# Port of Weipa Ambient Marine Water Quality Monitoring Program: Annual Report 2019-2020

**Nathan Waltham, Jordan Iles, James Whinney, Simon Macdonald, Blake Ramsby, and Rachael Macdonald**

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A Report for North Queensland Bulk Ports Corporation

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# EXECUTIVE SUMMARY

**Background**

1. North Queensland Bulk Ports has implemented an ambient marine water quality monitoring program surrounding the Port of Weipa. The objectives of the program are to establish a long term water quality dataset to characterise marine water quality conditions within the waters within and around the port operation. These data are also used to support future planned activities.
2. This program has incorporated a combination of spot field measurements and high frequency continuous data loggers, laboratory analysis for a range of nutrient, herbicides and heavy metals.

**Climatic conditions**

1. Total wet season rainfall during the 2019-2020 monitoring period was 1449 mm, which is slightly below the long-term median. Most of the rainfall was recorded during the wet season, with little to no rainfall occurring during the dry winter months.
2. The daily average wind speed and direction recorded at the Weipa airport was predominantly from the south east and east, reaching speeds up to and above 25 km $h^{-1}$

**Water chemistry**

1. Water quality conditions were measured at all sites on a ~6 weekly basis. Parameters collected were water temperature, electrical conductivity, pH, dissolved oxygen and photosynthetically active radiation at three depths (surface, mid-water and bottom), along with Secchi disk depth.
2. The water column is well mixed, with depth profiles for dissolved oxygen, temperature, electrical conductivity and pH showing only minor gradients of change.
3. Particulate nitrogen (PN) concentrations exceed guideline values during all 2019-2020 surveys at all sites. Particulate phosphorus (PP) concentrations occasionally exceeded guideline values and were much more variable than PN over the reporting period.
4. Chlorophyll-*a* concentrations exceed guideline values during all 2019-2020 surveys at all sites.
5. Metals were not found to be above the 95% level of protection trigger values for marine waters. Silver, Cadmium, Copper, Nickel, Zinc, and Mercury were not detected (< LOD). Lead and Arsenic were detected at low concentrations.
6. Pesticides were not present above the trigger values for the GBR. The herbicides Chlorpyrifos, Diazinon, Hexazinone, and Ametryn were not detected (< LOD). Diuron was detected at low concentrations at all sites. The insecticides Atrazine and Simazine were not detected (< LOD).

**Sediment deposition and turbidity**

1. Continuous sediment deposition and turbidity logging data supports the pattern found more broadly in north Queensland coastal marine environments, that during dry periods with minimal rainfall, elevated turbidity experienced is likely in relation to re-suspension of sediment and this has been most notable here when examining closely the RMS water depth and NTUe/SSC data. Large peaks in NTUe/SSC and RMS water depth were recorded over periods longer than a week, giving rise to the notion that the re-suspension events can occur over extended periods.
2. Sediment deposition rates around Weipa were much higher than measured across other north Queensland coastal marine sites investigated during the same period.

**Photosynthetically active radiation (PAR)**

1. Patterns of light were similar among all the coastal sites. Generally, shallow inshore sites reached higher levels of benthic PAR and were more variable than deeper water coastal sites and sites of closer proximity to one another were more similar than distant sites.
2. At many of the sites where both turbidity and benthic light were measured, the concentration of suspended solids in the water column explained less than half of the variation in PAR. As PAR is more biologically relevant to the health of photosynthetic benthic habitats such as seagrass, algae and

corals it is becoming more useful as a management response tool when used in conjunction with known thresholds for healthy growth for these habitats. For this reason, it is important to include photosynthetically active radiation (PAR) in the suite of water quality variables when capturing local baseline conditions of ambient water quality.

**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.

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# 1 INTRODUCTION

## 1.1 Port operations

The Port of Weipa is situated on the western side of Cape York Peninsula in northern Queensland (Figure 1.1). It is located within the township of Weipa, where the Embley, Mission and Pine River's converge and discharge into the Gulf of Carpentaria. The port has a series of operational and associated loading/unloading facilities. The port is operated by North Queensland Bulk Ports Corporation (NQBP). Along with other NQBP ports in Queensland, Port of Weipa requires routine maintenance dredging to maintain declared navigational depths within the swing basin and berth areas, departure path and aprons. Any dredging activity necessary in the operating ports in the region are undertaken in accordance with Commonwealth and State approvals.

## 1.2 Program outline

In order to better define the potential impacts associated with port operations and to characterise the natural variability in key water quality parameters within the adjacent sensitive habitats, NQBP committed to an ambient marine water quality monitoring program in and around the coastal waters of Weipa (Table 1.1). As part of this program, water quality parameters are being investigated at a range of sites to build on 19 years of seagrass monitoring and three years of monitoring of photosynthetically active radiation (PAR) that has already been undertaken by NQBP. This monitoring program contains a range of ambient water quality components that collectively continue to characterise the natural variability in key water quality parameters, including those experienced at the nearest sensitive receiving habitat, predominately seagrass (Taylor et al., 2015).

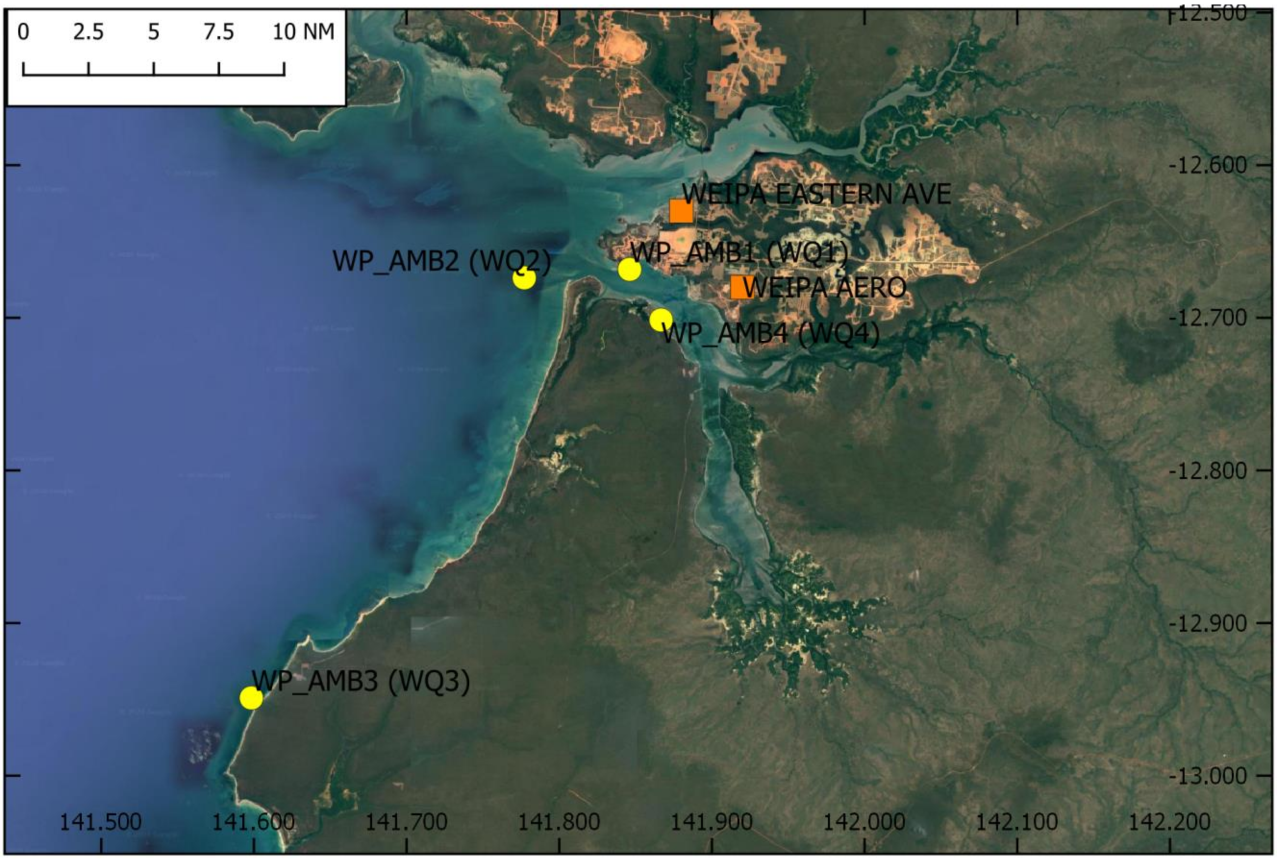



**Figure 1.1** Location of water quality monitoring sites (yellow circle) utilised in the 2019-2020 reporting period. Also shown are meteorological stations (orange square), and stream gauging stations (blue triangle) referred to in this report.

**Table 1.1** Locations of the ambient marine water quality monitoring program sites

| Site name | Site code | Latitude | Longitude | Water quality | Logger |
|---|---|---|---|---|---|
| WQ1 | WP_AMB1 | -12.668283 | 141.846133 | Yes | Yes |
| WQ2 | WP_AMB2 | -12.673778 | 141.777081 | Yes | Yes |
| WQ3 | WP_AMB3 | -12.94905 | 141.59835 | Yes | Yes |
| WQ4 | WP_AMB4 | -12.701431 | 141.8667 | Yes | Yes |

## 1.3 Program objectives

The goal of the program is to characterise the ambient marine water quality monitoring within the region within and adjacent to Port of Weipa. This report provides a review and analysis of data collected between 01/07/2019 and 30/06/2020. These data are part of a longer term commitment to monitor and characterise receiving water quality conditions, to support future planned asset management and protection of this coastal port.

# 2 METHODOLOGY

## 2.1 Ambient water quality

Spot water quality samples were collected at sites approximately on a 6 week basis (Table 3.1) from a research vessel. At each site, a calibrated multiprobe is used to measure water temperature, salinity, dissolved oxygen (%), 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.

In aligning with the ambient marine water quality monitoring in other NQBP ports (Ports of Mackay and Hay Point, and Port of Abbott Point) the water quality program design below was completed. The list of parameters examined consisted:

- 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 (Low LOR suite (EP234(A-I)) including: diuron, ametryn, atrazine, terbutryn. Note that pesticides are suspected to be in low concentrations during periods of low rainfall runoff, and only detectable following rainfall. As a consequence sampling of only two events at all sites for pesticides, one during the dry and a wet season – though note that the timing of each are dependent on prevailing weather conditions, so the timing of each survey could differ from year to year.

**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 (i.e., DERM 2009b; APHA 2005; Standards Australia 1998). 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, and herbicides are analysed by Australian Laboratory Service (ALS).

**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 $cm^{-1}$ |
| | Total Suspended Solids (TSS) | 2540 D @ 103 - 105°C | 0.2 mg $L^{-1}$ |
| | Turbidity | 2130 B | 0.1 NTU |
| | Salinity | | |
| | Dissolved Oxygen | | |
| | Light Attenuation | | |
| **Pesticides/herbicides** | | | |
| | *Organophosphate pesticides* | In house LC/MS method: EP234A | 0.0002-0.001 µg $L^{-1}$ |
| | *Thiocarbamates and Carbamates*<br>- Thiobencarb | In house LC/MS method: EP234B | 0.0002 µg $L^{-1}$ |
| | *Dinitroanilines*<br>- Pendimethalin | In house LC/MS method: EP234C | 0.001 µg $L^{-1}$ |
| | *Triazinone Herbicides*<br>- Hexazinone | In house LC/MS method: EP234D | 0.0002 µg $L^{-1}$ |
| | *Conazole and Aminopyrimidine Fungicides*<br>- Propiconazole, Hexaconazole, Difenoconazole, Flusilazole, Penconazole | In house LC/MS method: EP234E | 0.0002 µg $L^{-1}$ |
| | *Phenylurea Thizdiazolurea Uracil and Sulfonylurea Herbicides*<br>- Diuron, Ametryn, Atrazine, Cyanazine, Prometryn, Propazine, Simazine, Terbuthylazine, Terbutryn | In house LC/MS method: EP234F | 0.0002 µg $L^{-1}$ |
| **Nutrients** | | | |
| | Total Nitrogen and Phosphorus (TN, TP) | Simultaneous 4500-NO3- F and 4500-P F analyses after alkaline persulphate digestion | 25 µg N $L^{-1}$, 5 µg P $L^{-1}$ |

| | | | |
|---|---|---|---|
| | Filterable nutrients (nitrate, nitrite, ammonia, $NO_x$) | 4500-NO3- F | 1 µg N $L^{-1}$ |
| | Ammonia | 4500- NH3 G | 1 mg N $L^{-1}$ |
| | Filterable Reactive Phosphorus (FRP) | 4500-P F | 1 µg P $L^{-1}$ |
| | Chlorophyll | 10200-H | 0.1 µg $L^{-1}$ |
| **Trace Metals** | | | |
| | Arsenic, Cadmium, Copper, Lead, Nickel, Silver, Zinc, Mercury | 3125B ORC/ICP/MS | 0.05 to 100 µg $L^{-1}$ |

## 2.2 Plankton community

At all sites, a 60 µm plankton net (for phytoplankton) and a 500 µm plankton net (for zooplankton) was towed behind the survey vessel for approximately 100 m. The boat speed is reduced to approximately 6 knots, with a GPS waypoint taken at the start and end of each plankton tow. At the end of each plankton tow, the nets are retrieved, and the contents retained in the plastic jar attached to the net was immediately transferred to preservation containers. Samples were identified to the lowest possible taxon.

a) b)

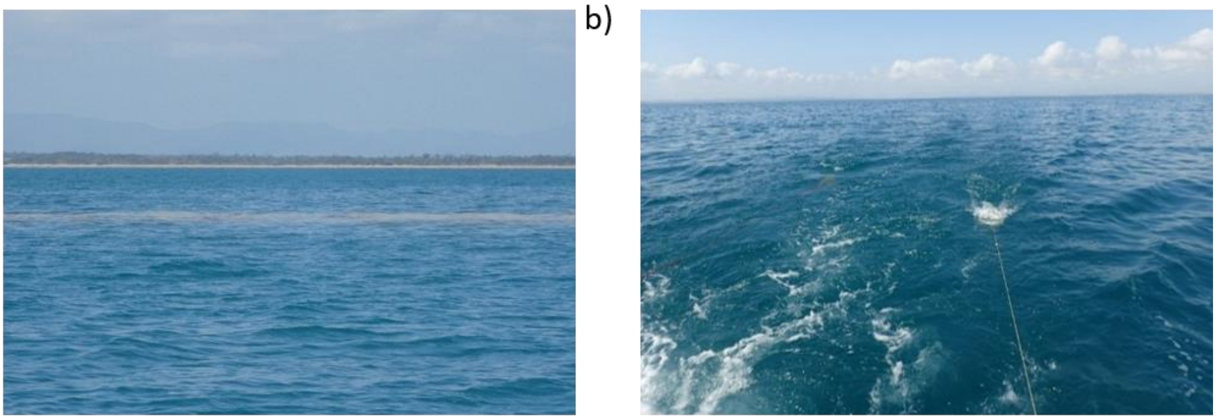


**Figure 2.2** Example plankton sample. a) Trichodesmium bloom on sea surface; b) phytoplankton (60 µm) tow behind the survey vessel.

## 2.3 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 2.3). 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.

### 2.3.1 Turbidity

The turbidity sensor provides data in Nephelometric Turbidity Unit's equivalent (NTUe) and can be calibrated to Suspended Sediment Concentration (SSC) in mg $L^{-1}$ (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.

### 2.3.2 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.

### 2.3.3 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 $n^{th}$ 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 1 m 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.

### 2.3.4 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.

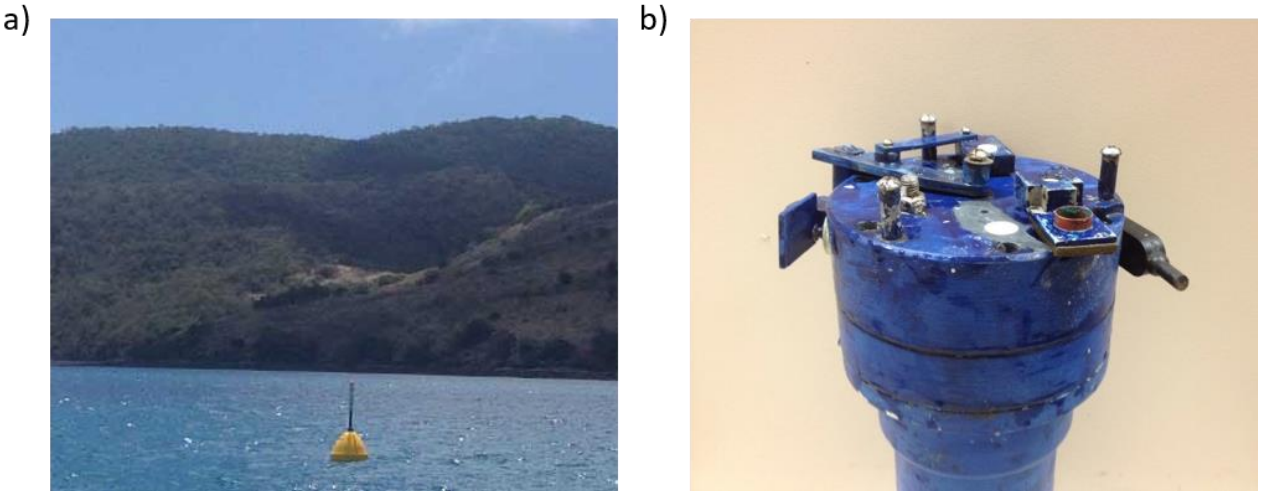



**Figure 2.3** Example coastal multiparameter water quality instrument: a) site navigation beacon for safety and instrument retrieval; b) instrument showing sensors and wiping mechanisms

### 2.3.5 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.

## 2.4 Marotte current meter

The Marotte HS (High Sampling Rate) is a drag-tilt current meter invented at the Marine Geophysics Laboratory (Figure 2.4). 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.

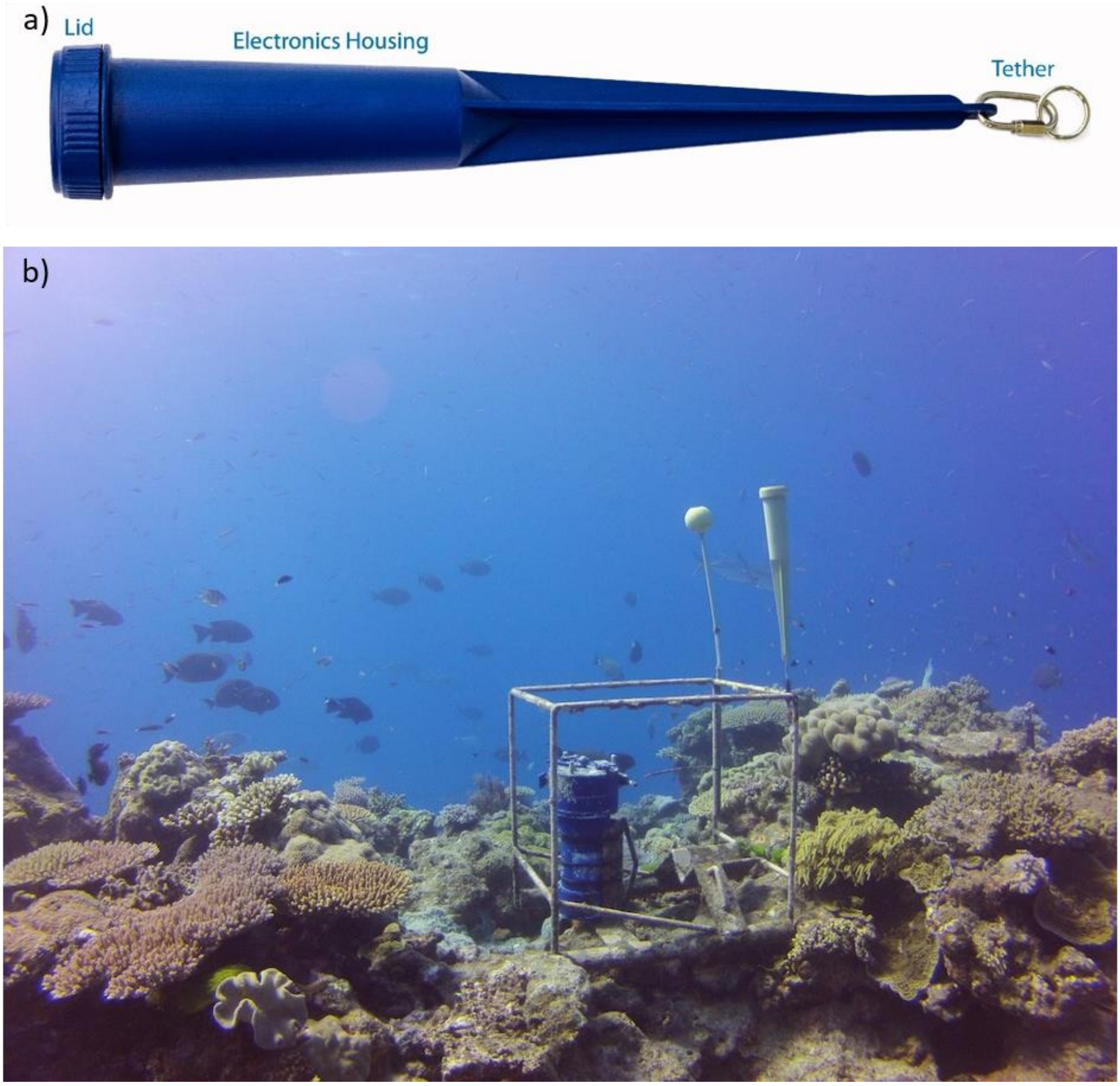



**Figure 2.4** a) Basic schematic of Marotte HS current meter; and b) Marotte HS alongside Marotte tethered to a nephelometer frame at Moore Reef. Image courtesy of Eric Fisher

# 3 RESULTS AND DISCUSSION

There were eight sampling and maintenance trips in the 2019-2020 reporting period (Table 3.1). Travel restrictions due to COVID-19 meant we were unable to complete water sampling in May 2020, although a local operator was able to exchange the loggers.

**Table 3.1** Summary of instrument maintenance and water quality surveys completed during the 2019-2020 reporting period

| Date | Nutrients, Chlorophyll-*a* | Metals, herbicides | Plankton | Logger maintenance |
|---|---|---|---|---|
| 12/06/2019 | Yes | - | - | Yes |
| 09/07/2019 | Yes | - | - | Yes |
| 27/08/2019 | Yes | Yes | - | Yes |
| 17/10/2019 | Yes | - | Yes | Yes |
| 20/11/2019 | Yes | - | - | Yes |
| 11/12/2019 | Yes | - | - | Yes |
| 05/03/2020 | Yes | - | Yes | Yes |
| 13/05/2020* | - | - | - | Yes |

* COVID-19 travel restrictions

## 3.1 Climatic conditions

Weather observations and hydrological data were compiled from the Bureau of Meteorology and the State of Queensland.

### 3.1.1 Rainfall

Daily rainfall for the Weipa region is shown on Figure 3.1. The first rainfall greater than 5 mm for the year occurred on 26/10/2019, with the rainfall onset occurring on 26/11/2019. The rainfall onset is calculated as the date when the rainfall total reaches 50 mm since 1st September. The 2019-2020 wet season rainfall total was 1449.3 mm (Weipa East Ave), which was less than the median wet season rainfall total calculated for wet seasons since 1961-1962 (Figure 3.2).

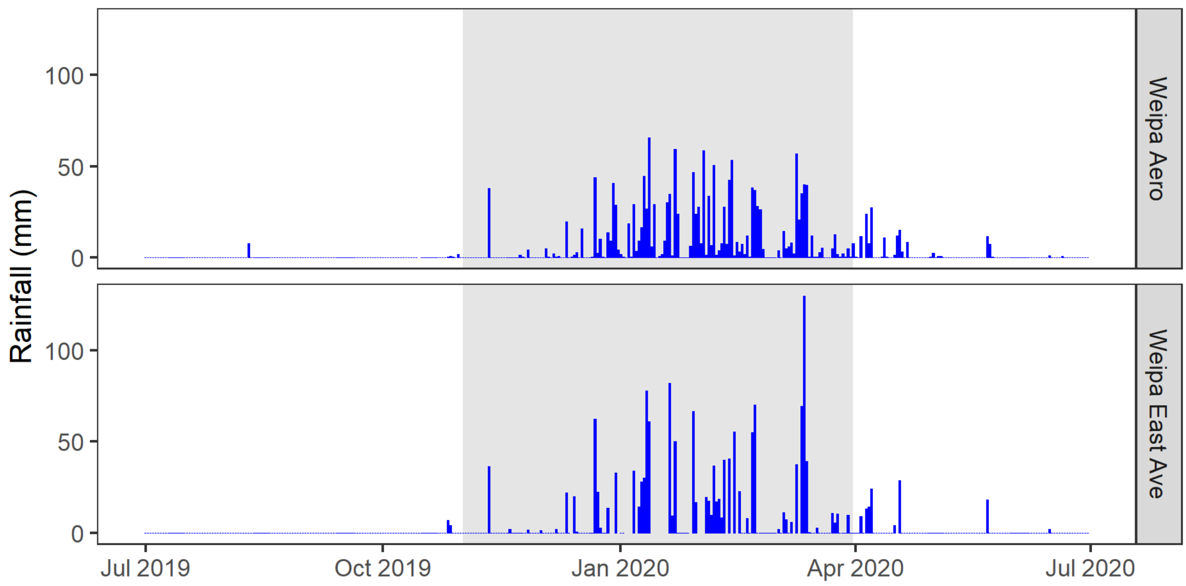



**Figure 3.1** Rainfall recorded at Weipa Aero (station 027045) and Weipa East Ave (station 027042) for the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: http://www.bom.gov.au/climate/data/

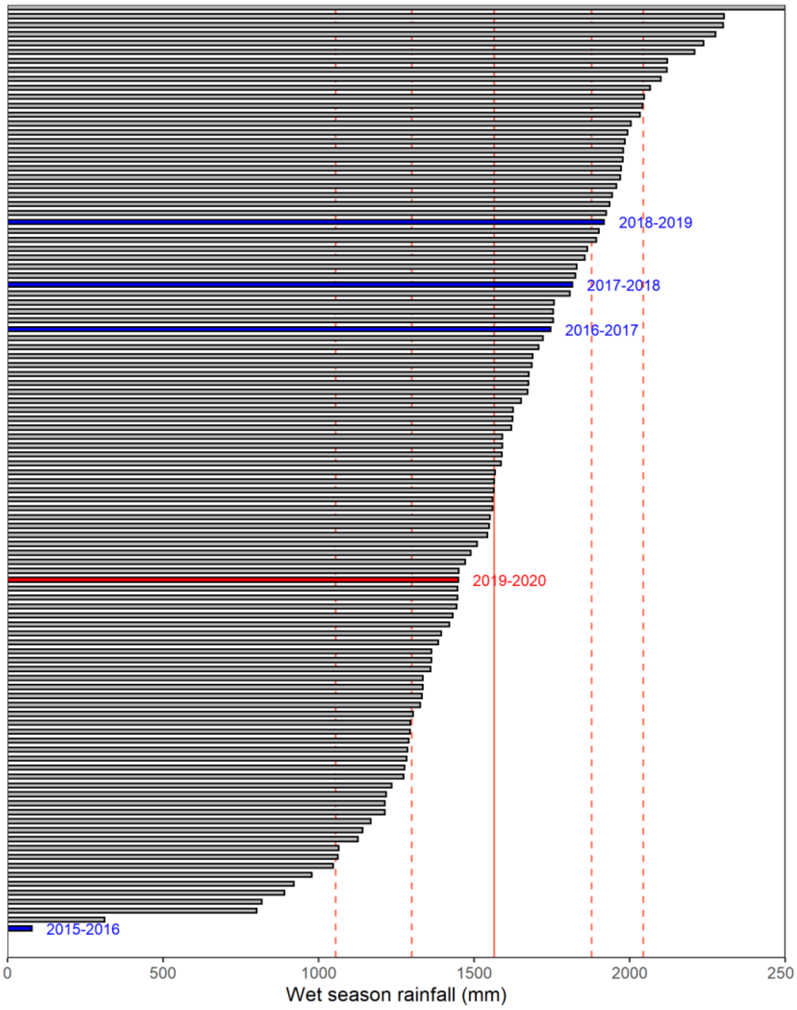



**Figure 3.2** Wet season rainfall for the Weipa region ranked in order of decreasing total wet season rainfall (mm). Daily rainfall data was obtained from the Weipa Eastern Ave weather station (station 027042). Totals were calculated for the wet season period 1st November to 31st March for each reporting year. Red bar represents the 2019-2020 reporting period, blue bars show total rainfall over the previous four years. Solid red line represents median wet season rainfall 1961-1962 to 2019-2020, dashed lines represent 10th, 25th, 75th, and 90th percentiles. Data source: http://www.bom.gov.au/climate/data/

### 3.1.2 River flows

The only local river gauging station near to Weipa is on the Watson River, which is located ~75 km south and does not discharge into the Mission River system where the Port is located. Therefore, although Watson River discharge has been used throughout this report to provide context for Port water quality conditions, results regarding the influence of water discharge on water quality variability should be interpreted with caution.

The hydrograph for Watson River shows onset of stream discharge on 28/01/2020 (**Error! Reference source not found.**). Total discharge for the 2019-2020 reporting period was 192 GL. There was a large discharge pulse on 14/03/2020 following rainfall. The hydrograph displays typical monsoonal rainfall patterns for this region. Weipa is located in a tropical environment where wet season rainfall can result in prolonged and elevated river discharge, particularly between November and April each year.

