

MARINE OUTFALLS SEAWATER QUALITY MONITORING

Annual Report 02

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1 INTRODUCTION

In 2017 the City of Cape Town (CCT) appointed the CSIR to assess the effects of domestic effluent discharged from the marine outfalls located at Hout Bay, Camps Bay and Green Point on human health and the surrounding marine environment (CSIR 2017). The assessment evaluated effects on receiving water quality, sediment properties and levels of contaminants in seafood organisms at sites located adjacent to the outfalls and found there to be minimal effects directly attributable to the discharges. It was however noted that the human health and/or environmental effects of the outfalls may change over time, and so the implementation of a comprehensive monitoring programme was recommended. Following and in accordance with this, after a tender process, CLS Southern Africa (CLS SA) was contracted by the CCT to conduct seasonal (winter and summer) monitoring of the three marine outfalls, for a period of three years from August 2019 to May 2022.

1.1 Scope of Work

The required scope of the monitoring as detailed in the tender documents (124S/2018/19) includes:

- weekly seawater quality monitoring (collection and analysis of seawater samples and water column profiling) at 16 prescribed nearshore sites around each of the three outfalls for a period of six weeks during winter (non-upwelling) and summer (upwelling) each year,
- weekly seawater quality monitoring of faecal indicator bacteria (collection and analysis of seawater samples) at three prescribed beach sites adjacent to each of the three outfalls over each six-week sampling season each year,
- seawater toxicity testing at two nearshore sites proximal to each of the three outfalls on alternate days over a 14-day period within each six-week sampling season each year,
- monitoring of contaminants in the flesh of mussels suspended at 12 prescribed sites in the receiving environment at each outfall over each six-week sampling season each year,
- deployment of an ADCP and thermistor string at one location at each of the three outfalls over one winter and one summer six-week sampling period (i.e., for one year only) to collect wave, current and temperature data for hydrodynamic model calibration, and
- three-dimensional numerical hydrodynamic modelling of plume dispersion in the receiving environment at each of the three outfalls over two periods representative of winter and summer (for one year only).

CLS SA has completed the second year of monitoring (i.e., the second seasonal cycle). Winter (non-upwelling) sampling was conducted in August/September 2020 and summer (upwelling) sampling was conducted in March/April 2021. All data and findings from each of these monitoring periods have been presented to the CCT in respective data reports (LT 839 DTR_03_V2.0 and LT 839 DTR_04_V1.0).

Following the completion of each year of monitoring, the submission of an annual report presenting and comparing all data for both seasons sampled at each of the three outfalls is required. This report fulfils this requirement and presents and compares the seasonal data collected during the second year of monitoring. Results are presented for each outfall separately in the appendices:

- APPENDIX A: Hout Bay
- APPENDIX B: Camps Bay
- APPENDIX C: Green Point

1.2 Report Objectives

The objectives of the second annual report are:

- to present and compare data collected in the winter (August-September 2020) monitoring period to those collected in the summer (March-April 2021) monitoring period,
- to check compliance of these data with relevant national water quality guidelines and highlight any outliers,
- to provide an assessment of the effects of the outfalls on the local marine ecology in the receiving environment outside of the presumed zone of initial dilution (ZID),
- to use data collected in the year two monitoring period for Camps Bay, to validate the revised sampling grid based on the ZIDs determined by dispersion modelling,
- to use data collected in this monitoring period at Hout Bay and Green Point, to enable refinement of sampling site locations at Hout Bay and Green Point for the third year of sampling.

2 APPROACH

The approach and sampling procedures are detailed in the Project Execution Plan (PEP submitted to the CCT (LT-839 PEP V1.0) as well as in the two respective data reports (LT 839 DTR_01_V2.0 and LT 839 DTR_02_V1.0). A summary is provided in Table 2.1.

Table 2.1: Summary of the sampling approach and analyses conducted during the second year of monitoring at the Hout Bay, Camps Bay and Green Point marine outfalls on behalf of the City of Cape Town.

Work scope component	Location	Frequency	Duration of monitoring	Sampling equipment	Parameters measured	Analytical practitioner
Seawater quality	16 prescribed sites in the nearshore surrounding each of the three outfalls.	Weekly	Six weeks in winter (non-upwelling) and six weeks in summer (upwelling).	3.5 L Niskin bottle	Enterococci, total suspended solids, total organic carbon, phosphorus (measured as orthophosphate), nitrogen (measured as ammonia)	CLS SA with analyses conducted by the CSIR
Seawater quality		Weekly	Six weeks in winter (non-upwelling) and four ¹ weeks in summer (upwelling).	Multi-parameter YSI EX02 CTD (measuring at a frequency of 4 Hz)	Temperature, conductivity, turbidity, pH, dissolved oxygen	CLS SA
Seawater quality	Three prescribed sites at beaches inshore and adjacent to each of the three outfalls.	Weekly	Six weeks in winter (non-upwelling) and four ¹ weeks in summer (upwelling).	5 L bucket or sampling bottle	Enterococci ¹	CLSA with analyses conducted by the CSIR
Seawater toxicity	Two sites in the nearshore surrounding each of the three outfalls	Alternate days	Two weeks that align with the winter (non-upwelling) and summer (upwelling) monitoring periods.	Sampling bottle	Toxicity of water samples to sea urchins.	CLS SA with analyses conducted by the CSIR
Trace metal contaminants in bivalve flesh ²	12 prescribed nearshore sites in the receiving environment surrounding each of the outfalls.	N/A	Mussels suspended at sites for duration of six-week sampling period in winter (non-upwelling) and summer (upwelling).	20 <i>Mytilus galloprovincialis</i> in a mesh bag suspended on moorings at each site	Mussel growth and trace metal (Zn, Cu, Ni) concentration in flesh	Anchor Environmental Consultants with analyses conducted by the CSIR
Notes: 1. Enterococci are the preferred bacterial indicator for coastal waters as they are more persistent than other indicators such as <i>E. coli</i> (Jin et al. 2004). 2. The ecological monitoring of mussel flesh was conducted by a third-party subcontractor. The results are referred to, and their detailed presentation is included in APPENDIX D.						

3 WATER QUALITY GUIDELINES

The water quality guidelines applied in this monitoring programme are summarised in Table 3.1. They are derived from the South African Water Quality Guidelines for Coastal Waters Volume 1: Natural Environment (Department of Water Affairs and Forestry (DWAF) 1995) and Volume 2: Recreational Use (Department of Environmental Affairs (DEA) 2012)

An update to the 1995 guidelines has been recommended to ensure alignment with current international practices (DEA 2018). It was recommended that guideline values should be derived from a site-specific reference system (i.e., obtained from a reference site) which should be determined as the range defined by the 20th and 80th percentiles of the seasonal distribution of a given parameter. These guidelines have not yet been gazetted, but are applied here for temperature, salinity, turbidity, pH, dissolved oxygen, total suspended solids, phosphorus (as orthophosphate) and nitrogen (ammonia) (Table 3.1). Note that no guidelines have been recommended for total organic carbon (TOC).

Table 3.1: South African Water Guidelines applicable to the receiving marine environment surrounding the three City of Cape Town marine outfalls at Hout Bay, Camps Bay and Green Point.

Constituent	Recommended Guideline	Reference
Temperature	Median salinity should range between the 20 th and 80 th percentiles of a site and season specific reference dataset.	DEA (2018)
Salinity	Median salinity should range between the 20 th and 80 th percentiles of a site and season specific reference dataset.	DEA (2018)
Turbidity	Median concentration should not exceed the 80 th percentile of a site and season specific reference dataset.	DEA (2018)
pH	Median pH should range between the 20 th and 80 th percentiles of a site and season specific reference dataset.	DEA (2018)
Dissolved oxygen	Median dissolved oxygen should not fall below the 20 th percentile of a site and season specific reference dataset.	DEA (2018)
Enterococci	90 th percentile $\leq$ 185 cfu/100 mL	DEA (2012)
Total suspended solids	Median concentration should not exceed the 80 th percentile of a site and season specific reference dataset.	DEA (2018)
Phosphorus (as orthophosphate)	Median concentration should not exceed the 80 th percentile of a site and season specific reference dataset.	DEA (2018)
Nitrogen (as ammonia)	Median concentration should not exceed the 80 th percentile of a site and season specific reference dataset. Toxicity: $\leq$ 600 μ g/L	DWAF (1995)

For the application of DEA (2018) guidelines, one reference site at each outfall was selected according to their locations offshore of each of the outfalls and predominant current directions. To increase the number of sample points, reference sites were grouped and the obtained guideline statistics (20th and 80th percentiles) were applied at all three outfalls. The justification for this is that oceanographic processes on the southwest coast of South Africa generally occur at the mesoscale (10-100 km) and thus similar salinity, pH and dissolved oxygen ranges are expected to occur at Hout Bay, Camps Bay and Green Point. Temperature-salinity (T-S) diagrams, plotted for reference sites at Hout Bay, Camps Bay and Green Point for the summer period (Figure 3.1) indicate that the sites have the same water body with a mild north-south temperature enhancement.

Percentile values were calculated over the six sampling weeks in winter and summer. Temperature, salinity, pH and dissolved oxygen data were obtained from the water column profiles. For the analyses of compliance of these variables with water quality guidelines, profile data were grouped into surface

(0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depths. For the analyses of compliance of total suspended solids, orthophosphate and ammonia with water quality guidelines, laboratory results for reference sites were also grouped into surface, mid and bottom depths based on the depth of sample collection.

Table 3.2: 20th and 80th percentiles of water quality constituents obtained from three reference sites offshore the Hout Bay, Camps Bay and Green Point outfalls. Percentile ranges are applied as guidelines to the relevant constituents as described in DEA (2018).

Constituent		Percentile	Depth		
			Surface (0-5 m)	Mid-depth (5-15 m)	Bottom (>15 m)
Winter					
n (profiles)			169	345	286
Temperature (°C)	20 th		12.36	11.73	10.90
	80 th		14.11	14.06	13.75
Salinity (PSU)	20 th		34.89	34.94	34.89
	80 th		35.24	35.24	35.17
Turbidity (FNU)	80 th		1.12	0.97	1.52
pH	20 th		8.44	8.43	8.46
	80 th		8.61	8.62	8.59
Dissolved oxygen (mg/L)	20 th		7.80	7.40	6.68
n (laboratory analyses)			18	18	18
Total suspended solids (mg/L)	80 th		8	6	23
Orthophosphate (µg/L)	80 th		35	30	42
Ammonia (µg/L)	80 th		49	31	31
Summer					
n (profiles)			161	329	292
Temperature (°C)	20 th		10.76	10.04	9.80
	80 th		14.37	13.27	11.94
Salinity (PSU)	20 th		34.59	34.59	34.59
	80 th		34.67	34.65	34.64
Turbidity (FNU)	80 th		0.34	0.29	0.35
pH	20 th		7.64	7.57	7.49
	80 th		7.90	7.85	7.76
Dissolved oxygen (mg/L)	20 th		7.01	4.87	2.79
n (laboratory analyses)			17 ¹	17 ¹	17 ¹
Total suspended solids (mg/L)	80 th		3	3	4
Orthophosphate (µg/L)	80 th		67	76	74
Ammonia (µg/L)	80 th		32	55	51
Notes:					
1. Analyses results for samples collected during week 1 at Camps Bay during the 2021 summer survey are not included in the calculations due to samples being collected too far from the specified locations.					

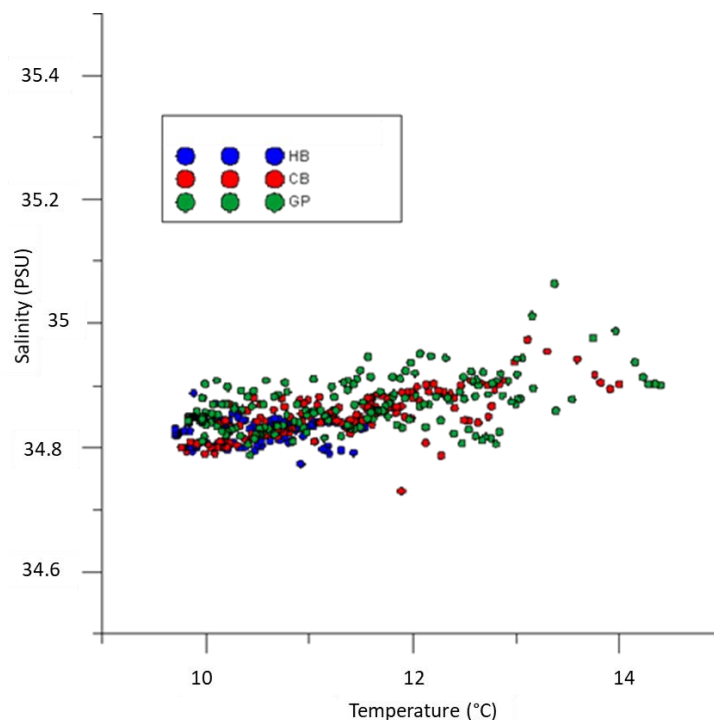


Figure 3.1: T-S diagrams for reference sites at Hout Bay (HB), Camps Bay (CB) and Green Point (GP) during the summer survey.

4 APPENDIX A: HOUT BAY

4.1 Description of the Outfall

The Hout Bay outfall was commissioned in 1993 and is located on the western side of Hout Bay. The pump station is located approximately 260 m to the south of Hout Bay harbour. The outfall extends in an easterly direction from the shoreline and then doglegs to the southwest. Effluent is discharged approximately 800 m from the rocky headlands on the western side of the bay and 2 500 m from the main swimming beach (Figure 4.1 and Figure 4.2). The diffuser is located at a depth of 37 m.

4.2 Sampling Locations

Figure 4.1 and Figure 4.2 shows the Hout Bay outfall, and locations of the respective sampling and measurement sites during each week of sampling in the winter (August-September 2020) and summer (March-April 2021) monitoring periods.

For the purposes of the initial survey design, the CCT estimated the zone of initial dilution (ZID) at the Hout Bay outfall to be within a 272 m radius from the diffusers. Results of the hydrodynamic modelling conducted by PRDW (2020) suggested that for Total Suspended Solids (TSS) a mixing zone distance of 450 m from the discharge is required to meet the required dilution of 2 587 (as determined by the CCT) in winter/spring, whereas in summer/autumn a mixing zone distance of 360 m is predicted. For enterococci, distances of 700 m and 600 m are predicted to be required in winter/spring and summer/autumn to meet the 90th percentile water quality guideline of 185 cfu/100 mL. This is included on the plots below.

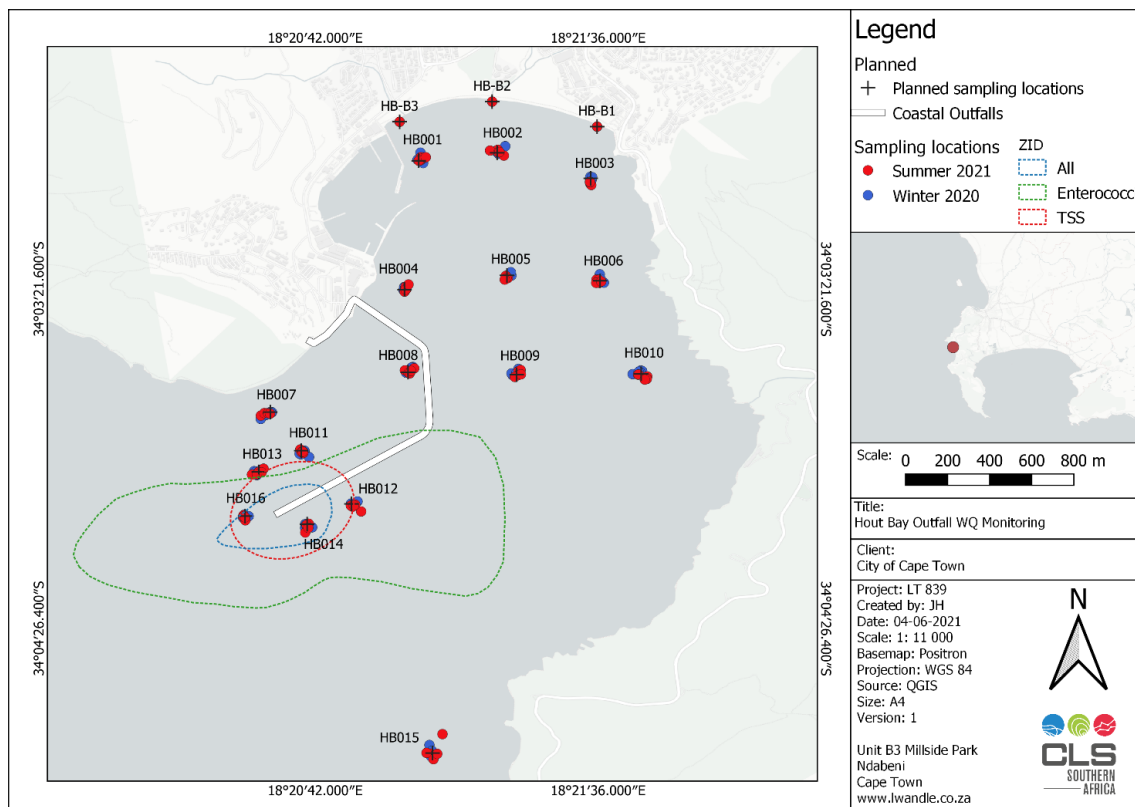


Figure 4.1: Map showing the Hout Bay outfall and the locations of nearshore and beach (HB-B1, HB-B2 and HB-B3) sites sampled during the winter (August-September 2020) and the summer (March-April 2021) monitoring periods.

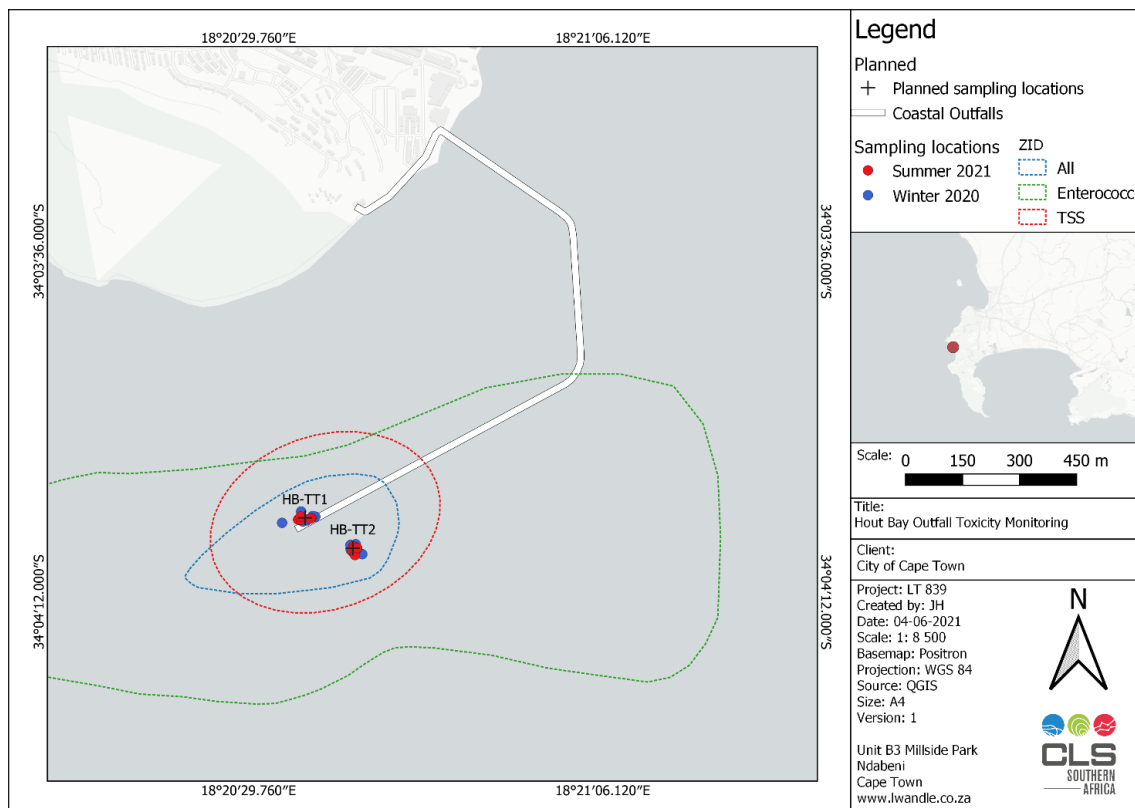


Figure 4.2: Map showing the Hout Bay outfall and the locations of the sites sampled for toxicity testing during the winter (August-September 2020) and the summer (March-April 2021) monitoring periods.

4.3 Nearshore Water Column Characteristics

The surface, middle and bottom depth values (grouped into 1 m bins) recorded seasonally at the Hout Bay outfall sampling sites for each measured water quality constituent (extracted from CTD data) are presented in the plots below. Parameters are also compared to relevant guidelines where appropriate.

4.3.1 Temperature

No distinct seasonal pattern was seen in the water column temperatures at sites sampled in Hout Bay in surface and middle waters (Figure 4.3). In bottom waters, temperatures recorded in winter were generally higher than those recorded in summer. Further, the lowest temperatures were mostly recorded in summer at all depths, this is characteristic of the seasonal upwelling in the region. Water column temperatures ranged between 9.99 and 14.16 °C in the winter survey and were between 9.21 and 15.14 °C during summer, which are within the expected range for the region. The summer survey generally had a greater range of temperatures measured at all depths and the winter survey had a higher inter-week variation in comparison to the winter survey.

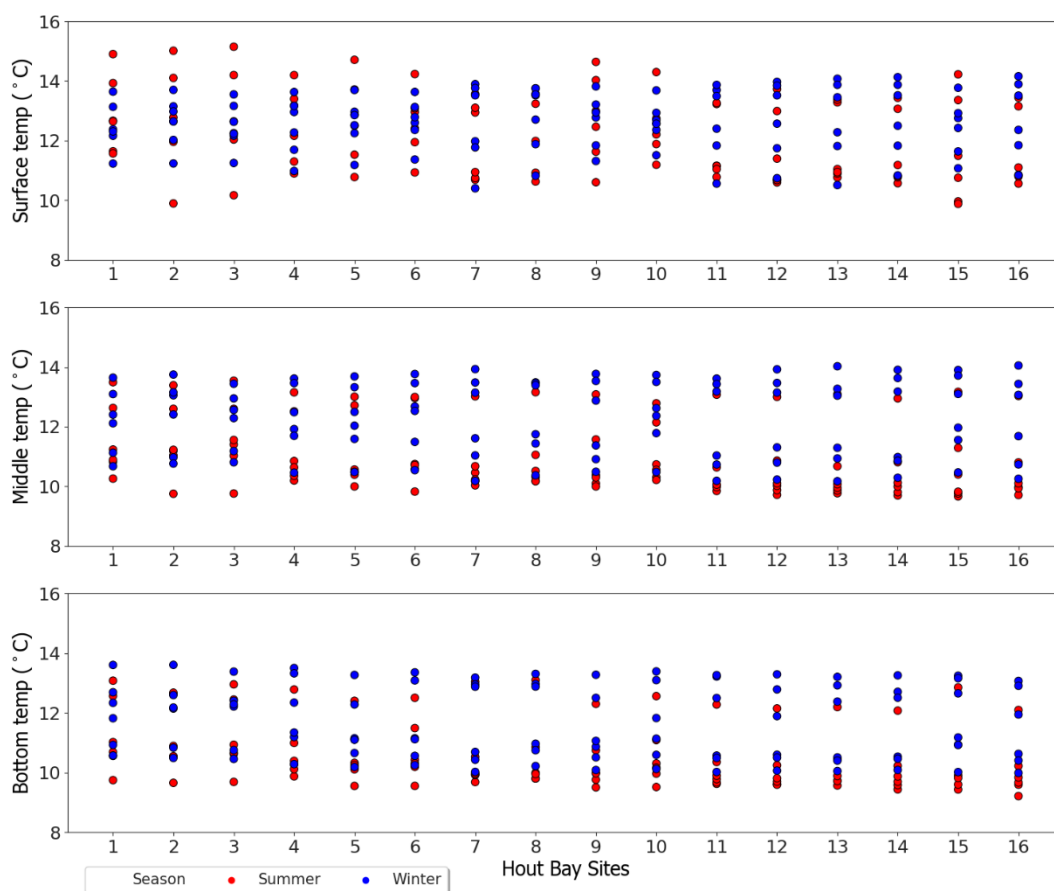


Figure 4.3 : Seasonal distribution of temperature (°C) measured at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys.

Temperature values at all depths in the nearfield of the discharge, represented by measurements from sites HB11, HB12, HB13, HB14 and HB16, were compliant with the stipulated guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 4.1). For this determination, nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.1: Median and mean temperature values (°C) in the surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	288	568	730
Median	13.02	13.04	11.44
Mean	12.68	12.34	11.75
Summer			
n	288	588	1117
Median	10.83	10.37	9.93
Mean	11.53	10.89	10.41

4.3.2 Salinity

Salinities recorded during the winter survey were generally higher than those recorded in summer, more notably in middle and bottom waters (Figure 4.4). Salinities ranged between 33.67 and 35.27 PSU and 34.01 and 34.86 PSU in the winter and summer, respectively. The lowest salinity (33.67 PSU) was recorded in surface waters at site HB6 during winter. The winter survey generally had a greater range of salinities (and a higher inter-week variation) than summer whilst both seasons displayed higher ranges in surface waters than in middle and bottom waters.

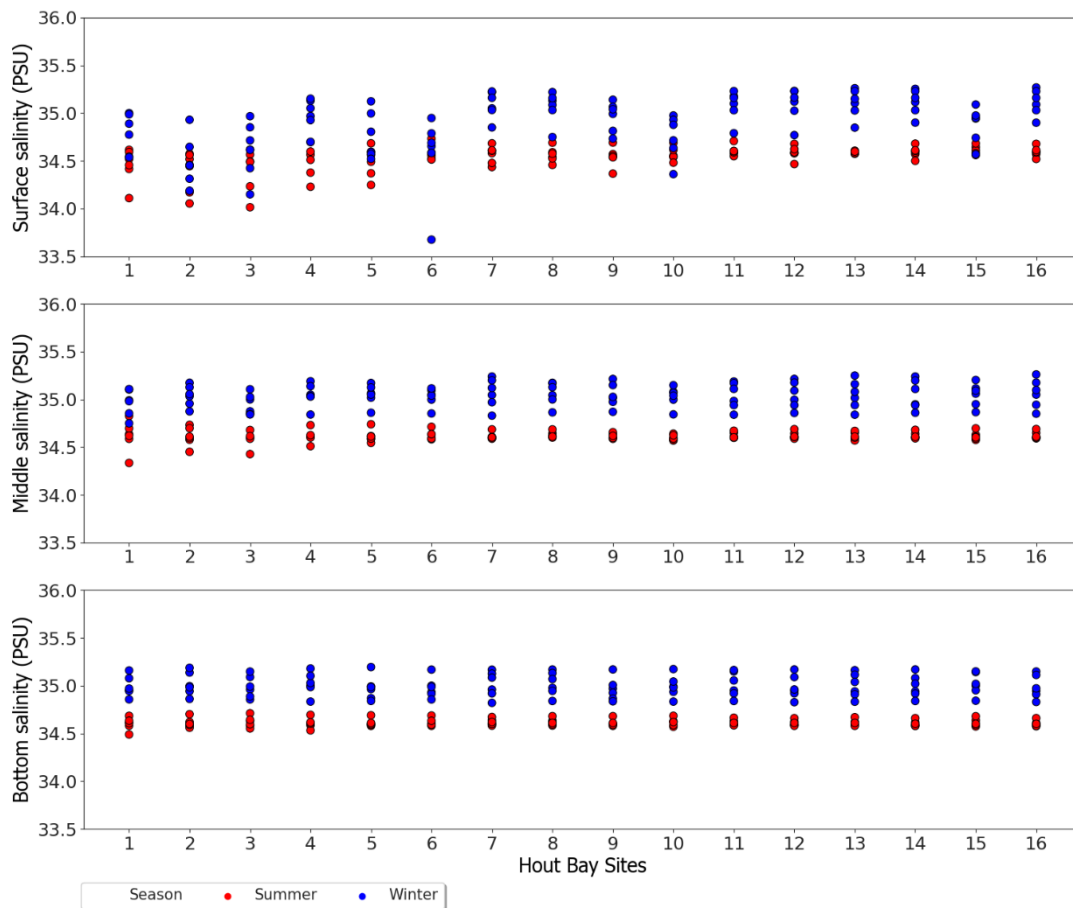


Figure 4.4: Seasonal distribution of salinity (PSU) measured at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys.

Measured salinity values were compliant with the DWAF (1995) stipulated guideline range (33-36 PSU) during the winter and summer monitoring periods. In the nearfield of the discharge, represented by measurements from stations HB7, HB8, HB9, HB11, HB12, HB13, HB14 and HB16, compliance was also met with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 4.2). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.2: Median and mean salinity values (PSU) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	288	568	730
Median	35.14	35.09	34.99
Mean	35.10	35.07	35.01
Summer			
n	288	588	1117
Median	34.59	34.60	34.60
Mean	34.60	34.62	34.61

4.3.3 Turbidity

The recorded turbidity values had a similar seasonal pattern to salinity with higher turbidity values generally recorded in winter for all depths (Figure 4.5). Turbidity values ranged between 0.03 and 9.07 FNU and 0.02 and 1.55 FNU in the winter and summer, respectively. The winter survey also had a greater range of turbidity values at all depths as well as a higher inter-week variation in comparison to the summer survey. The highest turbidity values were recorded in bottom waters during winter, with several sites recording values that exceeded 3 FNU.

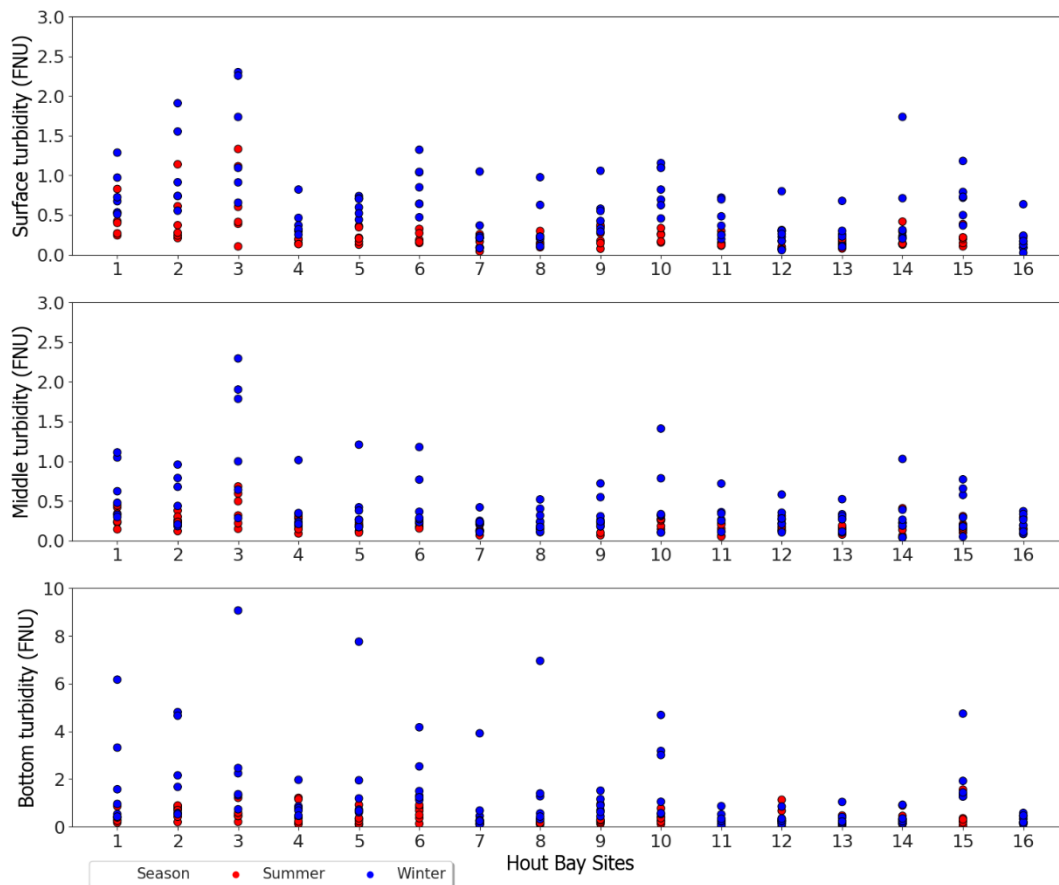


Figure 4.5: Seasonal distribution of turbidity (FNU) measured at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys. Note that the bottom depth plot has a different scale on the y-axis to aid presentation.

Turbidity values at all depths in the nearfield of the discharge, represented by measurements from sites HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 4.3). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.3: Median and mean turbidity values (FNU) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	287	566	730
Median	0.22	0.24	0.28
Mean	0.28	0.26	0.33
Summer			
n	288	588	1117
Median	0.15	0.15	0.16
Mean	0.16	0.16	0.18

4.3.4 pH

Similar to salinity and turbidity, pH levels measured during the winter survey were notably higher than those measured during the summer survey (Figure 4.6). pH ranged between 8.10 and 8.67 in the winter and between 7.42 and 7.87 in the summer. The summer survey generally displayed a higher inter-week variation at all depths.

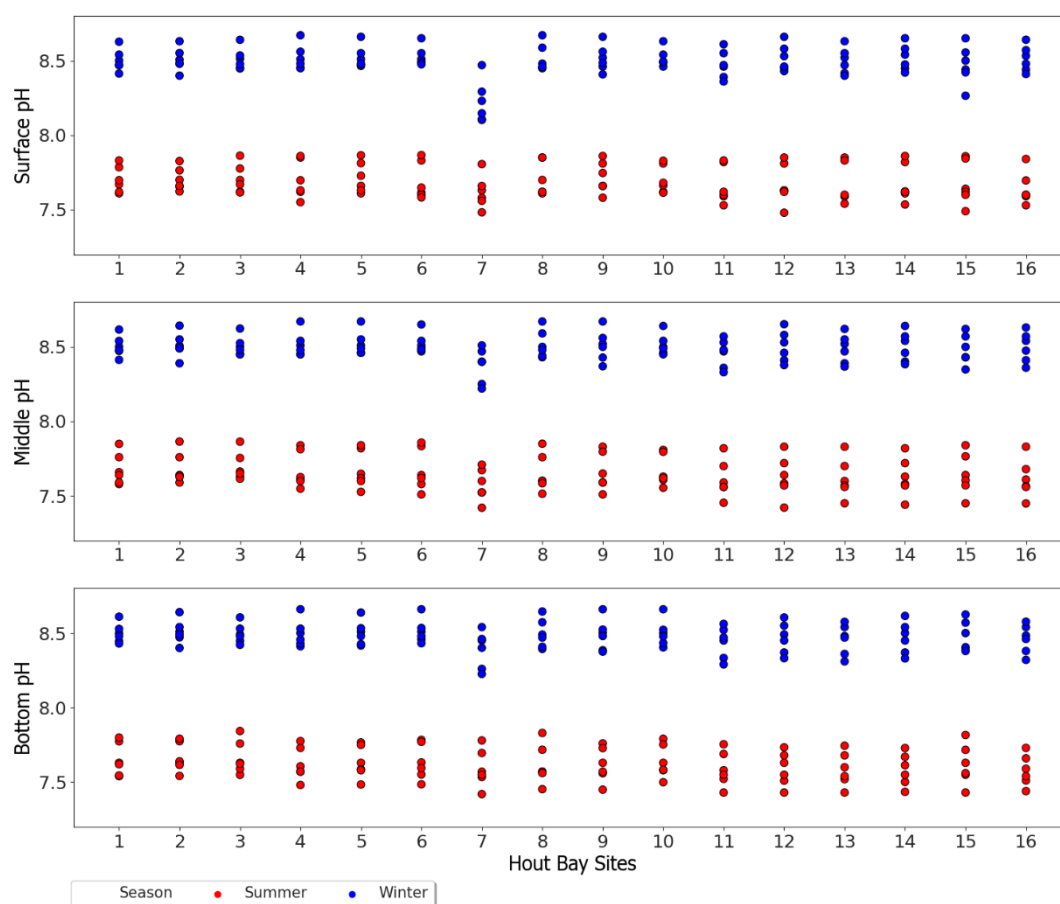


Figure 4.6: Seasonal distribution of pH measured at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys.

pH values at all depths in the nearfield water body, represented by measurements from sites HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 4.4). However, during winter the pH values at sites in the nearfield of the discharge exceeded the DWAF (1995) recommended guideline range (7.30 – 8.20). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

It must be noted that the range between the winter and summer pH values is large, and the summer values are notably lower than what was previously recorded during the year one summer survey (7.84 - 8.10). Because these low values occurred at all sites and all depths, the low pH values may be a result of instrument error, despite standard calibration procedures are conducted prior to each survey. Continued measurement of pH in future surveys will assist in establishing whether this is the case.

pH values during winter fell outside the range (7.6 – 8.1) previously recorded for the area (DEA 2015). High values (<8.1) were also noted in the year one annual report. Relatively elevated pH (>8) indicates the presence of a mainly oxic water column which suggests minimal remineralisation of organically rich sediments.

Table 4.4: Median and mean pH values in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	288	568	730
Median	8.48	8.48	8.47
Mean	8.51	8.50	8.47
Summer			
n	288	588	1117
Median	7.61	7.59	7.59
Mean	7.66	7.64	7.61

4.3.5 Dissolved Oxygen

Dissolved oxygen concentrations measured at the Hout Bay outfall were generally higher in winter compared to summer (Figure 4.7). The winter survey ranged between 4.88 and 9.30 mg/L while the summer survey ranged between 2.02 and 8.60 mg/L. The lowest concentrations (<3 mg/L) were recorded in bottom waters during the summer survey at sites HB7 - HB9 and HB11 - HB16. The recorded temperatures at these sites during summer were low (<10 °C), indicating that the dissolved oxygen concentrations recorded may be a result of upwelling processes in the area drawing hypoxic waters from deeper intermediate waters.

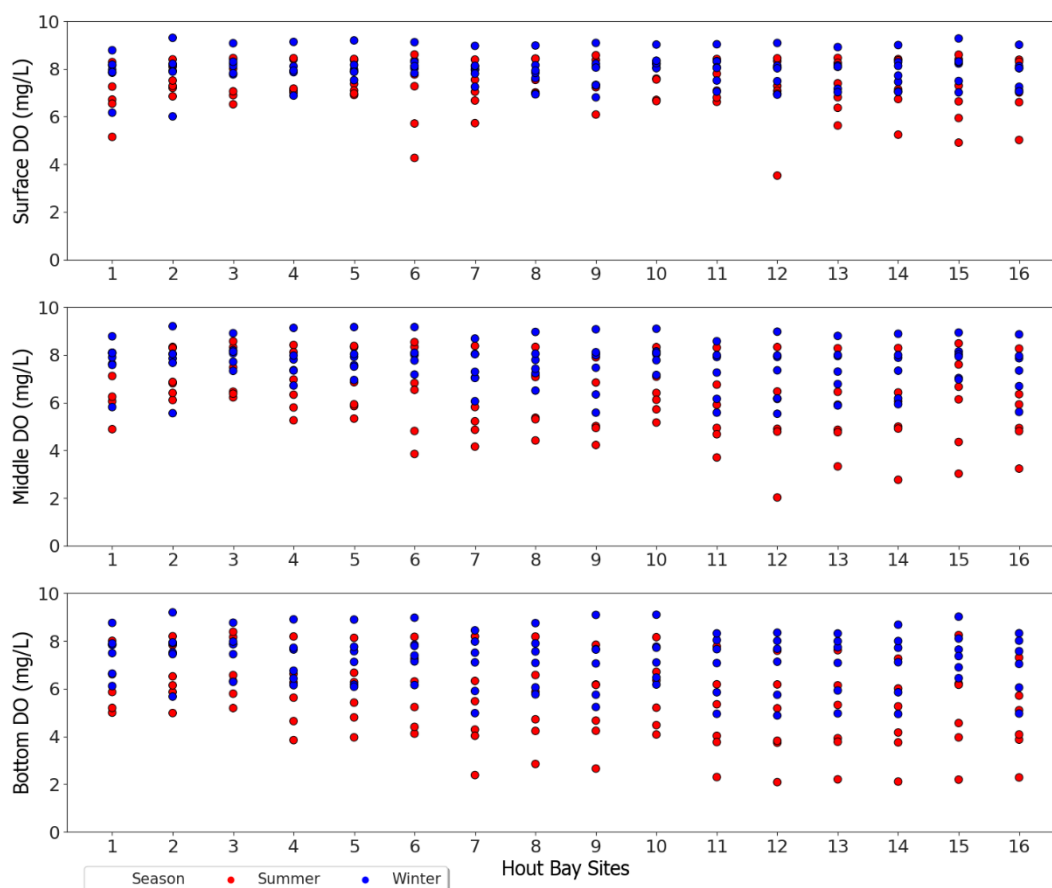


Figure 4.7: Seasonal distribution of dissolved oxygen (mg/L) measured at the Hout Bay outfall sites for the 2020 winter and 2021 summer surveys.

