

MARINE OUTFALLS SEAWATER QUALITY MONITORING

Annual Report 03

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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 third and final year of monitoring (i.e., the third seasonal cycle). Winter (non-upwelling) sampling was conducted in August/September 2021 and summer (upwelling) sampling was conducted in March/April 2022. All data and findings from each of these monitoring periods have been presented to the CCT in respective data reports (LT 839 DTR_05_V2.0 and LT 839 DTR_06_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 third 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 third annual report are:

- to present and compare data collected in the winter (August-September 2021) monitoring period to those collected in the summer (March-April 2022) monitoring period,
- to check compliance of these data with relevant national water quality guidelines and highlight any outliers, and
- to provide an assessment of the potential effects of the outfalls on the local marine ecology in the receiving environment outside of the presumed zone of initial dilution (ZID).

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_05_V2.0 and LT 839 DTR_06_V1.0). A summary is provided in Table 2.1.

Table 2.1: Summary of the sampling approach and analyses conducted during the third 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	CLS SA 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 values 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 put forward 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.

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 (measurements)			172	350	308
Temperature (° C)	20 th		13.22	13.00	11.75
	80 th		14.11	14.09	13.99
Salinity (PSU)	20 th		34.78	34.81	34.76
	80 th		34.99	34.99	34.98
Turbidity (FNU)	80 th		0.45	0.41	0.81
pH	20 th		8.08	8.08	8.01
	80 th		8.18	8.16	8.11
Dissolved oxygen (mg/L)	20 th		8.11	7.81	6.46
n (laboratory analyses)			18	18	18
Total suspended solids (mg/L)	80 th		3	4	8
Orthophosphate (µg/L)	80 th		25	27	41
Ammonia (µg/L)	80 th		33.8	24.2	24.8
Summer					
n (measurements)			163	327	307
Temperature (° C)	20 th		11.70	10.30	9.80
	80 th		14.10	12.34	11.94
Salinity (PSU)	20 th		34.60	34.60	34.59
	80 th		34.71	34.69	34.64
Turbidity (FNU)	80 th		0.37	0.32	0.33
pH	20 th		7.43	7.43	7.35
	80 th		7.73	7.67	7.54
Dissolved oxygen (mg/L)	20 th		5.45	4.66	2.99
n (laboratory analyses)			18	18	18
Total suspended solids (mg/L)	80 th		3	3	4
Orthophosphate (µg/L)	80 th		49	63	67
Ammonia (µg/L)	80 th		14.1	24.0	20.0

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 2021) and summer (March-April 2022) 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, based on the 300 m recommendation for offshore discharges in Anchor 2015. 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.

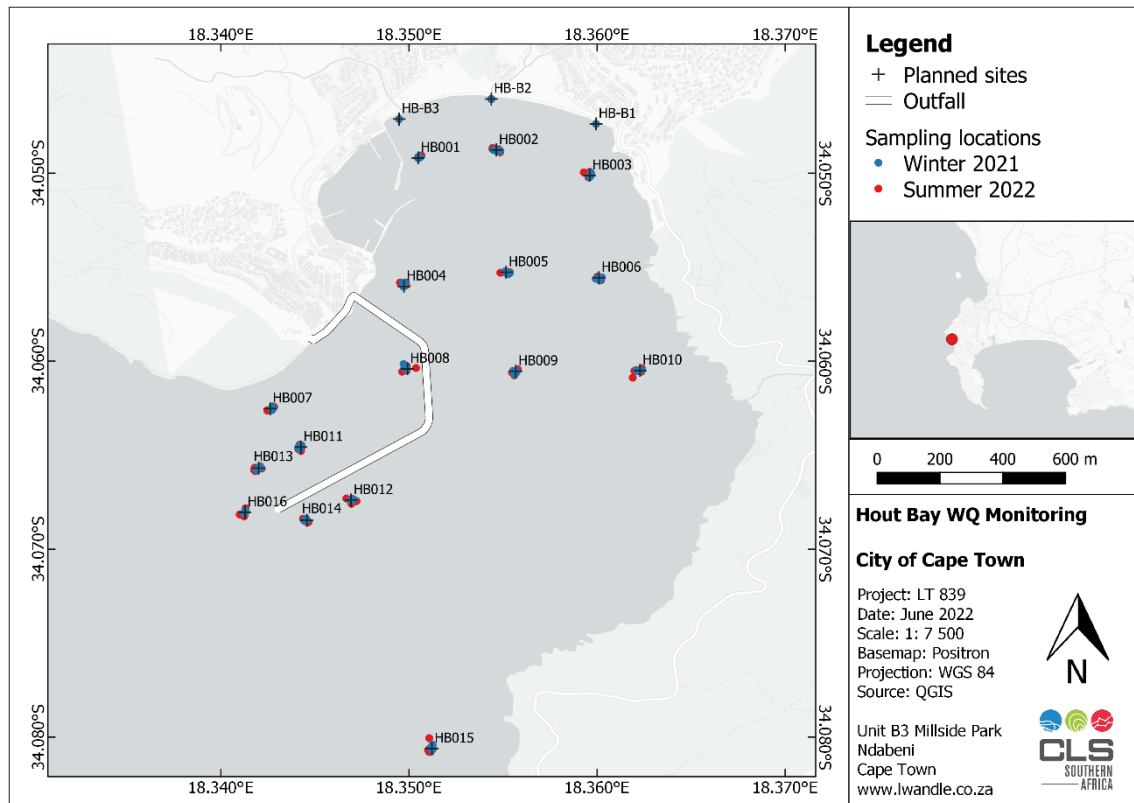


Figure 4.1: Map showing the Hout Bay outfall and the locations of nearshore and beach (HB-B1, HB-B2 and HB-B3) sites sampled during the winter (August-September 2021) and the summer (March-April 2022) monitoring periods.

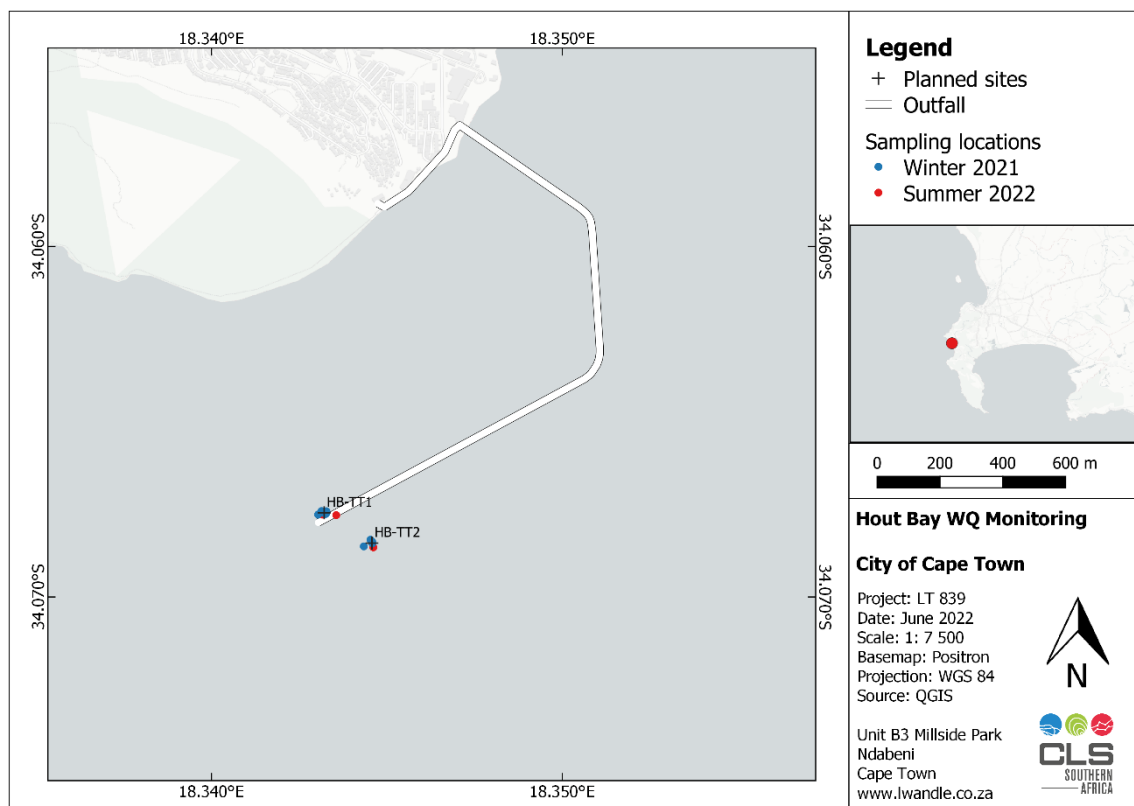


Figure 4.2: Map showing the Hout Bay outfall and the locations of the sites sampled for toxicity testing during the winter (August-September 2021) and the summer (March-April 2022) monitoring periods.

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 waters (Figure 4.3). In bottom and middle 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, which is characteristic of the seasonal upwelling in the region. Water column temperatures ranged between 8.38 and 14.21 °C in the winter survey and were between 9.41 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 a higher inter-week variation in comparison to the winter survey.

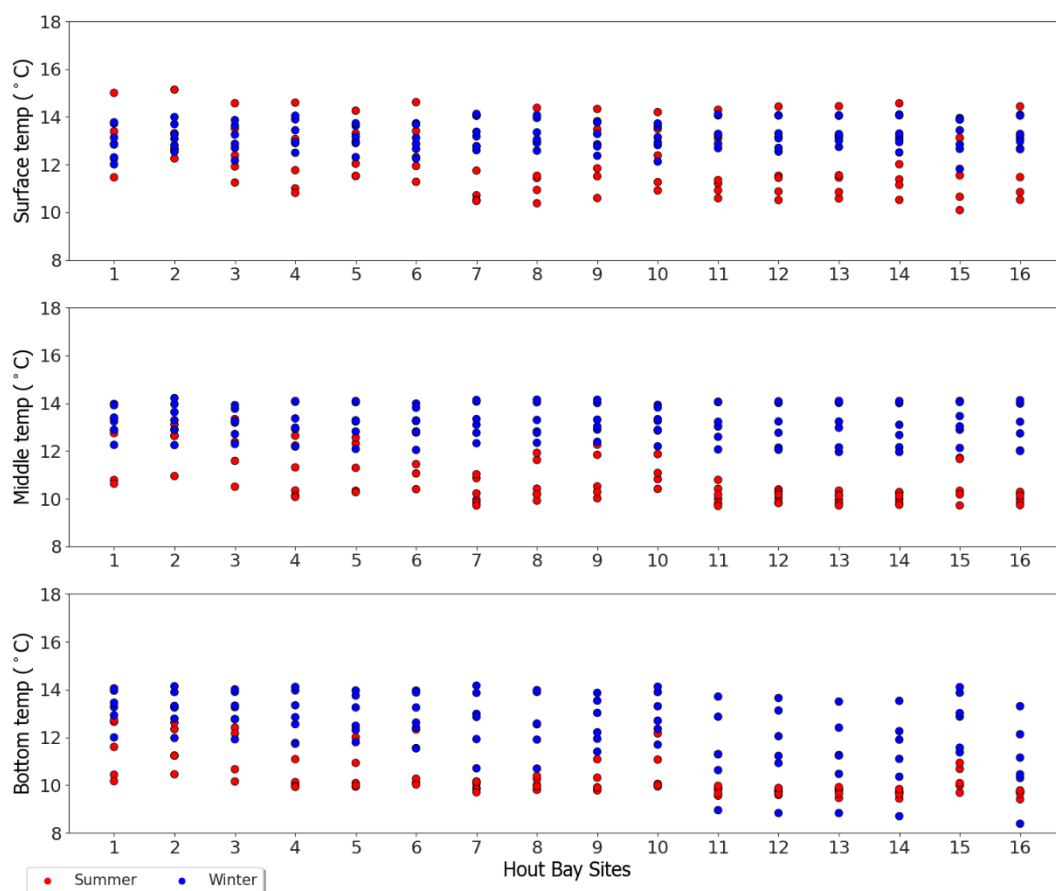


Figure 4.3 : Seasonal distribution of temperature (°C) measured at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys.

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	293	581	1113
Median	13.22	13.22	12.46
Mean	13.35	13.29	12.34
Summer			
n	287	592	1172
Median	11.18	11.19	9.83
Mean	11.61	10.58	9.88

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 33.19 and 35.25 PSU and 32.36 and 34.76 PSU in the winter and summer, respectively. The lowest salinity (32.36 PSU) was recorded in surface waters at site HB7 during summer. 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.

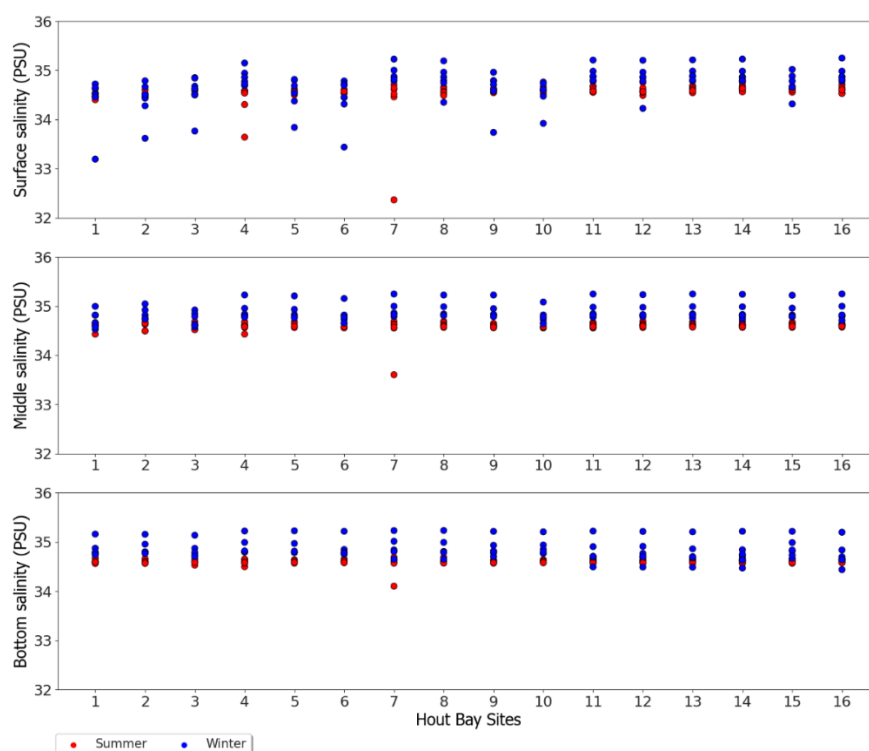


Figure 4.4: Seasonal distribution of salinity (PSU) measured at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys.

Apart from the Site 7 anomaly, 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	293	581	1113
Median	34.86	34.85	34.81
Mean	34.91	34.92	34.86
Summer			
n	287	592	1172
Median	34.61	34.61	34.61
Mean	34.62	34.62	34.62

4.3.3 Turbidity

Turbidity values ranged between 0.18 and 27.18 FNU and 0.16 and 31.92 FNU in the winter and summer surveys, respectively. The three highest turbidity values were recorded in surface waters, however the most prolonged higher turbidity is seen in the bottom water during both summer and winter with values regularly above 2 FNU.

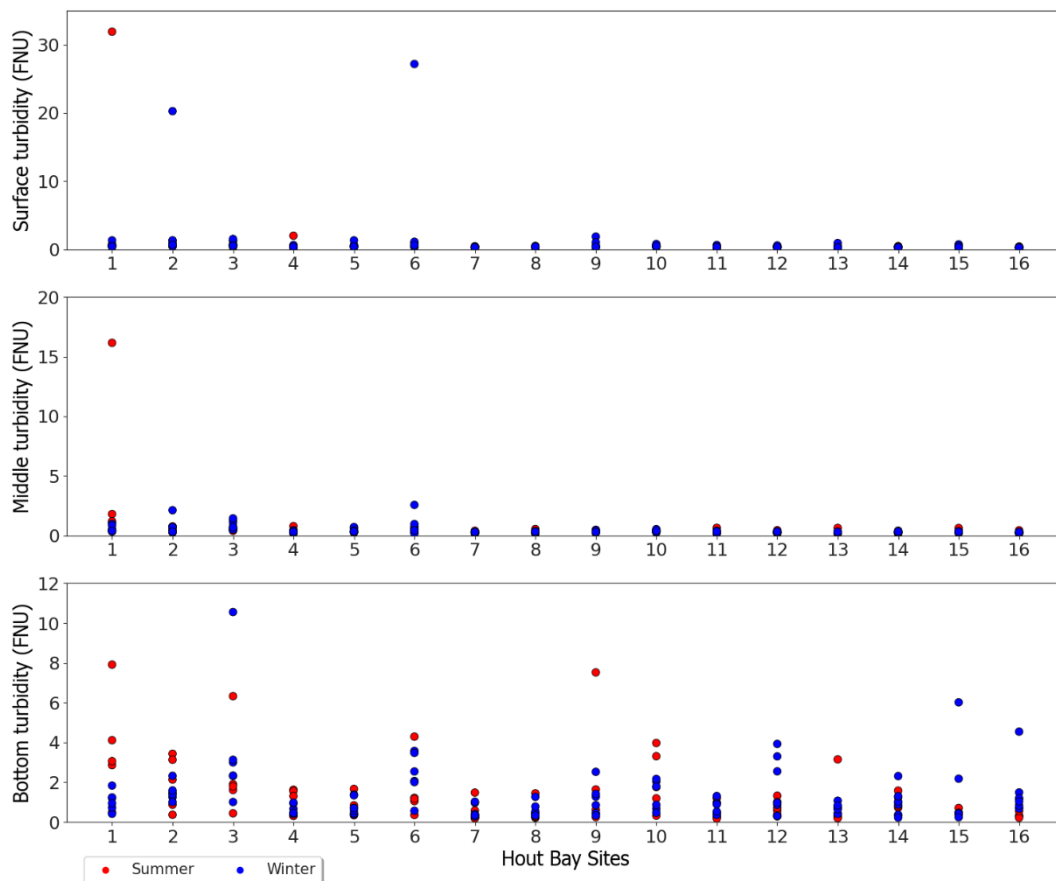


Figure 4.5: Seasonal distribution of turbidity (FNU) measured at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys. Note that all plots have different scales on the y-axis to aid presentation.

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	293	581	1113
Median	0.30	0.29	0.42
Mean	0.31	0.29	0.33
Summer			
n	287	592	1172
Median	0.29	0.25	0.26
Mean	0.31	0.28	0.35

4.3.4 pH

Similar to salinity, pH levels measured during the winter survey were notably higher than those measured during the summer survey (Figure 4.6). pH ranged between 7.81 and 8.13 in the winter and between 7.30 and 7.74 in the summer. The summer survey generally displayed 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.

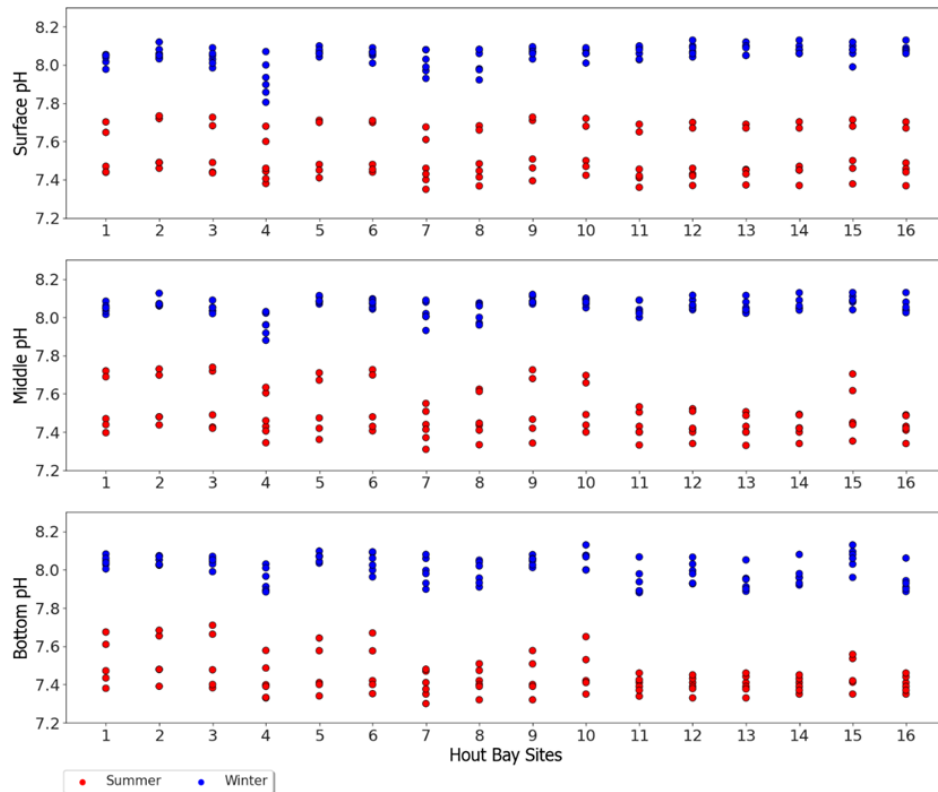


Figure 4.6: Seasonal distribution of pH measured at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys.

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). 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. The low values occurred at all sites and all depths in the year two summer data set as well. It was speculated that the low pH values may be a result of instrument error. However, standard calibration procedures are conducted prior to each survey and the reduced values were not seen during the winter period so it must be attributed to a different cause. 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	293	581	1113
Median	8.08	8.07	8.03
Mean	8.08	8.07	8.02
Summer			
n	287	592	1172
Median	7.45	7.43	7.41
Mean	7.51	7.47	7.42

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 5.70 and 8.83 mg/L while the summer survey ranged between 3.01 and 9.66 mg/L. During summer the recorded temperatures can be low (<10 °C), indicating that the lower dissolved oxygen concentrations recorded may be a result of upwelling processes in the area drawing hypoxic waters from deeper intermediate waters.

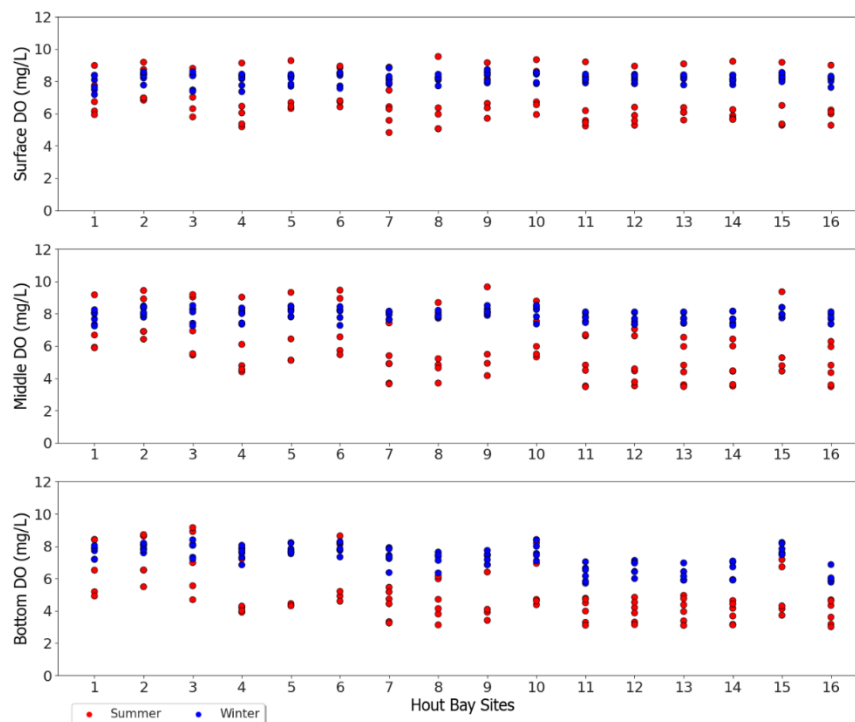


Figure 4.7: Seasonal distribution of dissolved oxygen (mg/L) measured at the Hout Bay outfall sites for the 2021 winter and 2022 summer surveys.

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 (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.

	Depth		
	Surface	Mid	Bottom
Winter			
n	293	581	1113
Median	8.11	7.89	7.28
Mean	8.09	7.93	7.15
Summer			
n	287	592	1172
Median	5.87	6.00	5.25
Mean	6.58	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 the samples collected at the beach sites.

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 HB11 at mid-depth during summer (Figure 4.9 and Figure 4.10).

The highest count occurred at HB-B2 beach site (4000 cfu/100 mL) during week 6 in winter. Moreover, during the winter survey surface counts of enterococci exceeded 400 cfu/100 mL on all but week 5 at the HB-B2 site. Site HB-B2 is located in the middle of Hout Bay swimming beach and is near the Disa River estuary mouth. During the winter survey period, the 90th percentile value at beach site HB-B3, was greater than the guideline as a result of a value of 251 cfu/100 mL being recorded during week 1. In summer, however HB-B3 enterococci levels exceed 400 cfu/100 mL during week 1, 2 and 6. 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).

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

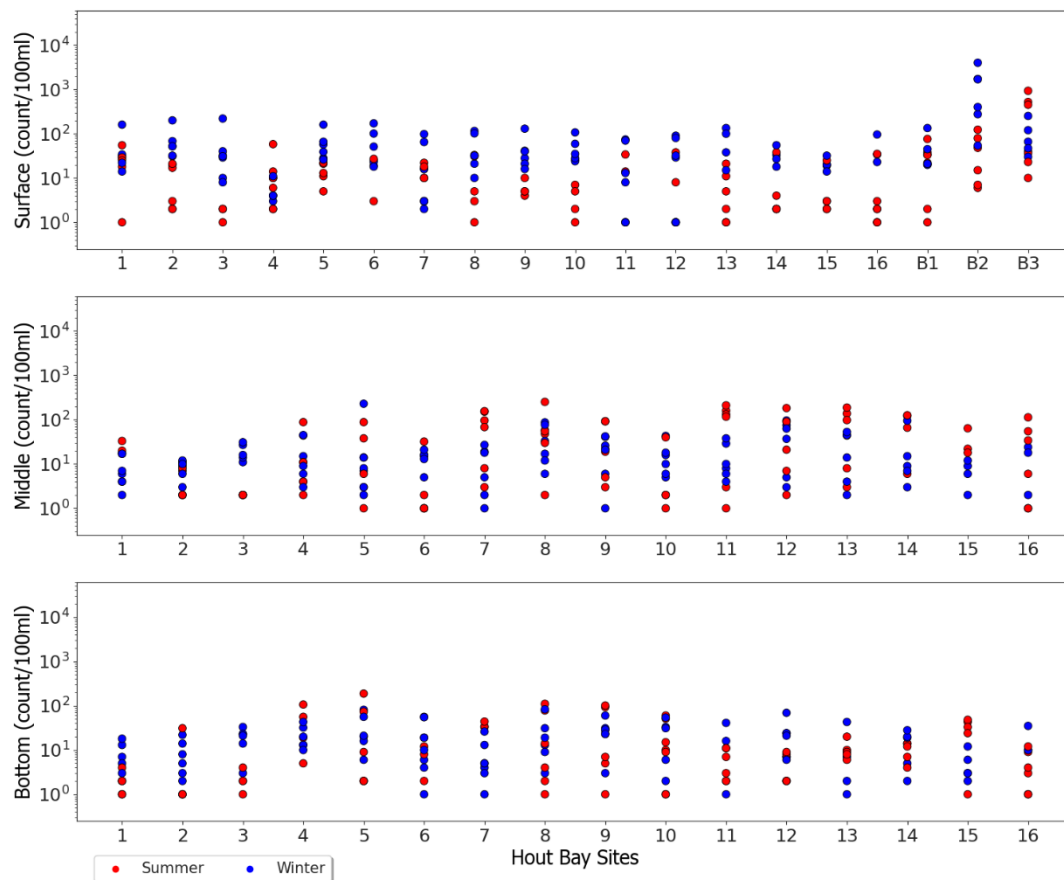


Figure 4.8: Seasonal distribution of enterococci (count/100 mL) measured at surface, mid- and bottom depths at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys. The enterococci counts measured at beach sites are included in the surface plot (B1, B2 and B3).

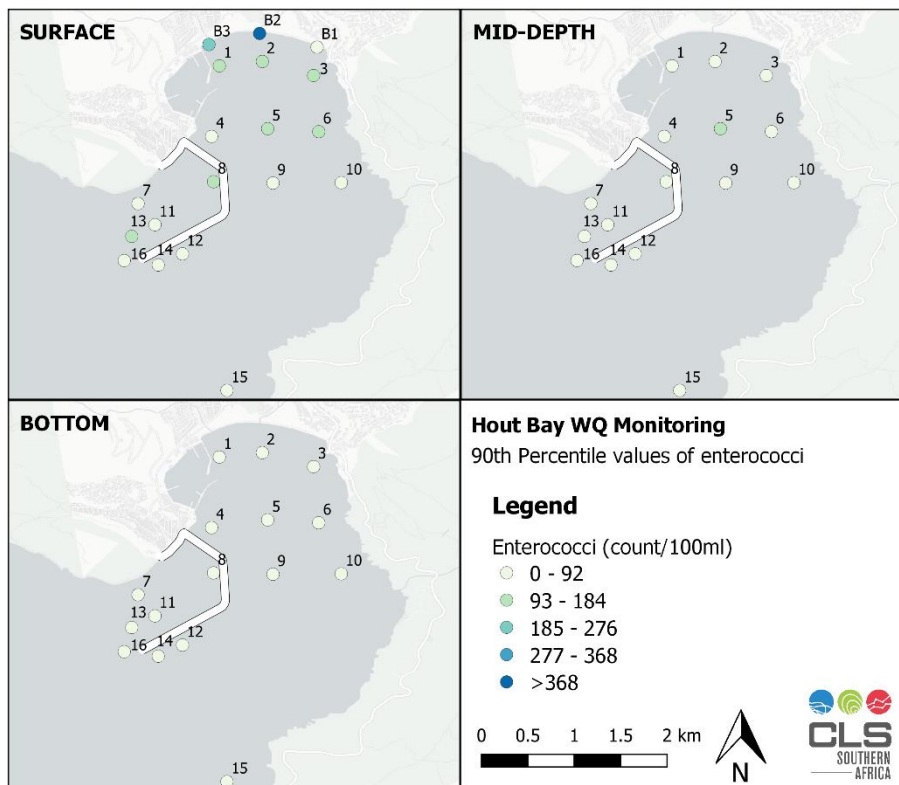


Figure 4.9: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

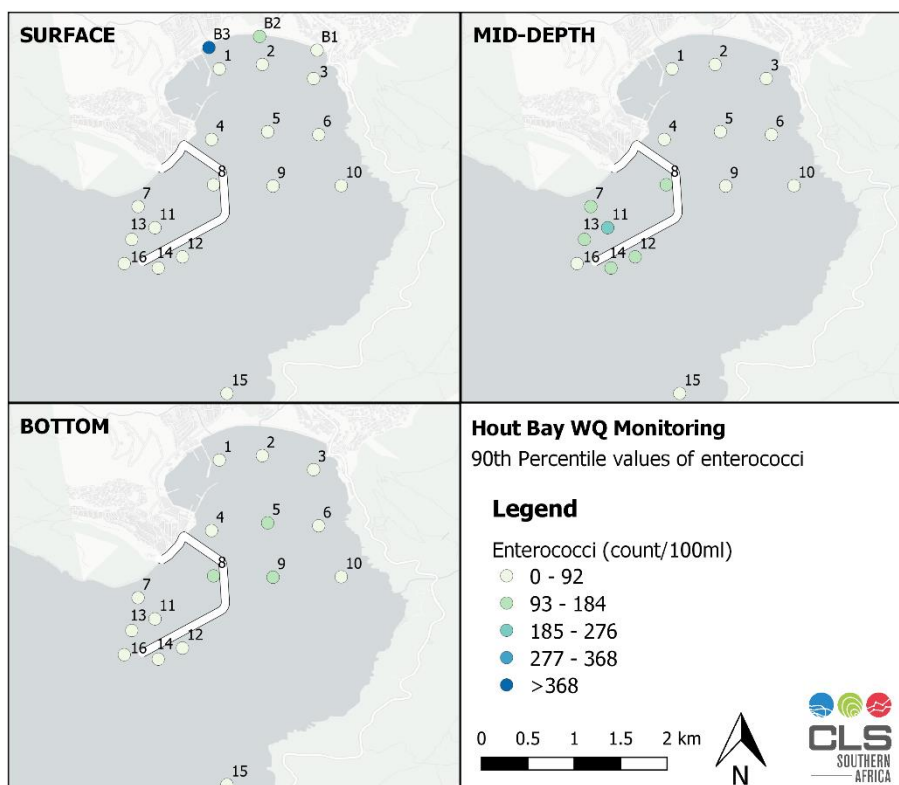


Figure 4.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Hout Bay outfall sites during the 2022 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

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 HB2 (15 mg/L) during week 6, HB12 (10 mg/L) during week 1 and HB3 (11 mg/L) during week 4 and in mid-depth waters at site HB2 (24 mg/L), HB4 (22 mg/L) and HB5 (10 mg/L) during week 6 in summer and winter. The bottom waters showed more inter-week variability at most sites during winter with large outliers occurring at site HB2 (118 mg/L) during week 6 and HB10 (128 mg/L) during week 10. (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 HB10 (17.5 mg/L) in bottom waters during winter. In the summer survey, median concentrations were all below 8 mg/L (Figure 4.13).