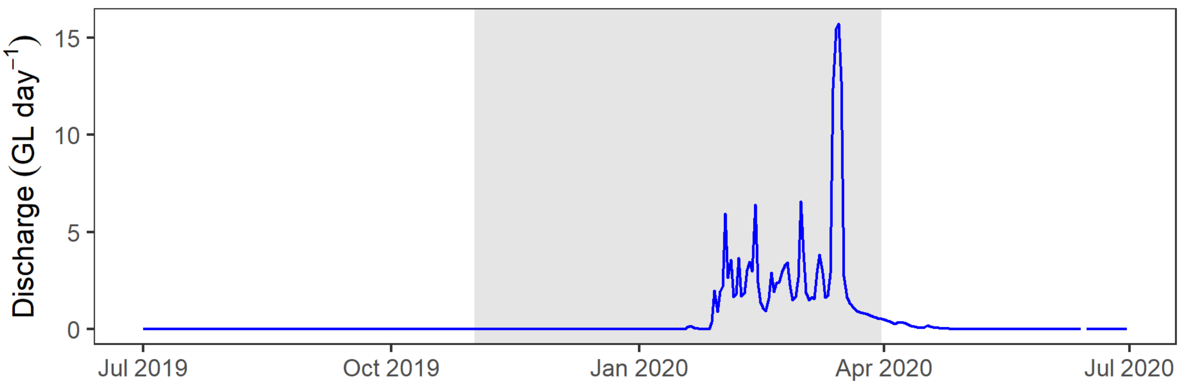



**Figure 3.3** Stream discharge (GL $d^{-1}$) from the Watson River (station 923001A) during the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: https://water-monitoring.information.qld.gov.au/.

## 3.2 Ambient water quality

### 3.2.1 Spot water quality physio-chemical

Water temperature ranged between 25.0 and 31.7 °C (Figure 3.4). 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. 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 33.2 and 54.0 mS $cm^{-1}$ (Figure 3.5). Conductivity values followed seasonality with higher values occurring during summer months and lower values during winter months. There was a drop in EC during March 2020 which we attribute to rainfall and increased freshwater discharge from the Embley River. A halocline was present in March 2020 with brackish water (~35 mS $cm^{-1}$) overlying more saline water. This halocline was most strongly observed at the two sites within the Embley River (WP_AMB1, WP_AMB4), while the coastal sites WP_AMB2 and WP_AMB3 did not show such a strong drop in electrical conductivity. Dissolved oxygen ranged between 32.7 to 115.3 %sat (Figure 3.6). The water column was well mixed, with dissolved oxygen saturation not significantly changing through the vertical profile. pH ranged between 7.7 and 8.7 (Figure 3.7).

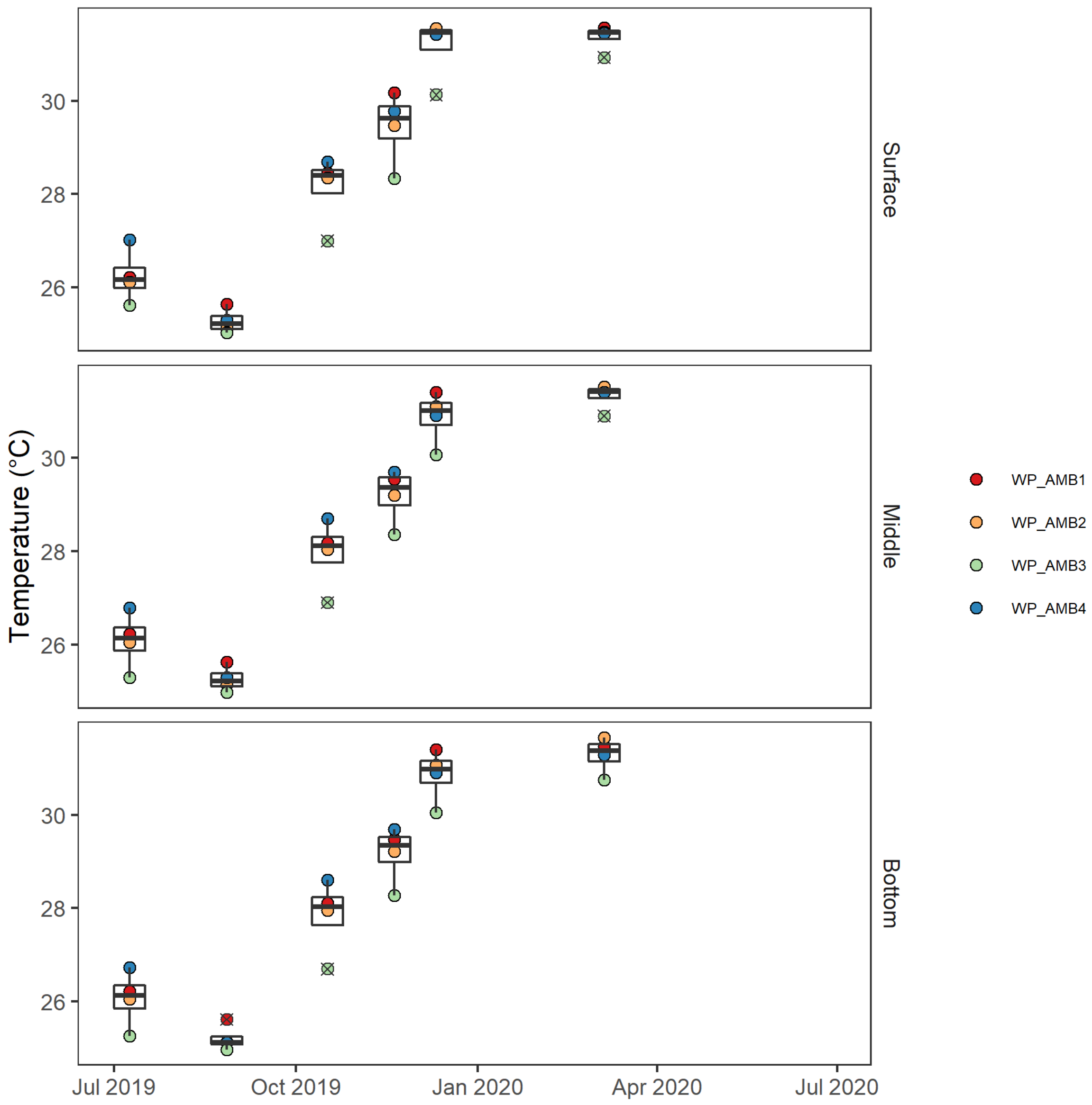



**Figure 3.4** Water temperature recorded at three depths at the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

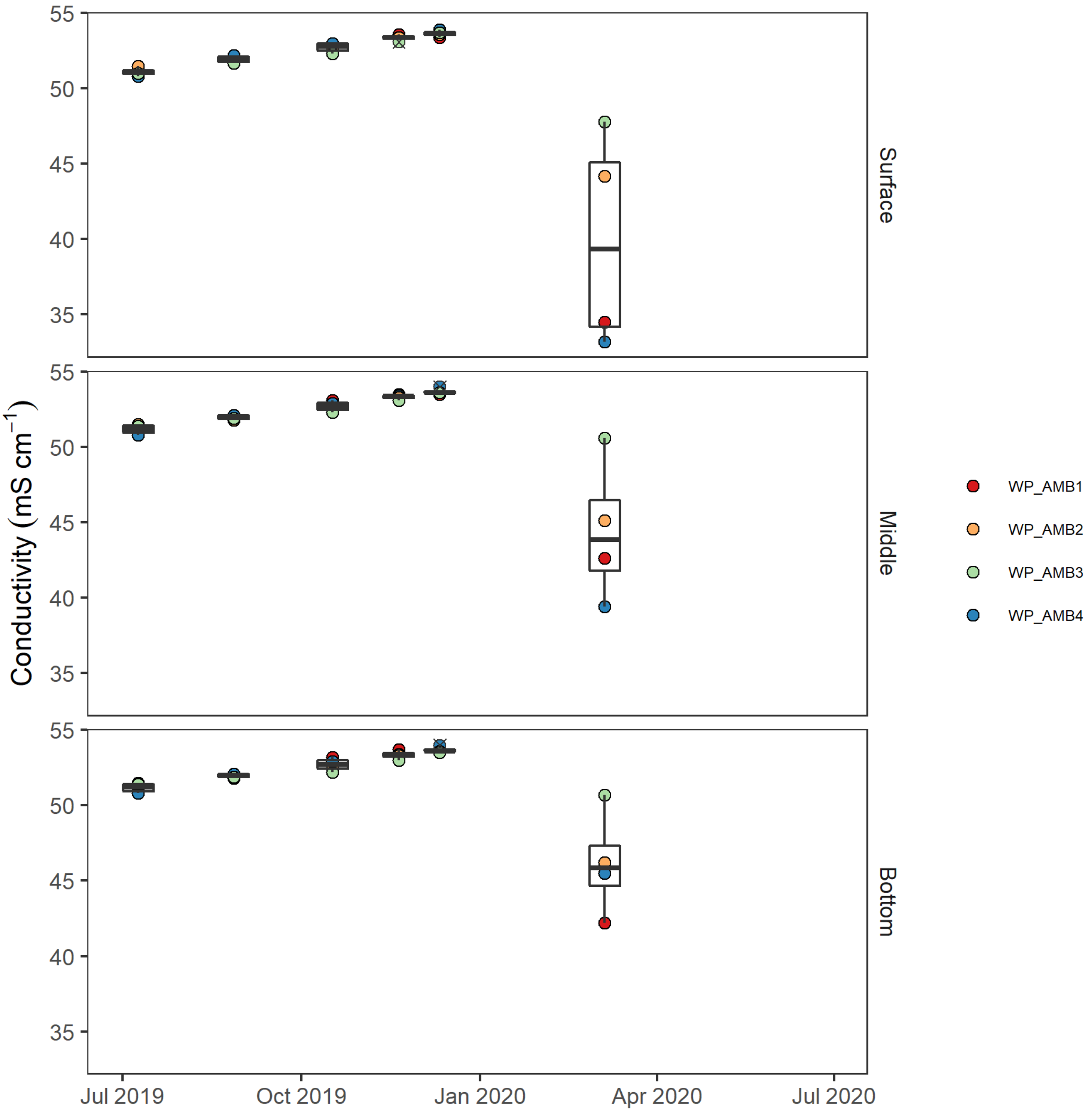



**Figure 3.5** Electrical conductivity recorded at three depths at the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

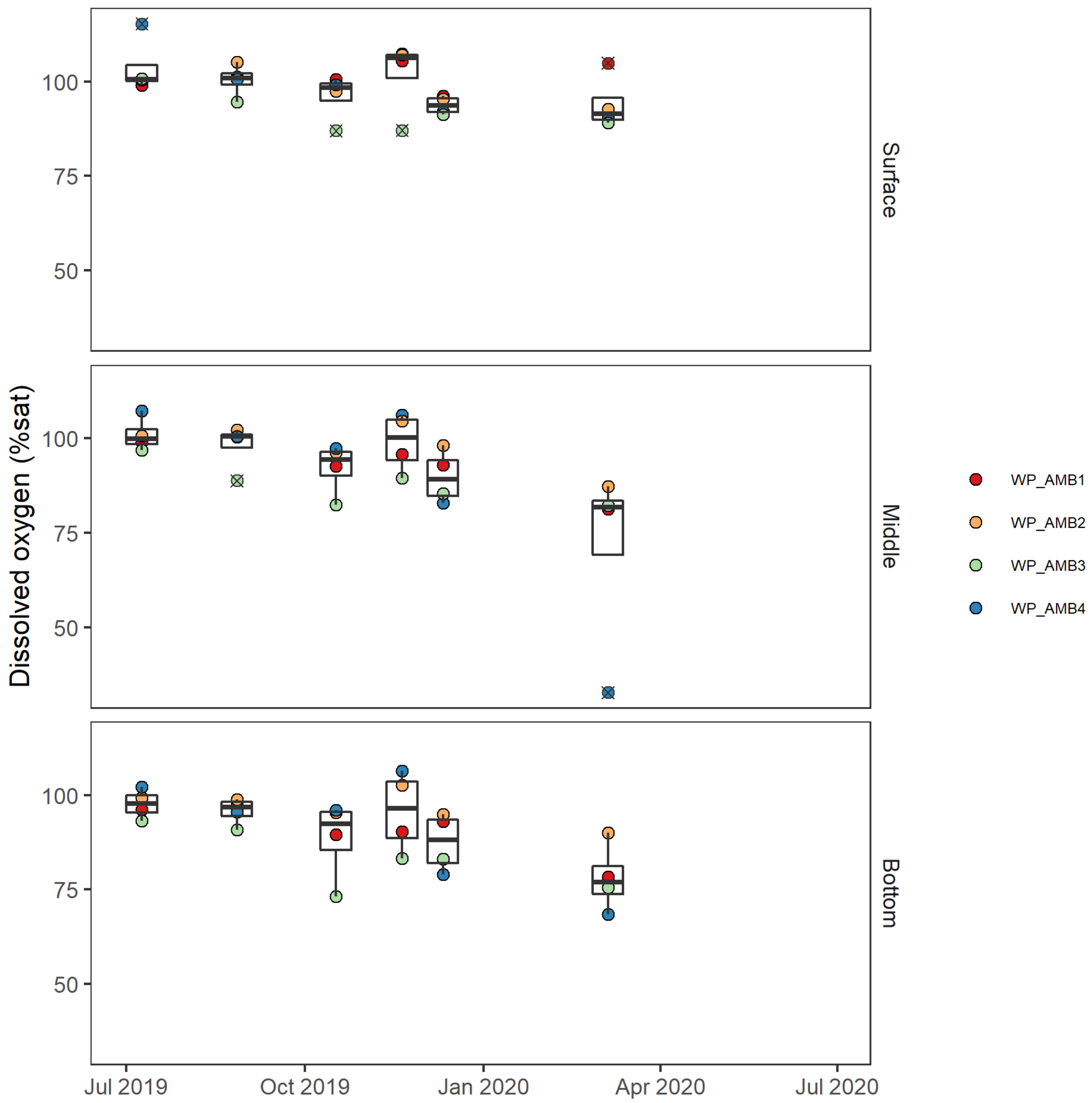



**Figure 3.6** Dissolved oxygen (%sat) recorded at three depths at the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

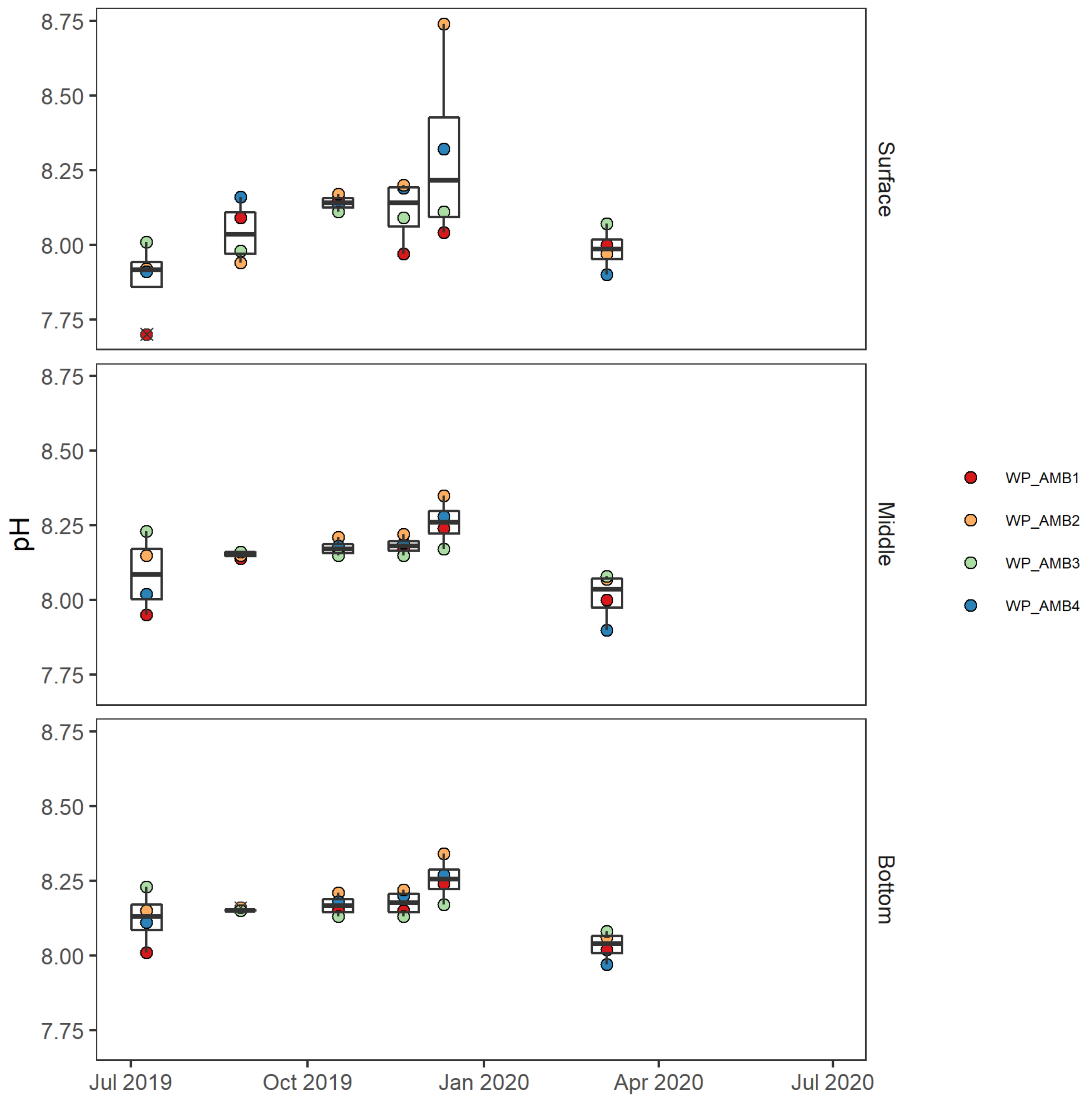



**Figure 3.7** pH recorded at three depths at the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

### 3.2.2 Nutrients, water clarity and chlorophyll-*a*

Particulate nitrogen (PN) and phosphorus (PP) concentrations were compared to the Water Quality Guidelines for the Great Barrier Marine Park Authority (GBRMPA, 2010) and the Queensland Water Quality Guidelines (DEHP, 2013). (Note that Weipa is not within the Great Barrier Reef World Heritage Area (GBRWHA), but GBRMPA guidelines are used to provide context when comparing to NQBP's other east-coast Ports that are located adjacent to the GBRWHA).

Particulate nitrogen (PN) concentrations ranged from 6 to 149 µg $L^{-1}$ (Figure 3.8). Mean PN across the four sites exceeded the GBRMPA guideline trigger value of 20 µg $L^{-1}$ for all sampling events. Particulate phosphorus (PP) concentrations ranged from 1 to 10 µg $L^{-1}$ (Figure 3.9). PP values were much more variable than PN over the reporting period.

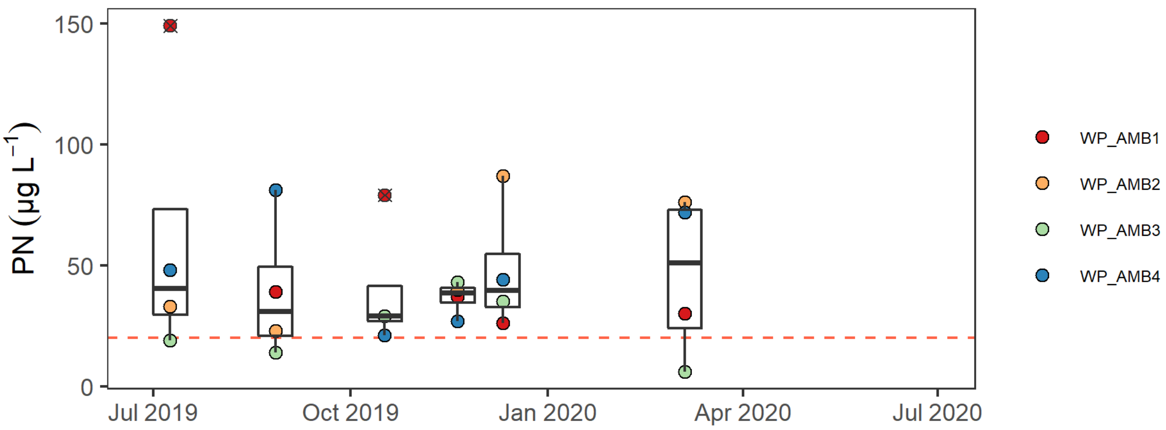



**Figure 3.8** Particulate nitrogen (PN) concentrations measured in water samples collected from the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

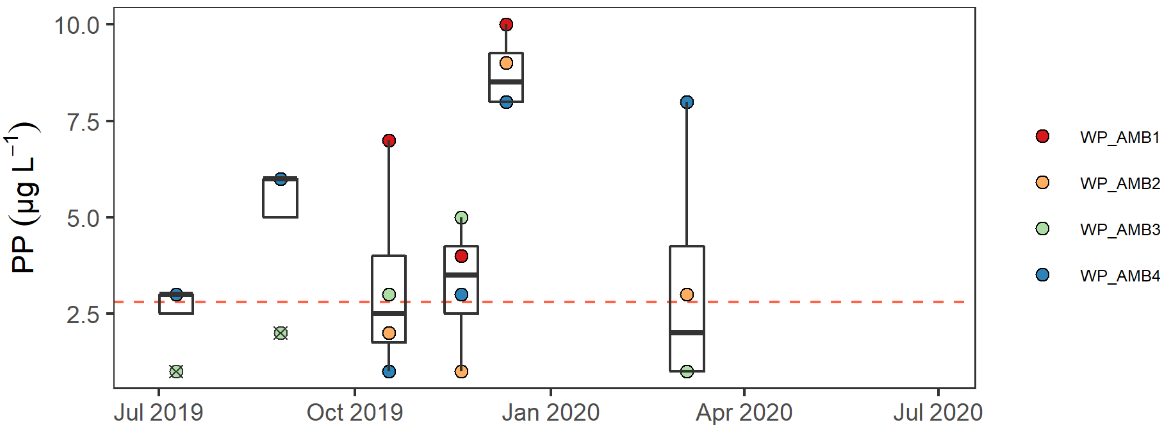



**Figure 3.9** Particulate phosphorus (PP) concentrations measured in water samples collected from the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

Total suspended solids ranged from 1.4 to 10 mg $L^{-1}$ (Figure 3.10). Mean TSS across the five sites exceeded the GBRMPA guideline trigger value of 2.0 mg $L^{-1}$ for all sampling events. Secchi depth ranged from 1.0 to 8.0 m (Figure 3.11). Chlorophyll-*a* concentrations ranged from 0.48 to 3.38 µg $L^{-1}$ (Figure 3.12). Chlorophyll-*a* concentrations exceeded the GBRMPA guideline trigger value for all sampling events.

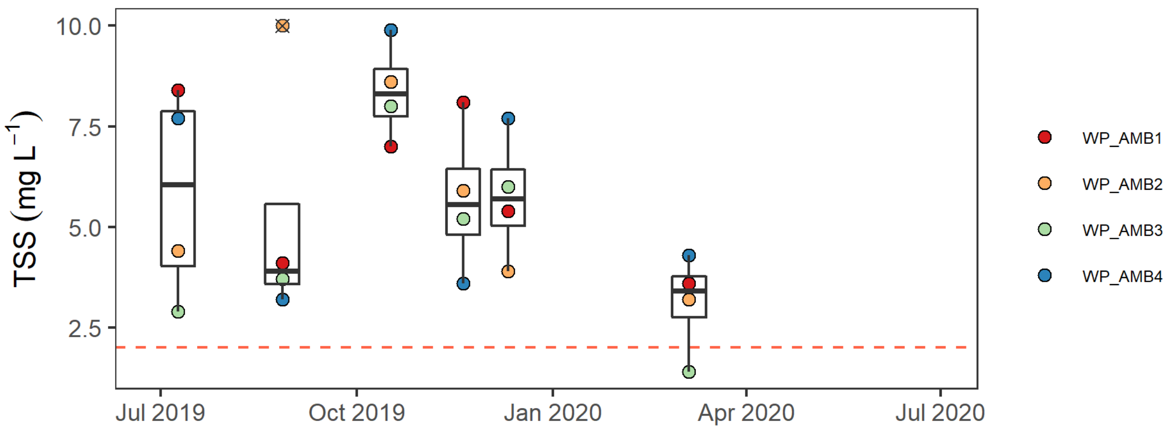



**Figure 3.10** Total suspended solids (TSS) measured in water samples at the four water quality sites throughout the reporting period. Outlier values are marked with an '×'.

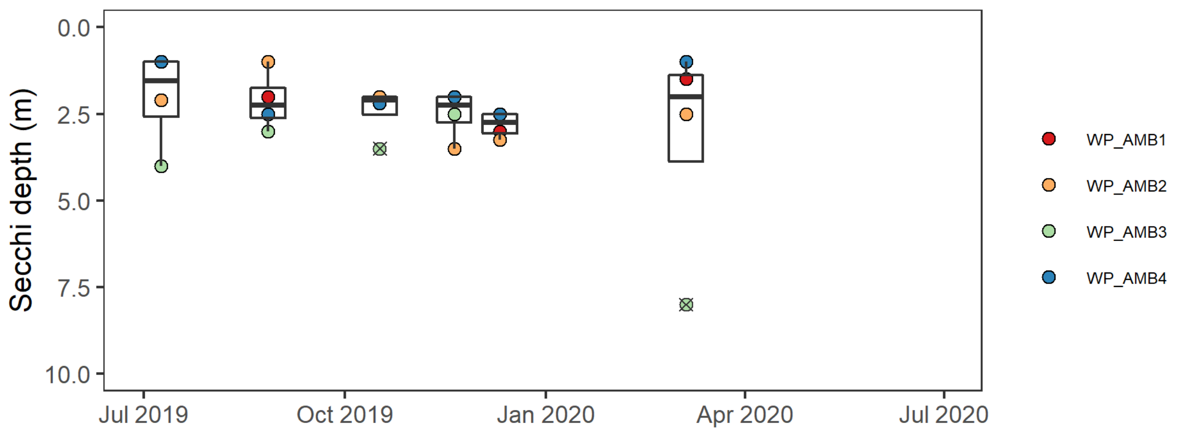



**Figure 3.11** Secchi disk depth recorded at the four water quality sites throughout the reporting period.

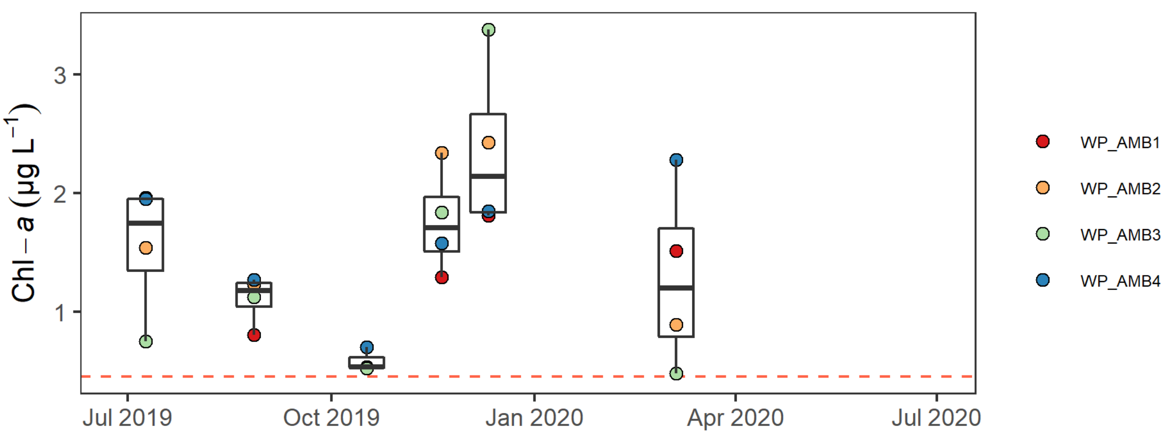



**Figure 3.12** Chlorophyll-*a* concentrations measured in water samples collected from the five water quality sites throughout the reporting period. Outlier values are marked with an '×'.

### 3.2.3 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, Nickel, Zinc, and Mercury were not detected (< LOD). Lead 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.

### 3.2.4 Pesticides

Pesticide concentrations are presented in **Table 3.3**. Concentrations were compared to the Great Barrier Reef Marine Park guideline trigger values for 95% protection level (GBRMPA, 2010). Pesticides targeted for analysis were not detected above the trigger values for the GBR. The herbicides Chlorpyrifos, Diazinon, Hexazinone, and Ametryn were not detected (< LOD). Diuron was detected at low concentrations at all sites. The insecticides Atrazine and Simazine were not detected (< LOD).

**Table 3.2** Heavy metal concentrations measured in water samples collected from the four 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 |
| | | | | | | | | | | | |
| **Aug-19** | 27/08/2019 | WP_AMB1 | WQ1 | < 0.1 | < 0.2 | < 1.0 | < 0.2 | < 0.5 | 1.6 | < 5 | < 0.0001 |
| | 27/08/2019 | WP_AMB2 | WQ2 | < 0.1 | < 0.2 | < 1.0 | 0.2 | < 0.5 | 1.6 | < 5 | < 0.0001 |
| | 28/08/2019 | WP_AMB3 | WQ3 | < 0.1 | < 0.2 | < 1.0 | < 0.2 | < 0.5 | 1.9 | < 5 | < 0.0001 |
| | 27/08/2019 | WP_AMB4 | WQ4 | < 0.1 | < 0.2 | < 1.0 | 0.4 | < 0.5 | 1.7 | < 5 | < 0.0001 |

**Table 3.3** Pesticide concentrations measured in water samples collected from the four water quality sites throughout the reporting period. Great Barrier Reef Marine Park guideline trigger values for 95% protection level are shown for comparison (GBRMPA, 2010).

| Month | Sample_date | Site_code | Site_name | Chlorpyrifos | Diazinon | Hexazinone | Diuron | Ametryn | Atrazine | Simazine |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Units | µg $L^{-1}$ | µg $L^{-1}$ | µg $L^{-1}$ | µg $L^{-1}$ | µg $L^{-1}$ | µg $L^{-1}$ | µg $L^{-1}$ |
| | | | Limit of reporting (LOR) | 0.001 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| | | | ANZECC 95% level | 0.009 | 0.01 | 1.2 | 1.6 | 1 | 1.4 | 3.2 |
| | | | | | | | | | | |
| **Aug-19** | 27/08/2019 | WP_AMB1 | WQ1 | < 0.001 | < 0.002 | < 0.002 | 0.0009 | < 0.002 | < 0.002 | < 0.002 |
| | 27/08/2019 | WP_AMB2 | WQ2 | < 0.001 | < 0.002 | < 0.002 | 0.0006 | < 0.002 | < 0.002 | < 0.002 |
| | 28/08/2019 | WP_AMB3 | WQ3 | < 0.001 | < 0.002 | < 0.002 | 0.0006 | < 0.002 | < 0.002 | < 0.002 |
| | 27/08/2019 | WP_AMB4 | WQ4 | < 0.001 | < 0.002 | < 0.002 | 0.0004 | < 0.002 | < 0.002 | < 0.002 |

## 3.3 Plankton communities

### 3.3.1 Abundance and Diversity

A total of 30 phytoplankton taxa were identified from phytoplankton net tow samples. Phytoplankton abundance ranged from 4530 to 66430 individuals (Figure 3.13). Phytoplankton was dominated by diatoms in October 2019, which shifted to cyanobacteria in March 2020. (Figure 3.14). In March 2020 Trichodesmium sp. was the dominant taxa present. Species richness ranged from 11 to 16 taxa for any one sampling event. Species richness was similar in October 2019 compared with March 2020. Shannon diversity (H') ranged from 0.13 to 1.94. Simpson diversity (D) ranged from 0.04 to 0.83 and was higher in October 2019 than March 2020 for the Embley River sites (WP_AMB1, WP_AMB2, WP_AMB4). Diversity was generally low at the southern WP_AMB3 site, with samples mostly consisting of Cyanobacteria, of which Trichodesmium was the dominant taxa.