Dissolved oxygen concentrations in the nearfield water body, represented by measurements from stations HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines (Table 3.2) during both the winter and summer monitoring periods with exception to surface waters during summer which fell marginally below the 20th percentile guideline (Table 4.5).

During both monitoring periods, median values indicate an oxic water body at all depths in the immediate vicinity surrounding the outfall. For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.5: Median mean dissolved oxygen concentrations (mg/L) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Hout Bay outfall. Median and mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	288	568	730
Median	8.01	7.86	7.23
Mean	7.87	7.56	7.09
Summer			
n	288	588	1117
Median	6.97	6.00	5.25
Mean	6.95	6.16	5.28

4.4 Nearshore and Beach Seawater Quality

The laboratory analysis results of enterococci, TSS, TOC, orthophosphate, and ammonia measured seasonally in water samples obtained from surface, middle and bottom depths at sites in the vicinity of the Hout Bay outfall are presented in the sections below. The results of the analyses of seawater toxicity, from two sites near the outfall, to sea urchins are included.

4.4.1 Enterococci

No clear seasonal pattern was seen in enterococci counts at sites sampled in Hout Bay (Figure 4.8). Individual measurements at all depths were predominantly below 100 cfu/100 mL during winter and summer. Counts exceeding this level were most frequently observed in surface waters. The highest count occurred at HB-B2 beach site (12 000 cfu/100 mL) during week 2 in summer. This also occurred in winter when a count of 860 cfu/100 mL was recorded in surface waters at HB-B2 during week 4.

During both winter and summer survey periods, the 90th percentiles counts in mid- and bottom depth waters at all nearshore sites sampled were compliant with the recommended DEA (2012) guideline (≤ 185 cfu/100 mL, Table 3.1), with the single exception of site HB3 at mid-depth during summer (Figure 4.9 and Figure 4.10). Exceedances in surface waters occurred at site HB2 during both winter and summer and at sites HB1, HB3 and HB5 during summer.

Beach site HB-B1 mostly had individual enterococci counts below 100 cfu /100 mL in winter and summer (Figure 4.8) and the 90th percentile values complied with the recommended guideline during both seasons (Figure 4.9 and Figure 4.10). During the winter survey period, beach site HB-B3 complied with the recommended guideline, although in summer, the 90th percentile value at this site was greater than the guideline as a result of a high value of 1 420 cfu/100 mL being recorded during week 2. At site HB-B2, several individual measurements exceeded 500 cfu/100 mL in winter and summer (Figure 4.8) and the 90th percentile values during both sampling seasons were greater than the recommended guideline. Site HB-B2 is located in the middle of Hout Bay swimming beach and is near the Disa River estuary mouth.

It must be noted that percentile values calculated for each site are based on six samples in winter and six in summer. High enterococci values thus affect the percentile values more than what could be the case if there were larger sample sizes.

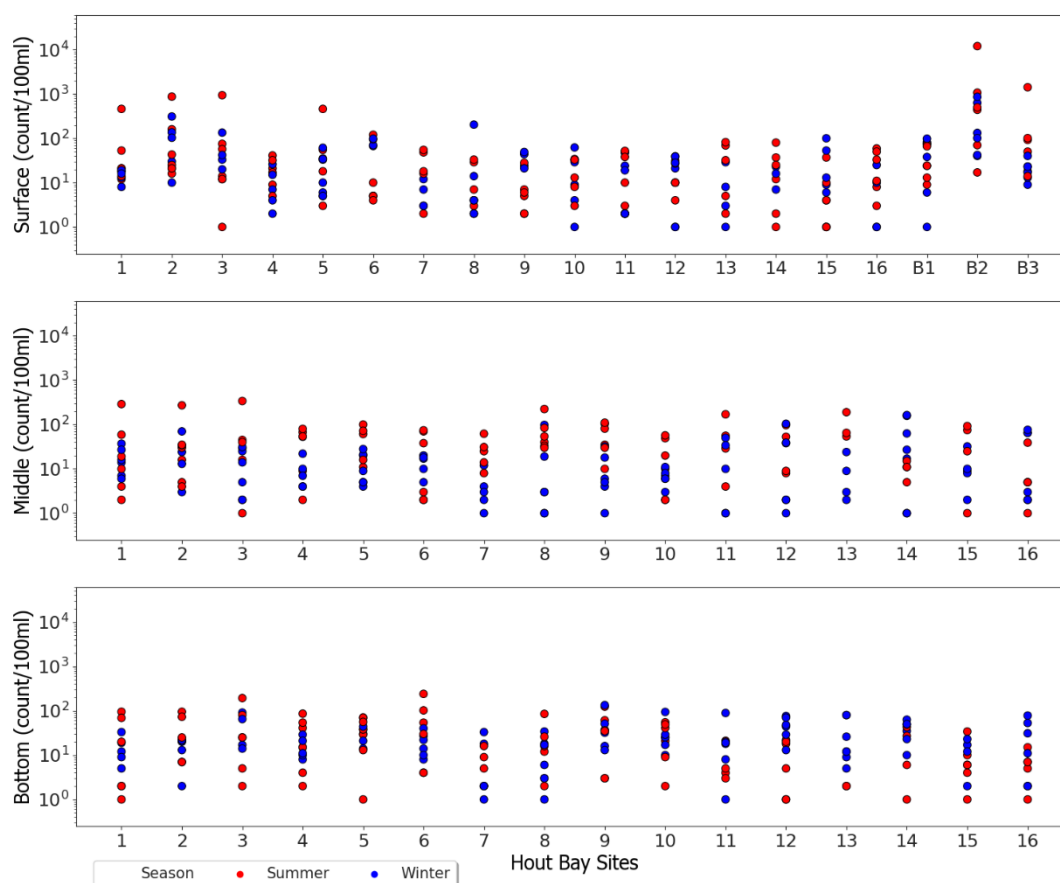


Figure 4.8: Seasonal distribution of enterococci (count/100 mL) measured at surface, mid- and bottom depths at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys. The enterococci counts measured at beach sites are included in the surface plot (B1, B2 and B3).

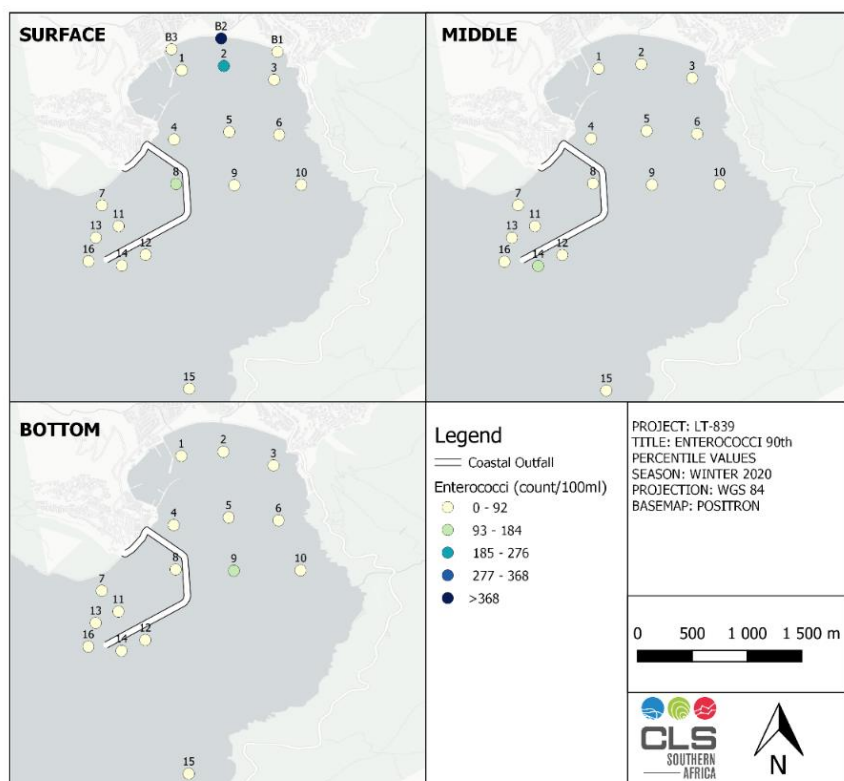


Figure 4.9: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Hout Bay outfall sites during the 2020 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

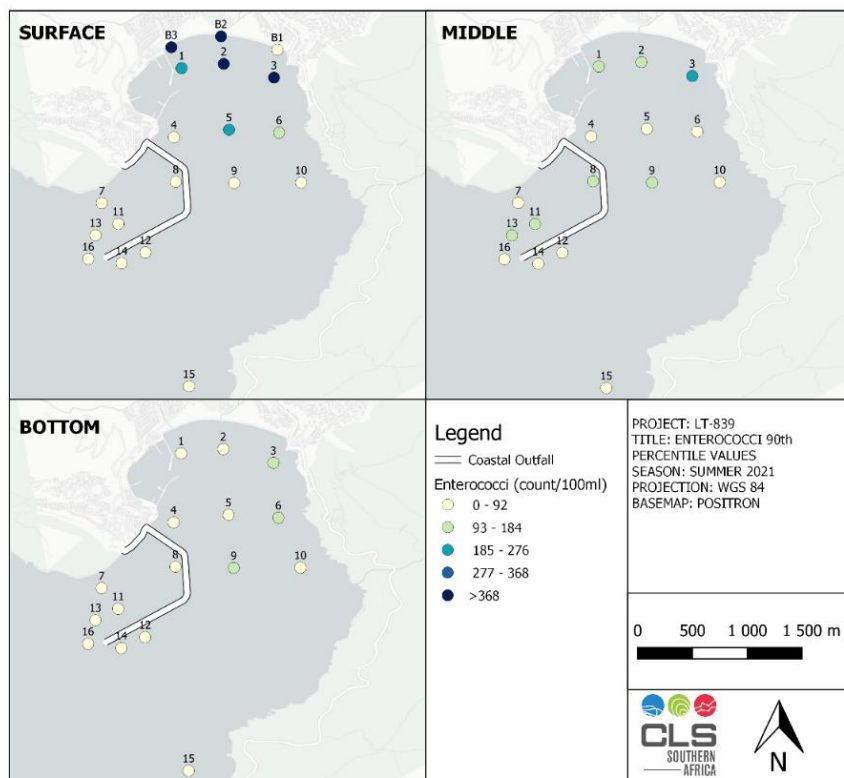


Figure 4.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

4.4.2 Total Suspended Solids

TSS concentrations were generally higher during the winter survey period than the summer survey period at all depths (Figure 4.11, Figure 4.12 and Figure 4.13). Outliers were recorded in surface waters at sites HB1 (64 mg/L) during week 3, and HB8 (47 mg/L) during week 3 and in mid-depth waters at site HB7 (36 mg/L). During winter, bottom waters showed more inter-week variability at most sites (Figure 4.11).

Median TSS concentrations were relatively higher (most sites were >4 mg/L) in bottom waters compared to surface and mid-depth waters during the winter survey period (Figure 4.12). The highest median concentration was recorded at HB3 (17 mg/L) in bottom waters during winter. In the summer survey, median concentrations were all below 4 mg/L (Figure 4.13).

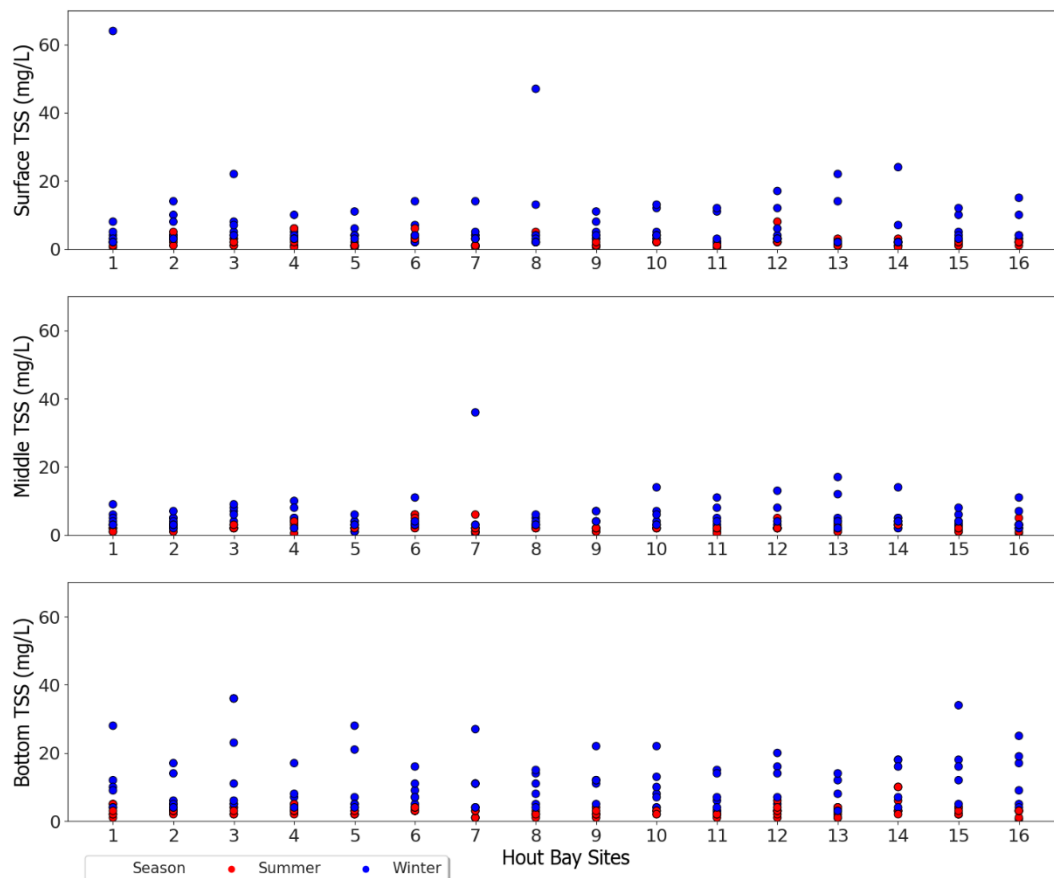


Figure 4.11: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2.

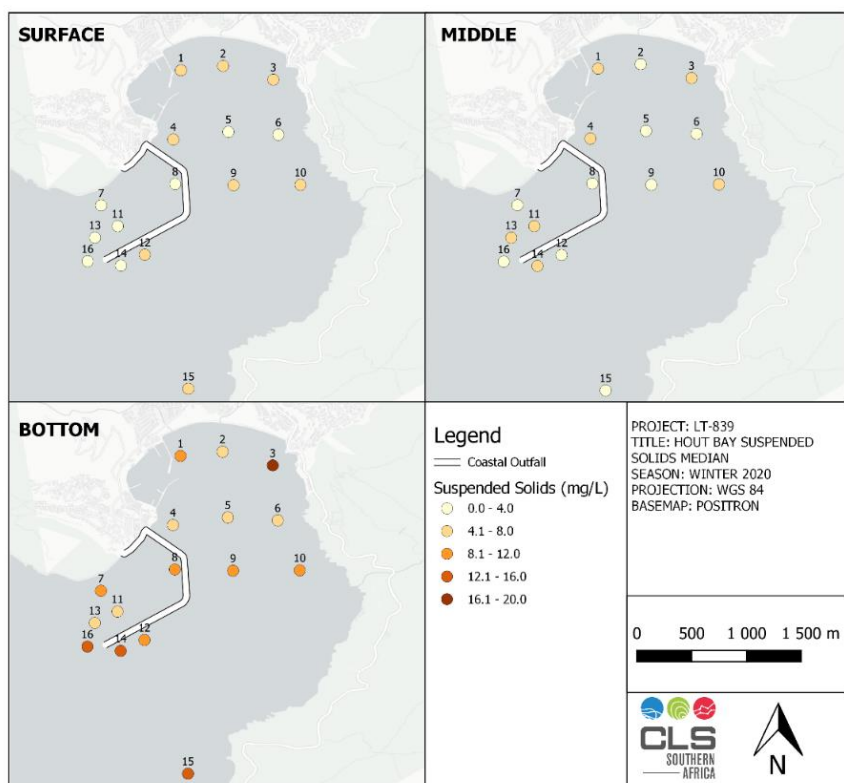


Figure 4.12: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2020 winter survey.

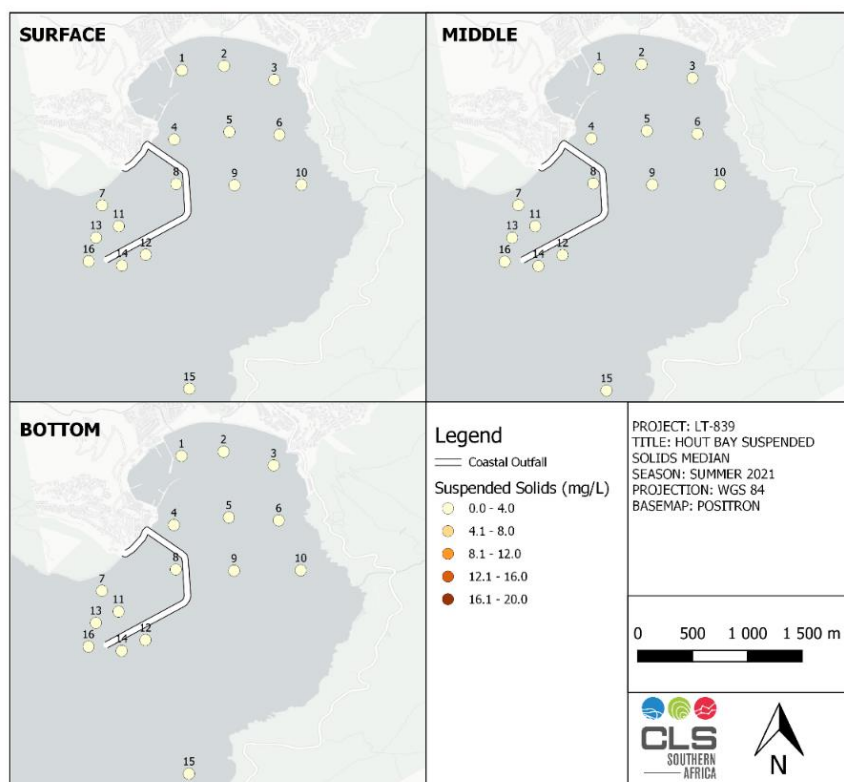


Figure 4.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 summer survey.

TSS values at all depths in the nearfield water body, represented by measurements from stations HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines during both the winter and summer monitoring periods. During both monitoring periods, median values in surface, mid and bottom waters fell below the 80th percentile guideline defined in Table 3.2 (Table 4.6). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.6: Median and mean total suspended solids values (mg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	3	4	9
Mean	7	6	10
Summer			
n	30	30	30
Median	2	2	3
Mean	2	2	3

4.4.3 Total Organic Carbon

No clear seasonal pattern was seen in TOC concentrations at the Hout Bay sites (Figure 4.14, Figure 4.15 and Figure 4.16). TOC concentrations in surface, middle and bottom waters were generally low and ranged between 0.5 and 3.5 mg/L during the winter survey and 0.3 and 2.5 mg/L during the summer survey (Figure 4.14). Both the winter and summer survey displayed high inter-week variation. The highest measurement was recorded at site HB13 (3.5 mg/L) during week 1 in winter. The highest median concentrations were also measured in winter at sites HB2 (2.0 mg/L) in surface waters, HB6 (1.8 mg/L) and HB11 (1.7 mg/L) in mid-depth waters and HB10 (1.8 mg/L) in bottom waters (Figure 4.15).

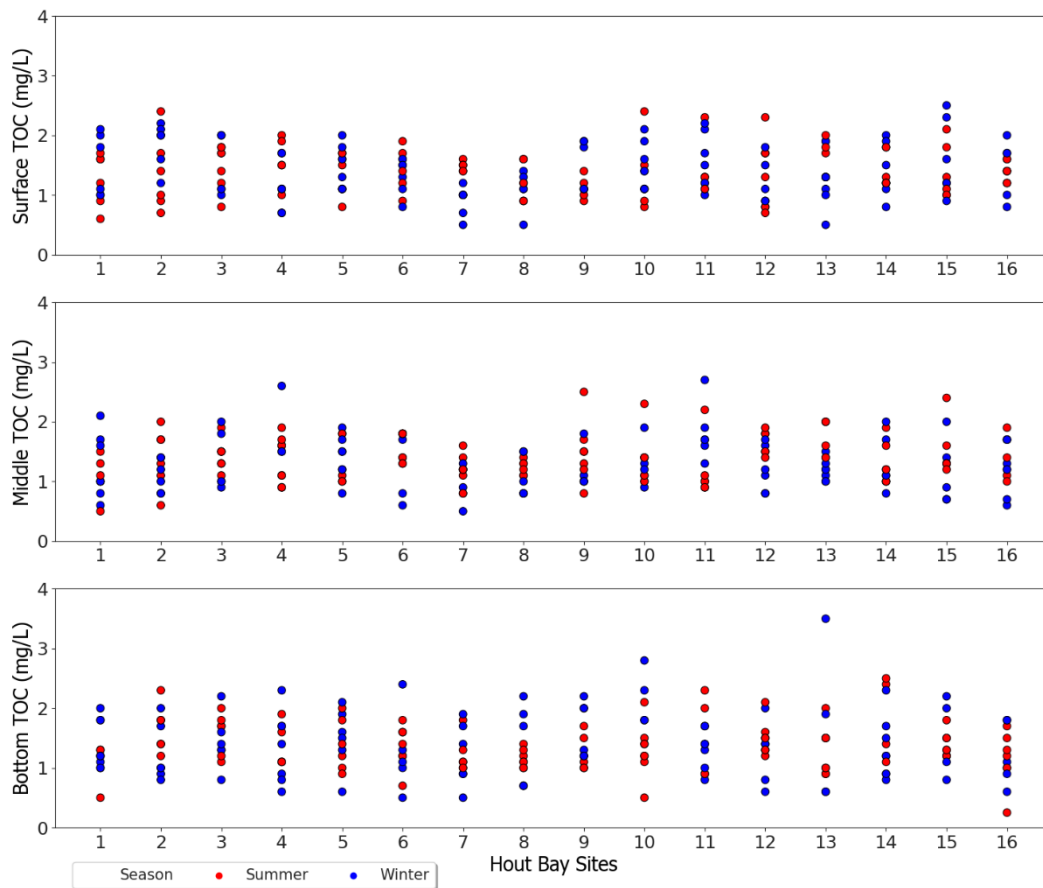


Figure 4.14: Seasonal distribution of total organic carbon (mg/L) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <0.5 mg/L) are presented as MDL/2.

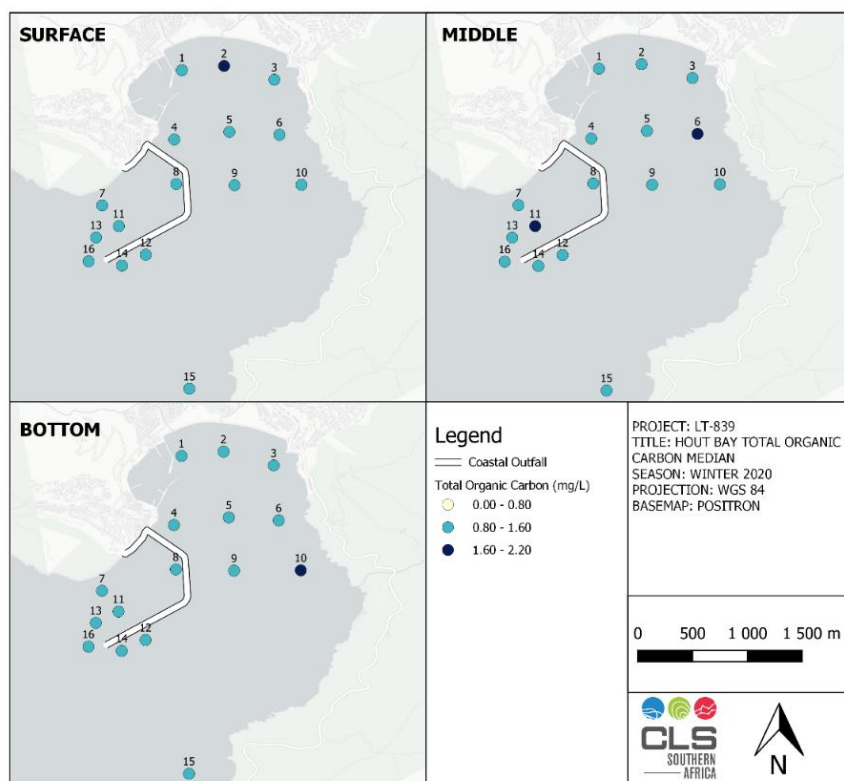


Figure 4.15: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2020 winter survey.

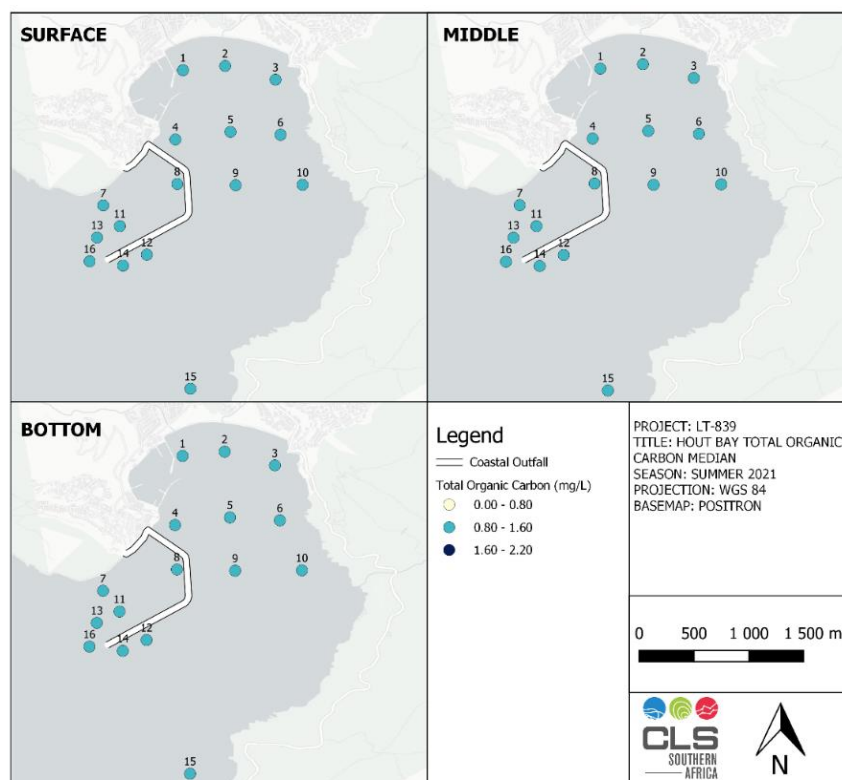


Figure 4.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 summer survey.

4.4.4 Orthophosphate

Orthophosphate concentrations were notably lower during the winter survey period than the summer survey period at all depths (Figure 4.17, Figure 4.18 and Figure 4.19). Individual measurements ranged between 9 and 51 $\mu\text{g/L}$ in winter and 19 and 90 $\mu\text{g/L}$ in summer. Both seasons displayed high inter-week variation. Median concentrations showed no clear spatial distribution patterns across depths and/or sample sites (Figure 4.18 and Figure 4.19).

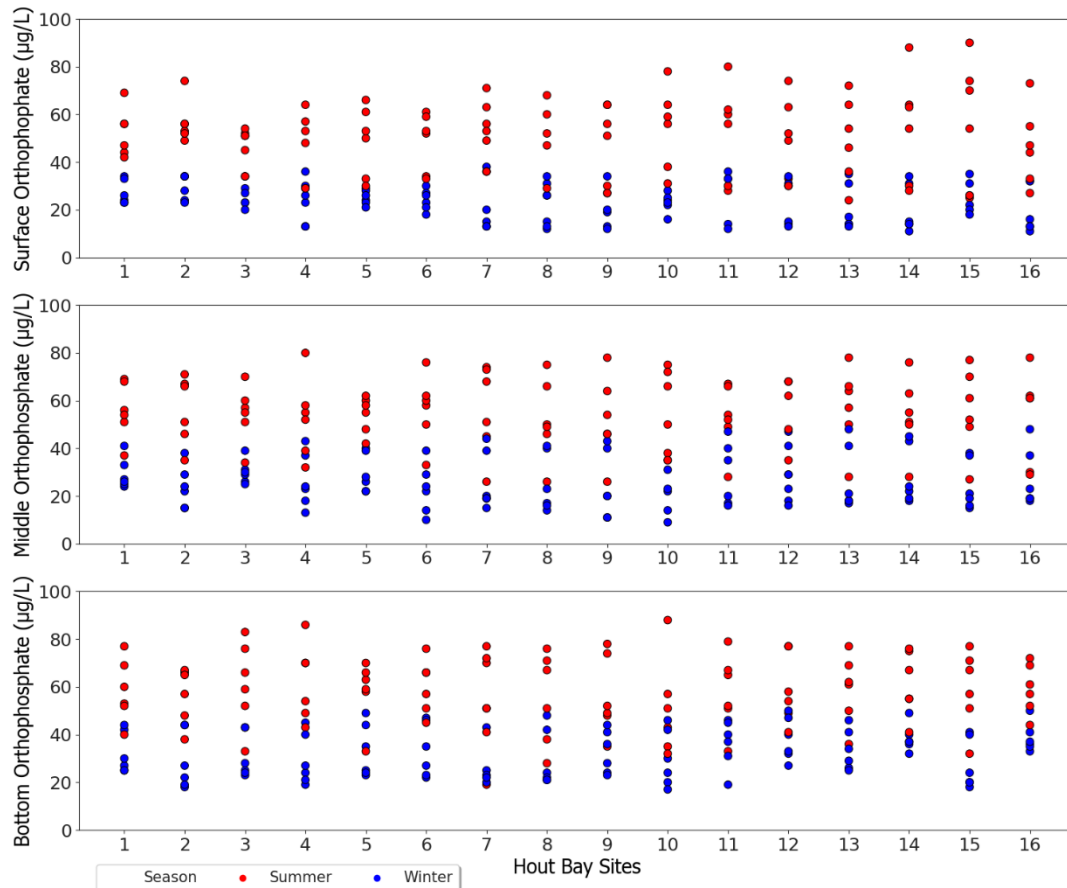


Figure 4.17: Seasonal distribution of orthophosphate ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys.

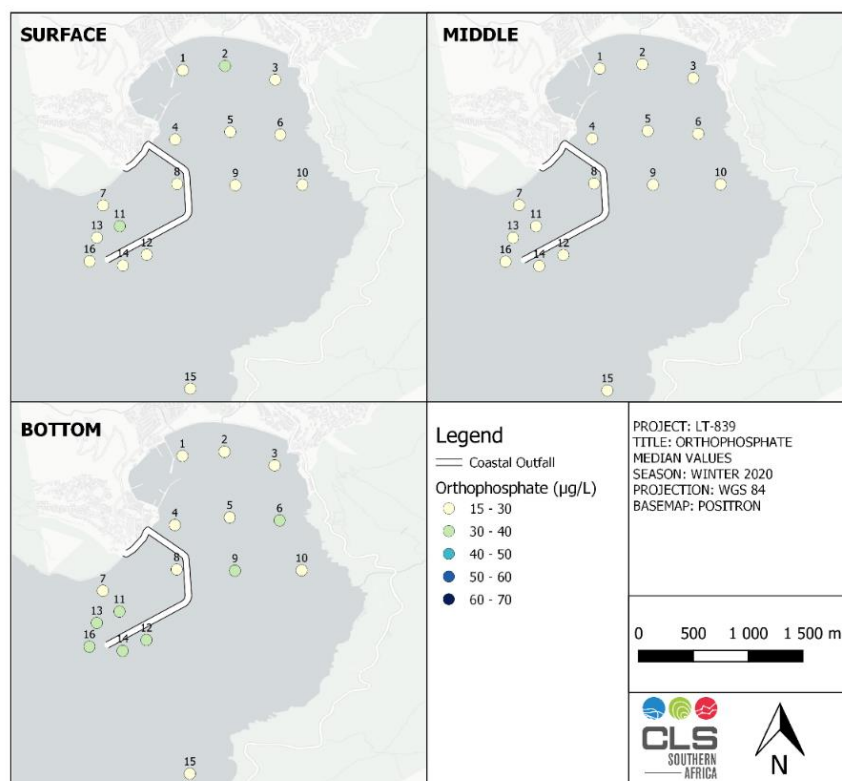


Figure 4.18: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2020 winter survey.

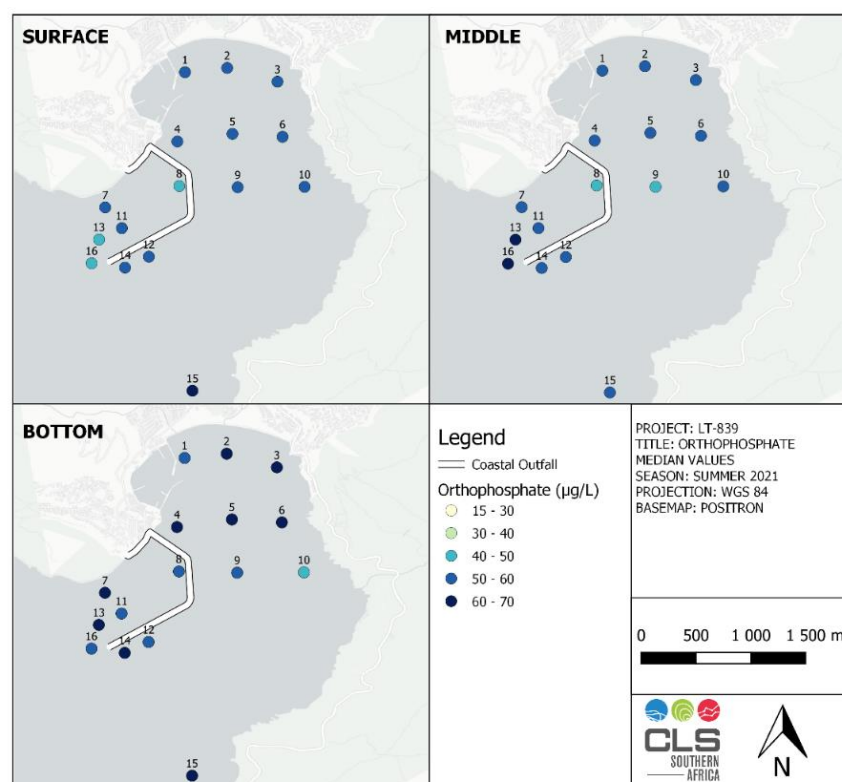


Figure 4.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 summer survey.

Orthophosphate values at all depths in the nearfield water body, represented by measurements from stations HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines during both the winter and summer monitoring periods. During both monitoring periods, median values in surface, mid and bottom waters fell below the 80th percentile guideline defined in Table 3.2 (Table 4.7) therefore in compliance with the guideline. For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.7: Median and mean orthophosphate values (µg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	16	23	37
Mean	22	28	37
Summer			
n	30	30	30
Median	53	56	60
Mean	51	54	59

4.4.5 Ammonia

Ammonia concentrations were generally lower during the winter survey period than the summer survey period at all depths (Figure 4.20). Concentrations ranged between <5 and 117 µg/L in winter and <5 and 190 µg/L in summer. The highest concentrations were recorded in surface waters, with several measurements exceeding 100 µg/L. Summer displayed higher inter-week variation than winter.

Median concentrations showed no clear spatial distribution patterns across depths and/or sample sites and no exceedances of the DWAF (1995) recommended guideline (600 µg/L, Table 3.1) were recorded (Figure 4.21 and Figure 4.22).

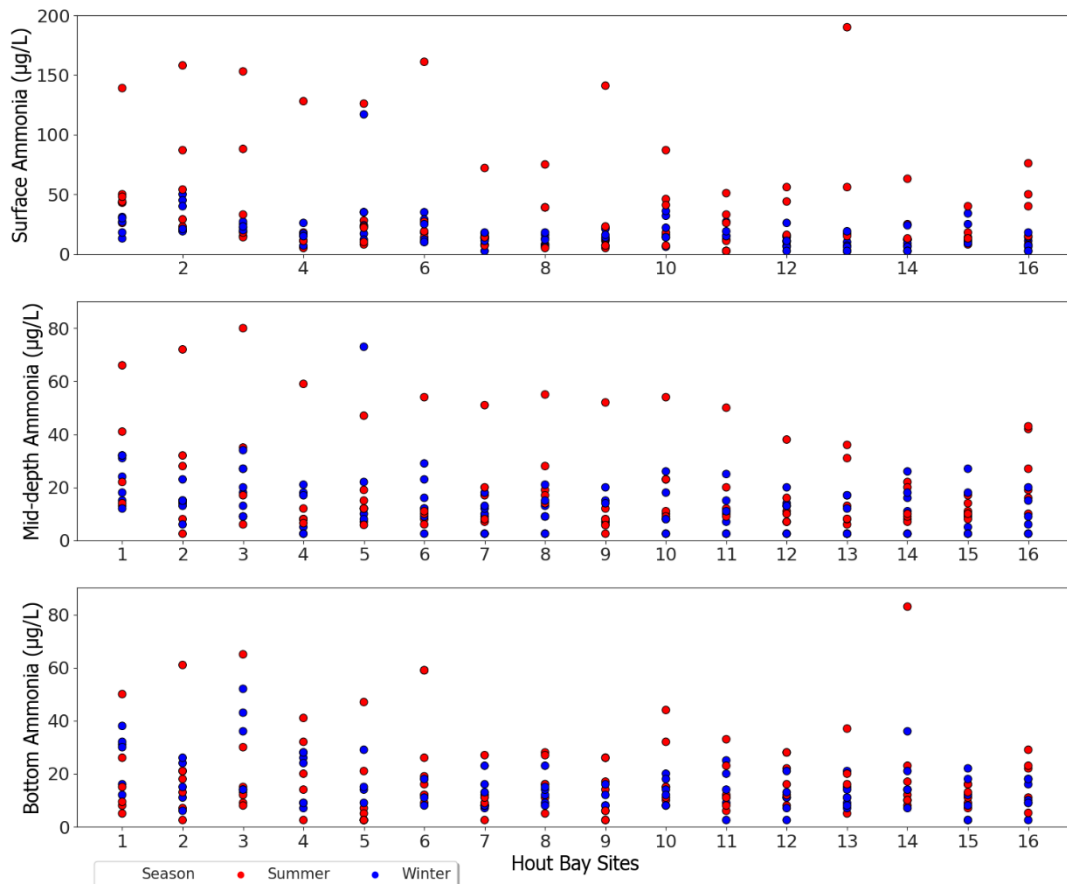


Figure 4.20: Seasonal distribution of ammonia (µg/L) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

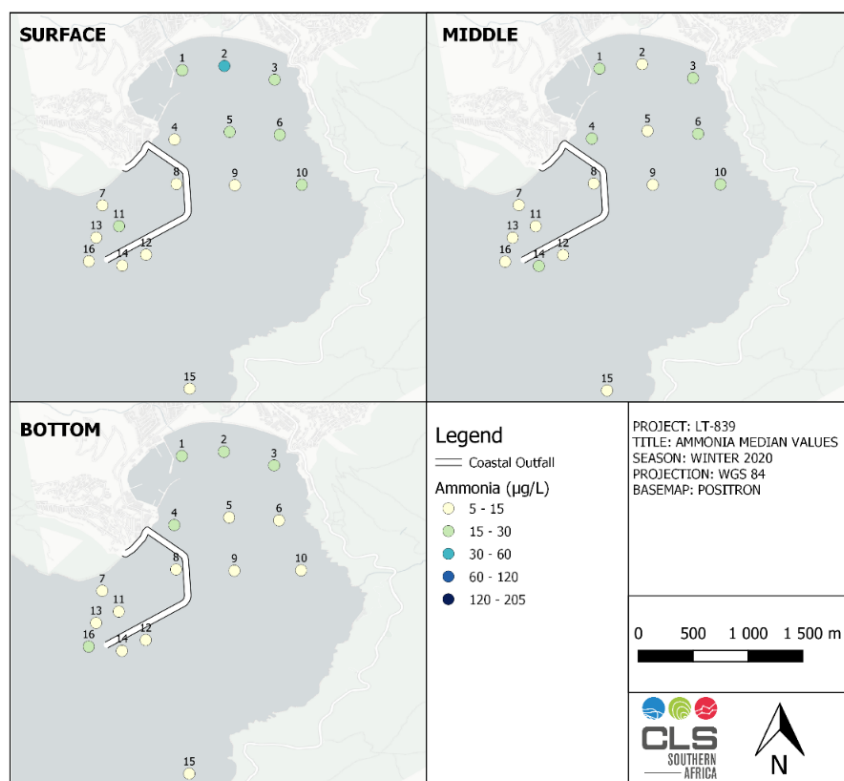


Figure 4.21: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2020 winter survey.

