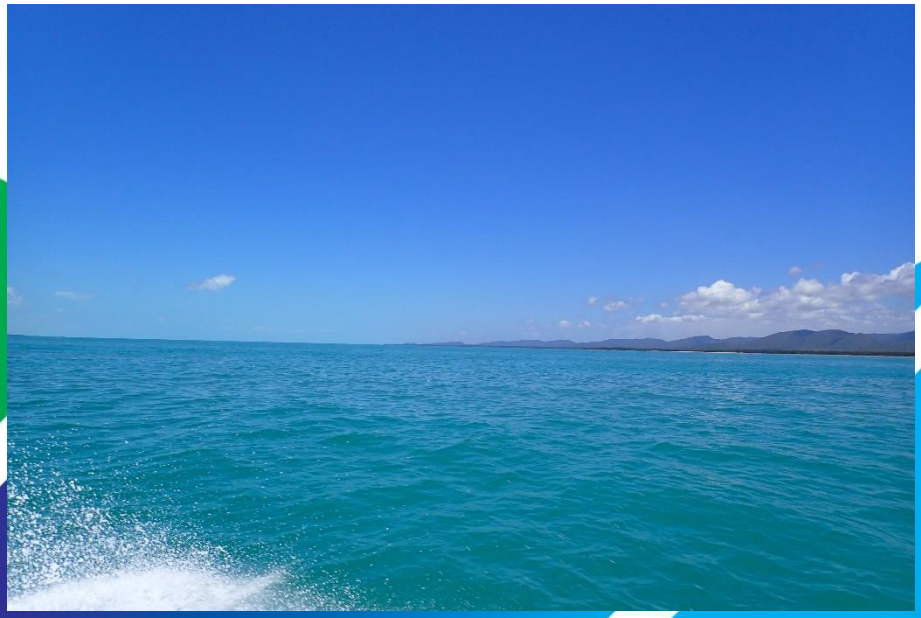
Port of Mackay and Hay Point Ambient Marine Water Quality Monitoring Program: Annual report 2019-2020

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

Report No. 20/47

December 2020



Port of Mackay and Hay Point Ambient Marine Water Quality Monitoring Program: Annual Report 2019-2020

A Report for North Queensland Bulk Ports Corporation

Report No. 20/47

December 2020

Prepared by Nathan Waltham, Jordan Iles, James Whinney, Blake Ramsby, and Rachael Macdonald

Centre for Tropical Water & Aquatic Ecosystem Research
(TropWATER)
James Cook University
Townsville
Phone : (07) 4781 4262
Email: TropWATER@jcu.edu.au
Web: www.jcu.edu.au/tropwater/

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For further information contact:
Dr Nathan Waltham
Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)
James Cook University
Nathan.waltham@jcu.edu.au

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EXECUTIVE SUMMARY

Background

1. North Queensland Bulk Ports commenced an ambient marine water quality monitoring program surrounding the Ports of Mackay and Hay Point in July 2014. The objective of the program is to progress a long term water quality dataset to characterise marine water quality conditions within the Mackay region that will support future planned port activities. This report presents data collected during the 2019/2020 annual monitoring period.
2. The program incorporates a field measurements and high frequency continuous data loggers, laboratory analysis for a range of nutrient, pesticides, and heavy metals.
3. Sites extend approximately 60km along the Mackay coastline, from Slade Islet to Freshwater Point, and offshore to Keswick Island. Sites in the network align with key sensitive receptor habitats (e.g. corals or seagrass), along with key features in the study region (e.g. river flow points). Coral and seagrass receptor habitat assessments are completed across the same study region and are available in companion reports on the TropWATER website (www.tropwater.com).

Climatic conditions

1. The total 2019-2020 wet season rainfall at Plane Creek Sugar Mill (17 km linear from Hay Point) was 1101 mm which is proximal to the long term average wet season total. This total is however lower than the 2018-2019 total.
2. The wet season rainfall contributed to at least four flow periods, but most notably during March 2020.

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. Seasonal differences in water quality were minor, except for temperature which continues to be highest during the summer months.
3. There was little difference in water temperature between the three depths examined, indicating that the water column was well mixed during each survey.
4. Particulate nitrogen concentrations exceeded the guidelines throughout most of the 2019-2020 monitoring period.
5. Chlorophyll-a concentrations exceeded the GBRMPA guideline trigger value for all sampling events except August 2019.
6. Metals targeted for analysis were not detected above the 95% level of protection trigger values for marine waters. Silver, Cadmium, Nickel, Zinc, and Mercury were not detected. Copper was detected at Mackay Harbour in August 2019 (though concentrations were below the guideline in the following survey in May 2020). Lead was detected in August 2019 at Slade Point, and Dudgeon Point but was at concentrations below guideline values. Arsenic was detected at low concentrations.
7. Pesticides targeted for analysis were not detected above the trigger values for the GBR. The herbicides Chlorpyrifos and Diazinon were not detected. Hexazinone and Diuron were present at low concentrations for numerous sites in August 2019 and in May 2020. The insecticides Ametryn and Simazine were not detected (< LOD). Atrazine was present at low concentrations for most sites in May 2020.
8. An assessment of the plankton community (both phytoplankton and zooplankton) was completed during this reporting period. There was a clear separation in the plankton community between most surveys, suggesting seasonal and inter-annual variation, and a weak relationship with available nutrients. *Trichodesmium* blooms were noted across the region during most surveys, primarily during late spring and early summer.

High frequency loggers

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. This is similar to the pattern observed in long term annual data sets at these sites.
2. Another important finding here was that deposition data did not indicate large deposits occurring at any of the monitored sites, and this is likely attributed to re-suspension of sediment by wave energy. SSC continues to regularly exceed relevant water quality guidelines at all sites, indicating that the development of local water quality guidelines is prudent. As part of this local water quality guideline development, it is recommended that the guidelines apply to benthic waters, adjacent to sensitive receptor habitats, rather than the current approach of surface water guidelines that can be well away from important habitats.
3. Fine-scale patterns of photosynthetically active radiation (PAR) continue to be 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, and rainfall events resulting from storms leading to increased catchment flows and an input of suspended solids – this trend was particularly the case given the extended wet season rainfall and runoff in the region following the monsoon that covered the region in February 2019.
4. 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. 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.
5. 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, the relationship between these two parameters is not always strong. 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.
6. Overall there was little consistent difference between wet and dry season PAR levels, suggesting that the increase in available light during the wet season is possibly offset by the increased cloud cover, which has been a pattern found in previous years. Most sites showed no difference between wet and dry, while AMB 1 and 2, showed increases of mean and median values during the dry season and AMB 12 showed a decrease in mean and median values.

Recommendations

1. The program this reporting period included nine monitoring sites, which has allowed us to continue characterising water quality in the Mackay region.
2. The elevated copper result recorded in the marina in August 2019 were below the guideline in the May 2020 survey, this result might be an anomaly, however, should be further checked for an emerging problem.

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1 INTRODUCTION

1.1 Port operations

The Port of Mackay and the Port of Hay Point are situated on the central Queensland Coast (Figure 1.1). The Port of Mackay is located approximately four kilometers north of the Pioneer River, and is enclosed by large break walls that protect the port and marina property, while also allowing exchange of oceanic waters. The port has a series of operational and associated loading/unloading facilities, and an extensive marina operation and commercial fishing fleet. The port is operated by North Queensland Bulk Ports Corporation (NQBP).

The Port of Hay Point is situated approximately 40kms to the south of Pioneer River and Mackay City. Two coal terminals operate in the port: 1) Dalrymple Bay Coal Terminal; and 2) BMA Hay Point Coal Terminal. Similar to Port of Mackay, NQBP is the authority for the port but does not directly operate these facilities.

In both ports, routine maintenance dredging is necessary to maintain declared navigational depths within the swing basin and berth areas, departure path and aprons, and Tug Harbour at the Port of Hay Point. For the Port of Mackay, the most recent dredging campaign was completed in 2013, while the last maintenance dredging campaign undertaken by NQBP at the Port of Hay Point was completed in 2010. Any dredging activity necessary in the operating ports in the region are undertaken in accordance with Commonwealth and State approvals with management objectives guided by the Port of Mackay Long Term Dredge Management Plan and the Port of Hay Point Dredge Management Plan.

1.2 Program outline

Routine maintenance dredging is periodically required at the Port of Mackay and Hay Point to maintain vessel navigational depths. NQBP are committed to complete a range of monitoring programs specific to each dredge campaign with the objective of identifying direct impacts of the dredging activity. 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 an ambient marine water quality monitoring program in and around the coastal waters of the Port of Hay Point and the Port of Mackay (Figure 1.1; Table 1.1). As part of this program, water quality parameters are being investigated at a range of sites, including a control site in the southern Whitsunday Islands (Keswick Island; AMB12). 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 habitats for both Ports.

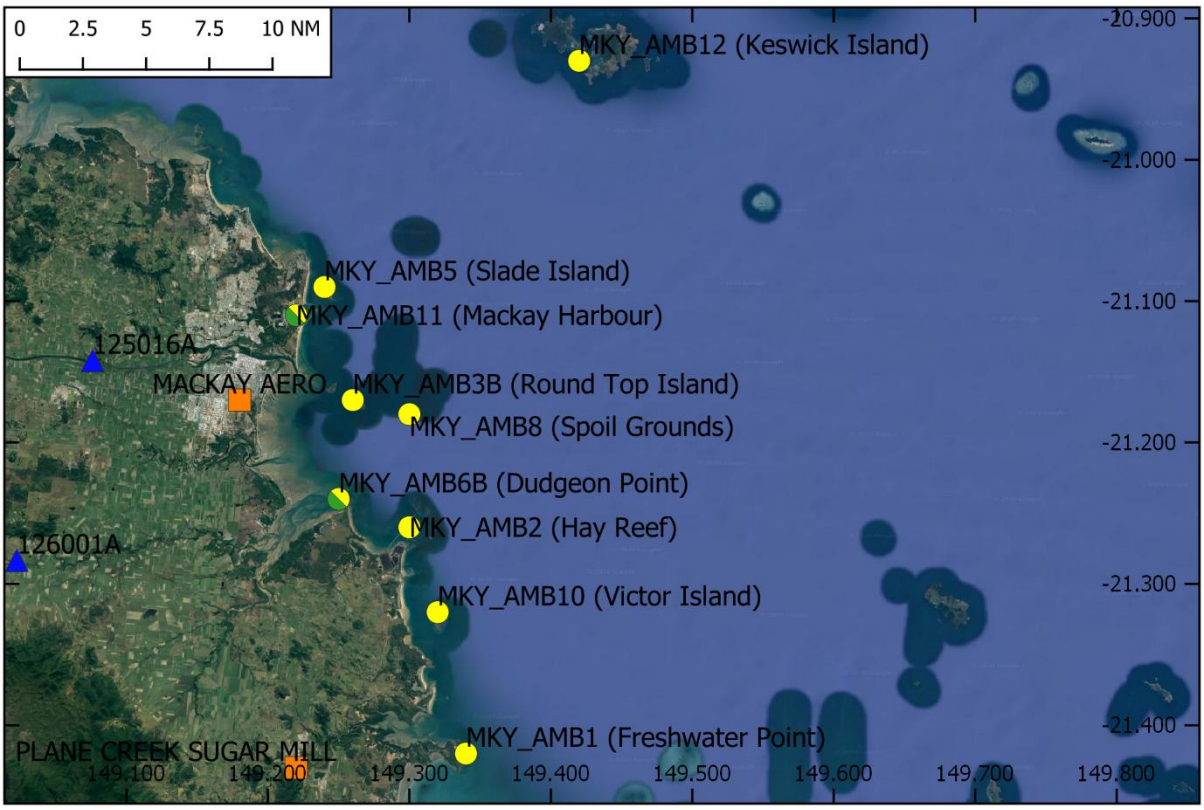

Figure 1.1 Location of water quality monitoring sites with loggers (yellow circle) and without loggers (yellow/green circles) utilised in the 2019-2020 reporting period. Also shown are meteorological stations (orange square), and stream gauging stations (blue triangle) referred to in this report.

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

Site name	Site code	Lat.	Long.	Water quality	Logger
Freshwater Point	MKY_AMB1	-21.42	149.34	Yes	Yes
Hay Reef	MKY_AMB2	-21.26	149.30	Yes	Yes
Round Top Island	MKY_AMB3B	-21.17	149.26	Yes	Yes
Slade Island	MKY_AMB5	-21.09	149.24	Yes	Yes
Dudgeon Point	MKY_AMB6B	-21.24	149.25	Yes	No
Spoil Grounds	MKY_AMB8	-21.18	149.30	Yes	Yes
Victor Island	MKY_AMB10	-21.32	149.32	Yes	Yes
Mackay Harbour	MKY_AMB11	-21.11	149.22	Yes	No
Keswick Island	MKY_AMB12	-20.93	149.42	Yes	Yes

1.3 Rainfall and river flows

Daily rainfall for the Mackay region is shown on Figure 1.2. The rainfall onset occurred on 12/10/2019 for Plane Creek, and 27/12/2020 for Mackay Aero. The rainfall onset is calculated as the date when the rainfall total reaches 50mm since 1st September. The 2019-2020 wet season rainfall total was 1100.6 mm, placing it as a slightly below the median wet season rainfall for 1912-1913 to 2019-2020 (Figure 1.3).

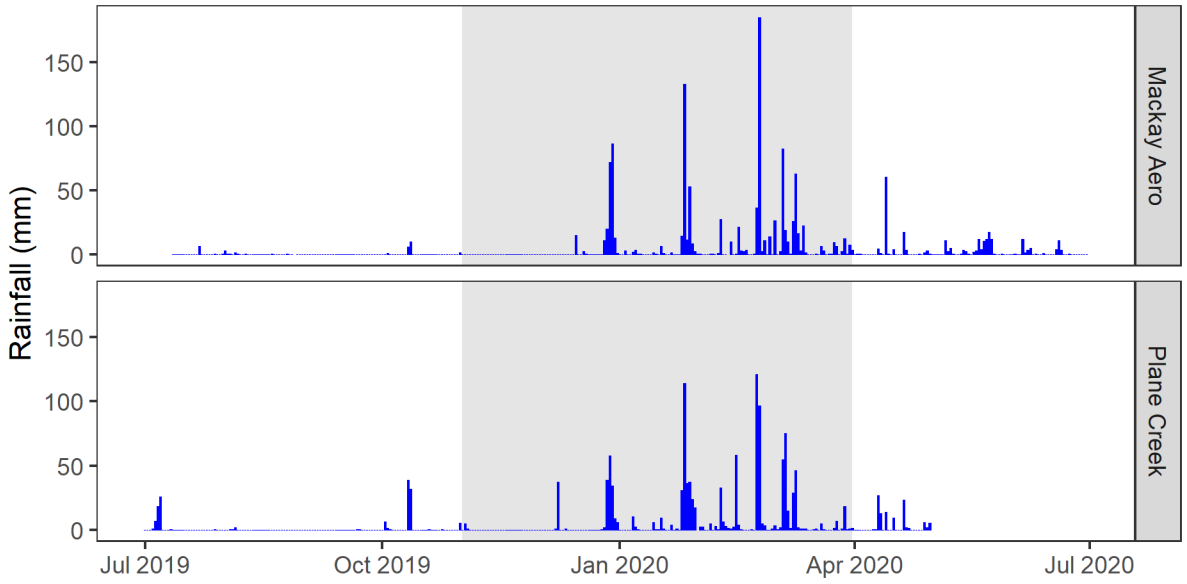

Figure 1.2 Rainfall recorded at Mackay Aero (station 033045) and Plane Creek Sugar Mill (station 033059) for the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: http://www.bom.gov.au/climate/data/

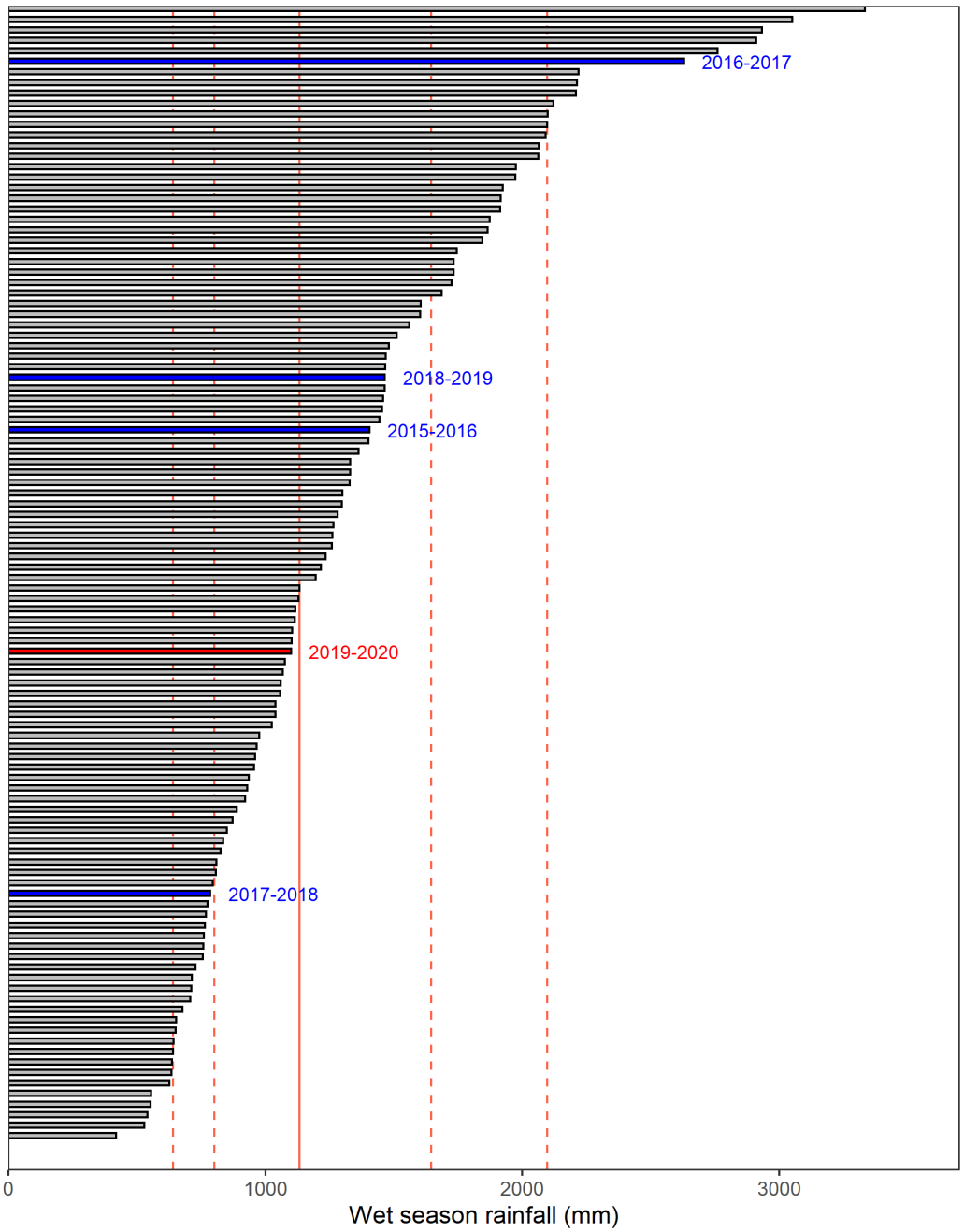

Figure 1.3 Wet season rainfall for the Mackay region ranked in order of decreasing total wet season rainfall (mm). Daily rainfall data was obtained from the Plane Creek Sugar Mill weather station (Station number 033059). Totals were calculated for the wet season period 1st November to 31st March for 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 1910-1911 to 2019-2020, dashed lines represent 10th, 25th, 75th, and 90th percentiles. Data source: http://www.bom.gov.au/climate/data/

Hydrographs for streams in the Pioneer Basin (Pioneer River) and Plane Basin (Sandy Creek) show onset of stream discharge on 28/12/2019 with a series of flow pulses through to March 2020 (Figure 1.4). Total discharge for the 2019-2020 reporting period was 426 GL (Pioneer River) and 124 GL (Sandy Creek).

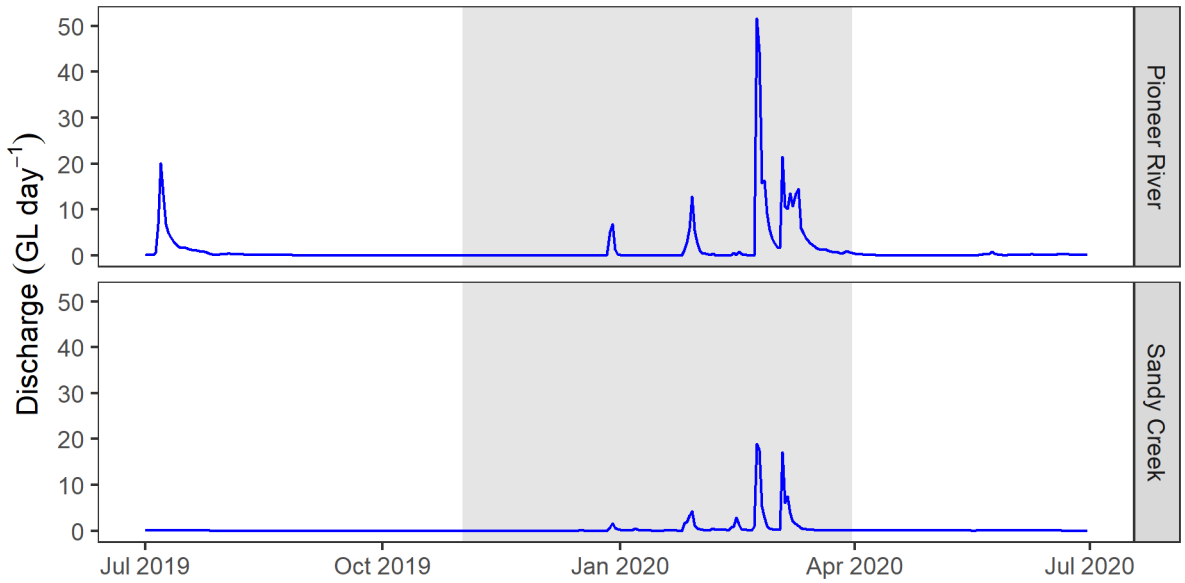

Figure 1.4 Stream discharge (GL d^{-1}) recorded for the Pioneer River (station 125007A) and Sandy Creek (station 126001A) during the 2019-2020 reporting period. The nominal wet season period is shaded grey. Data source: https://water-monitoring.information.qld.gov.au/.

1.4 Project objectives

The goal of the program is to characterise the ambient marine water quality monitoring within the region within and adjacent to Port of Mackay and Hay Point. This report provides a review and analysis of data collected between 01/07/2019 and 30/06/2020. These data are part of a long term commitment to monitor and characterise receiving water quality conditions, in particular to support future planned asset management and protection for both these ports.

2 METHODOLOGY

2.1 Ambient water quality

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

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

- Ultra-trace dissolved metals : arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn);
- Nutrients (particulate nitrogen and phosphorus);
- Chlorophyll-a; and
- Pesticides/herbicides (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. 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
Total Suspended Solids (TSS)	2540 D @ 103 - 105°C	0.2 mg/L
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
Thiocarbamates and Carbamates	In house LC/MS method: EP234B	0.0002 µg/L
Thiobencarb		
Dinitroanilines	In house LC/MS method: EP234C	0.001 µg/L
Pendimethalin		
Triazinone Herbicides	In house LC/MS method: EP234D	0.0002 µg/L
Hexazinone		
Conazole and Aminopyrimidine Fungicides	In house LC/MS method: EP234E	0.0002 µg/L
Propiconazole, Hexaconazole, Difenoconazole, Flusilazole, Penconazole		
Phenylurea Thizdiazolurea Uracil and Sulfonylurea Herbicides	In house LC/MS method: EP234F	0.0002 µg/L

Diuron, Ametryn, Atrazine, Cyanazine, Prometryn, Propazine, Simazine, Terbuthylazine, Terbutryn		
Nutrients		
Total Nitrogen and Phosphorus (TN/TP)	Simultaneous 4500-NO_3^- F and 4500-P F analyses after alkaline persulphate digestion	25 µg N/L 5 µg P/L
Filterable nutrients (nitrate, nitrite, ammonia, Nox)	4500-NO_3^- F	1 µg N/L
Ammonia	4500- NH_3 G	1 mg N/L
Filterable Reactive Phosphorus (FRP)	4500-P F	1 µg P/L
Chlorophyll	10200-H	0.1 µg/L
Trace Metals		
Arsenic, Cadmium, Copper, Lead, Nickel, Silver, Zinc, Mercury	3125B ORC/ICP/MS	0.05 to 100 µg/L

2.2 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 (Figure 2.2). The nets were towed at a speed of approximately 6 kts, with the position recorded by GPS at the start and end of each plankton tow. At the end of each plankton tow, the nets were 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.

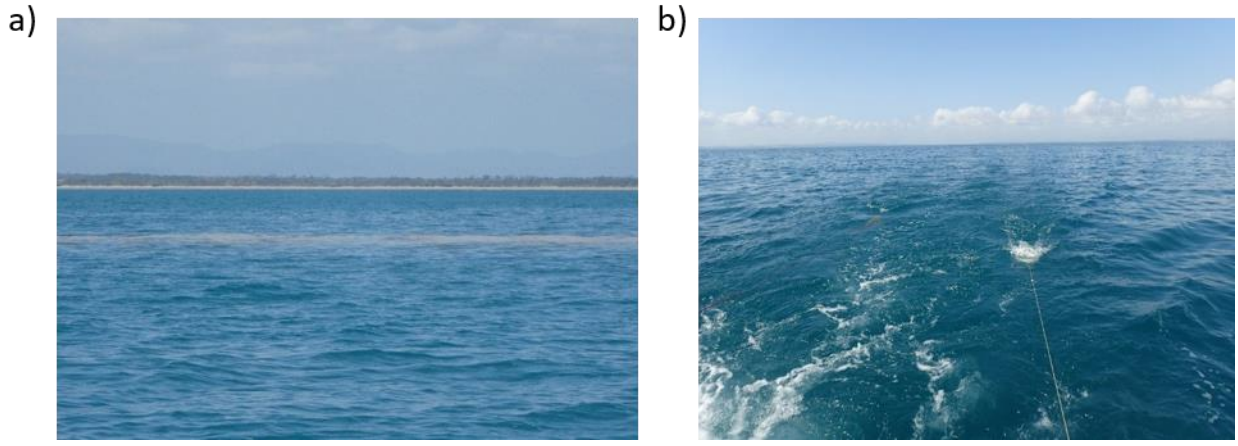

Figure 2.2 Example plankton sample. a) Trichodesmium bloom on sea surface; b) phytoplankton (60µm) tow behind the survey vessel

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 (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 nth of the 10 readings and $\overline{D}$ is the mean water depth of the n readings.

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

2.3.4 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.

a) b)

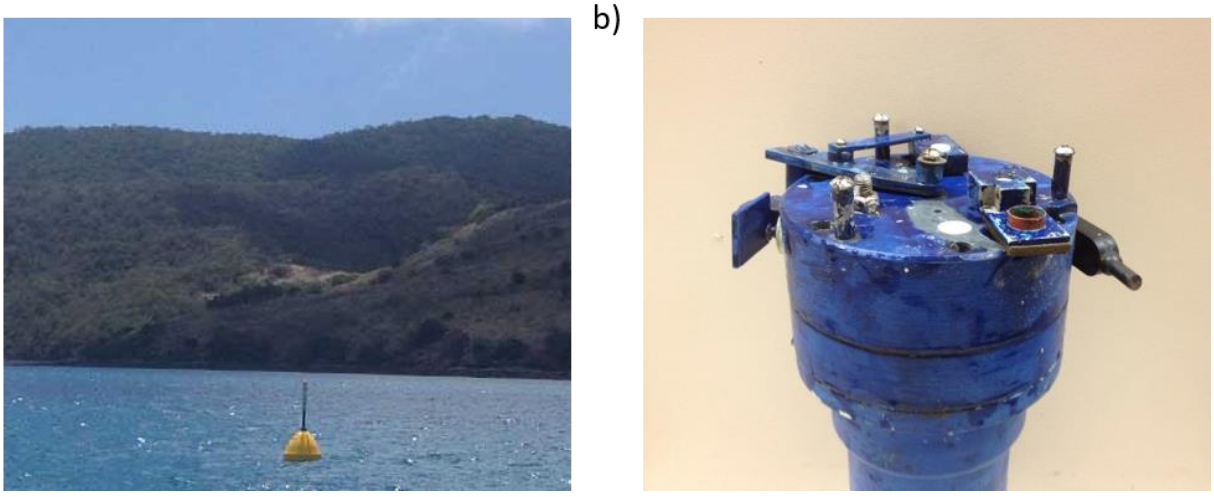

Figure 2.3 Example coastal multiparameter water quality instrument: a) site navigation beacon for safety and instrument retrieval; b) instrument showing sensors and wiping mechanisms

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.

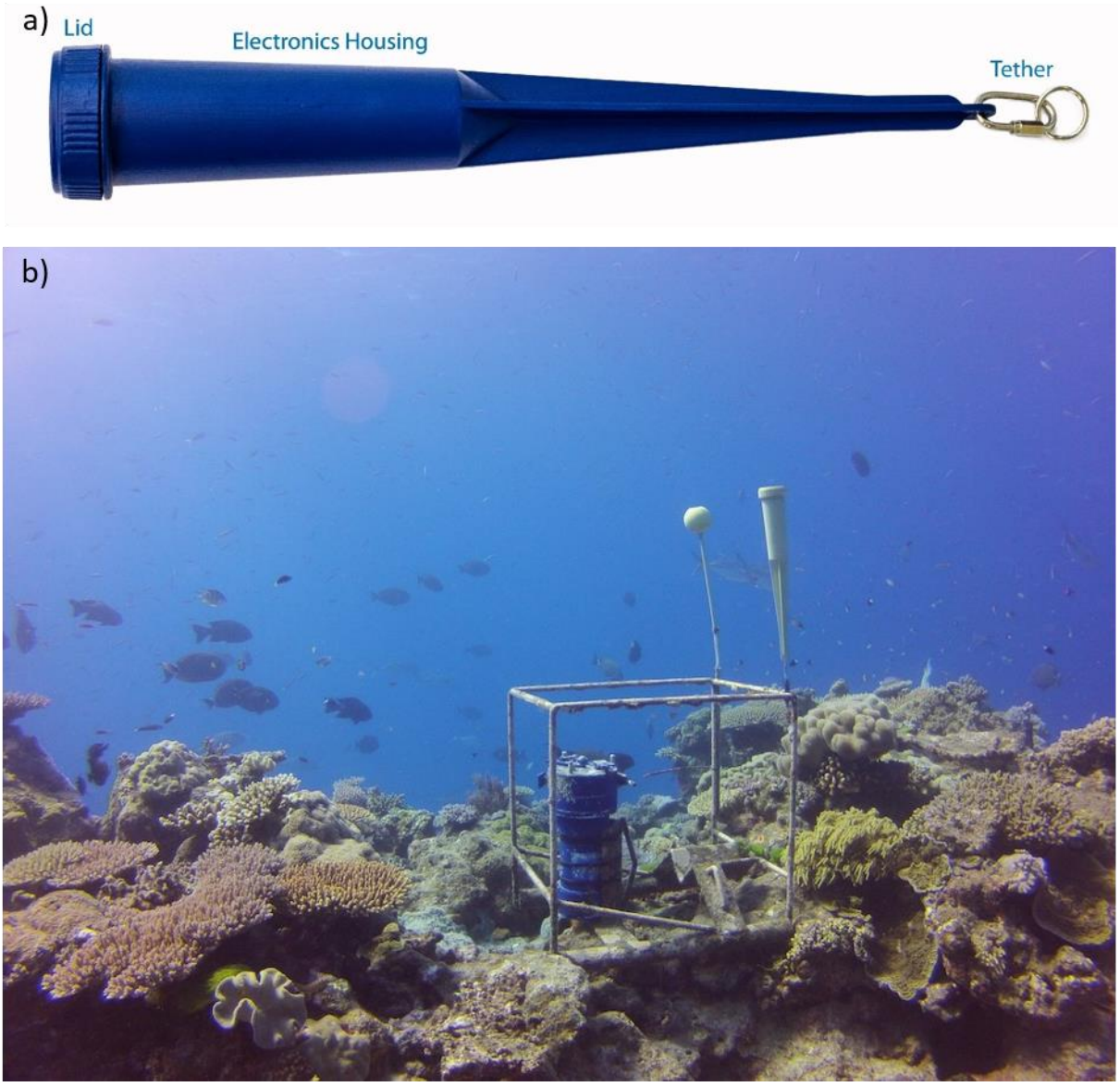

Figure 2.4 a) Basic schematic of Marotte HS current meter; and b) Marotte HS alongside Marotte at Moore Reef. Image courtesy of Eric Fisher

3 RESULTS AND DISCUSSION

There were nine sampling and maintenance trips in the 2019-2020 reporting period (Table 3.1).

Table 3.1 Summary of instrument maintenance and water quality surveys completed during the 2018/19 reporting period

Date	Nutrients, Chlorophyll-*a*	Metals, herbicides	Plankton	Logger
12/07/2019	Yes	-	Yes	Yes
14/08/2019	Yes	Yes	-	Yes
24/09/2019	Yes	-	Yes	Yes
02/11/2019	Yes	-	-	Yes
05/12/2020	Yes	-	-	Yes
11/01/2020	Yes*	-	-	Yes*
02/02/2020	Yes#	-	Yes	Yes#
02/04/2020	Yes	-	-	Yes
27/05/2020	Yes	Yes	-	Yes

* All sites except MKY_AMB2, MKY_AMB5, and MKY_AMB6B.
# MKY_AMB2, MKY_AMB5, and MKY_AMB6B only

3.1 Ambient water quality

3.1.1 Physio-chemical measurements

Water temperature ranged from 19.1 to 32.6 °C (Figure 3.1). There is a strong seasonal effect on water temperatures in the region, with the highest water temperatures observed during surveys in the summer months, and cool water temperatures observed during the winter months. 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 from 48.7 to 56.8 mS cm^{-1} and was in the range typical of seawater (Figure 3.2). Dissolved oxygen ranged from 19.2 to 145.6 %sat (Figure 3.3). pH ranged from 7.3 to 8.4 (Figure 3.4).

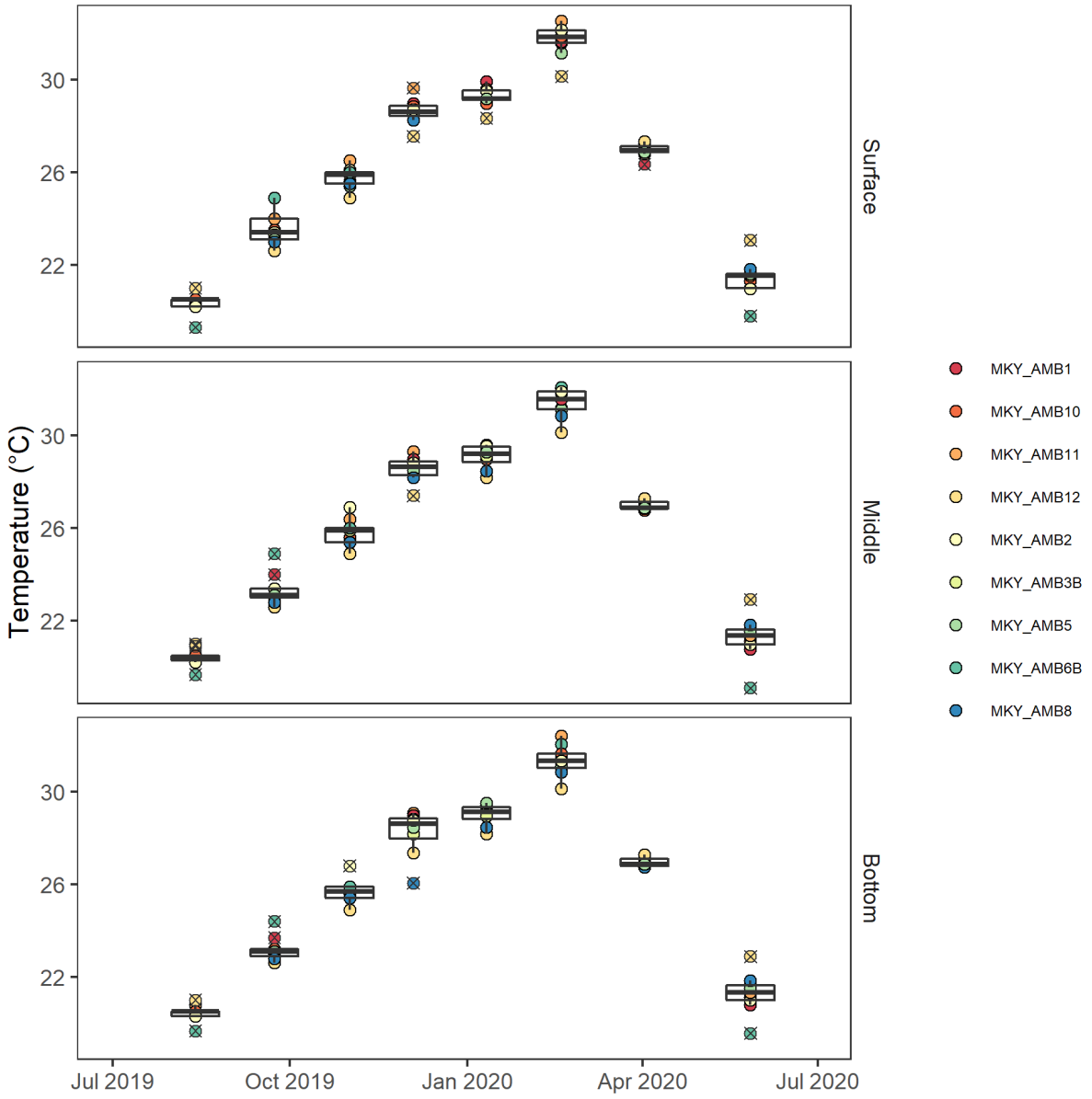

Figure 3.1 Water temperature recorded at three depths at the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'.

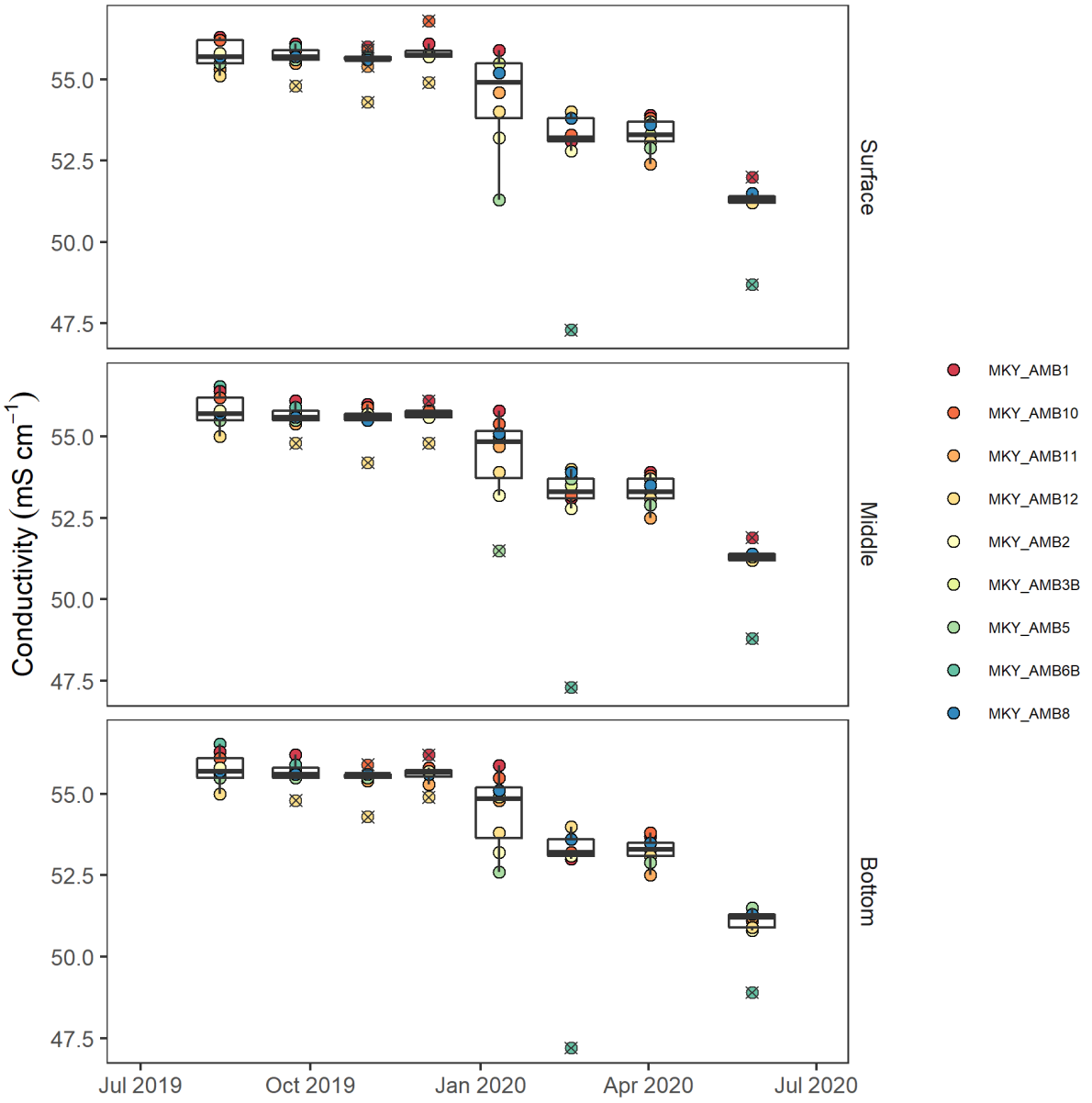

Figure 3.2 Electrical conductivity recorded at three depths at the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'.

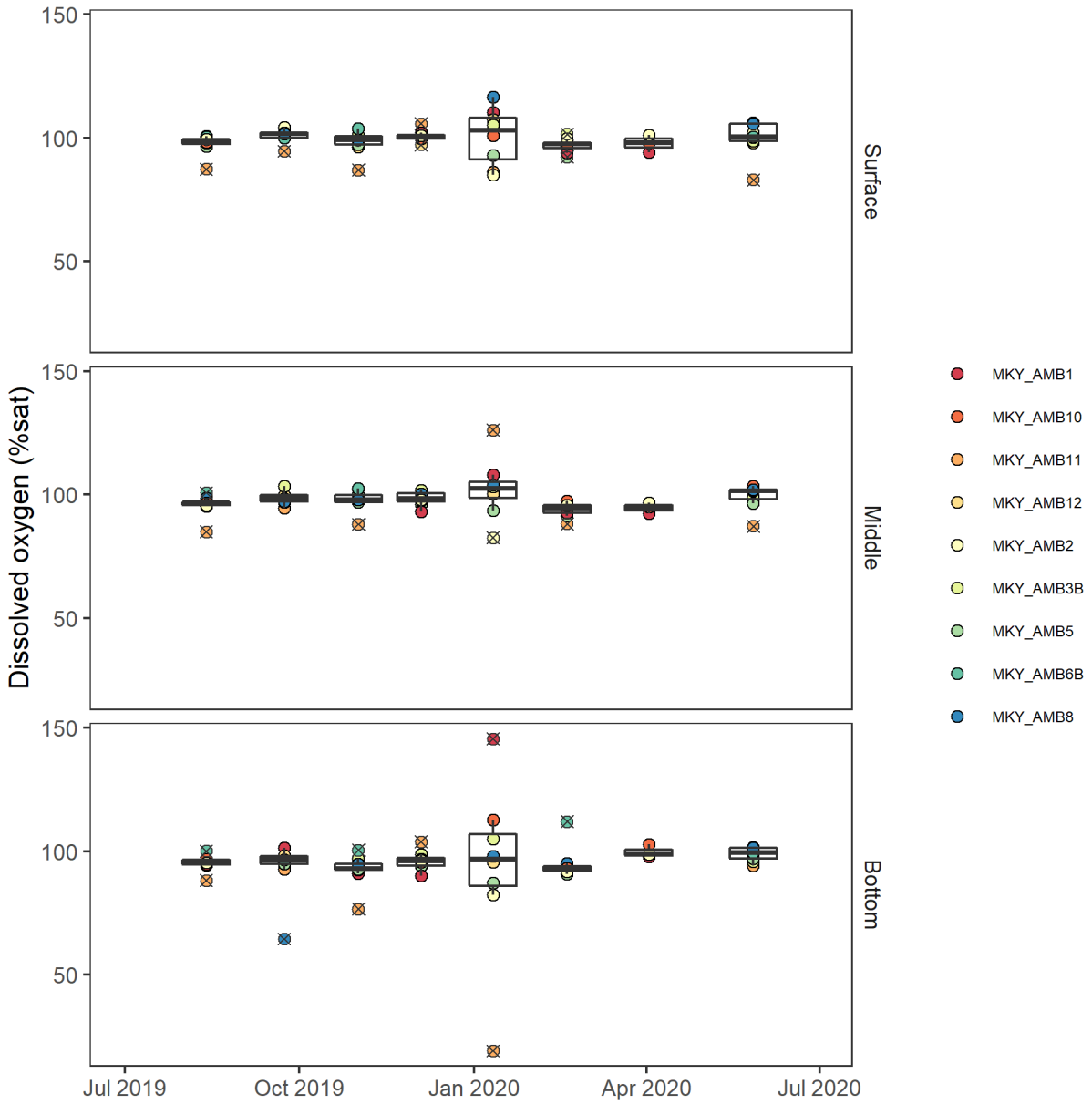

Figure 3.3 Dissolved oxygen (%sat) recorded at three depths at the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'.

