Port of Abbot Point Ambient Marine Water Quality Monitoring Program: Annual report 2020-2021

Nathan Waltham, Jordan Iles, Jamie Johns

Report No. 21/75

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A Report for North Queensland Bulk Ports Corporation

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EXECUTIVE SUMMARY

Background

1. In November 2017, North Queensland Bulk Ports implemented an ambient marine water quality monitoring program surrounding the Port of Abbot Point. The objective of the program is to collect a long term water quality dataset to characterise marine water quality conditions within the Abbot Point region, and to support future planned Port activities. This document reports on data collected from July 2020 to July 2021
2. This program has incorporated a combination approaches to collect ambient water quality data from the coastal ocean. The approaches adopted include spot field measurements and water sample collection, acquisition of data via deployment of high frequency continuous loggers, and laboratory analysis of samples for a range of nutrients, herbicides and heavy metals.
3. The Port of Abbot Point has five established sites for ambient water quality monitoring whose locations align with key sensitive receptor habitats (e.g. corals or seagrass), along with key features in the study region (e.g. river flow points). During this sampling year, however, the program was reduced to three strategic sites, to continue providing data to support port facility operations and planning.

Climatic conditions

1. The total wet season rainfall of Bowen region during 2020-2021 was average compared to wet season totals since records commenced.
2. Inter-annual variability of wet season rainfall and catchment discharge to the coastal ocean highlights the necessity for a long-term commitment to ambient marine monitoring programs, as continued monitoring will allow changes in ambient environmental conditions due to differences in annual rainfall to be better understood.

Ambient water quality

1. Water quality conditions were measured at all sites on a ~8 weekly basis. Parameters collected were water temperature, electrical conductivity, pH, and dissolved oxygen (at surface, mid and bottom water column) along with Secchi disk depth.
2. There was little difference in water temperature, conductivity, pH and dissolved oxygen between the three depths examined, indicating that the water column was generally well mixed during each survey.
3. Particulate nitrogen concentrations exceeded the guidelines throughout most of the monitoring period, mostly regularly at AMB4. TSS was generally below guidelines, along with particulate phosphorus.
4. Chlorophyll-*a* concentrations exceeded the GBRMPA guideline trigger value
5. Nickel, and Arsenic were detected in water samples, although the concentrations were below relevant guideline values. Copper was not detected during the post wet season survey, but was at all sites during the dry season survey. This result was unexpected and could reflect a contamination problem at the laboratory, or during field sampling. The team have discussed this to ensure that such contamination problems if caused during field sampling doesn't happen in the future.
6. Pesticides/herbicides were examined this year using passive sampling devices. This approach provides a more time integrated measure of the risks of contamination in the region. Unfortunately, while there were two separate ranges of deployment, only a single device was retrieved – the second was removed from the float on return either was caught by a recreational fisher person, or cut free. Concentrations were reported as less than values, with the exception of DEET, Diuron, and Hexazinone which were above limit of detection. When comparing to the draft GBRMPA guidelines, there were no exceedances above the 99% guidelines for species protection.

Sediment deposition and turbidity

1. RMS water height values were mostly driven by weather events and this is clearly evident in the data as peaks in RMS water heights were observed at the same times at all sites over the survey year. Variation in the magnitude of RMS water height values during peak events and during non-event periods differs among sites due to differences in water depth and site exposure to wave energy.
2. The NTUe/SSC time series data at each site followed a typical pattern of low background values with recurring peak events. These peak events occurred at the same times at each site and coincided with peaks in RMS water height. This is a typical pattern which is similar to data collected in coastal locations in north Queensland.
3. Time series deposition data shows that deposition tends to peak following high RMS water height events but with a lag so that peak deposition occurs at a time when RMS water height has decreased to near background levels. An explanation for this lag is that as waves resuspend sediment, little deposition is expected because the energy in the system will keep the sediment in suspension. It is only when waves decrease and there is no longer enough energy in the system to keep the same quantity of sediment in suspension that deposition begins to occur.
4. Current meter data indicates the prominent current direction and velocity at each site and shows that coastal current, tidal current or a combination of both influence current direction and magnitude. Unfortunately this reporting period had many problems with the units including flooding, or the connecting ends breaking free, which resulted in low return of data. The team are investigating other alternative ways to measure current, and will continue to explore options.

Photosynthetically active radiation (PAR)

1. Benthic PAR was highly variable within sites throughout the year, with peaks and troughs occurring both regularly and intermittently over time. Semi-regular oscillations between low and high PAR levels were overridden by larger episodic events caused by storm or rainfall events experienced in the region. The data series here continues to increase, which is slowly providing a greater insight into trends, and whether these be tidally influenced or dependent on seasonality and cloud cover.
2. There was low among site correlation in PAR. Less than 32% of the variation in PAR at a given site could be explained by the PAR at any other site, highlighting the influence of location conditions (depth, turbidity) on benthic irradiance.

Recommendations

1. This monitoring program has been underway for three years, and should remain in place to continue to characterise and build a detailed understanding of the water quality dynamics in and around this port facility. This understanding will continue to assist NQBP to manage current activities, but will also assist with future strategic planning and management.
2. During this monitoring period, two sites were decommissioned, as part of the continued rationalisation and optimisation of the program. Removing further sites from the network in the future, or indeed, moving sites, will require this careful consideration with respect to the key monitoring questions presented in this program.

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1 INTRODUCTION

1.1 Port operations

The Port of Abbot Point is situated in naturally deep waters off the central Queensland Coast (Figure 1.1). The Port of Abbot Point is located approximately 25 kilometers north of Bowen, and North Queensland Bulk Ports Corporation (NQBP) is the Port Authority. The Port has one operating terminal and provides important services for the surrounding region.

1.2 Program outline

NQBP committed to an ambient marine water quality monitoring program in and around the coastal waters of the Port of Abbot Point. The program aims to characterise the natural variability in water quality by monitoring key parameters. The monitoring program is designed to better define the potential impacts associated with port operations within port areas and adjacent sensitive habitats (Figure 1.1; Table 1.1). Routine maintenance dredging is periodically required at the Port of Abbot Point to maintain vessel navigational depths. As part of this program, water quality parameters are being investigated at a range of sites. This monitoring program contains a range of ambient water quality components that collectively continue to characterise the natural variability in key water quality parameters.

Figure 1.1 Location of water quality monitoring sites (green circle) utilised in the 2020-2021 reporting period, including sites decommissioned (yellow circle). Also shown are meteorological stations (red squire), and stream gauging stations (orange triangle) referred to in this report.

Table 1.1 Descriptions for the locations of the ambient marine water quality monitoring program sites

Site name	Site code	Latitude	Longitude	Water quality	Logger	Decommissioned
Euri Creek	AP_AMB1	-19.9047	148.1418	Yes	Yes	
Spoil Grounds	AP_AMB2	-19.8444	148.0077	Yes	Yes	Sept 2020
Elliot River	AP_AMB3	-19.8922	147.9368	Yes	Yes	Sept 2020
Camp Island	AP_AMB4	-19.8417	147.9058	Yes	Yes	
Holbourne Island	AP_AMB5	-19.7358	148.3593	Yes	Yes	

1.3 Rainfall and river flows

Daily rainfall for the Bowen region is shown on Figure 1.2. The first rainfall greater than 5 mm for the year occurred on 23/7/2020, with the rainfall onset occurring on 25/12/2020. The rainfall onset is calculated as the date when the rainfall total reaches 50mm since 1st September. The majority of rainfall occurred from 25/12/2020 though to 28/2/2021. The 2020-2021 wet season rainfall total was 596.2 mm, which was comparable to the median wet season rainfall total calculated for wet seasons since 1961-1962, but only marginally higher than the previous reporting period of 2019-2020 (Figure 1.3).

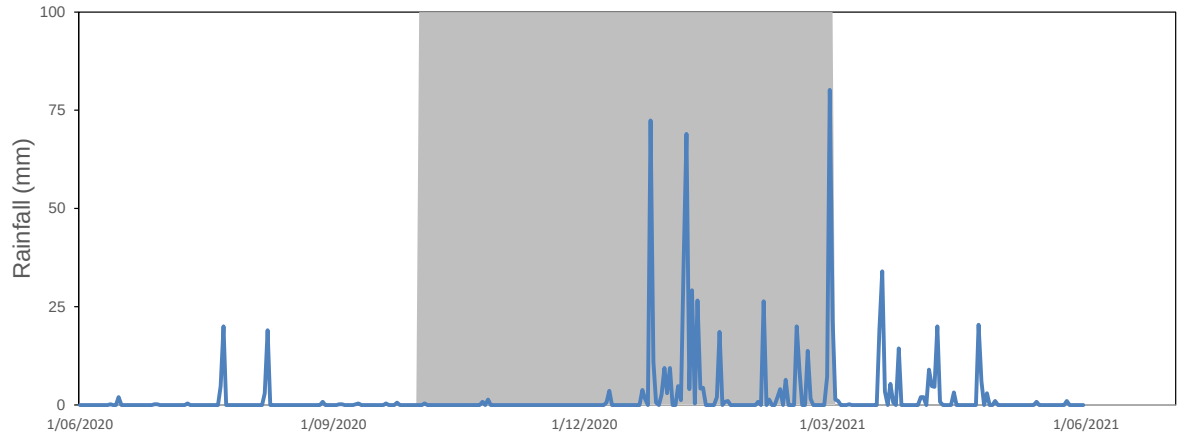


Figure 1.2 Rainfall recorded at Mount Danger (station 033096) for the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: http://www.bom.gov.au/climate/data/

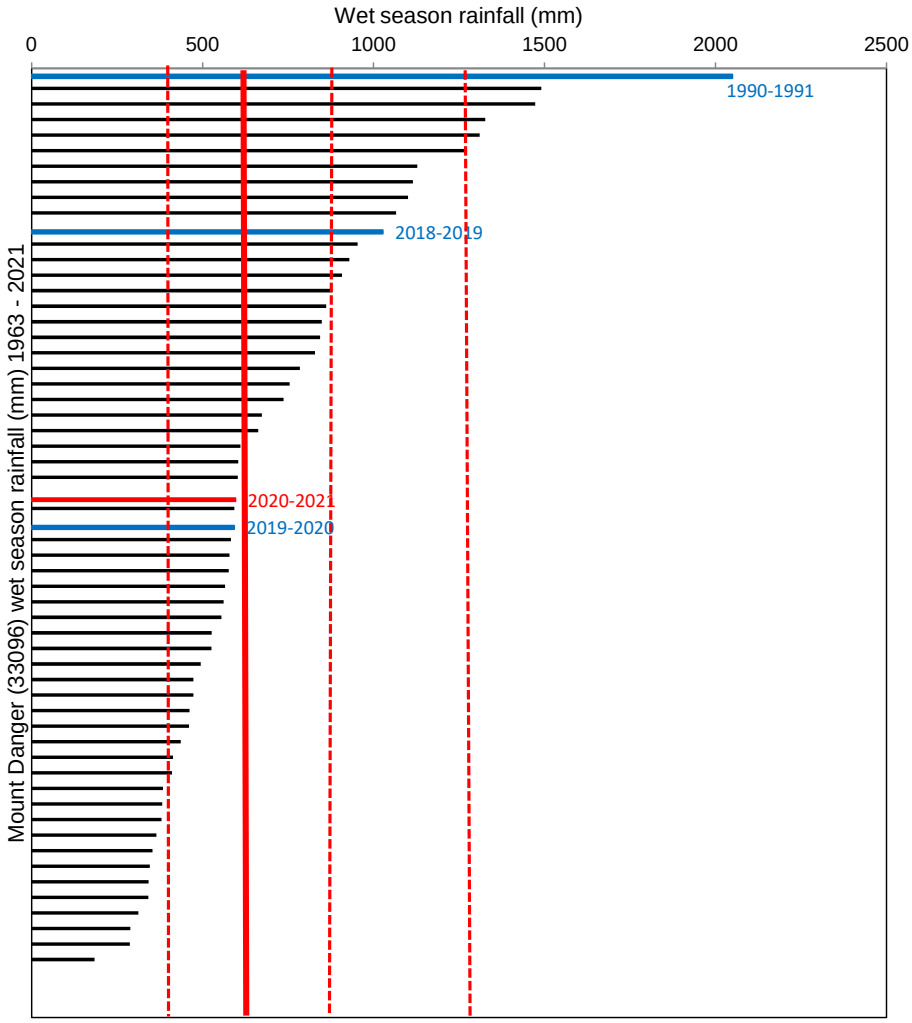


Figure 1.3 Wet season rainfall for the Bowen region ranked in order of decreasing total wet season rainfall (mm). Daily rainfall data was obtained from the Mount Danger weather station (station 033096). Totals were calculated for the wet season period 1st November to 31st March for each reporting year. Red bar represents the 2020-2021 reporting period, blue bars show total rainfall over the previous years. Solid red line represents median wet season rainfall, dashed lines represent 25th, 75th, and 90th percentiles. Data source: http://www.bom.gov.au/climate/data/

Hydrographs for streams from the Don River catchment show onset of stream discharge on 27/12/2020 with a series of pulses through to 25/03/2021 (A)

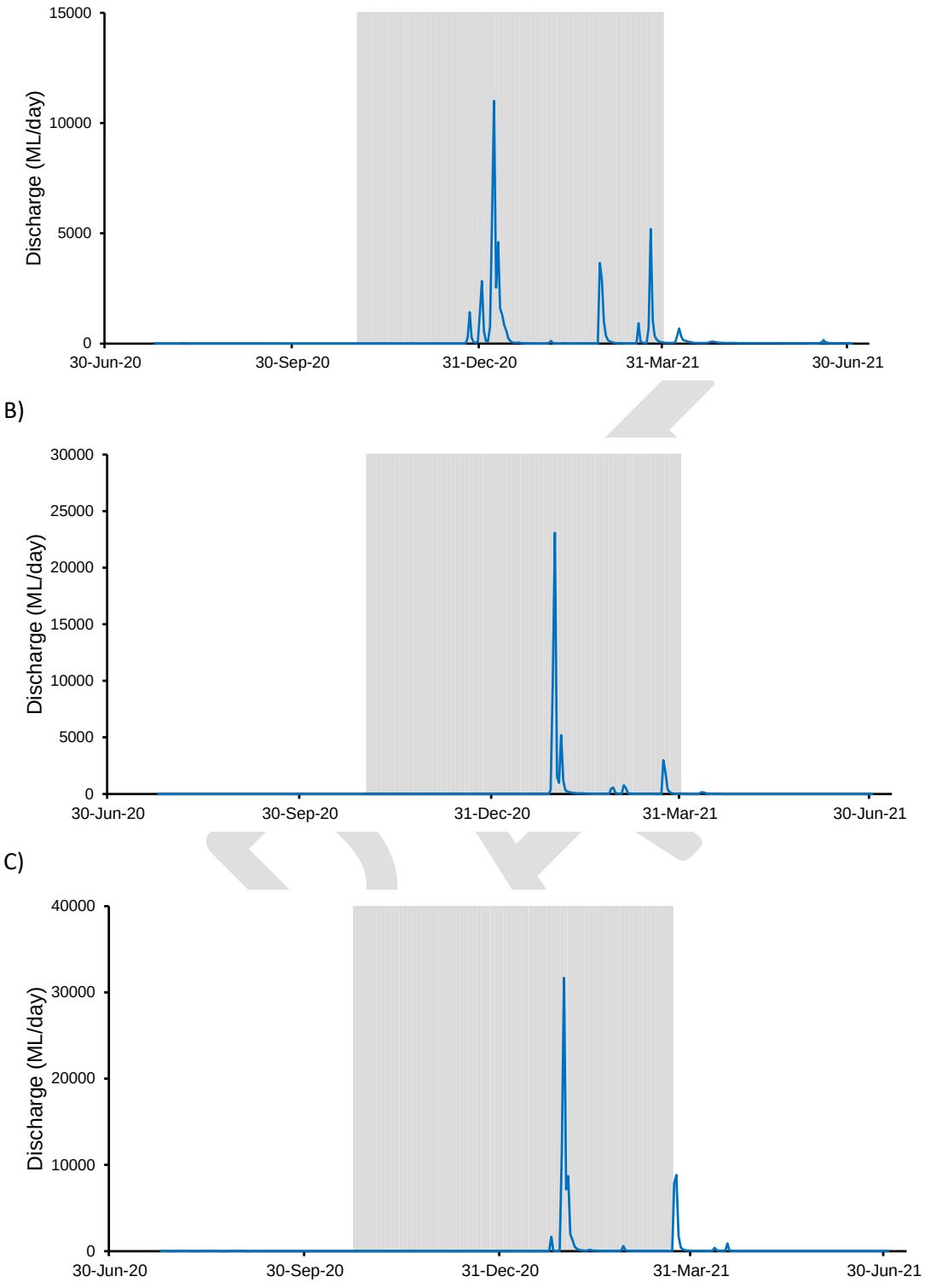


Figure 1.4). Total discharge for the 2020-2021 reporting period was 58.3 GL (Don River), 52.1 GL (Elliot River), and 89.5 GL (Euri Creek).

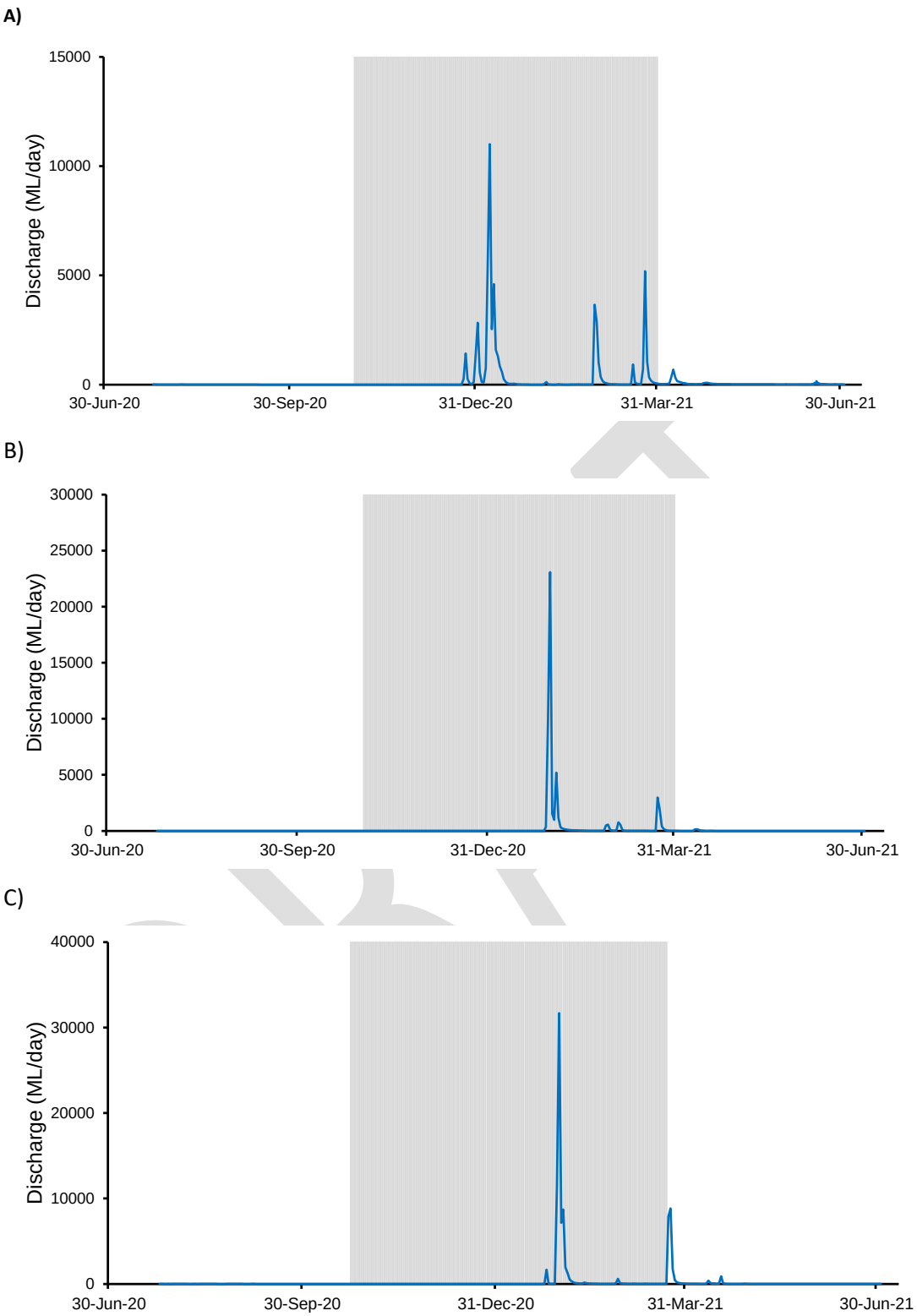


Figure 1.4 Stream discharge (GL d^{-1}) from: A) the Don River (station 121003A); B) Elliot River (station 121002A), and C) Euri Creek (station 121004A) during the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: https://water-monitoring.information.qld.gov.au/.

1.4 Project objectives

The goal of the program is to characterise the ambient marine water quality monitoring within the region and adjacent to the Port of Abbot Point. This report provides a review and analysis of data collected between 01/07/2020 and 30/06/2021. As part of this program review in 2019, it was determined that AP_AMB2 and AP_AMB3 be decommissioned which occurred in September 2020 as part of the new partnership arrangement between NQBP and JCU. Despite the decommissioning of these sites, some data was still collected between July 2020 and September 2020 and is presented in this report for completeness. These data are part of a longer-term commitment to monitor and characterise receiving water quality conditions, in particular to support future planned asset management and protection for both these ports.

2 METHODOLOGY

2.1 Ambient water quality

Spot water quality samples were collected at sites approximately on a 6 week basis (Table 1.1) from a research vessel. At each site, a calibrated multiprobe is used to measure water temperature, salinity, dissolved oxygen (%sat), pH, and turbidity (Figure 2.1). In addition to spot measurements, secchi disk depth is recorded, as a measure of the optical clarity of the water column, along with light attenuation using a LiCor meter. These field in-situ measurements are recorded at three depth horizons: a) surface (0.25m); b) mid-depth; and c) bottom horizon. The measurements assist in characterising water quality conditions in the water column.

In considering key priority outcomes outlined in recently published Coastal Strategic Assessment and Marine Strategic Assessments for the Great Barrier Reef World Heritage area (GBRMPA, 2013), the water quality program design below was completed. The list of parameters examined consisted of:

- Ultra-trace dissolved metals : arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn);
- Nutrients (particulate nitrogen and phosphorus);
- Chlorophyll-a; and
- Pesticides/herbicides were examined here using passive samplers - Queensland Alliance for Environmental Health Sciences (University of Queensland).

Figure 2.1 TropWATER staff conducting field water quality sampling

Sampling methodology, sample bottles, preservation techniques and analytical methodology (NATA accredited) were in accordance with standard methods. Field collected water samples were stored on ice in eskies immediately during field trips aboard the vessel, and transported back to refrigeration, before delivery to the TropWATER laboratory. For chlorophyll analysis, water was placed into a 1L dark plastic bottle and placed on ice for transportation back to refrigeration. For dissolved metals and nutrients, water was passed through a 0.45 µm disposable membrane filter (Sartorius), fitted to a sterile 60 mL syringe (Livingstone), and placed into 60 mL bottles (metals) and 10 mL bottles (nutrients) for posterior analysis in the laboratory. (The use of these field sampling equipment and procedures have been previously shown to reduce the risk of contamination of samples, contributing to false positive results for reporting; TropWATER, 2015). Unfiltered sample for total nitrogen and total phosphorus analysis were frozen in a 60 mL tube. All samples are kept in the dark and cold until processing in the laboratory, except nutrients which are stored frozen until processing.

Water for chlorophyll determination was filtered through a Whatman 0.45 µm GF/F glass-fibre filter with the addition of approximately 0.2 mL of magnesium carbonate within (less than) 12 hours after

collection. Filters are then wrapped in aluminium foil and frozen. Pigment determinations from acetone extracts of the filters were completed using spectrophotometry, method described in 'Standard Methods for the Examination of Water and Wastewater, 10200 H. Chlorophyll'.

Water samples are analysed using the defined analysis methods and detection limits outlined in Table 2.1. In summary, all nutrients were analysed using colorimetric method on OI Analytical Flow IV Segmented Flow Analysers. Total nitrogen and phosphorus and total filterable nitrogen and phosphorus are analysed simultaneously using nitrogen and phosphorous methods after alkaline persulphate digestion, following methods as presented in 'Standard Methods for the Examination of Water and Wastewater, 4500-NO3- F. Automated Cadmium Reduction Method' and in 'Standard Methods for the Examination of Water and Wastewater, 4500-P F. Automated Ascorbic Acid Reduction Method'. Nitrate, Nitrite and Ammonia were analysed using the methods 'Standard Methods for the Examination of Water and Wastewater, 4500-NO3- F. Automated Cadmium Reduction Method', 'Standard Methods for the Examination of Water and Wastewater, 4500-NO2- B. Colorimetric Method', and 'Standard Methods for the Examination of Water and Wastewater, 4500-NH3 G. Automated Phenate Method', respectively. Filterable Reactive Phosphorous is analysed following the method presented in 'Standard Methods for the Examination of Water and Wastewater, 4500-P F. Automated Ascorbic Acid Reduction Method'. Filterable heavy metals were analysed by Australian Laboratory Service (ALS). Passive samplers for pesticide/herbicides were analysed by the Queensland Alliance for Environmental Health Sciences (University of Queensland).

Table 2.1 Water analyses performed during the program

Parameter	APHA method number	Reporting limit
Routine water quality analyses		
pH	4500-H^+ B	-
Conductivity (EC)	2510 B	5 µS/cm
Total Suspended Solids (TSS)	2540 D @ 103 - 105°C	0.2 mg/L
Turbidity	2130 B	0.1 NTU
Salinity		
Dissolved Oxygen		
Light Attenuation		
Nutrients		
Total Nitrogen and Phosphorus (TN/TP)	Simultaneous 4500-NO_3^- F and 4500-P F analyses after alkaline persulphate digestion	25 µg N/L 5 µg P/L
Filterable nutrients (nitrate, nitrite, ammonia, Nox)	4500-NO_3^- F	1 µg N/L
Ammonia	4500- NH_3 G	1 mg N/L
Filterable Reactive Phosphorus (FRP)	4500-P F	1 µg P/L
Chlorophyll	10200-H	0.1 µg/L
Trace Metals		
Arsenic, Cadmium, Copper, Lead, Nickel, Silver, Zinc, Mercury	3125B ORC/ICP/MS	0.05 to 100 µg/L

2.2 Multiparameter water quality logger

Sediment deposition, turbidity, Photosynthetically Available Radiation (PAR), water depth, Root Mean Squared (RMS) water depth and water temperature were measured at seven sites using multiparameter water quality instruments manufactured at the Marine Geophysics Laboratory, School

of Engineering and Physical Sciences, James Cook University (Figure 2.2). These instruments are based on a Campbell's Scientific 1000 data logger that has been programmed to measure and store these marine physical parameters using specifically designed sensors.

2.2.1 Turbidity

The turbidity sensor provides data in Nephelometric Turbidity Unit's equivalent (NTUe) and can be calibrated to Suspended Sediment Concentration (SSC) in mg/L (Larcombe et al., 1995). The sensor is located on the side of the logger, pointing parallel light-emitting diodes (LED) and transmitted through a fibre optic bundle. The backscatter probe takes 250 samples in an eight second period to attain an accurate turbidity value. The logger is programmed to take these measurements at 10 minute intervals. The sensor interface is cleaned by a mechanical wiper at a two hour interval allowing for long deployment periods where bio-fouling would otherwise seriously affect readings.

It must be noted the international turbidity standard ISO7027 defines NTU only for 90 degree scatter, however, the Marine Geophysics Laboratory instruments obtain an NTUe value using 180 degree backscatter as it allows for much more effective cleaning. Because particle size influences the angular scattering functions of incident light (Ludwig and Hanes 1990; Conner and De Visser 1992; Wolanski et al., 1994; Bunt et al., 1999), instruments using different scattering angles can provide different measurements of turbidity (in NTU). This has to be acknowledged if later comparison between instruments collecting NTUe and NTU are to be made. To enhance the data, all sites were calibrated to provide a measure of SSC (mg L^{-1}) and enable for the accurate comparison between 90 degree backscatter and 180 degree backscatter measurements.

2.2.2 Sediment deposition

Deposition is recorded in Accumulated Suspended Sediment Deposition (ASSD) (mg cm^{-2}). The sensor is wiped clean of deposited sediment at a 2 hour interval to reduce bio-fouling and enable sensor sensitivity to remain high. The deposition sensor is positioned inside a small cup shape (16 mm diameter x 18 mm deep) located on the flat plate surface of the instrument facing towards the water surface. Deposited sediment produces a backscatter of light that is detected by the sensor. Deposited sediment is calculated by subtracting, from the measured data point, the value taken after the sensor was last wiped clean. This removes influence of turbidity from the value and re-zeros the deposition sensor every 2 hours.

If a major deposition event is in progress, the sensor reading will increase rapidly and will be considerably above the turbidity sensor response. Gross deposition will appear as irregular spikes in the data where the sediment is not removed by the wiper but by re-suspension due to wave or current stress. When a major net deposition event is in progress the deposited sediment will be removed by the wiper and the deposition sensor reading should fall back to a value similar to the turbidity sensor. The data will have a characteristic zigzag response as it rises, perhaps quite gently, and falls dramatically after the wipe (see Ridd et al., 2001).