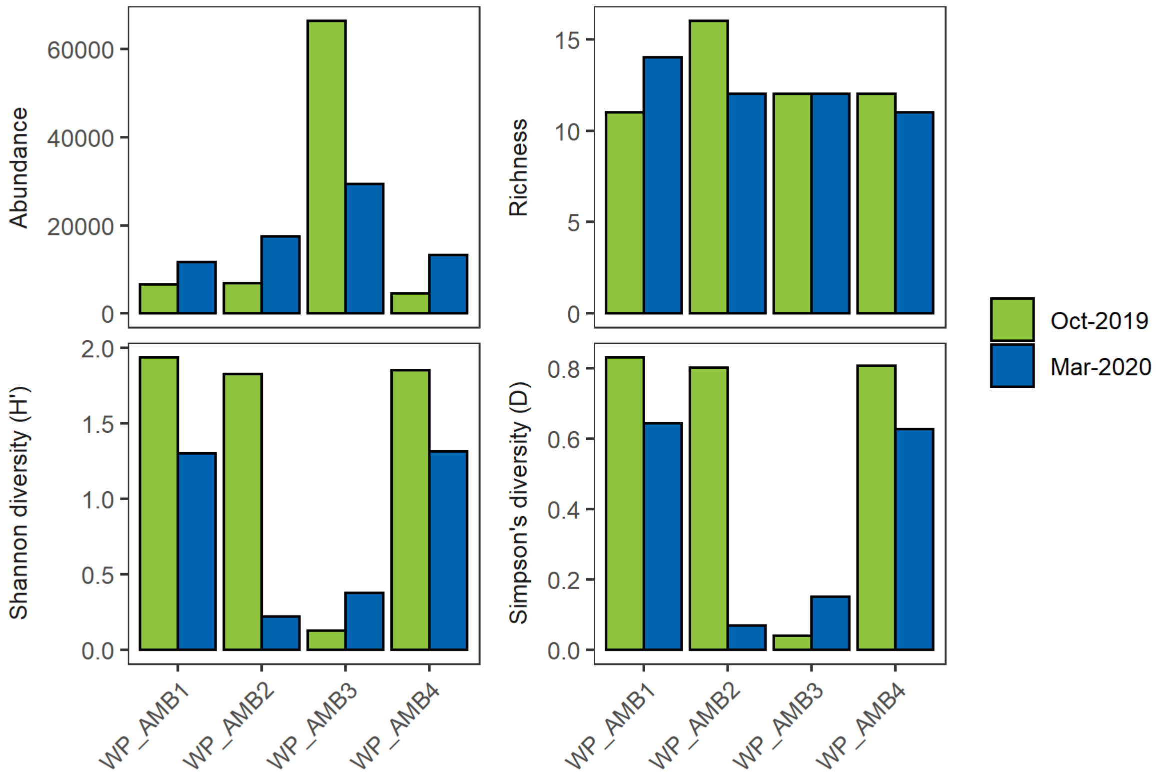



**Figure 3.13** Phytoplankton abundance, richness, and diversity indices calculated at each site during the October 2019 and March 2020 survey events.

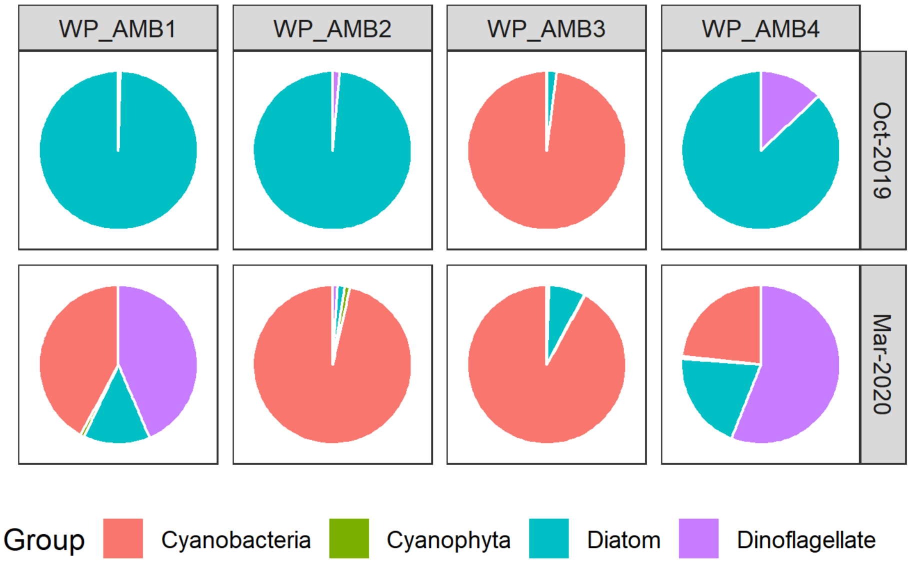



**Figure 3.14** Proportion of individuals present from each phytoplankton group in tow net samples.

A total of 19 zooplankton taxa were recorded during the surveys. Zooplankton abundance ranged from 5 to 207 individuals (Figure 3.15). Species richness ranged from 3 to 9 taxa for any one sampling event. Shannon diversity (H') ranged from 0.71 to 1.80. Simpson diversity (D) ranged from 0.35 to 0.82. The proportion of zooplankton individuals present in tow net samples is shown in Figure 3.16.

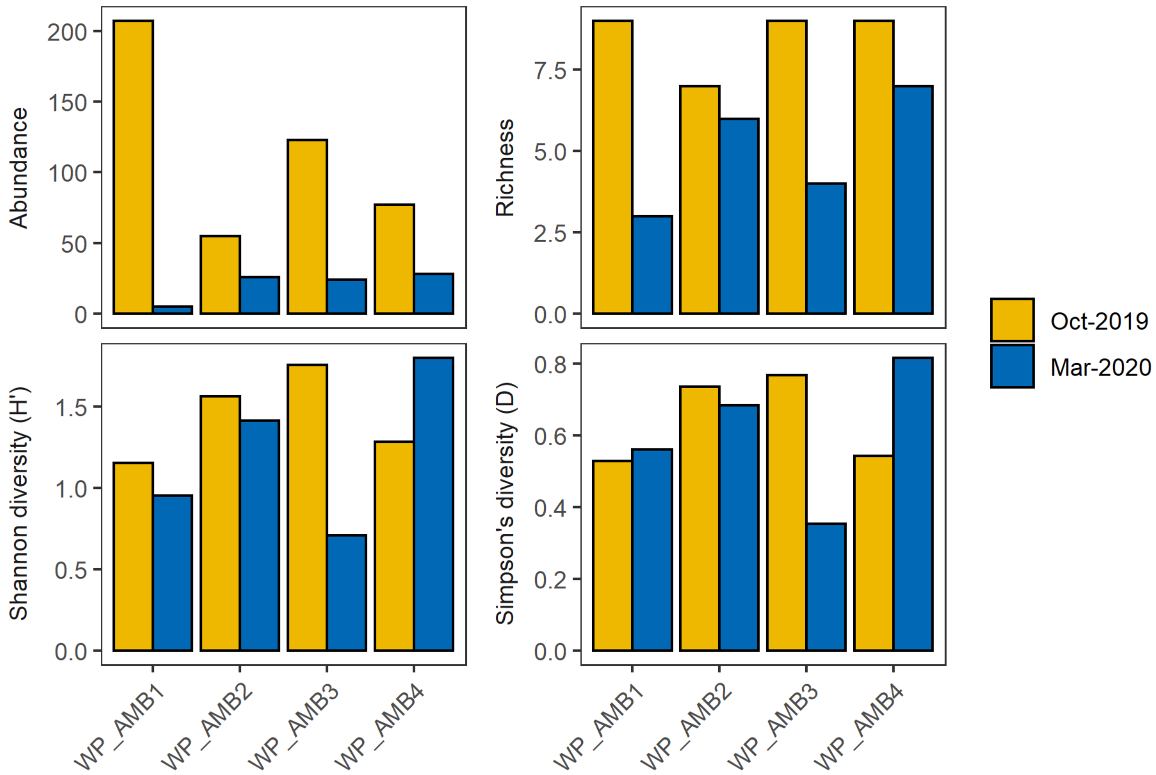



**Figure 3.15** Zooplankton abundance, richness, and diversity indices calculated at each site during the October 2019 and March 2020 survey events.

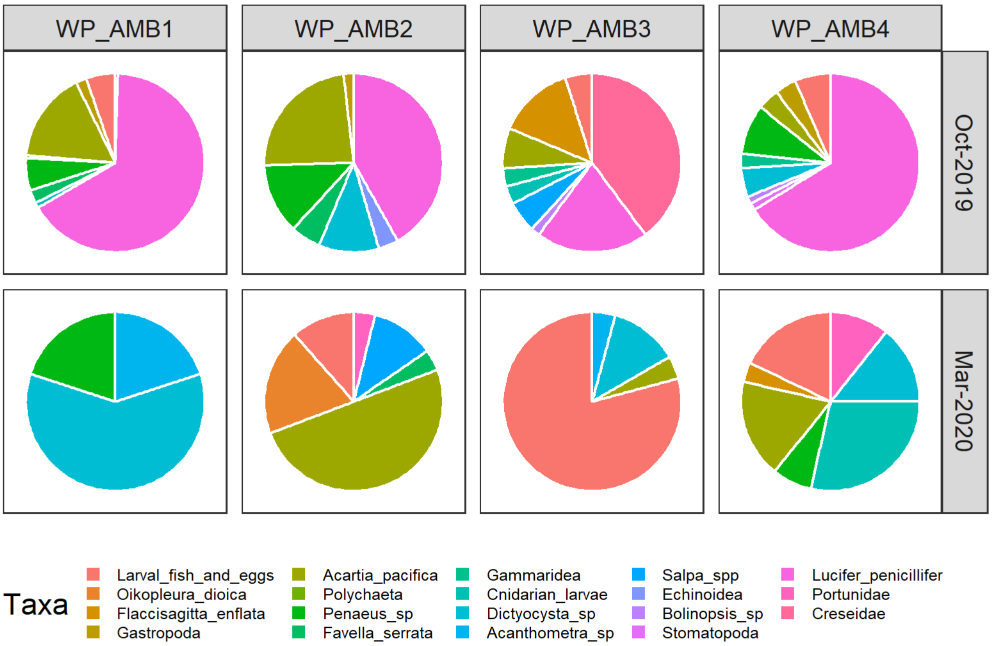



**Figure 3.16** Proportion of zooplankton individuals present in tow net samples.

### 3.3.2 Community structure

The plankton community was visualised via non-metric multidimensional scaling with comparison made between October 2019 and March 2020 sampling events. The phytoplankton community showed dissimilarity between events (**Figure 3.17**, ANOSIM: R = 0.85, *P* = 0.03). Dissimilarity was mostly driven by the Trichodesmium bloom which was present during the March 2020 sampling event. The zooplankton community was similar between sampling events (Figure 3.18, ANOSIM: R = 0.35, *P* = 0.09).

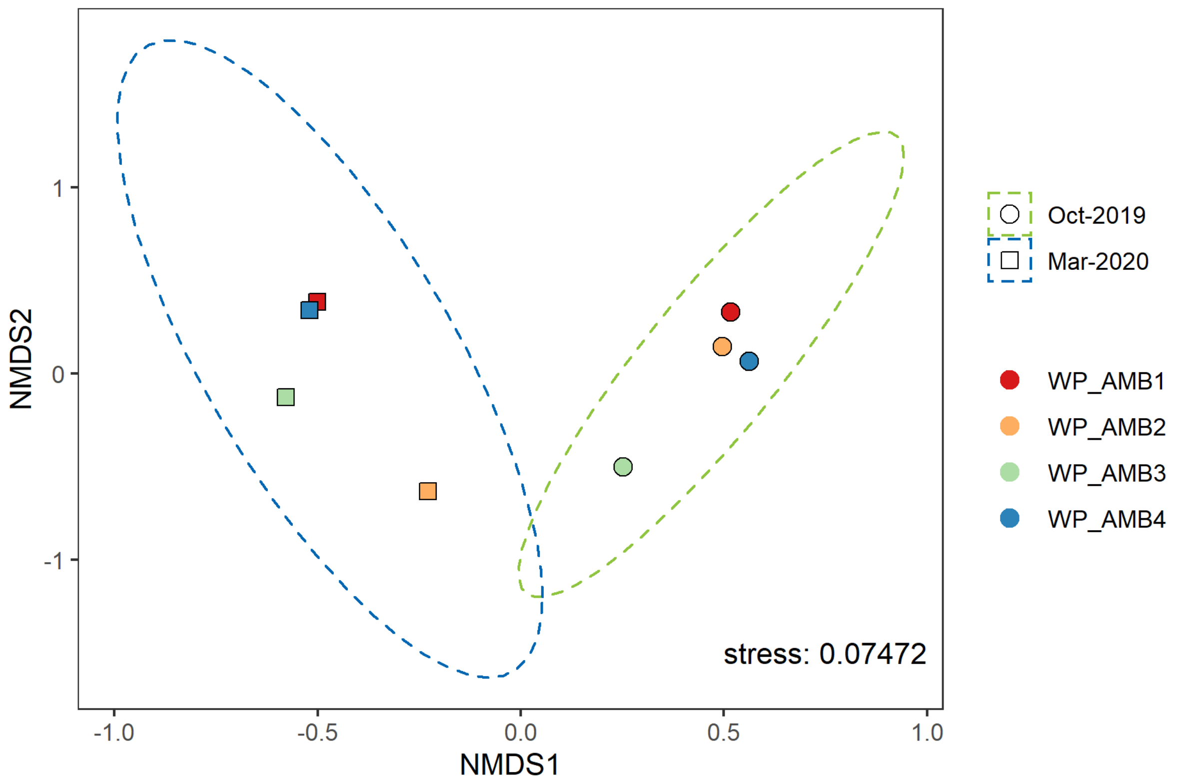



**Figure 3.17** Non-metric multidimensional scaling (nMDS) plot of phytoplankton communities based on abundance data from samples collected during the 2019-2020 period. Ellipses represent 95 % confidence interval for each survey period. Data has been squared root transformed on the Bray Curtis dissimilarity matrix.

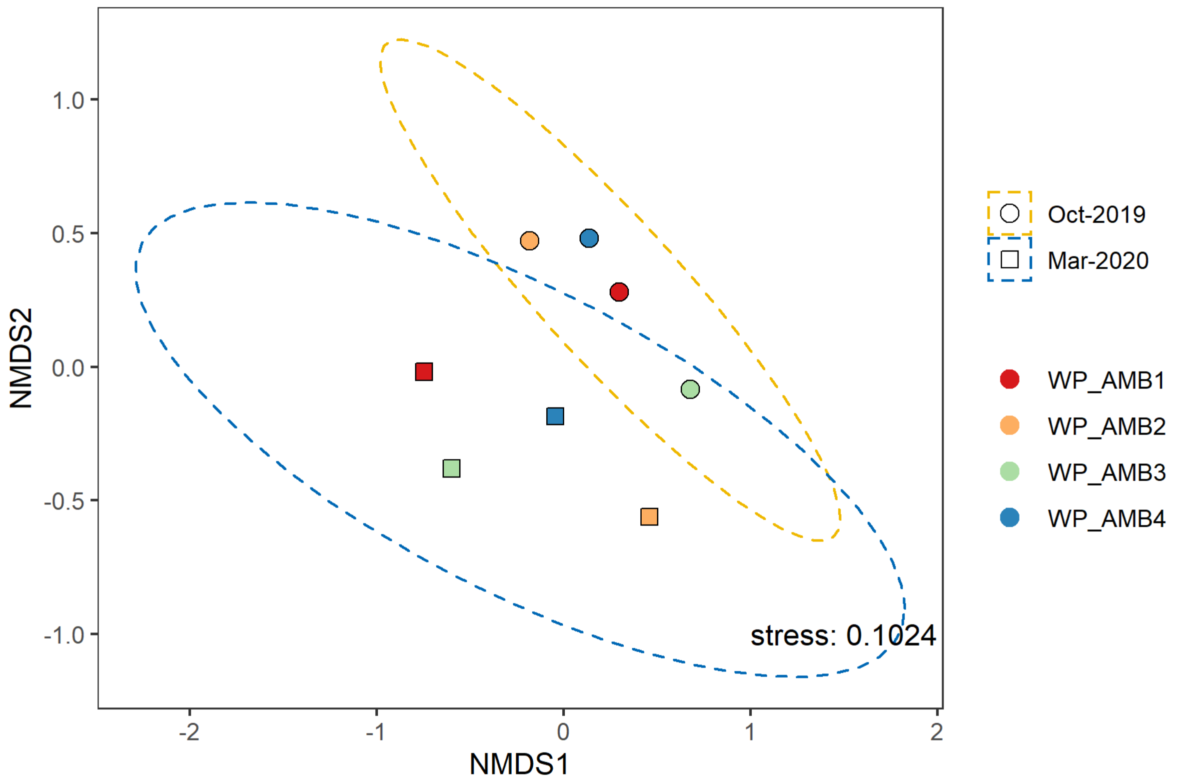



**Figure 3.18** Non-metric multidimensional scaling (nMDS) plot of zooplankton communities based on abundance data from samples collected during the 2019-2020 period. Ellipses represent 95 % confidence interval for each survey period. Data has been squared root transformed on the Bray Curtis dissimilarity matrix.

## 3.4 Multiparameter water quality logger

Instruments were deployed at four sites, WQ 1 to 4, from July 2019 to July 2020 (see Table 3.1). Using standard statistics, we describe observed trends and differences between sites and discuss the driving forces in these environments.

Data is presented as 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 active radiation (PAR; mol $m^{-2}$ $day^{-1}$) for each site. 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 $90^{th}$ and $10^{th}$ percentiles. Time series and monthly summaries are included in the appendices.

### 3.4.1 RMS water height

As mentioned in the methodology, root men square water height (RMS) is a proxy for wave energy or wave shear stress at the ocean floor (Macdonald, 2015). 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.

WQ1 and WQ4, located within the Embley River, were exposed to less wind and wave energy and had lower RMS than WQ2 and WQ3, located on the coast. Median RMS at WQ1 and WQ4 were 20% that of WQ2 and (Figure 3.19, Table 3.4). The upper quartile and $90^{th}$ percentile followed the same pattern, with values at WQ1 and WQ4 approximately 20 % that of WQ2.

The differences in RMS among the four sites has important implications for other water quality parameters. Similar RMS at WQ1 and WQ4 relative to WQ2 and WQ3 indicates that wave energy may explain differences in water quality between the two groups of sites but not within the two pairs of sites. For example, lower RMS would promote more sediment deposition and less sediment resuspension at WQ1 and WQ4 (in the Embley River) compared to WQ2 and WQ3 (on the coast). However, differences in water quality between WQ1 and WQ4 or between WQ2 and WQ3 could be due to different currents, depths, or benthic geologies.

The highest RMS values were observed between January and March (Appendix 1.2, Appendix 1.3).

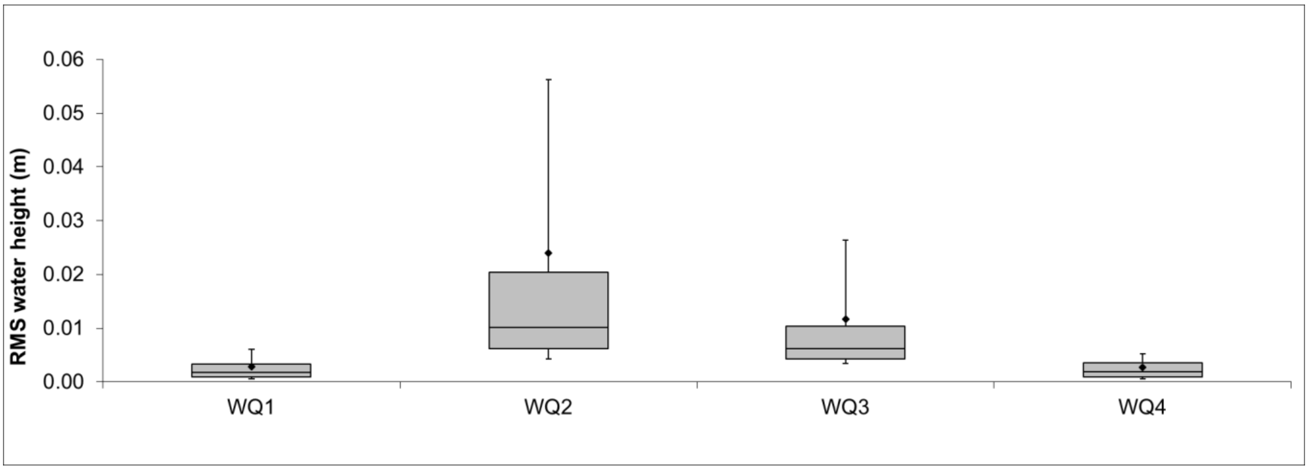



**Figure 3.19** Box plot of root mean square (RMS) of water height (m) at the five sites for the monitoring period from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$ and $90^{th}$ percentiles, respectively. The diamonds represent the mean values.

**Table 3.4** Summary of RMS water height (m) from July 2019 to July 2020.

| Site | WQ1 | WQ2 | WQ3 | WQ4 |
|---|---|---|---|---|
| **Mean** | 0.003 | 0.024 | 0.012 | 0.003 |
| **median** | 0.002 | 0.010 | 0.006 | 0.002 |
| **min** | 0.000 | 0.000 | 0.000 | 0.000 |
| **lower quartile** | 0.001 | 0.006 | 0.004 | 0.001 |
| **upper quartile** | 0.003 | 0.020 | 0.010 | 0.004 |
| **max** | 0.081 | 0.642 | 0.280 | 0.086 |
| **90th percentile** | 0.006 | 0.056 | 0.026 | 0.005 |
| **10th percentile** | 0.001 | 0.004 | 0.003 | 0.001 |
| **n** | 54712 | 54713 | 30988 | 54692 |
| **St. Dev** | 0.003 | 0.041 | 0.017 | 0.003 |
| **St. Error** | 0.000 | 0.000 | 0.000 | 0.000 |

### 3.4.2 NTUe/SSC

Median suspended sediment concentrations (SSC) were ≤12 mg $L^{-1}$ and 75 % quartiles were less than 23 mg $L^{-1}$ (Figure 3.20, Table 3.5). The highest SSC was observed farthest up the Embley River (WQ4), followed by outside the river mouth (WQ2), inside the river mouth (WQ1), and then far down the coast at Pera Heads (WQ3). The relatively high means and 90$^{th}$ percentiles compared to their respective medians indicate that WQ2 and WQ4 experienced more extreme turbidity events than the other sites during this monitoring period.

The NTUe/SSC time series data at each site (seen in Appendix 1.2) typically follows a pattern of low background values with recurring peak events. These peak events typically occur at the same times at each site and coincide with peaks in RMS water height (Ridd et al., 2001). Differences in turbidity between sites result from variation in RMS water height, site depth, benthic geology, hydrodynamics, and proximity to river mouths.

During this reporting period, SSC levels at WQ1 were relatively constant with the highest values observed in March 2020 (Appendix 1.2, Appendix 1.3). SSC at WQ2 was highest in September 2019 in an unusually high end to the dry season, with mean values approximately 5 times higher than wet season months. SSC at WQ3 peaked in July-August 2019 and Nov 2019-March 2020. At WQ4, the highest SSC was observed in July 2019, and April 2020.

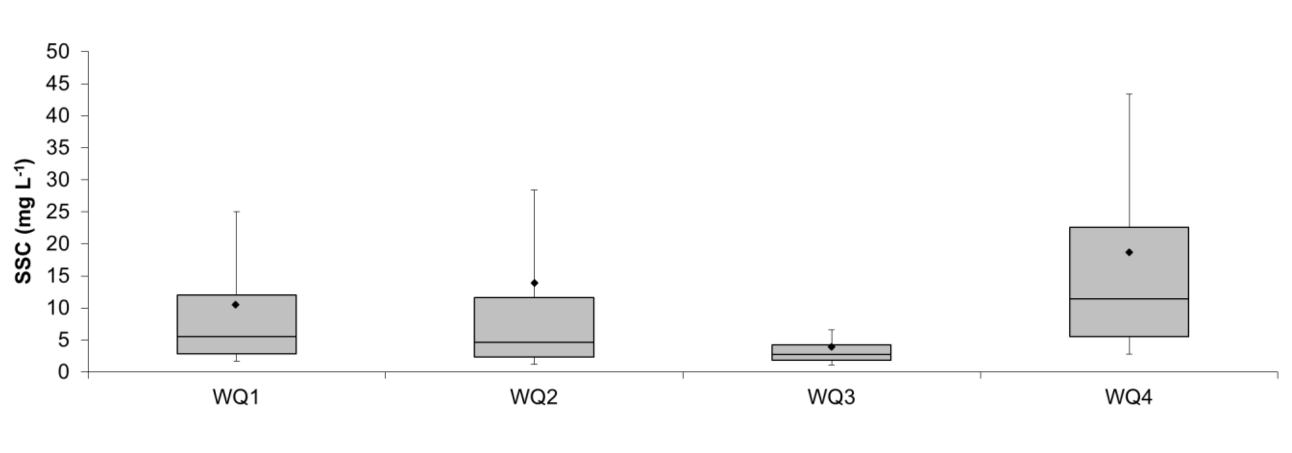



**Figure 3.20** Box plot of SSC (mg $L^{-1}$) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

**Table 3.5** Summary of SSC (mg $L^{-1}$) from July 2019 to July 2020.

| Site | WQ1 | WQ2 | WQ3 | WQ4 |
|---|---|---|---|---|
| **Mean** | 10.47 | 13.89 | 3.92 | 18.67 |
| **median** | 5.50 | 4.67 | 2.78 | 11.41 |
| **min** | 0.00 | 0.00 | 0.00 | 0.02 |
| **lower quartile** | 2.84 | 2.32 | 1.82 | 5.57 |
| **upper quartile** | 12.02 | 11.64 | 4.28 | 22.62 |
| **max** | 247.41 | 429.51 | 123.06 | 233.04 |
| **90th percentile** | 25.01 | 28.38 | 6.59 | 43.38 |
| **10th percentile** | 1.64 | 1.23 | 1.09 | 2.78 |
| **n** | 41574 | 37785 | 20272 | 35052 |
| **St. Dev** | 14.46 | 33.53 | 5.46 | 21.61 |
| **St. Error** | 0.07 | 0.17 | 0.04 | 0.12 |

### 3.4.3 Deposition

Deposition of sediment is a natural process in all coastal marine waters. Suspended sediment deposits 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 1.2). 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 and 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 (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.

Deposition rates were highest at WQ3 (Figure 3.21, Table 3.6). WQ4 had the second highest median deposition rate, followed by WQ2 and WQ1.

The monthly statistics indicate that deposition rates were variable within the Embley River (WQ1, WQ4) in June and July 2019 (Appendix 1.2, Appendix 1.3). Deposition rates outside the Embley River (WQ2, WQ3) were relatively high during May and June 2020.

Differences in deposition rates may be more easily visualised by estimating the thickness of the sediment deposited. For example, using the relationship between density, mass and volume: median deposition value of 5 mg cm$^{-2}$ day$^{-1}$ is equivalent to a layer of sediment of thickness less than 35 µm, assuming a sediment density of 1.5 g cm$^{-3}$.

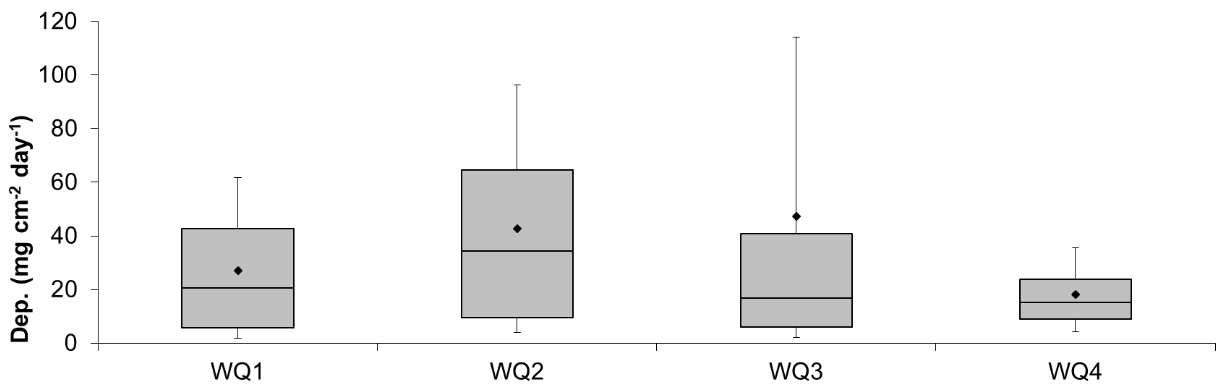



**Figure 3.21** Box plot of deposition rates (mg cm$^{-2}$ day$^{-1}$) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

**Table 3.6** Summary of the mean daily deposition rate (mg cm$^{-2}$ day$^{-1}$) statistics from July 2019 to July 2020.

| Site | WQ1 | WQ2 | WQ3 | WQ4 |
|---|---|---|---|---|
| **Mean** | 27.13 | 42.73 | 47.27 | 18.24 |
| **median** | 20.67 | 34.42 | 16.73 | 15.24 |
| **min** | 0.29 | 0.00 | 0.25 | 2.21 |
| **lower quartile** | 5.74 | 9.60 | 5.98 | 8.92 |
| **upper quartile** | 42.64 | 64.56 | 40.88 | 23.80 |
| **max** | 106.33 | 244.36 | 675.09 | 65.23 |
| **90th centile** | 61.80 | 96.29 | 114.25 | 35.65 |
| **10th centile** | 1.85 | 3.85 | 1.97 | 4.25 |
| **n** | 236 | 254 | 181 | 228 |
| **St. Dev** | 24.74 | 39.81 | 98.21 | 12.75 |
| **St. Error** | 1.61 | 2.50 | 7.30 | 0.84 |

### 3.4.4 Water temperature

Water temperatures were similar among all sites with medians of 27-29 °C and similar ranges of temperatures (Figure 3.22, Table 3.7). Water temperatures were highest in December-March and lowest in July-August (Appendix 1.2, Appendix 1.3). 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, and across the GBR (e.g. Johansen et al., 2015).