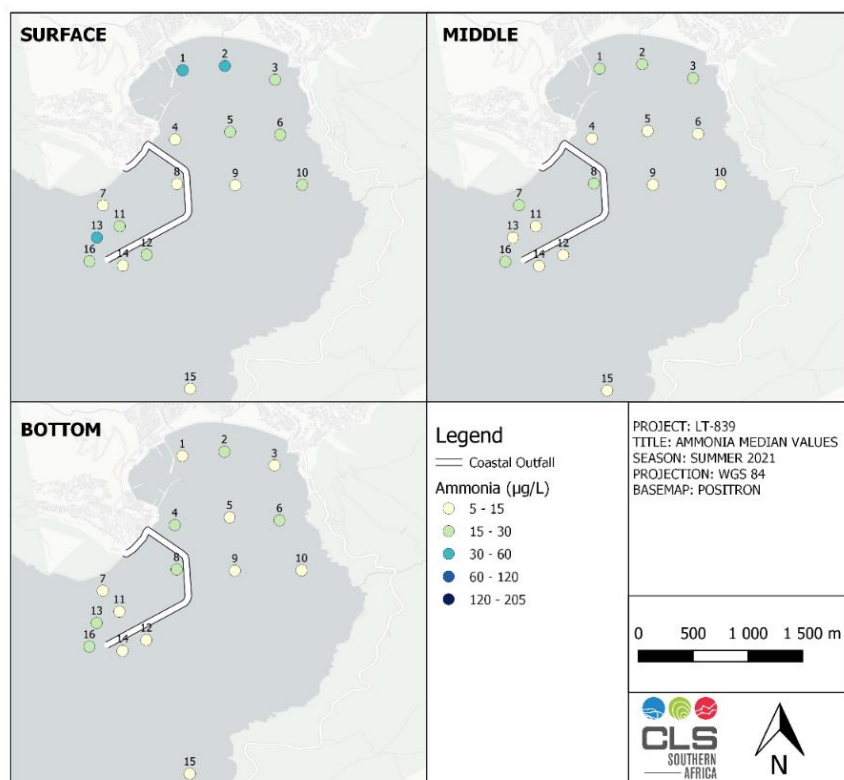


Figure 4.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 summer survey.

Further, ammonia values at all depths in the nearfield water body, represented by measurements from stations HB11, HB12, HB13, HB14 and HB16, were compliant with the recommended guidelines during both the winter and summer monitoring periods. During both monitoring periods, median values in surface, mid and bottom waters fell below the 80th percentile guideline defined in Table 3.2 therefore in compliance, however, the mean concentration at the surface in summer was slightly above the 80th percentile guideline (Table 4.8). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 4.8: Median and mean ammonia values ($\mu\text{g/L}$) in surface, mid and bottom waters measured at nearfield sites surrounding the Hout Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	12	14	14
Mean	13	14	15
Summer			
n	30	30	30
Median	17	13	14
Mean	34	18	18

4.4.6 Toxicity

The two nearshore sites sampled during the second year of monitoring showed no toxicity effects of seawater obtained from near the discharge on sea urchins (*Tripneustes gratilla* and *Echinometra mathaei*) fertilisation rates in either of the winter or summer sampling periods (Table 4.9).

Table 4.9: Sea urchin seawater toxicity test results. Samples were obtained from two nearshore sites in the vicinity of the Hout Bay outfall on alternate days during the winter (August-September 2020) and summer (March-April 2021) sampling periods. Toxicity classification is based on mean (n=4) fertilisation success rates. Grey blocks indicate that the survey did not take place.

Season	Date	Site	% Fertilisation Success				Mean	Std Dev	Faecal Indicator Bacteria
			1	2	3	4			
Tripneutes gratilla									
Winter	3 09 2020	HB-TT1	100	99	100	99	99.50	0.58	Not toxic
		HB-TT2	100	99	100	99	99.50	0.58	Not toxic
	4 09 2020	HB-TT1	99	99	100	99	99.25	0.50	Not toxic
		HB-TT2	100	99	100	99	99.50	0.58	Not toxic
	7 09 2020	HB-TT1	99	99	99	100	99.25	0.50	Not toxic
		HB-TT2	99	99	99	100	99.25	0.50	Not toxic
	9 09 2020	HB-TT1	100	99	99	100	99.50	0.58	Not toxic
		HB-TT2	100	99	99	100	99.50	0.58	Not toxic
	12 09 2020	HB-TT1	100	99	99	100	99.50	0.58	Not toxic
		HB-TT2	100	99	99	100	99.50	0.58	Not toxic
	17 09 2020	HB-TT1	99	99	98	98	98.50	0.58	Not toxic
		HB-TT2	98	99	98	98	98.25	0.50	Not toxic
	18 09 2020	HB-TT1	99	99	98	98	98.50	0.58	Not toxic
		HB-TT2	99	99	98	98	98.50	0.58	Not toxic
Summer	25 03 2021	HB-TT1S	100	100	99	99	99.50	0.58	Not toxic
		HB-TT1M	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	99.50	0.58	Not toxic
	27 03 2021	HB-TT1S							
		HB-TT1M							
		HB-TT2							
	29 03 2021	HB-TT1S	99	98	98	98	98.25	0.50	Not toxic
		HB-TT1M	99	99	99	98	98.75	0.50	Not toxic
		HB-TT2	99	99	98	98	98.50	0.58	Not toxic
	30 03 2021	HB-TT1S	99	99	98	98	98.50	0.58	Not toxic
		HB-TT1M	99	99	98	98	98.50	0.58	Not toxic
		HB-TT2	99	99	99	98	98.75	0.50	Not toxic
	31 03 2021	HB-TT1S	100	100	99	99	99.50	0.58	Not toxic
		HB-TT1M	99	100	99	99	99.25	0.50	Not toxic
		HB-TT2	99	100	99	99	99.25	0.50	Not toxic
	08 04 2021	HB-TT1S	99	99	100	100	99.50	0.58	Not toxic
		HB-TT1M	99	99	99	100	99.25	0.50	Not toxic
		HB-TT2	99	99	100	100	99.50	0.58	Not toxic
09 04 2021	HB-TT1S	99	99	100	100	99.50	0.58	Not toxic	
	HB-TT1M	99	99	100	100	99.50	0.58	Not toxic	
	HB-TT2	99	99	100	100	99.50	0.58	Not toxic	

4.5 Effects on Local Marine Ecology

Growth rates and trace metal accumulation in mussels (*Mytilus galloprovincialis*) at fixed monitoring stations surrounding the Hout Bay outfall and two control stations were compared across the winter 2020 and summer 2021 deployments. Results (detailed in APPENDIX D) indicated that mussel growth rates at the Hout Bay outfall were lower in summer than in winter. Growth rates also appeared to be higher at the monitoring (impact) stations located near the outfall than the control stations situated further afield during both seasons. The impact and control sites had an average growth rate of 0.082 and 0.04 mm/day in winter and 0.034 and 0.016 mm/day in summer, respectively.

Trace metal body burden concentrations at control and impact stations at Hout Bay also showed clear seasonal trends for nickel and zinc with a greater average loss (relative to baseline levels) observed during winter than summer. There was no evidence of seasonal differences in copper accumulation during the winter and summer deployments. Mussels at all locations accumulated copper relative to baseline concentration during both the winter and summer deployment. There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for “unimpacted” stations.

5 APPENDIX B: CAMPS BAY

5.1 Description of the Outfall

The Camps Bay outfall serves the Clifton, Camps Bay and Bakoven areas. It was commissioned in 1977 and extends seawards in a north-westerly direction to approximately 1 400 m from Camps Bay beach. It discharges effluent 600 m to the west of Maidens Cove and 800 m to the south-west of Clifton (Figure 5.1 and Figure 5.2). The diffusers are located at 23 m depth.

5.2 Sampling Locations

Figure 5.1 and Figure 5.2 show the Camps Bay outfall, as well as the location of the respective sampling sites during each week of sampling in the winter (August-September 2020) and summer (March-April 2021) monitoring periods. respectively. Figure 5.3 shows the location of the toxicity sampling sites for the winter and summer periods.

After the first week of sampling during the summer survey, it was realised that the sampled locations at Camps Bay did not align with the proposed site locations due to an issue the vessel's GPS projection system (Figure 5.2). This issue with the GPS was resolved during week two of sampling. The results for week 1 have been included in the seasonal distribution plots as a different colour and have been excluded in the compliance sections.

For the purposes of the initial survey design, the CCT estimated the zone of initial dilution (ZID) at the Camps Bay outfall to be within a 274 m radius from the diffuser. Results of the hydrodynamic modelling conducted by PRDW (2020) suggest that for TSS a mixing zone distance of 115 m from the discharge is required to meet the required dilution of 1 550 (as determined by the CCT) in winter/spring, whereas in summer/autumn a mixing zone distance of 160 m is predicted. For enterococci, distances of 260 m and 250 m are required in winter/spring and summer/autumn to meet the 90th percentile water quality guideline of 185 cfu/100 mL. This is included on the plots below.

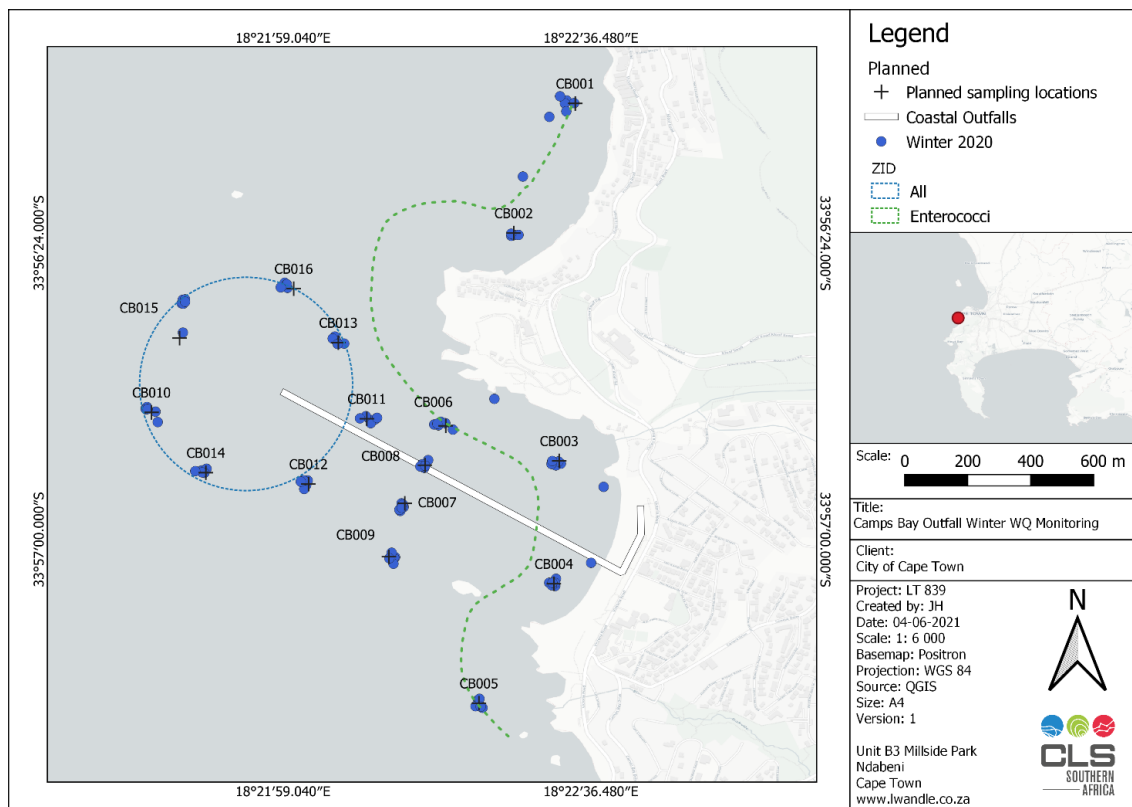


Figure 5.1: Map showing the Camps Bay outfall and the locations of nearshore and beach (CB-B1, CB-B2 and CB-B3) sites sampled during the winter (August-September 2020) monitoring periods.

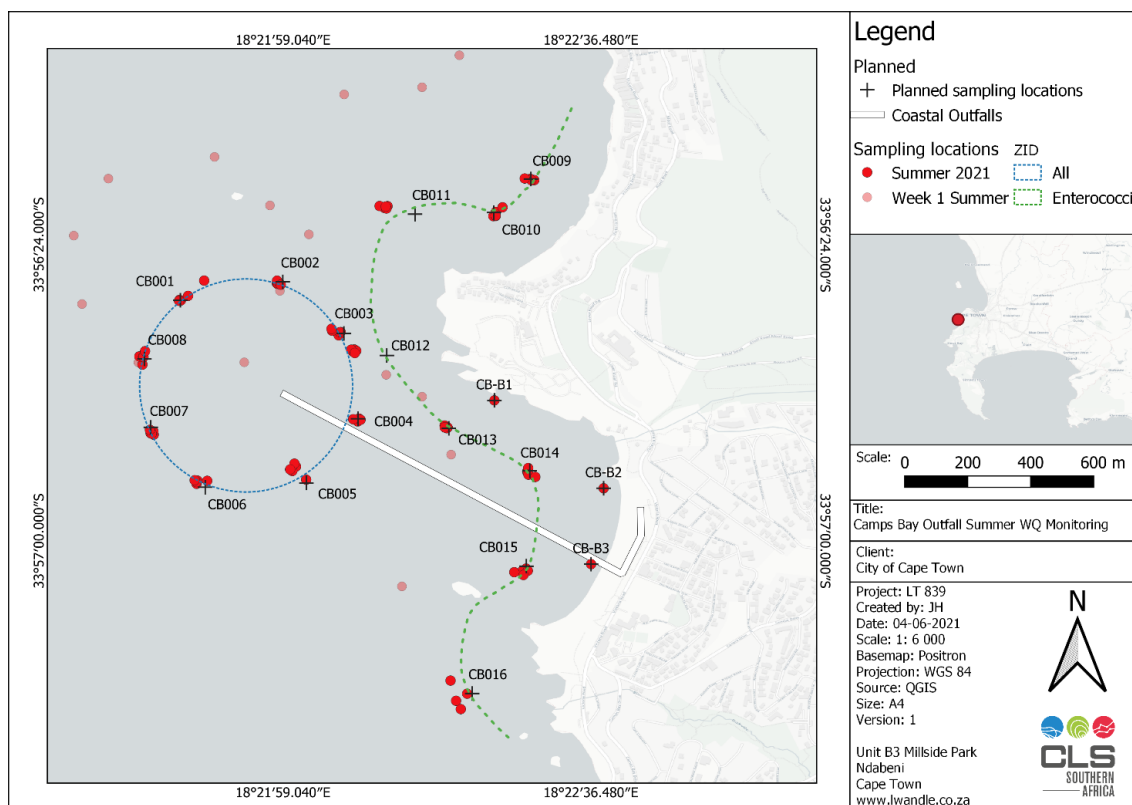


Figure 5.2: Map showing the Camps Bay outfall and the locations of nearshore and beach (CB-B1, CB-B2 and CB-B3) sites sampled during the summer (March-April 2021) monitoring periods.

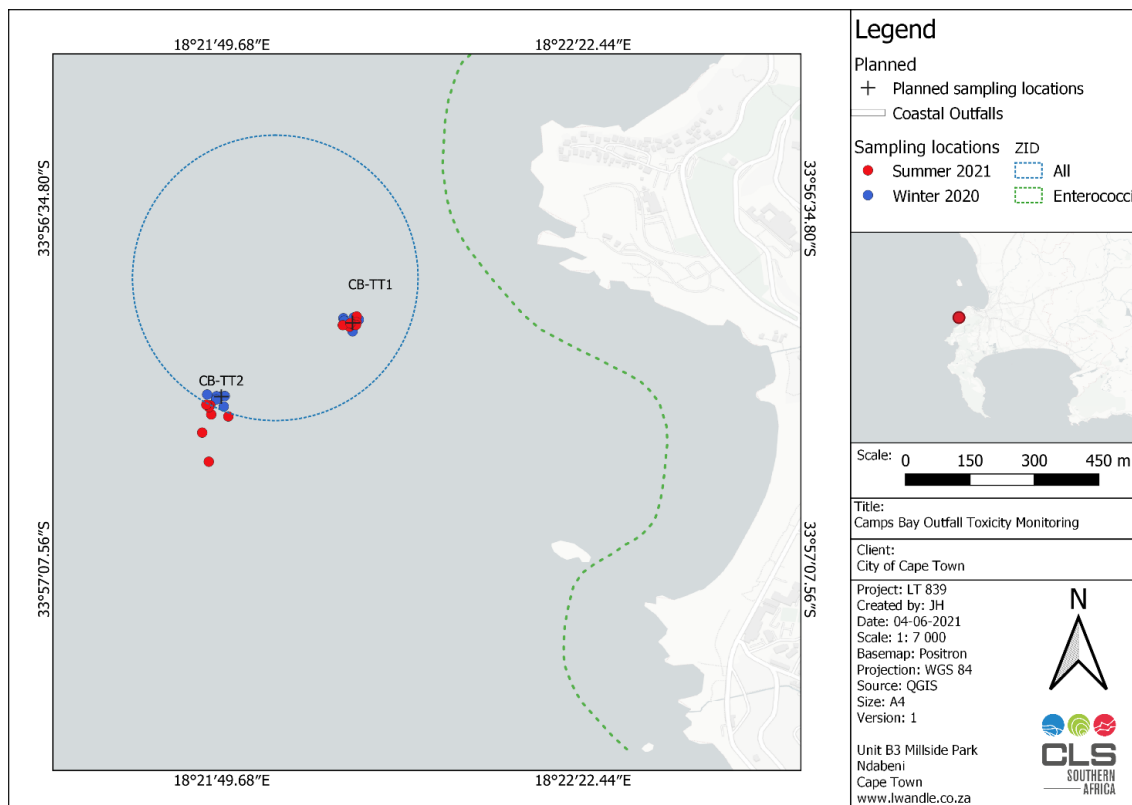


Figure 5.3: Map showing the Camps Bay outfall and the locations of the toxicity test sites sampled during the winter (August-September 2020) and the summer (March-April 2020) monitoring periods.

5.3 Nearshore Water Column Characteristics

The surface, middle and bottom depth values (grouped into 1 m bins) recorded seasonally at the Camps Bay outfall sampling sites for each measured water quality constituent (extracted from CTD data) are presented in the plots below¹. Parameters are also compared to relevant guidelines where appropriate.

5.3.1 Temperature

The water column temperatures for the summer and winter surveys were generally in similar ranges, except for surface layer temperatures in the winter survey being slightly cooler in the lower limits (Figure 5.4). Water column temperatures during the winter survey ranged between 9.89 and 15.06 °C and were between 9.59 and 14.86 °C during the summer survey. These fall within the expected range for the region. The winter survey had a greater range of temperatures measured at the surface and middle layers, while the summer survey had a higher range of temperatures at the bottom layer. The winter survey had high inter-week variation, specifically in the surface and middle layer of the water column.

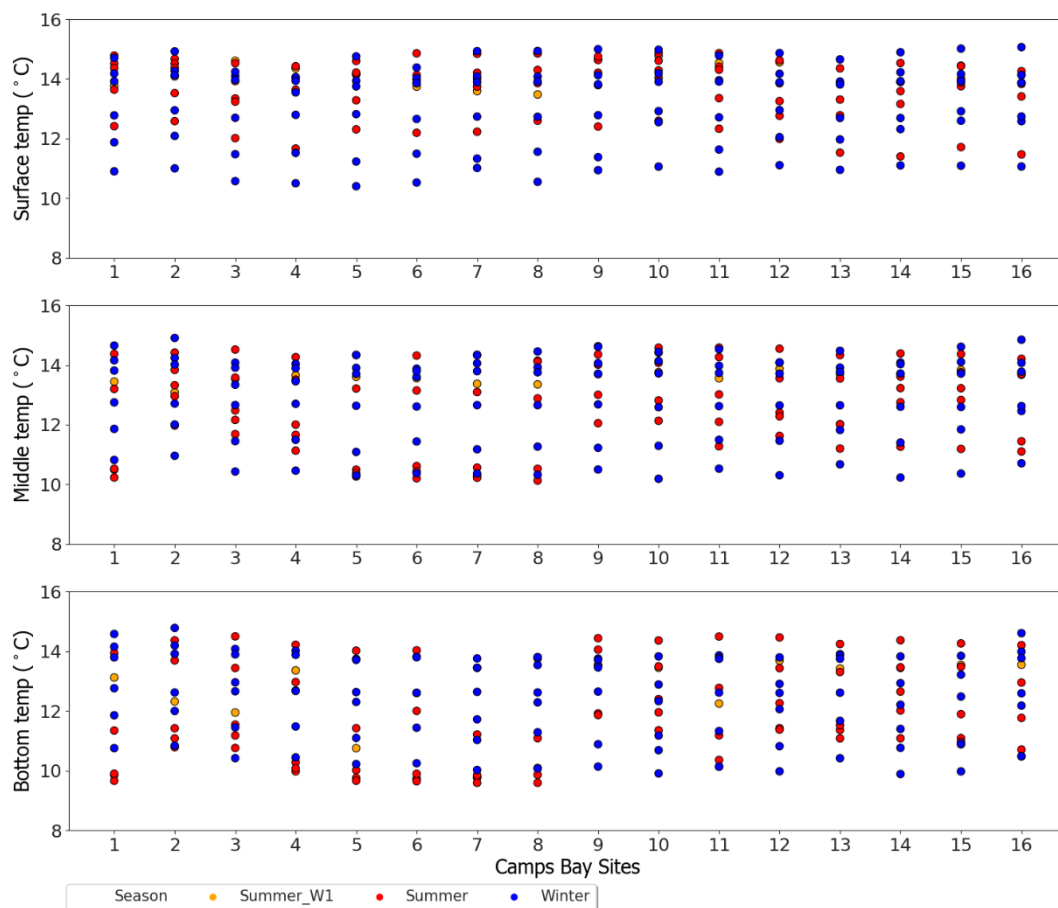


Figure 5.4: Seasonal distribution of temperature (°C) measured at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys.

Temperature values at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer², were compliant with the recommended guidelines during the winter monitoring period

¹ Camps Bay's week 1 summer 2021 measurements are plotted in a different colour due to the sampled locations for that week being displaced from the original sites.

² Analyses results for samples collected during week 1 at Camps Bay during the 2021 summer survey are not included in the calculations.

with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.1). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.1: Median and mean temperature values (°C) in the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Camps Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	344	560	357
Median	12.80	13.71	12.61
Mean	13.01	12.81	12.24
Summer			
n	328	558	434
Median	13.60	11.78	10.09
Mean	13.36	12.23	11.35

5.3.2 Salinity

Recorded winter survey salinity values were generally higher than those in summer (Figure 5.5). Salinities ranged between 34.61 and 35.34 PSU and 34.52 and 34.74 PSU in the winter and summer, respectively. The winter survey had a greater range of salinities measured at all depths and had higher inter-week variation in comparison to the summer survey.

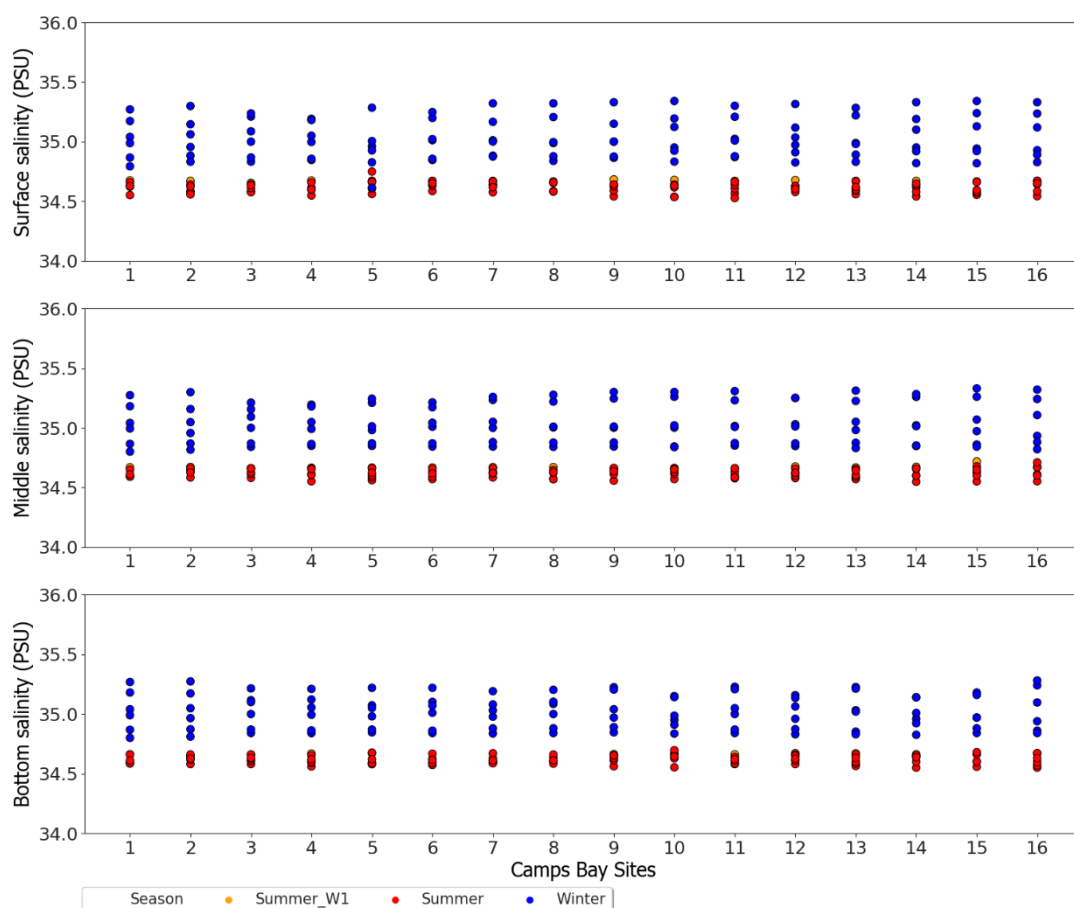


Figure 5.5: Seasonal distribution of salinity (PSU) measured at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys.

Salinity values at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.2). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.2: Median and mean salinity values (PSU) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Camps Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	344	560	357
Median	35.01	35.02	35.02
Mean	35.04	35.04	35.02
Summer			
n	328	558	434
Median	34.63	34.62	34.60
Mean	34.62	34.62	34.61

5.3.3 Turbidity

The turbidity values recorded in the winter survey were generally higher than those in the summer survey for all depths; values ranging between 0.06 and 8.26 FNU and 0.01 and 46.78 FNU respectively (Figure 5.6). The winter survey also had a greater range of turbidity at all depths as well as a higher inter-week variation in comparison to the summer survey.

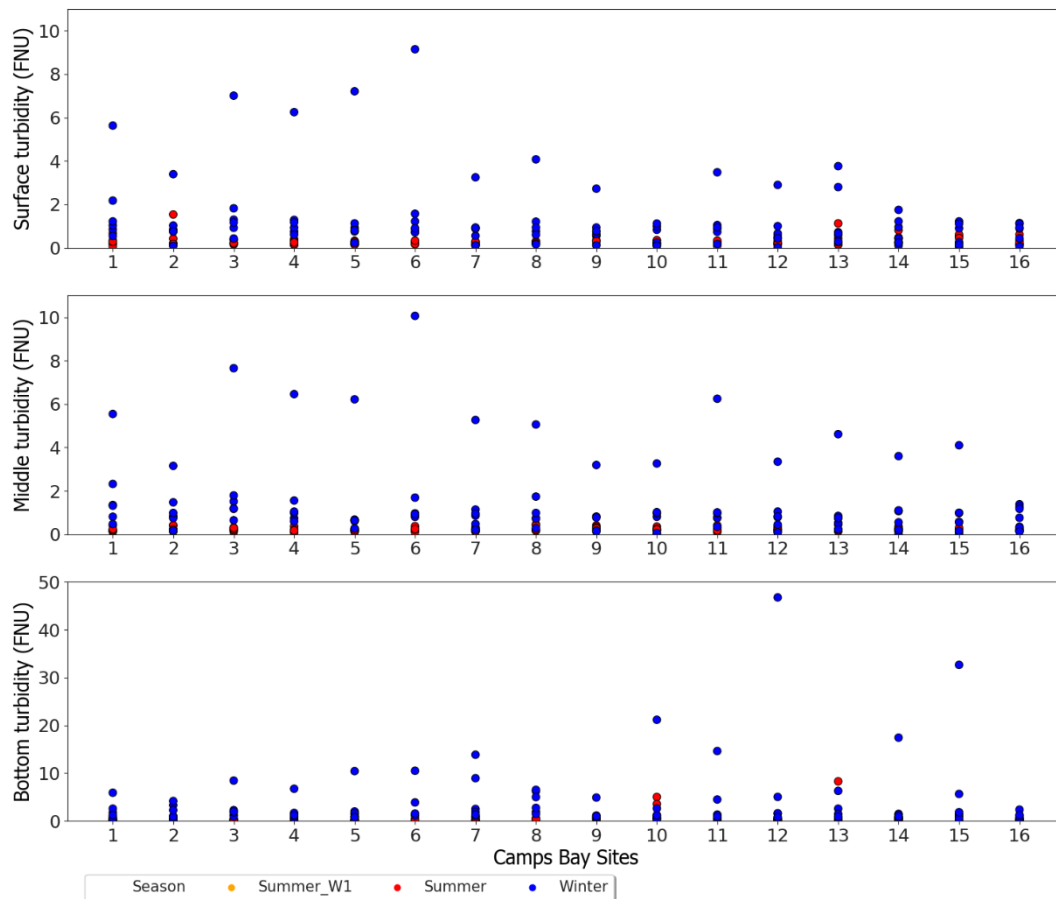


Figure 5.6: Seasonal distribution of turbidity (FNU) measured at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys. Note that the bottom depth plot has a different scale on the y-axis to aid presentation.

Turbidity values at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.3). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.3: Median and mean turbidity values (mg/L) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Camps Bay outfall. Mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	344	560	357
Median	0.79	0.83	0.86
Mean	0.98	1.28	2.41
Summer			
n	328	558	434
Median	0.23	0.21	0.22
Mean	0.26	0.24	0.25

5.3.4 pH

Similar to salinity and turbidity, pH levels measured during the winter survey were notably higher than those measured in summer (Figure 5.7). pH ranged between 8.34 and 8.68 in the winter and between 7.35 and 7.93 in the summer. The summer survey had higher pH ranges in the bottom and middle layers, while the winter survey had a higher pH range in the surface layer. The summer survey had a higher inter-week variation at the surface layer while the winter survey had a higher inter-week variation at the middle and bottom layers.

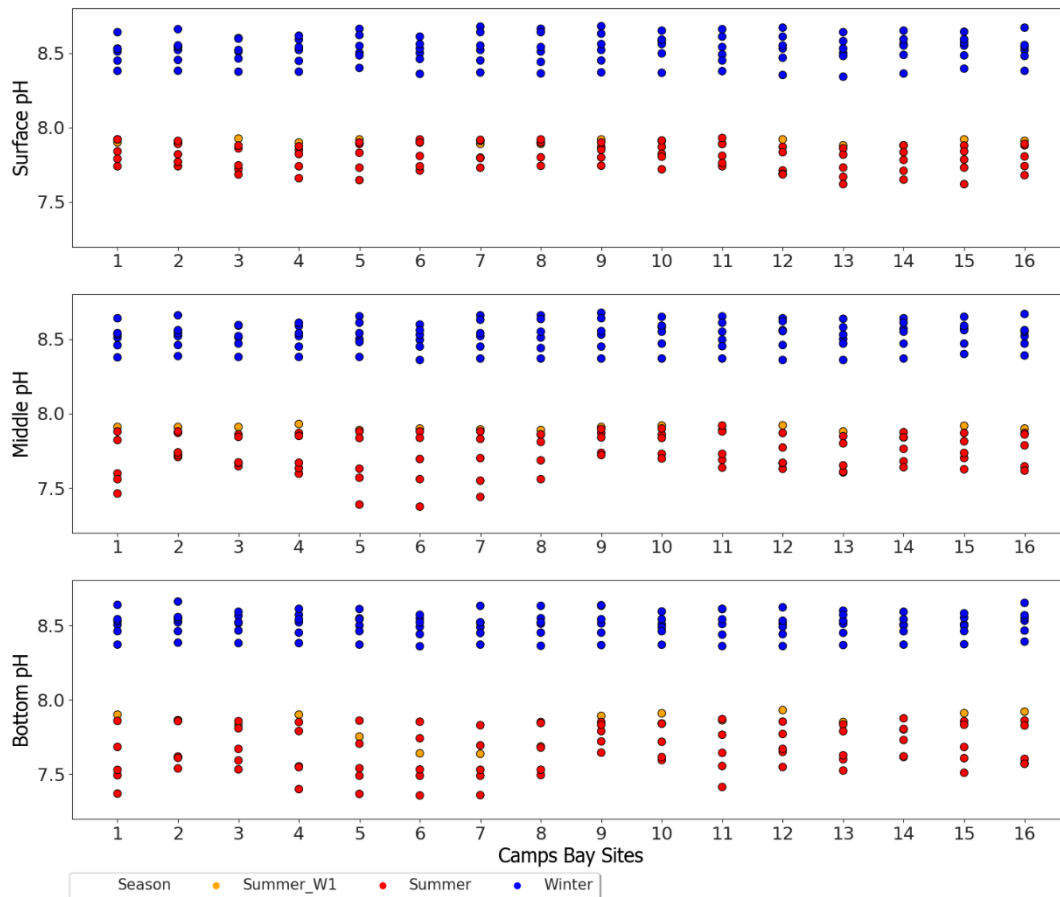


Figure 5.7: Seasonal distribution of pH measured at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys.

values at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.4). However, during winter the pH values at sites in the nearfield of the discharge exceeded the DWAF (1995) recommended guideline range (7.30 – 8.20). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

It must be noted that the range between the winter and summer pH values is large, and the summer values are notably lower than what was previously recorded during the year 1 summer survey (7.78 - 8.31). Because these low values occurred at all sites and all depths, the low pH values may be a result of instrument error, despite standard calibration procedures are conducted prior to each survey. Continued measurement of pH in future surveys will assist in establishing whether this is the case.

pH values during winter fell outside the range (7.6 – 8.1) previously recorded for the area (DEA 2015). High values (<8.1) were also noted in the year 1 annual report. Relatively elevated pH (>8) indicates the presence of a mainly oxidic water column which suggests minimal remineralisation of organically rich sediments.

Table 5.4: Median and mean pH values in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Camps Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	344	560	357
Median	8.54	8.55	8.53
Mean	8.53	8.53	8.51
Summer			
n	328	558	434
Median	7.78	7.70	7.56
Mean	7.79	7.71	7.64

5.3.5 Dissolved Oxygen

The dissolved oxygen concentrations for the summer and winter surveys were generally consistent in their upper limits. Other than this, the winter survey had generally higher levels than the summer survey (Figure 5.8). The winter survey concentrations ranged between 6.00 and 9.64 mg/L while the summer survey ranged between 1.15 and 9.97 mg/L. The lowest summer concentrations (<2 mg/L) were recorded in the bottom of the water column at sites CB1 and CB5-CB7. The recorded temperatures at some of these sites during summer were low (<10 °C), indicating that the dissolved oxygen concentrations recorded may be a result of upwelling processes in the area drawing hypoxic water from deeper intermediate waters.

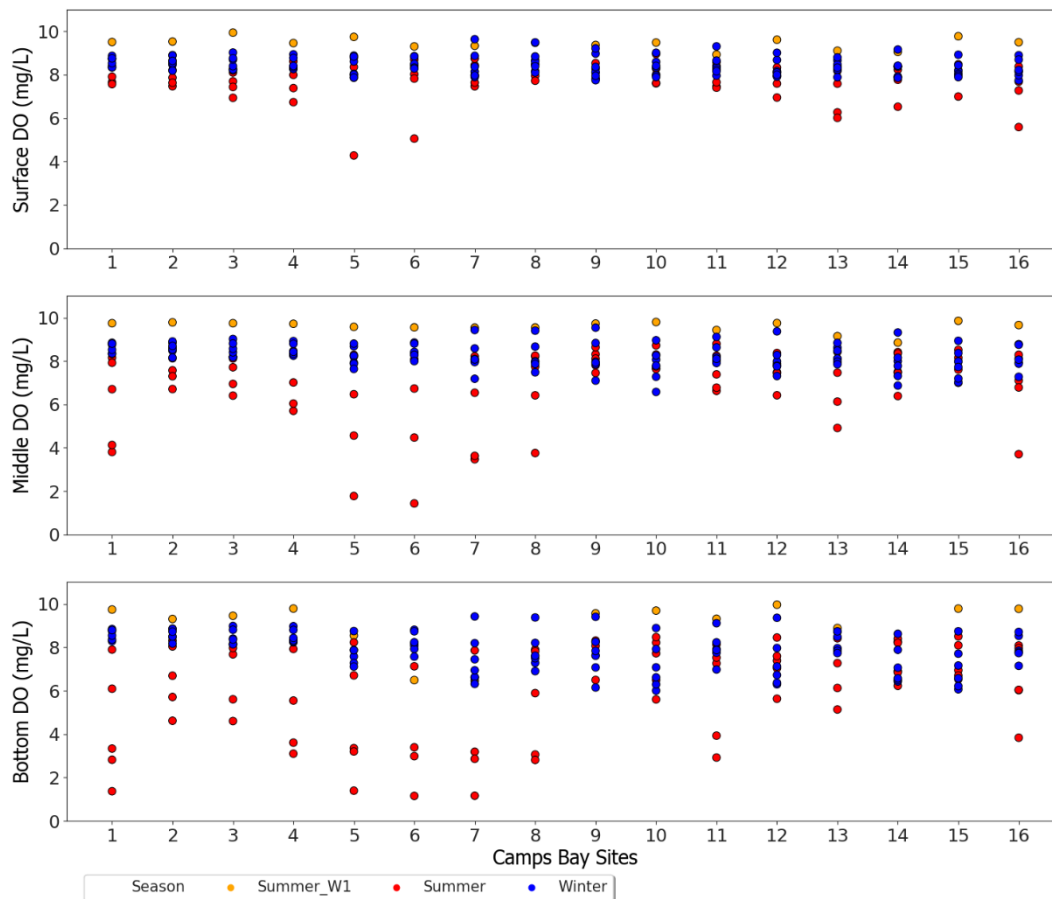


Figure 5.8: Seasonal distribution of dissolved oxygen (mg/L) measured at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys.

Dissolved oxygen concentrations at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.5). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.5: Median and mean dissolved oxygen concentrations (mg/L) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Camps Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	344	560	357
Median	8.15	7.96	7.61
Mean	8.25	8.07	7.58
Summer			
n	328	558	434
Median	7.94	7.31	5.31
Mean	7.70	6.65	5.26

5.4 Nearshore and Beach Seawater Quality

The laboratory analysis results of enterococci, TSS, TOC, orthophosphate, and ammonia measured seasonally in water samples obtained from surface, middle and bottom depths at sites in the vicinity of the Camps Bay outfall are presented in the sections below. The results of the analyses of seawater toxicity, from two sites near the outfall, to sea urchins are included.

5.4.1 Enterococci

No clear seasonal pattern was seen in enterococci counts at sites sampled in Camps Bay. Individual measurements were generally below 100 cfu/100 mL at all depths at all nearshore sites during both seasons (Figure 5.9) and the 90th percentile values for the winter and summer survey periods were all below the recommended DEA (2012) guideline ≤ 185 cfu/100 mL (Figure 5.10, Figure 5.11 and Table 3.1).

Individual enterococci counts at the three beach sites were also below 100 cfu/100 mL during both seasons (Figure 5.9) and the 90th percentile values at all three beach sites for the winter and summer survey periods were in compliance with the recommended guideline.