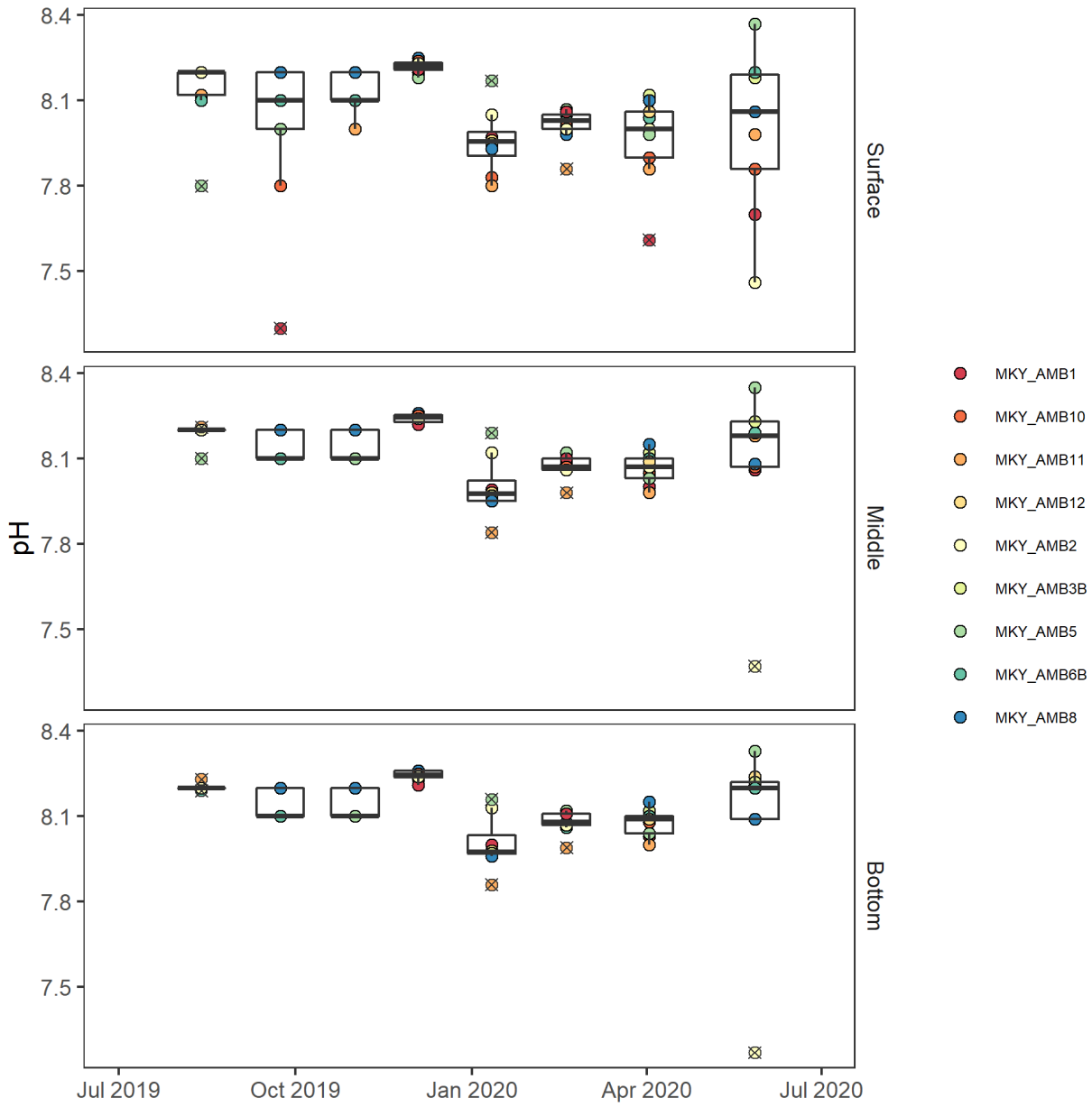

Figure 3.4 pH recorded at three depths at the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'.

3.1.2 Nutrients, water clarity and chlorophyll-*a*

Particulate nitrogen (PN) concentrations ranged from 2 to 181 µg L^{-1} (Figure 3.5). Mean PN across the nine sites exceeded the GBRMPA guideline trigger value of 20 µg L^{-1} for all sampling events with the exception of August 2019 and May 2020. Particulate phosphorus (PP) concentrations ranged from <1 to 13 µg L^{-1} (Figure 3.6). Mean PP exceeded the GBRMPA guideline trigger value of 2.8 µg L^{-1} in September, November, and December 2019.

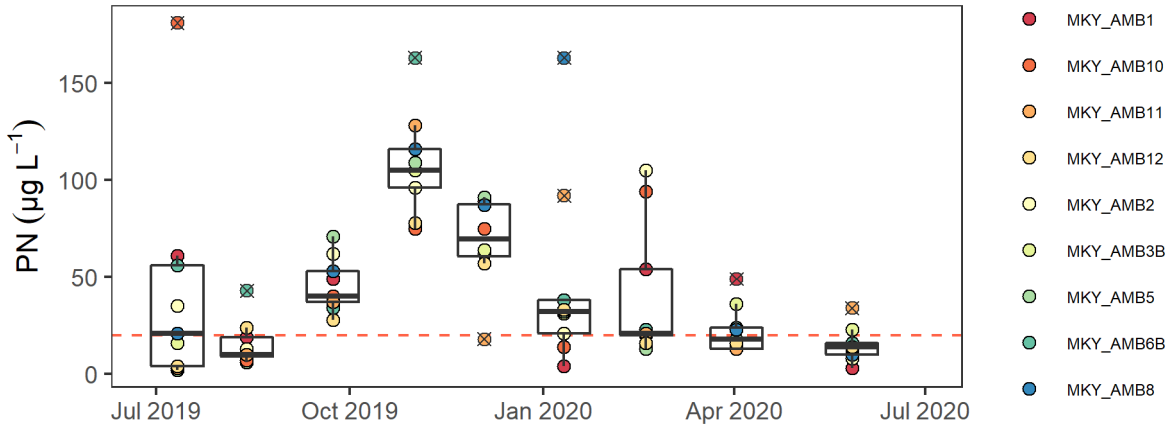

Figure 3.5 Particulate nitrogen (PN) concentrations measured in water samples collected from the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'. Horizontal dashed line indicates the GBRMPA open coastal guideline trigger value.

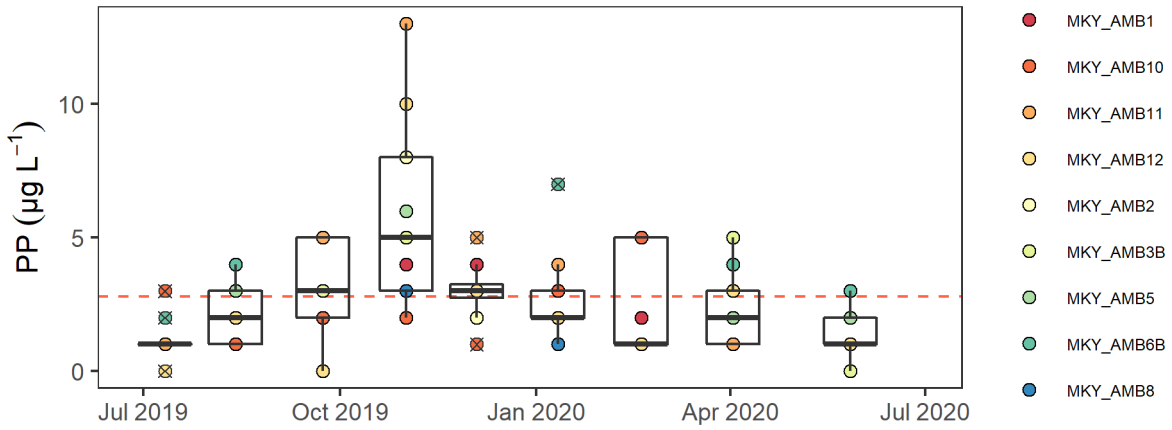

Figure 3.6 Particulate phosphorus (PP) concentrations measured in water samples collected from the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'. Horizontal dashed line indicates the GBRMPA open coastal guideline trigger value.

Total suspended solids ranged from 1.0 to 12.0 mg L^{-1} (Figure 3.7). Mean TSS across the nine sites exceeded the GBRMPA guideline trigger value of 2.0 mg L^{-1} for all sampling events with the exception of December 2019 (1.81 mg L^{-1}). Secchi depth ranged from 1.5 to 8.5 m (Figure 3.8). Chlorophyll-*a* concentrations ranged from 0.22 to 3.32 µg L^{-1} (Figure 3.9). Mean Chlorophyll-*a* concentrations exceeded the GBRMPA guideline trigger value for all sampling events except August 2019.

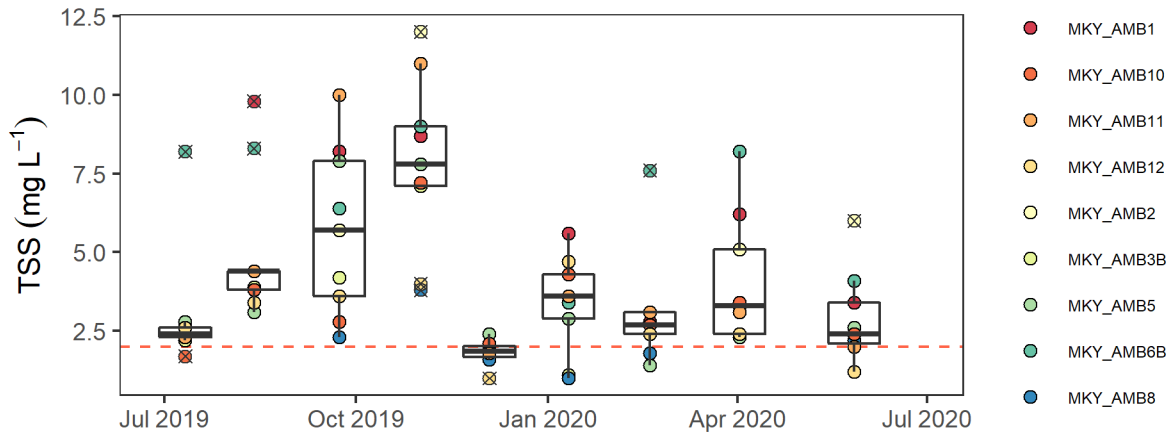

Figure 3.7 Total suspended solids (TSS) measured in water samples at the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'. Horizontal dashed line indicates the GBRMPA open coastal guideline trigger value.

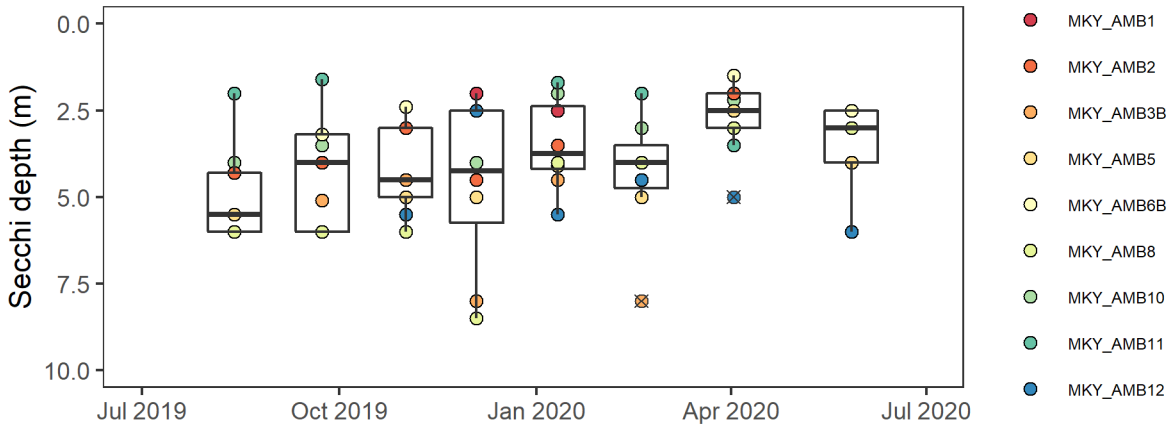

Figure 3.8 Secchi disk depth recorded at the nine water quality sites throughout the reporting period.

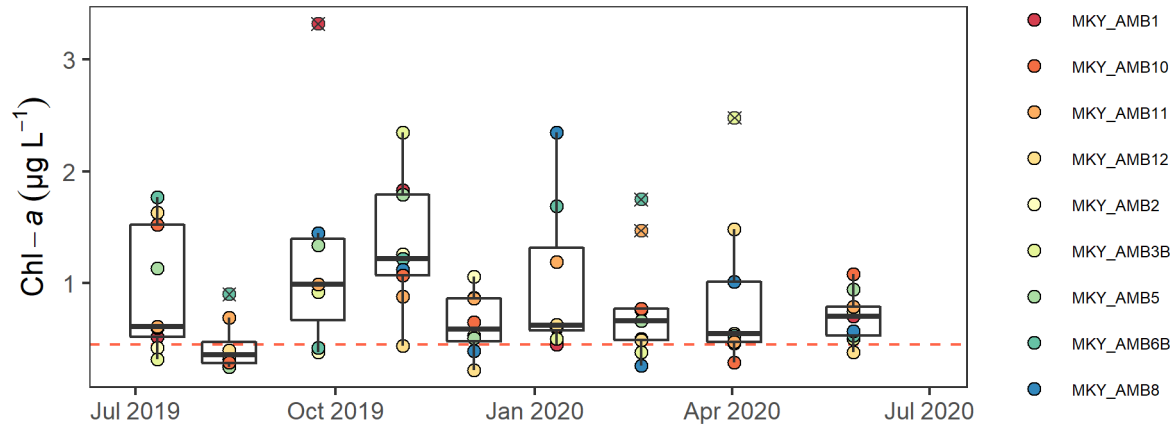

Figure 3.9 Chlorophyll-*a* concentrations measured in water samples collected from the nine water quality sites throughout the reporting period. Outlier values are marked with an '×'. Horizontal dashed line indicates the GBRMPA open coastal guideline trigger value.

3.1.3 Heavy metals

Heavy metal concentrations are presented in Table 3.2. Concentrations were compared to the ANZECC and ARMCANZ 2000 water quality guidelines (ANZECC, 2000). Metals targeted for analysis were not detected above the 95% level of protection trigger values for marine waters. Silver, Cadmium, Nickel, Zinc, and Mercury were not detected (< LOD). Copper was detected at MKY_AMB11 (Mackay Harbour) in August 2019. Copper was not detected at any of the other sites. Lead was detected in August 2019 at MKY_AMB5 (Slade Point), and MKY_AMB8 (Dudgeon Point) but was at concentrations below guideline values. Arsenic was detected at low concentrations (1.5 to 2.2 µg L^{-1}). Note that ANZECC guidelines do not have a trigger value for arsenic. A low reliability marine guideline trigger value of 4.5 µg L^{-1} for As (V) and 2.3 µg L^{-1} for As (III) has been derived (ANZECC, 2000), however, these trigger guidelines are only an indicative interim working level. Arsenic measured concentrations were below these low reliability trigger values, and similar concentrations have been recorded consistently at these sites since mid-2016.

Table 3.2 Heavy metal concentrations measured in water samples collected from the nine 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	14/08/2019	MKY_AMB1	Freshwater Point	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.5	< 5.0	< 0.001
	14/08/2019	MKY_AMB2	Hay Reef	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	2.2	< 5.0	< 0.001
	13/08/2019	MKY_AMB3B	Round Top Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.3	< 5.0	< 0.001
	13/08/2019	MKY_AMB5	Slade Island	< 0.1	< 0.2	< 1.0	0.4	< 0.5	1.6	< 5.0	< 0.001
	13/08/2019	MKY_AMB6B	Dudgeon Point	< 0.1	< 0.2	< 1.0	0.5	< 0.5	1.8	< 5.0	< 0.001
	13/08/2019	MKY_AMB8	Spoil Grounds	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.5	< 5.0	< 0.001
	14/08/2019	MKY_AMB10	Victor Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.6	< 5.0	< 0.001
	13/08/2019	MKY_AMB11	Mackay Harbour	< 0.1	< 0.2	2	< 0.2	< 0.5	1.7	< 5.0	< 0.001
	13/08/2019	MKY_AMB12	Keswick Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.6	< 5.0	< 0.001
May-20	27/05/2020	MKY_AMB1	Freshwater Point	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.6	< 5.0	< 0.001
	27/05/2020	MKY_AMB2	Hay Reef	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.7	< 5.0	< 0.001
	28/05/2020	MKY_AMB3B	Round Top Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.6	< 5.0	< 0.001
	28/05/2020	MKY_AMB5	Slade Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.7	< 5.0	< 0.001
	28/05/2020	MKY_AMB6B	Dudgeon Point	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.5	< 5.0	< 0.001
	28/05/2020	MKY_AMB8	Spoil Grounds	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.8	< 5.0	< 0.001
	27/05/2020	MKY_AMB10	Victor Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.7	< 5.0	< 0.001
	28/05/2020	MKY_AMB11	Mackay Harbour	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.6	< 5.0	< 0.001
	28/05/2020	MKY_AMB12	Keswick Island	< 0.1	< 0.2	< 1.0	< 0.2	< 0.5	1.9	< 5.0	< 0.001

3.1.4 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 and Diazinon were not detected (< LOD). Hexazinone and Diuron were present at low concentrations for numerous sites in August 2019 and in May 2020. The insecticides Ametryn and Simazine were not detected (< LOD). Atrazine was < LOD in August 2019 but present at low concentrations for most sites in May 2020.

Table 3.3 Pesticide concentrations measured in water samples collected from the five 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
			GBRMPA 95% level	0.009	0.01	1.2	1.6	1	1.4	3.2
Aug-19	14/08/2019	MKY_AMB1	Freshwater Point	< 0.001	< 0.0002	< 0.0002	0.0006	< 0.0002	< 0.0002	< 0.0002
	14/08/2019	MKY_AMB2	Hay Reef	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB3B	Round Top Island	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB5	Slade Island	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB6B	Dudgeon Point	< 0.001	< 0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB8	Spoil Grounds	< 0.001	< 0.0002	< 0.0002	0.0059	< 0.0002	< 0.0002	< 0.0002
	14/08/2019	MKY_AMB10	Victor Island	< 0.001	< 0.0002	< 0.0002	0.0005	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB11	Mackay Harbour	< 0.001	< 0.0002	< 0.0002	0.0090	< 0.0002	< 0.0002	< 0.0002
	13/08/2019	MKY_AMB12	Keswick Island	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
May-20	27/05/2020	MKY_AMB1	Freshwater Point	< 0.001	< 0.0002	< 0.0002	0.0037	< 0.0002	< 0.0002	< 0.0002
	27/05/2020	MKY_AMB2	Hay Reef	< 0.001	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
	28/05/2020	MKY_AMB3B	Round Top Island	< 0.001	< 0.0002	0.0002	0.0020	< 0.0002	0.0004	< 0.0002
	28/05/2020	MKY_AMB5	Slade Island	< 0.001	< 0.0002	0.0003	0.0004	< 0.0002	0.0006	< 0.0002
	28/05/2020	MKY_AMB6B	Dudgeon Point	< 0.001	< 0.0002	0.0014	0.0008	< 0.0002	0.0010	< 0.0002
	28/05/2020	MKY_AMB8	Spoil Grounds	< 0.001	< 0.0002	0.0002	0.0006	< 0.0002	0.0005	< 0.0002
	27/05/2020	MKY_AMB10	Victor Island	< 0.001	< 0.0002	< 0.0002	0.0031	< 0.0002	0.0006	< 0.0002
	28/05/2020	MKY_AMB11	Mackay Harbour	< 0.001	< 0.0002	< 0.0002	0.0023	< 0.0002	0.0005	0.0002
	28/05/2020	MKY_AMB12	Keswick Island	< 0.001	< 0.0002	0.0003	0.0025	< 0.0002	0.0007	< 0.0002

3.2 Plankton communities

3.2.1 Diversity and abundance

A total of 46 phytoplankton taxa were identified from phytoplankton net tow samples. Phytoplankton abundance ranged from 2890 to 172610 individuals (Figure 3.10). Cyanobacteria was proportionally most common group in September 2019 (Figure 3.11). *Trichodesmium* sp. was the dominant taxa present. Species richness ranged from 9 to 25 taxa for any one sampling event. Shannon diversity (H') ranged from 0.08 to 2.20. Simpson diversity (D) ranged from 0.02 to 0.86. Species richness and diversity were highest in February 2020.

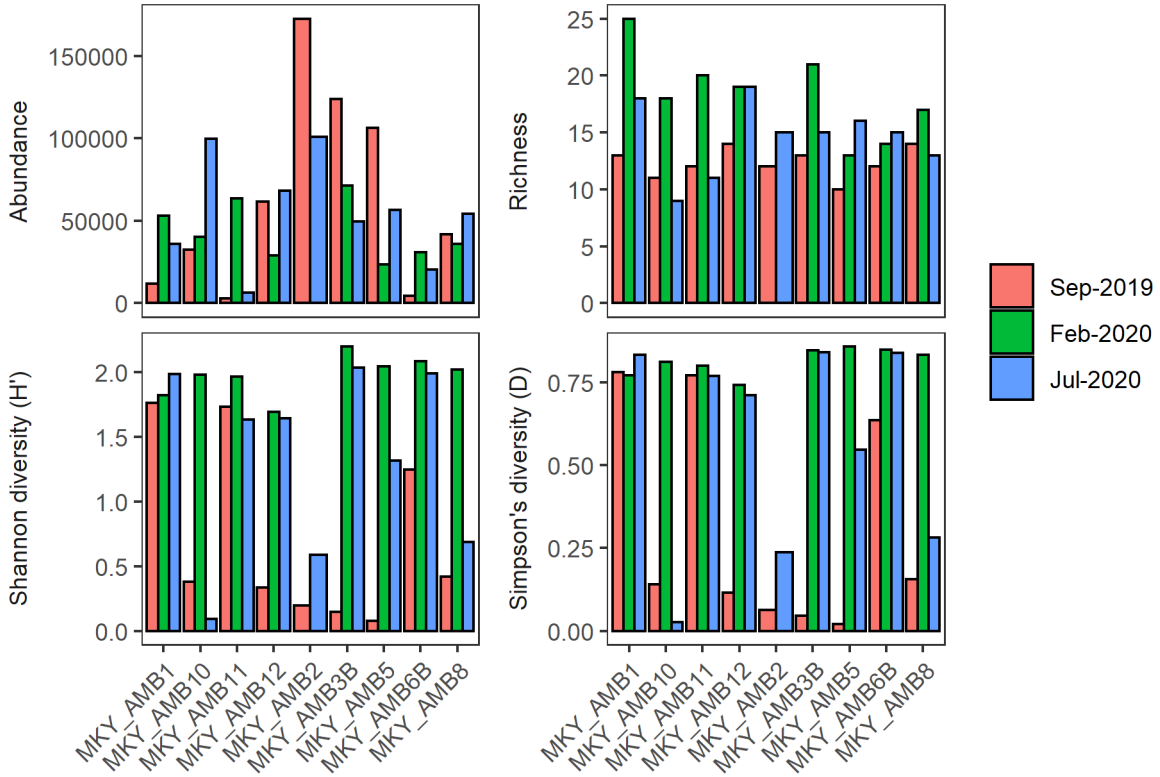

Figure 3.10 Phytoplankton abundance, richness, and diversity indices calculated at each site during the three survey events.

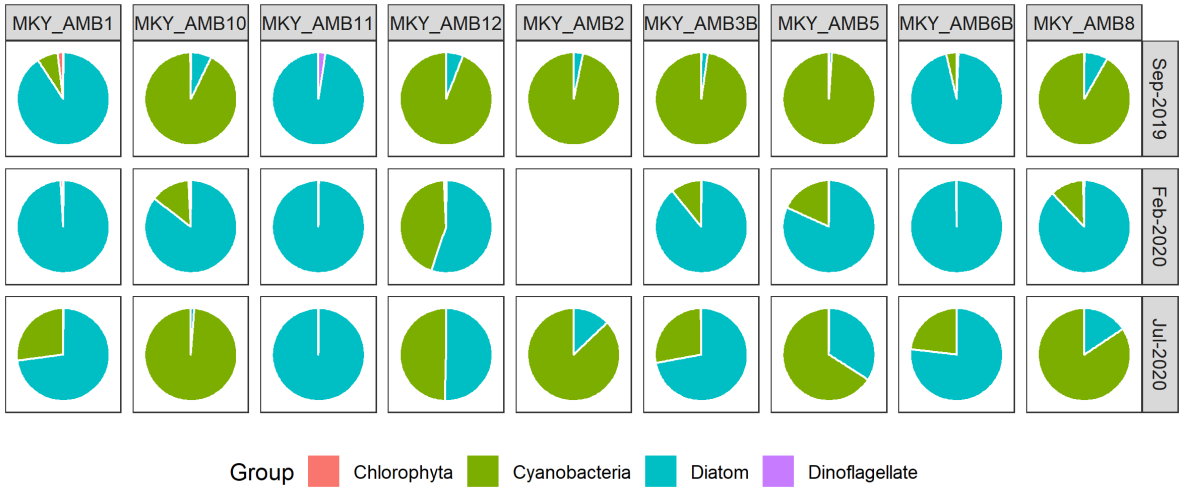

Figure 3.11 Proportion of individuals present from each phytoplankton group in tow net samples.

A total of 30 zooplankton taxa were identified from zooplankton net tow samples. Zooplankton abundance ranged from 8 to 66 individuals (Figure 3.12). Species richness ranged from 3 to 12 taxa for any one sampling event. Shannon diversity (H') ranged from 0.90 to 2.22. Simpson diversity (D) ranged from 0.50 to 0.88. The proportion of zooplankton individuals present in tow net samples is shown in Figure Figure 3.13.

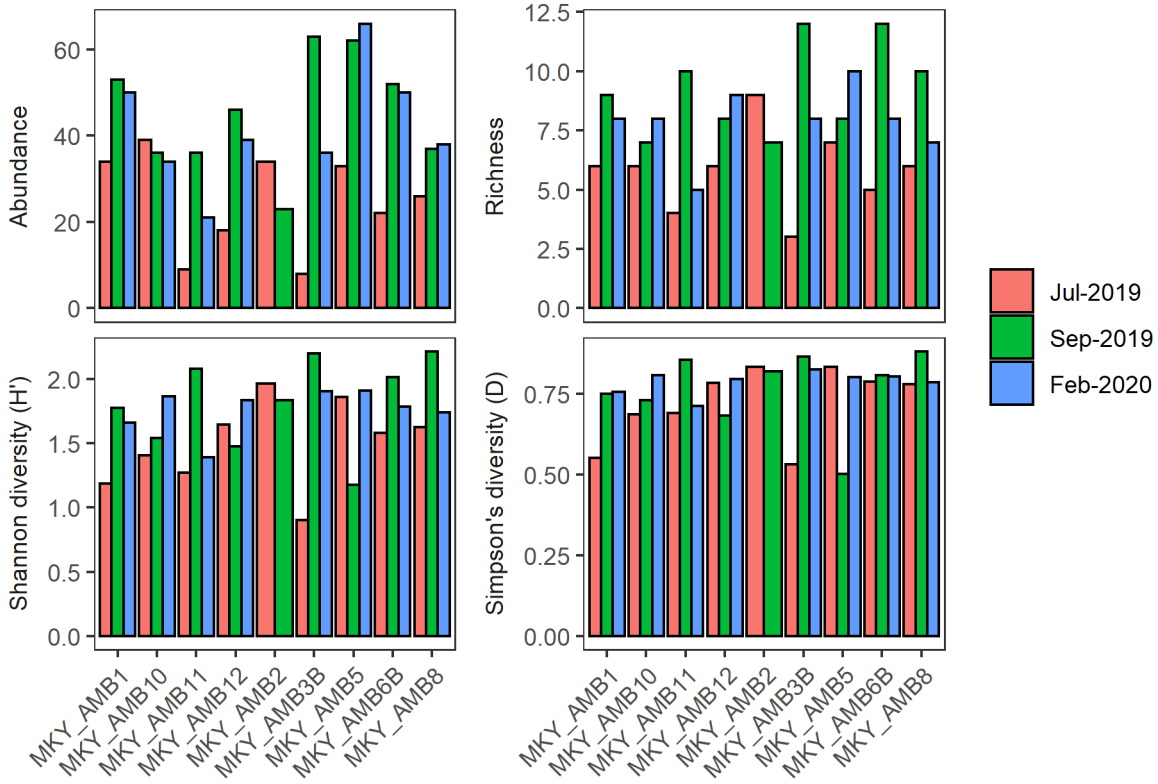

Figure 3.12 a) Species richness of zooplankton and b) total abundance of zooplankton at each site for each survey

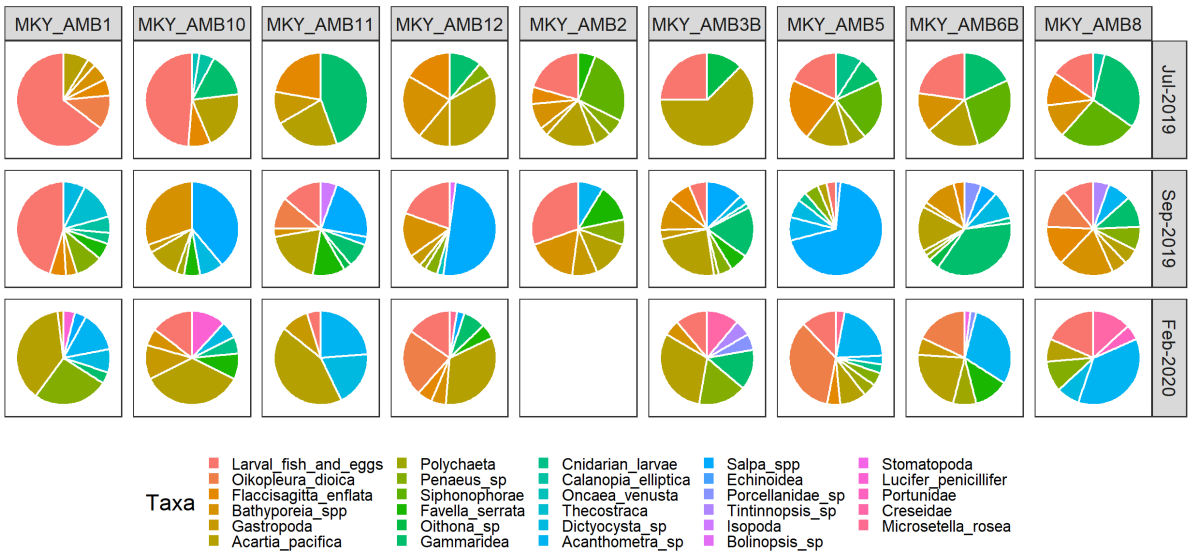

Figure 3.13 Proportion of zooplankton individuals present in tow net samples.

3.2.2 Community structure

The plankton community was visualised via non-metric multidimensional scaling with comparison made between September 2019, February 2020 and July 2020 sampling events. The phytoplankton community showed dissimilarity between events (Figure 3.14, ANOSIM: R = 0.86, P = 0.001). The zooplankton community was dissimilar between sampling events (Figure 3.15, ANOSIM: R = 0.33, P = 0.001).

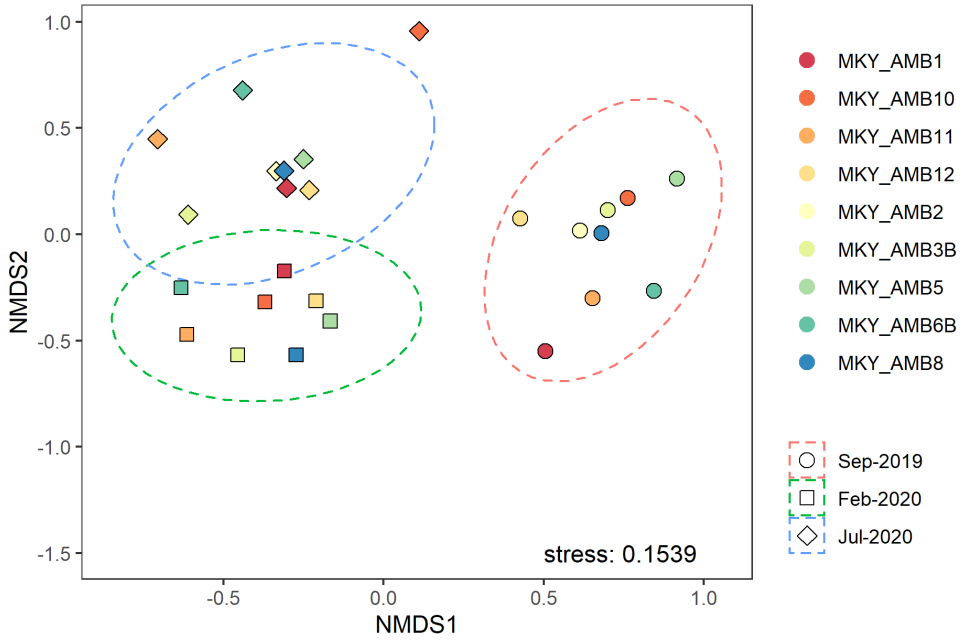

Figure 3.14 Non-metric multidimensional scaling (nMDS) plot of phytoplankton abundance data from samples collected during the 2019-2020 period. Ellipses represent 95 % confidence interval for each survey period. Data has been squared root transformed on the Bray Curtis distance matrix.

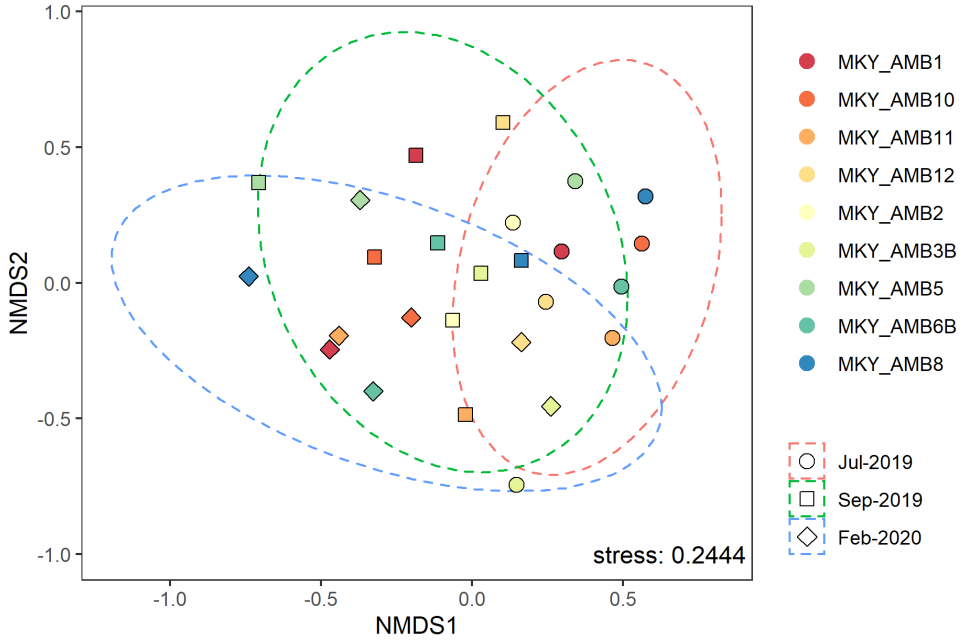

Figure 3.15 Non-metric multidimensional scaling (nMDS) plot of zooplankton communities based on abundance data from samples collected during the 2019-2020 period. Ellipses represent 95 % confidence interval for each survey period. Data has been squared root transformed on the Bray Curtis dissimilarity matrix.

3.3 Multiparameter water quality logger

Instruments were deployed at seven sites from July 2019 to July 2020 (Table 1.1). Using standard statistics, we describe observed trends and differences between sites and discuss the driving forces in these environments. Several loggers were not retrieved or flooded leading to gaps in data, including July at Freshwater, Jan – Feb at Roundtop, Nov – Dec at Slade, Nov- Dec and Feb at Spoil Grounds. Additionally, data are missing from all sites for the time period April – May/June, corresponding directly to COVID-19 related deployment restrictions. See time series in the appendices for exact dates.

Data are 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 available 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 90th and 10th percentiles. Time series and monthly summaries are included in the appendices.

3.3.1 RMS water height

AMB12 had lower RMS values than all other sites with a median of 0.005 m and the lowest variance in RMS values (Figure 3.16, Table 3.4). Results are similar to the previous year's (2018-2019) findings and are due to the site being positioned in the lee of Keswick and St Bees Islands that shelter it from wind and waves. AMB1, AMB2, AMB3, AMB8 and AMB10 have median RMS ≤0.022; AMB5 had the highest median RMS ≤0.035.

The RMS water height time series shows that large peaks occur at the same time across multiple sites throughout the year (Appendix A2). These synchronised peaks are due to weather driven wave events being the strongest driver of wave shear stress on the ocean floor. Differences in RMS among sites is due to variations in site exposure and water depth. The monthly summaries indicated that RMS was typically highest in December-February (Appendix A3).

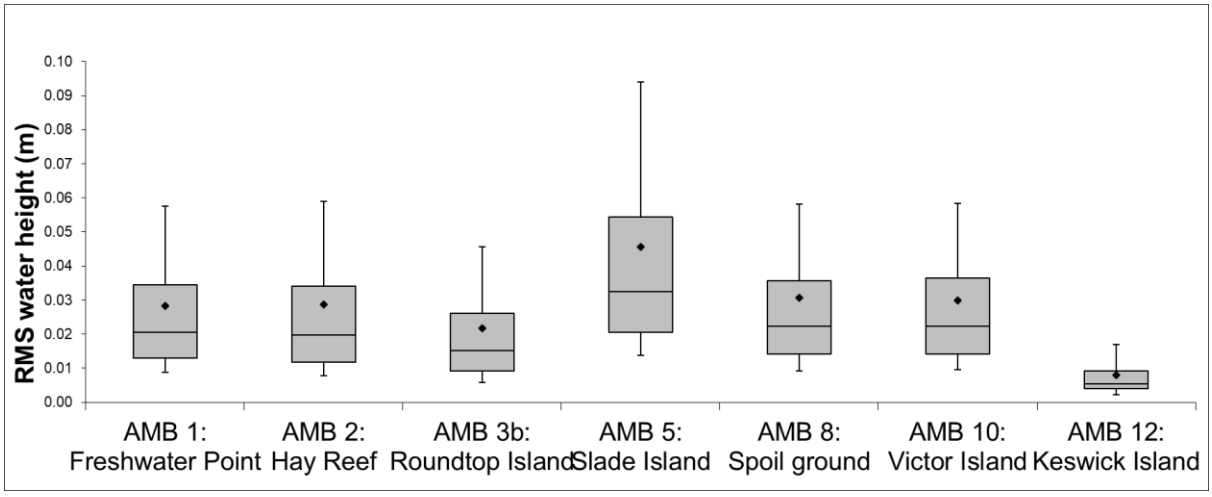

Figure 3.16 Box plot of root mean square (RMS) of water height (m) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamonds represent the mean values.

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

Site	AMB 1: Freshwater Point	AMB 2: Hay Reef	AMB 3b: Roundtop Island	AMB 5: Slade Island	AMB 8: Spoil ground	AMB 10: Victor Island	AMB 12: Keswick Island
Mean	0.028	0.029	0.022	0.046	0.031	0.030	0.008
median	0.021	0.020	0.015	0.032	0.022	0.022	0.005
min	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lower quartile	0.013	0.012	0.009	0.020	0.014	0.014	0.004
upper quartile	0.035	0.034	0.026	0.054	0.036	0.036	0.009
max	0.354	0.452	0.398	0.543	0.472	0.384	0.113
90th percentile	0.058	0.059	0.046	0.094	0.058	0.058	0.017
10th percentile	0.009	0.008	0.006	0.014	0.009	0.010	0.002
n	43261	36063	43645	31268	34303	49211	49216
St. Dev	0.025	0.029	0.021	0.042	0.030	0.026	0.008
St. Error	0.000	0.000	0.000	0.000	0.000	0.000	0.000

3.3.2 NTUe/SSC

The NTUe/SSC time series data at each site follows a typical pattern of low background values with recurring peak events (Appendix A2). These peak events occurred at the same times at each site and often coincide with peaks in RMS water height. Peaks in SSC occurred throughout the year (Appendix A3). This is a typical pattern as identified in past reports and is similar to data collected in coastal locations in north Queensland (Ridd et al., 2001). Differences in SSC between sites result from differences in RMS water height, site depth, benthic geology, hydrodynamics and proximity to river mouths. High variance in NTUe/SSC is the result of large spikes in suspended sediment driven by the re-suspension of sediment due to weather driven wave events.

AMB3b, AMB5, AMB8 and AMB12 had median SSC values below 1 mg L^{-1} and the least variance in SSC. AMB2 also had median SSC values below 1 mg L^{-1}, but the second-highest variance (Figure 3.17, Table 3.5). Several factors contribute to low SSC at AMB3, including that the site is sheltered from the trade south east weather systems which could result in less re-suspension of sediments by wave energy and that the coarse sediment at this site is not resuspended easily. AMB1 and AMB10 had higher median SSC (2.0 – 2.4 mg L^{-1}). These sites are closer to the coast and are likely affected by coastal currents moving across shallow areas with high resuspension rates (Macdonald et al. 2013).

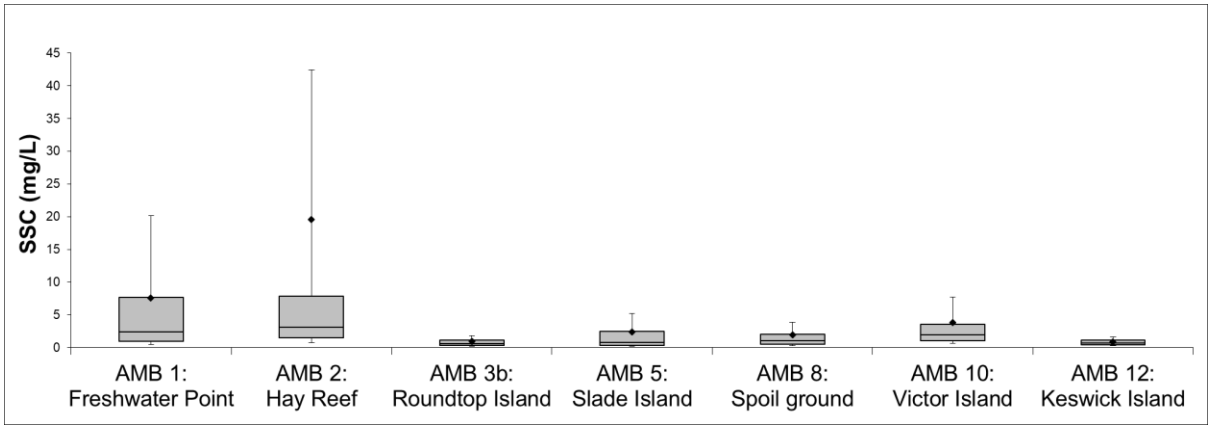

Figure 3.17 Box plot of suspended sediment concentration (SSC; mg L^{-1}) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

Table 3.5 Summary of suspended sediment concentration (mg L^{-1}) from July 2019 to July 2020.

