can accumulate contaminants from their direct environment. Sampling cockles to determine the amount of contaminants in their flesh is required at three sites. Cockle samples were collected by hand at low tide and within 20 m of the stormwater outfall at the Kitchener Street, Orari Street, and Portobello Road sites. Cockles were returned to the laboratory (Ryder Environmental) where they were measured before being delivered to the Eurofins laboratory for analysis for copper, lead, arsenic, cadmium, chromium, polycyclic aromatic hydrocarbons (PAHs), and enterococci (the marine faecal indicator bacteria).

Figure 5. Otago Harbour biological sampling sites. Aerial photo from Google Earth.

3. Results and Discussion

3.1 Stormwater – Dry weather

Dry weather sampling of stormwater outfalls was undertaken under the required weather and tidal conditions in August, September, and December 2018, and in April and May 2019 (see Appendix Two for sampling data). Dry weather sampling could not be undertaken during the other months between July 2018 and June 2019 due to weather conditions not being suitable (e.g., no antecedent dry period of at least 72 hours) and/or tidal conditions not being suitable for sampling (e.g., low tide in the middle of the night).

Dry weather sampling at the stormwater outfalls is undertaken to determine background contaminant levels. High faecal indicator concentrations under dry conditions could be due to stormwater and wastewater systems cross-connections, but can also be influenced by surface runoff from surrounding land (e.g., dog faeces, bird droppings). To understand potential sources of contaminants, looking at both the FWA levels (which indicate possible wastewater infiltration) and the *E. coli* concentrations (which can come from a variety of sources) for each sample is important. If FWA levels remain low but *E. coli* concentrations are high, the result may indicate contamination from, for instance, surface runoff. If both FWA levels and *E. coli* concentrations are high, the result may indicate possible wastewater contamination.

Sampling undertaken in August and September 2018 revealed variable levels for FWAs and/or *E. coli*. Sampling at outfall 3 (Shore Street catchment) revealed *E. coli* concentrations exceeded the trigger level of 550 cfu/100mL on both sampling occasions. However, FWA levels only exceeded trigger levels on one sampling occasion. Sampling at outfalls 24 and 25 (both Halsey Street catchment) revealed *E. coli* concentrations exceeded the trigger level of 550 cfu/100mL on both sampling occasions, but FWA levels were below trigger levels (Appendix Two). Variable results such as these are similar to results from previous years of monitoring.

In late November 2018, a heavy rain event with the potential to result in overflows of wastewater into the stormwater network occurred in Dunedin city. Sampling of harbour water quality in the vicinity of stormwater outfalls during this event (initiated by DCC to understand potential impacts of any wastewater overflows on the receiving waters) revealed high faecal contaminant concentrations, likely as a result of wastewater overflows into the stormwater network. Dry weather sampling was undertaken two weeks after this rain event in early December 2018, when the required conditions of an antecedent dry period of at least 72 hours and suitable tide conditions were met. This sampling also included sites only required to be sampled once every six months. The dry weather sampling revealed high *E. coli* concentrations and FWA levels at many of the outfalls sampled. These high contaminant concentrations in the outfalls were likely to have been influenced by the preceding rain event, with remnant wastewater in the stormwater system potentially continuing to be discharged with residual flows under the drier conditions. It should be noted, however, that laboratory error resulted in many samples being over-diluted (due to the expectation of high faecal contaminant concentrations as were found in samples collected during the heavy rain event) and detection limits were set too high, resulting in several concentrations that are not useful for interpretation (e.g., < 100,000 cfu/100mL).

Sampling undertaken in April and May 2019 revealed similarly variable levels for FWAs and/or *E. coli* as found in August and September 2018. Outfalls 6 and 7 (both Portsmouth Drive catchment) had high FWA and *E. coli* concentrations in May 2019, with outfall 7 having especially high *E. coli* concentrations. FWA levels were low at most other outfalls (Appendix Two).

Catchments with three consecutive sampling occasions with both elevated *E. coli* and FWAs are subject to further investigation. For example, sampling in previous years revealed high levels of *E. coli* and FWAs at Bauchop Street outfalls and subsequent investigations found an illegal connection that has since been rectified. Between July 2018 and June 2019, no outfalls had consistently high results, and therefore no further investigations are required.

3.2 Stormwater – Wet weather

Between July 2018 and June 2019 the conditions required to undertake wet weather sampling at stormwater outfalls (i.e., at low tide, within one hour of the commencement of a rain event (more than 2.5 mm of rain), following an antecedent dry period of at least 72 hours) were not met within daylight hours (required for safety reasons), and no wet weather sampling was therefore able to completed in 2018-19.

3.3 Automated sampler – Wet weather

While sampling of wet weather events at several stormwater outfalls could not be undertaken under suitable conditions between July 2018 and June 2019, sampling of stormwater during a wet weather event was undertaken by the automated sampler. The ISCO automated sampler, located at a Mason Street catchment site, was triggered successfully under correct conditions for two rain events, on 25 February 2019 (rainfall event of 5.2 mm) and 26 March 2019 (rainfall event of 6.4 mm).

Of the contaminants tested for during the rainfall events, concentrations of cadmium, lead, and PAH were all below detectable limits throughout each event, and all but two samples (out of 24) from the March event had concentrations of copper lower than detectable limits. Arsenic concentrations were relatively stable throughout both rainfall events, with only minor variation during the March event, while pH was stable during the March event (Appendix Three).

Contaminant concentrations during a rainfall event are generally expected to follow a pattern of low initial concentrations at the start of the event, increasing contaminant concentrations with the first flush of runoff, and then gradually decreasing concentrations as the rainfall event progresses. However, the intensity of the rainfall event, the rate of onset of the rainfall, and the length of the antecedent dry period can influence concentrations, resulting in different contaminant concentrations with time during each rainfall event. As the February and March 2019 rainfall events both had similar, and relatively low, total rainfall (5.2 mm and 6.4 mm respectively, compared to rainfall of 17.6 mm in a November 2016 rain event), similar patterns of contaminant concentrations might be expected during both events. However, concentrations of contaminants that were above detectable limits were variable during and between the rainfall events (Figure 6), possibly due to differing rates of rainfall onset. Zinc and nickel concentrations were highest at the start of each event and decreased quickly as each event continued. During the March event, chromium and oil and grease concentrations started relatively low but peaked with high concentrations approximately 40-50 minutes into the event. Suspended solids and *E. coli* concentrations were more variable, with *E. coli* concentrations remaining low throughout the February event, but with considerable fluctuations throughout the March event.

These variable results have also been found during previous years of monitoring, and previous automatic sampling has also found similar contaminant concentrations in other catchments. Some contaminant concentrations during the 2019 rainfall events were, however, slightly lower than found previously (e.g., zinc), which may be due to the relatively low total amount and possibly intensity of the rainfall during the 2019 events. More intense rainfall is expected to transport higher contaminant concentrations in surface runoff to the stormwater.

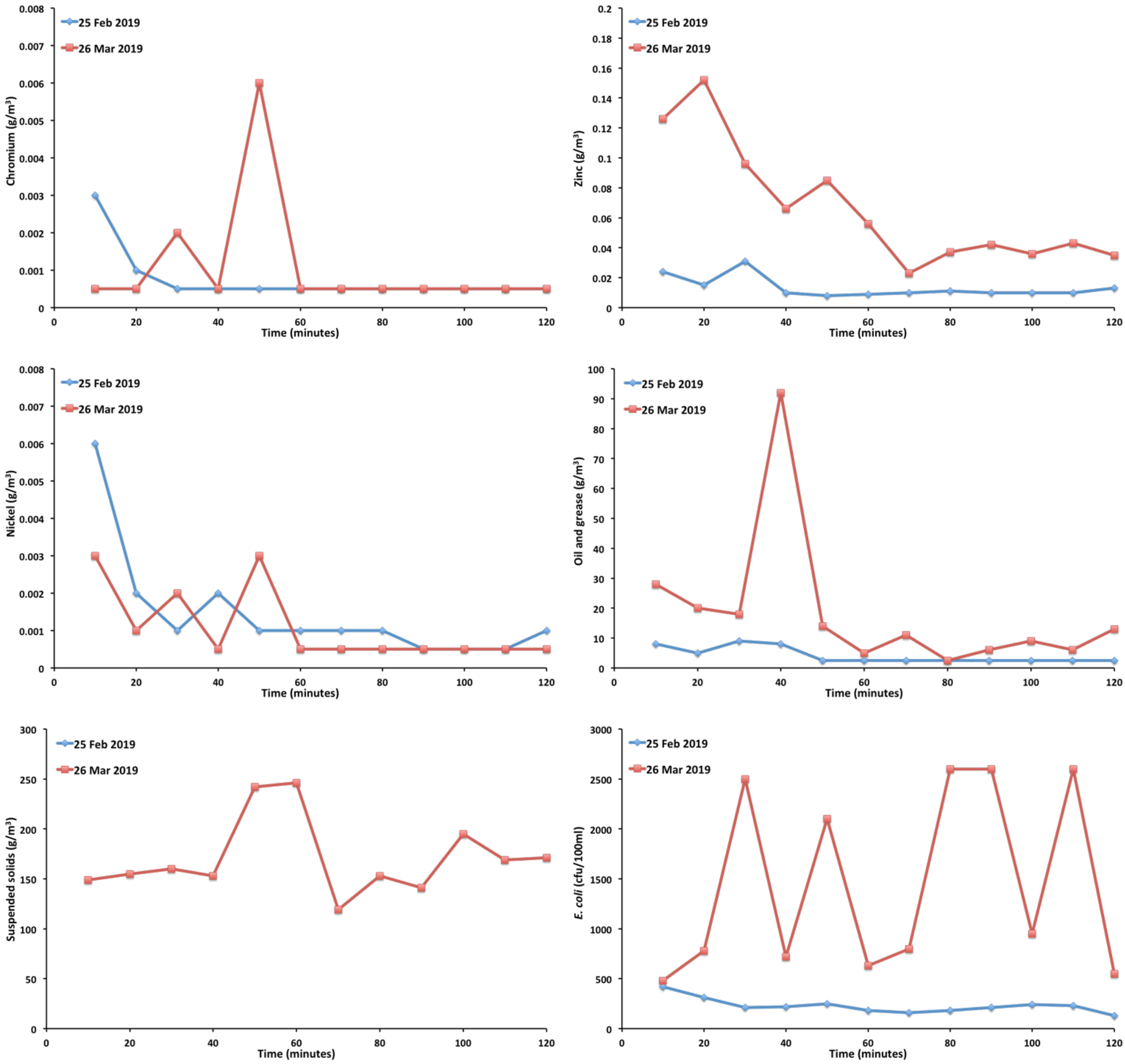


Figure 6. Concentrations of selected contaminants collected by the ISCO automated sampler in the Mason Street stormwater catchment. See Appendix Three for all data. Samples collected every ten minutes over a two-hour period during rainfall events on 25 February and 26 March 2019. Note suspended solids data is not available for the February 2019 sampling event (due to laboratory constraints).