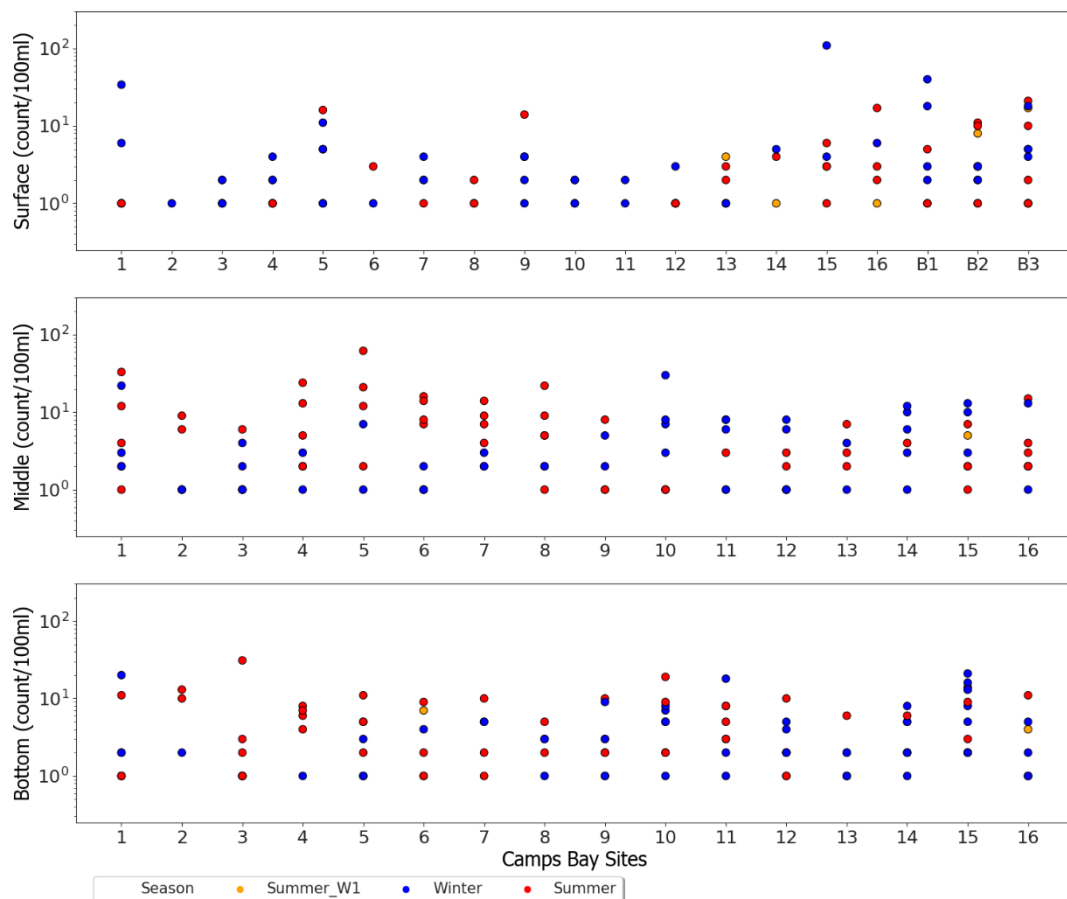


Figure 5.9: Seasonal distribution of enterococci (cfu/100 mL) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys. The enterococci counts measured at beach sites are included in the surface plot (B1, B2 and B3).

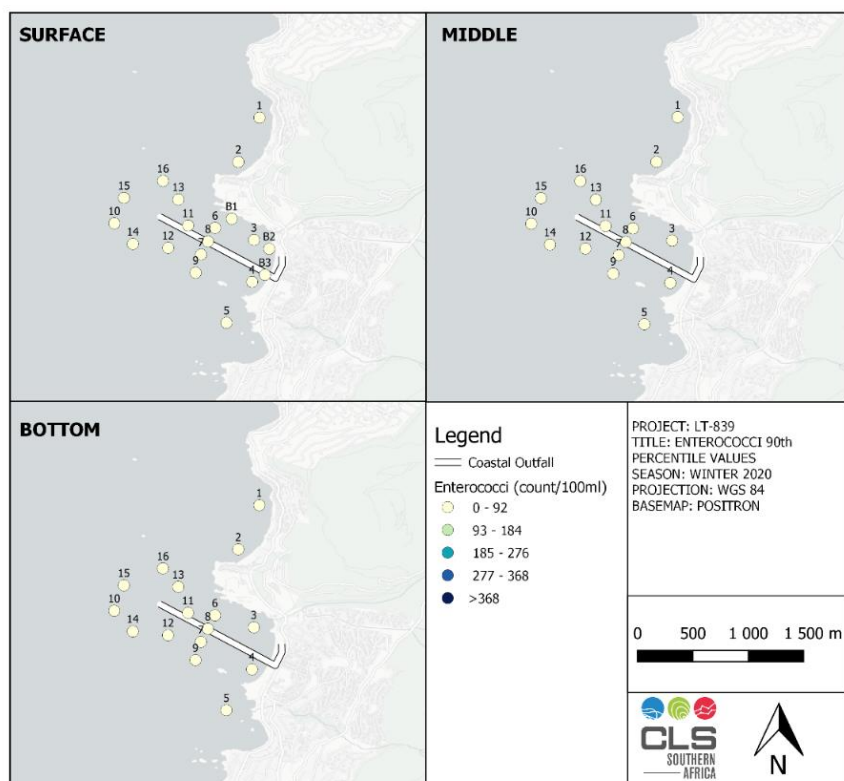


Figure 5.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Camps Bay outfall sites during the 2020 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

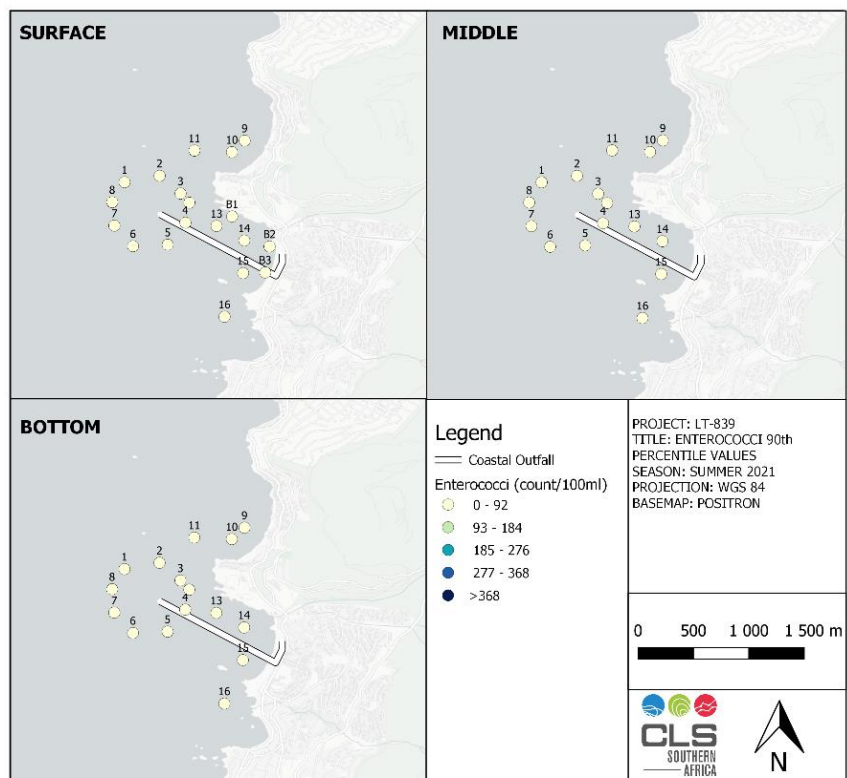


Figure 5.11: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

5.4.2 Total Suspended Solids

TSS concentrations were generally higher during the winter survey than the summer survey in surface, middle and bottom waters surrounding the Camps Bay outfall (Figure 5.12, Figure 5.13 and Figure 5.14). Outliers were recorded during the winter at a number of sites at the surface and mid-depth of the water column. The largest outlier was recorded at site CB15 with a concentration of 103 mg/L in bottom waters during week 1 (Figure 5.14).

Median TSS concentrations were relatively higher (most sites were >8 mg/L) in bottom waters compared to surface mid-depth waters during the winter survey period (Figure 5.13). The highest median concentrations were recorded at CB10 (19 mg/L) and CB15 (20 mg/L) in bottom waters during winter. In the summer survey, median concentrations were all below 4 mg/L with exception to site CB10 (Figure 5.14).

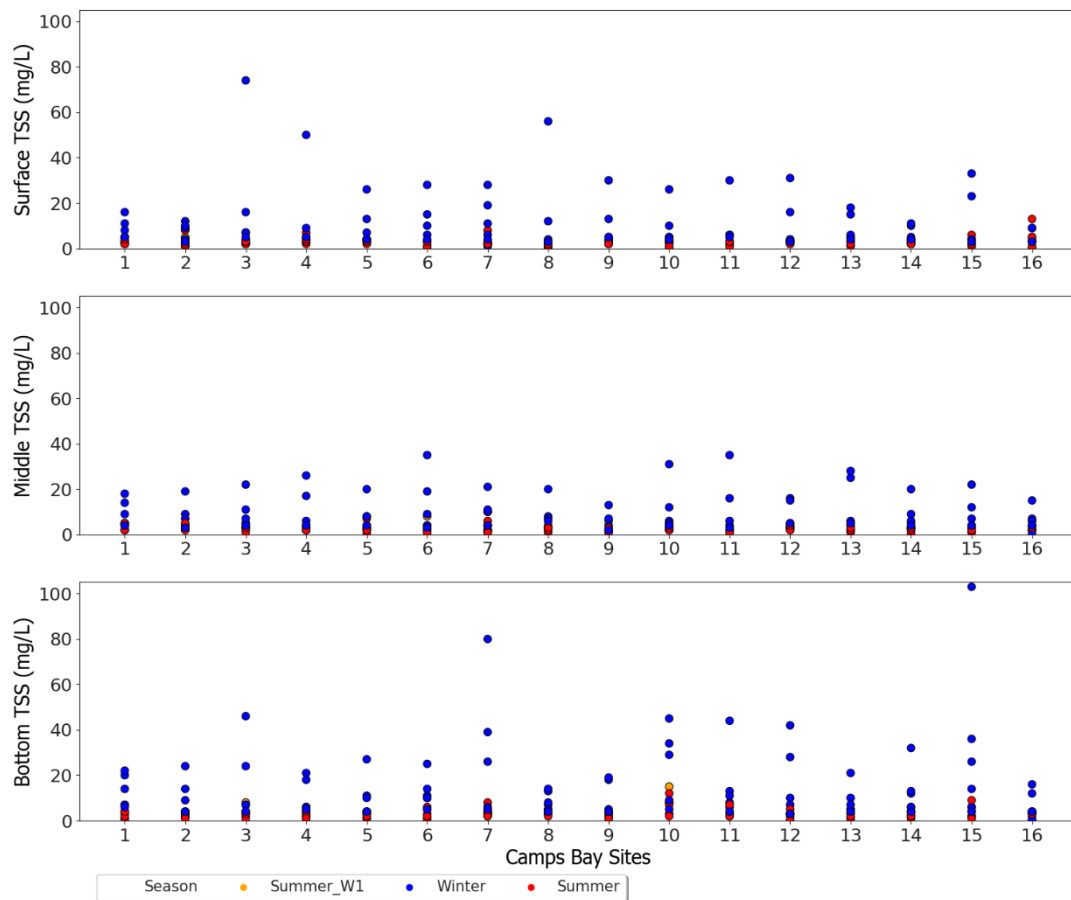


Figure 5.12: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2.

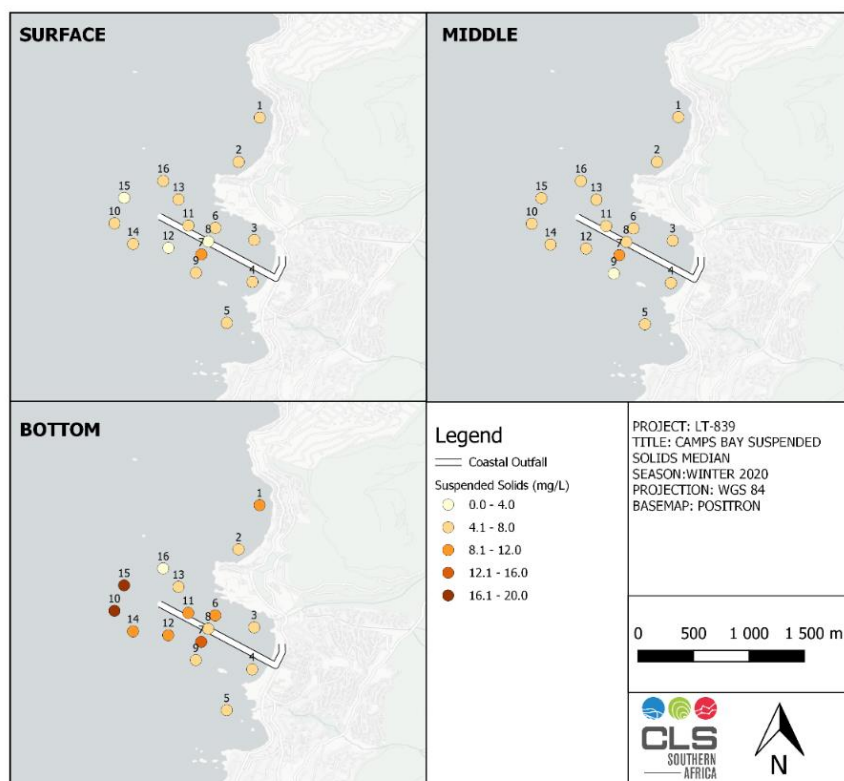


Figure 5.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2020 winter survey.

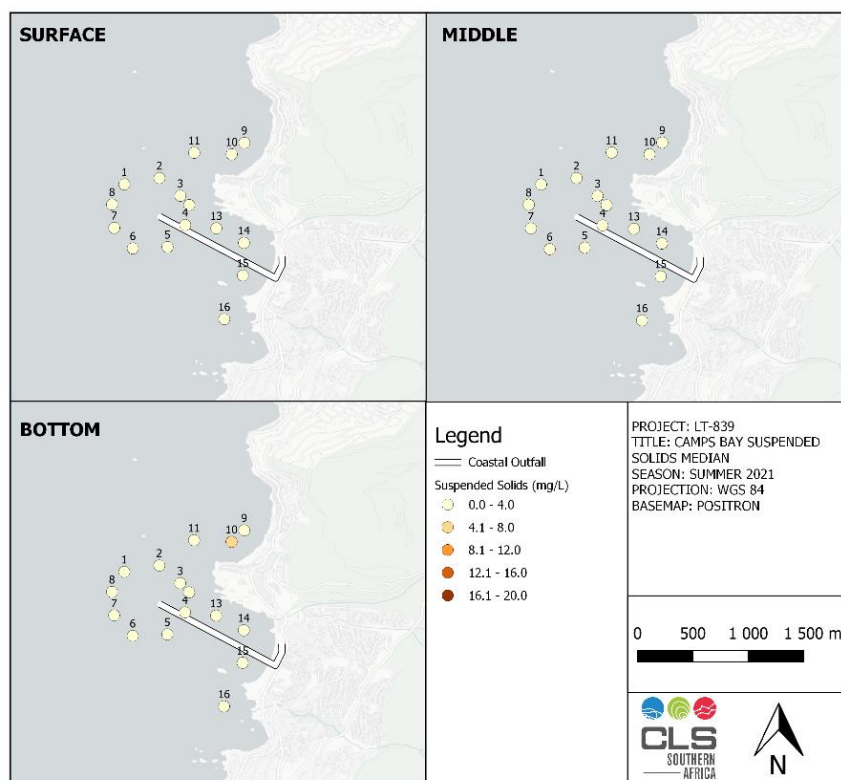


Figure 5.14: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 summer survey.

TSS values at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.6). However, mean TSS values in surface and mid-depth waters were slightly over the guideline. For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.6: Median and mean total suspended solids values (mg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Camps Bay outfall. Mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	42	42	42
Median	5	6	9
Mean	9	9	16
Summer			
n	35	35	35
Median	3	2	3
Mean	3	3	4

5.4.3 Total Organic Carbon

No distinct seasonal pattern was seen in TOC concentrations at the Camps Bay sites, however individual measurements showed that the lowest concentrations were often recorded in winter at all depths (Figure 5.15, Figure 5.16 and Figure 5.17). TOC concentrations in surface, middle and bottom waters at Camps Bay were low and ranged between 0.5 and 4.3 mg/L during the winter survey and 0.5 and 3.3 mg/L during the summer survey (Figure 5.15). Both the winter and summer surveys had high inter-week variation.

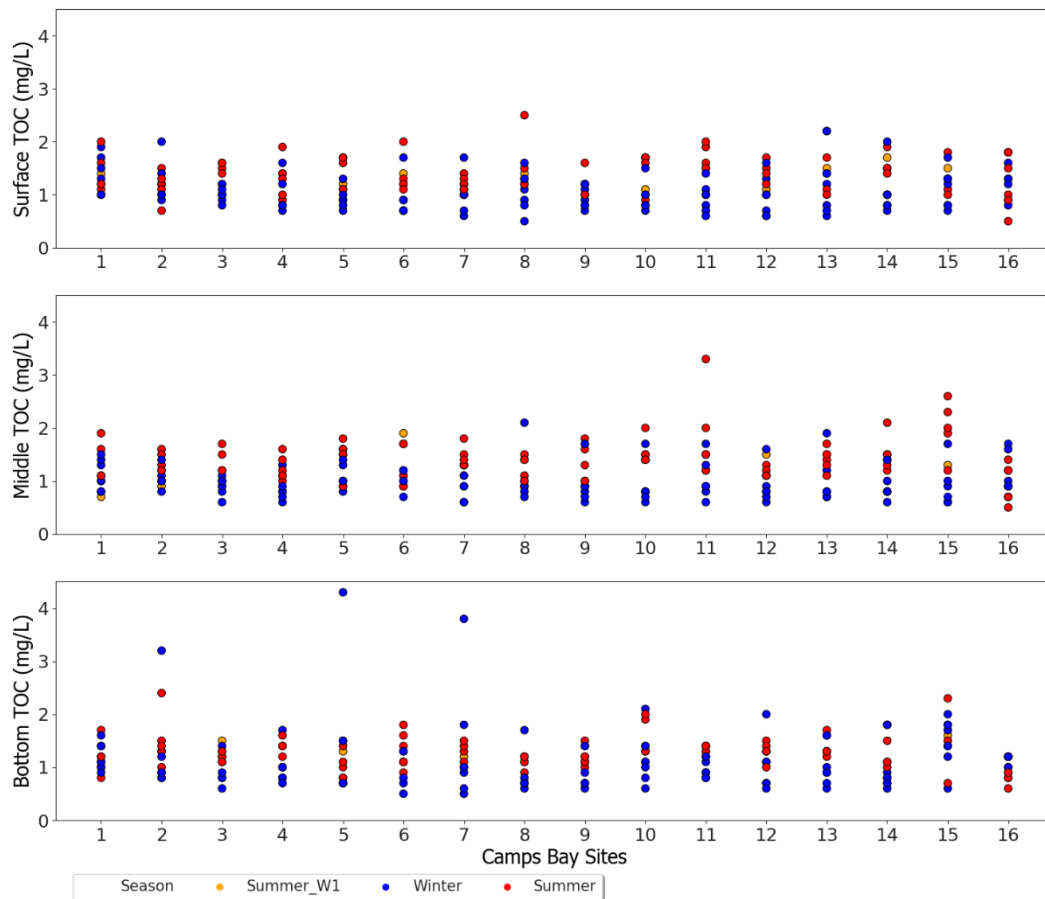


Figure 5.15: Seasonal distribution of total organic carbon (mg/L) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys.

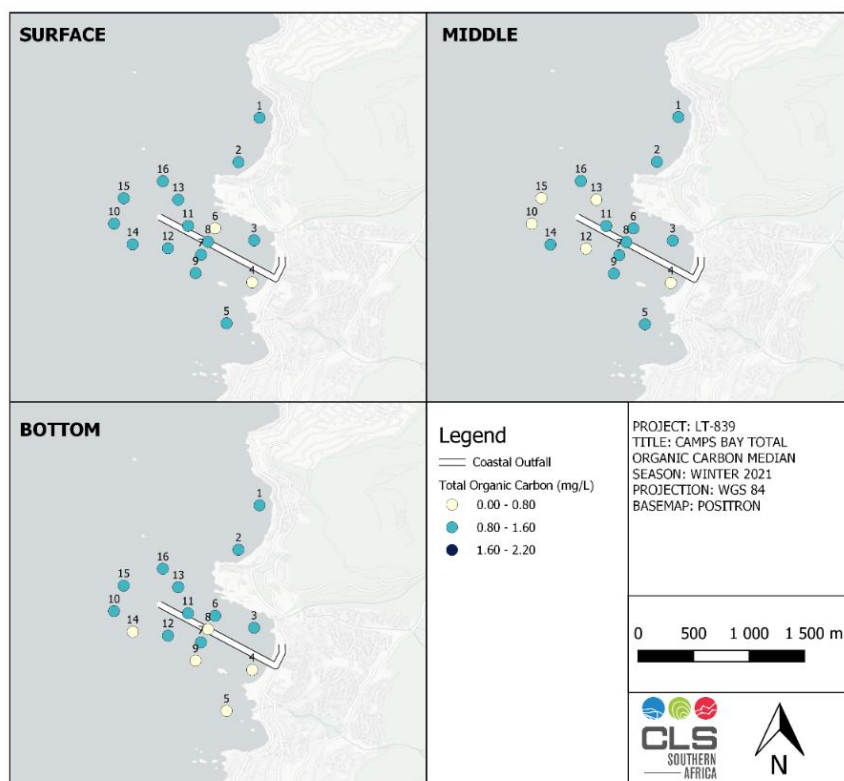


Figure 5.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2020 winter survey.

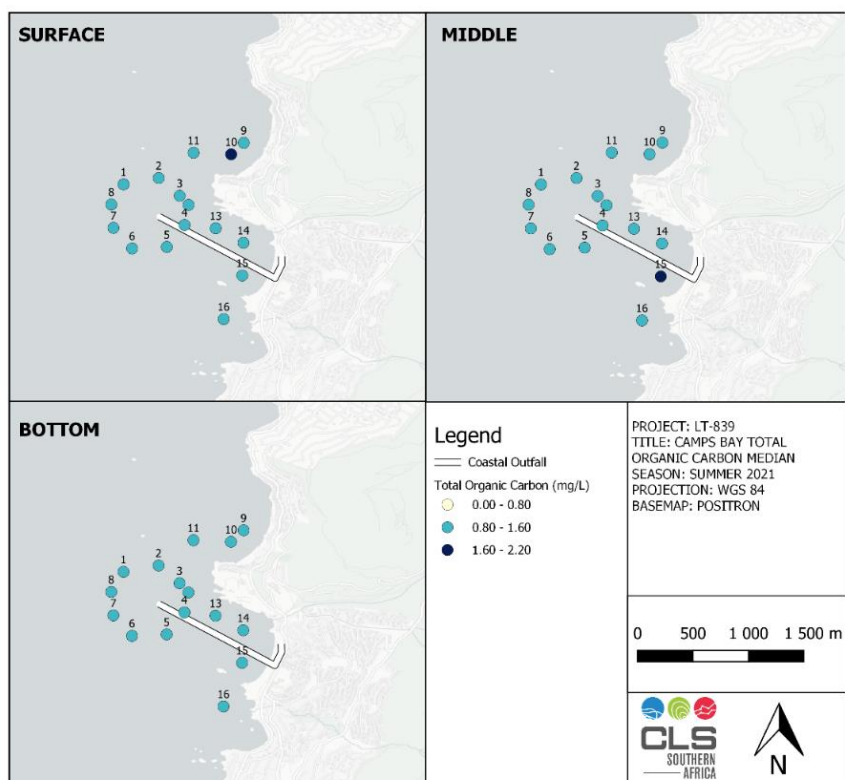


Figure 5.17: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 summer survey.

5.4.4 Orthophosphate

Orthophosphate concentrations were mostly lower during the winter survey period than the summer survey period at all depths (Figure 5.18, Figure 5.19 and Figure 5.20). Individual measurements ranged between 6 and 106 $\mu\text{g/L}$ in winter and 19 and 93 $\mu\text{g/L}$ in summer (excluding the 2021 summer week 1 results). Both seasons displayed high inter-week variation.

During winter, median concentrations were elevated ($>70 \mu\text{g/L}$) at sites CB1, CB5, CB7 and CB8 in bottom waters (Figure 5.20). These sites are located at the edge of the mixing zone.

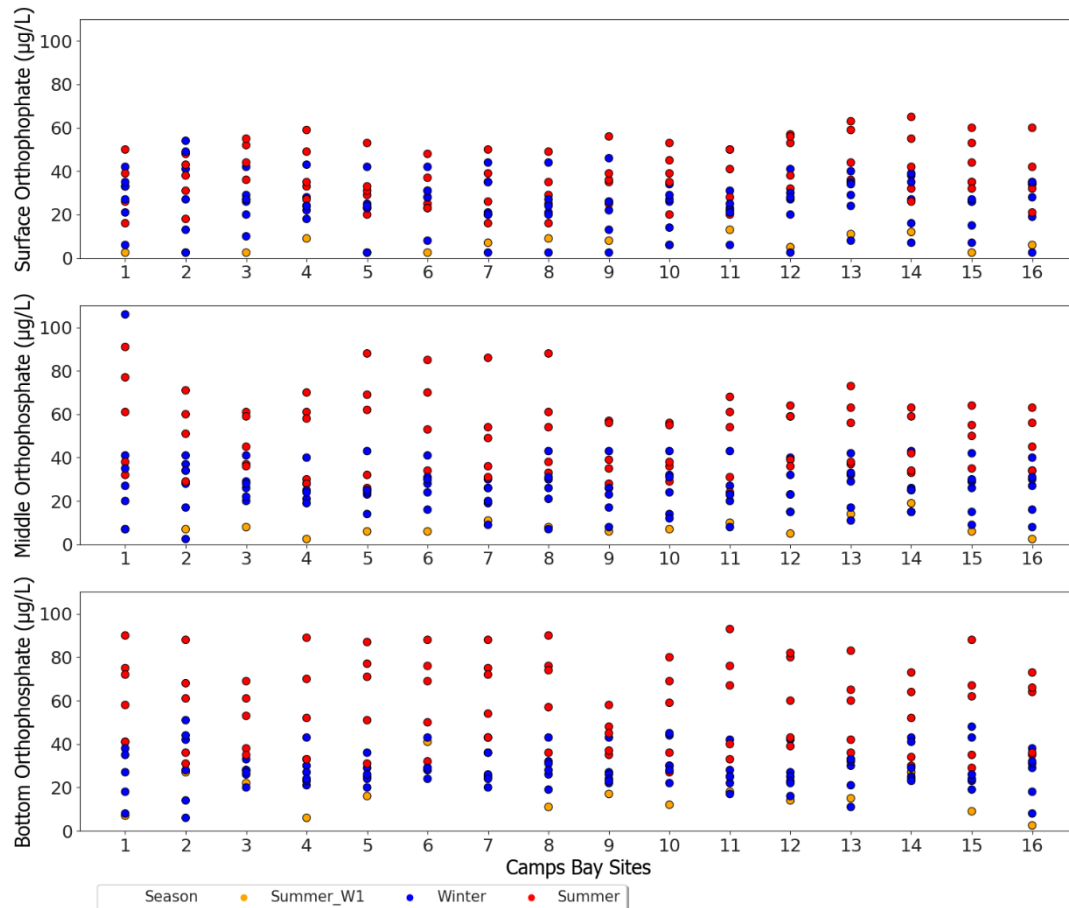


Figure 5.18: Seasonal distribution of orthophosphate ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

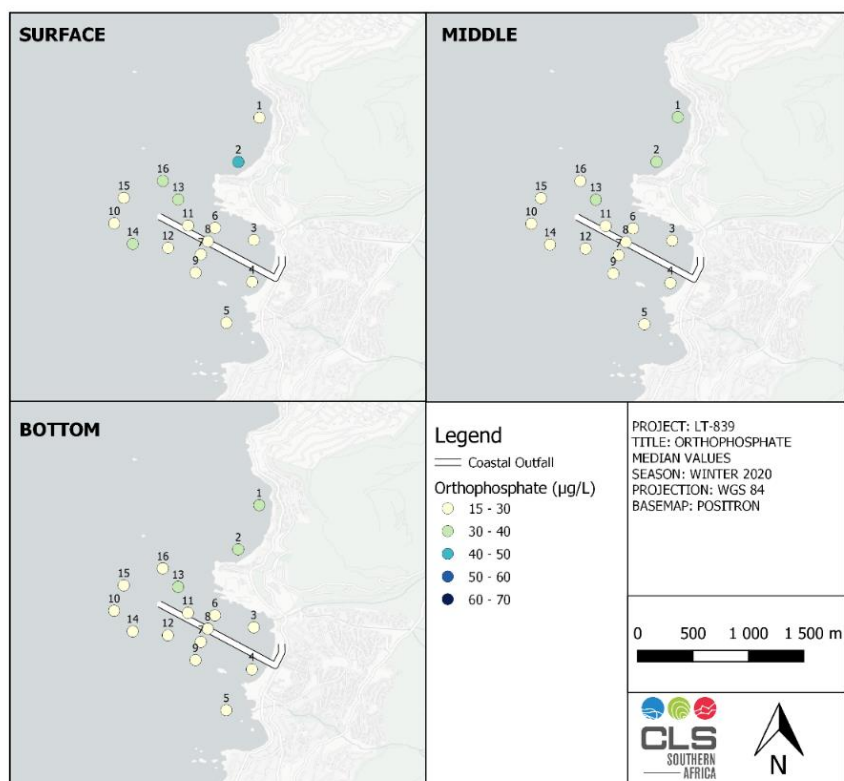


Figure 5.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall during the 2020 winter survey.

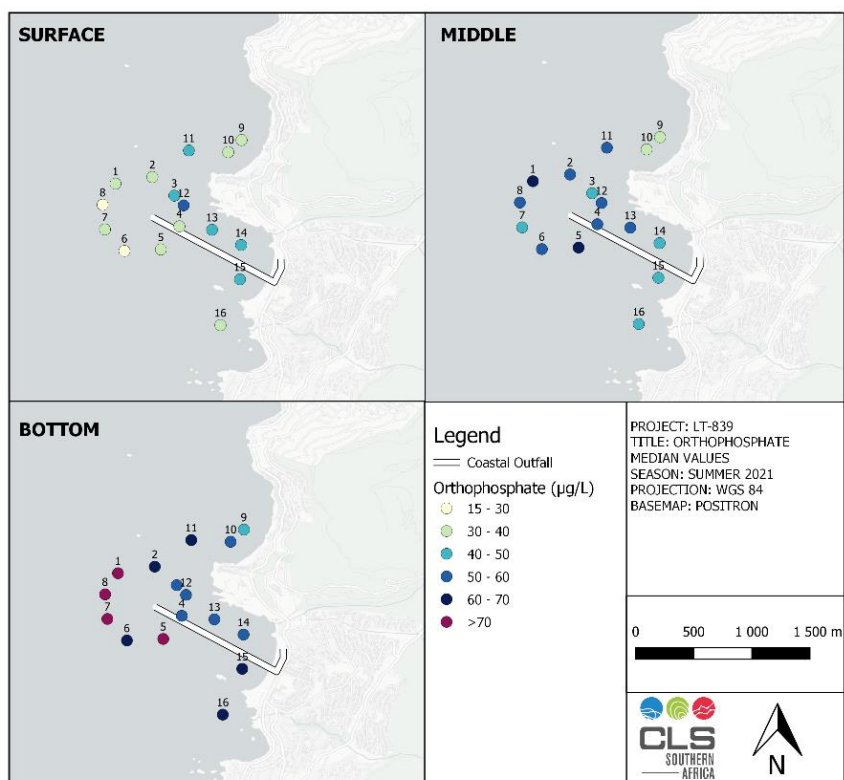


Figure 5.20: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall during the 2021 summer survey.

Orthophosphate concentrations at all depths in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines during the winter and summer monitoring periods with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 5.7). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.7: Median and mean orthophosphate values ($\mu\text{g/L}$) in surface, mid and bottom waters measured at nearfield sites surrounding the Camps Bay outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	42	42	42
Median	27	26	28
Mean	26	25	29
Summer			
n	35	35	35
Median	39	54	60
Mean	41	50	58

5.4.5 Ammonia

No distinct seasonal pattern was seen in ammonia concentrations at the Camps Bay sites, however individual measurements showed that the highest concentrations were often recorded in summer at all depths (Figure 5.21, Figure 5.22 and Figure 5.23). Concentrations ranged between <5 and 141 $\mu\text{g/L}$ in winter and <5 and 99 $\mu\text{g/L}$ in summer. The highest concentration was recorded in surface waters at site CB2 (141 $\mu\text{g/L}$). Summer displayed higher inter-week variation than winter.

Median concentrations showed that the higher values generally occurred north of pipeline and at site CB5 (winter) and CB16 (summer), although concentrations did not exceed the DWAF (1995) recommended guideline (600 $\mu\text{g/L}$, Table 3.1).

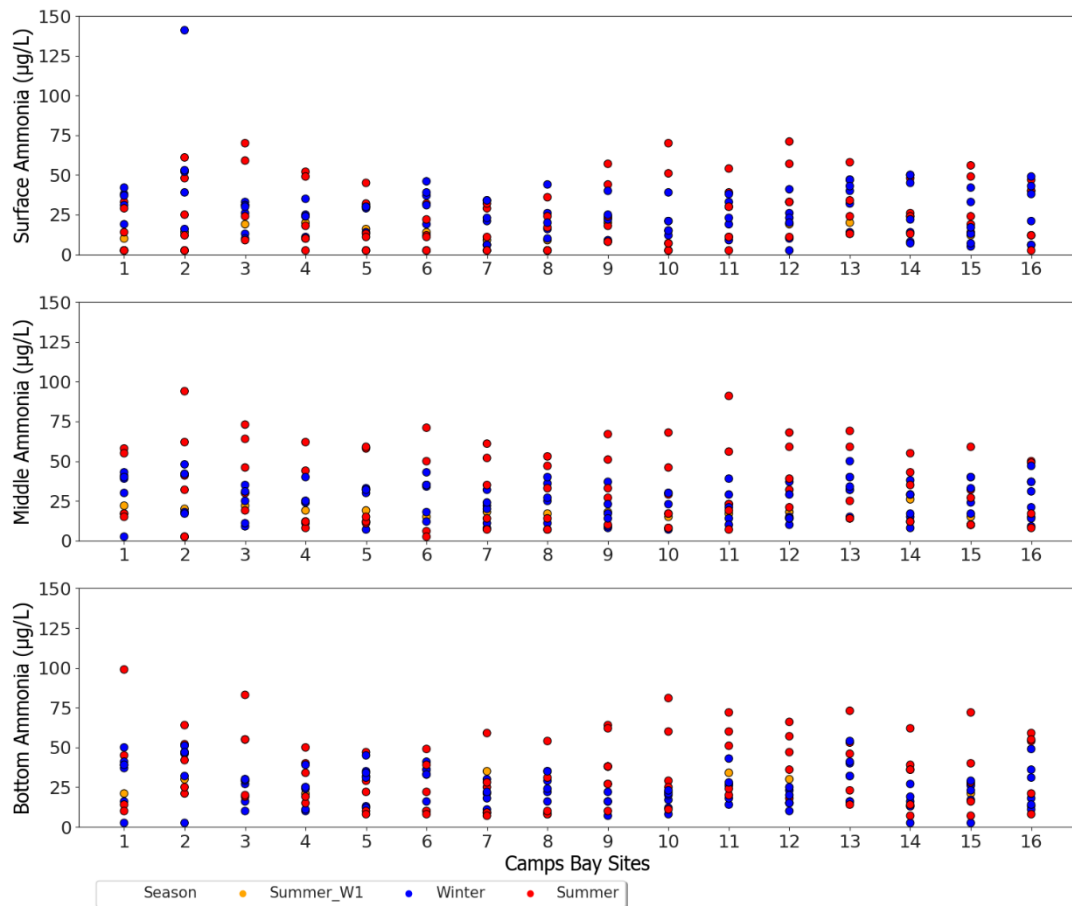


Figure 5.21: Seasonal distribution of ammonia ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Camps Bay outfall sites during the 2020 winter and 2021 summer¹ surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

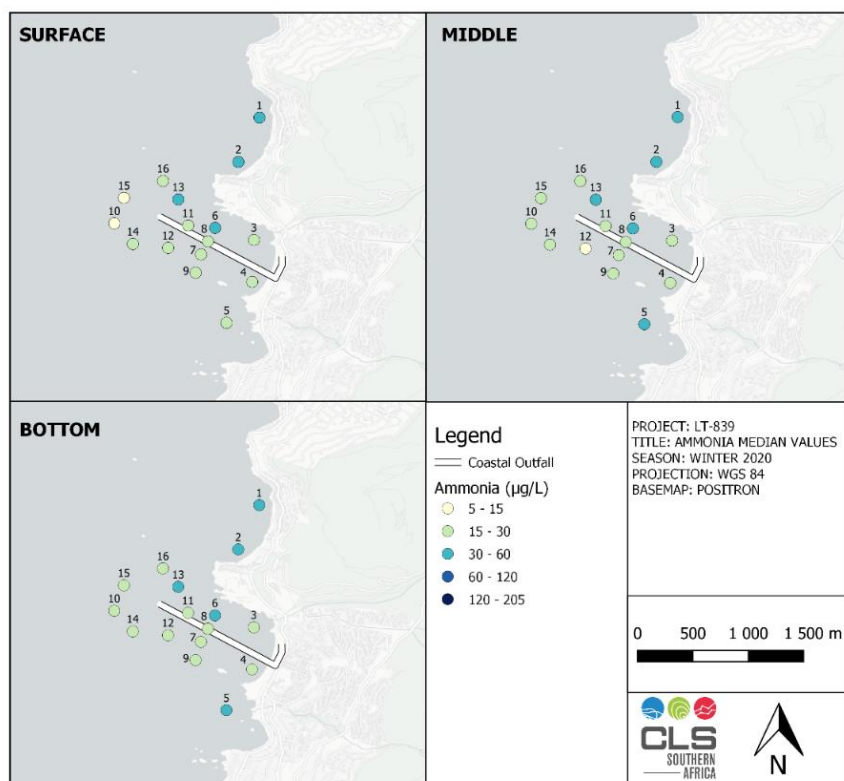


Figure 5.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall sites during the 2020 winter survey.

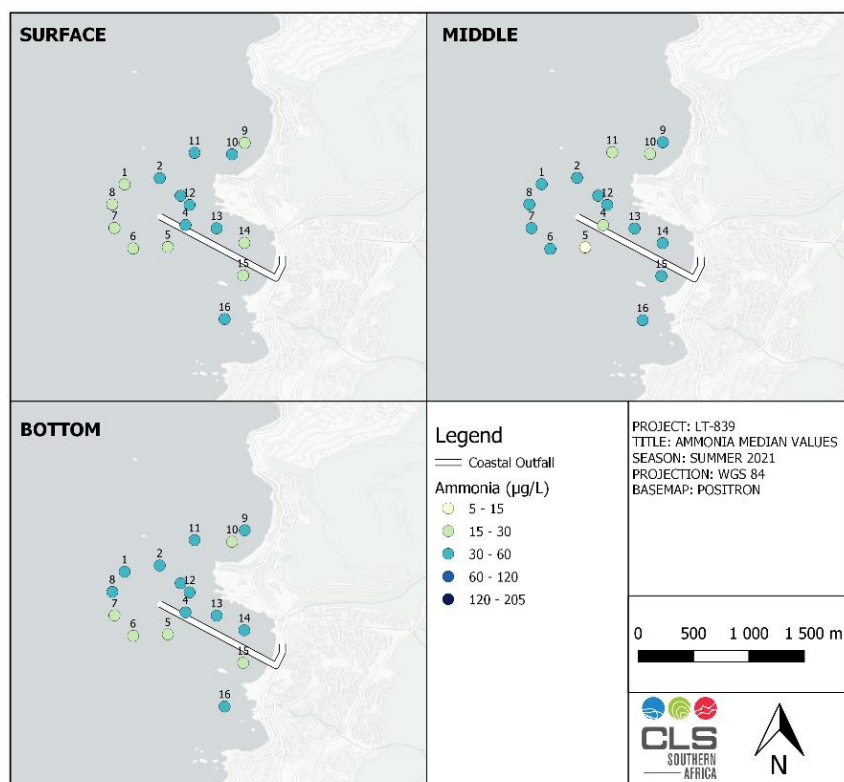


Figure 5.23: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 summer survey.

