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PORT OF ROCKHAMPTON WATER QUALITY MONITORING PROGRAM: 2022 ANNUAL REPORT

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EXECUTIVE SUMMARY

Vision Environment has undertaken ambient water quality monitoring at the Port of Rockhampton (PoR) since 2014, in order to establish a valid ambient dataset for comparison during future maintenance dredging campaigns at this port. Sampling is undertaken concurrently with the Port Curtis Integrated Monitoring Program (PCIMP) monitoring in Gladstone harbour, in order to provide easy comparisons of data across the different monitoring programs.

During 2022, monitoring of water physicochemical parameters, nutrients, chlorophyll *a* and metal(loid) concentrations was undertaken in March, June, August and November at three sites. Water quality results were compared to Water Quality Objectives (WQO) for the Fitzroy Basin, as well as adjacent and reference PCIMP zones. Of note were the high flow conditions of the Fitzroy River during November 2022, which meant that WQO were not applicable during this survey.

Sub-surface physicochemical parameters were similar across the PoR sites within each survey but often varied across the surveys due to metocean influences such as ambient temperature, ambient light and rainfall. Water pH remained within recommended WQO ranges throughout the year, while sub-surface turbidity and total suspended solid (TSS) concentrations often exceeded the 80th percentile WQO. Dissolved oxygen concentrations were also elevated during the Wet Season surveys (March and November).

Concentrations of several nutrients (filterable reactive phosphorus (FRP), total nitrogen and nitrogen oxides (NOx)) were higher during the Wet Season surveys. Consequently, chlorophyll *a* concentrations, which increase in response to increased light, temperature and nutrient availability, were also higher during the Wet Season. Ammonia concentrations tended to be higher during the Dry Season months, while total phosphorus and dissolved and total organic carbon did not exhibit clear temporal variation during 2022. Exceedances of the WQO were regularly recorded for total phosphorus, FRP, total nitrogen, ammonia and NOx at PoR. In comparison with PCIMP monitoring zones, significantly higher concentrations of total phosphorus, FRP, total nitrogen and NOx were recorded at the PoR sites during 2022, similar to previously recorded results.

Dissolved forms of most metal(loid)s were not detected during the 2022 surveys, with several total metal(loid)s also below laboratory reporting limits. Concentrations of most total metal(loid)s were lower during November than during earlier 2022 surveys. No exceedances of the 95% AWQG for metal(loid)s was recorded at PoR. In comparison with PCIMP monitoring zones, significantly higher concentrations of total aluminium, arsenic, chromium, iron, manganese, nickel, and dissolved and total vanadium were recorded at the PoR sites during 2022, similar to previously recorded results.

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ACRONYMS

ALS	Australian Laboratory Services
ANOVA	Analysis of Variance
APHA	American Public Health Association
AWQG	Australian Water Quality Guidelines
BOM	Bureau of Meteorology
DEHP	Department of Environment and Heritage Protection (now DES)
DES	Department of Environment and Science
DOC	Dissolved Organic Carbon
DSITIA	Department of Science, Information Technology, Innovation and the Arts, Queensland
FB	Field Blank
FRP	Filterable Reactive Phosphorus
GPC	Gladstone Ports Corporation Ltd
LOR	Limit of Reporting
LSD	Least Significant Difference
LTMDMP	Long Term Maintenance Dredging Management Plan
NMI	National Measurement Institute
PAR	Photosynthetically Active Radiation
PCIMP	Port Curtis Integrated Monitoring Program
PCO	Principal Coordinates Ordination
PoG	Port of Gladstone
PoR	Port of Rockhampton
QA/QC	Quality Assurance/Quality Control
QWQG	Queensland Water Quality Guidelines
SE	Standard error
TOC	Total Organic Carbon
TSS	Total Suspended Solids
VE	Vision Environment
WQG	Water Quality Guidelines
WQO	Water Quality Objectives

1 INTRODUCTION

The Port of Rockhampton (PoR) is situated in the Fitzroy River delta area, and is managed by Gladstone Ports Corporation Ltd (GPC). Maintenance dredging at PoR is guided by the Long-Term Maintenance Dredging Management Plan (LMDMP) for the PoR (GPCL, 2018), which has the objective to provide a long term sustainable approach to maintenance dredging. While dredging is predicted to occur every five years, the most recent maintenance dredge program at this port occurred in 2011.

Ambient water quality monitoring at PoR sites (Figure 1) has been undertaken since 2014 (Vision Environment, 2016, 2017a, 2018a, 2019a, 2020a, 2021a, 2022a, b, c, d, e), and is used to establish a valid ambient dataset for comparison during future dredging campaigns. Quarterly water quality monitoring at PoR coincides with the Port Curtis Integrated Monitoring Program (PCIMP) monitoring at 54 sites in Gladstone harbour (Figure 2), with methodologies aligning to provide easy comparisons of both current and historical data.

This report provides details of the methodology and results of the monitoring undertaken by Trinity Consultants Australia trading as Vision Environment ANZ (VE) for this project during 2022, in addition to providing a comparison with 2022 PCIMP data from adjacent and reference zones (Figure 3).

2 METHODOLOGY

2.1 Sites

During 2022, water quality monitoring for the three PoR sites (Figure 1) was undertaken by VE on four occasions aligning with PCIMP monitoring in Gladstone (March, June, August and November 2022). These sites are in a shallow (~ 4 to 10 m depth) mangrove dominated estuary, which is highly influenced by large tidal flows (~ 0.4 m/s). The Queensland Department of Science, Information Technology and Innovation (DSITI) classify the lower estuarine reaches of the Fitzroy River (in which the PoR sites are located) as a 'High Ecological Value' area. However, as the sites are located adjacent to Port Alma, a classification of 'Moderately Disturbed' would be more appropriate.

PCIMP zones adjacent to and/or similar in ambient conditions to the PoR (Figure 3) include the Narrows (six sites: NW10 to NW60) and Western Basin (six sites: WB10 to WB60). Reference sites for comparison include the Colosseum Inlet (four sites: RCI10 to RCI40) and Rodds Bay (three sites: RB10 to RB30).

2.2 Physicochemical Depth Profiling

During each survey, depth-profiling of physicochemical parameters (temperature, conductivity, pH, turbidity and dissolved oxygen) was undertaken at 0.5 to 1 m depth intervals using a multiparameter water quality meter (YSI ProDSS), which was calibrated and tested prior to sampling. Triplicate sub-surface readings (0.5 m depth) were recorded at each site.

2.3 Water Sample Collection

Water sampling was undertaken in accordance with standard protocols derived from worldwide authorities including:

- Australian and New Zealand Standards for water quality sampling (AS/NZS, 1998a, b, c, d);
- American Public Health Association Standard Methods for the Examination of Water and Wastewater (APHA, 2017);

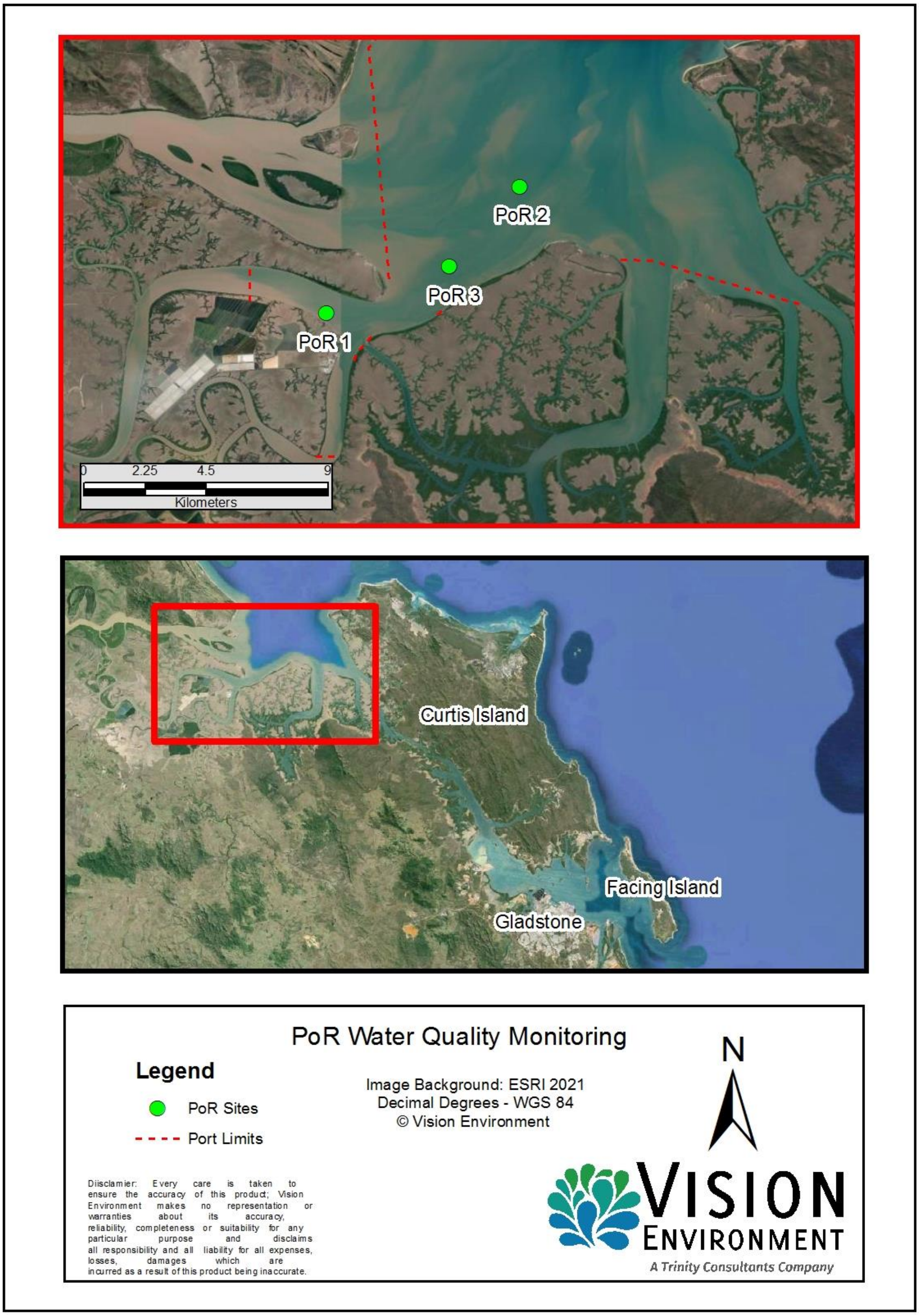

Figure 1 Location of the three monitoring sites for GPC PoR Water Quality monitoring.

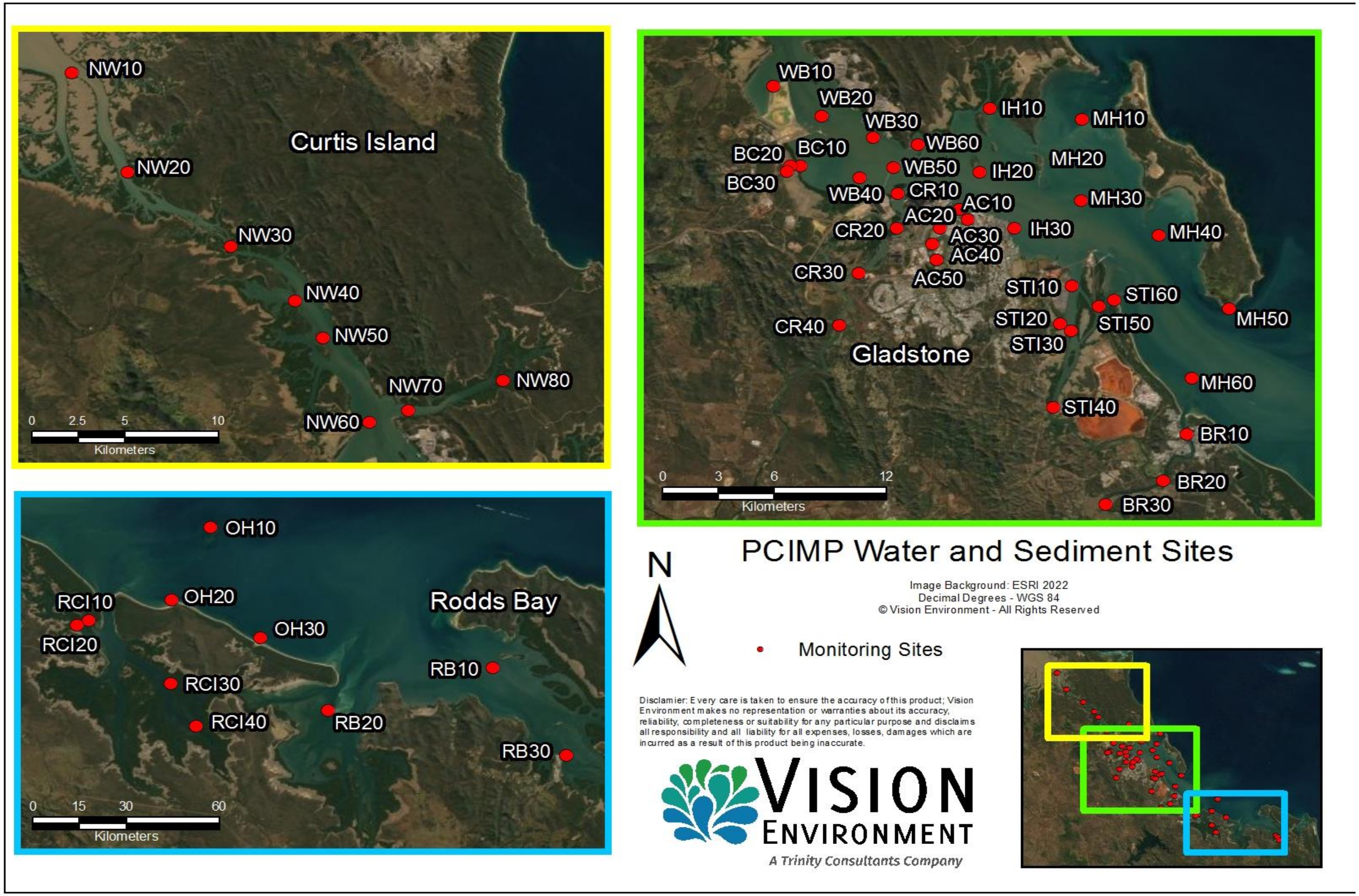

Figure 2 Location of PCIMP water quality monitoring sites in 2022.