Site	AMB 1: Freshwater Point	AMB 2: Hay Reef	AMB 3b: Roundtop Island	AMB 5: Slade Island	AMB 8: Spoil ground	AMB 10: Victor Island	AMB 12: Keswick Island
Mean	7.56	19.52	0.98	2.41	1.91	3.80	0.90
median	2.38	3.10	0.64	0.80	1.01	1.91	0.70
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00
lower quartile	0.98	1.52	0.37	0.37	0.54	1.09	0.43
upper quartile	7.67	7.82	1.12	2.49	2.01	3.60	1.10
max	182.65	1002.62	63.73	195.87	28.24	117.07	18.79
90th percentile	20.16	42.39	1.83	5.17	3.85	7.73	1.68
10th percentile	0.49	0.77	0.22	0.18	0.34	0.63	0.27
n	32647	22129	23189	18322	28595	31352	34069
St. Dev	13.88	58.42	1.51	5.83	2.87	6.45	0.82
St. Error	0.08	0.39	0.01	0.04	0.02	0.04	0.00

3.3.3 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 A2). 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.

AMB5 had the highest median, mean and upper quartile deposition rate while AMB3b had the lowest deposition rates (Figure 3.18, Table 3.6). Among the upper quartiles, ≥3 mg cm^{-2} d^{-1} for AMB1, AMB2 and AMB10 compared to ≤2.7 mg cm^{-2} d^{-1} for AMB3b, AMB8 and AMB12. The most deposition occurred in September at AMB3b and AMB10 and in October at AMB1, AMB8 and AMB12. Deposition was highest in March at AMB2 (Appendix A3).

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; a 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}.

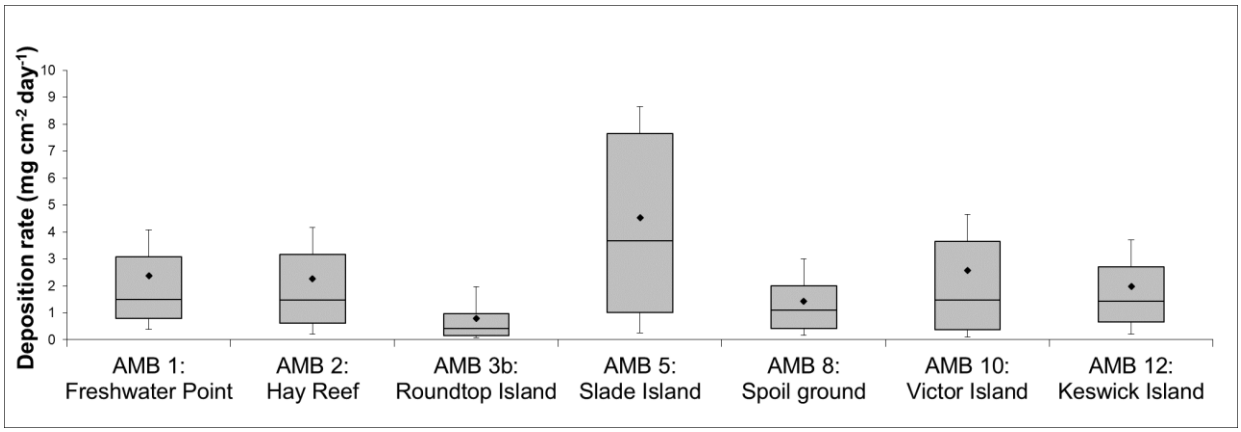

Figure 3.18 Box plot of hourly deposition rate (mg cm^{-2} day^{-1}) at the seven sites for the monitoring period July 2019 to July 2020.

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

Site	AMB 1: Freshwater Point	AMB 2: Hay Reef	AMB 3: Roundtop Island	AMB 5: Slade Island	AMB 8: Spoil ground	AMB 10: Victor Island	AMB 12: Keswick Island
Mean	2.38	2.27	0.80	4.53	1.43	2.57	1.99
Median	1.49	1.47	0.42	3.67	1.09	1.47	1.42
Minimum	0.10	0.00	0.01	0.03	0.00	0.02	0.03
Lower quartile	0.79	0.61	0.16	1.02	0.41	0.38	0.65
Upper quartile	3.07	3.17	0.96	7.65	2.00	3.66	2.70
Maximum	11.08	14.67	6.74	14.77	7.77	24.67	9.53
90^{th} percentile	6.16	5.52	1.89	10.02	3.09	6.40	4.81
10^{th} percentile	0.38	0.20	0.07	0.26	0.16	0.11	0.20
n	195	220	212	90	198	278	266
St. Dev	2.26	2.38	1.05	3.89	1.34	3.20	1.92
St. Error	0.16	0.16	0.07	0.41	0.10	0.19	0.12

3.3.4 Water temperature

Water temperature was similar among all sites (Figure 3.19, Table 3.7). Mean monthly temperature peaked between December and March at approximately 30 °C (Appendix A3); a factor that was also observed in the field in-situ water temperature surveys. The lowest mean monthly temperatures were observed between May to July, where values dropped to approximately 20 °C (Appendix A3). Decreases in temperature over short time periods match with increases in RMS water depth. Water temperature is generally 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. Johanson et al., 2015).

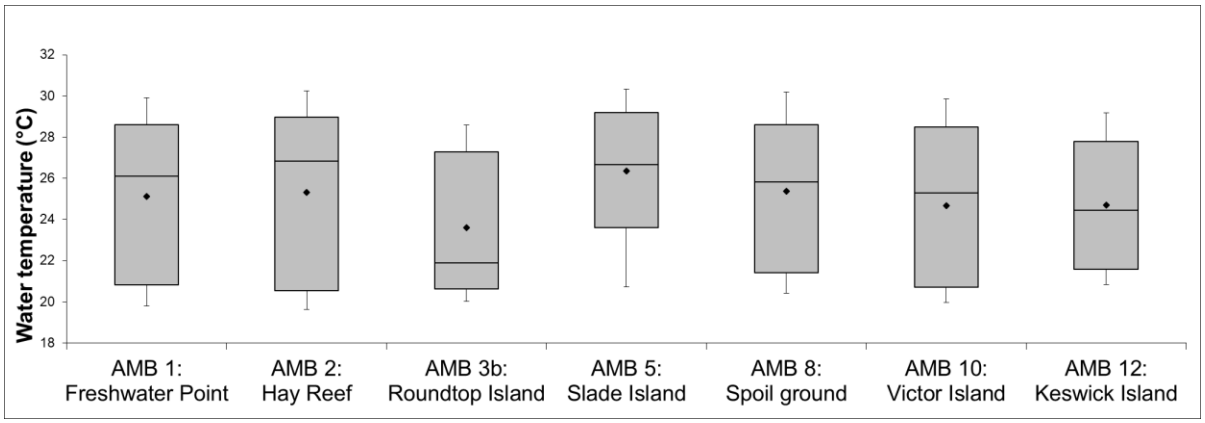

Figure 3.19 Box plot of the water temperature (°C) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

Table 3.7 Summary of water temperature (°C) for the monitoring period from July 2019 to July 2020.

Site	AMB 1: Freshwater Point	AMB 2: Hay Reef	AMB 3: Roundtop Island	AMB 5: Slade Island	AMB 8: Spoil ground	AMB 10: Victor Island	AMB 12: Keswick Island
Mean	25.12	25.32	23.62	26.37	25.38	24.67	24.69
Median	26.09	26.83	21.88	26.66	25.83	25.28	24.44
Minimum	18.30	18.68	18.97	17.69	19.01	18.67	20.19
Lower quartile	20.81	20.55	20.62	23.60	21.40	20.72	21.59
Upper quartile	28.60	28.97	27.29	29.20	28.60	28.49	27.79
Maximum	31.86	31.62	30.83	31.64	31.42	31.58	30.48
90th percentile	29.91	30.25	28.59	30.33	30.20	29.85	29.17
10th percentile	19.81	19.63	20.03	20.72	20.42	19.97	20.85
n	43221	36027	39352	31255	35763	49180	49166
St. Dev	3.89	4.27	3.48	3.44	3.78	3.90	3.26
St. Error	0.02	0.02	0.02	0.02	0.02	0.02	0.01

3.3.5 Photosynthetically active radiation (PAR)

Benthic PAR was influenced by water depth, as the lowest PAR was measured at deepest site (AMB 8; Figure 3.20, Table 3.8). The highest median PAR was measured at AMB10, which also has the highest upper quartile of 7.2 mol m^{-2} d^{-1} (Figure 3.17). Three sites had upper quartiles ≥3.8 mol m^{-2} d^{-1} (AMB3b, AMB5, AMB8), indicating that 25 % of days at these sites had greater than 3.8 mol m^{-2} d^{-1}.

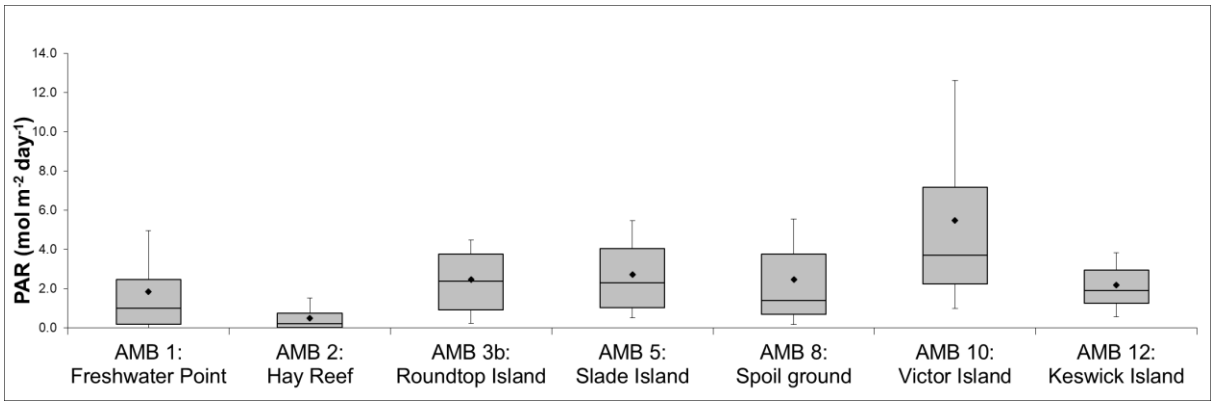

Figure 3.20 Box plot of PAR (mol m^{-2} day^{-1}) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10th, 25th, 50th, 75th and 90th percentiles, respectively. The diamond represents the mean value.

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

Site	AMB 1: Freshwater Point	AMB 2: Hay Reef	AMB 3: Roundtop Island	AMB 5: Slade Island	AMB 8: Spoil ground	AMB 10: Victor Island	AMB 12: Keswick Island
Mean	1.86	0.50	2.46	2.72	2.47	5.47	2.18
Median	0.99	0.22	2.39	2.30	1.40	3.70	1.92
Minimum	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Lower quartile	0.18	0.02	0.93	1.04	0.69	2.24	1.26
Upper quartile	2.46	0.74	3.77	4.06	3.76	7.18	2.96
Maximum	11.87	3.09	8.12	7.19	11.20	28.19	7.62
90th percentile	4.97	1.52	4.49	5.47	5.56	12.64	3.84
10th percentile	0.00	0.00	0.22	0.51	0.16	0.98	0.56
n	299	248	240	125	214	212	320
St. Dev	2.36	0.69	1.72	1.91	2.38	4.90	1.41
St. Error	0.14	0.04	0.11	0.17	0.16	0.34	0.08

Benthic PAR was highly variable throughout the year. For most sites, PAR was highest in July-September and in March (Figure 3.21). Semi-regular oscillations between low and high PAR were overridden by larger episodic events caused by storms or rainfall (Figure 3.22).

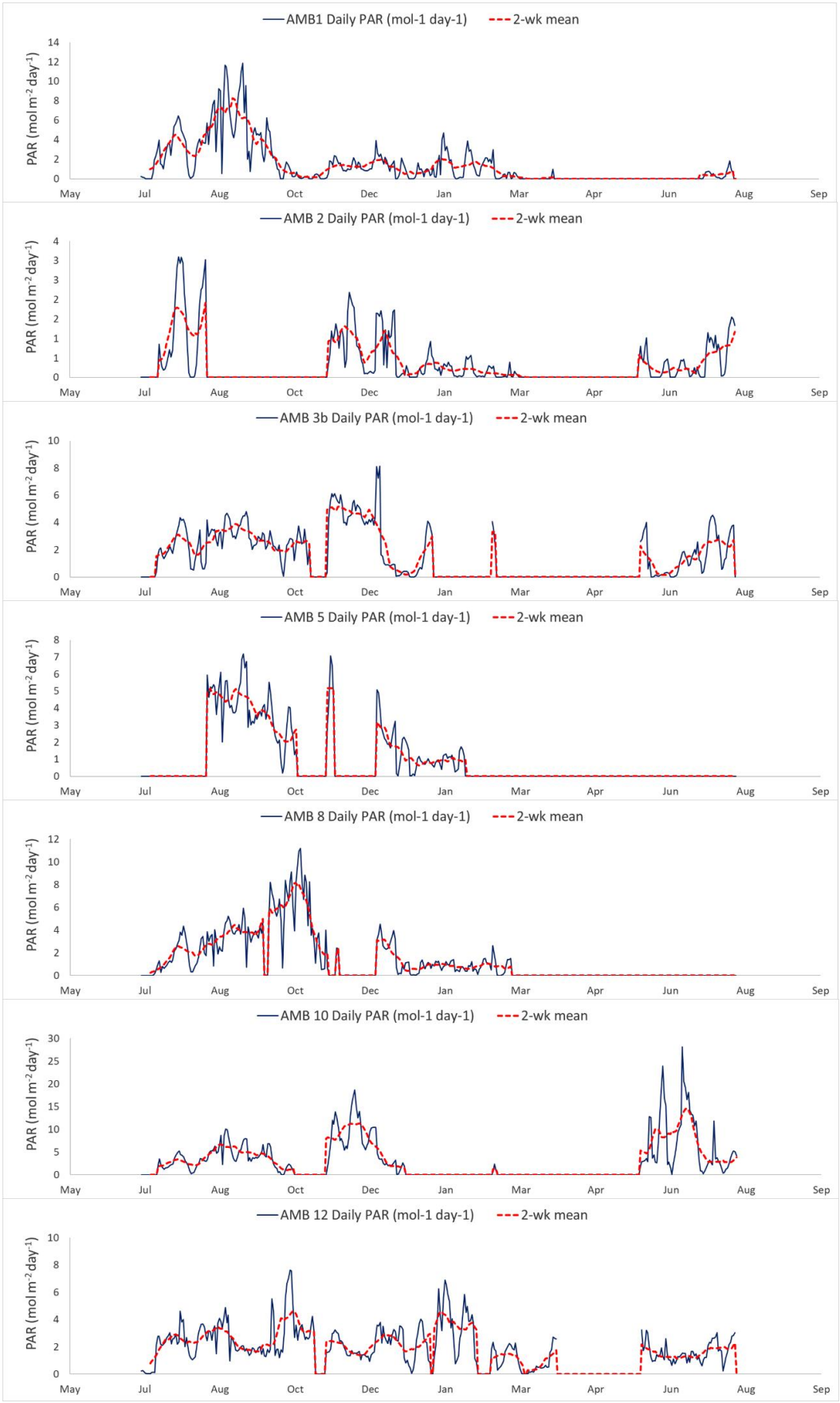

Figure 3.21 Time series of daily PAR (mol m^{-2} day^{-1}) from July 2019 to July 2020. Daily PAR is plotted in blue and a 2-week moving average of daily PAR is plotted in red.

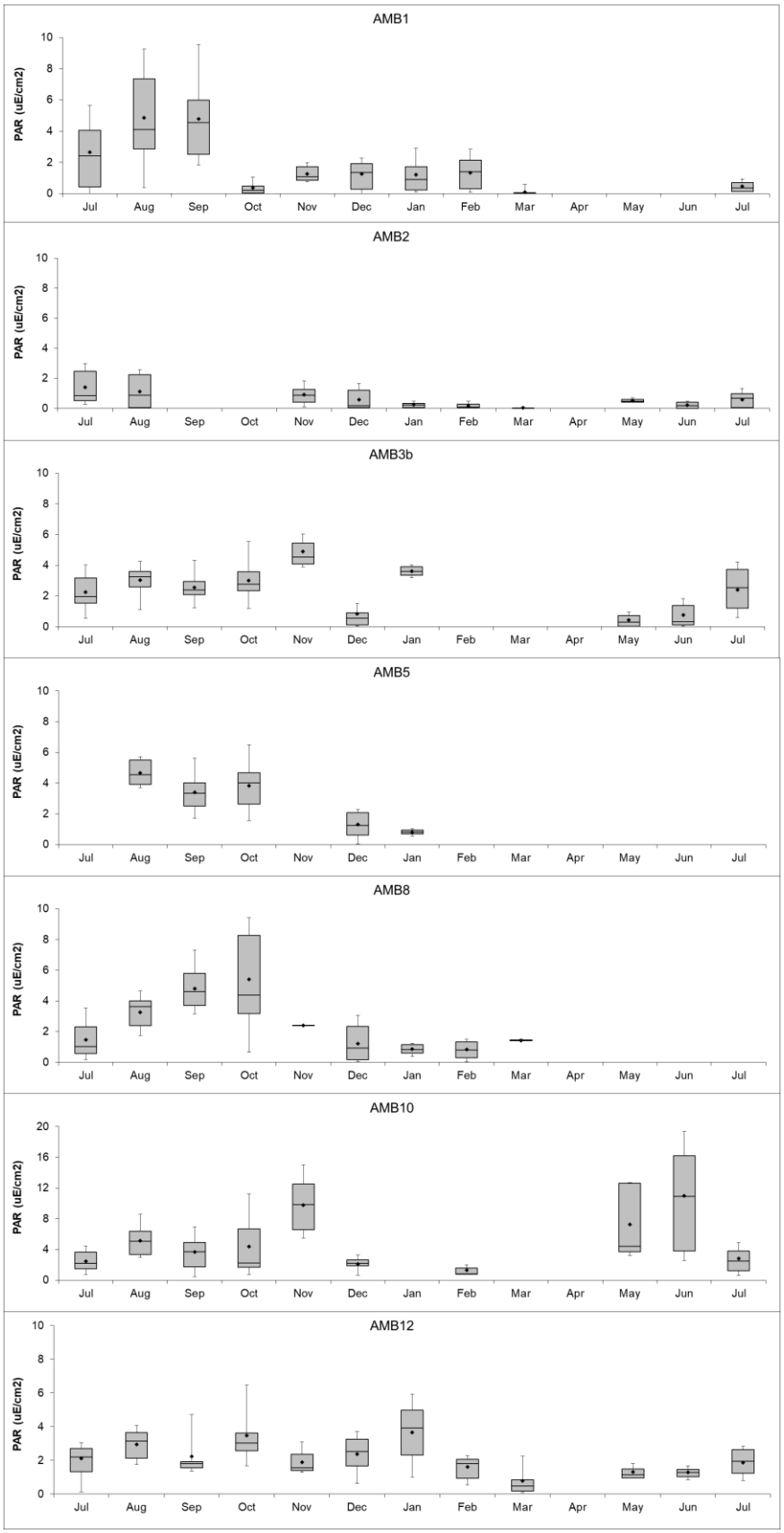

Figure 3.22 Monthly boxplots of total daily PAR (mol m^{-2} day^{-1}) from July 2019 to July 2020. The lower whisker, lower edge of the box, central line, upper edge of the box and upper whisker represent the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles, respectively. The diamond represents the mean value.

3.3.6 Similarities in patterns of PAR among sites

There are no significant correlations between the benthic PAR at any pairwise comparisons (Figure 3.23). No association were found above R^2 = 0.28. This is in contrast to the previous annual period which showed associations of R^2 > 0.65 between three sites. This analysis assists in understanding site redundancy opportunities, without missing important detail in characterising water quality in the region.

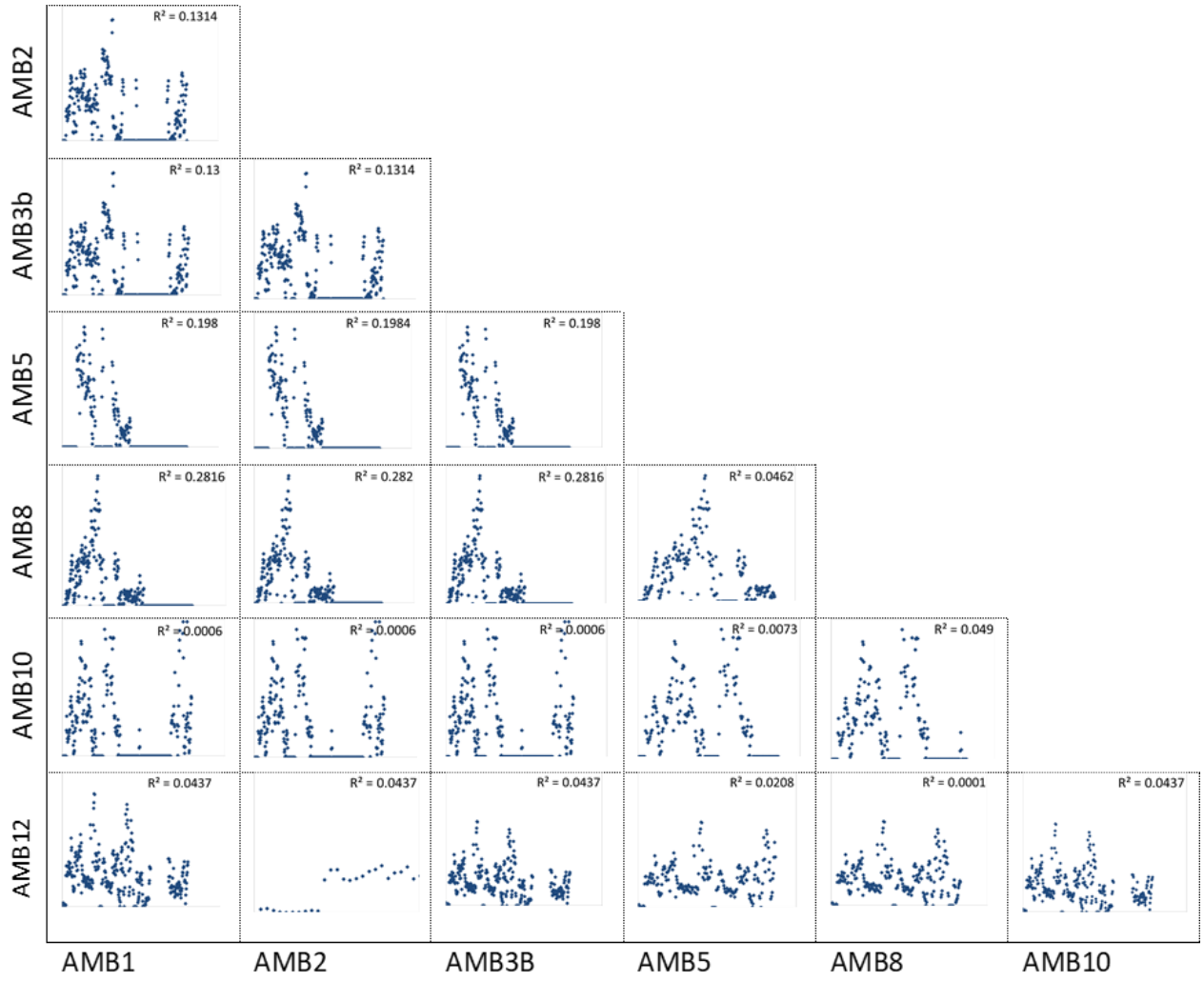

Figure 3.23 Scatterplots of the pairwise comparisons among sites indicating the strength of the relationships between patterns of daily PAR. R^2 values are presented for each comparison

3.3.7 Annual site comparison

Comparison of the data 2014-2020 provides a perspective of trends in the monitored environment. Weather can induce small variations between years, but consistent differences between sites suggest characteristic differences in aquatic environments.

RMS water height

RMS water height values are expected to change each year if there are changes to the locations where data was located or a change in weather events for the year. RMS values in 2019-2020 largely reflected the differences observed in previous years (Figure 3.24). Slight differences in RMS are most likely due to variation in weather between years.

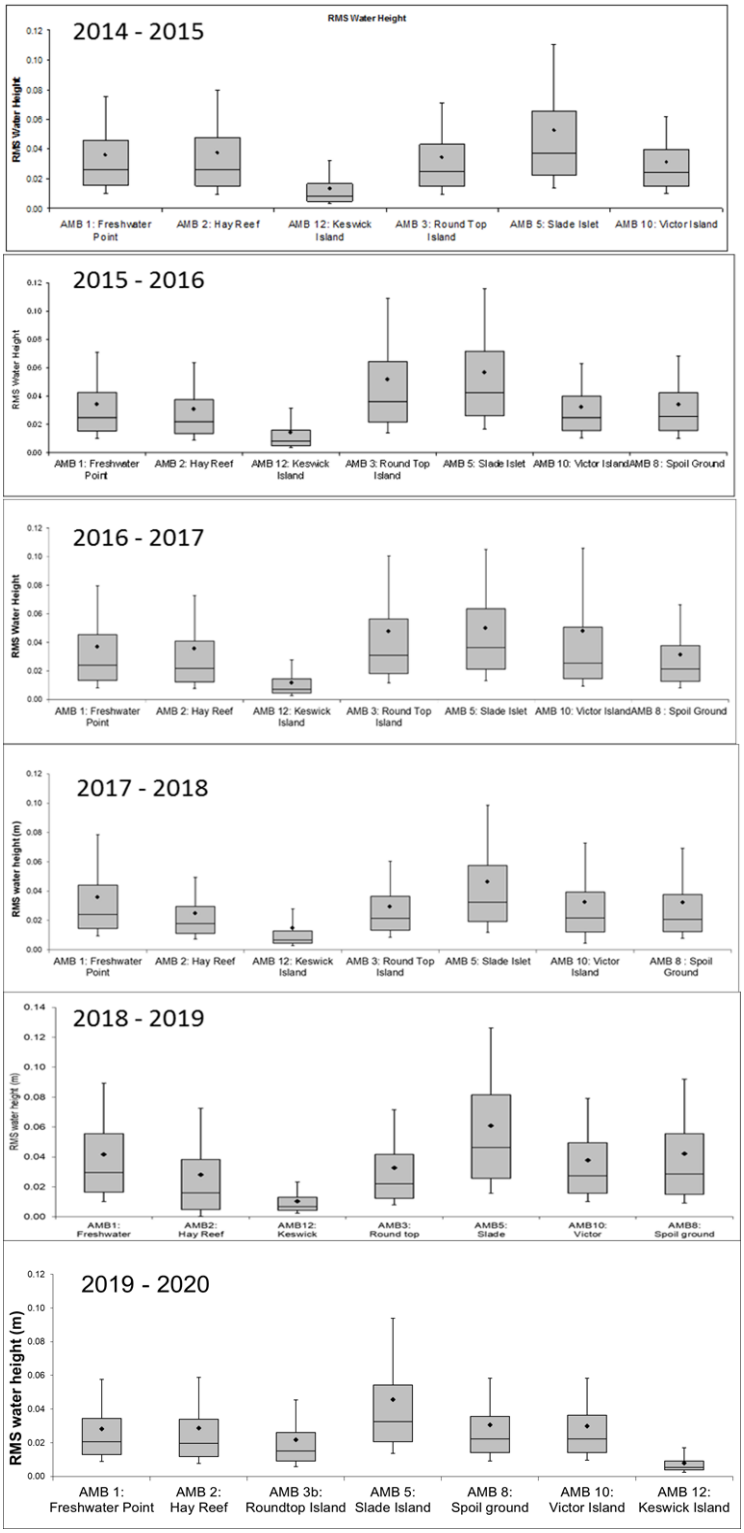

Figure 3.24 Annual summaries of RMS water height (m) from 2014-2020. Note that the sites are numerically ordered for 2019-2020.

NTUe/SSC

Differences in SSC between sites are largely consistent between years (Figure 3.25). AMB12 and AMB3 consistently had the lowest SSC, while AMB1, AMB2, and AMB10 typically had high SSC. Large SSC events during later years, such as Tropical Cyclone Debbie in 2017, are likely causes for the increased variance compared to the 2014-2015 year.

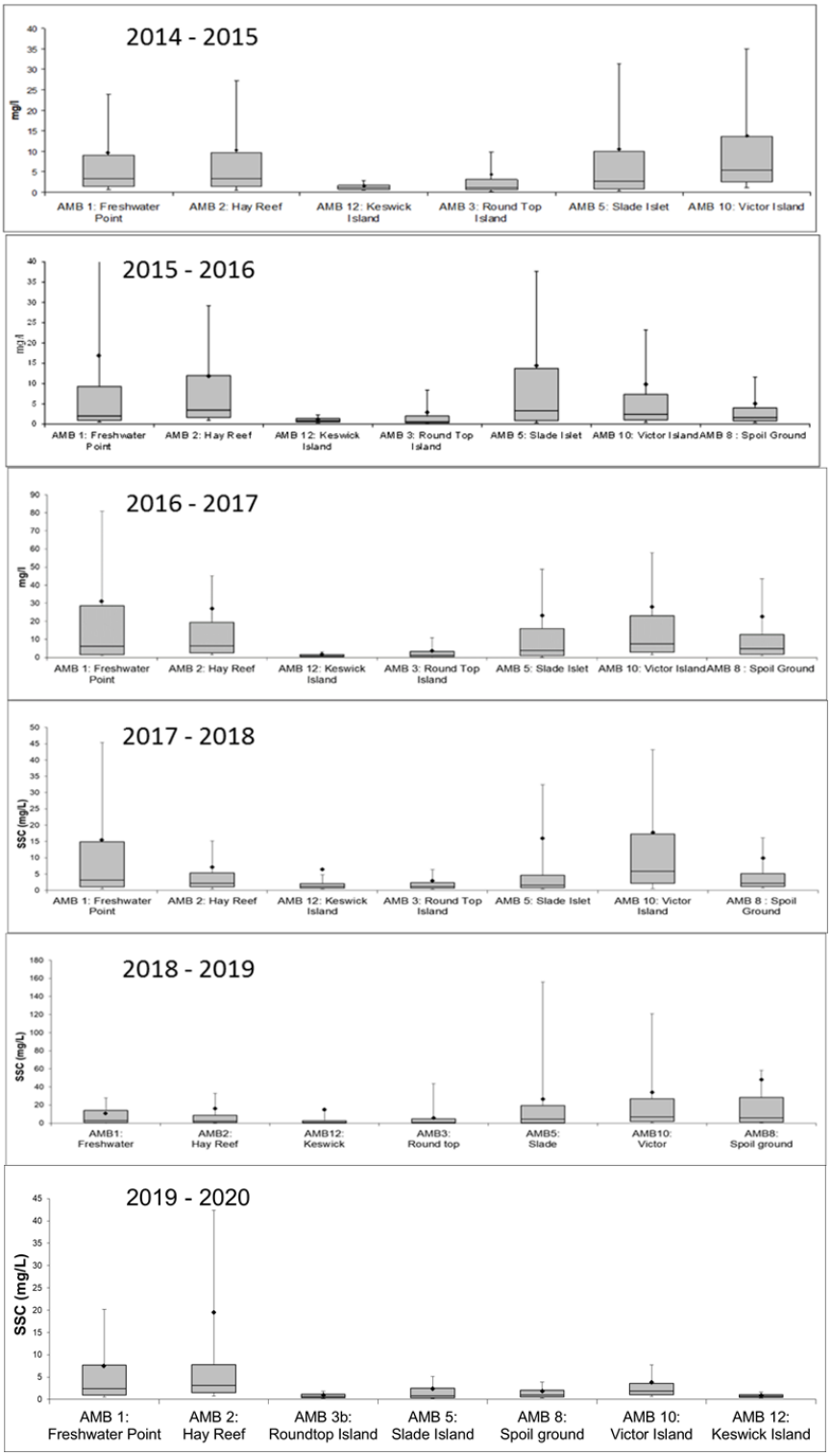

Figure 3.25 Annual summaries of suspended sediment concentration (SSC) from 2014-2020. Note that different scales are used between years.

Deposition rate

Deposition rates decreased significantly across all sites in 2019-2020 compared to previous years, (Figure 3.26). AMB5 displayed the highest deposition relative to all others sites for the current period, but this was not the case in previous years.

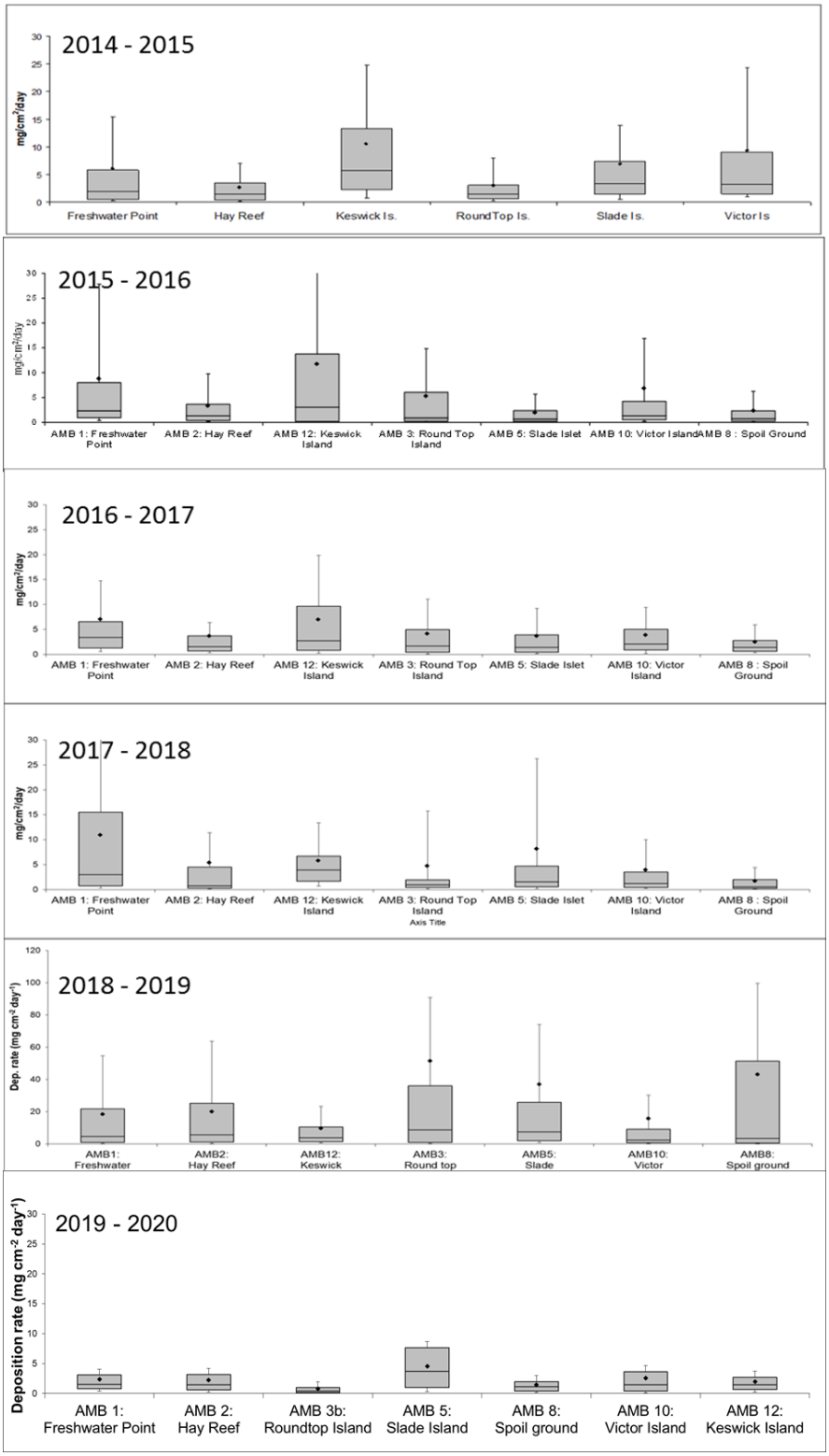

Figure 3.26 Annual summaries of daily deposition (mg cm^{-2} day^{-1}) from 2014-2020. Note that different scales are used between years.

3.3.8 Seasonal variation: wet vs dry

A comparison of wet and dry season water quality (2014-2020) suggests that the wet season coincides with increased suspended sediments, increased sediment deposition, and decreased irradiance at some sites. Temperatures were higher in the wet season at all sites. No clear seasonal pattern was observed for RMS across all sites.

Sites AMB1 and AMB2, exhibited the strongest seasonal differences, including increased SSC (Figure 3.28) and decreased PAR (Figure 3.30). Interestingly, the remaining sites AMB3b, AMB5, AMB8, AMB10 and AMB12 exhibited similar suspended sediments across both seasons. All sites exhibited weak seasonal differences in sediment deposition for the 2019-2020 period (Figure 3.29).

RMS water height

Wet seasons are associated with large storms, wind and rain. It is often assumed that there is a large difference in wave energy between the wet and dry seasons in the Mackay region, but the combined data from 2014-2020 indicate that there is not a large difference in RMS between seasons (Figure 3.27, all years). For 2019-2020, there was slightly higher median and upper quartile RMS during the wet season at AMB12, however the difference between seasons was weak at all other sites.

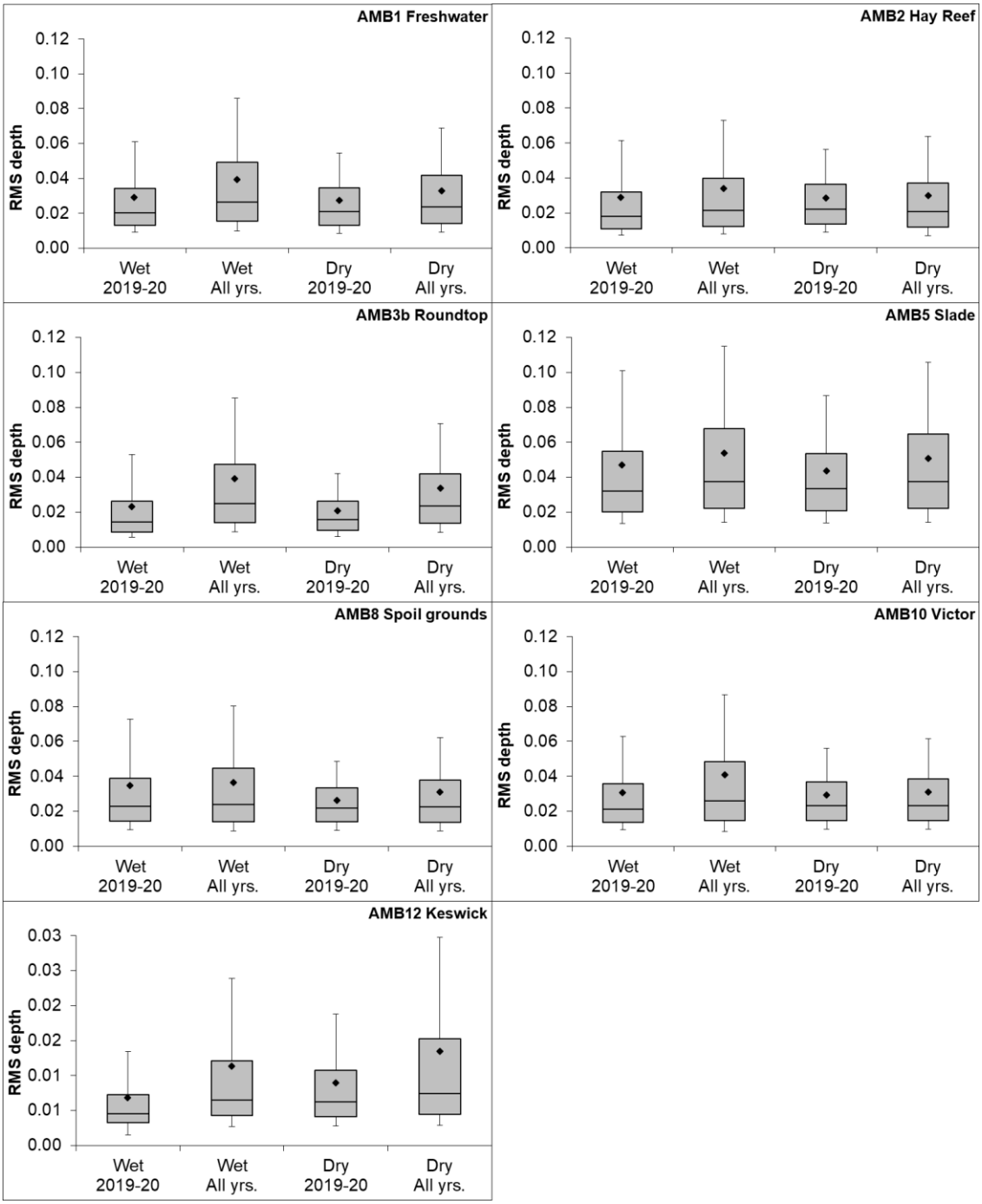

Figure 3.27 RMS water height box plots for each monitoring site. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or all available wet seasons (2014-2020). Note that a different scale is used for AMB12 compared to the other sites.

SSC

For most sites, suspended sediment concentrations (SSC) were slightly higher during the wet season, however the difference was less than previous years (Figure 3.28). AMB 3b showed decreased SSC during the wet season, however SSC was low throughout the entire year at this site, with mean SSC <1 mg/l. Although much weaker this year, the seasonal effect on SSC is supported by higher mean and 90th percentiles during the wet season, indicating that high turbidity events were more extreme than in the dry season.