Ammonia concentrations in the nearfield of the discharge, represented by measurements from sites CB10, CB11, CB12, CB13, CB14 and CB16 in winter and sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8 in summer, were compliant with the recommended guidelines (Table 3.2) during both monitoring periods with an exception in surface waters during the summer survey where the guideline was marginally exceeded (Table 5.8). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 5.8: Median and mean orthophosphate values ($\mu\text{g/L}$) in surface, mid and bottom waters measured at nearfield sites surrounding the Camps Bay outfall. Median and mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	42	42	42
Median	21	21	21
Mean	24	23	23
Summer			
n	35	35	35
Median	33	37	39
Mean	35	37	41

5.4.6 Toxicity

The two nearshore sites sampled during the second year of monitoring showed no toxicity effects of seawater obtained from near the discharge on sea urchins (*Tripneutes gratilla* and *Echinometra mathaei*) in terms of fertilisation rates in either of the winter or summer sampling periods (Table 5.9).

Table 5.9: Sea urchin seawater toxicity test results. Samples were obtained from two nearshore sites in the vicinity of the Camps Bay outfall on alternate days during the winter (August-September 2020) and summer (March-April 2021) sampling periods. Toxicity classification is based on mean (n=4) fertilisation success rates.

Season	Date	Site	% Fertilisation Success				Mean	Std Dev	Toxicity Classification
			1	2	3	4			
Tripneutes gratilla									
Winter	3 09 2020	CB-TT1	100	99	100	99	99.50	0.58	Not toxic
		CB-TT2	100	99	100	99	99.50	0.58	Not toxic
	4 09 2020	CB-TT1	100	99	100	99	99.50	0.58	Not toxic
		CB-TT2	99	99	100	99	99.25	0.50	Not toxic
	7 09 2020	CB-TT1	100	99	99	100	99.50	0.58	Not toxic
		CB-TT2	100	99	99	100	99.50	0.58	Not toxic
	9 09 2020	CB-TT1	99	99	99	100	99.25	0.50	Not toxic
		CB-TT2	100	99	99	100	99.50	0.58	Not toxic
	12 09 2020	CB-TT1	100	99	99	100	99.50	0.58	Not toxic
		CB-TT2	100	99	99	100	99.50	0.58	Not toxic
	17 09 2020	CB-TT1	99	99	98	98	98.50	0.58	Not toxic
		CB-TT2	99	99	98	98	98.50	0.58	Not toxic
18 09 2020	CB-TT1	99	99	99	98	98.75	0.50	Not toxic	
	CB-TT2	99	99	98	98	98.50	0.58	Not toxic	
Summer	25 03 2021	CB-TT1S	100	100	99	99	99.50	0.58	Not toxic
		CB-TT1M	100	100	99	99	99.50	0.58	Not toxic
		CB-TT2	99	100	99	99	99.25	0.50	Not toxic
	27 03 2021	CB-TT1S	99	99	99	98	98.75	0.50	Not toxic
		CB-TT1M	99	99	98	98	98.50	0.58	Not toxic
		CB-TT2	99	99	98	98	98.50	0.58	Not toxic
	29 03 2021	CB-TT1S	99	99	98	98	98.50	0.58	Not toxic
		CB-TT1M	99	99	98	98	98.50	0.58	Not toxic
		CB-TT2	99	99	98	98	98.50	0.58	Not toxic
	30 03 2021	CB-TT1S	99	99	98	98	98.50	0.58	Not toxic
		CB-TT1M	99	99	98	98	98.50	0.58	Not toxic
		CB-TT2	99	99	98	99	98.75	0.58	Not toxic
	31 03 2021	CB-TT1S	99	99	100	100	99.50	0.58	Not toxic
		CB-TT1M	99	99	100	100	99.50	0.58	Not toxic
		CB-TT2	99	99	100	100	99.50	0.58	Not toxic
	8 04 2021	CB-TT1S	99	99	100	100	99.50	0.58	Not toxic
		CB-TT1M	99	99	99	100	99.25	0.50	Not toxic
		CB-TT2	99	99	99	100	99.25	0.50	Not toxic
9 04 2021	CB-TT1S	99	99	100	100	99.50	0.58	Not toxic	
	CB-TT1M	99	99	100	100	99.50	0.58	Not toxic	
	CB-TT2	99	99	100	100	99.50	0.58	Not toxic	

5.5 Effects on Local Marine Ecology

Growth rates and trace metal accumulation in mussels (*Mytilus galloprovincialis*) at fixed monitoring stations surrounding the Camps Bay outfall and two control stations were compared across the winter 2020 and summer 2021 deployments. Results (detailed in APPENDIX D) indicated that mussel growth rates at the Camps Bay outfall were lower in summer than in winter. Growth rates also appeared to be marginally higher at the monitoring (impact) stations located near the outfall than the control stations situated further afield during both seasons.

Trace metal body burden concentrations at control and impact stations at Camps Bay also showed clear seasonal trends for nickel and zinc with a greater average loss (relative to baseline levels) observed during winter than summer. There was no evidence of seasonal differences in copper accumulation during the winter and summer deployments. Mussels at all locations accumulated copper relative to baseline concentration during both the winter and summer deployment. There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for “unimpacted” stations.

6 APPENDIX C: GREEN POINT

6.1 Description of the Outfall

The Green Point outfall extends approximately 1 600 m offshore of Mouille Point in a north-westerly direction and discharges effluent into Table Bay, to the west of the Port of Cape Town (Figure 6.1 and Figure 6.2). It was commissioned in 1993 and serves the area from Woodstock to Bantry Bay. The diffusers are located at a depth of 26 m.

6.2 Sampling Locations

Figure 6.1 and Figure 6.2 show the Green Point outfall, as well as the locations of the sampling sites during each week of sampling in the winter (August-September 2020) and summer (March-April 2020) monitoring periods.

For the purposes of the initial survey design, the CCT estimated the zone of initial dilution at the Green Point outfall to be within a 256 m radius from the diffuser. Results of the hydrodynamic modelling conducted by PRDW (2020) suggest that for TSS a mixing zone distance of 1 400 m from the discharge is required to meet the required dilution of 1 753 (as determined by the CCT, detailed in APPENDIX D) in winter/spring, whereas in summer/autumn a mixing zone distance of 940 m is required. For enterococci, distances of 3 200 m and 2 300 m are required in winter/spring and summer/autumn to meet the 90th percentile water quality guideline of 185 cfu/100 mL. This is included on the plots below.

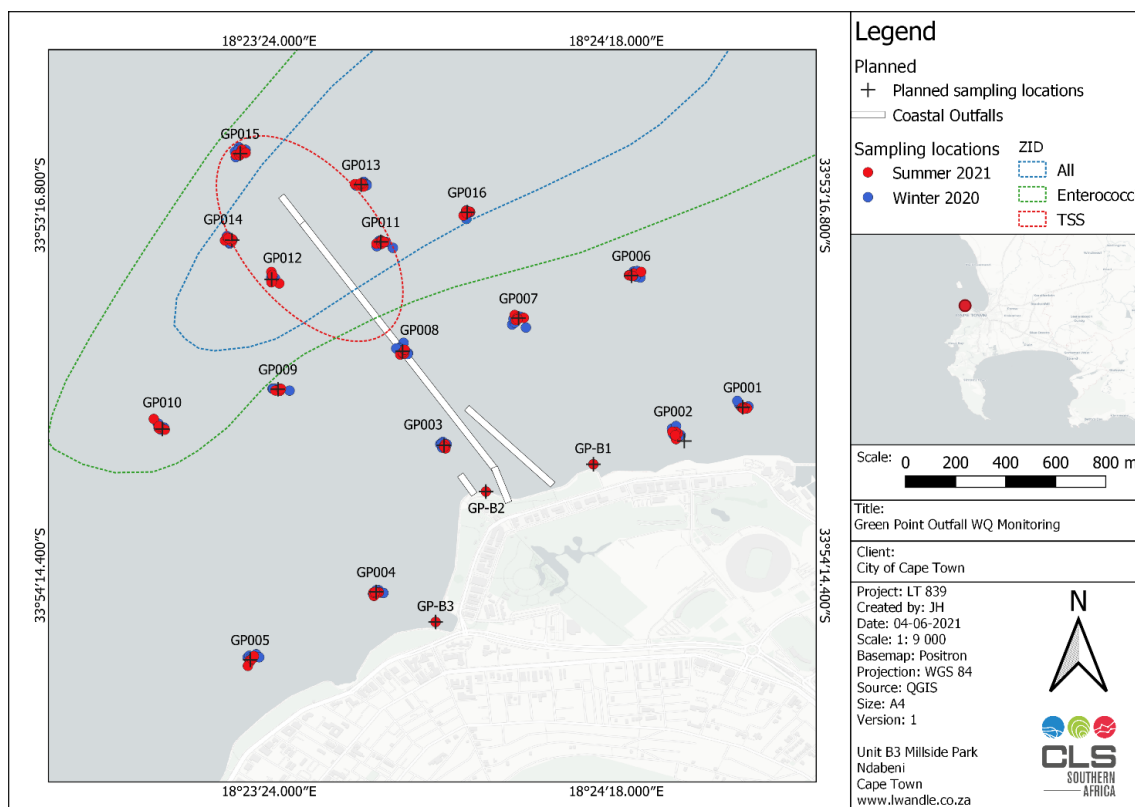


Figure 6.1: Map showing the Green Point outfall and the locations of nearshore and beach (GP-B1, GP-B2 and GP-B3) sites sampled during the winter (August-September 2020) and the summer (March-April 2021) monitoring periods.

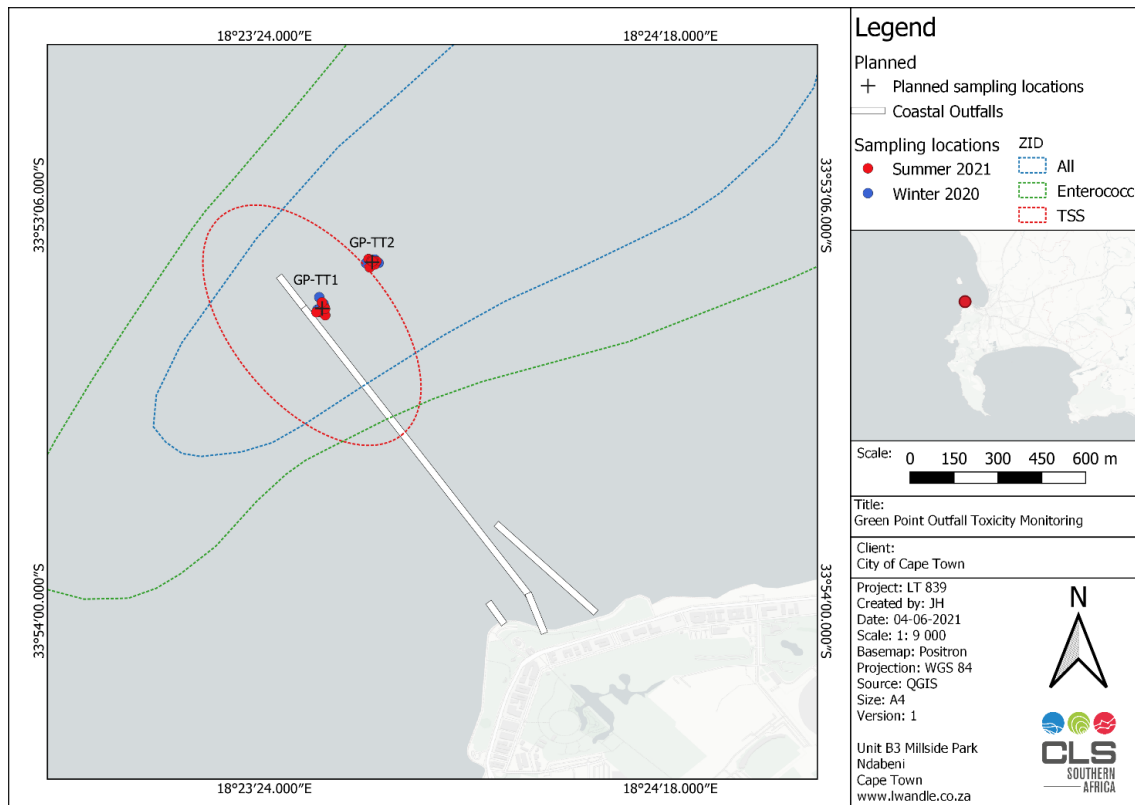


Figure 6.2: Map showing the Green Point outfall and the locations of the toxicity sites sampled during the winter (August-September 2020) and the summer (March-April 2021) monitoring periods.

6.3 Nearshore Water Column Characteristics

The surface, middle and bottom depth values recorded seasonally at the Green Point outfall sampling sites for each measured water quality constituent (extracted from CTD data) are presented in the plots below. Parameters are also compared to relevant guidelines where appropriate.

6.3.1 Temperature

No distinct seasonal pattern was seen in the water column temperatures at sites sampled at the Green Point outfall (Figure 6.3), although the lowest temperatures were mostly recorded in summer, most notably at mid-depth. This is characteristic of the seasonal upwelling in the region. Water column temperatures ranged between 9.69 and 15.76 °C in winter and 9.57 and 16.64 °C in summer. These are in the expected range for the region. Summer temperatures showed a greater range and a higher inter-week variation at mid- and bottom depths compared to in the surface.

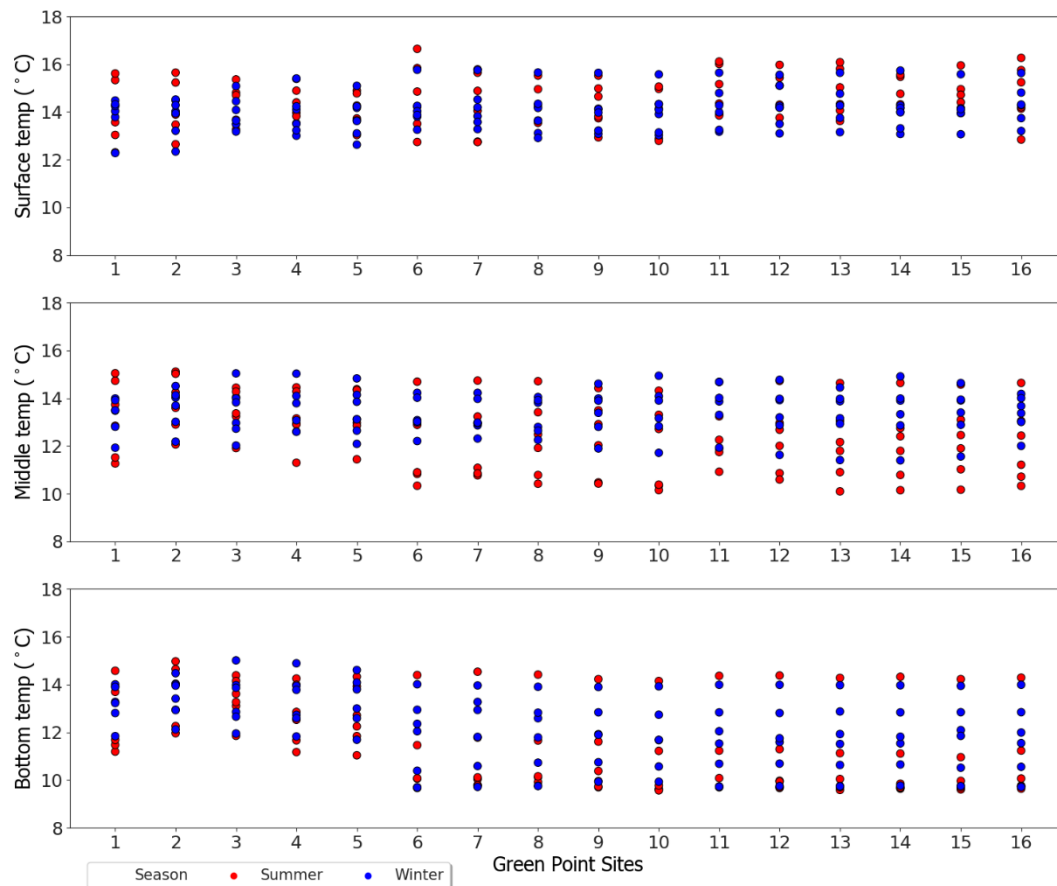


Figure 6.3: Seasonal distribution of temperature (°C) measured at the Green Point outfall sites during the 2020 winter and 2021 summer surveys.

Temperature values at all depths in the nearfield of the discharge, represented by measurements from sites GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines during the winter and summer monitoring periods with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 6.1). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.1: Median and mean temperature values (°C) in the surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	289	581	629
Median	13.97	13.78	12.81
Mean	13.98	13.55	12.31
Summer			
n	287	587	643
Median	14.14	12.53	10.11
Mean	14.04	12.59	10.97

6.3.2 Salinity

Salinities recorded during the summer survey were generally lower than those recorded in winter, more notably in middle and bottom waters (Figure 6.4). Salinities ranged between 32.94 and 35.41 PSU and 33.77 and 35.22 PSU in the winter and summer, respectively. The winter survey had a greater range of salinities measured at all depths and had higher inter-week variation in comparison to the summer survey.

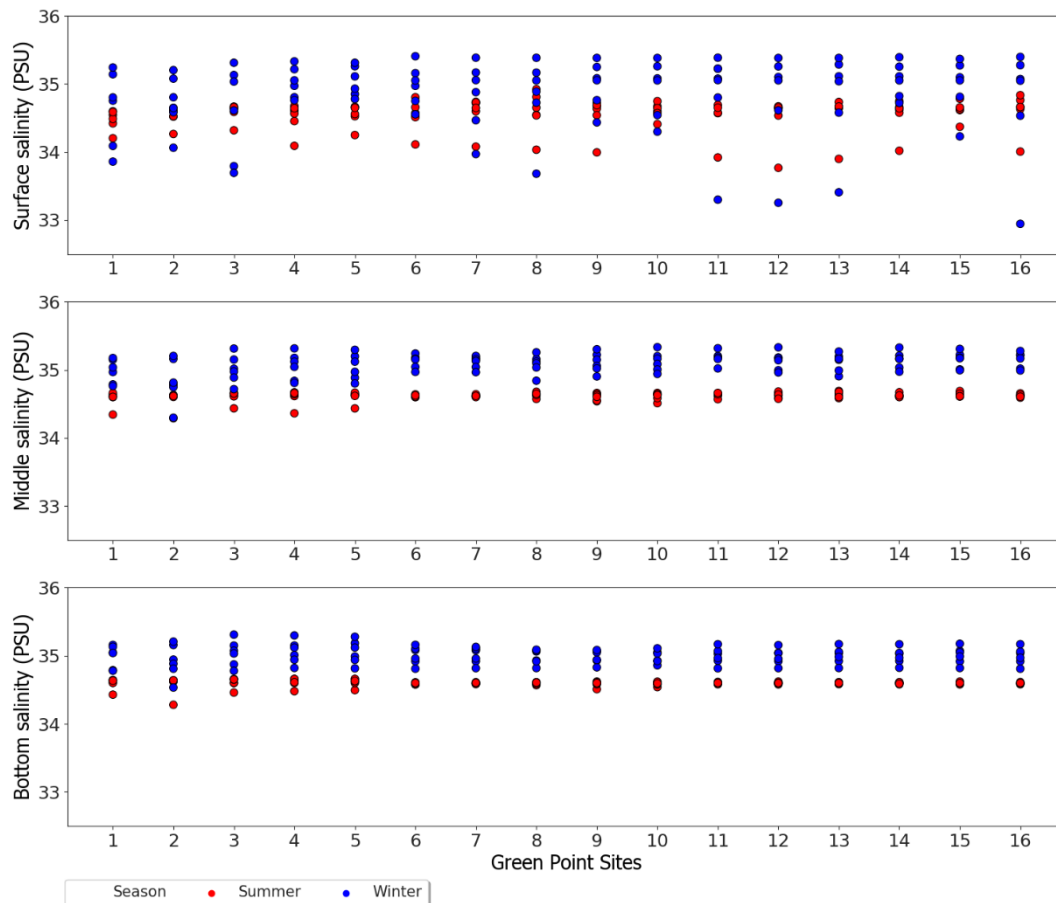


Figure 6.4: Seasonal distribution of salinity (PSU) measured at the Green Point outfall sites during the 2020 winter and 2021 summer surveys.

Measured salinity values were compliant with the DWAF (1995) recommended guideline range (33-36 PSU) during the winter and summer monitoring periods. In the nearfield of the discharge, represented by measurements from stations GP11, GP12, GP13, GP14 and GP16, compliance was also met with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 6.2). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.2: Median and mean salinity values (PSU) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	289	581	629
Median	35.08	35.16	35.05
Mean	35.05	35.14	35.05
Summer			
n	287	587	643
Median	34.66	34.63	34.60
Mean	34.62	34.63	34.61

6.3.3 Turbidity

The recorded turbidity values had a similar seasonal pattern to salinity with lower turbidity values generally recorded in summer for all depths (Figure 6.5). Turbidity values ranged between 0.01 and 17.11 FNU and 0.08 and 7.66 FNU in the winter and summer, respectively. The winter survey also had a greater range of turbidity at all depths as well as a higher inter-week variation in comparison to the summer survey.

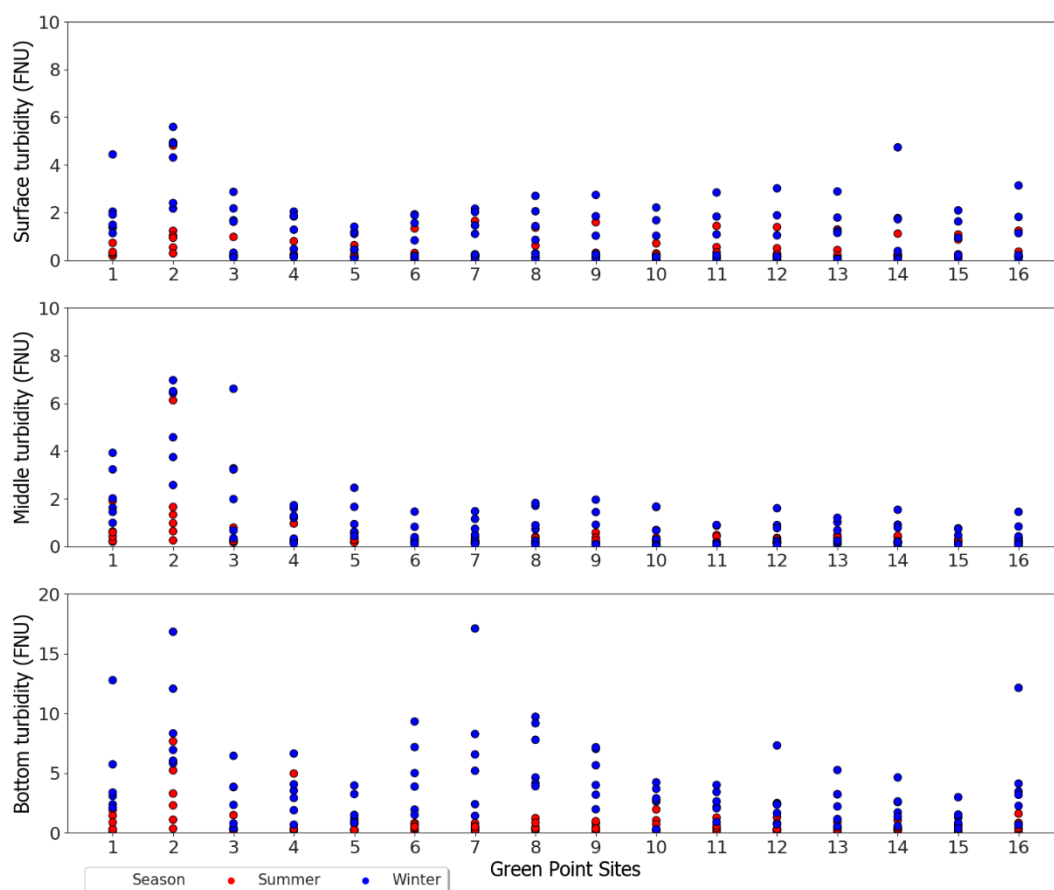


Figure 6.5: Seasonal distribution of turbidity (FNU) measured at the Green Point outfall sites during the 2020 winter and 2021 summer surveys. Note that the bottom depth plot has a different scale on the y-axis to aid presentation.

Turbidity values at all depths in the nearfield of the discharge, represented by measurements from sites GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines during the seasonal monitoring periods with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 6.1). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.3: Median and mean turbidity values (FNU) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	281	575	629
Median	0.70	0.42	1.22
Mean	0.81	0.57	1.34
Summer			
n	287	587	643
Median	0.21	0.20	0.24
Mean	0.31	0.24	0.32

6.3.4 pH

Similar to salinity and turbidity, pH levels measured during the winter survey were notably higher than those measured during the summer survey (Figure 6.6). pH ranged between 8.41 and 8.69 in the winter and between 7.34 and 7.99 in the summer. The summer survey had higher pH ranges as well as a higher inter-week variation at all depths. These seasonal patterns observed are consistent with temperature as cooler waters generally have a lower pH due to capacity to hold higher pCO₂ levels.

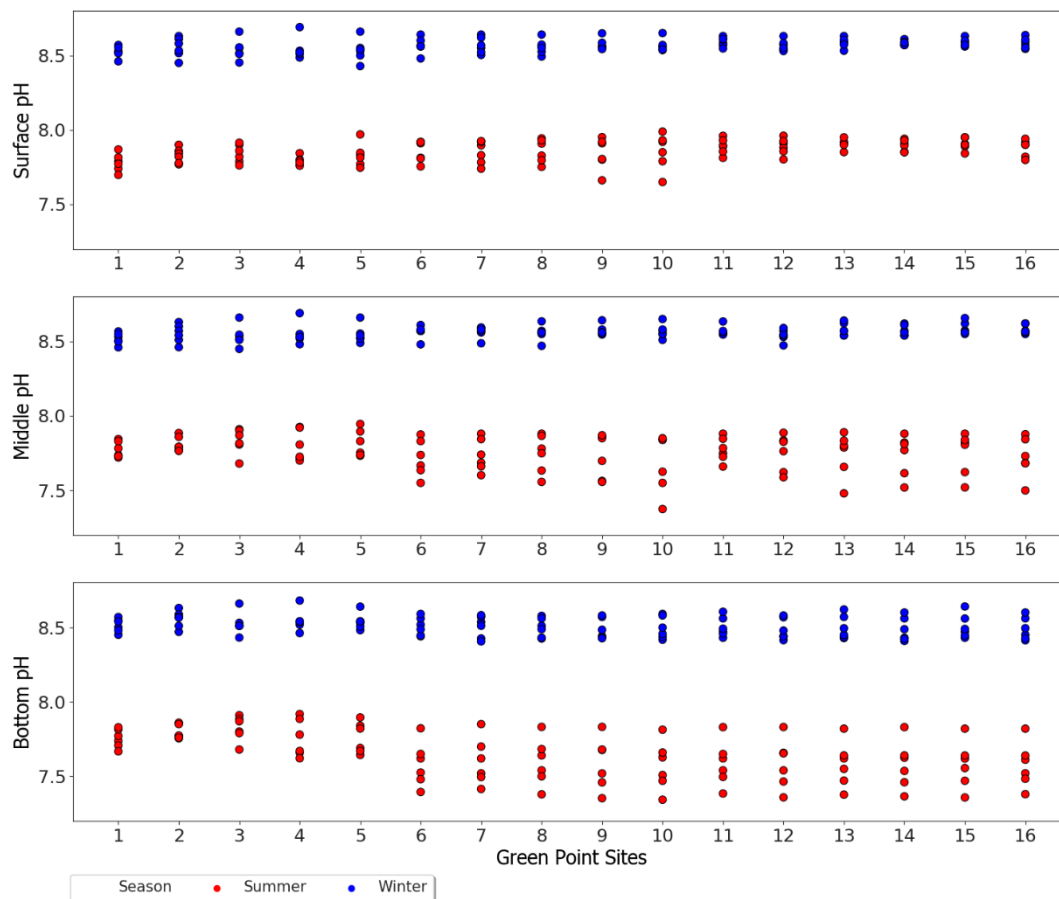


Figure 6.6: Seasonal distribution of pH measured at the Green Point outfall sites during the 2020 winter and 2021 summer surveys.

pH values at all depths in the nearfield water body, represented by measurements from sites GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines during the winter monitoring period with the median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones falling into the ranges defined in Table 3.2 (Table 6.4). However, during winter the pH values at sites in the nearfield of the discharge exceeded the DWAF (1995) recommended guideline range (7.30 – 8.20). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

It must be noted that the range between the winter and summer pH values is large and the summer pH values are notably lower than what was previously recorded during the year 1 summer survey (7.76 - 8.35). Because these low values occurred at all sites and all depths, the low pH values may be a result of instrument error, even though standard calibration procedures are conducted prior to each survey. Continued measurement of pH in future surveys will assist in establishing whether this is the case.

pH values during winter fell outside the range (7.6 – 8.1) previously recorded for the area (DEA 2015). High values (<8.1) were also noted in the year 1 annual report. Relatively elevated pH (>8) indicates the presence of a mainly oxic water column which suggests minimal remineralisation of organically rich sediments.

Table 6.4: Median and mean pH values in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	289	581	629
Median	8.58	8.57	8.53
Mean	8.59	8.58	8.53
Summer			
n	287	587	643
Median	7.89	7.81	7.62
Mean	7.88	7.78	7.61

6.3.5 Dissolved Oxygen

Dissolved oxygen concentrations measured at the Green Point outfall were generally higher in winter compared to summer and ranged between 5.72 and 9.67 mg/L and 0.84 and 9.61 mg/L in winter and summer respectively (Figure 6.7). The lowest concentrations were recorded the bottom during the summer survey at sites GP6 to GP16. The recorded temperatures at some of these sites during summer were low (<10 °C), indicating that the dissolved oxygen concentrations recorded may be a result of upwelling processes in the area drawing hypoxic waters from deeper intermediate waters. This is consistent to that observed in the year one report.

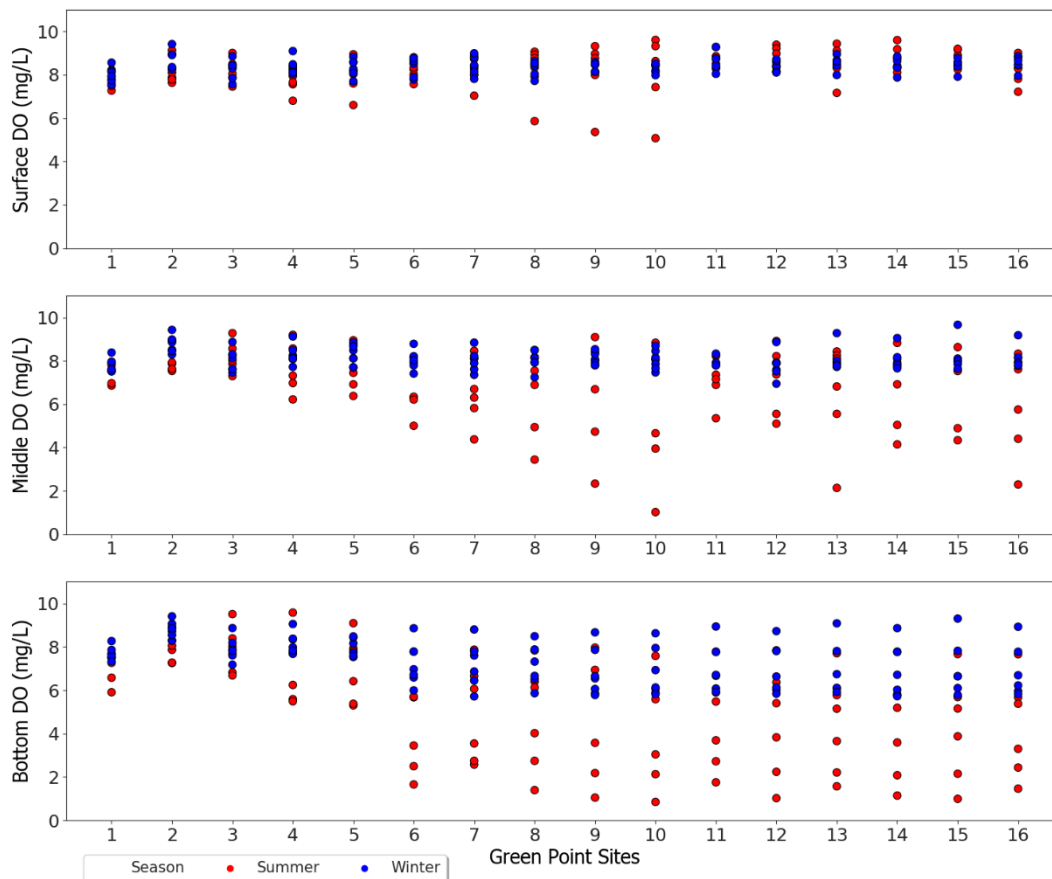


Figure 6.7: Seasonal distribution of dissolved oxygen (mg/L) measured at the Green Point outfall sites during the 2020 winter and 2021 summer surveys.

Dissolved oxygen concentrations at all depths in the nearfield water body, represented by measurements from stations GP2, GP3, GP4, GP7, GP8, GP9, GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines during both the winter and summer monitoring periods. During both monitoring periods, median values in each of the surface (0 – 5 m), mid (5 – 15 m) and bottom (>15 m) depth zones fell into the ranges defined in Table 3.2 (Table 6.5) and indicate an oxic water body at all depths in the immediate vicinity surrounding the outfall. For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.5: Median and mean dissolved oxygen concentrations (mg/L) in surface (0 - 5 m), mid (5 – 15 m) and bottom (>15 m) waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	289	581	629
Median	8.49	8.10	7.35
Mean	8.53	8.21	7.38
Summer			
n	287	587	643
Median	8.50	7.91	5.48
Mean	8.51	7.28	5.09

6.4 Nearshore and Beach Seawater Quality

The laboratory analysis results of enterococci, total suspended solids, total organic carbon, orthophosphate and ammonia measured seasonally in water samples obtained from surface, middle and bottom depths at sites in the vicinity of the Green Point outfall are presented in the sections below. The results of the analyses of seawater toxicity, from two sites near the outfall, to sea urchins are also included.

6.4.1 Enterococci

No clear seasonal pattern was seen in enterococci counts at sites sampled at Green Point (Figure 6.8). Surface and mid-depth values were generally higher than those measured in bottom waters. The highest individual measurements were measured at beach site GP-B3 with several values exceeding 10 000 cfu/100 mL during winter and summer.

During both winter and summer survey periods, the 90th percentiles in surface and mid-depth waters at several nearshore sites exceeded the recommended DEA 2012 guideline (185 cfu/100 mL, Table 3.1). During winter, exceedances were recorded at sites GP11, GP14 and GP15 in surface waters and at sites GP12 and GP13 in mid-depth waters (Figure 6.9). During summer, exceedances were recorded at sites GP4 in surface waters and at sites GP7, GP9, GP11, GP13, GP14 and GP16 in mid-depth waters (Figure 6.10). Similar patterns of exceedance were observed in the year one annual report.

The 90th percentile values at beach sites GP-B1 and GP-B3 exceeded the recommended guideline during both surveys (Figure 6.9 and Figure 6.10). At site GP-B3, the 90th percentile values for both seasons were particularly high: 1 295 and 10 000 cfu/100 mL in winter and summer, respectively. Site GP-B3, located at Three Anchor Bay, recorded exceedances of the recommended guideline during both seasons in year one.

It must be noted that percentile values calculated for each site for each season are based on six samples in each season. High enterococci values thus affect the percentile values more than what could be the case if there were larger sample sizes.

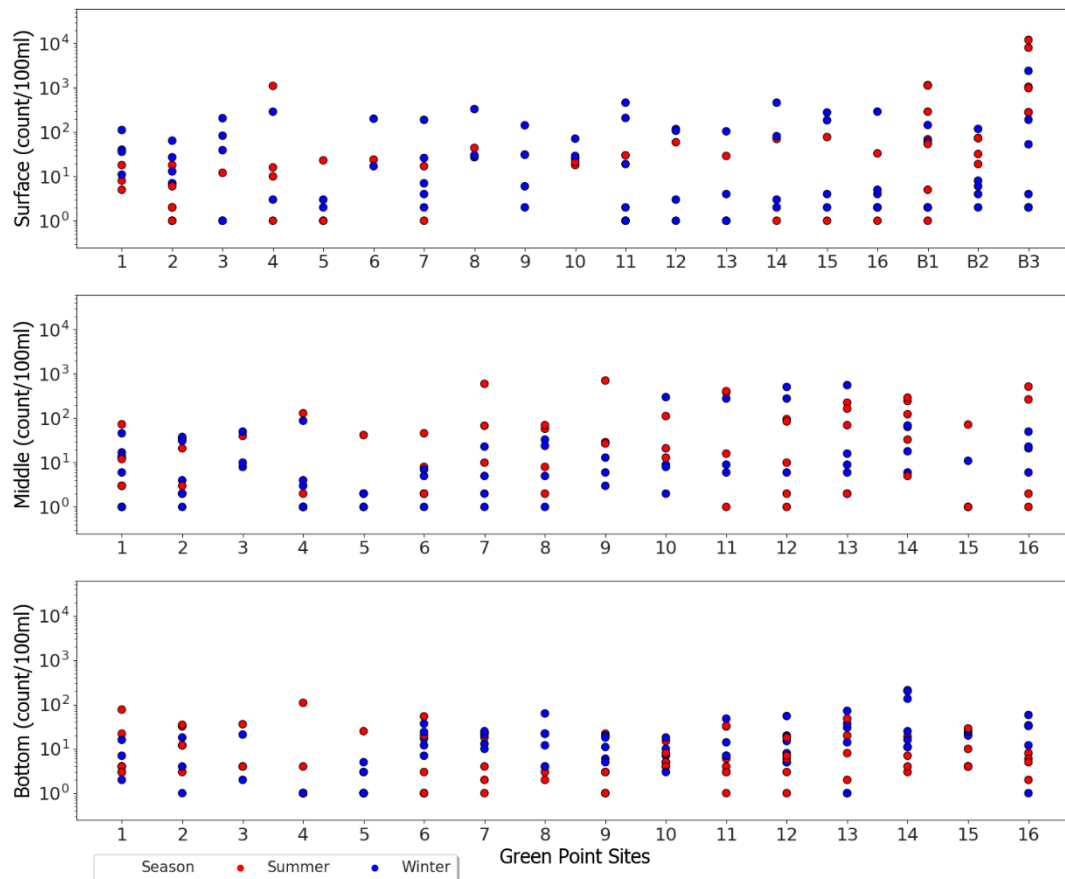


Figure 6.8: Seasonal distribution of enterococci (cfu/100 mL) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2020 winter and 2021 summer surveys.

