Southern Mackay Ambient Marine Water Quality Monitoring Program: Annual report 2020-2021

Nathan Waltham and Jordan Iles

Report No. 21/71

December 2021

Southern Mackay Ambient Marine Water Quality Monitoring Program: Annual report 2020 -2021

A Report for Healthy Rivers to Reef Partnership

Report No. 21/71

December 2021

Prepared by Nathan Waltham and Jordan Iles

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/

Information should be cited as:

Waltham, NJ & Iles, JA 2021, 'Southern Mackay Ambient Marine Water Quality Monitoring Program: Annual report 2020-2021', Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 21/71, James Cook University, Townsville, 30 pp.

For further information contact:

Dr Nathan Waltham
Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)
James Cook University
nathan.waltham@jcu.edu.au

This publication has been compiled by the Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER), James Cook University.

TABLE OF CONTENTS

TABLE OF FIGURES

1 INTRODUCTION

1.1 Southern Mackay program

TropWATER (Centre for Tropical Water and Aquatic Ecosystem Research), James Cook University, has been commissioned to assist Healthy Rivers to Reef Partnership collect ambient marine water quality data for the southern Mackay region as part of the Mackay-Whitsunday – Isaac regional report card that is released each year. This report card provides an overview of the health and condition of regional catchments, rivers, creeks and nearshore habitats, and will be used in the future to set strategic, collaborative, management action plans to protect regional marine, freshwater and estuarine ecosystems. This update report has been prepared for the 2020-2021 monitoring period.

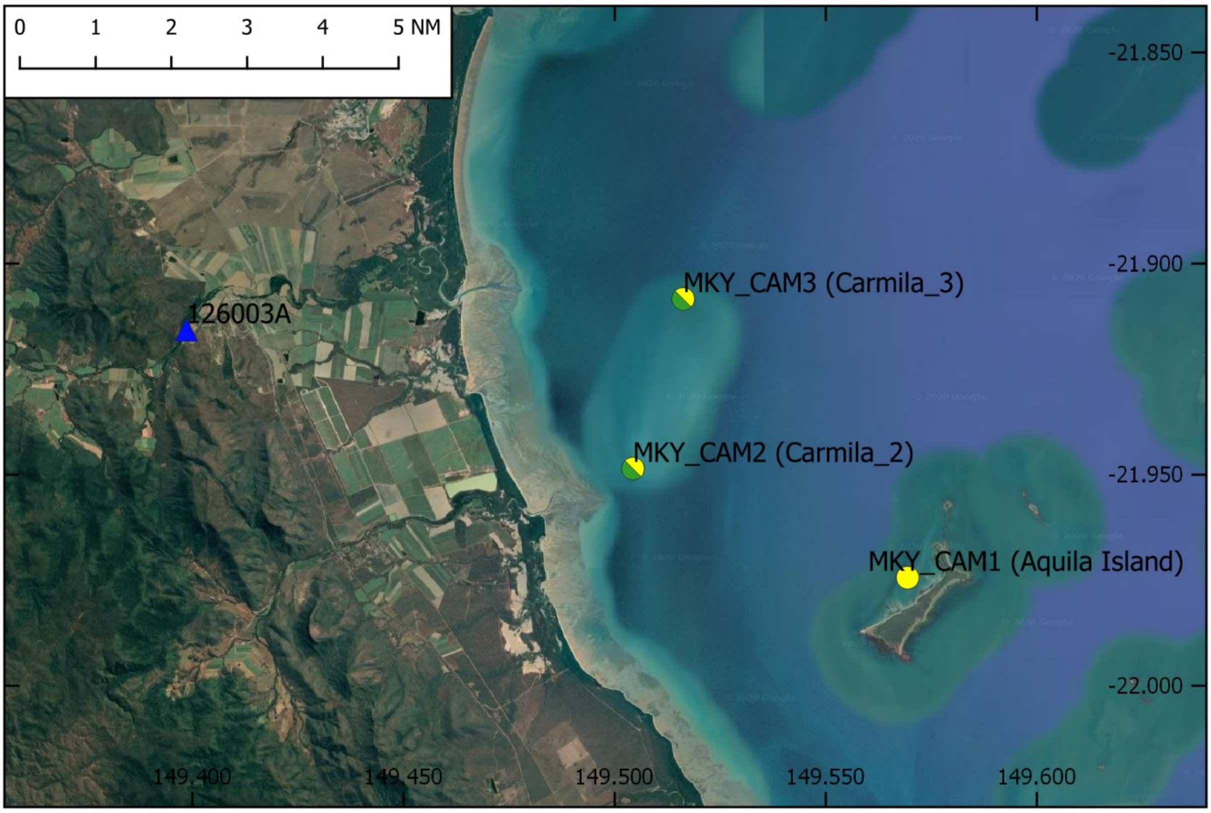

Figure 1.1 Location of water quality monitoring sites with loggers (yellow circle) and without loggers (yellow/green circles) utilised in the 2020-2021 reporting period. Also shown is the stream gauging station (blue triangle) referred to in this report.