Deposition data is provided as a measurement of deposited sediment in mg cm^{-2} and as a deposition rate in mg cm^{-2} d^{-1}. The deposition rate is calculated over the 2 hour interval between sensor wipes and averaged over the day for a daily deposition rate. The deposition rate is useful in deposition analysis as it describes more accurately the net deposition of sediment by smoothing spikes resulting from gross deposition events.

2.2.3 Pressure

A pressure sensor is located on the horizontal surface of the water quality logging instrument. The pressure sensor is used to determine changes in water depth due to tide and to produce a proxy for

wave action. Each time a pressure measurement is made the pressure sensor takes 10 measurements over a period of 10 seconds. From these 10 measurements, average water depth (m) and Root Mean Square (RMS) water height are calculated. RMS water height, D_{rms}, is calculated as follows:

$$D_{rms} = \sqrt{\sum_{n=1}^{10} (D_n - \overline{D})^2 / n}$$

Equation 1 : where D_n is the nth of the 10 readings and $\overline{D}$ is the mean water depth of the n readings.

The average water depth and RMS water depth can be used to analyse the influence that tide and water depth may have on turbidity, deposition and light levels at an instrument location. The RMS water height is a measure of short term variation in pressure at the sensor. Changes in pressure over a 10 second time period at the sensor are caused by wave energy. RMS water height can be used to analyse the link between wave re-suspension and SSC. It is important to clearly establish that RMS water height is not a measurement of wave height at the sea surface. What it does provide is a relative indication of wave shear stress at the sea floor that is directly comparable between sites of different depths. For example, where two sites both have the same surface wave height, if site one is 10 m deep and has a measurement of 0.01 RMS water height and site two is 1m deep and has a measurement of 0.08 RMS water height. Even though the surface wave height is the same at both sites, the RMS water height is greater at the shallower site and we would expect more re-suspension due to wave shear stress at this site.

2.2.4 Water temperature

Water temperature values are obtained with a thermistor that records every 10 minutes. The sensor is installed in a bolt that protrudes from the instrument and gives sensitive temperature measurements.

a) b)

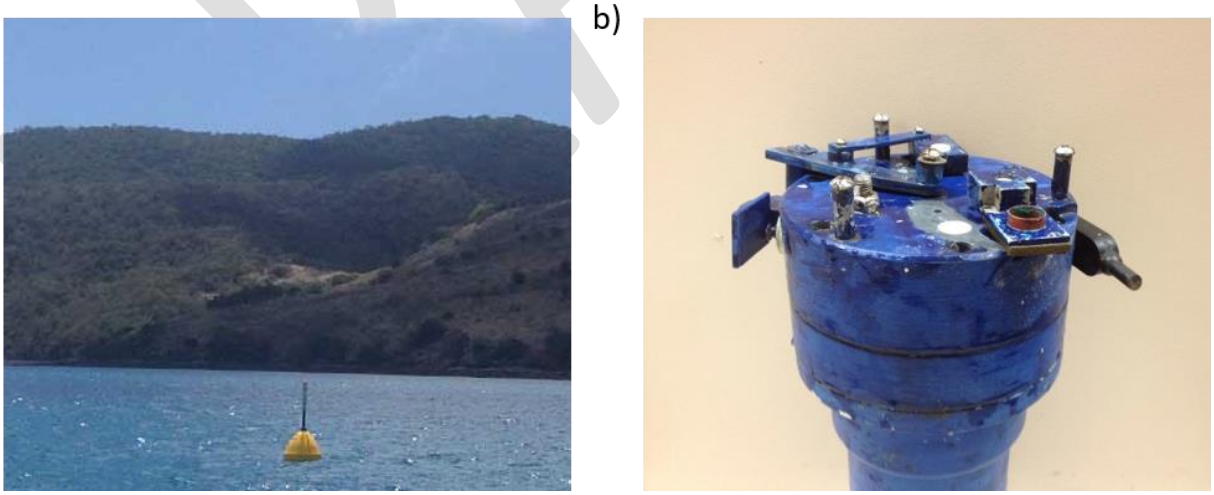


Figure 2.2 Example coastal multiparameter water quality instrument: a) site navigation beacon for safety and instrument retrieval; b) instrument showing sensors and wiping mechanisms

2.2.5 Photosynthetically Active Radiation (PAR)

A PAR sensor, positioned on the horizontal surface of the water quality logging instrument, takes a PAR measurement at ten (10) minute intervals for a one second period. To determine total daily PAR (mol m^{-2} d^{-1}) the values recorded are multiplied by 600 to provide an estimate of PAR for a 10 minute period and then summed for each day.

2.3 Marotte current meter

The Marotte HS (High Sampling Rate) is a drag-tilt current meter invented at the Marine Geophysics Laboratory (Figure 2.3). The instrument records current speed and direction with an inbuilt accelerometer and magnetometer. The current speed and direction data are smoothed over a 10-minute period. The instruments are deployed attached the nephelometer frames and data is download when the instruments are retrieved. Inclusion of this current meter has been added to the program as a way to trial new technology, gather new data and to add value to the project outcomes and deliverables.

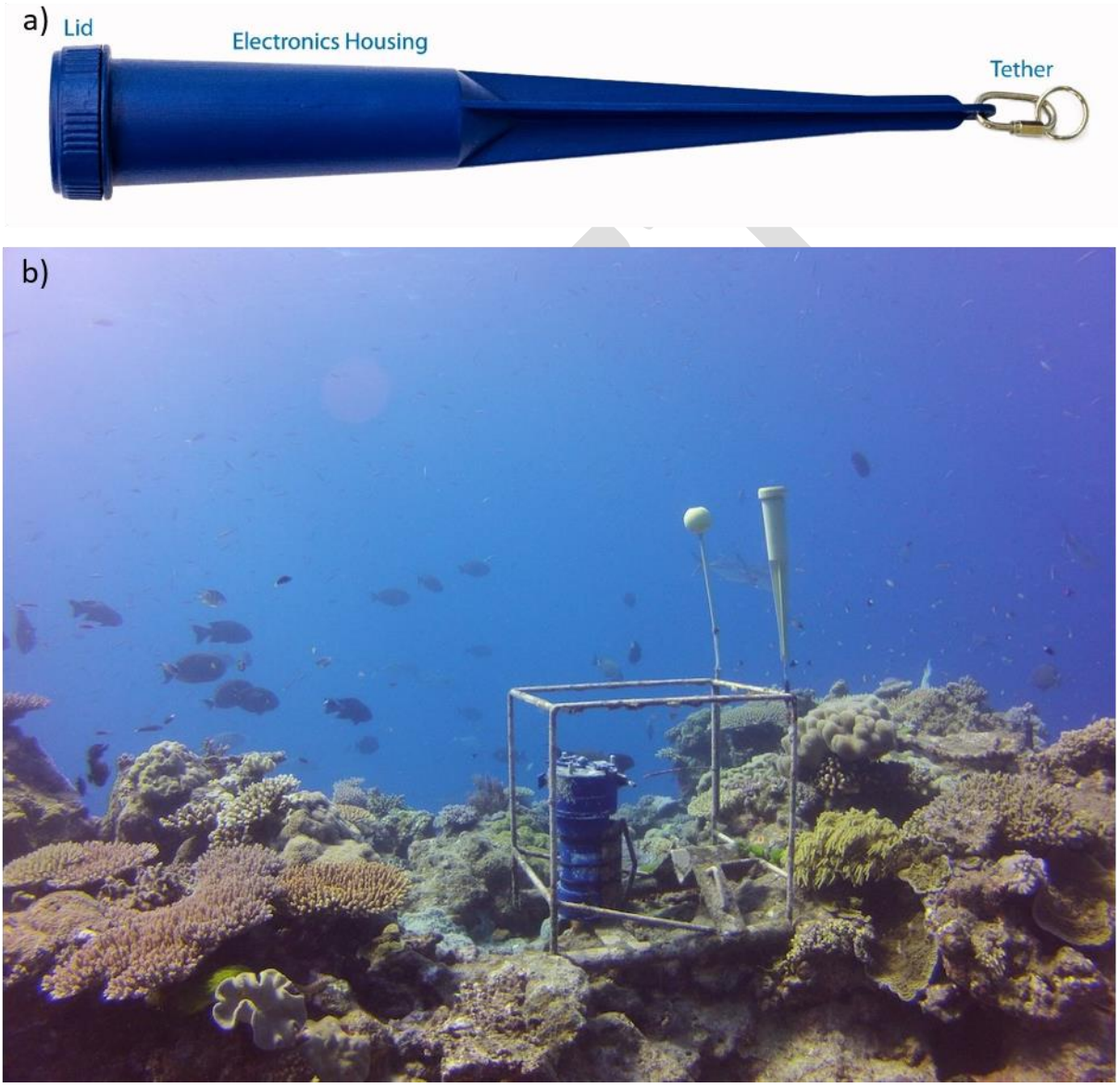


Figure 2.3 a) Basic schematic of Marotte HS current meter; and b) Marotte HS alongside Marotte at Moore Reef. Image courtesy of Eric Fisher

3 RESULTS AND DISCUSSION

There were six sampling and maintenance trips in the 2020-2021 reporting period (Table 3.1). Travel restrictions due to COVID-19 meant we were unable to complete water sampling between May and September 2020. It is noted that two rounds of data are not shown due to instrument failure, or where the sampling gear was in use in another port facility; this has been resolved by purchasing a new instrument, more careful timing of surveys in our scheduling, and further training to staff on instrument use to eliminate this problem in the future.

Table 3.1 Summary of instrument maintenance and water quality surveys completed during the 2020/21 reporting period. Note that the dry season metal sampling was completed September 2021.

Date	Nutrients, TSS, pH, EC, Chl-a	Metals	Logger maintenance
23/09/2020	Yes	-	Yes
05/11/2020	Yes	Yes	Yes
15/12/2000	Yes	-	Yes
09/02/2021	Yes	-	Yes
25/03/2021	Yes	-	Yes
26/05/2021	Yes	-	Yes

3.1 Ambient water quality

3.1.1 Physio-chemical measurements

Water temperature ranged between 20.7 and 30.2 °C (Figure 3.1). There is a strong seasonal effect on water temperatures in the region, with the highest water temperatures observed during surveys in the summer months, and cool water temperatures observed during the winter months (Figure 3.1). The annual temperature range at the offshore site AP_AMB5 (Holbourne Island) was less than inshore sites. Water temperature was generally similar through the water column for all sites, indicating that the water column profile is vertically well mixed throughout the region. Electrical conductivity (EC) ranged 48.0 and 55.3 mS cm^{-1} and was in the range typical of seawater (Figure 3.2). Conductivity values followed seasonality with higher values occurring during summer months and lower values during winter months. Dissolved oxygen ranged between 87 to 112 %sat (Figure 3.3). The water column was well mixed, with dissolved oxygen saturation not significantly changing through the vertical profile. pH ranged between 7.4 and 9.2 (Figure 3.4).

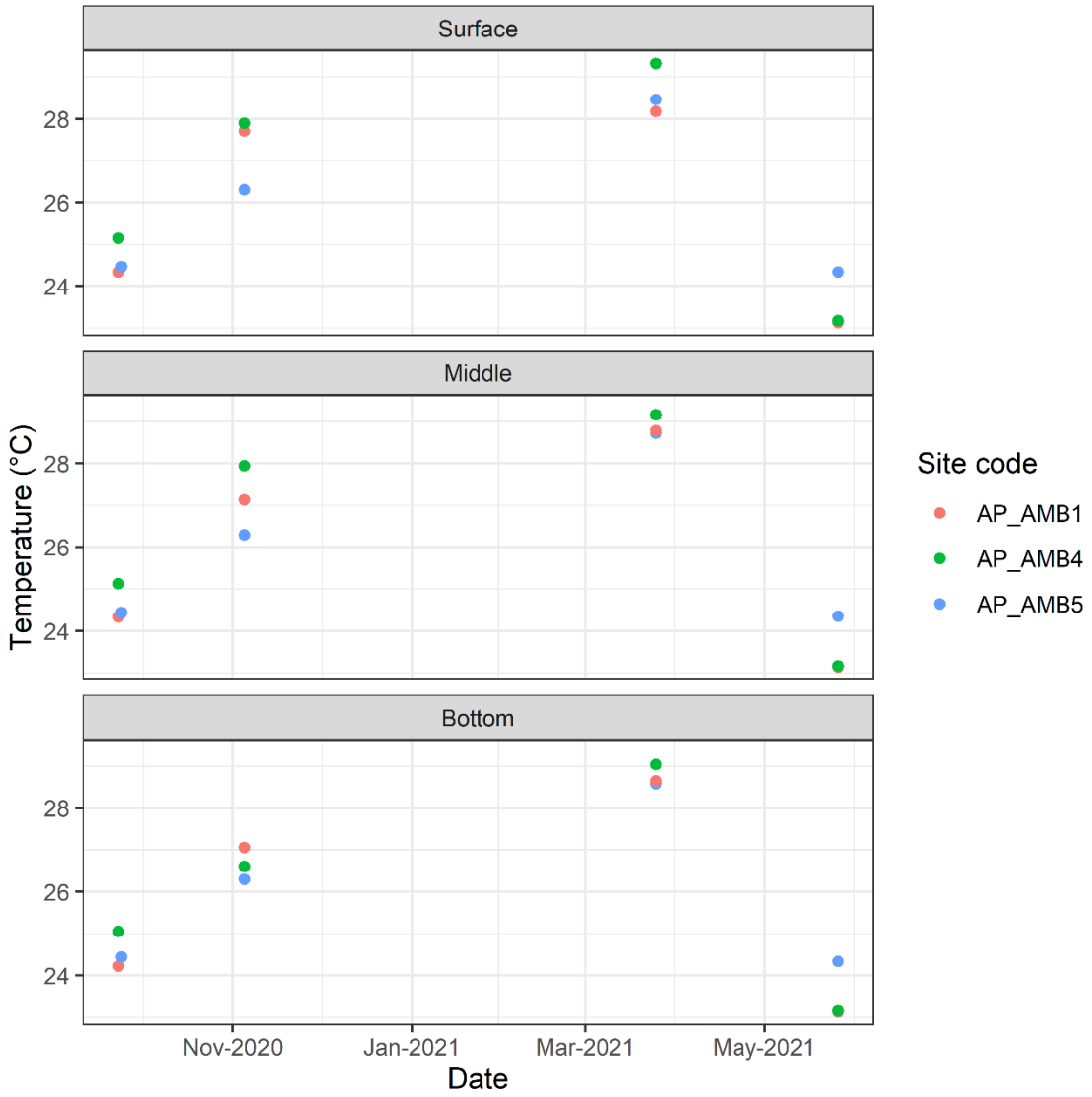


Figure 3.1 Water temperature recorded at three depths at the water quality sites throughout the reporting period.

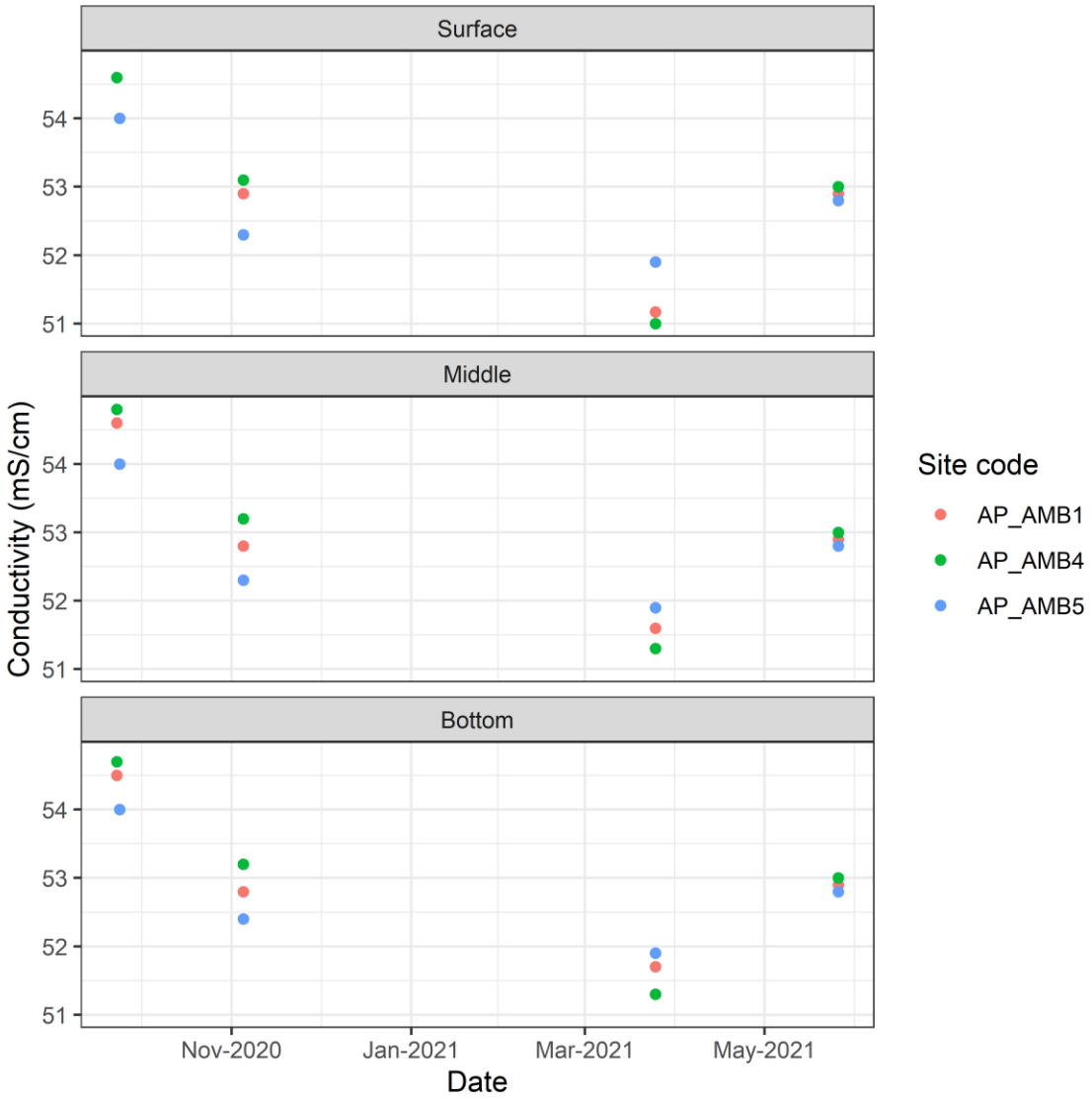


Figure 3.2 Electrical conductivity recorded at three depths at the water quality sites throughout the reporting period.

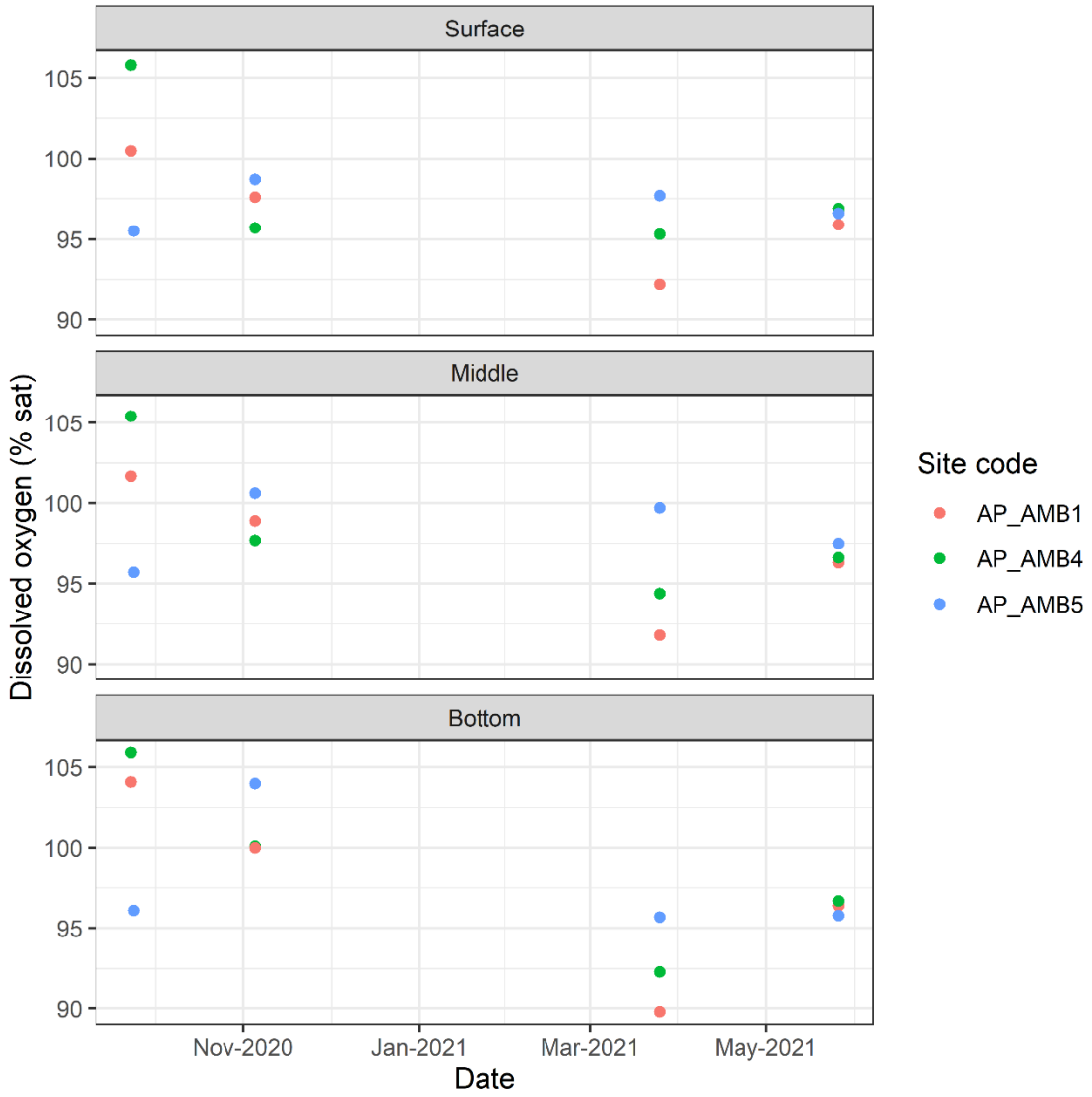


Figure 3.3 Dissolved oxygen (%sat) recorded at three depths at the water quality sites throughout the reporting period.

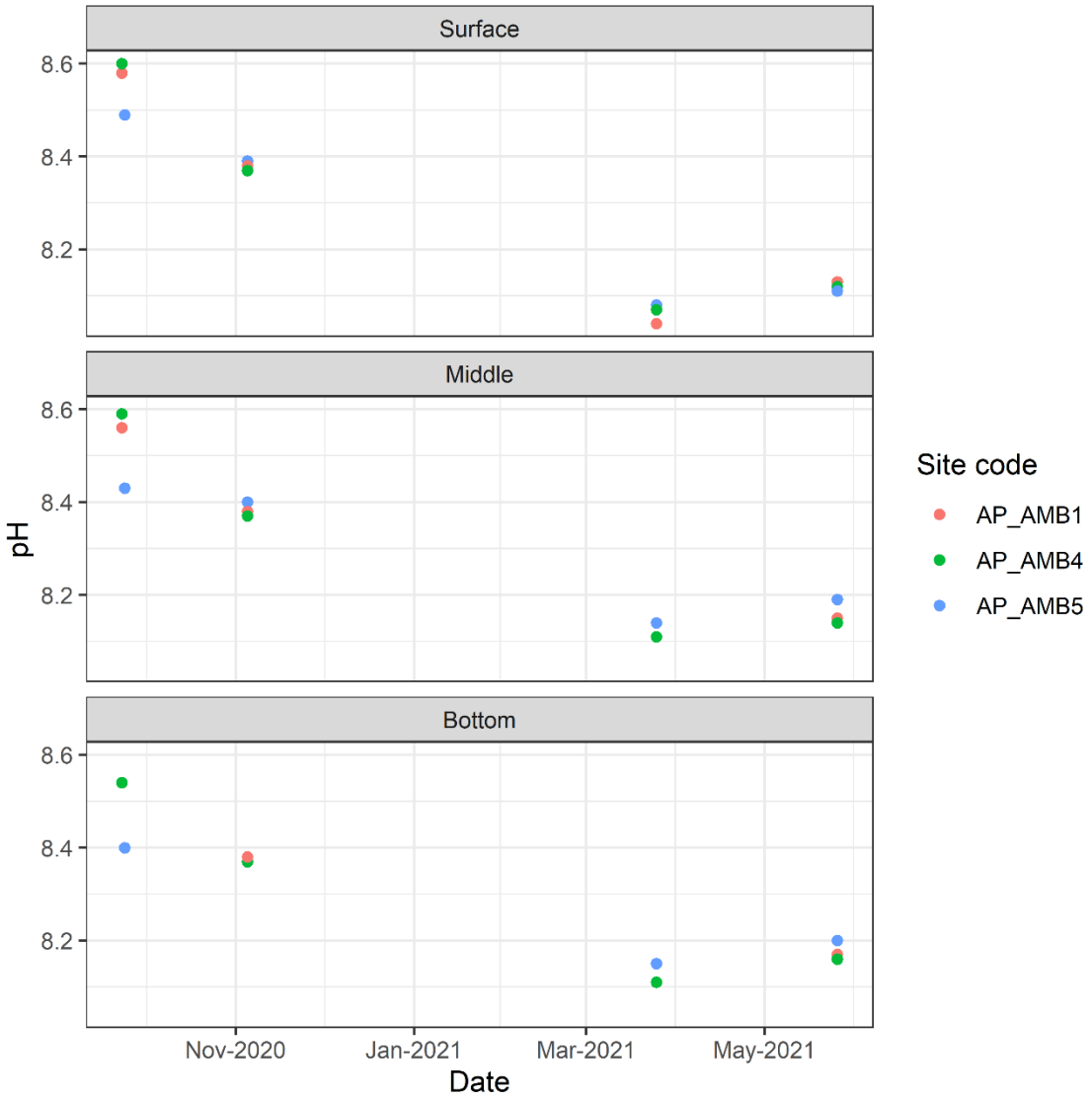


Figure 3.4 pH recorded at three depths at the water quality sites throughout the reporting period.

3.1.2 Nutrients, water clarity and chlorophyll-*a*

Particulate nitrogen (PN) concentrations ranged from 2 to 120 µg L^{-1} (Figure 3.5). Mean PN across the sites exceeded the GBRMPA guideline trigger value of 20 µg L^{-1} for all sampling events with the exception of March 2021 where all samples were below the guideline.

Particulate phosphorus (PP) concentrations ranged from <1 to 7 µg L^{-1} (Figure 3.6). Mean PP was generally below the GBRMPA guideline trigger value of 2.8 µg L^{-1} for all sampling events, though can be elevated above the guideline during the summer months, presumably a response to rainfall and catchment delivery of nutrients to coastal waters in the region.