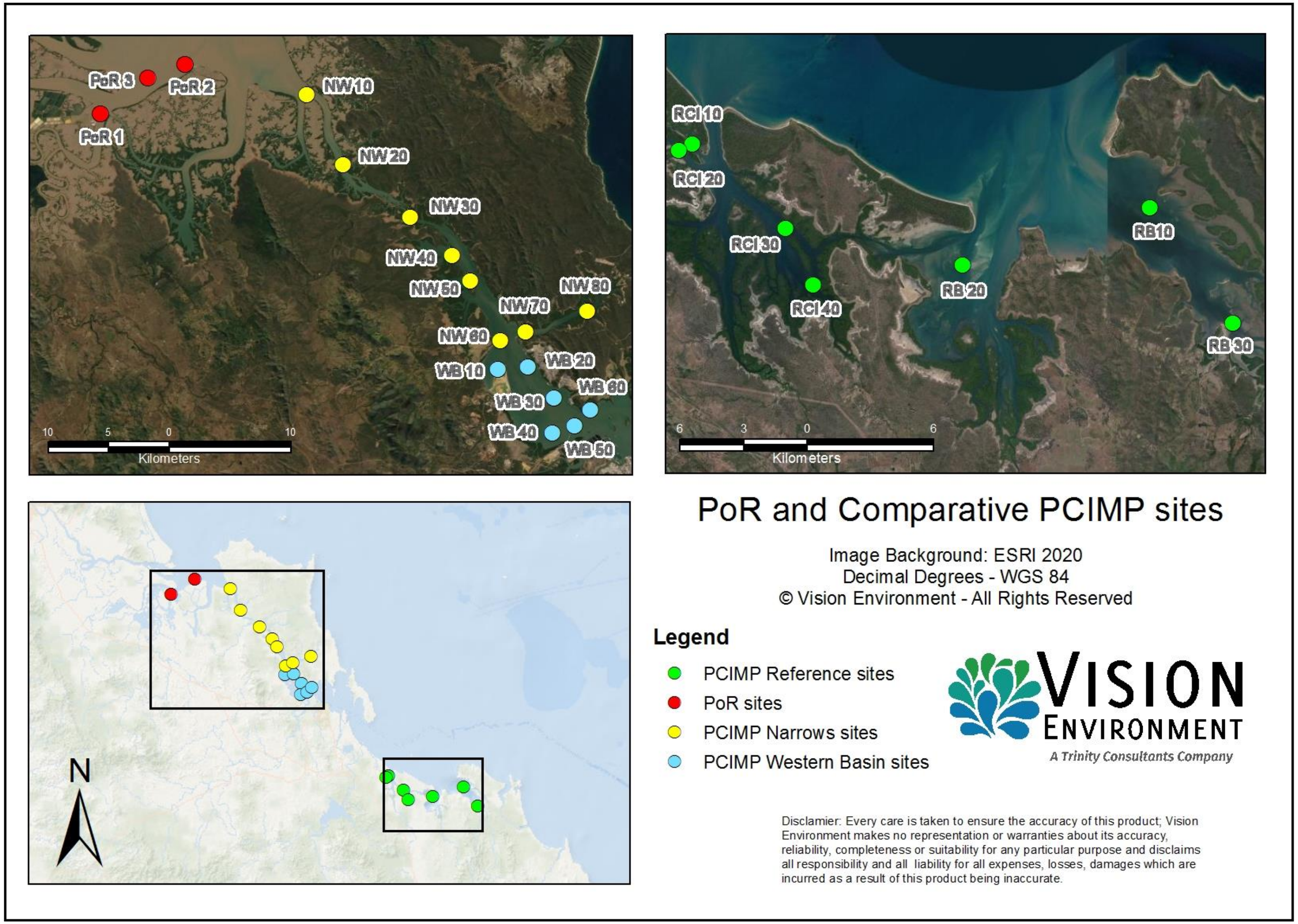

Figure 3 Location of PoR sites in comparison with sites in adjacent PCIMP zones (Narrows and Western Basin) and PCIMP reference sites (Colosseum Inlet and Rodds Bay).

- Australian and New Zealand Water Quality Guidelines (ANZG, 2018, 2021);
- Queensland Water Quality Guidelines (DERM, 2009); and
- Department of Environment and Science Monitoring and Sampling Manual (DES, 2018)

Water samples for analyses were collected from a depth of 0.5 m using a Perspex pole sampler with a 1 L Nalgene bottle attached. Prior to sample collection at each site, Nalgene bottles were triple rinsed in ambient water. Note that Nalgene bottles were acid-washed with hydrochloric acid and triple rinsed in Milli-Q water in the VE laboratory clean room, prior to sampling. Powder free gloves were worn to avoid sample contamination. A variety of laboratory provided sample bottles were required for the different analyses at each site, with different treatment and preservation requirements for each bottle (Table 1).

Table 1 Summary of sample containers, and treatment and preservation requirements.

Bottle	Parameters	Field Treatment	Preservation	Analytical Laboratory
100 ml Plastic	Total metals	-	Acidified with HNO_3 to pH 2, stored at 4°C.	NMI
100 ml Plastic	Dissolved metals	Filtered	Acidified with HNO_3 to pH 2, stored at 4°C.	
500 ml Plastic	TSS	-	Stored at 4°C	
250 ml Plastic	Total nutrients	-	Frozen prior to transport to laboratory.	Queensland Health
125 ml Plastic	Dissolved nutrients	Filtered	Frozen prior to transport to laboratory.	
1 L Plastic	Chlorophyll *a*	-	Filtered at VE lab, filter paper frozen prior transport to laboratory.	ALS

Samples that did not require filtration (Total Suspended Solids [TSS], total metal(loid)s, total nutrients and chlorophyll *a*), were decanted directly into the laboratory provided sample bottles. Samples that required filtration (dissolved metal(loid)s and nutrients) were filtered *in situ*, using a sterile syringe to pass water through a cellulose acetate membrane pre-filter (Minisart 17593K, pore size 1.2 µm), followed by a finer filter (Minisart 16555K, pore size 0.45 µm). Each individually pre-packaged syringe and filter was pre-rinsed with site water prior to filtration.

Field blanks (FB) were collected during each survey. FB are created by taking a complete set of sample bottles into the field each day, along with a supply of NMI provided Milli-Q water in acid washed Nalgene bottles. The Milli-Q water is treated as if it was a field collected sample and placed into the laboratory sample bottles by directly decanting (or filtering as required) for each parameter, thus undergoing identical field processes as the field samples. If contamination is present in these samples it indicates that contamination has been sourced from field processes or sample bottles.

All bottles were stored cool on the research vessel, prior to being stored as per Table 1 at the VE laboratory. Water samples were dispatched from VE to arrive at the nominated National Association of Testing Authorities (NATA) accredited laboratories within their recommended holding times.

To extend holding times for chlorophyll *a*, samples were pre-processed at VE (within 24 h of collection) through a 0.45 µm glass fiber filters, using a manifold and vacuum pump with the volume of water passed through the filter recorded (500 mL). Filter papers were folded, placed in aluminium foil within airtight plastic bags, and then frozen to extend the holding period of these samples to 28 days, in accordance with APHA method 10200H (APHA, 2017).

2.4 Water Quality Objectives

Historically, monitoring data from the Queensland Central Coast has been compared to Queensland Water Quality Guidelines or QWQG, and Australian Water Quality Guidelines or AWQG (ANZG, 2018, 2021, DERM, 2009). However, the Queensland Department of Science Information Technology and Innovation (DSITI) have developed local water quality guidelines (WQG)/water quality objectives (WQO) for the Fitzroy Basin fresh, estuarine and marine waters (DSITI, 2017), which are based on the 80th percentile of historical site data. Where there are no local WQO provided by DSITI, the QWQG and AWQG should be used as a default (DSITI, 2017). The WQO for the PoR monitoring sites are those listed for Fitzroy lower estuary, which are applicable to non-high flow conditions only (DSITI, 2017).

Varying WQOs apply to each of the PCIMP zones. The Department of Environment and Heritage Protection (DEHP) classified the Narrows, Colosseum Inlet and Rodds Bay as slightly disturbed, with the Western Basin classified as moderately disturbed (DEHP, 2014). WQOs have been derived for both base and event flows in Port Curtis. However, only base flow WQO were applicable for PCIMP data collected during 2022.

Metal(loid) concentrations are compared to the AWQG (ANZG, 2018, 2021) and aluminium compared to trigger values derived by Golding et al. (2015). For metal(loid)s, trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived. These guidelines refer to dissolved metal(loid)s, which are those which pass through a 0.45 µm membrane filter (APHA, 2017), as these are considered to be the potential bioavailable fraction (ANZG, 2018, 2021). Total metal(loid)s are the concentration of metal(loid)s determined in an unfiltered sample (those bound to sediments or colloidal particles). DSITIA (2014) state that water quality zones which are designated as moderately disturbed (such as the Western Basin) are proposed to meet the 95% AWQG trigger value, while zones classified as slightly disturbed (such as the Narrows, Colosseum Inlet and Rodds Bay) are proposed to meet the 99% AWQG trigger value.

2.5 Data Analysis

Data for each site was collated for each survey, and means and standard errors calculated for each physicochemical, and water parameter for each site and zone during each survey. Results were tabulated and plotted.

Along with the relevant PCIMP data, two-way analyses of variance (ANOVA) were undertaken to determine whether there were any significant statistical differences in parameters between zones (spatial variation) or across 2022 surveys (temporal variation). Data were tested for homogeneity of variance and normality. Significance levels were increased ($P < 0.01$, 99% confidence intervals) where data did not meet that criterion (O'Neill, 2000, Underwood, 1997). To determine where significant differences existed, Fisher's Least Significant Difference (LSD) *Post hoc* tests were used.

3 RESULTS & DISCUSSION

3.1 Meteorological Conditions

Figure 4 presents the climatic conditions (rainfall, wind, Fitzroy and Calliope River flow and lunar phases) recorded during 2022, while Table 2 outlines the climatic conditions experienced immediately prior to, and during, each water quality survey at the PoR sites.

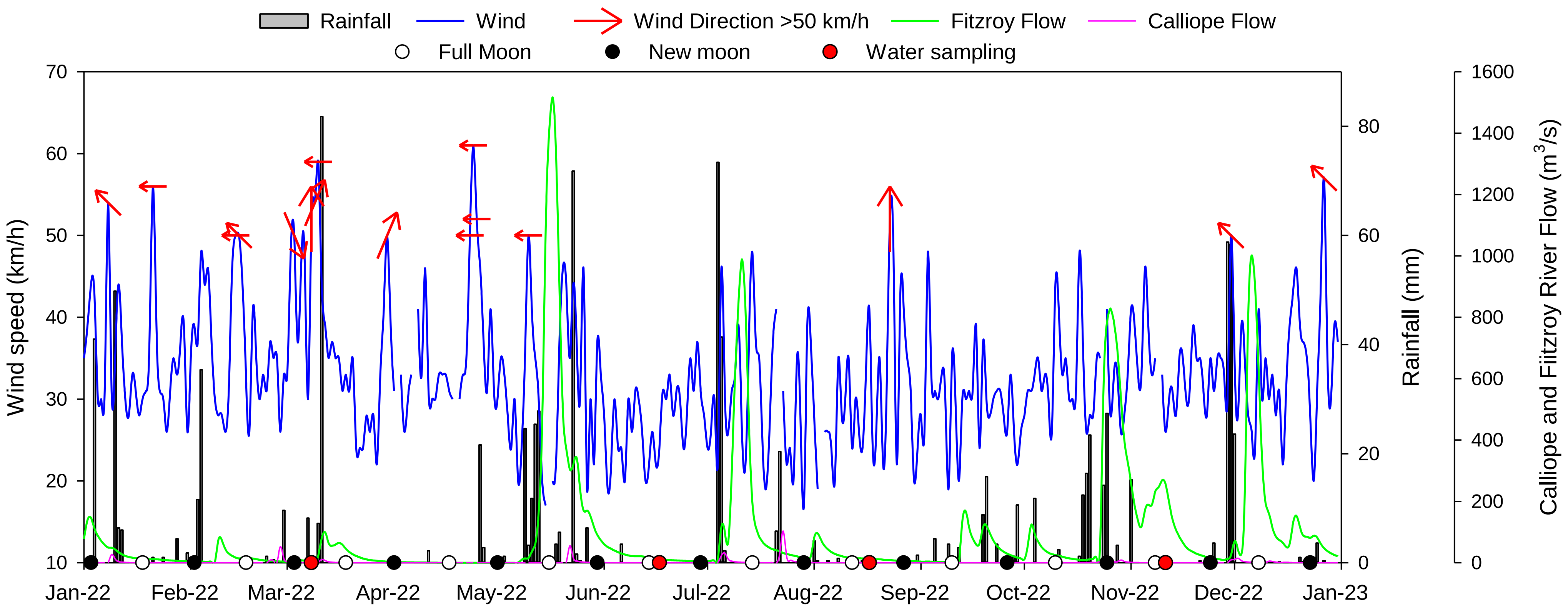

Figure 4 Rockhampton rainfall, wind, Fitzroy River flow (station 130005A), Calliope River flow (station132001A) and lunar phases during 2022 in relation to sampling events. *Note that the wind direction is pointing in the direction that the wind is blowing towards.*

Table 2 Summary of climatic conditions during the 2022 PoR surveys.
Rainfall includes amount recorded during the sampling day and one week prior at each site. Wind refers to the maximum wind gusts recorded during the sample day as recorded at the Rockhampton Aero Station 039083 (BOM, 2022). Tidal range measurements specified for Port Alma.

2022 Survey dates	Rainfall (mm)	Wind Gusts (km/h)	Tides
8 March	8	52 SSW	Approaching neap tide with first quarter moon on 10 March. Highest tidal range during sampling = 2.39 m
17 June	<1	24 SE	Approaching neap tide with full moon on 14 June. Highest tidal range during sampling = 3.29 m
17 August	<1	41 SW	Approaching neap tide with last quarter moon on 19 August. Highest tidal range during sampling = 3.27 m
11 November	<1	26 ESE	Just after spring tide with full moon on 8 November. Highest tidal range during sampling = 3.70 m

Approximately 960 mm of rainfall was recorded in Rockhampton Airport BOM station (039083) during 2022, slightly higher than the average annual rainfall of 815 mm recorded from 1939 to 2022 (BOM, 2022), but lower than the annual rainfall recorded in Gladstone in 2022 (1146 mm) as recorded by the Gladstone Airport BOM station (039326). However, rainfall data was unable to be recorded at Rockhampton for 69 days in 2022, and therefore reported amounts may be an underestimate of actual rainfall experienced. Overall, rainfall amounts were reasonably similar across the Wet Season months (January to April, November to December: 461 mm) and Dry Season (May to October: 501 mm). Highest monthly rainfall was recorded in May (184 mm), July (143 mm) and November (136 mm), with lowest rainfall in June (3 mm) and August (8 mm).