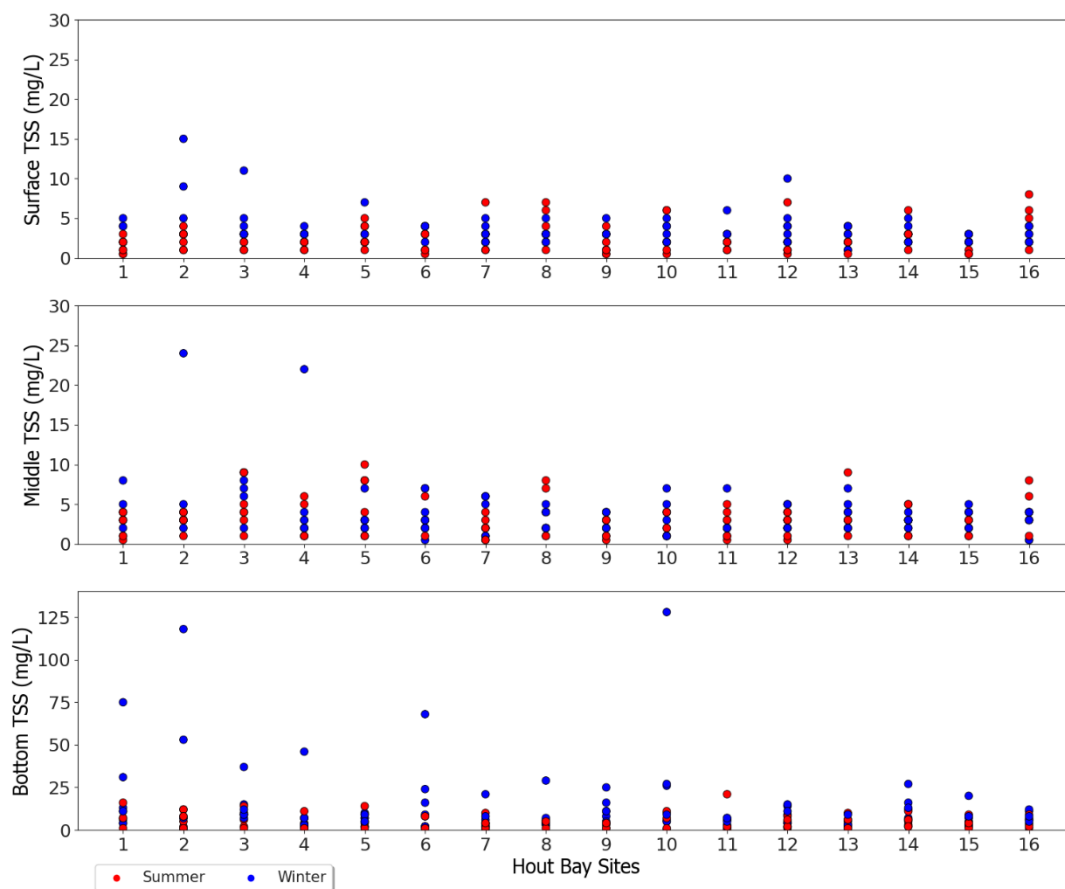


Figure 4.11: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2. All plots have different scales on the y axes to aid presentation.

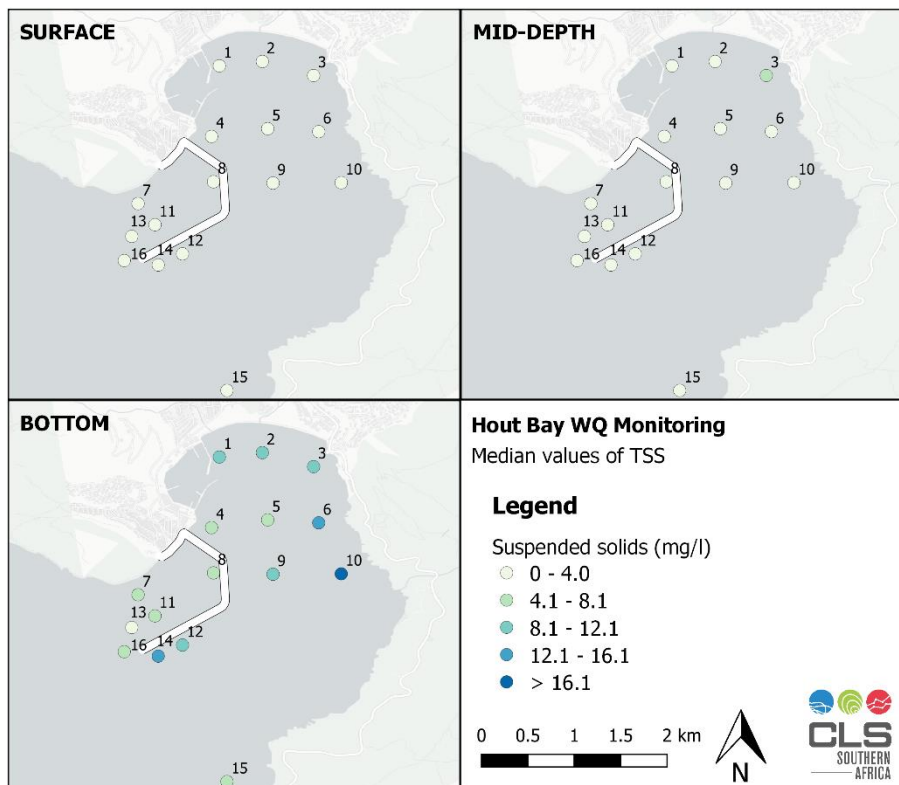


Figure 4.12: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 winter survey.

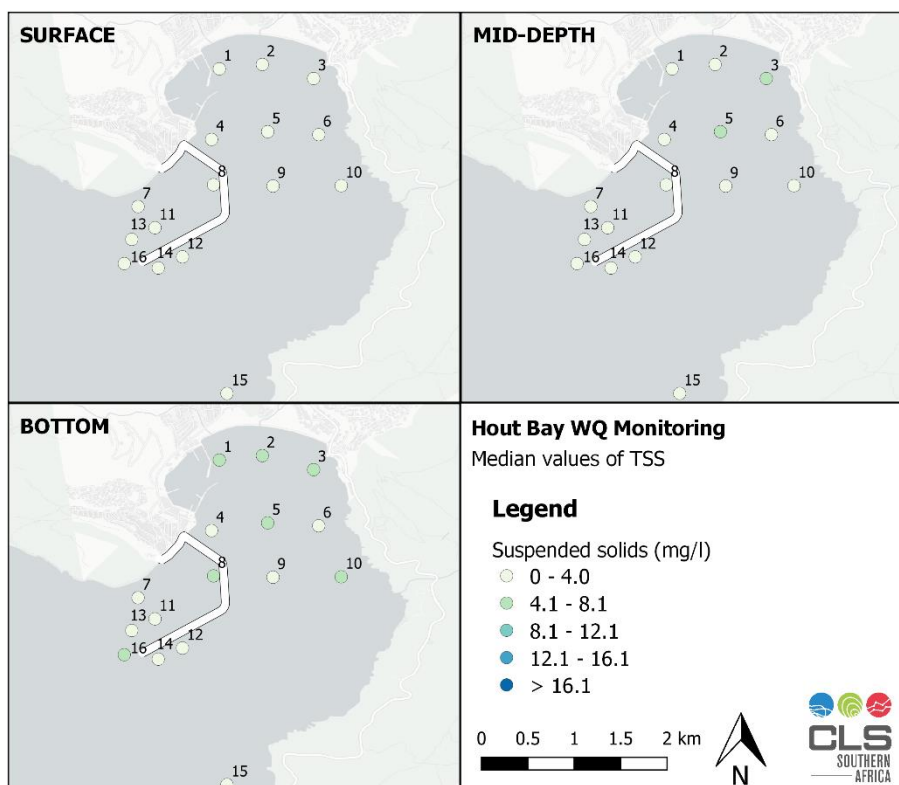


Figure 4.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2022 summer survey.

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	3	7
Mean	3	3	8
Summer			
n	30	30	30
Median	2	3	3
Mean	3	3	5

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 3.3 mg/L during the winter survey and 0.5 and 3.9 mg/L during the summer survey (Figure 4.14). Both the winter and summer surveys displayed high inter-week variation.

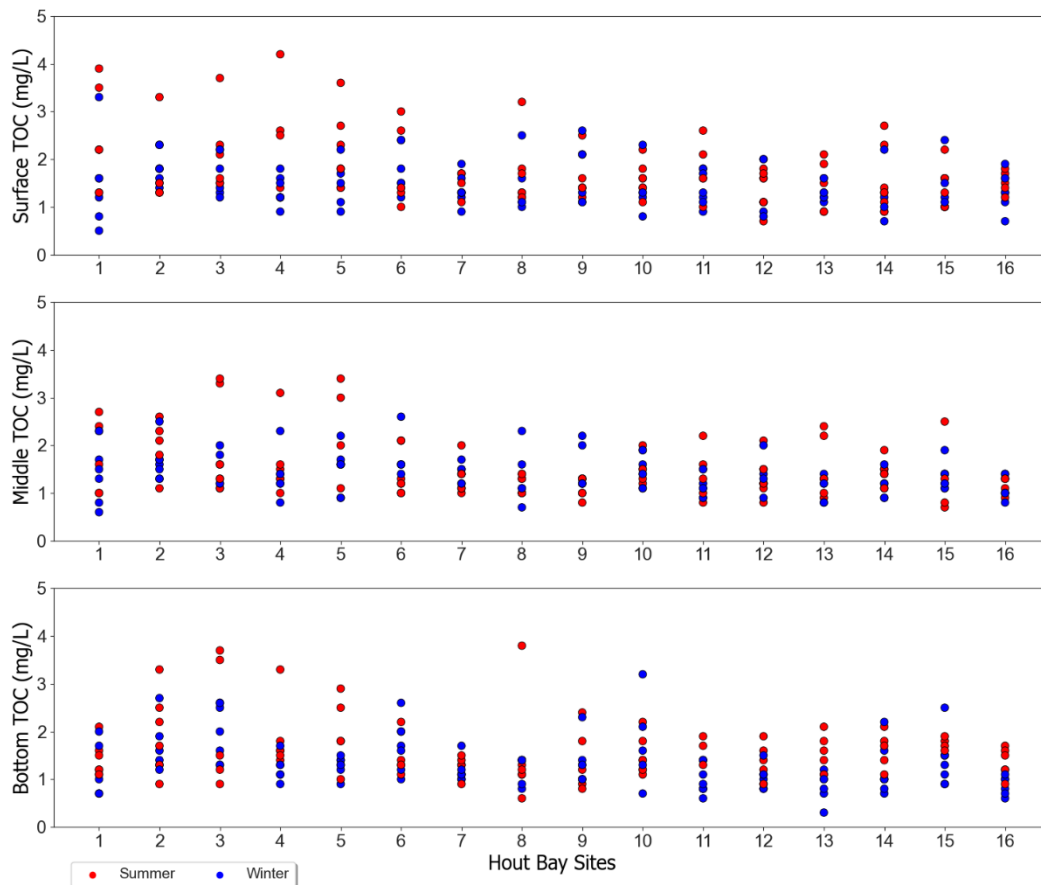


Figure 4.14: Seasonal distribution of total organic carbon (mg/L) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <0.5 mg/L) are presented as MDL/2.

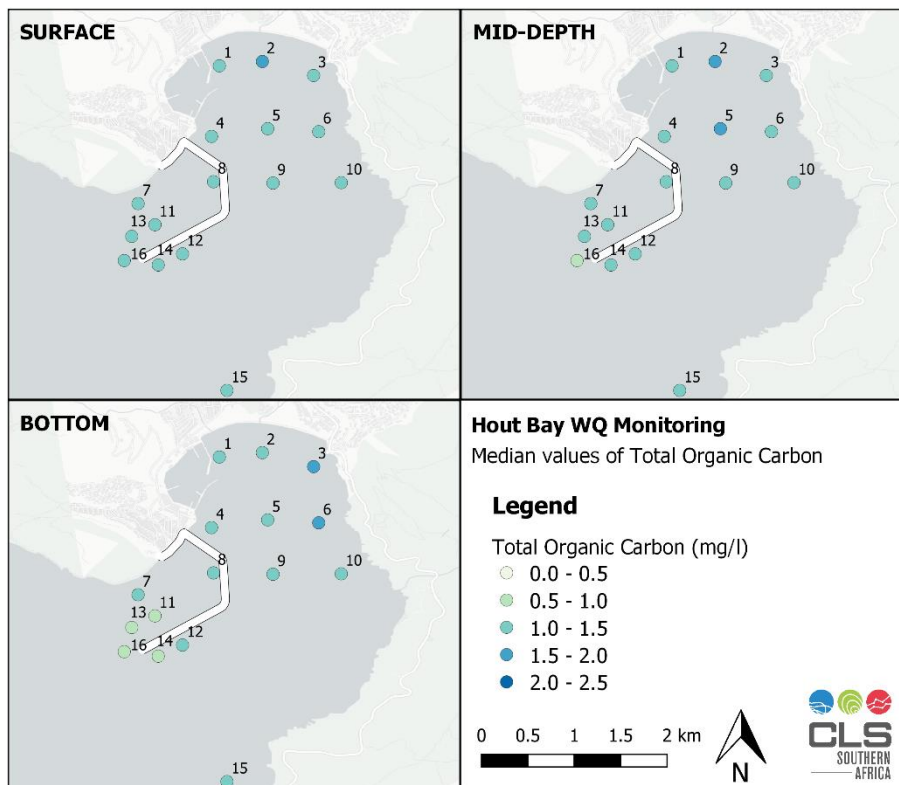


Figure 4.15: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 winter survey.

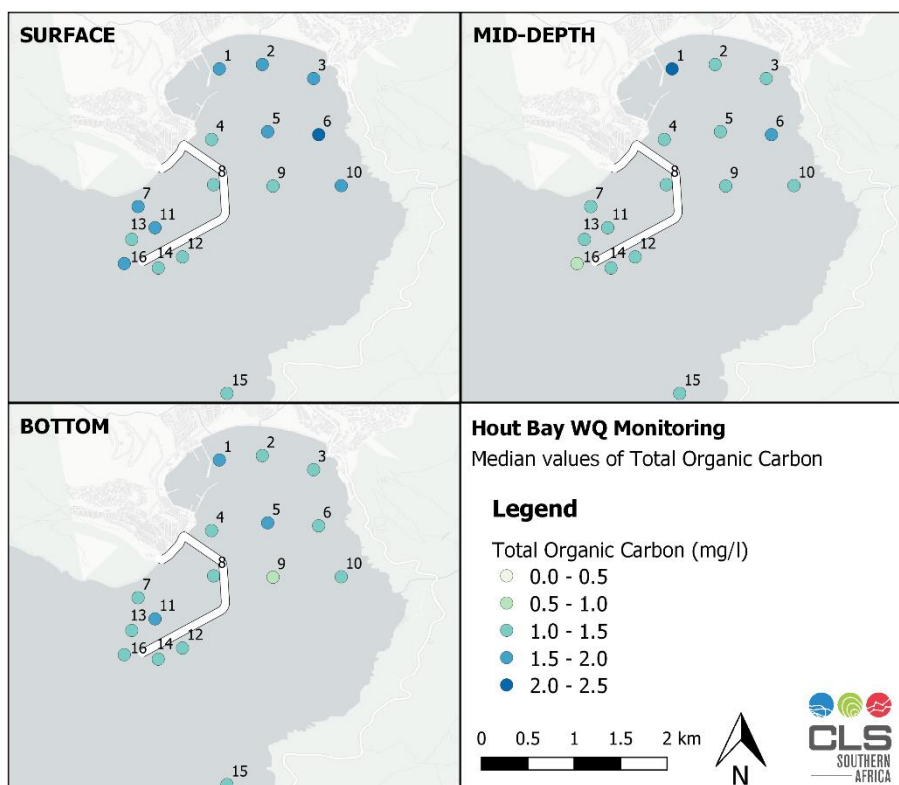


Figure 4.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Hout Bay outfall sites during the 2022 summer survey.

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 12 and 56 $\mu\text{g/L}$ in winter and 6 and 79 $\mu\text{g/L}$ 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).

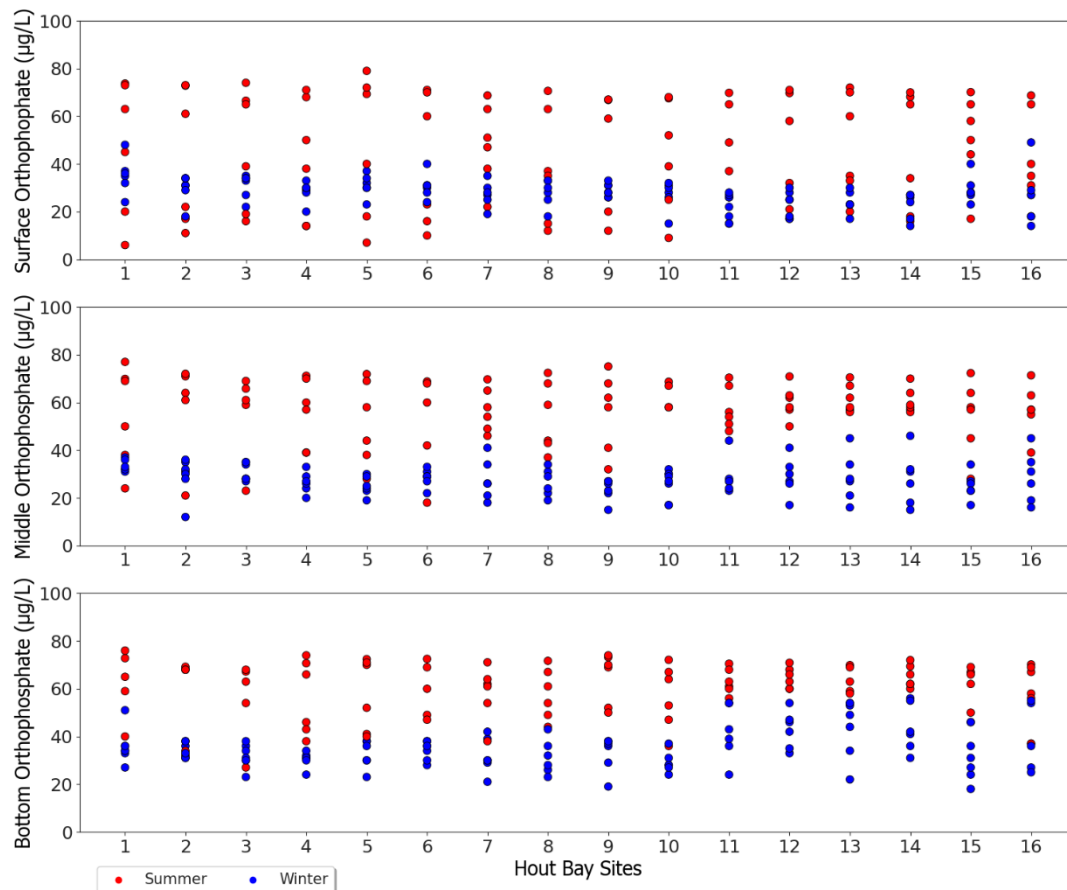


Figure 4.17: Seasonal distribution of orthophosphate ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys.

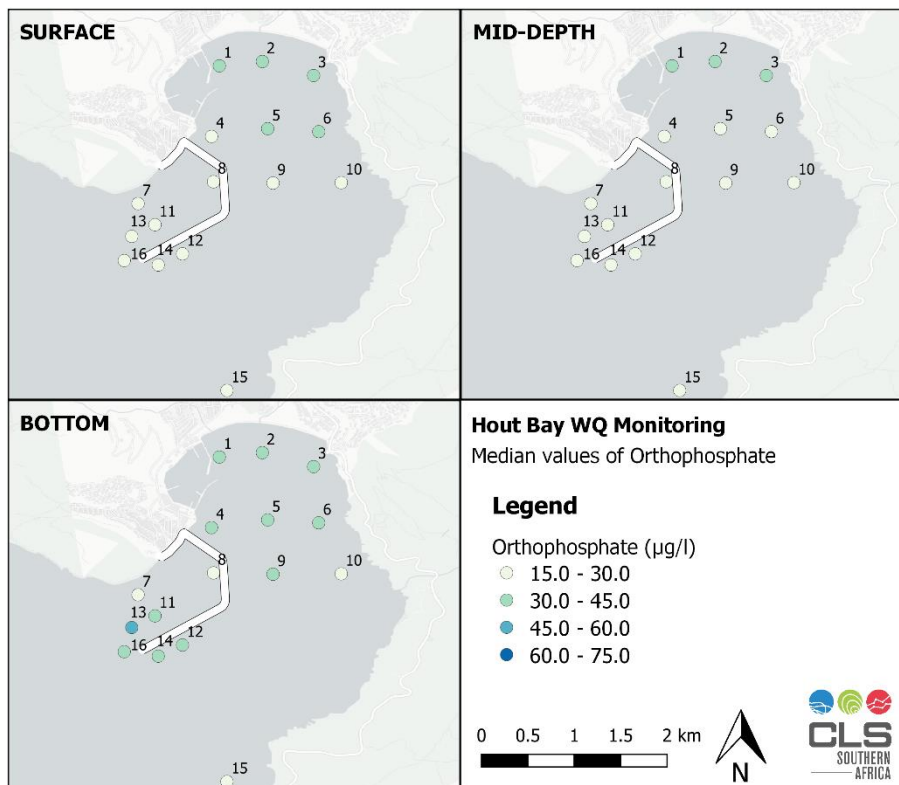


Figure 4.18: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 winter survey.

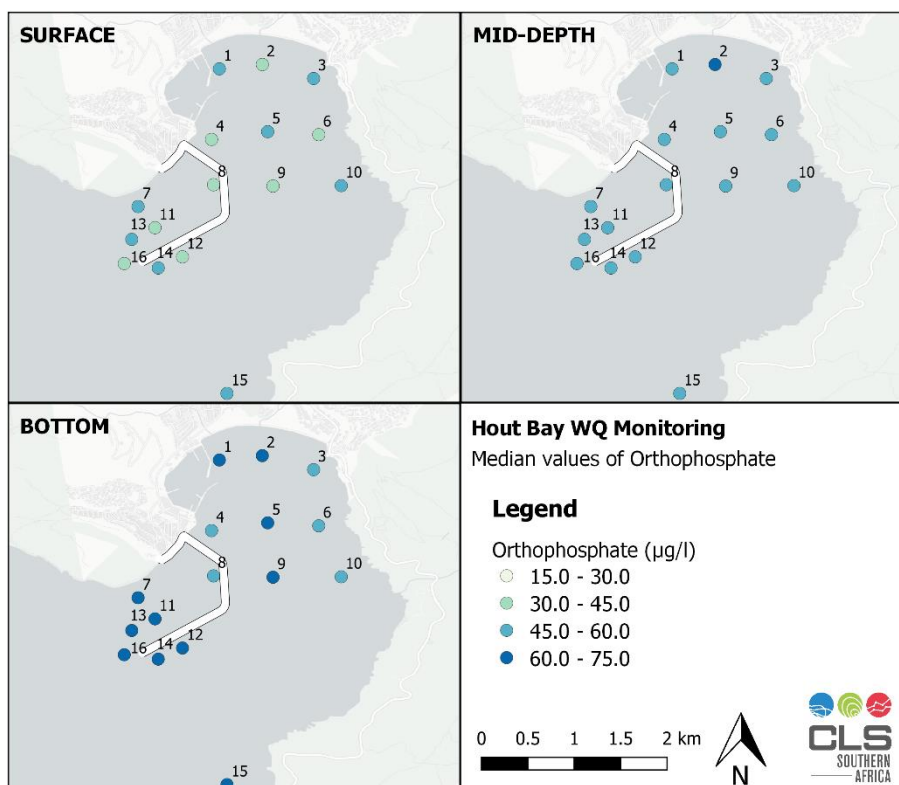


Figure 4.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2022 summer survey.

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	25	27	29
Mean	24	29	42
Summer			
n	30	30	30
Median	39	58	59
Mean	45	59	63

4.4.5 Ammonia

Ammonia concentrations were generally lower during the summer survey period than the winter survey period at all depths (Figure 4.20). Concentrations ranged between <5 and 71 µg/L in winter and <5 and 54 µg/L in summer.

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).

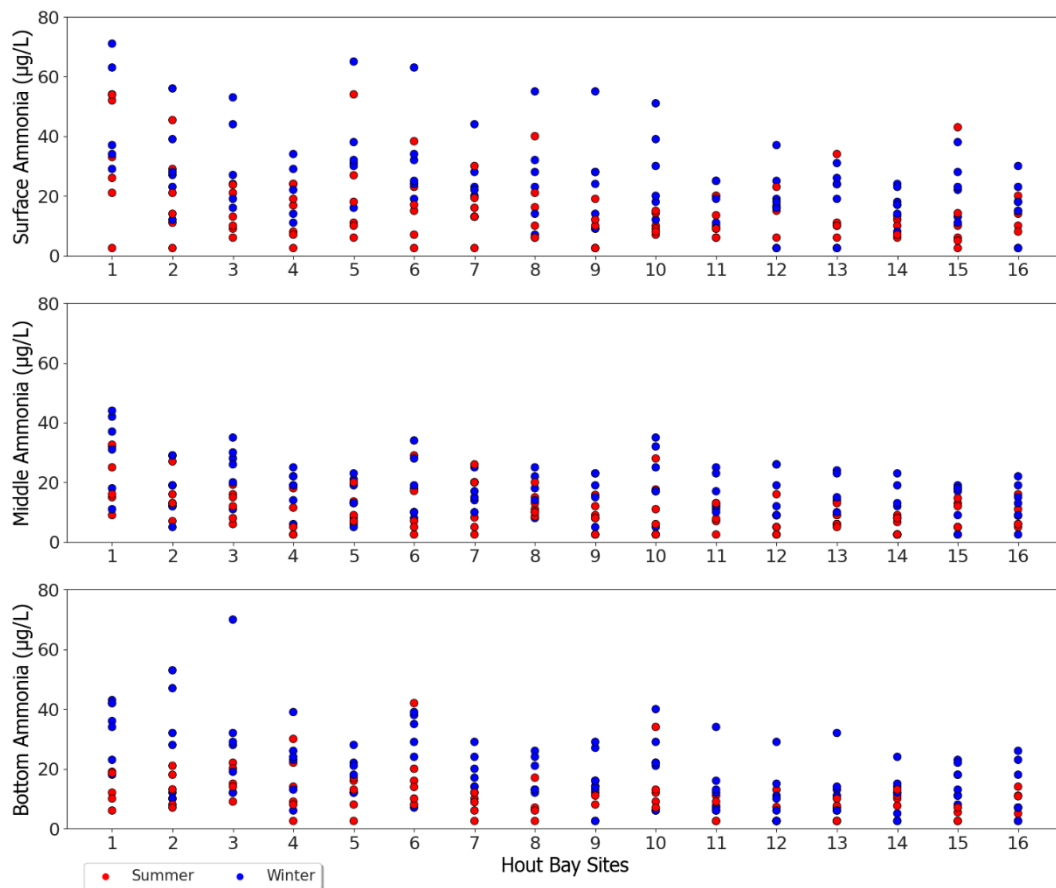


Figure 4.20: Seasonal distribution of ammonia ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Hout Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

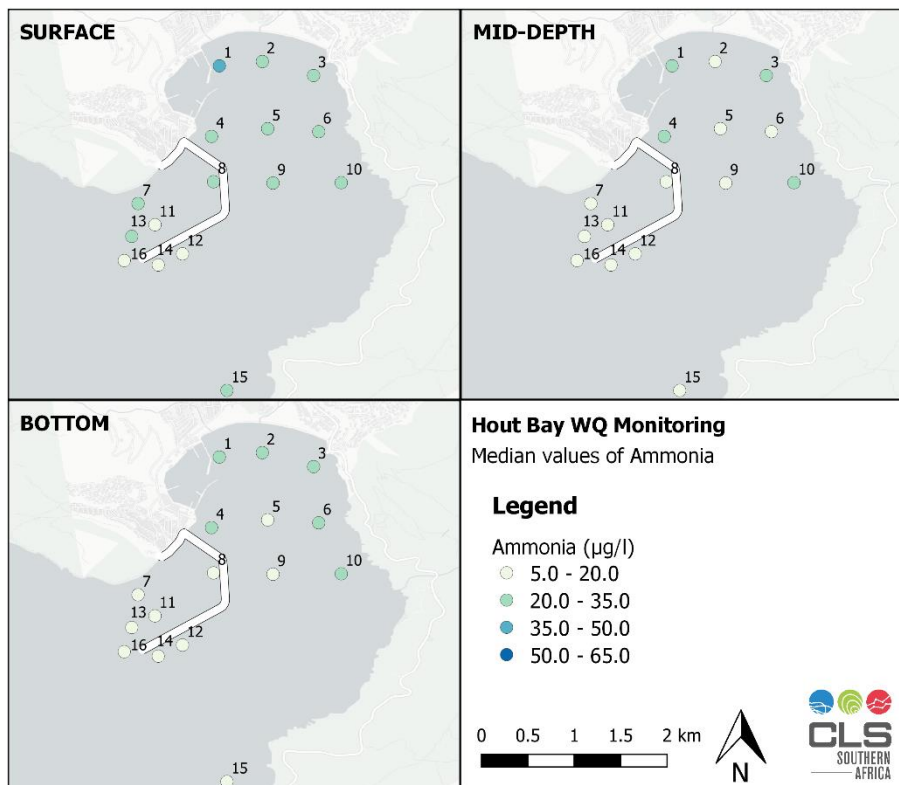


Figure 4.21: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2021 winter survey.

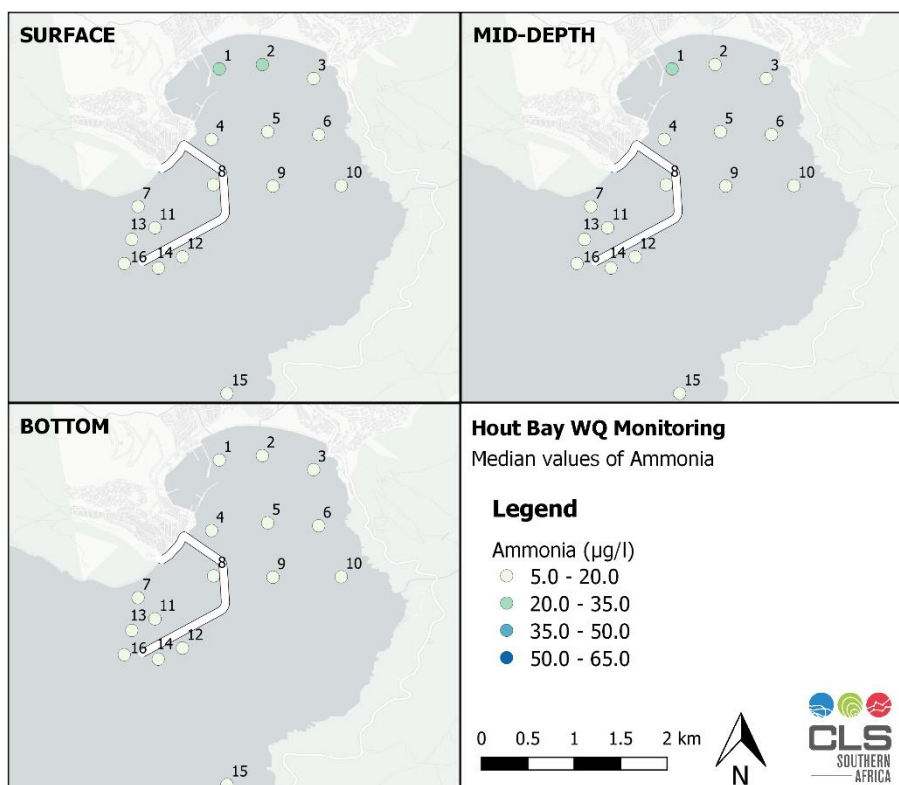


Figure 4.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Hout Bay outfall sites during the 2022 summer survey.