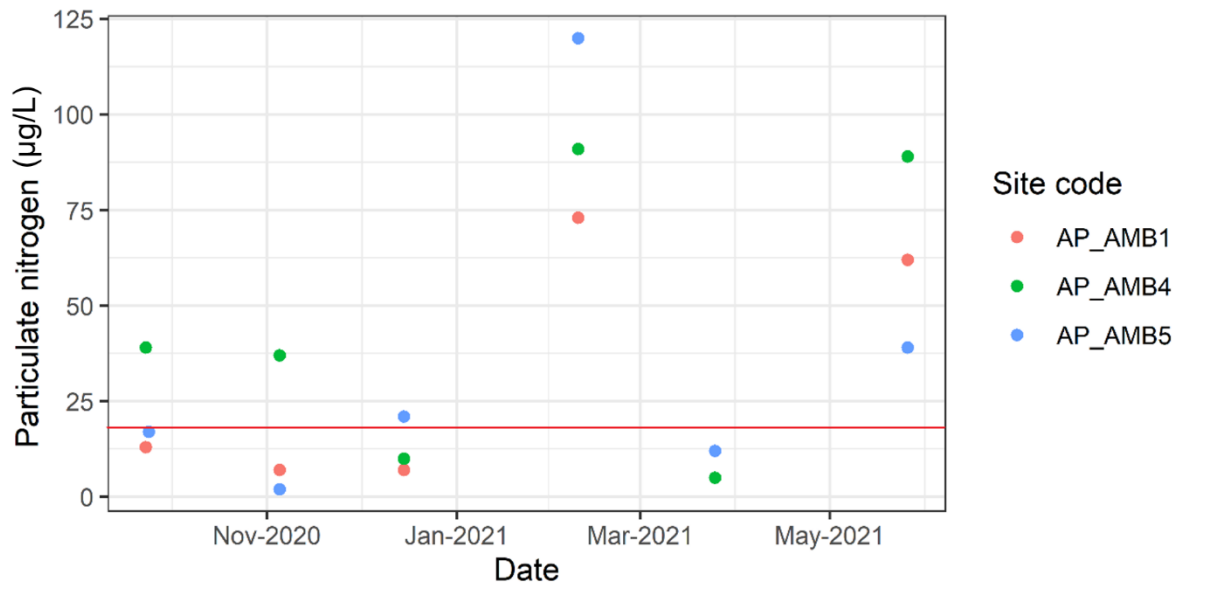


Figure 3.5 Particulate nitrogen (PN) concentrations measured in water samples collected from the water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

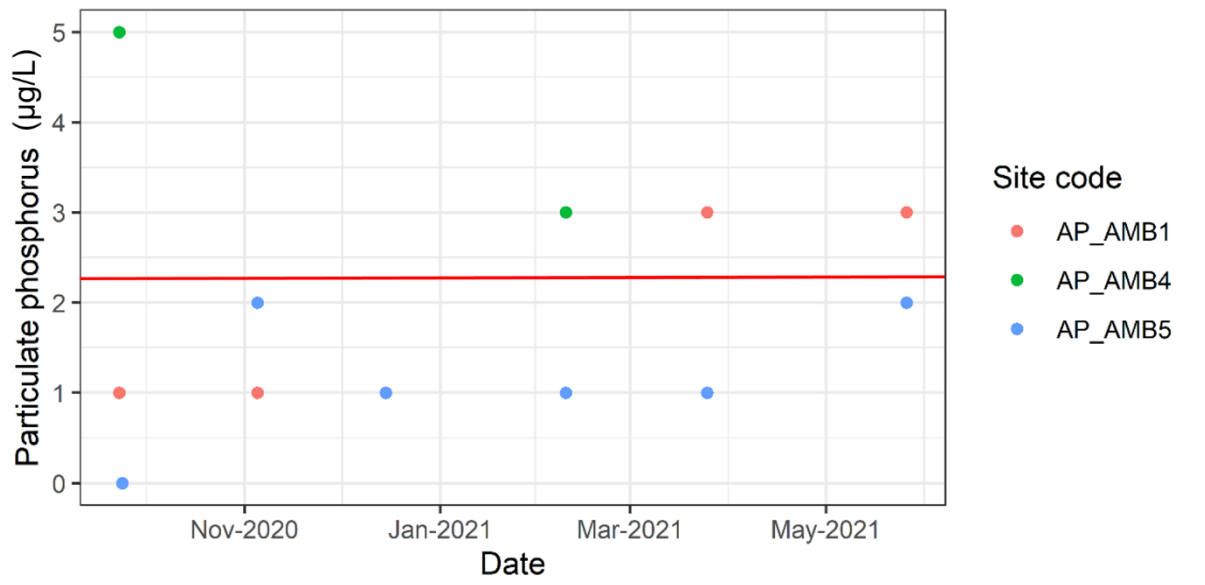


Figure 3.6 Particulate phosphorus (PP) concentrations measured in water samples collected from the water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

Total suspended solids ranged from 0.11 to 3.6 mg L^{-1} (Figure 3.7). Mean TSS across the sites were generally below the GBRMPA guideline trigger value of 2.0 mg L^{-1} for all sampling events. Secchi depth ranged from 4.0 to 12.4 m (Figure 3.8). Chlorophyll-*a* concentrations ranged from 0.20 to 2.05 µg L^{-1} (Figure 3.9). Chlorophyll-*a* concentrations ranged from <0.2 to 2.05 exceeded the GBRMPA guideline trigger value in December 2020 (mean = 0.78 µg L^{-1}) and July 2021 (mean = 0.25 µg L^{-1}).

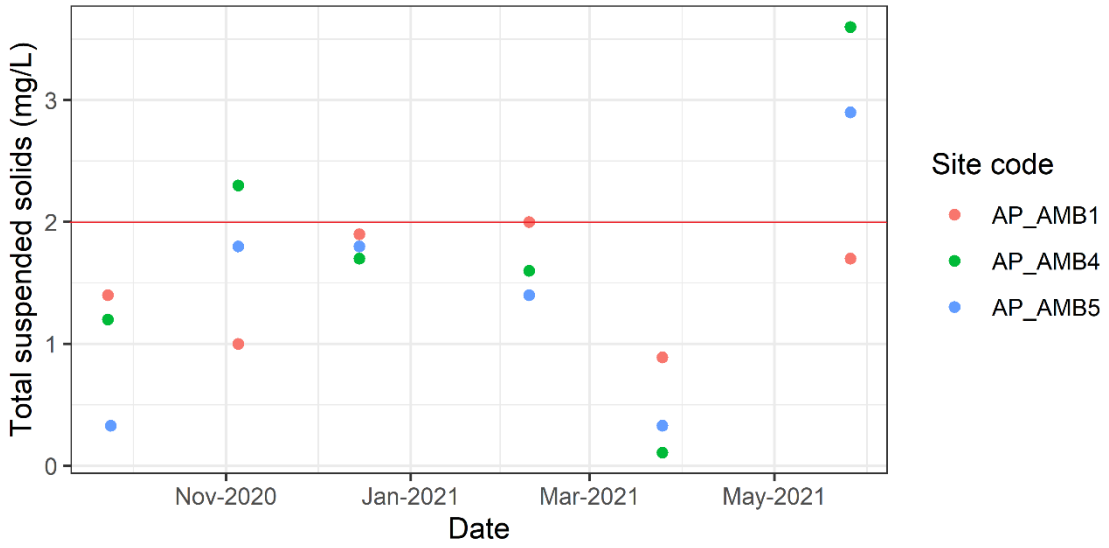


Figure 3.7 Total suspended solids (TSS) measured in water samples at the water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

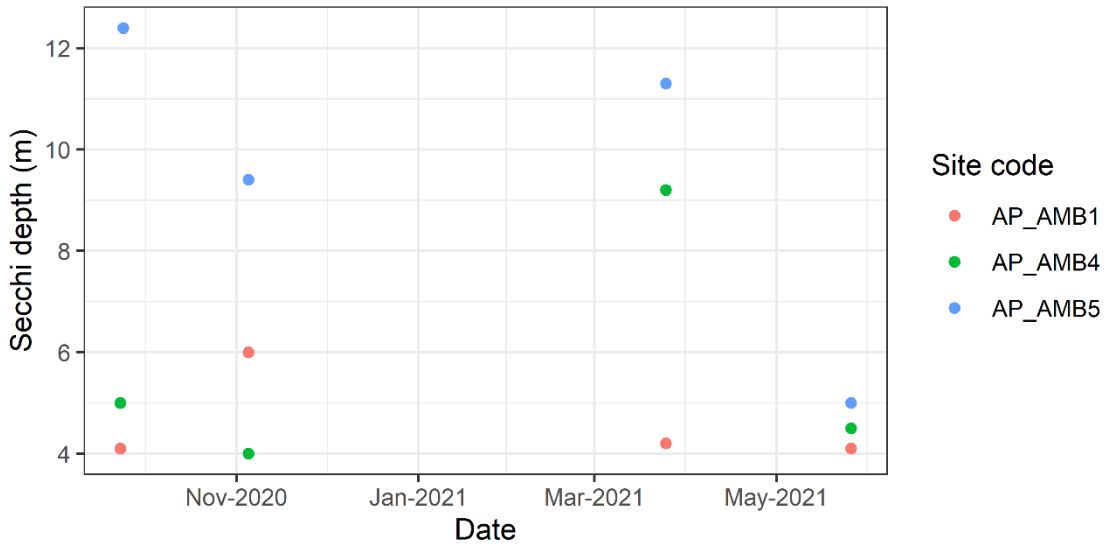


Figure 3.8 Secchi disk depth recorded at the water quality sites throughout the reporting period.

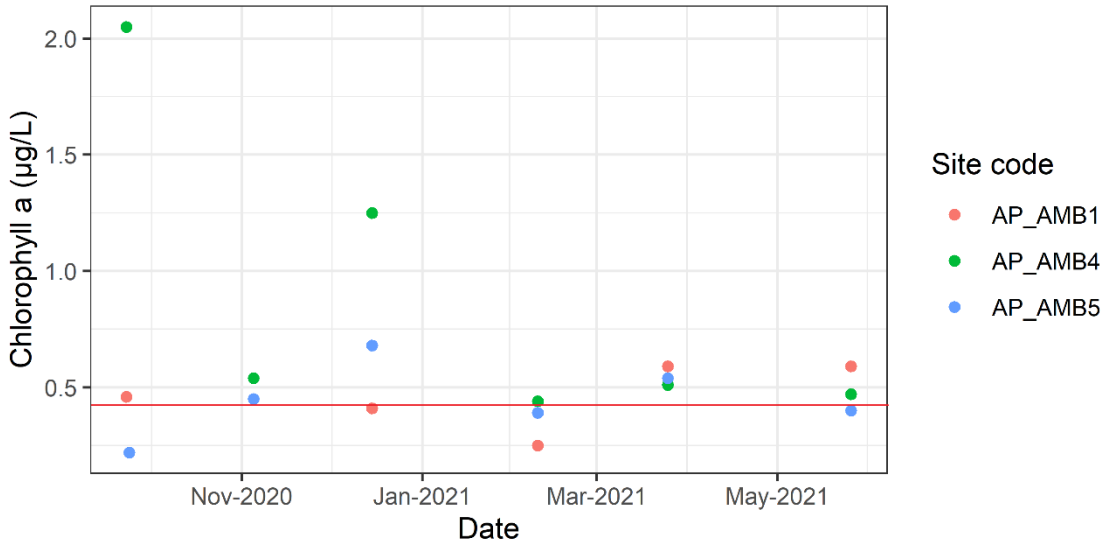


Figure 3.9 Chlorophyll-*a* concentrations measured in water samples collected from the water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

3.1.3 Heavy metals

Heavy metal concentrations are presented in Table 3.2. Concentrations were compared to the ANZECC and ARMCANZ 2000 water quality guidelines (ANZECC, 2000). Metals targeted for analysis were not detected above the 95% level of protection trigger values for marine waters. Silver, Cadmium, Copper, Zinc, and Mercury were not detected (< LOD). Nickel, and Arsenic were detected at low concentrations. Note that ANZECC guidelines do not have a trigger value for arsenic. A low reliability marine guideline trigger value of 4.5 µg/L for As (V) and 2.3 µg/L for As (III) has been derived (ANZECC, 2000), however, these trigger guidelines are only an indicative interim working level. Copper was detected during the September campaign at all sites. The elevation in copper has not been recorded previously in the monitoring. It either represents a true detection, or in fact could be due to a contamination issue (i.e at the laboratory, or in the field). TropWATER are looking further into this and will report in the next annual report.

Table 3.2 Heavy metal concentrations measured in water samples collected from the five water quality sites throughout the reporting period. ANZECC and ARMCANZ 2000 water quality guideline 95% level of protection trigger values for marine waters are shown for comparison (ANZECC, 2000).

Month	Sample_date	Site_code	Site_name	Silver	Cadmium	Copper	Lead	Nickel	Arsenic	Zinc	Mercury
			Units	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}	mg L^{-1}
			Limit of reporting (LOR)	0.1	0.2	1	0.2	0.5	-	5	0.001
			ANZECC 95% level	1.4	5.5	1.3	4.4	70	-	15	0.4
Feb-21	9/02/2021	AP_AMB1	Euri Creek	<0.1	<0.2	<1	<0.2	<0.5	1.8	<5	<0.0001
	9/02/2021	AP_AMB4	Camp Island	<0.1	<0.2	<1	<0.2	<0.5	1.7	<5	<0.0001
	9/02/2021	AP_AMB5	Holbourne Island	<0.1	<0.2	<1	<0.2	7.7	2	<5	<0.0001
Sept-21	14/09/2021	AP_AMB1	Euri Creek	<0.1	<0.2	**2**	<0.2	<0.5	1.4	<5	<0.0001
	14/09/2021	AP_AMB4	Camp Island	<0.1	<0.2	**2**	<0.2	<0.5	2.8	<5	<0.0001
	14/09/2021	AP_AMB5	Holbourne Island	<0.1	<0.2	**2**	<0.2	<0.5	1.5	<5	<0.0001

3.1.4 Pesticides

Pesticide concentrations are presented in Table 3.3. Concentrations were reported as less than values, with the exception of DEET, Diuron, and Hexazinone which were detected above limit of detection. When comparing to the draft GBRMPA guidelines, there were no exceedances above the 99% guidelines for species protection (King et al., 2017a, b).

Table 3.3 Pesticide concentrations measured in passive sample deployed at AMB 1. Deployment period was 43 days respectively. Date shown is the retrieval date.

AP AMB1	GBRMPA 99% (2018)	5/12/2020
unit	µg/L	ng/L
2,4-D	1000	*<0.810*
Ametryn	0.1	*<1.45*
Atrazine		*<0.190*
Atrazine desethyl		*<0.230*
Bromacil		*<0.130*
Carbendazim		*<0.230*
DEET		**1.25**
Diazinon		*<0.190*
Diclofenac		*<0.030*
Diuron	0.43	**0.950**
Fipronil	0.0034	*<0.080*
Fluometuron	20	*<0.140*
Haloxyfop	590	*<0.100*
Hexazinone	1.8	**0.270**
Hydrochlorthiazide		*<0.180*
MCPA	1	*<0.580*
Metolachlor (S+R)	0.0002	*<0.190*
Prometryn	0.11	*<0.320*
Propoxur		*<0.160*
Simazine	28	*<0.130*
Tebuthiuron	4.7	*<0.150*
Terbuthylazine	0.4	*<0.180*
Terbutryn	0.079	*<1.24*
Triclopyr	0.36	*<0.480*
Trimethoprim		*<0.080*

3.2 Multiparameter water quality logger

Instruments were deployed at five sites, AMB 1 to 5, from July 2020 to July 2021. Using standard statistics, we describe observed trends and differences between sites and discuss the driving forces in these environments. For each site, an annual statistical summary of root mean square water height (RMS; m), suspended sediment concentration (SSC; mg l^{-1}), sediment deposition rate (mg cm^{-2} day^{-1}), water temperature (°C), and photosynthetically available radiation (PAR; mol m^{-2} d^{-1}) is presented. The summary is depicted using box plots, whereby the central diamonds represent the mean value, the central line represents the median value, and the central box represents the range of the 25 and 75% quartiles. The vertical bars represent the range of the 90th and 10th percentiles. Time series and monthly summaries are included in the appendices.

Table 3.4 Data recovery (%) at each Abbot Point site between July 2020 and July 2021. Data recovery is reported as a percentage of 10 minute intervals for suspended sediment concentration (SSC), root mean square water depth (RMS), temperature, and depth. Recovery is reported as a proportion of days with data for deposition rate and photosynthetically available radiation (PAR). AMB 2 and 3, highlighted dark red, have limited data in comparison to other sites; both were decommissioned in September 2020.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
SSC	0.46	0.00	0.09	0.50	0.71
Deposition rate	0.75	0.23	0.02	0.67	0.72
PAR	1.00	0.23	0.23	0.78	0.67
RMS	1.00	0.23	0.23	0.90	0.91
Temperature	1.00	0.23	0.23	0.79	0.91
Depth	1.00	0.23	0.23	0.90	0.91
Mean recovery	0.87	0.19	0.17	0.76	0.81

3.2.1 RMS water height

Root mean square water height (RMS) is mostly driven by weather events that increase RMS simultaneously at all sites. Variation in RMS during and in-between peak events differs among sites due to differences in water depth and exposure to wave energy. All sites had similar RMS values, with median values ranging from 0.010 m to 0.024 m (Figure 3.10,

Table **3.5**). AMB2 and AMB5 had the lowest median RMS while AMB3 had the highest median RMS. Peaks in RMS occurred throughout the deployment period at all sites (Appendix A1.2, Appendix A1.3).

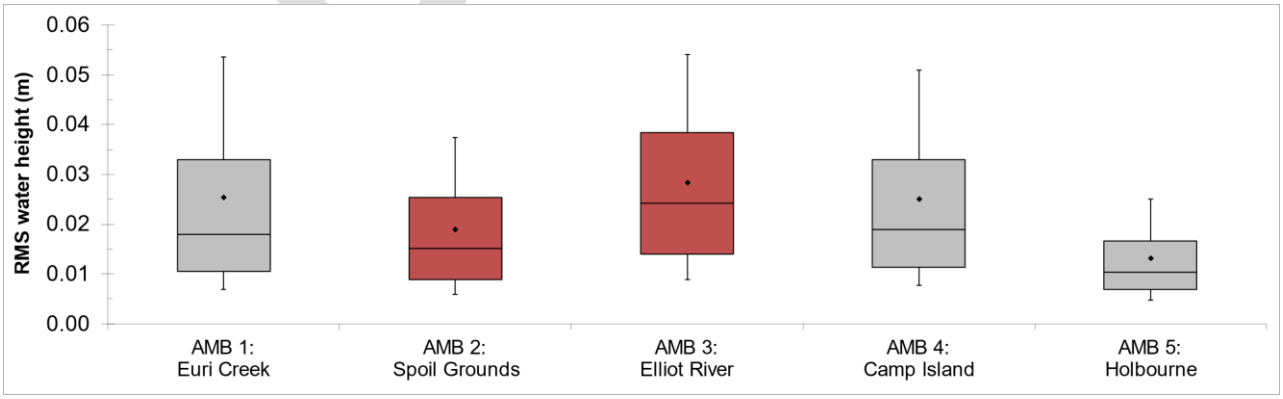


Figure 3.10 Box plot of RMS water height (m) at the five sites for the monitoring period from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamonds represent the mean values. AMB 2 and 3, highlighted dark red, have limited data in comparison to other sites; both were decommissioned in September 2020.

Table 3.5 Summary of RMS water height (m) statistics at the five sites from July 2020 to July 2021.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
Mean	0.025	0.019	0.028	0.025	0.013
median	0.018	0.015	0.024	0.019	0.010
min	0.000	0.000	0.000	0.000	0.000
lower quartile	0.010	0.009	0.014	0.011	0.007
upper quartile	0.033	0.025	0.038	0.033	0.017
max	0.294	0.123	0.190	0.264	0.116
90th percentile	0.054	0.037	0.054	0.051	0.025
10th percentile	0.007	0.006	0.009	0.008	0.005
n (recordings)	**52,544**	**12,168**	**12,172**	**47,425**	**47,880**
f (year obtained)**	**1.000**	**0.232**	**0.232**	**0.902**	**0.911**
St. Dev	0.022	0.014	0.019	0.020	0.009
St. Error	0.000	0.000	0.000	0.000	0.000

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 52560 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

3.2.2 NTUe/SSC

Median suspended sediment concentrations (SSC) were ≤1.8 mg L^{-1} at all sites (Figure 3.11, Table 3.6). Higher mean SSC at AMB1 suggests that this site experienced more extreme turbidity events during the monitoring period. AMB5 had the lowest SSC compared to the other sites, probably due to the location of this site well offshore from any river discharge plume.

The NTUe/SSC time series data follows a typical pattern of low background values with recurring peak events (Appendix A1.2). Most sites exhibited SSC extremes in October-December (Appendix A1.2). These events typically occurred simultaneously at all sites and coincided with increases in RMS. This is a typical pattern which is similar to data collected in coastal locations in north Queensland by the James Cook University (Ridd et al., 2001). Differences in NTUe/SSC among sites result from differences in RMS water height, water depth, benthic geology, hydrodynamics, and proximity to river mouths.

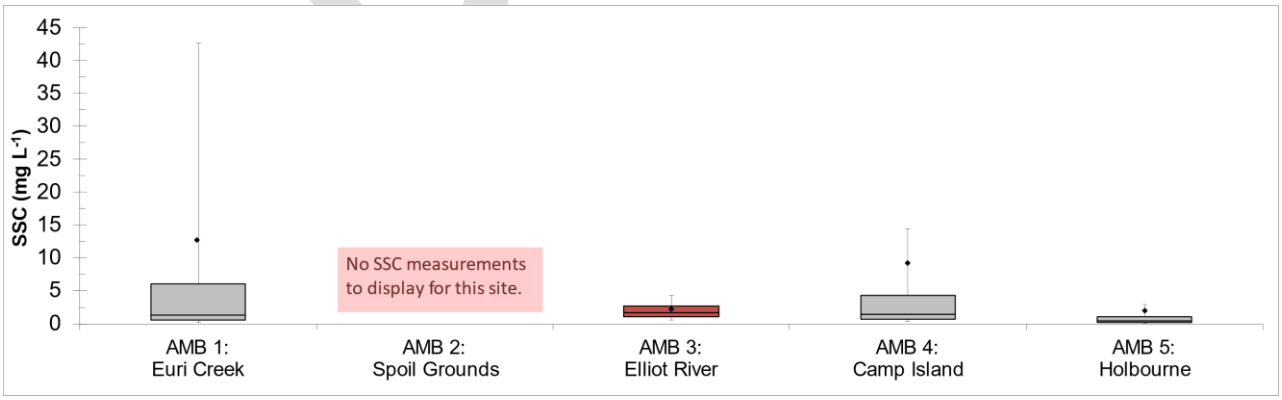


Figure 3.11 Box plot of SSC (mg L^{-1}) from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Table 3.6 Summary of SSC (mg L^{-1}) statistics at the five sites from July 2020 to July 2021.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
Mean	12.609		2.175	9.138	1.930
median	1.317		1.715	1.422	0.483
min	0.000		0.107	0.000	0.000
lower quartile	0.535		1.070	0.647	0.247
upper quartile	6.093		2.665	4.251	1.064
max	386.994		18.371	604.767	220.799
90^{th} percentile	42.540		4.285	14.363	2.991
10^{th} percentile	0.233		0.570	0.331	0.118
n (recordings)	**23,945**	**0**	**4,725**	**26,339**	**37,437**
f (year obtained)**	**0.456**	**0.000**	**0.090**	**0.501**	**0.712**
St. Dev	30.516		1.790	32.545	6.459
St. Error	0.197		0.026	0.201	0.033

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 52560 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

3.2.3 Deposition

Deposition of sediment is a natural process in all coastal marine waters. Suspended sediment is transported by currents and deposited in environments where wave energy is not sufficient to keep sediment suspended in the water column. The time series of deposition rates indicate that deposition peaks following RMS events but with a lag so that peak deposition occurs when RMS has decreased to near background levels (Appendix A1.2). An explanation for this lag is that, as waves resuspend sediment, little deposition occurs because the energy in the system keeps sediment in suspension. However, when waves decrease and there is no longer enough energy in the system to keep sediment in suspension, deposition occurs.

Management of marine habitats requires that sediment deposition be monitored for changes from ambient values. The Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA 2010) set a sediment deposition trigger value at a mean annual value of 3 mg cm^{-2} day^{-1} and a daily maximum of 15 mg cm^{-2} day^{-1}. However, the Guidelines suggest that 10 mg cm^{-2} day^{-1} sedimentation is valid in areas of coarse sediment, large grainsize, or low organic content which can occur in coastal areas of the GBR lagoon.

All coastal sites (AMB1-4), as well as AMB5, exceeded the mean sediment deposition trigger value (Figure 3.12, Table 3.7). However, as these deposition rates are not normally distributed, we focus our interpretation on median values, which ranged from 0.3 (AMB3) – 31.1 (AMB2) mg cm^{-2} day^{-1}.

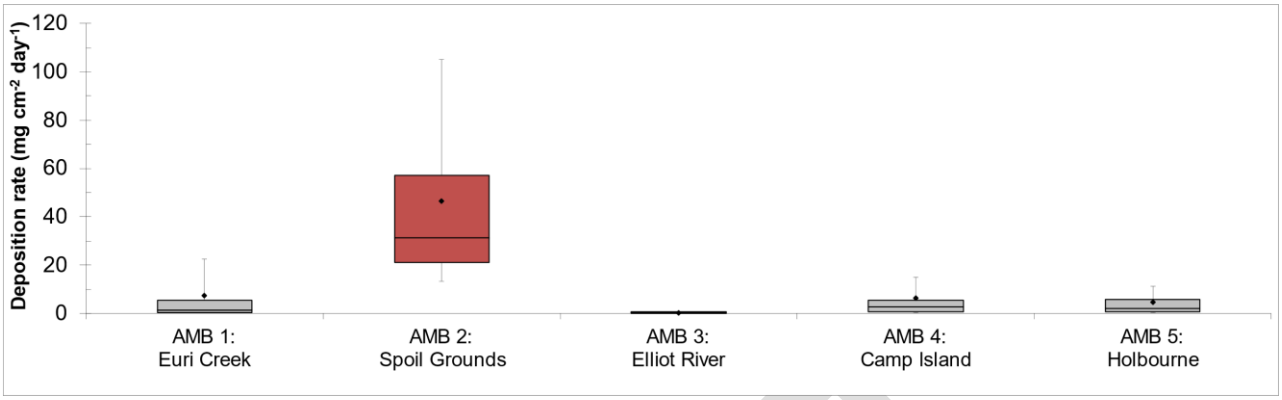


Figure 3.12 Box plot of deposition rates (mg cm^{-2} day^{-1}) from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Table 3.7 Summary of the mean daily deposition rate (mg cm^{-2} day^{-1}) statistics from July 2020 to July 2021.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
Mean	7.519	46.635	0.423	6.536	4.785
median	1.525	31.144	0.320	2.626	2.192
min	0.006	4.113	0.068	0.087	0.016
lower quartile	0.518	20.948	0.142	0.866	0.785
upper quartile	5.419	57.183	0.427	5.556	5.781
max	142.660	196.691	1.287	122.118	41.691
90^{th} percentile	22.534	104.929	0.866	14.970	11.340
10^{th} percentile	0.190	13.332	0.084	0.335	0.232
n (recordings)	**272**	**85**	**6**	**244**	**263**
f (year obtained)**	**0.745**	**0.233**	**0.016**	**0.668**	**0.721**
St. Dev	17.262	40.970	0.448	13.490	6.823
St. Error	1.047	4.444	0.183	0.864	0.421

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 365 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

3.2.4 Water temperature

Water temperatures were similar among all sites with medians of 21-27 °C and similar ranges of temperatures (Figure 3.13, Table 3.8). Water temperature at all sites approached 30 °C from December until March (Appendix A.2). Water temperature is not considered to be a compliance condition for approval operations, however the temperature data presented here holds importance in future interpretation of ecological processes in the region (e.g. Johanson et al., 2015).

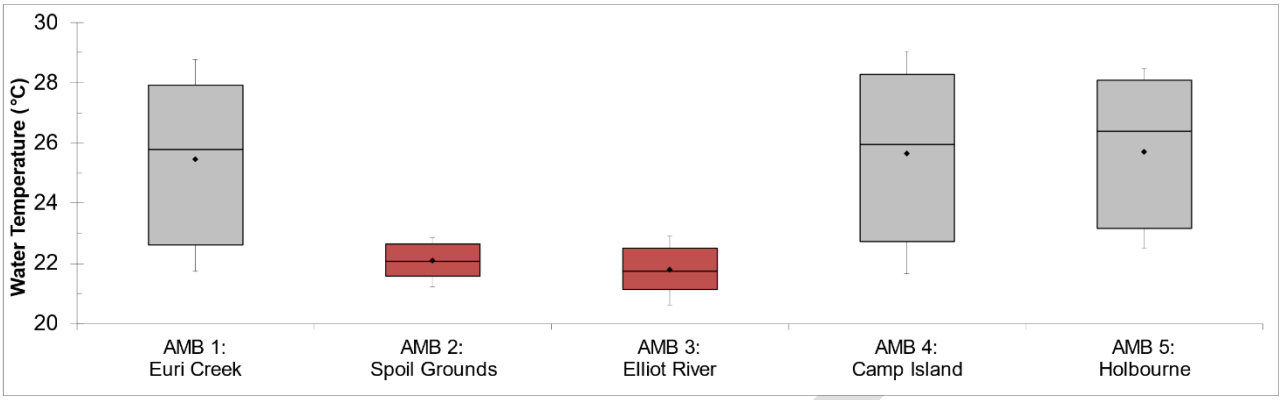


Figure 3.13 Box plot of the water temperature (°C) from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Table 3.8 Summary of water temperature (°C) from July 2020 to July 2021.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
Mean	25.463	22.089	21.806	25.659	25.708
median	25.800	22.060	21.750	25.950	26.400
min	20.260	20.790	19.900	20.320	20.950
lower quartile	22.610	21.570	21.150	22.720	23.160
upper quartile	27.910	22.630	22.510	28.270	28.090
max	30.160	23.860	24.680	30.820	29.280
90^{th} percentile	28.770	22.870	22.920	29.050	28.470
10^{th} percentile	21.740	21.230	20.620	21.650	22.500
n(recordings)	**52,528**	**12,168**	**12,172**	**41,662**	**47,870**
f (year obtained)**	**0.999**	**0.232**	**0.232**	**0.793**	**0.911**
St. Dev	2.745	0.651	0.893	2.840	2.410
St. Error	0.012	0.006	0.008	0.014	0.011

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 52560 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

3.2.5 PAR

Mean levels of benthic photosynthetically available radiation (PAR) ranged from 0.15 to 5.6 mol m^{-2} day^{-1} (Figure 3.14, Table 3.9). AMB3 and AMB5 had the highest mean and variance in PAR, while AMB2 had the lowest mean and lowest variance in PAR, likely due to its deeper location.

Benthic PAR was highly variable within sites throughout the year, but PAR was generally highest in July-August and December-January, and lower during March to May (Figure 3.15, Figure 3.16). Semi-regular oscillations between low and high PAR were overridden by larger episodic events caused by storm or rainfall.