High flows (> 75.9 m^3/s as per DSITI, (2017)) from the Fitzroy River were recorded on 88 days during 2022, during January, May, July, September, October, November and December. Maximum flow rates (1517 m^3/s) were recorded on 17 May (DNRM, 2022b). High flows were occurring during the November survey, and as such, WQO were not applicable to the November PoR sampling results.

Flows from the Calliope River increased after rainfall periods throughout the year (DNRM, 2022a) but remained at Baseflow conditions (< 100 m^3/s) during the entirety of 2022, with the exception of 23 July (104 m^3/s). As such, standard WQO could be used for comparison to all the collected PCIMP data (EHP, 2014).

As typically found, Rockhampton winds during 2022 were primarily blowing from a south south-easterly and easterly direction (62%), while maximum wind gusts from a westerly direction occurred 19% of the time, as did winds from a northerly direction. Maximum daily wind gusts were typically between 30 to 40 km/h, with just 4% of gusts greater than 50 km/h (Figure 5).

PoR water quality sampling surveys were generally undertaken during the approach of neap tides. Sampling was conducted at high tide during all surveys with highest tidal range during the surveys ranging from 2.39 m in March to 3.70 m in November (Table 2).

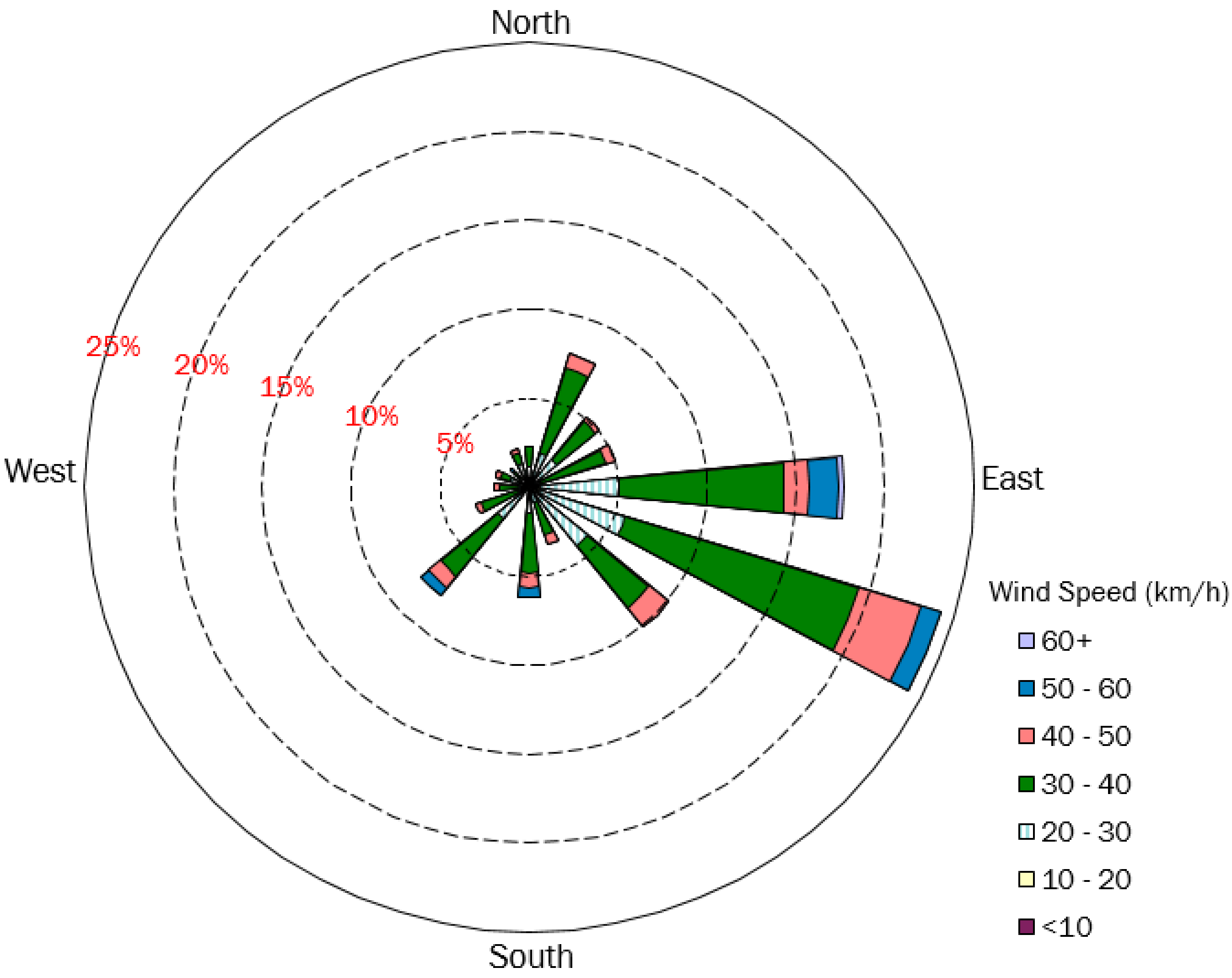

Figure 5 Windrose of daily maximum wind gusts at Rockhampton Airport Station during 2022. *Data sources from BOM. Note that the roses display the proportion of wind speeds (varying colours) blowing from various directions.*

3.2 Physicochemical Parameters and TSS

Sub-surface (0.5 m depth) means for each physicochemical parameter at PoR sites across the four surveys are exhibited in Table 3, while physicochemical depth-profiles can be found in the Appendix (Figure A1). The results, in addition to concurrent PCIMP results at adjacent (Narrows and Western Basin) and Reference (Colosseum Inlet and Rodds Bay) zones, are presented in Figures 6 and 7, as well as Table A1 within the Appendix. Two-way ANOVA results can also be found in the Appendix (Table A4).

Sub-surface physicochemical parameters were similar across the PoR sites within each survey but often varied across the surveys. Typical seasonality was exhibited, with higher temperatures during the Wet Season surveys of March and November (30.0 and 24.1 °C, respectively) and lower temperatures (19.4 to 20.0 °C) during the Dry Season surveys of June and August (Table 3). Sub-surface pH remained consistent throughout the year ranging from 8.0 to 8.1 and within the recommended QWQG range of 7.2 to 8.3 during all surveys (Table 3).

Table 3 Mean sub-surface physicochemical parameters and total suspended solid concentrations at individual PoR sites during 2022 surveys. *Values are means ± se (n = 6, TSS n = 1). 20th to 80th WQO percentile ranges listed for pH and DO, with two 80th percentile trigger value for turbidity listed: Wet Season (March and November) and Dry Season (June and August). Green shading indicates values outside of the WQO recommended range (DSITI, 2017). *QWQG value used for comparison for TSS (DERM, 2009). Note that WQO were not applicable during the November survey due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.*

Parameter	March 2022			June 2022			August 2022			November 2022			20th to 80th WQO
	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	
Temperature (°C)	30.0 ± 0.0	30.0 ± 0.0	30.0 ± 0.0	19.4 ± 0.0	20.0 ± 0.0	19.5 ± 0.0	19.5 ± 0.0	19.4 ± 0.0	19.5 ± 0.0	24.3 ± 0.0	24.2 ± 0.0	23.9 ± 0.0	-
Conductivity (mS/cm)	53.0 ± 0.0	53.4 ± 0.0	53.5 ± 0.0	48.4 ± 0.0	49.4 ± 0.0	49.6 ± 0.0	48.6 ± 0.0	49.8 ± 0.0	49.6 ± 0.0	46.1 ± 0.1	49.6 ± 0.1	46.8 ± 0.0	-
pH	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.0 ± 0.0	8.1 ± 0.0	8.1 ± 0.0	8.1 ± 0.0	7.2 - 8.3
Dissolved oxygen (% sat.)	96 ± 0	96 ± 0	97 ± 0	90 ± 0	93 ± 0	92 ± 0	92 ± 0	93 ± 0	95 ± 0	98 ± 0	100 ± 0	98 ± 0	87 - 95
Turbidity (NTU)	13 ± 0	40 ± 0	38 ± 2	35 ± 0	17 ± 0	27 ± 2	37 ± 1	35 ± 2	27 ± 0	11 ± 0	9 ± 0	32 ± 1	W = 30 D = 12
TSS (mg/L)	16	64	57	40	35	26	66	49	36	16	17	17	20*

Sub-surface conductivity was higher during the March 2022 survey (~ 53 mS/cm) than during the subsequent 2022 surveys (46 to 49 mS/cm). This is likely to be due to the high levels of rainfall recorded during the subsequent survey months, or during the months prior (May: 184 mm; July: 143 mm; October: 113 mm; and November: 136 mm), while rainfall during February and March 2022 remained less than 100 mm monthly.

Sub-surface dissolved oxygen tended to be lower during the Dry Season surveys (90 to 95% saturation) than during the Wet Season surveys (96 to 100% saturation). Dissolved oxygen concentrations during March and November were higher than the 80th percentile WQO (95% saturation), although WQO were not applicable during November due to the high flow conditions. Higher dissolved oxygen during the Wet Season surveys was likely due to higher levels of photosynthesis within the water column at these times. Microalgal populations increase with warmer temperatures and increased light (Popovich and Marcovecchio, 2008) leading to increased photosynthetic activity. This pattern is commonly recorded in Port Curtis (Vision Environment, 2017b, 2018b, 2019b, 2020b, 2021b, 2022f).

Sub-surface turbidity tended to vary across the sites during each survey, with no consistent spatial pattern evident during 2022. Exceedances of the 80th percentile WQO were evident for each site during the Dry Season months (> 12 NTU), with Wet Season exceedances (> 30 NTU) recorded at two sites during March. WQO were not applicable during the November 2022 survey. TSS results paralleled turbidity results, ranging from 16 to 66 mg/L across 2022.

Within the water column, temperature and pH tended to remain consistent with depth (Figure A1 in Appendix). During the November survey, conductivity at PoR2 and PoR3 demonstrated variation with water depth, indicating the presence of a lower salinity plume in the top 1 to 2 m of the water column, most likely associated with the high flow conditions of the Fitzroy River. Both dissolved oxygen and turbidity consistently exhibited variation with water depth. Dissolved oxygen concentrations tended to decrease slightly with depth, most likely due to reduced photosynthetic activity in the reduced light environment of deeper waters. Turbidity generally increased near the benthos due to sediment resuspension, often reach over 100 NTU (Figure A1 in Appendix).

Comparison with PCIMP Monitoring Results

Whole water column physiochemical parameter results from PoR were compared to the adjacent PCIMP monitoring zones of the Narrows and Western Basin, as well as the PCIMP reference zones of Colosseum Inlet and Rodds Bay (Figures 6 and 7). As expected, temperatures across all zones were significantly ($P < 0.05$) higher during the Wet Season months (March and November, survey means of 29.7 and 24.8 °C, respectively), than during June and August (18.8 and 19.3 °C). Temperature at PoR (annual mean 23.3 °C) was similar to the Narrows and Western Basin zones (23.3 °C), all of which were significantly ($P < 0.05$) higher than the Reference zones (22.8 to 22.9 °C).

Conductivity was significantly ($P < 0.05$) higher at PoR, Narrows and Western Basin during March (53.4 to 55.1 mS/cm) than during subsequent surveys (48.9 to 52.7 mS/cm), while the outer harbour Reference zones exhibited their highest conductivity during November (53.8 to 54.2 mS/cm) in comparison to previous surveys (43.4 to 51.8 mS/cm). Conductivity in PoR (annual mean of 50.3 mS/cm) was slightly lower than the Narrows and Western Basin (51.6 to 52.0 mS/cm), but higher than Colosseum Inlet (49.9 mS/cm).

The pH at PoR (annual mean of 8.0) was significantly higher than the Narrows, Western Basin and Colosseum Inlet (7.9), as typically seen (Vision Environment, 2020a, 2021a, 2022e).

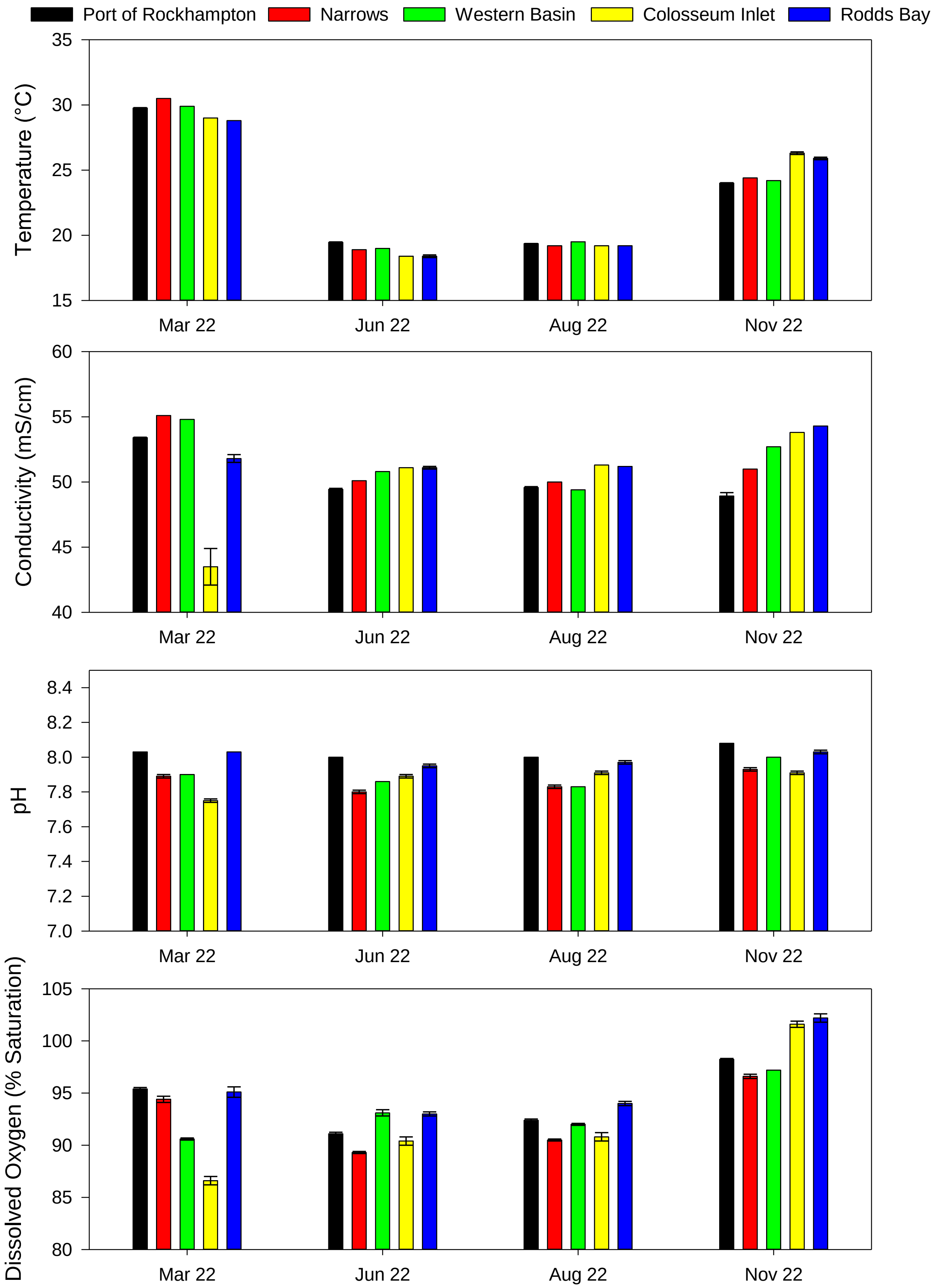

Figure 6 Mean survey temperature, conductivity, pH and dissolved oxygen at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 71 to 141).