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 and therefore were 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	19	15	13
Mean	20	16	15
Summer			
n	30	30	30
Median	12	9	10
Mean	13	9	9

4.4.6 Toxicity

The two nearshore sites sampled during the third 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 2021) and summer (March-April 2022) 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	Toxicity Classification
			1	2	3	4			
Tripneutes gratilla									
Winter	02/09/2021	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	98	99	99	99.00	0.82	Not toxic
	07/09/2021	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	99.50	0.58	Not toxic
	08/09/2021	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	99	99	99	99.25	0.50	Not toxic
	09/09/2021	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	99.50	0.58	Not toxic
	14/09/2021	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	99.50	0.58	Not toxic
	15/09/2021	HB-TT1	99	99	99	99	99.00	0.00	Not toxic
		HB-TT2	100	98	99	99	99.00	0.82	Not toxic
	HB-TT1								
	HB-TT2								
Echinometra Mathaei									
Summer	24/03/2022	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	99.50	0.58	Not toxic
	27/03/2022	HB-TT1	100	100	99	99	99.50	0.58	Not toxic
		HB-TT2	100	100	99	99	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 2021 and summer 2022 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.

Trace metal body burden concentrations at control and impact stations at Hout Bay also showed clear seasonal trends for zinc with a greater average loss (relative to baseline levels) observed during winter than summer. There was evidence of seasonal differences in copper accumulation with average concentrations higher in summer compared to winter. 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 a depth of 23 m.

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 2021) and summer (March-April 2022) monitoring periods. respectively. Figure 5.2 shows the location of the toxicity sampling sites for the winter and summer periods.

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 based on the 300 m recommendation for offshore discharges in Anchor 2015. 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.

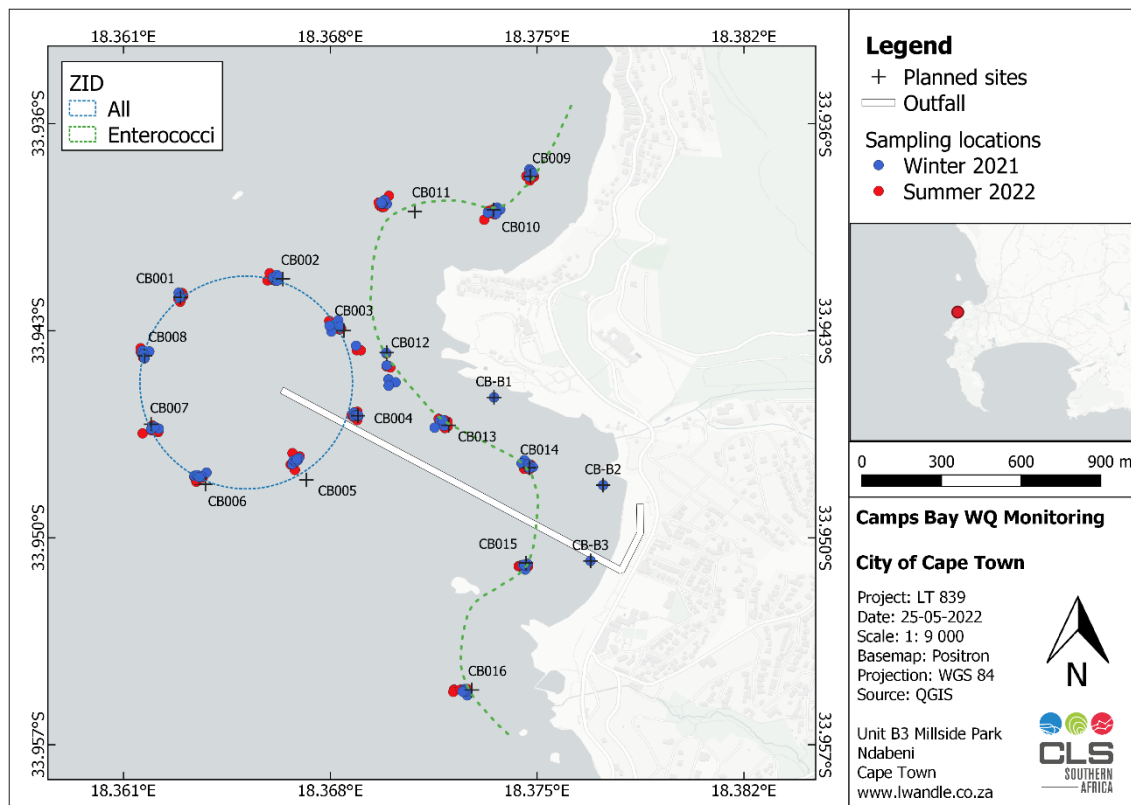


Figure 5.1: Map showing the Camps Bay outfall and the locations of nearshore and beach (CB-B1, CB-B2 and CB-B3) sites sampled during the winter (August-September 2021) and summer (March-April 2022) monitoring periods. A low enterococci boundary line is shown in green.

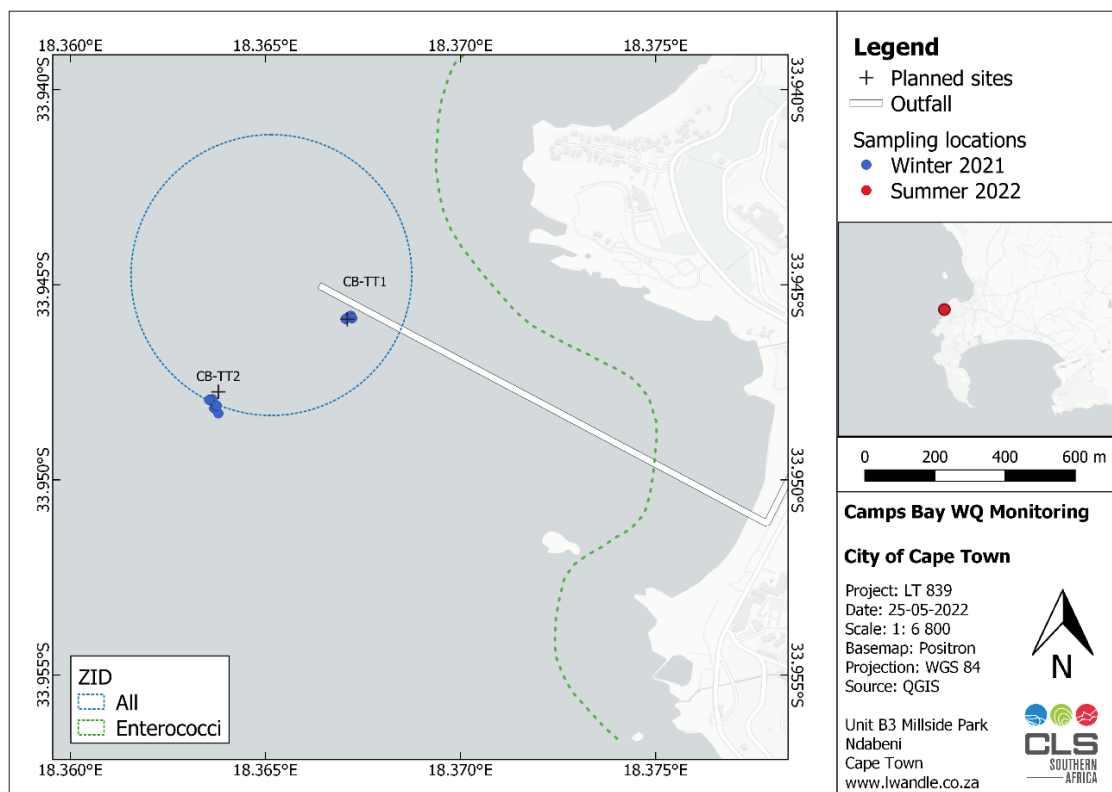


Figure 5.2: Map showing the Camps Bay outfall and the locations of the toxicity test sites sampled during the winter (August-September 2021) and the summer (March-April 2022) monitoring periods. A low enterococci boundary line is shown in green.

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 below. Parameters are also compared to relevant guidelines where appropriate.

5.3.1 Temperature

Water column temperatures during the winter survey ranged between 10.85 and 14.31 °C and were between 9.66 and 16.36 °C during the summer survey (Figure 5.3). These fall within the expected range for the region. The summer survey had a greater range of temperatures measured at all depth layers with a high inter-week variation.

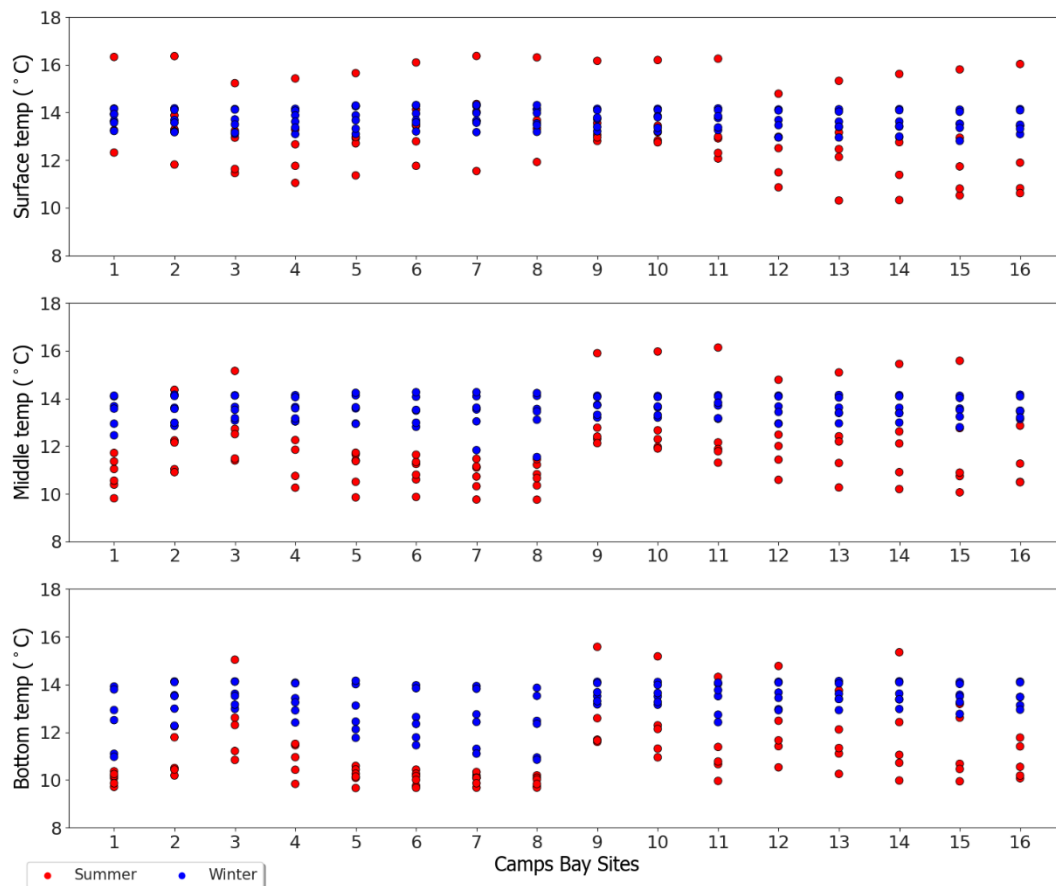


Figure 5.3: Seasonal distribution of temperature (°C) measured at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys.

Temperature values at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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 5.1). 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	404	664	511
Median	13.66	13.59	12.89
Mean	13.70	13.55	12.99
Summer			
n	360	661	533
Median	12.59	11.16	10.29
Mean	12.80	11.29	10.33

5.3.2 Salinity

Recorded winter survey salinity values were generally higher than those in summer (Figure 5.4). Salinities ranged between 34.65 and 35.28 PSU and 34.65 and 34.56 and 34.84 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.

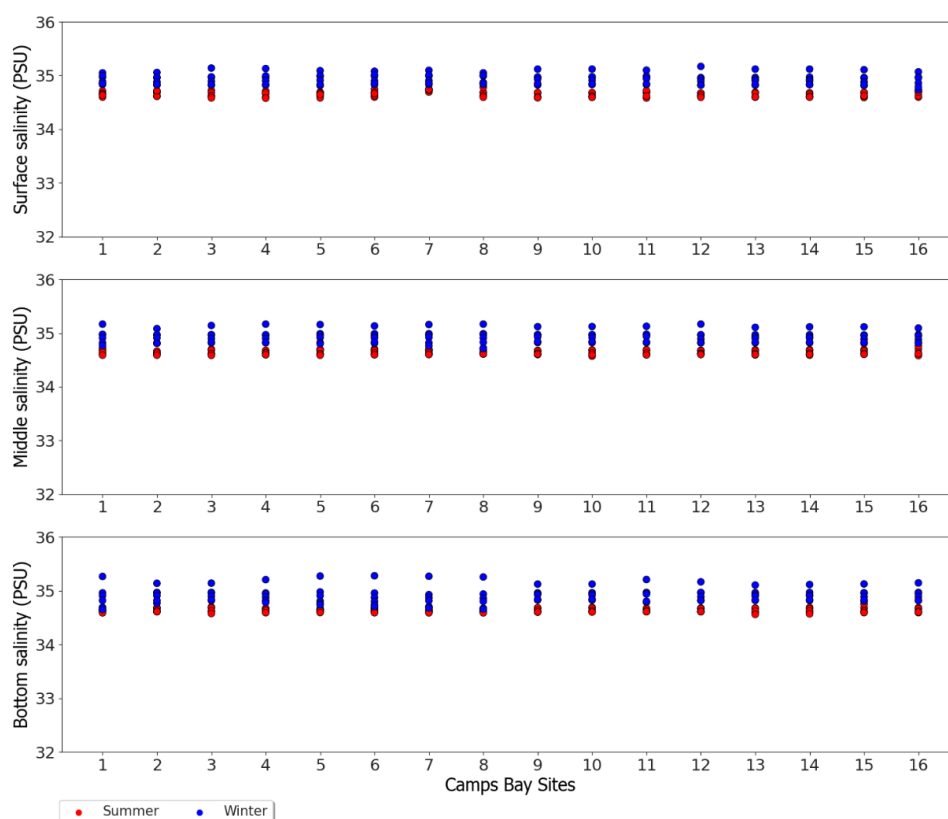


Figure 5.4: Seasonal distribution of salinity (PSU) measured at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys.

Salinity values at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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	404	664	511
Median	34.91	34.95	34.89
Mean	34.94	34.95	34.91
Summer			
n	360	661	533
Median	34.66	34.63	34.63
Mean	34.66	34.65	34.64

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 0.19 and 12.27 FNU and 0.15 and 20.70 FNU respectively (Figure 5.5). 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.

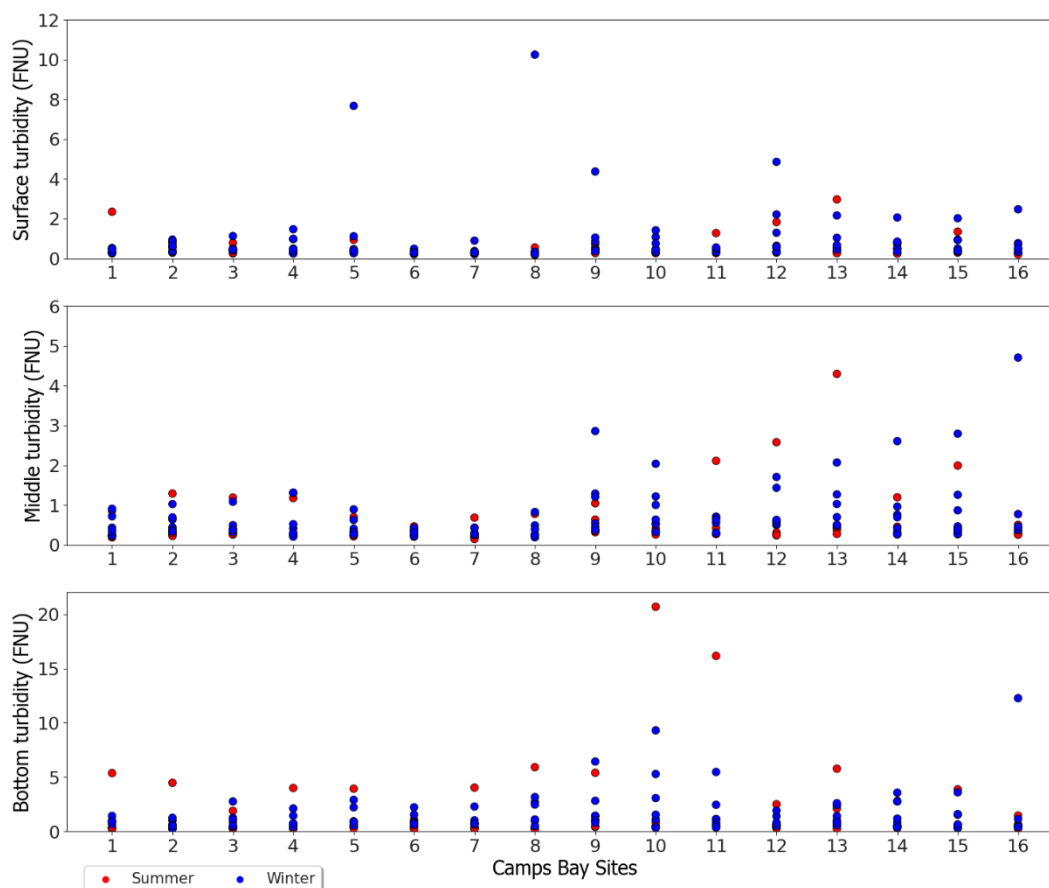


Figure 5.5: Seasonal distribution of turbidity (FNU) measured at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys. Note that all plots have different scales on the y-axis to aid presentation.

Turbidity values at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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	404	664	511
Median	0.39	0.36	0.50
Mean	0.63	0.49	0.75
Summer			
n	360	661	533
Median	0.30	0.27	0.26
Mean	0.36	0.44	0.53

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 5.6). pH ranged between 7.96 and 8.21 in the winter and between 7.23 and 7.86 in the summer. 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. These seasonal patterns observed are consistent with temperature as cooler waters generally have a lower pH due to capacity to hold higher pCO₂ levels.

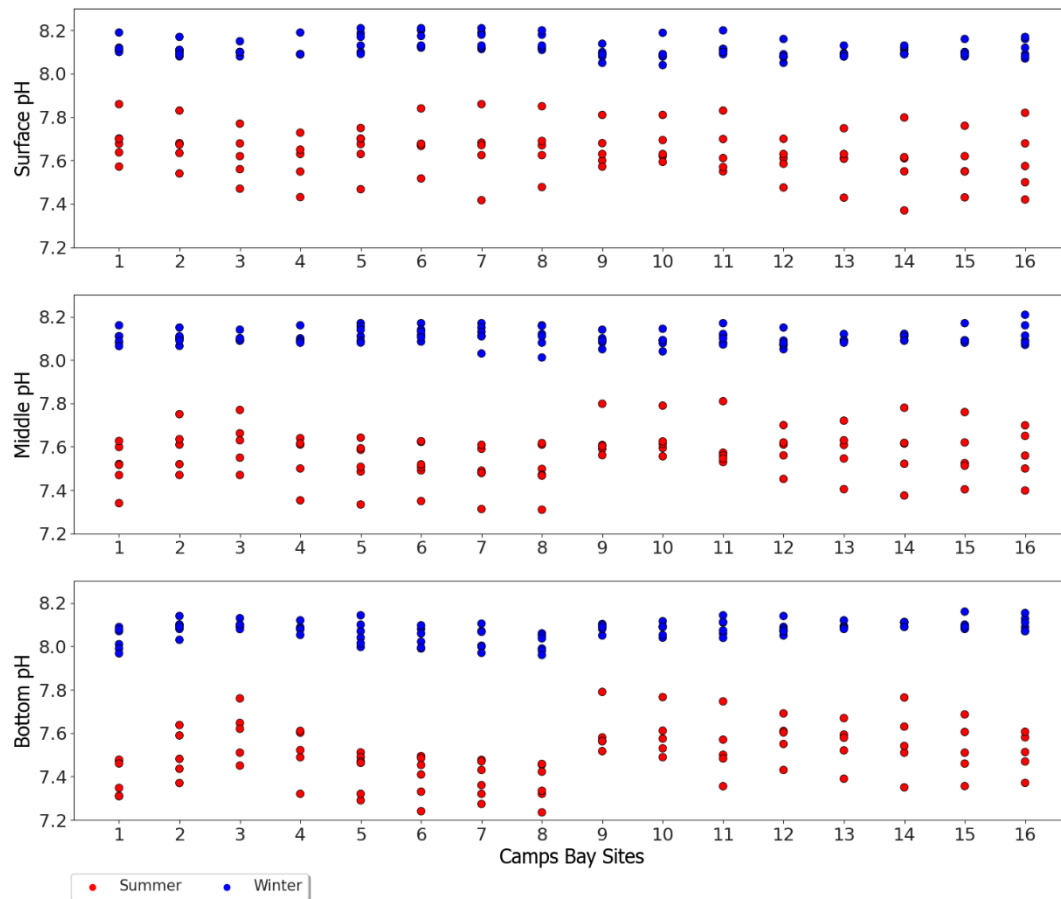


Figure 5.6: Seasonal distribution of pH measured at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys.

Values at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB6, CB7 and CB8, 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 both seasons, 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.

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	404	664	511
Median	8.12	8.12	8.07
Mean	8.13	8.12	8.06
Summer			
n	360	661	533
Median	7.63	7.54	7.47
Mean	7.62	7.54	7.44

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 5.7). The winter survey concentrations ranged between 5.53 and 9.14 mg/L while the summer survey ranged between 1.84 and 10.24 mg/L. The lowest summer concentrations (<2 mg/L) were recorded in the bottom of the water column.

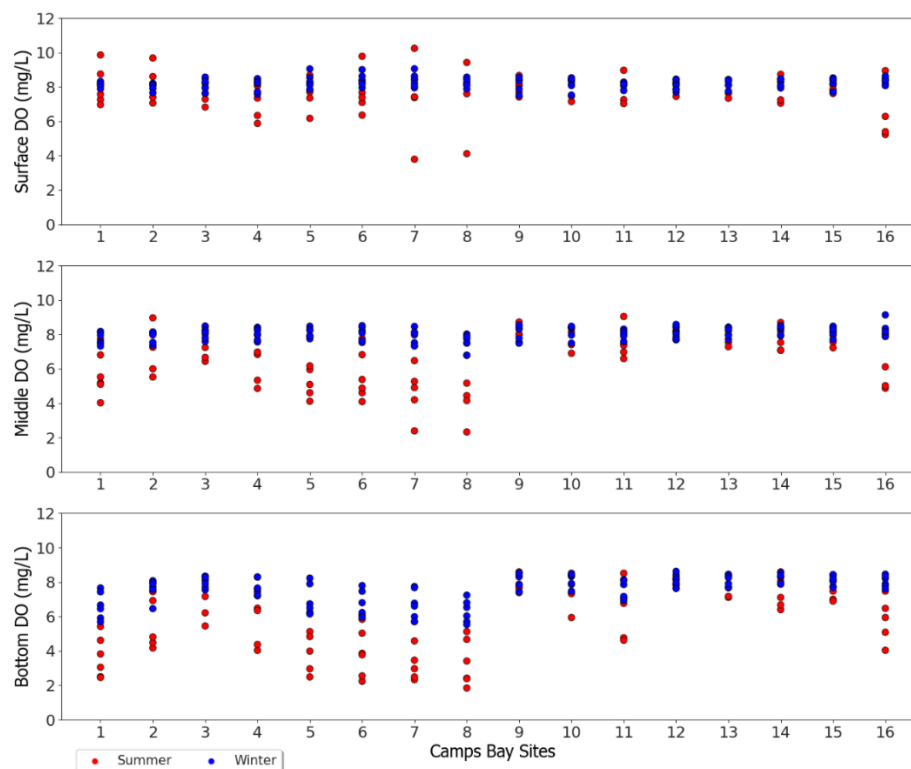


Figure 5.7: Seasonal distribution of dissolved oxygen (mg/L) measured at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys.

Dissolved oxygen concentrations at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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	404	664	511
Median	8.19	8.08	7.15
Mean	8.20	8.03	7.12
Summer			
n	360	661	533
Median	7.40	5.80	4.10
Mean	7.34	5.95	4.29

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 5.8) and the 90th percentile values for the winter and summer survey periods were below the recommended DEA (2012) guideline ≤185 cfu/100 mL (Figure 5.9, Figure 5.10 and Table 3.1). This is true for all sites apart from CB5 at mid depth which exceeded the guideline with a 90th percentile of 217 cfu/100 mL.

Individual enterococci counts at the CB-B1 and CB-B2 beach sites were below 100 cfu/100 mL during both seasons and the 90th percentile values at these beach sites for the winter and summer survey periods were in compliance with the recommended guideline. Site CB-B3 was compliant during winter but not during summer where the 90th percentile value was 1 005 cfu/100 mL (Figure 5.8)

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

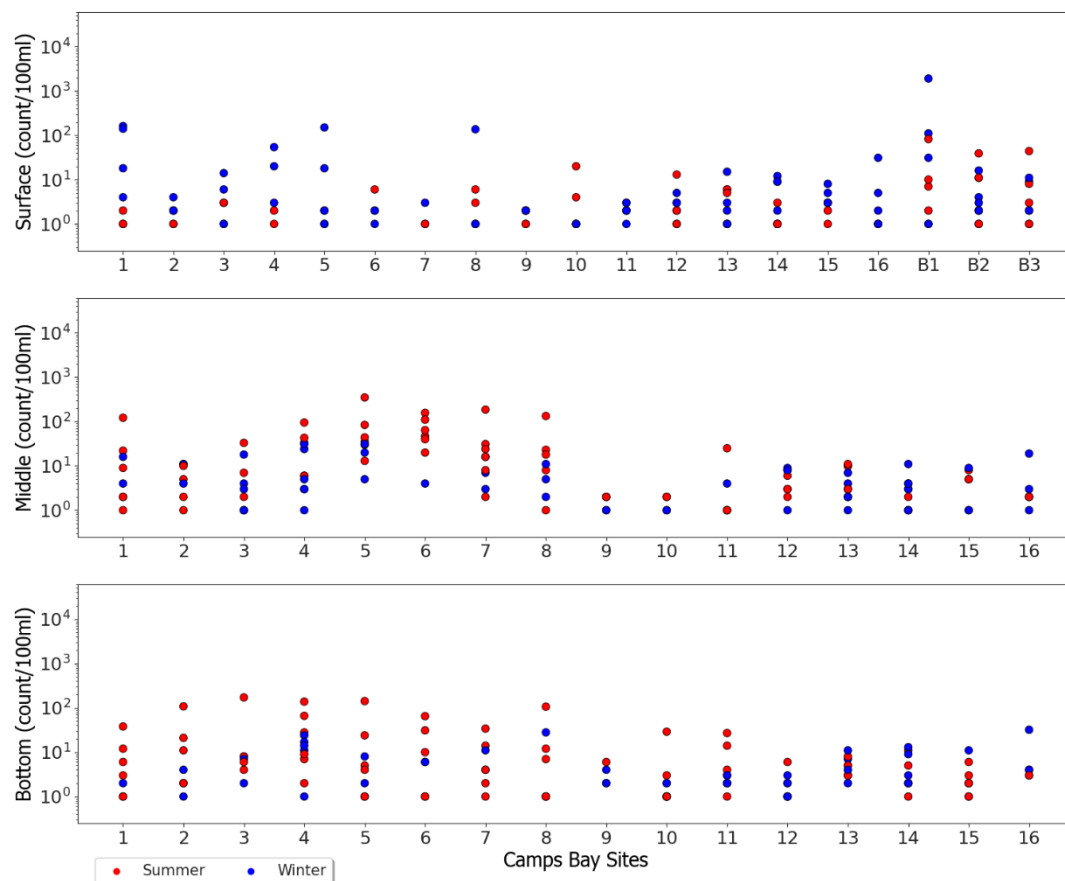


Figure 5.8: Seasonal distribution of enterococci (cfu/100 mL) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys. The enterococci counts measured at beach sites are included in the surface plot (B1, B2 and B3).

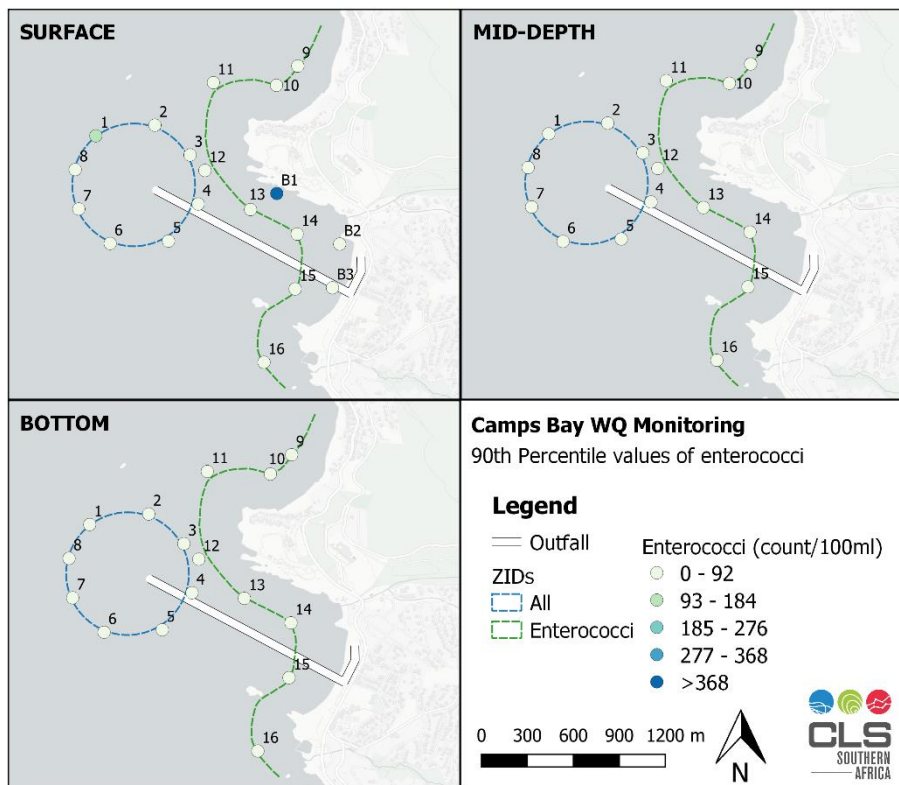


Figure 5.9: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

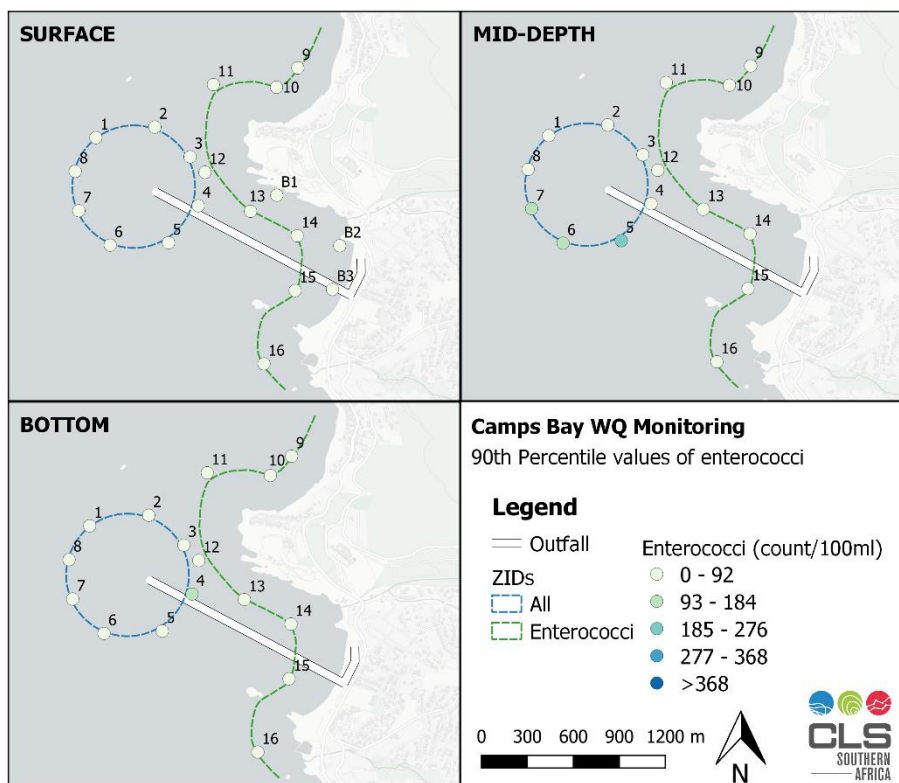


Figure 5.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Camps Bay outfall sites during the 2022 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

5.4.2 Total Suspended Solids

TSS concentrations were variable during the winter survey and summer survey in surface, middle and bottom waters surrounding the Camps Bay outfall (Figure 5.11, Figure 5.12 and Figure 5.13). Outliers were recorded during the summer at a number of sites at the surface and bottom of the water column. The largest outlier was recorded at site CB9 with a concentration of 80 mg/L in bottom waters during week 3 (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 5.12). The highest median concentrations were recorded at CB9, CB10, and CB11 in bottom waters during winter. In the summer survey, median concentrations were all below 8 mg/L (Figure 5.13).