In addition to the two rainfall events sampled by the ISCO automated sampler, the sampler was incorrectly triggered (i.e., false alarms) on nine occasions between July 2018 and June 2019. False alarms can be due to a range of causes, including the sampler being triggered when insufficient total rain falls during an event, the sampler incorrectly filling all bottles, the sampler being triggered but tidal conditions resulting in potential for saltwater intrusion (depending on the site of the sampler in the catchment), and/or a malfunction or maintenance issue with the sampler (e.g., perforated tubing within the sampler, flat battery).

The ISCO automated sampler will remain at its current location until a third rainfall event is successfully sampled and will then be moved to the Halsey Street catchment in 2019-20.

3.4 Harbour water

Sampling of harbour water quality is required on four occasions, targeting two rainfall events and two dry periods. Between July 2018 and June 2019, however, the weather (i.e., following an antecedent dry period, within three hours of the commencement of a rain event (more than 2 mm of rain)) and tidal (i.e., mid-flood tide and mid-ebb tide at times when sampling can be completed safely) conditions required for sampling a rainfall event did not coincide, and therefore no rainfall events were able to be sampled.

The weather and tidal conditions required for sampling a dry period were met only once between July 2018 and June 2019, on 9 April 2019, and sampling was therefore undertaken at the six required sites on a mid-ebb and a mid-flood tide (Table 1).

Sampling results (except for enterococci) are compared against ANZECC (2000) trigger levels for ‘slightly-moderately disturbed’ ecosystems, with concentrations below the 95% protection level trigger values indicating low risk of adverse biological effects, with 95% of species expected to be protected. However, the trigger levels are not ‘magic numbers’ at which an effect occurs if exceeded (ANZECC 2000), and instead are used as a trigger for response (e.g., further monitoring or actions). Enterococci are compared against the Ministry for the Environment (2003) alert (amber) limit, which considers the potential risk for recreational use. Although the upper harbour basin is popular with wind surfers, paddle boarders, and other boat users when conditions permit, it is not a recognised swimming area. Consequently, the alert (amber) limit could be considered conservative and potentially not appropriate for much of the time.

Results of the April 2019 dry period sampling revealed that on the mid-ebb tide (i.e., outgoing tide), copper concentrations exceeded trigger levels at all six harbour sites (Table 1). Lead and zinc concentrations exceeded trigger levels at one and two sites respectively. Concentrations of all three of these contaminants exceeded trigger levels at the Mason site only.

During the mid-flood tide (i.e., incoming tide), copper concentrations again exceeded trigger levels at all six sites, with lead and zinc exceeding trigger levels at two and three sites respectively, and enterococci exceeding the alert (amber) limit at two sites (Table 1).

In contrast to the mid-ebb tide samples, copper was the only contaminant that exceeded trigger levels at the Mason site, while the Substation and Andersons Bay Inlet sites both had exceedances of all four of these contaminants.

Table 1. Harbour water sampling data from a dry weather sampling event on 9 April 2019. Orange cells indicate values exceed trigger levels.

	Cadmium (g/m^3)	Copper (g/m^3)	Lead (g/m^3)	Zinc (g/m^3)	Enterococci (cfu/100mL)
Trigger levels	**0.0055**[1]	**0.0013**[1]	**0.0044**[1]	**0.015**[1]	**140**[2]
Mid-ebb tide					
Wickliffe (H1)	<0.0002	0.0039	<0.0005	0.007	<4
Mason (H2)	<0.0002	0.0132	0.0058	0.037	20
Kitchener (H3)	<0.0002	0.0082	<0.0005	0.008	12
Substation (H6)	<0.0002	0.0084	0.0035	0.019	80
Vauxhall (H4)	<0.0002	0.0073	<0.0005	0.005	48
Andersons Bay Inlet (H5)	<0.0002	0.0082	0.0011	0.008	120
Mid-flood tide					
Wickliffe (H1)	<0.0002	0.0056	<0.0005	0.007	23
Mason (H2)	<0.0002	0.0120	0.0014	0.010	8
Kitchener (H3)	<0.0002	0.0088	<0.0005	0.022	16
Substation (H6)	0.0003	0.0189	0.0179	0.099	13,000
Vauxhall (H4)	<0.0002	0.0075	<0.0005	0.006	4
Andersons Bay Inlet (H5)	<0.0002	0.0129	0.0066	0.027	1,200

1. ANZECC (2000) trigger values for protection of 95% of species (from resource consent).

2. Ministry for the Environment (2003) alert (amber) limit (from resource consent). The alert (or amber) mode is triggered when a single sample is greater than 140 enterococci per 100 mL for marine waters.

These samples were collected during a dry weather period, and therefore indicate background contaminant levels in harbour water without any influence from high volume stormwater inputs. Flood tides (incoming tides) can lead to higher concentrations of contaminants in the upper harbour, with other inputs to the harbour (e.g., the Water of Leith) also potentially contributing contaminants. The contaminant of most concern from these samples is copper, which exceeded trigger levels at all sites. Copper is widely used in a range of applications, including vehicle brakes, plumbing (e.g., piping, gutters and downpipes), and a range of agricultural and industrial activities. The exceedances of lead and zinc were not consistent between the different stages of the tide, except zinc which exceeded trigger levels at the Substation site during both tide stages and had higher concentrations during the flood tide. The Substation site also had the highest enterococci concentration, but as sources of enterococci include faecal deposition by animals (e.g., birds, dogs), determining the source of any contamination may be difficult. Lead has historically been used in paint and petrol, but persists in plumbing (e.g., pipes, roofing) and can be sourced from industrial activities. Zinc is commonly associated with galvanised building materials (e.g., roofs), and also industrial activities.

Copper and zinc have previously exceeded trigger levels during dry period sampling (e.g., in 2017). Wet weather sampling has typically revealed higher concentrations of these contaminants in the harbour, likely due to runoff from the catchments entering the harbour. Copper concentrations in harbour water during the 2019 dry period sampling were generally higher than found during both dry and wet period sampling in 2017-18, but the exceedance of copper trigger levels at all sites in 2019 indicates that higher levels are unlikely to be the result of single or point source discharges.

The resource consent states that if harbour water quality sampling identifies contaminants at a level exceeding the trigger values, the level of contamination shall be confirmed by re-sampling and re-analysis. Subsequently, if the harbour water quality is confirmed as exceeding the trigger values, the protocol outlined in Condition 10 of the permits shall be implemented. The exceedance of the trigger levels in early April 2019 therefore required confirmation (by re-sampling and re-analysis) of the contaminant levels. However, re-sampling requires the appropriate weather (i.e., an antecedent dry period) and tidal conditions (i.e., mid-flood tide and mid-ebb tide at times when sampling can be completed safely) to be met, to allow for comparable results from the original exceedance. Unfortunately these conditions were not met and subsequently no re-sampling could be undertaken.

Harbour water – stormwater comparison

The April 2019 dry period sampling of harbour water was undertaken on the same day as dry weather sampling of stormwater outfalls. A comparison of stormwater and harbour water results on this sampling occasion is useful to investigate potential influences of the stormwater on harbour water quality. While there is no exact relationship between enterococci and *E. coli* concentrations (Ministry for the Environment 2003), both are used as indicators of faecal contamination.

The dry-weather stormwater discharge from outfall 3 (Shore Street catchment) had an *E. coli* concentration of 21,000 cfu/100mL, while harbour water collected at the nearby Andersons Bay Inlet on the outgoing tide had an enterococci concentration of only 120 cfu/100mL. On the incoming tide, when contaminants can be transported back into the upper harbour and subsequently concentrations can be higher, the enterococci concentration increased to 1,200 cfu/100mL.

The highest *E. coli* concentration in dry-weather stormwater discharges near the Substation harbour water site (from outfall 8, Orari Street catchment) was 390 cfu/100mL, while the harbour water on the outgoing tide had an enterococci concentration of 80 cfu/100mL and on the incoming tide, when concentrations can be higher, the enterococci concentration was much higher at 13,000 cfu/100mL.

These comparisons reveal the complexity of stormwater and harbour water, with examples of high stormwater contaminant concentrations not leading to high harbour water contaminant concentrations (e.g., Shore Street and Andersons Bay Inlet), and low stormwater contaminant concentrations only contributing small amounts of contaminants to high harbour water contaminant concentrations (e.g., Orari Street and Substation). These variable results indicate that contamination of the harbour water can be influenced by contributions from dry stormwater discharges, but contributions from sources other than stormwater, such as surface runoff, are also important. The results also highlight the potential for dilution once discharges reach the receiving environment.

3.5 Harbour sediment

Sampling of harbour sediment quality was undertaken at the four upper harbour sites (see Figure 4) in June 2019. As found during previous sampling, surface sediments (where visible) were generally clean with little surface detritus.

Contaminant concentrations in harbour sediments were well below the trigger levels listed in the resource consent, with only exceedances of the low ANZECC (2000) trigger levels for lead, mercury, and zinc occurring (Appendix Four). Lead concentrations at Halsey Street and Shore Street were above the ANZECC (2000) low trigger, but were well below both the ANZECC (2000) high trigger and the 2013 trigger level listed in the resource consent. Similarly, mercury concentrations at Shore Street were above the ANZECC (2000) low trigger, but were well below the ANZECC (2000) high trigger. Zinc concentrations at Halsey Street and Shore Street were above the ANZECC (2000) low trigger, but were well below the ANZECC (2000) high trigger and were considerably lower than the 2013 trigger level listed in the resource consent (Appendix Four). These results reveal that while concentrations of some contaminants were slightly elevated at some sites, overall concentrations were low and all well below the 2013 trigger levels listed in the resource consent.

Contaminant concentrations in sediments have been generally considerably lower in recent years than at some historic sites. The Kitchener Street site has historically had high values of metal contaminants, which may have been influenced by the close proximity of the site to scrap metal yards. Sites in the vicinity of the South Dunedin (Portobello Road) outfall have had high PAH concentrations due to historic contamination from stormwater, especially from the old gas works. However, improvements in wastewater/stormwater connections and the cessation of many industrial activities have reduced contaminant input to the harbour. In 2019 sediment samples, PAH concentrations at all sites were low (all less than 2 mg/kg), which is considerably lower than historic concentrations. For instance, sampling at the Orari Street site in 2018 found a PAH concentration of 142.82 mg/kg, which is very high compared to the 2019 concentration at this site of <0.75 mg/kg (i.e., below laboratory detectable limits). It should be noted that contaminated sediment can be remediated naturally when fresh sediments, able to support viable biological populations, settle on top of them (ANZECC 2000). However, the lower contaminant concentrations found in sediments in 2019 are likely to be part of expected variability, and slight increases to concentrations that fall within natural variability at some sites should not be cause for alarm in subsequent sampling. It is also possible that extreme weather events in the future could disturb and redistribute some of the contaminated sediments along the harbour foreshore.