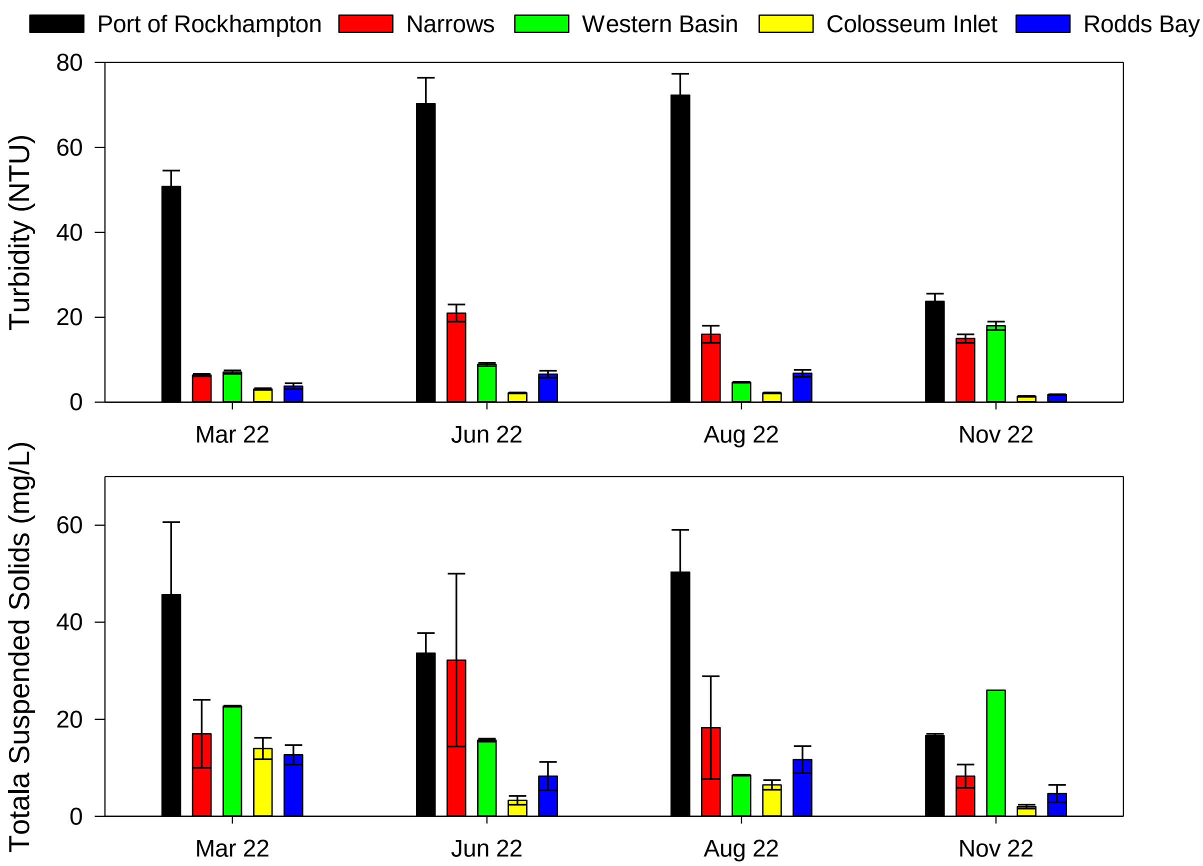

Figure 7 Mean turbidity and total suspended solids at PoR, and adjacent and reference PCIMP zones. *Values are means ± se (n = 3 to 141).*

Highest pH in all zones was exhibited during the November 2022 survey (survey mean of 8.0), than during prior 2022 surveys (7.9).

Dissolved oxygen across all zones was significantly ($P < 0.05$) higher during November (survey mean of 99% saturation) than during prior surveys (91 to 92% saturation). Oxygen concentrations at PoR (annual mean of 94% saturation) were similar to the Narrows and Western basin (93% saturation), and lower than Rodds bay concentrations (96% saturation).

In most zones, turbidity was highest during the Dry Season months (survey means of 18 to 23 NTU) than during the Wet Season (13 NTU). This is likely due to the rainfall experienced during the Dry Season, immediately prior to sampling. As previously reported (Vision Environment, 2020a, 2021a, 2022e), turbidity at PoR (annual mean of 59 NTU) was significantly higher than the four PCIMP zones, with intermediate turbidity at the Narrows and Western Basin (10 to 15 NTU), and lowest turbidity at Colosseum Inlet and Rodds Bay (2 to 5 NTU). TSS concentrations exhibited the same spatial pattern, with significantly higher TSS at PoR (annual mean of 37 mg/L), intermediate TSS at the Narrows and Western Basin (18 to 19 mg/L), and lowest TSS at Colosseum Inlet and Rodds Bay (6 to 9 mg/L).

3.3 Chlorophyll *a* and Nutrients

Tabulated nutrient and chlorophyll *a* results for 2022 can be found in Table 4. The results, in addition to concurrent PCIMP sampling at adjacent and reference zones, are presented in Figures 8 and 9, and Table A2 within the Appendix. Two-way ANOVA results can also be found in the Appendix (Table A4).

Table 4 Chlorophyll *a* and nutrient concentrations at PoR during 2022 surveys.
N = 1. Green shading indicates exceedances of the 80th percentile WQO value (DSITI, 2017). Note that WQO were not applicable during the November survey due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.

Parameter (µg/L)	March 2022			June 2022			August 2022			November 2022			WQO
	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	
Total Phosphorus	28	46	39	43	36	30	47	38	33	49	29	49	29
Filterable Reactive Phosphorus	16	13	9	12	8	7	11	8	9	30	18	32	7
Total Nitrogen	190	280	230	220	210	180	190	170	150	300	200	270	220
Ammonia	<2	<2	2	11	15	4	8	15	4	11	3	2	10
Nitrogen oxides	60	58	32	35	27	23	31	20	21	96	57	100	9
Chlorophyll *a*	1.5	1.4	1.4	0.6	1.7	0.4	0.7	0.3	0.8	1.1	1.0	1.5	2
TOC (mg/L)	2	2	2	2	2	2	2	2	2	3	2	2	-
DOC (mg/L)	1.5	1.4	1.3	1.9	1.7	1.8	1.2	1.2	1.1	1.8	1.7	1.5	-

Total phosphorus at all three PoR sites (28 to 49 µg/L) exceeded the WQO of 29 µg/L during most surveys, although WQO were not applicable during November 2022. No consistent temporal or spatial variation was evident across the surveys or sites.

Filterable reactive phosphorus (FRP) concentrations were lower than total concentrations, ranging from 7 µg/L to 32 µg/L, all higher than or equal to the WQO of 7 µg/L. Highest concentrations were evident during November (18 to 32 µg/L) when WQO were not applicable, compared to the prior surveys (7 to 16 µg/L).

Total nitrogen, which includes both organic and inorganic forms, ranged from 150 to 300 µg/L, with highest values in November (200 to 300 µg/L) and March (190 to 280 µg/L) compared to the Dry Season surveys (150 to 220 µg/L). Concentrations at two sites in March exceeded the WQO of 220 µg/L, with WQO not appliable during November.

In contrast, ammonia concentrations were generally higher during the Dry Season surveys (4 to 15 µg/L) in comparison to March (<2 µg/L) and November (2 to 11 µg/L). Exceedances of the WQO (10 µg/L) were recorded in at least one site during the June and August surveys.

The readily bioavailable form of nitrogen oxides (NOx) paralleled total nitrogen concentrations, being higher in November (57 to 100 µg/L) and March (32 to 60 µg/L) than the Dry Season surveys (20 to 35 µg/L). All NOx concentrations were higher than the WQO of 9 µg/L.

Chlorophyll *a* concentrations were higher during March (1.4 to 1.5 µg/L) and November (1.0 to 1.5 µg/L) than the Dry Season surveys (0.3 to 1.7 µg/L) but all concentrations remained below the WQO (2 µg/L). Chlorophyll *a* concentrations provide an indication of algal biomass within the water column. Microalgal populations respond to increased temperature and light (Popovich and Marcovecchio, 2008), in addition to elevated nutrients, all of which were available during the March and November surveys.

Total Organic Carbon (TOC) concentrations ranged from 2 to 3 mg/L at all sites and during all surveys. As expected, Dissolved Organic Carbon (DOC) concentrations were lower than TOC and ranged from 1.1 mg/L to 1.9 mg/L.

In summary, concentrations of FRP, total nitrogen, NOx and subsequently, chlorophyll a, were higher during the Wet Season surveys, while ammonia concentrations were higher during the Dry Season. No distinct temporal pattern was evident for total phosphorus or organic carbon during 2022.

Comparison with PCIMP Monitoring Results

Nutrient results from PoR were compared to the adjacent PCIMP monitoring zones of the Narrows and Western Basin, as well as the PCIMP reference zones of Colosseum Inlet and Rodds Bay (Figures 8 and 9).

No temporal variation in total phosphorus or ammonia across the surveys was evident for any of the zones. In contrast, FRP, total nitrogen and chlorophyll *a* concentrations were significantly ($P < 0.05$) higher in the five zones during March (survey means of 3 µg/L, 201 µg/L and 1.6 µg/L , respectively) and November (6 µg/L, 183 µg/L and 1.1 µg/L, respectively), than during the Dry Season surveys (2 to 3 µg/L, 122 to 153 µg/L and 0.8 µg/L, respectively). DOC and TOC were also significantly higher during one or more of the Wet Season surveys, than the Dry Season surveys.

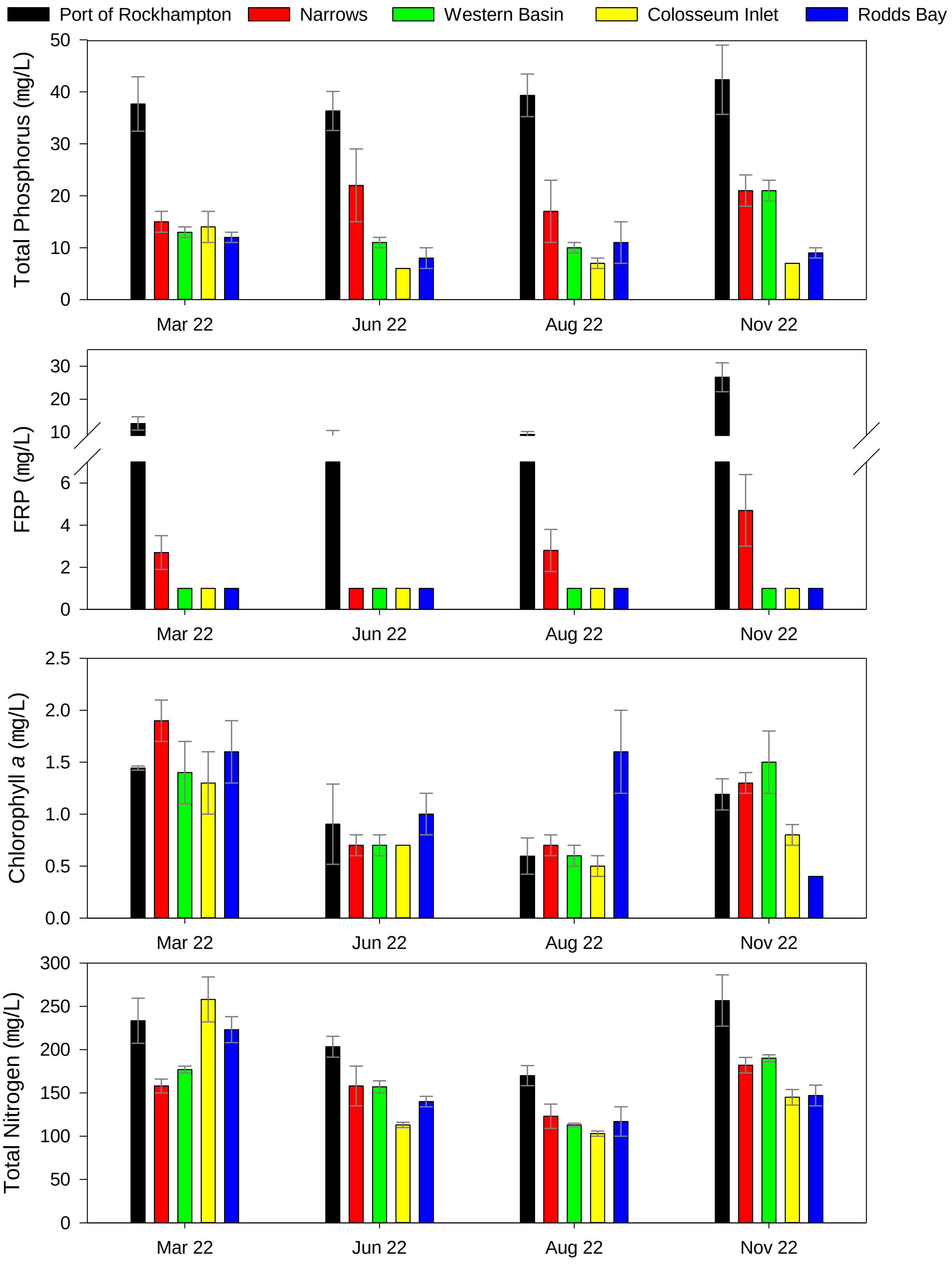

Figure 8 Mean total phosphorus, filterable reactive phosphorus, chlorophyll *a* and total nitrogen concentrations at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR was used in the plots.