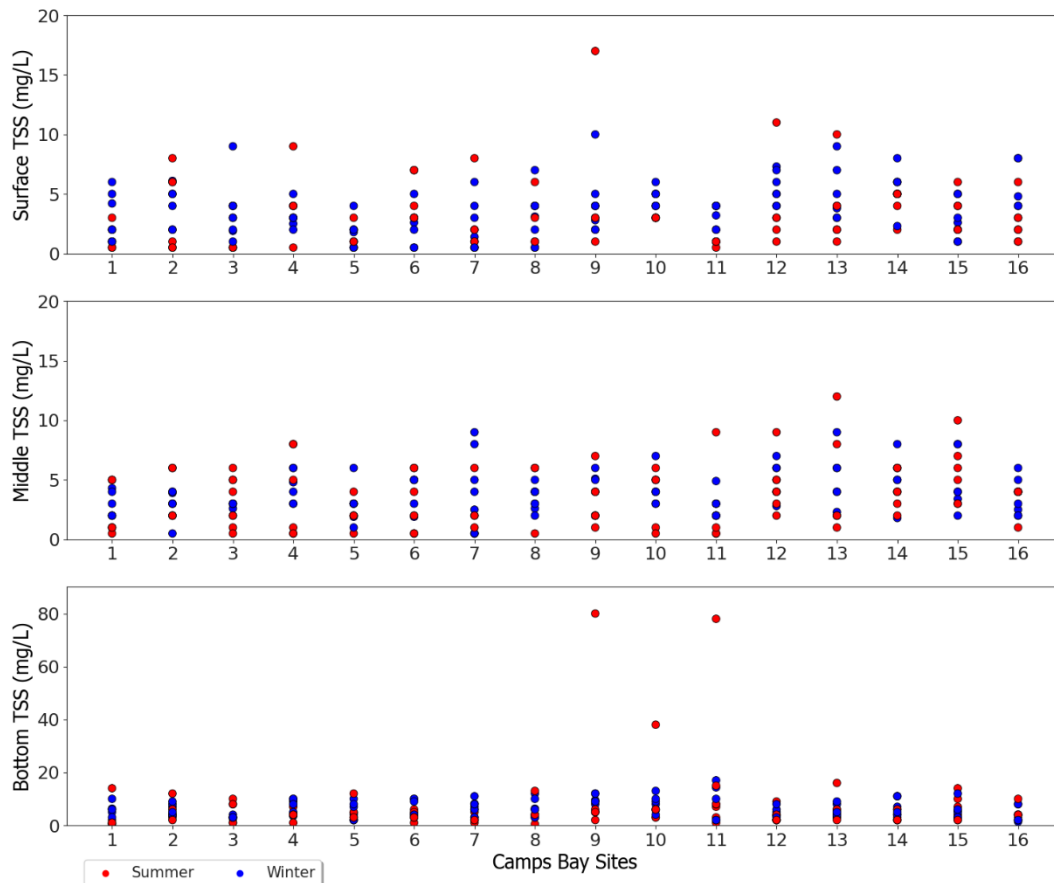


Figure 5.11: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2. All plots have different scales on the y axes to aid presentation.

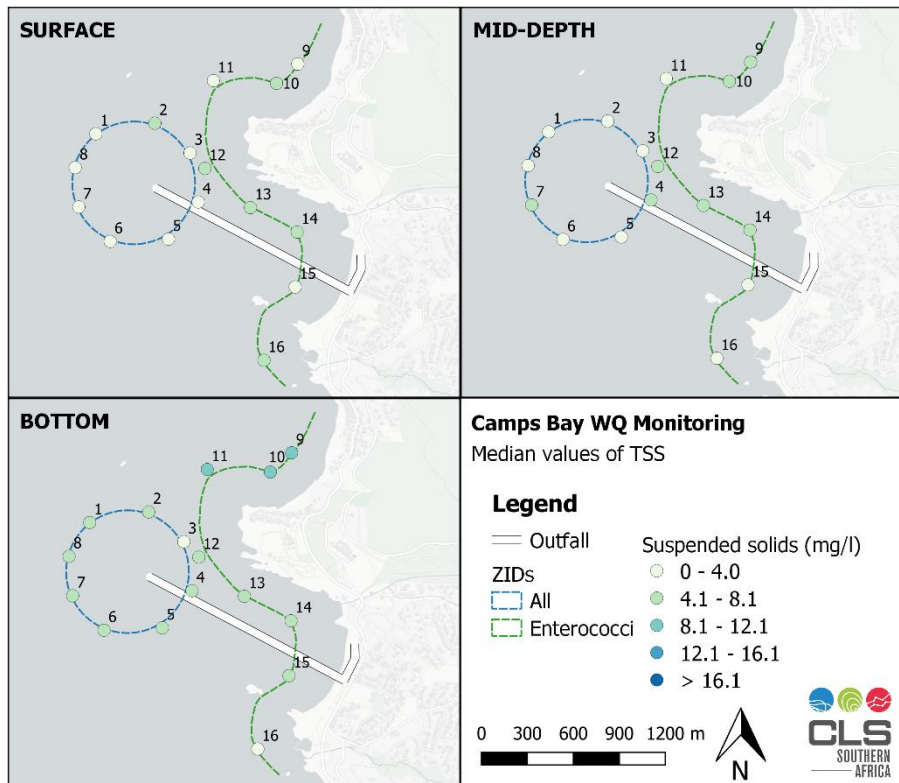


Figure 5.12: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 winter survey.

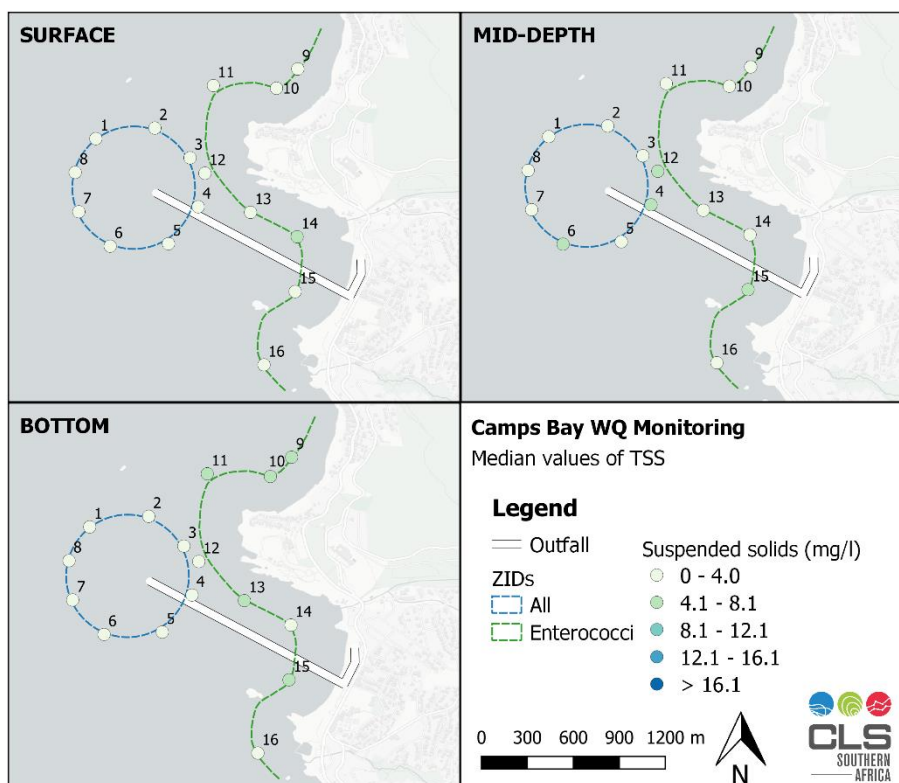


Figure 5.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2022 summer survey.

TSS values at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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	3	3	6
Mean	3	4	6
Summer			
n	42	42	42
Median	3	3	4
Mean	4	4	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 5.14, Figure 5.15 and Figure 5.16). TOC concentrations in surface, middle and bottom waters at Camps Bay were low and ranged between 0.5 and 3.0 mg/L during the winter survey and 0.5 and 4.3 mg/L during the summer survey (Figure 5.14). Both the winter and summer surveys had high inter-week variation.

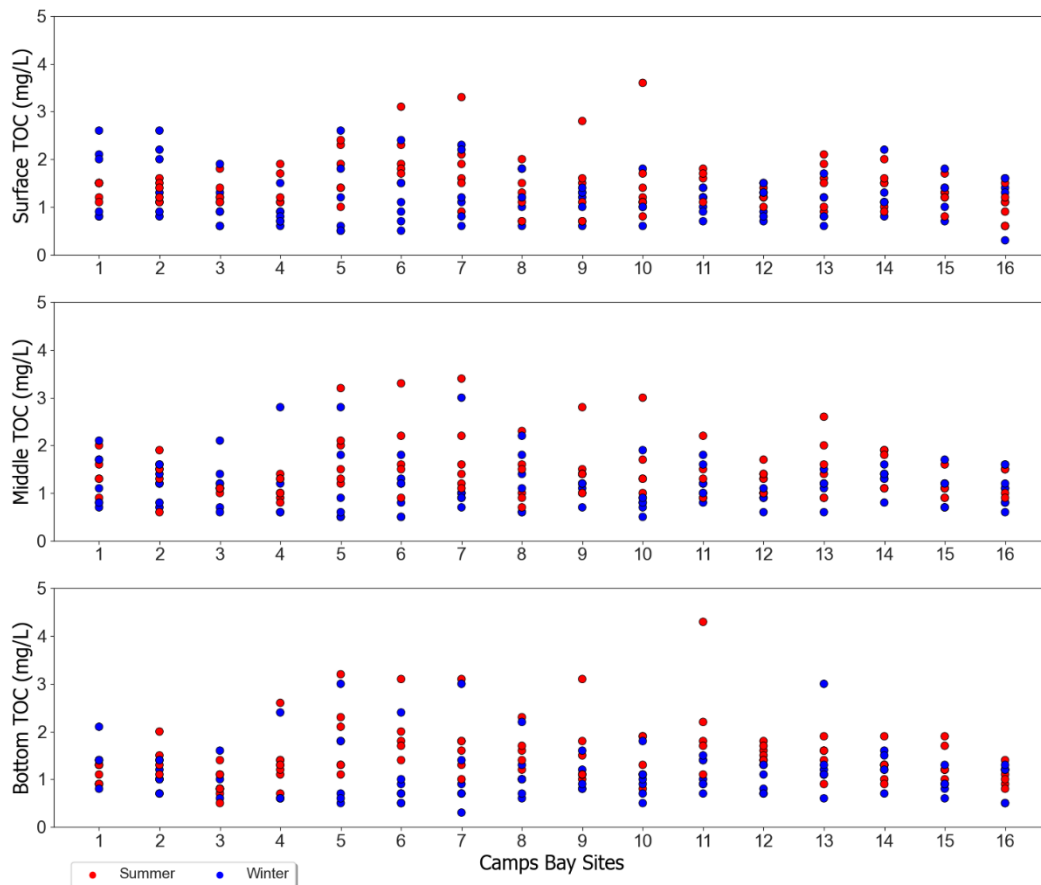


Figure 5.14: Seasonal distribution of total organic carbon (mg/L) measured at surface, mid- and bottom depths at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys.

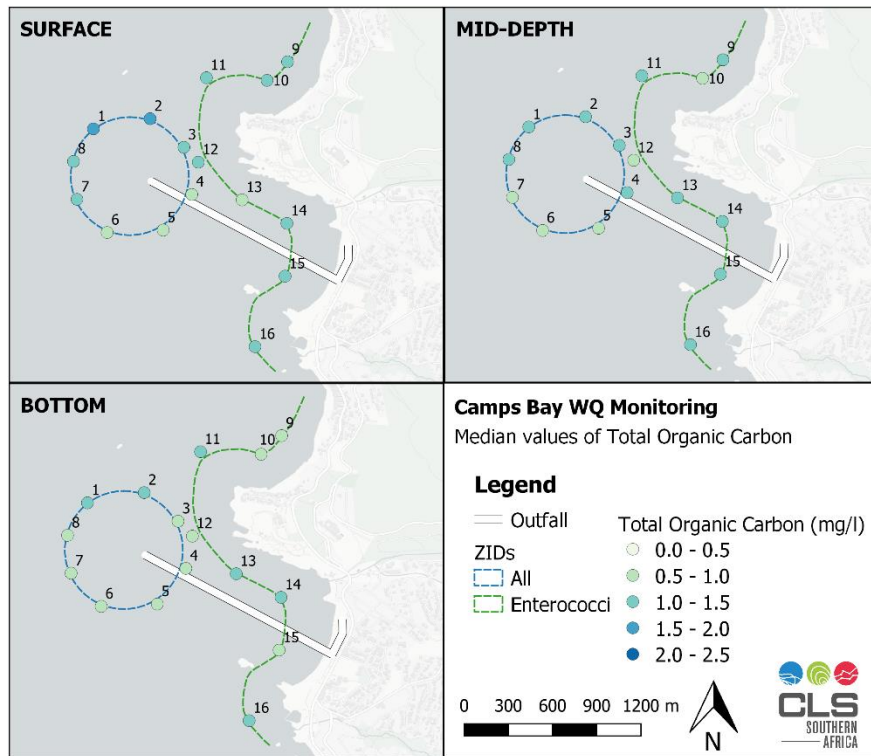


Figure 5.15: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 winter survey.

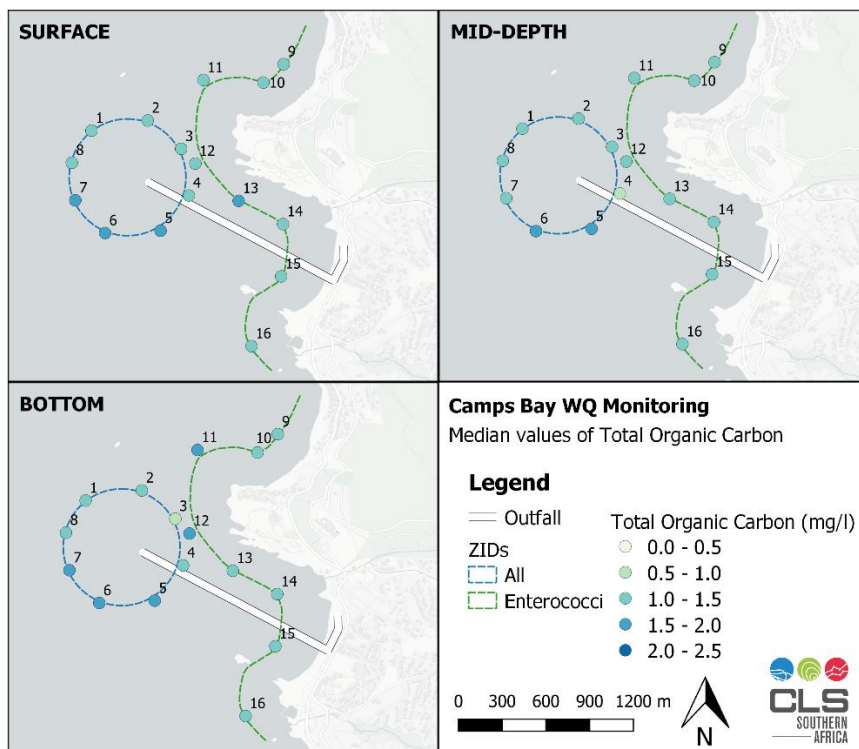


Figure 5.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Camps Bay outfall sites during the 2022 summer survey.

5.4.4 Orthophosphate

Orthophosphate concentrations were mostly lower during the winter survey period than the summer survey period at all depths (Figure 5.17, Figure 5.18 and Figure 5.19). Individual measurements ranged between 11 and 80 µg/L in winter and <5 and 74 µg/L in summer (excluding the 2022 summer week 1 results). Both seasons displayed high inter-week variation.

During winter, median concentrations were elevated (>70 µg/L) at sites CB1, CB5, CB7 and CB8 in bottom waters (Figure 5.19). These sites are located at the edge of the mixing zone.

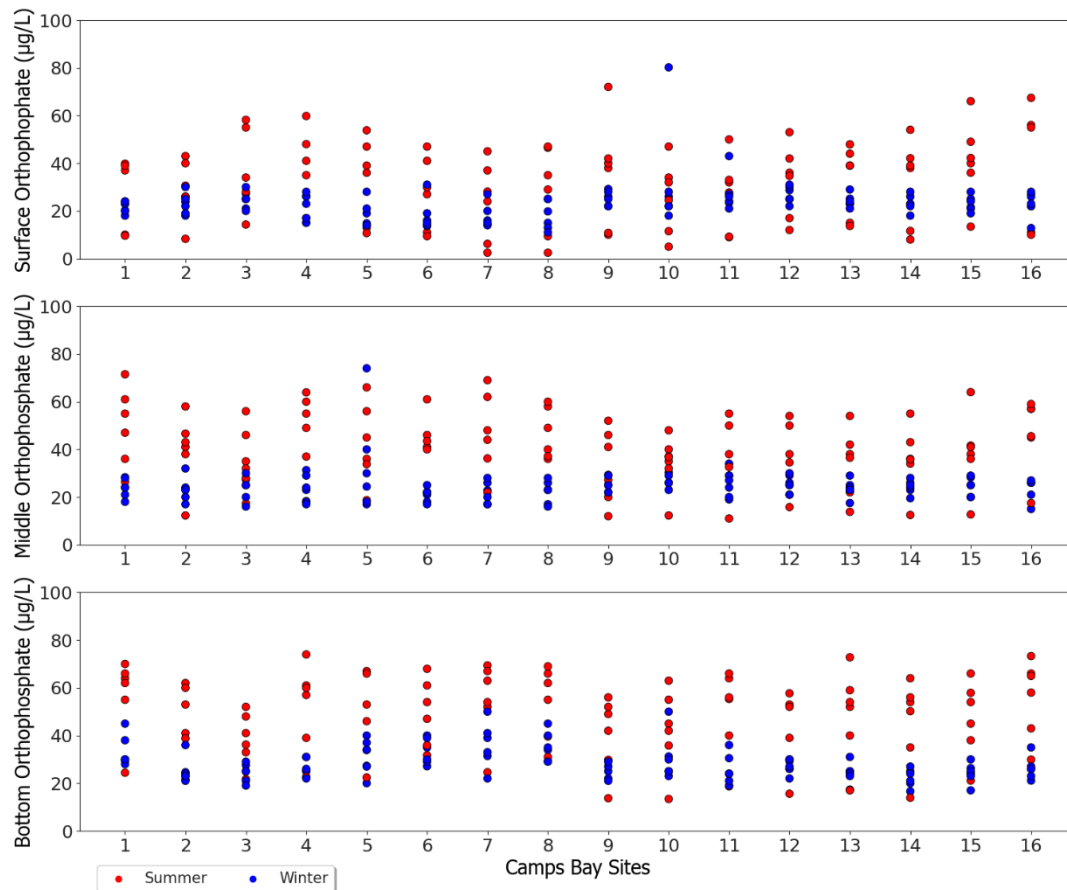


Figure 5.17: Seasonal distribution of orthophosphate (µg/L) measured at the surface, mid- and bottom depths at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

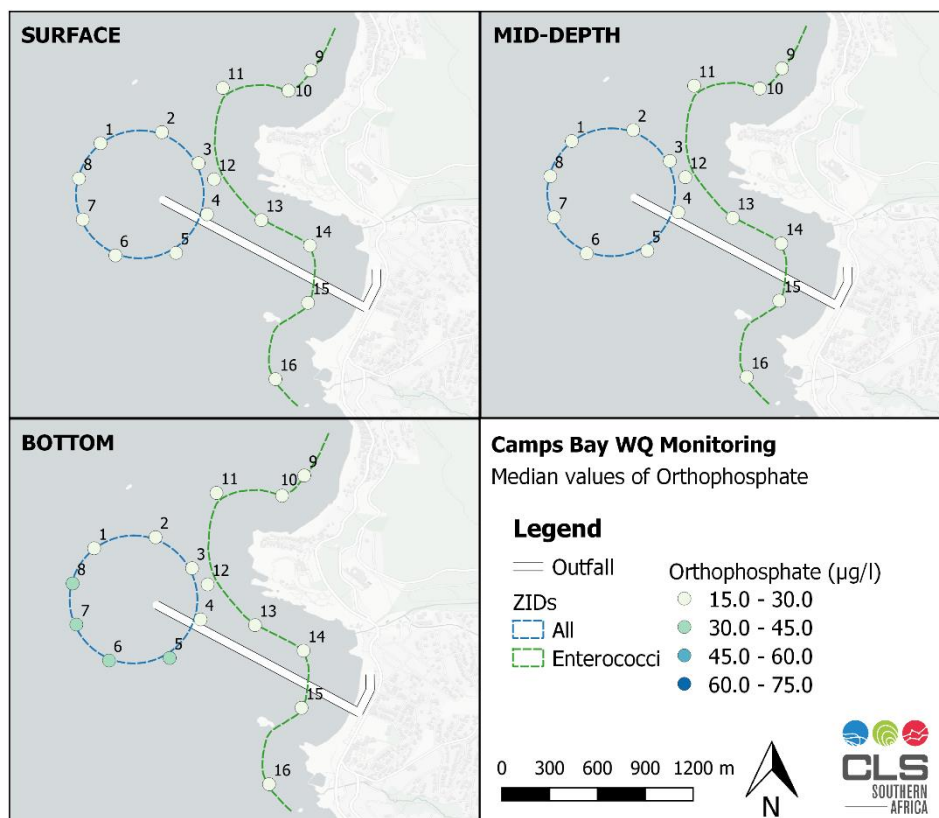


Figure 5.18: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall during the 2021 winter survey.

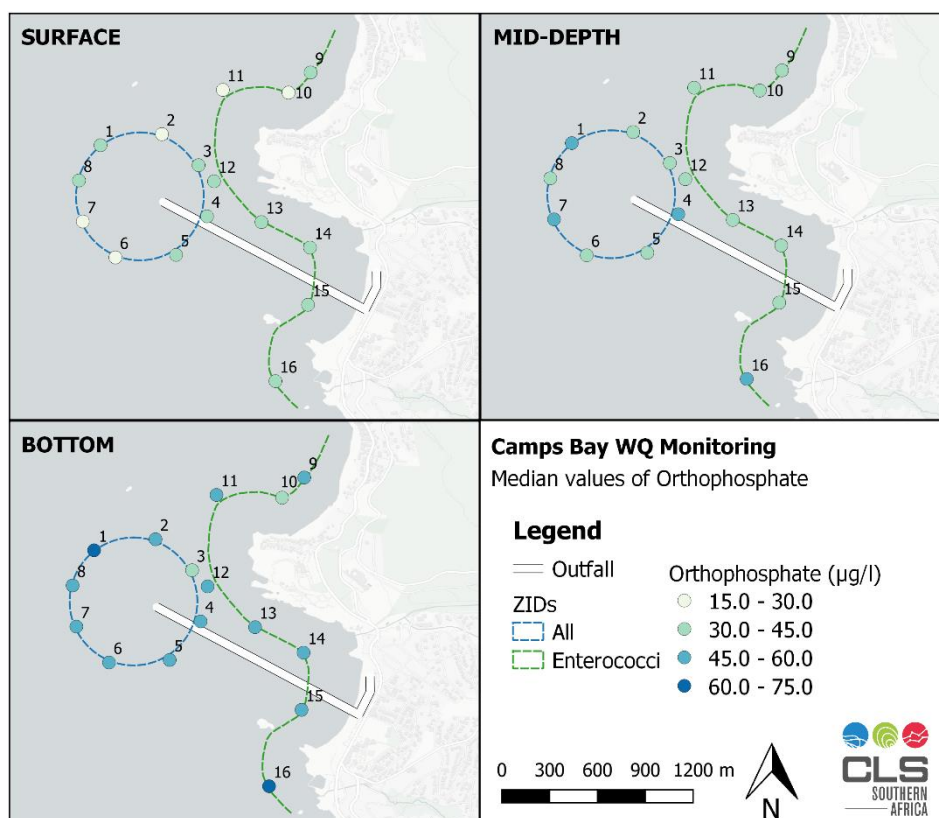


Figure 5.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall during the 2022 summer survey.

Orthophosphate concentrations at all depths in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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 (µg/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	20	23	29
Mean	20	24	30
Summer			
n	42	42	42
Median	32	43	53
Mean	32	43	49

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 5.20, Figure 5.21 and Figure 5.22). Concentrations ranged between <5 and 73 µg/L in winter and <5 and 48 µg/L in summer. The highest concentration was recorded in surface waters at site CB2 (141 µg/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 µg/L, Table 3.1).

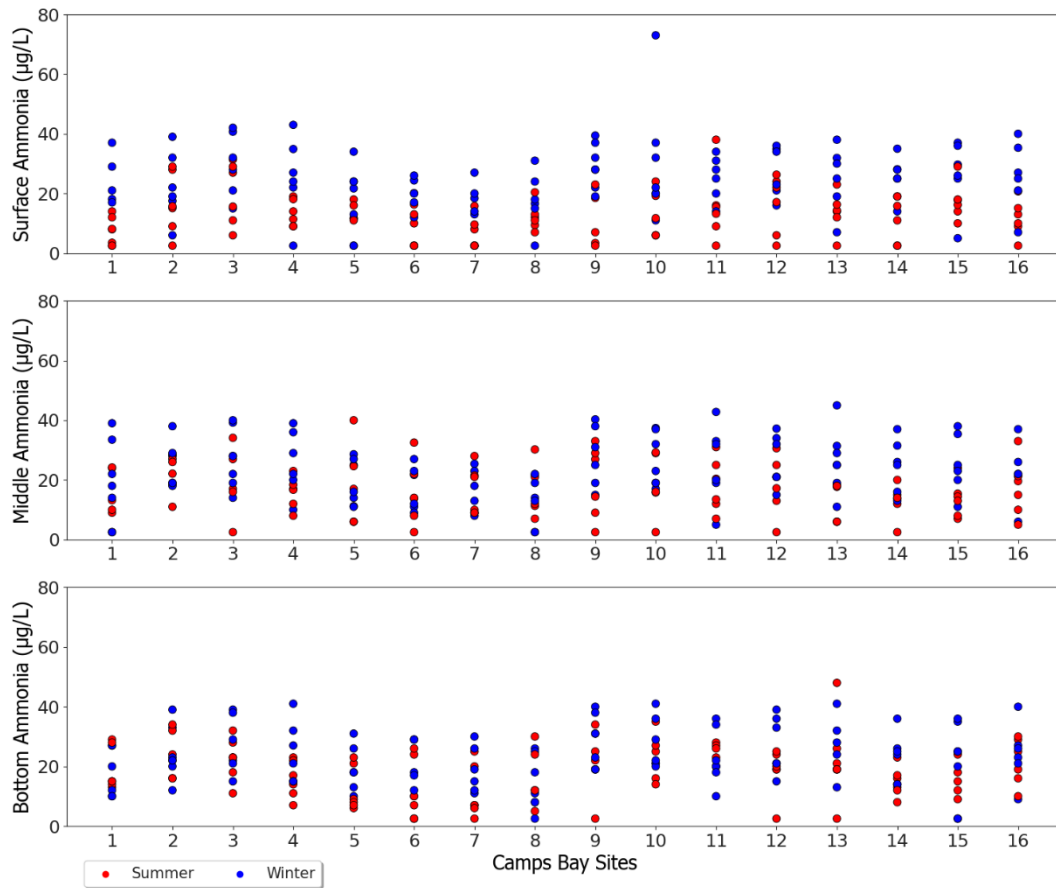


Figure 5.20: Seasonal distribution of ammonia ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Camps Bay outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2.

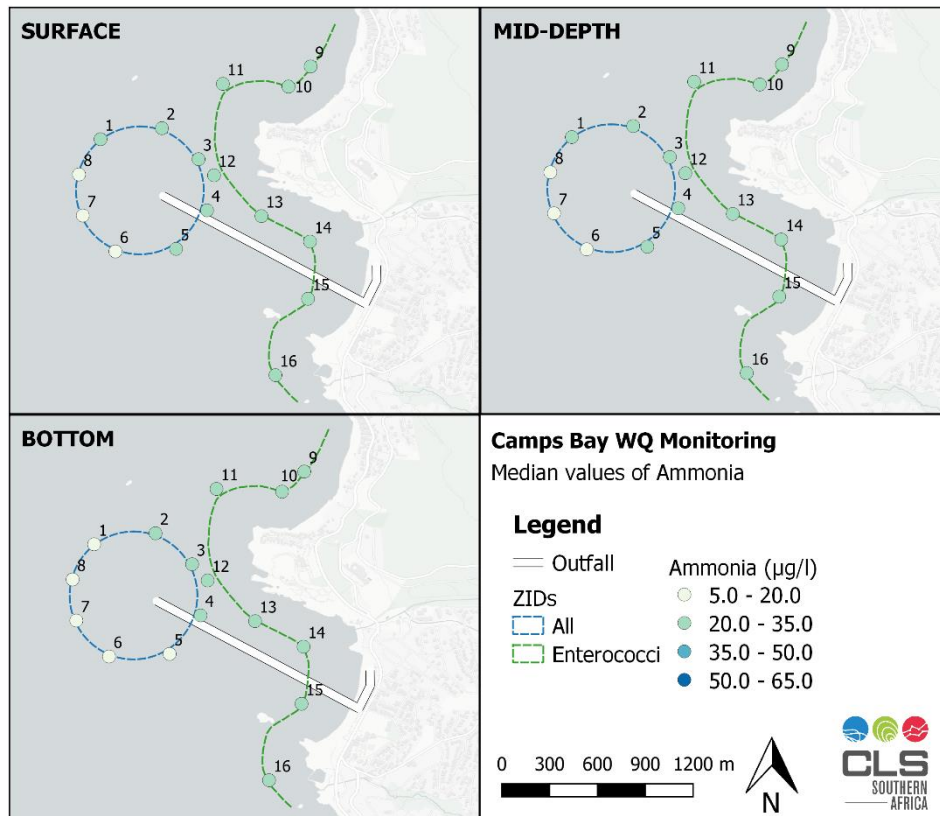


Figure 5.21: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall sites during the 2021 winter survey.

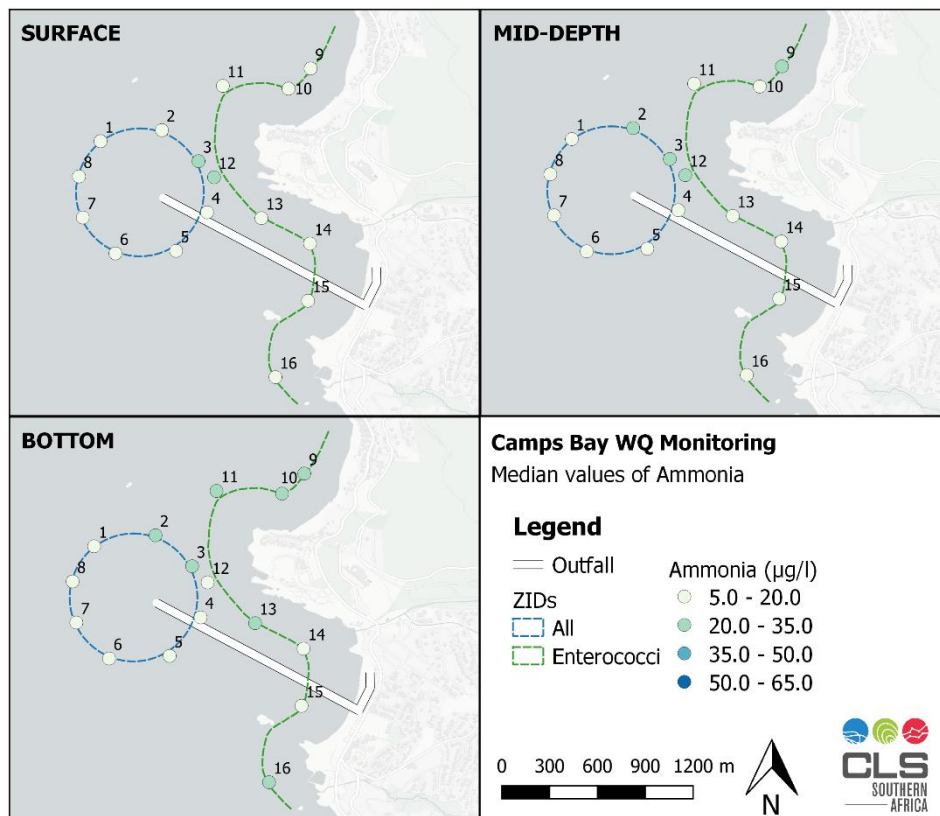


Figure 5.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Camps Bay outfall sites during the 2022 summer survey.