3.6 Harbour biological

Macroflora

Macroflora, the plants and algae present on the harbour bed, and therefore influenced by contaminants within the harbour water and sediments, were surveyed at the five Otago Harbour sites at low tide on 9 April 2019. Diversity of macroflora was generally similar across each site, and between sites (Figure 7). The highest diversity of macroflora was at the Orari Street site, while no macroflora were found more than 5 m from the outfall at the Portobello Road site. The control sites at Burkes and Macandrew Bay had generally lower diversity across each site than at the sites near stormwater outfalls, except for the areas at Portobello Road where no macroflora were observed. However, the range of diversity was similar at all of the sites where macroflora were present. Overall, macroflora diversity was similar in 2019 to that seen previously (e.g., between one and two taxa per site in 2017, between one and four taxa per site in 2015).

Cover of the harbour bed by macroflora was more variable than diversity between sites, with all areas at Orari Street covered, less than 20% of the bed at Kitchener Street covered, and less than 2% cover at the other three sites (Figure 7). The high cover levels at Orari Street were dominated by the red algae *Ceramium*, with some green algae (e.g., *Codium*) on top of the red algae (Figure 8) (see Appendix Five). The high cover levels at Orari Street were very localised, only affecting approximately 50 m of the foreshore. The red algae *Ceramium* was found at all sites, and also dominated cover at Kitchener Street, but at much lower abundance than at Orari Street. It is suspected that the majority of the macroflora at Orari Street was drift algae. Consequently, while its presence within the harbour may be due to higher temperatures, high sunlight levels, and possible nutrient enrichment, its presence at the Orari Street site would be mainly due to wind and tide conditions prevailing at the time. In July 2019, cover of the algae was observed to be decreasing, possibly due to colder weather. Should extensive beds persist at this site, further investigations into nutrient concentrations in the surrounding water may be useful.

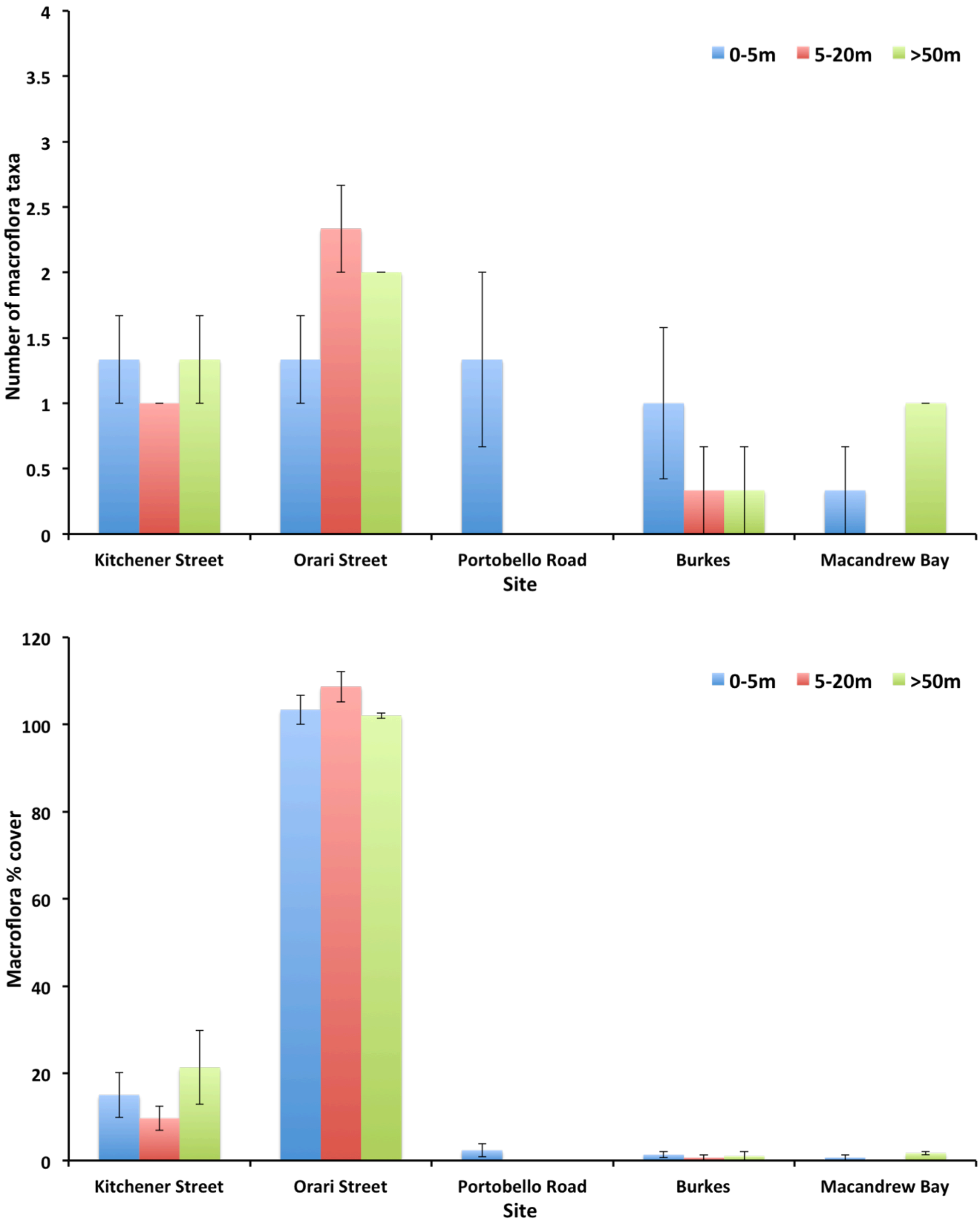


Figure 7. Mean number of macroflora taxa (top) and mean percentage cover by macroflora (bottom) at the five harbour biological sites, April 2019. Means +/- one standard error.

Figure 8. Examples of macroflora at Otago Harbour sites, April 2019.* Codium *(green algae) on top of extensive beds of* Ceramium *(red algae) at Orari Street site (left) and no macroflora at Burkes (right).

Overall, macroflora cover was similar in 2019 at Portobello Road and the two control sites to 2017 results, with generally less than 3% total cover per quadrat. However, cover was higher at Kitchener Street and considerably higher at Orari Street in 2019 than in 2017. The 2015 survey found higher cover levels than in 2017, with high cover of *Ceramium* at the Kitchener Street site (up to 80% cover per quadrat). These results indicate the variability in macroflora throughout the harbour. As biological surveys are generally undertaken at similar times each year (in the years surveys are required), seasonal effects should be minimised. However, weather conditions prior to each survey can influence cover, with stable conditions (e.g., calm harbour conditions) providing more suitable conditions for macroflora growth than more variable conditions (e.g., high winds and wave action), which can distribute drifting algae throughout the harbour.

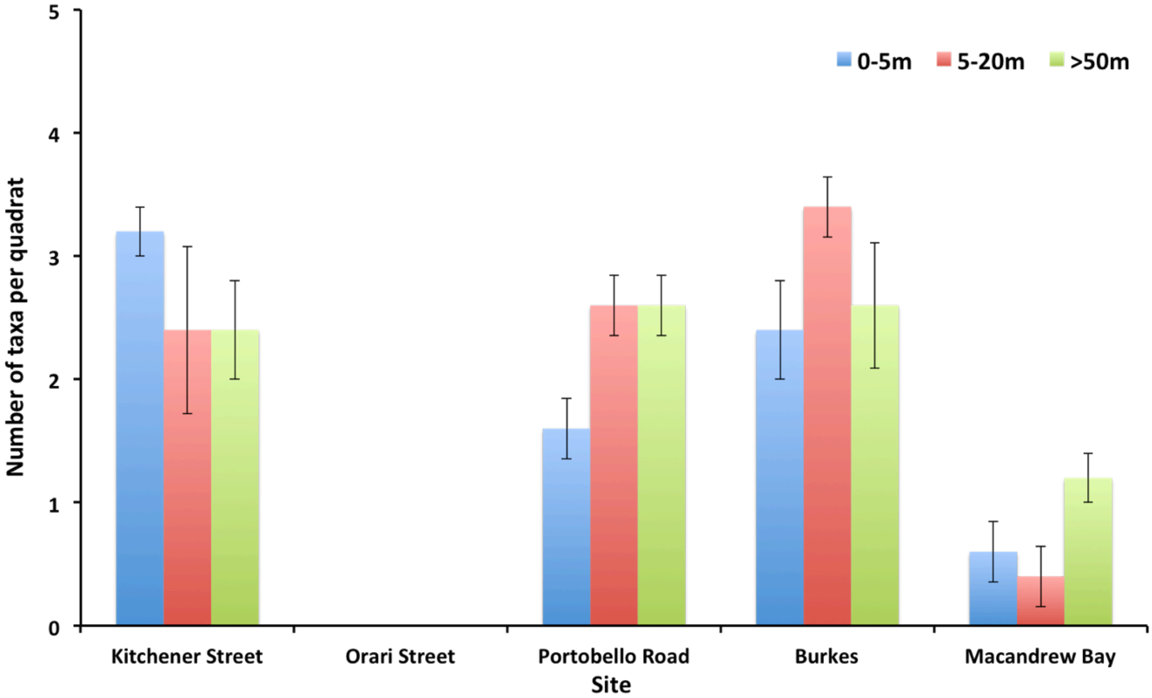
Epifauna

Epifauna, the invertebrates living on the harbour bed, and therefore influenced by contaminants within the harbour water and sediments, were surveyed at the five Otago Harbour sites at low tide on 9 April 2019. Diversity of epifauna was variable within and between sites (Figure 9). At Kitchener Street, diversity seemed to decrease with distance from the outfall, while diversity increased with distance at other sites, a more expected result. No epifauna were observed at Orari Street due to the extensive cover of macroflora. Aside from Orari Street, the Macandrew Bay control site had the lowest diversity of epifauna, with similar ranges of diversity at the other three sites, including at the other control site, Burkes.

Molluscs were the most diverse group of taxa, with a total of eight different molluscan taxa found overall (see Appendix Six). The number of molluscan taxa at each area of a site ranged between one (0-5 m at Macandrew Bay) to six (>50 m at Burkes), but most areas had three to four different molluscs. Other taxa recorded during the survey were *Macophthalmus* crabs and *Anthopleura* anemones. Differences between 2019 results and previous surveys include the absence of tubeworms and barnacles at Kitchener Street in 2019. These animals were found on rocks near the Kitchener Street outfall in 2017, but spatial variation in communities between surveys is expected due to the low number of rocks, which can support diverse communities, at the different sites. The random placement of quadrats may also mean the rocks surveyed in the past were not surveyed on this occasion.