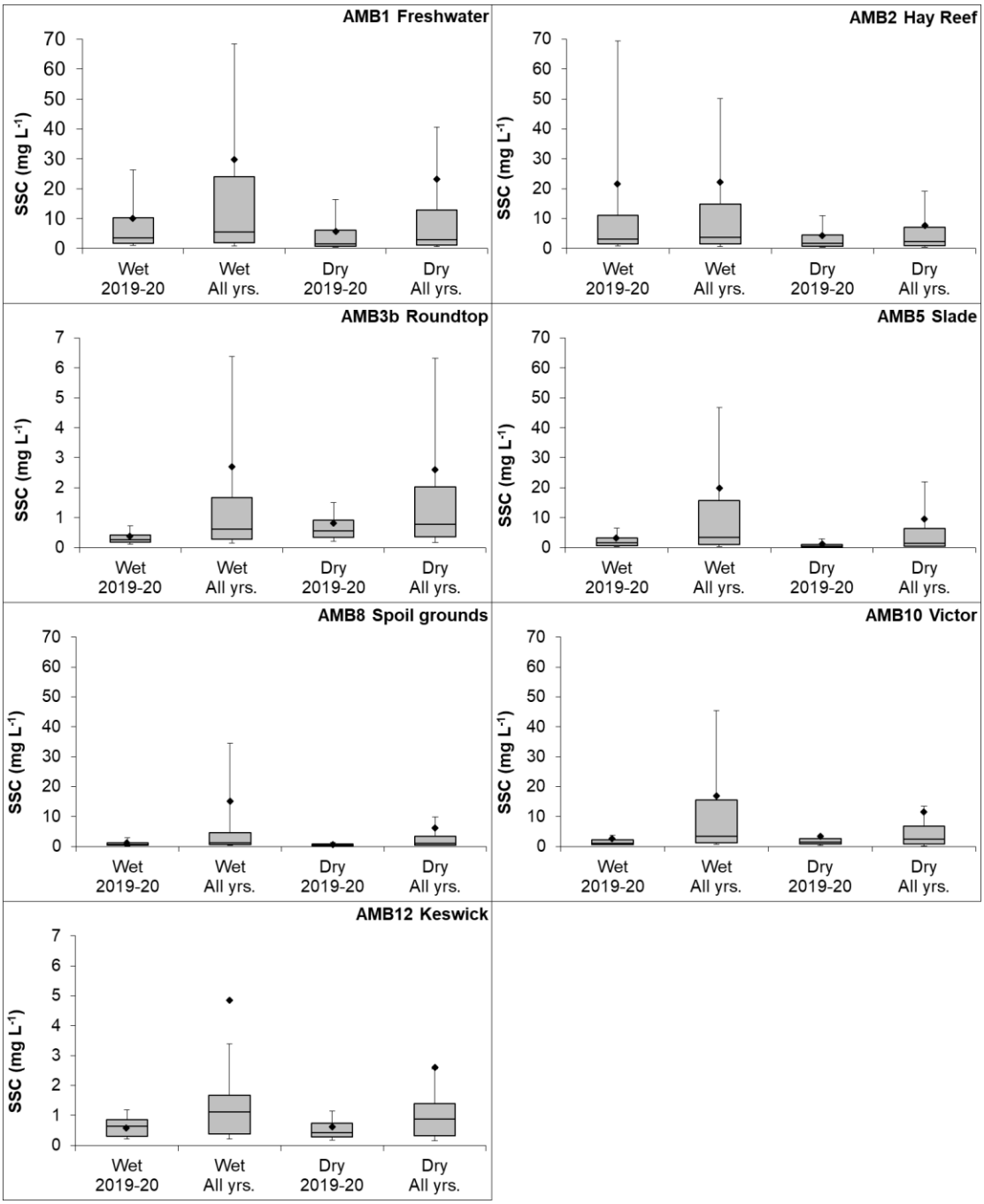

Figure 3.28 Suspended sediment concentration (SSC) box plots for each monitoring site. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or all available wet seasons (2014-2020). Note that different scales are used for different sites.

Hourly deposition rate

For the 2019-2020 monitoring year, median and upper quartile sediment deposition rates in the wet season were lower than the dry at all sites, with the exception of AMB5. This is in contrast to the previous year, which showed an overall increase in deposition rates during the wet season. The mechanism behind this change is unclear, however this likely links to the reduced levels of SSC during

this period. Investigating the season to season variance in deposition rate values in future studies could verify the seasonal patterns depicted here.

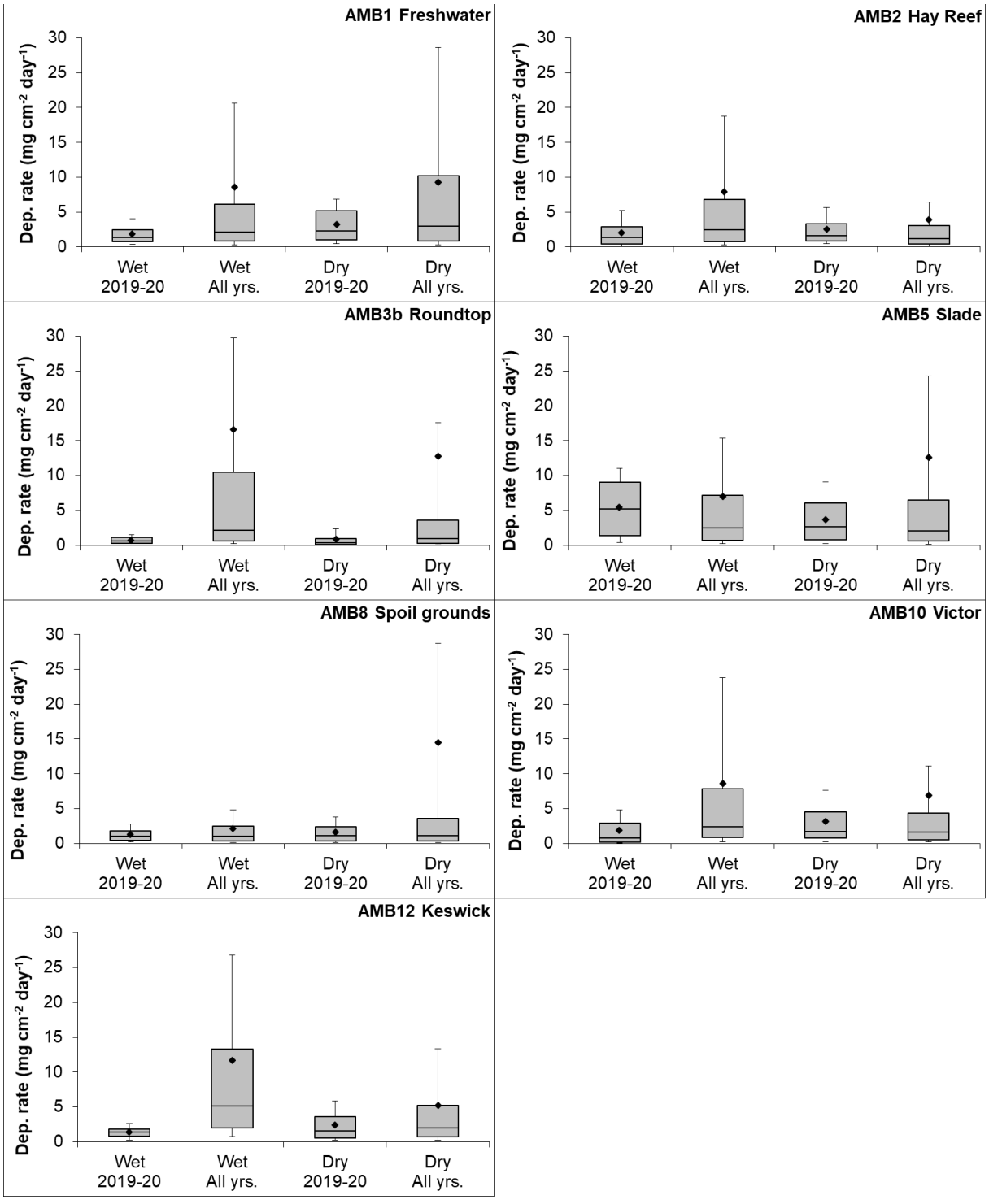

Figure 3.29 Sediment deposition rates (mg cm^{-2} day^{-1}) box plots for each monitoring site. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or all available wet seasons (2014-2020).

Total daily PAR

Most sites had similar photosynthetically available radiation statistics across the wet and dry seasons as the previous year. The usual profile of reduced PAR during the wet compared to the dry season was

observed. However, the exceptions were AMB3b and AMB10 which had notably higher wet season PAR values than the dry season (PAR; Figure 3.30). This suggests that at most sites, higher SSC (Figure 3.28) or more cloud cover could be responsible for reduced benthic PAR during the wet season.

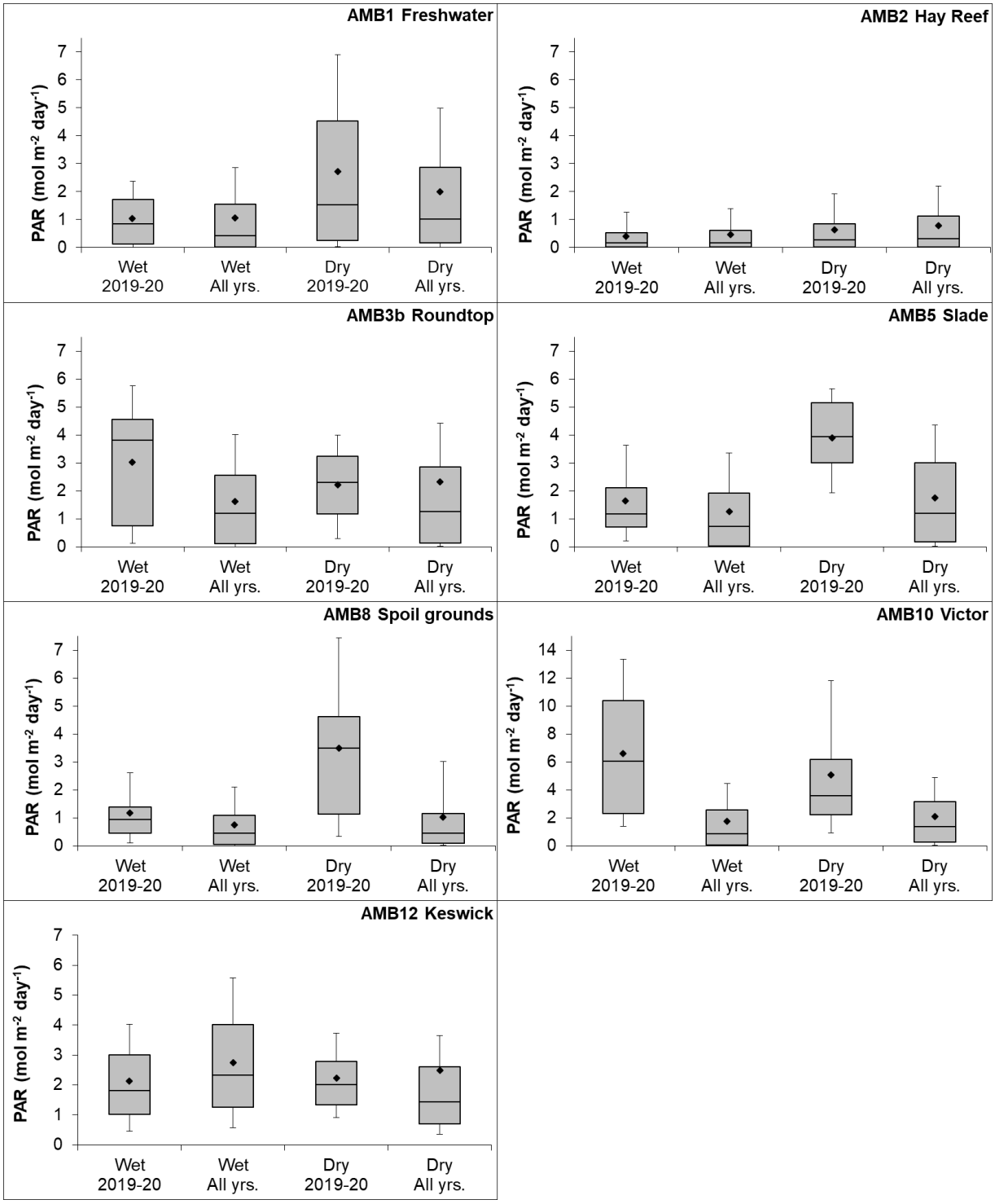

Figure 3.30 Photosynthetically available radiation (mol m^{-2} day^{-1}) box plots for each monitoring site. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or all available wet seasons (2014-2020). Note the doubled y-axis scale on AMB10 Victor.

Water temperature

Median temperatures during the wet season (28-29 °C) are notably higher than in the dry season (22-24 °C; Figure 3.31).

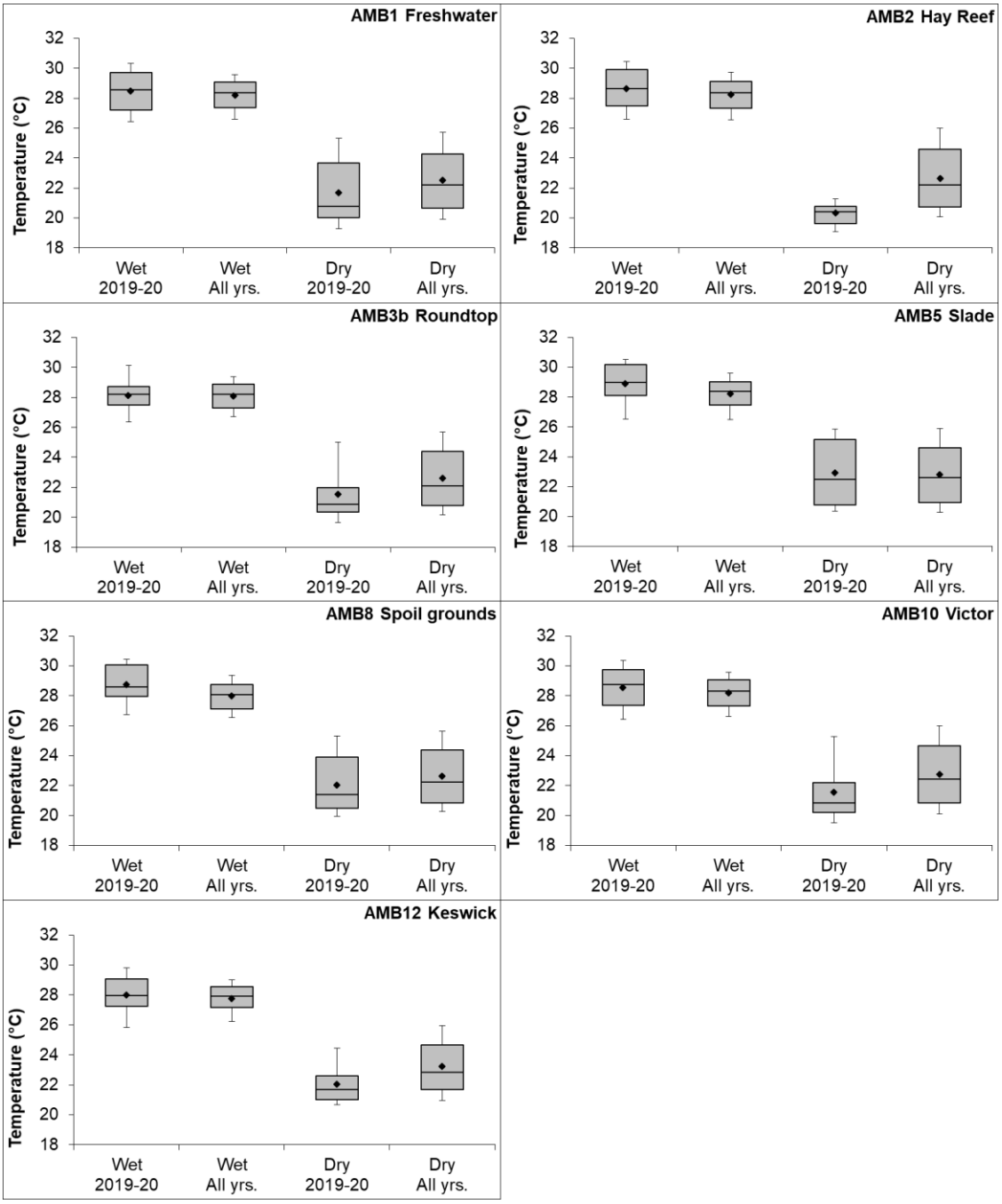

Figure 3.31 Temperature (°C) box plots for each monitoring site. Boxes represent the wet (1 November-31 March) and dry seasons (1 April-31 October) using either one wet season (2019-2020) or all available wet seasons (2014-2020).

3.3.9 Current meter

Marotte HS current meter instruments were deployed throughout 2019 and 2020 on the seven monitoring sites in the Mackay area. The monitoring periods that were achieved from instrument deployments are listed below

Site name	Site code	Monitoring start	Monitoring end
Freshwater Point	AMB 1	1st July 2019	6th April 2020
Hay Reef	AMB 2	10th July 2019	1st July 2020
Keswick Island	AMB 12	10th July 2019	29th June 2020
Round Top Island	AMB 3b	11th July 2019	1st July 2020
Slade Island	AMB 5	11th July 2019	8th April 2020
Spoil Grounds	AMB 8	10th July 2019	19th February 2020
Victor Island	AMB 10	12th July 2019	2nd April 2020

Current meter data indicates the prominent current direction, current velocity and water temperature at each monitoring site. Data shows that coastal current, tidal current or a combination of both influence current direction and magnitude. A short and long animation illustrating how the current speed and direction changes over time at each site are accessible to view via sharepoint (Figure 3.32). Links to the videos are provided below.

- Monthly(long) video: https://www.youtube.com/watch?v=4KEZkysQSac
- Yearly(short) video: https://www.youtube.com/watch?v=z5zgnpnLgCk

The three figures that are found on the next two pages present the current meter data individually for all seven sites and across the achieved monitoring periods. This includes a) rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading*) (Figure 3.33). b) rose-plots displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*) (Figure 3.34). c) A bivariate plot presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*) (Figure 3.35). Presented together, these figures highlight the overall current direction experienced at each collection site as well as provide 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.

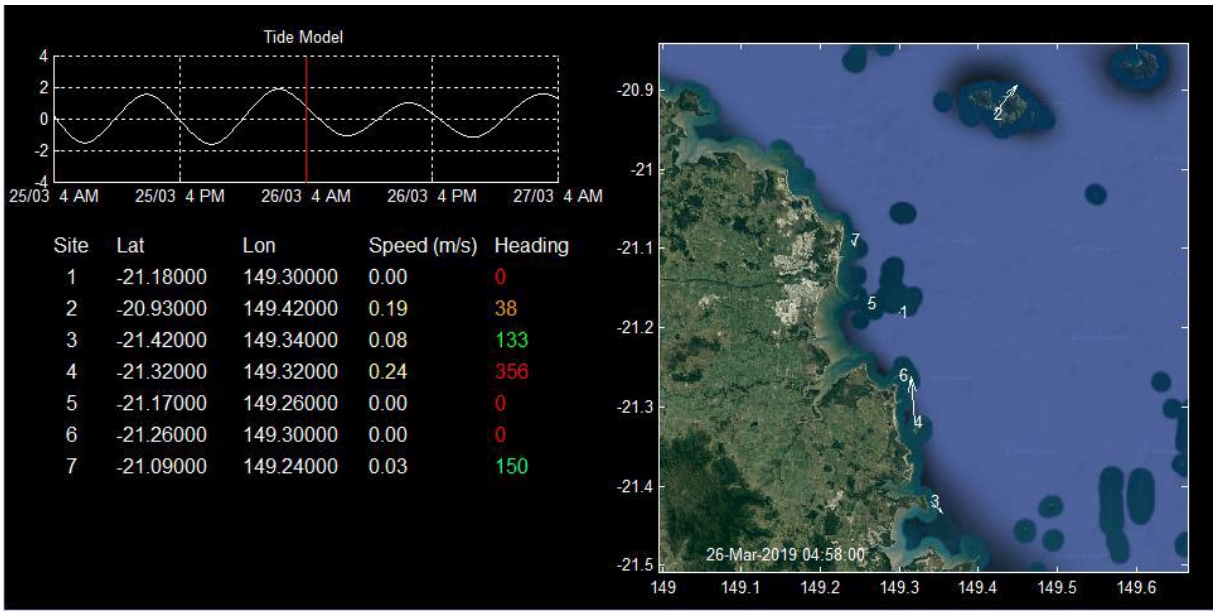

Figure 3.32 Example screengrab from current speed and direction animations

Current Meter Annual Rose Plots

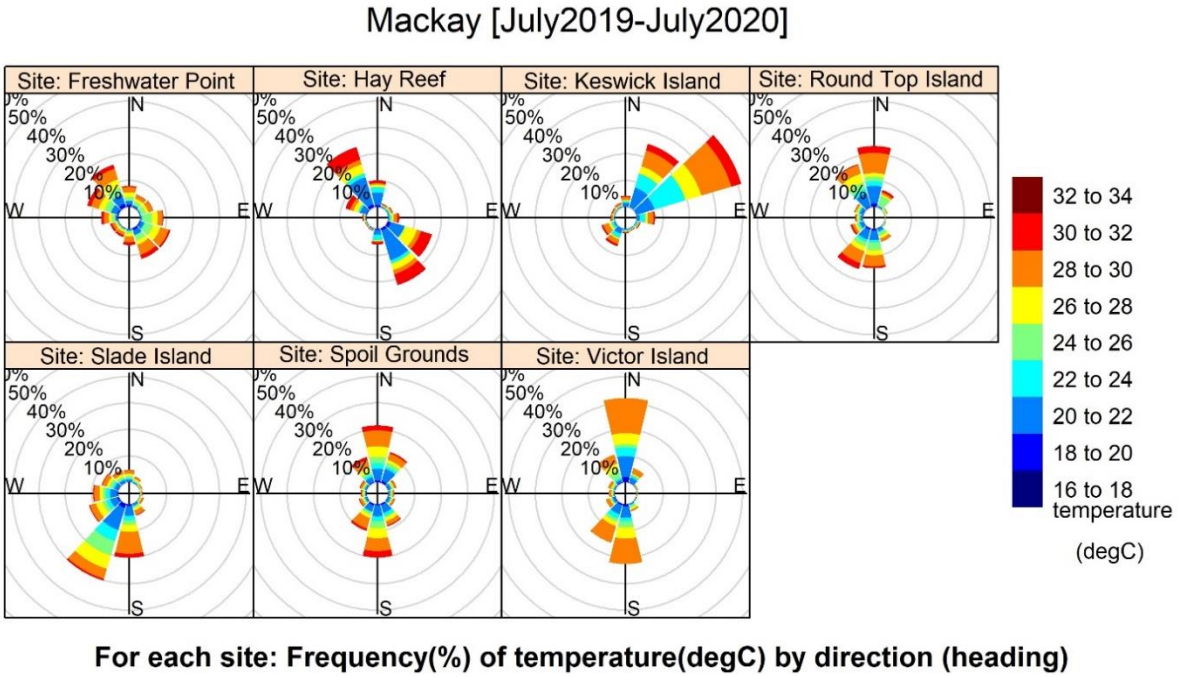

Figure 3.33 Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading), for each of the seven sites over the monitoring period July 2019 to July 2020.

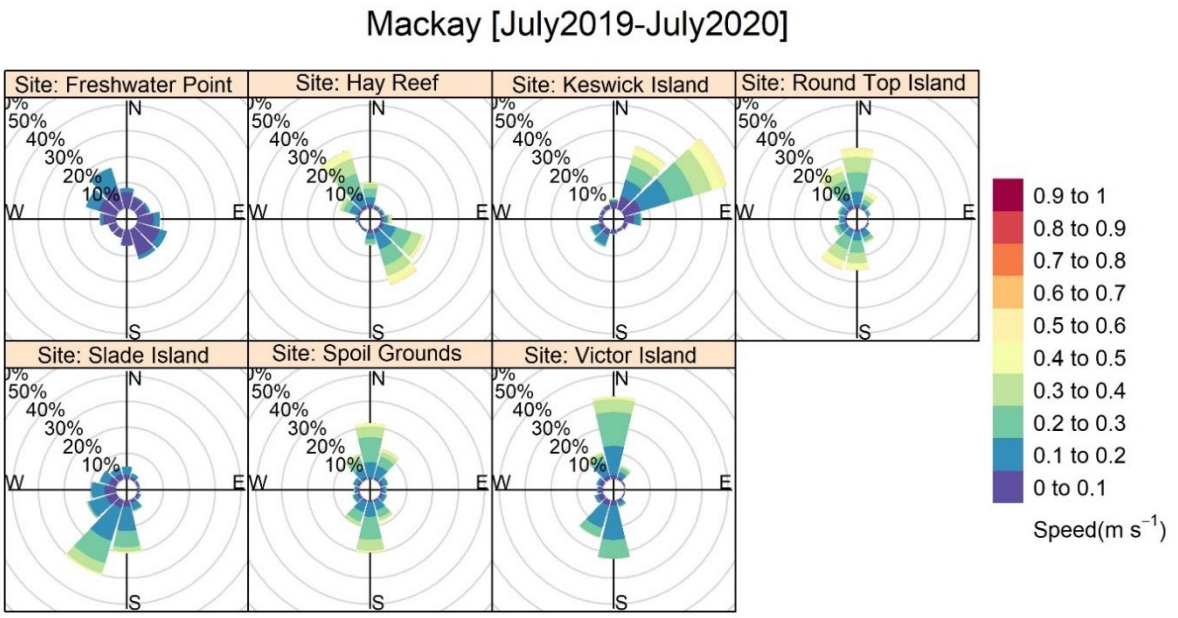

Figure 3.34 Rose-plots displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading), for each of the seven sites over the monitoring period July 2019 to July 2020

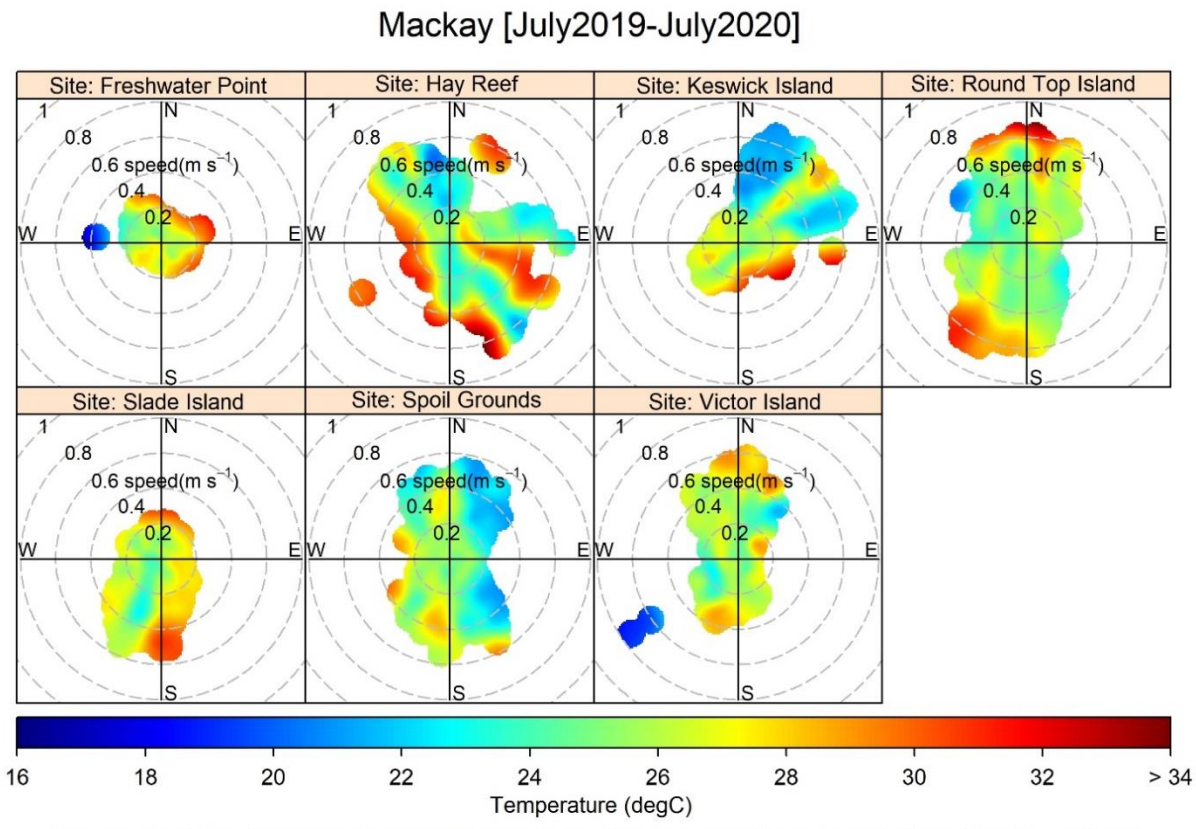

Figure 3.35 For each of the seven sites and across the monitoring period of July 2019 to July 2020, bivariate plots displaying average values for recorded water temperature (°C) that are calculated with respect to current speed (m/s) and current direction (heading).

Current meter data during the Dry Season(April – October)

Below is a summary of current meter data that was collected during months of the dry season period (April-October). This includes, a) Rose-plots displaying the frequency of recorded water temperature (°C) with respect to current direction (heading*) (**Figure 3.36**). b) Rose-plots displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*) (**Figure 3.37**). c) Bi-variate plots presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*) (**Figure 3.38**).

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

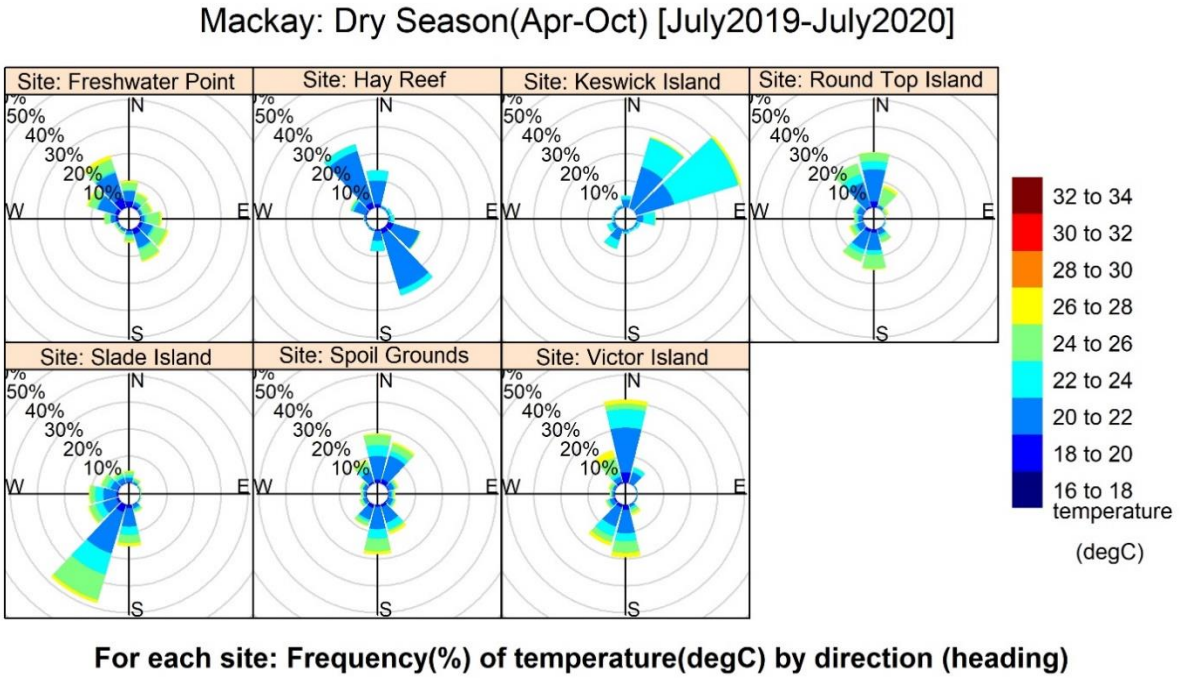

Figure 3.36 Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading), for each of the seven sites during the dry season months (April-October) across the monitoring period July 2019 to July 2020

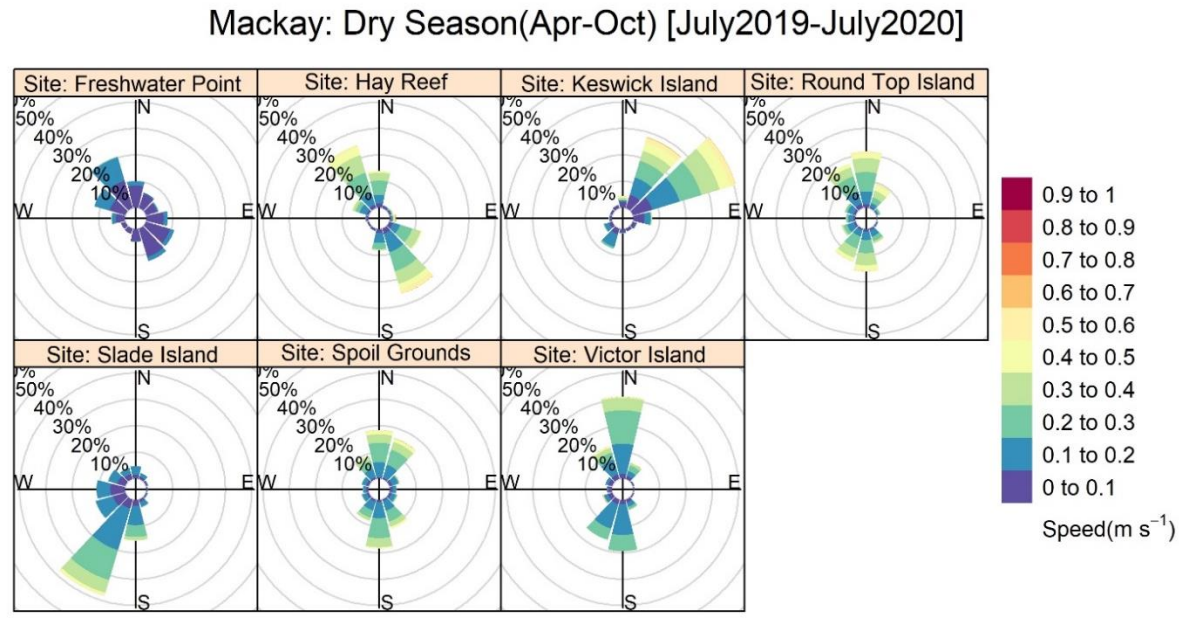

Figure 3.37 Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the seven sites during the dry season months (April-October) across the monitoring period July 2019 to July 2020

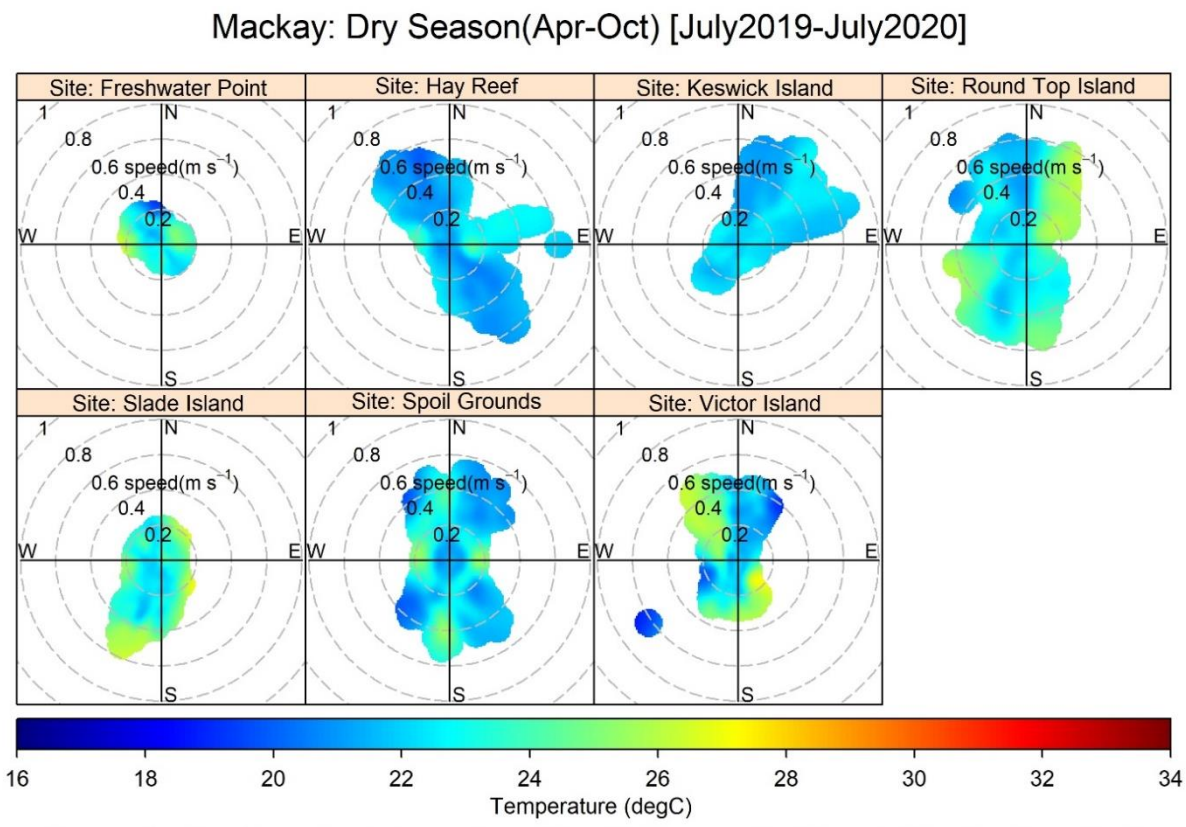

Figure 3.38 For each of the seven sites and during the dry season months (April-October) across the monitoring period of July 2019 to July 2020, bivariate plots displaying average values for recorded water temperature (°C), calculated with respect to current speed (m/s) and current direction.

Current meter data during the Wet Season (November-March)

Current meter data that was collected during months of the wet season period (November-March) is summarised below. a) Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading*) (Figure 3.39). b) Rose-plots displaying the frequency of recorded current speeds (m/s) with respect to current direction (heading*) (Figure 3.40). c) Bi-variate plots presenting averaged water temperature (°C) calculated with respect to current speed (m/s) and current direction (heading*) (Figure 3.41).

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

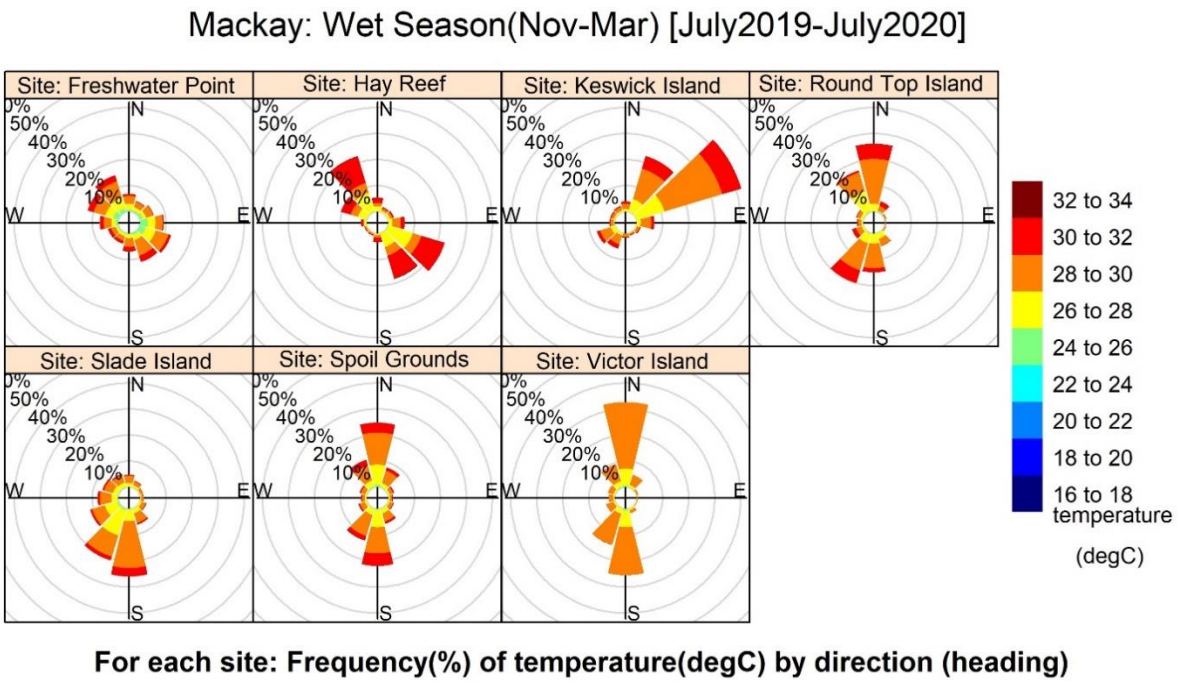

Figure 3.39 Rose-plots displaying the frequency of recorded water temperatures (°C) with respect to current direction (heading), for each of the seven sites during wet season months (November-March) across the monitoring period July 2019 to July 2020

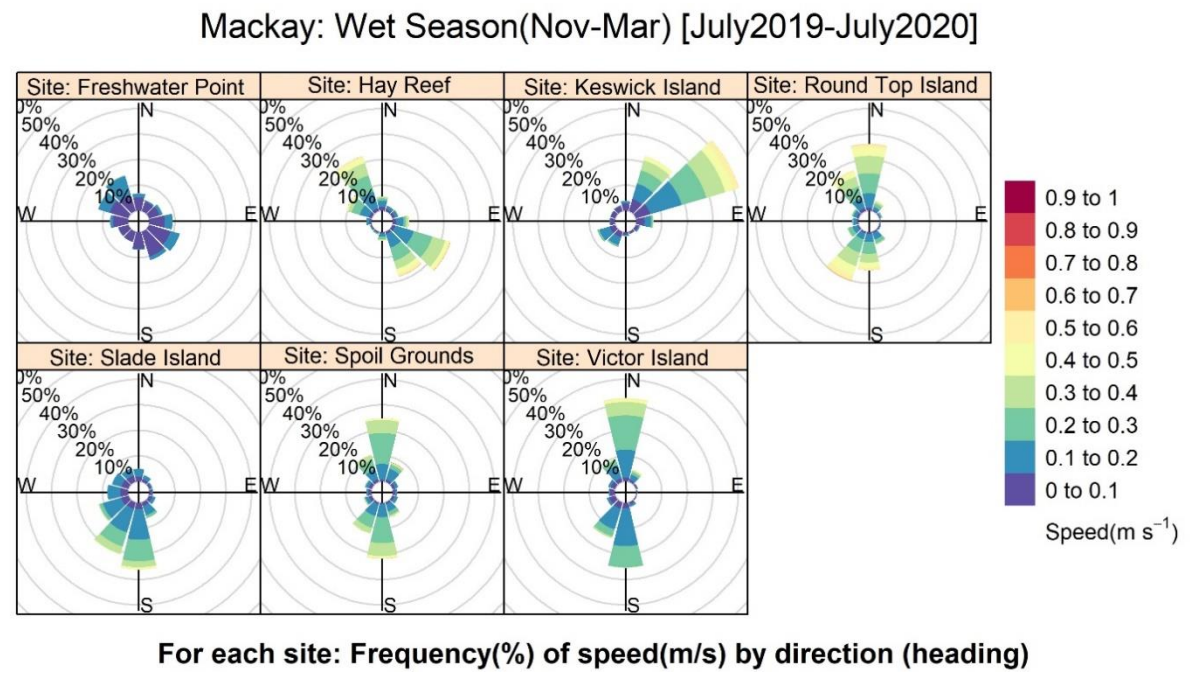

Figure 3.40 Rose-plots displaying the frequency of recorded current speed (m/s) with respect to current direction (heading), for each of the seven sites during wet season months (November-March) across the monitoring period July 2019 to July 2020

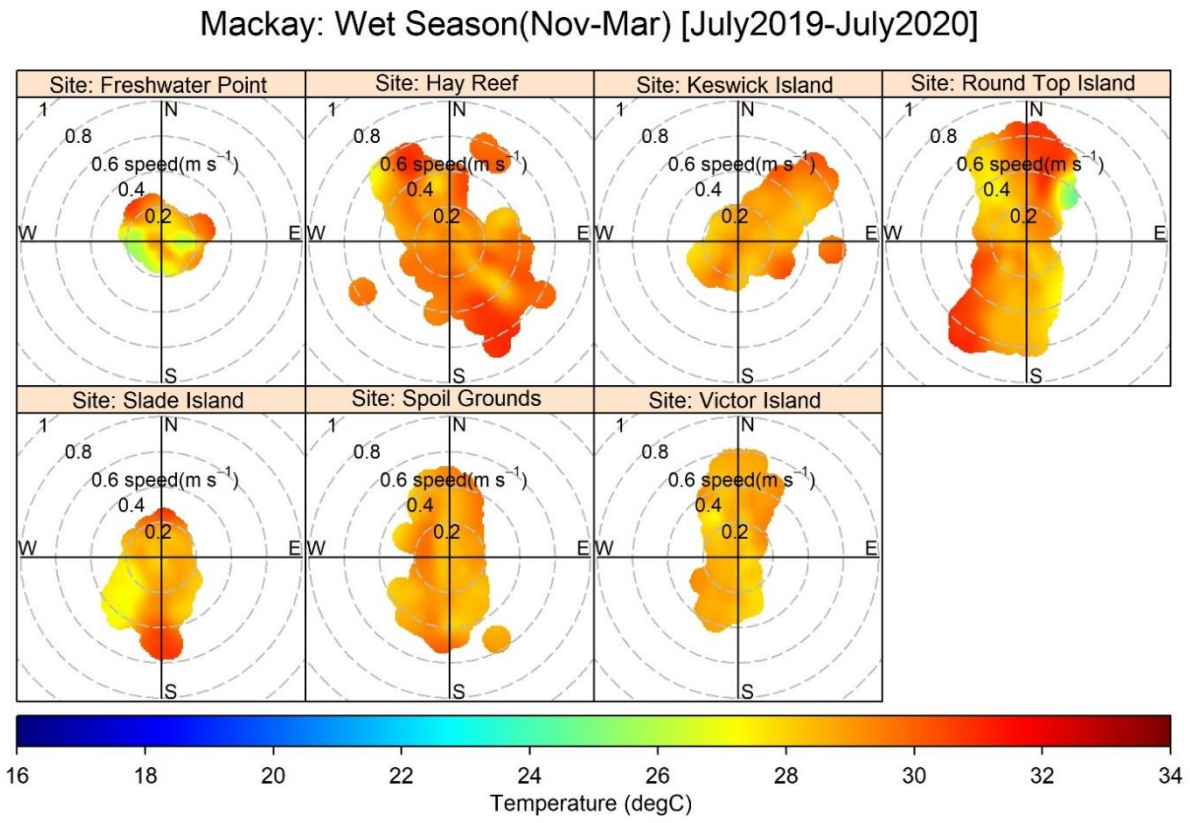

Figure 3.41 For each of the five sites and during wet season months (November-March) across the monitoring period of July 2019 to July 2020, bi-variate plots displaying average values for recorded water temperature (°C), calculated with respect to current speed (m/s) and current direction.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Climatic conditions

1. The total 2019-2020 wet season rainfall at Plane Creek Sugar Mill (17 km linear from Hay Point) was 1101 mm which is proximal to the long term average wet season total. This total is however lower than the 2018-2019 total.
2. The wet season rainfall contributed to at least four flow periods, but most notably during March 2020.