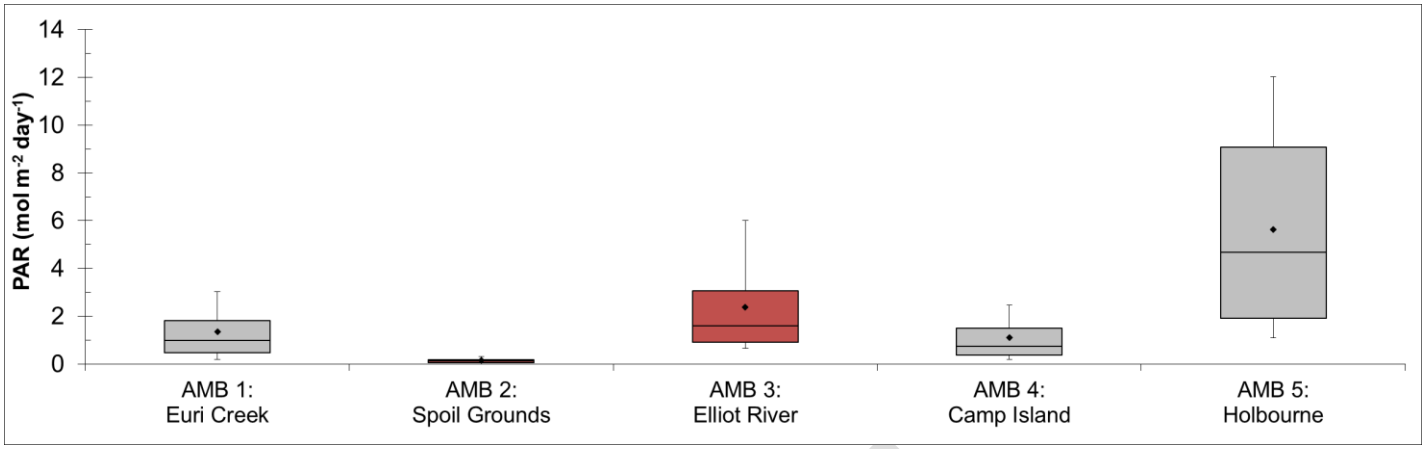


Figure 3.14 Box plot of daily PAR (mol m^{-2} day^{-1}) from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Table 3.9 Summary of daily PAR (mol m^{-2} day^{-1}) from July 2020 to July 2021.

Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
Mean	1.358	0.147	2.371	1.102	5.644
median	0.982	0.124	1.593	0.740	4.668
min	0.002	0.002	0.130	0.003	0.047
lower quartile	0.486	0.067	0.903	0.370	1.924
upper quartile	1.808	0.184	3.073	1.497	9.090
max	6.750	0.462	9.845	5.823	15.136
90th percentile	3.039	0.311	6.015	2.476	12.029
10th percentile	0.195	0.038	0.669	0.187	1.104
n	**364**	**85**	**85**	**286**	**243**
f (year obtained)**	**0.997**	**0.233**	**0.233**	**0.784**	**0.666**
St. Dev	1.226	0.109	2.267	1.091	4.103
St. Error	0.064	0.012	0.246	0.065	0.263

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 365 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

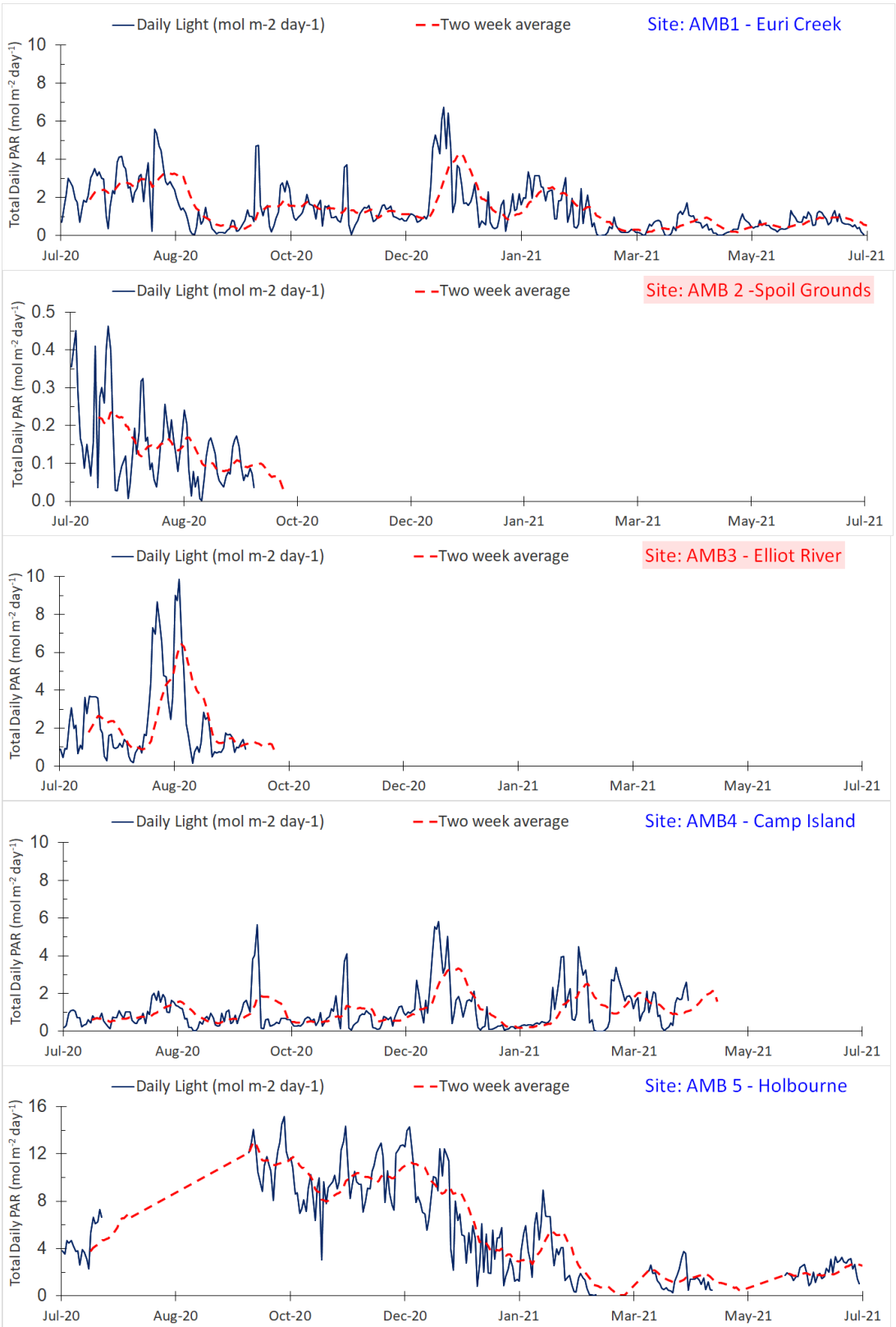


Figure 3.15 Time series of total daily PAR (mol m^{-2} day^{-1}) from July 2020 to July 2021. Daily mean PAR is plotted in blue and a 2-week moving average of daily mean PAR is plotted in red. Note that AMB5: Holbourne Island is shown on a different y-axis scale relative to the other sites. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

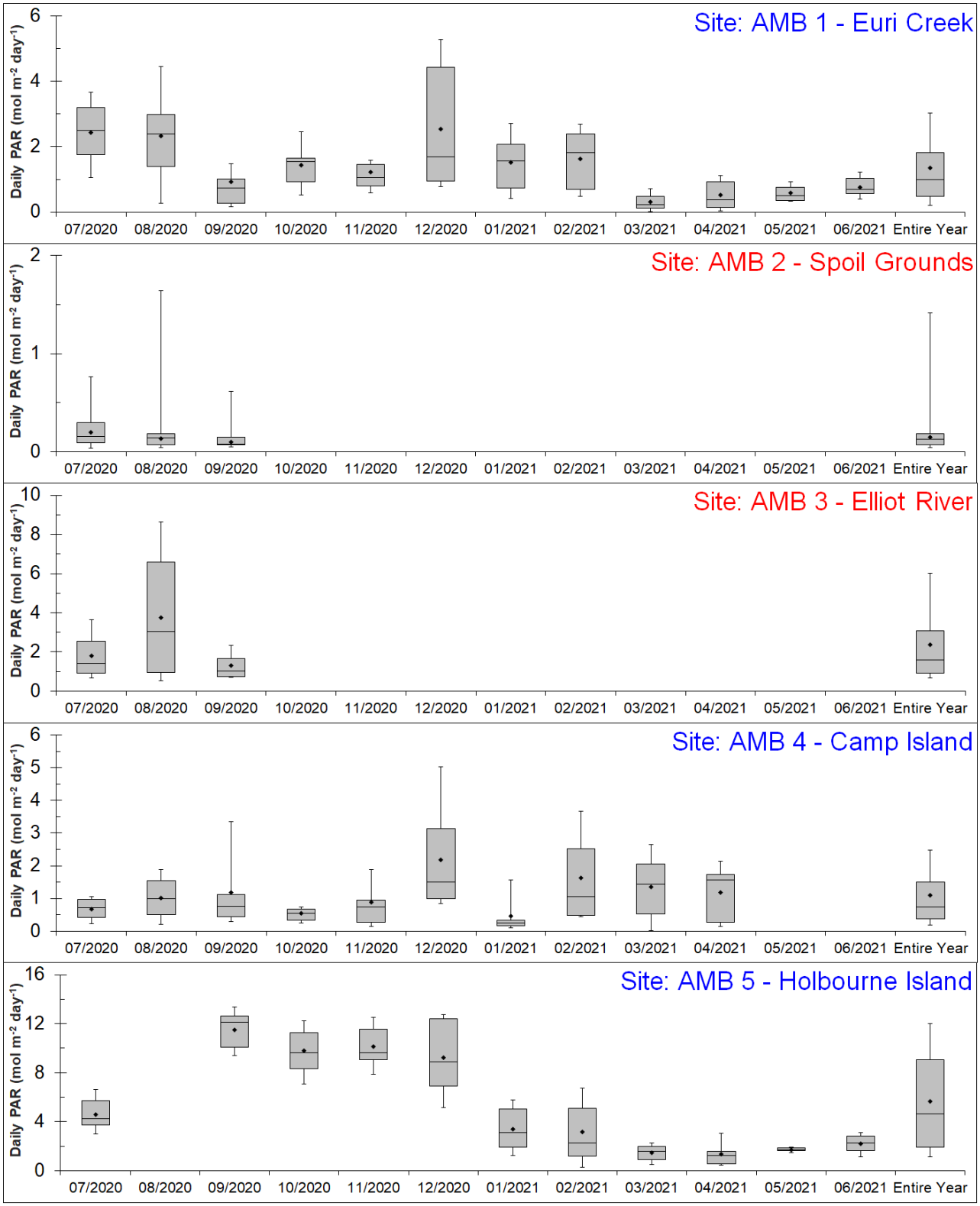
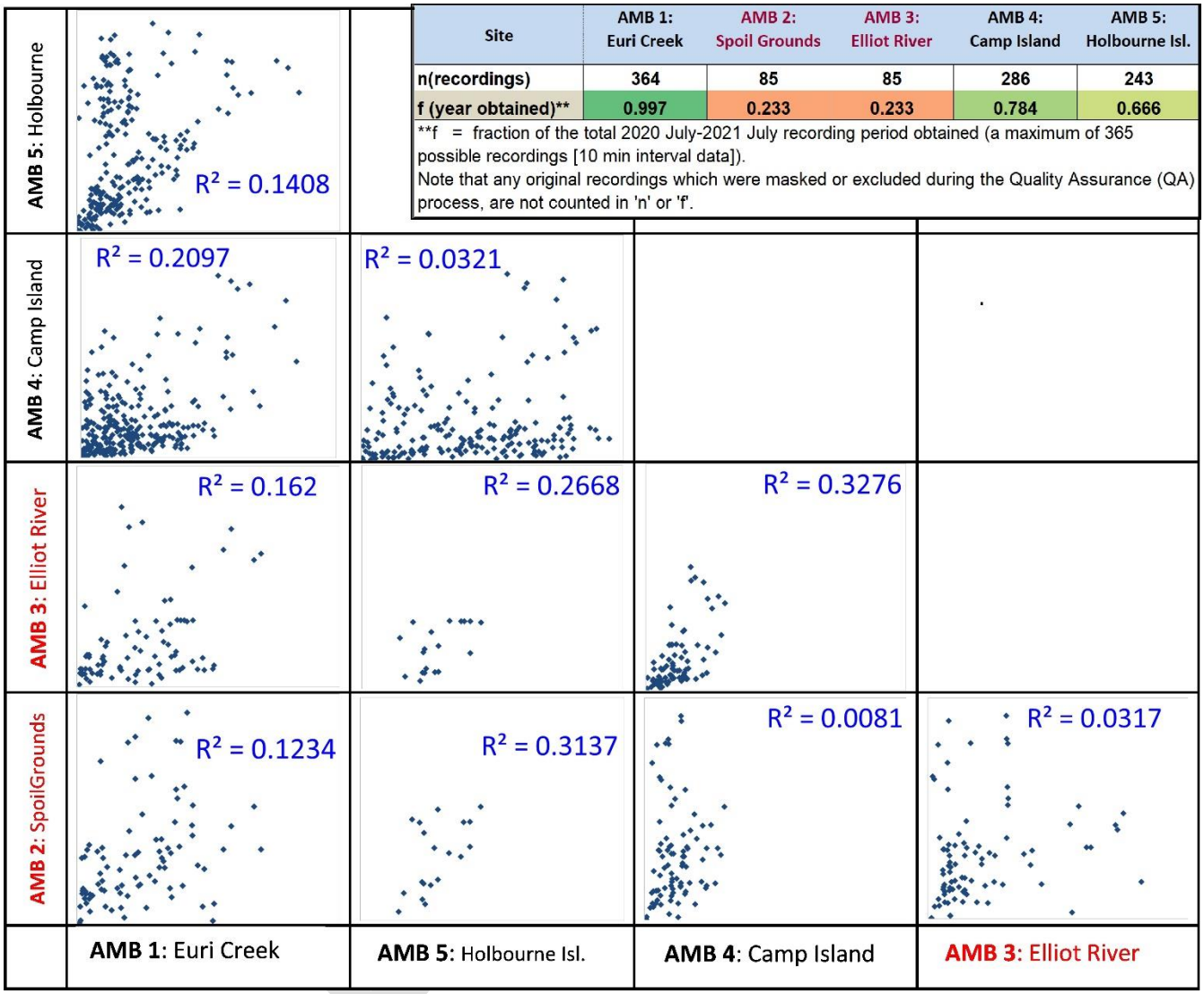


Figure 3.16 Monthly boxplots illustrating the variation in total daily PAR (mol m^{-2} day^{-1}) from July 2020 to July 2021. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value. Note AMB3 and AMB5 are on y-axis scales up to 24 while AMB1, 2, and 4 are on scales up to 8. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Similarities in patterns of PAR among sites

Direct comparisons of PAR among sites are confounded by the different water depths at each location. However, there are some weak relationships between the benthic PAR at different locations (Figure 3.17). Less than 32% of the variation in PAR at a given site could be explained by the PAR at any other site, highlighting the influence of location conditions (depth, turbidity, etc.) on benthic irradiance. AMB3 and AMB4 have the strongest association (R^2 = 0.32) while AMB2 and AMB5 have the second strongest association (R^2 = 0.31).



Site	AMB 1: Euri Creek	AMB 2: Spoil Grounds	AMB 3: Elliot River	AMB 4: Camp Island	AMB 5: Holbourne Isl.
n(recordings)	364	85	85	286	243
f (year obtained)**	0.997	0.233	0.233	0.784	0.666

**f = fraction of the total 2020 July-2021 July recording period obtained (a maximum of 365 possible recordings [10 min interval data]).
Note that any original recordings which were masked or excluded during the Quality Assurance (QA) process, are not counted in 'n' or 'f'.

Figure 3.17 Scatterplots of PAR between sites indicating the strength of the relationships between patterns of daily PAR. R^2 values are presented for each comparison. AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

3.2.6 Comparison between wet and dry seasons

A comparison of wet seasons (current year 2020-2021 and all** previous year combined, 2017-2021) and dry seasons (current year 2020-2021 and all** previous year combined, 2017-2021) water quality suggests that there are only slight differences in RMS, SSC, sediment deposition rates, and PAR between seasons.

Note: Supplementary table added below about maximum (and also general) seasonal data coverage across all sites.

Related Year	Wet Season Period		Dry Season Period	
	start	end	start	end
2017	18/11/2017	31/03/2018	N/A	N/A
2018	01/11/2018	31/03/2019	01/04/2018	31/10/2018
2019	01/11/2019	25/03/2020	01/04/2019	31/10/2019
2020	01/11/2020	31/03/2021	01/07/2020	31/10/2020
2021	N/A	N/A	01/04/2021	30/06/2021

**= all processed and combined deployment that was available on hand (prior to 2020) and had also been segmented into Wet and dry season period data.

For both sites AMB 2 and 3 (decommissioned in September 2020), logged data within the July 2020-July 2021 period only covers 1/07/2020-23/09/2020. Hence these two sites, only one dry season period 1/04/2020-31/10/2020 is covered (partially) for the observation period and no wet season periods are covered at all.

RMS water height

Overall, RMS was similar between seasons (

Figure **3.18**). However, several sites exhibit marginally higher RMS in the dry season, including AMB 1, AMB2, and AMB 4.

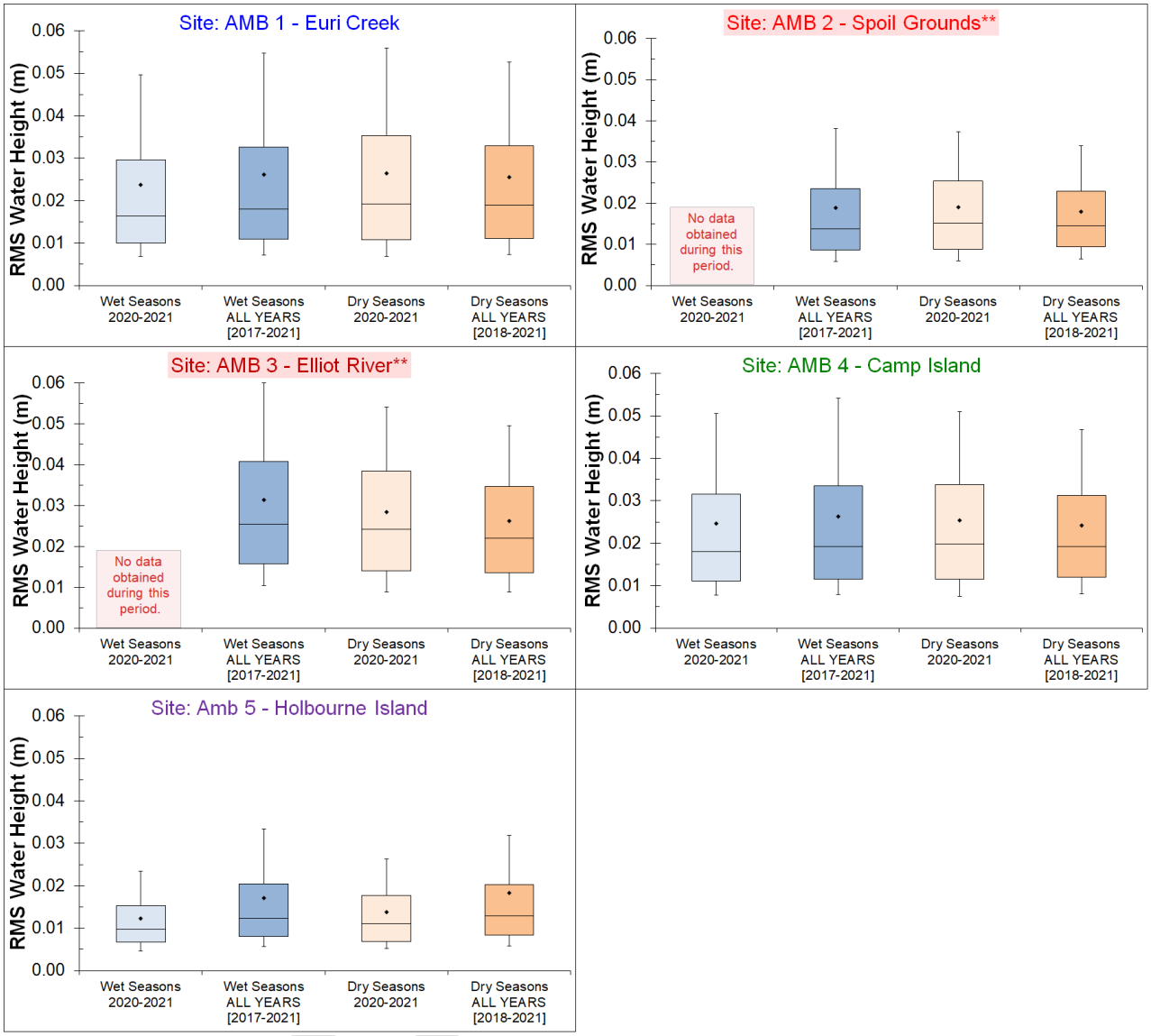


Figure 3.18 RMS box plots for AMB1-AMB5. Blue boxes represent the wet season (1 November- 31 March) while orange boxes represent the dry season (1 April - 31 October). AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

SSC

Turbidity was largely similar between seasons (Figure 3.19). Several sites had marginally higher turbidity in the wet season (AMB1, AMB2, AMB3), but there was considerable overlap with the dry season data. AMB4 and AMB5 may exhibit the opposite trend, with slightly higher turbidity in the dry season.

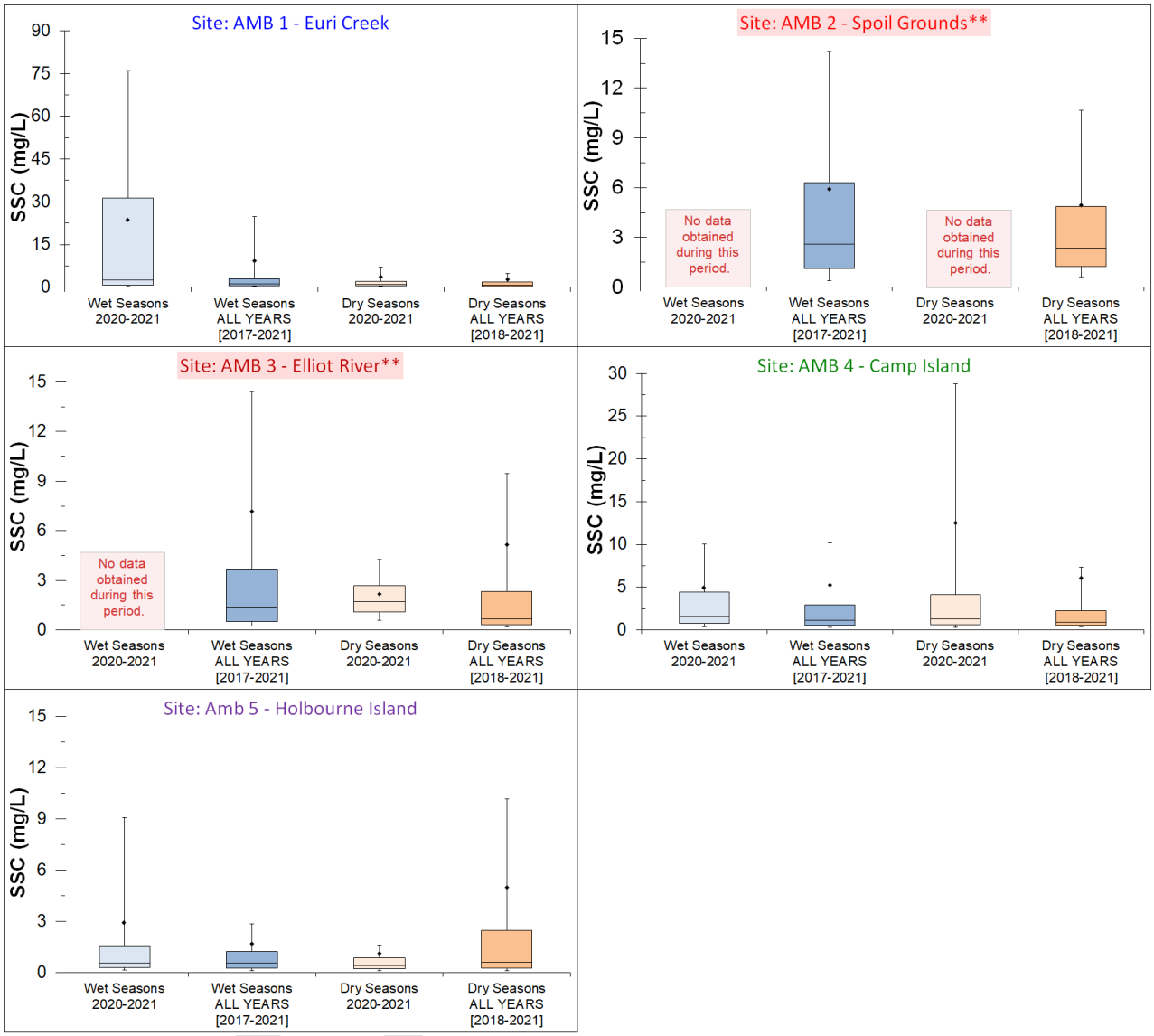


Figure 3.19 SSC box plots for AMB1-AMB5. Blue boxes represent the wet season (1 November-31 March) while orange boxes represent the dry season (1 April - 31 October). AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Deposition rate

Only AMB3 showed evidence of increased deposition during the wet season (Figure 3.20). AMB2 had higher deposition rates in the dry season compared to the wet season. Rates in the dry season compared to the wet season.

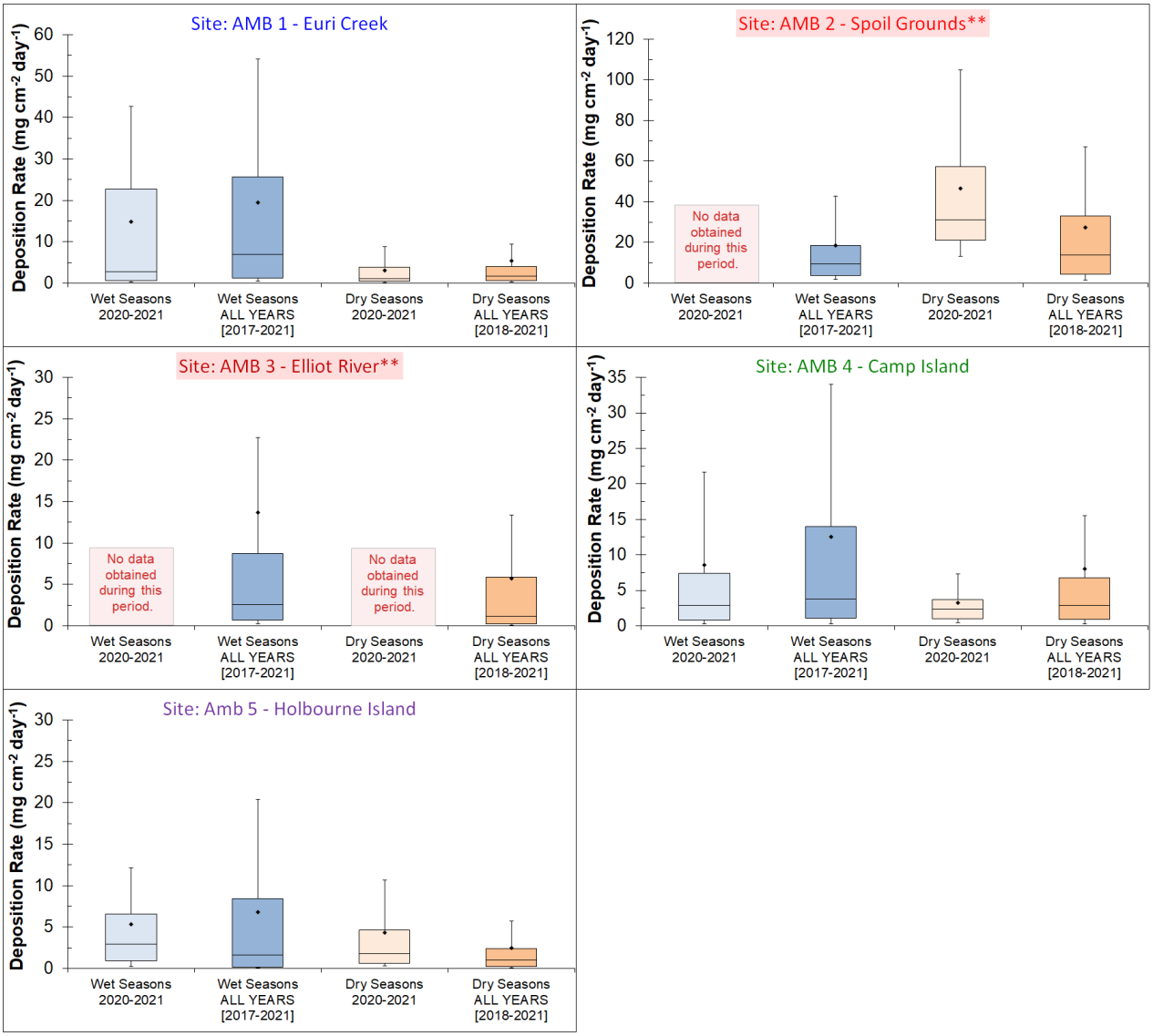


Figure 3.20 Deposition box plots for AMB1-AMB5. Blue boxes represent the wet season (1 November- 31 March) while orange boxes represent the dry season (1 April - 31 October). AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Total daily PAR

Photosynthetically available radiation (PAR) could differ between seasons due to longer daylength or increased cloud cover during the wet season. Daily PAR did not exhibit a consistent difference between seasons (Figure 3.21). Daily PAR totals for AMB1 and AMB2 were generally similar between wet and dry seasons, except for AMB5 where PAR was higher in the wet season, which was also observed in 2019-2020 period. These sites suggest that there isn't a general pattern in PAR between seasons. Differences in depth, distance from the coast, and distance from river mouths may influence how PAR differs between seasons at a given location.