Abundance of epifauna was highest near the Kitchener Street outfall (0-5 m), where high numbers of *Anthopleura* anemones were found (Figure 9, Appendix Six). High epifaunal abundance was also found at the Portobello Road site (5-20 m), where high numbers of cockles were found. Abundance of epifauna in other areas at the Kitchener Street and Portobello Road sites was similar to abundance at the Burkes control site, while overall abundance was low at Macandrew Bay.

As described above, the 2019 survey did not find tubeworms and barnacles near the Kitchener Street outfall, as was found in 2017. However, abundance of epifauna was highest in this area during both surveys, with high abundance of anemones found in 2019 instead of tubeworms and barnacles. This indicates the suitability of this area for epifaunal communities to maintain high abundance, regardless of the substrate (e.g., soft mud, rocks) available. However, Kitchener Street near the outfall supports more hard material (e.g., rocks, car tyres) than other sites surveyed in the harbour, and this substrate likely provides suitable substrate for large numbers of animals. *Anthopleura* anemones generally attach themselves to cockle shells or small rocks, and their high abundance may therefore indicate high prevalence of suitable substrate, including cockles, near the Kitchener Street outfall. It should be noted that, while cockles were found at this site, they were not overly abundant within sampled quadats and abundance may be quite spatially variable.



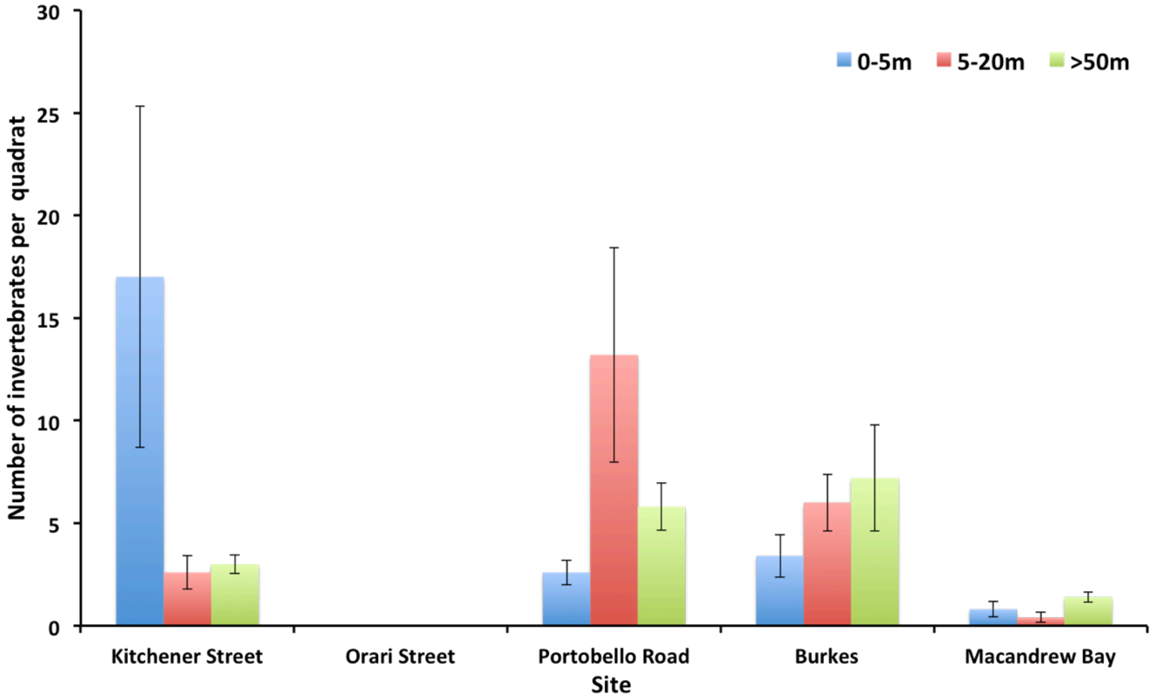


Figure 9. Mean number of epifauna taxa per quadrat (top) and mean number of epifauna individuals per quadrat (bottom) at the five harbour biological sites, April 2019. Means +/- one standard error. Note that high cover of macroflora resulted in no epifauna being observed at the Orari Street site.

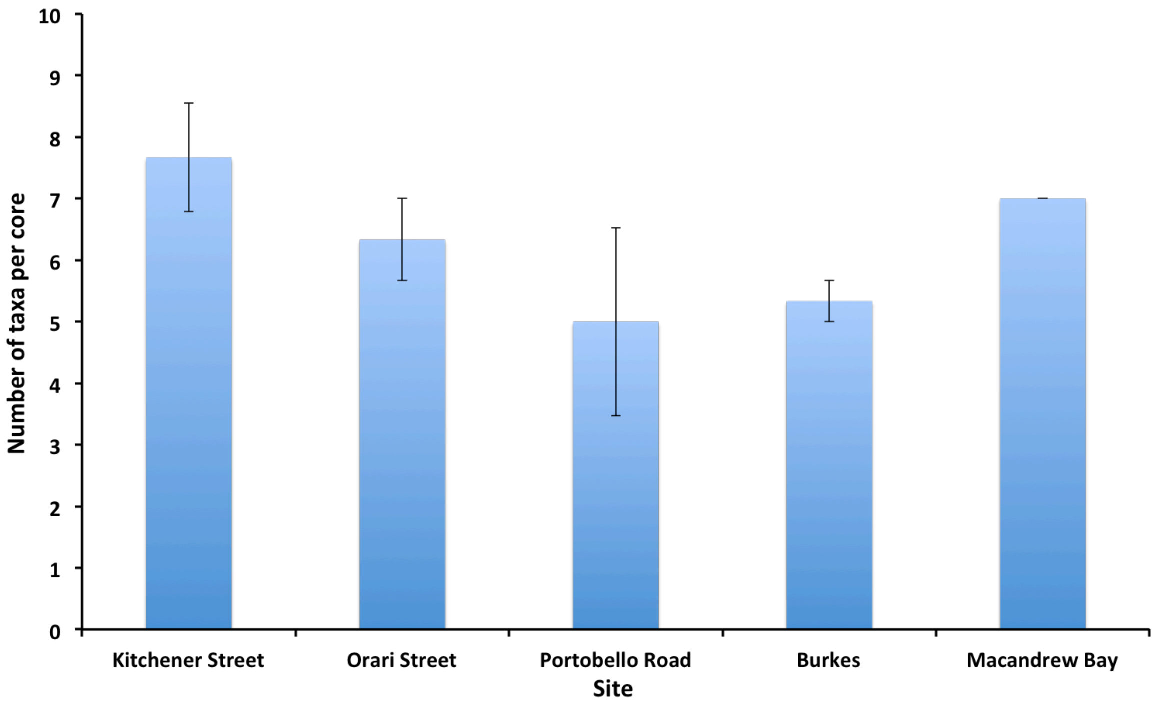
Infauna

Infauna, the invertebrates that live within the harbour sediments and could therefore be affected by contaminants within the sediments, were surveyed at the five Otago Harbour sites at low tide on 9 April 2019. Diversity of the infauna was very similar at each site, with the lowest diversity at Portobello Road and Burkes (Figure 10). Overall, infaunal diversity at the two control sites was very similar to diversity at the sites affected by stormwater outfalls. Total diversity was lower in 2019 than in previous surveys, with 20 different taxa found in 2015, 26 in 2017, and only 16 in 2019. Diversity per site in 2019 (8-11 taxa per site) was lower at each site than in 2017 (12-14 taxa per site) but was similar to or slightly lower than diversity found in 2015 (9-15 taxa per site). Variability between core samples and between surveys is likely influenced by spatial differences in infauna communities across each site, and the nature of random sampling as well.

Polychaetes were the most diverse group of taxa, with eight different polychaete taxa found overall and between six and seven different polychaete taxa found at each site (see Appendix Seven). Similar diversity of polychaetes have been found in previous surveys. Amphipods were found at each site except at Macandrew Bay, while *Edwardsia neozelanica* (the burrowing anemone) was only found at Macandrew Bay. The lower overall diversity in 2019 than in recent surveys is due to lower diversity of molluscs. Only three molluscan taxa were found in 2019, compared to six different molluscs in 2015 and nine different molluscs in 2017.

As for diversity of infauna taxa, abundance of infauna was variable across sites with the lowest abundance at Burkes (Figure 10). Infauna abundance at the two control sites was generally similar to abundance at the sites affected by stormwater outfalls. However, abundance at Macandrew Bay was slightly higher than at the other sites. As seen in 2015 and 2017 surveys, glycerid polychaetes were the most abundant taxon with spionid polychaetes also relatively abundant, but cockles were less abundant in 2019 than in both the 2015 and 2017 surveys (see Appendix Seven). Overall, abundance of infauna was similar to that seen in previous surveys (e.g., 2015, 2017).

In general, the infauna found at the Otago Harbour sites is typical of sheltered harbours in southern New Zealand, and there is no evidence that contaminants carried by stormwater are having anything more than a very minor effect on the intertidal communities of the upper harbour basin.



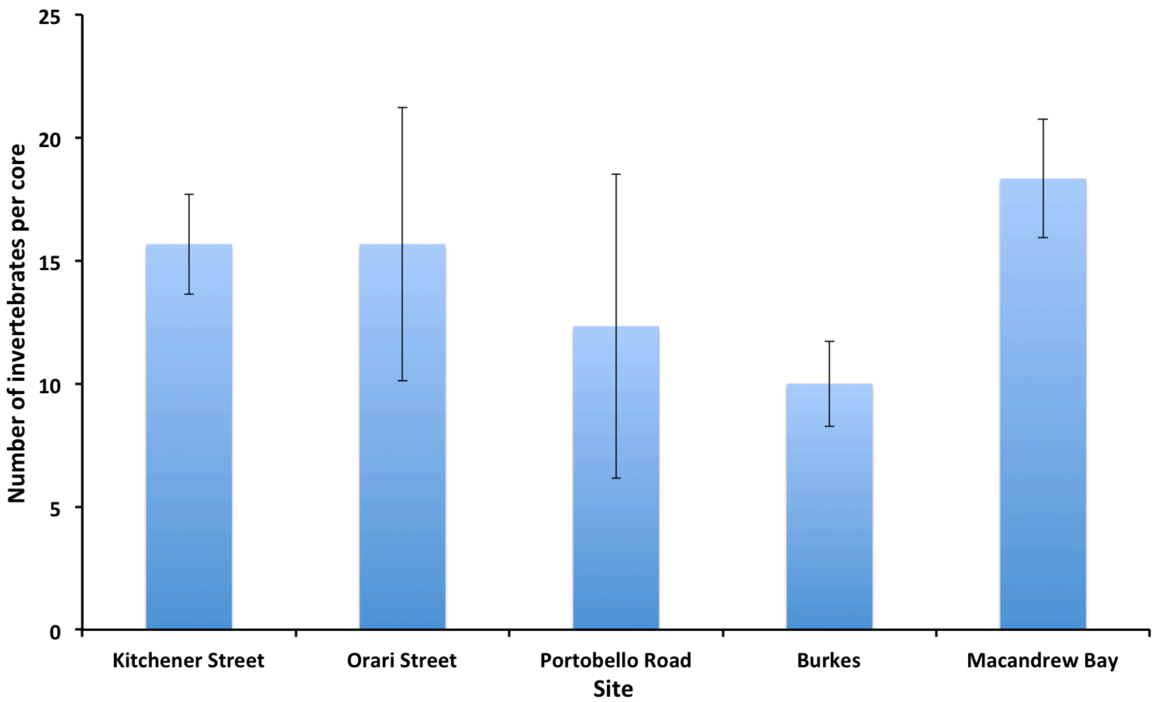


Figure 10. Mean number of infauna taxa per core (top) and mean number of infauna individuals per core (bottom) at the five harbour biological sites, April 2019. Means +/- one standard error.