4.1.2 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. Seasonal differences in water quality were minor, except for temperature which continues to be highest during the summer months.
3. There was little difference in water temperature between the three depths examined, indicating that the water column was well mixed during each survey.
4. Particulate nitrogen concentrations exceeded the guidelines throughout most of the 2019-2020 monitoring period.
5. Chlorophyll-a concentrations exceeded the GBRMPA guideline trigger value for all sampling events except August 2019.
6. Metals targeted for analysis were not detected above the 95% level of protection trigger values for marine waters. Silver, Cadmium, Nickel, Zinc, and Mercury were not detected. Copper was detected at Mackay Harbour in August 2019 (though concentrations were below the guideline in the following survey in May 2020). Lead was detected in August 2019 at Slade Point, and Dudgeon Point but was at concentrations below guideline values. Arsenic was detected at low concentrations.
7. Pesticides targeted for analysis were not detected above the trigger values for the GBR. The herbicides Chlorpyrifos and Diazinon were not detected. Hexazinone and Diuron were present at low concentrations for numerous sites in August 2019 and in May 2020. The insecticides Ametryn and Simazine were not detected (< LOD). Atrazine was present at low concentrations for most sites in May 2020.
8. An assessment of the plankton community (both phytoplankton and zooplankton) was completed during this reporting period. There was a clear separation in the plankton community between most surveys, suggesting seasonal and inter-annual variation, and a weak relationship with available nutrients. *Trichodesmium* blooms were noted across the region during most surveys, primarily during late spring and early summer.

4.1.3 High frequency loggers

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. This is similar to the pattern observed in long term annual data sets at these sites.
2. Another important finding here was that deposition data did not indicate large deposits occurring at any of the monitored sites, and this is likely attributed to re-suspension of sediment by wave energy. SSC continues to regularly exceed relevant water quality guidelines at all sites, indicating that the development of local water quality guidelines is prudent. As

part of this local water quality guideline development, it is recommended that the guidelines apply to benthic waters, adjacent to sensitive receptor habitats, rather than the current approach of surface water guidelines that can be well away from important habitats.

3. The 2019-2020 comparison of wet and dry seasons shows little difference in SSC for most sites, which lower mean and median values compared to previous years. However there were small differences for sites AMB 1 and AMB2, whereby the upper quartiles were 50 % higher than in the dry season. There was no discernible difference in wet and dry RMS wave height statistics.
4. The five year-long data set comparing wet and dry seasons shows little difference in SSC for the sites AMB 3, 8 and 12, however there were small differences for sites AMB 1, 2, 5, and 10, where means and medians were 30-40% higher than in the dry season.
5. Fine-scale patterns of photosynthetically active radiation (PAR) continue to be 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, and rainfall events resulting from storms leading to increased catchment flows and an input of suspended solids – this trend was particularly the case given the extended wet season rainfall and runoff in the region following the monsoon that covered the region in February 2019.
6. 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. 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.
7. 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, the relationship between these two parameters is not always strong. 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.
8. Overall the difference between wet and dry season PAR levels remained similar to previous years. Three sites had decreased PAR during the wet season (AMB1, AMB5, AMB8); Three sites showed very little difference between wet and dry seasons (AMB2, AMB3, AMB12); and interestingly one site (AMB10) showed an increase in median PAR of almost 50% in the wet season.

4.2 Recommendations

1. The program this reporting period included nine monitoring sites, which has allowed us to continue characterising water quality in the Mackay region.
2. The elevated copper result recorded in the marina in August 2019 were below the guideline in the May 2020 survey, this result might be an anomaly, however, should be further checked for an emerging problem.

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A1 CALIBRATION PROCEDURES

A1.1 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/cm^2 using the methodology outlined in Ridd *et al* (2001) 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.

A1.2 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 r^2 value equal to or greater than 0.9.

A1.3 Light Calibration

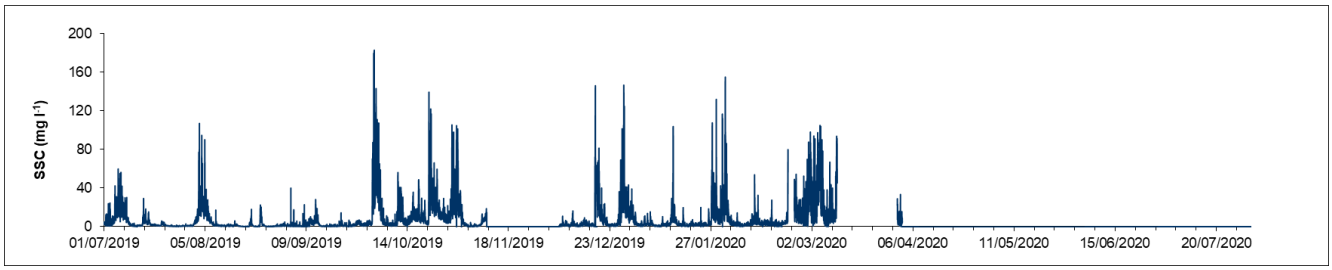
The light sensors on each logger are calibrated every six months or after every deployment. The light sensor is calibrated against a LICOR U250A submersible sensor that was calibrated in the factory within the last 12 months. The results of the logger light sensor and LICOR U250A are compared and a calibration 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.

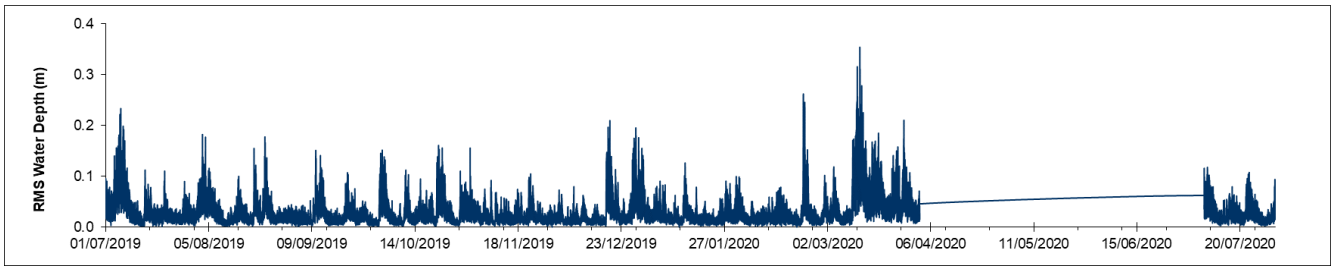
A1.4 Pressure Sensor Calibration

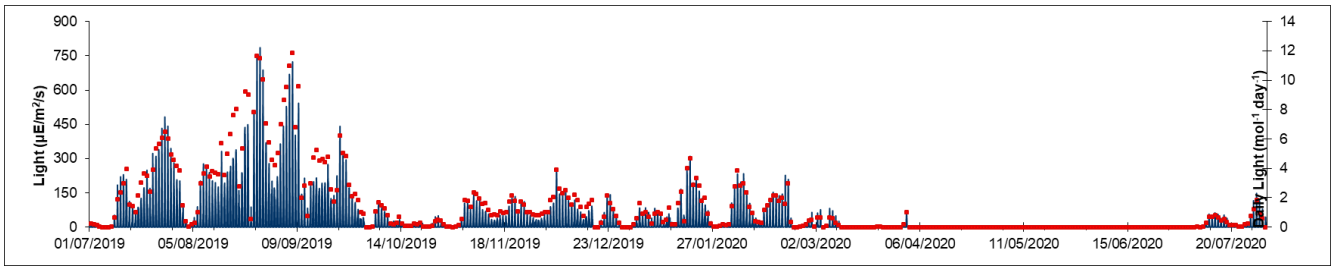
All pressure sensors are calibrated against a pressure gauge and the pressure is converted into depth in metres.

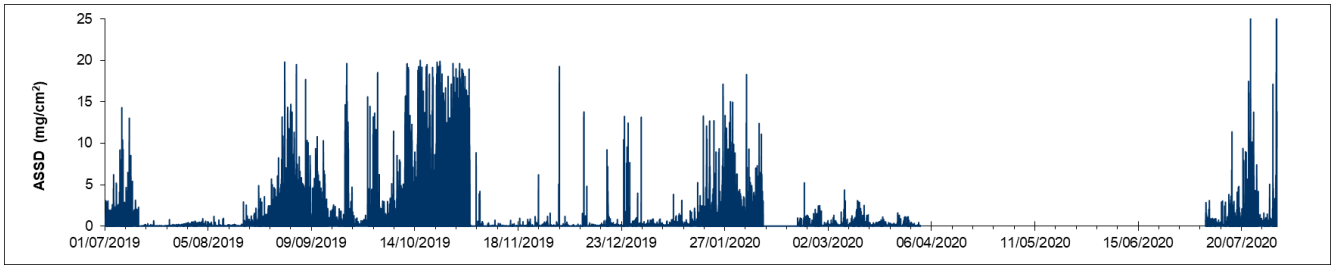
A2 TIME SERIES DATA

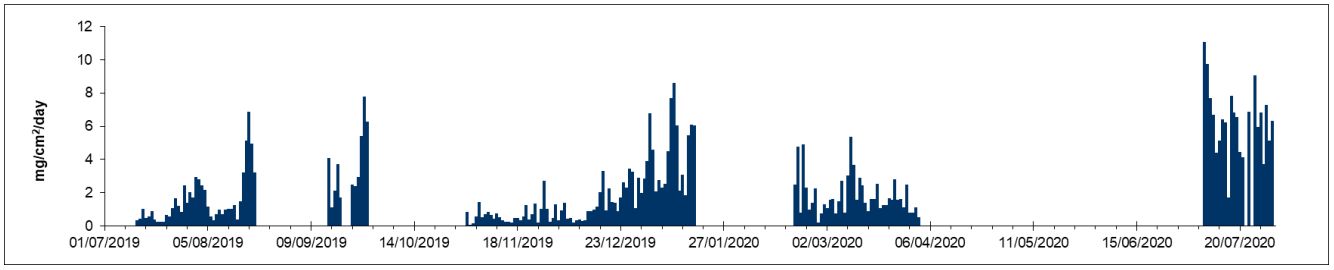
A2.1 AMB1: Freshwater Point

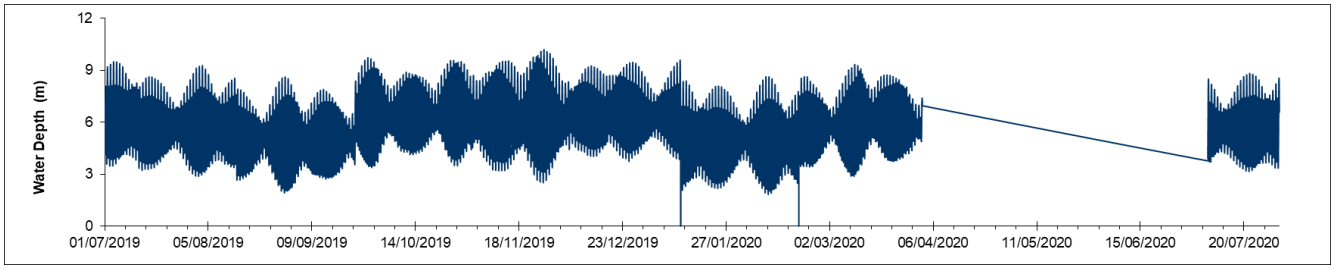


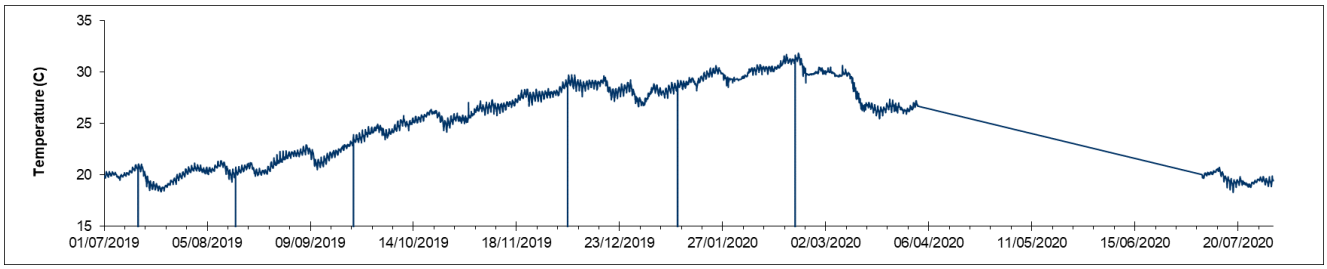




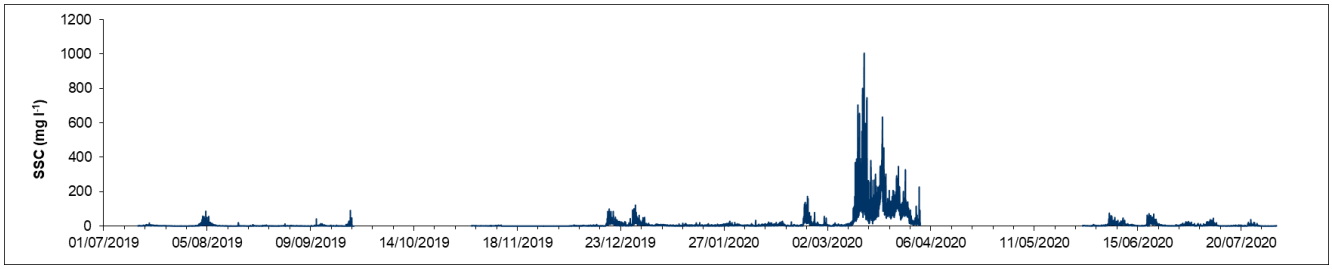


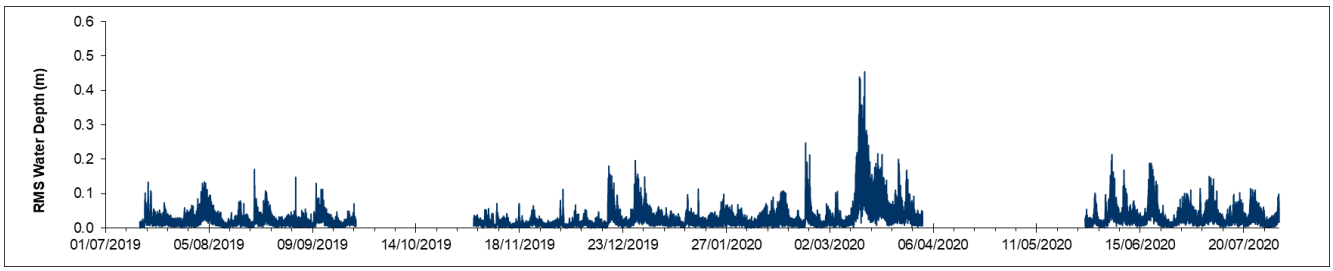


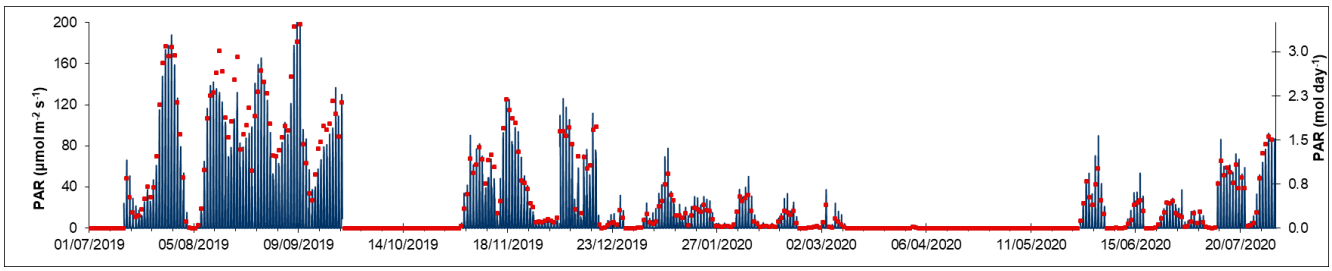


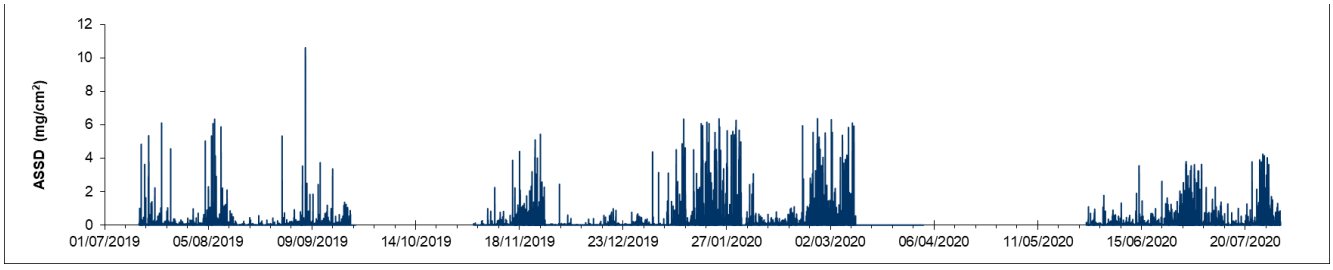


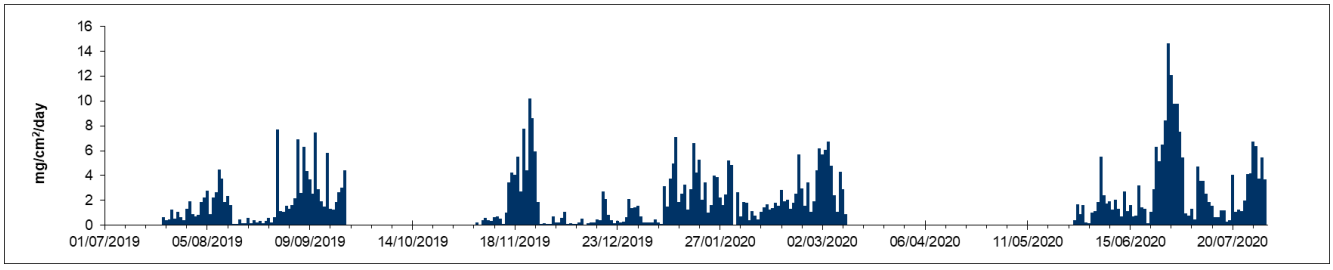
A2.2 AMB2: Hay Reef

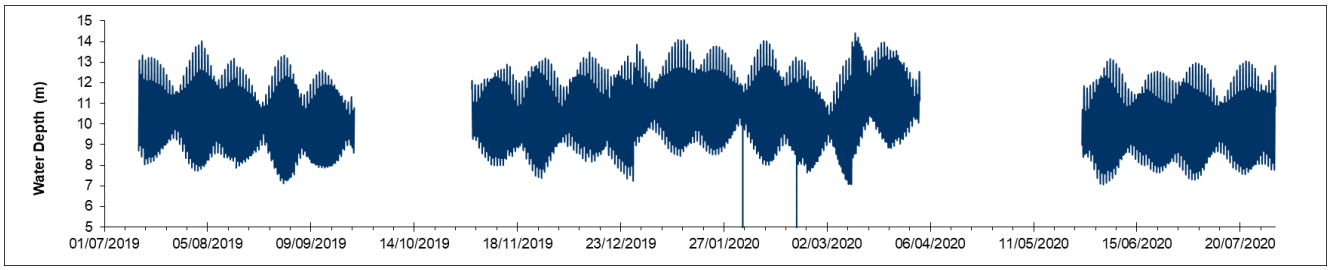


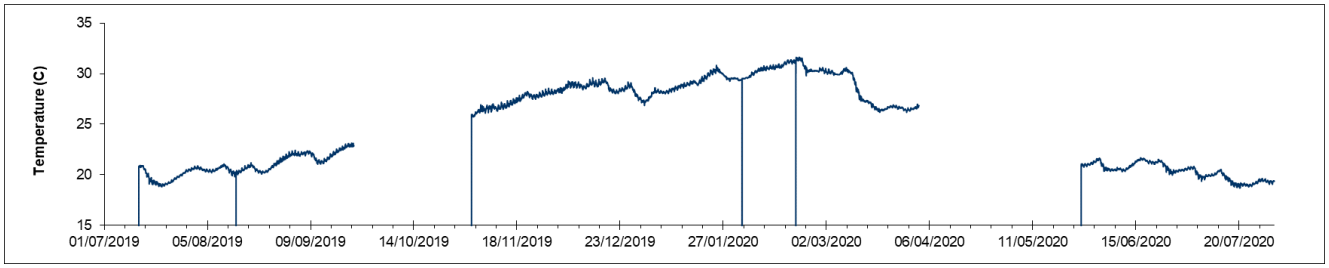




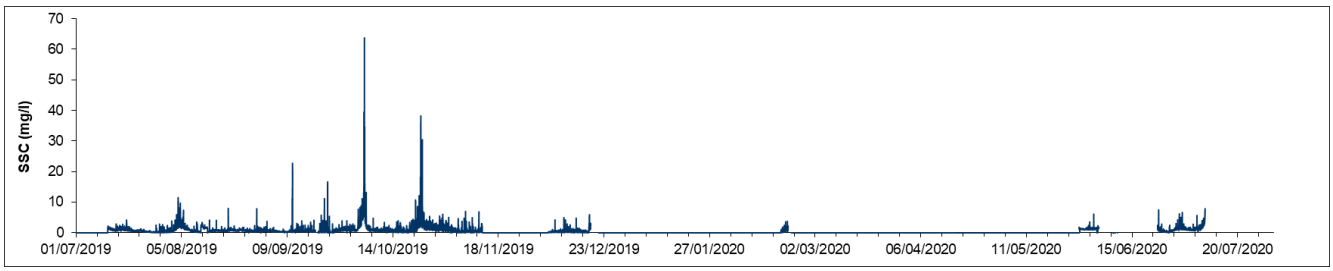


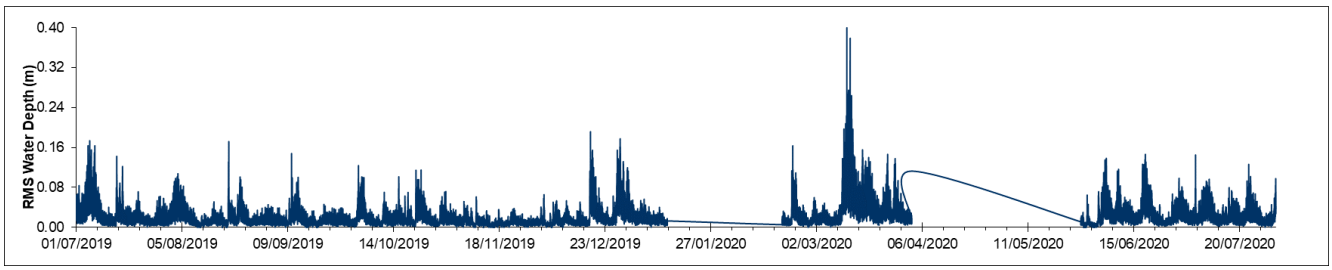


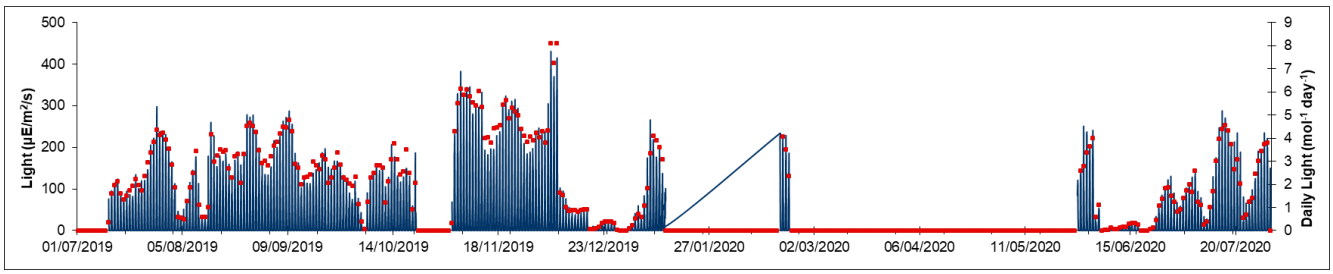


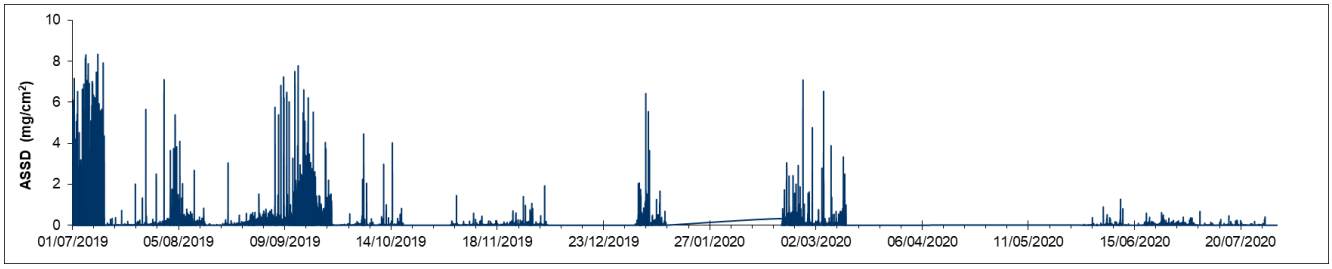


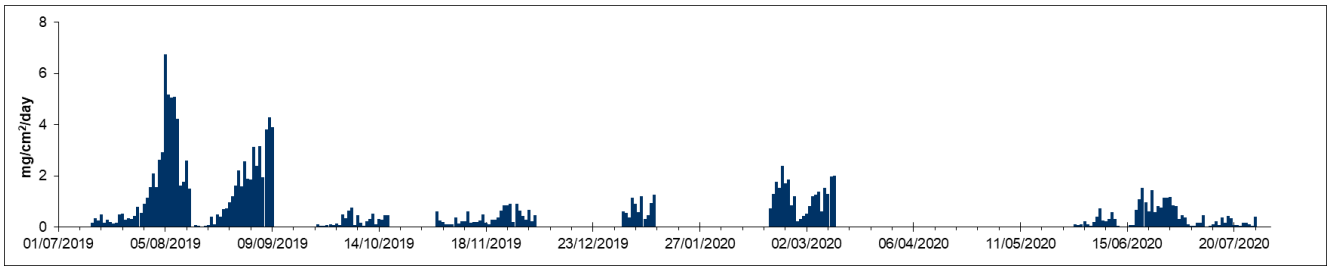
A2.3 AMB3: Round Top Island

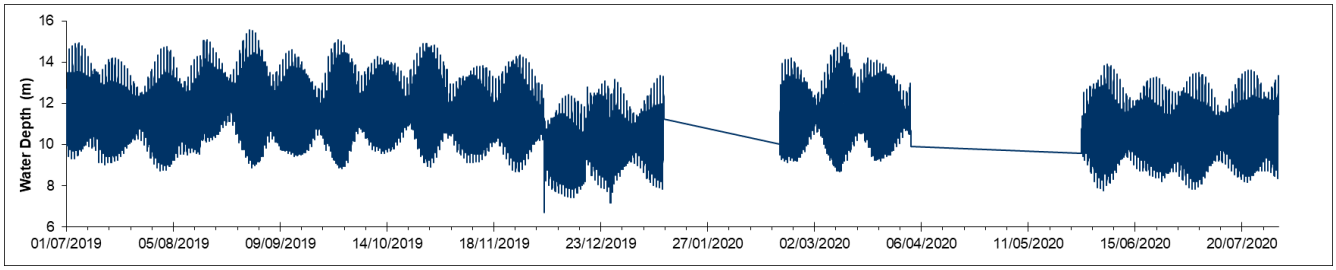


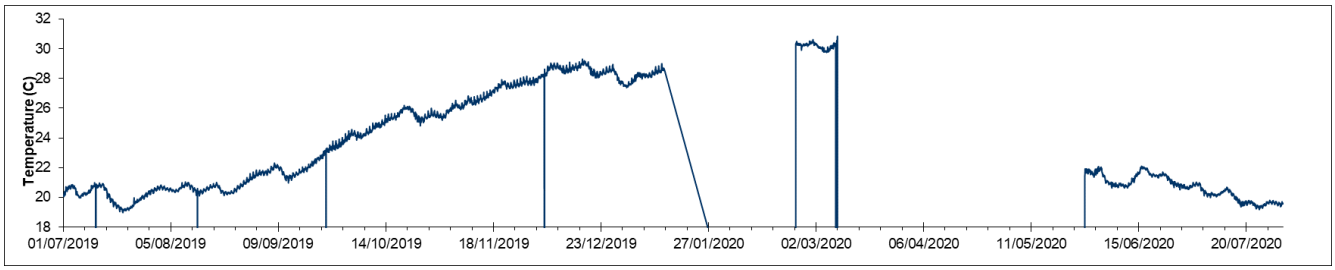




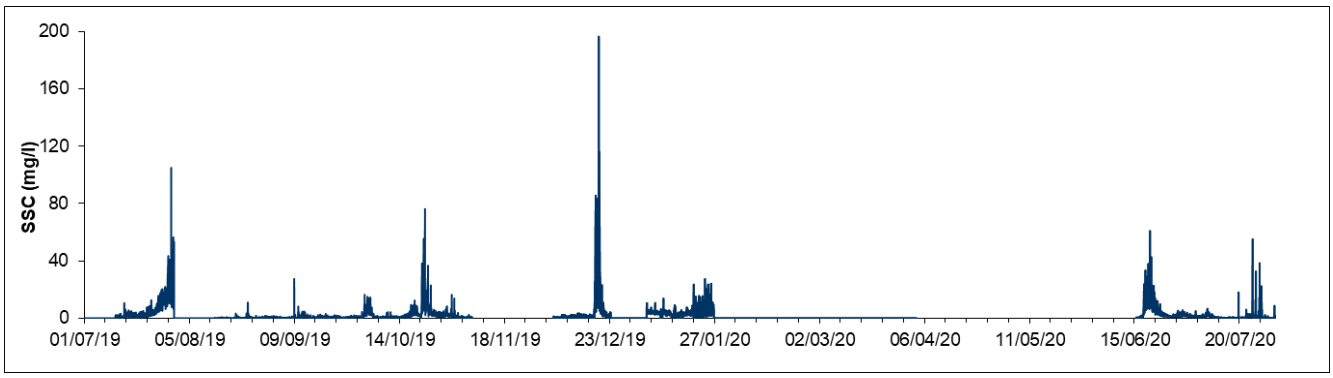


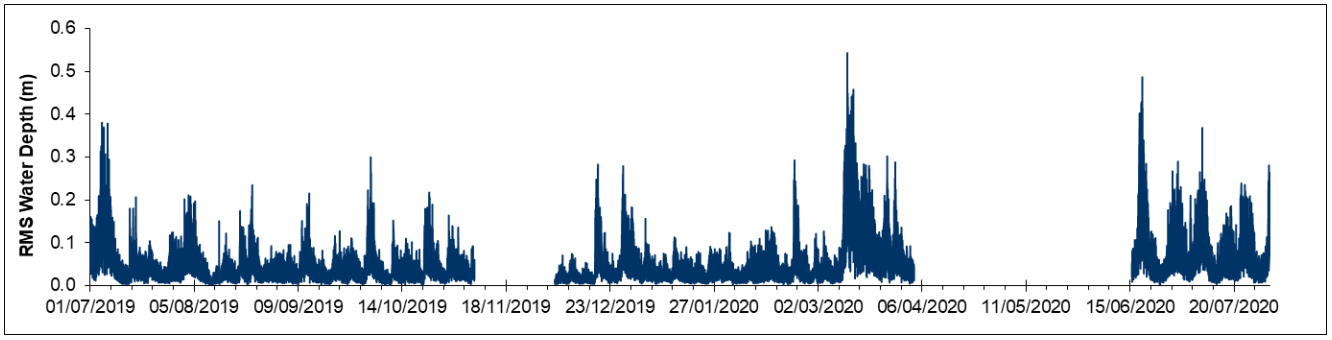


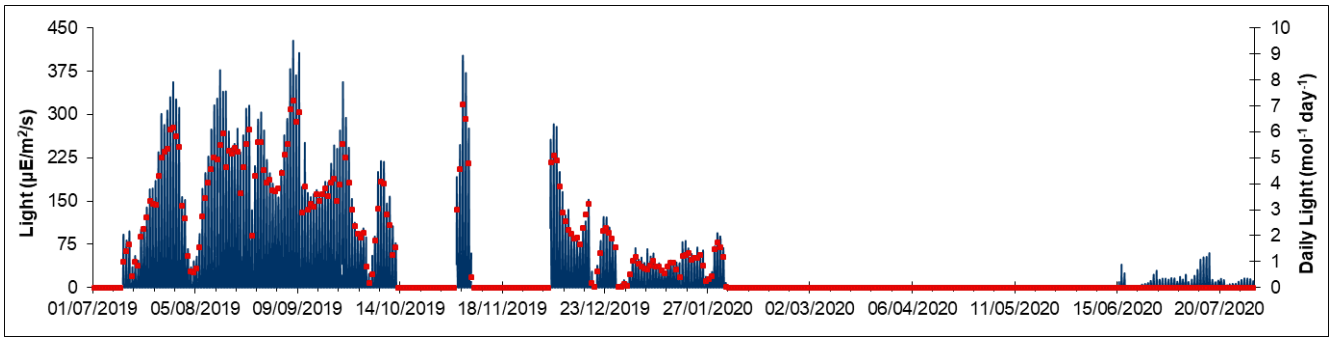


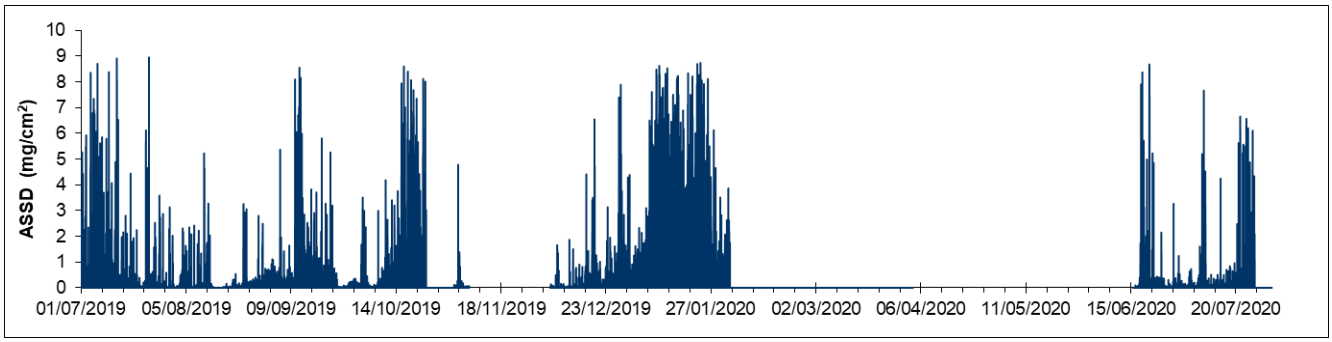


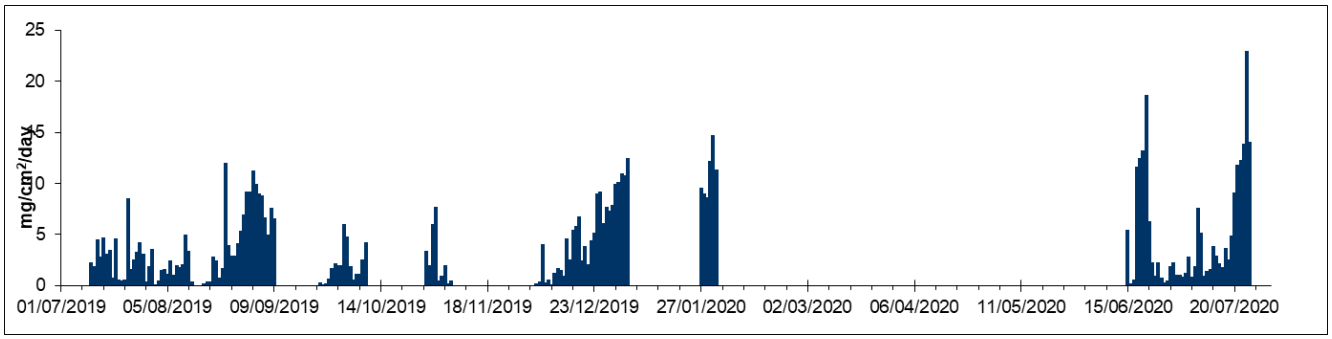
A2.4 AMB5: Slade Island

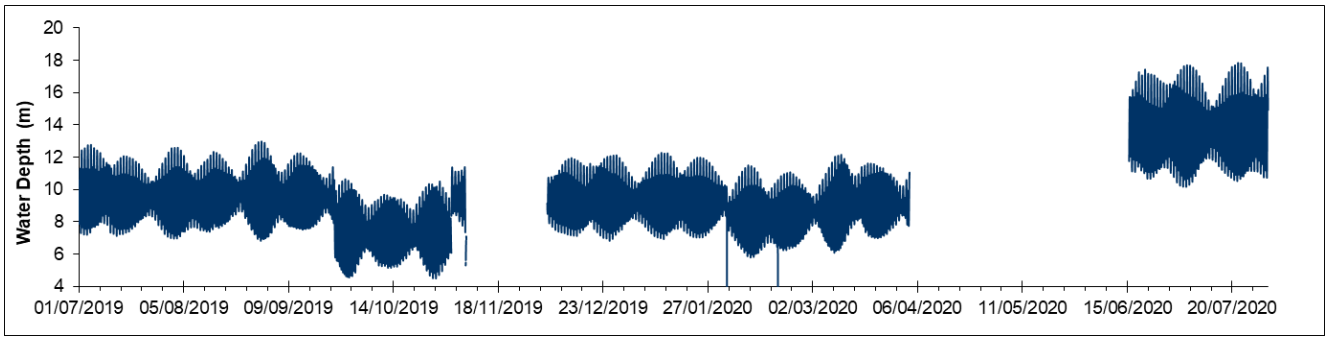


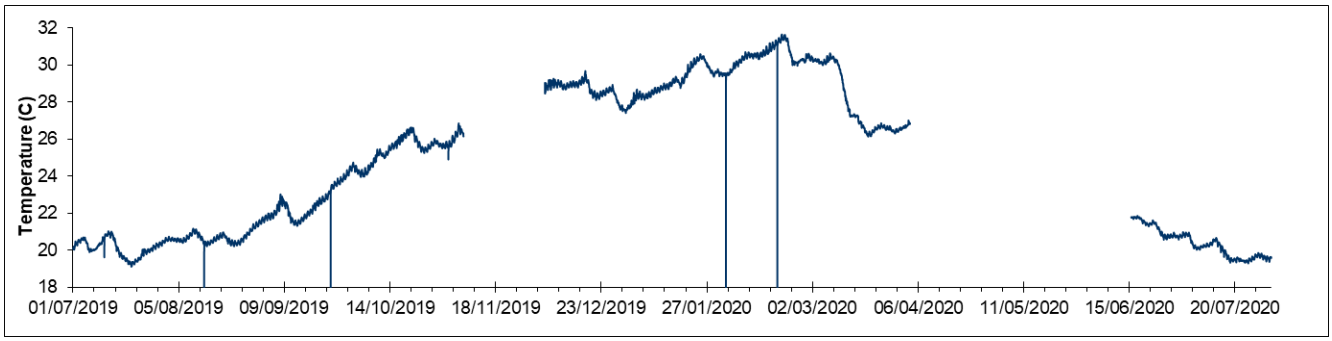



Light (µE/m²/s)
Daily Light (mol⁻¹ day⁻¹)
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