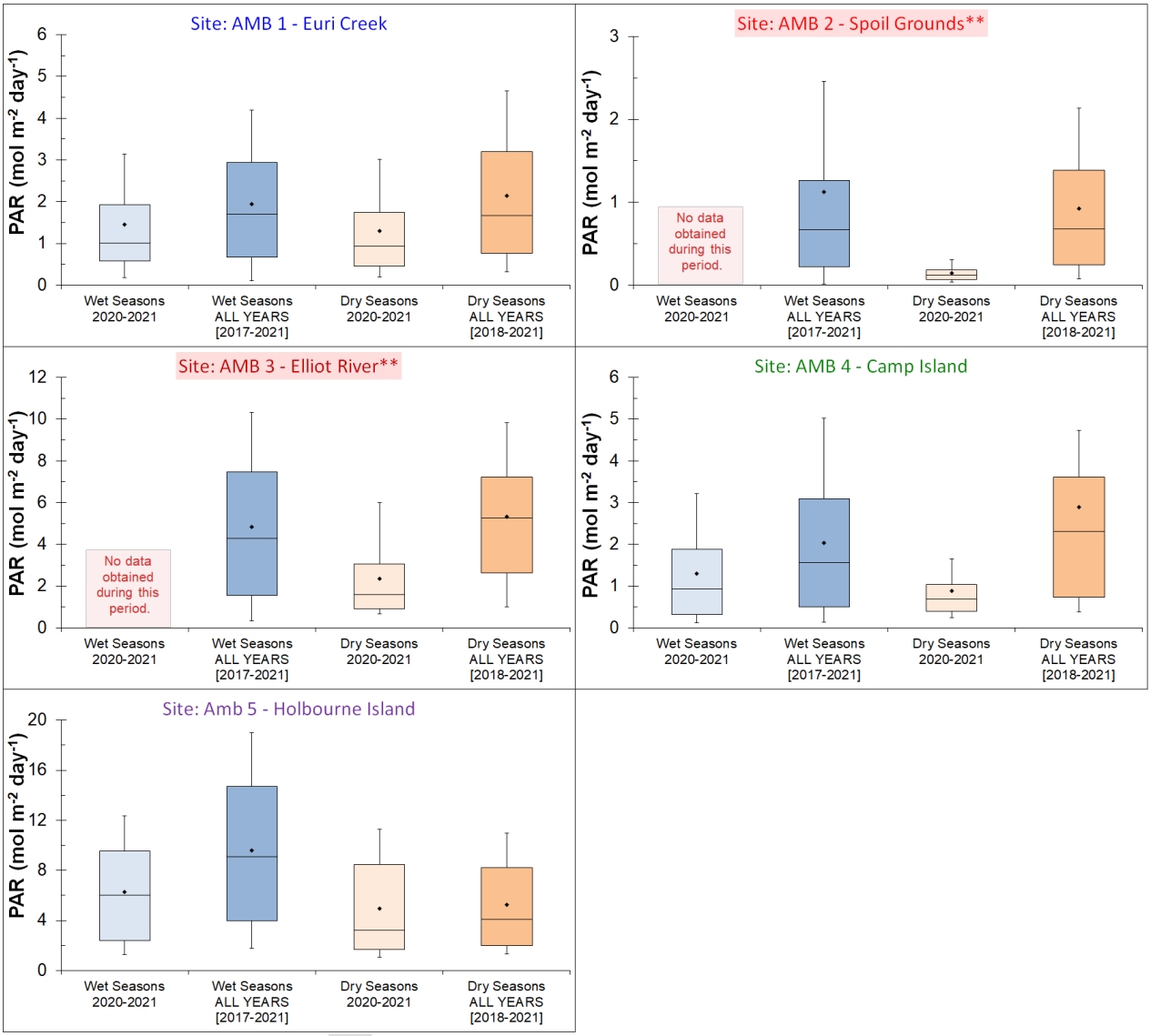


Figure 3.21 PAR box plots for AMB1-AMB5. Blue boxes represent the wet season (1 November- 31 March) while orange boxes represent the dry season (1 April - 31 October). AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

Water temperature

There is a clear difference in water temperature between the wet and dry seasons (

Figure **3.22**). Temperatures are higher during the wet season, with median temperatures between 28 and 29 °C at all sites, while median dry season temperatures ranged from 22 to 23 °C.

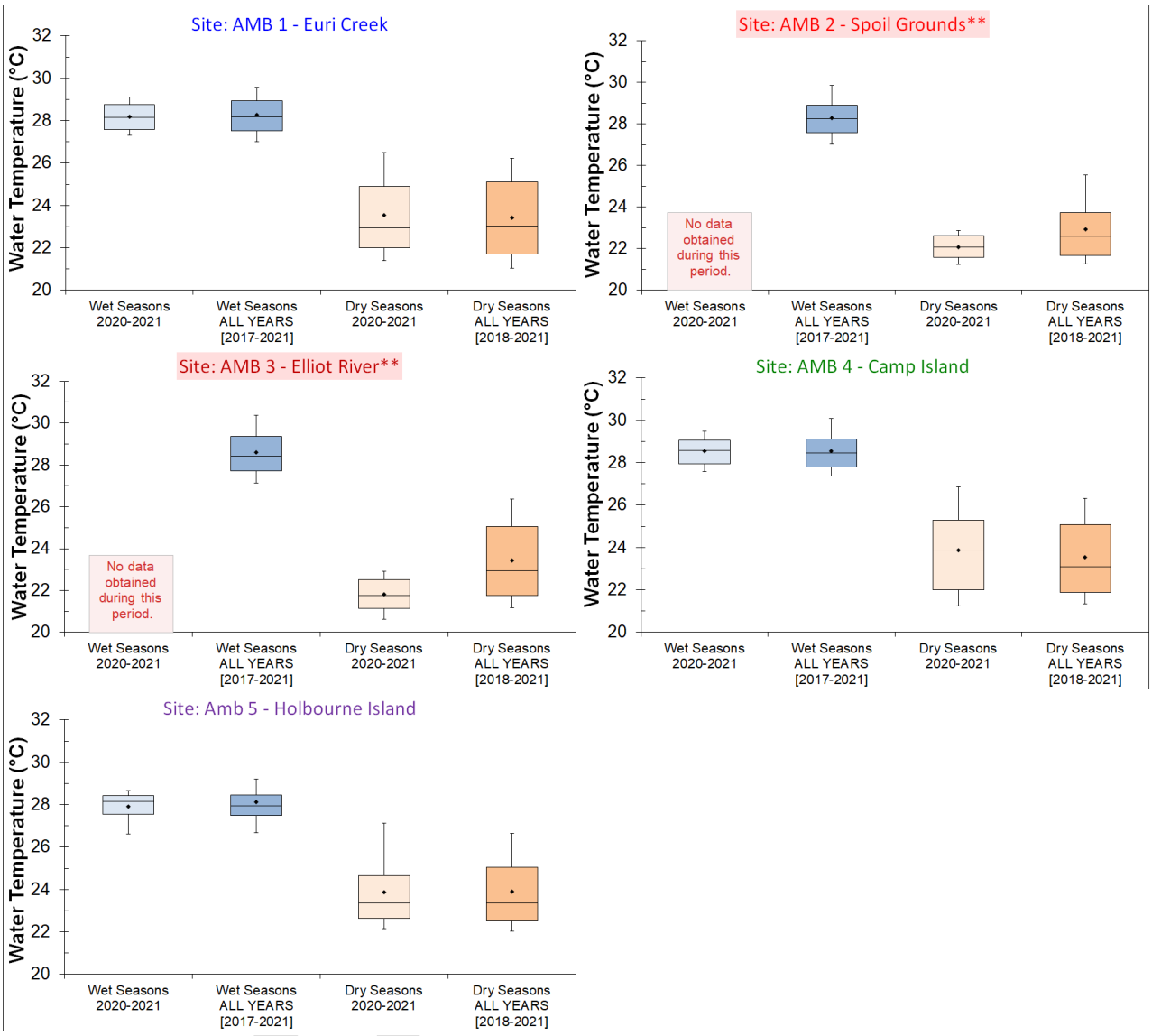


Figure 3.22 Temperature boxplots for AMB1-AMB5. Blue boxes represent the wet season (1 November- 31 March) while orange boxes represent the dry season (1 April - 31 October). AMB 2 and 3, have limited data in comparison to other sites; both were decommissioned in September 2020.

3.3 Marotte HS current meter

Marotte HS current meter instruments were deployed throughout the monitoring period of July 2020 to July 2021, for Bowen sites AMB 1-5. However, following September 2020, current meter instruments were temporarily decommissioned for usage in Bowen deployments and then later re-applied for ongoing deployments from February 2020 and onwards; except for sites AMB2 and AMB3 which were entirely decommissioned for deployments beyond September 2020. The reason for the breaks in data series was either flooding of the instruments or the units were missing because of fouling and units breaking free. With the exception of the time period between September 2020 and February 2021, data is available throughout the (remaining) monitoring period between July 2020 to July 2021 for AMB1 and AMB5. However, as for site AMB4, data is only available after late May 2021 due to unexpected instrument failures and issues experienced during earlier deployments. The obtained current meter data indicates the prominent current direction, current speed, and water temperature at each site. Data shows that coastal current, tidal current or a combination of both influence current direction and magnitude. The figures presented display the current meter data in current rose which provide a visual representation of the frequency of current speed, direction, and temperature. On the proceeding pages the presented results of obtained current meter data indicate the prominent water current direction, water current speed (m/s), and water temperature (°C) at each Mackay location.

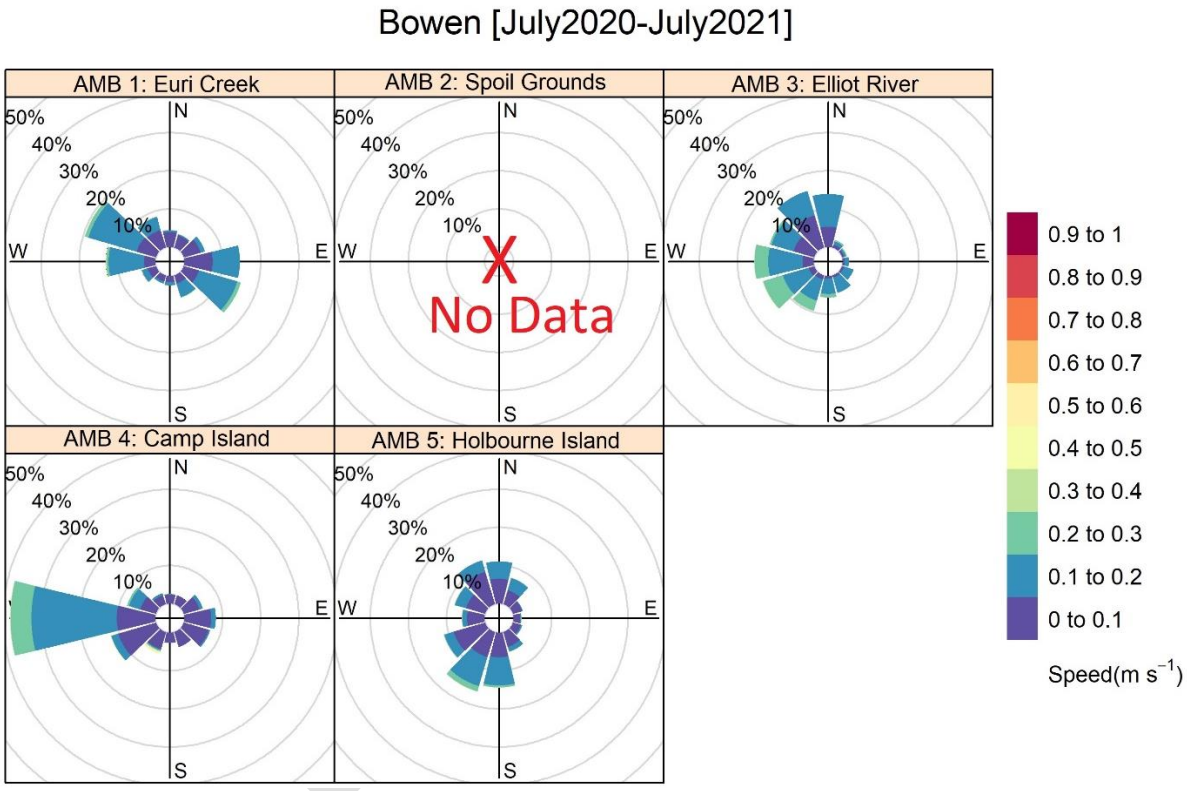


Figure 3.23 Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the five Bowen sites and covering the monitoring period July 2020 to July 2021.

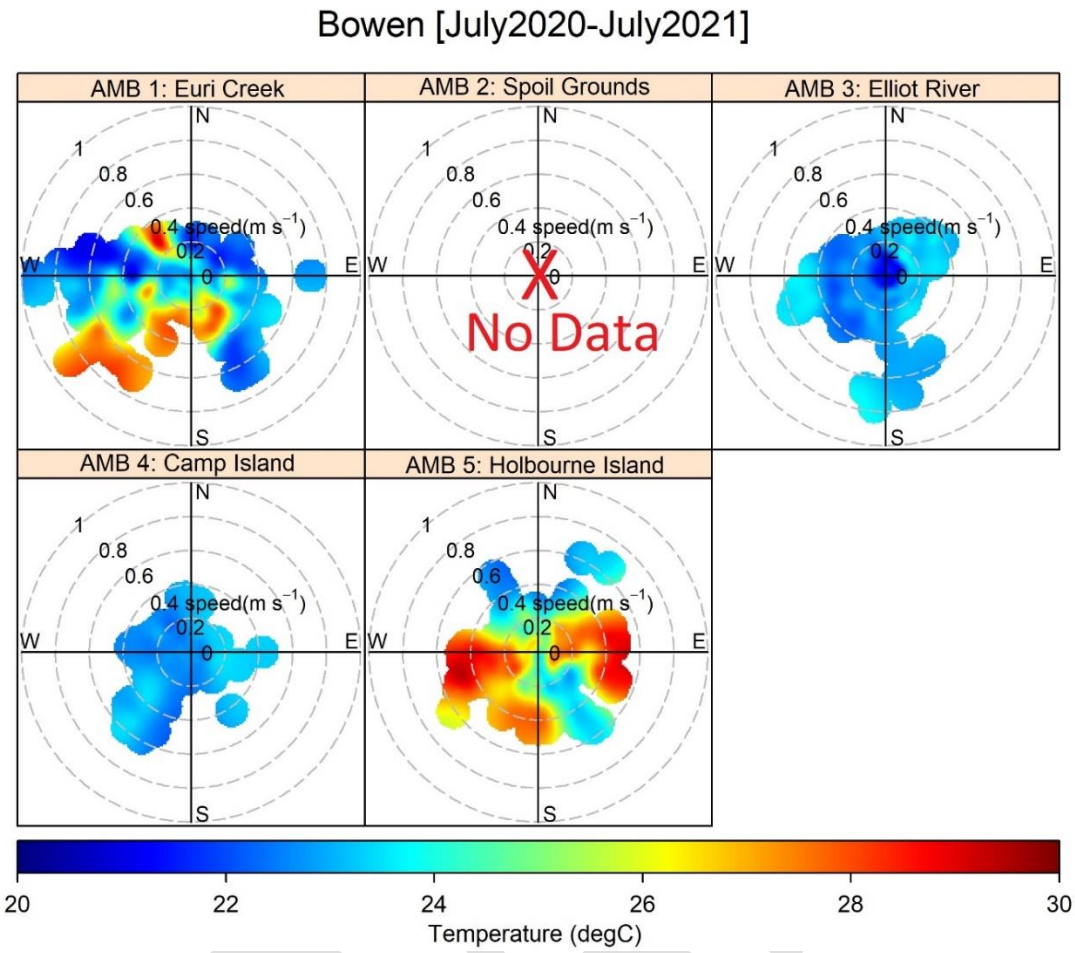


Figure 3.24 For each of the five Bowen sites and covering the monitoring period July 2020 to July 2021, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed (m/s) and current direction (heading). The position of the data, within each plot, indicates current direction and the distance from the origin indicates current speed (m/s). Data points are coloured according to calculated average water temperature (°C).

Current Meter data*: *during the Dry Season Periods (1st April – 31st October)

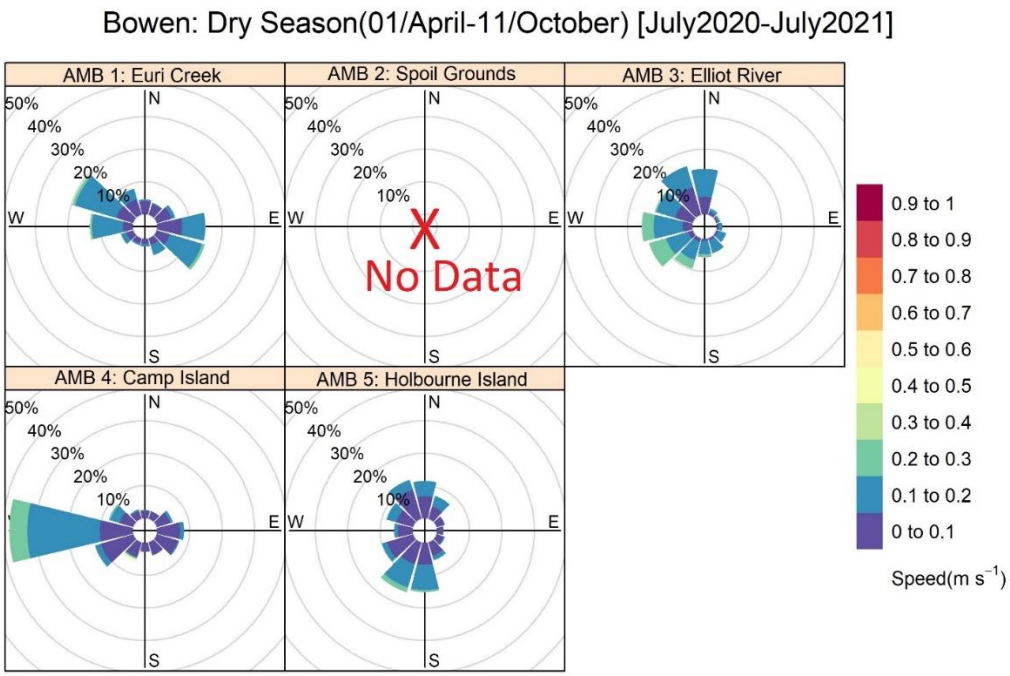


Figure 3.3.6 Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the five Bowen sites during the dry season months (April-October) across the monitoring period July 2020 to July 2021.

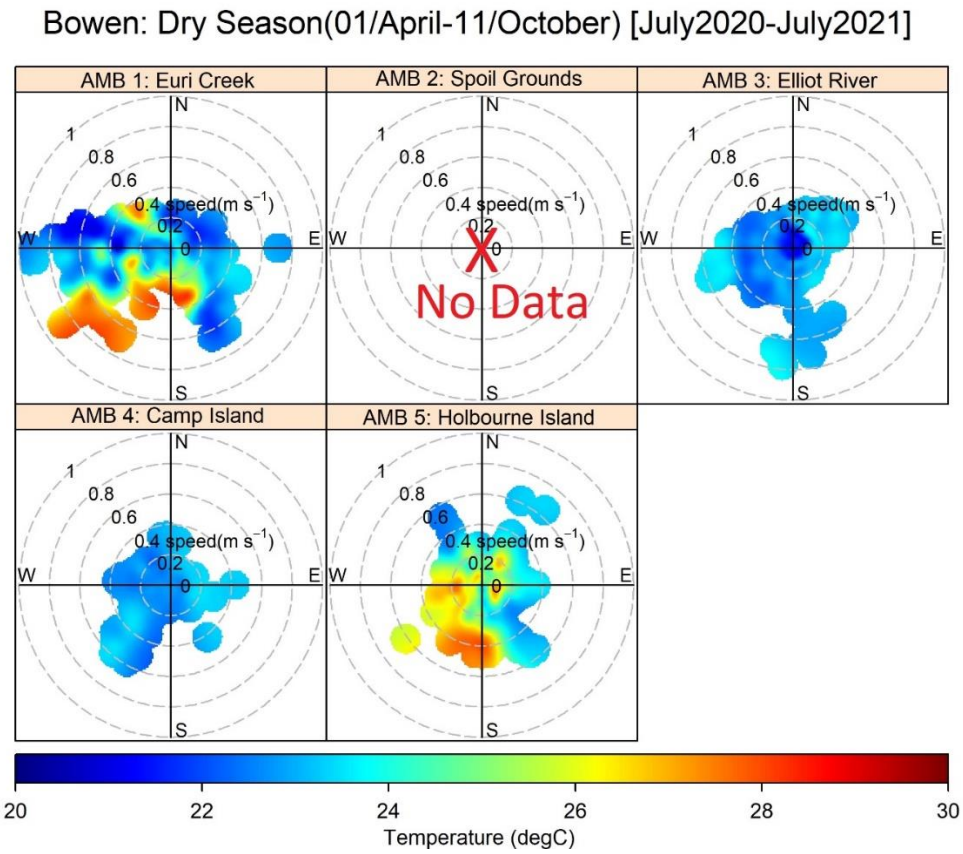


Figure 3.3.7 For each of the five Bowen sites during the dry season months (April-October) across the monitoring period July 2020 to July 2021, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed (m/s) and current direction (heading). The position of the data, within each plot, indicates current direction and the distance from the origin indicates current speed (m/s). Data points are coloured according to calculated average water temperature (°C).

Current Meter *data: during the Wet Season Periods (11th November – 31st March)*

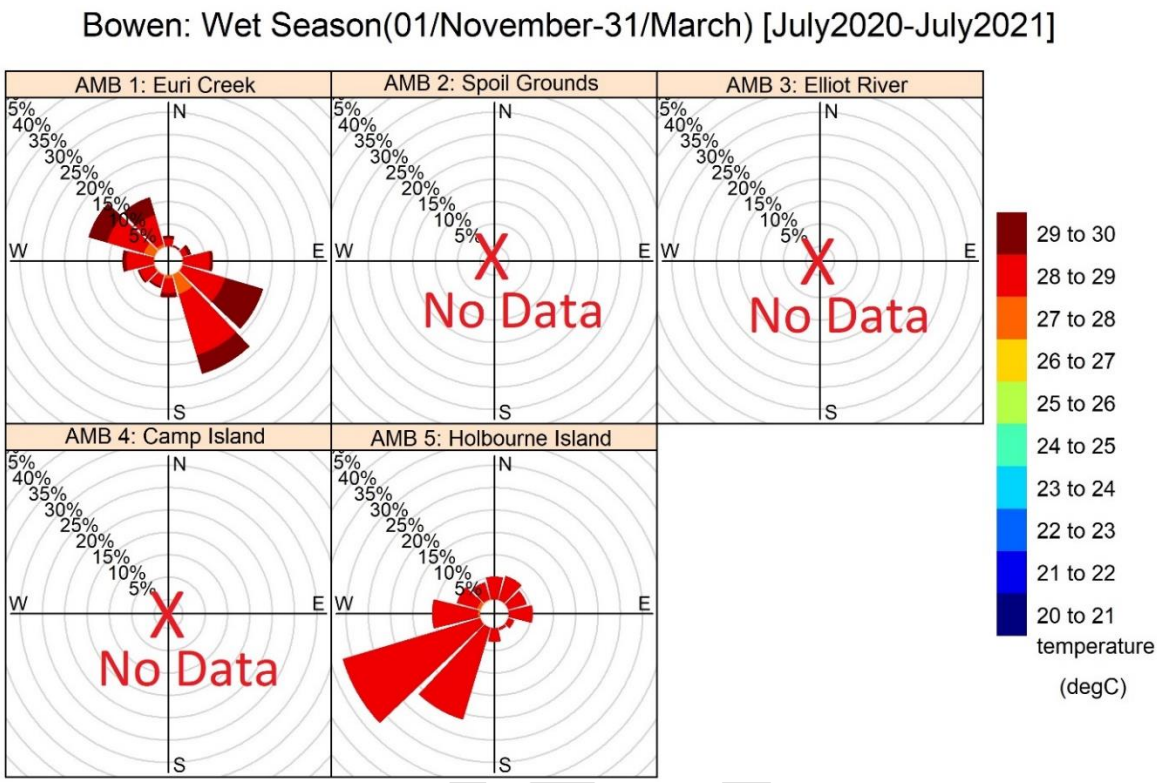


Figure 3.3.8 Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading), for each of the five Bowen sites during the wet season months (November-March) across the monitoring period July 2020 to July 2021.

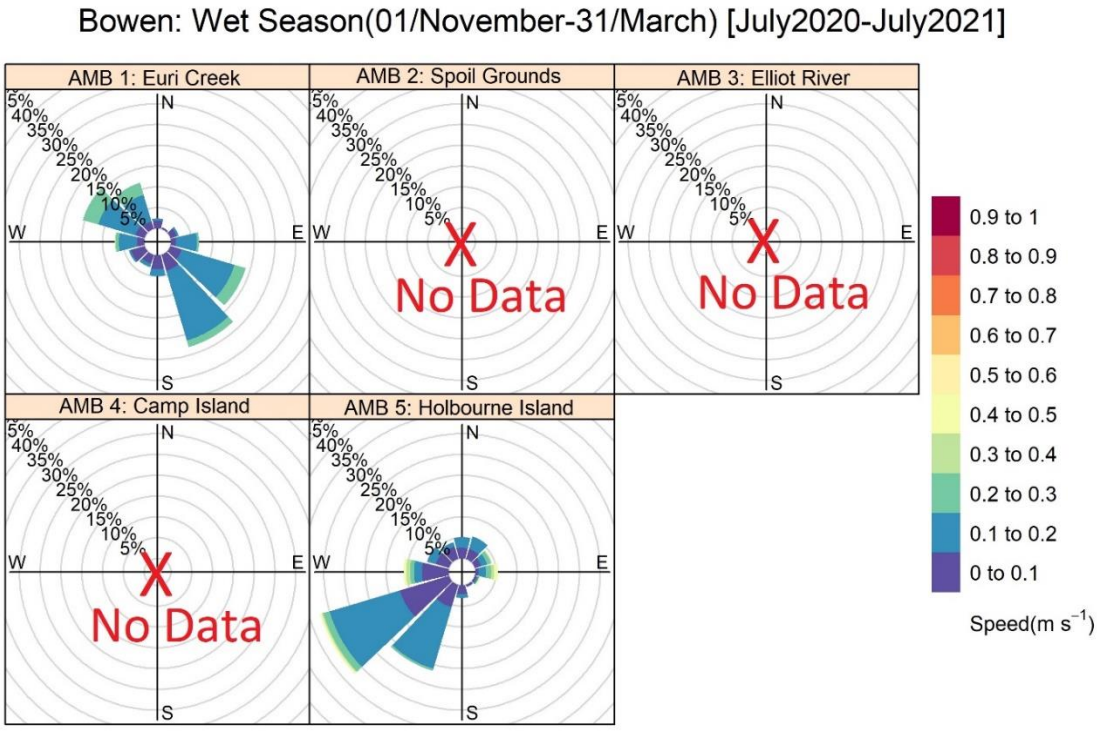


Figure 3.3.9 Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the five Bowen sites during the wet season months (November-March) across the monitoring period July 2020 to July 2021.

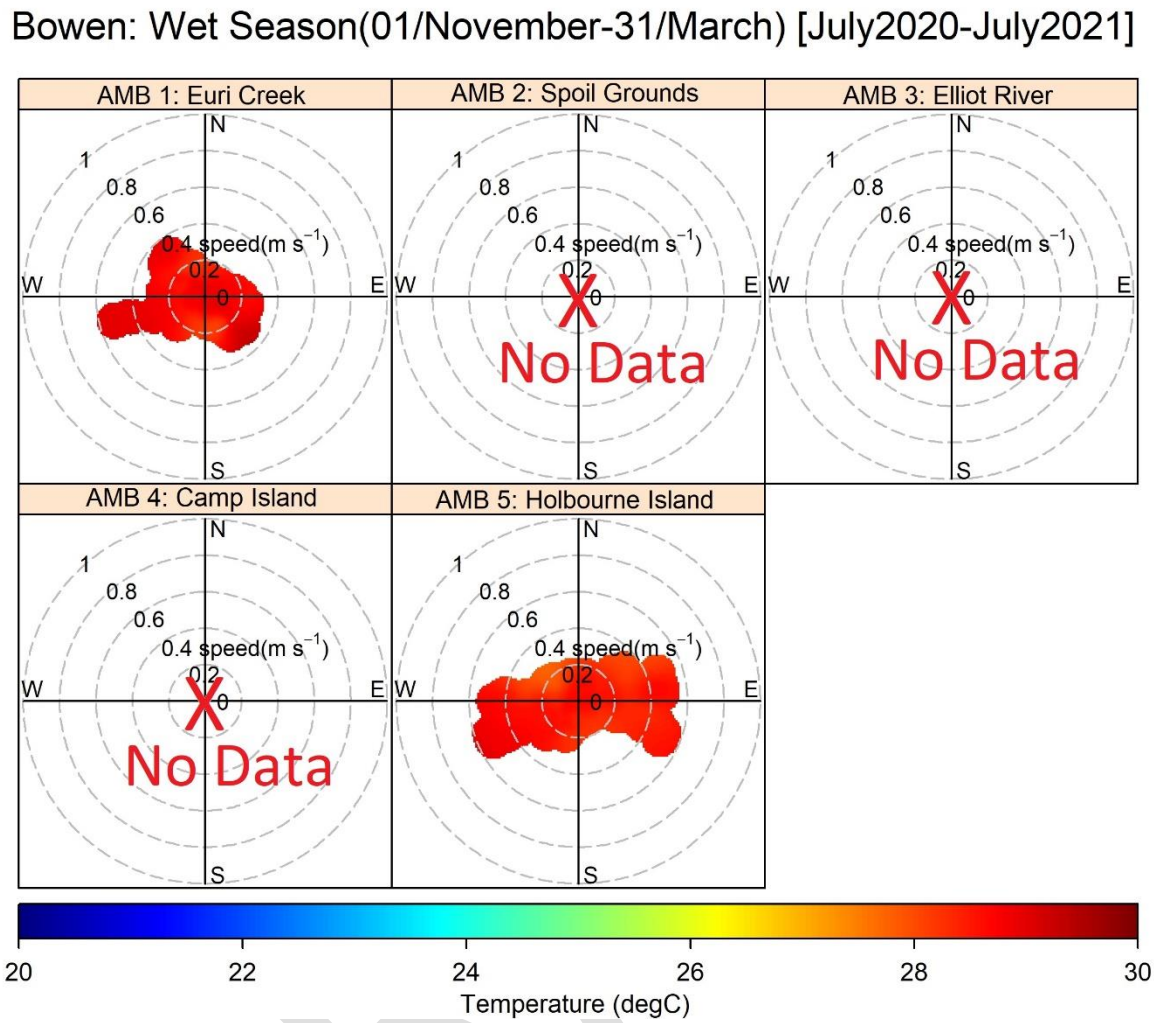


Figure 3.3.10 For each of the five Bowen sites during the wet season months (November-March) across the monitoring period July 2020 to July 2021, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed (m/s) and current direction (heading). The position of the data, within each plot, indicates current direction and the distance from the origin indicates current speed (m/s). Data points are coloured according to calculated average water temperature (°C).