Ammonia concentrations in the nearfield of the discharge, represented by measurements from sites CB2, CB3, CB4, CB5, CB6, CB7 and CB8, 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 Ammonia (mg/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	22	22	21
Mean	24	21	22
summer			
n	42	42	42
Median	13	17	7
Mean	15	19	17

5.4.6 Toxicity

The two nearshore sites sampled during the third 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 2021) and summer (March-April 2022) 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	02/09/2021	CB-TT1	99	100	99	99	99.25	0.50	Not toxic
		CB-TT2	100	100	99	99	99.50	0.58	Not toxic
	07/09/2021	CB-TT1	100	100	98	99	99.25	0.96	Not toxic
		CB-TT2	100	100	99	99	99.50	0.58	Not toxic
	08/09/2021	CB-TT1	100	100	99	99	99.50	0.58	Not toxic
		CB-TT2	100	99	99	99	99.25	0.50	Not toxic
	09/09/2021	CB-TT1	100	100	99	99	99.50	0.58	Not toxic
		CB-TT2	99	100	99	98	99.00	0.82	Not toxic
	14/09/2021	CB-TT1	99	99	99	99	99.00	0.00	Not toxic
		CB-TT2	100	100	99	99	99.50	0.58	Not toxic
	15/09/2021	CB-TT1	100	100	99	99	99.50	0.58	Not toxic
		CB-TT2	100	100	99	99	99.50	0.58	Not toxic
Echinometra mathaei									
Summer	24/03/2022	CB-TT1	100	100	99	99	99.50	0.58	Not toxic
		CB-TT2	100	99	99	99	99.25	0.50	Not toxic
	27/03/2022	CB-TT1	100	99	99	99	99.25	0.50	Not toxic
		CB-TT2	100	100	99	99	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 2021 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 zinc with a greater average loss (relative to baseline levels) observed during winter than summer. Significant differences between impact and control stations were observed in the summer 2022 deployment for Camps Bay, with impact sites having greater loss of zinc concentration compared to the control samples. There was no evidence of seasonal differences in copper or zinc accumulation during the winter and summer deployments. Mussels at all locations accumulated copper and zinc 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 28 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 2021) and summer (March-April 2022) monitoring periods.

For the purposes of the initial survey design, the CCT estimated the allowable zone of initial dilution (ZID) at the Green Point outfall to be within a 256 m radius from the diffuser, based on the 300 m recommendation for offshore discharges in Anchor 2015. 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) 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.

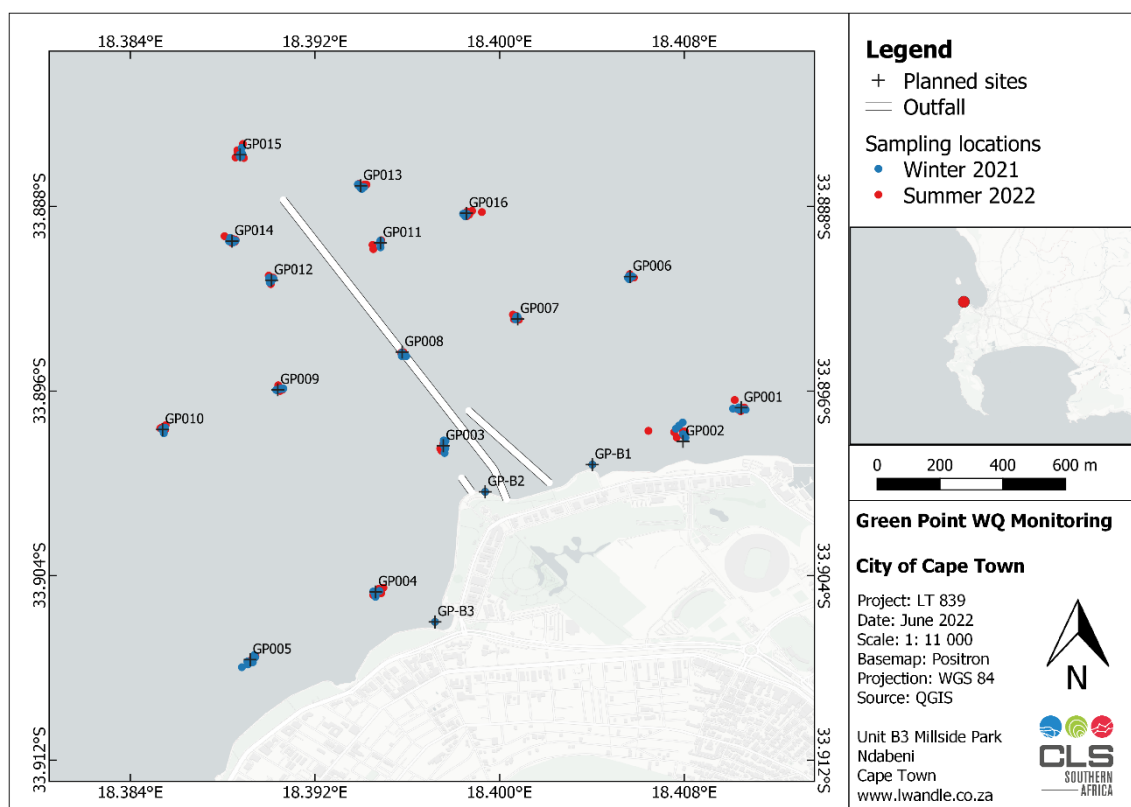


Figure 6.1: Map showing the Green Point outfall and the locations of nearshore and beach (GP-B1, GP-B2 and GP-B3) sites sampled during the winter (August-September 2021) and the summer (March-April 2022) monitoring periods.

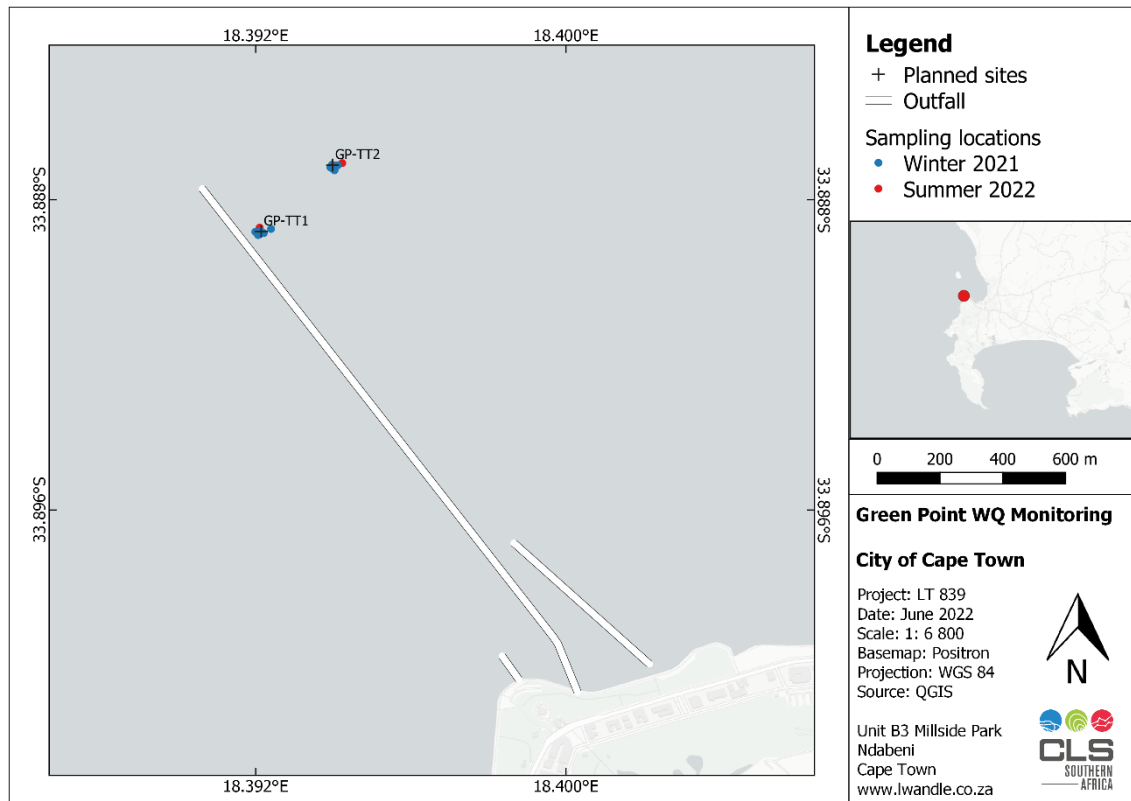


Figure 6.2: Map showing the Green Point outfall and the locations of the toxicity sites sampled during the winter (August-September 2021) and the summer (March-April 2022) monitoring periods.

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 and bottom depths. This is characteristic of the seasonal upwelling in the region. Water column temperatures ranged between 9.60 and 17.40 °C in winter and 10.76 and 14.28 °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.

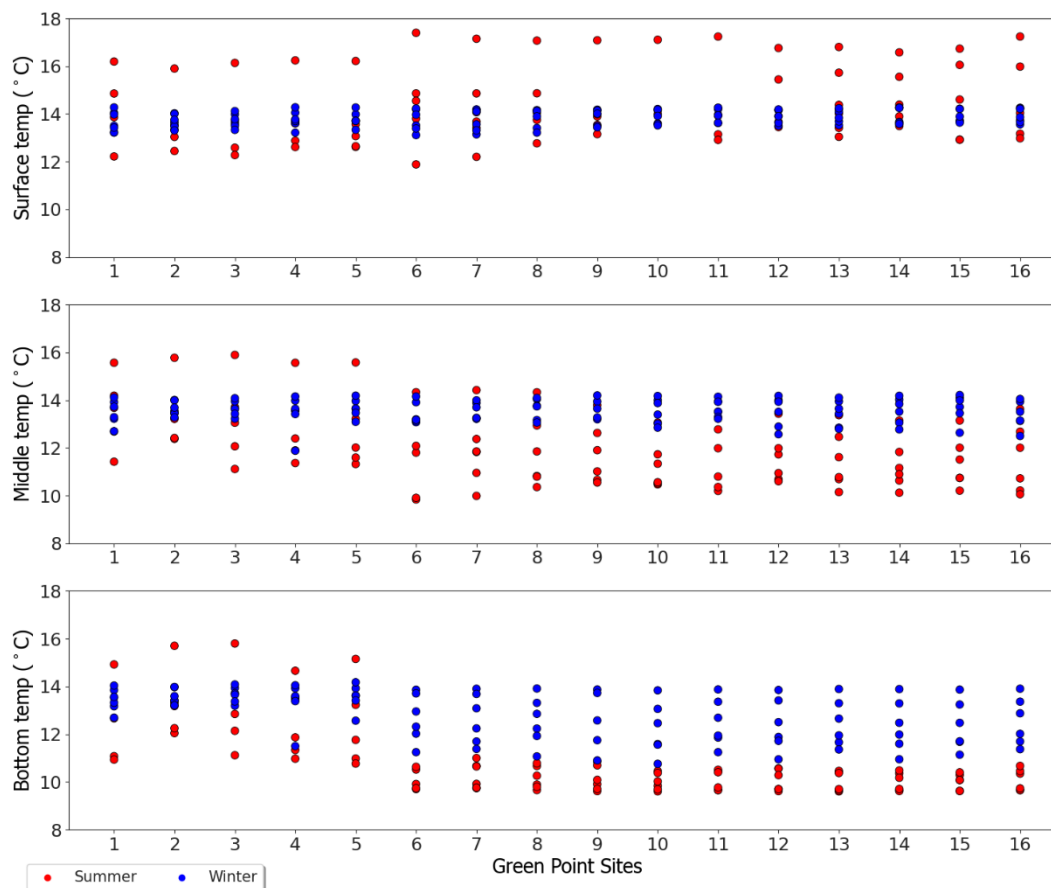


Figure 6.3: Seasonal distribution of temperature (°C) measured at the Green Point outfall sites during the 2021 winter and 2022 summer surveys.

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	285	587	648
Median	14.01	13.88	12.72
Mean	13.91	13.70	12.73
Summer			
n	280	592	657
Median	13.54	11.83	10.28
Mean	13.92	11.97	10.33

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 33.78 and 35.26 PSU and 34.48 and 34.80 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.

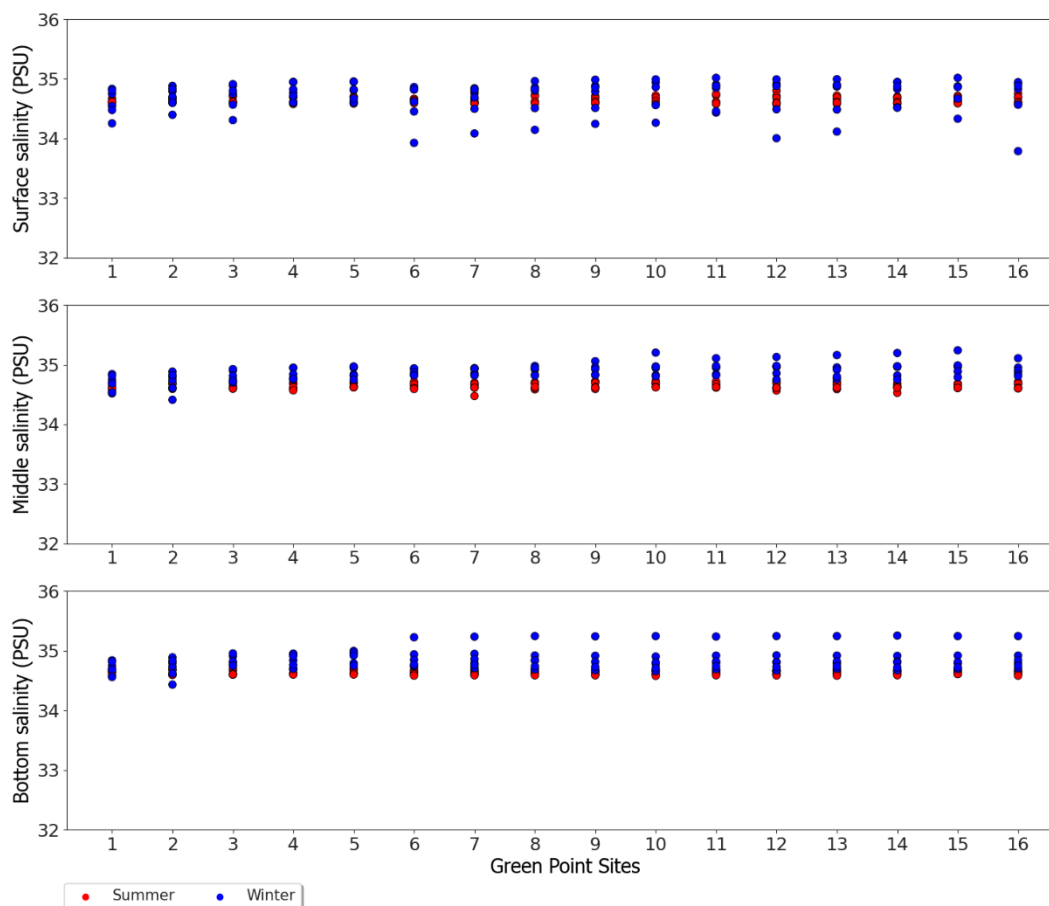


Figure 6.4: Seasonal distribution of salinity (PSU) measured at the Green Point outfall sites during the 2021 winter and 2022 summer surveys.

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	285	587	648
Median	34.89	34.95	34.84
Mean	34.84	34.93	34.90
Summer			
n	280	592	657
Median	34.66	34.62	34.63
Mean	34.66	34.65	34.64

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 0.17 and 59.21 FNU and 0.15 and 21.10 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.

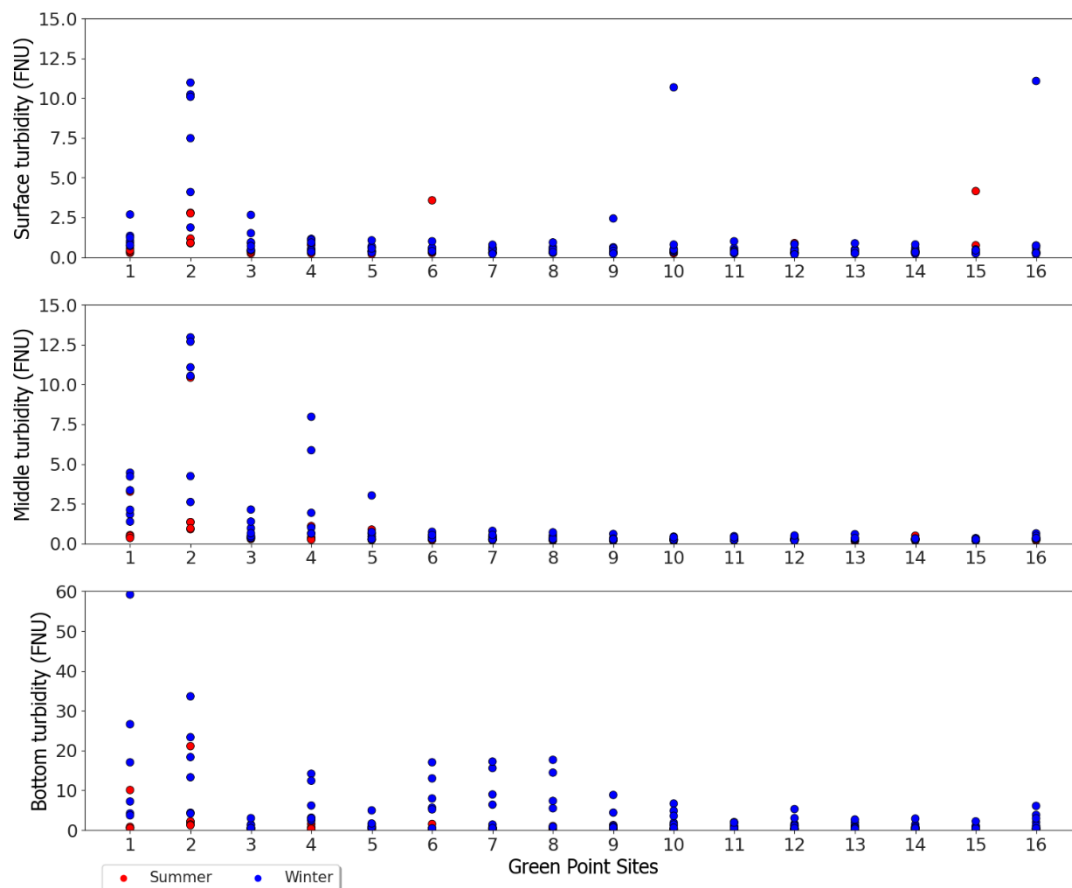


Figure 6.5: Seasonal distribution of turbidity (FNU) measured at the Green Point outfall sites during the 2021 winter and 2022 summer surveys. Note that the bottom depth plot has a different scale on the y-axis to aid presentation.

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	285	587	648
Median	0.33	0.30	0.51
Mean	0.58	0.36	0.80
Summer			
n	280	592	657
Median	0.27	0.25	0.27
Mean	0.28	0.26	0.31

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 7.91 and 8.20 in the winter and between 7.30 and 7.88 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.

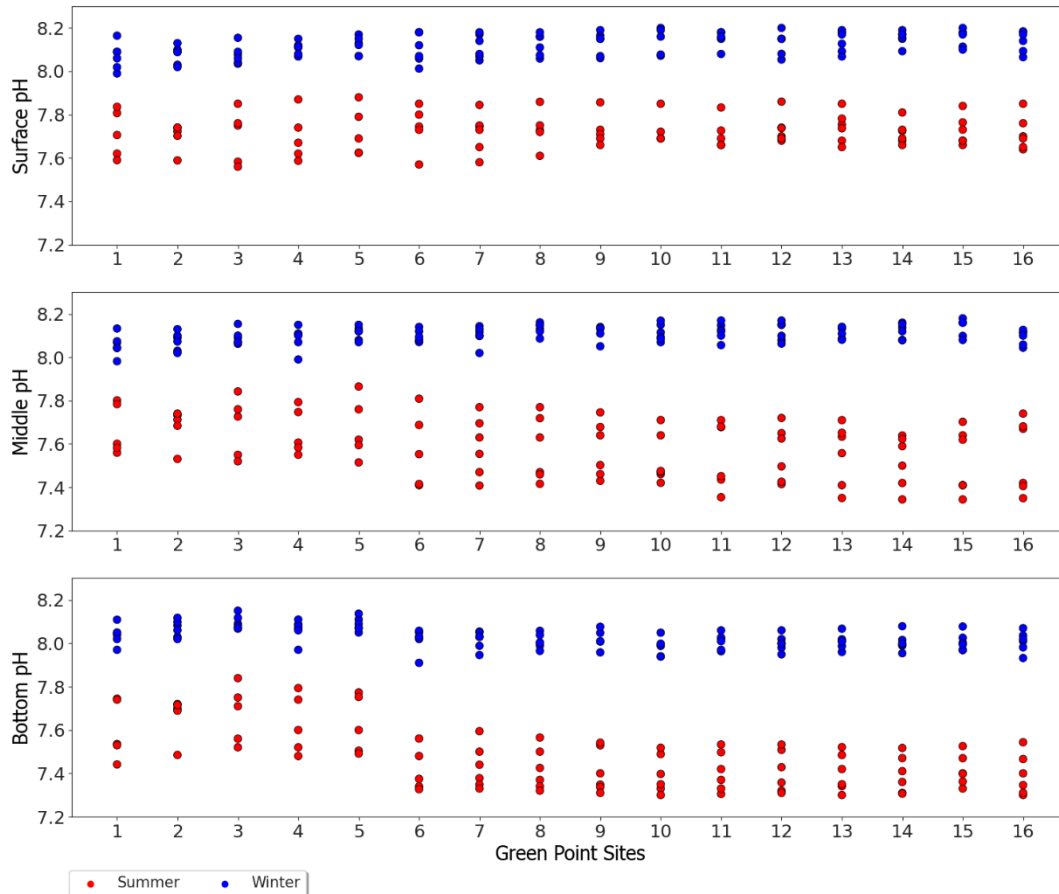


Figure 6.6: Seasonal distribution of pH measured at the Green Point outfall sites during the 2021 winter and 2022 summer surveys.

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). 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 6.4: 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	285	587	648
Median	8.16	8.14	8.04
Mean	8.15	8.13	8.04
Summer			
n	280	592	657
Median	7.69	7.62	7.42
Mean	7.71	7.59	7.44

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 5.37 and 9.29 mg/L and 1.67 and 10.33 mg/L in winter and summer respectively (Figure 6.7). The lowest concentrations were recorded at the bottom during the summer survey at site GP10. 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 first and second annual report.

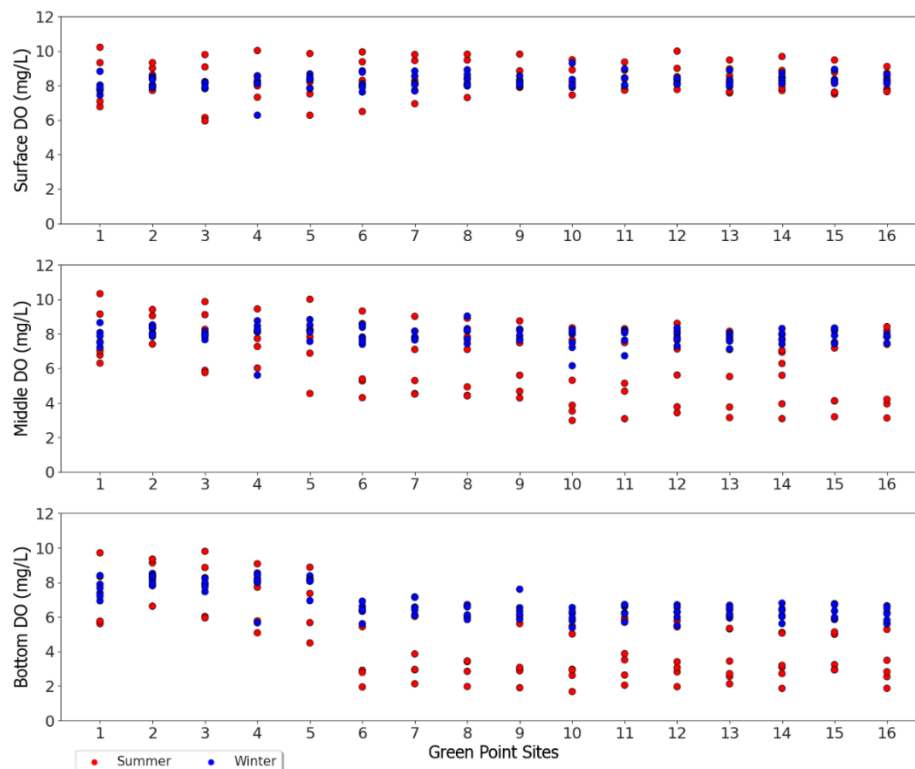


Figure 6.7: Seasonal distribution of dissolved oxygen (mg/L) measured at the Green Point outfall sites during the 2021 winter and 2022 summer surveys.

Dissolved oxygen 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

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	285	587	648
Median	8.33	8.11	6.74
Mean	8.36	8.08	6.77
Summer			
n	280	592	657
Median	7.96	7.08	3.69
Mean	8.22	6.53	4.43

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 5 000 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 GP7 in mid depth waters, GP11 in surface waters and at GP13 in both surface and mid-depth waters (Figure 6.9). During summer, exceedances were recorded at sites GP11, GP12, GP14 and GP15 at mid depth waters (Figure 6.10). Similar patterns of exceedance were observed in the previous two annual reports.

The 90th percentile values at beach sites GP-B1, GP-B2 and GP-B3 exceeded the recommended guideline during winter (Figure 6.10). During summer site the 90th percentile values for site GP-B3 was particularly high at 13 000 cfu/100 mL. Site GP-B3, located at Three Anchor Bay, recorded exceedances of the recommended guideline during both seasons in previous two annual reports.

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

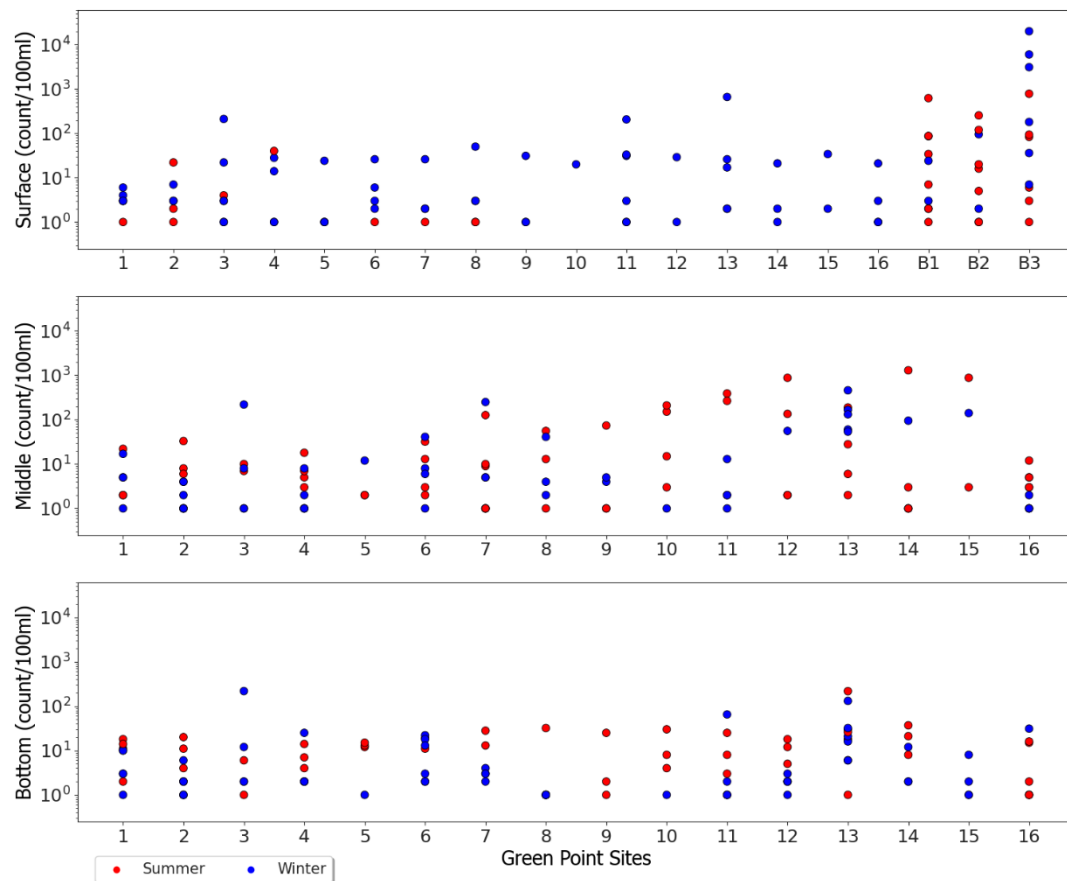


Figure 6.8: Seasonal distribution of enterococci (cfu/100 mL) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2021 winter and 2022 summer surveys.

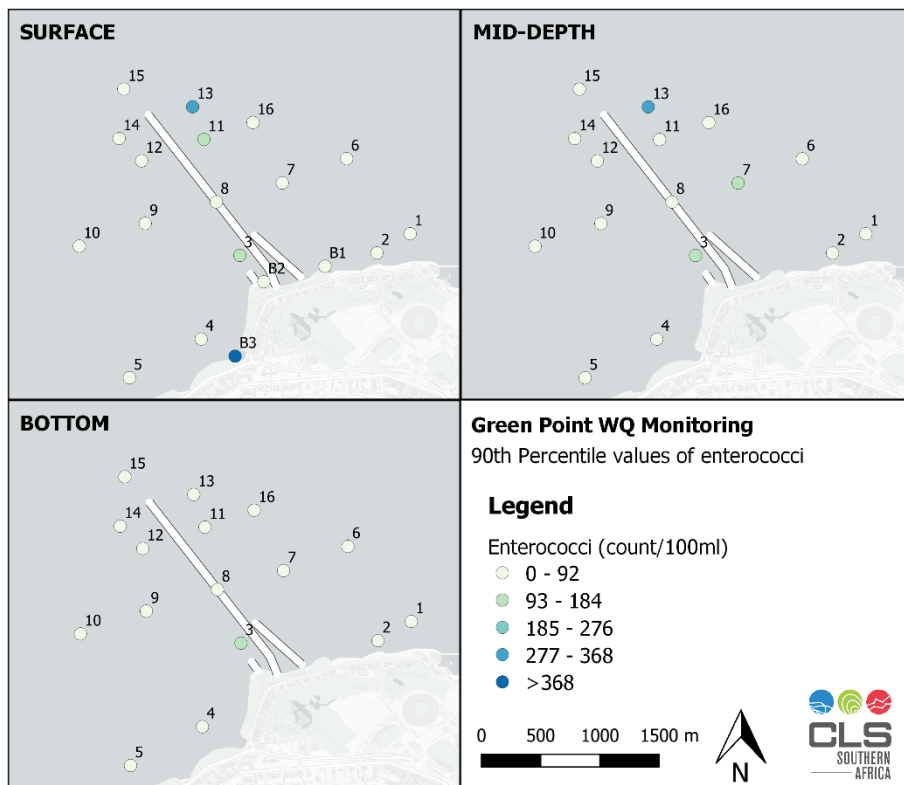


Figure 6.9: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Green Point outfall sites during the 2021 winter survey. The beach sites are included in the surface plot (B1, B2 and B3).