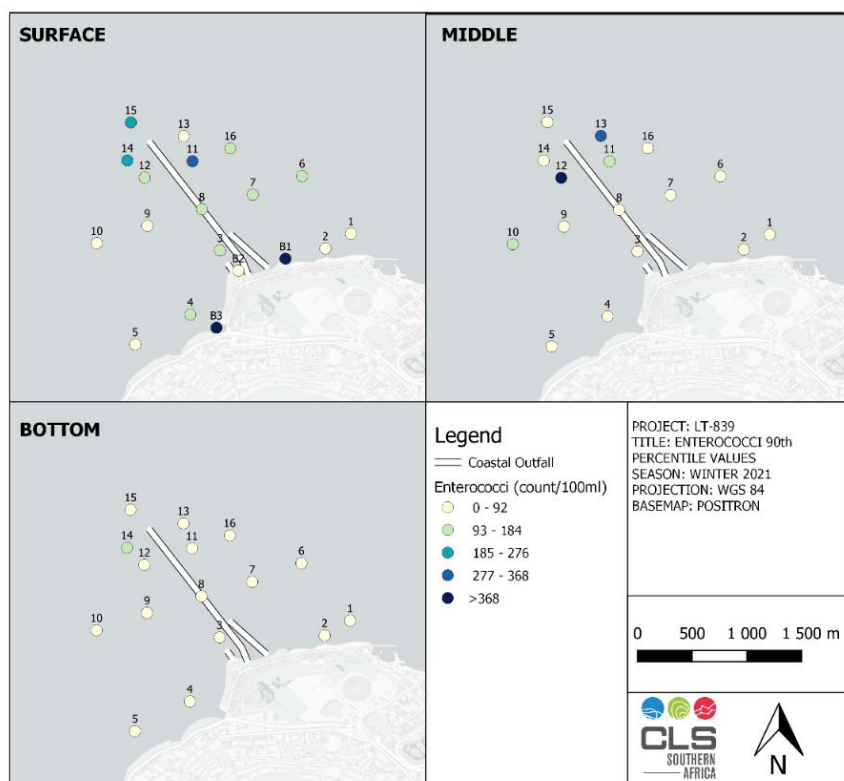


Figure 6.9: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Green Point outfall sites during the 2020 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

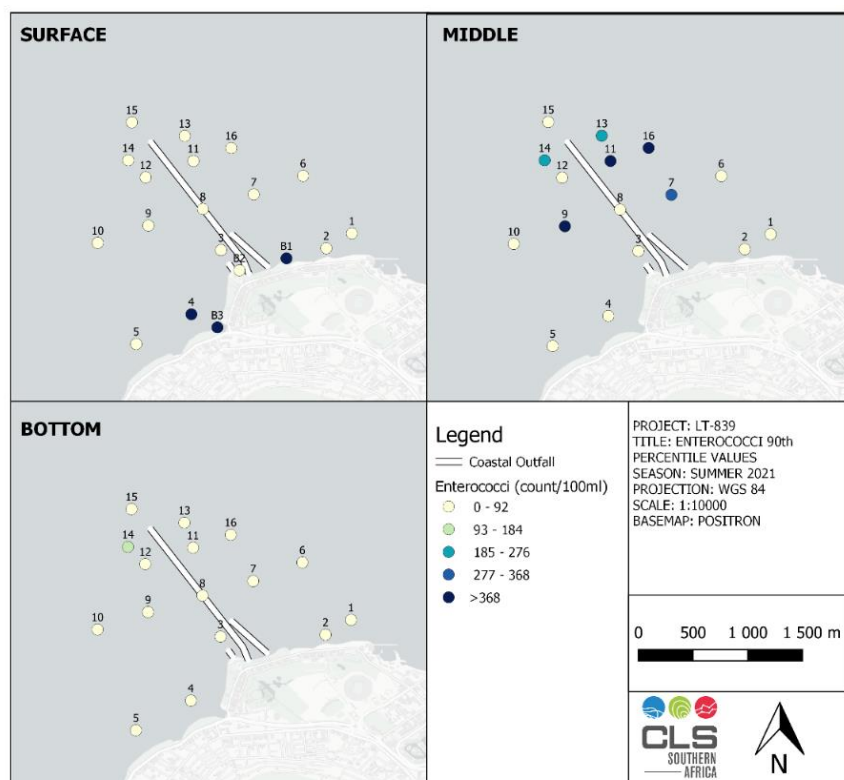


Figure 6.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Green Point outfall sites during the 2021 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

6.4.2 Total Suspended Solids

TSS concentrations were generally higher during the winter survey than during the summer survey in surface, mid-depth and bottom waters surrounding the Green Point outfall (Figure 6.11, Figure 6.12 and Figure 6.13). Outliers were recorded GP2 at all depths and GP16 in mid-depth waters. The largest outlier was recorded at site GP2 with a concentration of 70 mg/L in bottom waters during week 1 (Figure 6.11).

Median TSS concentrations were relatively higher (all sites were >4 mg/L) in bottom waters compared to surface and mid waters during the winter survey period (Figure 6.12). The highest median concentration was recorded at GP2 (17 mg/L) in bottom waters during winter. This is consistent with the findings in the year 1 annual report. In the summer survey, median concentrations were mostly below 4 mg/L with the exceptions of site GP2 in mid and bottom waters (Figure 6.13).

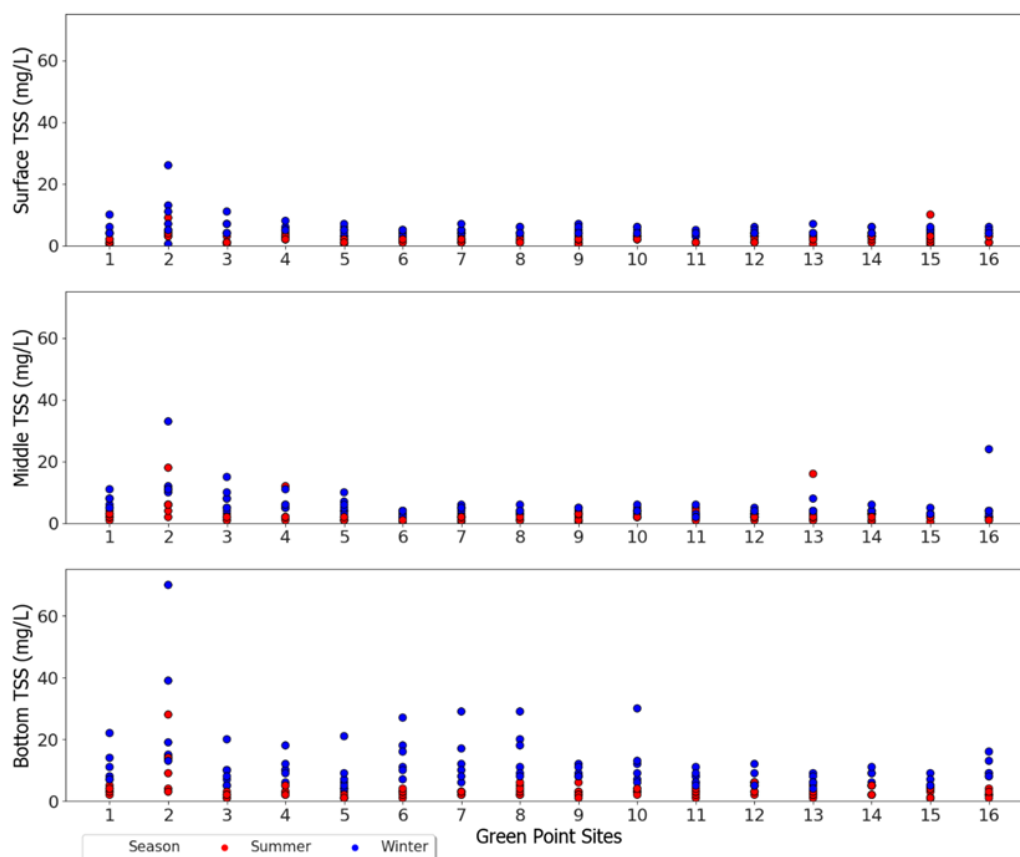


Figure 6.11: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2.

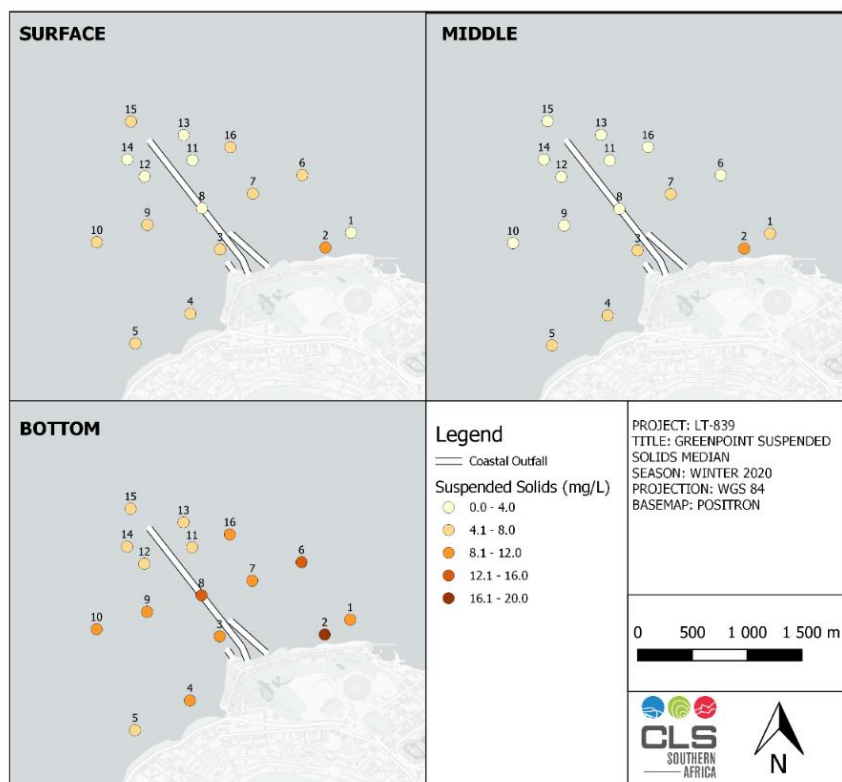


Figure 6.12: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2020 winter survey.

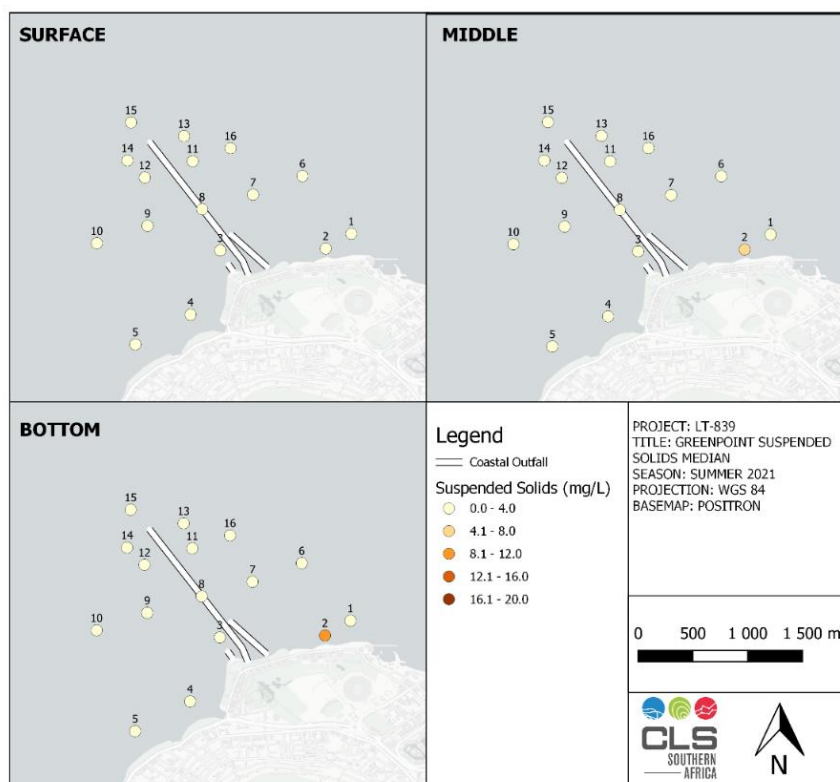


Figure 6.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2021 summer survey.

TSS values at all depths in the nearfield water body, represented by measurements from stations GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines during both the winter and summer monitoring periods. During both monitoring periods, median values in surface, mid and bottom waters fell into the ranges defined in Table 3.2 (Table 6.6). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.6: Median and mean total suspended solids values (mg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Green Point outfall.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	4	4	8
Mean	4	4	8
Summer			
n	30	30	30
Median	3	2	3
Mean	2	3	3

6.4.3 Total Organic Carbon

No clear seasonal pattern was seen in TOC concentration at the Green Point sites (Figure 6.14, Figure 6.15 and Figure 6.16). TOC concentrations in surface, mid- and bottom waters at Green Point were generally low and ranged between 0.5 and 3.7 mg/L during the winter survey and 0.6 and 2.8 mg/L during the summer survey (Figure 6.17). Both the winter and summer survey had high inter-week variation.

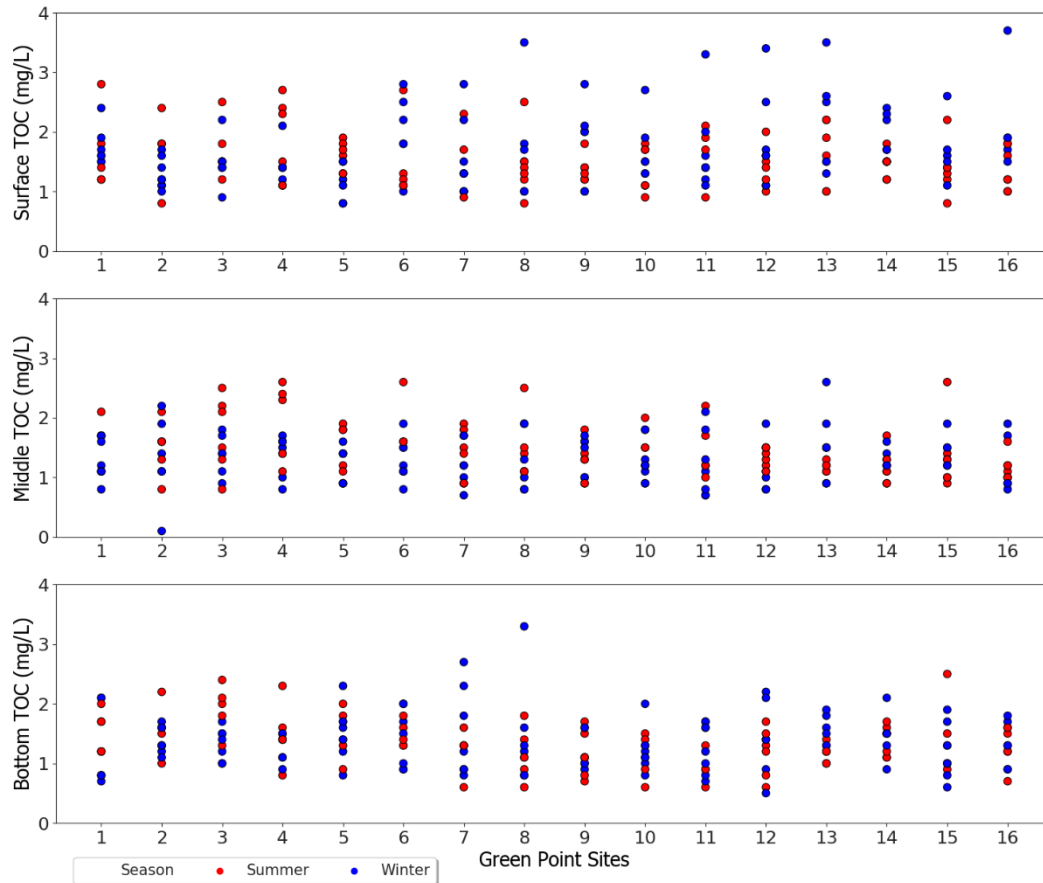


Figure 6.14: Seasonal distribution of total organic carbon (mg/L) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <0.5 mg/L) are presented as MDL/2.

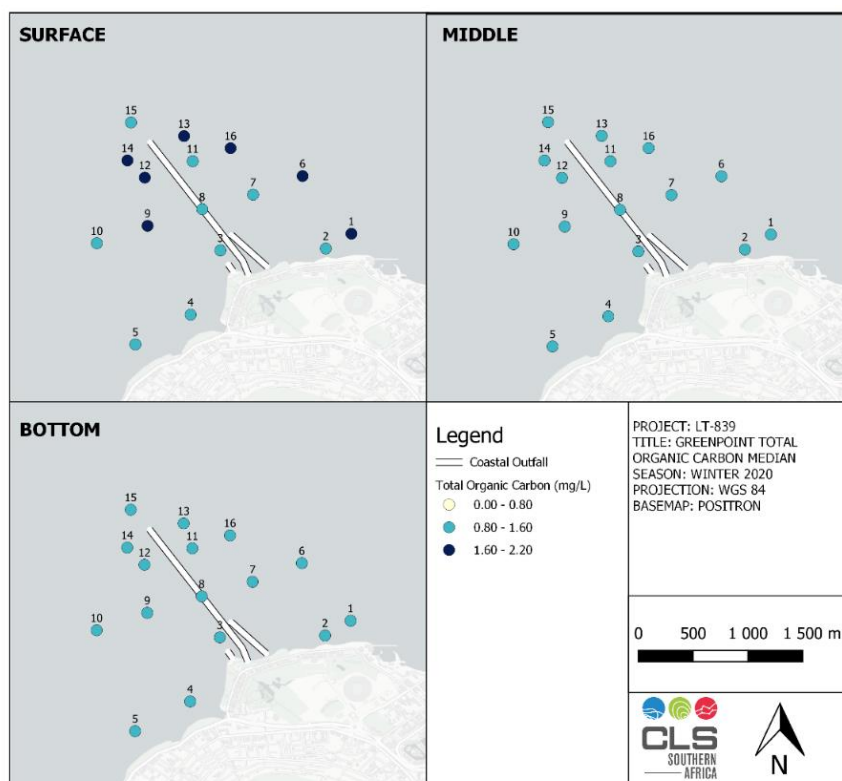


Figure 6.15: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2020 winter survey.

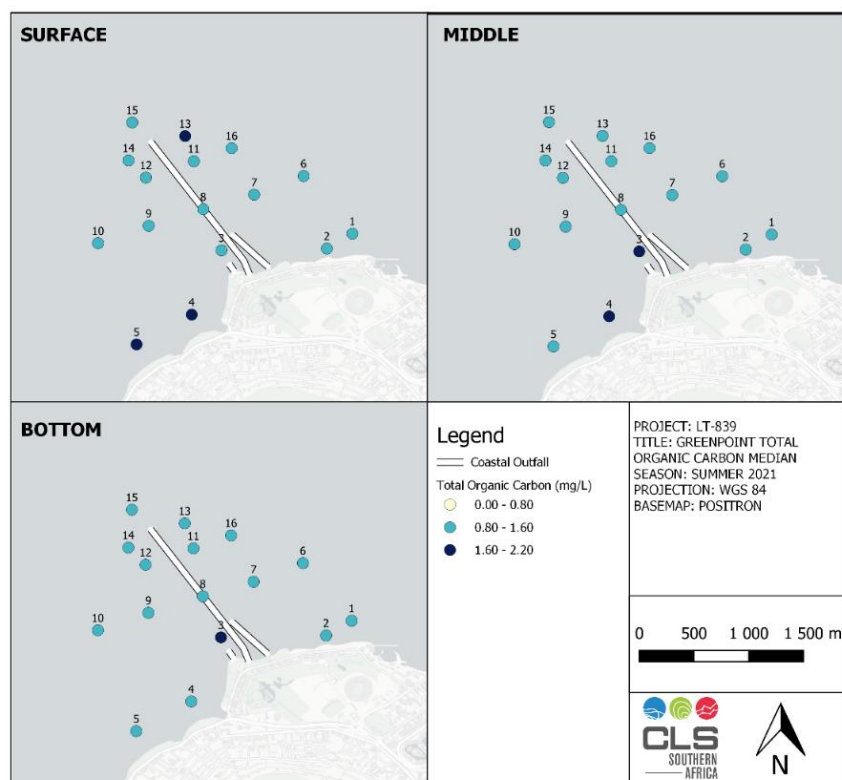


Figure 6.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2021 summer survey.

6.4.4 Orthophosphate

Orthophosphate concentrations were notably lower during the winter survey period than the summer survey period in mid-depth and bottom waters (Figure 6.17, Figure 6.18 and Figure 6.19). The reverse is observed at the surface where winter measurements were generally higher than summer. The highest concentrations were measured at the surface with several sites recording concentrations greater than 100 µg/L. Individual measurements ranged between <5 and 152 µg/L in winter and <5 and 127 µg/L in summer. Both seasons displayed high inter-week variation.

Median concentrations showed spatial distribution patterns across depths and/or sample sites (Figure 6.18 and Figure 6.19) sites GP6-GP12 and GP16 showed slightly elevated orthophosphate concentrations at the surface during the winter survey whilst concentration were elevated in mid-depth and bottom waters at most sites (Figure 6.18).

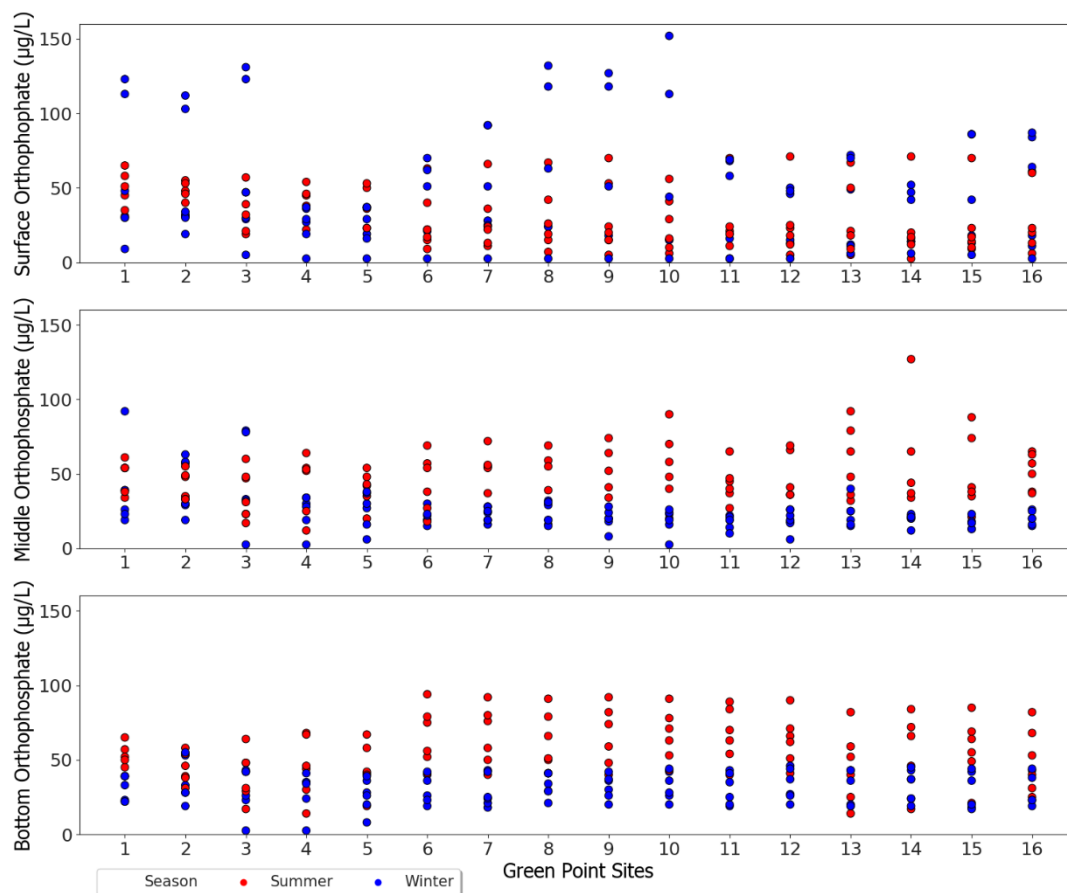


Figure 6.17: Seasonal distribution of orthophosphate (µg/L) measured at the surface, mid- and bottom depths at the Green Point outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

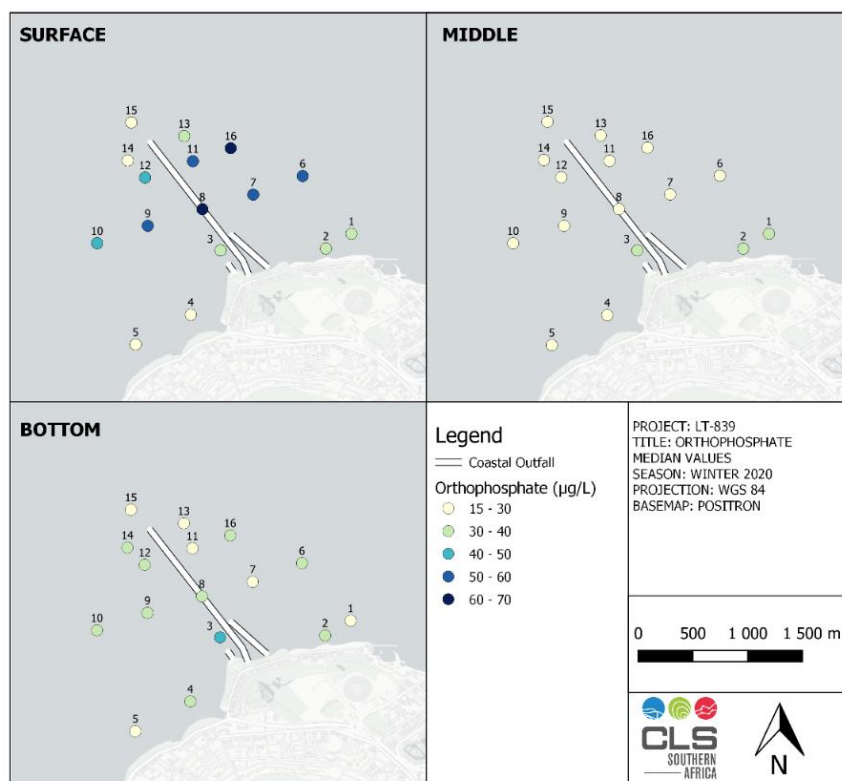


Figure 6.18: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall during the 2020 winter survey.

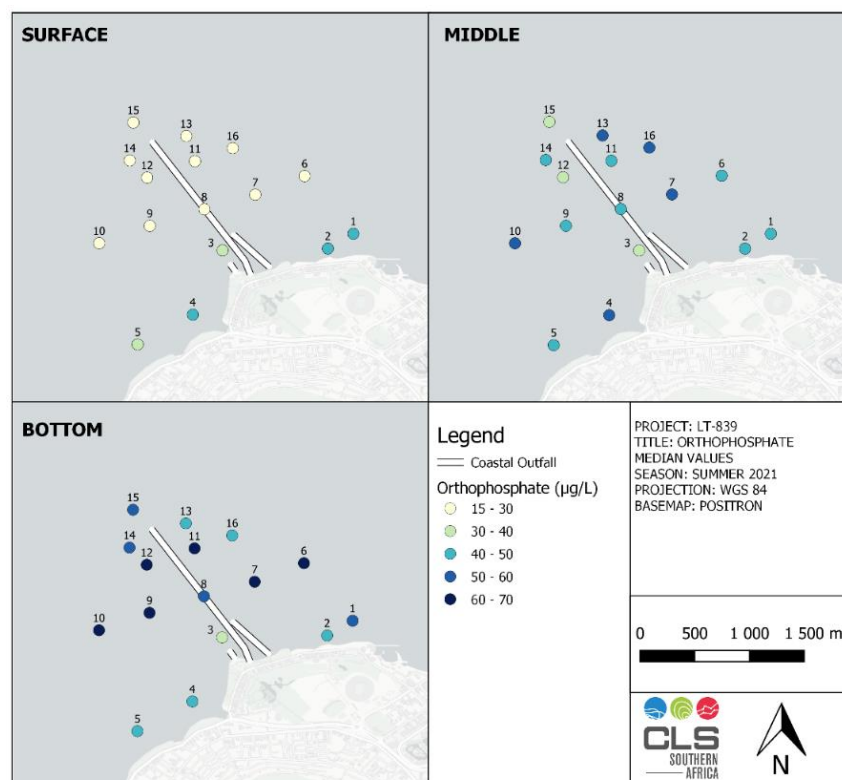


Figure 6.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall during the 2021 summer survey.

Orthophosphate values at all depths in the nearfield water body, represented by measurements from stations GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines defined in Table 3.2 during the winter and summer monitoring periods, with exception of surface waters during winter, which exceeded the 80th percentile guideline (Table 6.7). For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.7: Median and mean orthophosphate values (µg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Green Point outfall. Median and mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	46	20	31
Mean	39	20	32
Summer			
n	30	30	30
Median	20	45	57
Mean	28	51	56

6.4.5 Ammonia

Similar to orthophosphate, ammonia concentrations were generally higher during the summer survey period than the winter survey period in mid-depth and bottom waters whilst in surface waters, winter concentrations were higher than summer (Figure 6.20, Figure 6.21 and Figure 6.22). The highest concentrations were measured in surface waters during winter, and this is evident in the individual measurements (Figure 6.20) as well as the median concentrations (Figure 6.21).

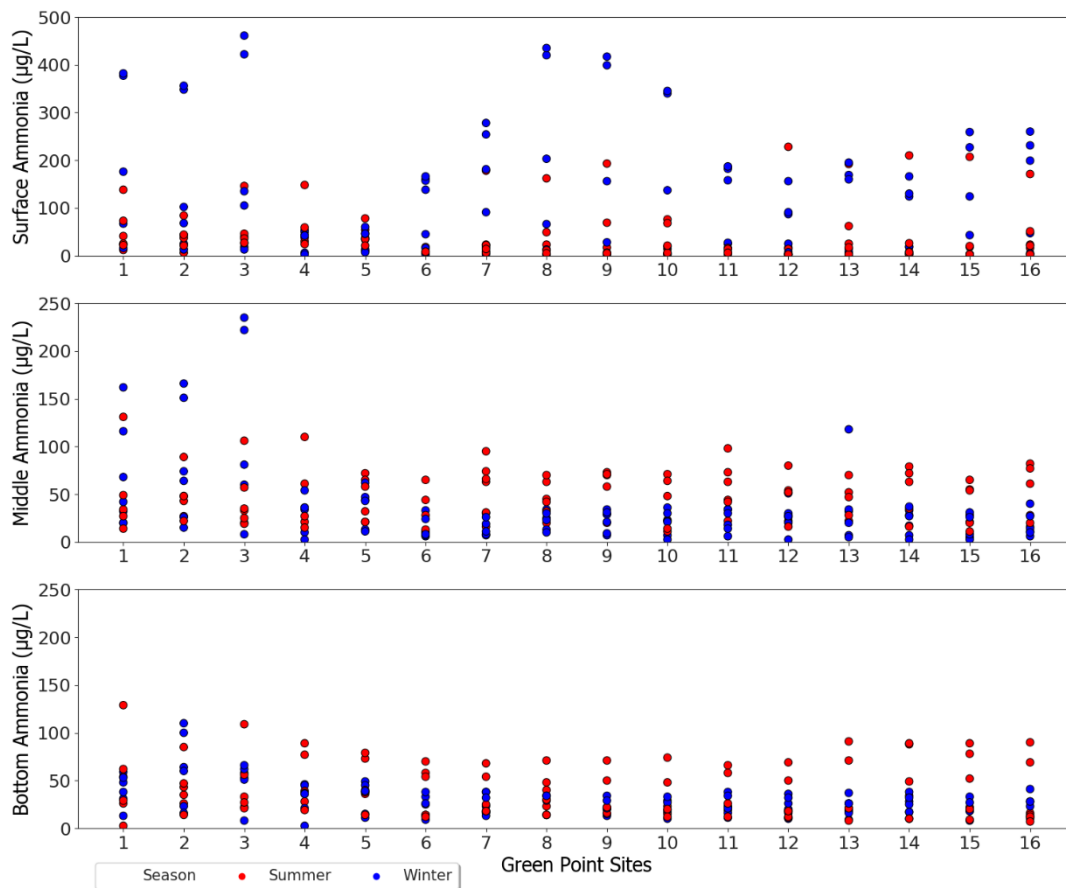


Figure 6.20: Seasonal distribution of ammonia ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Green Point outfall sites during the 2020 winter and 2021 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

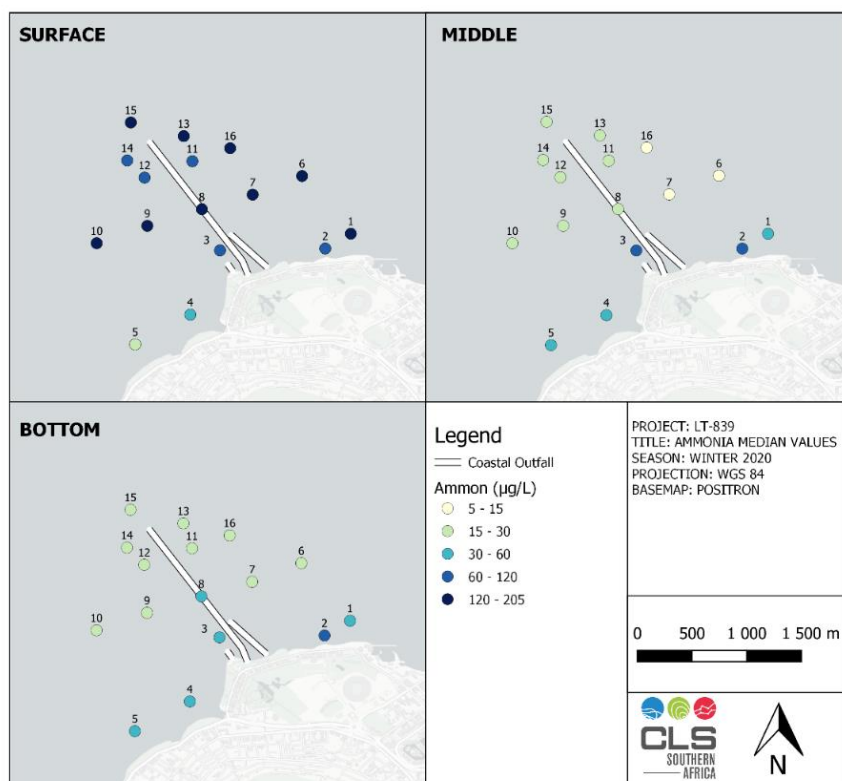


Figure 6.21: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall sites during the 2020 winter survey.

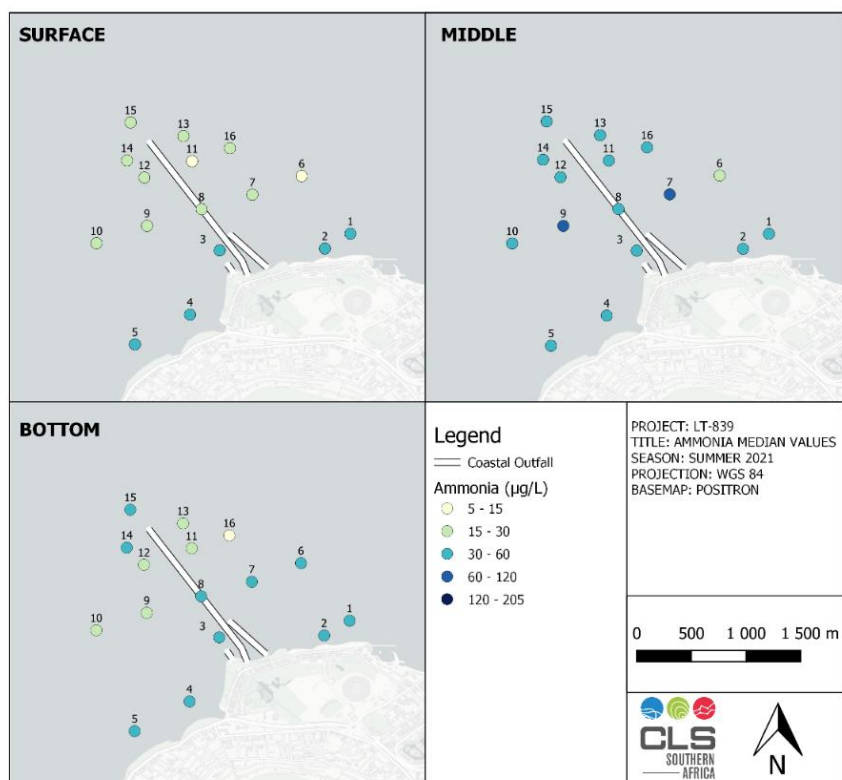


Figure 6.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall sites during the 2021 summer survey.

Similar to orthophosphate, ammonia concentrations at all depths in the nearfield water body, represented by measurements from stations GP11, GP12, GP13, GP14 and GP16, were compliant with the recommended guidelines defined in Table 3.2 during both seasons, with exception to the median concentration in surface waters during winter, which exceeded the 80th percentile guideline (Table 6.8). All median concentrations were below the DWAF (1995) recommended guideline of 600 µg/L. For this determination nearfield sites were grouped based on their location in relation to the ZID and distance from the discharge to increase replication.

Table 6.8: Median and mean ammonia values (µg/L) in surface, mid and bottom waters measured at nearfield sites surrounding the Green Point outfall. Median and mean values that exceed the guideline are highlighted in bold.

	Depth		
	Surface	Mid	Bottom
Winter			
n	30	30	30
Median	108	27	23
Mean	103	26	24
Summer			
n	30	30	30
Median	20	46	22
Mean	61	47	37

6.4.6 Toxicity

The two nearshore sites sampled during the monitoring showed no toxicity effects of seawater obtained from near the discharge on sea urchins (*Tripneustes gratilla* and *Echinometra mathaei*) in terms of fertilisation rates in either of the winter or summer sampling periods (Table 5.6).

Table 6.9: Sea urchin seawater toxicity test results. Samples were obtained from two nearshore sites in the vicinity of the Green Point outfall on alternate days during the winter (August-September 2020) and summer (March-April 2021) sampling periods. Toxicity classification is based on mean (n=4) fertilisation success rates.

Season	Date	Site	% Fertilisation Success				Mean	Std Dev	Toxicity Classification
			1	2	3	4			
Tripneutes gratilla									
Winter	3 09 2020	GP-TT1	100	99	100	99	99.50	0.58	Not toxic
		GP-TT2	100	99	100	99	99.50	0.58	Not toxic
	4 09 2020	GP-TT1	99	99	100	99	99.25	0.50	Not toxic
		GP-TT2	100	99	100	99	99.50	0.58	Not toxic
	7 09 2020	GP-TT1	99	99	99	100	99.25	0.50	Not toxic
		GP-TT2	100	99	99	100	99.50	0.58	Not toxic
	9 09 2020	GP-TT1	99	99	99	100	99.25	0.50	Not toxic
		GP-TT2	100	99	99	100	99.50	0.58	Not toxic
	12 09 2020	GP-TT1	100	99	99	100	99.50	0.58	Not toxic
		GP-TT2	100	99	99	100	99.50	0.58	Not toxic
	17 09 2020	GP-TT1	99	99	98	98	98.50	0.58	Not toxic
		GP-TT2	99	99	99	98	98.75	0.50	Not toxic
18 09 2020	GP-TT1	99	99	98	98	98.50	0.58	Not toxic	
	GP-TT2	99	99	98	98	98.50	0.58	Not toxic	
Summer	25 03 2021	GP-TT1S	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2M	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	99	100	99	99	99.25	0.50	Not toxic
	27 03 2021	GP-TT1S	99	99	98	98	98.50	0.58	Not toxic
		GP-TT1M	99	99	98	98	98.50	0.58	Not toxic
		GP-TT2	99	99	98	98	98.50	0.58	Not toxic
	29 03 2021	GP-TT1S	99	99	98	98	98.50	0.58	Not toxic
		GP-TT1M	99	98	98	98	98.25	0.50	Not toxic
		GP-TT2	99	99	98	98	98.50	0.58	Not toxic
	30 03 2021	GP-TT1S	99	99	99	98	98.75	0.50	Not toxic
		GP-TT1M	99	99	98	98	98.50	0.58	Not toxic
		GP-TT2	99	99	98	98	98.50	0.58	Not toxic
	31 03 2021	GP-TT1S	99	99	99	99	99.00	0.00	Not toxic
		GP-TT1M	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	99.50	0.58	Not toxic
	8 04 2021	GP-TT1S	99	99	100	100	99.50	0.58	Not toxic
		GP-TT1M	99	99	99	100	99.25	0.50	Not toxic
		GP-TT2	99	99	100	100	99.50	0.58	Not toxic
9 04 2021	GP-TT1S	99	99	100	100	99.50	0.58	Not toxic	
	GP-TT1M	99	99	99	100	99.25	0.50	Not toxic	
	GP-TT2	99	99	100	100	99.50	0.58	Not toxic	

6.5 Effects on Local Marine Ecology

Growth rates and trace metal accumulation in mussels (*Mytilus galloprovincialis*) at fixed monitoring stations surrounding the Green Point outfall and two control stations were compared across the winter 2020 and summer 2021 deployments. Results (detailed in APPENDIX D) indicated that mussel growth rates at the Green Point outfall were lower in summer than in winter. Unlike Hout Bay and Camps Bay, growth rates at the monitoring (impact) stations located near the outfall and control stations situated further afield had similar growth rates during both seasons.

Trace metal concentrations at control and impact stations at Green Point also showed clear seasonal trends for nickel and zinc with a greater average loss (relative to baseline levels) observed during winter than summer. There was no evidence of seasonal differences in copper accumulation during the winter and summer deployments. Mussels at all locations accumulated copper relative to baseline concentration during both the winter and summer deployment. There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for “unimpacted” stations.

7 SUMMARY

Overall, most water quality parameters measured at the sites in the receiving environment at the Hout Bay, Camps Bay and Green Point outfalls were compliant with the guidelines put forward in Table 3.1 and Table 3.2.

Non-compliance events were recorded at Hout Bay for the following parameters:

- Dissolved oxygen: In surface waters at sites in the nearfield of the discharge during the summer survey period.
- Enterococci: In surface waters at site HB2 during both winter and summer survey periods and at sites HB1, HB3 and HB5 during summer. In the mid-depth waters at site HB3 during summer. At beach sites HB-B2 during both seasons and HB-B3 during summer.

Non-compliance events were recorded at Camps Bay for the following parameters:

- Ammonia: In surface waters at sites in the nearfield of the discharge during the summer survey period.