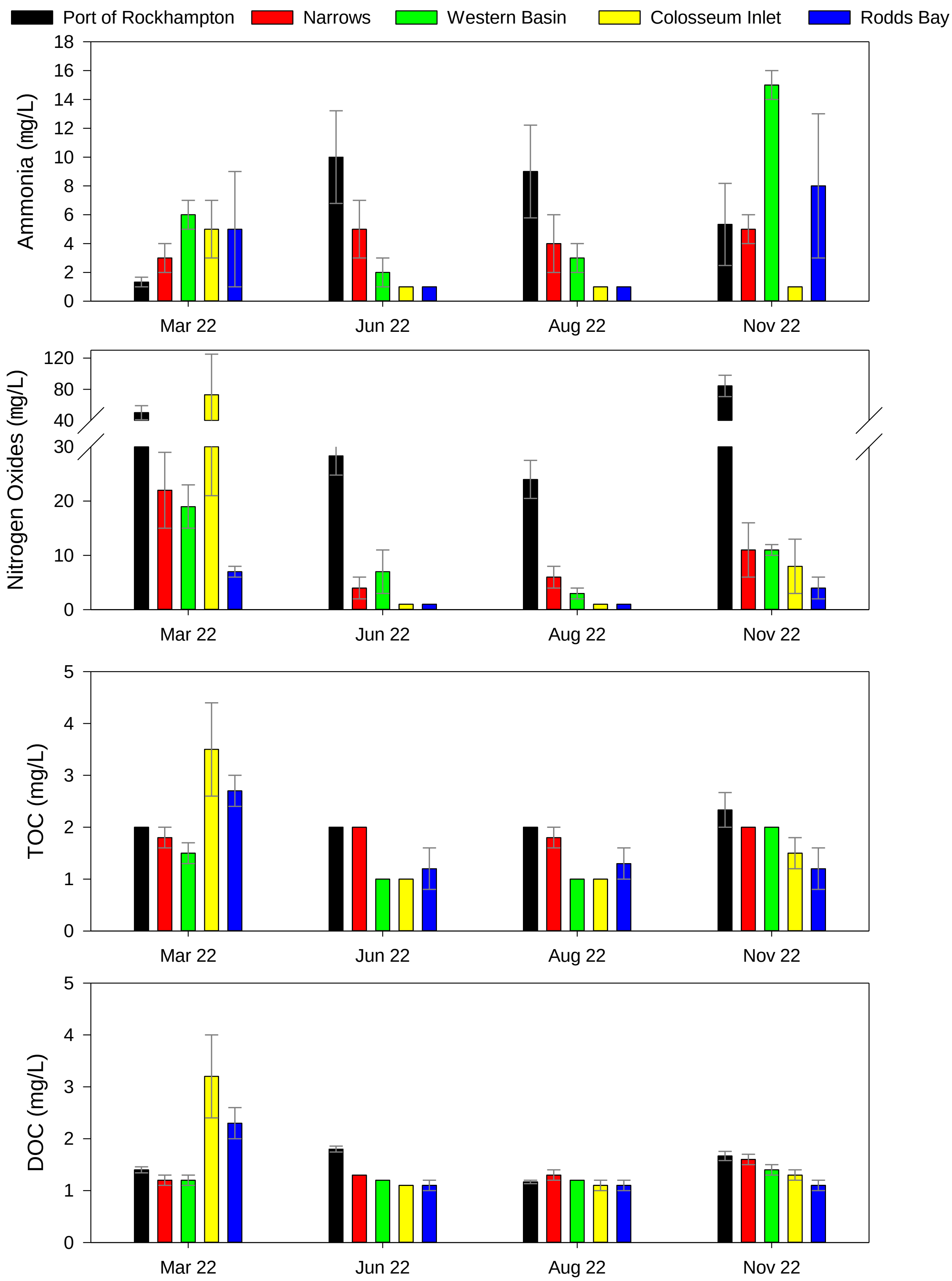

Figure 9 Mean ammonia, NOx, total and dissolved organic carbon concentrations at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.

Total phosphorus was significantly ($P < 0.05$) higher in PoR (annual mean of 39 µg/L) than all four PCIMP zones (8 to 19 µg/L), as was FRP (14 µg/L compared to <2 to 3 µg/L), total nitrogen (216 µg/L compared to 154 to 158 µg/L) and NOx (47 µg/L compared to 3 to 21 µg/L), similar to what has been recorded previously (Vision Environment, 2020a, 2021a, 2022e). Ammonia, chlorophyll a, DOC and TOC concentrations at PoR were similar to most of the PCIMP zones.

It is likely that the elevated forms of nitrogen and phosphorus in PoR compared to PoG adjacent zones are a result of differing anthropogenic activities (farming in comparison to industrial) between the two areas.

3.4 Total and Dissolved Metal(loid)s

Total and dissolved metal(loid) results at PoR can be found in Table 5. These results, in addition to concurrent PCIMP sampling results at adjacent and reference zones, are presented in Figures 10 to 14, and Table A3 within the Appendix. Two-way ANOVA results can be found in the Appendix (Table A4). Only dissolved metal(loid) forms were compared to AWQG.

Many metal(loid)s were at or below laboratory LOR at the PoR sites (Table 5), including total and dissolved cadmium, cobalt, gallium, lead, mercury, silver and tin. Dissolved forms of chromium, cobalt, copper, iron and manganese were also at or below LOR, but total forms were detected. Dissolved nickel was detected only during the March survey, while dissolved zinc was detected only during March and November. Both dissolved and total arsenic, molybdenum and vanadium were detected at PoR sites during each survey.

No metal(loid) WQO were exceeded at PoR. Concentrations of total aluminium, iron, nickel, vanadium and zinc were generally found at lower concentrations during the November survey, reflecting the generally lower TSS concentrations during this month. Metal(loid) ions will preferentially bind to the suspended small particles and organic matter that contain a large surface charge and numerous binding sites (Simpson *et al.*, 2005, Simpson *et al.*, 2013). Total chromium and copper were higher in March than during subsequent surveys, while dissolved and total arsenic and molybdenum concentrations remained reasonably consistent across the four surveys.

In summary, the dissolved form of most metals were not detected during the 2022 surveys, with some total metals also below laboratory LOR. Concentrations of most total metals were lower during November than during prior 2022 surveys, while highest concentrations of total chromium and copper were recorded during March.

Comparison with PCIMP Monitoring Results

Metal(loid) results from PoR were compared to the adjacent PCIMP monitoring zones of the Narrows and Western Basin, as well as the PCIMP reference zones of Colosseum Inlet and Rodds Bay (Figures 8 and 9).

In comparison with the PCIMP zones, PoR sites exhibited significantly ($P < 0.05$) higher concentrations of total aluminium, arsenic, chromium, iron, manganese, nickel, and dissolved and total vanadium. Concentrations of dissolved aluminium, arsenic, copper, and dissolved and total molybdenum and zinc at PoR were found at similar concentrations to one or more PCIMP zones.

Table 5 Total and dissolved metal concentrations at PoR during 2022 surveys.
N = 1. Green shading indicates exceedances of the 95% species protection AWQG value which is applicable to PoR sites. Note that speciation measures have not been carried out on chromium, and thus these forms (Cr(III) and Cr(VI)) could potentially contribute to total concentrations. Note that WQO were not applicable during the November survey due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.

Metal (µg/L)		March 2022			June 2022			August 2022			November 2022			95% AWQG
		PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	
Aluminium	Dissolved	8	<5	10	<5	7	8	<5	<5	<5	<5	<5	6.2	24
	Total	610	3300	2700	1600	1300	1000	540	1500	1160	620	310	830	-
Arsenic	Dissolved	1.4	1.4	1.5	1.1	1.2	1.3	1.1	1.2	1.1	1.3	1.3	1.3	-
	Total	1.5	2	1.9	1.7	1.7	1.6	1.6	1.8	1.7	1.4	1.4	1.5	-
Cadmium	Dissolved	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	5.5
	Total	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Chromium	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	Cr (III) 27.4 Cr (VI) 4.4
	Total	11	4.4	3.4	2.2	1.7	1.4	<1	<1	1.4	1.1	<1	1.7	-
Cobalt	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
	Total	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Copper	Dissolved	1	<1	<1	<1	<1	<1	<1	<1	<1	1.1	<1	<1	1.3
	Total	1.4	2.6	2.1	1.5	<1	<1	1.1	1.2	1.2	<1	<1	1.1	-
Gallium	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
	Total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Iron	Dissolved	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-
	Total	560	3000	2400	1800	1600	1200	810	2010	1590	700	360	1000	-
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Manganese	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-

Metal (µg/L)		March 2022			June 2022			August 2022			November 2022			95% AWQG
		PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	PoR1	PoR2	PoR3	
	Total	7.1	36	29	23	21	16	29	27	22	8.6	6	14	-
Mercury	Dissolved	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.4
	Total	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-
Molybdenum	Dissolved	11	11	11	9.9	10	10	10	9	10	8.6	9.3	8.6	-
	Total	11	11	11	9.9	11	10	8.9	10	11	8.8	9.8	8.9	-
Nickel	Dissolved	2	1.1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	70
	Total	1.9	4.1	3.1	3	2.5	2	1.7	2.9	2.5	1.3	<1	1.9	-
Silver	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.4
	Total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Tin	Dissolved	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
	Total	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
Vanadium	Dissolved	3.3	3.2	3.1	2.6	2.3	2	2	1.8	2	2.5	2.1	2.8	100
	Total	4.2	7.8	6.8	5.1	4.8	4.2	4	5.2	4.8	3.3	2.7	4	-
Zinc	Dissolved	<1	1.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	5.5	8
	Total	2.6	5.1	3.8	1.9	2.1	1.8	2.6	2.9	3.4	1.9	1	2.5	-

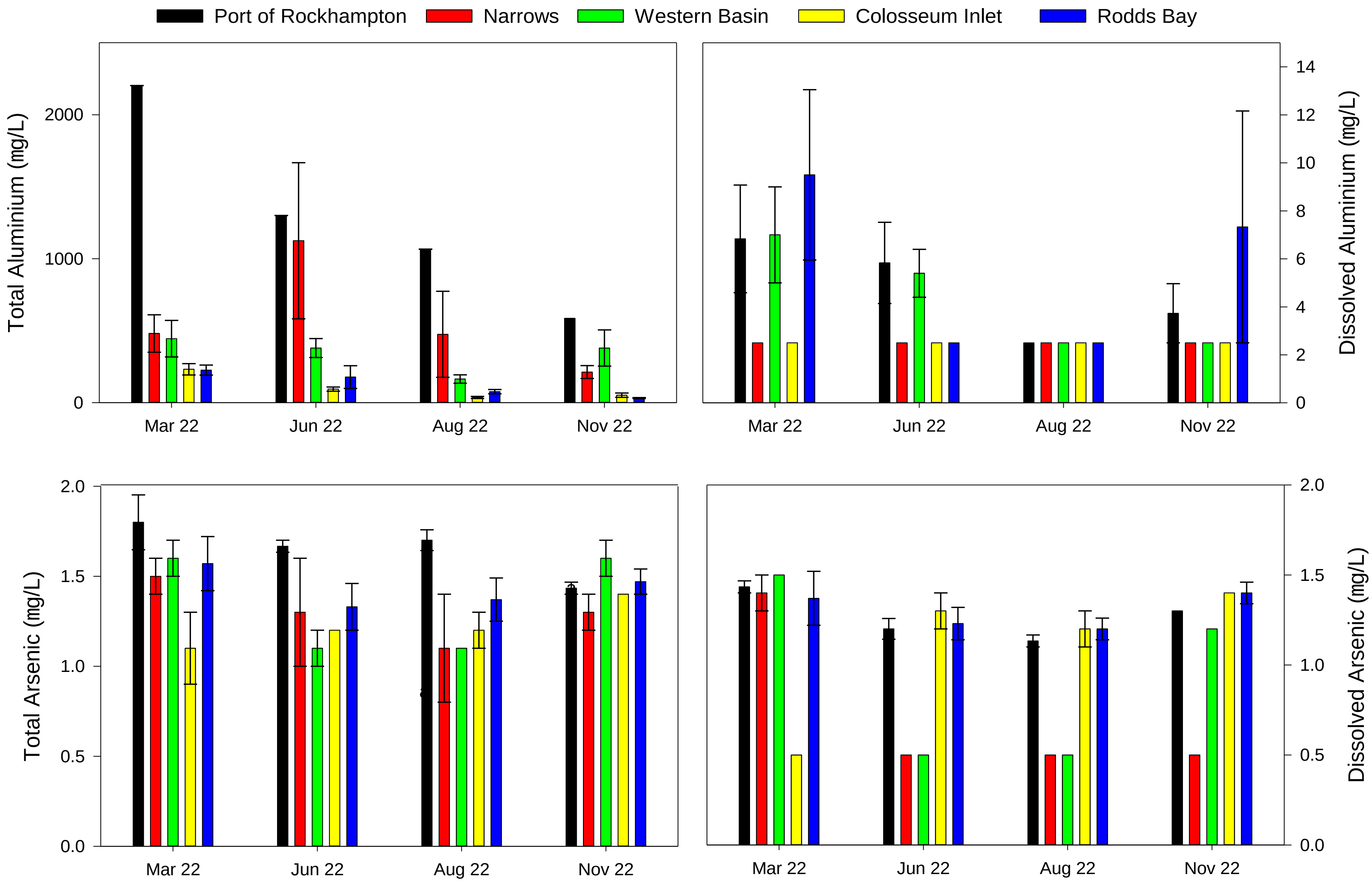

Figure 10 Mean total and dissolved aluminium and arsenic concentrations at PoR, and adjacent and reference PCIMP zones. *Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.*