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Climatic conditions

1. The total wet season rainfall of Bowen region during 2020-2021 was average compared to wet season totals since records commenced.
2. Inter-annual variability of wet season rainfall and catchment discharge to the coastal ocean highlights the necessity for a long-term commitment to ambient marine monitoring programs, as continued monitoring will allow changes in ambient environmental conditions due to differences in annual rainfall to be better understood.

4.1.2 Ambient water quality

1. Water quality conditions were measured at all sites on a ~8 weekly basis. Parameters collected were water temperature, electrical conductivity, pH, and dissolved oxygen at three depths (surface, mid-water and bottom), along with Secchi disk depth.
2. Seasonal differences in water quality were minor, except for temperature which was highest during the summer months (this continues to be a common trend in the region).
3. There was little difference in water temperature, conductivity, pH and dissolved oxygen between the three depths examined, indicating that the water column was generally well mixed during each survey.
4. Particulate nitrogen concentrations exceeded the guidelines throughout most of the monitoring period, mostly regularly at AMB4. TSS was generally below guidelines, along with particulate phosphorus.
5. Chlorophyll-*a* concentrations exceeded the GBRMPA guideline trigger value
6. Nickel, and Arsenic were detected in water samples, although the concentrations were below relevant guideline values. Copper was not detected during the post wet season survey, but was at all sites during the dry season survey. This result was unexpected and could reflect a contamination problem at the laboratory, or during field sampling. The team have discussed this to ensure that such contamination problems if caused during field sampling doesn't happen in the future.
7. Pesticides/herbicides were examined this year using passive sampling devices. This approach provides a more time integrated measure of the risks of contamination in the region. Unfortunately, while there were two separate deployments scheduled, which were completed, only a single device was retrieved – the second deployment was missing from the float on return either being caught from a recreational fisher person, or was cut free on the ground line. Concentrations were reported as less than values, with the exception of DEET, Diuron, and Hexazinone which were above limit of detection. When comparing to the draft GBRMPA guidelines, there were no exceedances above the 99% guidelines for species protection.

4.1.3 Sediment deposition and turbidity

1. RMS water height values were mostly driven by weather events and this is clearly evident in the data as peaks in RMS water heights were generally observed at the same times at all sites over the survey year. Variation in the magnitude of RMS water height values during peak events and during non-event periods differs among sites due to differences in water depth and site exposure to wave energy.
2. The NTUe/SSC time series data at each site followed a typical pattern of low background values with recurring peak events. These peak events occurred at generally the same times at each site and coincide with peaks in RMS water height. This is a typical pattern which is similar to data collected in coastal locations in north Queensland.
3. Time series deposition data shows that deposition tends to peak following high RMS water height events but with a lag so that peak deposition occurs at a time when RMS water height has decreased to near background levels. An explanation for this lag is that as waves resuspend sediment, little deposition is expected because the energy in the system will keep the sediment in suspension. It is only when waves decrease and there is no longer enough energy in the system to keep the same quantity of sediment in suspension that deposition begins to occur.
4. Current meter data indicates the prominent current direction and velocity at each site and shows that coastal current, tidal current or a combination of both influence current direction and magnitude.

Unfortunately this reporting period had many problems with the units including flooding, or the connecting ends breaking free, which resulted in low return of data. The team are investigating other alternative ways to measure current, and will continue to explore options.

4.1.4 Photosynthetically active radiation (PAR)

1. Benthic PAR was highly variable within sites throughout the year, with peaks and troughs occurring both regularly and intermittently over time. Semi-regular oscillations between low and high PAR levels were overridden by larger episodic events caused by storm or rainfall events experienced in the region. The data series here continues to increase, which is slowly providing a greater insight into trends, which should be explored further.
2. There was low among site correlation in PAR. Less than 32% of the variation in PAR at a given site could be explained by the PAR at any other site, highlighting the influence of location conditions (depth, turbidity, etc.) on benthic irradiance. Removing sites from the network in the future, will require this careful consideration.

4.2 Recommendations

4.2.1 Consolidation of the water quality loggers

1. This monitoring program has been underway for several years, and should remain in place to continue to characterise and build a detailed understanding of the water quality dynamics in and around this port facility. This understanding will continue to assist NQBP to manage current activities, but will also assist with future strategic planning and management.
2. During this monitoring period, two sites were decommissioned, as part of the continued rationalisation and optimisation of the program, leaving three key sites remaining for future ambient monitoring.

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A1 APPENDIX

A1.1 Calibration procedures

Turbidity/Deposition Calibration

The turbidity and deposition sensors on each instrument are calibrated to a set of plastic optical standards that give consistent NTU return values. This enables the calculation of raw data values into NTU values. The NTU values can then be converted into SSC and ASSD values through the SSC calibration process. Deposition sensors are calibrated to give measurements in units of mg/cm2 using the methodology outlined in Ridd et al (2000) and Thomas et al (2003). Instruments are calibrated every six months or after every deployment. Sediment samples are taken at each deployment site and used to determine sediment calibration coefficients used to account for variations in grain size and shape that can alter the implied SSC value.

SSC Calibration

An instrument is placed in a large container (50 l) with black sides and the output is read on a computer attached to the logger. Saltwater is used to fill the container. Sediment from the study site is added to a small container of salt water and agitated. The water-sediment slurry is then added to the large container which is stirred with a small submerged pump. A water sample is taken and analysed for total suspended sediment (TSS) using standard laboratory techniques in the ACTFR laboratory at JCU which is accredited for these measurements. Approximately 6 different concentrations of sediment are used for each site. TSS is then plotted against the NTU reading from the logger for each of the different sediment concentrations. A linear correlation between NTU and SSC is then calculated. The correlations typically have an r2 value equal to or greater than 0.9.

Light Calibration

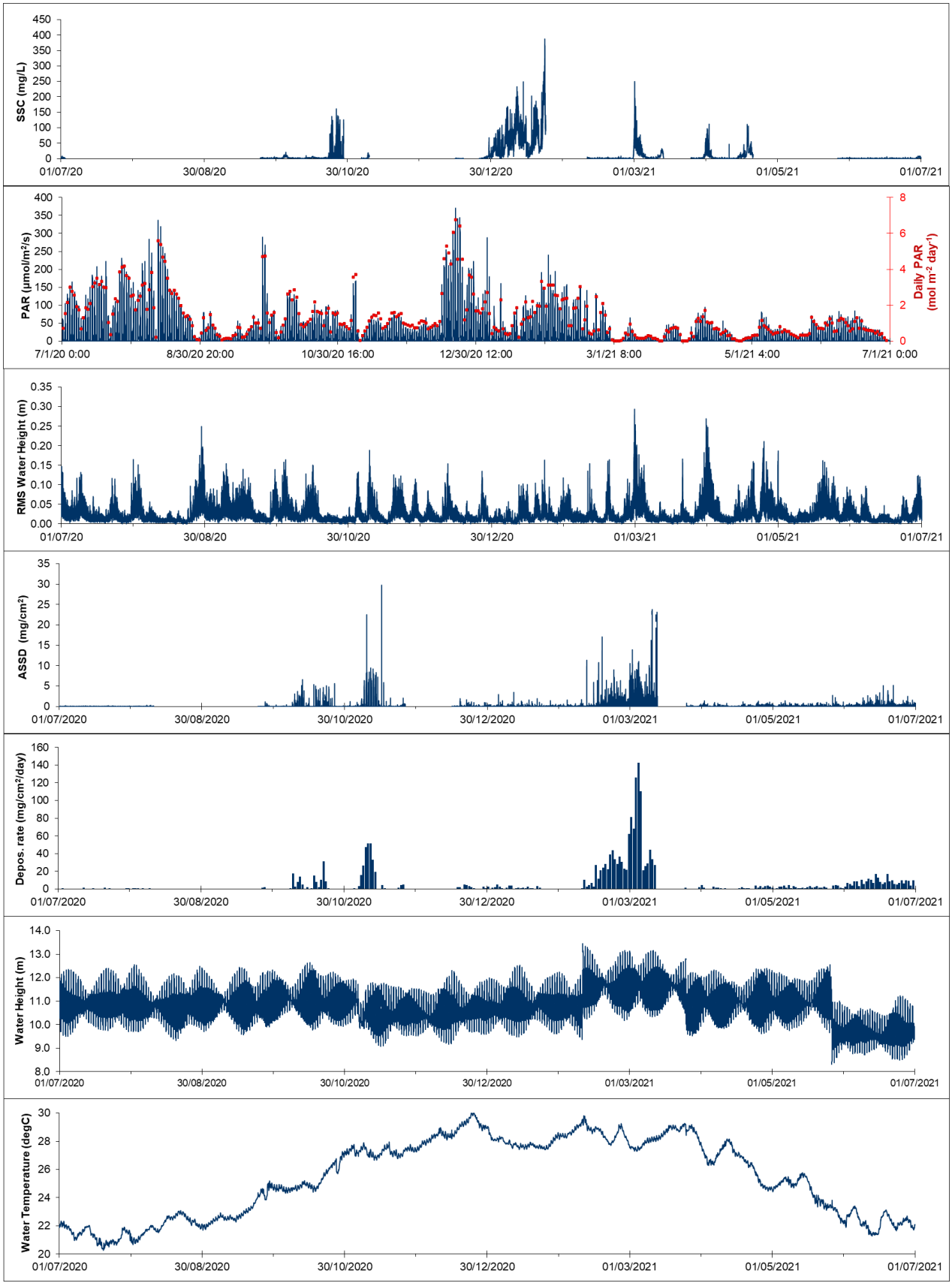
The light sensors on each logger are calibrated every six months or after every deployment. The light sensor is calibrated against a LICOR U250A submersible sensor that was calibrated in the factory within the last 12 months. The results of the logger light sensor and LICOR U250A are compared and a calibration coefficient is used to ensure accurate reporting of PAR data. An infield comparison between the logger light sensor and LICOR U250A is made on deployment of the instruments to ensure accurate reporting of the data. In field calibration of the nephelometer light sensor against the LICOR U250A at varying depth has been carried out to account for changes in sensitivity changes at depth.

Pressure Sensor Calibration

All pressure sensors are calibrated against a pressure gauge and the pressure is converted into depth in metres.

A1.2 Time series data

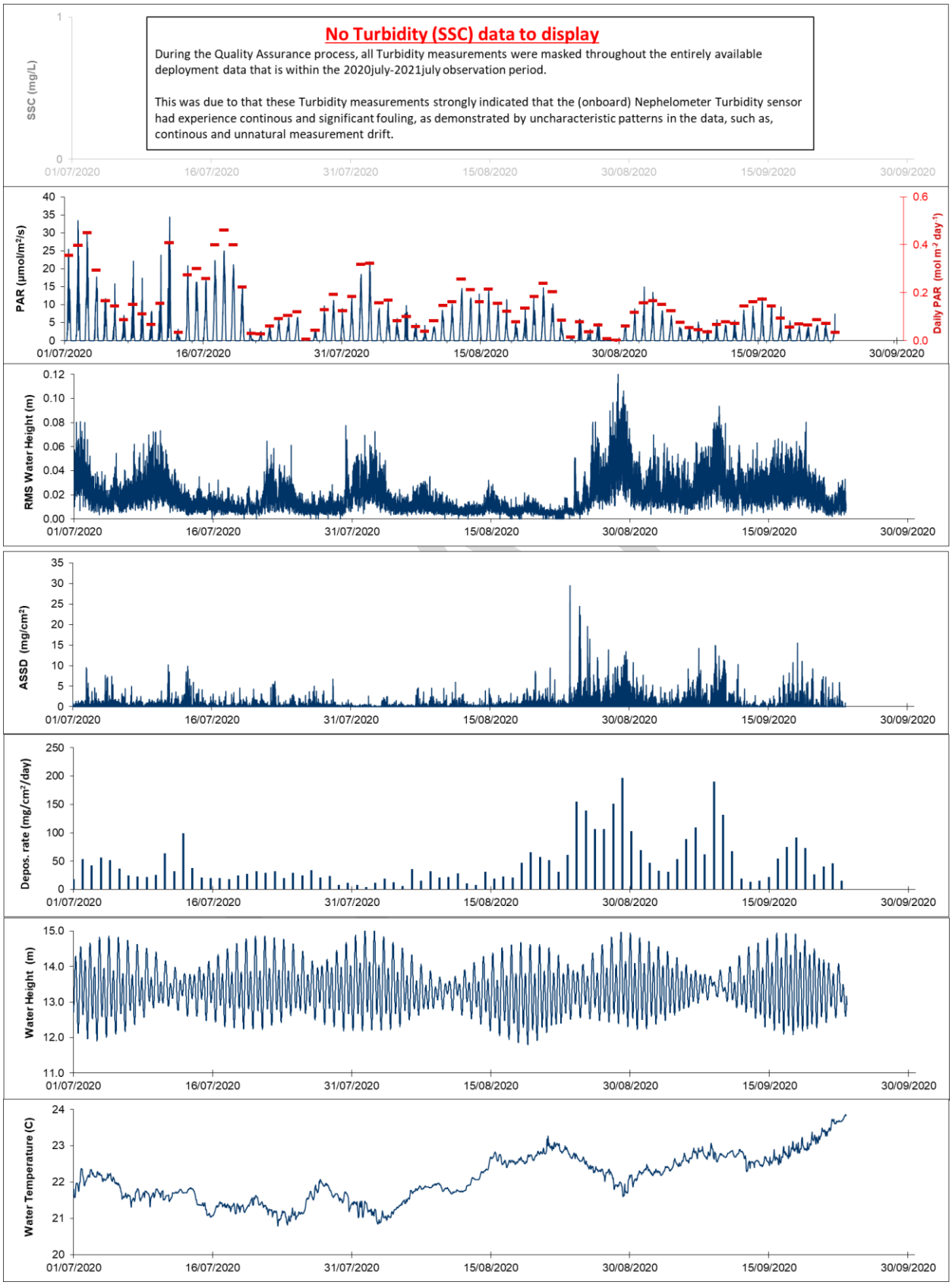
AMB 1: Euri Creek



AMB 2: Spoil Grounds

Note: AMB 2 has limited data in comparison to other sites; both were decommissioned in September 2020.

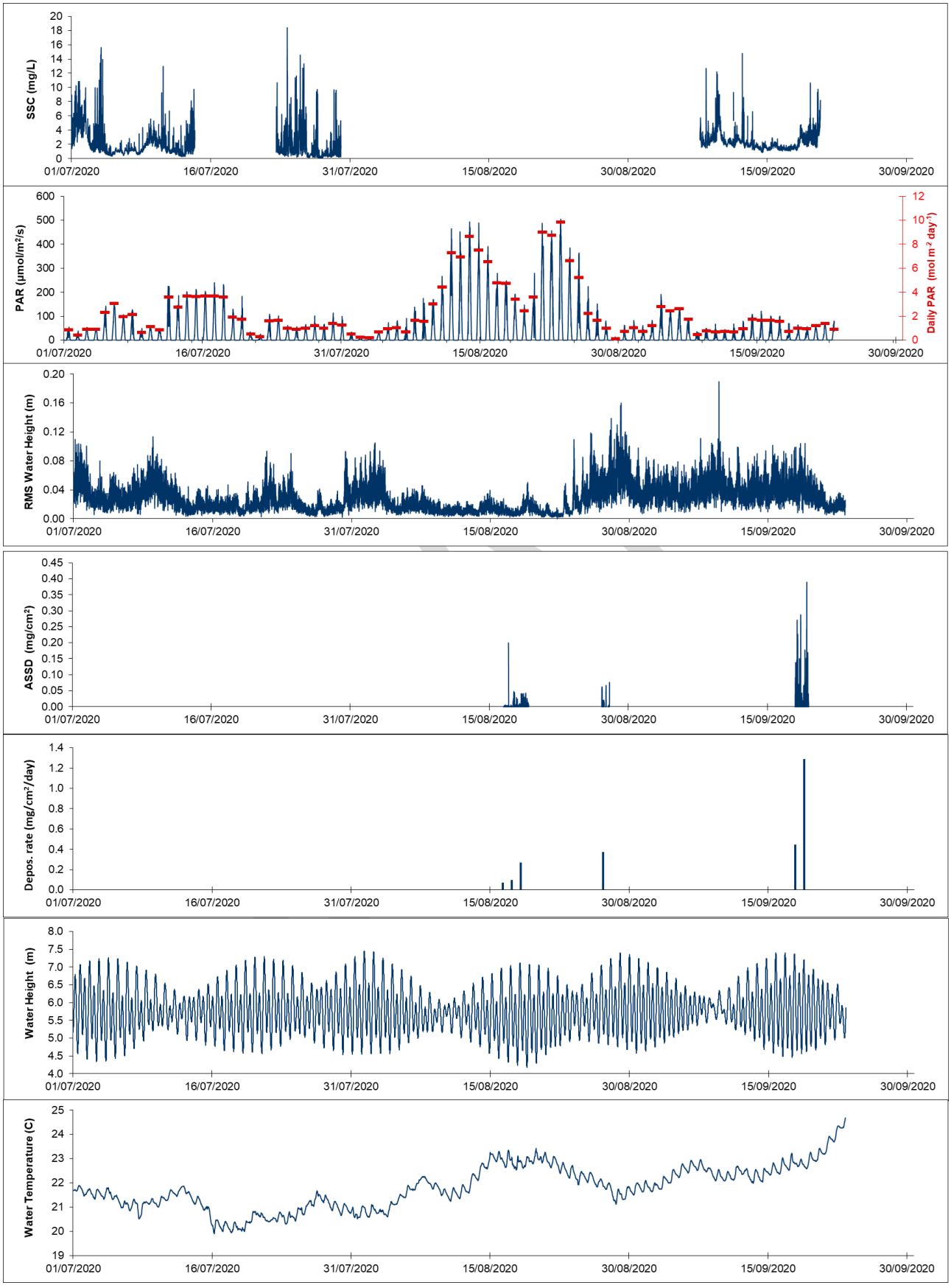
>axis limits have been reduced to 30/09/2020



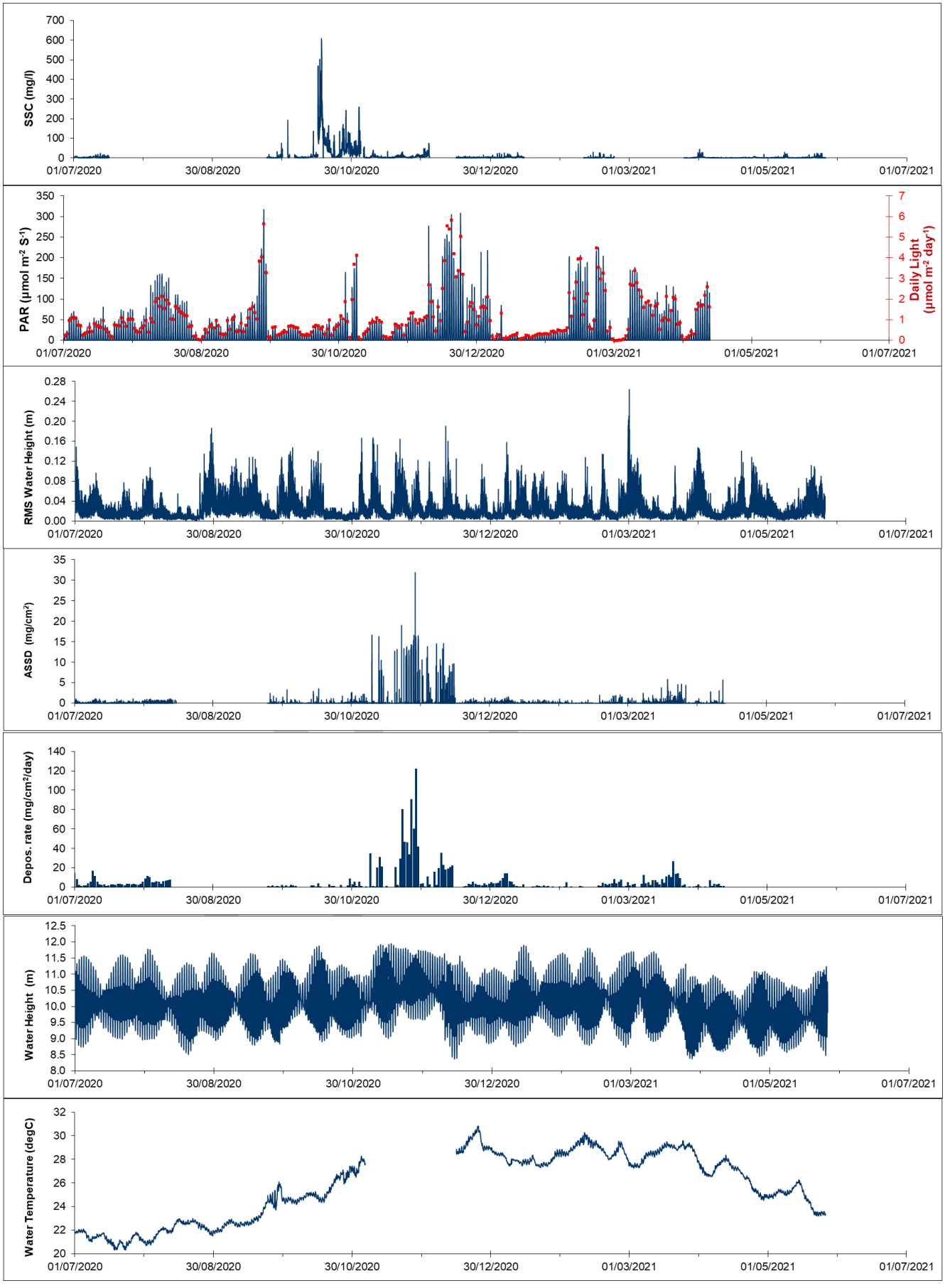
AMB 3: Elliot River

Note: AMB 3 has limited data in comparison to other sites; both were decommissioned in September 2020.

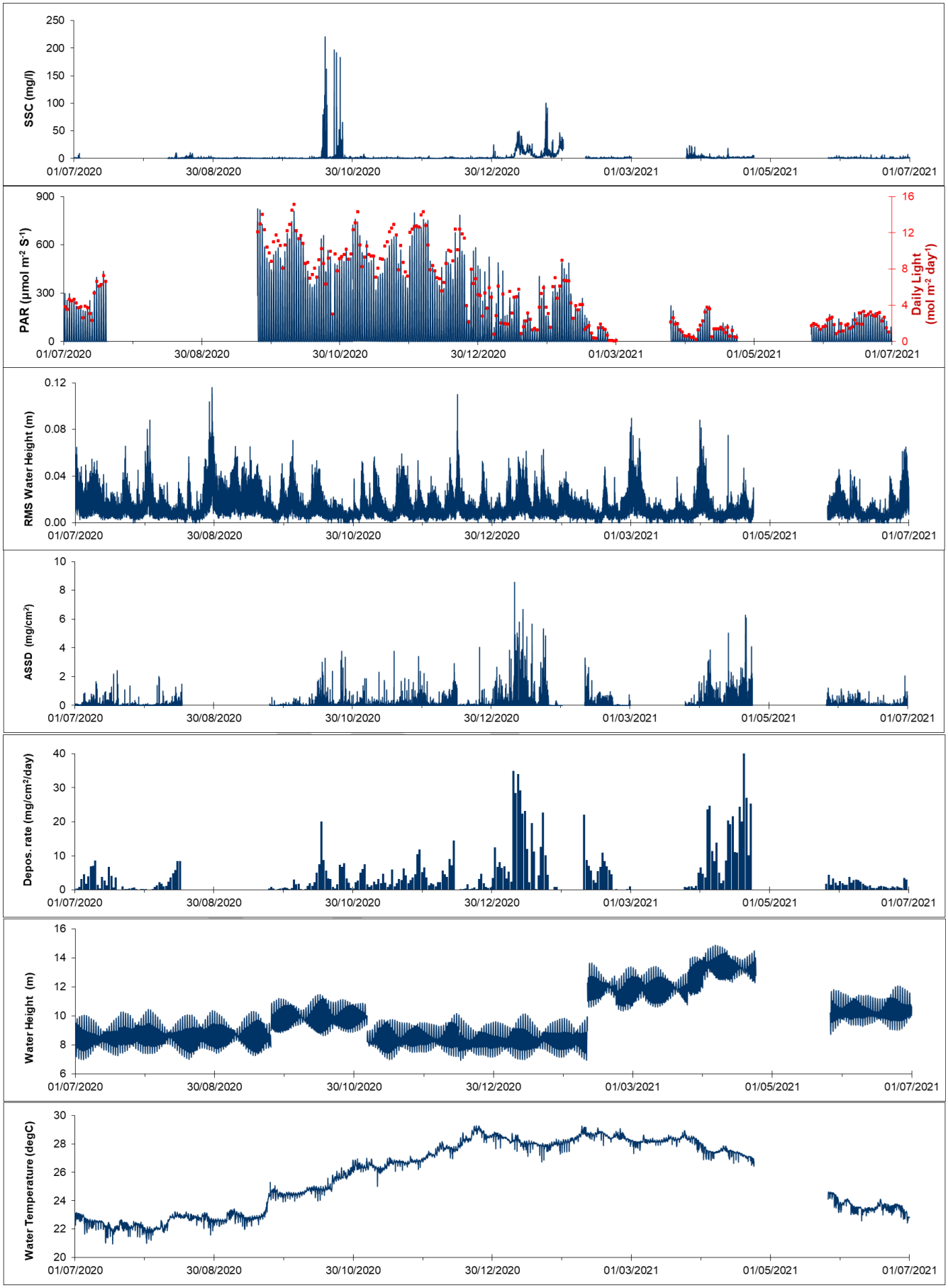
>axis limits have been reduced to 30/09/2020



AMB 4: Camp Island



AMB 5: Holbourne Island



A1.3 SUMMARY OF MONTHLY STATISTICS

AMB 1 – Euri Creek

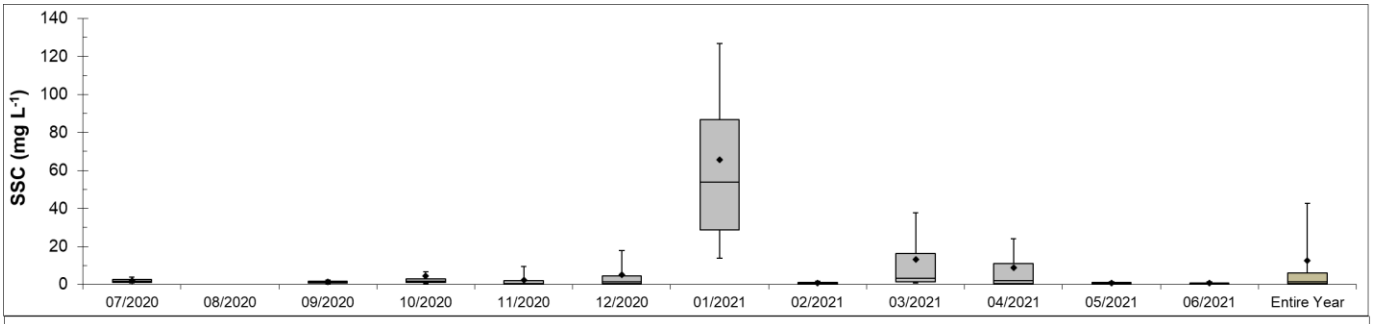
Turbidity (SSC)	SSC 07/2020	SSC 08/2020	SSC 09/2020	SSC 10/2020	SSC 11/2020	SSC 12/2020	SSC 01/2021	SSC 02/2021	SSC 03/2021	SSC 04/2021	SSC 05/2021	SSC 06/2021	SSC Entire Year
Mean	2.09		1.39	4.49	2.31	5.22	65.61	0.87	13.09	8.92	0.85	0.69	12.61
median	1.81		1.23	1.72	0.54	1.26	53.80	0.61	3.24	1.93	0.78	0.41	1.32
min	0.43		0.00	9.78	0.00	27.35	0.00	0.00	0.00	0.00	0.00	0.00	7.00
lower	1.23		0.85	1.03	0.17	0.38	28.58	0.36	1.27	0.60	0.54	0.20	0.54
upper	2.53		1.73	2.82	2.01	4.48	86.70	1.14	16.15	11.09	1.09	0.77	6.09
max	7.84		6.58	160.62	18.98	67.30	386.99	15.89	249.77	110.99	4.55	8.40	386.99
90th percentile	3.99		2.39	6.59	9.34	17.91	126.63	1.80	37.60	23.99	1.41	1.33	42.54
10th percentile	0.85		0.62	0.60	0.00	0.14	13.82	0.19	0.77	0.25	0.42	0.06	0.23
n(recordings obtained)	294	0	1048	4005	490	1427	3127	2821	2797	2844	775	4317	23945
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	0.066	0.000	0.243	0.897	0.113	0.320	0.700	0.700	0.627	0.658	0.174	0.999	0.456
St. Dev	1.32		0.76	12.68	3.73	9.56	53.34	0.96	23.10	14.91	0.43	0.98	30.52
St. Error	0.08		0.02	0.20	0.17	0.25	0.95	0.02	0.44	0.28	0.02	0.01	0.20