Cockles - Contaminants

Shellfish are filter feeders and can therefore accumulate contaminants from their environment. Sampling of cockle flesh from sites in Otago Harbour revealed contaminant concentrations were similar at each site, with no apparent patterns relative to the stormwater outfalls except for higher concentrations of lead, enterococci, and PAH at the Portobello Road site than at the other two sites (Table 2).

Table 2. Contaminant concentrations in cockle flesh, 4 April 2019.

	Arsenic (total) (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Enterococci (cfu/200g)	PAH[1] (mg/kg)
Portobello Road	5.8	0.039	0.5	1	0.22	72	1.356 - 1.361
Orari Street	6.2	0.021	0.39	1.17	0.01	<10	0.036 - 0.044
Kitchener Street	5.12	0.018	0.36	1.2	0.1	10	0.023 - 0.034

1. PAH = polycyclic aromatic hydrocarbons. PAH concentration ranges are between known concentrations and the maximum possible concentrations (as some samples below laboratory detection limits).

Enterococci concentrations in 2019 were considerably lower at each site than found in 2015 and 2017 sampling, while concentrations of arsenic, cadmium, chromium, copper, lead, and PAH in 2019 were all within the range of concentrations found at each site from previous sampling. Metal concentrations were all considerably lower than the high 2015 concentrations.

Cockles collected from the Portobello Road site have previously had much higher PAH concentrations than at the other sites, likely as a result of historic contamination of that site. PAH concentrations in cockle flesh have fluctuated over time but concentrations in 2019 fell within the range of concentrations seen from previous monitoring (Figure 11).

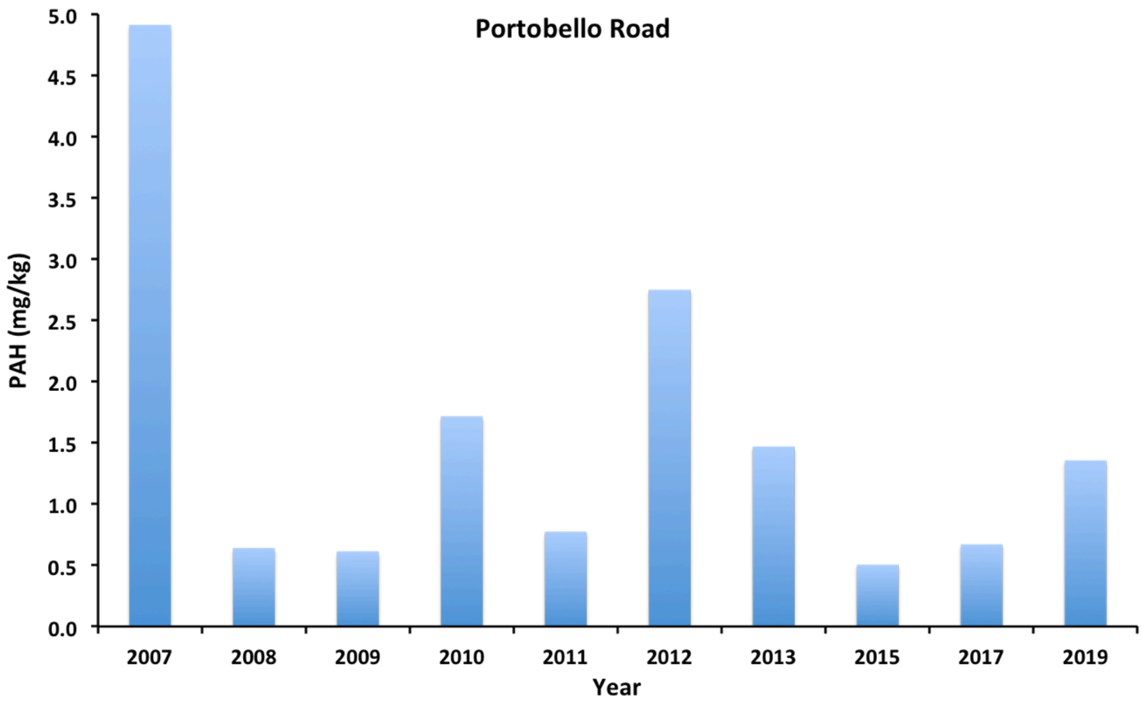


Figure 11. Concentrations of PAHs in cockle flesh at the Portobello Road site, 2007 to 2019.

Of the contaminants required for testing in cockle flesh by resource consent, Food Standards Australia New Zealand (FSANZ) (2017a) has set maximum concentrations for the heavy metals arsenic, cadmium (limit 2 mg/kg), and lead (limit 2 mg/kg) in shellfish as food. Cockles at all sites had cadmium and lead concentrations well below the FSANZ (2017a) maximum concentrations (Table 3). For arsenic, the FSANZ (2017a) provides guidelines for levels of inorganic arsenic in shellfish (limit 1 mg/kg) but total arsenic is typically assessed due to the difficulty and expense of measuring inorganic arsenic. United States Food and Drug Administration (USFDA) (1993) proposed estimating inorganic arsenic as only 10% of the arsenic in shellfish, allowing conversion of total arsenic to estimates of inorganic arsenic (rather than having results specific for inorganic arsenic). Using this approach, inorganic arsenic concentrations in Otago Harbour cockles (approximately 0.5-0.6 mg/kg) were well below the 1 mg/kg FSANZ (2017a) maximum concentration (Table 3).

Table 3. Maximum concentrations of contaminants in shellfish as food from FSANZ (2017a). For the Otago Harbour sites, 'Lower' indicates concentrations in cockle flesh on 4 April 2019 were lower than maximum concentrations.

	Maximum concentration in shellfish for food	Portobello Road	Orari Street	Kitchener Street
Food Standards Australia New Zealand (2017a)	Arsenic (inorganic): 1 mg/kg	Lower[1]	Lower[1]	Lower[1]
	Cadmium: 2 mg/kg	Lower	Lower	Lower
	Lead: 2 mg/kg	Lower	Lower	Lower

1. Arsenic concentrations lower than maximum concentrations when converted from total arsenic to the required inorganic arsenic, using the 10% conversion from USFDA (1993).

Ministry of Health (1995) microbiological reference criteria for food states that harvested and unprocessed shellfish with less than 230 faecal coliform bacteria per 100 g of flesh are 'acceptable' and shellfish with more than 330 faecal coliform bacteria per 100 g of flesh are 'unacceptable'. More recently, microbiological limits in food set by FSANZ (2017b) includes an unacceptable level for *E. coli* of 7/g (i.e., 700 MPN/100g) in bivalve molluscs. Concentrations in Otago Harbour cockles (≤72 cfu/200g) were well below all of these limits.

These results all indicate that the Otago Harbour cockles sampled in April 2019 would be considered safe to eat from metal and faecal contaminant perspectives. However, there are no known limits for PAH concentrations, and the higher PAH concentrations at the Portobello Road site remain of concern. It should be noted that cockles are not known to be gathered by recreational harvesters in the upper harbour basin as they are perceived to be contaminated and too small to be worthwhile.

A comparison of contaminant concentrations in cockle flesh with contaminant concentrations in harbour water (from dry weather sampling) finds metal concentrations were considerably higher in cockle flesh than in harbour water in 2019. A similar result was found in 2017 when both dry and wet weather harbour water sampling was undertaken. However, in 2019 enterococci concentrations were low in cockle flesh at all three sites, with higher concentrations in harbour water only at the two sites where concentrations exceeded trigger levels (i.e., Substation, Andersons Bay Inlet). This supports the premise that there is a relationship between shellfish contamination and water quality, with filter feeding shellfish accumulating contaminants from their environment. However, the lower enterococci concentrations in the cockle flesh at all three sites indicates the complexity of the relationship between contaminant concentrations in the harbour water and shellfish with rate of accumulation of various contaminants and flushing of shellfish with 'cleaner water' (depuration) being highly variable.

Comparing contaminant concentrations in cockle flesh with contaminant concentrations in harbour sediments presents further information regarding the relationship between cockles and their environment, and the influence of stormwater inputs on this relationship. In harbour sediment, contaminant concentrations were generally one to two orders of magnitude higher than in cockle flesh, a result also seen in 2017.

Overall, these results confirm that cockles in the harbour accumulate contaminants from their environment. However, the generally higher contaminant concentrations in cockle flesh than in harbour water, but much lower concentrations in cockle flesh than in harbour sediments, shows that contaminants in the shellfish are generally derived from the water column, rather than the surrounding sediment. This is not unexpected, given that the cockles feed by filtering water and not by ingesting sediment.

Cockles - Size

Measuring cockle length is useful to determine if there is any relationship between contaminant concentrations and the size of cockles. Of the three sites where cockles are sampled, cockles have historically been largest at the Kitchener Street site, with decreasing size across the foreshore at Orari Street, and with the smallest at the Portobello Road site (Figure 12). The smaller size of the cockles at the Portobello Road site may have been influenced by the historic PAH contamination at this site but could also be influenced by exposure at low tides. However, in 2019, while cockle lengths at the Portobello Road and Orari Street sites were very similar, cockles were slightly smaller at the Orari Street site than at the Portobello Road site (mean lengths of 28.1 mm and 28.5 mm respectively) (Figure 12). It is unlikely that this result is due to the considerably lower PAH concentrations found in sediment samples at the Portobello Road site in 2019 than in previous years as growth of cockles in the upper harbour is very slow. Note that PAH concentrations in cockle flesh at Portobello Road did not noticeably decrease but instead remained within the range of concentrations seen from previous monitoring (see Figure 11). Overall, cockle lengths at Kitchener Street were smaller than found in previous surveys, but cockle lengths at Orari Street and Portobello Road were within the range of previous surveys (Figure 12).