1.2 Rainfall and river flows

Daily rainfall for the Mackay region is shown on (Figure 1.2). The rainfall onset occurred on 3/01/2020 for Plane Creek. The rainfall onset is calculated as the date when the rainfall total reaches 50mm since 1st September. Total rainfall during the 2020-2021 wet season was 1002.6 mm, placing it as a slightly below the median wet season rainfall for 1912-1913 to 2020-2021 (Figure 1.3). Rainfall in recent years has also been highlighted indicating the high inter-annual variability of rainfall. This highlights the necessity for a long term commitment to ambient marine monitoring programs to capture and understand this variability.

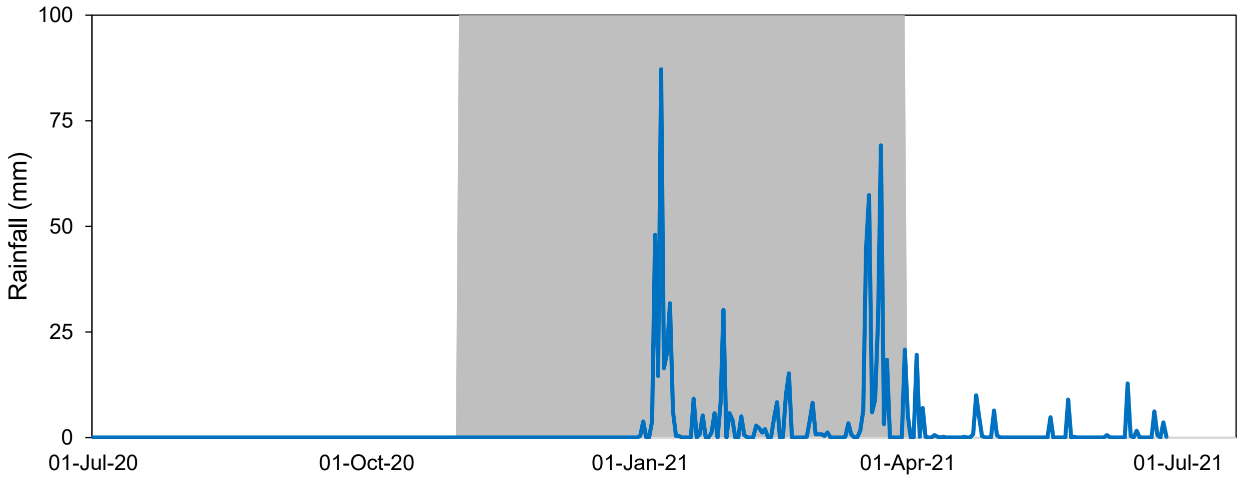

Figure 1.2 Rainfall recorded at Plane Creek Sugar Mill (station 033059) for the 2020-2021 reporting period. The nominal wet season period is shaded grey. Data source: http://www.bom.gov.au/climate/data/