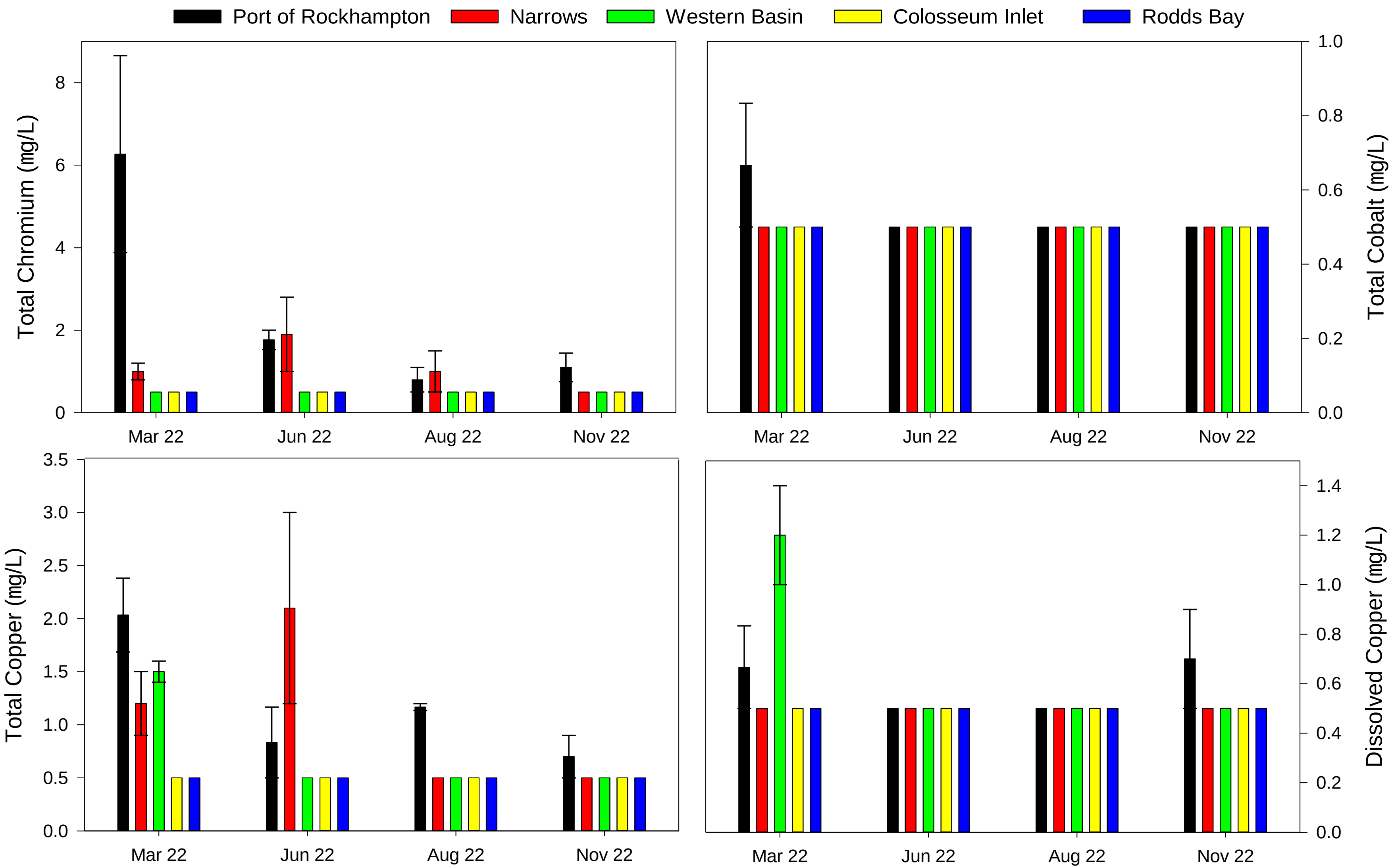

Figure 11 Mean total chromium, cobalt and copper and dissolved copper concentrations at PoR, and adjacent and reference PCIMP zones. *Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.*

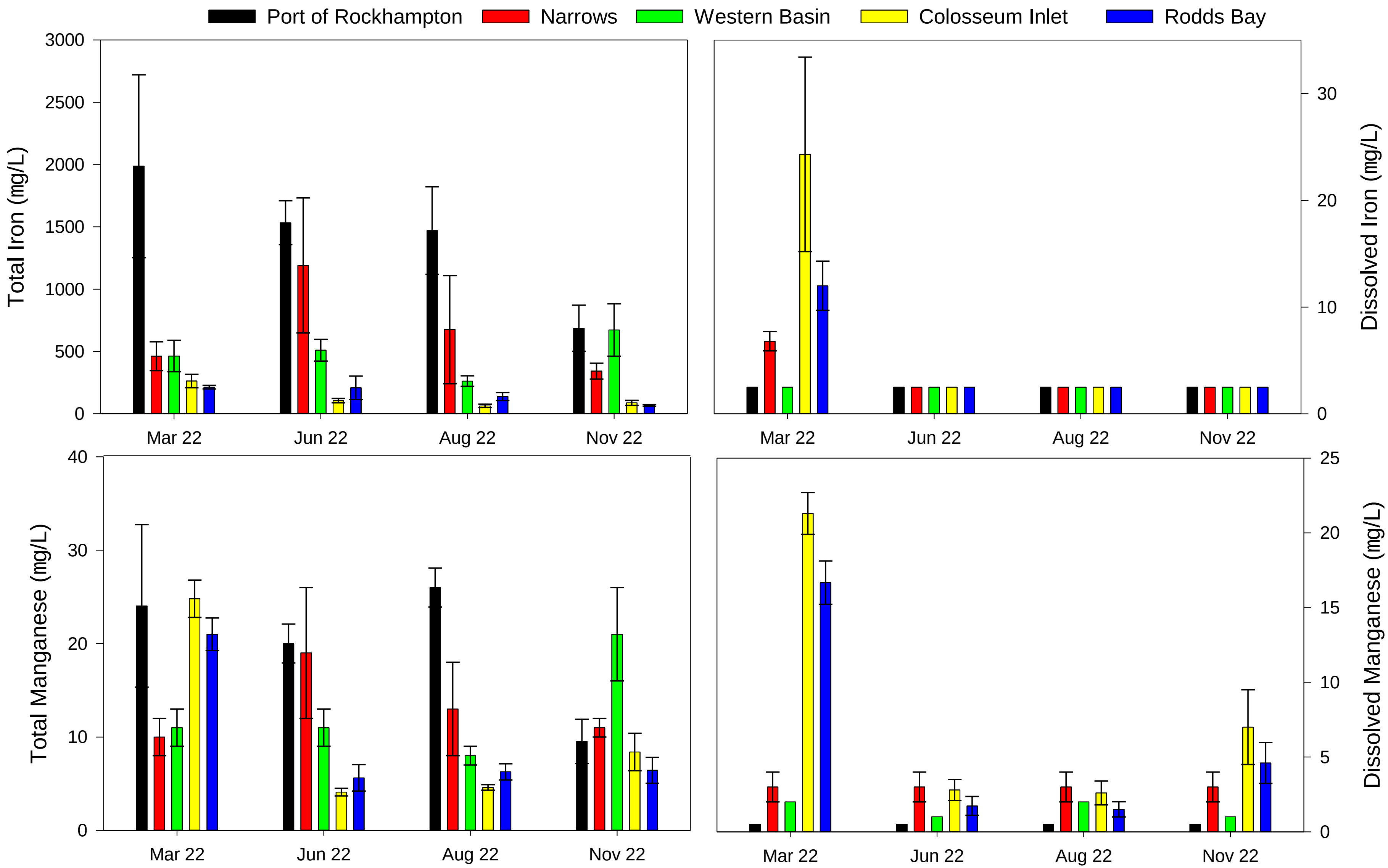

Figure 12 Concentrations of total and dissolved iron and manganese at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.

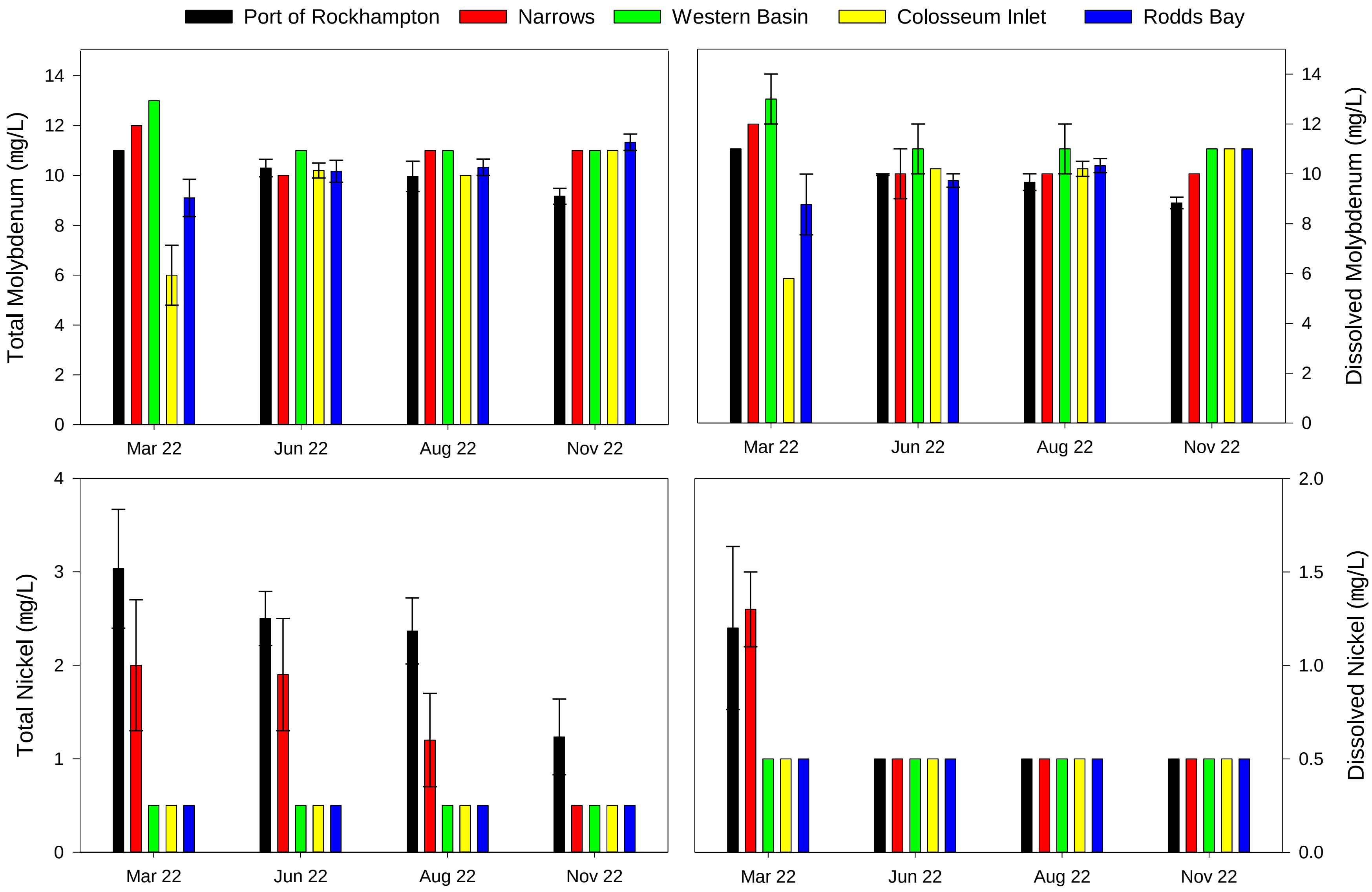

Figure 13 Concentrations of total and dissolved molybdenum and nickel at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.

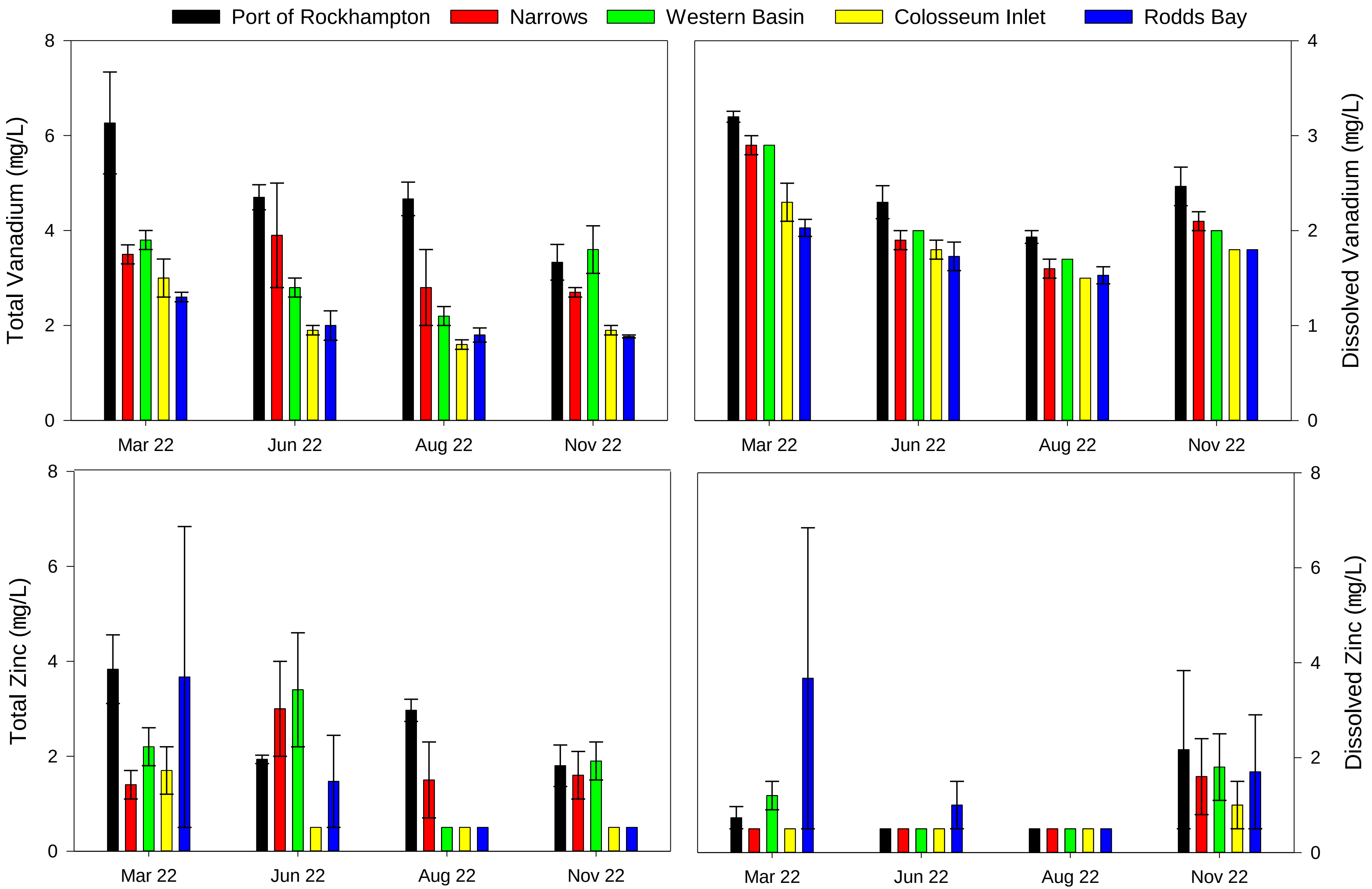

Figure 14 Concentrations of total and dissolved vanadium and zinc at PoR, and adjacent and reference PCIMP zones.
Values are means ± se (n = 3 to 6). For concentrations below LOR, half the LOR is displayed in the plots.