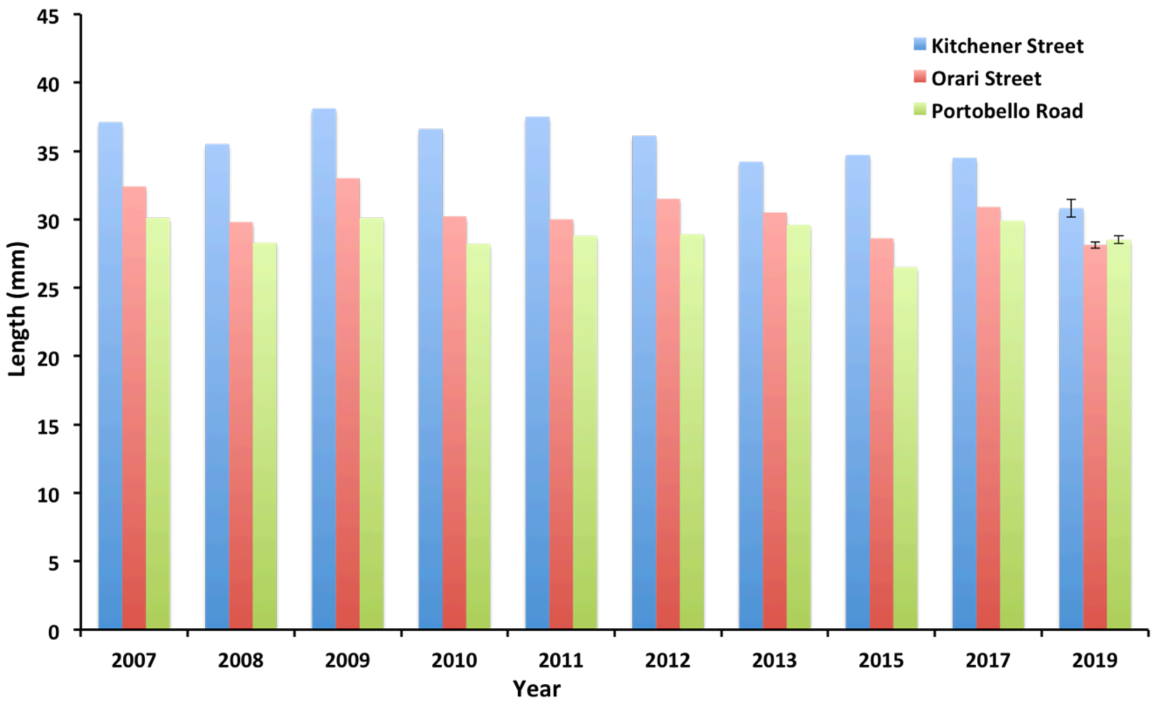


Figure 12. Mean cockle lengths (mm) at the three harbour biological sites, 2007 to 2019. Error bars for 2019 means are +/- one standard error.

Summary

In general, sampling of harbour biological communities has not revealed any significant differences between sites that could be attributed directly to stormwater discharges. Macroflora communities were highly variable and there was no relationship between proximity to stormwater outfalls and macroflora, which is a similar result to those from previous surveys. Further and wider investigations may be required if drift macroflora continue to flourish within the upper harbour (as evidenced by the cover at the Orari Street site). However, it must be noted that this is more likely related to wider nutrient inputs and temperature changes than to stormwater. Epifaunal communities were variable, with different taxa dominating at each site. This result is most likely due to the availability of stable substrate rather than any influence of stormwater discharges. Infaunal communities in 2019 were similar to those found in previous surveys and typical of sheltered harbours in southern New Zealand. Contaminant concentrations in cockles were generally low, and the cockles sampled in April 2019 would be considered safe to eat from metal and faecal contaminant perspectives but the influence of PAH is unknown. The higher PAH concentrations at the Portobello Road site than at the other sites remains of concern, but concentrations in 2019 were within the range of concentrations found in previous surveys.

4. Conclusion

General

Monitoring of Dunedin's stormwater discharges and receiving environments (Otago Harbour) was undertaken between July 2018 and June 2019. Sampling included stormwater quality during dry weather conditions, automated sampling of stormwater quality during wet weather conditions, harbour water quality during dry weather conditions, harbour sediments, and harbour biological communities.

The results of the 2018-2019 monitoring continues to build on previous years of sampling in characterising the quality of the stormwater discharged to Otago Harbour, and identifying any effects of these discharges on harbour environments and biological communities. The sampling results are also used to identify any areas where improvements and/or remediation may be required, such as outfalls where results indicate possible cross-connections between stormwater and wastewater systems.

Stormwater – Dry weather

Dry weather sampling at the stormwater outfalls in 2018-2019, undertaken to determine background contaminant levels, found contaminant concentrations were heavily influenced by a rain event in November 2018 where there were potential wastewater overflows into the stormwater system. Sampling of dry weather discharges following this event revealed high concentrations of faecal indicators (which can be from multiple sources) and high levels of FWAs (usually associated with human faecal contamination). However, other sampling results in 2018-2019 were more variable, and there were no outfalls with consistently high results and therefore no outfalls require further investigation. However, as sampling was not able to be undertaken each month in 2018-2019 (due to conditions not being suitable each month, e.g., weather, tides), results from 2019-2020 sampling should be regularly reviewed to identify any potential issues.

Automated sampler – Wet weather

The only wet weather sampling of stormwater able to be undertaken between July 2018 and June 2019 (due to conditions not being suitable) was automated sampling of stormwater discharges during two rain events in the Mason Street catchment. Results for the contaminants were variable between and during each rain event, despite similar total rainfall during each event. Contaminant concentrations were generally similar to those found in previous monitoring of other catchments, but some concentrations were slightly lower. This may be influenced by the duration of the antecedent dry period prior to a rain event, and to the intensity of rainfall during each rain event as more intense rain is expected to transport higher contaminant concentrations in surface runoff to the stormwater. This could be attributed to the low total amount of rainfall. The ISCO automated sampler will remain at its current location until a third rainfall event is successfully sampled and will then be moved to the Halsey Street catchment in 2019-2020.

Harbour water

Harbour water can be difficult to monitor for contaminants due to movement of contaminants around the harbour by tides, currents, and wind action. Sampling both incoming and outgoing tides attempts to capture contaminants, with outgoing tides likely to move contaminants down harbour and incoming tides likely to lead to higher concentrations of contaminants in the upper harbour. Harbour water quality sampling in 2018-2019 could only be undertaken during a dry weather period, and results revealed copper concentrations exceeded trigger levels at all sites during both tidal stages. High copper concentrations have also been found in previous years. The high copper concentrations at all sites indicates the source of the copper is unlikely to be a single or point source discharge, but determining the exact source is difficult as copper is used in vehicle brakes, plumbing, and agricultural and industrial activities.

Harbour sediment

Contaminant concentrations in harbour sediments were low in 2019, and were less than trigger levels specified in the resource consent. For some contaminants the concentrations were less than laboratory detectable limits. Concentrations of metals have been high at some sites during previous sampling due to industrial activity in the catchment, and PAH concentrations have been high due to historic contamination of stormwater. However, changes to industrial activities and improvements to wastewater/stormwater networks have reduced the amount of contaminants entering the harbour, which ultimately result in reduced contaminant concentrations in surficial harbour sediments. For example, PAH concentrations were low in 2019, and were considerably lower than found in 2018 (e.g., a reduction at the Orari Street site from 142.82 mg/kg in 2018 to <0.75 mg/kg in 2019). Contaminated sediments will continue to be flushed out of the upper harbour, but may also be remediated naturally as fresh sediments settle on top of them. Movement of sediments during weather events could, however, disturb and redistribute, or expose historically contaminated sediment. Continued sampling of harbour sediment quality at the current sites will contribute to increasing understanding of sediment quality in the harbour, and provide meaningful comparison with historic data.

Harbour biological

Biological communities at Otago Harbour sites influenced by stormwater outfalls were similar to those at sites with no stormwater inputs, and were similar to those found during previous surveys. Communities continue to have low diversity of macroflora, epifauna, and infauna, with high variability between sites. Different substrates (e.g., mud, rocks) influenced the amount of habitat available for colonisation. Similar results have been found during previous surveys, and the communities have been found to be typical of similar environments in southern New Zealand. Of interest in 2019 was the abundance of macroflora at the Orari Street site. Should the abundance at this site continue, further investigation may be required. Overall, biological communities in Otago Harbour showed no signs of any adverse effects due to stormwater discharges.

Summary

This report has summarised the July 2018 to June 2019 monitoring of Dunedin's stormwater and receiving environments, as required of DCC by ORC resource consents. Results from this monitoring period have not indicated any stormwater outfalls with possible cross-connections between stormwater and wastewater systems, has not identified any sites requiring immediate further investigation, and has not identified any significant adverse effects of stormwater discharges on the receiving environment. Continued sampling and analysis of results will assist in determining potential issues in the stormwater network, which will allow DCC to undertake any required remediation to reduce the potential for adverse effects on the receiving environment.

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Appendix One: Stormwater outfalls

Table A1.1. Dunedin stormwater outfall information.

Outfall	DCC reference	Resource consent	Location	Catchment	Frequency of dry weather sampling
1	SWX03979	RM11.313.10	Second Beach	St Clair	Monthly
2	SWX00011 & SWX00012	RM11.313.10	St Clair Beach	St Clair	Six monthly
3	SWX04625	RM11.313.04	Shore Street	Shore Street	Monthly
4	SWX03649	RM11.313.09	Portobello Road	South Dunedin	Monthly
5	SWX03644	RM11.313.07	Teviot Street	Portsmouth Drive	Monthly
6	SWX03640	RM11.313.07	Midland Street	Portsmouth Drive	Monthly
7	SWX03631	RM11.313.07	Orari Street	Portsmouth Drive	Monthly
8	SWX03635 & SWX70740	RM11.313.08	Orari Street	Orari Street	Monthly
9	SWX03579	RM11.313.07	Kitchener Street	Portsmouth Drive	Six monthly
10	SWX03568	RM11.313.06	Kitchener Street	Kitchener Street	Monthly
11	SWX70102	RM11.313.06	French Street	Kitchener Street	Six monthly
12	SWX03547	RM11.313.06	Kitchener Street	Kitchener Street	Monthly
13	SWX03562	RM11.313.06	Birch Street	Kitchener Street	Six monthly
14	SWX03556	RM11.313.06	Birch Street	Kitchener Street	Six monthly
15	SWX03559	RM11.313.06	Wharf Street	Kitchener Street	Six monthly
16	SWZ70569	RM11.313.06	Fryatt Street	Kitchener Street	Six monthly
17	SWX03540	RM11.313.06	Fryatt Street	Kitchener Street	Six monthly
18	SWX03536	RM11.313.06	Fryatt Street	Kitchener Street	Six monthly
19	SWX03532	RM11.313.06	Fryatt Street	Kitchener Street	Six monthly
20	SWX70370	RM11.313.06	Fryatt Street	Kitchener Street	Six monthly
21	SWX03489	RM11.313.05	Mason Street	Mason Street	Six monthly
22	SWX03506	RM11.313.03	Bauchop Street	Halsey Street	Six monthly
23	SWX03466	RM11.313.03	Bauchop Street	Halsey Street	Monthly
24	SWX03455	RM11.313.03	Halsey Street	Halsey Street	Monthly
25	SWX03450	RM11.313.03	Halsey Street	Halsey Street	Monthly
26	SWX03472	RM11.313.03	Halsey Street	Halsey Street	Monthly
27	SWX03718	RM11.313.03	Wickliffe Street	Halsey Street	Monthly
28	SWX02628	RM11.313.02	Magnet Street	Ravensbourne	Six monthly
29	SWX02623	RM11.313.02	Magnet Street	Ravensbourne	Six monthly
30	SPN02502	RM11.313.02	Ravensbourne Road	Ravensbourne	Monthly
31	SWX12941	RM11.313.01	George Street /SH88	Port Chalmers	Six monthly
32	SWX12994	RM11.313.01	Sawyers Bay, Watson Park	Port Chalmers	Monthly
33	SWX12879	RM11.313.01	George Street (Port Otago)	Port Chalmers	Monthly