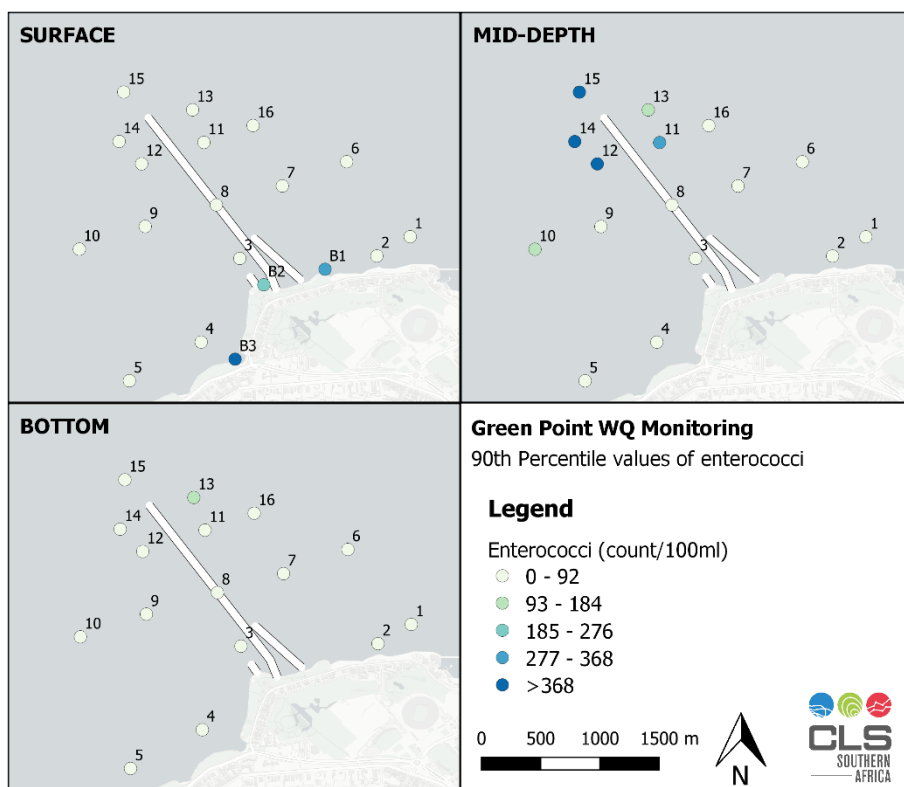


Figure 6.10: Map showing the 90th percentile values of enterococci (cfu/100 mL) at the surface, middle and bottom at the Green Point outfall sites during the 2022 summer survey. The beach sites are included in the surface plot (B1, B2 and B3).

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 at GP2 and GP4 at all depths and GP1 and GP6 in bottom-depth waters. The largest outlier was recorded at site GP2 with a concentration of 116 mg/L in bottom waters during week 6 (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). This is consistent with the findings in the year one and two annual reports. In the summer survey, median concentrations were mostly below 8 mg/L with the exceptions of site GP2 in mid and bottom waters (Figure 6.13).

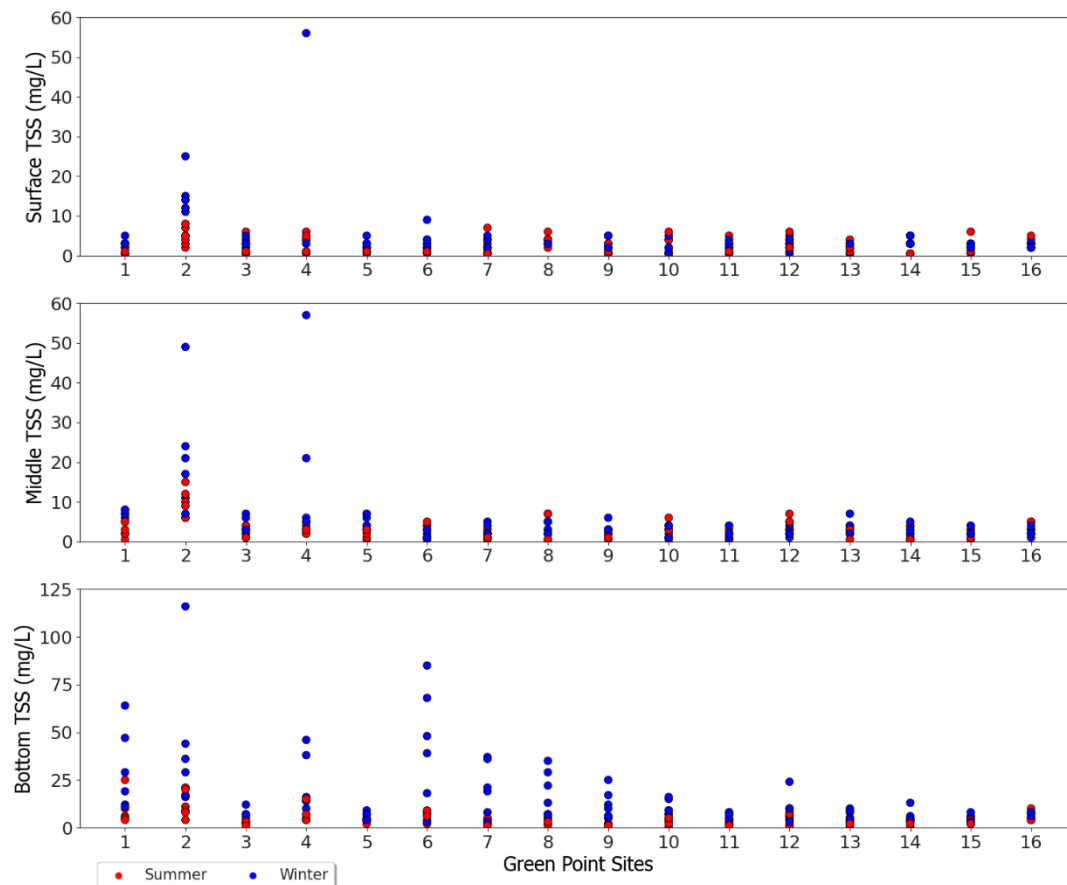


Figure 6.11: Seasonal distribution of suspended solids (mg/L) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <1) are presented as MDL/2. The bottom plot has a difference scale on the y axis to aid presentation.

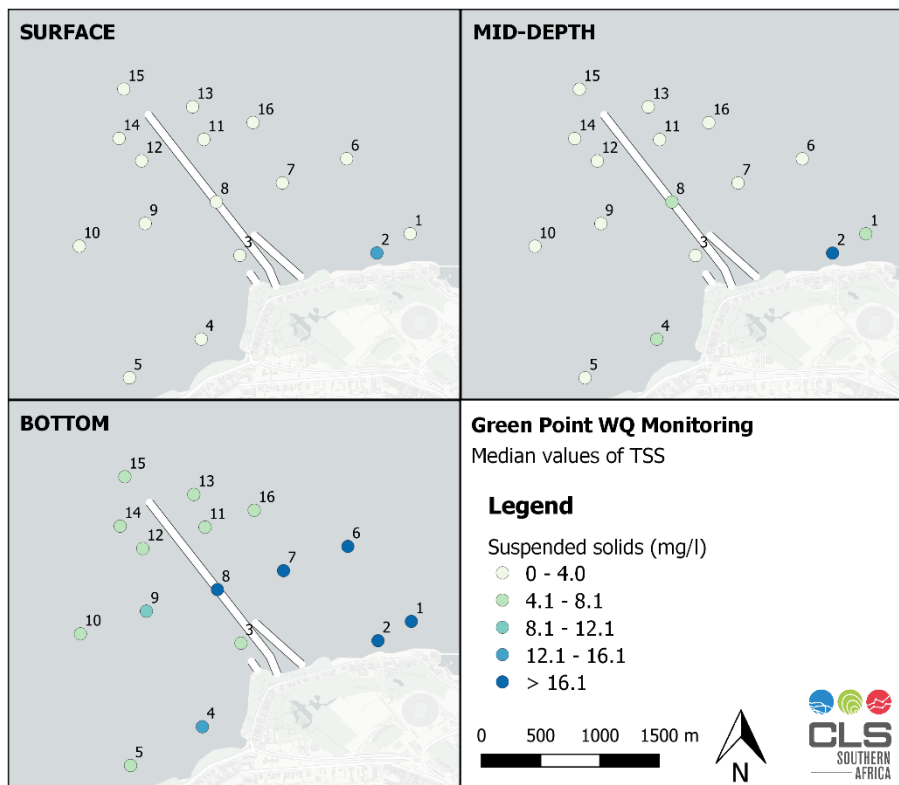


Figure 6.12: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2021 winter survey.

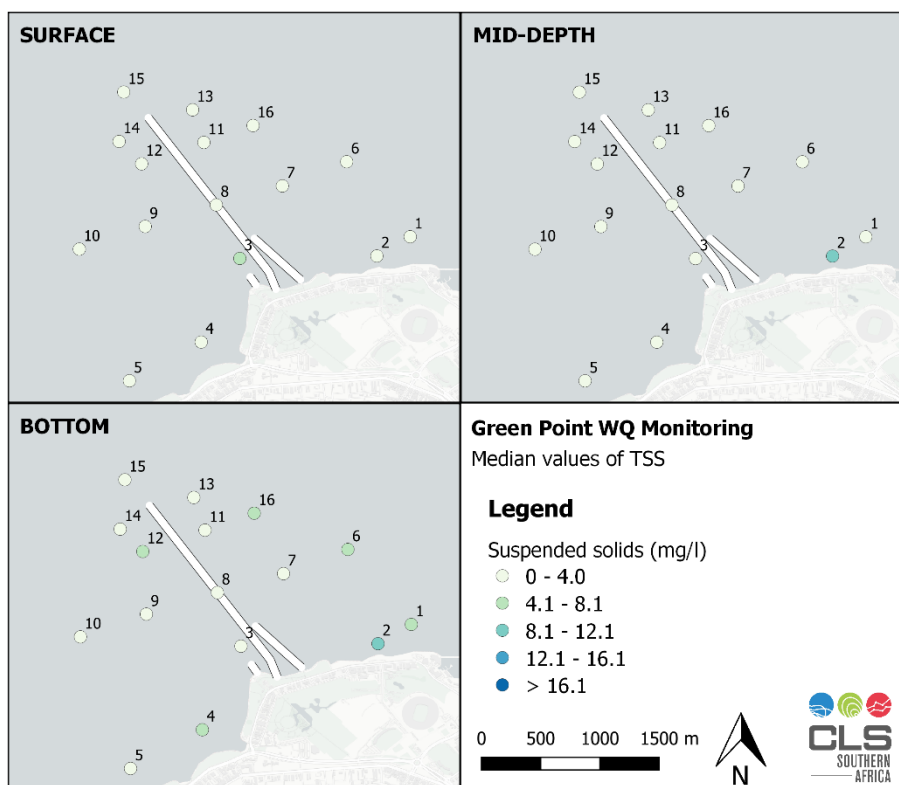


Figure 6.13: Map showing the median concentration of total suspended solids (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2022 summer survey.

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	3	3	7
Mean	3	3	7
Summer			
n	30	30	30
Median	3	3	4
Mean	3	3	4

6.4.3 Total Organic Carbon

No clear seasonal pattern was evident 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 0.6 and 6.1 mg/L during the winter survey and 0.6 and 3.7 mg/L during the summer survey (Figure 6.17). Both the winter and summer survey had high inter-week variation.

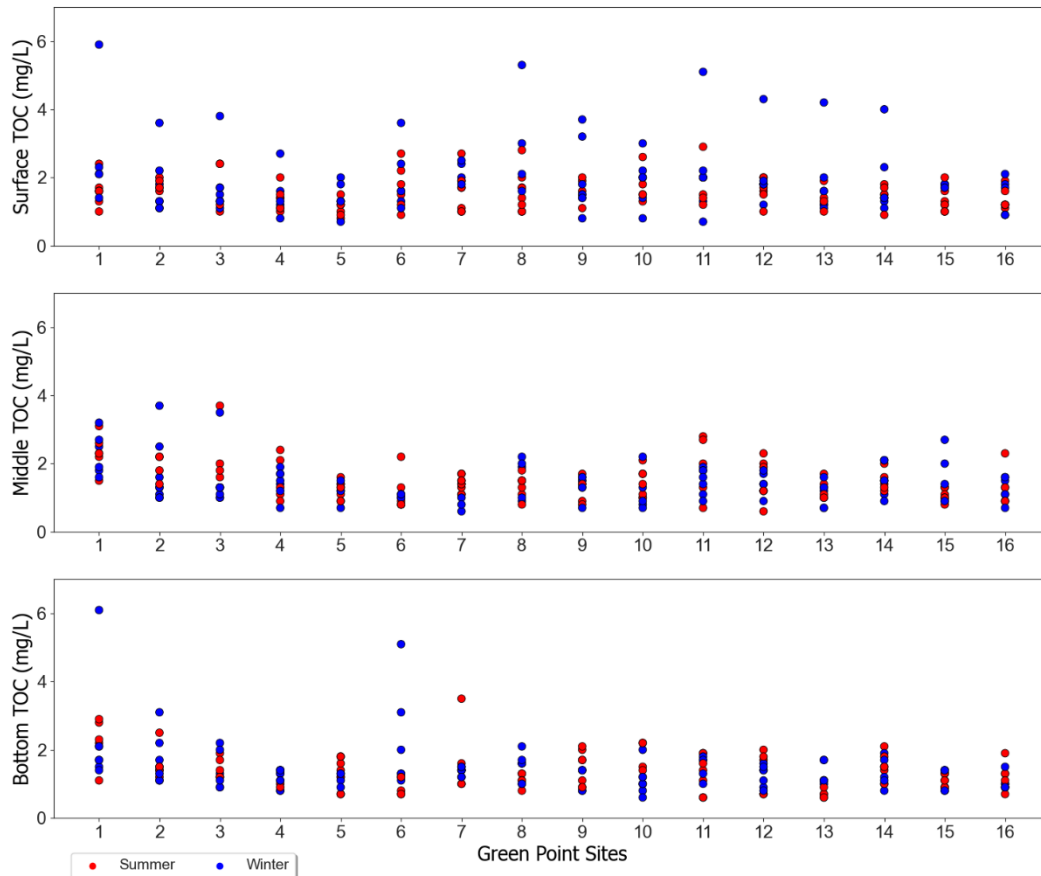


Figure 6.14: Seasonal distribution of total organic carbon (mg/L) measured at surface, mid- and bottom depths at the Green Point outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <0.5 mg/L) are presented as MDL/2.

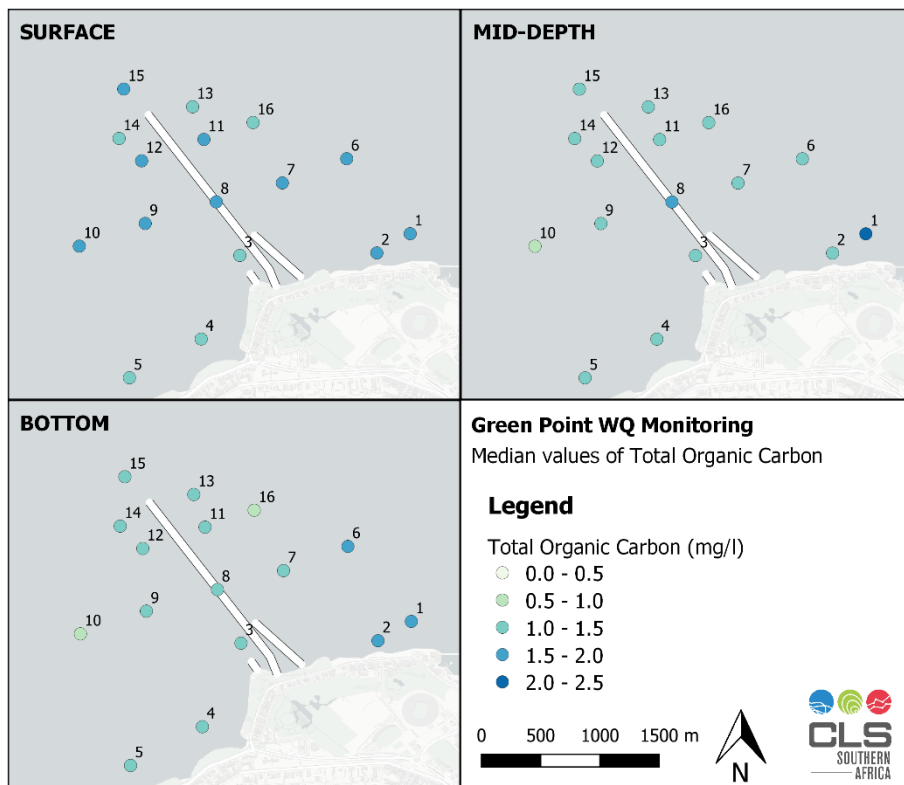


Figure 6.15: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2021 winter survey.

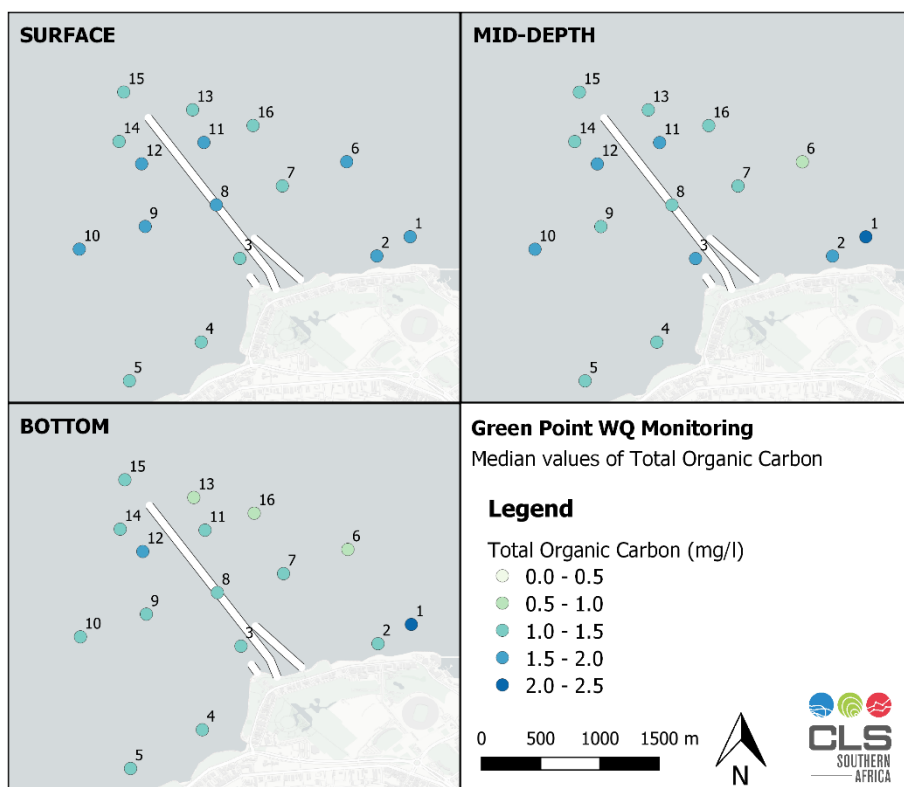


Figure 6.16: Map showing the median concentration of total organic carbon (mg/L) at the surface, middle and bottom at the Green Point outfall sites during the 2022 summer survey.

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 96 µg/L in winter and <5 and 174 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 concentrations were elevated in mid-depth and bottom waters at most sites (Figure 6.18).

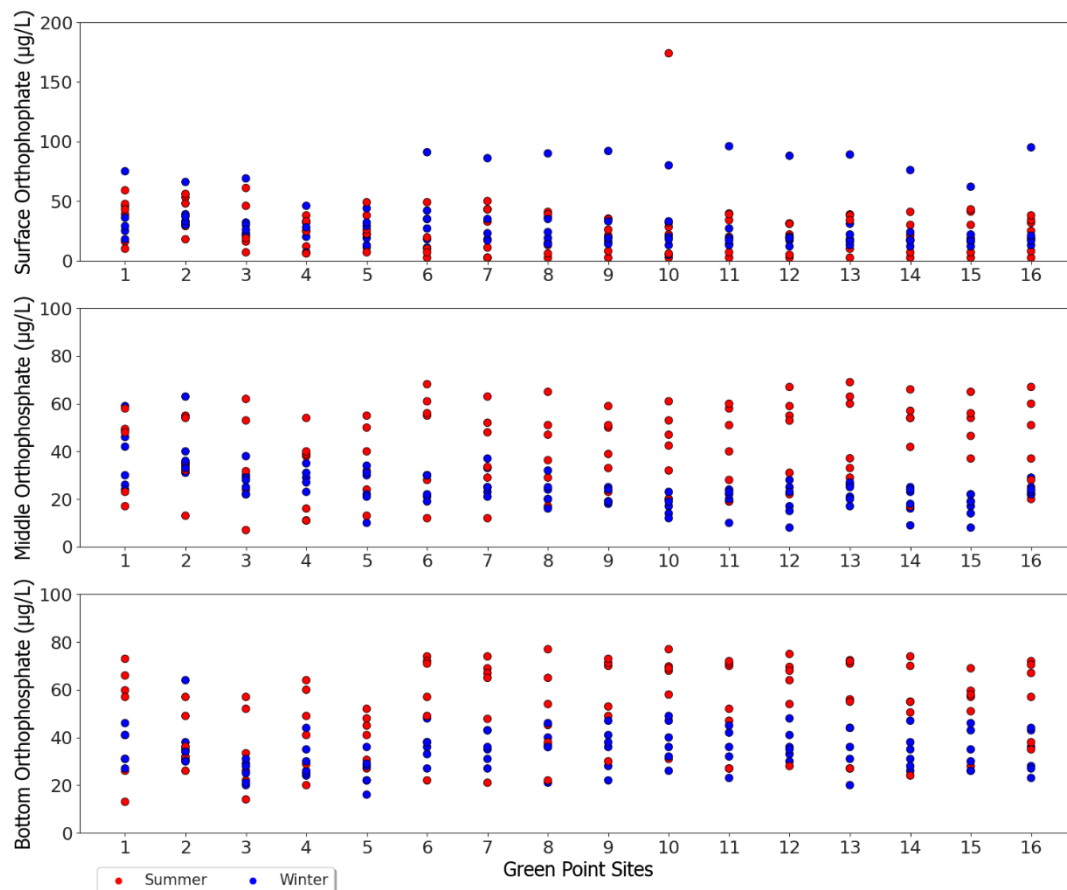


Figure 6.17: Seasonal distribution of orthophosphate (µg/L) measured at the surface, mid- and bottom depths at the Green Point outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2. The surface plot has a difference scale on the y axis to aid presentation.

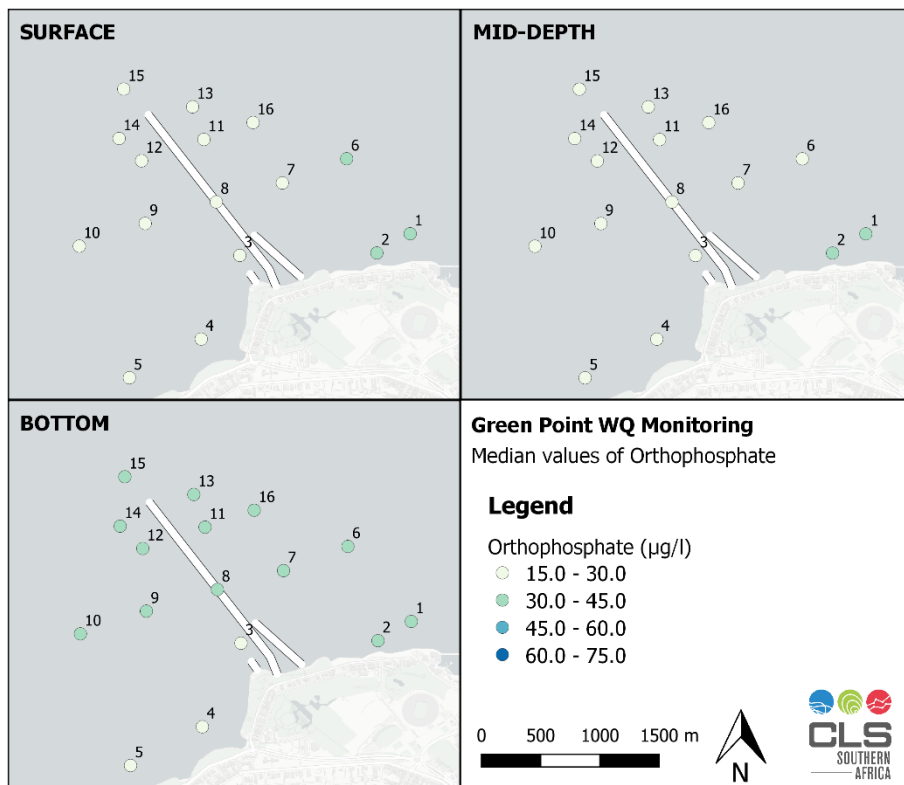


Figure 6.18: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall during the 2021 winter survey.

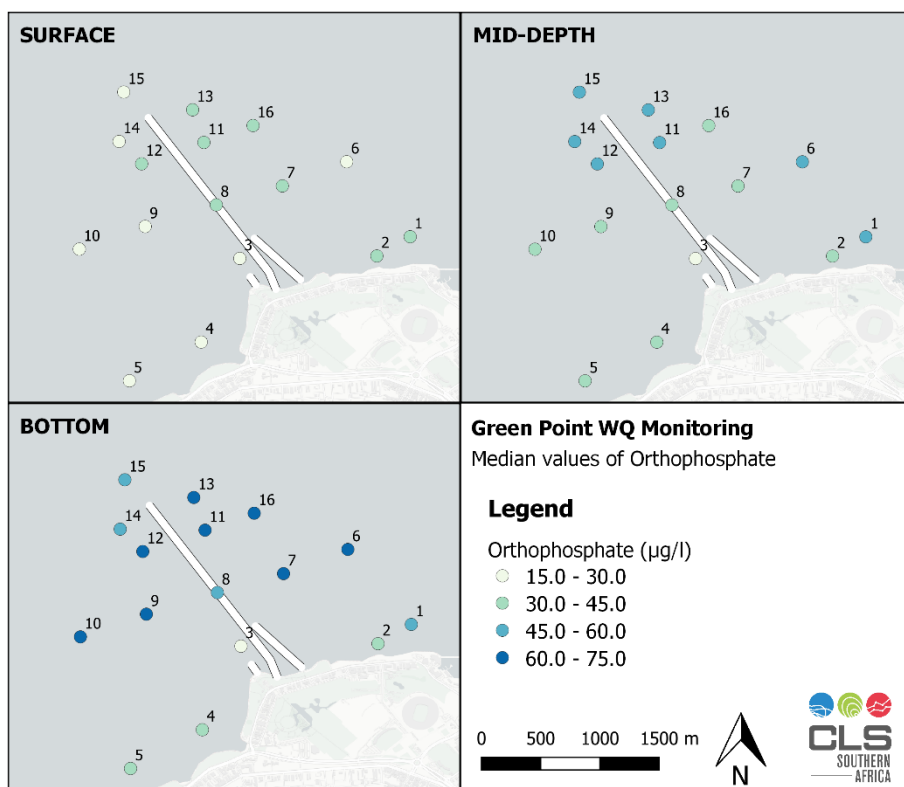


Figure 6.19: Map showing the median concentration of orthophosphate ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall during the 2022 summer survey.

Orthophosphate values at all depths in the nearfield water body, represented by median 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	19	23	21
Mean	30	21	35
Summer			
n	30	30	30
Median	31	52	61
Mean	26	46	57

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). The range of measurements was between <5 ug and 201 µg/L in winter and <5 ug and 217 µg/L in summer.

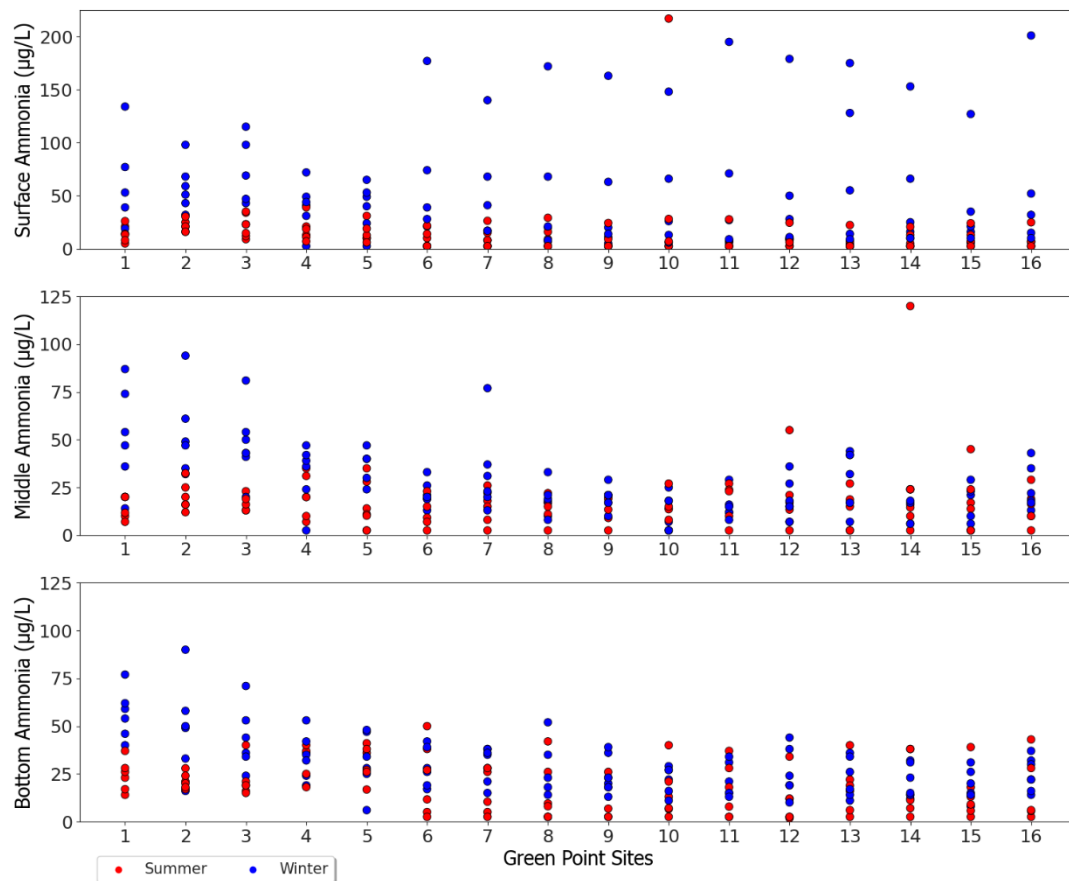


Figure 6.20: Seasonal distribution of ammonia ($\mu\text{g/L}$) measured at the surface, mid- and bottom depths at the Green Point outfall sites during the 2021 winter and 2022 summer surveys. Note: values below the minimum detection limit (MDL, <5) are presented as MDL/2. The surface plot has a difference scale on the y axis to aid presentation.

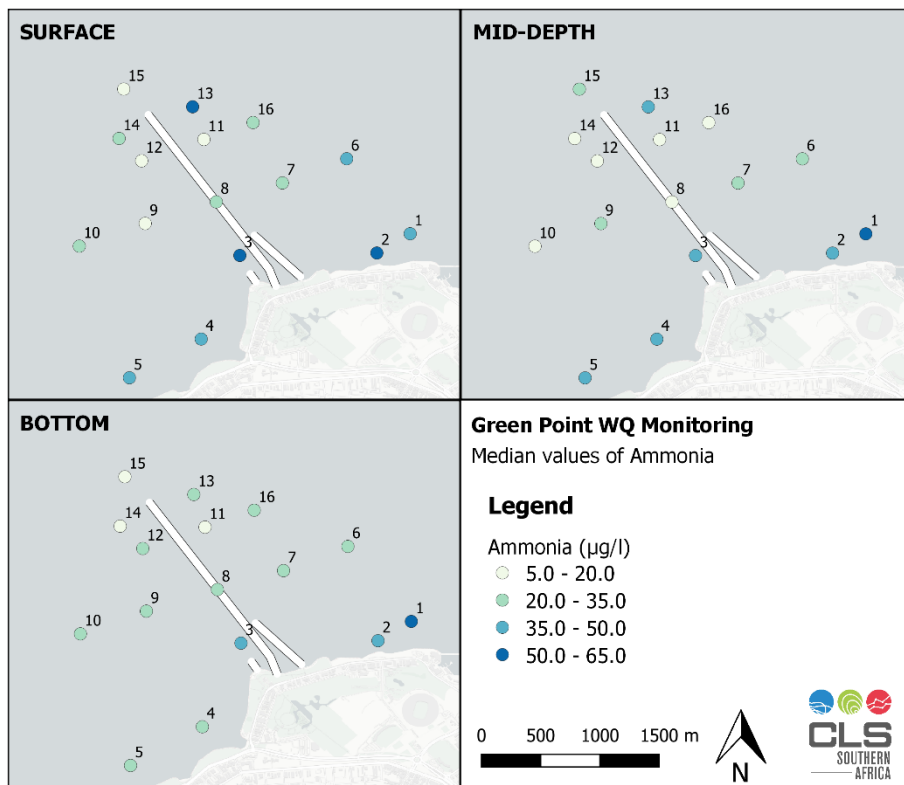


Figure 6.21: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall sites during the 2021 winter survey.