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5 APPENDIX

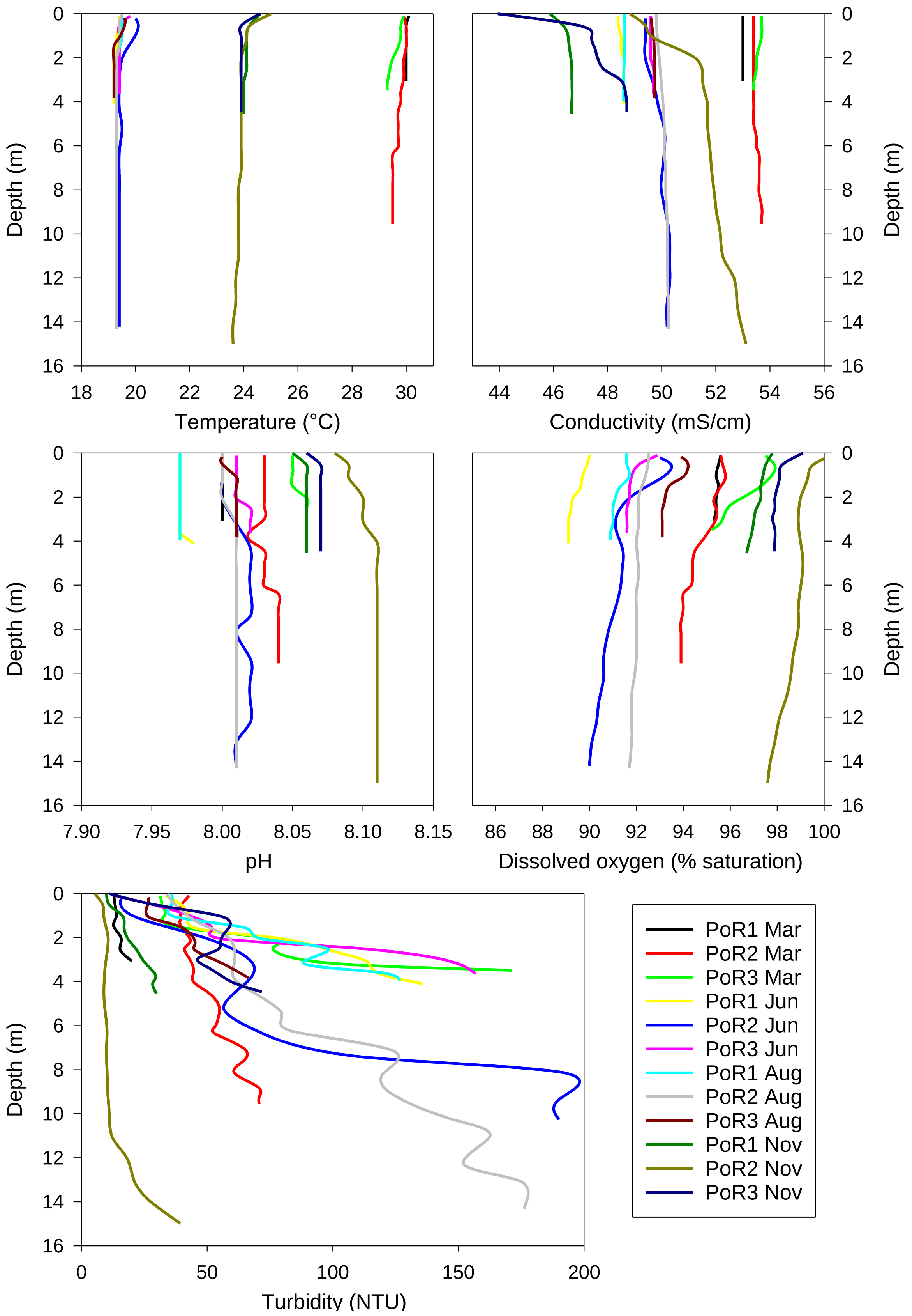

Figure A1 Depth-profiled physicochemical parameters at all Port of Rockhampton sites during 2022.

Table A1 Whole water column physicochemical parameters and TSS at PoR, and adjacent and reference PCIMP zones during 2022 surveys.
Values are means ± se (whole column n = 71 to 141, TSS n = 3 to 6). 20th to 80th WQO percentile ranges listed for pH and DO, with two 80th percentile trigger value for turbidity listed: Wet Season (March and November) and Dry Season (June and August). No WQO are available for TSS, so QWQG used (DERM, 2009). Values exceeding WQO or QWQG are highlighted in green. Note that WQO were not applicable at PoR sites during the November survey due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.

Site	Survey	Temperature (°C)	Conductivity (mS/cm)	pH	Turbidity (NTU)	Dissolved oxygen (% sat.)	TSS (mg/L)
PoR	Mar-22	29.8 ± 0.0	53.4 ± 0.0	8.0 ± 0.0	51 ± 4	95 ± 0	17 ± 7
	Jun-22	19.5 ± 0.0	49.4 ± 0.1	8.0 ± 0.0	70 ± 6	91 ± 0	32 ± 18
	Aug-22	19.4 ± 0.0	49.6 ± 0.1	8.0 ± 0.0	72 ± 5	92 ± 0	18 ± 11
	Nov-22	24.0 ± 0.0	48.9 ± 0.3	8.1 ± 0.0	24 ± 2	98 ± 0	8 ± 2
	WQO	**-**	**-**	**7.2 – 8.3**	**W = 30, D = 12**	**87-95**	**20**
NW	Mar-22	30.5 ± 0.0	55.1 ± 0.1	7.9 ± 0.0	6.4 ± 0.3	94 ± 0	17 ± 7
	Jun-22	18.9 ± 0.0	50.1 ± 0.1	7.8 ± 0.0	21 ± 2	89 ± 0	32 ± 18
	Aug-22	19.2 ± 0.0	50.0 ± 0.0	7.8 ± 0.0	16 ± 2	90 ± 0	18 ± 11
	Nov-22	24.4 ± 0.0	51.0 ± 0.1	7.9 ± 0.0	15 ± 1	97 ± 0	8 ± 2
	WQO	**-**	**-**	**7.4 – 8.3**	**W = 30, D = 12**	**87 - 95**	**20**
WB	Mar-22	29.9 ± 0.0	54.8 ± 0.0	7.9 ± 0.0	7.1 ± 0.4	91 ± 0	23 ± 7
	Jun-22	19.0 ± 0.0	50.8 ± 0.0	7.9 ± 0.0	8.9 ± 0.4	93 ± 0	16 ± 3
	Aug-22	19.5 ± 0.0	49.4 ± 0.1	7.8 ± 0.0	4.7 ± 0.1	92 ± 0	9 ± 1
	Nov-22	24.2 ± 0.0	52.7 ± 0.0	8.0 ± 0.0	18 ± 1	97 ± 0	26 ± 8
	WQO	**-**	**-**	**7.4 – 8.3**	**W = 29, D = 17**	**91 - 100**	**20**
RCI	Mar-22	29.0 ± 0.0	43.5 ± 1.4	7.8 ± 0.0	3.1 ± 0.2	87 ± 0	14 ± 2
	Jun-22	18.4 ± 0.0	51.1 ± 0.0	7.9 ± 0.0	2.2 ± 0.1	90 ± 0	3 ± 1
	Aug-22	19.2 ± 0.0	51.3 ± 0.0	7.9 ± 0.0	2.2 ± 0.1	91 ± 0	7 ± 1
	Nov-22	26.3 ± 0.1	53.8 ± 0.0	7.9 ± 0.0	1.4 ± 0.1	102 ± 0	2 ± 0
	WQO	**-**	**-**	**7.4 – 8.3**	**W = 14, D = 4**	**86 - 97**	**20**
RB	Mar-22	28.8 ± 0.0	51.8 ± 0.3	8.0 ± 0.0	3.8 ± 0.7	95 ± 0	13 ± 2
	Jun-22	18.4 ± 0.1	51.1 ± 0.1	7.9 ± 0.0	6.6 ± 0.8	93 ± 0	8 ± 3
	Aug-22	19.2 ± 0.0	51.2 ± 0.0	8.0 ± 0.0	6.8 ± 0.8	94 ± 0	12 ± 3
	Nov-22	25.9 ± 0.1	54.3 ± 0.0	8.0 ± 0.0	1.8 ± 0.1	102 ± 0	5 ± 2
	WQO	**-**	**-**	**7.4 – 8.3**	**W = 12, D = 7**	**93 - 98**	**20**

Table A2 Chlorophyll *a* and nutrient concentrations at PoR, and adjacent and reference PCIMP zones during 2022 surveys.
Values are means ± se (n = 3 to 6). Green shading indicates exceedances of the 80th percentile WQO value (DSITI, 2017, EHP, 2014). Note that WQO were not applicable during the November survey due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.

Site	Survey	Chlorophyll *a* (µg/L)	Phosphorous (µg/L)	FRP (µg/L)	Nitrogen (µg/L)	Ammonia (µg/L)	NOx (µg/L)	TOC (mg/L)	DOC (mg/L)
PoR	Mar-22	1.4 ± 0.0	38 ± 5	13 ± 2	233 ± 26	<2	50 ± 9	2.0 ± 0.0	1.4 ± 0.1
	Jun-22	0.9 ± 0.4	36 ± 4	9 ± 2	203 ± 12	10 ± 3	28 ± 4	2.0 ± 0.0	1.8 ± 0.1
	Aug-22	0.6 ± 0.2	39 ± 4	9 ± 1	170 ± 12	9 ± 3	24 ± 4	2.0 ± 0.0	1.2 ± 0.0
	Nov-22	1.2 ± 0.1	42 ± 7	27 ± 4	257 ± 30	5 ± 3	84 ± 14	2.3 ± 0.3	1.7 ± 0.1
	WQG	**2.0**	**29**	**7**	**220**	**10**	**9**	**-**	**-**
NW	Mar-22	1.9 ± 0.2	15 ± 2	3 ± 1	158 ± 8	3 ± 1	22 ± 7	1.8 ± 0.2	1.2 ± 0.1
	Jun-22	0.7 ± 0.1	22 ± 7	<2	158 ± 23	5 ± 2	4 ± 2	2.0 ± 0.0	1.3 ± 0.0
	Aug-22	0.7 ± 0.1	17 ± 6	3 ± 1	123 ± 14	4 ± 2	6 ± 2	1.8 ± 0.2	1.3 ± 0.1
	Nov-22	1.3 ± 0.1	21 ± 3	5 ± 2	182 ± 9	5 ± 1	11 ± 5	2.0 ± 0.0	1.6 ± 0.1
	WQG	**2.0**	**29**	**7**	**220**	**10**	**9**	**-**	**-**
WB	Mar-22	1.4 ± 0.3	13 ± 1	<2	177 ± 4	6 ± 1	19 ± 4	1.5 ± 0.2	1.2 ± 0.1
	Jun-22	0.7 ± 0.1	11 ± 1	<2	157 ± 7	2 ± 1	7 ± 4	1.0 ± 0.0	1.2 ± 0.0
	Aug-22	0.6 ± 0.1	10 ± 1	<2	113 ± 2	3 ± 1	3 ± 1	1.0 ± 0.0	1.2 ± 0.0
	Nov-22	1.5 ± 0.3	21 ± 2	<2	190 ± 4	15 ± 1	11 ± 1	2.0 ± 0.0	1.4 ± 0.1
	WQG	**2.0**	**29**	**7**	**210**	**8**	**16**	**-**	**-**
RCI	Mar-22	1.3 ± 0.3	14 ± 3	<2	258 ± 26	5 ± 2	73 ± 52	3.5 ± 0.9	3.2 ± 0.8
	Jun-22	0.7 ± 0.0	6 ± 0	<2	113 ± 3	<2	<2	1.0 ± 0.0	1.1 ± 0.0
	Aug-22	0.5 ± 0.1	7 ± 1	<2	103 ± 3	<2	<2	1.0 ± 0.0	1.1 ± 0.1
	Nov-22	0.8 ± 0.1	7 ± 0	<2	145 ± 9	<2	8 ± 5	1.5 ± 0.3	1.3 ± 0.1
	WQG	**1.4**	**15**	**3**	**180**	**15**	**5**	**-**	**-**
RB	Mar-22	1.6 ± 0.3	12 ± 1	<2	223 ± 15	5 ± 4	7 ± 1	2.7 ± 0.3	2.3 ± 0.3
	Jun-22	1.0 ± 0.2	8 ± 2	<2	140 ± 6	<2	<2	1.2 ± 0.4	1.1 ± 0.1
	Aug-22	1.6 ± 0.4	11 ± 4	<2	117 ± 17	<2	<2	1.3 ± 0.3	1.1 ± 0.1
	Nov-22	0.4 ± 0.0	9 ± 1	<2	147 ± 12	8 ± 5	4 ± 2	1.2 ± 0.4	1.1 ± 0.1
	WQG	**2.2**	**21**	**3**	**200**	**4**	**3**	**-**	**-**

Table A3 Total and dissolved metal concentrations at PoR, and adjacent and reference PCIMP zones during 2022 surveys. *Values are means ± se (n = 3 to 6). Note the 99% AWQG applicable to Narrows, Colosseum Inlet and Rodds Bay (DSITIA, 2014, EHP, 2014). AWQG applicable to dissolved metal concentrations only. Note that WQO were not applicable during the November survey at PoR due to high flow conditions, with yellow shading indicating values outside WQO recommended ranges if they were applicable.*