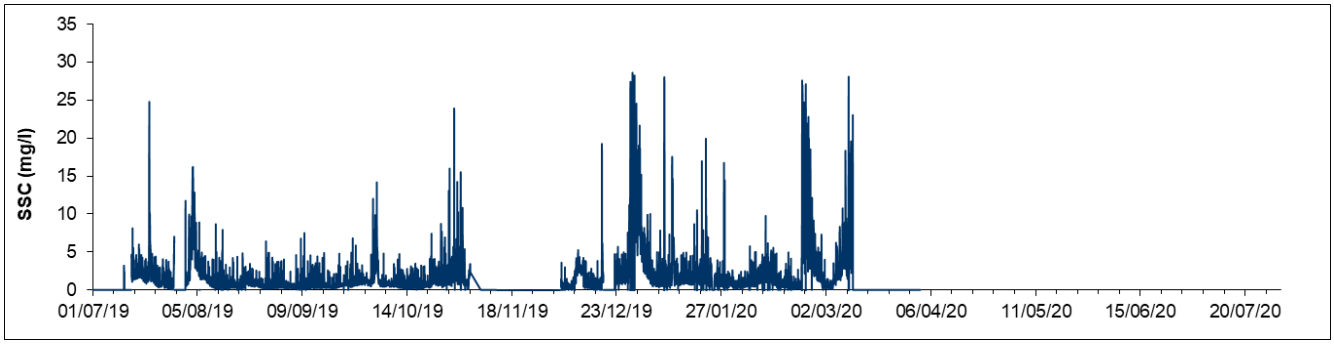

ASSD (mg/cm²)
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

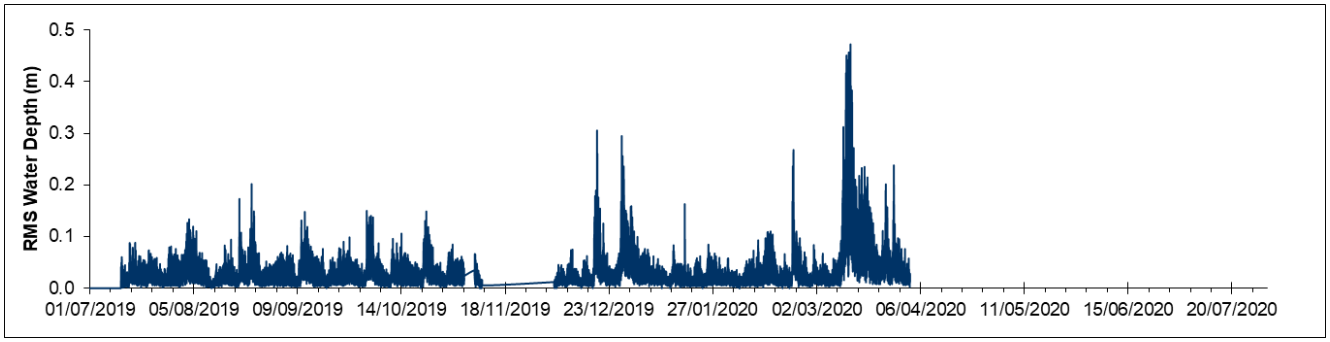

mg/cm²/day
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

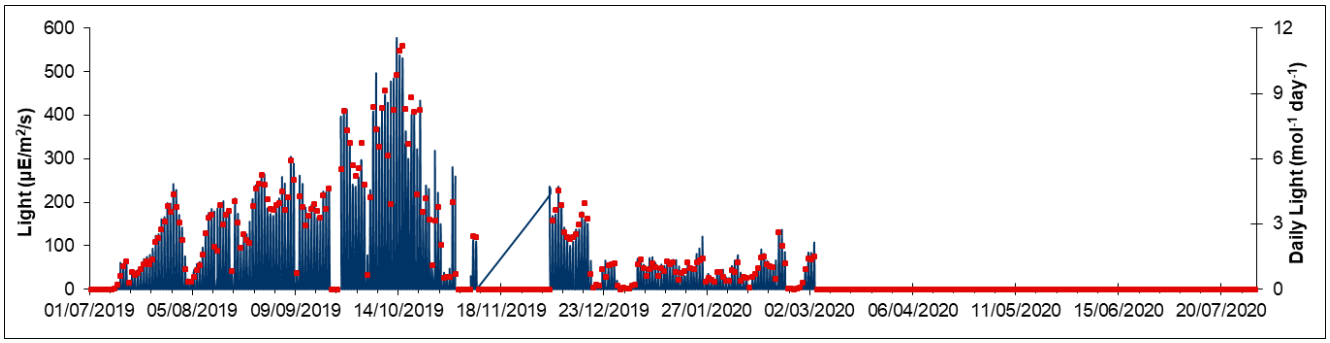

Water Depth (m)
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

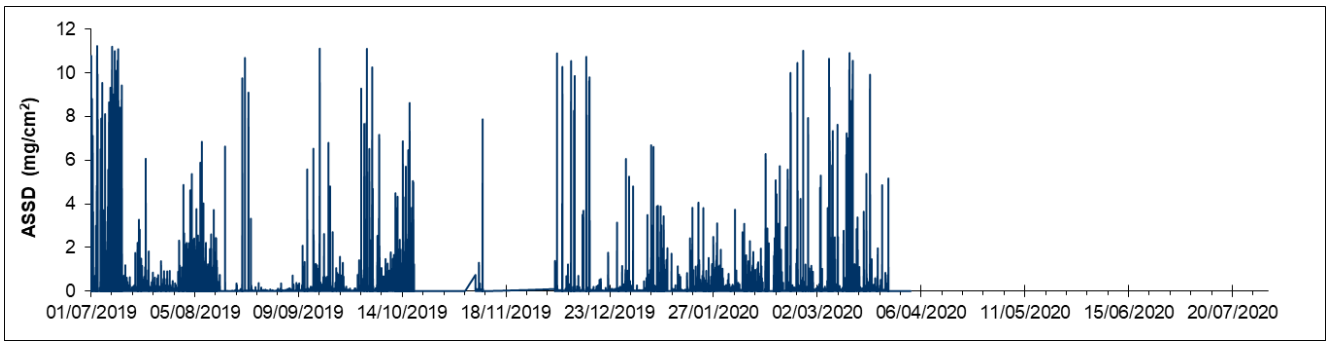

Temperature (C)
01/07/2019 05/08/2019 09/09/2019 14/10/2019 18/11/2019 23/12/2019 27/01/2020 02/03/2020 06/04/2020 11/05/2020 15/06/2020 20/07/2020

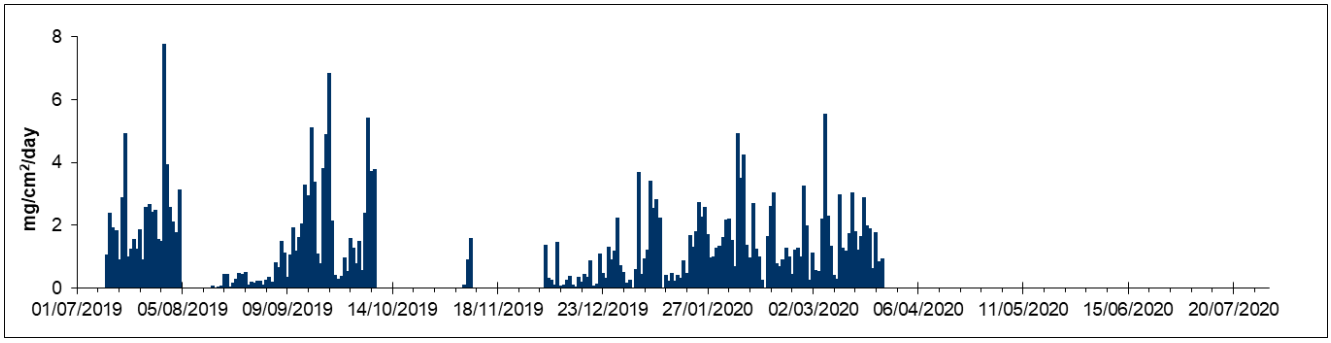
A2.5 AMB8: Spoil ground

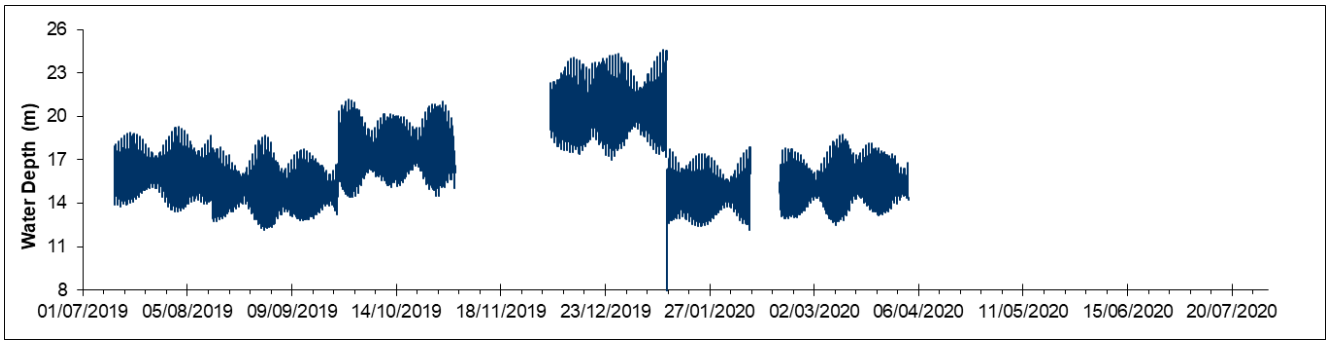


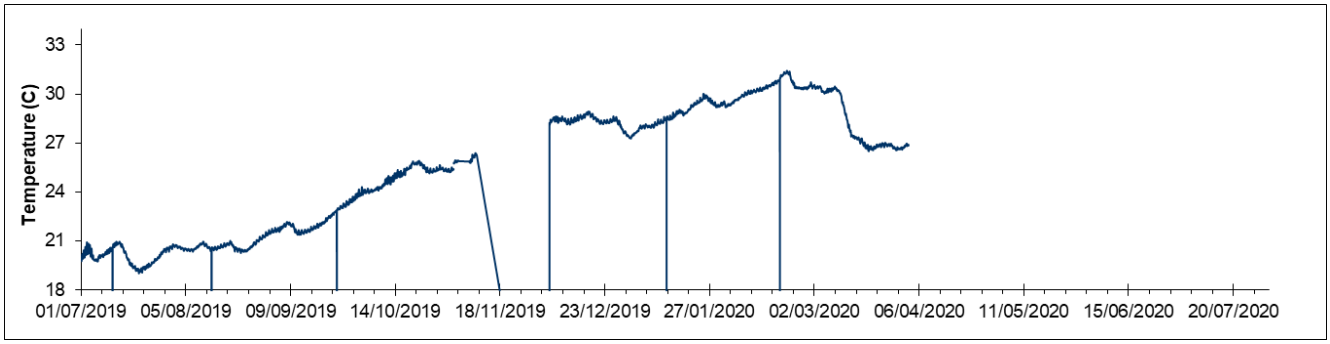




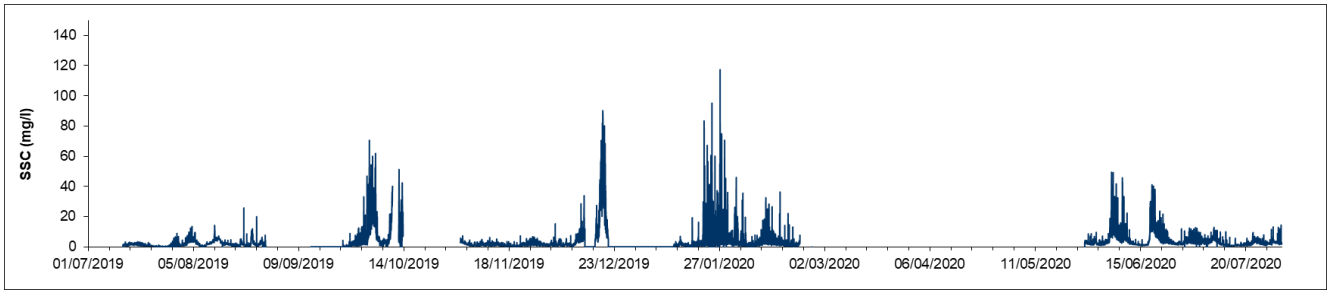


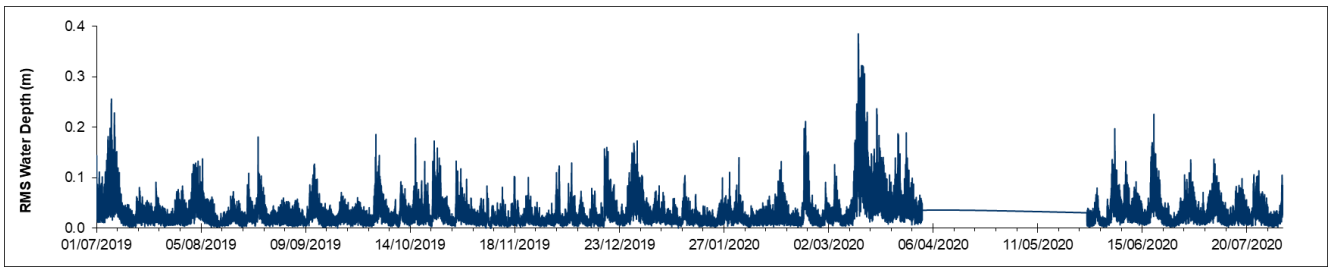


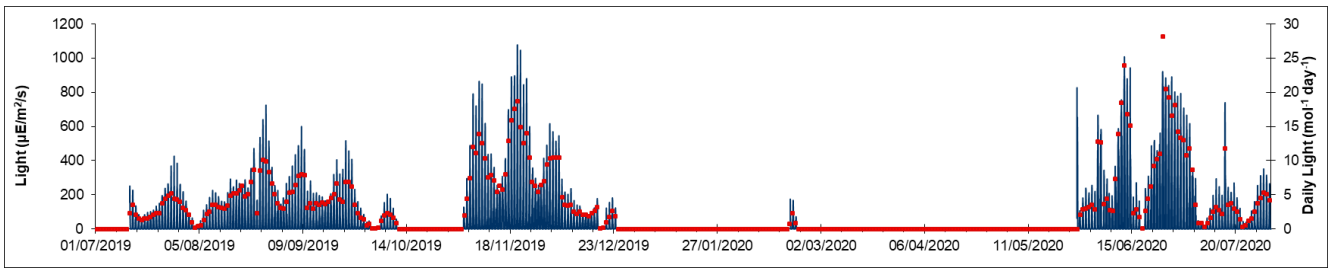

Water Depth (m)
26
23
20
17
14
11
8
01/07/2019
05/08/2019
09/09/2019
14/10/2019
18/11/2019
23/12/2019
27/01/2020
02/03/2020
06/04/2020
11/05/2020
15/06/2020
20/07/2020

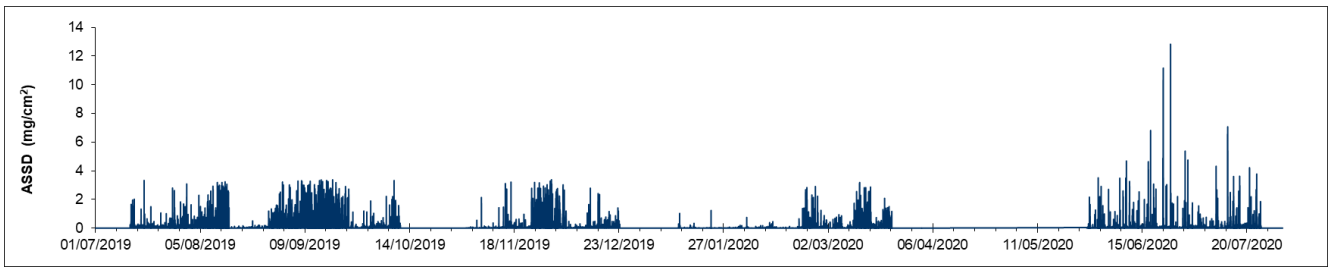

Temperature (C)
33
30
27
24
21
18
01/07/2019
05/08/2019
09/09/2019
14/10/2019
18/11/2019
23/12/2019
27/01/2020
02/03/2020
06/04/2020
11/05/2020
15/06/2020
20/07/2020

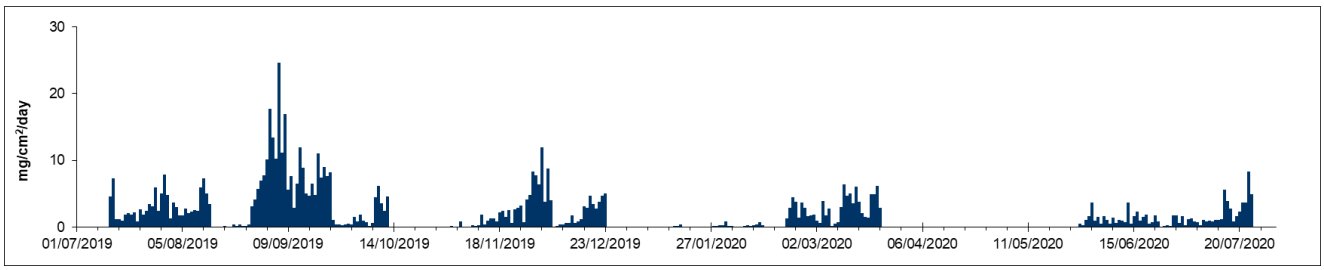
A2.6 AMB10: Victor Island

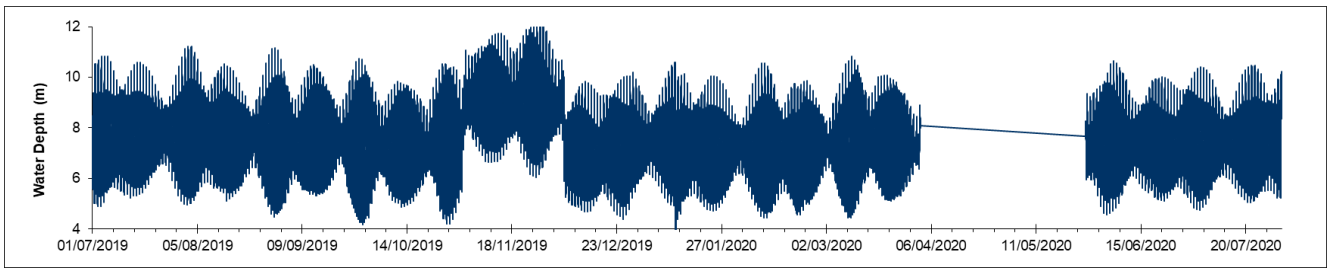


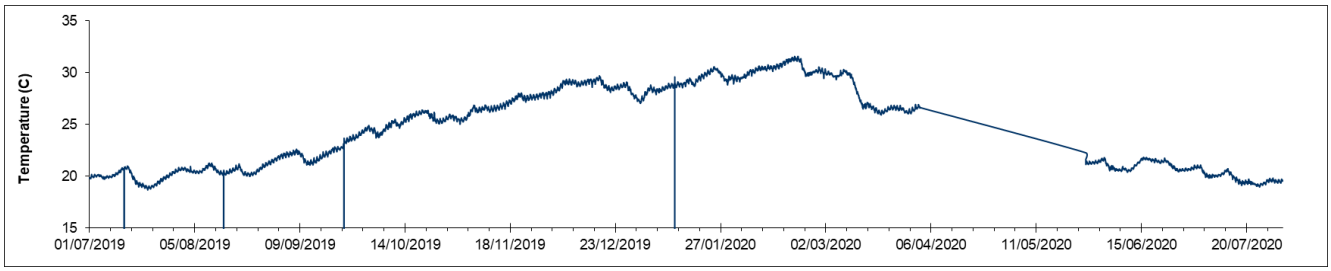




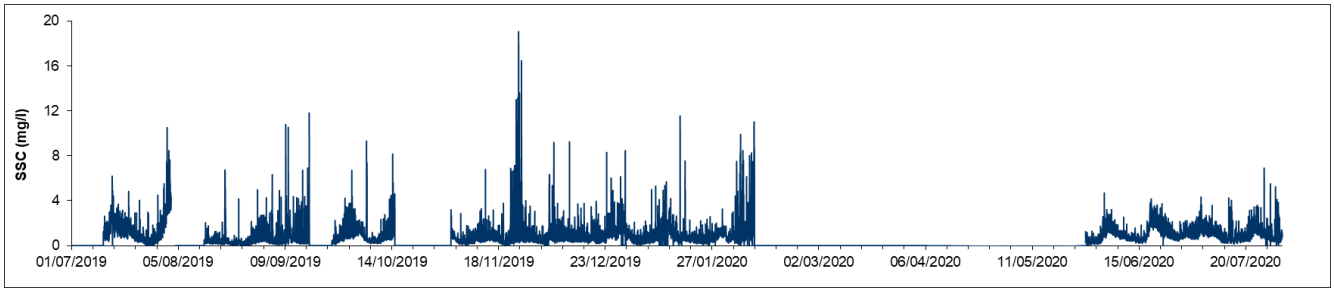


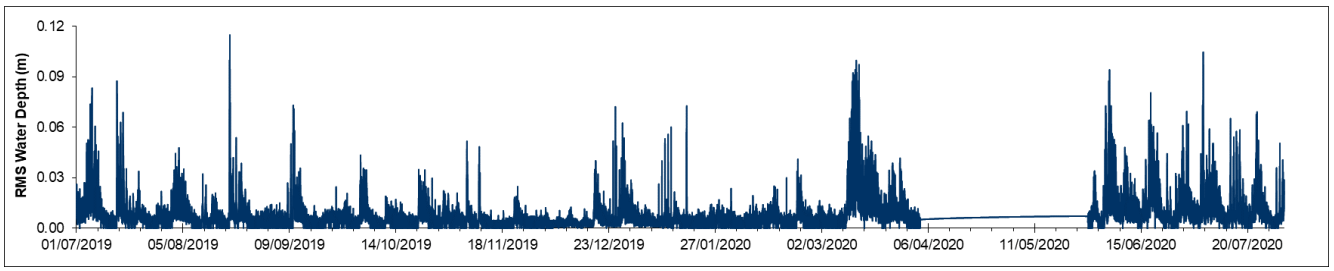


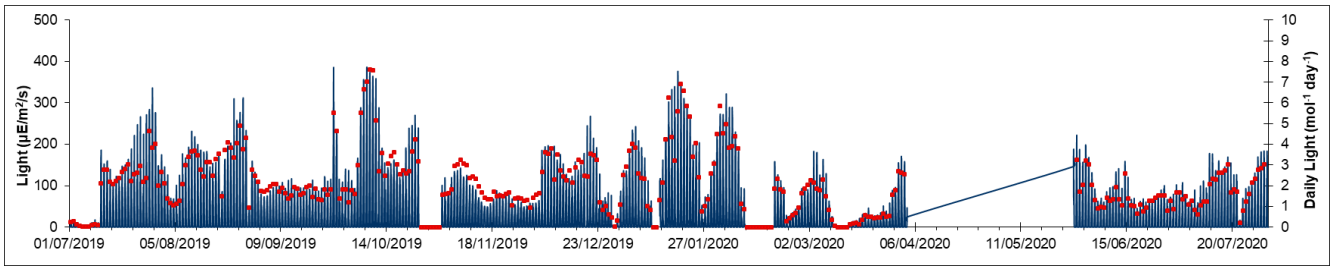


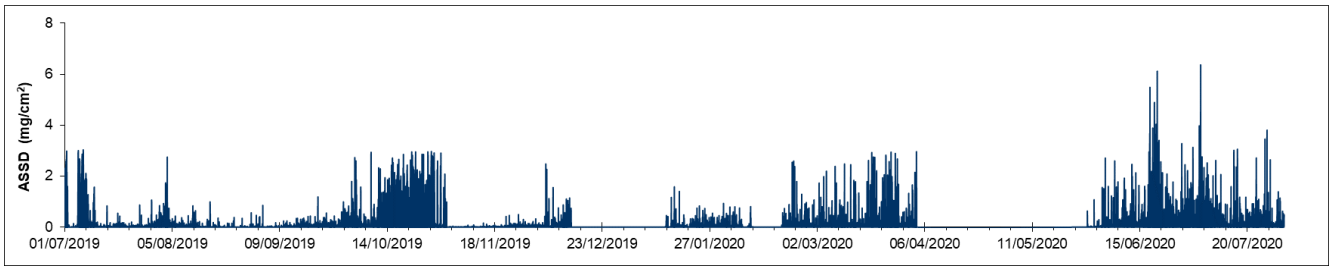


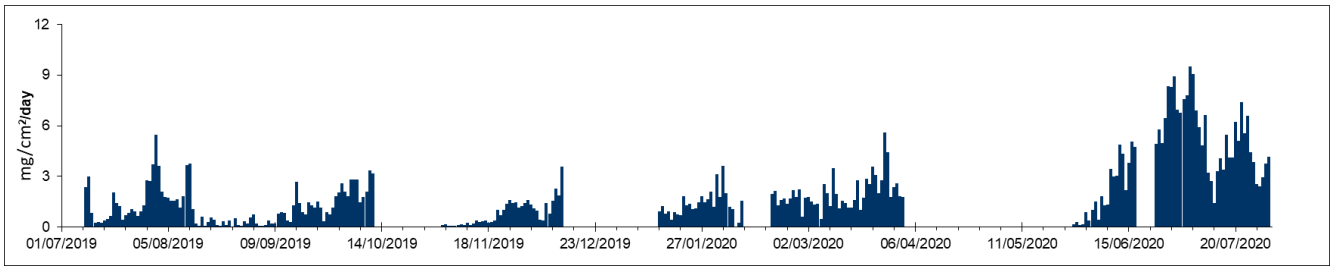
A2.7 AMB12: Keswick Island

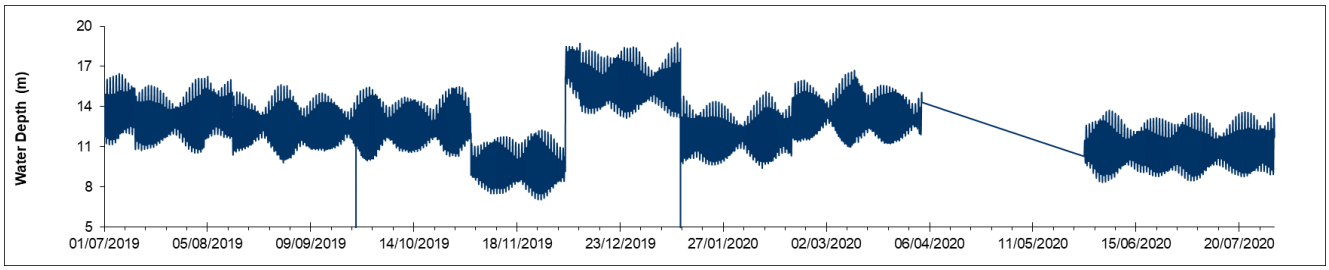


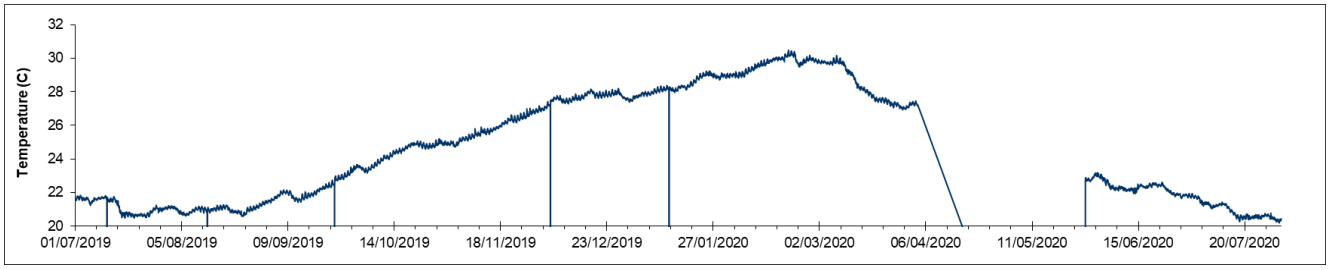









Water Depth (m)
20
17
14
11
8
5
01/07/2019
05/08/2019
09/09/2019
14/10/2019
18/11/2019
23/12/2019
27/01/2020
02/03/2020
06/04/2020
11/05/2020
15/06/2020
20/07/2020


Temperature (C)
32
30
28
26
24
22
20
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

A3 SUMMARY OF MONTHLY STATISTICS

A3.1 AMB1: Freshwater Point

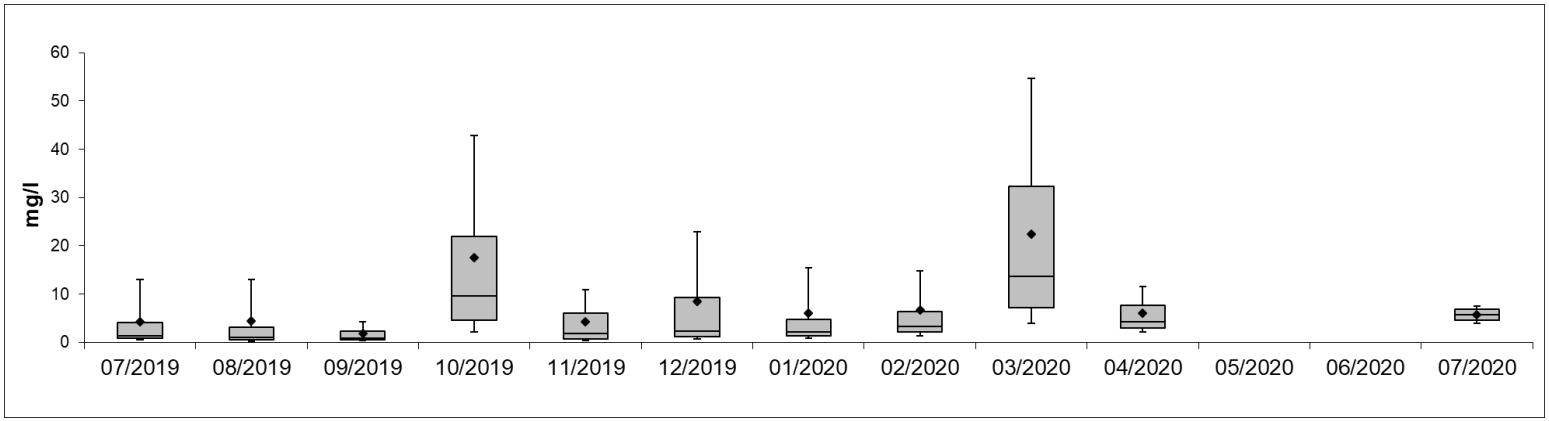
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	4.27	4.40	1.83	17.57	4.23	8.47	6.10	6.67	22.35	6.01			5.73
median	1.39	0.97	0.89	9.64	1.80	2.35	2.15	3.33	13.61	4.20			5.71
min	0.00	0.00	0.06	0.63	0.00	0.00	0.00	0.05	0.01	0.40			3.16
lower	0.83	0.44	0.49	4.50	0.69	1.16	1.28	2.09	7.14	3.02			4.55
upper	4.16	3.12	2.33	21.88	6.09	9.23	4.74	6.43	32.31	7.57			6.81
max	59.74	106.03	39.60	182.65	37.26	146.23	131.78	154.14	104.02	33.37			8.82
90th percentile	12.98	12.93	4.30	42.92	10.89	22.82	15.41	14.78	54.75	11.53			7.47
10th percentile	0.54	0.20	0.32	2.22	0.34	0.68	0.82	1.31	3.91	2.12			3.92
n	4460	4461	4316	4458	1360	3758	4453	3824	1367	190	0	0	3484
St. Dev	6.74	9.53	2.45	21.99	5.55	14.89	11.53	10.43	20.96	4.83			1.36
St. Error	0.10	0.14	0.04	0.33	0.15	0.24	0.17	0.17	0.57	0.35			0.02

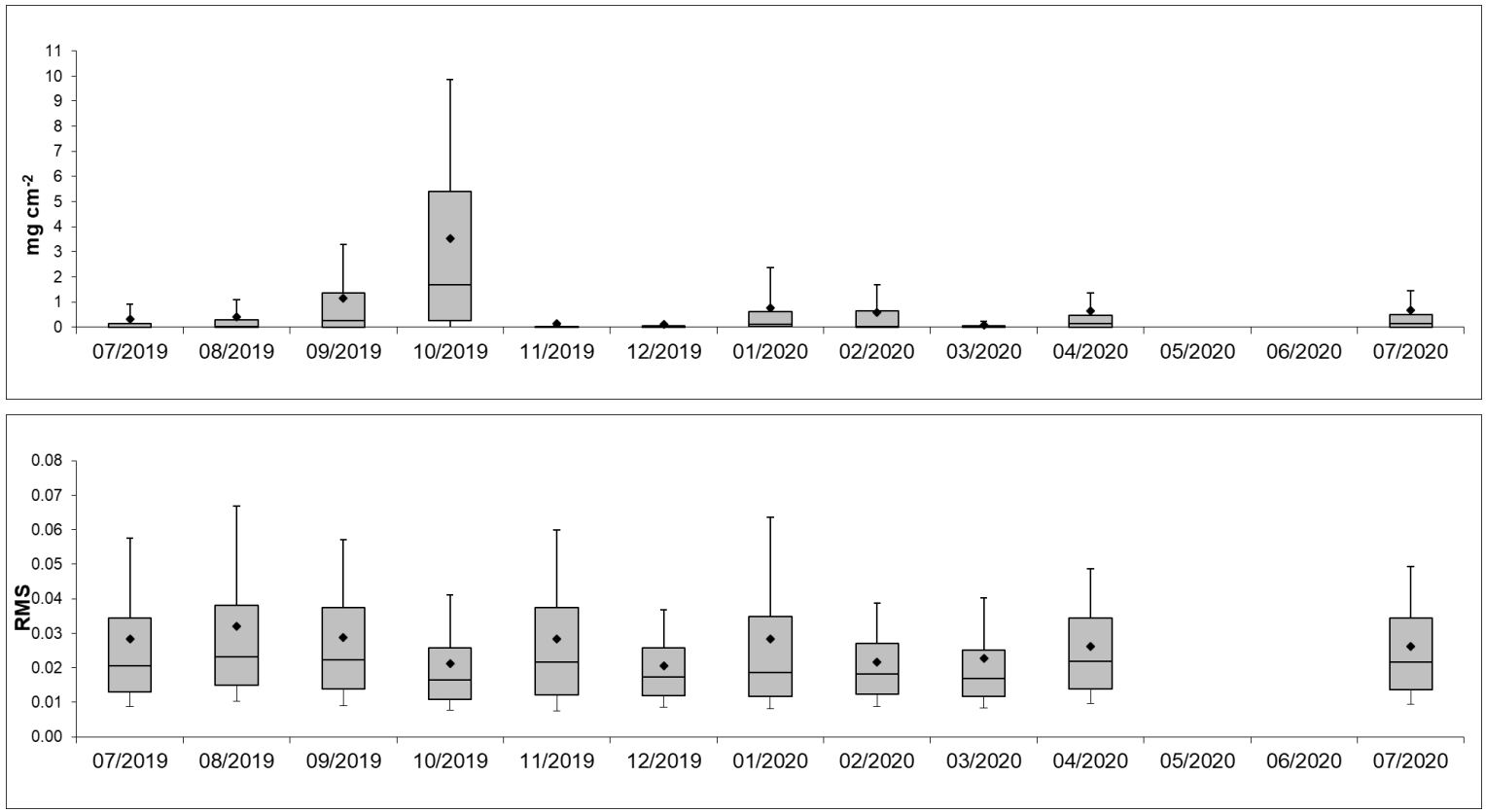
	ASSD 07/2019	ASSD 08/2019	ASSD 09/2019	ASSD 10/2019	ASSD 11/2019	ASSD 12/2019	ASSD 01/2020	ASSD 02/2020	ASSD 03/2020	ASSD 04/2020	ASSD 05/2020	ASSD 06/2020	ASSD 07/2020
Mean	0.31	0.40	1.15	3.53	0.14	0.12	0.75	0.57	0.09	0.65			0.68
median	0.00	0.02	0.27	1.68	0.00	0.00	0.11	0.03	0.00	0.13			0.15
min	0.00	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	0.25	0.00	0.00	0.01	0.00	0.00	0.00			0.00
upper	0.14	0.28	1.36	5.39	0.01	0.04	0.62	0.66	0.05	0.48			0.51
max	13.86	19.51	19.36	19.48	18.58	19.22	16.72	17.92	4.24	43.12			43.12
90th percentile	0.91	1.09	3.29	9.86	0.04	0.12	2.36	1.70	0.23	1.36			1.45
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	4460	4461	4307	4286	4243	4461	4457	2488	4444	3667	0	0	3476
St. Dev	0.93	1.15	2.10	4.31	0.99	0.86	1.64	1.20	0.26	2.07			2.12
St. Error	0.01	0.02	0.03	0.07	0.02	0.01	0.02	0.02	0.00	0.03			0.04

	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	0.028	0.032	0.029	0.021	0.028	0.021	0.028	0.022	0.023	0.03			0.03
median	0.021	0.023	0.022	0.017	0.022	0.017	0.019	0.018	0.017	0.02			0.02
min	0.000	0.002	0.001	0.002	0.002	0.000	0.002	0.003	0.002	0.00			0.00
lower	0.013	0.015	0.014	0.011	0.012	0.012	0.012	0.012	0.012	0.01			0.01
upper	0.035	0.038	0.037	0.026	0.037	0.026	0.035	0.027	0.025	0.03			0.03
max	0.354	0.233	0.182	0.151	0.157	0.155	0.207	0.126	0.259	0.12			0.12
90th percentile	0.058	0.067	0.057	0.041	0.060	0.037	0.064	0.039	0.040	0.05			0.05
10th percentile	0.009	0.010	0.009	0.008	0.008	0.009	0.008	0.009	0.008	0.01			0.01
n	4462	4463	4318	4464	4244	4462	4458	4175	4464	3675	0	0	3484
St. Dev	0.027	0.021	0.016	0.022	0.013	0.026	0.014	0.021	0.039	0.02			0.02
St. Error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.00			0.00

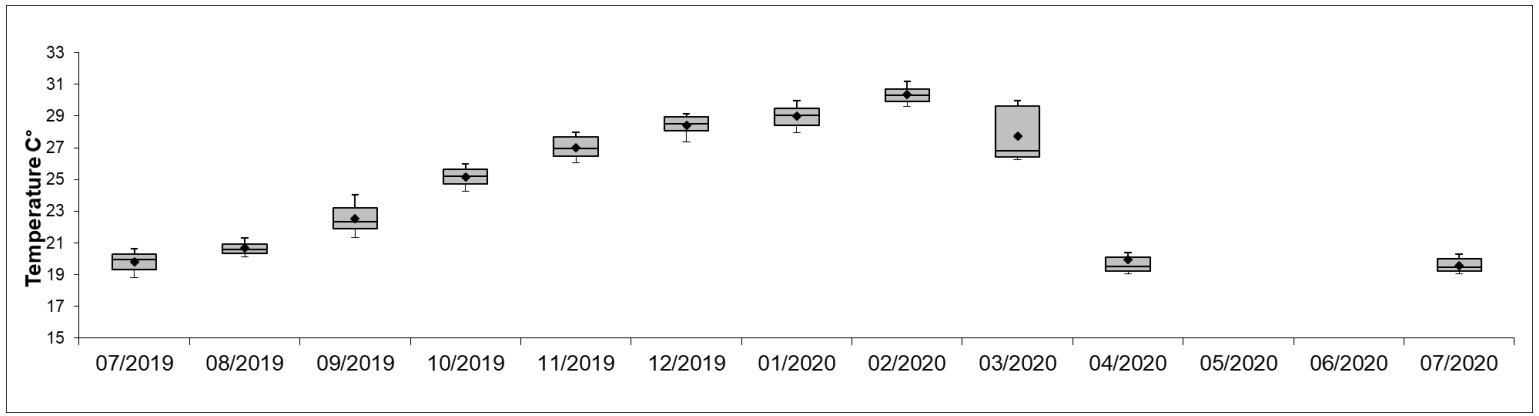
	Temp 07/2019	Temp 08/2019	Temp 09/2019	Temp 10/2019	Temp 11/2019	Temp 12/2019	Temp 01/2020	Temp 02/2020	Temp 03/2020	Temp 04/2020	Temp 05/2020	Temp 06/2020	Temp 07/2020
Mean	19.81	20.67	22.52	25.14	27.02	28.43	28.99	30.35	27.73	19.96			19.58
median	19.94	20.60	22.32	25.21	26.95	28.53	29.04	30.33	26.81	19.51			19.47
min	18.36	19.31	20.51	23.44	25.11	26.65	27.17	28.96	25.47	18.30			18.30
lower	19.31	20.34	21.91	24.70	26.48	28.07	28.40	29.91	26.43	19.23			19.22
upper	20.28	20.93	23.20	25.63	27.68	28.93	29.46	30.72	29.65	20.08			20.01
max	31.86	31.86	31.86	31.86	31.86	31.86	31.86	31.86	31.86	27.22			20.74
90th percentile	20.62	21.32	24.02	25.97	27.99	29.14	29.97	31.21	29.98	20.40			20.28
10th percentile	18.81	20.13	21.35	24.26	26.06	27.39	27.97	29.60	26.24	19.04			19.04
n	4453	4457	4312	4464	4244	4458	4451	4167	4464	3675	0	0	3484
St. Dev	0.65	0.48	0.94	0.63	0.73	0.66	0.74	0.59	1.57	1.69			0.47
St. Error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03			0.01

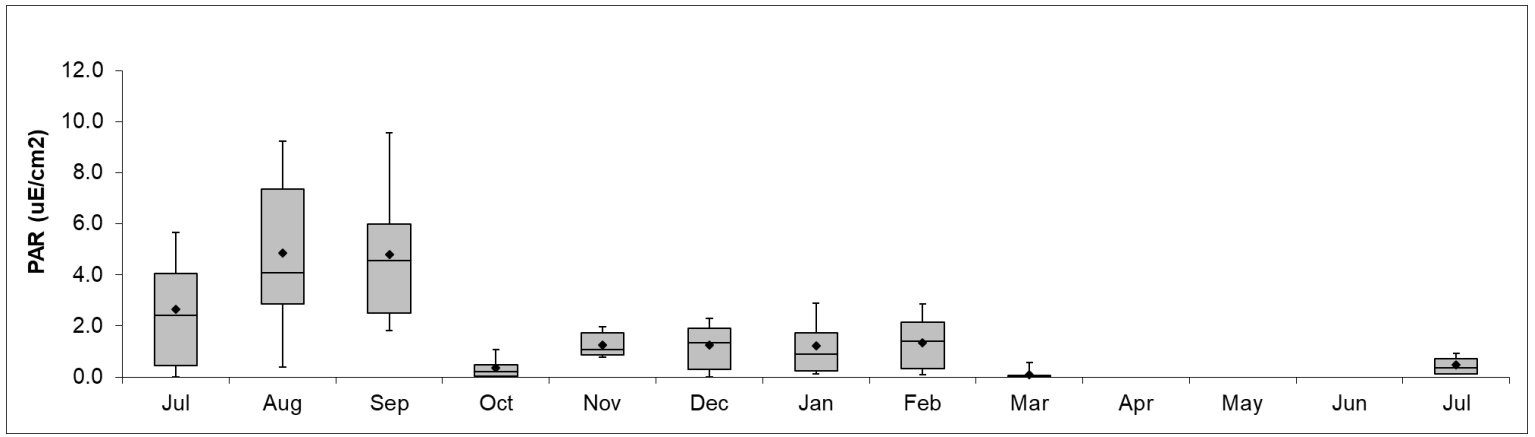
	Light 07/2019	Light 08/2019	Light 09/2019	Light 10/2019	Light 11/2019	Light 12/2019	Light 01/2020	Light 02/2020	Light 03/2020	Light 04/2020	Light 05/2020	Light 06/2020	Light 07/2020
Mean	2.65	4.85	4.79	0.38	1.26	1.26	1.23	1.33	0.11				0.47
median	2.41	4.09	4.56	0.21	1.07	1.35	0.91	1.40	0.00				0.35
min	0.00	0.04	0.75	0.00	0.04	0.00	0.02	0.00	0.00				0.00
lower	0.44	2.87	2.51	0.04	0.86	0.30	0.24	0.32	0.00				0.13
upper	4.06	7.36	5.99	0.47	1.73	1.92	1.72	2.14	0.06				0.71
max	6.47	11.67	11.87	1.71	2.38	3.91	4.70	3.87	0.67				1.86
90th percentile	5.66	9.24	9.55	1.06	1.98	2.29	2.90	2.86	0.58				0.93
10th percentile	0.01	0.39	1.83	0.01	0.78	0.00	0.12	0.09	0.00				0.02
n	31	31	30	31	30	31	31	29	31	0	0	0	23
St. Dev	2.13	3.36	2.95	0.47	0.59	0.99	1.24	1.11	0.22				0.46
St. Error	0.38	0.60	0.54	0.08	0.11	0.18	0.22	0.21	0.04				0.10




mg cm-2
0
1
2
3
4
5
6
7
8
9
10
11
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

RMS
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
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°
33
31
29
27
25
23
21
19
17
15
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 (uE/cm2)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

A3.2 AMB2: Hay Reef

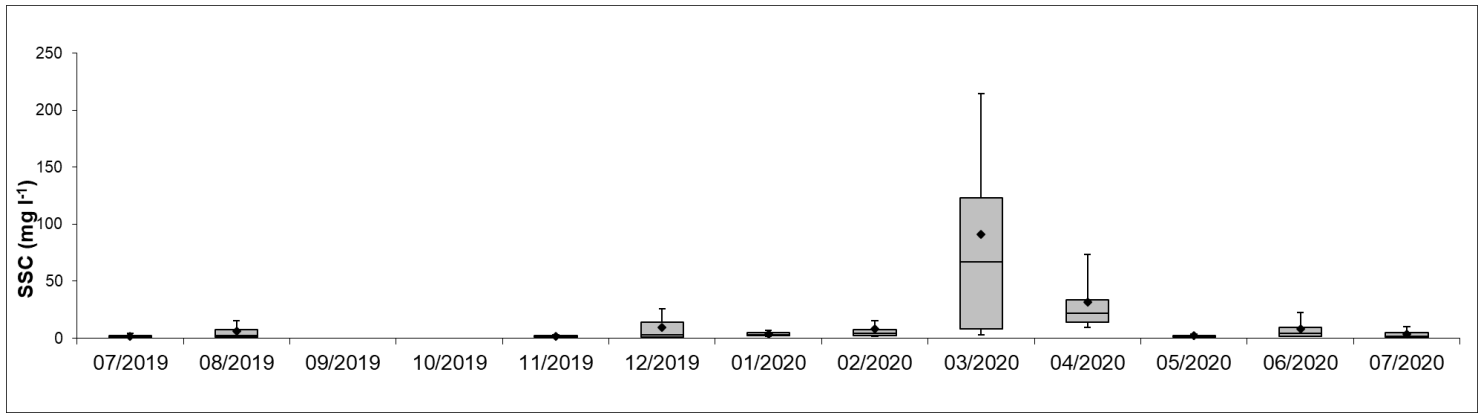
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	1.76	5.88			1.66	9.31	3.82	7.98	90.83	31.54	2.08	8.28	3.75
median	1.29	2.27			1.50	3.05	3.23	3.96	67.10	21.91	1.78	4.04	1.85
min	0.00	0.03			0.05	0.00	0.06	0.00	0.07	3.71	0.46	0.56	0.02
lower	0.53	0.81			1.11	1.29	2.09	2.28	8.39	14.09	1.21	1.95	0.80
upper	2.37	7.67			2.08	14.31	4.78	7.29	123.06	33.84	2.58	9.77	4.83
max	17.69	85.88			5.66	121.94	28.41	172.83	1002.62	224.33	9.87	75.49	45.98
90th percentile	3.98	15.49			2.64	25.49	7.06	15.35	214.15	73.28	3.52	22.45	9.86
10th percentile	0.32	0.47	0.00	0.00	0.84	0.74	1.34	1.40	2.62	9.60	0.87	1.40	0.45
n	2791	1964			1440	3826	4444	4095	4464	201	662	4315	4463
St. Dev	1.61	8.42			0.75	12.65	2.63	13.95	110.49	31.36	1.31	10.24	4.64
St. Error	0.03	0.19			0.02	0.20	0.04	0.22	1.65	2.21	0.05	0.16	0.07