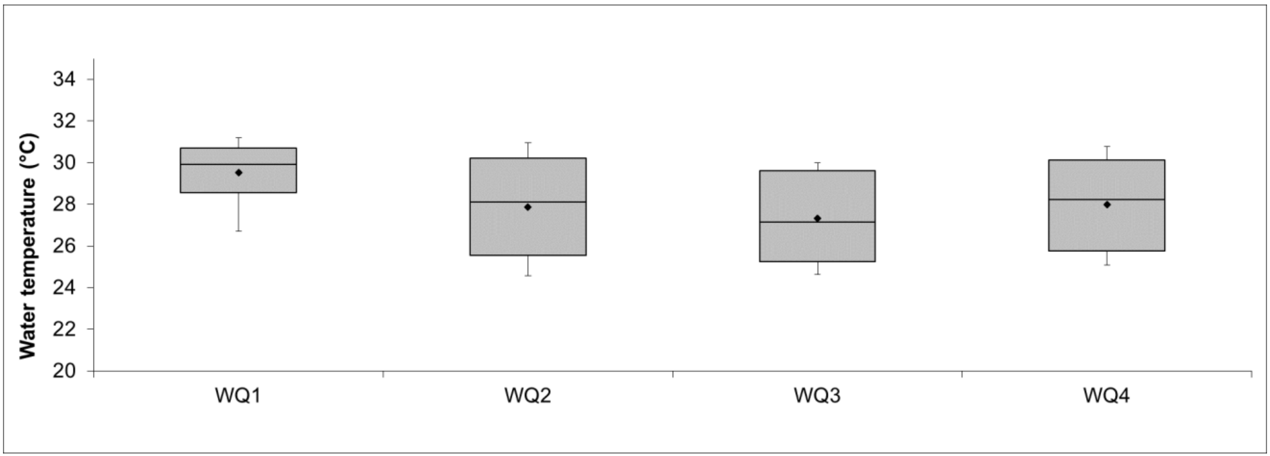



**Figure 3.22** Box plot of the water temperature (°C) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

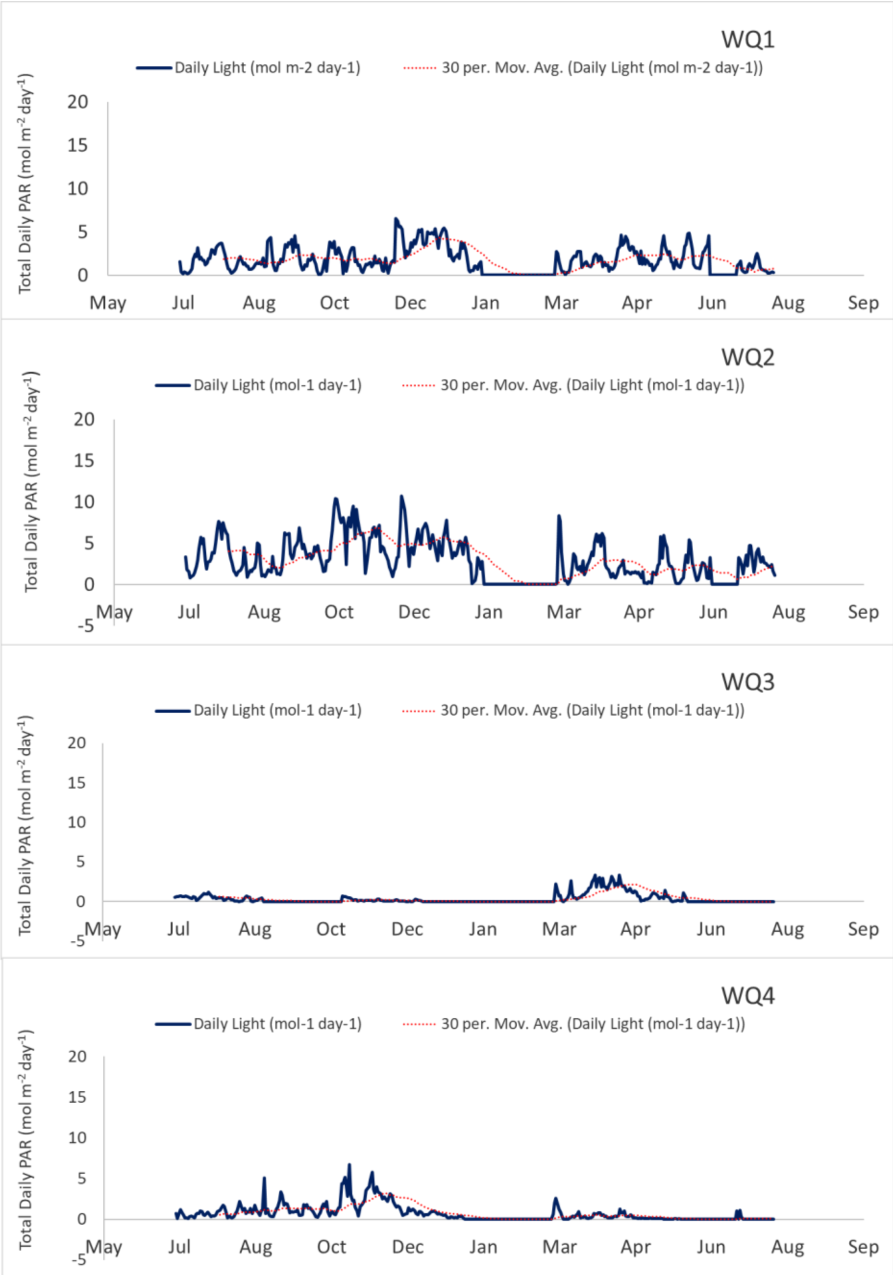
**Table 3.7** Summary of water temperature (°C) from July 2019 to July 2020.

| Site | WQ1 | WQ2 | WQ3 | WQ4 |
|---|---|---|---|---|
| **Mean** | 29.51 | 27.88 | 27.34 | 28.00 |
| **median** | 29.92 | 28.10 | 27.13 | 28.24 |
| **min** | 25.50 | 23.04 | 23.83 | 0.00 |
| **lower quartile** | 28.57 | 25.54 | 25.24 | 25.77 |
| **upper quartile** | 30.70 | 30.21 | 29.62 | 30.13 |
| **max** | 32.34 | 31.93 | 30.99 | 31.87 |
| **90th centile** | 31.18 | 30.94 | 29.99 | 30.78 |
| **10th centile** | 26.71 | 24.56 | 24.64 | 25.07 |
| **n** | 34932 | 54666 | 30962 | 54663 |
| **St. Dev** | 1.56 | 2.49 | 2.07 | 2.28 |
| **St. Error** | 0.01 | 0.01 | 0.01 | 0.01 |

### 3.4.5 Photosynthetically active radiation (PAR)

Mean levels of benthic photosynthetically active radiation (PAR) ranged from 0.97 to 3.49 mol $m^{-2}$ $day^{-1}$ (Figure 3.23, Table 3.8). WQ2 had the highest median and variance in PAR. WQ3 had the lowest median PAR but also had light levels within the range observed at the other sites.

Benthic PAR was highly variable throughout the year, but PAR highest in October-December for WQ1, WQ2




and WQ4 (

**Figure 3.24**, Figure 3.25). Semi-regular oscillations between low and high PAR were overridden by larger episodic events caused by storm or rainfall.

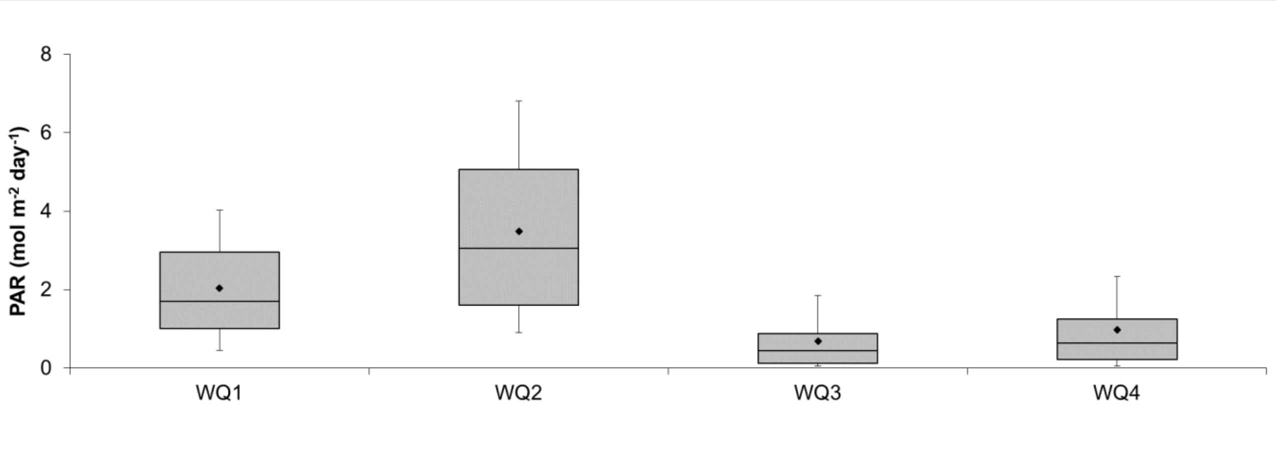



**Figure 3.23** Box plot of daily PAR (mol $m^{-2}$ $day^{-1}$) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

**Table 3.8** Summary of daily PAR (mol $m^{-2}$ $day^{-1}$) from July 2019 to July 2020.

| Site | WQ1 | WQ2 | WQ3 | WQ4 |
|---|---|---|---|---|
| **Mean** | 2.03 | 3.49 | 0.68 | 0.97 |
| **median** | 1.70 | 3.05 | 0.45 | 0.63 |
| **min** | 0.00 | 0.06 | 0.00 | 0.00 |
| **lower quartile** | 1.00 | 1.60 | 0.12 | 0.21 |
| **upper quartile** | 2.95 | 5.07 | 0.87 | 1.24 |
| **max** | 6.58 | 10.69 | 3.34 | 6.71 |
| **90th percentile** | 4.02 | 6.80 | 1.86 | 2.34 |
| **10th percentile** | 0.45 | 0.90 | 0.05 | 0.05 |
| **n** | 331 | 330 | 199 | 296 |
| **St. Dev** | 1.38 | 2.30 | 0.76 | 1.09 |
| **St. Error** | 0.08 | 0.13 | 0.05 | 0.06 |

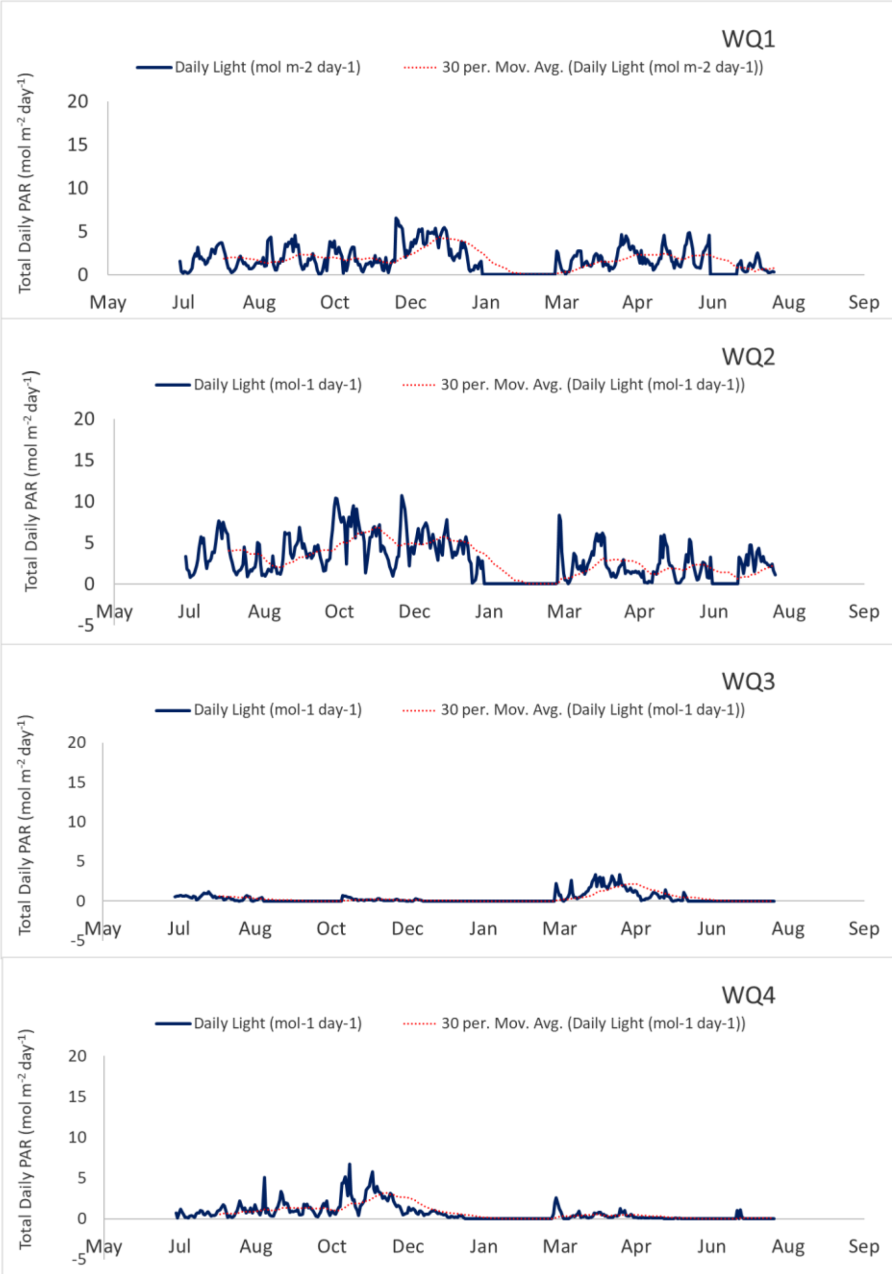



**Figure 3.24** Time series of total daily PAR (mol $m^{-2}$ $day^{-1}$) from July 2019 to July 2020. Daily mean PAR is plotted in blue and a 2-week moving average of daily mean PAR is plotted in red.

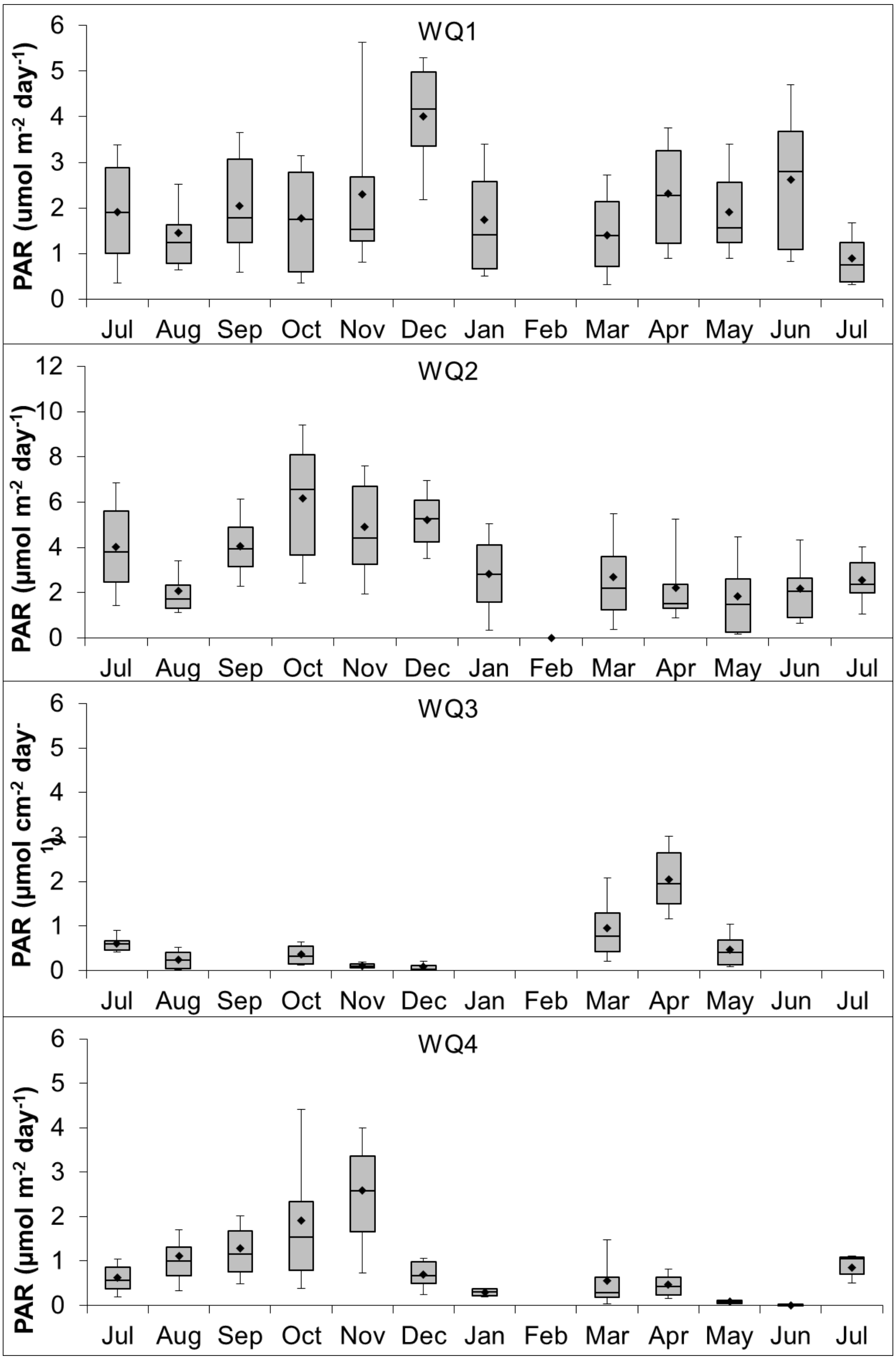



**Figure 3.25** Monthly boxplots illustrating the variation in total daily PAR (mol m$^{-2}$ day$^{-1}$) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10$^{th}$, 25$^{th}$, 50$^{th}$, 75$^{th}$ and 90$^{th}$ percentiles, respectively. The diamond represents the mean value. Note for WQ2, the y-axis limit is double that of the other sites.

***Similarities in patterns of PAR among sites***

There are no significant relationships between the benthic PAR at different sites (

Figure **3.26**). This highlights the influence of site-specific conditions (depth, turbidity, etc.) on benthic irradiance. WQ1 and WQ4 and WQ2 have the strongest associations ($R^2$ ~ 0.2) whilst the other sites have associations even less than this. This analysis assists in understanding site redundancy opportunities, without missing important detail in characterising water quality in the region.

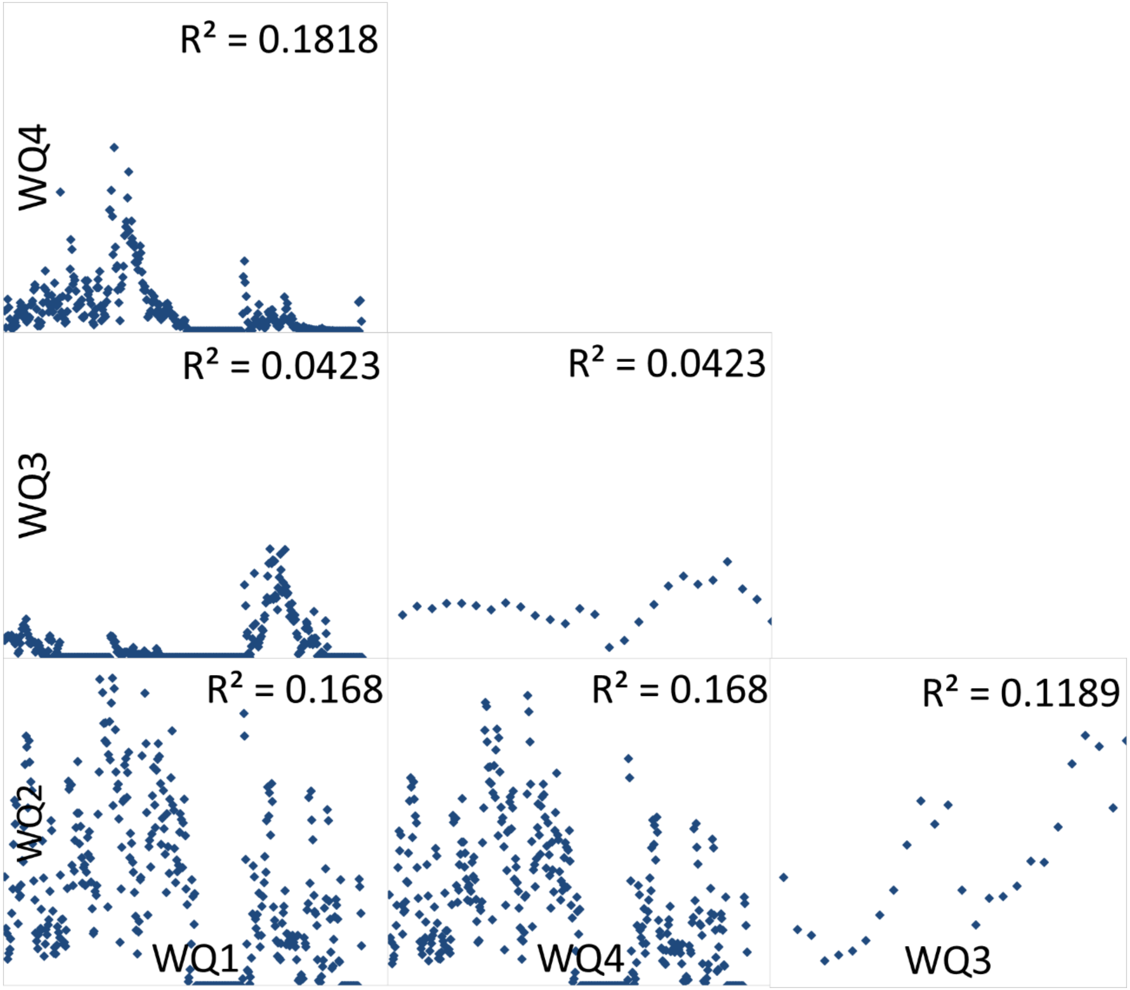



**Figure 3.26** Scatterplots of PAR between sites indicating the strength of the relationships between patterns of daily PAR for 2019-2020. $R^2$ values are presented for each comparison.

### 3.4.6 Seasonal variation: wet vs dry seasons

A comparison of wet and dry season water quality (2017-2020) suggests that, with some exceptions, periods of increased RMS, SSC, deposition rates, and increased PAR during the wet season.

***RMS water height***

Median, mean and upper quartile values were higher during wet seasons across all sites (Figure 3.27). Median RMS the wet season was double that of the dry season at most sites. The expanded upper quartiles indicate more periods of high RMS during the wet seasons. There was not a great difference in RMS between the 2019-2020 data and the cumulative 2017-2020 seasonal data.

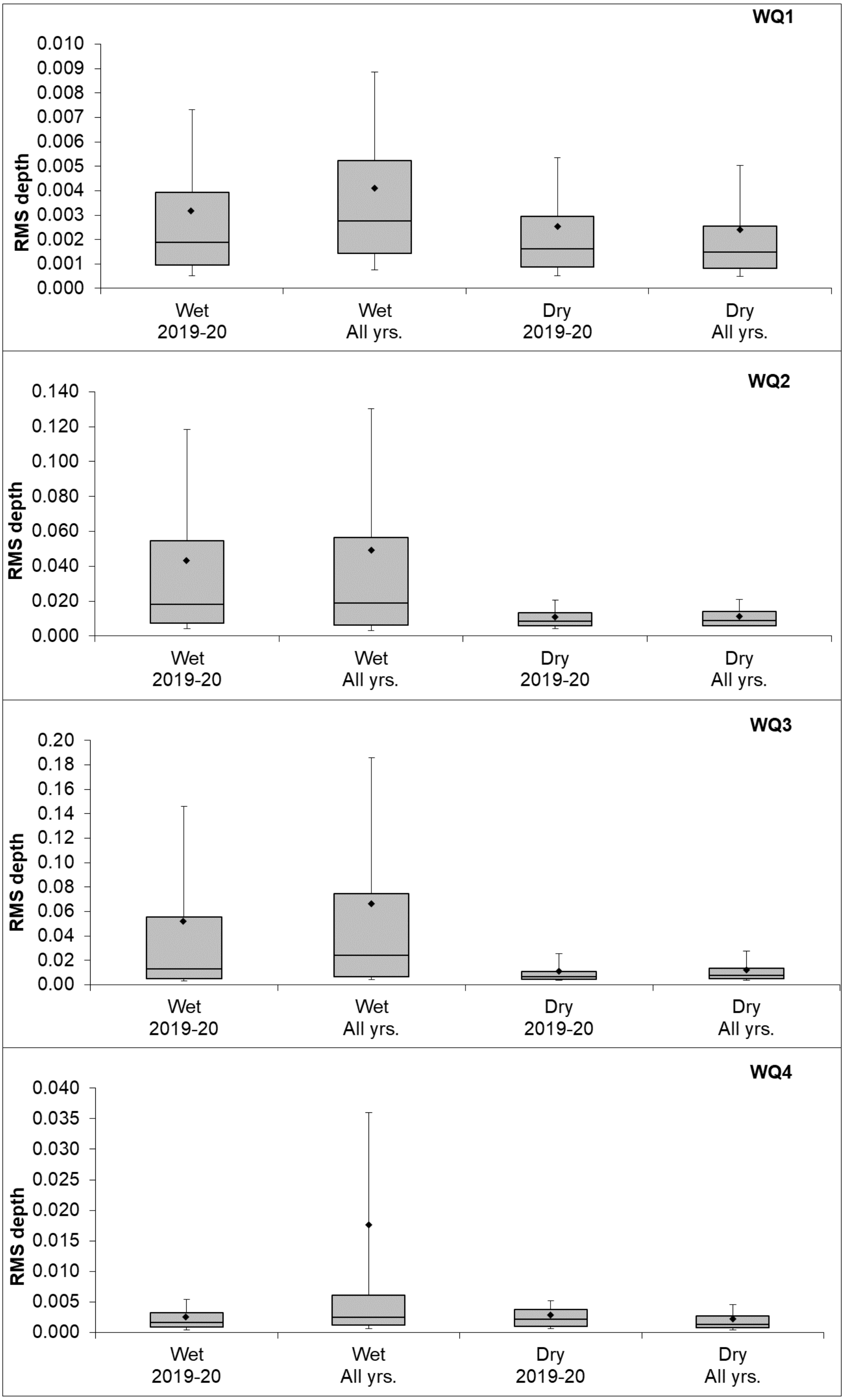



**Figure 3.27** RMS box plots for WQ1-WQ4. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or three wet seasons (2017-2020).

***NTUe/SSC***

Differences in suspended sediment concentration (SSC) between seasons are less straightforward than for RMS. While median SSC was somewhat similar between wet and dry seasons, the SSC upper quartiles were typically three-fold higher during the wet season, indicating more extreme turbidity events (e.g. WQ2, WQ3, WQ4; Figure 3.28). The exception to this was WQ2, which showed unusually small SSC statistics for the current wet season. Notably, SSC at WQ1 was relatively constant throughout the deployment period (Figure 3.28, Appendix 1.3).

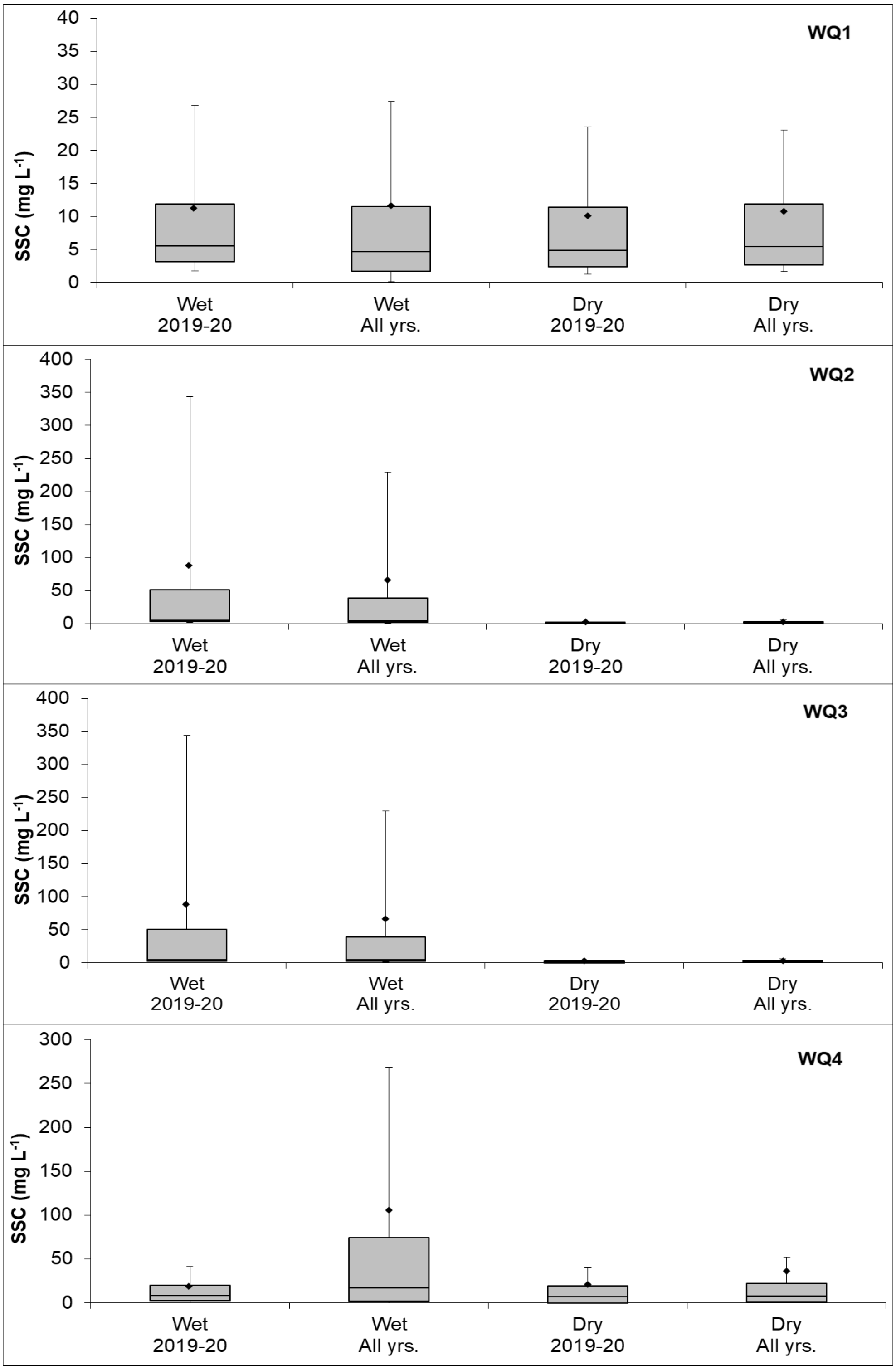



**Figure 3.28** SSC box plots for WQ1-WQ4. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or three wet seasons (2017-2020).