Appendix Two: Stormwater – dry weather

Table A2.1. FWA levels and* E. coli *concentrations from dry weather sampling between July 2018 and June 2019. Outfalls marked with grey cells are sampled six-monthly. Orange cells indicate values exceed trigger levels: FWA level of 0.1 (recommended by B. Gilpin in personal communication to B. Stewart),* E. coli *trigger level of 550 cfu/100mL (Ministry for the Environment (2003) action (red) limit). *Note December 2018* E. coli *results include several values with very high detection limits (e.g., <100,000). These values have not been highlighted as exceedances due to the high detection limit.

Outfall	August 2018		September 2018		December 2018		April 2019		May 2019	
	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)
1	0.056	3,400	0.057	323	0.061	910	0.038	510	0.046	3,700
2					NF	NF				
3	0.089	30,000	0.102	2,880	0.128	2,100	0.070	21,000	0.058	490
4	0.029	<4	0.017	<1	0.130	3,700	0.030	220	0.036	420
5	0.128	152	0.078	29	0.118	90,000	0.091	2,900	0.072	5,800
6	0.113	904	0.046	14	0.129	18,000	0.080	92	0.113	2,000
7	NF	NF	NF	NF	0.071	12,000	NF	NF	0.113	470,000
8	0.072	731	0.072	460	0.076	1,500	0.025	390	0.070	590
9					0.124	20,000				
10	0.047	365	0.052	130	0.125	<100,000*	0.046	2,600	0.035	630
11					0.220	<100,000*				
12	NF	NF	0.046	7	0.193	1,300	0.027	4	0.021	<4
13					NF	NF				
14					NF	NF				
15					NF	NF				
16					NF	NF				

Table A2.1 continued. FWA levels and* E. coli *concentrations from dry weather sampling between July 2018 and June 2019. Outfalls marked with grey cells are sampled six-monthly. Outfalls with consistently no flows (including outfalls sampled six-monthly) have been omitted. Orange cells indicate values exceed trigger levels: FWA level of 0.1 (recommended by B. Gilpin in personal communication to B. Stewart),* E. coli *trigger level of 550 cfu/100mL (Ministry for the Environment (2003) action (red) limit). *Note December 2018* E. coli *results include several values with very high detection limits (e.g., <100,000). These values have not been highlighted as exceedances due to the high detection limit.

Outfall	August 2018		September 2018		December 2018		April 2019		May 2019	
	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)	FWA	*E. coli* (cfu/100mL)
17					NF	NF				
18					NF	NF				
19					NF	NF				
20					NF	NF				
21					0.104	<100,000*				
22					NF	NF				
23	0.037	156	0.046	204	0.091	<100,000*	0.028	3,700	0.037	350
24	0.027	2,900	0.037	3,720	0.040	<100,000*	0.031	1,400	0.039	15,000
25	0.072	40,000	0.050	3,920	0.044	50,000	0.030	50,000	0.057	200,000
26	NF	NF	NF	NF	0.133	<10,000*	NF	NF	NF	NF
27	0.080	381	0.039	2,600	0.082	100,000	0.064	28,000	0.077	25,000
28					0.056	7,300				
29					0.054	600				
30	0.084	4	0.109	2	0.117	<100	0.100	24	0.125	8
31					0.076	100				
32	0.151	4	0.120	2	0.143	26,000	NF	NF	NF	NF
33	0.084	635	0.073	285	0.091	1,600	0.057	7,400	0.062	3,300

Appendix Three: Automated sampler – wet weather

Table A3.1. ISCO automated sampling results, 25 February 2019. Note Eurofins was unable to process samples for pH and suspended solids due to insufficient sample volume.

Time (min.)	pH	Total suspended solids (g/m^3)	Oil and grease (g/m^3)	Arsenic (g/m^3)	Cadmium (g/m^3)	Chromium (g/m^3)	Copper (g/m^3)	Lead (g/m^3)	Nickel (g/m^3)	Zinc (g/m^3)	*E. coli* (cfu/100mL)	PAH[1] (mg/L)
10	-	-	8	0.003	<0.001	0.003	<0.002	<0.001	0.006	0.024	420	<0.0051
20	-	-	5	0.003	<0.001	0.001	<0.002	<0.001	0.002	0.015	310	<0.0051
30	-	-	9	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.031	210	<0.0051
40	-	-	8	0.003	<0.001	<0.001	<0.002	<0.001	0.002	0.01	220	<0.0051
50	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.008	250	<0.0051
60	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.009	180	<0.0051
70	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.01	160	<0.0051
80	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.011	180	<0.0051
90	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	<0.001	0.01	210	<0.0051
100	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	<0.001	0.01	240	<0.0051
110	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	<0.001	0.01	230	<0.0051
120	-	-	<5	0.003	<0.001	<0.001	<0.002	<0.001	0.001	0.013	130	<0.0051

1. PAH = polycyclic aromatic hydrocarbons. '< value' indicates all concentrations below laboratory detection limits.

Table A3.2. ISCO automated sampling results, 26 March 2019.

Time (min.)	pH	Total suspended solids (g/m^3)	Oil and grease (g/m^3)	Arsenic (g/m^3)	Cadmium (g/m^3)	Chromium (g/m^3)	Copper (g/m^3)	Lead (g/m^3)	Nickel (g/m^3)	Zinc (g/m^3)	*E. coli* (cfu/100mL)	PAH[1] (mg/L)
10	7.7	149	28	0.003	<0.001	<0.001	<0.002	<0.001	0.003	0.126	480	<0.0051
20	7.8	155	20	0.004	<0.001	<0.001	0.003	<0.001	0.001	0.152	780	<0.0051
30	7.9	160	18	0.005	<0.001	0.002	0.003	<0.001	0.002	0.096	2,500	<0.0051
40	7.9	153	92	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.066	720	<0.0051
50	7.9	242	14	0.005	<0.001	0.006	<0.002	<0.001	0.003	0.085	2,100	<0.0051
60	7.9	246	5	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.056	630	<0.0051
70	7.9	119	11	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.023	800	<0.0051
80	7.9	153	<5	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.037	2,600	<0.0051
90	7.9	141	6	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.042	2,600	<0.0051
100	7.9	195	9	0.004	<0.001	<0.001	<0.002	<0.001	<0.001	0.036	950	<0.0051
110	7.9	169	6	0.005	<0.001	<0.001	<0.002	<0.001	<0.001	0.043	2,600	<0.0051
120	7.9	171	13	0.003	<0.001	<0.001	<0.002	<0.001	<0.001	0.035	550	<0.0051

1. PAH = polycyclic aromatic hydrocarbons. '< value' indicates all concentrations below laboratory detection limits.

Appendix Four: Harbour sediment

Table A4.1. Harbour sediment contaminant concentrations, 7 June 2019. Trigger values are specified in resource consents.

	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	WAE Copper[1] (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)	PAH[2] (mg/kg)	TPH[3] (mg/kg)	OCP[4] (mg/kg)
2013 trigger levels	19	1.7	80	-	122	209	-	21	902	183	-	-
ANZECC (2000) ISQG-Low[5]	20	1.5	80	-	65	50	0.15	21	200	4	-	-
ANZECC (2000) ISQG-High[5]	70	10	370	-	270	220	1	52	410	45	-	-
Halsey Street	14.6	0.17	25.2	33	35.6	51.9	0.1	14.8	264	0.72-1.17	52	<0.7
Kitchener Street	13.1	0.18	27.8	17.1	23.8	22.9	0.1	19.4	113	<0.75	14	<0.7
Orari Street	2.2	0.04	5.2	14.2	3.1	5.4	<0.1	2.9	28.6	<0.75	19	<0.7
Shore Street	13.6	0.19	30.8	25	34.3	73.4	0.2	20.9	243	1.18-1.53	83	<0.7

1. WAE copper = Weak-acid extractable copper.

2. PAH = polycyclic aromatic hydrocarbons. PAH concentration ranges are between known concentrations and the maximum possible concentrations (as some samples below laboratory detection limits). '< value' indicates all concentrations below laboratory detection limits.

3. TPH = total petroleum hydrocarbons – maximum content.

4. OCP = organochlorine pesticides. '< values' indicate all concentrations below laboratory detection limits.

5. ANZECC (2000) interim sediment quality (ISQG) guideline values, as listed in the resource consent.

Appendix Five: Harbour biological - macroflora

Table A5.1. Percentage cover of macroflora taxa at the five harbour biological sites, 7 April 2019.

	Kitchener Street									**Orari Street**									**Portobello Road**									**Burkes**									**Macandrew Bay**								
	0-5m			**5-20m**			**>50m**			**0-5m**			**5-20m**			**>50m**			**0-5m**			**5-20m**			**>50m**			**0-5m**			**5-20m**			**>50m**			**0-5m**			**5-20m**			**>50m**		
Taxon	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Ceramium uncinatum	8	8	25	15	8	6	8	37	15	100	100	100	100	100	100	100	100	100		4	1							2		1			2			3							2	1	2
Codium fragilis												10	3	5	15	3	2	1																											
Gracilaria chilensis																																					2								
Lenormandia species																				1	1									1															
Ulva species		4							4					3																															
Total % cover	8	12	25	15	8	6	8	37	19	100	100	110	103	108	115	103	102	101	0	5	2	0	0	0	0	0	0	2	0	2	0	0	2	0	0	3	2	0	0	0	0	0	2	1	2
Number of taxa	1	2	1	1	1	1	1	1	2	1	1	2	2	3	2	2	2	2	0	2	2	0	0	0	0	0	0	1	0	2	0	0	1	0	0	1	1	0	0	0	0	0	1	1	1
Mean % cover		15			9.7			21.3			103.3			108.7			102			2.3			0			0			1.3			0.7			1			0.7			0			1.7	
Mean number of taxa		1.3			1			1.3			1.3			2.3			2			1.3			0			0			1			0.3			0.3			0.3			0			1	

Appendix Six: Harbour biological - epifauna

Table A6.1. Number of epifauna invertebrates per quadrat at the five harbour biological sites, 7 April 2019.