Non-compliance events were recorded at Green Point for the following parameters:

- Enterococci: In surface waters at sites GP11, GP14 and GP15 and at sites GP12 and GP13 in mid-depth waters during the winter survey. In surface waters at site GP4 during the summer survey and in mid-depth waters at sites GP7, GP9, GP11, GP13, GP14 and GP16 during the summer survey. At beach sites GP-B1 and GP-B3 during both summer and winter surveys.
- Orthophosphate: In surface waters at nearfield sites of the discharge during the winter survey.
- Ammonia: In surface waters at nearfield sites of the discharge during the winter survey.

It is notable that toxicity testing of water samples drawn from probable effluent plume areas at all three outfalls indicated a non-toxic environment and that possible deleterious ecological effects of the discharges on the surrounding marine environment are unlikely to be persistent. This is supported by the biomonitoring surveys which concluded that there was no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls compared to those further afield at all three outfalls. Growth rates appeared to be slightly higher at monitoring stations than the control stations although it is thought that the higher growth rates at the diffusers are a function of higher levels of organic matter and increased nutrient loading present in the water column in the immediate vicinity of the outfalls.

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- Jin, G., Engle, A.J., Bradford, H., Jeng, H. 2004. Comparison of E. coli, Enterococci and faecal coliform as indicators for brackish water quality assessment. Water Environment Research 76: 245-255.

9 APPENDIX D: BIOMONITORING REPORT



CITY OF CAPE TOWN

EFFLUENT PIPELINES BIOMONITORING

ANNUAL REPORT

WINTER 2020-SUMMER 2021



June 2021



ANCHOR
research & monitoring

CITY OF CAPE TOWN

EFFLUENT PIPELINES BIOMONITORING

Annual Report

June 2021

Report prepared for



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EXECUTIVE SUMMARY

A long-term environmental monitoring programme has been implemented for the City's Marine outfall effluent discharge areas based on the City's Outfalls Marine Discharge Monitoring Guidelines. Anchor Research and Monitoring (Pty) Ltd (Anchor) was appointed in conjunction with Lwandle Marine Environment Services (Lwandle) and the CSIR to undertake a monitoring program to assess impacts associated with the discharge of effluent by the City of Cape Town through three outfalls offshore at Hout Bay, Camps Bay and Green Point as required by the Coastal Waters Discharge Permit (CWDP) issued for these outfalls by the Department of Environmental Affairs: Oceans and Coasts.

A seasonal, bi-annual monitoring programme has been implemented to assess the impact of effluents on marine bioindicators. Due to its life history and filter feeding nature, the alien mussel species *Mytilus galloprovincialis* that is abundant on Cape Town rocky shores, was selected for use as an appropriate bioindicator species. This document compares the results of mussel growth and accumulation of trace metals (Zn, Cu, Ni) by mussels between the Winter 2020 and Summer 2021 deployments. During Winter 2020 the mussels were deployed for 58-76 days due the Covid-19 lockdown preventing the retrieval of the moorings after the scheduled 8 weeks as initially planned, whilst the Summer 2021 deployment was for a period of 56 days.

There were clear seasonal differences in the growth rate of mussels used in the two monitoring experiments, with lower average growth rates at all sites recorded during the summer deployment. This is attributed to both lower particulate organic matter and temperature of upwelled water which is more prevalent off the Cape Peninsula during the spring and summer period than winter. Seasonal spawning of mussels in summer and the resultant allocation of energy to reproduction rather than growth is also probably a cause of the observed seasonal growth differences. Growth rates appear to be slightly higher at some sites located in proximity to the outfalls than at control sites further afield, this was more evident during the summer season. It is expected that the higher growth rates at the outfalls and greater average growth rates at the outfalls compared to the controls, are a function of higher levels of organic matter and increased nutrient loading present in the water column in the vicinity of the outfalls.

Trace metal accumulation in mussels also showed clear seasonal trends. There was no evidence of seasonal differences in copper accumulation during the winter 2020 and summer 2021 deployments, but mussels did lose nickel and zinc at a greater rate during the winter deployment. This may be a result of the extended deployment time and a spawning event having taken place during the winter deployment. Mussels at all locations accumulated Cu relative to baseline concentration during both the 2020 winter and 2021 summer deployment. There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for "unimpacted" sites.

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1 BACKGROUND

In 2017 the City of Cape Town (CoCT) conducted a survey that investigated the performance and effects of the domestic effluent outfalls offshore of Hout Bay, Camps Bay and Green Point (Table Bay). The CSIR (2017) found minimal environmental or human health effects specifically attributable to substances discharged through the outfalls (Figure 1-1). Subsequently, a long-term environmental monitoring programme has been implemented for the City's Marine outfall effluent discharge areas based on the City's Outfalls Marine Discharge Monitoring Guidelines. The environmental and/or human health effects of the outfalls may change over time, so the CoCT requires that the effects of the outfalls be carefully monitored and reported on. To ensure the integrity of the marine receiving environment is not unacceptably compromised, the Department of Environmental Affairs issues Coastal Waters Discharge Permits in terms of the Integrated Coastal Management Act, 2008 (Act No. 24 of 2008). The permits stipulate the conditions under which the discharge is legally authorised. The purpose of this report is to demonstrate compliance with the condition of authorisation for effluent discharge in terms of environmental impact monitoring and reporting and to demonstrate and report on the potential impacts of effluent on marine receptors over a three-year period (2019-2022).



Figure 1-1. Sewage outfall plume at Green Point (Table Bay), Cape Town. Photo taken by Jean Tresfon, 2017.

1.1 Scope of Works

Anchor Research and Monitoring (Pty) Ltd (Anchor) was appointed in conjunction with Lwandle Marine Environment Services (Lwandle) and the CSIR to undertake a monitoring program to assess impacts associated with the discharge of effluent by the City of Cape Town through three outfalls offshore at Hout Bay, Camps Bay and Green Point as required by the Coastal Waters Discharge Permit (CWDP) issued by the Department of Environmental Affairs: Oceans and Coasts for these outfalls. The outfalls are owned and operated by the City of Cape Town and average discharge volumes at each pipeline in Summer/Autumn 2020 were much less than (Green Point and Camps Bay) or similar (Hout Bay) to the license discharge volumes, while Winter/Spring 2020 discharge volumes slightly exceeded (by 2.3%) the license discharge volume for Hout Bay, but was well within the license discharge limit for Green Point and Camps Bay (Table 1.1).

Table 1.1. The three sea outfalls (pipelines) owned and operated by the City of Cape Town with permissible, current and design discharge volumes (CSIR 2020).

Outfall	Distance offshore (m)	Discharge Depth (m)	Number of Diffusers	Design Capacity (ML.day ⁻¹)	Current (2020) Discharge Summer/Autumn (ML.day ⁻¹)	Current (2020) Discharge Winter/Spring (ML.day ⁻¹)	License Discharge (ML.day ⁻¹)
Green Point	1676	28	16	40.0	18.1	23.80	27.3
Camps Bay	1497	23	8	5.0	1.68	1.96	2.3
Hout Bay	2162	39	14 (5 operable)	9.6	5.05	5.32	5.2

A seasonal, bi-annual monitoring programme has been implemented to assess the impact of effluents on marine bioindicators. Due to its life history and filter feeding nature, the alien mussel species *Mytilus galloprovincialis* that is abundant on Cape Town rocky shores, was selected for use as an appropriate bioindicator species. The monitoring programme has three broad objectives, namely:

1. To assess the seasonal growth rate of the Mediterranean mussel, *M. galloprovincialis* at sampling stations surrounding the Green Point, Camps Bay and Hout Bay effluent pipelines over a 6-8 week period and whether or not growth rates are enhanced or suppressed by the increased presence of effluent (proximity to effluent diffuser);
2. To assess if the rate at which trace metal accumulation by *M. galloprovincialis* in Green Point, Camps Bay and Hout Bay is changing over time in relation to proximity to effluent diffusers; and;
3. To assess geographical variation in bioaccumulation rates by mussels in the respective bays and to assess potential links with effluent discharge.

This document compares the results of growth and accumulation of trace metals (Zn, Cu, Ni) by mussels between the Winter 2020 and Summer 2021 deployments. The report serves the equally important roles of providing managers of the Green Point, Camps Bay and Hout Bay wastewater works with strategic information for managing the discharges and of informing the public on the status (or health) of the marine receiving environments. This report details the annual comparison of the growth rates and trace metal analysis between the second winter and summer sampling periods.

2 APPROACH

2.1 Mussel collection and analysis

Mussels were collected from the shore at Scarborough on the western coast of the Cape Peninsula which is located in the controlled use zone of the Table Mountain National Park MPA in an area where pollution loading is known to be low (Sparks *et al* 2018) (Figure 2-1). *Mytilus galloprovincialis* is an alien mussel species and was specifically selected over one of the indigenous mussel species that occur on the Peninsula (*Choromytilus meridionalis*, *Aulacomya ater* or *Perna perna*) for the following reasons:

1. The study will entail temporary translocation but ultimately removal of the test organisms from the Peninsula. Use of an alien species is thus favoured.
2. Numbers of indigenous mussels on the Cape Peninsula are low and are in decline due to invasion by *M. galloprovincialis*. Removal of indigenous mussels is therefore not advisable.
3. *M. galloprovincialis* are widely used for biomonitoring elsewhere in South Africa and in other parts of the world and data are thus more directly comparable with data from other studies.

Live mussels with shell lengths in the range 40-50 mm were collected from a rocky shelf area at spring low tide in Scarborough, Cape Town (Figure 2-2). Mussels were positively identified to species level, and the lengths were recorded before they were used to stock the mussel bags (Figure 2-3). Approximately 40 mussels were randomly selected from the initial batch of 1 000 collected and the tissue was extracted, homogenized and submitted to Stellenbosch CSIR Coastal Laboratory for baseline trace metal analysis for Zn, Cu and Ni. The mussels collected for the baseline analysis for the summer 2021 experiment were of poor condition with very little tissue being present in each shell, having possibly undergone a spawning event (van Erkom Schurink & Griffiths, 1991, 1993), this meant that only enough tissue for one baseline sample could be submitted for the summer experiment. The remaining mussels were then subdivided into 36 mesh bags (20 per bag) and deployed on the moorings for a scheduled 6-week (winter) and 8-week (summer) period. On completion of a seasonal experimental period, the moorings were retrieved, mussels recovered and measured to assess the average growth increment for each sampling site. (Figure 2-3). Tissue was also extracted from each mussel, homogenized and submitted to Stellenbosch CSIR Coastal Laboratory for trace metal analysis.

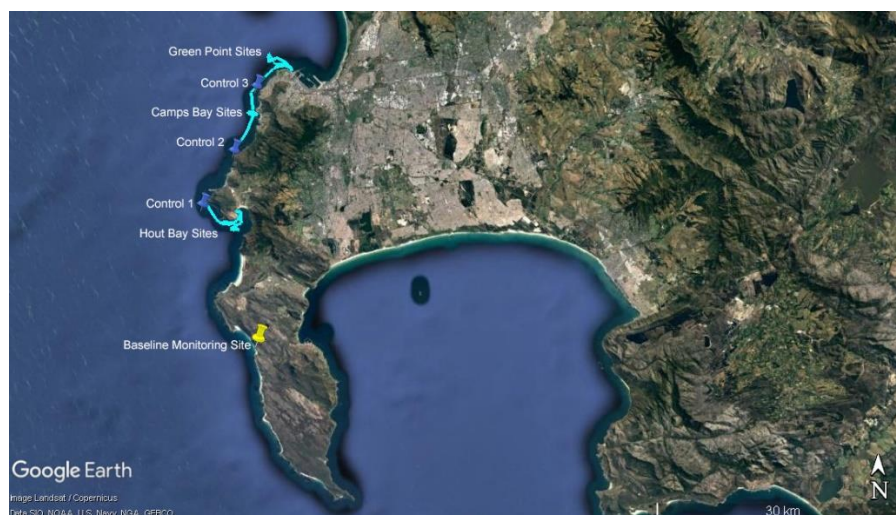


Figure 2-1. Map of Cape Town showing the baseline mussel collection site, the three outfall locations and three control site locations.



Figure 2-2. *Mytilus galloprovincialis* collection site at Scarborough, Cape Town rocky shelf on the spring low tide, and species identification, count and measurement process for the mussel bags.



Figure 2-3. Laboratory mussel length measurements for growth rate at the end of the 6–8-week deployment period and mussel dissection sample preparation for the trace metal analysis.

2.2 Mooring design setup and deployment

At each outfall, twelve fixed monitoring stations were positioned in a cross formation around the diffuser of each individual pipeline (Figure 2-4). Stations were positioned approximately 100 m, 300 m, 600 m in four directions moving outwards from each effluent outfall. At each station, a mooring comprised of an anchor (20 kg section of railway track), a nylon rope (12 mm) and a subsurface buoy (30 cm diameter) was deployed (Figure 2-5). Mussels (*Mytilus galloprovincialis*) were collected and suspended in a mesh bag on each mooring. The mussel bag was placed at 4-8 m depth below the surface for 58-76 and 56 days during the winter and summer periods, respectively. This procedure will be replicated for a further two seasons with ongoing winter 2021 and summer 2022 deployments.

The same mooring configuration was replicated at the initial two control sites off the Sentinel (Control 1-Hout Bay), Oudekraal (Control 2- Camps Bay) and a third control site was added off Sea Point (Control 3- Green Point). but with three mussel bags attached per mooring line for additional replication if required (e.g. if a mussel bag detached). Moorings were designed in such a way that the probability of entanglement by marine mammals was low (no loose or horizontal lines were used) and that the risks of mortality that could result from entanglement were minimised (moorings were light enough such that even small cetaceans could reach the surface to breathe even if they did become entangled).

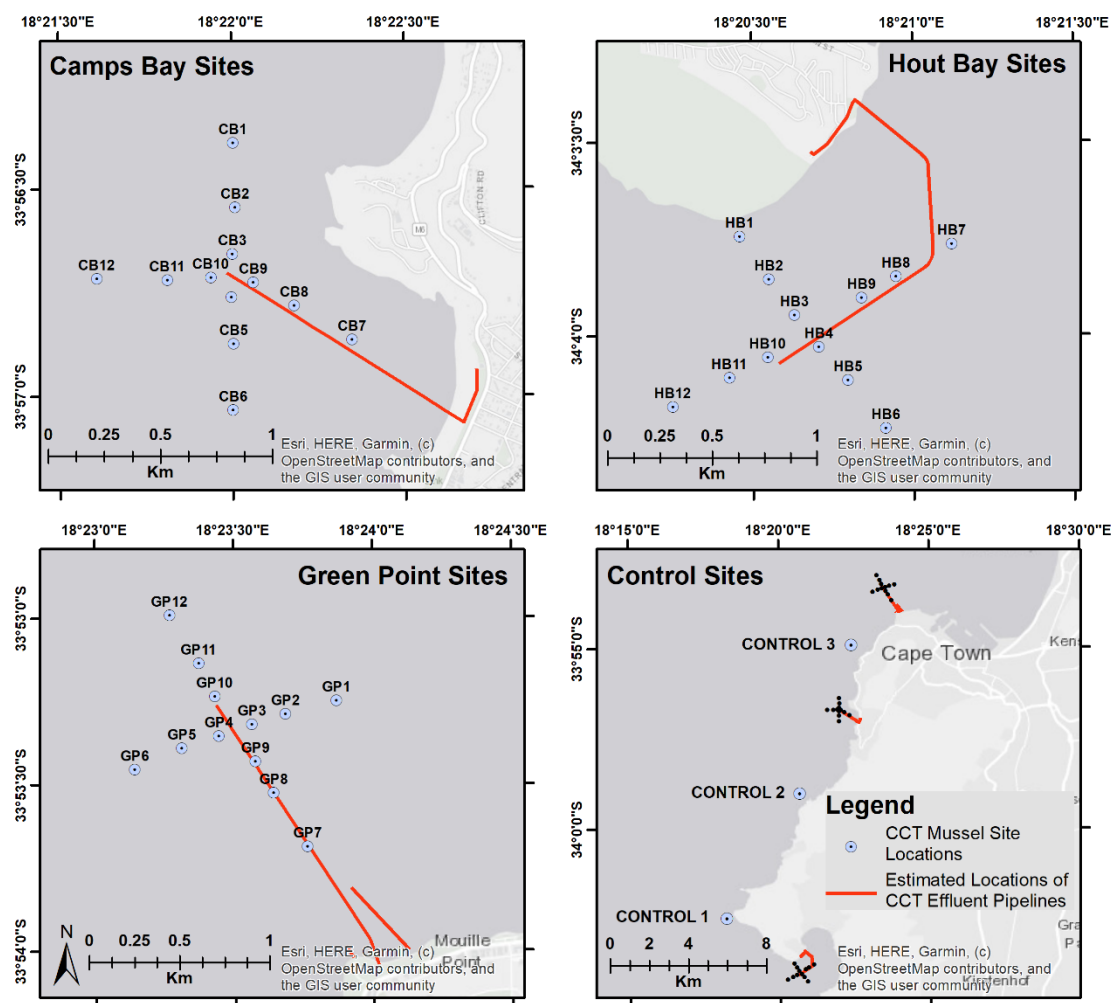


Figure 2-4. Maps of the Cape Town area, showing the positions of the Green Point, Camps Bay and Hout Bay outfalls (approximate outfall locations are denoted by red lines). Locations of ecological biomonitoring stations in Green Point, Camps Bay and Hout Bay are also shown and referred to in the remainder of the report with an E in front of the site name (E_HB1 for example).

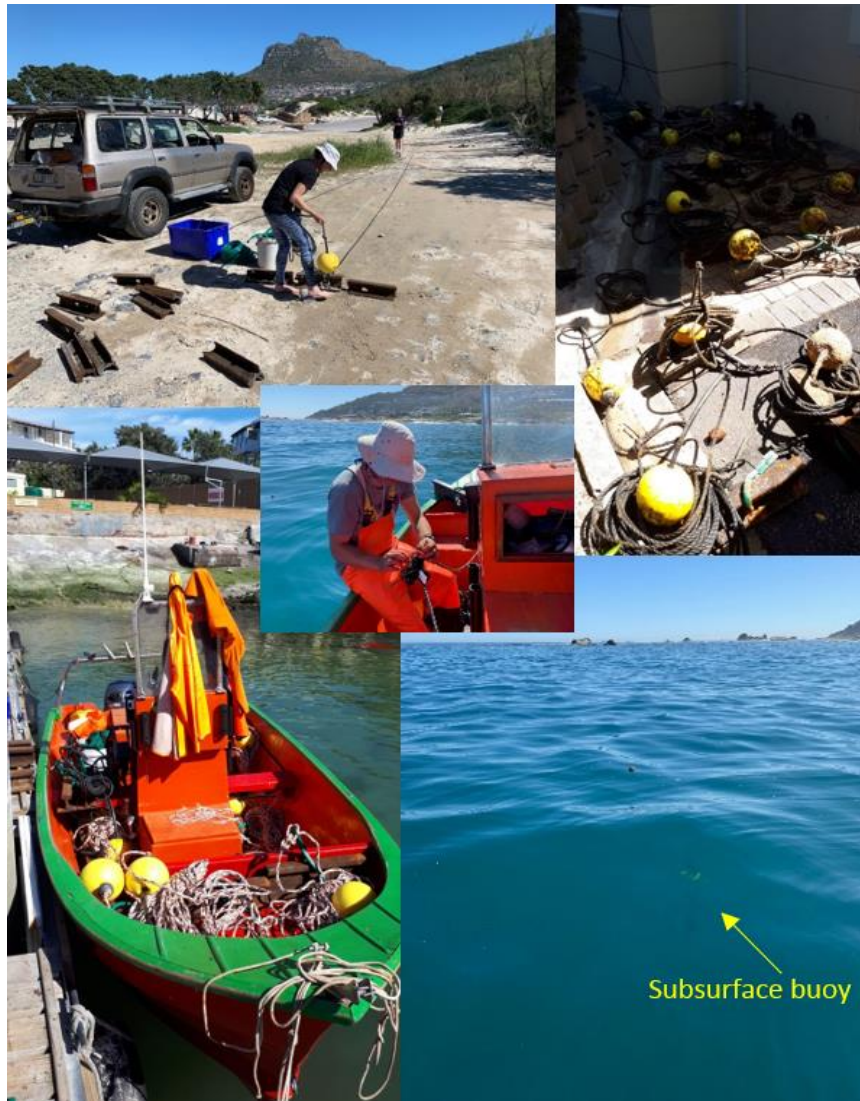


Figure 2-5. Mooring make up, bag attachment and deployment at Green Point, Camps Bay and Hout Bay.

3 RESULTS AND DISCUSSION

3.1 Mooring retrieval success rate

During the 2020 winter deployment period several moorings were lost at both the Green Point and Camps Bay outfalls. Four out of 12 moorings were missing at Green Point (GP2, 4, 9 and 10) and one out of 12 moorings at Camps Bay was missing (CB 11), whilst the mussel bag had broken off mooring CB 6. During the 2021 summer deployment period, 2 out of the 12 moorings at Green Point, and 3 out of 12 moorings were missing at Hout Bay.

It is likely that moorings were lost as a result of being ridden over or entangled by vessels that traversed through these sites, or they were pulled up by boat operators suspecting illegal fishing activities during spring low tides. Shipping traffic was noted as being very intensive through the Green Point and Hout Bay sites during the deployment and retrieval periods (several large vessels were observed moving through the mooring arrays each hour during the deployment and retrieval periods) but lower at the Camps Bay and Control sites. A comprehensive search and recovery procedure was attempted for all missing moorings during both seasonal surveys.

An essential outcome of any outfall biomonitoring programme is to determine if effluent discharge is significantly, negatively impacting on the ecology of the receiving environment and/or is posing a risk to the health of humans that use that environment (CSIR 2017). Biological indicators, in this case mussels *M. galloprovincialis*, were used to measure biological and chemical impacts. Two different metrics, variation in growth rate and variation in trace metal levels in mussel tissue in relation to distance from the outfalls was used to assess the extent of these impacts for the three deep-water sewage outfalls in the Cape Town area. Growth rates and trace metal accumulation were compared across winter and summer seasons as both of these are known to vary seasonally (growth rates e.g. Van Erkom Schurink and Griffiths (1993); trace metals e.g. Bezuidenhout *et al.* (2015), Sparks *et al.* (2018).

3.2 *Mytilus galloprovincialis* growth rates

The mussel growth rate averaged across all monitoring stations at the Camps Bay in summer and Green Point outfalls (both seasons) were marginally greater than the controls (Figure 3-1 & Figure 3-2). The difference in mean growth rate between impact sites surrounding the outfall and the controls was much greater at Camps Bay in Winter and at Hout Bay in both seasons (Figure 3-2). The average growth rate in winter for the control and impact sites at Camps Bay was 0.052 mm/day and 0.075 mm/day, respectively while at Hout Bay the control and impact sites had an average growth rate of 0.04 mm/day and 0.082 mm/day in winter and 0.016 mm/day and 0.034 mm/day in summer, respectively. Further, mean mussel growth rates proved to be statistically significantly different between seasons for control and impact stations across all sites (Mann-Whitney U, $P < 0.05$). Winter showed a greater number of statistical differences between sites than summer where the Green Point control and impact stations were significantly different from control stations at Camps Bay and Hout Bay (Tukey Post-Hoc, $P < 0.05$); whilst the Camps Bay control and impact stations were significantly different from the Hout Bay control station (Tukey Post-Hoc, $P < 0.05$). This is evident in the larger

mean winter growth rates at Green Point compared to controls at Camps Bay and Hout Bay (Figure 3-2).

At monitoring stations surrounding the outfalls, growth rates are greater than the controls situated further afield, this was more evident at Camps Bay and Hout Bay than at Green Point (Figure 3-1). It is expected that the higher growth rates at the diffusers compared to the controls, are a function of higher levels of organic matter and increased nutrient loading present in the water column in the vicinity of the outfalls. Both of which would have had a net positive effect on mussel growth. These findings are in line with those included in the CSIR (2017) and Bustamante and Branch (1996) reports that document increased mussel growth rate in association with high levels of particulate organic matter (POM) which is an important food supply. These and other studies have recorded faster growth rates in *M. galloprovincialis* as well as greater average POM concentrations occurring in moderately exposed sites in comparison to sheltered sites (Bustamante and Branch 1996, Steffani and Branch 2003). Mussel growth rates recorded in the present study do suggest that the mooring stations located at the three outfalls have a greater food supply (POM) than the control sites. Clear seasonal differences were however still evident; whereby average growth rate was greater in winter than summer.

Numerous studies have documented the differential effects of upwelling on mussel growth; where some report that mussels at upwelling sites would have greater growth than those downstream (Xavier et al. 2007); and other authors observed the opposite trend – faster mussel growth associated with sites of weaker upwelling and higher temperatures (Menge *et al.* 1997a,b; Sanford and Menge 2000; Phillips 2005; Blanchette *et al.* 2006, 2007). The latter is often characterized by greater onshore concentrations of Chl-*a* (Menge *et al.* 1997a,b; Sanford and Menge 2000; Wieters *et al.* 2003). Upwelling centres have colder water; are nutrient rich but poor in Chl-*a* and POM (Graham and Largier 1997; Wieters *et al.* 2003). Besides food availability, it appears that temperature is an influential factor in driving the observed differential growth rates between the two seasons. A study from Van Erkom Schurink and Griffiths (1993) provided strong evidence that temperature (rather than food availability) was the main variable determining the growth rates of various southern African mussel species, including *M. galloprovincialis*, which yielded faster growth rates in warmer temperatures. In the present study, mussel growth rate was evidently reduced in summer compared to winter, and these findings are in line with the reports previously mentioned, considering upwelling events which result in clear and cold water near the coast, generally occur in spring-summer (Shannon 1985).

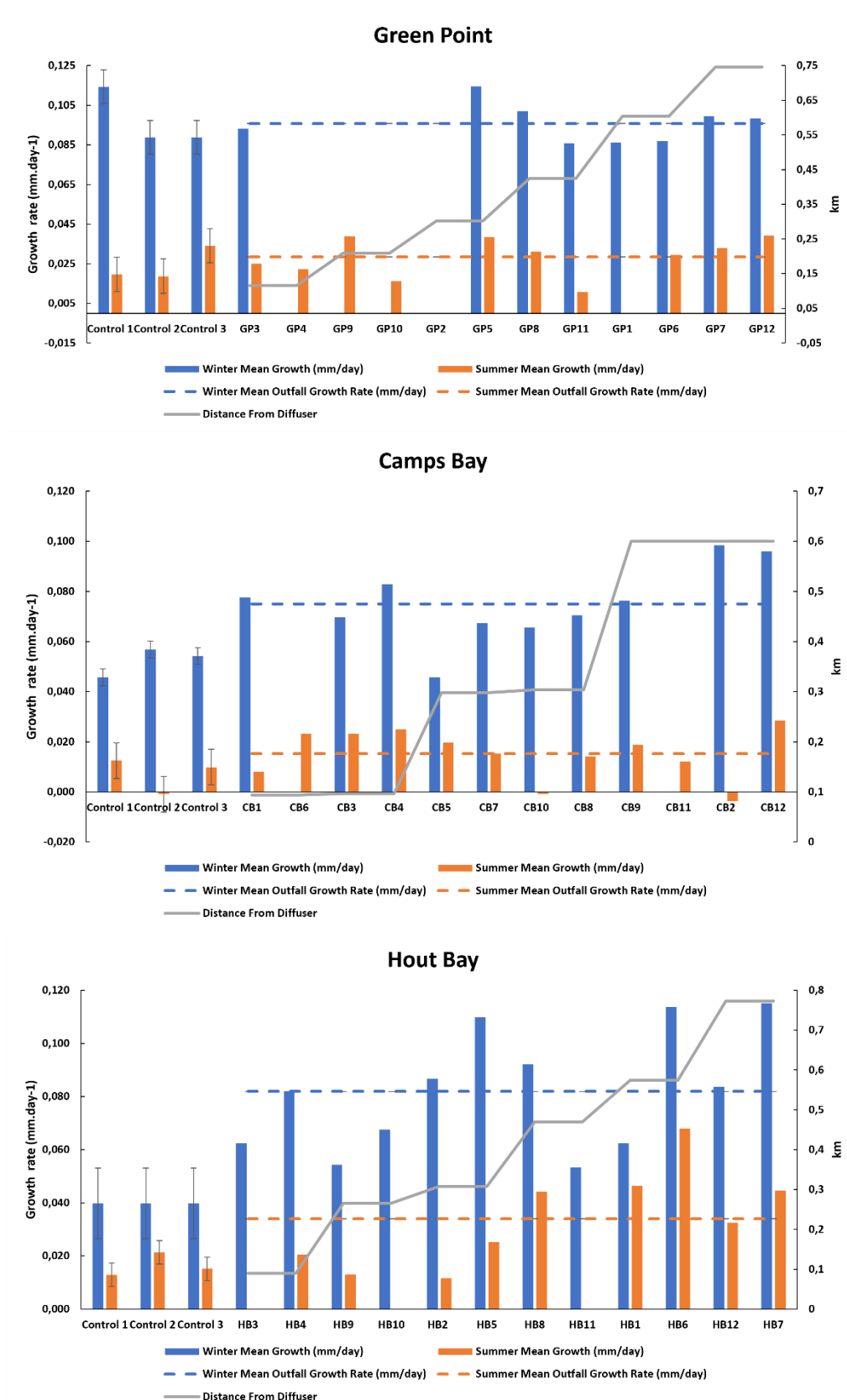


Figure 3-1. *Mytilus galloprovincialis* growth rates (mm/day) on left axis over a 58-76 day period, July to October 2020 (Winter), and a 56 day period, February to April 2021 (Summer) in relation to distance from effluent diffuser, grey line (km) on right axis for three different deep-water outfall locations, Green Point, Camps Bay, and Hout Bay. The dotted lines indicate the mean growth (mm) for each outfall location.

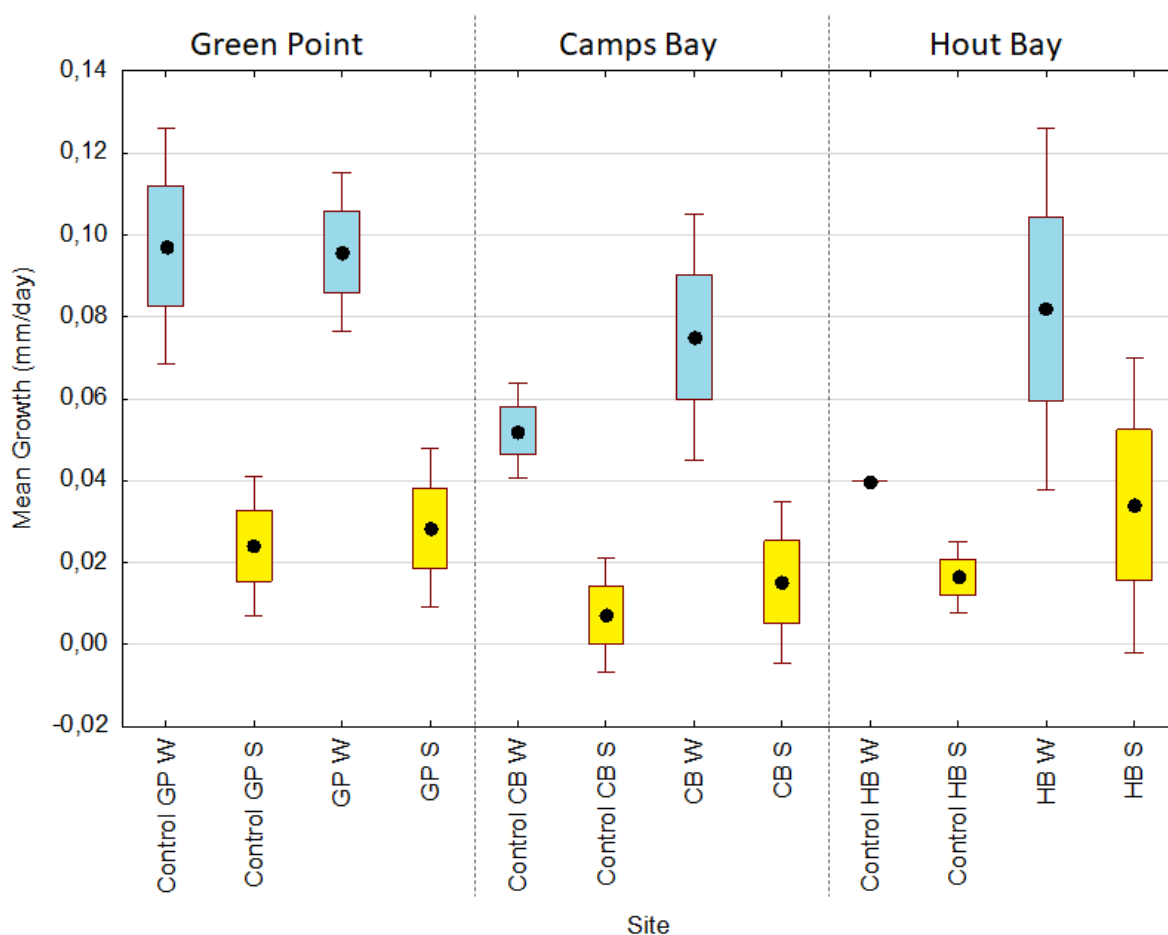


Figure 3-2 Mean *Mytilus galloprovincialis* growth rates (mm/day) for Winter 2020 (W; blue) and Summer 2021 (S; yellow). The dotted lines separate the mean growth (mm) for Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

3.3 Trace metal content

Mussels have the ability to accumulate metals from the marine environment and have been used to assess coastal environmental pollution since the 1970s through Mussel Watch programs and similar studies (Goldberg 1975). Change in trace metal content for mussels deployed at stations surrounding each of the deep-water outfalls and at the control stations relative to baseline (pre-deployment) levels are shown in Figure 3-4, Figure 3-3 and Figure 3-5 below. This change can be positive (due to a greater rate of intake of trace metals relative to excretion, resulting in accumulation), or negative (due to lower uptake rate, a greater excretion rate or decrease in concentration due to growth of the mussel).

Trace metal concentrations at control and impact stations for Green Point, Camps Bay and Hout Bay were significantly different between Winter and Summer with the average loss of nickel and zinc been greater during the winter season (Mann-Whitney U, $P < 0.05$). This is in contrast to the results of the 2019-2020 trials when mussels lost more / gained less trace metals during the summer deployment. Further analysis of pairwise comparisons of treatments within each season for each metal are provided below.

3.3.1.1 Nickel (Ni)

The average daily loss of nickel by mussels was significantly greater across all stations (impacts and controls) during the winter 2020 deployment than the summer 2021 deployment (Figure 3-3). Differences in Nickel concentrations between impact and control stations in winter were not statistically significantly different (Kruskal-Wallis, $P > 0.05$), but were significantly different in summer (Tukey Post-Hoc, $P < 0.05$). The average daily loss of nickel by mussels at Green Point impact stations were significantly greater than that by mussels at the control and impact stations at Camps Bay and Hout Bay (Tukey Post-Hoc, $P < 0.05$). (Figure 3-3).

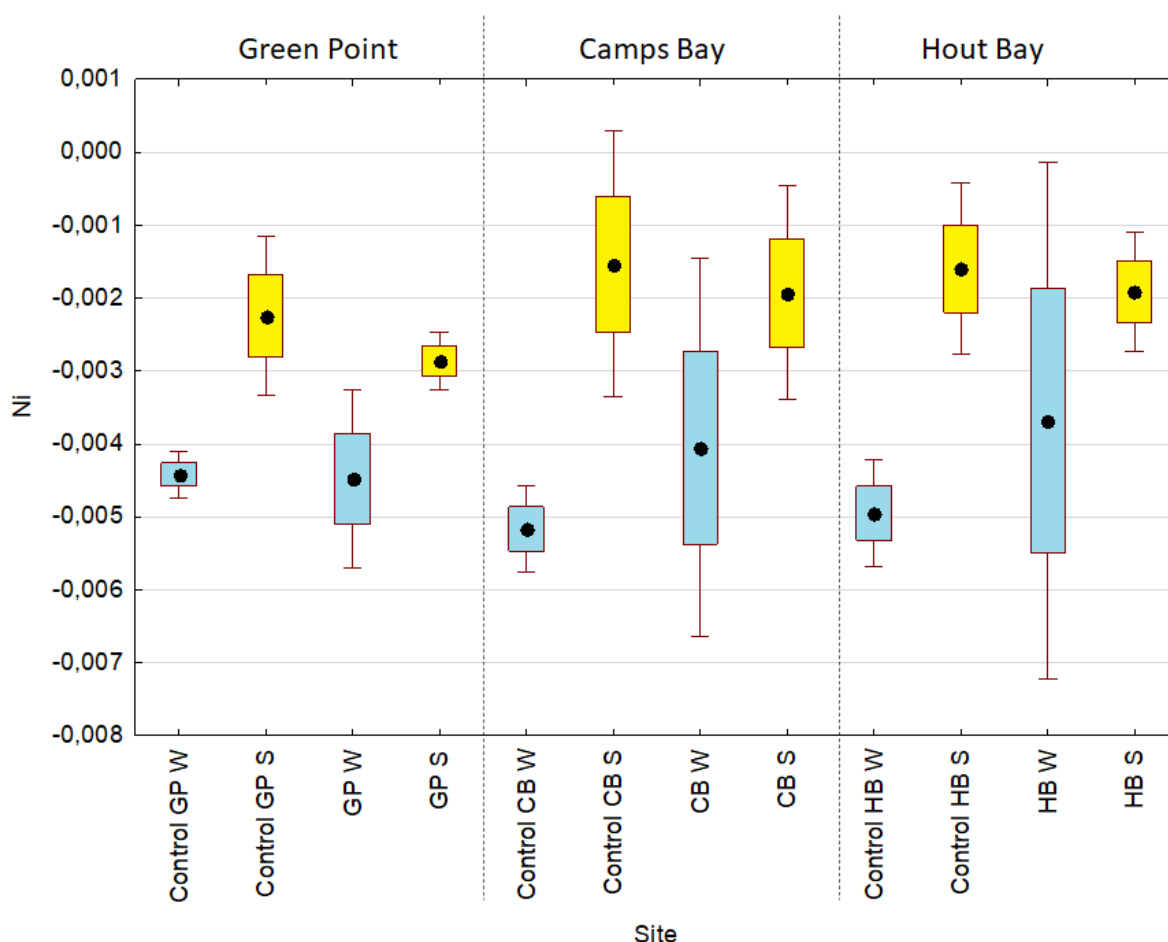


Figure 3-3 Mean change in levels of Nickel (Ni) content for mussels deployed in Winter 2020 (W; blue) and Summer 2021 (S; yellow) at sites surrounding the deep-water outfalls at Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

3.3.1.2 Copper (Cu)

Control and impact stations across all sites were not statistically significantly different between stations (Kruskal Wallis, $P > 0.05$). Average Copper concentrations were marginally higher in Summer than winter (Figure 3-4 and Figure 3-6), 0.029 mg/kg and 0.022 mg/kg respectively, with the exception of one station (GP7) that appears to be an outlier with a Cu concentration change of 10.6 mg/kg total wet weight over the summer deployment period (Figure 3-4 and Figure 3-6). Copper accumulation was on average greater in summer than winter at most outfall sites, (especially Green Point), but these differences were not statistically significant (Figure 3-4, Figure 3-6).