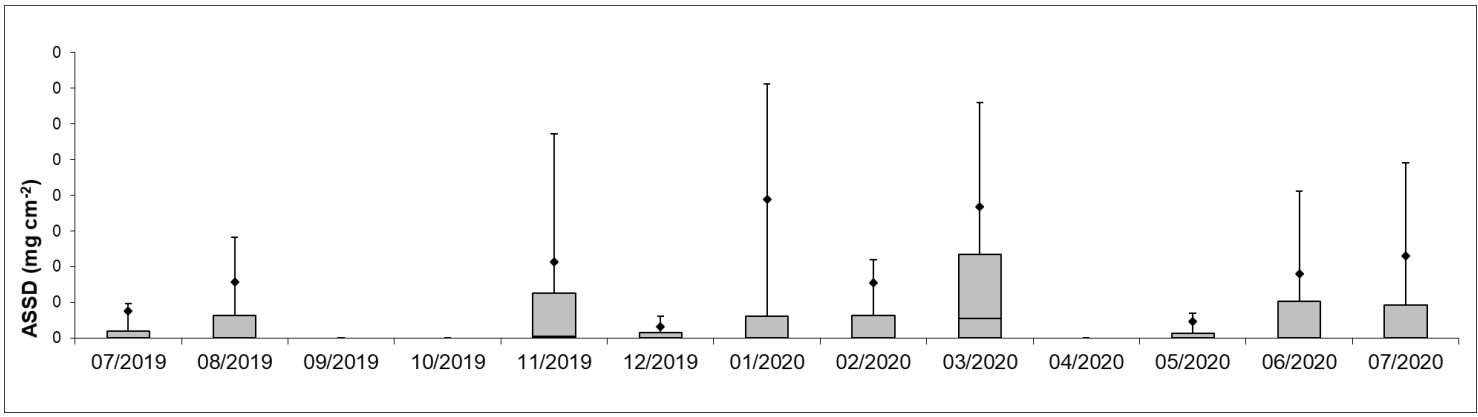
	ASSD 07/2019	ASSD 08/2019	ASSD 09/2019	ASSD 10/2019	ASSD 11/2019	ASSD 12/2019	ASSD 01/2020	ASSD 02/2020	ASSD 03/2020	ASSD 04/2020	ASSD 05/2020	ASSD 06/2020	ASSD 07/2020
Mean	0.04	0.08			0.11	0.02	0.19	0.08	0.18		0.02	0.09	0.11
median	0.000	0.000			0.002	0.000	0.000	0.000	0.027		0.00	0.00	0.00
min	0.000	0.000			0.000	0.000	0.000	0.000	0.000		0.00	0.00	0.00
lower	0.000	0.000			0.000	0.000	0.000	0.000	0.000		0.00	0.00	0.00
upper	0.010	0.032			0.062	0.007	0.030	0.031	0.117		0.01	0.05	0.05
max	6.103	6.313			5.311	2.443	6.338	6.343	6.286		1.09	3.71	4.15
90th percentile	0.048	0.141			0.286	0.030	0.356	0.109	0.330		0.03	0.21	0.25
10th percentile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.00	0.00	0.00
n	2789	1954			4020	4458	4404	3815	1357	0	663	4307	4422
St. Dev	0.259	0.381			0.336	0.070	0.689	0.372	0.608		0.10	0.29	0.39
St. Error	0.005	0.009			0.005	0.001	0.010	0.006	0.017		0.00	0.00	0.01

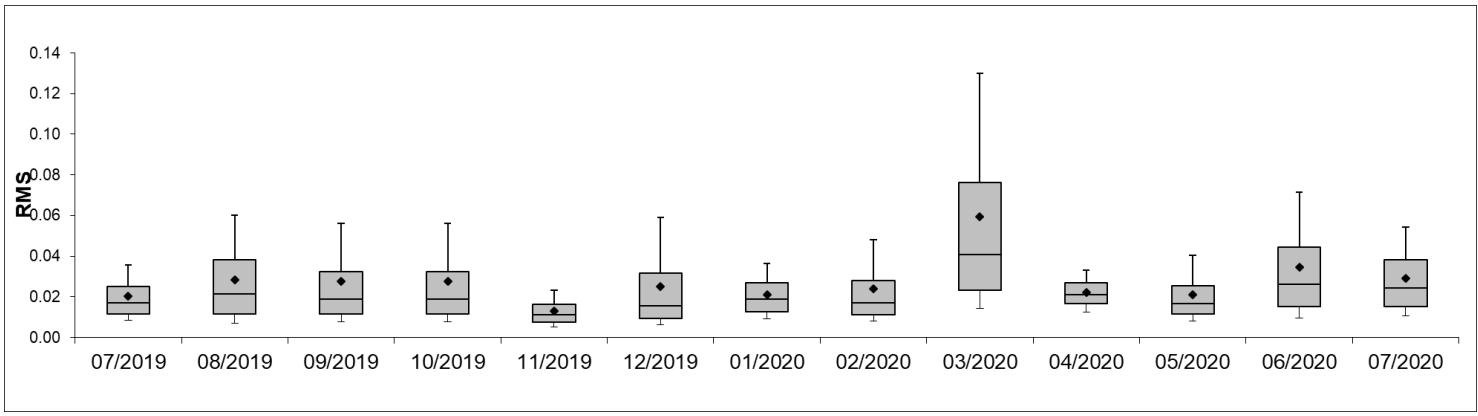
	RMS 07/2019	RMS 08/2019	RMS 09/2019	RMS 10/2019	RMS 11/2019	RMS 12/2019	RMS 01/2020	RMS 02/2020	RMS 03/2020	RMS 04/2020	RMS 05/2020	RMS 06/2020	RMS 07/2020
Mean	0.020	0.028	0.028	0.028	0.013	0.025	0.021	0.024	0.059	0.022	0.021	0.034	0.029
median	0.017	0.021	0.019	0.019	0.011	0.016	0.019	0.017	0.041	0.021	0.017	0.026	0.024
min	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.003	0.000	0.003
lower	0.012	0.012	0.012	0.012	0.008	0.009	0.013	0.011	0.023	0.017	0.011	0.015	0.015
upper	0.025	0.038	0.033	0.033	0.016	0.032	0.027	0.028	0.076	0.027	0.026	0.044	0.038
max	0.134	0.134	0.452	0.452	0.071	0.196	0.113	0.247	0.452	0.051	0.101	0.212	0.150
90^{th} percentile	0.036	0.060	0.056	0.056	0.023	0.059	0.036	0.048	0.130	0.033	0.040	0.071	0.054
10^{th} percentile	0.008	0.007	0.008	0.008	0.005	0.006	0.009	0.008	0.014	0.012	0.008	0.009	0.010
n	2792	1965	41828	41828	4021	4462	4464	4099	4464	201	663	4320	4464
St. Dev	0.013	0.022	0.028	0.028	0.008	0.024	0.012	0.022	0.055	0.008	0.015	0.028	0.019
St. Error	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	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	19.80	20.52	24.79	24.79	27.17	28.54	29.03	30.47	27.97	26.67	21.03	20.88	19.66
median	19.76	20.50	26.41	26.41	27.15	28.62	29.04	30.46	27.16	26.66	21.02	20.85	19.56
min	18.81	19.80	18.68	18.68	25.70	26.85	27.29	29.30	26.16	26.52	20.75	19.96	18.68
lower	19.20	20.36	20.58	20.58	26.59	28.29	28.33	30.23	26.56	26.58	20.95	20.48	19.16
upper	20.40	20.67	28.74	28.74	27.83	28.93	29.55	30.83	29.98	26.76	21.09	21.29	20.08
max	20.92	21.06	31.62	31.62	28.55	29.58	30.82	31.62	30.60	26.97	21.37	21.67	20.83
90^{th} percentile	20.67	20.83	30.17	30.17	28.04	29.12	30.10	31.25	30.20	26.84	21.22	21.47	20.55
10^{th} percentile	19.03	20.26	19.83	19.83	26.29	27.77	28.10	29.59	26.42	26.53	20.89	20.36	19.00
n	2777	1965	41784	41784	4014	4462	4464	4094	4464	201	654	4320	4464
St. Dev	0.63	0.23	4.19	4.19	0.70	0.52	0.78	0.56	1.61	0.12	0.13	0.44	0.56
St. Error	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	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	1.40	1.22			0.89	0.58	0.25	0.16	0.03		0.45	0.23	7.00
median	0.85	0.93			0.81	0.18	0.22	0.07	0.00		0.42	0.18	0.68
min	0.19	0.00			0.03	0.00	0.01	0.00	0.00		0.12	0.00	0.00
lower	0.51	0.06			0.36	0.05	0.06	0.03	0.00		0.39	0.00	0.06
upper	2.47	2.29			1.25	1.21	0.33	0.28	0.01		0.53	0.42	0.99
max	3.09	3.02			2.19	1.73	0.92	0.57	0.39		0.80	1.02	200.31
90^{th} percentile	2.97	2.66			1.81	1.65	0.47	0.47	0.10		0.69	0.47	1.43
10^{th} percentile	0.26	0.00			0.11	0.00	0.03	0.01	0.00		0.23	0.00	0.02
n	19	14	30	31	29	31	31	29	31	2	5	30	31
St. Dev	1.12	1.18			0.63	0.68	0.22	0.18	0.08		0.24	0.25	35.88
St. Error	0.26	0.32			0.12	0.12	0.04	0.03	0.01		0.11	0.05	6.44


250
200
150
100
50
0
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


ASSD (mg cm-2)
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


RMS
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0.10
0.08
0.06
0.04
0.02
0.00
07/2019
08/2019
09/2019
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11/2019
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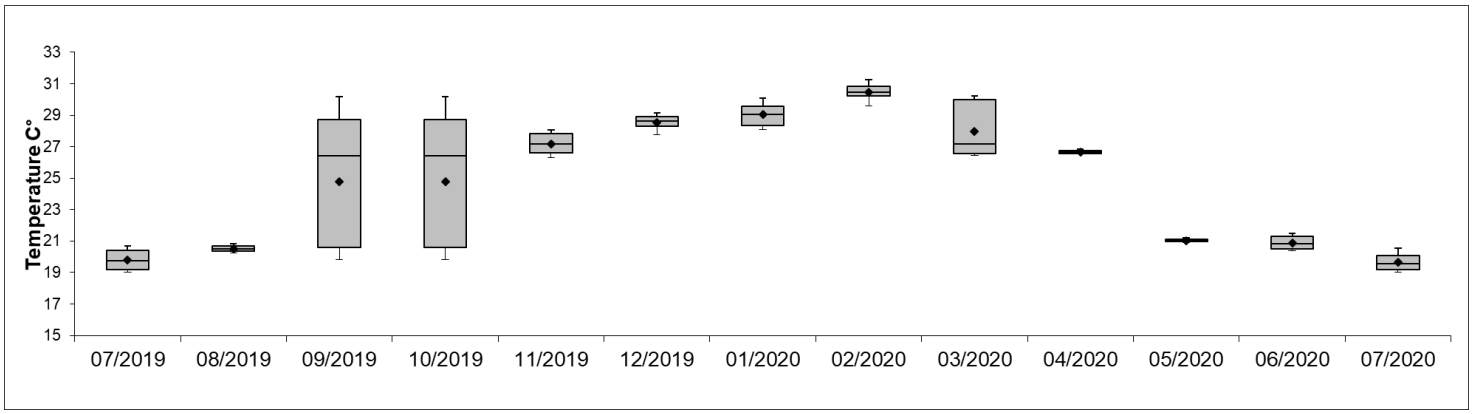
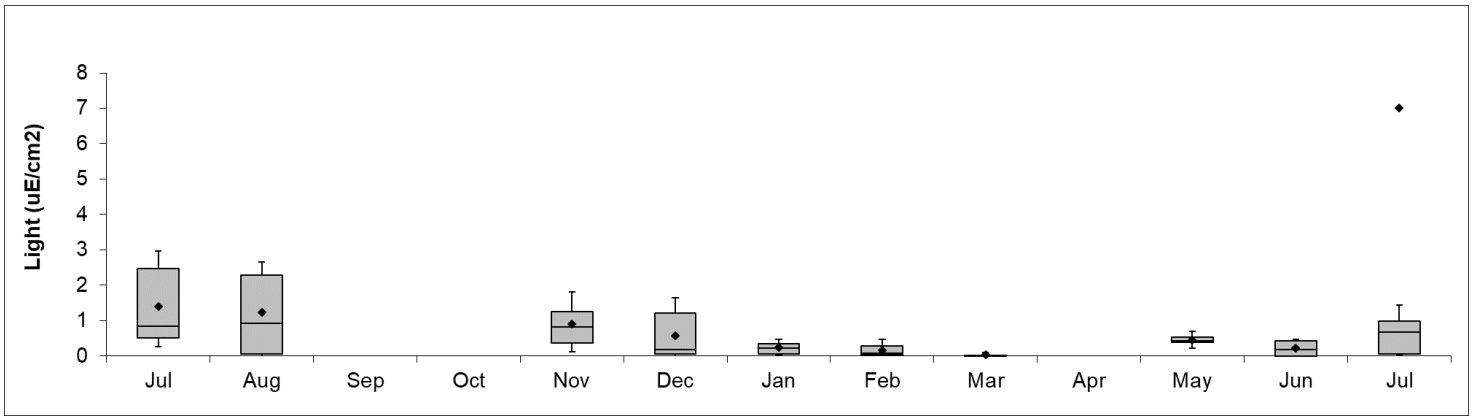
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


Temperature C°
33
31
29
27
25
23
21
19
17
15
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


Light (uE/cm2)
8
7
6
5
4
3
2
1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

A3.3 AMB3: Round Top Island

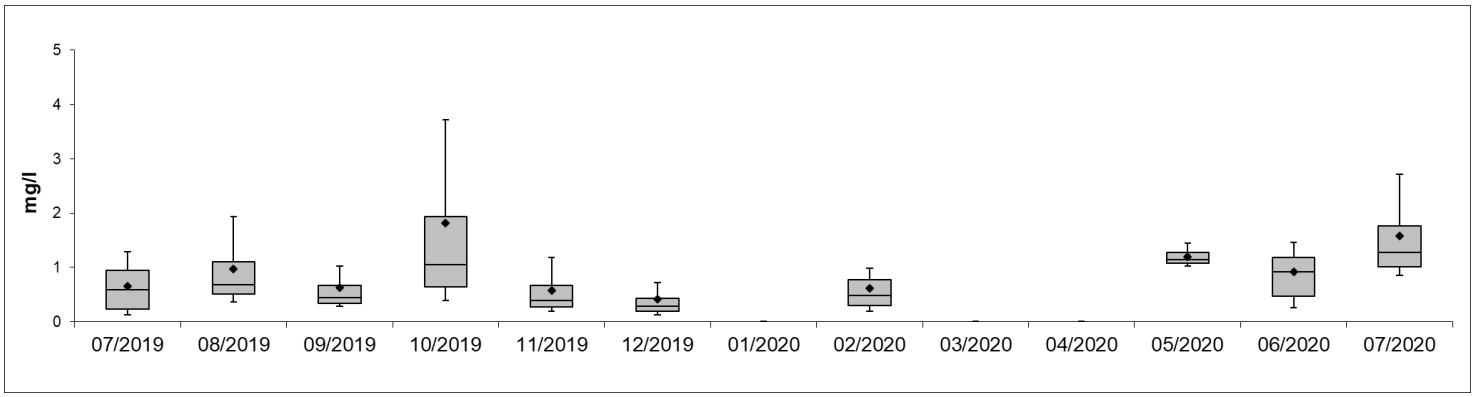
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	0.65	0.97	0.63	1.82	0.58	0.41		0.61			1.20	0.91	1.58
median	0.59	0.67	0.45	1.05	0.39	0.28		0.48			1.15	0.92	1.27
min	0.03	0.01	0.00	0.00	0.01	0.00		0.07			0.94	0.00	0.28
lower	0.23	0.51	0.34	0.64	0.27	0.19		0.30			1.07	0.47	1.00
upper	0.95	1.11	0.66	1.94	0.66	0.43		0.77			1.27	1.18	1.77
max	4.16	11.43	22.27	63.73	6.98	5.91		3.72			3.55	7.45	7.86
90th percentile	1.28	1.93	1.02	3.71	1.18	0.72		0.98			1.45	1.46	2.71
10th percentile	0.12	0.36	0.28	0.38	0.19	0.12		0.18			1.02	0.25	0.85
n	2945	4445	4099	4456	1664	2013	0	348	0	0	517	1515	1187
St. Dev	0.48	0.87	0.99	2.85	0.58	0.51		0.50			0.21	0.64	0.95
St. Error	0.01	0.01	0.02	0.04	0.01	0.01		0.03			0.01	0.02	0.03

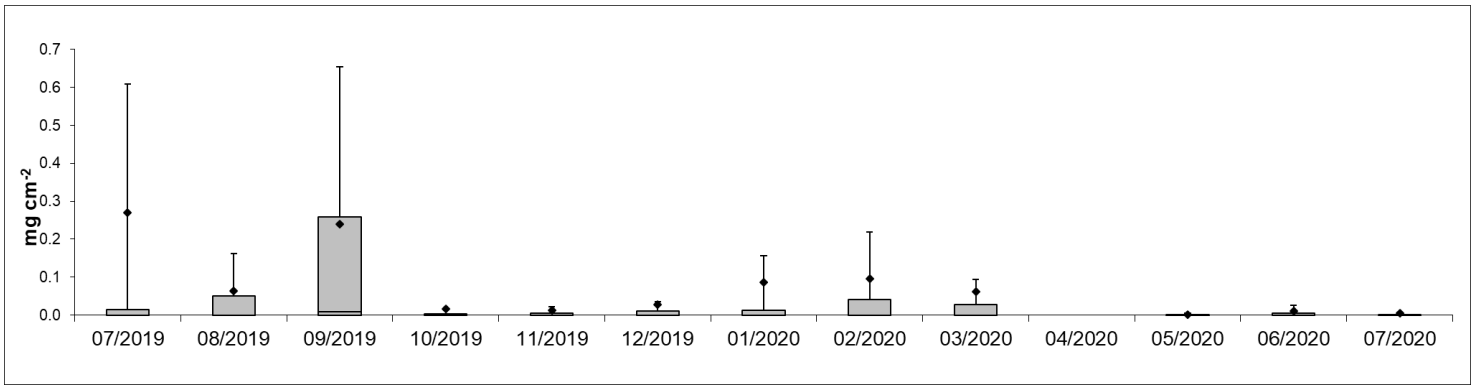
	ASSD 07/2019	ASSD 08/2019	ASSD 09/2019	ASSD 10/2019	ASSD 11/2019	ASSD 12/2019	ASSD 01/2020	ASSD 02/2020	ASSD 03/2020	ASSD 04/2020	ASSD 05/2020	ASSD 06/2020	ASSD 07/2020
Mean	0.27	0.06	0.24	0.02	0.01	0.03	0.09	0.10	0.06		0.00	0.01	0.00
median	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
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	0.00
upper	0.01	0.05	0.26	0.00	0.00	0.01	0.01	0.04	0.03		0.00	0.00	0.00
max	8.09	5.34	7.77	4.45	1.42	1.92	6.42	7.07	6.53		0.04	1.26	0.67
90th percentile	0.61	0.16	0.65	0.02	0.02	0.04	0.16	0.22	0.09		0.00	0.03	0.01
10th 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	4394	4461	4271	2440	3867	491	1466	1356	1574	0	517	4320	3886
St. Dev	0.94	0.24	0.58	0.16	0.07	0.17	0.38	0.38	0.30		0.00	0.05	0.03
St. Error	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01		0.00	0.00	0.00

	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	0.024	0.019	0.015	0.019	0.010	0.023	0.016	0.020	0.040	0.016	0.009	0.027	0.023
median	0.017	0.014	0.012	0.014	0.009	0.014	0.015	0.013	0.028	0.015	0.007	0.022	0.019
min	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000
lower	0.010	0.009	0.008	0.008	0.006	0.008	0.010	0.008	0.016	0.011	0.004	0.012	0.012
upper	0.029	0.024	0.018	0.024	0.013	0.028	0.020	0.022	0.053	0.019	0.012	0.036	0.029
max	0.173	0.171	0.148	0.124	0.061	0.191	0.056	0.163	0.398	0.113	0.064	0.144	0.145
90^{th} percentile	0.051	0.039	0.025	0.040	0.018	0.052	0.026	0.045	0.086	0.024	0.018	0.054	0.041
10^{th} percentile	0.007	0.006	0.006	0.005	0.004	0.005	0.007	0.006	0.011	0.009	0.003	0.007	0.008
n	4462	4463	4319	4464	4319	4457	1674	1357	4464	220	518	4320	4464
St. Dev	0.021	0.015	0.011	0.015	0.006	0.023	0.008	0.020	0.036	0.009	0.007	0.021	0.014
St. Error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	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	20.11	20.63	22.22	25.08	26.87	28.42	28.22	30.28	30.10		21.69	21.22	20.00
median	20.20	20.59	21.94	25.28	26.82	28.49	28.23	30.27	30.08		21.69	21.17	19.98
min	18.97	20.10	20.97	23.78	25.19	27.38	27.54	29.90	29.75		21.36	20.51	19.18
lower	19.69	20.44	21.63	24.47	26.27	28.18	28.09	30.24	29.94		21.61	20.83	19.59
upper	20.58	20.76	22.82	25.53	27.57	28.73	28.40	30.31	30.26		21.79	21.53	20.39
max	20.98	21.70	24.28	26.18	28.15	29.30	28.99	30.51	30.83		21.92	22.09	21.02
90^{th} percentile	20.75	20.97	23.45	25.87	27.77	28.90	28.57	30.37	30.34		21.85	21.87	20.72
10^{th} percentile	19.25	20.31	21.43	24.16	25.90	27.77	27.74	30.21	29.82		21.51	20.73	19.45
n	4448	4456	4311	4464	4311	4449	1674	664	1137	0	510	4320	4464
St. Dev	0.53	0.27	0.77	0.62	0.73	0.41	0.29	0.08	0.20		0.13	0.42	0.48
St. Error	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	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	2.24	3.03	2.56	3.01	4.91	0.83	3.61				0.43	0.75	2.41
median	1.96	3.25	2.38	2.77	4.53	0.54	3.61				0.30	0.32	2.56
min	0.36	0.59	0.06	0.31	3.80	0.00	3.10				0.01	0.00	0.27
lower	1.54	2.59	2.10	2.34	4.08	0.13	3.34				0.01	0.13	1.22
upper	3.17	3.59	2.95	3.58	5.44	0.91	3.91				0.72	1.39	3.73
max	4.35	4.68	4.79	6.12	8.09	8.12	4.10				1.13	2.58	4.55
90^{th} percentile	4.03	4.26	4.31	5.55	6.04	1.53	4.02				0.97	1.83	4.22
10^{th} percentile	0.57	1.11	1.25	1.18	3.89	0.03	3.19				0.01	0.04	0.60
n	27	31	30	20	30	31	5	0	0	0	4	30	24
St. Dev	1.20	1.10	1.08	1.53	1.04	1.44	0.41				0.54	0.77	1.41
St. Error	0.23	0.20	0.20	0.34	0.19	0.26	0.18				0.27	0.14	0.29


mg/l
0
1
2
3
4
5
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


mg cm-2
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0.4
0.5
0.6
0.7
07/2019
08/2019
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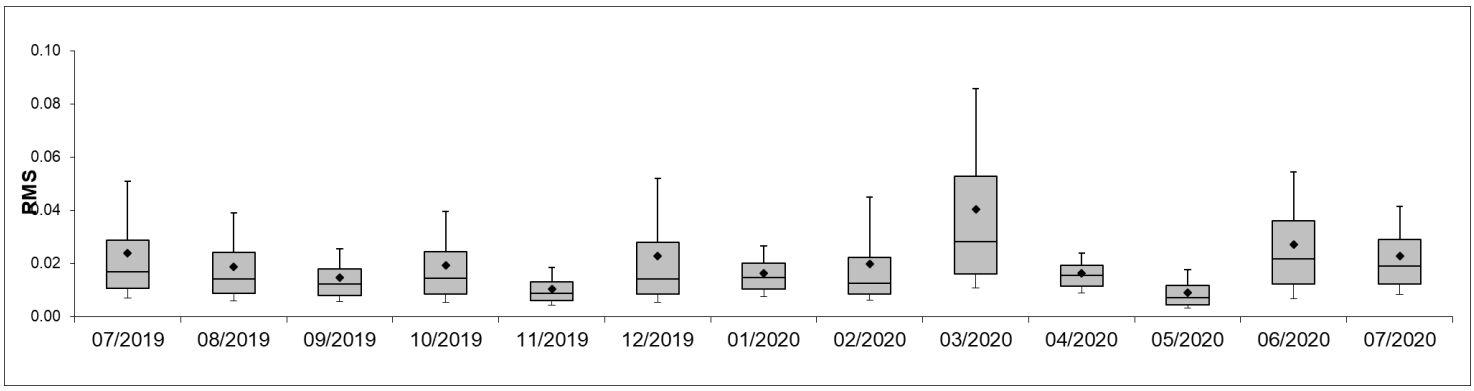
06/2020
07/2020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07/2019
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02/2020
03/2020
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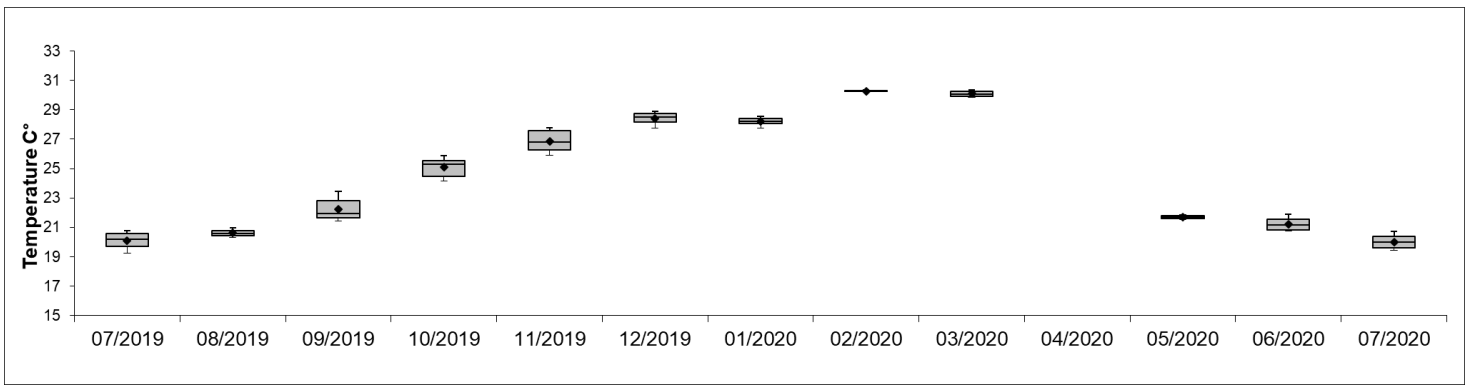
05/2020
06/2020
07/2020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17
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23
25
27
29
31
33
07/2019
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10/2019
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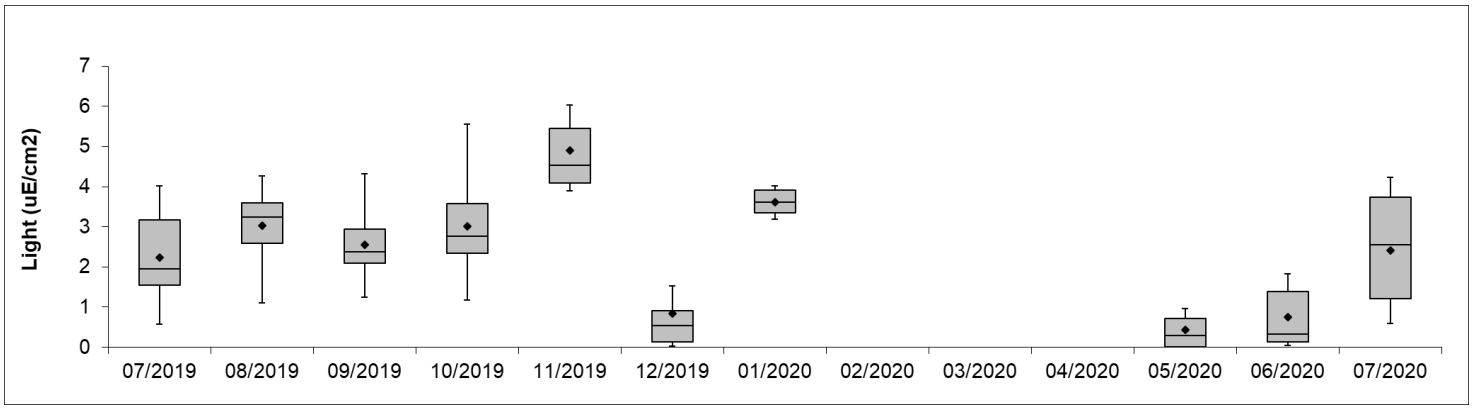
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


Light (uE/cm2)
7
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3
2
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07/2019
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09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020

A3.4 AMB5: Slade Island

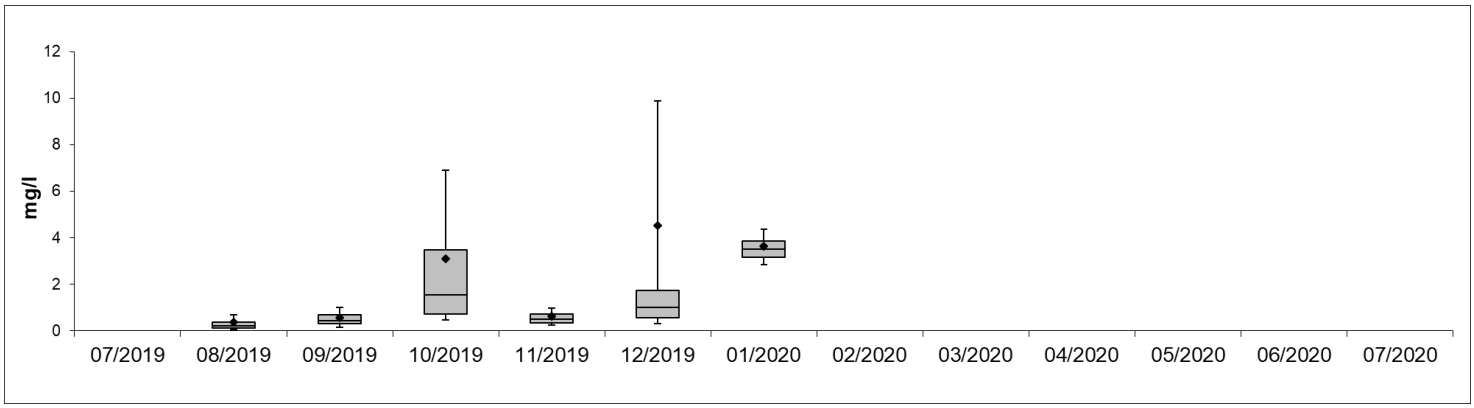
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean		0.36	0.57	3.10	0.62	4.53	3.62						
median		0.21	0.44	1.54	0.49	1.00	3.51						
min		0.00	0.00	0.00	0.06	0.00	1.88						
lower		0.11	0.29	0.72	0.32	0.56	3.16						
upper		0.38	0.68	3.47	0.70	1.72	3.86						
max		10.95	26.93	76.09	13.75	195.87	13.64						
90th percentile		0.68	0.99	6.88	0.96	9.87	4.36						
10th percentile		0.06	0.16	0.44	0.24	0.29	2.84						
n	0	2676	4317	4464	893	2754	1172	0	0	0	0	0	0
St. Dev		0.61	0.77	4.88	0.83	12.44	0.99						
St. Error		0.01	0.01	0.07	0.03	0.24	0.03						

	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	0.31	0.08	0.30	0.46	0.03	0.15	1.10						
median	0.00	0.01	0.09	0.06	0.00	0.01	0.45						
min	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	0.04						
upper	0.00	0.06	0.31	0.36	0.01	0.11	1.37						
max	8.56	3.21	8.48	8.55	4.78	7.88	8.55						
90th percentile	0.80	0.18	0.67	1.13	0.05	0.37	3.11						
10th percentile	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
n	1485	2677	4304	3278	706	3969	1615	0	0	0	0	0	0
St. Dev	1.05	0.24	0.70	1.07	0.21	0.47	1.62						
St. Error	0.03	0.00	0.01	0.02	0.01	0.01	0.04						

	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	0.09	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.08	0.03	0.05	0.05	0.05
median	0.08	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06	0.03	0.04	0.04	0.04
min	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
lower	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	0.02
upper	0.12	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.11	0.04	0.06	0.06	0.06
max	0.38	0.23	0.21	0.30	0.13	0.28	0.16	0.29	0.54	0.09	0.54	0.54	0.54
90^{th} percentile	0.17	0.07	0.06	0.08	0.05	0.09	0.05	0.09	0.17	0.05	0.10	0.10	0.10
10^{th} percentile	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01
n	1490	2677	4319	4464	901	3981	1674	1501	4464	336	42707	42707	42707
St. Dev	0.06	0.02	0.02	0.03	0.02	0.04	0.02	0.04	0.07	0.01	0.04	0.04	0.04
St. Error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	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	20.30	20.69	22.48	25.35	26.03	28.63	28.36	30.67	28.01	26.72			
median	20.33	20.62	22.35	25.50	25.97	28.77	28.39	30.43	27.24	26.70			
min	19.89	17.69	21.31	23.95	24.89	27.40	27.65	29.95	26.13	26.59			
lower	20.06	20.43	21.77	24.83	25.67	28.41	28.24	30.18	26.54	26.64			
upper	20.51	20.87	23.00	25.82	26.33	28.97	28.57	31.31	30.13	26.79			
max	20.71	21.63	24.54	26.62	26.84	29.67	28.87	31.64	30.62	27.00			
90^{th} percentile	20.59	21.25	23.80	26.20	26.57	29.10	28.72	31.45	30.29	26.87			
10^{th} percentile	20.01	20.33	21.56	24.27	25.55	27.78	27.91	30.12	26.39	26.61			
n	1490	2677	4310	4464	897	3981	1674	1501	4464	336	0	0	0
St. Dev	0.23	0.35	0.83	0.68	0.38	0.47	0.28	0.55	1.67	0.10			
St. Error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	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		4.66	3.41	3.82		1.30	0.81						
median		4.54	3.34	4.02		1.25	0.82						
min		2.01	0.19	1.27		0.02	0.39						
lower		3.92	2.51	2.62		0.61	0.69						
upper		5.52	4.02	4.67		2.09	0.95						
max		6.87	7.19	7.06		3.22	1.20						
90^{th} percentile		5.72	5.61	6.49		2.29	1.03						
10^{th} percentile		3.70	1.71	1.56		0.05	0.55						
n	7	19	30	11	1	28	12	0	0	0	0	0	0
St. Dev		1.11	1.65	1.86		0.93	0.22						
St. Error		0.25	0.30	0.56		0.18	0.06						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07/2019
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01/2020
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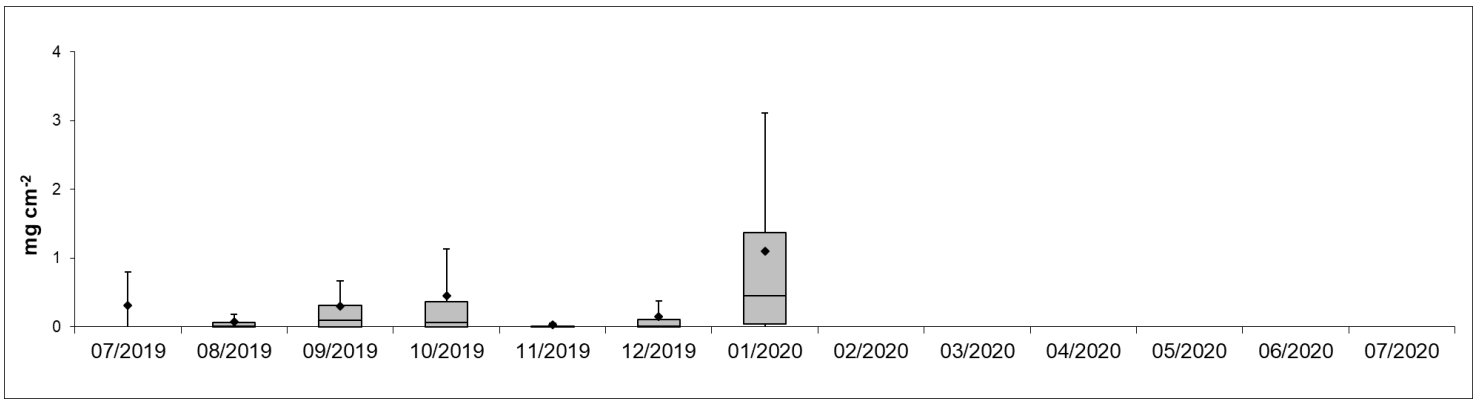
03/2020
04/2020
05/2020
06/2020
07/2020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07/2019
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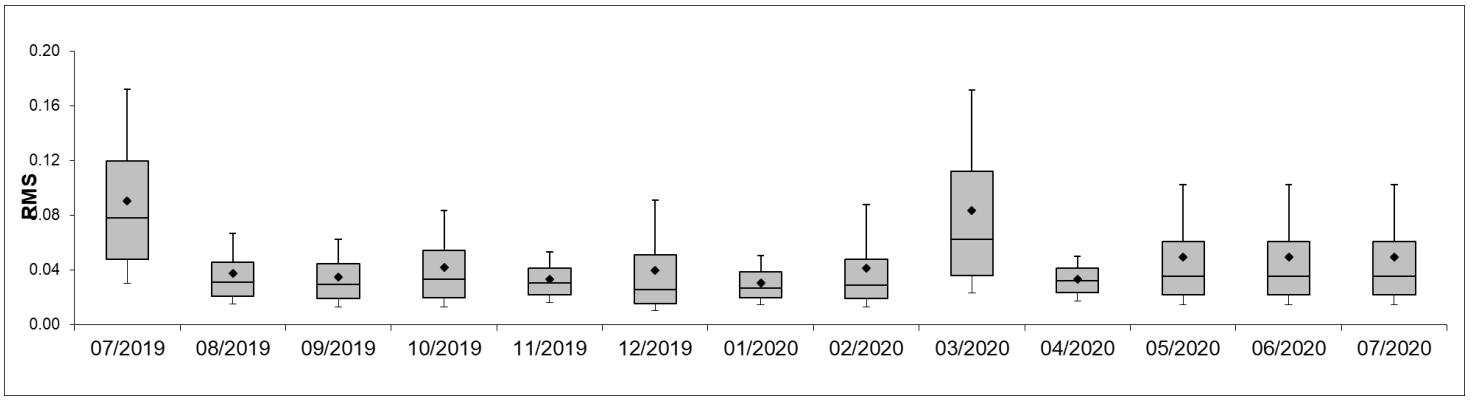
04/2020
05/2020
06/2020
07/2020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07/2019
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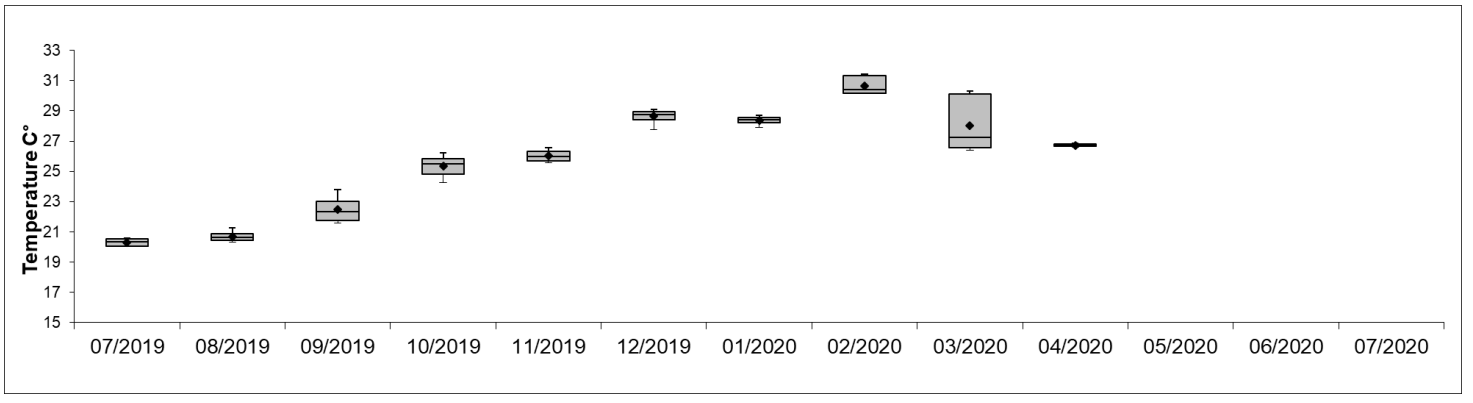
05/2020
06/2020
07/2020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07/2019
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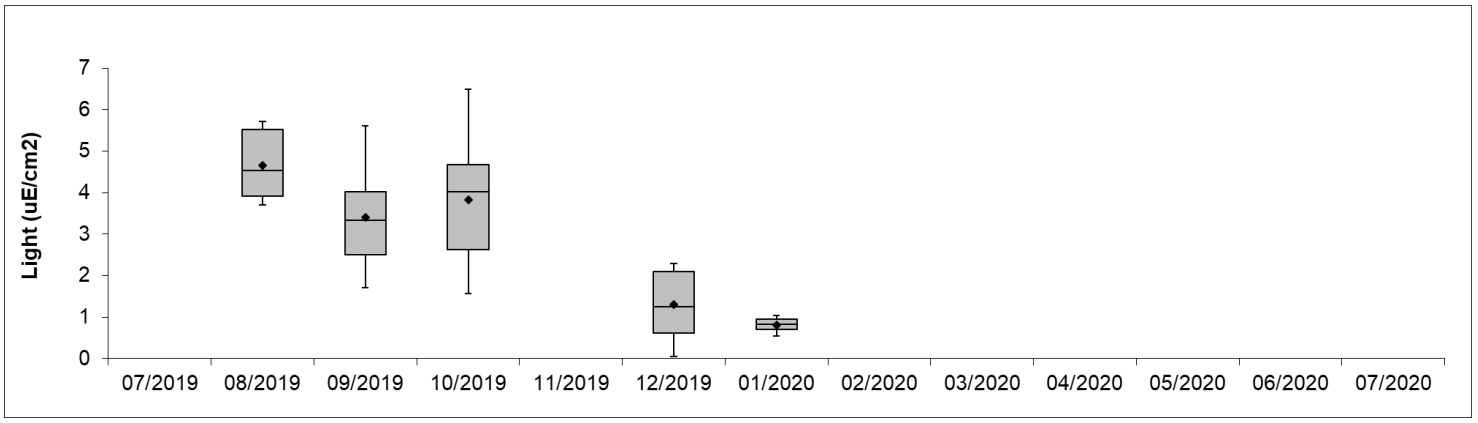
06/2020
07/2020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07/2019
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11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020