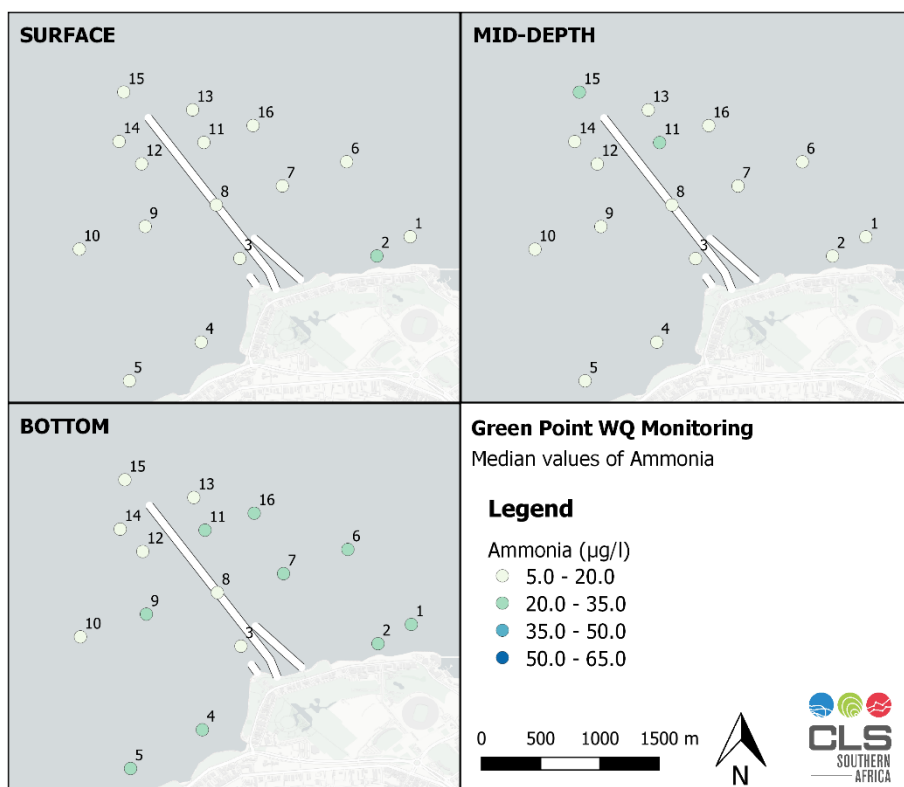


Figure 6.22: Map showing the median concentration of ammonia ($\mu\text{g/L}$) at the surface, middle and bottom at the Green Point outfall sites during the 2022 summer survey.

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	26	18	22
Mean	56	21	23
Summer			
n	30	30	30
Median	8	17	19
Mean	13	23	21

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 2021) and summer (March-April 2022) 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	02/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	98	99.25	0.96	Not toxic
	07/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	99.50	0.58	Not toxic
	08/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	99.50	0.58	Not toxic
	09/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	99	100	99	99	99.25	0.50	Not toxic
	14/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	99	99	99	99.25	0.50	Not toxic
	15/09/2021	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	99.50	0.58	Not toxic
		GP-TT1							
		GP-TT2							
Echinometra mathaei									
Summer	24/03/2022	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	99.50	0.58	Not toxic
	27/03/2022	GP-TT1	100	100	99	99	99.50	0.58	Not toxic
		GP-TT2	100	100	99	99	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 2021 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.

Trace metal concentrations at control and impact stations at Green Point also showed clear seasonal trends for zinc with a greater average loss (relative to baseline levels) observed during summer than winter. Significant differences in copper concentrations between control and impact stations were detected at Green Point. 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 in terms of enterococci counts were recorded at Hout Bay for the following parameters:

- Enterococci: In mid-waters at site HB11 during the summer survey periods and at beach sites HB-B3 during both seasons and HB-B2 during summer.

Non-compliance events in terms of enterococci counts were recorded at Camps Bay for the following parameters:

- Enterococci: At beach site CB-B3 during the summer survey.

Non-compliance events in terms of enterococci counts were recorded at Green Point for the following parameters:

- Enterococci: In surface waters at sites GP11 and surface and mid-depth waters at GP13 during the winter survey. In surface waters in mid-depth waters at sites GP11, GP12, GP14, and GP15 during the summer survey. At beach sites GP-B1, GP-B2 and GP-B3 during winter and GP-B3 during the summer 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 in mussels 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 nearfield monitoring stations than the farfield 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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9 APPENDIX D: BIOMONITORING REPORT



CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

CITY OF CAPE TOWN
EFFLUENT PIPELINES BIOMONITORING
ANNUAL REPORT
WINTER 2021-SUMMER 2022



May 2022



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CITY OF CAPE TOWN

EFFLUENT PIPELINES BIOMONITORING

Annual Report

May 2022

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 growth and accumulation of trace metals (Zn, Cu, Ni) by mussels between the Winter 2021 and Summer 2022 deployments. During Winter 2021 the mussels were deployed for 58-93 days due to adverse winter weather delaying the retrieval of the moorings after the scheduled 8 weeks as initially planned, whilst the Summer 2022 deployment was for a period of 59-66 days.

There were clear seasonal differences in the growth rate of mussels with significantly lower average growth rates at all sites recorded during the summer deployment compared to winter. Seasonally reduced summer growth of mussels was also observed in the previous 2019-2020 and 2020-2021 monitoring deployments. This is attributed to both lower POM and temperature of upwelled water which is more prevalent off the Cape Peninsula during the spring and summer period than winter as previously documented in literature (Shannon 1985, van Erkom Schurink & Griffiths 1993, Xavier *et al.* 2007). 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 appeared to be slightly higher at monitoring stations located at intermediate distances from the outfalls than those in close proximity to the diffusers or at control stations located further afield.

Trace metal accumulation in mussels also showed clear seasonal trends. Average loss of zinc concentration was found to be significantly greater during the Winter 2021 deployment compared to Summer 2022 at Green Point. Similar trends were observed for copper particularly at Camps Bay and Hout Bay. These may likely be a result of the extended deployment time and a spawning event having taken place during the Winter 2021 deployment (that extended into spring) as previously observed in the 2020-2021 study. In contrast, average loss of nickel overall was found to be to be significantly greater during the summer season which supported the findings reported from literature (Bezuidenhout *et al.* 2015, Sparks *et al.* 2018) and the previous 2019-2020 study.

The main purpose of this outfall biomonitoring programme was to determine if effluent discharge from the three deep-water sewage outfalls (Hout Bay, Camps Bay and Green Point) in Cape Town were negatively impacting the receiving environment. Mussels *M. galloprovincialis* were utilized as biological indicators and the variation in growth rate and trace metal concentration in mussel tissue in relation to distance from the outfalls was used to assess the extent of these impacts. Findings from the last three annual biomonitoring reports, provide clear evidence that seasonality played an

influential role in the growth rate and trace metal accumulation or loss of *M. galloprovincialis*. Additionally, variation in growth rate across the three outfalls indicated possible suppression of growth very close to the diffusers and enhanced growth at monitoring stations located at an intermediate distance from the outfalls compared to stations further afield (including controls). Despite these being more pronounced in winter, 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 general vicinity of the outfalls. For trace metal levels, 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 and at the controls. In most cases a decline in trace metal concentration over baseline levels was observed. Additionally, all three metals (Zn, Cu and Ni) recorded in mussel tissue at all monitoring stations were below international food quality guidelines.

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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, 2020 and design discharge volumes (CSIR 2021)

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 2022 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 third and final 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 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.

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 the winter and summer deployments. During Winter 2021 the mussels were deployed for 58-93 days (8-13 weeks) whilst the Summer 2022 deployment was for a period of 59-66 days (8-9 weeks).

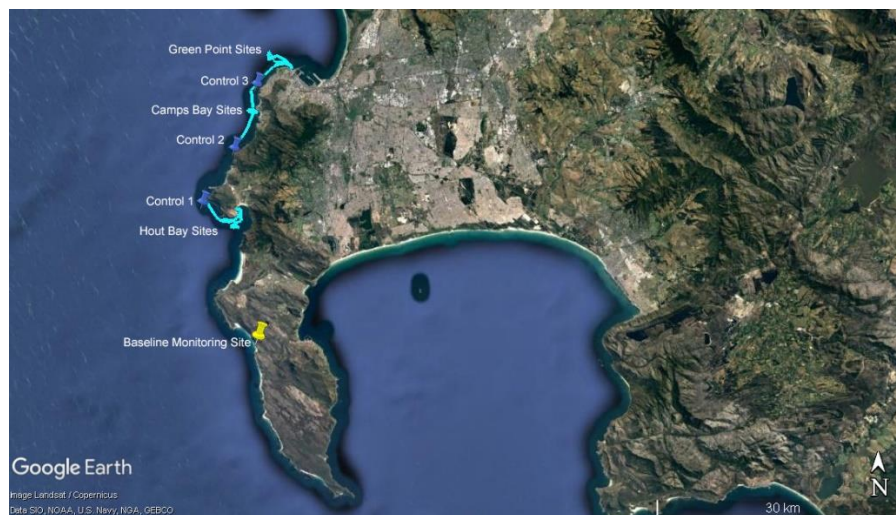


Figure 2-1. Map of Cape Town showing the baseline mussel collection site, the three outfall locations and three control site locations.



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.

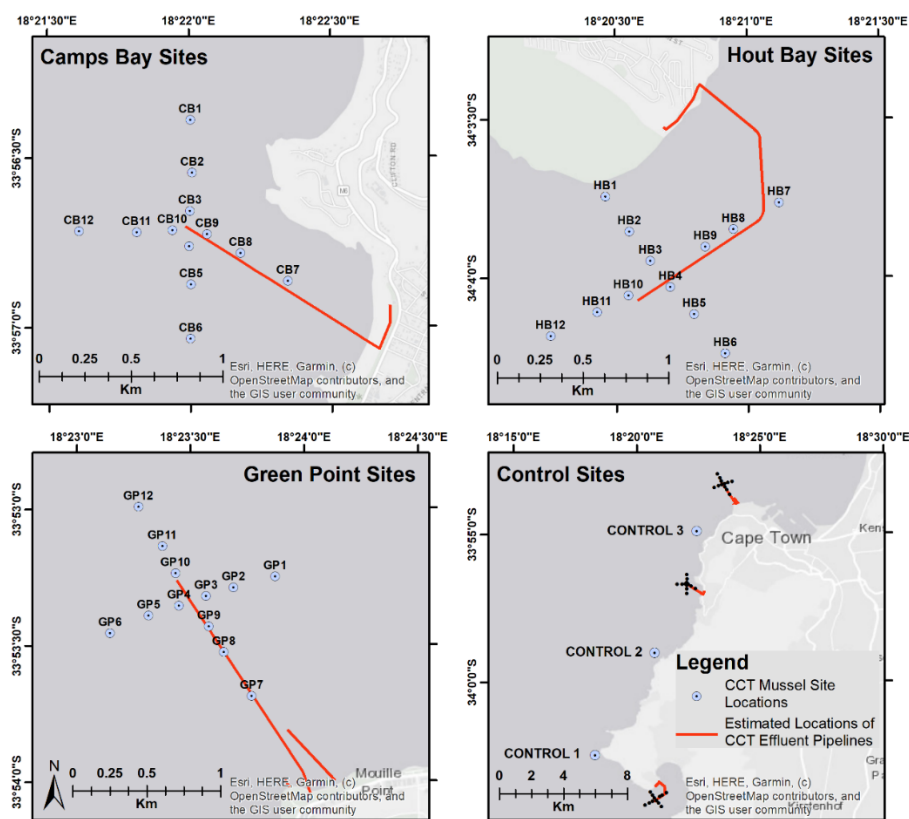


Figure 2-4. Maps of the Cape Town area, showing the positions of the Green Point, Camps Bay and Hout Bay outfalls (approximate outfall locations are denoted by red lines). Locations of ecological biomonitoring stations in Green Point, Camps Bay and Hout Bay are also shown and referred to in the remainder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

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). The mitigation through mooring design appeared effective as no marine mammal interactions with the moorings were reported during the three-year duration of the project.



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 Winter 2021 deployment, 1 out of the 12 moorings at Green Point, and 1 out of 12 at Camps Bay moorings were lost. During the Summer 2022 deployment period, 2 out of the 12 moorings at Green Point, and 1 out of 12 moorings were missing at Camps 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 & Griffiths 1993; trace metals e.g. Bezuidenhout *et al.* 2015, Sparks *et al.* 2018).

3.2 *Mytilus galloprovincialis* growth rates

Mussel growth across all monitoring stations (both impact and control) at each of the three outfall sites (Figure 3-1) were found to be significantly different between winter and summer deployments (One-way ANOVA: F-value = 20.37, $p < 0.05$). Across all outfall sites in both winter and summer deployments, impact stations generally had a greater growth rate compared to the controls. However, these were not statistically supported, except for Hout Bay in Winter 2021 (Post-hoc Tukey: $p > 0.05$). Impact stations at all three outfall sites showcased that average growth rate was significantly greater in winter compared to summer (Post-hoc Tukey, $p < 0.05$, Figure 3-2). Green Point outfall exhibited the highest average growth rate (i.e. 0.096 mm/day) across the impact sites in winter followed by Hout Bay (0.082 mm/day) and Camps Bay (0.075 mm/day). The latter pattern did not persist in summer as Hout Bay had the greatest average growth rate (0.032 mm/day) followed by both Camps Bay and Green Point having similar growth rates of ~0.018 mm/day.

Mussel growth rate appears to be greater at the monitoring stations surrounding the outfalls compared to the controls further afield, which was well observed at Camps Bay and Hout Bay as opposed to Green Point (Figure 3-2). 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; in which both would have had a net positive effect on mussel growth. These findings are in line with previous studies (Bustamante & Branch 1996, CSIR 2017) whereby the authors documented 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 & Branch 1996, Steffani & Branch 2003). Mussel growth rates recorded in the present study likely suggest that the mooring stations located at the three outfalls have a greater food supply (POM) than the control sites.

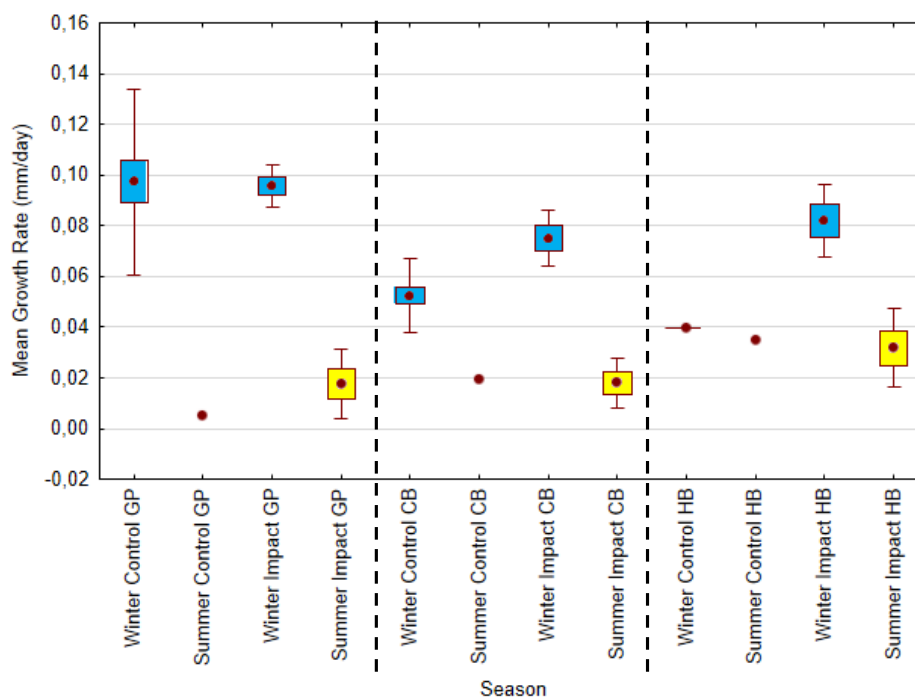


Figure 3-1 Mean *Mytilus galloprovincialis* growth rates (mm/day) for Winter 2021 (blue) and Summer 2022 (yellow). The dotted lines separate the mean growth (mm) for Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

Numerous studies have documented the differential effects of upwelling on mussel growth; where some report that mussels would have greater growth at upwelling sites compared to those downstream (Xavier *et al.* 2007); and other authors observed the opposite trend – rapid mussel growth associated with sites of weaker upwelling and higher temperatures (Menge *et al.* 1997a, b, Sanford & 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 & Menge 2000, Wieters *et al.* 2003). Upwelling centres have colder water, are nutrient rich but poor in Chl-*a* and POM (Graham & Largier 1997, Wieters *et al.* 2003). Apart from 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 & Griffiths (1993) provided strong evidence that temperature (rather than food availability) was the main driver in 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 significantly lower in summer compared to winter (Figure 3-2), and these findings were similarly observed in the previous 2019-2020 and 2020-2021 monitoring reports. These results are further supported from literature (van Erkom Schurink & Griffiths 1993, Xavier *et al.* 2007), considering upwelling events which result in clear and cold water near the coast, generally occur in spring-summer (Shannon 1985).

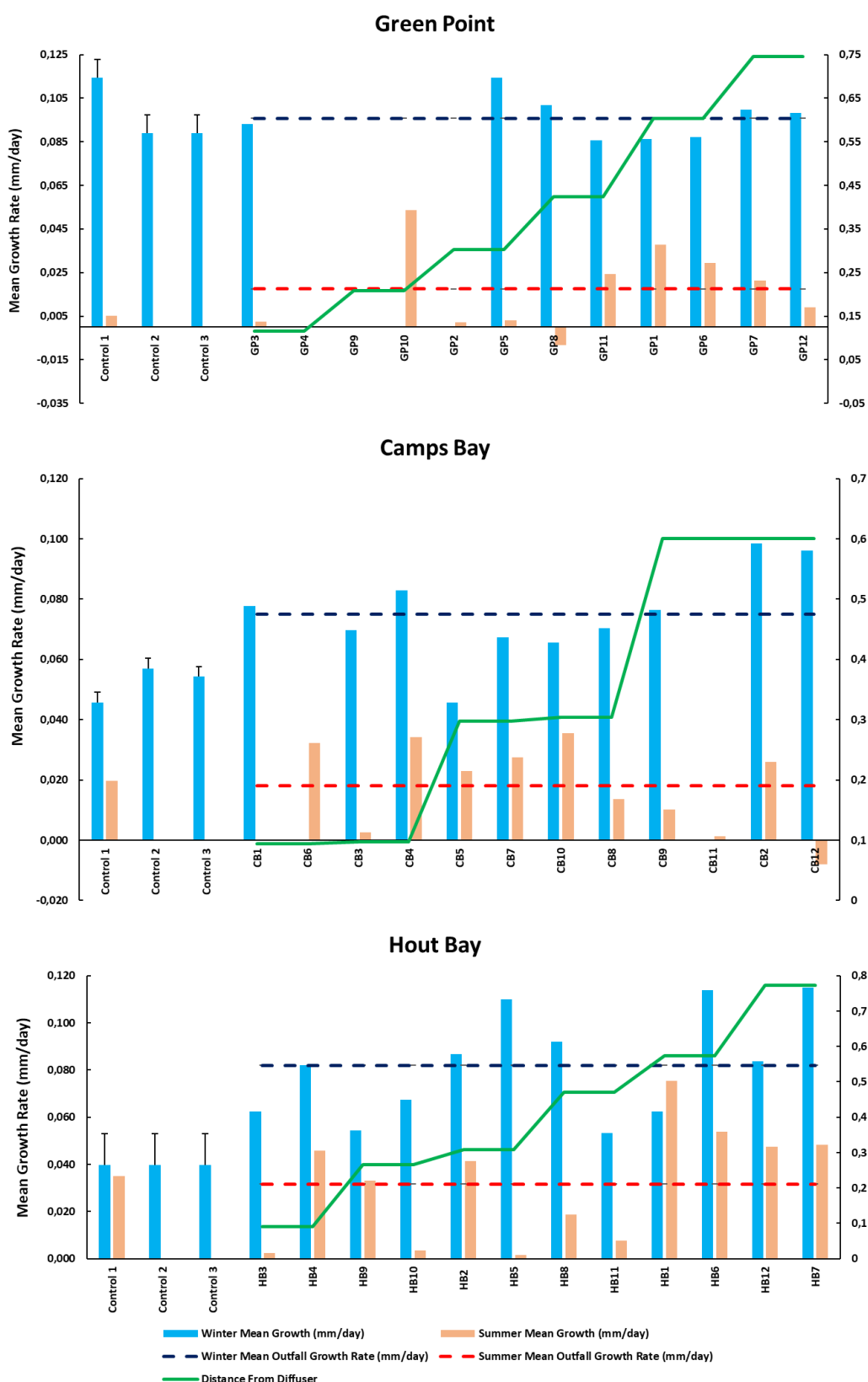


Figure 3-2. *Mytilus galloprovincialis* growth rates (mm/day) on left axis over an 8-13 week period, August to October 2021 (Winter), and a 8-9 week period, February to April 2022 (Summer) in relation to distance from effluent diffuser, grey line (km) on right axis for three different deep-water outfall locations, Green Point, Camps Bay, and Hout Bay. The dotted lines indicate the mean growth (mm) for each outfall location.

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 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 monitoring stations (both control and impact) were found to be significantly different between winter and summer deployments (One-way ANOVA, $p < 0.05$, Figure 3-3), with the average loss of zinc observed to be significantly greater during the winter season for Green Point only (Post-hoc Tukey, $p < 0.05$). The latter pattern was also observed for copper for Camps Bay and Hout Bay (Post-hoc Tukey, $p < 0.05$). However, average loss of nickel was found to be significantly greater during the summer season for Camps Bay and Hout Bay (Post-hoc Tukey, $p < 0.05$). Further analysis of pairwise comparisons of treatments within each season for each metal are provided below in Figure 3-4.

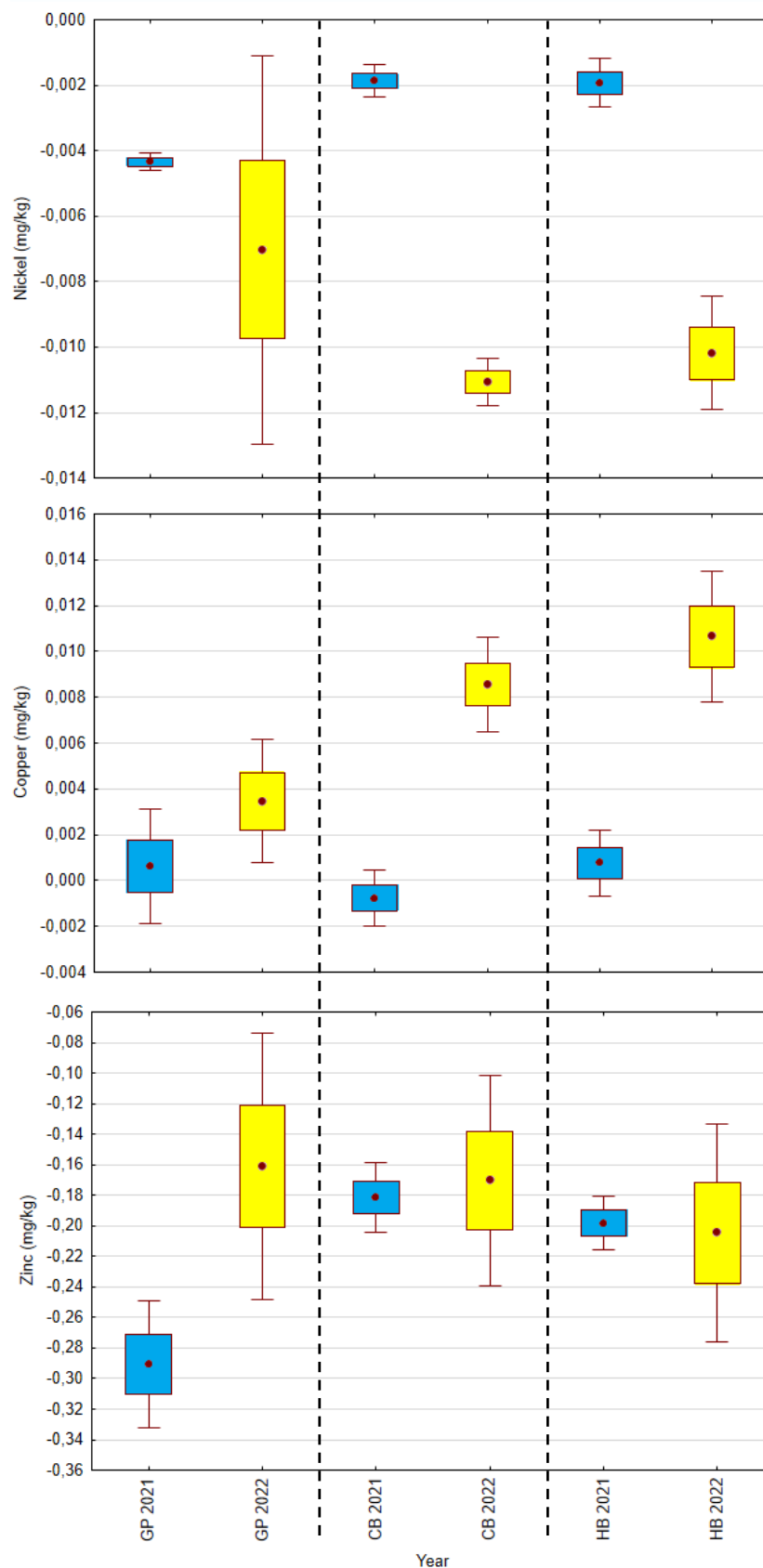


Figure 3-3 Mean change in levels of nickel, copper and zinc content for mussels deployed in winter 2021 (blue) and summer 2022 (yellow) at sites surrounding the deep-water outfalls at Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

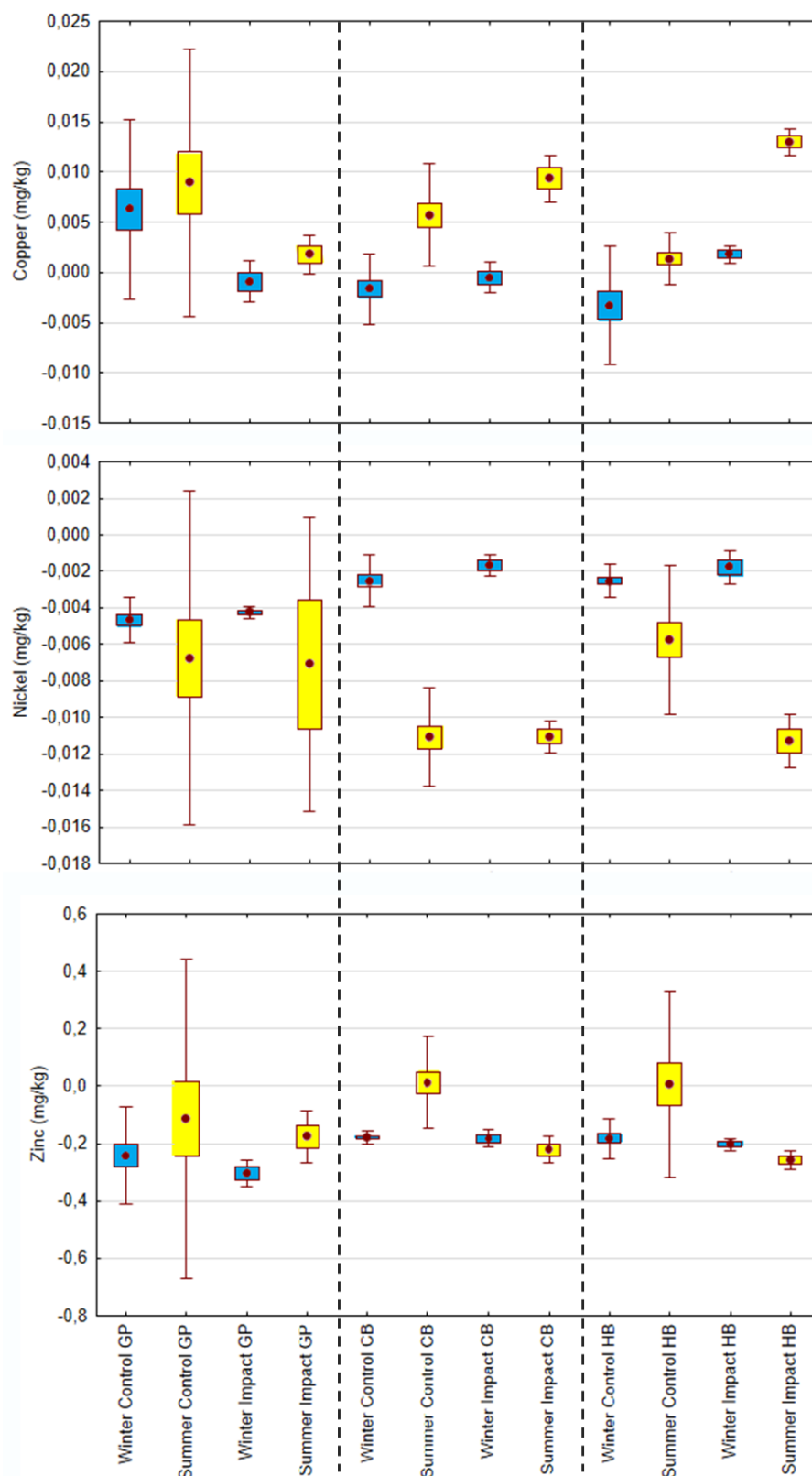


Figure 3-4 Mean change in levels of nickel, copper and zinc content for mussels deployed in Winter 2021 (blue) and Summer 2022 (yellow) between treatments (control vs impact sites) surrounding the deep-water outfalls at Green Point (GP), Camps Bay (CB) and Hout Bay (HB).

Nickel (Ni)

Differences in nickel concentrations between impact and control stations at all three bays were not significantly different in both summer and winter deployments (Post-hoc Tukey, $p > 0.05$).

Copper (Cu)

During the 2021 winter deployment, significant differences in copper concentrations between control and impact stations were only detected at Green Point (Post-hoc Tukey, $p < 0.05$). These differences were also observed in the 2022 summer deployment except for Camps Bay.). Interestingly at Green Point, both winter and summer deployments indicated a significant loss of copper concentration at the impact sites in comparison to the control samples, however, impact sites at Hout Bay indicated a significant accumulation of copper compared to the controls during summer 2022. Overall, average copper concentrations were generally higher (in some cases significantly so) in summer compared to winter (Figure 3-3).

Zinc (Zn)

Differences between impact and control stations across all three sites were not statistically detected in winter 2021 (Post-hoc Tukey, $p > 0.05$). However, significant differences between impact and control stations were observed in the summer 2022 deployment for Camps Bay and Hout Bay (Post-hoc Tukey, $p > 0.05$), with impact sites having greater loss of zinc concentration compared to the control samples.

The 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 on Figure 3-5 below. There was no significant correlation (Pearson's correlation co-efficient, $p > 0.05$) between trace metal accumulation and the distance from the deep-water outfalls at Green Point, Camps Bay and Hout Bay during the winter and summer deployments. Therefore, there is no evidence to suggest that the rates of trace metal bioaccumulation were higher at stations close to the outfalls relative to those further afield. Additionally, zinc 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 zinc had the highest accumulation in mussels (after Fe) compared to the other trace metals tested. Furthermore, Eisler (1981) reports that molluscs preferably accumulate zinc, which explains the high concentrations of zinc recorded in mussels in the present study.

Various other monitoring studies have shown notably higher concentrations of trace metals (particularly copper and zinc) 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. However, this was not observed in the recent deployments, where there were significantly greater losses of copper and zinc (on average) during the 2021 winter deployment than the 2022 summer deployment. The latter pattern was also observed in the 2020-2021 study for nickel and zinc.

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 & 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 van Erkom Schurink & 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 2020-2021 deployments and the present monitoring study. It is, however, possible that the extended winter 2020 deployment (58-76 day) 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. The latter could also explain the winter 2021 findings as mussels were in the water for an even longer deployment period (58-93 days).