***Deposition***

Median deposition rates were lower during the wet season compared to the dry for WQ1 and WQ2 (Figure 3.29). The most apparent seasonal pattern was higher deposition rates at WQ3, with maximum rates being over three times higher than the other sites (Appendix 1.3).

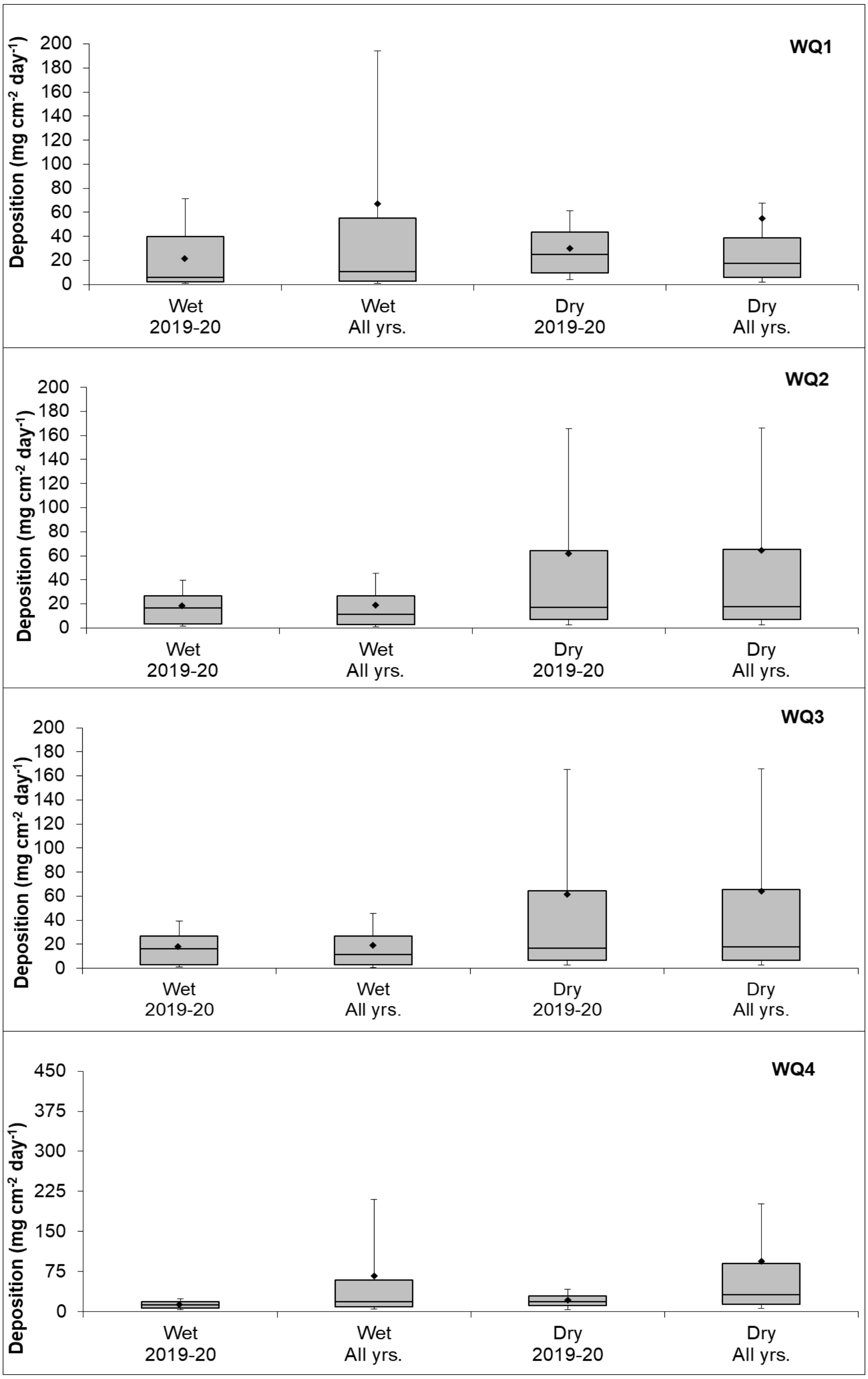



**Figure 3.29** Deposition box plots for WQ1-WQ4. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or three wet seasons (2017-2020).

***Photosynthetically active radiation***

Photosynthetically active radiation (PAR) could differ between seasons due to longer day length or increased cloud cover during the wet season. Seasonal differences in PAR overall much less than seen in previous years (Figure 3.31). WQ1 and WQ2 had largely similar upper PAR values during both seasons. Comparison of these four sites suggest that there isn't a general pattern in PAR between seasons, especially at sites close to shore. Differences in depth, distance from the coast, and distance from river mouths may influence how PAR differs between seasons at a given location.

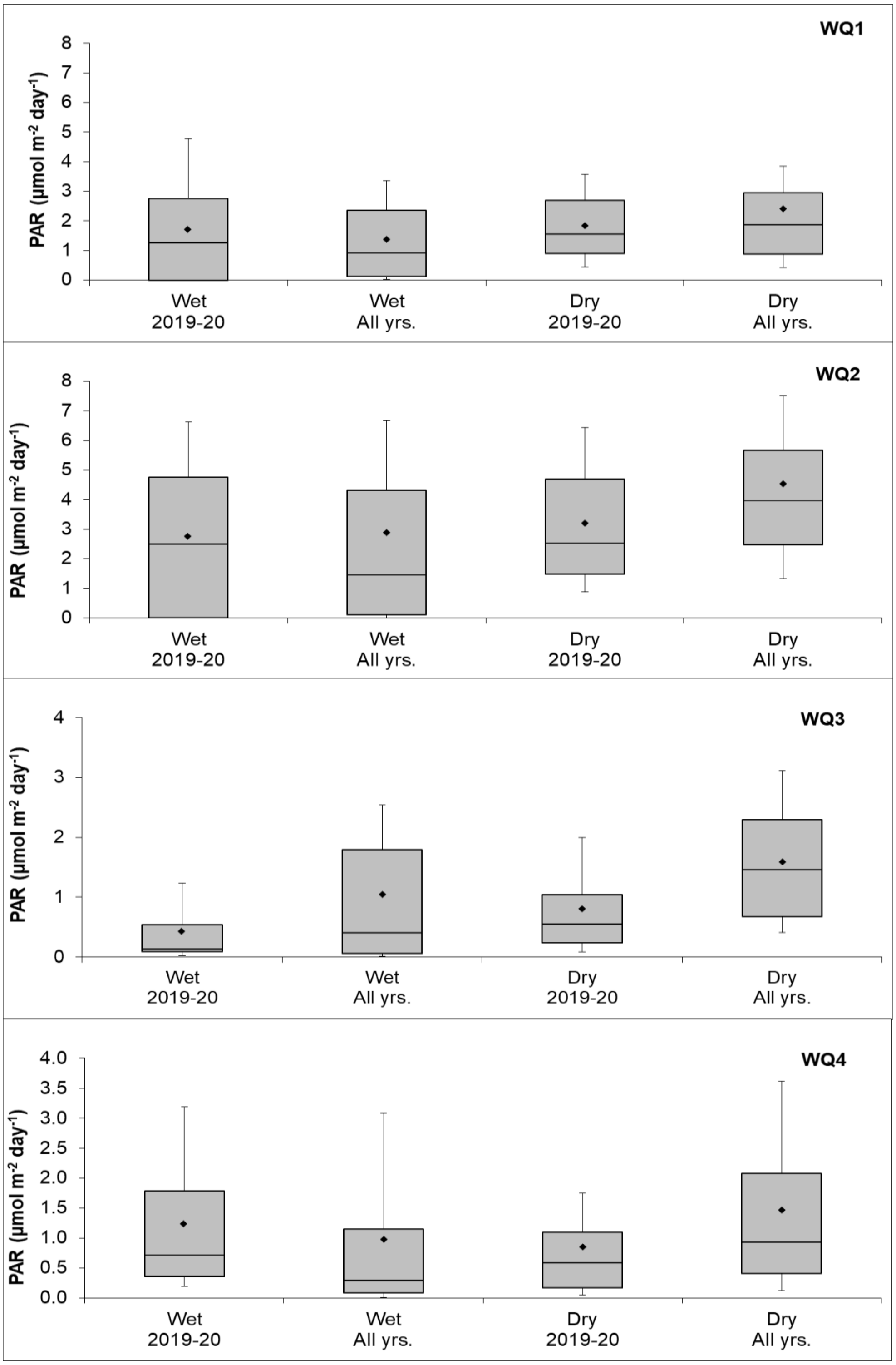



**Figure 3.30** PAR box plots for WQ1-WQ4. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or three wet seasons (2017-2020).

***Water temperature***

Temperatures were higher during the wet season, typically >28 °C, and lower during the dry season, typically <28 °C (Figure 3.30). Median temperatures were ~30 °C in the wet season and ~27 °C in the dry season. Median temperatures during the 2019-2020 dry season at WQ3 and WQ4 were similar to the combined 2017-2020 dry seasons. This is in contrast to the previous annual reporting period, where medians were found to be much higher in the dry season.

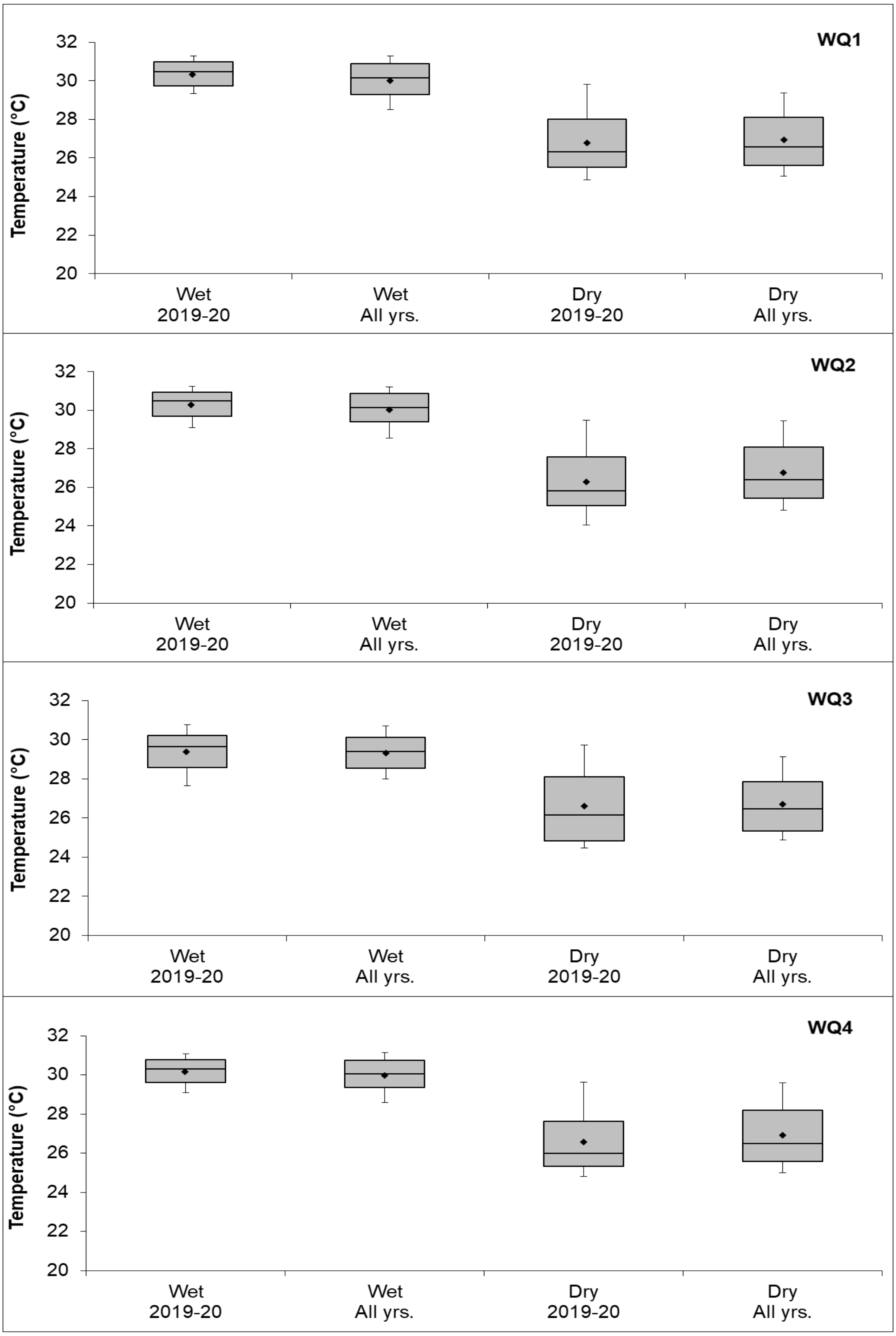



**Figure 3.31** Water temperature box plots for WQ1-WQ4. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or three wet seasons (2017-2020).

### 3.5 Current meter

Current meter data was collected at all four sites. The current meter data indicates the prominent current direction, velocity 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 below display the current meter data in current rose and average current speed rose diagrams. The current rose diagrams provide a visual representation of relative prominence of current velocity and direction. The average current speed rose diagrams displays the average current speed in every direction. Presented together these diagrams highlight the prominent direction of current and the average velocity of the current in this direction. The monitoring periods that were achieved from Instrument deployments are listed below for the four sites:

| Site name | Site code | Monitoring start | Monitoring end |
|---|---|---|---|
| **WQ1** | AMB 1 | 1st July 2019 | 18th June 2020 |
| **WQ2** | AMB 2 | 1st July 2019 | 5th May 2020 |
| **WQ3** | AMB 3 | 1st July 2019 | 16th June 2020 |
| **WQ4** | AMB 4 | 1st July 2019 | 22nd June 2020 |

Videos illustrating the overtime change of current speed and direction at each collection site is shared privately on YouTube:

- Long video(monthly): https://www.youtube.com/watch?v=2sFlHIInSi0
- Short video(yearly): https://www.youtube.com/watch?v=g0a8nT16cv8

The three figures that are found on the next two pages present the current meter data individually for all four sites and across the achieved monitoring periods:

- A rose-plot displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading*).
- A rose-plot displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*).
- A bivariate plot presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*).

And presented together, these figures highlight the overall current direction experienced at each collection site as well as providing a summary for a range of typically experienced water temperatures (°C) and current speeds(m/s) with respect to current direction(heading*).

*heading is defined by degrees (angle) rotating clockwise from facing North.

### 3.5.1 Current Speed, Direction and Temperature

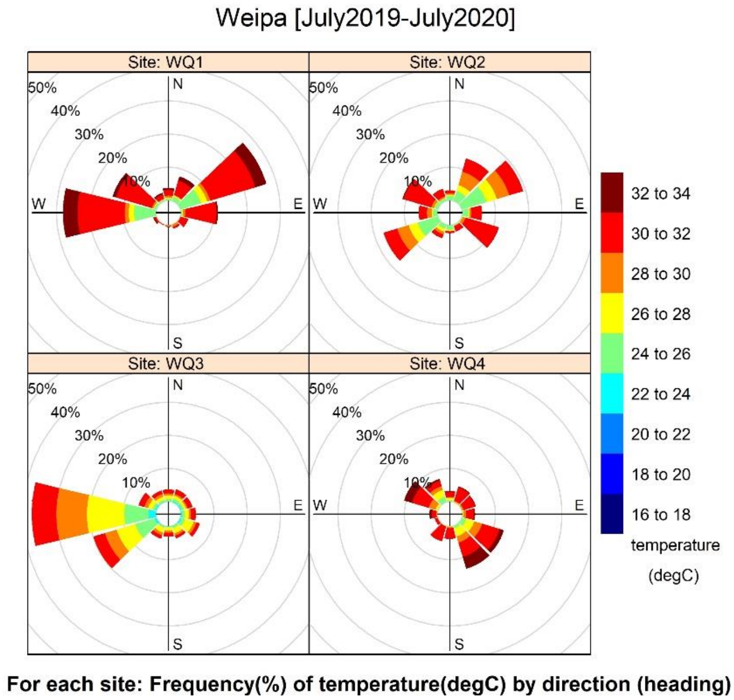



**Figure 3.32** Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction(heading), for each of the four sites over the monitoring period July 2019 to July 2020.

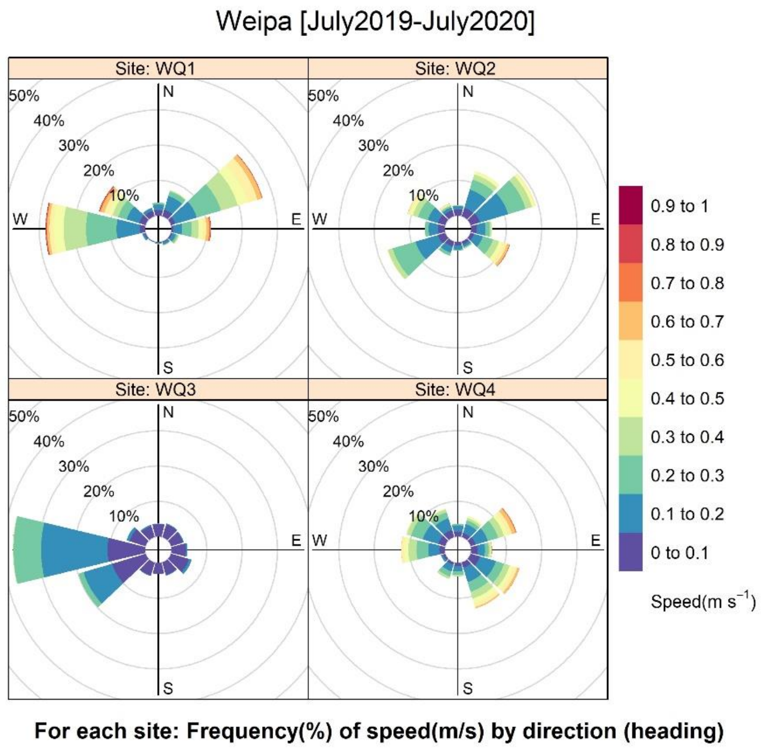



**Figure 3.33** Rose-plots displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading), for each of the four sites over the monitoring period July 2019 to July 2020

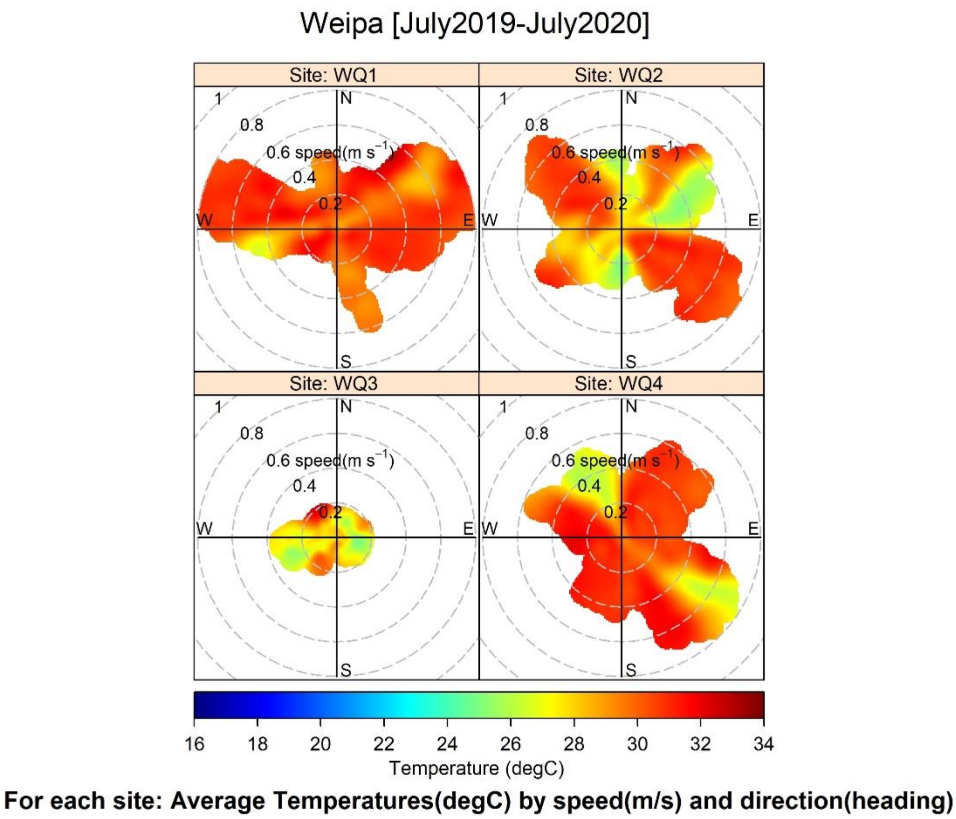



**Figure 3.34** For each of the four sites and across the monitoring period of July 2019 to July 2020, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed(m/s) and current direction(heading).

### 3.5.2 Dry Season (April – October)

Concerning current meter data that was collected during months of the dry season period (April-October), the three figures below and on the next page present and summarise this data:

- A rose-plot displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading*).
- A rose-plot displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*).
- A bivariate plot presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*).

*heading is defined by degrees (angle) rotating clockwise from facing North.

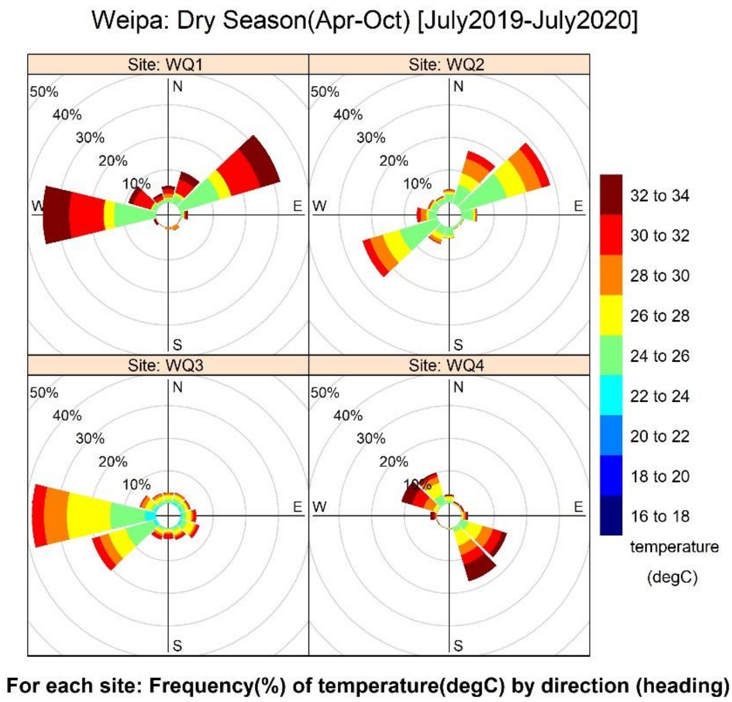



**Figure 3.35** Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction(heading), for each of the four sites during the dry season months (April-October) across the monitoring period July 2019 to July 2020

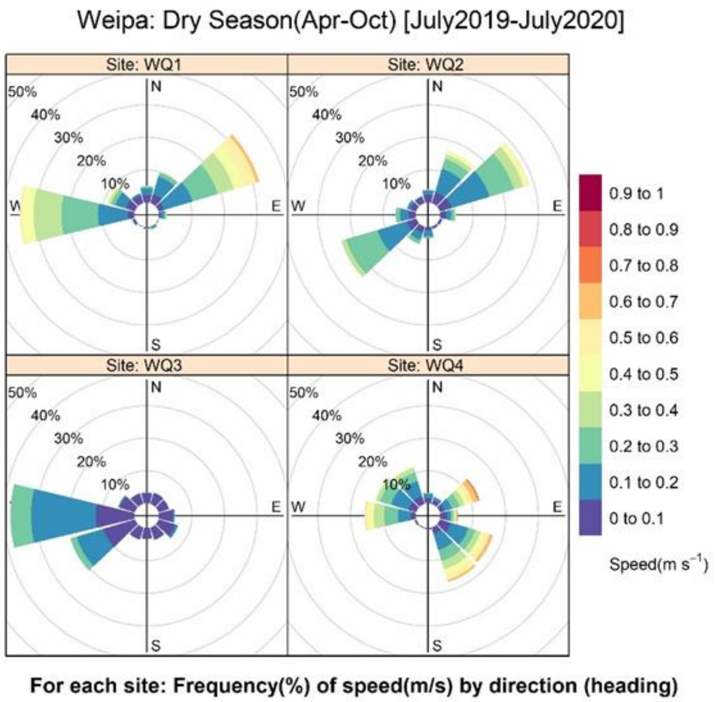



**Figure 3.36** Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the four sites during the dry season months (April-October) across the monitoring period July 2019 to July 2020

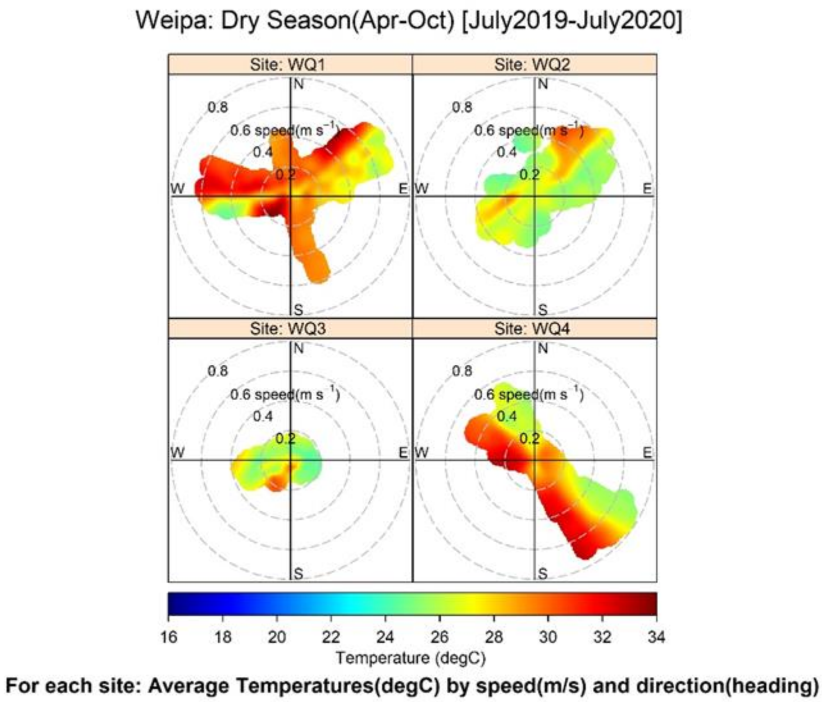



**Figure 3.37** For each of the four sites and during the dry season months (April-October) across the monitoring period of July 2019 to July 2020, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed(m/s) and current direction.

### 3.5.3 Wet season (November-March)

Concerning current meter data that was collected during months of the wet season period (November-March), the three figures below and on the next page present and summarise the data (Figure 3.38) and (Figure 3.39).

- A rose-plot displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading*).
- A rose-plot displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*).
- A bivariate plot presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*).

*heading is defined by degrees (angle) rotating clockwise from facing North.