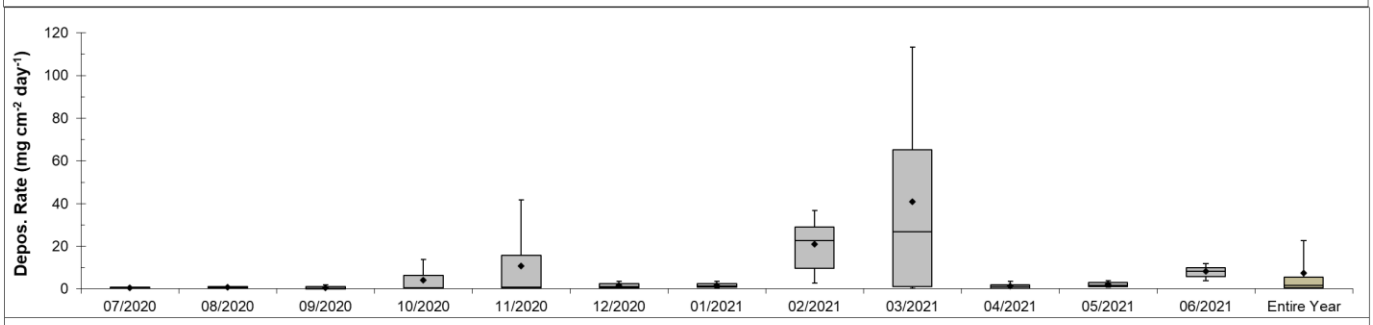
Deposition Rate (mg/[cm^2 day])	Dep. Rate 07/2020	Dep. Rate 08/2020	Dep. Rate 09/2020	Dep. Rate 10/2020	Dep. Rate 11/2020	Dep. Rate 12/2020	Dep. Rate 01/2021	Dep. Rate 02/2021	Dep. Rate 03/2021	Dep. Rate 04/2021	Dep. Rate 05/2021	Dep. Rate 06/2021	Dep. Rate Entire Year
Mean	0.56	0.75	0.66	4.23	10.80	1.70	1.74	20.98	40.81	1.41	2.09	8.20	7.52
median	0.51	0.70	0.19	0.57	0.95	1.13	1.30	22.75	26.87	1.02	1.69	8.28	1.53
min	0.17	0.57	0.01	0.01	0.03	0.16	0.36	1.01	0.11	0.08	0.19	2.96	0.01
lower	0.35	0.62	0.05	0.13	0.42	0.52	0.86	9.70	1.12	0.26	1.11	5.77	0.52
upper	0.65	0.90	1.12	6.43	15.72	2.47	2.57	28.93	65.12	1.82	3.03	9.85	5.42
max	1.59	0.99	2.08	31.02	51.40	4.84	4.97	43.51	142.66	4.37	4.69	17.10	142.66
90th percentile	0.87	0.95	1.94	13.79	41.78	3.64	3.60	36.80	113.30	3.50	3.95	11.87	22.53
10th percentile	0.28	0.59	0.01	0.05	0.14	0.36	0.57	2.80	0.17	0.17	0.76	3.84	0.19
n(recordings obtained)	31	9	7	31	25	17	22	20	19	30	31	30	272
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	0.290	0.233	1.000	0.833	0.548	0.710	0.714	0.613	1.000	1.000	1.000	0.745
St. Dev	0.31	0.16	0.90	7.05	17.23	1.47	1.25	13.04	45.64	1.31	1.25	3.47	17.26
St. Error	0.06	0.05	0.34	1.27	3.45	0.36	0.27	2.92	10.47	0.24	0.22	0.63	1.05

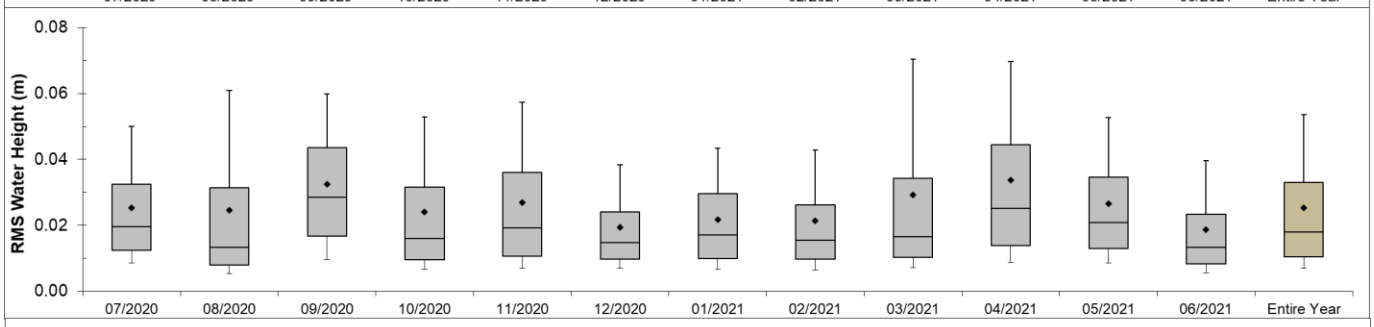
RMS Water Height (M)	RMS 07/2020	RMS 08/2020	RMS 09/2020	RMS 10/2020	RMS 11/2020	RMS 12/2020	RMS 01/2021	RMS 02/2021	RMS 03/2021	RMS 04/2021	RMS 05/2021	RMS 06/2021	RMS Entire Year
Mean	0.0253	0.0246	0.0324	0.0240	0.0269	0.0194	0.0217	0.0213	0.0293	0.0337	0.0266	0.0187	0.0253
median	0.0196	0.0134	0.0285	0.0161	0.0193	0.0147	0.0170	0.0155	0.0166	0.0252	0.0209	0.0133	0.0179
min	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
lower	0.0124	0.0079	0.0168	0.0095	0.0107	0.0097	0.0100	0.0097	0.0102	0.0139	0.0129	0.0083	0.0104
upper	0.0324	0.0314	0.0435	0.0315	0.0361	0.0240	0.0296	0.0263	0.0342	0.0445	0.0346	0.0234	0.0330
max	0.1647	0.2495	0.1509	0.1636	0.1886	0.1540	0.1634	0.2081	0.2938	0.2472	0.1864	0.1239	0.2938
90th percentile	0.0501	0.0609	0.0599	0.0529	0.0573	0.0383	0.0434	0.0429	0.0704	0.0697	0.0527	0.0396	0.0536
10th percentile	0.0086	0.0054	0.0096	0.0067	0.0069	0.0069	0.0066	0.0065	0.0072	0.0087	0.0086	0.0056	0.0069
n(recordings obtained)	4464	4464	4317	4464	4315	4461	4464	4031	4462	4320	4462	4320	52544
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.999	1.000	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
St. Dev	0.0186	0.0268	0.0206	0.0211	0.0220	0.0151	0.0160	0.0186	0.0330	0.0278	0.0195	0.0159	0.0224
St. Error	0.0003	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0003	0.0005	0.0004	0.0003	0.0002	0.0001

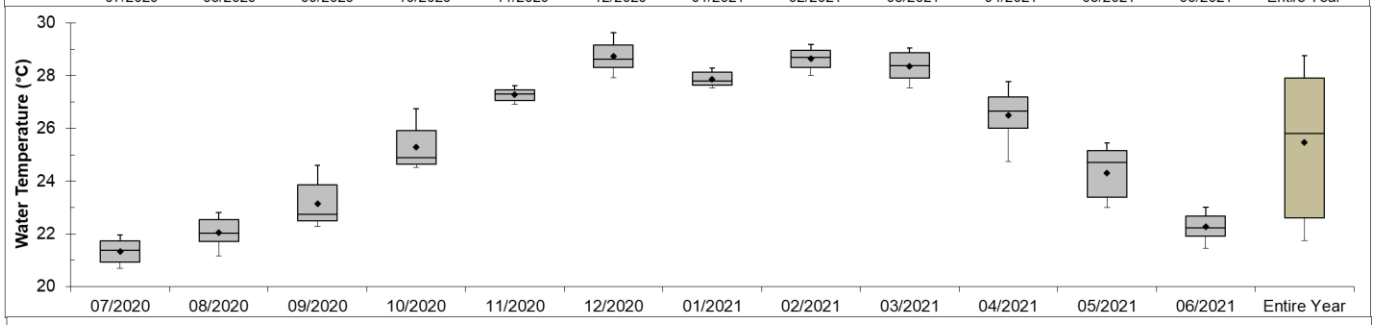
Water Temperature (degC)	Temp 07/2020	Temp 08/2020	Temp 09/2020	Temp 10/2020	Temp 11/2020	Temp 12/2020	Temp 01/2021	Temp 02/2021	Temp 03/2021	Temp 04/2021	Temp 05/2021	Temp 06/2021	Temp Entire Year
Mean	21.34	22.05	23.13	25.30	27.28	28.73	27.87	28.65	28.36	26.51	24.30	22.27	25.46
median	21.38	22.03	22.74	24.89	27.30	28.63	27.80	28.70	28.37	26.66	24.70	22.23	25.80
min	20.26	20.67	21.74	24.32	26.66	27.35	27.41	27.71	27.29	24.47	22.15	21.28	20.26
lower	20.92	21.72	22.49	24.65	27.07	28.31	27.63	28.32	27.90	26.01	23.40	21.91	22.61
upper	21.74	22.54	23.87	25.91	27.47	29.16	28.14	28.95	28.86	27.19	25.15	22.67	27.91
max	22.34	23.08	25.19	27.48	27.96	30.16	28.62	29.82	29.26	28.17	25.77	23.41	30.16
90th percentile	21.96	22.81	24.60	26.75	27.61	29.64	28.29	29.18	29.05	27.77	25.44	23.02	28.77
10th percentile	20.70	21.16	22.28	24.51	26.92	27.92	27.53	28.01	27.53	24.75	23.01	21.46	21.74
n(recordings obtained)	4464	4464	4311	4464	4315	4461	4464	4031	4457	4320	4457	4320	52528
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.998	1.000	0.999	0.999	1.000	1.000	0.998	1.000	0.998	1.000	0.999
St. Dev	0.49	0.59	0.88	0.85	0.26	0.62	0.29	0.45	0.56	1.01	0.99	0.52	2.75
St. Error	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01

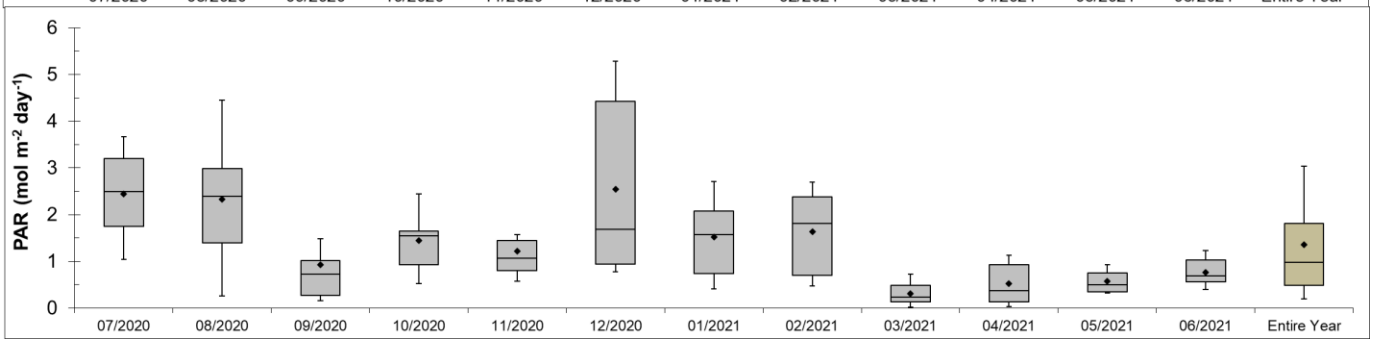
Daily PAR (mol m-2 day-1)	Light 07/2020	Light 08/2020	Light 09/2020	Light 10/2020	Light 11/2020	Light 12/2020	Light 01/2021	Light 02/2021	Light 03/2021	Light 04/2021	Light 05/2021	Light 06/2021	Light Entire Year
Mean	2.44	2.33	0.92	1.45	1.21	2.55	1.52	1.64	0.31	0.52	0.58	0.76	1.36
median	2.49	2.40	0.73	1.54	1.06	1.68	1.57	1.82	0.23	0.37	0.50	0.69	0.98
min	0.38	0.06	0.08	0.20	0.04	0.68	0.22	0.08	0.00	0.00	0.20	0.04	0.00
lower	1.75	1.39	0.28	0.93	0.80	0.95	0.74	0.70	0.13	0.14	0.34	0.57	0.49
upper	3.20	2.99	1.02	1.65	1.45	4.42	2.08	2.38	0.48	0.93	0.75	1.03	1.81
max	4.17	5.60	4.75	2.87	3.71	6.75	3.33	3.14	0.96	1.70	1.32	1.30	6.75
90th percentile	3.66	4.45	1.49	2.45	1.58	5.29	2.71	2.70	0.72	1.13	0.93	1.23	3.04
10th percentile	1.05	0.26	0.16	0.53	0.58	0.78	0.41	0.47	0.02	0.03	0.33	0.40	0.19
n(recordings obtained)	31	31	30	31	30	31	31	28	31	30	31	29	364
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.967	0.997
St. Dev	1.03	1.47	1.12	0.68	0.77	1.98	0.87	0.93	0.27	0.48	0.28	0.34	1.23
St. Error	0.19	0.26	0.20	0.12	0.14	0.36	0.16	0.18	0.05	0.09	0.05	0.06	0.06


SSC (mg L-1)
140
120
100
80
60
40
20
0
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year


Depos. Rate (mg cm-2 day-1)
120
100
80
60
40
20
0
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year


RMS Water Height (m)
0.08
0.06
0.04
0.02
0.00
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year


Water Temperature (°C)
30
28
26
24
22
20
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year


PAR (mol m-2 day-1)
6
5
4
3
2
1
0
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year

AMB 2 – Spoil Grounds

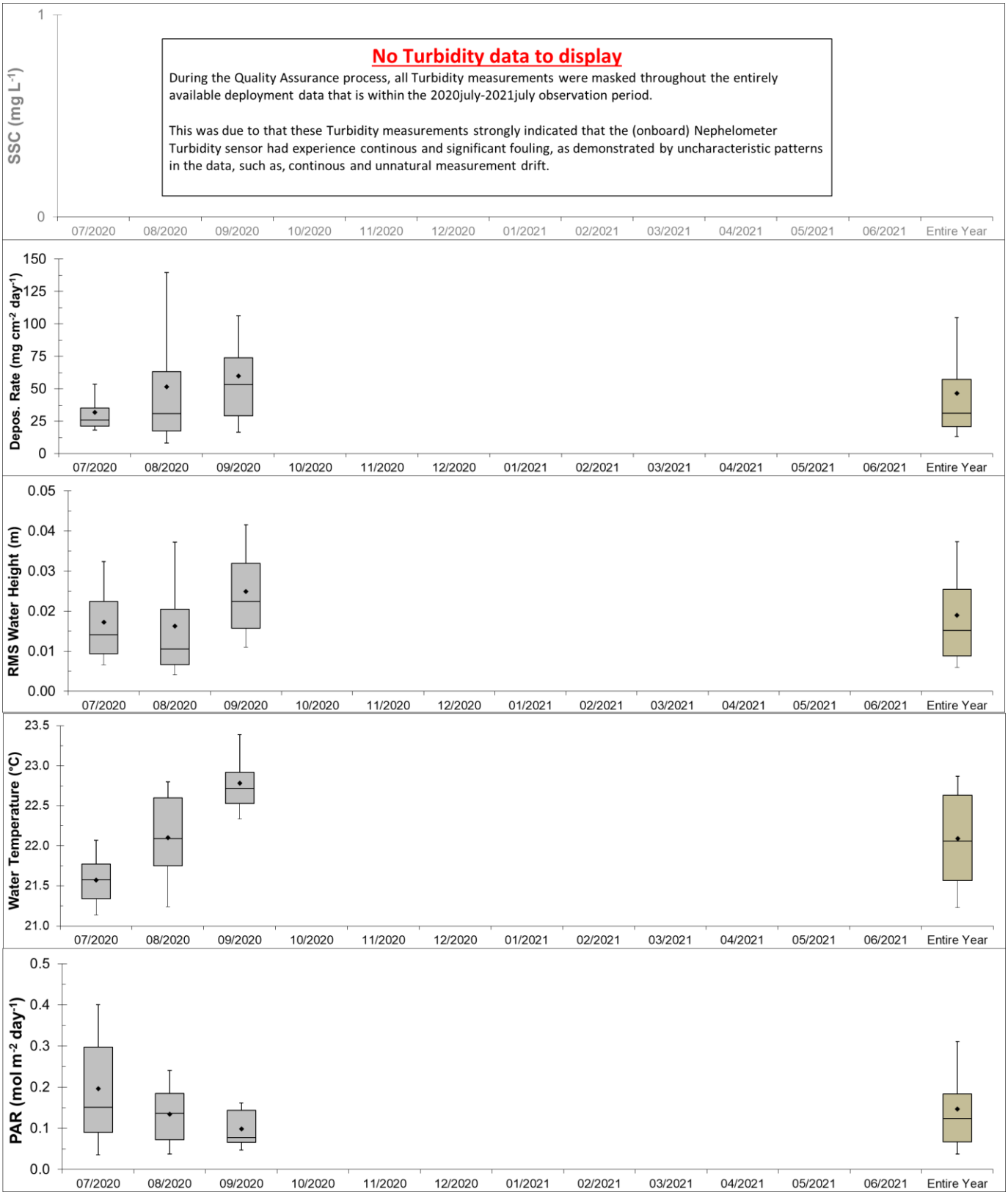
Turbidity (SSC)	SSC 07/2020	SSC 08/2020	SSC 09/2020	SSC 10/2020	SSC 11/2020	SSC 12/2020	SSC 01/2021	SSC 02/2021	SSC 03/2021	SSC 04/2021	SSC 05/2021	SSC 06/2021	SSC Entire Year
Mean													
median													
min													
lower													
upper													
max													
90th percentile													
10th percentile													
n(recordings obtained)	0	0	0	0	0	0	0	0	0	0	0	0	0
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
St. Dev													
St. Error													

Deposition Rate (mg/[cm^2 day])	Dep. Rate 07/2020	Dep. Rate 08/2020	Dep. Rate 09/2020	Dep. Rate 10/2020	Dep. Rate 11/2020	Dep. Rate 12/2020	Dep. Rate 01/2021	Dep. Rate 02/2021	Dep. Rate 03/2021	Dep. Rate 04/2021	Dep. Rate 05/2021	Dep. Rate 06/2021	Dep. Rate Entire Year
Mean	31.76	51.70	59.86										46.63
median	25.74	30.96	53.22										31.14
min	7.59	4.11	13.69										4.11
lower	21.22	17.35	29.03										20.95
upper	35.08	63.16	73.92										57.18
max	99.01	196.69	189.90										196.69
90th percentile	53.49	139.51	106.10										104.93
10th percentile	18.23	8.19	16.38										13.33
n(recordings obtained)	31	31	23	0	0	0	0	0	0	0	0	0	85
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	1.000	0.767	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233
St. Dev	17.93	51.68	42.40										40.97
St. Error	3.22	9.28	8.84										4.44

RMS Water Height (M)	RMS 07/2020	RMS 08/2020	RMS 09/2020	RMS 10/2020	RMS 11/2020	RMS 12/2020	RMS 01/2021	RMS 02/2021	RMS 03/2021	RMS 04/2021	RMS 05/2021	RMS 06/2021	RMS Entire Year
Mean	0.0173	0.0163	0.0250										0.0190
median	0.0141	0.0106	0.0224										0.0152
min	0.0000	0.0000	0.0025										0.0000
lower	0.0093	0.0066	0.0157										0.0088
upper	0.0225	0.0205	0.0320										0.0254
max	0.0807	0.1231	0.0937										0.1231
90th percentile	0.0324	0.0373	0.0415										0.0374
10th percentile	0.0066	0.0041	0.0110										0.0059
n(recordings obtained)	4464	4464	3240	0	0	0	0	0	0	0	0	0	12168
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232
St. Dev	0.0112	0.0152	0.0126										0.0137
St. Error	0.0002	0.0002	0.0002										0.0001

Water Temperature (degC)	Temp 07/2020	Temp 08/2020	Temp 09/2020	Temp 10/2020	Temp 11/2020	Temp 12/2020	Temp 01/2021	Temp 02/2021	Temp 03/2021	Temp 04/2021	Temp 05/2021	Temp 06/2021	Temp Entire Year
Mean	21.57	22.10	22.78										22.09
median	21.58	22.09	22.72										22.06
min	20.79	20.85	22.18										20.79
lower	21.34	21.75	22.53										21.57
upper	21.77	22.60	22.92										22.63
max	22.38	23.27	23.86										23.86
90th percentile	22.07	22.80	23.39										22.87
10th percentile	21.14	21.24	22.34										21.23
n(recordings obtained)	4464	4464	3240	0	0	0	0	0	0	0	0	0	12168
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232
St. Dev	0.33	0.57	0.38										0.65
St. Error	0.00	0.01	0.01										0.01

Daily PAR (mol m-2 day-1)	Light 07/2020	Light 08/2020	Light 09/2020	Light 10/2020	Light 11/2020	Light 12/2020	Light 01/2021	Light 02/2021	Light 03/2021	Light 04/2021	Light 05/2021	Light 06/2021	Light Entire Year
Mean	0.20	0.13	0.10										0.15
median	0.15	0.14	0.08										0.12
min	0.01	0.00	0.04										0.00
lower	0.09	0.07	0.07										0.07
upper	0.30	0.18	0.14										0.18
max	0.46	0.32	0.17										0.46
90th percentile	0.40	0.24	0.16										0.31
10th percentile	0.04	0.04	0.05										0.04
n(recordings obtained)	31	31	23	0	0	0	0	0	0	0	0	0	85
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	1.000	0.767	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233
St. Dev	0.14	0.09	0.05										0.11
St. Error	0.03	0.02	0.01										0.01


SSC (mg L-1)
No Turbidity data to display
During the Quality Assurance process, all Turbidity measurements were masked throughout the entirely available deployment data that is within the 2020july-2021july observation period.
This was due to that these Turbidity measurements strongly indicated that the (onboard) Nephelometer Turbidity sensor had experience continous and significant fouling, as demonstrated by uncharacteristic patterns in the data, such as, continous and unnatural measurement drift.
Depos. Rate (mg cm-2 day-1)
RMS Water Height (m)
Water Temperature (°C)
PAR (mol m-2 day-1)
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year

AMB 3 – Elliot River

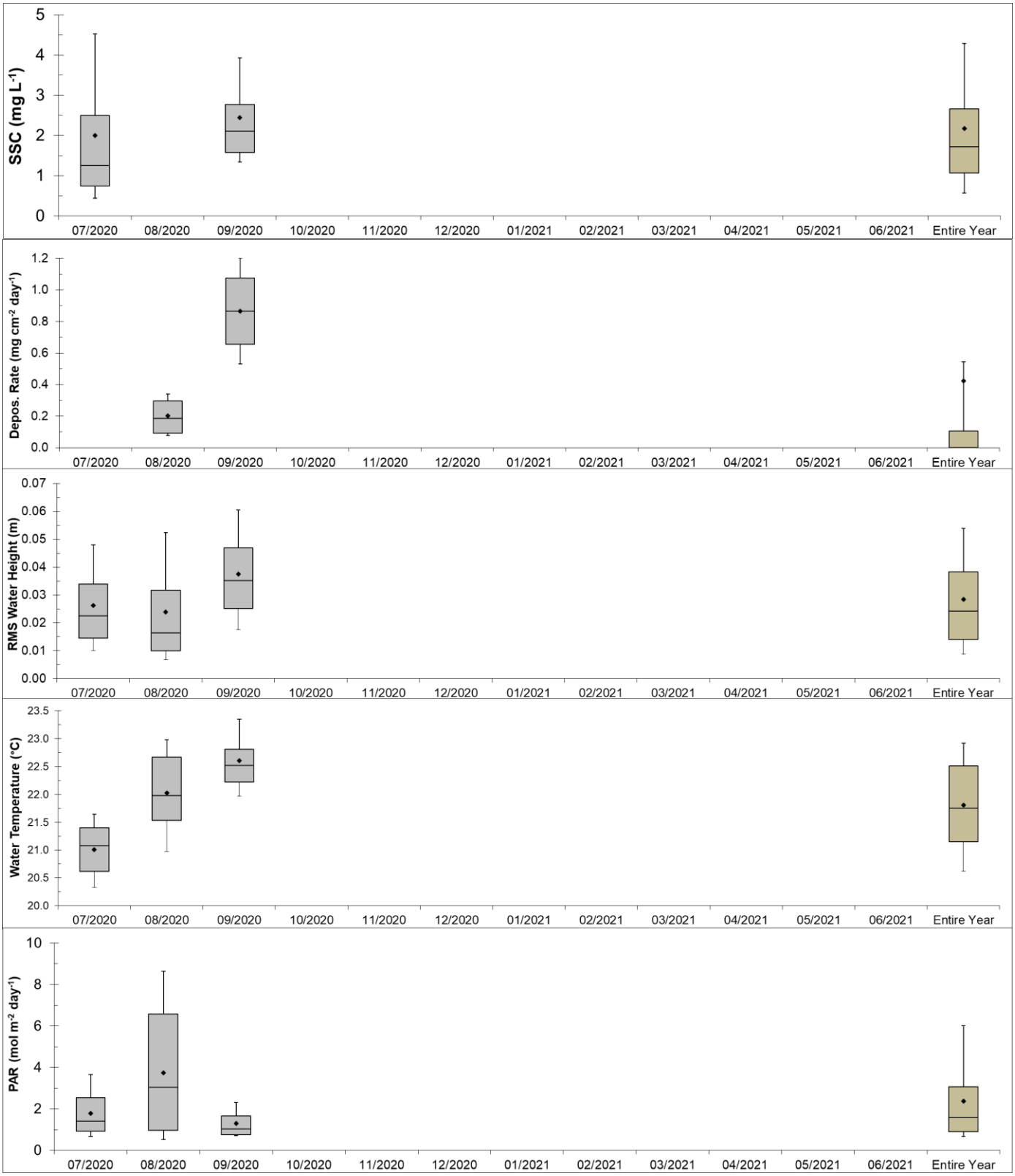
Turbidity (SSC)	SSC 07/2020	SSC 08/2020	SSC 09/2020	SSC 10/2020	SSC 11/2020	SSC 12/2020	SSC 01/2021	SSC 02/2021	SSC 03/2021	SSC 04/2021	SSC 05/2021	SSC 06/2021	SSC Entire Year
Mean	2.00		2.45										2.17
median	1.26		2.11										1.71
min	0.11		0.00										7.00
lower	0.75		1.58										1.07
upper	2.50		2.77										2.66
max	18.37		14.78										18.37
90th percentile	4.53		3.92										4.28
10th percentile	0.44		1.34										0.57
n(recordings obtained)	2872	0	1853	0	0	0	0	0	0	0	0	0	4725
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	0.643	0.000	0.429	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.090
St. Dev	2.00		1.37										1.79
St. Error	0.04		0.03										0.03

Deposition Rate (mg/[cm^2 day])	Dep. Rate 07/2020	Dep. Rate 08/2020	Dep. Rate 09/2020	Dep. Rate 10/2020	Dep. Rate 11/2020	Dep. Rate 12/2020	Dep. Rate 01/2021	Dep. Rate 02/2021	Dep. Rate 03/2021	Dep. Rate 04/2021	Dep. Rate 05/2021	Dep. Rate 06/2021	Dep. Rate Entire Year
Mean		0.20	0.87										0.42
median		0.18	0.87										0.32
min		0.07	0.45										0.07
lower		0.09	0.66										0.14
upper		0.30	1.08										0.43
max		0.37	1.29										1.29
90th percentile		0.34	1.20										0.87
10th percentile		0.08	0.53										0.08
n(recordings obtained)	0	4	2	0	0	0	0	0	0	0	0	0	6
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	0.000	0.129	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016
St. Dev		0.14	0.59										0.45
St. Error		0.07	0.42										0.18