	Kitchener Street															Orari Street															Portobello Road														
	0-5m					5-20m					>50m					0-5m					5-20m					>50m					0-5m					5-20m					>50m				
Taxon	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Mollusca																																													
Amphibola crenata	1		1			1							2																		1														
Austrovenus stutchburyi	2	2		1	4	1	1	2	1	1		1		1	1																1	3	1	2	3	4	3	3	20	28	3	6	8	2	2
Cominella glandiformis											1																										1								
Diloma subrostrata																																													1
Macomona liliana																																				1									
Melagraphia aethiops																																													
Micrelenchus species	1	1	1	1		1		1			2		2	1																					1						1	1	1		1
Zeacumantus species															1																					1		1		1					
Crustacea																																													
Macrophthalmus species				1	1			1						1																		1						1	1	1	1	1		1	
Cnidaria - Anthozoa																																													
Anthopleura aureoradiata	13	46	5		4	1		1	1			1		1																															
Number of invertebrates per quadrat	17	49	7	3	9	4	1	5	2	1	3	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	1	2	4	6	4	5	21	30	5	8	9	3	4
Number of taxa per quadrat	4	3	3	3	3	4	1	4	2	1	2	2	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	2	3	2	3	2	3	3	3	2	2	3
Mean number of invertebrates per quadrat	17					2.6					3					0					0					0					2.6					13					5.8				
Mean number of taxa per quadrat	3.2					2.4					2.4					0					0					0					1.6					2.6					2.6				

	Burkes															Macandrew Bay														
	0-5m					5-20m					>50m					0-5m					5-20m					>50m				
Taxon	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Mollusca																														
Amphibola crenata	2	1	1	1	4	3		1	2				2																	
Austrovenus stutchburyi				1	1	1	1			2				1	2	2	1			1				1		1		2	1	1
Cominella glandiformis																														
Diloma subrostrata											6		2	6																
Macomona liliana																														
Melagraphia aethiops							1	1		7	9	2																		
Micrelenchus species	1					1					1		2		1														1	
Zeacumantus species	1		1						1	1	1				1															
Crustacea																														
Macrophthalmus species				1	2	2	2	2	1	1															1					
Cnidaria - Anthozoa																														
Anthopleura aureoradiata																											1			
Number of invertebrates per quadrat	4	1	2	3	7	7	4	4	4	11	17	2	6	7	4	2	1	0	0	1	0	0	0	1	1	1	1	2	2	1
Number of taxa per quadrat	3	1	2	3	3	4	3	3	3	4	4	1	3	2	3	1	1	0	0	1	0	0	0	1	1	1	1	1	2	1
Mean number of invertebrates per quadrat	3.4					6					7.2					0.8					0.4					1.4				
Mean number of taxa per quadrat	2.4					3.4					2.6					0.6					0.4					1.2				

Appendix Seven: Harbour biological - infauna

Table A7.1. Number of infauna invertebrates per core sample at the five harbour biological sites, 7 April 2019.

	Kitchener Street			Orari Street			Portobello Road			Burkes			Macandrew Bay		
Taxon	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Cnidaria - Anthozoa															
Edwardsia neozelanica													1	1	2
Annelida - Polychaeta															
Abarenicola affinis					1	2	1								2
Capitellidae	1	1			2	2	2				1		1	1	2
Glyceridae	8	5	3	2	4	16	9	5	1		1	6	12	9	5
Maldanidae	1	1	2							1		1			
Nephtyidae	2	1	1		1		2			1	1	1	2	1	1
Nereididae	2	2	1	1	2	1	2	1	1	1	1		3	1	2
Opheliidae												1			
Spionidae	2	3	3	2	3	3	4	2	1	6	3	3	3	2	1
Hemichordata - Enteropneusta					1										
Crustacea - Amphipoda															
Lysianassidae												1			
Oedicerotidae	1														
Phoxocephalidae	1			1		1	3	2							
Mollusca - Bivalvia															
Austrovenus stutchburyi	1			1											
Macomona liliana		2	2			1							1	2	
Nucula species		1					1			1					
Number of invertebrates per core sample	19	16	12	7	14	26	24	10	3	10	7	13	23	17	15
Number of taxa per core sample	9	8	6	5	7	7	8	4	3	5	5	6	7	7	7
Mean number of invertebrates per core sample		15.7			15.7			12.3			10			18.3	
Mean number of taxa per core sample		7.7			6.3			5			5.3			7	

Appendix Eight: Cockle flesh results corrections

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Memorandum

To: Georgia Cowie and Karen Sannazzaro, **Dunedin City Council**

From: Ben Ludgate, **Ryder Environmental Limited**

Date: 25 October 2019

Subject: **Stormwater monitoring 2018-19 – corrections to results**

Dear Georgia and Karen,

We have been advised by Eurofins that results for contaminant concentrations in cockle flesh, sampled from Otago Harbour as part of the stormwater biological sampling in 2019, were issued with incorrect units for Enterococci. The incorrect reporting was due to data transcription errors between Eurofins laboratories. The results were provided to us with units of cfu/200g, but should have had units of cfu/g. We are liaising with Eurofins to ensure such errors will not occur in the future.

Table 1 below presents the data provided in the original report issued to Dunedin City Council, and the corrected data as provided by Eurofins (converted from cfu/g to cfu/200g). The corrected data indicate considerably higher Enterococci concentrations than originally reported.

Table 1. Reported and corrected data for Enterococci in cockle flesh in 2019.

Site	**Original data** Cockles – Enterococci (reported incorrectly as cfu/200g)	**Corrected data** Cockles – Enterococci (cfu/200g)
Portobello Road	72	14,000
Orari Street	<10	<2,000
Kitchener Street	10	2,000

As the original report issued to Dunedin City Council included interpretation of Enterococci concentrations in cockle flesh, sections of the report need to be revised. Report sections referring to Enterococci concentrations in cockle flesh are provided below with updated interpretations of the corrected data.

Results and Discussion, Harbour Biological, Cockles - Contaminants, Page 29:
Original report:
'Sampling of cockle flesh from sites in Otago Harbour revealed contaminant concentrations were similar at each site, with no apparent patterns relative to the stormwater outfalls except for higher concentrations of lead, enterococci, and PAH at the Portobello Road site than at the other two sites.

Enterococci concentrations in 2019 were considerably lower at each site than found in 2015 and 2017 sampling, ….'.

Updated interpretation:
The statement regarding higher concentrations of enterococci at Portobello Road than at the other two sites is still correct.

The corrected data for 2019 samples have the units cfu/200g, while results from 2015 and 2017 had units of MPN/100g (note 2015 and 2017 samples were processed by Citilab). For more informative comparisons between years, the 2019 results can be converted from cfu/200g to cfu/100g (noting that cfu and MPN are comparable) (Table 2). Enterococci concentrations at Portobello Road in 2019 were lower than in 2015 but higher than in 2017. Similarly, Orari Street concentrations in 2019 were lower than in 2015, but it is uncertain if 2019 concentrations were lower or higher than in 2017 at this site. The uncertainty is due to the high laboratory detection limit used in 2019. Enterococci concentrations at Kitchener Street were similar in all three years.

Table 2. Enterococci concentrations in cockles in 2015, 2017, and corrected data for 2019 (converted from cfu/200g to cfu/100g).

Site	**2015** Cockles – Enterococci (MPN/100g)	**2017** Cockles – Enterococci (MPN/100g)	**2019 - Corrected** Cockles – Enterococci (cfu/100g)
Portobello Road	>18,000	490	7,000
Orari Street	16,000	700	<1,000
Kitchener Street	1,400	1,300	1,000

Results and Discussion, Harbour Biological, Cockles - Contaminants, Page 31:
Original report:
'*Ministry of Health (1995) microbiological reference criteria for food states that harvested and unprocessed shellfish with less than 230 faecal coliform bacteria per 100 g of flesh are 'acceptable' and shellfish with more than 330 faecal coliform bacteria per 100 g of flesh are 'unacceptable'. More recently, microbiological limits in food set by FSANZ (2017b) includes an unacceptable level for* E. coli *of 7/g (i.e., 700 MPN/100g) in bivalve molluscs. Concentrations in Otago Harbour cockles (≤72 cfu/200g) were well below all of these limits.*

These results all indicate that the Otago Harbour cockles sampled in April 2019 would be considered safe to eat from metal and faecal contaminant perspectives.

However, in 2019 enterococci concentrations were low in cockle flesh at all three sites, with higher concentrations in harbour water only at the two sites where concentrations exceeded trigger levels (i.e., Substation, Andersons Bay Inlet). This supports the premise that there is a relationship between shellfish contamination and water quality, with filter feeding shellfish accumulating contaminants from their environment. However, the lower enterococci concentrations in the cockle flesh at all three sites indicates the complexity of the relationship between contaminant concentrations in the harbour water and shellfish with rate of accumulation of various contaminants and flushing of shellfish with 'cleaner water' (depuration) being highly variable. '

Updated interpretation:
The statement regarding concentrations of faecal contaminants in Otago Harbour cockles being below the stated limits is now incorrect. Except for the Orari Street site where Enterococci concentration was <1,000 cfu/100g and therefore the actual concentration is uncertain, Enterococci concentrations at both Kitchener Street and Portobello Road were well above the Ministry of Health

(1995) criteria and the FSANZ (2017b) levels for shellfish. The corrected results therefore indicate that the Otago Harbour cockles sampled in April 2019 would not be considered safe to eat from a faecal contaminant perspective.

The discussion of the complexity of the relationship between contaminant concentrations in the harbor water and shellfish still applies. As seen by the lower 2017 Enterococci concentrations in cockles, the concentrations can vary widely and accumulation and flushing of shellfish will continue to be highly variable.

Results and Discussion, Harbour Biological, Summary, Page 33:
Original report:
'*Contaminant concentrations in cockles were generally low, and the cockles sampled in April 2019 would be considered safe to eat from metal and faecal contaminant perspectives but the influence of PAH is unknown.*'

Updated interpretation:
The corrected results indicate that the Otago Harbour cockles sampled in April 2019 would not be considered safe to eat from a faecal contaminant perspective.

Do not hesitate to contact me should you require any further information or clarification of the above.

Yours sincerely,

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