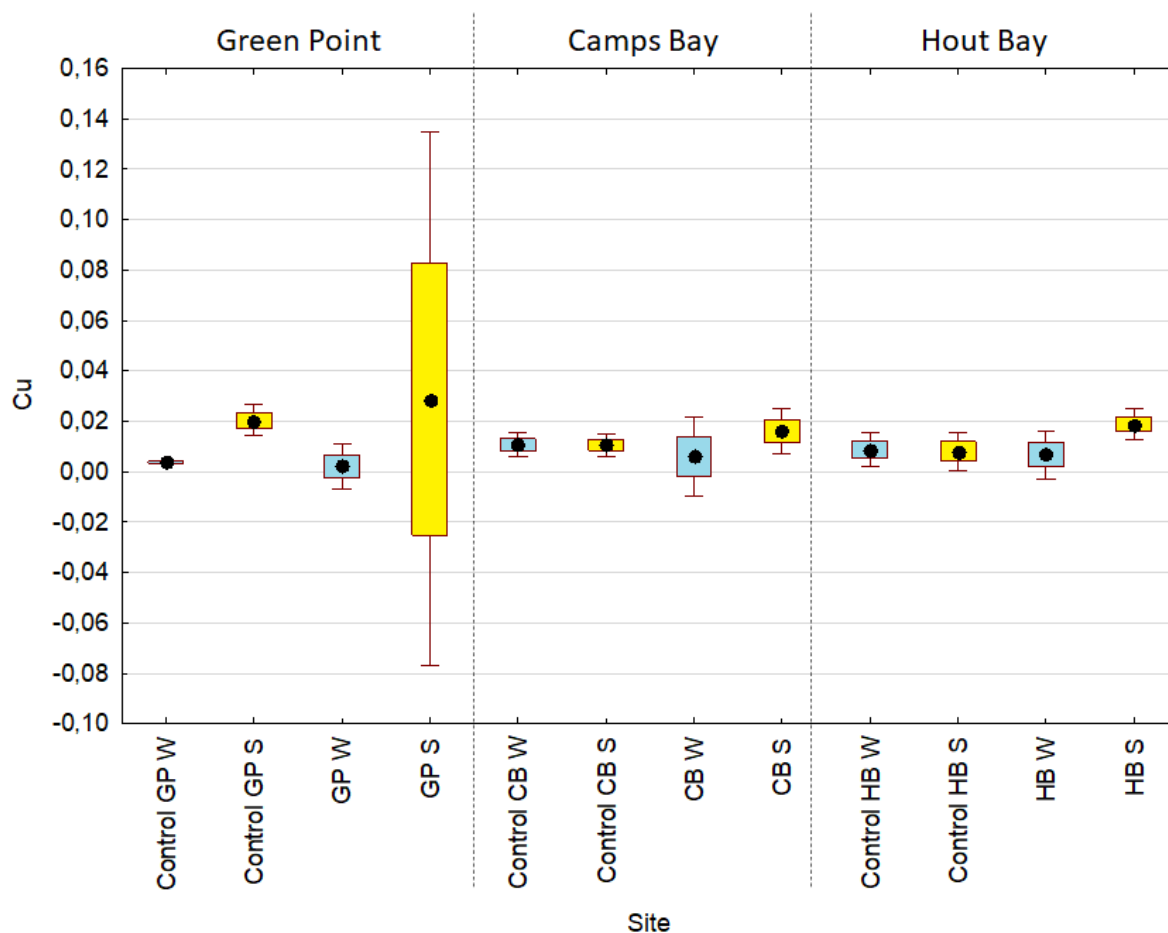


Figure 3-4. Mean change (mg/kg) in levels of Copper (Cu) content for mussels deployed in Winter 2020 (W; blue) and Summer 2021 (S; yellow) at sites surrounding the deep-water outfalls at Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

3.3.1.3 Zinc (Zn)

There was no significant difference between impact and control stations in Winter and Summer (Kruskal-Wallis, $P < 0.05$). Concentrations of Zinc were higher in summer with a smaller mean change (loss) in concentration (Figure 3-5 and Figure 3-6). The average negative change in Zinc concentrations across all sites were greatest at control sites in Camps Bay during winter, while average levels were greatest (smallest losses) at Camps Bay control station during summer (Figure 3-5 and Figure 3-6).

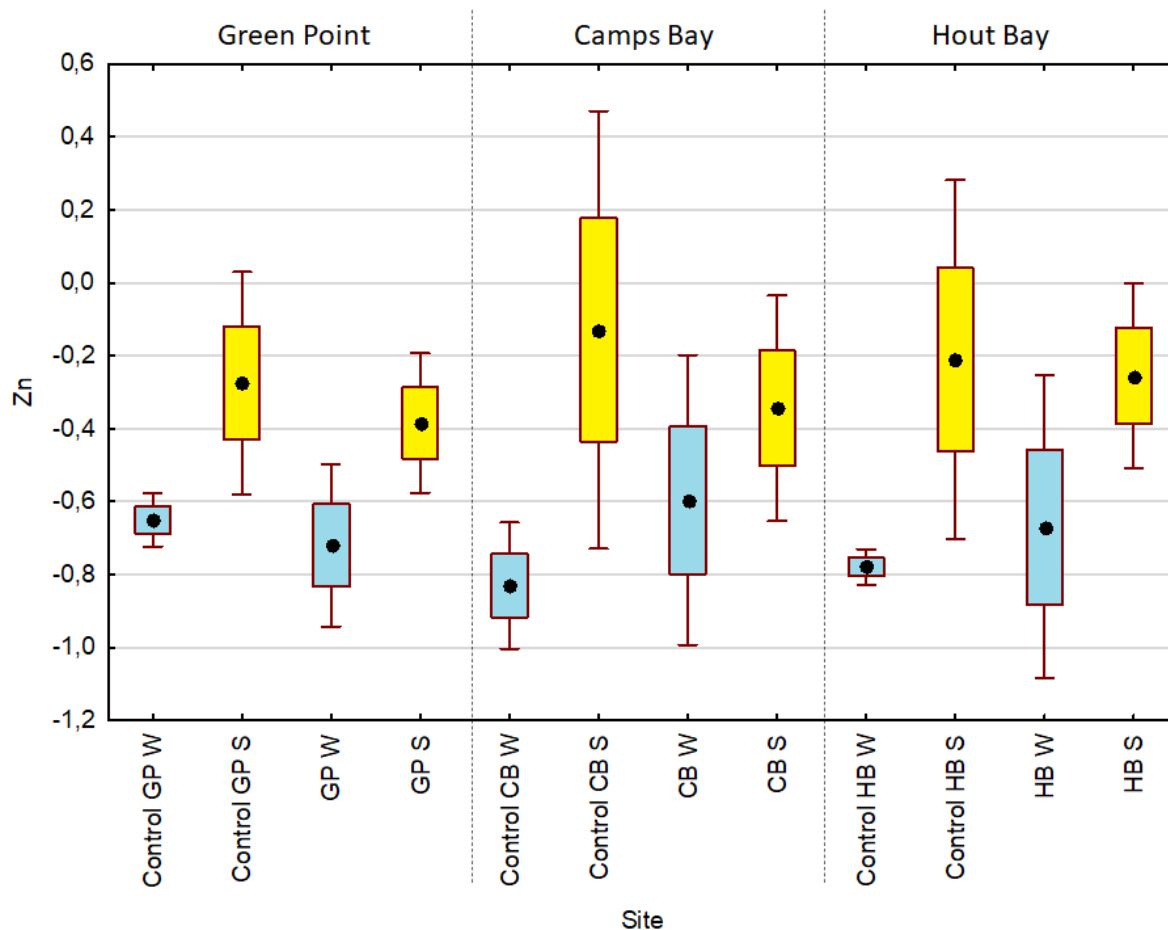


Figure 3-5 Mean change in levels of Zinc (Zn) content for mussels deployed in Winter 2020 (W; blue) and Summer 2021(S; yellow) at sites surrounding the deep-water outfalls at Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield (Figure 3-6). Additionally, Zn was observed to have the highest concentration (and average loss) in mussels compared to the other two metals in the winter season. The latter was also reported in Bezuidenhout *et al.* 2015, where Zn had the highest accumulation in mussels (after Fe) compared to the other trace metals tested. Furthermore, Eisler (1981) reports that molluscs preferably accumulate Zn, which explains the high concentrations of Zn recorded in mussels in the present study.

Various other monitoring studies have shown notably higher concentrations of trace metals (particularly Cu and Zn) in the mussel *M. galloprovincialis* compared to the present study (Fatoki 2012; Bezuidenhout *et al.* 2015; Sparks et al 2018, Firth 2019). Firth (2019) observed no significant seasonal patterns in the concentration of these trace metals for *M. galloprovincialis*; which contradicts the results of this study in which there were clear seasonal differences. However, Bezuidenhout *et al.* (2015) and Sparks et al (2018) documented distinct seasonal differences, whereby trace metal accumulation in mussels was greater in winter compared to summer, which support the findings of the 2019-2020 study, but not the 2020-2021 study when there were, on average significantly greater losses of nickel and zinc during the 2020 winter deployment than the 2021 Summer deployment. Interestingly, Bezuidenhout *et al.* (2015) reports that several factors (particularly the reproductive cycle) can influence the rate of metal accumulation in mussels. The study suggested that the observed

seasonal dynamics of trace metal concentrations could be a result of the spawning that takes place in summer; with the subsequent large release of gametes (Van Erkom Schurink and Griffiths 1991); effectively eliminating any trace metal accumulation in the gametes from the mussel's bodies (Bezuidenhout *et al.* 2015). The latter is supported by the Van Erkom Schurink and Griffiths (1991) study; whereby the reproductive cycle and output in four southern African mussel species were compared; and *M. galloprovincialis* had the greatest gonad material accumulation (weight increase of 3-fold over spawned condition) and release within a single spawn cycle. Summer spawning activity could explain the greater levels of nickel and zinc loss and smaller copper gain during the 2020 Summer deployment when compared to 2019 winter deployment but offers little insight into the contradictory results obtained during the Winter 2020 and Summer 2021 deployments. It is, however, possible that the extended Winter 2020 deployment due to COVID restrictions resulted in mussels spawning towards the end of the deployment period (October 2020) and thereby losing a greater amount of trace metals from their tissues.

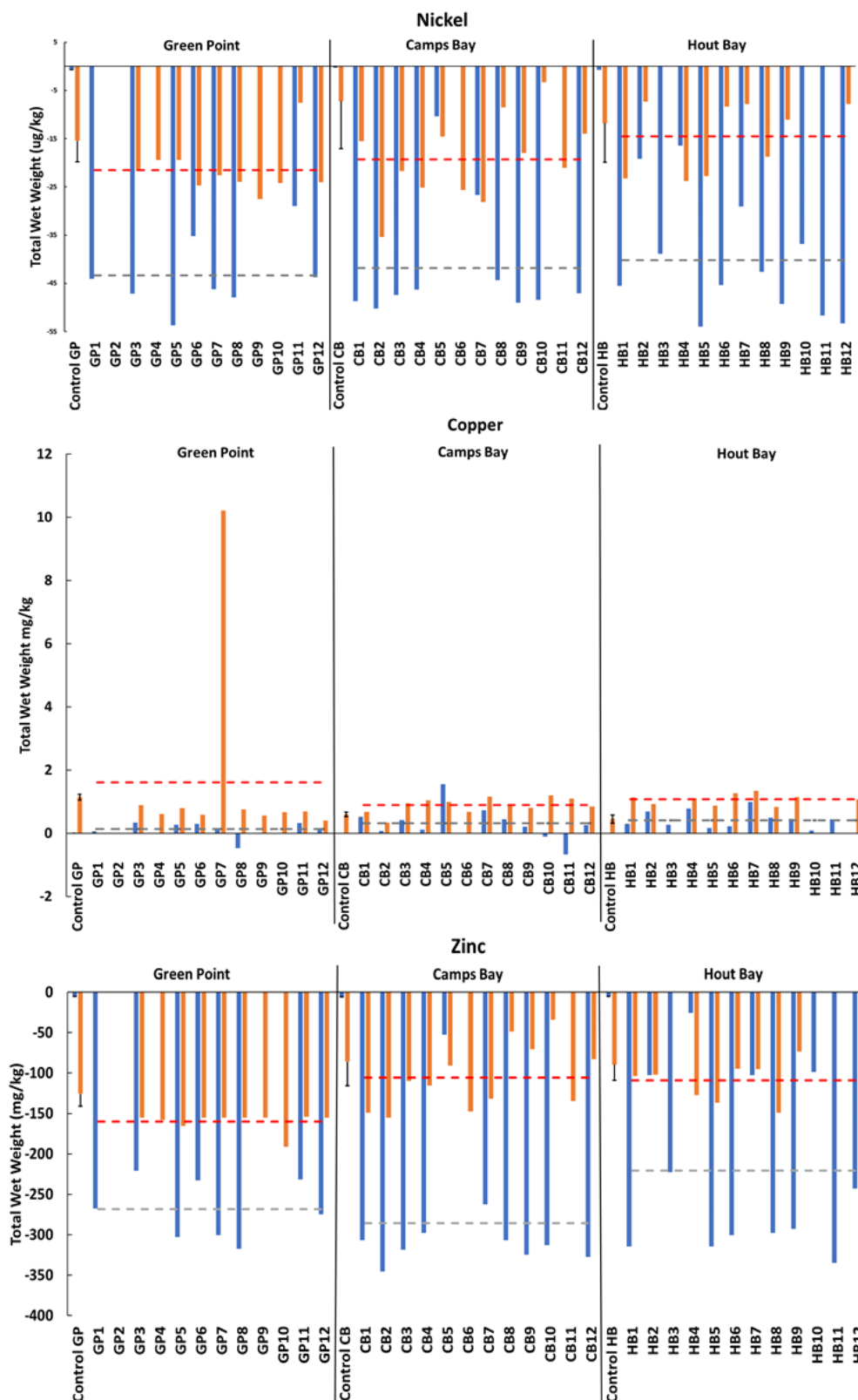


Figure 3-6 Total change in levels of trace metal content for the full deployment period in Winter 2020 (58-76 days) and Summer 2021 (56 days) at sites surrounding the deep-water outfalls at Green Point, Camps Bay and Hout Bay, and at the control locations at Sea point, Oudekraal and Kabonkelberg relative to baseline (pre-deployment) levels. Stations are arranged at increasing distances from the outfalls in each case (distance from the outfall increases moving to the right). The dotted grey (Winter 2020) and red (Summer 2021) line indicates the average change across all stations at each site.

4 CONCLUSIONS

There were clear seasonal differences in the growth rate of mussels used in the two monitoring experiments, with lower average growth rates at all sites recorded during the summer deployment. This is attributed to both lower particulate organic matter and temperature of upwelled water which is more prevalent off the Cape Peninsula during the spring and summer period than winter. Seasonal spawning of mussels in summer and the resultant allocation of energy to reproduction rather than growth is also probably a cause of the observed seasonal growth differences. Growth rates during both seasons appear to be slightly higher at monitoring stations located around the Hout Bay and Camps Bay outfalls than those at control stations located further afield (this was not the case at Green Point where control and monitoring stations had similar growth rates). It is thought that the higher growth rates at the diffusers compared to the controls, are a function of higher levels of organic matter and increased nutrient loading present in the water column in the immediate vicinity of the outfalls.

Trace metal accumulation in mussels also showed clear seasonal trends. There was no evidence of seasonal differences in copper accumulation during the winter 2020 and summer 2021 deployments, but mussels did lose nickel and zinc at a greater rate during the winter deployment. This may be a result of the extended deployment time and a spawning event having taken place during the winter deployment. Mussels at all locations accumulated Cu relative to baseline concentration during both the 2020 winter and 2021 summer deployment. There is no evidence to suggest that the rate of metal bioaccumulation was higher at stations close to the outfalls relative to those further afield. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for “unimpacted” sites.

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6 APPENDICES

Table 6.1 Winter season 2, September to October 2020, *Mytilus galloprovincialis* growth rate raw data. September data is at the start of the 6 week period, pre-deployment, and October data is at the end of the 6 week period, post-deployment.

Date	Sites	Replicates																				Mean Length (mm)	6 Week Growth Rate (mm)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
21-Jul-20	GP1	44	50	45	49	43	49	41	48	45	48	46	43	44	49	41	40	42	43	45	50	45,25	
21-Jul-20	GP2	46	45	50	45	42	43	49	42	44	49	45	43	50	42	41	49	43	50	48	44	45,5	
21-Jul-20	GP3	45	43	46	44	47	49	48	47	46	47	47	49	42	41	42	48	49	43	46	46	45,75	
21-Jul-20	GP4	49	40	41	46	49	50	46	42	45	45	43	43	46	43	48	47	48	46	42	42	45,05	
21-Jul-20	GP5	43	42	42	40	45	43	41	43	42	46	47	47	43	46	47	43	41	41	43	47	43,6	
21-Jul-20	GP6	45	46	44	47	45	45	46	42	50	42	46	45	49	43	43	45	49	41	50	46	45,45	
21-Jul-20	GP7	40	48	44	47	40	48	45	40	41	41	45	41	45	48	42	41	46	45	45	41	43,65	
21-Jul-20	GP8	47	45	49	49	42	49	49	47	45	42	46	43	42	46	45	43	46	49	41	41	45,3	
21-Jul-20	GP9	44	47	45	50	45	40	42	40	42	43	43	45	45	44	45	45	46	42	42	42	43,85	
21-Jul-20	GP10	44	47	41	45	47	42	43	45	50	43	50	42	42	46	47	46	45	43	45	43	44,8	
21-Jul-20	GP11	42	45	49	41	44	44	46	41	46	50	49	44	44	50	46	48	50	45	45	40	45,45	
21-Jul-20	GP12	47	50	50	42	44	42	45	42	44	49	47	40	42	40	50	43	46	46	46	42	44,85	
21-Jul-20	CB1	46	47	48	43	40	50	44	46	45	44	48	46	45	49	50	41	43	44	44	41	45,2	
21-Jul-20	CB2	45	41	45	43	47	41	45	48	42	47	47	41	41	46	50	49	42	48	40	40	44,4	
21-Jul-20	CB3	47	49	42	47	50	49	46	42	41	49	45	47	45	44	44	42	48	43	43	43	45,3	
21-Jul-20	CB4	49	49	40	45	40	45	47	50	50	49	41	42	40	41	42	47	45	45	43	41	44,55	
21-Jul-20	CB5	50	40	46	42	46	49	47	46	50	41	40	40	49	46	41	44	45	45	50	44	45,05	
21-Jul-20	CB6	48	42	43	47	49	40	41	41	48	50	48	48	40	44	47	50	49	48	41	50	45,7	

Date	Sites	Replicates																				Mean Length (mm)	6 Week Growth Rate (mm)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
21-Jul-20	CB7	49	50	40	43	44	42	49	41	45	50	49	42	46	49	49	49	41	43	40	45	45,3	
21-Jul-20	CB8	50	45	43	42	42	42	48	47	41	49	46	43	46	43	44	45	43	48	40	45	44,6	
21-Jul-20	CB9	49	44	40	47	41	45	40	45	45	45	45	42	43	46	40	44	40	42	43	41	43,35	
21-Jul-20	CB10	47	41	43	42	50	41	45	50	49	49	47	43	50	41	49	42	42	47	43	45	45,3	
21-Jul-20	CB11	42	46	49	49	50	49	40	44	42	45	44	45	43	49	43	46	49	49	41	43	45,4	
21-Jul-20	CB12	49	48	45	45	47	45	44	47	42	45	49	45	49	46	40	48	42	50	42	42	45,5	
22-Jul-20	HB1	50	50	50	50	48	49	49	46	42	48	49	50	46	43	42	42	44	44	42	47	46,55	
22-Jul-20	HB2	50	50	41	45	41	42	43	44	50	44	49	40	41	44	42	49	49	41	47	46	44,9	
22-Jul-20	HB3	44	43	45	41	43	43	44	43	45	49	50	48	41	49	44	40	45	43	43	41	44,2	
22-Jul-20	HB4	50	50	50	50	44	50	40	44	50	41	40	46	47	46	44	41	44	45	41	42	45,25	
22-Jul-20	HB5	47	44	45	41	49	47	46	50	41	41	49	42	50	42	40	50	40	42	40	40	44,3	
22-Jul-20	HB6	47	44	44	40	43	47	42	42	43	49	49	44	50	44	41	45	49	42	42	43	44,5	
22-Jul-20	HB7	50	45	50	42	46	42	44	43	45	45	45	48	43	44	48	43	42	40	42	47	44,7	
22-Jul-20	HB8	49	47	47	42	47	40	41	40	40	42	49	44	42	48	47	42	41	49	47	47	44,55	
22-Jul-20	HB9	47	47	47	50	49	48	49	42	43	46	49	41	48	45	44	43	50	47	46	47	46,4	
22-Jul-20	HB10	50	48	44	43	42	43	45	45	43	45	49	47	40	49	40	49	49	42	45	47	45,25	
22-Jul-20	HB11	44	45	48	40	41	45	49	45	43	43	45	47	48	45	42	43	43	47	49	46	44,9	
22-Jul-20	HB12	42	41	41	42	42	49	42	42	44	44	41	50	50	46	50	42	50	47	46	45	44,8	
22-Jul-20	C1a	43	40	45	45	45	47	48	45	44	48	45	40	43	48	49	43	42	48	50	49	45,35	
22-Jul-20	C1b	50	47	49	47	48	48	43	42	41	46	44	47	46	50	48	50	48	45	45	46	46,5	
22-Jul-20	C1c	44	42	42	45	46	43	41	43	42	45	44	45	45	50	42	47	45	41	43	41	43,8	
22-Jul-20	C2a	46	49	45	50	40	45	43	46	43	50	45	40	46	44	49	45	48	46	49	44	45,65	
22-Jul-20	C2b	47	43	44	43	45	43	44	43	47	43	45	44	42	41	46	49	50	49	49	48	45,25	

Date	Sites	Replicates																				Mean Length (mm)	6 Week Growth Rate (mm)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
22-Jul-20	C2c	45	44	50	50	45	45	45	45	46	41	49	49	41	42	46	45	44	45	48	43	46,05	
22-Jul-20	C3a	50	45	49	45	42	45	47	45	41	45	45	49	40	49	50	48	49	47	46	44	45,6	
22-Jul-20	C3b	47	47	49	47	47	43	42	42	43	43	49	45	49	49	49	44	41	46	45	45	45,3	
22-Jul-20	C3c	50	48	49	47	47	45	49	40	42	44	49	44	44	41	42	42	46	43	45	49	45,25	
21-Jul-20	C3a	50	45	49	45	42	45	47	45	41	45	45	49	40	49	50	48	49	47	46	44	45,5	
21-Jul-20	C3b	47	47	49	47	47	43	42	42	43	43	49	45	49	49	49	44	41	46	45	45	46,05	
Collection																							
17-Sep-20	GP1e	47	48	50	52	52	53	54	50	52	52	47	51	48	46	53	54	45	44	52	55	50,25	0,09
17-Sep-20	GP3e	57	50,5	49	55	47	53	52	48	52	51	52,5	53	51	54	50	49	48	44	52	55	51,15	0,09
05-Oct-20	GP5e	56	52	56	51	58	48	55	54	54	50	48	58	50	52	52	50	51	49	50	52	52,30	0,11
17-Sep-20	GP6e	49	47	48	46	52	54	47	50	52	46	50	57	46	45	52	49	54	56	53	57	50,50	0,09
17-Sep-20	GP7e	54	52	50	48	49	50	50	48	42	50	44	48	52	54	52	48	54	46	48	44	49,43	0,10
17-Sep-20	GP8e	55	56,5	46	47	50	52	49	54	52	58	52	49	50	56	46	48,5	54	52	46		51,21	0,10
17-Sep-20	GP11e	52	54	48	52	48	55	48	52	56	54	46	54	49	52	48	49	50	47	44		50,42	0,09
17-Sep-20	GP12e	52	42	53	48	52	55	47	52	47	49	55	54	52	47	49	45	54	55	48	55	50,55	0,10
05-Oct-20	CB1e	42	44	45	56	59	54	51	49	55	57	45	52	46	52	49	55	54	52	51	54	51,10	0,08
17-Sep-20	CB2e	51	42	52	54	50	52	54	49	54	57	46	49	50	46	55	48	47	46			50,11	0,10
05-Oct-20	CB3e	50	59	52	45	48	54	51	46	55	52	49	52	57	53	53	46	47	53	45	45	50,60	0,07
05-Oct-20	CB4e	53	55	53	58	48	50	51	49	52	55	56	49	41	54	55	50	49	48	46	45	50,85	0,08
17-Sep-20	CB5e	50	52	48	52	47	44	42	46	45	44	45	54	48	50	44	50	52	54	47	40	47,70	0,05
05-Oct-20	CB7e	55	60	42	49	47	52	53	53	50	53	46	46	49	55	52	55	54	44	43		50,42	0,07
05-Oct-20	CB8e	48	48	47	54	50	56	48	50	44	53	50	52	51	50	51	53	52	45	54	43	49,95	0,07
05-Oct-20	CB9e	52	50	50	53	53	50	51	53	54	53	47	54	49	45	49	44	45	43	44	44	49,15	0,08

Date	Sites	Replicates																				Mean Length (mm)	6 Week Growth Rate (mm)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
17-Sep-20	CB10e	58	50	46	47	53	45	44	53	45	48	54	50	47	55	54	52	45	44	43		49,11	0,07
05-Oct-20	CB12e	54	53	56	64	55	56	58	51	52	53	48	47	50	49	56	50	49	56	51	48	52,80	0,10
18-Sep-20	HB1e	52	51	53	52	46	45	52	49	44	54	49	48	46	54	48	53	52	53	53	52	50,30	0,06
18-Sep-20	HB2e	48	54	52	50	49	50	55	52	46	54	53	54	50	45	52	46	48	50	42	52	50,10	0,09
18-Sep-20	HB3e	49	45	44	55	52	44	49	48	42	41	52	44	50	50	49	48	45	54	52	46	47,95	0,06
18-Sep-20	HB4e	53	52	51	44	54	58	47	56	46	48	57	56	44	43	46	50	52	46			50,17	0,08
18-Sep-20	HB5e	44,5	48	48,5	55,5	56,5	55,5	44,5	55	45	53,5	52	49	46	52	54	52,5	50	49	56		50,89	0,11
18-Sep-20	HB6e	52	49	51	53	47	51,5	52	49	55	56	51	53,5	54	46,5	56	50	45	51	54	50	51,33	0,11
18-Sep-20	HB7e	53	52	49	52	54	55	50	48,5	49	53	50	52	54	52	46	56	50	52	53		51,61	0,12
18-Sep-20	HB8e	50	49	52	52,5	52,5	49	45	51	46	46	56	51	50	42,5	51	53	49	54	54	48	50,08	0,09
18-Sep-20	HB9e	47	51	55	48,5	49	49	49,5	48	47,5	53	50	48,5	50,5	50	49	50	51	54	43		49,66	0,05
18-Sep-20	HB10e	54	52	52	45	44	46	48	46	52	50	52	48	54	44	54	49	52	52	44	48	49,30	0,07
18-Sep-20	HB11e	48	44	48	50	52	45	50	52	47	50	46	44	48	47	44	54	46	52	50	45	48,10	0,05
18-Sep-20	HB12e	46	52	51	46	45	51,5	52	52	51	46	47	45	54	50	46	50	46	57	59		49,82	0,08
18-Sep-20	C1ae HB	47	48	44	48	42	45	48	44	48	47	52	47	45	43	47	50	48	45	46		46,53	0,02
18-Sep-20	C1be HB	47	49	45	47	50	52	50	45	44	48	52	52	54	52	48	47	52	44	48	46	48,60	0,04
18-Sep-20	C1ce HB	47	54	52	45	47	50	49	48	45	40	48	46	45	54	48	45					47,69	0,06
17-Sep-20	C2ae CB	52	46	48	44	44	42	47	49	53	50	46	48	46	50	49	54	52	44	54	48	48,30	0,05
17-Sep-20	C2be CB	50	54	54	42	48	48	50	47	53	54	47	47	45	44	44	50	54	45	48	47	48,55	0,06
17-Sep-20	C2ce CB	49	52	47	48	49	47	43	45	47	52	55										48,55	0,05
05-Oct-20	C3a GP	63	55	55	51	49	60	50	53	57	54	55	58	55	50	54	53	53	59	56		54,74	0,11
05-Oct-20	C3b GP	51	57	52	53	54	48	58	48	55	52	51	52	47	53	52	50	58	48	51	57	52,35	0,09
05-Oct-20	C3c GP	58	57	55	60	55	51	52	47	55	52	51	58	50	49	51	51	46	55	40	48	52,05	0,09

Table 6.2 Summer season 2, February to April 2021, *Mytilus galloprovincialis* growth rate raw data. February data is at the start of the 8 week period, pre-deployment, and April data is at the end of the 8 week period, post-deployment.

Date	Sites	Replicates																				Mean Length (mm)	Growth Rate (mm/day)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
16-Feb-21	GP1	45	46	42	44	41	48	42	42	43	40	40	42	43	41	48	40	42	45	40	45	42,95	
16-Feb-21	GP2	43	47	41	41	40	41	46	43	44	42	45	43	46	42	46	42	49	44	42	47	43,7	
16-Feb-21	GP3	46	47	40	45	41	40	41	41	41	41	43	44	44	44	46	44	50	46	40	50	43,7	
16-Feb-21	GP4	50	49	43	46	44	47	47	40	41	42	41	40	44	41	40	42	48	48	41	41	43,75	
16-Feb-21	GP5	46	48	42	44	43	45	41	47	41	40	49	41	39	42	42	44	45	41	43	40	43,15	
16-Feb-21	GP6	42	42	40	45	43	41	42	40	43	41	40	44	41	48	45	43	42	43	42	40	42,35	
16-Feb-21	GP7	44	49	45	41	41	40	42	43	40	41	47	40	45	41	47	41	42	40	42	40	42,55	
16-Feb-21	GP8	45	44	41	44	40	44	45	44	40	45	42	40	43	45	43	43	44	47	42	41	43,1	
16-Feb-21	GP9	49	41	41	49	47	42	45	42	44	46	44	47	41	40	45	48	45	47	40	44	44,35	
16-Feb-21	GP10	50	41	46	42	40	41	43	43	43	43	42	41	41	43	44	42	47	38	42	42	42,7	
16-Feb-21	GP11	46	45	45	44	43	48	43	45	41	44	43	40	41	49	44	45	44	42	44	43	43,95	
16-Feb-21	GP12	42	42	42	41	50	43	44	40	42	45	44	42	45	48	47	44	45	40	41	42	43,45	
16-Feb-21	CB1	50	45	44	40	42	40	40	44	41	43	40	44	44	45	40	41	45	40	43	41	42,95	
16-Feb-21	CB2	40	40	42	46	40	42	43	42	43	42	42	44	43	44	47	42	40	41	42	45	43,7	
16-Feb-21	CB3	44	43	47	42	45	46	41	42	44	43	44	50	42	42	48	46	48	43	46	45	43,7	
16-Feb-21	CB4	47	40	44	43	40	41	47	46	43	42	47	40	46	44	44	42	45	43	43	43	43,75	
16-Feb-21	CB5	44	42	49	40	41	44	48	42	42	42	49	42	41	44	48	43	42	40	41	47	43,15	
16-Feb-21	CB6	45	44	41	47	49	48	47	44	48	42	43	41	41	41	49	41	43	43	49	48	42,35	
16-Feb-21	CB7	41	44	40	42	43	49	42	45	44	40	40	40	46	43	41	41	44	40	42	44	42,55	
16-Feb-21	CB8	44	45	40	45	40	40	44	43	44	45	42	45	42	46	41	40	40	44	45	43	42,9	
16-Feb-21	CB9	41	49	44	41	41	42	40	41	40	46	41	45	41	43	48	44	44	48	46	43	43,4	

Date	Sites	Replicates																				Mean Length (mm)	Growth Rate (mm/day)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
17-Feb-21	C3b	49	43	46	46	40	47	41	44	42	41	45	42	44	45	41	46	44	41	43	45	43,75	
17-Feb-21	C3c	42	40	46	42	42	45	48	49	44	45	49	43	43	45	43	43	41	45	41	50	44,3	
Collection																							
12-Apr-21	GP1e	40	48	41	42	49	47	46	52	44	40	46	42	47	44	42	48	48	50	43	43	45,1	0,03
12-Apr-21	GP3e	50	55	49	44	43	50	42	44	47	43	42	46	44	40	42	43	48	41	47	45	45	0,02
12-Apr-21	GP5e	49	43	46	44	50	41	48	44	44	40	44	43	45	50	44	50	48	41	45	47	45,30	0,04
12-Apr-21	GP6e	43	48	46	44	42	40	42	47	49	43	45	44	43	42	50	40	45	43	42	42	44,00	0,03
12-Apr-21	GP7e	42	45	45	42	42	47	44	46	42	43	42	48	52	45	44	40	44	45	46	44	44,40	0,03
12-Apr-21	GP8e	48	42	44	42	45	45	45	47	44	42	49	44	44	47	46	48	43	44	45	43	44,85	0,03
12-Apr-21	GP11e	45	50	45	50	42	50	46	53	48	45	47	49	45	42	45	47	43	45	47		46,53	0,04
12-Apr-21	GP12e	48	44	52	45	44	46	40	42	40	50	48	40	43	42	43	45	42	42			44,35	0,02
12-Apr-21	CB1e	48	42	42	43	44	40	40	45	43	46	45	45	44	40	40	42	45	42	42		43,05	0,01
12-Apr-21	CB2e	48	42	43	40	42	47	40	40	42	42	42	42	45	40	42	42	40				42,29	0,00
12-Apr-21	CB3e	45	42	44	43	47	45	44	43	52	49	48	45	42	49	49	44	45	47	49	45	45,85	0,02
12-Apr-21	CB4e	50	43	47	44	47	50	43	44	45	44	40	42	45	46	48	44	43	45	43		44,89	0,02
12-Apr-21	CB5e	47	50	42	46	49	44	43	45	42	44	43	42	44	45	46	49	48	44	40	40	44,65	0,02
12-Apr-21	CB7e	50	46	44	48	42	46	52	40	50	42	40	44	51	50	52	44	44	43			46,00	0,02
12-Apr-21	CB8e	46	44	49	43	50	42	44	43	45	46	44	40	41	40	40	44	43	40	44	40	43,40	0,02
12-Apr-21	CB9e	42	44	45	40	42	44	45	46	44	47	42	40	40	50	40	45	40	46	48		43,68	0,01
12-Apr-21	CB10e	47	48	44	42	46	46	43	44	44	48	41	48	51	46	44	42	40	45	40	40	44,45	0,02
12-Apr-21	CB12e	40	49	46	45	50	48	47	47	48	42	49	42	40	46	46	52	40	45	42	46	45,5	0,00
13-Apr-21	HB1e	49	45	46	52	46	44	48	45	42	50	45	52	55	48	44	46	49	42	47	48	47,15	0,05
13-Apr-21	HB2e	48	45	47	43	45	45	48	51	43	45	45	42	48	43	45	40	45	47	44	45	45,20	0,01

Date	Sites	Replicates																				Mean Length (mm)	Growth Rate (mm/day)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
13-Apr-21	HB3e	48	49	44	46	50	51	46	40	48	47	48	49	44	44	48	46	40	44	43	45	46,00	0,02
13-Apr-21	HB4e	50	44	50	42	47	49	48	44	44	48	49	48	42	50	46	45	48	44	42		46,32	0,03
13-Apr-21	HB5e	52	52	47	48	50	52	50	52	45	48	48	49	48	42	52	47	45	46	49	42	48,20	0,07
13-Apr-21	HB6e	44	42	40	46	45	47	54	51	47	53	50	49	46	42	42	40	44	45	47	55	46,45	0,04
13-Apr-21	HB7e	53	44	52	42	46	42	44	47	46	48	49	44	46	50	46	49	45	44	46		46,47	0,04
13-Apr-21	HB8e	44	50	44	47	46	45	45	48	40	42	40	44	45	40	44	47	46	49	42		44,63	0,01
13-Apr-21	HB9e	48	49	44	46	50	51	46	40	48	47	48	49	44	44	48	46	40	44	43	45	46,00	0,02
13-Apr-21	HB12e	47	46	52	43	50	45	47	46	48	50	42	45	45	40	48	47	52	40	43	40	45,80	0,03
13-Apr-21	C1ae HB	42	48	42	40	42	47	45	48	42	45	45	40	43	40	44	45	44	49	48	45	44,20	0,01
13-Apr-21	C1be HB	50	42	48	46	47	45	44	42	42	44	42	44	43	44	43	49	48	45	46		44,95	0,02
13-Apr-21	C1ce HB	45	51	46	49	44	40	50	48	47	50	42	46	43	42	40	43	48	42	45	42	45,15	0,02
13-Apr-21	C2ae CB	48	47	42	43	46	45	48	42	46	42	42	49	44	42	45	44	43	44	46	44	44,60	0,01
13-Apr-21	C2be CB	46	47	42	44	45	44	45	46	43	42	47	45	46	45	42	40	41	44	42	45	44,05	0,00
13-Apr-21	C2ce CB	47	46	44	42	46	50	44	50	44	43	44	49	45	48	46	42	40	42	45		45,11	0,01
12-Apr-21	C3a GP	49	52	49	46	45	46	47	45	40	42	43	47	40	40	45	42	42	40	44	40	44,20	0,02
12-Apr-21	C3b GP	43	45	48	44	42	45	48	50	50	45	43	49	45	40	45	44	47	50	50		45,95	0,02
12-Apr-21	C3c GP	45	46	48	45	48	44	48	43	44	50	42	41	45	46	46	43	42	50	44		45,26	0,03
12-Apr-21	C3d GP	42	48	46	47	49	41	43	40	45	43	45	44	48	42	42	40	40	44	48	50	44,35	0,02

Table 6.3 *Mytilus galloprovincialis* trace metal test results for Cu, Ni, and Zn at Camp's Bay, Hout Bay, and Green Point (Table Bay). Results from Winter 2, September 2020 to October 2020 are presented below. Three baseline samples were included in lieu of lost samples and in order to capture a more robust, mean baseline value for each trace metal. (GP = Green Point, CB = Camps Bay, HB = Hout Bay, C = Control).

	Zn Total Wet Weight (mg/kg)	Cu Total Wet Weight (mg/kg)	Ni Total Wet Weight (µg/kg)
South African Standard	No SA Standard	No SA Standard	No SA Standard
International Standard	150-1000	70	50 (mg/kg)
Baseline	68,66	0,67	0,40
GP1	24,6	0,72	0,135
GP3	21,56	1,008	0,182
GP5	14,96	0,935	<0.1
GP6	33,49	0,969	0,17
GP7	22,44	0,816	0,102
GP8	20,74	0,816	0,085
GP11	39,71	0,988	0,171
GP12	24,96	0,784	0,128
CB1	20	1,168	0,096
CB2	18,43	0,741	0,057
CB3	21,28	1,078	0,084
CB4	22,35	0,78	0,105
CB5	58,25	2,225	0,35
CB7	42	1,4	0,14
CB8	24,32	1,104	0,096
CB9	19,63	0,871	0,078
CB10	20,25	0,555	0,09
CB12	21,6	0,93	0,075
HB1	23,1	0,946	0,088
HB2	49,5	1,35	0,3
HB3	29,8	0,94	0,18
HB4	52,2	1,45	0,377
HB5	14,74	0,836	0,088
HB6	23,29	0,884	0,102
HB7	39,6	1,65	0,3
HB8	26,04	1,155	0,105
HB9	19,36	1,122	0,11
HB10	31,84	0,752	0,304
HB11	17	1,105	0,068
HB12	15,36	0,672	0,16
C1a HB			
C1b HB	21,12	1,184	0,08
C1c HB	21	1,395	0,12

C2a CB	18,15	1,275	0,12
C2b CB	17	1,156	0,085
C2c CB	26,39	1,43	0,104
C3a GP	20,32	0,976	0,064

Table 6.4 *Mytilus galloprovincialis* trace metal test results for Cu, Ni, and Zn at Camp's Bay, Hout Bay, and Green Point (Table Bay). Results from Summer 2, February 2021 to April 2021 are presented below. (GP = Green Point, CB = Camps Bay, HB = Hout Bay, C = Control).

	Zn Total Wet Weight (mg/kg)	Cu Total Wet Weight (mg/kg)	Ni Total Wet Weight (µg/kg)
South African Standard	No SA Standard	No SA Standard	No SA Standard
International Standard	150-1000	70	50 (mg/kg)
Baseline	47	0,448	0,2552
GP3	25,3	1,334	0,1
GP4	27,6	1,056	0,097152
GP5	27,6	1,242	0,089953
GP6	22,31	1,035	0,1
GP7	24,44	10,66	0,1
GP8	23,04	1,2	0,1
GP9	19,44	1,008	0,1
GP10	22,8	1,104	0,064488
GP11	39,42	1,134	0,101493
GP12	23	0,851	0,1
CB1	31,51	1,127	0,106421
CB2	11,6	0,78	0,1
CB3	25,3	1,403	0,145866
CB4	21,85	1,495	0,139909
CB5	32,4	1,44	0,164952
CB5	21,34	1,122	0,108218
CB7	18,86	1,61	0,123556
CB8	38,5	1,342	0,207064
CB9	29,04	1,254	0,1848
CB10	43,68	1,652	0,221228
CB12	25,92	1,536	0,121176
HB1	23,75	1,575	0,151825
HB2	39,69	1,377	0,153279
HB4	23,25	1,55	0,1285
HB5	24,25	1,325	0,1189
HB6	38,7	1,71	0,1608
HB7	39,2	1,792	0,160048
HB8	28,25	1,275	0,1065

HB9	35,96	1,595	0,1820185
HB12	39,2	1,512	0,155596
C1a HB	38,08	1,148	0,171276
C1b HB	47,6	0,76	0,19678
C1c HB	19,95	0,779	0,130169
C2a CB	21,63	1,113	0,112287
C2b CB	55,68	1,131	0,213643
C2c CB	42,02	0,902	0,183348
C3a GP	26,25	1,8	0,128475
C3b GP	32,64	1,56	0,144576
C3c GP	24	1,368	0,087048
C3d GP	43,42	1,638	0,159614



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