RMS Water Height (M)	RMS 07/2020	RMS 08/2020	RMS 09/2020	RMS 10/2020	RMS 11/2020	RMS 12/2020	RMS 01/2021	RMS 02/2021	RMS 03/2021	RMS 04/2021	RMS 05/2021	RMS 06/2021	RMS Entire Year
Mean	0.0263	0.0239	0.0375										0.0284
median	0.0225	0.0165	0.0352										0.0242
min	0.0021	0.0000	0.0053										0.0000
lower	0.0145	0.0099	0.0252										0.0140
upper	0.0339	0.0318	0.0470										0.0384
max	0.1134	0.1599	0.1896										0.1896
90th percentile	0.0480	0.0524	0.0605										0.0540
10th percentile	0.0101	0.0067	0.0175										0.0089
n(recordings obtained)	4464	4464	3244	0	0	0	0	0	0	0	0	0	12172
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232
St. Dev	0.0159	0.0201	0.0172										0.0187
St. Error	0.0002	0.0003	0.0003										0.0002

Water Temperature (degC)	Temp 07/2020	Temp 08/2020	Temp 09/2020	Temp 10/2020	Temp 11/2020	Temp 12/2020	Temp 01/2021	Temp 02/2021	Temp 03/2021	Temp 04/2021	Temp 05/2021	Temp 06/2021	Temp Entire Year
Mean	21.01	22.02	22.61										21.81
median	21.08	21.98	22.52										21.75
min	19.90	20.52	21.63										19.90
lower	20.62	21.53	22.22										21.15
upper	21.40	22.67	22.81										22.51
max	21.89	23.42	24.68										24.68
90th percentile	21.64	22.98	23.35										22.92
10th percentile	20.33	20.97	21.97										20.62
n(recordings obtained)	4464	4464	3244	0	0	0	0	0	0	0	0	0	12172
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.751	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232
St. Dev	0.49	0.72	0.59										0.89
St. Error	0.01	0.01	0.01										0.01

Daily PAR (mol m-2 day-1)	Light 07/2020	Light 08/2020	Light 09/2020	Light 10/2020	Light 11/2020	Light 12/2020	Light 01/2021	Light 02/2021	Light 03/2021	Light 04/2021	Light 05/2021	Light 06/2021	Light Entire Year
Mean	1.79	3.75	1.30										2.37
median	1.40	3.04	1.03										1.59
min	0.29	0.13	0.47										0.13
lower	0.92	0.97	0.75										0.90
upper	2.54	6.59	1.66										3.07
max	3.68	9.84	2.82										9.84
90th percentile	3.66	8.64	2.32										6.02
10th percentile	0.67	0.51	0.71										0.67
n(recordings obtained)	31	31	23	0	0	0	0	0	0	0	0	0	85
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	1.000	0.767	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233
St. Dev	1.12	3.10	0.65										2.27
St. Error	0.20	0.56	0.14										0.25


SSC (mg L-1)
0
1
2
3
4
5
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year
Depos. Rate (mg cm-2 day-1)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
RMS Water Height (m)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Water Temperature (°C)
20.0
20.5
21.0
21.5
22.0
22.5
23.0
23.5
PAR (mol m-2 day-1)
0
2
4
6
8
10

AMB 4 – Camp Island

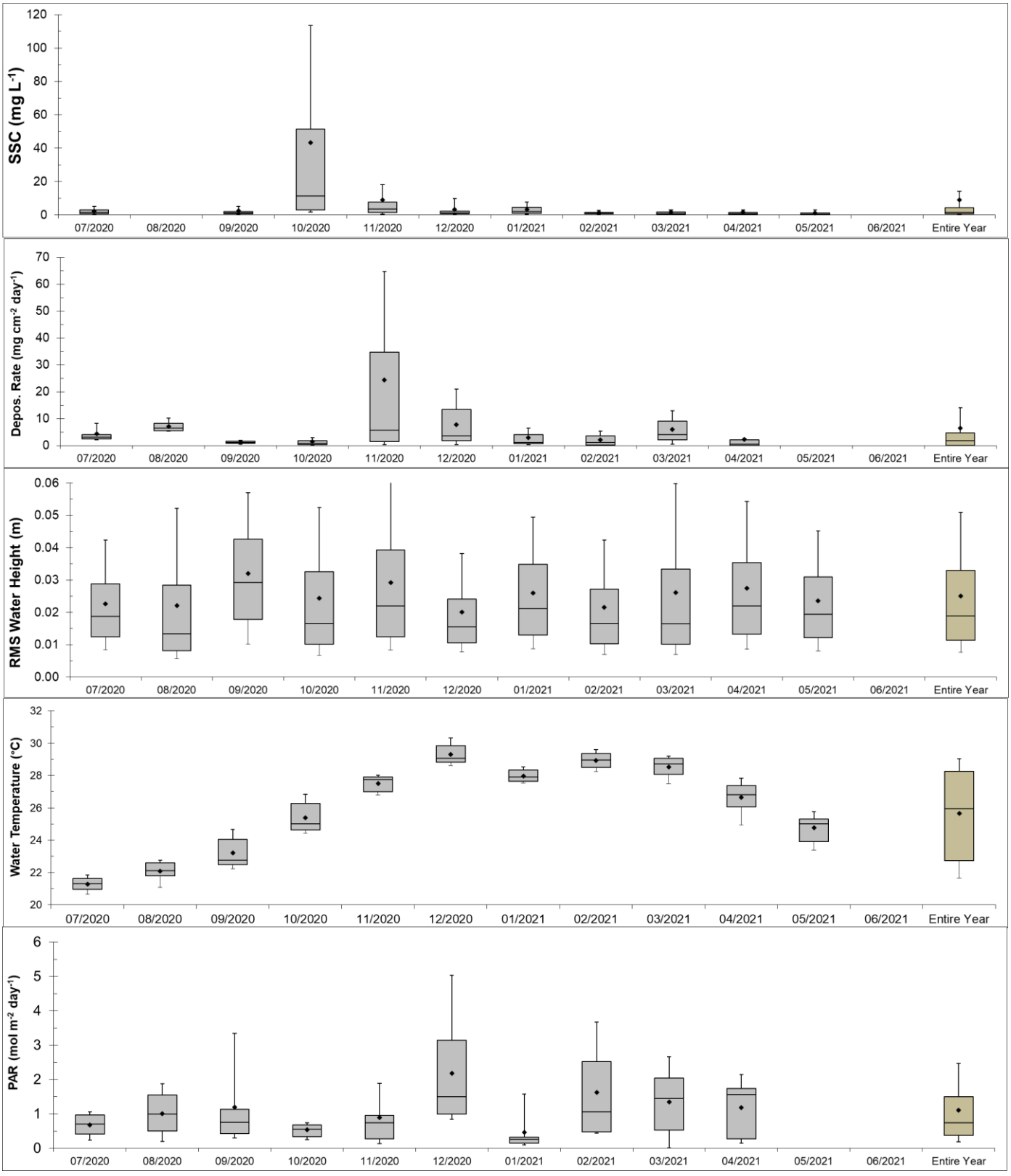
Turbidity (SSC)	SSC 07/2020	SSC 08/2020	SSC 09/2020	SSC 10/2020	SSC 11/2020	SSC 12/2020	SSC 01/2021	SSC 02/2021	SSC 03/2021	SSC 04/2021	SSC 05/2021	SSC 06/2021	SSC Entire Year
Mean	2.32		2.65	43.33	9.09	3.30	3.23	1.58	1.76	1.63	1.36		9.14
median	1.45		1.28	11.36	3.54	1.14	2.00	0.99	0.79	0.81	0.54		1.42
min	0.13		0.00	8.90	0.00	28.44	0.00	0.00	0.00	0.00	0.00		7.00
lower	0.82		0.78	3.01	1.46	0.62	0.88	0.65	0.41	0.50	0.24		0.65
upper	3.11		2.11	51.40	7.85	2.30	4.51	1.57	1.80	1.46	1.18		4.25
max	22.96		74.50	604.77	259.13	74.06	27.88	29.15	27.35	43.53	42.13		604.77
90th percentile	5.15		5.17	113.58	18.05	9.71	7.63	2.80	3.04	3.10	3.03		14.36
10th percentile	0.55		0.42	1.65	0.56	0.30	0.54	0.43	0.22	0.32	0.09		0.33
n(recordings obtained)	2087	0	920	3785	4128	2796	1856	1935	948	4306	3578	0	26339
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	0.468	0.000	0.213	0.848	0.956	0.626	0.416	0.480	0.212	0.997	0.802	0.000	0.501
St. Dev	2.29		5.17	73.66	20.71	6.46	3.33	2.28	2.96	2.93	2.71		32.54
St. Error	0.05		0.17	1.20	0.32	0.12	0.08	0.05	0.10	0.04	0.05		0.20

Deposition Rate (mg/[cm^2 day])	Dep. Rate 07/2020	Dep. Rate 08/2020	Dep. Rate 09/2020	Dep. Rate 10/2020	Dep. Rate 11/2020	Dep. Rate 12/2020	Dep. Rate 01/2021	Dep. Rate 02/2021	Dep. Rate 03/2021	Dep. Rate 04/2021	Dep. Rate 05/2021	Dep. Rate 06/2021	Dep. Rate Entire Year
Mean	4.39	7.11	1.22	1.48	24.42	7.77	3.01	2.17	6.05	2.22			6.54
median	3.05	6.45	1.12	0.85	5.74	3.63	1.14	1.12	4.06	1.38			2.63
min	1.38	3.70	0.12	0.19	0.19	0.15	0.24	0.09	0.18	0.39			0.09
lower	2.54	5.48	0.84	0.43	1.45	1.86	0.65	0.25	2.08	0.90			0.87
upper	4.05	8.32	1.71	1.79	34.73	13.46	4.03	3.63	9.00	3.09			5.56
max	17.13	11.83	2.31	9.19	122.12	35.58	14.48	8.17	26.72	7.38			122.12
90th percentile	8.21	10.22	2.01	2.95	64.66	20.96	6.55	5.29	13.00	3.48			14.97
10th percentile	2.08	5.32	0.53	0.30	0.42	0.33	0.35	0.15	0.46	0.47			0.34
n(recordings obtained)	31	12	8	31	29	31	31	28	31	12	0	0	244
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	0.387	0.267	1.000	0.967	1.000	1.000	1.000	1.000	0.400	0.000	0.000	0.668
St. Dev	3.77	2.33	0.70	1.74	31.51	9.23	3.81	2.37	5.83	1.98			13.49
St. Error	0.68	0.67	0.25	0.31	5.85	1.66	0.68	0.45	1.05	0.57			0.86

RMS Water Height (M)	RMS 07/2020	RMS 08/2020	RMS 09/2020	RMS 10/2020	RMS 11/2020	RMS 12/2020	RMS 01/2021	RMS 02/2021	RMS 03/2021	RMS 04/2021	RMS 05/2021	RMS 06/2021	RMS Entire Year
Mean	0.0227	0.0221	0.0320	0.0244	0.0293	0.0200	0.0260	0.0216	0.0261	0.0275	0.0235		0.0250
median	0.0188	0.0133	0.0292	0.0166	0.0219	0.0156	0.0212	0.0166	0.0165	0.0219	0.0194		0.0189
min	0.0024	0.0000	0.0024	0.0000	0.0000	0.0028	0.0025	0.0000	0.0000	0.0000	0.0000		0.0000
lower	0.0124	0.0081	0.0179	0.0102	0.0125	0.0106	0.0130	0.0104	0.0102	0.0133	0.0121		0.0114
upper	0.0289	0.0284	0.0426	0.0325	0.0393	0.0241	0.0348	0.0272	0.0334	0.0354	0.0310		0.0329
max	0.1452	0.1844	0.1284	0.1450	0.1669	0.1904	0.1581	0.1891	0.2640	0.1455	0.1116		0.2640
90th percentile	0.0424	0.0522	0.0570	0.0524	0.0611	0.0382	0.0495	0.0424	0.0598	0.0543	0.0451		0.0509
10th percentile	0.0085	0.0057	0.0102	0.0068	0.0083	0.0078	0.0087	0.0070	0.0070	0.0086	0.0081		0.0076
n(recordings obtained)	4464	4464	4314	4464	4318	4462	4464	4030	4455	4320	3670	0	47425
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	0.998	1.000	0.822	0.000	0.902
St. Dev	0.0146	0.0216	0.0187	0.0206	0.0229	0.0151	0.0175	0.0168	0.0248	0.0198	0.0155		0.0195
St. Error	0.0002	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	0.0004	0.0003	0.0003		0.0001

Water Temperature (degC)	Temp 07/2020	Temp 08/2020	Temp 09/2020	Temp 10/2020	Temp 11/2020	Temp 12/2020	Temp 01/2021	Temp 02/2021	Temp 03/2021	Temp 04/2021	Temp 05/2021	Temp 06/2021	Temp Entire Year
Mean	21.28	22.09	23.22	25.38	27.50	29.32	27.97	28.94	28.54	26.64	24.76		25.66
median	21.31	22.11	22.75	25.01	27.74	29.06	27.90	28.95	28.71	26.82	25.00		25.95
min	20.32	20.71	21.80	24.18	26.50	28.44	27.30	27.77	27.26	24.53	23.20		20.32
lower	20.97	21.80	22.48	24.65	27.00	28.83	27.65	28.49	28.08	26.06	23.91		22.72
upper	21.63	22.59	24.04	26.28	27.91	29.84	28.33	29.36	29.07	27.38	25.32		28.27
max	22.11	22.99	26.10	27.45	28.28	30.82	28.85	30.27	29.59	28.36	26.26		30.82
90th percentile	21.84	22.75	24.67	26.85	28.01	30.33	28.53	29.61	29.21	27.83	25.76		29.05
10th percentile	20.66	21.09	22.24	24.44	26.81	28.61	27.51	28.24	27.49	24.95	23.40		21.65
n(recordings obtained)	4464	4464	4309	4464	642	2380	4464	4030	4455	4320	3670	0	41662
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	0.997	1.000	0.149	0.533	1.000	1.000	0.998	1.000	0.822	0.000	0.793
St. Dev	0.43	0.57	1.05	0.93	0.49	0.64	0.38	0.54	0.63	1.00	0.85		2.84
St. Error	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01		0.01

Daily PAR (mol m-2 day-1)	Light 07/2020	Light 08/2020	Light 09/2020	Light 10/2020	Light 11/2020	Light 12/2020	Light 01/2021	Light 02/2021	Light 03/2021	Light 04/2021	Light 05/2021	Light 06/2021	Light Entire Year
Mean	0.68	1.01	1.19	0.54	0.89	2.18	0.47	1.62	1.34	1.18			1.10
median	0.71	1.00	0.75	0.55	0.74	1.50	0.26	1.06	1.45	1.56			0.74
min	0.13	0.03	0.13	0.25	0.05	0.42	0.05	0.07	0.00	0.03			0.00
lower	0.41	0.50	0.43	0.34	0.27	1.00	0.15	0.48	0.53	0.27			0.37
upper	0.96	1.55	1.13	0.67	0.96	3.14	0.33	2.52	2.04	1.73			1.50
max	1.12	2.12	5.65	1.20	4.12	5.82	2.11	4.47	3.38	2.59			5.82
90th percentile	1.05	1.88	3.34	0.74	1.89	5.03	1.57	3.66	2.66	2.15			2.48
10th percentile	0.23	0.20	0.30	0.26	0.14	0.84	0.09	0.44	0.01	0.14			0.19
n(recordings obtained)	31	31	30	31	30	31	31	28	31	12	0	0	286
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.400	0.000	0.000	0.784
St. Dev	0.30	0.63	1.30	0.23	0.95	1.61	0.56	1.34	0.96	0.90			1.09
St. Error	0.05	0.11	0.24	0.04	0.17	0.29	0.10	0.25	0.17	0.26			0.06


SSC (mg L-1)
120
100
80
60
40
20
0
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year
Depos. Rate (mg cm-2 day-1)
70
60
50
40
30
20
10
0
RMS Water Height (m)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Water Temperature (°C)
32
30
28
26
24
22
20
PAR (mol m-2 day-1)
6
5
4
3
2
1
0

AMB 5 – Holbourne

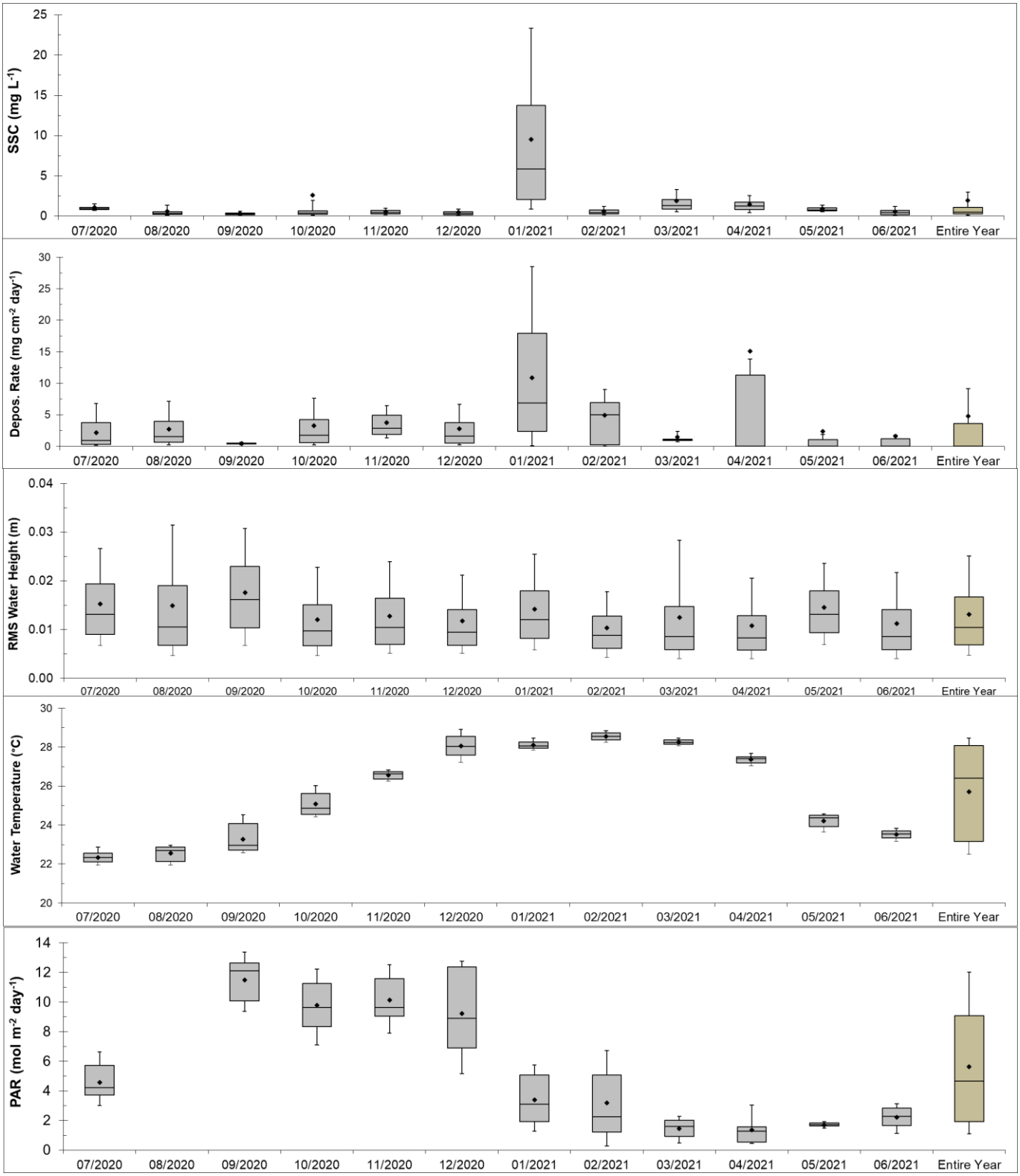
Turbidity (SSC)	SSC 07/2020	SSC 08/2020	SSC 09/2020	SSC 10/2020	SSC 11/2020	SSC 12/2020	SSC 01/2021	SSC 02/2021	SSC 03/2021	SSC 04/2021	SSC 05/2021	SSC 06/2021	SSC Entire Year
Mean	1.08	0.60	0.33	2.59	0.55	0.49	9.55	0.57	1.91	1.47	0.92	0.57	1.93
median	0.89	0.31	0.28	0.36	0.45	0.33	5.84	0.41	1.30	1.26	0.77	0.43	0.48
min	0.61	0.00	0.00	8.64	0.00	26.88	0.00	0.00	0.00	0.00	0.00	0.00	7.00
lower	0.79	0.19	0.18	0.20	0.28	0.15	2.04	0.26	0.84	0.82	0.63	0.16	0.25
upper	1.07	0.53	0.39	0.66	0.70	0.56	13.75	0.76	2.03	1.71	1.00	0.73	1.06
max	9.34	10.56	3.27	220.80	7.97	25.13	100.34	4.80	23.60	18.53	5.50	7.67	220.80
90th percentile	1.50	1.36	0.58	1.93	0.95	0.87	23.36	1.19	3.29	2.56	1.37	1.17	2.99
10th percentile	0.73	0.11	0.10	0.11	0.17	0.06	0.86	0.14	0.52	0.43	0.52	0.05	0.12
n(recordings obtained)	395	3013	4308	4460	4316	4460	4284	2781	992	3306	804	4318	37437
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	0.088	0.675	0.997	0.999	0.999	0.999	0.960	0.690	0.222	0.765	0.180	1.000	0.712
St. Dev	0.81	0.97	0.25	13.08	0.46	1.10	10.55	0.50	2.48	1.25	0.58	0.64	6.46
St. Error	0.04	0.02	0.00	0.20	0.01	0.02	0.16	0.01	0.08	0.02	0.02	0.01	0.03

Deposition Rate (mg/[cm^2 day])	Dep. Rate 07/2020	Dep. Rate 08/2020	Dep. Rate 09/2020	Dep. Rate 10/2020	Dep. Rate 11/2020	Dep. Rate 12/2020	Dep. Rate 01/2021	Dep. Rate 02/2021	Dep. Rate 03/2021	Dep. Rate 04/2021	Dep. Rate 05/2021	Dep. Rate 06/2021	Dep. Rate Entire Year
Mean	2.18	2.69	0.46	3.26	3.74	2.76	10.86	4.93	1.46	15.10	2.38	1.60	4.78
median	0.95	1.54	0.45	1.76	2.88	1.62	6.87	5.00	0.99	11.38	1.94	1.22	2.19
min	0.07	0.13	0.10	0.12	0.94	0.02	0.02	0.03	0.62	1.90	1.27	0.50	0.02
lower	0.33	0.68	0.37	0.56	1.89	0.50	2.36	0.20	0.89	7.50	1.52	0.80	0.79
upper	3.79	3.94	0.52	4.27	4.94	3.74	17.93	6.93	1.10	22.69	3.00	2.40	5.78
max	8.67	8.52	0.85	20.11	11.80	14.54	34.94	22.15	5.08	41.69	4.39	3.90	41.69
90th percentile	6.79	7.11	0.67	7.61	6.45	6.68	28.46	8.99	2.40	25.21	3.84	2.99	11.34
10th percentile	0.19	0.23	0.23	0.27	1.36	0.21	0.10	0.06	0.71	3.83	1.36	0.58	0.23
n(recordings obtained)	31	16	7	31	30	31	30	20	8	23	6	30	263
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	1.000	0.516	0.233	1.000	1.000	1.000	0.968	0.714	0.258	0.767	0.194	1.000	0.721
St. Dev	2.48	2.80	0.23	4.09	2.69	3.21	10.87	5.36	1.47	10.05	1.22	1.00	6.82
St. Error	0.44	0.70	0.09	0.73	0.49	0.58	1.98	1.20	0.52	2.09	0.50	0.18	0.42

RMS Water Height (M)	RMS 07/2020	RMS 08/2020	RMS 09/2020	RMS 10/2020	RMS 11/2020	RMS 12/2020	RMS 01/2021	RMS 02/2021	RMS 03/2021	RMS 04/2021	RMS 05/2021	RMS 06/2021	RMS Entire Year
Mean	0.0152	0.0149	0.0176	0.0121	0.0128	0.0118	0.0142	0.0103	0.0125	0.0108	0.0145	0.0113	0.0131
median	0.0131	0.0106	0.0162	0.0098	0.0105	0.0095	0.0121	0.0088	0.0085	0.0083	0.0132	0.0085	0.0104
min	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0025	0.0000	0.0000
lower	0.0090	0.0068	0.0104	0.0067	0.0069	0.0068	0.0082	0.0062	0.0058	0.0058	0.0093	0.0058	0.0068
upper	0.0194	0.0191	0.0230	0.0151	0.0164	0.0141	0.0180	0.0127	0.0147	0.0129	0.0180	0.0141	0.0167
max	0.0647	0.1159	0.0654	0.0706	0.0591	0.1099	0.0623	0.0913	0.0893	0.0813	0.0457	0.0646	0.1159
90th percentile	0.0266	0.0315	0.0307	0.0228	0.0239	0.0212	0.0255	0.0178	0.0284	0.0205	0.0236	0.0217	0.0251
10th percentile	0.0068	0.0047	0.0067	0.0046	0.0051	0.0051	0.0058	0.0043	0.0041	0.0041	0.0069	0.0041	0.0048
n(recordings obtained)	4464	4464	4319	4464	4317	4462	4464	4029	4462	3310	805	4320	47880
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	1.000	1.000	0.999	1.000	1.000	0.999	1.000	0.766	0.180	1.000	0.911
St. Dev	0.0084	0.0121	0.0094	0.0079	0.0082	0.0079	0.0083	0.0066	0.0109	0.0084	0.0070	0.0082	0.0091
St. Error	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0001	0.0000

Water Temperature (degC)	Temp 07/2020	Temp 08/2020	Temp 09/2020	Temp 10/2020	Temp 11/2020	Temp 12/2020	Temp 01/2021	Temp 02/2021	Temp 03/2021	Temp 04/2021	Temp 05/2021	Temp 06/2021	Temp Entire Year
Mean	22.34	22.55	23.27	25.08	26.57	28.07	28.10	28.55	28.25	27.36	24.21	23.51	25.71
median	22.33	22.70	22.97	24.85	26.62	28.04	28.06	28.55	28.23	27.40	24.36	23.53	26.40
min	20.95	21.00	21.97	23.94	25.00	26.88	26.73	27.43	27.32	26.42	23.17	22.43	20.95
lower	22.11	22.14	22.72	24.55	26.37	27.59	27.94	28.37	28.15	27.18	23.92	23.35	23.16
upper	22.55	22.87	24.07	25.63	26.75	28.56	28.25	28.72	28.37	27.51	24.51	23.69	28.09
max	23.16	23.23	25.30	26.87	27.14	29.28	28.77	29.26	28.94	28.01	24.62	24.13	29.28
90th percentile	22.87	22.97	24.52	26.03	26.84	28.91	28.47	28.85	28.46	27.67	24.57	23.84	28.47
10th percentile	21.94	21.94	22.56	24.43	26.25	27.23	27.84	28.25	28.07	27.05	23.64	23.17	22.50
n(recordings obtained)	4464	4464	4319	4464	4313	4462	4464	4030	4455	3310	805	4320	47870
T(recordings possible)	4464	4464	4320	4464	4320	4464	4464	4032	4464	4320	4464	4320	52560
f(period obtained; n/T)	1.000	1.000	1.000	1.000	0.998	1.000	1.000	1.000	0.998	0.766	0.180	1.000	0.911
St. Dev	0.36	0.43	0.76	0.64	0.24	0.61	0.27	0.25	0.19	0.25	0.37	0.29	2.41
St. Error	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.01

Daily PAR (mol m-2 day-1)	Light 07/2020	Light 08/2020	Light 09/2020	Light 10/2020	Light 11/2020	Light 12/2020	Light 01/2021	Light 02/2021	Light 03/2021	Light 04/2021	Light 05/2021	Light 06/2021	Light Entire Year
Mean	4.57		11.49	9.78	10.13	9.21	3.40	3.18	1.46	1.36	1.70	2.21	5.64
median	4.23		12.11	9.64	9.64	8.91	3.11	2.24	1.60	1.27	1.72	2.27	4.67
min	2.30		8.83	3.03	7.08	2.16	0.83	0.05	0.09	0.25	1.33	0.87	0.05
lower	3.72		10.09	8.34	9.06	6.91	1.93	1.21	0.93	0.55	1.63	1.66	1.92
upper	5.71		12.64	11.26	11.57	12.39	5.07	5.08	2.00	1.56	1.84	2.84	9.09
max	7.28		14.04	15.14	14.33	14.29	6.09	8.94	2.63	3.77	1.95	3.32	15.14
90th percentile	6.62		13.39	12.23	12.53	12.75	5.76	6.71	2.28	3.05	1.91	3.13	12.03
10th percentile	3.00		9.38	7.11	7.90	5.15	1.26	0.27	0.48	0.46	1.47	1.14	1.10
n(recordings obtained)	19	0	7	31	30	31	31	28	8	23	6	29	243
T(recordings possible)	31	31	30	31	30	31	31	28	31	30	31	30	365
f(period obtained; n/T)	0.613	0.000	0.233	1.000	1.000	1.000	1.000	1.000	0.258	0.767	0.194	0.967	0.666
St. Dev	1.43		1.87	2.46	1.86	3.19	1.73	2.60	0.85	1.01	0.22	0.73	4.10
St. Error	0.33		0.71	0.44	0.34	0.57	0.31	0.49	0.30	0.21	0.09	0.14	0.26


SSC (mg L-1)
Depos. Rate (mg cm-2 day-1)
RMS Water Height (m)
Water Temperature (°C)
PAR (mol m-2 day-1)
07/2020
08/2020
09/2020
10/2020
11/2020
12/2020
01/2021
02/2021
03/2021
04/2021
05/2021
06/2021
Entire Year

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