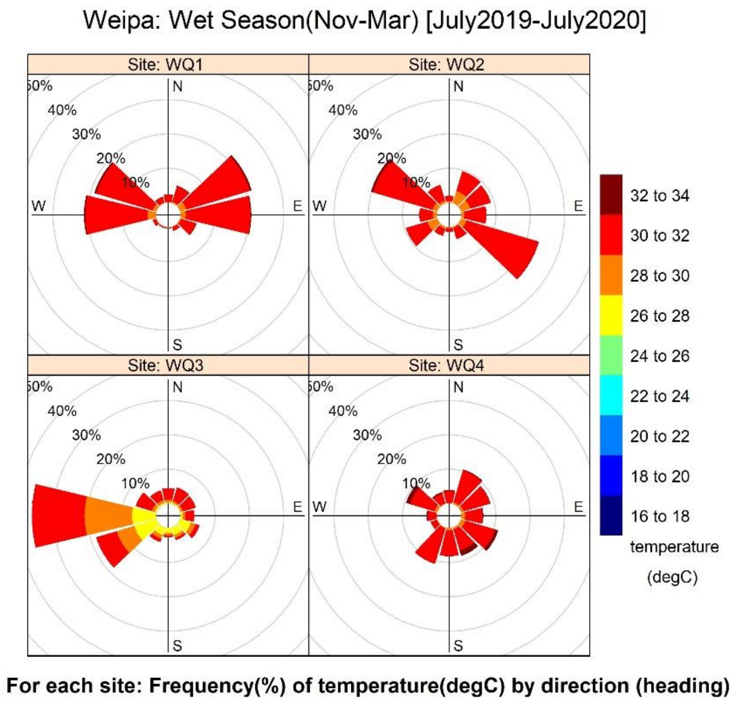



**Figure 3.38** Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction(heading), for each of the four sites during wet season months (November-March) across the monitoring period July 2019 to July 2020

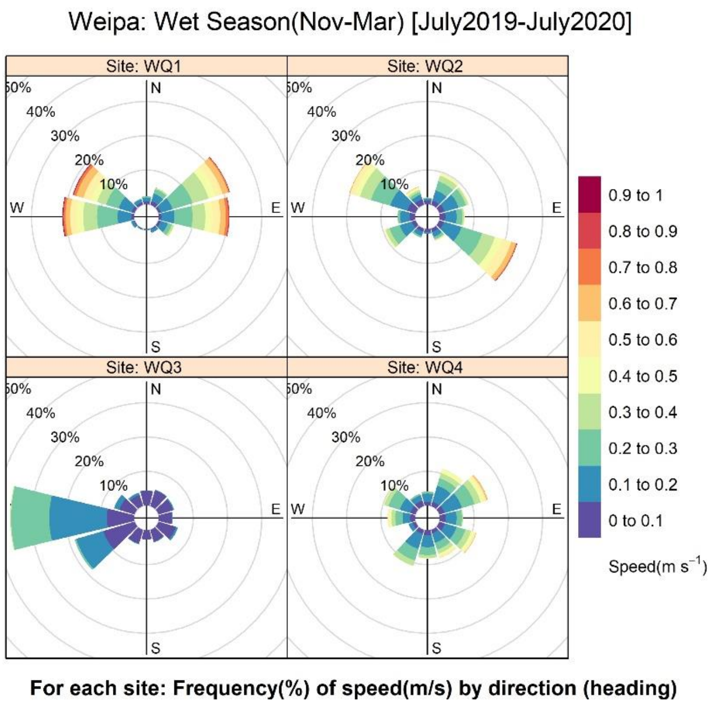
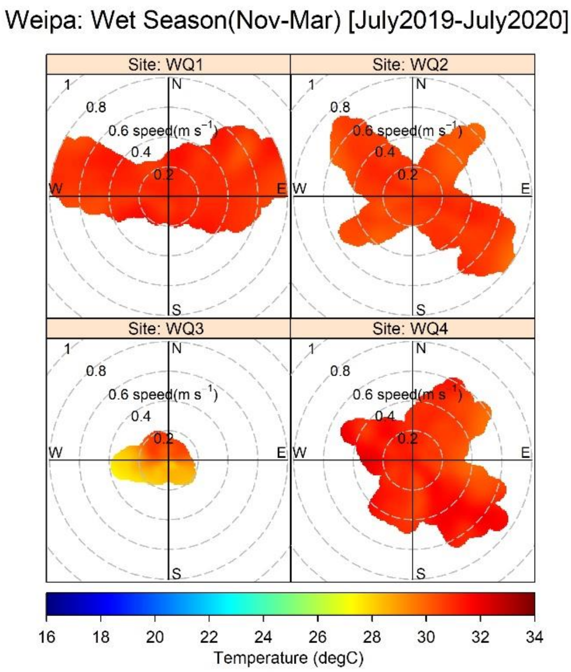



**Figure 3.39** Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction(heading), for each of the four sites during wet season months (November-March) across the monitoring period July 2019 to July 2020




**For each site: Average Temperatures(degC) by speed(m/s) and direction(heading)**

# 4 CONCLUSIONS AND RECOMMENDATIONS

## 4.1 Conclusions

### 4.1.1 Climatic conditions

1. The 2019-2020 wet season was much lower when compared to the previous year monitoring (2018-2019 wet season was in the order of the 80th percentile for rainfall in the region). This is an important factor to consider when interpreting data during this monitoring period. Comparison of these data with future years will be important to characterise ambient water quality conditions. It is important to capture monitoring data over a range of climatic conditions, which continues to be a key conclusion reported as part of the Port of Mackay and Hay Point program.
2. The daily average wind speed and direction recorded at Weipa airport for the reporting period was predominantly from the south east and east and rarely reached speeds greater than 24 km $h^{-1}$

### 4.1.2 Ambient water quality

1. There continues to be a seasonal pattern for water temperature emerging, with highest water temperatures experienced during summer months, while winter months experience cooler conditions. This pattern follows previous years at this port, but also other port programs along the east coast of Queensland.
2. The water column is well mixed, with depth profiles for dissolved oxygen, temperature, electrical conductivity and pH showing only minor gradients of change, a pattern that continues to be observed at all sites. This well mixing is particularly important when considering dissolved oxygen concentrations, which is known to reach critical levels for fish in coastal waters elsewhere in Queensland.
3. Turbidity values are generally higher at depth, contributing to a difference in water clarity between the surface and bottom water horizons. Higher turbidity values at the bottom water horizon is probably related to RMS wave height, currents, and sediment resuspension processes. The elevated turbidity in the bottom horizon becomes an important consideration when examining sensitive receptor habitats, such as seagrass which are sensitive to water clarity changes. Measuring bottom horizon turbidity is a very relevant component of this program; surface measurements for turbidity, or indeed suspended solid concentrations, might not be an entirely relevant measure when the objective is to protect and enhance benthic habitats.
4. Particulate nitrogen (PN) and phosphorus (PP) concentrations exceed guideline values during all surveys and at all sites. This pattern continues and requires further discussion with relevant authorities to address the source of nutrient supply or, indeed, whether there is a need for local guidelines.
5. Chlorophyll-*a* concentrations exceed guideline values during all surveys and at all sites.
6. Phytoplankton and zooplankton communities had a very different species composition between surveys which could reflect local seasonal conditions – this pattern will be further explored as more data becomes available for the region.
7. Trace metals were generally well below guideline values throughout the reporting year.
8. The major pesticide and herbicide concentrations were not detected above the limit of reporting

### 4.1.3 Sediment deposition and turbidity

1. Continuous sediment deposition and turbidity logging data supports the pattern found more broadly in North Queensland coastal marine environments, that during dry periods with minimal rainfall, elevated turbidity along the coastline is driven by the re-suspension of sediment and this has been most notable here given the links drawn between RMS water depth and NTUe/SSC. Large peaks in NTUe/SSC and RMS water depth were recorded over periods longer than a week.

2. Sediment deposition rates around Weipa were lower than measured in previous years, which may reflect the rainfall patterns in the region this year.

#### 4.1.4 Photosynthetically active radiation (PAR)

1. Fine-scale patterns of PAR are primarily driven by tidal cycles with fortnightly increases in PAR coinciding with neap tides and lower tidal flows. Larger episodic events which lead to extended periods of low light conditions are driven by a combination of strong winds leading to increases in wave height and resuspension of particles (Orpin and Ridd 2012), and rainfall events resulting from storms leading to increased catchment flows and an input of suspended solids (Fabricius et al., 2013).
2. Patterns of light were similar among all the coastal sites. Light penetration in water is affected in an exponential relationship with depth as photons are absorbed and scattered by particulate matter (Kirk 1985; Davis-Colley and Smith 2001). Therefore variation in depth at each location means benthic PAR is not directly comparable among sites as a measure of water quality. Generally, however, shallow inshore sites reached higher levels of benthic PAR and were more variable than deeper water coastal sites and sites of closer proximity to one another were more similar than distant sites.
3. While turbidity is the main indicator of water quality used in monitoring of dredge activity and benthic light is significantly correlated with suspended solid concentrations (Erftemeijer and Lewis 2006; Erftemeijer et al., 2012), the relationship between these two parameters is not always strong (Sofonia and Unsworth 2010). At many of the sites where both turbidity and benthic light were measured, the concentration of suspended solids in the water column explained less than half of the variation in PAR. As PAR is more biologically relevant to the health of photosynthetic benthic habitats such as seagrass, algae and corals it is becoming more useful as a management response tool when used in conjunction with known thresholds for healthy growth for these habitats (e.g., Chartrand et al., 2012). For this reason, it is important to include photosynthetically active radiation (PAR) in the suite of water quality variables when capturing local baseline conditions of ambient water quality.

### 4.2 Recommendations

2. 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.

# 5 REFERENCES

**ANZECC and ARMCANZ** (2000) Australian Water Quality Guidelines for Fresh and Marine Waters. Australia and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

**APHA** (2005) Standard Methods for the examination of water and waste water. 21st Edition. American Public Health Association. Washington, D.C.

**Brodie, J. E., Kroon, F. J., Schaffelke, B., Wolanski, E. C., Lewis, S. E., Devlin, M. J., Bohnet, I. C, Bainbridge, Z. T., Waterhouse, J., Davis, A. M.** (2012) Terrestrial pollutant runoff to the Great Barrier Reef: an update of issues, priorities and management responses. Marine Pollution Bulletin, 65, 81-100.

**Bunt, J., Larcombe, P., Jago, C. F.** (1999) Quantifiying the response of optical backscatter devices and transmissiometers to variations in suspended particulate matter (SPM). Continental Shelf Research 19: 1199-1220

**Capone, D. G., Zehr, J. P., Paerl, H. W., Bergman, B., Carpenter, E. J.** (1997). Trichodesmium, a globally significant marine cyanobacterium. Science, 276, 1221-1229.

**Conner, C. S., De Visser, A. M.** (1992) A laboratory investigation of particle size effects on an optical backscatterance sensor. Marine Geology 108:151-159

**Cook, R. D., Weisberg, S.** (1982) Residuals and Influence in Regression. Chapman and Hall.

**Crawley, M.J.** (2007) The R Book. John Wiley and Sons, Ltd.

**DEHP** (2013) Queensland Water Quality Guidelines, Version 3, Department of Environment and Heritage Protection. Brisbane

**Dennison, W. C., Orth, R. J., Moore, K. A., Stevenson, J. C., Carter, V., Kollar, S., . . . Batiuk, R. A.** (1993). Assessing Water Quality with Submersed Aquatic Vegetation. Bioscience, 43(2), 86-94.

**Devlin, M. J., McKinna, L. W., Alvarez-Romero, J. G., Petus, C., Abott, B., Harkness, P., Brodie, J.** (2012) Mapping the pollutants in surface riverine flood plume waters in the Great Barrier Reef, Australia. Marine Pollution Bulletin, 65, 224-235. doi: 10.1016/j.marpolbul.2012.03.001

**Erftemeijer, P. L. A., B. Riegl, B. W. Hoeksema, Todd, P. A.** (2012) Environmental impacts of dredging and other sediment disturbances on corals: A review. Marine Pollution Bulletin 64, 1737-1765.

**Erftemeijer, P. L. A., Lewis, R. R. R.** (2006) Environmental impacts of dredging on seagrasses: a review. Marine Pollution Bulletin 52, 1553-1572.

**Fabricius, K. E., G. De'ath, C. Humphrey, I. Zagorskis, Schaffelke, B.** (2013) Intra-annual variation in turbidity in response to terrestrial runoff on near-shore coral reefs of the Great Barrier Reef. Estuarine, Coastal and Shelf Science 116, 57-65.

**Fox, J., Monette, G.** (1992) Generalized collinearity diagnostics. JASA, 87, 178–183.

**GBRMPA** (2010) Water quality guidelines for the Great Barrier Reef Marine Park 2010 current edition. Great Barrier Reef Marine Park Authority.

**Gordon, H. R.** (1989). Can the Lambert-Beer law be applied to the diffuse attenuation coefficient of ocean water? Limnology and Oceanography, 34(8), 1389-1409. doi:10.4319/lo.1989.34.8.1389

**Grömping, G.** (2006) Relative Importance for Linear Regression in R: The Package relaimpo. Journal of Statistical Software, 17, 1-27.

**Jerlov, N. G.** (1976). Marine optics. Amsterdam: Elsevier Scientific Pub. Co.

**Johansen, J. L., Pratchett, M. S., Messmer, V., Coker, D. J., Tobin, A. J., Hoey, A. S.** (2015) Large predatory coral trout species unlikely to meet increasing energetic demands in a warming ocean. Scientific Reports, 5.

**Kirk, J. T. O.** (1985) Effects of suspendiods (turbidity) on penetration of solar rediation in aquatic ecosystems. Hydrobiologia, 125, 195-208.

**Kirk, J. T. O.** (1994). Light and photosynthesis in aquatic ecosystems. Cambridge [England]: Cambridge University Press.

**Kirk, J. T. O.** (1977). Attenuation of Light in Natural Waters. Aust. J. Mar. Freshwater Res.,, 28, 497-508.

**Kroon, F. J., Kuhnert, P. M., Henderson, B. L., Wilkinson, S. N., Kinsey-Henderson, A., Abbott, B., Brodie. J. E., Turner, R. D.** (2012) River loads of suspended solids, nitrogen, phosphorus and herbicides delivered to the Great Barrier Reef lagoon. Marine Pollution Bulletin, 65, 167-181.

**Larcombe P, Ridd PV, Prytz A, Wilson, B.** (1995) Factors controlling suspended sediment ion inner-shelf coral reefs, Townsville, Australia. Coral Reefs 14:163-171

**Logan, M., Fabricius, K., Weeks, S., Rodriguez, A., Lewis, S., Brodie, J.** (2014) Tracking GBR water clarity over time and demonstrating the effects of river discharge events. Progress Report: Southern and Northern NRM Regions. Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (53pp.).

**Ludwig, K. A., Hanes, D. M.** (1990) A laboratory explanation of optical backscatterance suspended solids sensors exposed to sand-mud mixtures. Mar Geol 94:173-179

**Macdonald, R.K.** (2015). Turbidity and Light Attenuation in Coastal Waters of the Great Barrier Reef (Doctoral dissertation). Retrieved from https://researchonline.jcu.edu.au/46029/

**Mobley, C. D.** (1994). Light and Water: Radiative Transfer in Natural Waters: Academic Press.

**Orpin, A. R., Ridd, P. V.** (2012) Exposure of inshore corals to suspended sediments due to wave-resuspension and river plumes in the central Great Barrier Reef: A reappraisal. Continental Shelf Research 47, 55-67.

**R Core Team** (2015) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

**Schaffelke, B., Carleton, J., Skuza, M., Zagorskis, I., Furnas, M. J.** (2012) Water quality in the inshore Great Barrier Reef lagoon: Implications for long-term monitoring and management. Marine Pollution Bulletin, 65(4), 249-260.

**Sofonia, J. J., Unsworth, R. K. F.** (2010) Development of water quality thresholds during dredging for the protection of benthic primary producer habitats. Journal of Environmental Monitoring 12:159-163.

**Standards Australia** (1998) Water Quality – Sampling. Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples. AS/NZS 5667.1:1998. Standards Australia, Homebush.

**Taylor, H.A., Rasheed, M.A., Carter, A.B.** (2015) Port of Weipa long-term seagrass monitoring 2000 – 2014. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 15/02, 41 pp.

**Thomas, S., Ridd, P. V., Renagi, O.** (2003) Laboratory investigation on the effect of particle size, water flow and bottom surface roughness upon the response of an upward- pointing optical backscatter sensor to sediment accumulation. Continental Shelf Research. 23, 1545-1557.

**TropWATER** (2015) Assessment of the contamination risk posed by sampling consumables to the detection and monitoring of filterable metals in water samples. Internal report. Centre for Tropical Water and Aquatic Ecosystem Research, James Cook University.

**Wolanski, E., Delesalle, B., Gibbs, R.** (1994) Carbonate mud in Mataiva Atoll, French Polynesia: Suspension and export. Marine Pollution Bulletin 29:36-41.

# A1 APPENDIX

## A1.1 Calibration procedures

### A1.1.1 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.

### A1.1.2 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.

### A1.1.3 Light Calibration

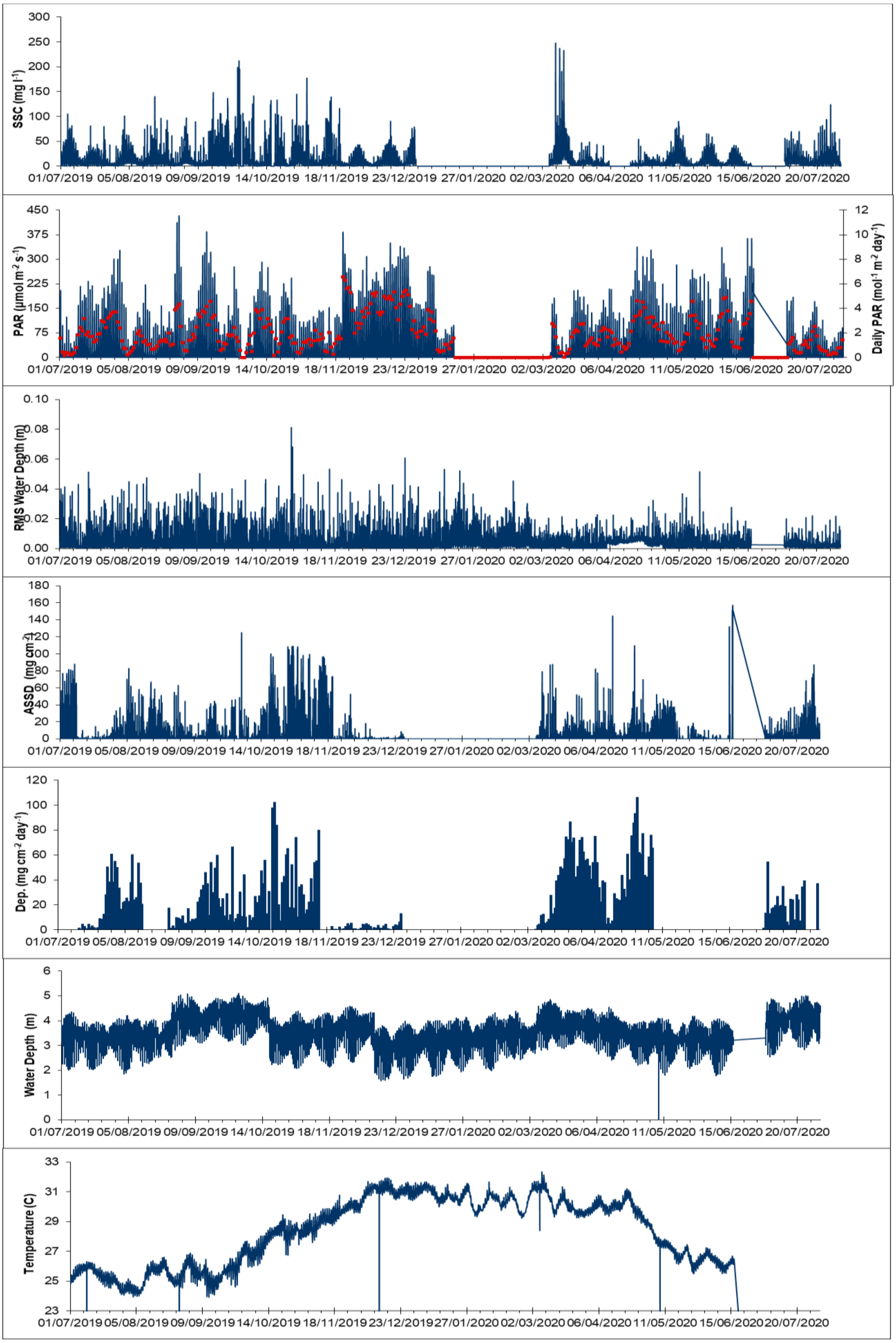
The light sensors on each logger are calibrated every six months or after every deployment. The light sensor is calibrated against a LICOR U250A submersible sensor that was calibrated in the factory within the last 12 months. The results of the logger light sensor and LICOR U250A are compared and a calibration coefficient is used to ensure accurate reporting of PAR data. An in-field 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.

### A1.1.4 Pressure Sensor Calibration

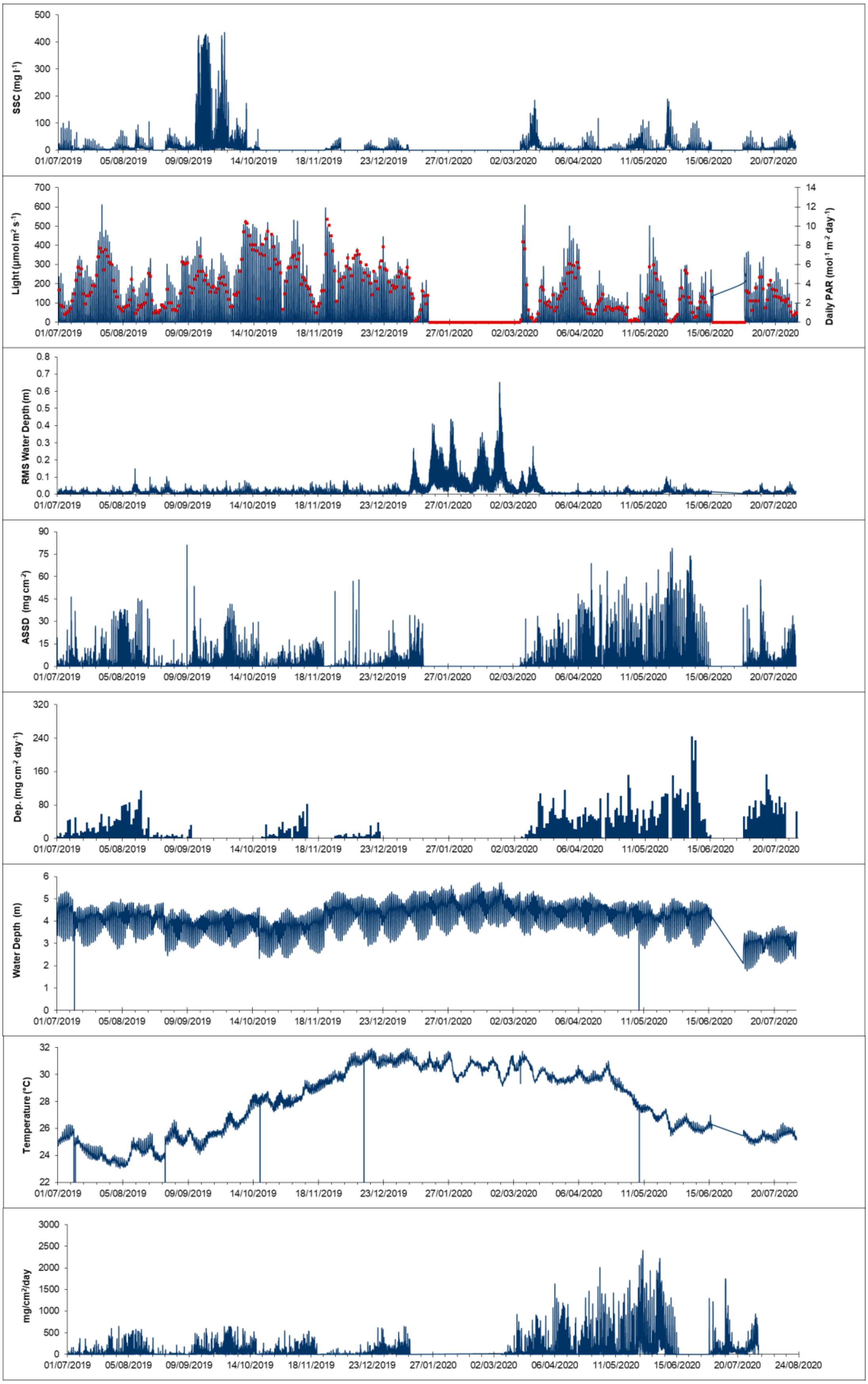
All pressure sensors are calibrated against a pressure gauge and the pressure is converted into depth in metres.

## A1.2 Time Series

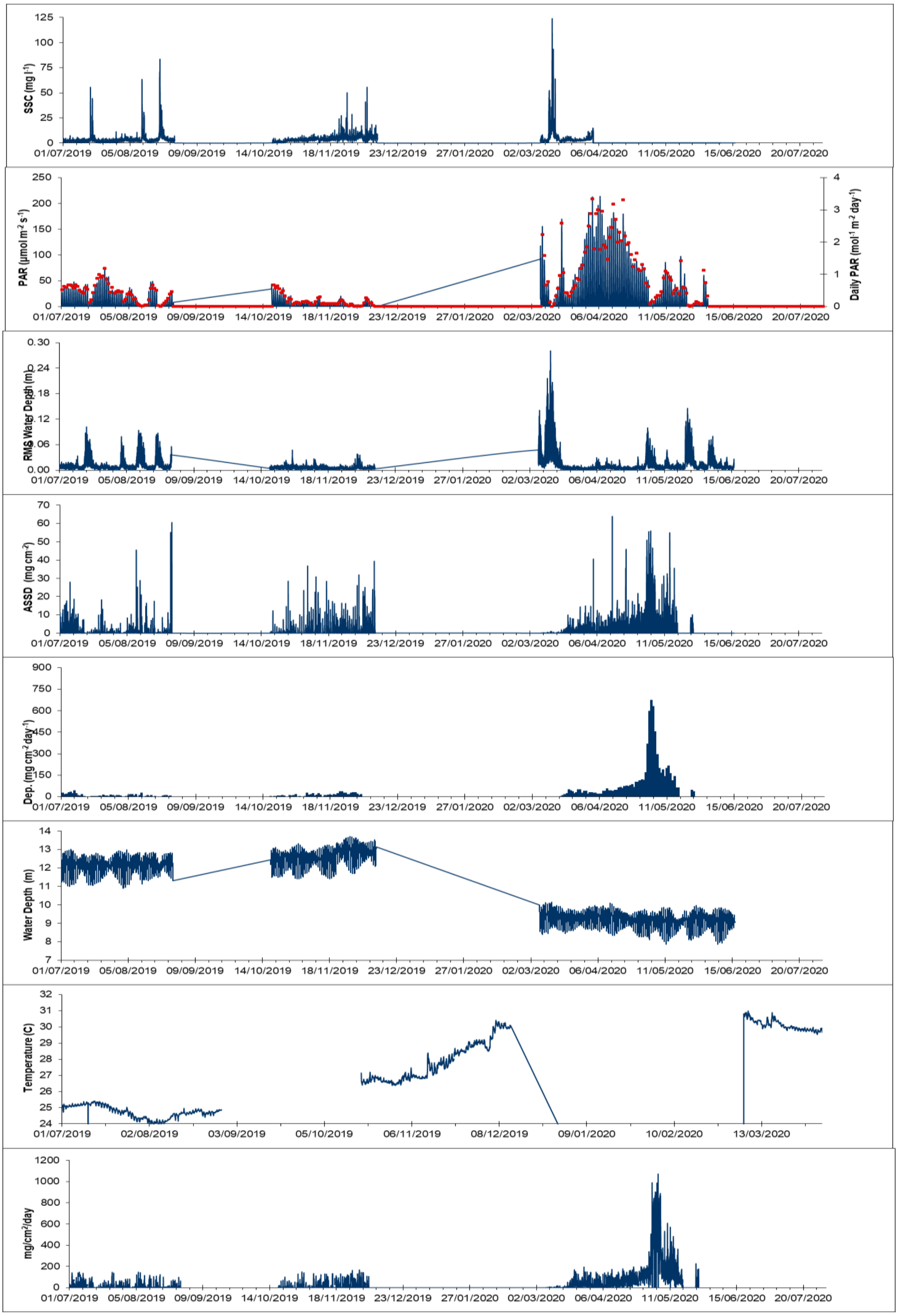
### A1.2.1 WQ1



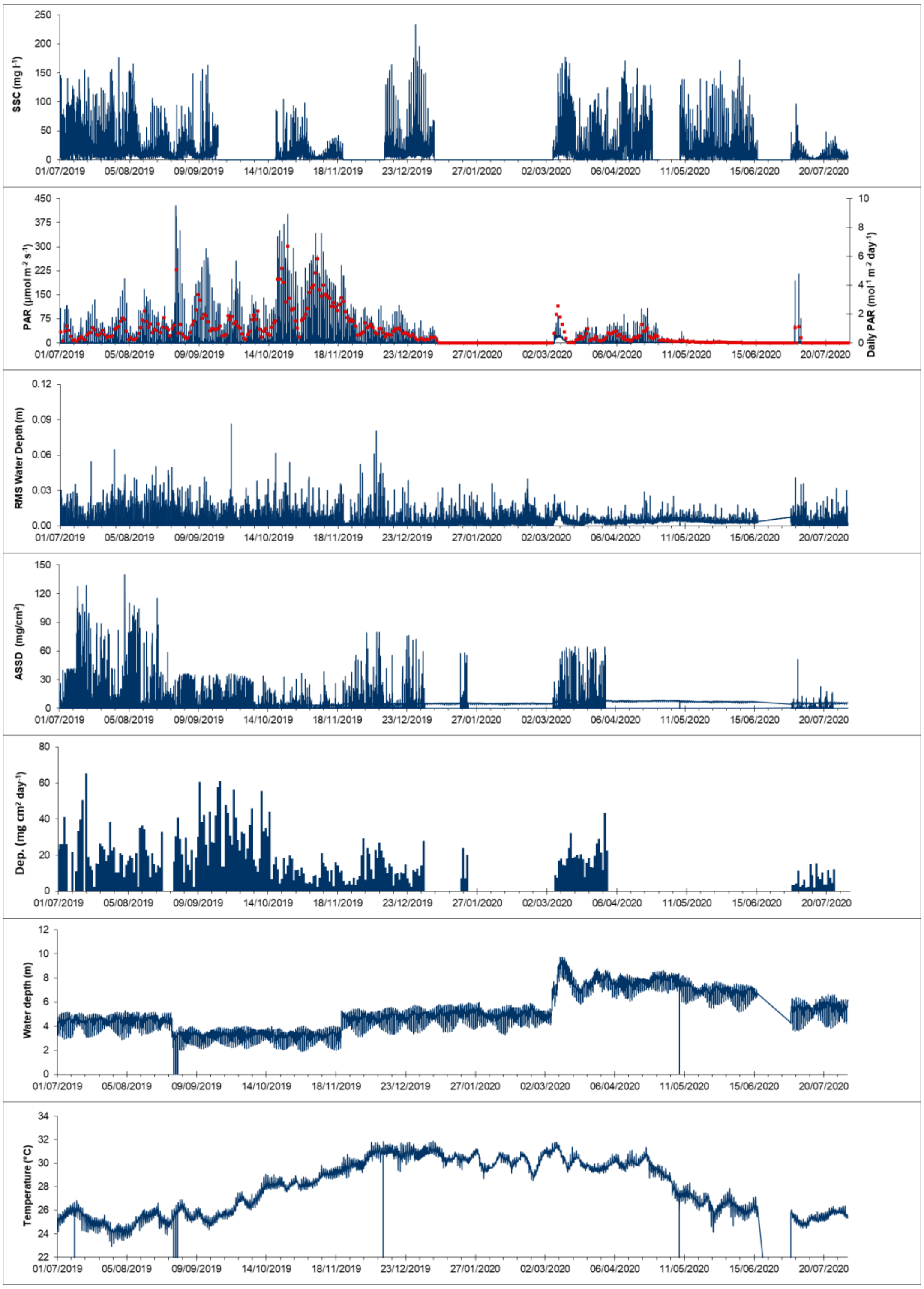
**A1.2.2 WQ2**


SSC (mg l⁻¹)
0 100 200 300 400 500
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
Light (µmol m² s⁻¹)
0 100 200 300 400 500 600 700
Daily PAR (mol⁻¹ m² day⁻¹)
0 2 4 6 8 10 12 14
RMS Water Depth (m)
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
ASSD (mg cm⁻²)
0 15 30 45 60 75 90
Dep. (mg cm⁻² day⁻¹)
0 80 160 240 320
Water Depth (m)
0 1 2 3 4 5 6
Temperature (°C)
22 24 26 28 30 32
mg/cm²/day
0 500 1000 1500 2000 2500 3000
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020 24/08/2020