Site	Survey	Aluminium (µg/L)		Arsenic (µg/L)		Cadmium (µg/L)		Chromium (µg/L)		Cobalt (µg/L)		Copper (µg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
PoR	Mar-22	7 ± 2	2203 ± 815	1.4 ± 0.0	1.8 ± 0.2	<0.1	<0.1	<1	6.3 ± 2.4	<1	<1	<1	2.0 ± 0.3
	Jun-22	6 ± 2	1300 ± 173	1.2 ± 0.1	1.7 ± 0.0	<0.1	<0.1	<1	1.8 ± 0.2	<1	<1	<1	<1
	Aug-22	<5	1067 ± 281	1.1 ± 0.0	1.7 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	1.2 ± 0.0
	Nov-22	<5	587 ± 151	1.3 ± 0.0	1.4 ± 0.0	<0.1	<0.1	<1	1.1 ± 0.3	<1	<1	<1	<1
NW	Mar-22	<5	481 ± 130	1.4 ± 0.1	1.5 ± 0.1	<0.1	<0.1	<1	1.0 ± 0.2	<1	<1	<1	1.2 ± 0.3
	Jun-22	<5	1125 ± 542	<1	1.3 ± 0.3	<0.1	<0.1	<1	1.9 ± 0.9	<1	<1	<1	2.1 ± 0.9
	Aug-22	<5	475 ± 299	<1	1.1 ± 0.3	<0.1	<0.1	<1	1.0 ± 0.5	<1	<1	<1	<1
	Nov-22	<5	213 ± 45	<1	1.3 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
WB	Mar-22	7 ± 2	445 ± 127	1.5 ± 0.0	1.6 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	1.2 ± 0.2	1.5 ± 0.1
	Jun-22	5 ± 1	380 ± 66	<1	1.1 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Aug-22	<5	165 ± 29	<1	1.1 ± 0.0	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Nov-22	<5	380 ± 126	1.2 ± 0.0	1.6 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
RCI	Mar-22	<5	233 ± 39	<1	1.1 ± 0.2	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Jun-22	<5	95 ± 14	1.3 ± 0.1	1.2 ± 0.0	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Aug-22	<5	37 ± 7	1.2 ± 0.1	1.2 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Nov-22	<5	52 ± 15	1.4 ± 0.0	1.4 ± 0.0	<0.1	<0.1	<1	<1	<1	<1	<1	<1
RB	Mar-22	10 ± 4	227 ± 35	1.4 ± 0.1	1.6 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Jun-22	<5	178 ± 79	1.2 ± 0.1	1.3 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Aug-22	<5	77 ± 15	1.2 ± 0.1	1.4 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
	Nov-22	7 ± 5	32 ± 4	1.4 ± 0.1	1.5 ± 0.1	<0.1	<0.1	<1	<1	<1	<1	<1	<1
95% AWQG		**24**		**-**		**5.5**		**Cr(III) 27.4, Cr(VI) 4.4**		**1**		**1.3**	
99% AWQG		**2.1**		**-**		**0.7**		**Cr(III) 7.7, Cr(VI) 0.14**		**0.005**		**0.3**	

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Site	Survey	Gallium (µg/L)		Iron (µg/L)		Lead (µg/L)		Manganese (µg/L)		Mercury (µg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
PoR	Mar-22	<1	<1	<5	1987 ± 734	<1	<1	<1	24 ± 9	<0.05	<0.05
	Jun-22	<1	<1	<5	1533 ± 176	<1	<1	<1	20 ± 2	<0.05	<0.05
	Aug-22	<1	<1	<5	1470 ± 352	<1	<1	<1	26 ± 2	<0.05	<0.05
	Nov-22	<1	<1	<5	687 ± 185	<1	<1	<1	10 ± 2	<0.05	<0.05
NW	Mar-22	<1	<1	7 ± 1	462 ± 116	<1	<1	3 ± 1	10 ± 2	<0.05	<0.05
	Jun-22	<1	<1	<5	1190 ± 542	<1	<1	3 ± 1	19 ± 7	<0.05	<0.05
	Aug-22	<1	<1	<5	675 ± 434	<1	<1	3 ± 1	13 ± 5	<0.05	<0.05
	Nov-22	<1	<1	<5	342 ± 64	<1	<1	3 ± 1	11 ± 1	<0.05	<0.05
WB	Mar-22	<1	<1	<5	463 ± 126	<1	<1	2 ± 0	11 ± 2	<0.05	<0.05
	Jun-22	<1	<1	<5	510 ± 87	<1	<1	1 ± 0	11 ± 2	<0.05	<0.05
	Aug-22	<1	<1	<5	262 ± 42	<1	<1	2 ± 0	8 ± 1	<0.05	<0.05
	Nov-22	<1	<1	<5	672 ± 210	<1	<1	1 ± 0	21 ± 5	<0.05	<0.05
RCI	Mar-22	<1	<1	24 ± 9	263 ± 54	<1	<1	21 ± 1	25 ± 2	<0.05	<0.05
	Jun-22	<1	<1	<5	105 ± 17	<1	<1	3 ± 1	4 ± 0	<0.05	<0.05
	Aug-22	<1	<1	<5	63 ± 14	<1	<1	3 ± 1	5 ± 0	<0.05	<0.05
	Nov-22	<1	<1	<5	87 ± 20	<1	<1	7 ± 3	8 ± 2	<0.05	<0.05
RB	Mar-22	<1	<1	12 ± 2	213 ± 15	<1	<1	17 ± 1	21 ± 2	<0.05	<0.05
	Jun-22	<1	<1	<5	208 ± 94	<1	<1	2 ± 1	6 ± 1	<0.05	<0.05
	Aug-22	<1	<1	<5	138 ± 32	<1	<1	2 ± 1	6 ± 1	<0.05	<0.05
	Nov-22	<1	<1	<5	67 ± 7	<1	<1	5 ± 1	6 ± 1	<0.05	<0.05
95% AWQG		-		-		4.4		-		0.4	
99% AWQG		-		-		2.2		-		0.1	

Site	Survey	Molybdenum (µg/L)		Nickel (µg/L)		Silver (µg/L)		Tin (µg/L)		Vanadium (µg/L)		Zinc (µg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
PoR	Mar-22	11 ± 0	11 ± 0	1.2 ± 0.4	3.0 ± 0.6	<1	<1	<1	<1	3.2 ± 0.1	6.3 ± 1.1	<1	3.8 ± 0.7
	Jun-22	10 ± 0	10 ± 0	<1	2.5 ± 0.3	<1	<1	<1	<1	2.3 ± 0.2	4.7 ± 0.3	<1	1.9 ± 0.1
	Aug-22	10 ± 0	10 ± 1	<1	2.4 ± 0.4	<1	<1	<1	<1	1.9 ± 0.1	4.7 ± 0.4	<1	3.0 ± 0.2
	Nov-22	9 ± 0	9 ± 0	<1	1.2 ± 0.4	<1	<1	<1	<1	2.5 ± 0.2	3.3 ± 0.4	2.2 ± 1.7	1.8 ± 0.4
NW	Mar-22	12 ± 0	12 ± 0	1.3 ± 0.2	2.0 ± 0.7	<1	<1	<1	<1	2.9 ± 0.1	3.5 ± 0.2	<1	1.4 ± 0.3
	Jun-22	10 ± 1	10 ± 0	<1	1.9 ±0.6	<1	<1	<1	<1	1.9 ± 0.1	3.9 ± 1.1	<1	3.0 ± 1.0
	Aug-22	10 ± 0	11 ± 0	<1	1.2 ± 0.5	<1	<1	<1	<1	1.6 ± 0.1	2.8 ± 0.8	<1	1.5 ± 0.8
	Nov-22	10 ± 0	11 ± 0	<1	<1	<1	<1	<1	<1	2.1 ± 0.1	2.7 ± 0.1	1.6 ± 0.8	1.6 ± 0.5
WB	Mar-22	13 ± 1	13 ± 0	<1	<1	<1	<1	<1	<1	2.9 ± 0.0	3.8 ± 0.2	1.2 ± 0.3	2.2 ± 0.4
	Jun-22	11 ± 1	11 ± 0	<1	<1	<1	<1	<1	<1	2.0 ± 0.0	2.8 ± 0.2	<1	3.4 ± 1.2
	Aug-22	11 ± 1	11 ± 0	<1	<1	<1	<1	<1	<1	1.7 ± 0.0	2.2 ± 0.2	<1	<1
	Nov-22	11 ± 0	11 ± 0	<1	<1	<1	<1	<1	<1	2.0 ± 0.0	3.6 ± 0.5	1.8 ± 0.7	1.9 ± 0.4
RCI	Mar-22	6 ± 0	6 ± 1	<1	<1	<1	<1	<1	<1	2.3 ± 0.2	3.0 ± 0.4	<1	1.7 ± 0.5
	Jun-22	10 ± 0	10 ± 0	<1	<1	<1	<1	<1	<1	1.8 ± 0.1	1.9 ± 0.1	<1	<1
	Aug-22	10 ± 0	10 ± 0	<1	<1	<1	<1	<1	<1	1.5 ± 0.0	1.6 ± 0.1	<1	<1
	Nov-22	11 ± 0	11 ± 0	<1	<1	<1	<1	<1	<1	1.8 ± 0.0	1.9 ± 0.1	1.0 ± 0.5	<1
RB	Mar-22	9 ± 1	9 ± 1	<1	<1	<1	<1	<1	<1	2.0 ± 0.1	2.6 ± 0.1	3.7 ± 3.2	3.7 ± 3.2
	Jun-22	10 ± 0	10 ± 0	<1	<1	<1	<1	<1	<1	1.7 ± 0.1	2.0 ± 0.3	1.0 ± 0.5	1.5 ± 1.0
	Aug-22	10 ± 0	10 ± 0	<1	<1	<1	<1	<1	<1	1.5 ± 0.1	1.8 ± 0.2	<1	<1
	Nov-22	11 ± 0	11 ± 0	<1	<1	<1	<1	<1	<1	1.8 ± 0.0	1.8 ± 0.0	1.7 ± 1.2	<1
95% AWQG		-		70		1.4		-		100		8	
99% AWQG		-		7		0.8		-		50		3.3	

Table A4 Results of two-way ANOVAs for PoR statistical comparison with PCIMP zones.
Note no analyses able to be performed for, total and dissolved cadmium, gallium, mercury, lead, silver and tin, and dissolved chromium, cobalt, copper and nickel, as site concentrations generally < LOR.

Parameter	Zone		Survey		Interaction		Comment
	P-value	F statistic	P-value	F statistic	P-value	F statistic	
Temperature	<0.05	14	<0.05	100561	<0.05	443	Temperatures were significantly different for each survey, increasing in temperature from June< August< November< March. Temperatures in PoR, NW and WB were significantly higher than RB and RCI.
Conductivity	<0.05	48	<0.05	55	<0.05	107	Conductivity in June and August were significantly lower than March and November. Conductivity lowest in RCI and highest in RB. Intermediate conductivity in PoR
pH	<0.05	580	<0.05	228	<0.05	61	pH was significantly lower in June and August, than March and November. pH in PoR and RB were significantly higher than other zones.
Turbidity	<0.05	351	<0.05	39	<0.05	32	Turbidity was significantly higher in June and August than March and November. Turbidity was significantly highest in PoR than other zones.
Dissolved Oxygen	<0.05	138	<0.05	1064	<0.05	88	DO significantly higher in November than other surveys. DO was significantly higher in RB and lower in NW and RCI. Intermediate DO in PoR.
TSS	<0.05	6	0.51	1	0.65	1	TSS was significantly highest in PoR than other zones.
Chlorophyll *a*	0.17	2	<0.05	14	<0.05	3	Chlorophyll *a* was significantly higher in March than all other surveys.
Phosphorus	<0.05	31	0.51	<1	0.65	<1	Phosphorus was significantly highest in PoR than other zones.
FRP	<0.05	95	<0.05	17	<0.05	9	FRP was significantly higher in November than all other surveys. FRP was significantly higher in PoR than all other zones.
Nitrogen	<0.05	12	<0.05	33	<0.05	5	Nitrogen was significantly higher in March than other surveys. Nitrogen was significantly higher in PoR than all other zones
Ammonia	<0.05	4	<0.05	4	<0.05	4	Ammonia was significantly higher in November than all other surveys. Ammonia was significantly higher in WB than all zones except PoR.
Nitrogen oxides	<0.05	7	<0.05	6	<0.05	2	NOx was significantly higher in March than other surveys except November. NOx was significantly higher in PoR than all other zones
TOC	<0.05	6	<0.05	12	<0.05	6	TOC was significantly higher in March than all other surveys. TOC was significantly higher in PoR than RB and WB.

Parameter	Zone		Survey		Interaction		Comment
	P-value	F statistic	P-value	F statistic	P-value	F statistic	
DOC	<0.05	4	<0.05	12	<0.05	8	DOC was significantly higher in March than all other surveys. DOC was significantly higher in RCI and PoR than WB.
Dissolved Al	0.30	1	<0.05	6	<0.01	0.38	Dissolved Al was significantly higher in March than in November and August.
Total Al	<0.05	11	<0.05	3	0.15	2	Total Al was significantly higher in March and June than in November. Total Al was significantly highest in PoR than other zones.
Dissolved As	<0.05	8	<0.05	9	<0.05	4	Dissolved As was significantly higher in March and November than June and August Dissolved As was significantly highest in PoR and RB than in NW and WB
Total As	<0.05	3	0.15	2	0.56	<1	Total As was significantly highest in PoR than all other zones except RB
Total Cr	<0.05	4	0.08	2	0.05	2	Total Cu in PoR was significantly higher than other zones except NW.
Total Co	0.42	<1	0.86	<1	0.76	<1	
Total Cu	<0.05	4	0.08	2	0.05	2	Total Cu in PoR was significantly higher than other zones except NW.
Dissolved Fe	<0.05	5	<0.05	15	<0.05	5	Dissolved Fe in March was significantly higher than all other surveys. Dissolved Fe in RCI was significantly higher than all other zones.
Total Fe	<0.05	11	0.21	2	0.32	1	Total Fe in PoR was significantly higher than all other zones.
Dissolved Mn	<0.05	42	<0.05	51	<0.05	19	Dissolved Mn was higher in March than all other surveys Dissolved Mn in PoR was significantly lower than all other zones
Total Mn	<0.05	3	<0.05	3	<0.05	3	Total Mn was significantly higher in March than August. Total Mn in PoR was significantly higher than all other zones
Dissolved Mo	<0.05	26	0.34	1	<0.05	18	Dissolved Mo was significantly higher in WB than all other zones.
Total Mo	<0.05	23	0.21	2	<0.05	14	Total Mo was significantly higher in WB than all other zones.
Total Ni	<0.05	14	0.09	2	0.57	<1	Total Ni significantly highest in PoR followed by NW than other zones
Dissolved V	<0.05	36	<0.05	130	<0.05	3	Dissolved V significantly highest in March than all other surveys. Dissolved V significantly highest in PoR than all other zones.
Total V	<0.05	13	<0.05	6	0.33	1	Total V significantly highest in March than all other surveys. Total V significantly highest in PoR than all other zones.
Dissolved Zn	0.39	1	<0.05	3	0.74	<1	Dissolved Zn significantly higher in November than June & August.
Total Zn	0.09	2	<0.05	3	0.28	1	Total Zn significantly higher in March and June than August.