A3.5 AMB8: Spoil Ground

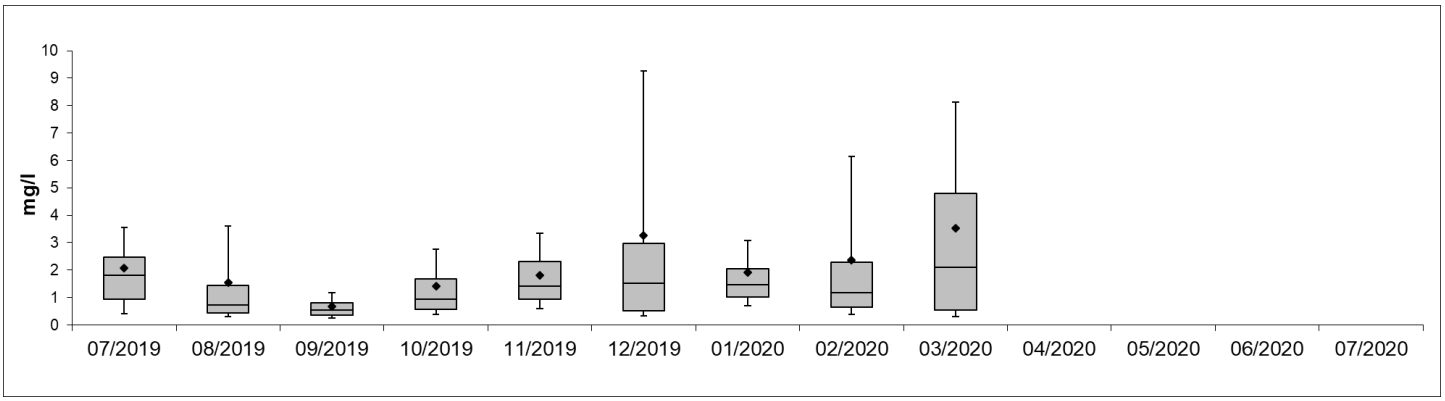
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	2.08	1.54	0.68	1.41	1.82	3.26	1.93	2.37	3.52				
median	1.81	0.72	0.55	0.93	1.40	1.51	1.46	1.16	2.10				
min	0.05	0.11	0.02	0.02	0.09	0.01	0.12	0.07	0.00				
lower	0.93	0.44	0.35	0.56	0.95	0.51	1.01	0.64	0.55				
upper	2.48	1.44	0.80	1.69	2.32	2.98	2.05	2.29	4.79				
max	24.76	16.19	7.51	23.77	10.66	28.24	27.82	27.23	27.91				
90th percentile	3.56	3.59	1.19	2.75	3.34	9.27	3.07	6.13	8.13				
10th percentile	0.41	0.31	0.25	0.38	0.59	0.32	0.69	0.39	0.31				
n	2088	4323	4298	4410	443	3301	4257	4052	1423	0	0	0	0
St. Dev	2.14	2.22	0.58	1.59	1.36	4.93	2.22	3.40	4.07				
St. Error	0.05	0.03	0.01	0.02	0.06	0.09	0.03	0.05	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	0.51	0.15	0.07	0.36	0.04	0.08	0.08	0.13	0.19				
median	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	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	0.14	0.02	0.03	0.25	0.00	0.00	0.02	0.04	0.05				
max	11.11	10.69	10.99	10.90	7.88	10.90	6.68	11.02	10.92				
90th percentile	1.36	0.35	0.09	1.05	0.03	0.03	0.12	0.25	0.24				
10th percentile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
n	4194	4457	4313	2435	620	3950	4266	3746	3465	0	0	0	0
St. Dev	1.45	0.61	0.45	0.93	0.38	0.67	0.35	0.57	0.86				
St. Error	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01				

	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	0.02	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.06	0.02			
median	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02			
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
lower	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01			
upper	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.08	0.02			
max	0.09	0.20	0.15	0.15	0.07	0.31	0.16	0.27	0.47	0.06			
90^{th} percentile	0.04	0.05	0.05	0.05	0.04	0.08	0.04	0.05	0.13	0.03			
10^{th} percentile	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01			
n	2953	4462	4317	4464	831	3963	4460	4174	4464	215	0	0	0
St. Dev	0.01	0.02	0.02	0.02	0.01	0.03	0.01	0.02	0.06	0.01			
St. Error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			

	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	20.06	20.67	22.18	24.92	25.83	28.32	28.75	30.30	28.16	26.85			
median	20.10	20.61	21.94	25.15	25.88	28.38	28.81	30.34	27.28	26.85			
min	19.01	20.26	21.33	23.62	25.20	27.27	27.41	29.19	26.49	26.74			
lower	19.67	20.49	21.65	24.26	25.50	28.24	28.12	30.01	26.79	26.82			
upper	20.48	20.78	22.68	25.42	26.13	28.53	29.37	30.60	30.15	26.88			
max	20.96	21.55	23.87	25.91	26.38	28.93	30.01	31.42	30.61	26.96			
90^{th} percentile	20.72	21.01	23.28	25.69	26.26	28.65	29.60	31.11	30.38	26.91			
10^{th} percentile	19.33	20.42	21.50	24.01	25.30	27.70	27.92	29.50	26.68	26.78			
n	4449	4453	4310	4464	825	3957	4451	4174	4464	215	0	0	0
St. Dev	0.50	0.24	0.67	0.63	0.34	0.35	0.67	0.53	1.58	0.05			
St. Error	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	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	1.47	3.27	4.80	5.42	2.40	1.21	0.85	0.84	1.43				
median	1.04	3.62	4.61	4.37	2.40	0.94	0.83	0.82	1.41				
min	0.00	0.84	0.64	0.53	2.38	0.00	0.34	0.00	1.39				
lower	0.58	2.39	3.70	3.19	2.39	0.17	0.60	0.30	1.40				
upper	2.31	4.01	5.80	8.26	2.41	2.33	1.16	1.34	1.46				
max	4.35	5.23	8.38	11.20	2.42	3.97	1.39	2.62	1.50				
90^{th} percentile	3.53	4.64	7.33	9.42	2.42	3.06	1.24	1.50	1.48				
10^{th} percentile	0.20	1.75	3.16	0.66	2.39	0.05	0.40	0.03	1.39				
n	31	31	27	27	2	28	31	26	3	0	0	0	0
St. Dev	1.28	1.15	1.92	3.39	0.03	1.20	0.32	0.68	0.06				
St. Error	0.23	0.21	0.37	0.65	0.02	0.23	0.06	0.13	0.04				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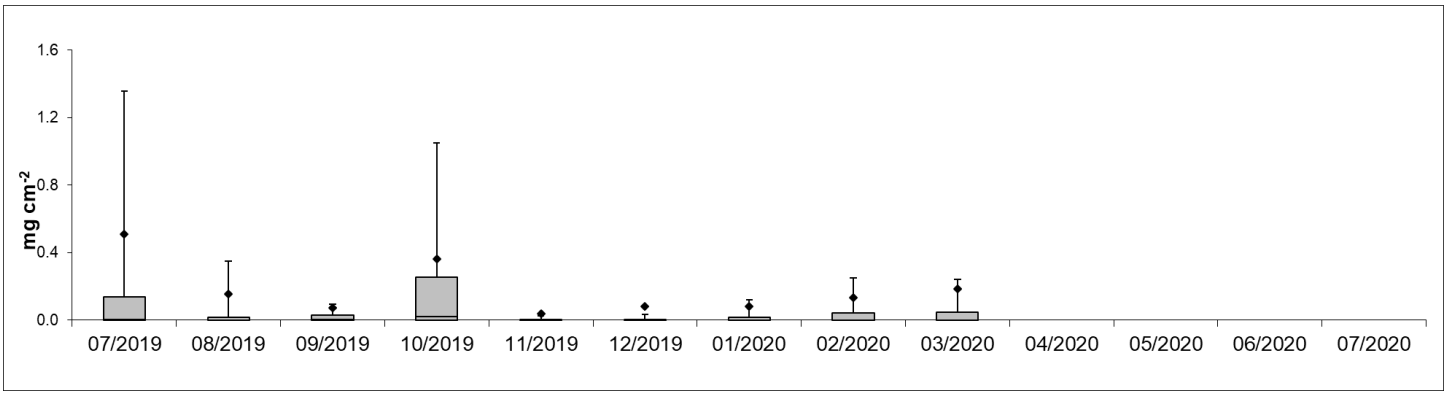
07/2020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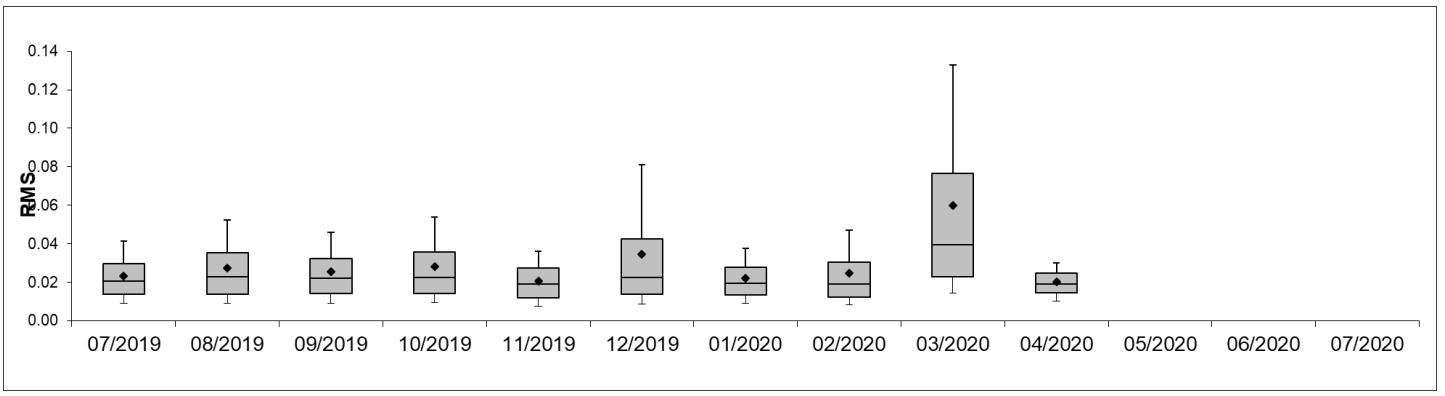
07/2020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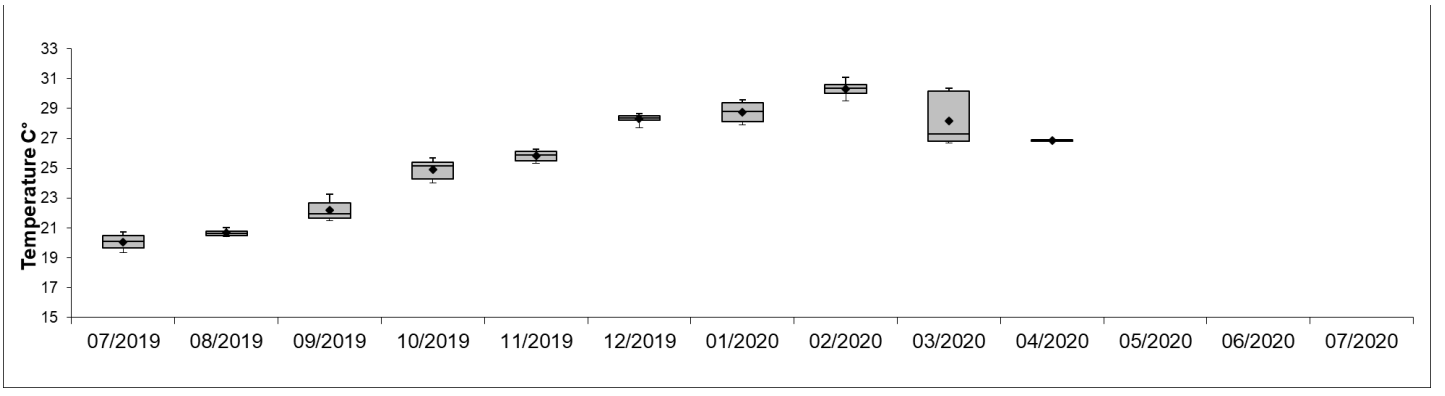
07/2020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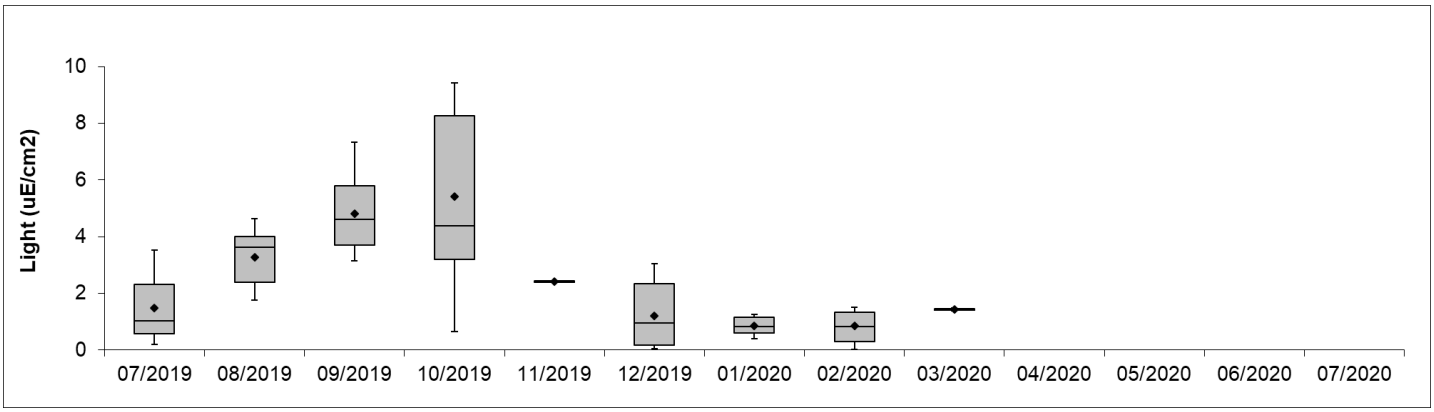
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03/2020
04/2020
05/2020
06/2020
07/2020

A3.6 AMB10: Victor Is.

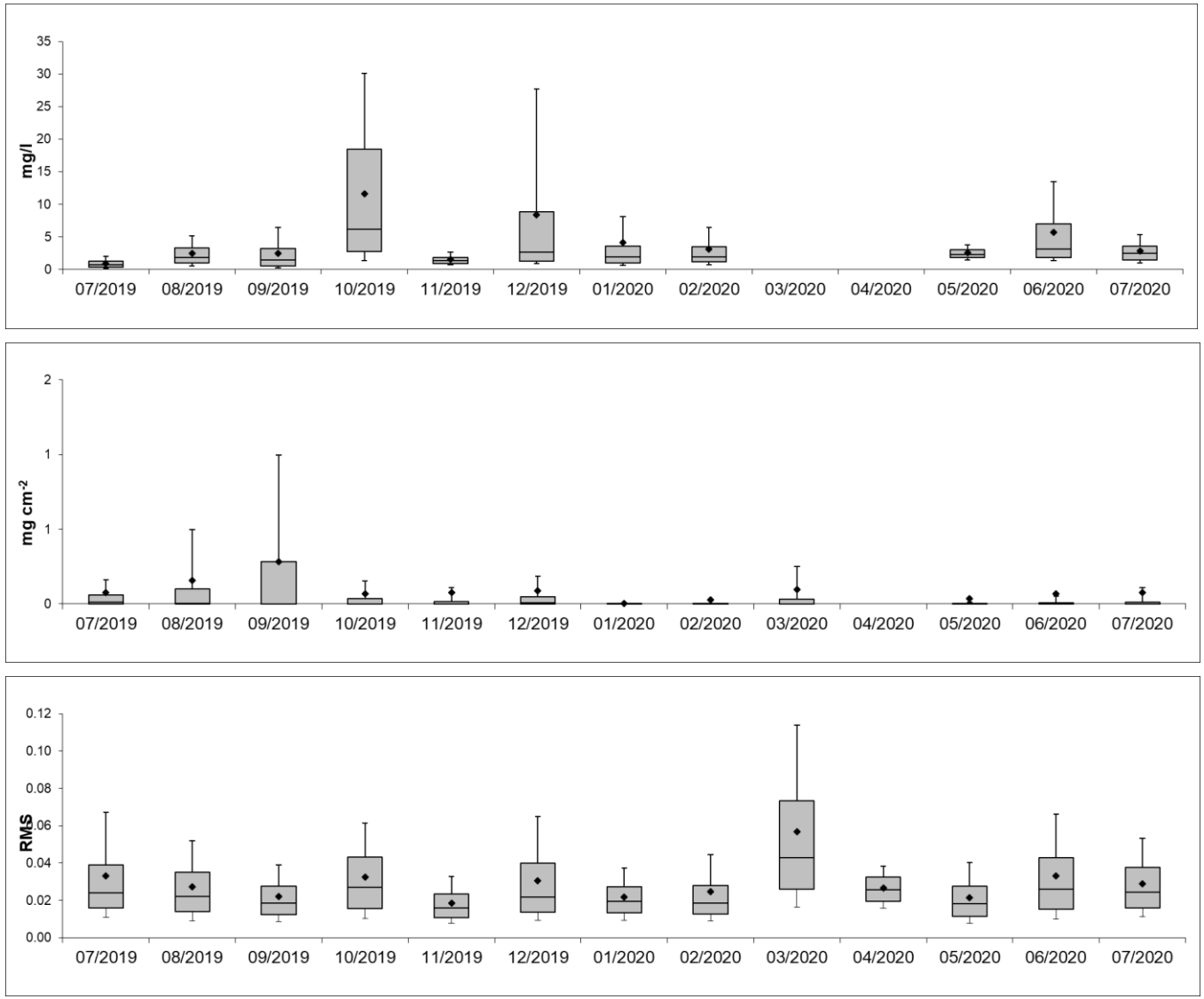
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	0.93	2.41	2.45	11.59	1.52	8.38	4.09	3.10			2.51	5.70	2.85
median	0.72	1.82	1.40	6.11	1.31	2.66	1.88	1.94			2.30	3.10	2.46
min	0.03	0.00	0.00	0.00	0.19	0.08	0.06	0.00			1.19	0.89	0.57
lower	0.31	0.97	0.50	2.69	0.92	1.23	1.01	1.15			1.79	1.84	1.43
upper	1.29	3.30	3.17	18.45	1.81	8.86	3.59	3.44			3.00	6.95	3.56
max	8.92	25.62	32.92	70.46	7.32	90.18	117.07	45.65			9.67	49.42	14.37
90th percentile	2.02	5.17	6.40	30.06	2.63	27.69	8.05	6.38			3.73	13.47	5.34
10th percentile	0.16	0.54	0.19	1.33	0.66	0.85	0.60	0.71			1.46	1.37	0.96
n	2806	3990	1031	1536	4208	2386	2860	3117	0	0	650	4316	4452
St. Dev	0.82	2.04	3.12	11.83	0.92	13.08	8.07	3.91			1.04	6.40	1.93
St. Error	0.02	0.03	0.10	0.30	0.01	0.27	0.15	0.07			0.04	0.10	0.03

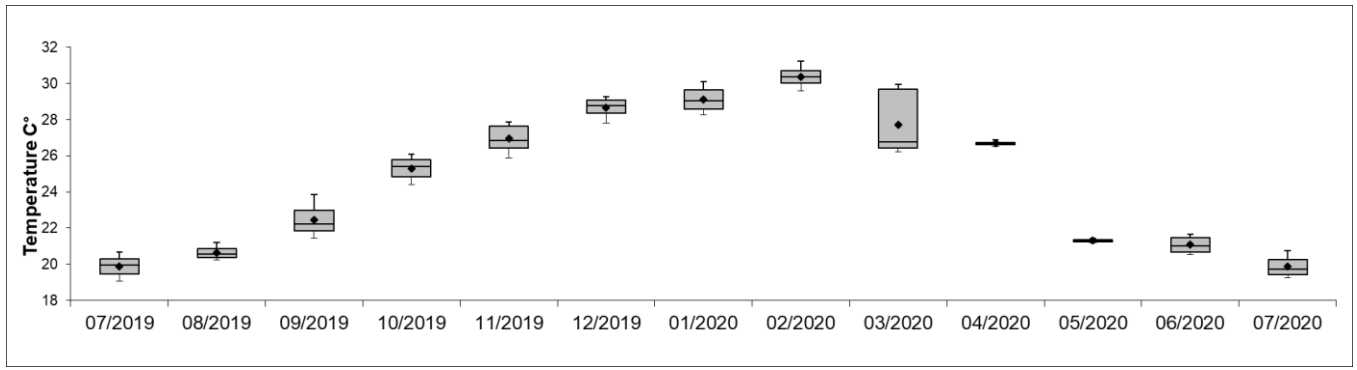
	ASSD 07/2019	ASSD 08/2019	ASSD 09/2019	ASSD 10/2019	ASSD 11/2019	ASSD 12/2019	ASSD 01/2020	ASSD 02/2020	ASSD 03/2020	ASSD 04/2020	ASSD 05/2020	ASSD 06/2020	ASSD 07/2020
Mean	0.08	0.16	0.28	0.07	0.08	0.09	0.00	0.03	0.10		0.03	0.07	0.08
median	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00		0.00	0.00	0.00
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	0.00
upper	0.06	0.10	0.28	0.04	0.01	0.05	0.00	0.00	0.03		0.00	0.01	0.01
max	3.27	3.23	3.35	3.30	3.35	3.00	1.23	2.91	3.18		3.51	12.83	7.06
90th percentile	0.16	0.50	1.00	0.15	0.11	0.19	0.01	0.02	0.25		0.01	0.05	0.11
10th 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	2806	4432	4163	1429	4095	3190	2903	4168	3211	0	651	4320	3456
St. Dev	0.22	0.38	0.58	0.22	0.32	0.27	0.04	0.16	0.30		0.23	0.51	0.36
St. Error	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01		0.01	0.01	0.01

	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	0.033	0.027	0.022	0.032	0.019	0.031	0.022	0.025	0.057	0.027	0.021	0.033	0.029
median	0.024	0.022	0.019	0.027	0.016	0.022	0.019	0.019	0.043	0.026	0.018	0.026	0.024
min	0.002	0.002	0.000	0.003	0.000	0.003	0.002	0.002	0.004	0.009	0.003	0.002	0.002
lower	0.016	0.014	0.013	0.016	0.011	0.014	0.013	0.013	0.026	0.019	0.011	0.015	0.016
upper	0.039	0.035	0.028	0.043	0.024	0.040	0.027	0.028	0.073	0.032	0.028	0.043	0.038
max	0.253	0.180	0.127	0.185	0.102	0.171	0.110	0.210	0.384	0.065	0.080	0.226	0.135
90^{th} percentile	0.067	0.052	0.039	0.061	0.033	0.065	0.037	0.045	0.114	0.038	0.040	0.066	0.053
10^{th} percentile	0.011	0.009	0.009	0.010	0.008	0.009	0.009	0.009	0.016	0.016	0.008	0.010	0.011
n	4463	4456	4319	4464	4319	4460	4460	4175	4464	196	651	4320	4464
St. Dev	0.028	0.019	0.014	0.022	0.011	0.025	0.012	0.021	0.046	0.010	0.014	0.025	0.018
St. Error	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	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	19.90	20.64	22.47	25.30	26.94	28.66	29.10	30.38	27.73	26.68	21.32	21.08	19.87
median	19.96	20.56	22.21	25.39	26.86	28.77	29.03	30.35	26.77	26.67	21.32	21.03	19.74
min	18.67	19.98	21.07	23.70	25.03	27.04	27.29	29.12	25.92	26.50	21.13	20.39	18.96
lower	19.46	20.36	21.85	24.83	26.44	28.36	28.57	30.01	26.44	26.62	21.24	20.67	19.41
upper	20.31	20.87	22.99	25.79	27.63	29.07	29.63	30.72	29.68	26.74	21.37	21.48	20.25
max	20.99	21.75	24.71	26.41	28.19	29.71	30.58	31.58	30.38	26.93	22.27	21.84	21.08
90^{th} percentile	20.66	21.19	23.86	26.09	27.86	29.26	30.09	31.23	29.95	26.88	21.45	21.65	20.74
10^{th} percentile	19.06	20.23	21.46	24.40	25.88	27.81	28.26	29.58	26.22	26.54	21.20	20.55	19.24
n	4452	4449	4313	4464	4319	4460	4460	4168	4464	196	651	4320	4464
St. Dev	0.56	0.37	0.89	0.63	0.75	0.56	0.69	0.56	1.57	0.11	0.10	0.43	0.55
St. Error	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.00	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	2.47	5.13	3.66	4.40	9.77	2.11		1.31			7.28	10.99	2.81
median	2.19	5.06	3.70	2.24	9.86	2.18		0.84			4.40	10.92	2.51
min	0.23	2.21	0.02	0.00	3.56	0.05		0.75			2.88	0.07	0.27
lower	1.50	3.32	1.71	1.68	6.55	1.86		0.79			3.69	3.78	1.21
upper	3.65	6.38	4.91	6.69	12.54	2.65		1.59			12.65	16.21	3.79
max	5.24	10.10	8.00	12.02	18.70	3.52		2.33			12.77	28.19	11.82
90^{th} percentile	4.43	8.54	6.94	11.25	15.02	3.28		2.03			12.72	19.34	4.89
10^{th} percentile	0.74	2.97	0.45	0.76	5.47	0.65		0.76			3.21	2.57	0.62
n	26	31	30	10	30	17	0	3	0	0	5	30	25
St. Dev	1.43	2.21	2.43	4.32	3.95	0.98		0.89			4.99	7.28	2.40
St. Error	0.28	0.40	0.44	1.37	0.72	0.24		0.51			2.23	1.33	0.48


mg/l
35
30
25
20
15
10
5
0
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
mg cm-2
2
1
1
0
RMS
0.12
0.10
0.08
0.06
0.04
0.02
0.00


Temperature C°
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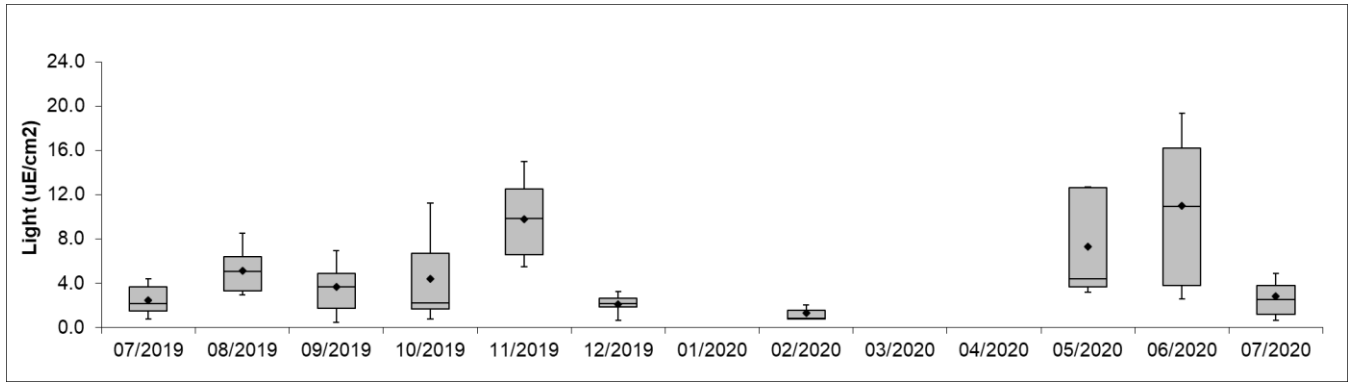
30
28
26
24
22
20
18
07/2019
08/2019
09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


Light (uE/cm2)
24.0
20.0
16.0
12.0
8.0
4.0
0.0
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

A3.7 AMB12: Keswick Island

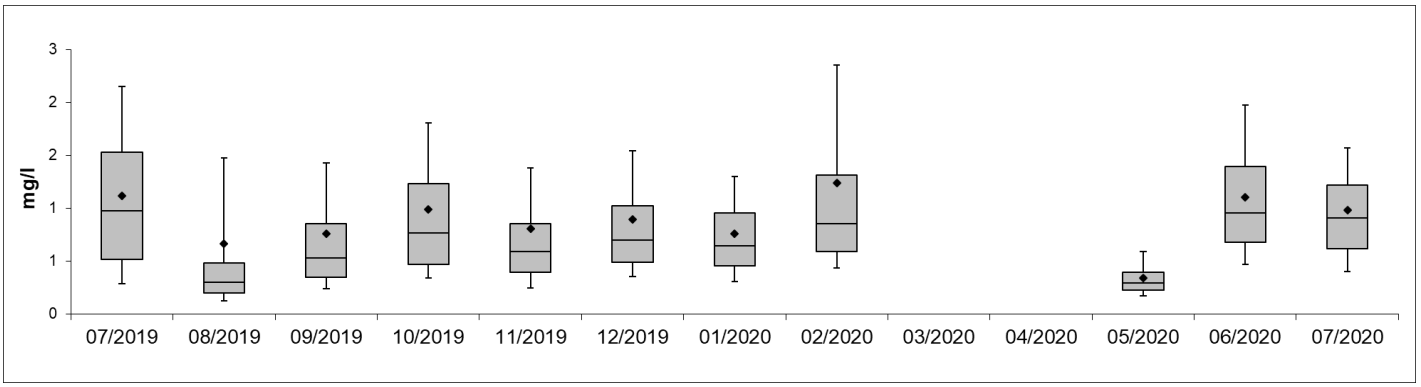
	SSC 07/2019	SSC 08/2019	SSC 09/2019	SSC 10/2019	SSC 11/2019	SSC 12/2019	SSC 01/2020	SSC 02/2020	SSC 03/2020	SSC 04/2020	SSC 05/2020	SSC 06/2020	SSC 07/2020
Mean	1.12	0.67	0.76	0.99	0.81	0.89	0.76	1.24			0.34	1.10	0.98
median	0.97	0.30	0.53	0.76	0.59	0.70	0.64	0.85			0.29	0.95	0.91
min	0.00	0.00	0.08	0.18	0.00	0.00	0.00	0.00			0.08	0.13	0.16
lower	0.52	0.20	0.35	0.46	0.40	0.49	0.45	0.59			0.22	0.68	0.62
upper	1.53	0.48	0.85	1.23	0.85	1.02	0.95	1.31			0.39	1.39	1.22
max	6.19	10.46	11.81	9.18	18.79	9.19	11.43	10.97			1.29	4.64	6.86
90th percentile	2.15	1.47	1.43	1.81	1.38	1.54	1.30	2.35			0.59	1.98	1.57
10th percentile	0.29	0.12	0.24	0.34	0.25	0.35	0.31	0.43			0.17	0.47	0.40
n	2924	2884	3236	2016	4106	4177	4199	1252	0	0	509	4318	4448
St. Dev	0.79	1.11	0.81	0.81	1.01	0.76	0.52	1.30			0.18	0.61	0.53
St. Error	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.04			0.01	0.01	0.01

	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	0.12	0.03	0.02	0.26	0.02	0.04	0.03	0.05	0.09	0.14	0.01	0.18	0.17
median	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04
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	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	0.00	0.00
upper	0.04	0.01	0.01	0.26	0.01	0.02	0.01	0.02	0.03	0.05	0.00	0.15	0.18
max	2.96	2.70	1.18	2.94	2.08	2.48	1.56	2.59	2.93	2.96	1.07	6.00	6.34
90th percentile	0.24	0.07	0.04	0.93	0.03	0.08	0.06	0.11	0.21	0.47	0.01	0.51	0.45
10th 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	0.00
n	4422	4453	4316	4410	4319	1724	2751	2586	4397	338	510	4252	4437
St. Dev	0.36	0.12	0.06	0.50	0.08	0.16	0.09	0.15	0.28	0.37	0.07	0.44	0.37
St. Error	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01

	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	0.008	0.006	0.006	0.005	0.005	0.005	0.005	0.014	0.005	0.008	0.013	0.011
median	0.007	0.006	0.004	0.005	0.004	0.004	0.004	0.005	0.009	0.005	0.007	0.010	0.008
min	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
lower	0.004	0.004	0.004	0.004	0.003	0.002	0.003	0.004	0.005	0.004	0.004	0.006	0.005
upper	0.012	0.010	0.007	0.007	0.005	0.006	0.006	0.007	0.017	0.007	0.011	0.017	0.014
max	0.087	0.113	0.073	0.043	0.052	0.072	0.072	0.041	0.099	0.012	0.034	0.094	0.105
90^{th} percentile	0.022	0.016	0.010	0.013	0.007	0.012	0.007	0.009	0.030	0.008	0.017	0.028	0.022
10^{th} percentile	0.003	0.003	0.003	0.000	0.000	0.001	0.002	0.003	0.004	0.003	0.003	0.004	0.004
n	4462	4459	4317	4464	4319	4461	4459	4174	4464	343	510	4320	4464
St. Dev	0.010	0.008	0.006	0.005	0.004	0.006	0.004	0.004	0.013	0.002	0.006	0.011	0.009
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	21.17	20.97	22.14	24.33	25.87	27.64	28.40	29.65	28.41	27.28	22.83	22.30	20.94
median	21.09	20.98	21.99	24.54	25.80	27.64	28.29	29.76	28.15	27.28	22.79	22.29	20.75
min	20.49	20.58	21.27	23.19	24.72	26.82	27.59	28.82	26.93	27.17	22.65	21.65	20.19
lower	20.73	20.84	21.69	23.78	25.35	27.50	28.04	29.33	27.41	27.23	22.73	22.12	20.53
upper	21.60	21.09	22.48	24.84	26.41	27.84	28.89	29.96	29.69	27.32	22.90	22.45	21.31
max	21.83	21.47	23.60	25.20	27.17	28.20	29.24	30.48	30.17	27.46	23.17	23.18	21.94
90^{th} percentile	21.69	21.18	23.02	24.93	26.76	27.97	29.02	30.15	29.78	27.38	23.06	22.74	21.72
10^{th} percentile	20.63	20.73	21.53	23.46	25.01	27.24	27.83	29.00	27.12	27.20	22.71	21.89	20.42
n	4451	4450	4317	4464	4313	4455	4451	4174	4464	343	500	4320	4464
St. Dev	0.42	0.17	0.56	0.58	0.63	0.28	0.46	0.41	1.07	0.07	0.13	0.31	0.48
St. Error	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.00	0.01	0.00	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	2.11	2.94	2.24	3.48	1.89	2.38	3.67	1.61	0.78		1.31	1.29	1.87
median	2.21	3.14	1.80	3.02	1.57	2.52	3.92	1.80	0.49		1.14	1.28	1.94
min	0.02	0.94	1.21	1.56	0.94	0.04	0.77	0.29	0.00		0.92	0.65	0.22
lower	1.32	2.13	1.56	2.56	1.40	1.66	2.31	0.93	0.19		0.97	1.04	1.23
upper	2.72	3.66	1.92	3.62	2.37	3.26	4.97	2.06	0.84		1.48	1.47	2.63
max	4.63	4.88	6.65	7.62	3.60	4.02	6.90	3.80	2.71		2.04	2.59	3.04
90^{th} percentile	3.03	4.07	4.71	6.47	3.08	3.70	5.93	2.28	2.25		1.82	1.66	2.83
10^{th} percentile	0.15	1.74	1.37	1.69	1.30	0.62	1.03	0.55	0.09		0.94	0.85	0.81
n	31	31	30	24	30	31	29	20	25	0	4	30	24
St. Dev	1.12	0.95	1.40	1.73	0.75	1.15	1.84	0.83	0.84		0.52	0.39	0.83
St. Error	0.20	0.17	0.26	0.35	0.14	0.21	0.34	0.19	0.17		0.26	0.07	0.17


mg/l
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2
2
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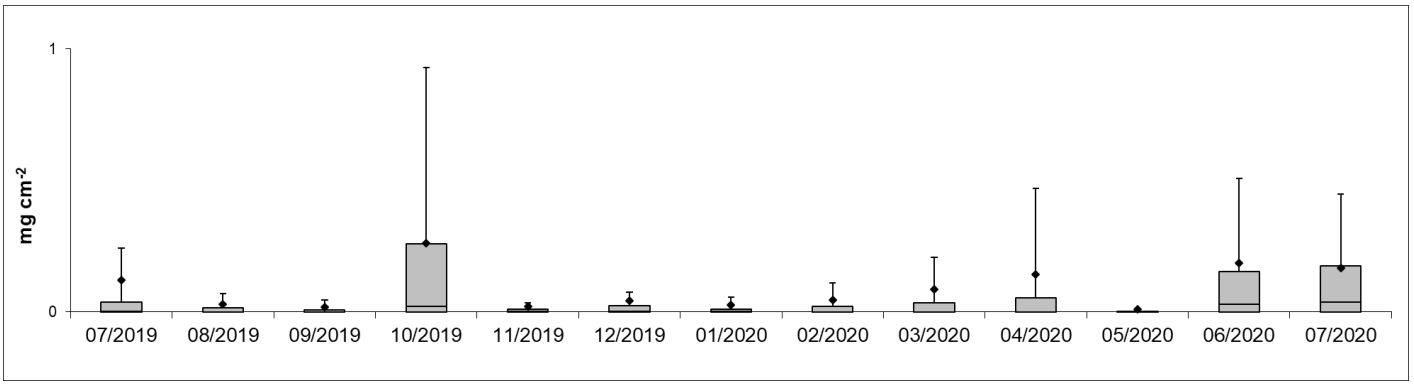
07/2019
08/2019
09/2019
10/2019
11/2019
12/2019
01/2020
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


mg cm-2
1
0
07/2019
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10/2019
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12/2019
01/2020
02/2020
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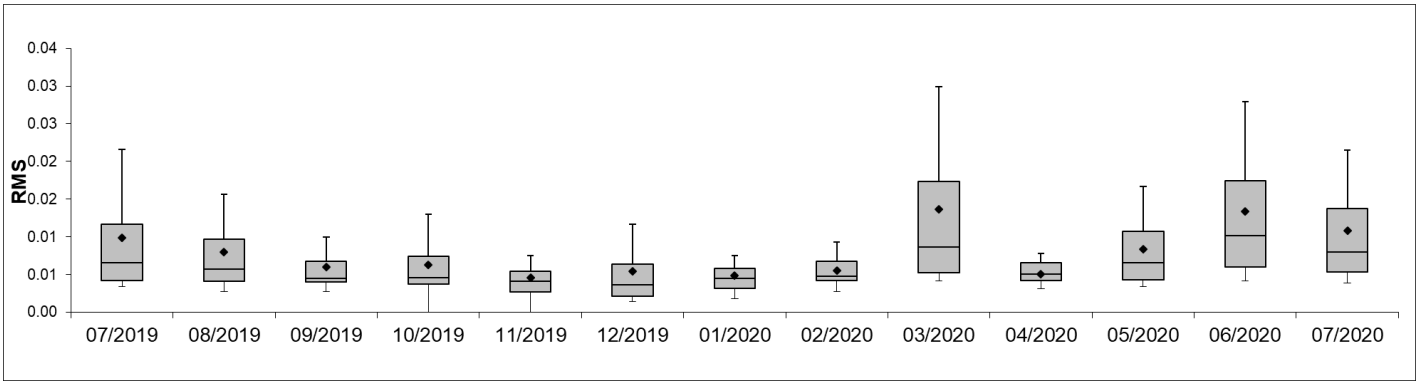
06/2020
07/2020


RMS
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0.02
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0.01
0.00
07/2019
08/2019
09/2019
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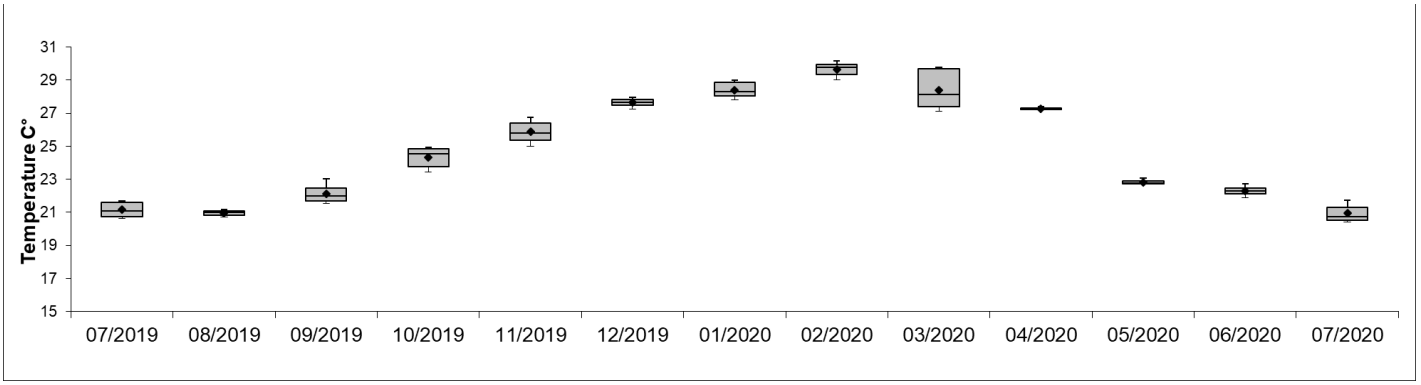
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


Temperature C°
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29
27
25
23
21
19
17
15
07/2019
08/2019
09/2019
10/2019
11/2019
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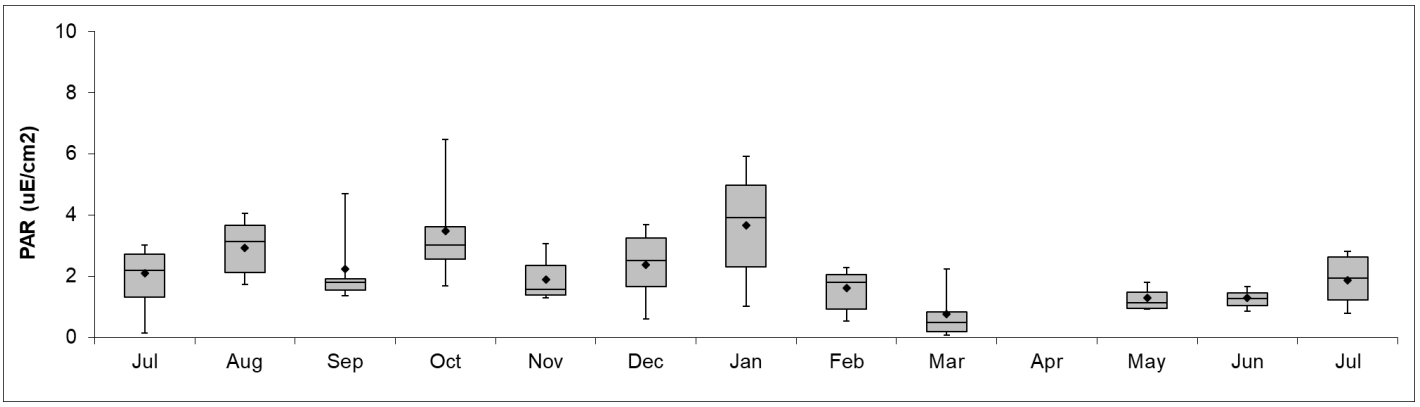
02/2020
03/2020
04/2020
05/2020
06/2020
07/2020


PAR (uE/cm2)
10
8
6
4
2
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

A4 MAROTTE CURRENT METER ANIMATIONS

Link to Monthly (long) video: https://www.youtube.com/watch?v=4KEZkysQSac

Link to Yearly (short) video: https://www.youtube.com/watch?v=z5zgnpnLgCk

Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER)

ATSIP Building
James Cook University
Townsville Qld 4811

Phone: 07 4781 4262
Fax: 07 4781 5589
Email: TropWATER@jcu.edu.au

Web: www.jcu.edu.au/tropwater/