### A1.2.3 WQ3


SSC (mg l⁻¹)
0 25 50 75 100 125
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
PAR (µmol m⁻² s⁻¹)
0 50 100 150 200 250
Daily PAR (mol⁻¹ m⁻² day⁻¹)
0 1 2 3 4
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
RMS Water Depth (m)
0.00 0.06 0.12 0.18 0.24 0.30
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
ASSD (mg cm⁻²)
0 10 20 30 40 50 60 70
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
Dep. (mg cm⁻² day⁻¹)
0 150 300 450 600 750 900
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
Water Depth (m)
7 8 9 10 11 12 13 14
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020
Temperature (C)
24 25 26 27 28 29 30 31 32
01/07/2019 02/08/2019 03/09/2019 05/10/2019 06/11/2019 08/12/2019 09/01/2020 10/02/2020 13/03/2020
mg/cm²/day
0 200 400 600 800 1000 1200
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

### A1.2.4 WQ4


SSC (mg l⁻¹)
PAR (µmol m⁻² s⁻¹)
Daily PAR (mol⁻¹ m⁻² day⁻¹)
RMS Water Depth (m)
ASSD (mg/cm²)
Dep. (mg cm² day⁻¹)
Water depth (m)
Temperature (°C)
01/07/2019
05/08/2019
09/09/2019
14/10/2019
18/11/2019
23/12/2019
27/01/2020
02/03/2020
06/04/2020
11/05/2020
15/06/2020
20/07/2020

## A1.3 Monthly statistics

### A1.3.1 WQ1

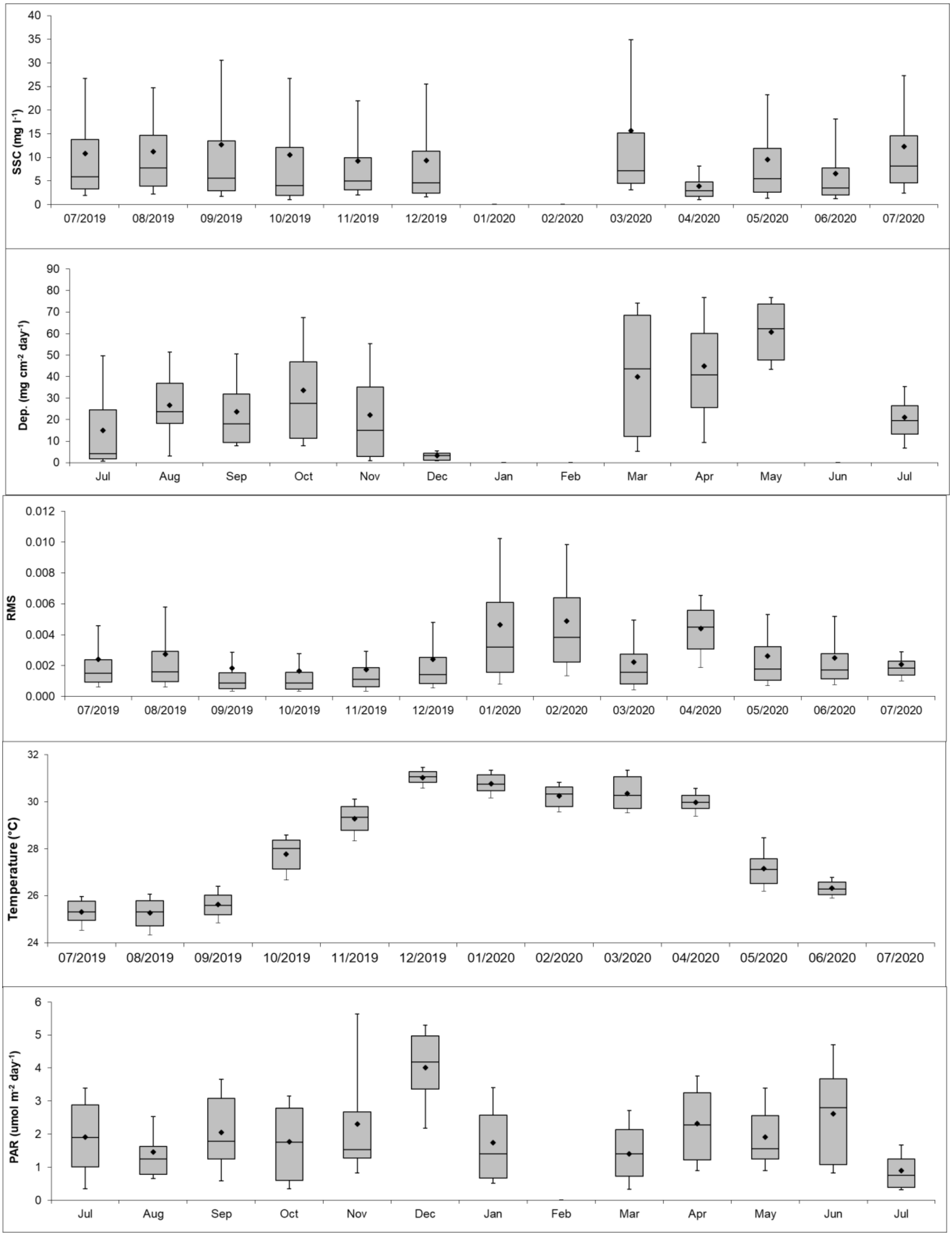
| | SSC 07/2019 | SSC 08/2019 | SSC 09/2019 | SSC 10/2019 | SSC 11/2019 | SSC 12/2019 | SSC 01/2020 | SSC 02/2020 | SSC 03/2020 | SSC 04/2020 | SSC 05/2020 | SSC 06/2020 | SSC 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 10.78 | 11.24 | 12.64 | 10.53 | 9.27 | 9.37 | | | 15.68 | 3.93 | 9.49 | 6.60 | 12.29 |
| median | 5.88 | 7.75 | 5.59 | 3.96 | 4.94 | 4.53 | | | 7.14 | 2.88 | 5.45 | 3.51 | 8.13 |
| min | 0.01 | 0.00 | 0.00 | 2.10 | 0.00 | 29.57 | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| lower | 3.28 | 3.92 | 2.86 | 1.95 | 3.10 | 2.43 | | | 4.49 | 1.73 | 2.57 | 2.01 | 4.61 |
| upper | 13.80 | 14.60 | 13.44 | 12.08 | 9.95 | 11.31 | | | 15.16 | 4.81 | 11.84 | 7.74 | 14.50 |
| max | 104.52 | 139.51 | 211.57 | 144.46 | 176.52 | 89.62 | | | 247.41 | 53.92 | 89.86 | 42.11 | 123.80 |
| 90th percentile | 26.66 | 24.67 | 30.55 | 26.65 | 21.99 | 25.47 | | | 34.90 | 8.14 | 23.24 | 18.11 | 27.23 |
| 10th percentile | 1.87 | 2.26 | 1.70 | 1.02 | 2.01 | 1.67 | | | 3.13 | 0.98 | 1.36 | 1.25 | 2.45 |
| n | 4435 | 4271 | 3851 | 3786 | 4079 | 3968 | 0 | 0 | 3775 | 2684 | 4384 | 2235 | 4031 |
| St. Dev | 12.10 | 11.18 | 18.93 | 16.41 | 12.62 | 11.37 | | | 24.92 | 3.71 | 11.04 | 7.55 | 12.59 |
| St. Error | 0.18 | 0.17 | 0.31 | 0.27 | 0.20 | 0.18 | | | 0.41 | 0.07 | 0.17 | 0.16 | 0.20 |

| | ASSD 07/2019 | ASSD 08/2019 | ASSD 09/2019 | ASSD 10/2019 | ASSD 11/2019 | ASSD 12/2019 | ASSD 01/2020 | ASSD 02/2020 | ASSD 03/2020 | ASSD 04/2020 | ASSD 05/2020 | ASSD 06/2020 | ASSD 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 4.02 | 3.13 | 1.83 | 4.36 | 3.74 | 0.10 | | | 1.89 | 2.65 | 4.07 | 1.97 | 2.24 |
| median | 0.05 | 0.19 | 0.00 | 0.01 | 0.01 | 0.00 | | | 0.14 | 0.33 | 0.00 | 0.00 | 0.06 |
| min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| lower | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| upper | 1.07 | 1.95 | 0.48 | 1.44 | 0.79 | 0.03 | | | 1.36 | 2.47 | 4.72 | 0.00 | 0.98 |
| max | 87.21 | 82.12 | 45.88 | 124.89 | 107.39 | 17.66 | | | 87.16 | 144.55 | 50.82 | 157.07 | 86.89 |
| 90th percentile | 9.77 | 9.45 | 4.47 | 9.98 | 8.66 | 0.14 | | | 4.70 | 7.20 | 14.00 | 0.00 | 5.61 |
| 10th percentile | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n | 4459 | 4454 | 4318 | 4459 | 4164 | 3837 | 0 | 0 | 3792 | 4320 | 4462 | 2236 | 4121 |
| St. Dev | 11.77 | 7.97 | 5.66 | 13.74 | 12.15 | 0.61 | | | 5.60 | 7.25 | 7.91 | 16.49 | 6.88 |
| St. Error | 0.18 | 0.12 | 0.09 | 0.21 | 0.19 | 0.01 | | | 0.09 | 0.11 | 0.12 | 0.35 | 0.11 |

| | RMS 07/2019 | RMS 08/2019 | RMS 09/2019 | RMS 10/2019 | RMS 11/2019 | RMS 12/2019 | RMS 01/2020 | RMS 02/2020 | RMS 03/2020 | RMS 04/2020 | RMS 05/2020 | RMS 06/2020 | RMS 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0024 | 0.0027 | 0.0018 | 0.0017 | 0.0017 | 0.0024 | 0.0046 | 0.0049 | 0.0022 | 0.0044 | 0.0026 | 0.0025 | 0.0021 |
| median | 0.0015 | 0.0016 | 0.0009 | 0.0009 | 0.0011 | 0.0014 | 0.0032 | 0.0038 | 0.0016 | 0.0045 | 0.0018 | 0.0017 | 0.0018 |
| min | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 | 0.0003 |
| lower | 0.0009 | 0.0009 | 0.0005 | 0.0005 | 0.0006 | 0.0008 | 0.0016 | 0.0022 | 0.0008 | 0.0031 | 0.0010 | 0.0011 | 0.0014 |
| upper | 0.0024 | 0.0029 | 0.0015 | 0.0016 | 0.0019 | 0.0025 | 0.0061 | 0.0064 | 0.0027 | 0.0056 | 0.0032 | 0.0028 | 0.0023 |
| max | 0.0513 | 0.0476 | 0.0504 | 0.0813 | 0.0533 | 0.0608 | 0.0531 | 0.0454 | 0.0228 | 0.0324 | 0.0516 | 0.0277 | 0.0221 |
| 90$^{th}$ percentile | 0.0046 | 0.0058 | 0.0028 | 0.0028 | 0.0029 | 0.0048 | 0.0102 | 0.0099 | 0.0049 | 0.0065 | 0.0053 | 0.0052 | 0.0029 |
| 10$^{th}$ percentile | 0.0006 | 0.0006 | 0.0003 | 0.0003 | 0.0003 | 0.0005 | 0.0008 | 0.0013 | 0.0004 | 0.0019 | 0.0007 | 0.0008 | 0.0010 |
| n | 4461 | 4455 | 4320 | 4461 | 4230 | 4461 | 4464 | 4176 | 4462 | 4320 | 4462 | 2243 | 4121 |
| St. Dev | 0.0034 | 0.0038 | 0.0040 | 0.0036 | 0.0030 | 0.0036 | 0.0046 | 0.0039 | 0.0023 | 0.0021 | 0.0027 | 0.0025 | 0.0015 |
| St. Error | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0000 |

| | Temp 07/2019 | Temp 08/2019 | Temp 09/2019 | Temp 10/2019 | Temp 11/2019 | Temp 12/2019 | Temp 01/2020 | Temp 02/2020 | Temp 03/2020 | Temp 04/2020 | Temp 05/2020 | Temp 06/2020 | Temp 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 25.30 | 25.26 | 25.62 | 27.77 | 29.27 | 31.03 | 30.76 | 30.24 | 30.35 | 29.98 | 27.15 | 26.32 | |
| median | 25.32 | 25.32 | 25.58 | 28.00 | 29.33 | 31.06 | 30.75 | 30.32 | 30.26 | 29.97 | 27.11 | 26.28 | |
| min | 24.05 | 23.93 | 23.91 | 25.94 | 27.61 | 29.57 | 29.36 | 29.22 | 28.41 | 28.76 | 25.50 | 25.50 | |
| lower | 24.95 | 24.72 | 25.19 | 27.13 | 28.78 | 30.83 | 30.47 | 29.80 | 29.71 | 29.71 | 26.53 | 26.05 | |
| upper | 25.76 | 25.79 | 26.03 | 28.37 | 29.79 | 31.29 | 31.14 | 30.62 | 31.06 | 30.26 | 27.57 | 26.58 | |
| max | 26.29 | 26.76 | 27.48 | 29.46 | 30.77 | 31.93 | 31.66 | 31.66 | 32.34 | 31.20 | 29.17 | 27.24 | 0.00 |
| 90$^{th}$ percentile | 25.97 | 26.07 | 26.41 | 28.58 | 30.11 | 31.45 | 31.35 | 30.83 | 31.35 | 30.57 | 28.46 | 26.78 | |
| 10$^{th}$ percentile | 24.52 | 24.33 | 24.85 | 26.67 | 28.33 | 30.57 | 30.16 | 29.56 | 29.53 | 29.39 | 26.19 | 25.90 | |
| n | 4453 | 4449 | 4320 | 4453 | 4223 | 4451 | 4464 | 4176 | 4462 | 4320 | 4462 | 2243 | |
| St. Dev | 0.53 | 0.65 | 0.62 | 0.74 | 0.66 | 0.38 | 0.46 | 0.47 | 0.72 | 0.45 | 0.81 | 0.35 | |
| St. Error | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | |

| | Light 07/2019 | Light 08/2019 | Light 09/2019 | Light 10/2019 | Light 11/2019 | Light 12/2019 | Light 01/2020 | Light 02/2020 | Light 03/2020 | Light 04/2020 | Light 05/2020 | Light 06/2020 | Light 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 1.90 | 1.45 | 2.05 | 1.77 | 2.31 | 4.02 | 1.74 | | 1.40 | 2.32 | 1.91 | 2.61 | 0.89 |
| median | 1.90 | 1.24 | 1.79 | 1.75 | 1.53 | 4.18 | 1.40 | | 1.40 | 2.28 | 1.56 | 2.80 | 0.75 |
| min | 0.16 | 0.21 | 0.51 | 0.00 | 0.23 | 1.66 | 0.42 | | 0.03 | 0.43 | 0.51 | 0.76 | 0.22 |
| lower | 1.00 | 0.78 | 1.24 | 0.59 | 1.28 | 3.36 | 0.67 | | 0.72 | 1.22 | 1.24 | 1.08 | 0.39 |
| upper | 2.89 | 1.63 | 3.08 | 2.79 | 2.67 | 4.97 | 2.58 | | 2.13 | 3.25 | 2.56 | 3.67 | 1.24 |
| max | 3.70 | 4.32 | 4.54 | 3.88 | 6.58 | 5.48 | 3.86 | | 2.75 | 4.61 | 4.54 | 4.87 | 2.52 |
| 90$^{th}$ percentile | 3.39 | 2.53 | 3.66 | 3.15 | 5.63 | 5.29 | 3.40 | | 2.72 | 3.76 | 3.39 | 4.70 | 1.67 |
| 10$^{th}$ percentile | 0.35 | 0.65 | 0.59 | 0.35 | 0.82 | 2.18 | 0.51 | | 0.32 | 0.89 | 0.90 | 0.83 | 0.32 |
| n | 31 | 31 | 30 | 31 | 30 | 31 | 16 | 0 | 27 | 30 | 31 | 15 | 27 |
| St. Dev | 1.14 | 1.02 | 1.17 | 1.21 | 1.80 | 1.13 | 1.17 | | 0.89 | 1.17 | 1.00 | 1.52 | 0.61 |
| St. Error | 0.20 | 0.18 | 0.21 | 0.22 | 0.33 | 0.20 | 0.29 | | 0.17 | 0.21 | 0.18 | 0.39 | 0.12 |


SSC (mg l-1)
07/2019 08/2019 09/2019 10/2019 11/2019 12/2019 01/2020 02/2020 03/2020 04/2020 05/2020 06/2020 07/2020
Dep. (mg cm-2 day-1)
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
RMS
07/2019 08/2019 09/2019 10/2019 11/2019 12/2019 01/2020 02/2020 03/2020 04/2020 05/2020 06/2020 07/2020
Temperature (°C)
07/2019 08/2019 09/2019 10/2019 11/2019 12/2019 01/2020 02/2020 03/2020 04/2020 05/2020 06/2020 07/2020
PAR (umol m-2 day-1)
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul

**A1.3.2 WQ2**

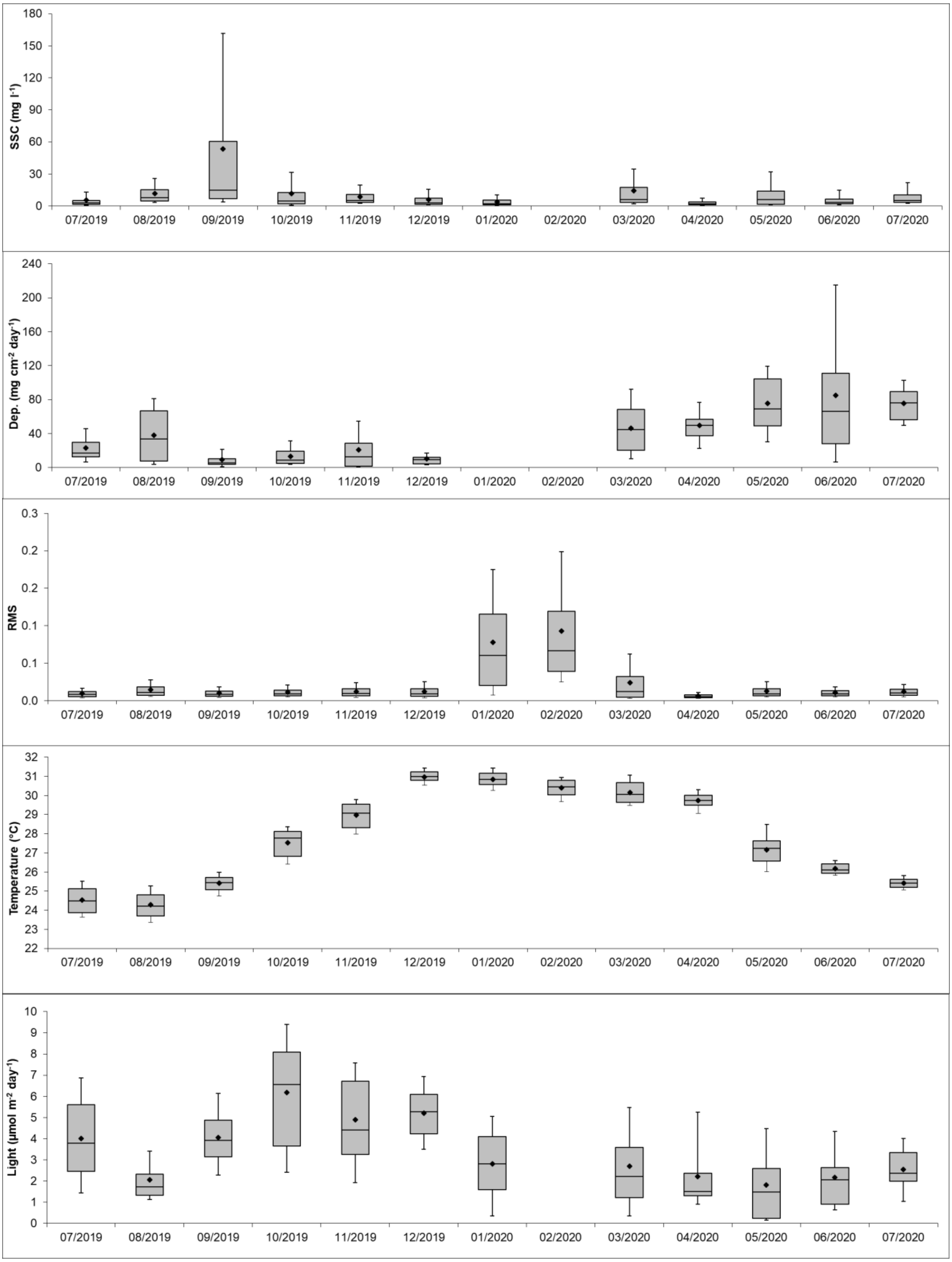
| | SSC 07/2019 | SSC 08/2019 | SSC 09/2019 | SSC 10/2019 | SSC 11/2019 | SSC 12/2019 | SSC 01/2020 | SSC 02/2020 | SSC 03/2020 | SSC 04/2020 | SSC 05/2020 | SSC 06/2020 | SSC 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 5.55 | 11.89 | 53.52 | 11.54 | 8.44 | 5.91 | 3.98 | | 14.22 | 3.74 | 13.02 | 6.67 | 8.88 |
| median | 2.83 | 7.84 | 14.82 | 4.73 | 5.15 | 2.71 | 2.20 | | 5.89 | 2.16 | 6.03 | 3.23 | 5.00 |
| min | 0.06 | 1.19 | 0.03 | 0.00 | 1.56 | 0.18 | 0.07 | | 0.10 | 0.00 | 0.00 | 0.15 | 0.80 |
| lower | 1.60 | 4.76 | 6.67 | 2.17 | 3.25 | 1.67 | 1.19 | | 3.54 | 1.32 | 1.78 | 1.88 | 3.32 |
| upper | 5.14 | 15.16 | 60.36 | 12.61 | 10.99 | 7.12 | 5.60 | | 17.50 | 3.62 | 13.99 | 6.24 | 10.28 |
| max | 106.37 | 105.08 | 429.51 | 171.30 | 45.21 | 46.01 | 20.28 | | 184.98 | 116.74 | 189.15 | 107.60 | 72.36 |
| $90^{th}$ percentile | 12.89 | 25.71 | 161.76 | 31.24 | 19.60 | 15.81 | 10.16 | | 34.66 | 7.25 | 32.01 | 14.59 | 21.95 |
| $10^{th}$ percentile | 0.87 | 3.25 | 3.61 | 0.83 | 2.66 | 1.14 | 0.79 | | 2.11 | 0.78 | 0.96 | 1.04 | 2.40 |
| n | 4333 | 3474 | 4200 | 2259 | 1221 | 2796 | 636 | 0 | 3782 | 4291 | 4448 | 2234 | 4111 |
| St. Dev | 8.98 | 11.14 | 82.79 | 17.94 | 7.75 | 7.13 | 4.01 | | 19.69 | 6.02 | 20.48 | 10.98 | 9.32 |
| St. Error | 0.14 | 0.19 | 1.28 | 0.38 | 0.22 | 0.13 | 0.16 | | 0.32 | 0.09 | 0.31 | 0.23 | 0.15 |

| | ASSD 07/2019 | ASSD 08/2019 | ASSD 09/2019 | ASSD 10/2019 | ASSD 11/2019 | ASSD 12/2019 | ASSD 01/2020 | ASSD 02/2020 | ASSD 03/2020 | ASSD 04/2020 | ASSD 05/2020 | ASSD 06/2020 | ASSD 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.85 | 1.79 | 1.33 | 1.74 | 0.88 | 0.81 | 2.28 | | 1.56 | 2.60 | 5.84 | 5.96 | 3.04 |
| median | 0.01 | 0.06 | 0.07 | 0.05 | 0.00 | 0.03 | 0.82 | | 0.14 | 0.00 | 0.36 | 0.08 | 1.18 |
| min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| lower | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 |
| upper | 0.23 | 0.67 | 0.93 | 1.31 | 0.49 | 0.54 | 2.83 | | 0.92 | 1.38 | 4.78 | 5.51 | 3.56 |
| max | 46.36 | 45.16 | 81.16 | 40.69 | 50.20 | 57.76 | 33.88 | | 34.67 | 68.86 | 77.45 | 73.61 | 57.12 |
| $90^{th}$ percentile | 1.91 | 3.66 | 3.46 | 4.65 | 2.75 | 2.25 | 6.38 | | 4.22 | 5.72 | 22.36 | 21.63 | 8.08 |
| $10^{th}$ percentile | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| n | 4457 | 4461 | 4318 | 4456 | 4096 | 4459 | 1872 | 0 | 3796 | 4320 | 4461 | 2237 | 4114 |
| St. Dev | 3.08 | 5.60 | 3.87 | 4.40 | 2.33 | 2.79 | 3.91 | | 3.98 | 7.22 | 11.80 | 12.03 | 5.21 |
| St. Error | 0.05 | 0.08 | 0.06 | 0.07 | 0.04 | 0.04 | 0.09 | | 0.06 | 0.11 | 0.18 | 0.25 | 0.08 |

| | RMS 07/2019 | RMS 08/2019 | RMS 09/2019 | RMS 10/2019 | RMS 11/2019 | RMS 12/2019 | RMS 01/2020 | RMS 02/2020 | RMS 03/2020 | RMS 04/2020 | RMS 05/2020 | RMS 06/2020 | RMS 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.009 | 0.014 | 0.010 | 0.012 | 0.012 | 0.012 | 0.078 | 0.093 | 0.024 | 0.007 | 0.013 | 0.011 | 0.012 |
| median | 0.008 | 0.011 | 0.008 | 0.009 | 0.010 | 0.009 | 0.061 | 0.067 | 0.012 | 0.005 | 0.009 | 0.009 | 0.010 |
| min | 0.000 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.006 | 0.001 | 0.000 | 0.001 | 0.002 | 0.001 |
| lower | 0.005 | 0.007 | 0.006 | 0.006 | 0.006 | 0.006 | 0.020 | 0.039 | 0.005 | 0.004 | 0.006 | 0.007 | 0.007 |
| upper | 0.012 | 0.018 | 0.012 | 0.014 | 0.016 | 0.016 | 0.116 | 0.119 | 0.032 | 0.008 | 0.016 | 0.013 | 0.015 |
| max | 0.052 | 0.148 | 0.079 | 0.080 | 0.078 | 0.079 | 0.437 | 0.642 | 0.279 | 0.064 | 0.101 | 0.064 | 0.073 |
| 90$^{th}$ percentile | 0.016 | 0.028 | 0.018 | 0.021 | 0.024 | 0.025 | 0.175 | 0.199 | 0.062 | 0.011 | 0.025 | 0.019 | 0.022 |
| 10$^{th}$ percentile | 0.004 | 0.005 | 0.004 | 0.005 | 0.004 | 0.004 | 0.008 | 0.025 | 0.003 | 0.003 | 0.005 | 0.005 | 0.005 |
| n | 4459 | 4462 | 4320 | 4461 | 4241 | 4460 | 4464 | 4176 | 4462 | 4320 | 4461 | 2237 | 4114 |
| St. Dev | 0.006 | 0.011 | 0.007 | 0.008 | 0.009 | 0.010 | 0.070 | 0.079 | 0.028 | 0.004 | 0.010 | 0.006 | 0.008 |
| St. Error | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | Temp 07/2019 | Temp 08/2019 | Temp 09/2019 | Temp 10/2019 | Temp 11/2019 | Temp 12/2019 | Temp 01/2020 | Temp 02/2020 | Temp 03/2020 | Temp 04/2020 | Temp 05/2020 | Temp 06/2020 | Temp 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 24.53 | 24.29 | 25.41 | 27.53 | 28.96 | 30.97 | 30.83 | 30.40 | 30.16 | 29.72 | 27.16 | 26.17 | 25.42 |
| median | 24.50 | 24.21 | 25.44 | 27.77 | 29.06 | 30.99 | 30.84 | 30.45 | 30.06 | 29.73 | 27.22 | 26.10 | 25.42 |
| min | 23.23 | 23.04 | 24.08 | 25.91 | 27.54 | 29.48 | 29.41 | 29.16 | 29.22 | 28.68 | 25.44 | 25.61 | 24.73 |
| lower | 23.86 | 23.70 | 25.06 | 26.81 | 28.32 | 30.78 | 30.57 | 30.03 | 29.63 | 29.48 | 26.57 | 25.92 | 25.19 |
| upper | 25.13 | 24.80 | 25.71 | 28.12 | 29.53 | 31.22 | 31.15 | 30.80 | 30.66 | 30.00 | 27.62 | 26.42 | 25.61 |
| max | 26.29 | 26.40 | 27.15 | 28.84 | 30.32 | 31.93 | 31.93 | 31.38 | 31.73 | 31.00 | 28.91 | 27.12 | 26.41 |
| 90$^{th}$ percentile | 25.50 | 25.26 | 25.99 | 28.36 | 29.78 | 31.43 | 31.44 | 30.94 | 31.07 | 30.29 | 28.48 | 26.60 | 25.80 |
| 10$^{th}$ percentile | 23.64 | 23.36 | 24.73 | 26.40 | 27.98 | 30.52 | 30.27 | 29.67 | 29.48 | 29.07 | 26.02 | 25.82 | 25.06 |
| n | 4448 | 4455 | 4320 | 4450 | 4232 | 4451 | 4464 | 4176 | 4462 | 4320 | 4461 | 2237 | 4114 |
| St. Dev | 0.72 | 0.71 | 0.52 | 0.74 | 0.67 | 0.41 | 0.47 | 0.48 | 0.59 | 0.45 | 0.82 | 0.31 | 0.29 |
| St. Error | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |

| | Light 07/2019 | Light 08/2019 | Light 09/2019 | Light 10/2019 | Light 11/2019 | Light 12/2019 | Light 01/2020 | Light 02/2020 | Light 03/2020 | Light 04/2020 | Light 05/2020 | Light 06/2020 | Light 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 4.00 | 2.07 | 4.06 | 6.18 | 4.89 | 5.20 | 2.82 | | 2.69 | 2.20 | 1.82 | 2.18 | 2.56 |
| median | 3.80 | 1.73 | 3.92 | 6.56 | 4.42 | 5.27 | 2.82 | | 2.21 | 1.51 | 1.47 | 2.05 | 2.37 |
| min | 0.81 | 0.90 | 1.20 | 1.33 | 0.97 | 2.86 | 0.11 | | 0.06 | 0.79 | 0.10 | 0.52 | 0.71 |
| lower | 2.46 | 1.32 | 3.16 | 3.66 | 3.27 | 4.24 | 1.59 | | 1.23 | 1.30 | 0.24 | 0.90 | 2.00 |
| upper | 5.61 | 2.31 | 4.88 | 8.09 | 6.71 | 6.10 | 4.11 | | 3.59 | 2.36 | 2.60 | 2.62 | 3.34 |
| max | 7.66 | 5.06 | 6.88 | 10.44 | 10.69 | 7.82 | 5.72 | | 8.35 | 6.21 | 5.98 | 5.40 | 4.70 |
| 90$^{th}$ percentile | 6.86 | 3.40 | 6.14 | 9.40 | 7.59 | 6.95 | 5.06 | | 5.48 | 5.24 | 4.47 | 4.34 | 4.00 |
| 10$^{th}$ percentile | 1.43 | 1.14 | 2.29 | 2.42 | 1.94 | 3.50 | 0.34 | | 0.36 | 0.90 | 0.15 | 0.64 | 1.04 |
| n | 31 | 31 | 30 | 31 | 30 | 31 | 15 | | 27 | 30 | 31 | 15 | 28 |
| St. Dev | 2.09 | 1.09 | 1.45 | 2.74 | 2.51 | 1.30 | 1.79 | | 2.15 | 1.60 | 1.73 | 1.50 | 1.11 |
| St. Error | 0.38 | 0.20 | 0.26 | 0.49 | 0.46 | 0.23 | 0.46 | | 0.41 | 0.29 | 0.31 | 0.39 | 0.21 |