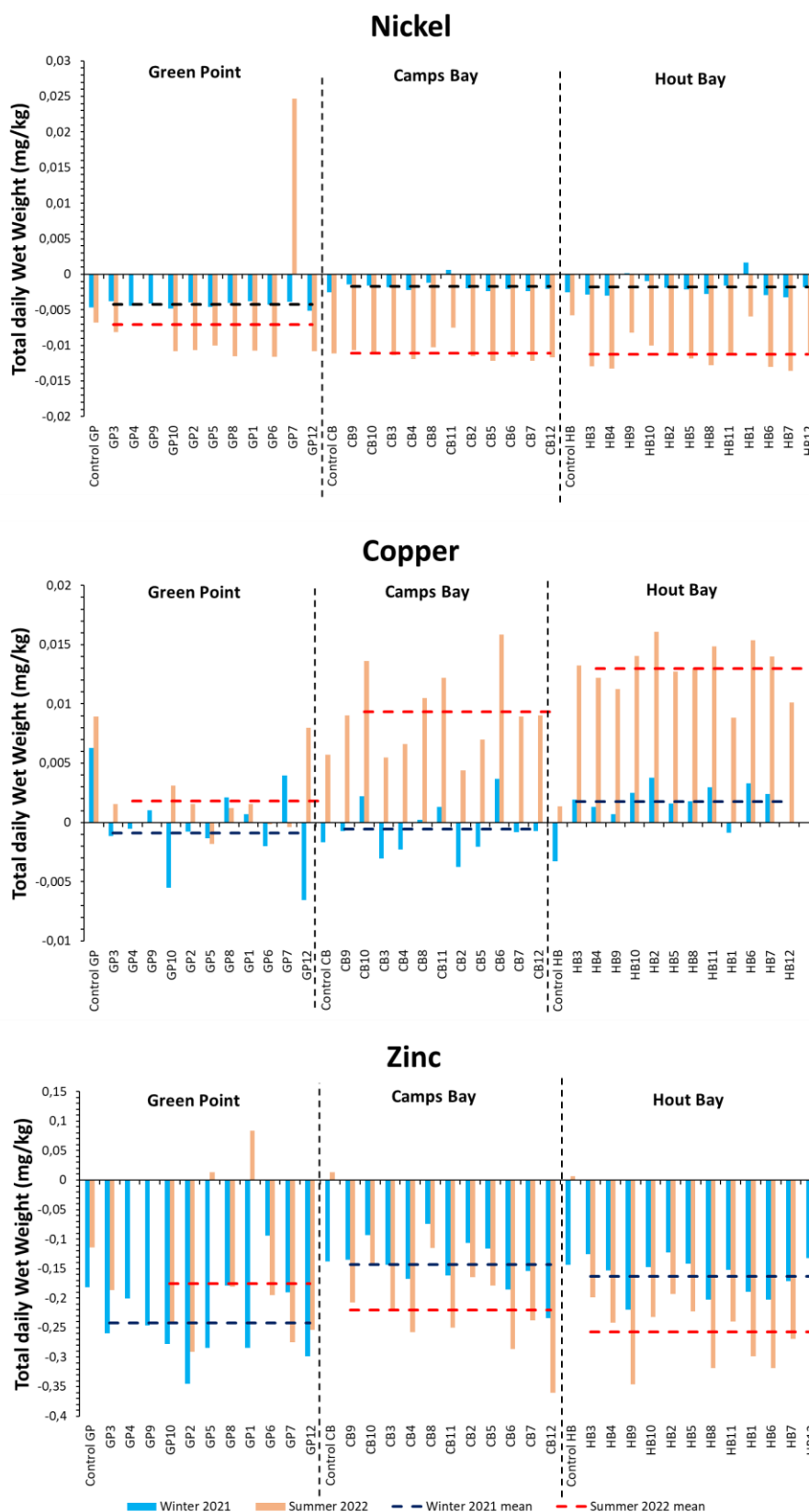


Figure 3-5 Total change in levels of trace metal content for the full deployment period in Winter 2021 (58-93 days) and Summer 2022 (59-66 days) at sites surrounding the deep-water outfalls at Green Point, Camps Bay and Hout Bay, and at the control locations at Sea point, Oudekraal and Kabonkelberg relative 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).

4 CONCLUSIONS

There were clear seasonal differences in the growth rate of mussels used in the present monitoring experiments, with significantly lower average growth rates at all sites recorded during the summer deployment compared to winter. These findings were similarly observed in the previous 2019-2020 and 2020-2021 monitoring reports. This is attributed to both lower POM and temperature of upwelled water which is more prevalent off the Cape Peninsula during the spring and summer period than winter as previously documented in literature (Shannon 1985, van Erkom Schurink & Griffiths 1993, Xavier *et al.* 2007). 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 appeared 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).

Trace metal accumulation in mussels also showed clear seasonal trends. Average loss of zinc concentration was found to be significantly greater during the Winter 2021 deployment compared to Summer 2022 at Green Point alone. Similar trends were also observed for copper particularly at Camps Bay and Hout Bay. These may likely be a result of the extended deployment time and a spawning event having taken place during the Winter 2021 deployment as previously observed in the 2020-2021 study. In contrast, average loss of nickel overall was found to be to be significantly greater during the summer season which concurs with some of the literature (Bezuidenhout *et al.* 2015, Sparks *et al.* 2018) and the previous 2019-2020 study. Overall, mussels at all locations accumulated copper relative to baseline concentration during the Summer 2022 deployment and to some degree in Winter 2021. No mussels accumulated copper to above food quality guidelines or levels reported in the literature for “unimpacted” sites.

The main purpose of this outfall biomonitoring programme was to determine if effluent discharge from the three deep-water sewage outfalls (Hout Bay, Camps Bay and Green Point) in Cape Town were negatively impacting the receiving environment. Mussels *M. galloprovincialis* were utilized as biological indicators and the variation in their growth rate and trace metal level in mussel tissue in relation to distance from the outfalls was used to assess the extent of these impacts. Findings over the last three annual biomonitoring reports, provide clear evidence that seasonality played an influential role in the growth rate and trace metal accumulation of *M. galloprovincialis*. Additionally, variation in growth rate across the three outfalls indicated no immediate signs of negative impact over the three years, but rather the growth rates appear to be slightly higher at monitoring stations located the intermediate vicinity of the outfalls compared to stations further afield (including controls). Despite these being more pronounced in winter, 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 vicinity of the outfalls. For trace metal levels, 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. Additionally, all three metals (Zn, Cu and Ni) recorded in mussel tissue at all monitoring stations were below international quality guidelines.

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6 APPENDICES

Table 6.1 Winter 2021, 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)	Growth Rate (mm/day)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
06-Aug-21	GP1	45	41	42	44	43	43	43	42	42	41	43	42	43	40	42	43	44	41	40	42	42.3	-
06-Aug-21	GP2	43	40	42	45	45	40	49	40	40	43	43	47	44	43	40	41	45	42	47	40	42.95	-
06-Aug-21	GP3	50	43	46	43	41	42	40	43	40	43	42	44	46	42	40	43	49	48	44	42	43.55	-
06-Aug-21	GP4	40	42	42	45	40	41	40	43	40	45	42	49	47	40	49	41	42	42	41	48	42.95	-
06-Aug-21	GP5	41	46	41	42	41	48	41	44	42	50	48	43	43	50	45	43	41	44	41	42	43.8	-
06-Aug-21	GP6	41	42	42	43	42	43	44	42	45	41	41	40	46	43	47	45	42	40	46	41	42.8	-
06-Aug-21	GP7	41	44	48	45	43	42	45	46	46	41	41	44	42	45	41	41	43	49	42	45	43.7	-
06-Aug-21	GP8	41	44	43	46	40	43	42	45	40	48	44	44	47	46	42	41	45	40	48	46	43.75	-
06-Aug-21	GP9	46	41	47	40	45	43	49	48	40	42	46	40	46	40	47	44	41	43	46	45	43.95	-
06-Aug-21	GP10	48	42	44	48	45	43	40	42	48	42	40	41	43	46	42	45	40	42	43	41	43.25	-
06-Aug-21	GP11	40	45	41	41	40	43	44	43	40	44	45	50	42	42	44	43	43	50	44	44	43.4	-
06-Aug-21	GP12	48	46	48	45	41	40	48	40	42	50	49	46	48	41	44	40	44	40	41	43	44.2	-
04-Aug-21	CB1	46	45	44	45	48	44	44	43	44	41	49	44	43	47	41	40	41	49	41	41	44	-
04-Aug-21	CB2	50	42	43	43	42	40	46	41	45	43	41	47	40	46	40	43	44	45	43	41	43.25	-
04-Aug-21	CB3	40	50	45	46	42	44	41	50	41	49	46	45	44	41	44	41	44	41	41	49	44.2	-
04-Aug-21	CB4	45	40	45	40	50	42	49	47	48	43	47	41	43	44	46	42	42	41	46	40	44.05	-
04-Aug-21	CB5	46	43	40	41	43	47	46	42	49	41	41	40	50	42	40	47	47	41	41	48	43.75	-
04-Aug-21	CB6	49	42	50	42	46	44	42	41	46	45	42	50	41	42	47	48	43	41	40	50	44.55	-

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		
04-Aug-21	CB7	48	50	43	43	45	42	40	46	40	49	45	50	50	46	46	40	45	49	44	48	45.45	-
04-Aug-21	CB8	40	41	41	43	46	41	48	47	41	45	43	44	42	45	45	45	46	43	44	42	43.6	-
04-Aug-21	CB9	46	41	42	43	48	43	47	47	41	48	47	44	41	48	46	45	40	45	46	47	44.75	-
04-Aug-21	CB10	43	44	46	40	41	49	43	48	47	41	46	48	49	40	47	43	41	43	41	40	44	-
04-Aug-21	CB11	48	50	42	44	49	42	41	41	47	48	43	49	42	46	47	46	48	45	45	48	45.55	-
04-Aug-21	CB12	45	46	43	42	40	45	45	48	44	42	42	40	42	42	48	40	49	43	44	41	43.55	-
02-Aug-21	HB1	47	42	41	45	43	42	40	40	44	42	43	50	45	45	42	42	41	48	46	44	43.6	-
02-Aug-21	HB2	50	42	44	46	42	41	48	46	45	41	46	46	50	49	47	46	42	41	41	41	44.7	-
02-Aug-21	HB3	40	42	43	42	44	45	41	42	40	50	46	43	45	45	44	41	50	50	41	43	43.85	-
02-Aug-21	HB4	50	49	43	46	45	50	45	45	41	42	41	46	46	43	47	40	41	43	47	44	44.7	-
02-Aug-21	HB5	46	42	43	44	49	48	45	49	46	43	42	40	44	42	45	44	47	42	40	43	44.2	-
02-Aug-21	HB6	40	45	41	46	46	44	41	48	47	42	50	41	40	44	41	41	43	49	42	46	43.85	-
02-Aug-21	HB7	48	49	43	44	47	49	47	43	41	47	42	48	49	47	46	47	41	50	44	43	45.75	-
02-Aug-21	HB8	45	41	48	44	42	50	46	41	48	40	50	44	41	49	40	41	42	41	44	47	44.2	-
02-Aug-21	HB9	50	50	48	45	43	44	46	48	40	50	44	42	44	40	47	45	44	47	43	42	45.1	-
02-Aug-21	HB10	50	48	47	42	43	50	48	44	47	41	45	48	43	44	48	43	45	41	45	50	45.6	-
02-Aug-21	HB11	45	45	44	48	50	42	48	41	40	50	41	41	44	49	45	42	46	44	44	41	44.5	-
02-Aug-21	HB12	42	50	43	44	42	49	49	42	42	42	41	45	43	42	46	50	47	44	49	50	45.1	-
04-Aug-21	GP Cont a	40	44	42	44	40	49	41	42	44	45	41	41	41	45	40	46	40	42	40	40	42.35	-
04-Aug-21	GP Cont b	40	40	42	40	40	42	48	50	49	50	40	43	45	40	46	40	41	47	44	41	43.4	-
04-Aug-21	GP Cont c	44	40	42	50	44	40	49	42	43	44	40	43	45	46	41	46	42	42	40	44	43.35	-
04-Aug-21	CB Cont a	43	40	43	40	46	45	43	47	44	47	42	46	42	47	41	47	49	49	41	45	44.35	-
04-Aug-21	CB Cont b	46	40	47	40	45	46	49	43	42	45	42	41	40	47	50	40	41	44	41	43	43.6	-

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		
04-Aug-21	CB Cont c	44	43	44	47	40	41	47	43	46	49	40	40	48	41	40	45	44	43	44	43	43.6	-
02-Aug-21	HB Cont a	41	40	40	42	41	40	42	40	50	43	41	41	42	44	44	44	41	43	42	50	42.55	-
02-Aug-21	HB Cont b	43	50	43	47	45	41	45	41	44	40	44	44	47	45	40	43	45	49	41	45	44.1	-
02-Aug-21	HB Cont c	44	41	46	43	48	47	49	41	48	40	48	43	48	44	45	40	40	40	47	46	44.4	-
POST-DEPLOYMENT																							
04-Oct-21	GP1	50	48	44	51	49	50	58	50	47	45	50	50	49	52	51	48	47	0	0	0	41.95	-0.01
04-Oct-21	GP2	51	47	0	49	49	43	54	45	50	46	47	48	48	50	45	46	48	40	47	46	44.95	0.03
04-Oct-21	GP3	47	48	52	51	48	56	51	44	41	54	48	42	51	48	53	51	45	40	41	42	47.65	0.07
04-Oct-21	GP4	0	48	56	56	49	49	47	46	50	43	44	47	41	43	51	42	44	53	49	50	45.4	0.04
04-Oct-21	GP5	55	49	47	56	45	46	43	48	51	42	50	55	48	45	49	45	46	46	54	43	48.15	0.08
04-Oct-21	GP6	48	50	49	46	48	49	43	43	53	43	44	44	40	45	44	45	45	44	48	50	46.05	0.06
04-Oct-21	GP7	56	48	46	49	43	43	46	46	49	48	48	44	50	42	50	46	52	46	50	51	47.65	0.07
04-Oct-21	GP8	51	52	44	45	40	49	45	49	45	40	45	52	49	50	52	48	52	46	45	49	47.4	0.06
04-Oct-21	GP9	52	48	40	50	45	50	45	50	45	43	46	53	50	42	43	55	56	45	50	55	48.15	0.07
04-Oct-21	GP10	49	46	52	48	51	56	48	47	48	50	51	42	47	46	46	41	53	50	42	50	48.15	0.08
04-Oct-21	GP12	53	44	45	51	50	43	42	50	45	50	52	52	40	60	53	60	50	45	40	50	48.75	0.08
27-Oct-21	CB2	51	48	46	43	49	50	46	56	43	53	51	41	54	49	48	48	46	44	44	0	45.5	0.02
27-Oct-21	CB3	46	47	50	49	43	44	45	49	57	50	56	55	55	50	53	53	52	48	47	0	47.45	0.04
27-Oct-21	CB4	48	52	48	60	54	52	47	49	54	44	44	48	49	51	59	48	53	52	46	49	50.35	0.07
27-Oct-21	CB5	51	45	50	48	45	46	50	50	52	48	50	50	46	45	48	42	51	55	44	47	48.15	0.05
27-Oct-21	CB6	49	59	55	50	52	51	49	56	47	57	60	53	47	48	49	52	47	0	0	0	44.05	-0.01
27-Oct-21	CB7	49	54	46	58	46	53	51	48	49	55	41	57	49	52	51	50	58	40	44	56	50.35	0.05
27-Oct-21	CB8	52	50	53	43	45	45	48	50	47	54	43	50	43	54	46	48	48	50	45	52	48.3	0.05

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		
27-Oct-21	CB9	50	50	50	45	48	50	52	48	51	47	46	43	48	41	49	46	45	52	48	43	47.6	0.03
27-Oct-21	CB10	45	48	53	52	43	49	53	53	43	49	49	47	43	43	45	48	47	49	0	39	44.9	0.01
27-Oct-21	CB11	50	53	54	48	58	53	59	47	49	59	56	50	50	45	49	51	51	50	47	53	51.6	0.07
27-Oct-21	CB12	50	50	54	58	54	60	50	46	62	52	54	59	54	49	54	62	50	51	44	43	52.8	0.10
27-Oct-21	HB1	55	53	52	46	48	52	51	52	48	42	46	53	50	56	46	56	54	56	59	47	51.1	0.08
27-Oct-21	HB3	51	52	43	50	59	48	49	49	50	45	45	51	52	46	53	52	52	54	46	0	47.35	0.04
27-Oct-21	HB4	51	45	54	52	53	54	50	52	39	54	57	50	55	48	51	45	61	51	58	51	51.55	0.07
27-Oct-21	HB5	52	48	44	55	51	42	50	47	58	49	47	48	48	47	55	47	50	51	49	49	49.35	0.06
27-Oct-21	HB6	61	48	50	58	47	47	42	48	58	51	57	52	42	63	47	56		53	50	54	51.79	0.09
27-Oct-21	HB7	56	54	56	56	49	54	55	49	51	58	44	52	53	54	57	49	51	59	51	51	52.95	0.08
27-Oct-21	HB8	52	52	58	47	59	49	49	54	50	49	59	52	53	57	45	56	46	52	50	0	49.45	0.06
27-Oct-21	HB9	50	57	48	50	54	50	50	44	51	40	54	56	44	54	51	56	56	55	48	52	51	0.06
27-Oct-21	HB10	55	49	49	54	50	40	47	48	43	50	50	52	50	50	48	52	52	51	46	53	49.45	0.04
27-Oct-21	HB11	52	47	56	54	44	50	40	57	52	60	54	50	57	44	48	55	58	55	53	55	52.05	0.08
27-Oct-21	HB12	59	58	54	58	46	41	42	54	52	54	57	49	55	53	52	51	57	52	46	49	51.95	0.07
04-Oct-21	GP Cont a	49	46	47	51	49	50	48	50	45	48	45	48	54	44	45	50	48	51	49	0	45.85	0.06
04-Oct-21	GP Cont b	53	52	49	47	54	49	53	52	49	47	48	46	46	45	49	44	51	47	44	52	48.85	0.09
04-Oct-21	GP Cont c	46	42	47	47	50	46	51	49	50	44	48	48	52	48	50	41	48	48	48	51	47.7	0.06
27-Oct-21	CB Cont a	56	50	57	60	55	55	54	45	54	40	55	56	58	50	50	51	44	47	56	53	52.3	0.09
27-Oct-21	CB Cont b	49	52	49	44	51	51	46	49	47	43	52	50	44	50	45	53	0	47	50	49	46.05	0.03
27-Oct-21	CB Cont c	48	58	50	54	56	56	52	43	50	48	45	56	46	48	50	48	50	46	48	52	50.2	0.07
27-Oct-21	HB Cont a	49	48	42	45	49	45	50	49	52	51	49	47	51	48	47	44	50	49	47	50	48.1	0.06
27-Oct-21	HB Cont b	47	53	50	52	49	51	51	40	46	50	47	45	51	50	50	48	56	54	51	0	47.05	0.03

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		
27-Oct-21	HB Cont c	46	50	50	53	55	45	50	47	48	47	51	53	51	48	51	51	51	48	54	47	49.8	0.06

Table 6.2 Summer 2022, February to April 2022, *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 ~9 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		
22-Feb	GP1	41	45	43	49	45	45	42	40	49	47	46	49	46	40	50	47	42	42	40	44	44.5	-
22-Feb	GP2	50	45	44	41	45	43	45	40	45	47	46	50	45	45	43	50	45	45	46	50	45.15	-
22-Feb	GP3	45	48	46	45	42	40	42	43	41	44	43	40	44	40	48	41	42	46	42	41	44.2	-
22-Feb	GP4	48	40	42	46	40	46	47	46	50	40	47	45	40	42	49	44	50	40	49	43	44.15	-
22-Feb	GP5	48	42	40	45	45	40	45	40	46	41	42	43	41	45	43	40	44	50	45	44	45.9	-
22-Feb	GP6	49	47	49	45	44	42	47	49	47	48	42	46	48	47	50	40	45	43	49	44	44.3	-
22-Feb	GP7	41	50	41	43	42	43	50	49	49	49	43	40	43	50	46	47	48	40	47	45	44.65	-
22-Feb	GP8	46	42	40	45	47	41	41	43	48	42	46	43	50	46	43	44	44	40	45	46	44.6	-
22-Feb	GP9	48	47	45	46	48	46	44	48	49	50	47	47	46	45	44	49	48	48	40	42	45.5	-
22-Feb	GP10	43	47	43	45	47	41	43	42	48	45	47	45	50	46	49	47	43	43	47	44	43.15	-
22-Feb	GP11	48	41	44	44	40	42	40	42	46	48	43	49	42	48	47	46	49	49	50	48	44.7	-
22-Feb	GP12	44	47	48	46	43	47	46	48	45	44	48	45	48	46	47	40	50	48	49	44	43.45	-
22-Feb	GP Control 1	40	48	41	46	41	49	47	46	42	49	47	46	41	43	46	47	45	48	43	42	46.05	-
22-Feb	CB1	41	47	43	42	41	44	40	48	40	49	47	48	44	44	42	42	48	49	48	47	45.3	-

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		
22-Feb	CB2	46	49	50	48	47	44	44	47	50	49	49	47	48	45	48	43	49	50	50	46	44.1	-
22-Feb	CB3	47	50	47	48	46	42	47	49	48	47	47	43	41	46	50	42	45	42	44	46	46.35	-
22-Feb	CB4	50	50	48	44	42	50	48	47	50	43	45	43	41	45	46	47	50	44	41	49	45.25	-
22-Feb	CB5	43	41	50	50	46	45	48	44	47	45	44	48	44	49	50	50	45	50	46	49	45.3	-
22-Feb	CB6	47	48	44	45	46	44	41	47	40	40	45	49	42	42	46	40	41	47	46	48	46.15	-
22-Feb	CB7	40	44	40	40	46	42	40	47	48	43	40	48	42	40	48	41	41	40	41	42	44.85	-
22-Feb	CB8	41	45	43	45	46	43	49	49	50	44	45	44	43	50	43	46	40	44	47	45	44.7	-
22-Feb	CB9	47	46	50	49	49	46	49	47	49	49	48	49	48	50	47	48	48	47	48	43	47.45	-
22-Feb	CB10	50	47	42	43	43	47	42	46	49	49	46	42	43	47	49	50	42	43	41	40	45.85	-
22-Feb	CB11	50	48	48	46	44	48	47	49	40	48	50	48	44	48	44	44	49	43	47	50	46.15	-
22-Feb	CB12	40	44	42	44	47	40	40	47	45	46	43	48	41	43	42	47	45	44	50	49	46.7	-
21-Feb	CB Control 1	49	43	45	45	43	43	49	45	48	49	43	43	45	47	49	41	49	50	50	48	44.4	-
21-Feb	HB1	46	50	48	47	44	42	42	50	46	44	50	43	47	50	47	45	48	40	42	42	42.65	-
21-Feb	HB2	43	49	43	42	45	47	47	48	42	40	43	43	49	50	41	43	44	40	43	48	45.1	-
21-Feb	HB3	50	48	47	44	45	42	42	47	50	47	47	48	48	46	48	44	43	45	48	42	47.85	-
21-Feb	HB4	43	42	50	45	45	42	47	48	44	49	46	50	45	47	41	42	45	45	46	50	45.05	-
21-Feb	HB5	41	44	45	48	44	45	42	40	46	46	40	45	46	40	47	42	47	45	41	42	46.75	-
21-Feb	HB6	49	43	47	48	46	47	45	47	42	40	44	42	43	46	45	46	48	40	48	46	44.35	-
21-Feb	HB7	41	49	49	48	46	47	46	48	46	44	50	48	46	48	48	42	49	43	44	47	46.2	-
21-Feb	HB8	46	49	47	48	47	44	46	49	46	48	49	46	44	50	42	49	43	44	44	47	45.65	-
21-Feb	HB9	50	49	48	41	41	43	45	41	49	43	42	46	44	48	50	46	43	45	41	50	44.5	-
21-Feb	HB10	41	45	43	49	45	45	42	40	49	47	46	49	46	40	50	47	42	42	40	44	46.05	-
21-Feb	HB11	50	45	44	41	45	43	45	40	45	47	46	50	45	45	43	50	45	45	46	50	45.6	-

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		
21-Feb	HB12	45	48	46	45	42	40	42	43	41	44	43	40	44	40	48	41	42	46	42	41	43.8	-
21-Feb	HB Control 1	48	40	42	46	40	46	47	46	50	40	47	45	40	42	49	44	50	40	49	43	45.1	-
POST-DEPLOYMENT																							
28-Apr	GP1	45	45	45	43	53	45	45	53	45	45	50	43	47	49	50	44	48	51	-	-	47.00	0.038
28-Apr	GP2	48	51	46	46	41	47	43	52	44	49	44	45	49	40	45	42	46	47	41	-	45.30	0.002
28-Apr	GP3	45	47	43	42	43	53	42	44	45	47	47	45	40	41	41	45	44	-	-	-	44.35	0.002
28-Apr	GP4	Empty																					
28-Apr	GP5	46	48	45	49	50	48	48	48	49	48	42	46	40	43	47	49	42	42	-	-	46.11	0.003
28-Apr	GP6	43	52	50	55	45	45	45	45	50	45	45	44	45	48	43	50	45	48	41	-	46.25	0.030
28-Apr	GP7	50	49	48	50	43	47	48	43	42	47	45	43	50	44	44	47	42	44	48	-	46.05	0.021
28-Apr	GP8	47	49	42	44	43	42	42	47	44	43	44	42	48	40	44	44	45	47	41	-	44.05	-0.008
28-Apr	GP9	Empty																					
28-Apr	GP10	45	47	47	46	47	49	50	43	42	47	48	47	50	42	48	48	46	50	45	-	46.68	0.054
28-Apr	GP11	48	48	49	43	44	40	47	43	50	44	53	43	48	45	50	51	43	47	45	-	46.30	0.024
28-Apr	GP12	43	45	42	44	45	46	43	46	50	40	50	44	43	44	42	42	45	42	42	-	44.05	0.009
21-Apr	GP Control 1	45	42	52	45	45	50	45	45	45	43	45	45	51	41	45	45	51	51	50	-	46.35	0.005
21-Apr	CB1	Empty																					
21-Apr	CB2	45	45	44	45	45	45	51	51	45	45	45	45	50	45	44	42	45	45	45	-	45.63	0.026
21-Apr	CB3	45	45	44	45	45	45	52	45	44	50	45	45	51	45	45	45	50	51	-	-	46.50	0.003
21-Apr	CB4	45	51	50	45	52	45	45	45	45	45	45	45	51	45	51	51	47	50	45	-	47.26	0.034
21-Apr	CB5	44	43	45	45	45	45	45	54	45	45	45	44	52	45	50	43	43	51	54	-	46.65	0.023
21-Apr	CB6	52	45	51	50	51	45	50	50	45	45	45	45	45	46	50	50	51	48	48	-	48.05	0.032
21-Apr	CB7	45	50	45	42	45	45	45	50	50	43	51	45	43	54	45	51	42	42	50	-	46.47	0.028

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		
21-Apr	CB8	45	51	45	45	45	50	45	44	44	41	41	41	44	45	51	50	50	45	44	-	45.50	0.014
21-Apr	CB9	52	44	51	50	50	55	45	51	45	50	45	45	45	48	50	51	44	50	45	-	48.05	0.010
21-Apr	CB10	45	52	53	45	45	45	54	45	45	51	45	45	45	50	51	50	45	45	51	-	47.95	0.036
21-Apr	CB11	53	45	45	45	45	44	44	41	44	45	45	44	43	45	45	53	45	45	-	-	46.22	0.001
21-Apr	CB12	45	45	52	45	44	45	45	51	45	42	50	50	52	42	43	45	45	46	-	-	46.22	-0.008
21-Apr	CB Control 1	43	45	44	50	42	51	45	45	45	50	45	45	45	45	45	45	45	45	-	-	45.56	0.020
20-Apr	HB1	50	50	49	46	42	48	46	47	49	45	41	45	52	50	55	48	45	45	42	-	47.10	0.075
20-Apr	HB2	51	53	55	52	45	43	45	45	45	45	45	43	51	51	48	45	45	42	51	-	47.55	0.042
20-Apr	HB3	47	45	49	48	47	49	47	55	49	48	52	46	46	46	51	49	48	47	45	-	48.00	0.003
20-Apr	HB4	50	54	54	48	45	50	49	46	46	48	45	44	41	49	46	51	47	47	45	-	47.75	0.046
20-Apr	HB5	48	49	53	46	43	48	51	49	43	50	40	44	43	47	51	50	45	45	44	-	46.85	0.002
20-Apr	HB6	50	50	49	46	45	46	48	44	47	47	51	51	44	45	45	53	44	48	50	-	47.53	0.054
20-Apr	HB7	47	48	47	48	52	52	46	49	52	53	48	50	50	51	48	46	46	53	49	-	49.05	0.048
20-Apr	HB8	48	46	45	51	46	52	43	48	45	45	52	48	45	43	51	45	44	44	48	-	46.75	0.019
20-Apr	HB9	51	45	47	46	47	45	45	49	47	45	46	48	45	44	42	46	48	48	50	-	46.45	0.033
20-Apr	HB10	48	52	43	43	50	42	46	48	49	40	45	46	48	50	45	43	48	48	45	-	46.26	0.004
20-Apr	HB11	46	50	47	50	53	41	45	47	45	43	43	42	44	51	45	53	46	44	45	-	46.05	0.008
20-Apr	HB12	47	46	50	49	47	54	43	48	44	43	43	43	48	48	52	48	44	44	46	-	46.60	0.047
20-Apr	HB Control 1	52	52	45	45	50	50	52	51	45	45	44	45	45	45	43	45	45	50	-	-	47.17	0.035

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 2021, August 2021 to October 2021 are presented below.

	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	1.24	0.18
GP1	30.4	1.156	0.17
GP2	26.86	1.134	0.18
GP3	31.86	1.17	0.144
GP4	35.28	1.121	0.133
GP5	30.4	1.083	0.152
GP6	41.42	1.43	0.176
GP7	35.86	1.323	0.168
GP8	36.54	1.26	0.16
GP9	32.6	0.88	0.12
GP10	30.8	1.24	0.18
GP12	29.6	0.82	0.1
CB2	37.18	0.858	0.22
CB3	33.81	0.924	0.231
CB4	31.68	0.99	0.198
CB5	36.34	1.012	0.184
CB5	30	1.536	0.216
CB7	32.89	1.127	0.184
CB8	40.11	1.218	0.294
CB9	34.65	1.134	0.273
CB10	38.41	1.403	0.253
CB11	32.16	1.32	0.456
CB12	25.62	1.134	0.21
HB1	29.26	1.121	0.551
HB2	35.5	1.55	0.225
HB3	35.19	1.38	0.138
HB4	32.64	1.32	0.12
HB5	33.75	1.35	0.2
HB6	28.08	1.508	0.13
HB7	31	1.425	0.1
HB8	28.08	1.368	0.144
HB9	26.45	1.265	0.414
HB10	33.22	1.43	0.308
HB11	32.75	1.475	0.25
HB12	34.65	1.197	0.231
GP Cont a	31.29	1.8	0.128

GP Cont b	38.85	1.56	0.145
GP Cont c	37.8	1.368	0.087
CB Cont a	34.04	1.113	0.112
CB Cont b	35.28	1.131	0.214
CB Cont c	33.66	0.902	0.183
HB Cont a	34.76	1.148	0.171
HB Cont b	35.2	0.76	0.197
HB Cont c	30.59	0.779	0.130

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 2022, February to April 2022 is presented below.

	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	46.9	0.6	0.9
GP1	52.44	0.703	0.19
GP2	27.72	0.702	0.198
GP3	34.58	0.703	0.361
GP5	47.8	0.48	0.24
GP6	34.01	0.589	0.133
GP7	28.75	0.575	2.53
GP8	35	0.68	0.14
GP10	30.82	0.805	0.184
GP11	32.11	0.836	0.152
GP12	30.13	0.127	0.184
CB2	37.18	0.858	0.22
CB3	33.81	0.924	0.231
CB4	31.68	0.99	0.198
CB5	36.34	1.012	0.184
CB5	30	1.536	0.216
CB7	32.89	1.127	0.184
CB8	40.11	1.218	0.294
CB9	34.65	1.134	0.273
CB10	38.41	1.403	0.253
CB11	32.16	1.32	0.456
CB12	25.62	1.134	0.21
HB1	29.26	1.121	0.551
HB2	35.5	1.55	0.225
HB3	35.19	1.38	0.138
HB4	32.64	1.32	0.12
HB5	33.75	1.35	0.2
HB6	28.08	1.508	0.13
HB7	31	1.425	0.1
HB8	28.08	1.368	0.144

	Zn Total Wet Weight (mg/kg)	Cu Total Wet Weight (mg/kg)	Ni Total Wet Weight (µg/kg)
HB9	26.45	1.265	0.414
HB10	33.22	1.43	0.308
HB11	32.75	1.475	0.25
HB12	34.65	1.197	0.231
GP Cont a	30.78	1.044	0.252
GP Cont b	34.44	0.861	0.651
GP Cont c	55.25	1.475	0.6
CB Cont a	46.62	1.008	0.315
CB Cont b	44.52	0.798	0.189
CB Cont c	51.87	1.008	0.231
HB Cont a	39.6	0.672	0.648
HB Cont b	54.96	0.744	0.456
HB Cont c	47.28	0.624	0.576



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