SSC (mg l⁻¹)
Dep. (mg cm⁻² day⁻¹)
RMS
Temperature (°C)
Light (µmol m⁻² day⁻¹)
07/2019
08/2019
09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020

### A1.3.3 WQ3

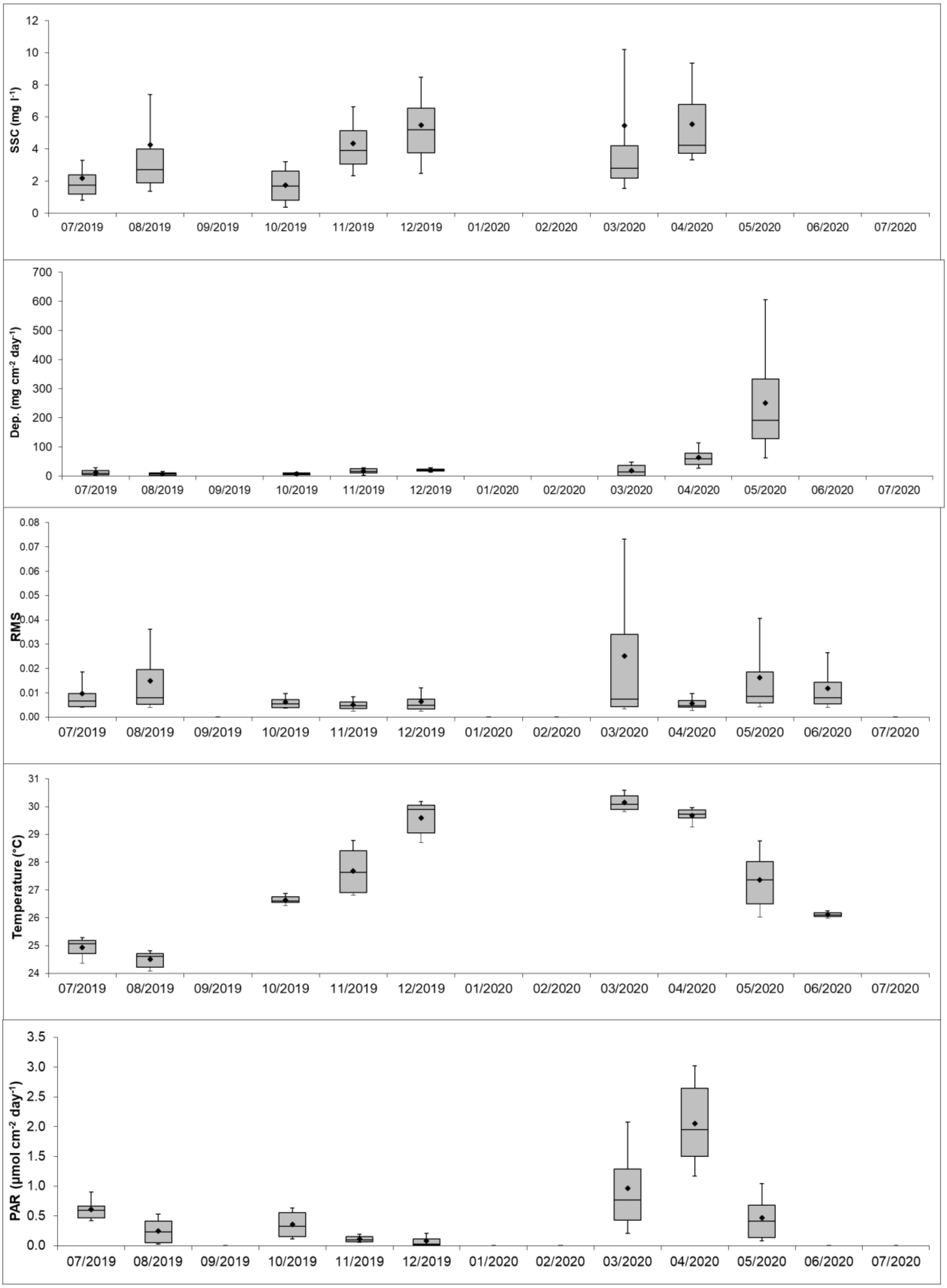
| | SSC 07/2019 | SSC 08/2019 | SSC 09/2019 | SSC 10/2019 | SSC 11/2019 | SSC 12/2019 | SSC 01/2020 | SSC 02/2020 | SSC 03/2020 | SSC 04/2020 | SSC 05/2020 | SSC 06/2020 | SSC 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 2.19 | 4.26 | | 1.76 | 4.34 | 5.50 | | | 5.47 | 5.56 | | | |
| median | 1.74 | 2.71 | | 1.67 | 3.92 | 5.20 | | | 2.81 | 4.25 | | | |
| min | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | | | 0.12 | 2.80 | | | |
| lower | 1.20 | 1.91 | | 0.81 | 3.06 | 3.76 | | | 2.18 | 3.72 | | | |
| upper | 2.39 | 4.00 | | 2.62 | 5.13 | 6.53 | | | 4.21 | 6.79 | | | |
| max | 55.56 | 83.14 | | 5.91 | 49.91 | 55.34 | | | 123.06 | 14.70 | | | |
| $90^{th}$ percentile | 3.31 | 7.39 | | 3.22 | 6.63 | 8.49 | | | 10.20 | 9.34 | | | |
| $10^{th}$ percentile | 0.82 | 1.36 | | 0.37 | 2.34 | 2.46 | | | 1.55 | 3.34 | | | |
| n | 4443 | 3944 | 0 | 1951 | 4238 | 1639 | 0 | 0 | 3682 | 299 | 0 | 0 | 0 |
| St. Dev | 2.79 | 6.05 | | 1.11 | 2.37 | 3.41 | | | 9.60 | 2.50 | | | |
| St. Error | 0.04 | 0.10 | | 0.03 | 0.04 | 0.08 | | | 0.16 | 0.14 | | | |

| | ASSD 07/2019 | ASSD 08/2019 | ASSD 09/2019 | ASSD 10/2019 | ASSD 11/2019 | ASSD 12/2019 | ASSD 01/2020 | ASSD 02/2020 | ASSD 03/2020 | ASSD 04/2020 | ASSD 05/2020 | ASSD 06/2020 | ASSD 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.44 | 0.43 | | 0.27 | 0.75 | 1.45 | | | 0.43 | 1.70 | 5.60 | | |
| median | 0.00 | 0.00 | | 0.00 | 0.00 | 0.24 | | | 0.03 | 0.52 | 2.53 | | |
| min | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.00 | | |
| lower | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.26 | | |
| upper | 0.23 | 0.05 | | 0.01 | 0.16 | 1.21 | | | 0.31 | 2.10 | 7.23 | | |
| max | 27.98 | 60.04 | | 27.83 | 36.16 | 38.59 | | | 14.85 | 63.95 | 54.99 | | |
| $90^{th}$ percentile | 0.90 | 0.42 | | 0.42 | 2.09 | 4.06 | | | 1.14 | 4.53 | 15.99 | | |
| $10^{th}$ percentile | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | | | 0.00 | 0.00 | 0.00 | | |
| n | 4452 | 3944 | 0 | 1952 | 4240 | 1639 | 0 | 0 | 3683 | 4320 | 2639 | 0 | 0 |
| St. Dev | 1.57 | 2.58 | | 1.43 | 2.38 | 3.41 | | | 1.15 | 3.63 | 7.99 | | |
| St. Error | 0.02 | 0.04 | | 0.03 | 0.04 | 0.08 | | | 0.02 | 0.06 | 0.16 | | |

| | RMS 07/2019 | RMS 08/2019 | RMS 09/2019 | RMS 10/2019 | RMS 11/2019 | RMS 12/2019 | RMS 01/2020 | RMS 02/2020 | RMS 03/2020 | RMS 04/2020 | RMS 05/2020 | RMS 06/2020 | RMS 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.010 | 0.015 | | 0.006 | 0.005 | 0.006 | | | 0.025 | 0.006 | 0.016 | 0.012 | |
| median | 0.007 | 0.008 | | 0.006 | 0.005 | 0.005 | | | 0.007 | 0.005 | 0.009 | 0.008 | |
| min | 0.000 | 0.000 | | 0.000 | 0.000 | 0.001 | | | 0.000 | 0.000 | 0.000 | 0.000 | |
| lower | 0.004 | 0.005 | | 0.004 | 0.004 | 0.003 | | | 0.004 | 0.004 | 0.006 | 0.006 | |
| upper | 0.010 | 0.020 | | 0.007 | 0.006 | 0.007 | | | 0.034 | 0.007 | 0.019 | 0.014 | |
| max | 0.102 | 0.094 | | 0.047 | 0.027 | 0.038 | | | 0.280 | 0.031 | 0.144 | 0.080 | |
| 90th percentile | 0.019 | 0.036 | | 0.010 | 0.008 | 0.012 | | | 0.073 | 0.010 | 0.041 | 0.027 | |
| 10th percentile | 0.004 | 0.004 | | 0.004 | 0.002 | 0.003 | | | 0.003 | 0.003 | 0.004 | 0.004 | |
| n | 4460 | 3945 | 0 | 1952 | 4240 | 1640 | 0 | 0 | 3683 | 4320 | 4464 | 2208 | 0 |
| St. Dev | 0.010 | 0.015 | | 0.003 | 0.003 | 0.005 | | | 0.035 | 0.003 | 0.018 | 0.010 | |
| St. Error | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | | | 0.001 | 0.000 | 0.000 | 0.000 | |

| | Temp 07/2019 | Temp 08/2019 | Temp 09/2019 | Temp 10/2019 | Temp 11/2019 | Temp 12/2019 | Temp 01/2020 | Temp 02/2020 | Temp 03/2020 | Temp 04/2020 | Temp 05/2020 | Temp 06/2020 | Temp 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 24.93 | 24.50 | | 26.65 | 27.68 | 29.59 | | | 30.16 | 29.68 | 27.37 | 26.11 | |
| median | 25.07 | 24.61 | | 26.61 | 27.63 | 29.90 | | | 30.08 | 29.73 | 27.36 | 26.10 | |
| min | 24.12 | 23.83 | | 26.38 | 26.40 | 28.49 | | | 29.70 | 28.96 | 25.50 | 25.84 | |
| lower | 24.71 | 24.22 | | 26.55 | 26.91 | 29.06 | | | 29.90 | 29.59 | 26.50 | 26.04 | |
| upper | 25.18 | 24.72 | | 26.75 | 28.42 | 30.05 | | | 30.39 | 29.88 | 28.02 | 26.18 | |
| max | 25.41 | 24.96 | | 27.20 | 29.21 | 30.41 | | | 30.99 | 30.22 | 29.04 | 26.39 | |
| 90th percentile | 25.28 | 24.81 | | 26.87 | 28.79 | 30.18 | | | 30.60 | 29.96 | 28.76 | 26.25 | |
| 10th percentile | 24.36 | 24.08 | | 26.45 | 26.81 | 28.70 | | | 29.82 | 29.27 | 26.03 | 25.98 | |
| n | 4451 | 3945 | 0 | 1945 | 4234 | 1640 | 0 | 0 | 3679 | 4320 | 4464 | 2208 | 0 |
| St. Dev | 0.33 | 0.28 | | 0.15 | 0.78 | 0.57 | | | 0.30 | 0.26 | 0.95 | 0.10 | |
| St. Error | 0.01 | 0.00 | | 0.00 | 0.01 | 0.01 | | | 0.01 | 0.00 | 0.01 | 0.00 | |

| | Light 07/2019 | Light 08/2019 | Light 09/2019 | Light 10/2019 | Light 11/2019 | Light 12/2019 | Light 01/2020 | Light 02/2020 | Light 03/2020 | Light 04/2020 | Light 05/2020 | Light 06/2020 | Light 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.61 | 0.25 | | 0.36 | 0.11 | 0.08 | | | 0.96 | 2.05 | 0.47 | | |
| median | 0.60 | 0.23 | | 0.33 | 0.10 | 0.03 | | | 0.76 | 1.95 | 0.41 | | |
| min | 0.12 | 0.01 | | 0.07 | 0.01 | 0.00 | | | 0.00 | 0.73 | 0.01 | | |
| lower | 0.47 | 0.05 | | 0.16 | 0.07 | 0.01 | | | 0.43 | 1.50 | 0.13 | | |
| upper | 0.67 | 0.41 | | 0.55 | 0.15 | 0.11 | | | 1.29 | 2.64 | 0.68 | | |
| max | 1.18 | 0.66 | | 0.67 | 0.30 | 0.27 | | | 2.59 | 3.34 | 1.42 | | |
| $90^{th}$ percentile | 0.90 | 0.53 | | 0.63 | 0.19 | 0.21 | | | 2.07 | 3.02 | 1.04 | | |
| $10^{th}$ percentile | 0.42 | 0.02 | | 0.11 | 0.06 | 0.00 | | | 0.21 | 1.17 | 0.08 | | |
| n | 31 | 27 | 0 | 13 | 30 | 11 | 0 | 0 | 25 | 30 | 31 | 1 | 0 |
| St. Dev | 0.22 | 0.20 | | 0.22 | 0.07 | 0.09 | | | 0.74 | 0.72 | 0.38 | | |
| St. Error | 0.04 | 0.04 | | 0.06 | 0.01 | 0.03 | | | 0.15 | 0.13 | 0.07 | | |


SSC (mg l⁻¹)
Dep. (mg cm⁻² day⁻¹)
RMS
Temperature (°C)
PAR (µmol cm⁻² day⁻¹)
07/2019
08/2019
09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020

### A1.3.4 WQ4

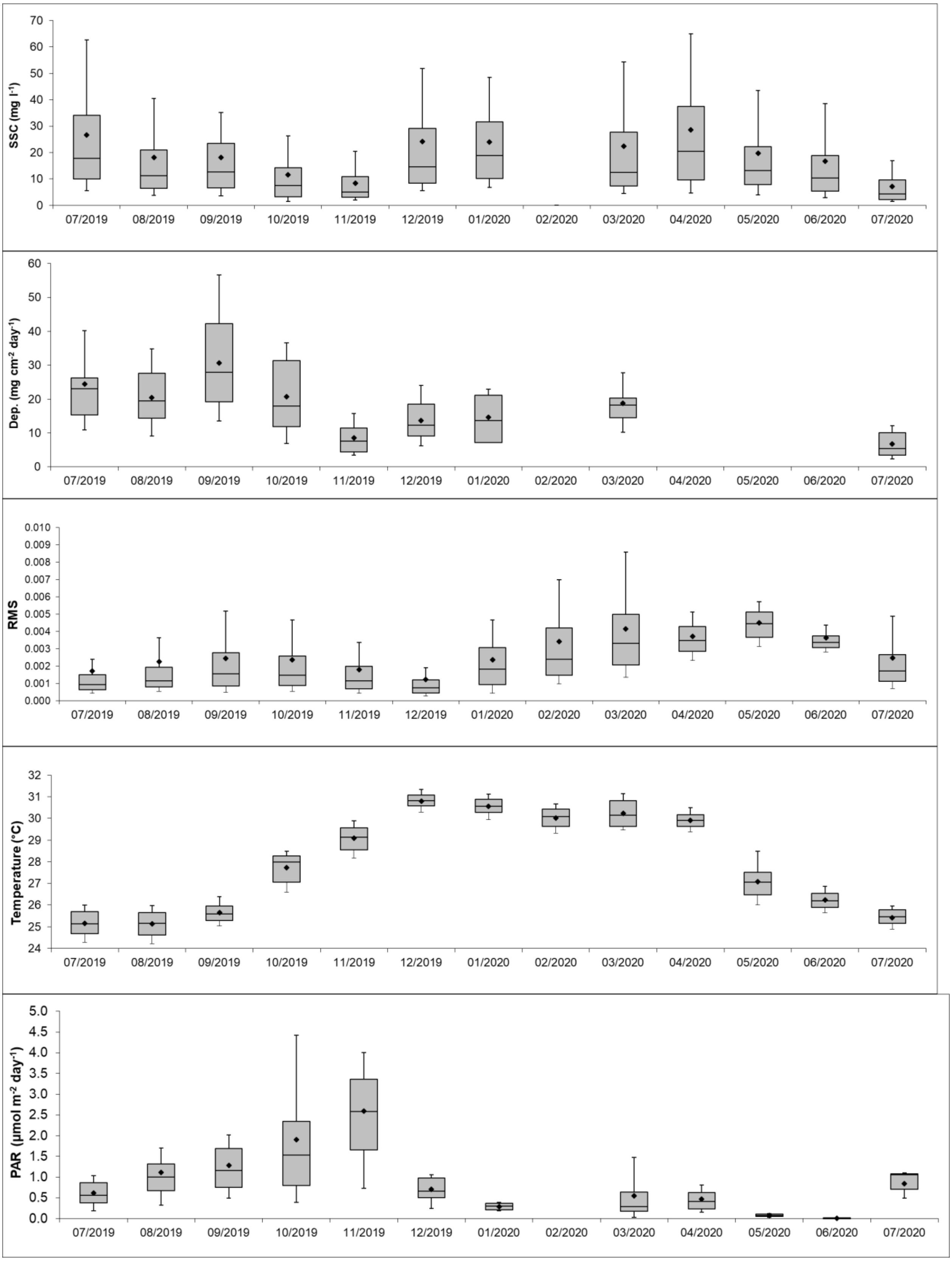
| | SSC 07/2019 | SSC 08/2019 | SSC 09/2019 | SSC 10/2019 | SSC 11/2019 | SSC 12/2019 | SSC 01/2020 | SSC 02/2020 | SSC 03/2020 | SSC 04/2020 | SSC 05/2020 | SSC 06/2020 | SSC 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 26.59 | 18.14 | 18.13 | 11.53 | 8.35 | 24.23 | 23.95 | | 22.36 | 28.65 | 19.77 | 16.70 | 7.14 |
| median | 17.82 | 11.26 | 12.65 | 7.58 | 4.96 | 14.63 | 18.88 | | 12.49 | 20.52 | 13.12 | 10.37 | 4.26 |
| min | 0.02 | 0.14 | 0.80 | 0.12 | 0.38 | 0.21 | 1.96 | | 0.15 | 0.33 | 0.66 | 0.26 | 0.03 |
| lower | 9.96 | 6.51 | 6.63 | 3.25 | 3.05 | 8.37 | 10.17 | | 7.31 | 9.69 | 7.83 | 5.43 | 2.24 |
| upper | 34.12 | 21.02 | 23.44 | 14.25 | 10.89 | 29.05 | 31.67 | | 27.69 | 37.55 | 22.29 | 18.81 | 9.72 |
| max | 176.27 | 165.42 | 163.81 | 104.92 | 97.77 | 233.04 | 149.37 | | 176.95 | 170.59 | 153.30 | 172.80 | 96.07 |
| 90$^{th}$ percentile | 62.57 | 40.51 | 35.09 | 26.29 | 20.41 | 51.91 | 48.43 | | 54.36 | 64.91 | 43.44 | 38.44 | 16.98 |
| 10$^{th}$ percentile | 5.60 | 3.85 | 3.57 | 1.51 | 1.97 | 5.63 | 6.75 | | 4.43 | 4.65 | 4.06 | 2.91 | 1.52 |
| n | 3732 | 4371 | 2409 | 1969 | 2807 | 2912 | 677 | 0 | 3610 | 3157 | 3276 | 2043 | 4089 |
| St. Dev | 25.01 | 20.39 | 17.93 | 12.92 | 8.21 | 26.97 | 18.35 | | 24.71 | 26.95 | 20.88 | 19.50 | 7.21 |
| St. Error | 0.41 | 0.31 | 0.37 | 0.29 | 0.15 | 0.50 | 0.71 | | 0.41 | 0.48 | 0.36 | 0.43 | 0.11 |

| | ASSD 07/2019 | ASSD 08/2019 | ASSD 09/2019 | ASSD 10/2019 | ASSD 11/2019 | ASSD 12/2019 | ASSD 01/2020 | ASSD 02/2020 | ASSD 03/2020 | ASSD 04/2020 | ASSD 05/2020 | ASSD 06/2020 | ASSD 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 7.95 | 5.64 | 3.31 | 1.55 | 0.76 | 1.86 | 1.89 | | 2.44 | | | | 0.30 |
| median | 0.19 | 0.04 | 0.20 | 0.00 | 0.00 | 0.01 | 0.00 | | 0.01 | | | | 0.00 |
| min | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | | | | 0.00 |
| lower | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | | | | 0.00 |
| upper | 6.88 | 2.31 | 2.64 | 0.34 | 0.06 | 0.32 | 0.39 | | 0.61 | | | | 0.10 |
| max | 128.60 | 140.20 | 36.14 | 36.69 | 55.91 | 79.62 | 57.89 | | 64.38 | | | | 51.13 |
| 90$^{th}$ percentile | 28.12 | 14.16 | 11.32 | 3.95 | 0.64 | 3.26 | 4.44 | | 4.40 | | | | 0.42 |
| 10$^{th}$ percentile | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | | | | 0.00 |
| n | 4459 | 4421 | 4318 | 4446 | 4241 | 4381 | 598 | 0 | 3801 | 0 | 0 | 0 | 3105 |
| St. Dev | 16.85 | 15.82 | 6.89 | 4.70 | 3.55 | 6.96 | 6.46 | | 8.36 | | | | 1.66 |
| St. Error | 0.25 | 0.24 | 0.10 | 0.07 | 0.05 | 0.11 | 0.26 | | 0.14 | | | | 0.03 |

| | RMS 07/2019 | RMS 08/2019 | RMS 09/2019 | RMS 10/2019 | RMS 11/2019 | RMS 12/2019 | RMS 01/2020 | RMS 02/2020 | RMS 03/2020 | RMS 04/2020 | RMS 05/2020 | RMS 06/2020 | RMS 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.002 | 0.003 | 0.004 | 0.004 | 0.005 | 0.004 | 0.002 |
| median | 0.001 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.003 | 0.003 | 0.004 | 0.003 | 0.002 |
| min | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.001 | 0.000 |
| lower | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | 0.003 | 0.004 | 0.003 | 0.001 |
| upper | 0.002 | 0.002 | 0.003 | 0.003 | 0.002 | 0.001 | 0.003 | 0.004 | 0.005 | 0.004 | 0.005 | 0.004 | 0.003 |
| max | 0.065 | 0.050 | 0.086 | 0.062 | 0.052 | 0.081 | 0.036 | 0.040 | 0.026 | 0.029 | 0.025 | 0.018 | 0.041 |
| 90th percentile | 0.002 | 0.004 | 0.005 | 0.005 | 0.003 | 0.002 | 0.005 | 0.007 | 0.009 | 0.005 | 0.006 | 0.004 | 0.005 |
| 10th percentile | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.002 | 0.003 | 0.003 | 0.001 |
| n | 4461 | 4429 | 4320 | 4461 | 4244 | 4461 | 4464 | 4032 | 4460 | 4320 | 4461 | 2241 | 4118 |
| St. Dev | 0.003 | 0.004 | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 | 0.003 | 0.002 | 0.001 | 0.001 | 0.003 |
| St. Error | 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 |

| | Temp 07/2019 | Temp 08/2019 | Temp 09/2019 | Temp 10/2019 | Temp 11/2019 | Temp 12/2019 | Temp 01/2020 | Temp 02/2020 | Temp 03/2020 | Temp 04/2020 | Temp 05/2020 | Temp 06/2020 | Temp 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 25.16 | 25.14 | 25.66 | 27.72 | 29.09 | 30.80 | 30.56 | 30.02 | 30.23 | 29.92 | 27.07 | 26.23 | 25.41 |
| median | 25.13 | 25.16 | 25.60 | 27.99 | 29.14 | 30.83 | 30.57 | 30.09 | 30.16 | 29.92 | 27.06 | 26.20 | 25.45 |
| min | 22.93 | 23.45 | 24.34 | 26.04 | 27.76 | 29.20 | 28.68 | 28.51 | 29.13 | 28.56 | 24.14 | 24.68 | 0.00 |
| lower | 24.68 | 24.62 | 25.28 | 27.05 | 28.56 | 30.58 | 30.27 | 29.63 | 29.64 | 29.63 | 26.47 | 25.90 | 25.15 |
| upper | 25.70 | 25.66 | 25.95 | 28.26 | 29.57 | 31.07 | 30.89 | 30.43 | 30.83 | 30.18 | 27.51 | 26.54 | 25.79 |
| max | 26.82 | 26.89 | 27.50 | 29.06 | 30.73 | 31.84 | 31.87 | 30.97 | 31.79 | 31.35 | 29.56 | 27.86 | 26.36 |
| 90th percentile | 26.00 | 25.97 | 26.39 | 28.48 | 29.90 | 31.34 | 31.13 | 30.66 | 31.14 | 30.49 | 28.48 | 26.87 | 25.95 |
| 10th percentile | 24.27 | 24.22 | 25.03 | 26.59 | 28.17 | 30.30 | 29.95 | 29.32 | 29.47 | 29.38 | 26.01 | 25.64 | 24.89 |
| n | 4449 | 4429 | 4320 | 4454 | 4244 | 4451 | 4464 | 4032 | 4460 | 4320 | 4461 | 2241 | 4118 |
| St. Dev | 0.66 | 0.66 | 0.53 | 0.72 | 0.63 | 0.42 | 0.47 | 0.51 | 0.65 | 0.44 | 0.91 | 0.49 | 1.12 |
| St. Error | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |

| | Light 07/2019 | Light 08/2019 | Light 09/2019 | Light 10/2019 | Light 11/2019 | Light 12/2019 | Light 01/2020 | Light 02/2020 | Light 03/2020 | Light 04/2020 | Light 05/2020 | Light 06/2020 | Light 07/2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.62 | 1.12 | 1.28 | 1.91 | 2.59 | 0.70 | 0.29 | | 0.55 | 0.48 | 0.08 | 0.01 | 0.84 |
| median | 0.56 | 1.00 | 1.16 | 1.53 | 2.58 | 0.66 | 0.30 | | 0.29 | 0.42 | 0.08 | 0.00 | 1.06 |
| min | 0.08 | 0.19 | 0.30 | 0.24 | 0.52 | 0.17 | 0.17 | | 0.01 | 0.13 | 0.02 | 0.00 | 0.36 |
| lower | 0.38 | 0.68 | 0.75 | 0.80 | 1.66 | 0.50 | 0.21 | | 0.18 | 0.24 | 0.05 | 0.00 | 0.71 |
| upper | 0.87 | 1.31 | 1.69 | 2.34 | 3.36 | 0.98 | 0.37 | | 0.64 | 0.63 | 0.11 | 0.02 | 1.09 |
| max | 1.51 | 5.09 | 3.35 | 6.71 | 5.83 | 1.40 | 0.40 | | 2.56 | 1.26 | 0.20 | 0.03 | 1.12 |
| 90$^{th}$ percentile | 1.04 | 1.71 | 2.02 | 4.42 | 4.00 | 1.06 | 0.39 | | 1.48 | 0.81 | 0.13 | 0.02 | 1.11 |
| 10$^{th}$ percentile | 0.19 | 0.33 | 0.49 | 0.39 | 0.73 | 0.24 | 0.19 | | 0.03 | 0.16 | 0.03 | 0.00 | 0.50 |
| n | 31 | 31 | 30 | 31 | 30 | 31 | 6 | 0 | 27 | 30 | 31 | 15 | 3 |
| St. Dev | 0.35 | 0.89 | 0.74 | 1.59 | 1.29 | 0.33 | 0.10 | | 0.65 | 0.28 | 0.04 | 0.01 | 0.42 |
| St. Error | 0.06 | 0.16 | 0.13 | 0.29 | 0.23 | 0.06 | 0.04 | | 0.12 | 0.05 | 0.01 | 0.00 | 0.24 |


SSC (mg l⁻¹)
Dep. (mg cm⁻² day⁻¹)
RMS
Temperature (°C)
PAR (µmol m⁻² day⁻¹)
07/2019
08/2019
09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020

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