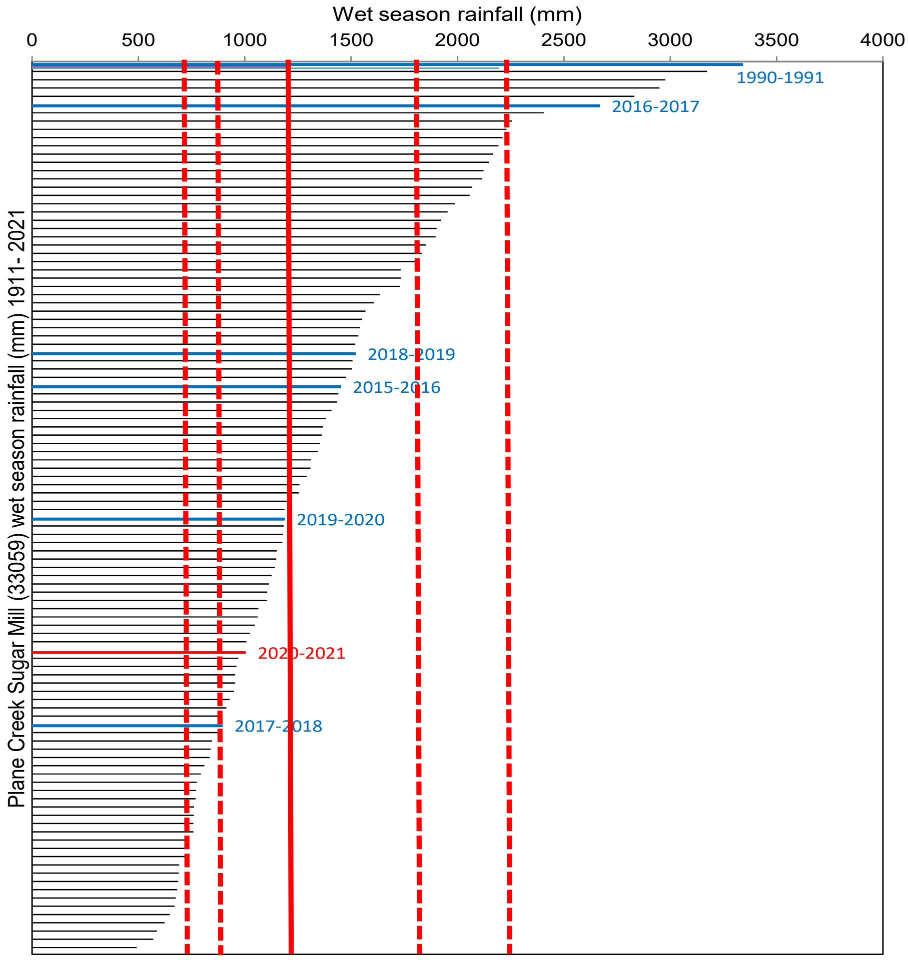

Figure 1.3 Wet season rainfall for the Mackay region ranked in order of decreasing total wet season rainfall (mm). Daily rainfall data was obtained from the Bureau of Meteorology Plane Creek Sugar Mill weather station (Station number 033059). Totals were calculated for the wet season period 1st November to 31st March for each reporting year. Red bar represents the current 2020-2021 ambient marine water quality monitoring period, blue bars show total rainfall over the previous five reporting years.

A hydrograph for Carmila Creek during the 2020-2021 reporting period show onset of stream discharge on 30/12/2020, with significant flows on 20/02/2021 and 023/03/2021 (Figure 1.4). Total discharge at Carmila Creek was 14 GL for the 2020-2021 reporting period, which is more than half the 2019-2020 reporting period (44 GL).

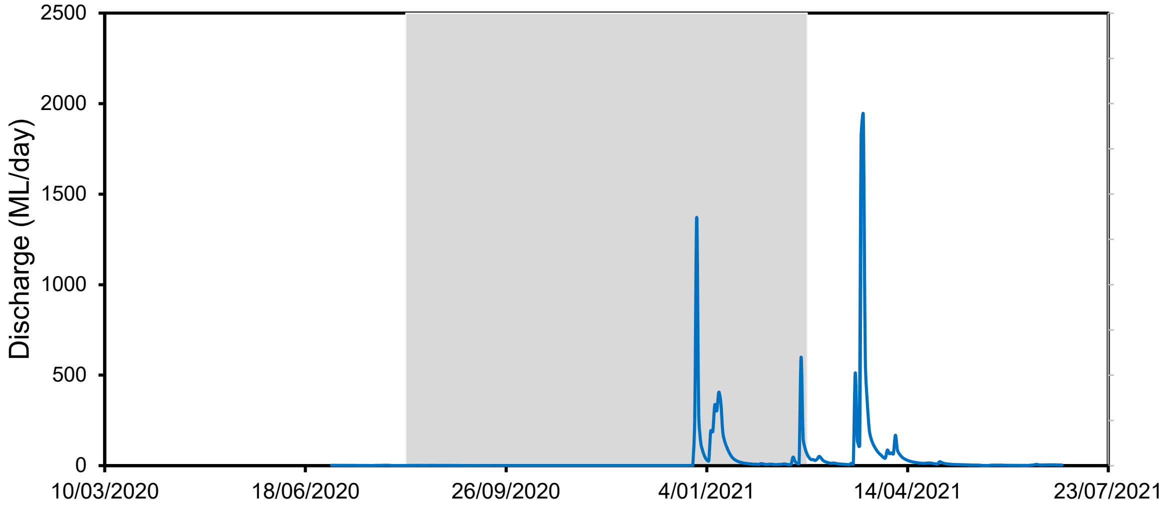

Figure 1.4 Discharge (GL day^{-1}) recorded at Carmila Creek (station 126003A) during the 2020-2021 reporting period

2 METHODOLOGY

2.1 Water quality monitoring sites

Three water quality monitoring sites were established in September 2017. Ambient water quality monitoring was conducted at all three sites approximately every 6 weeks, while a multiparameter instrument was deployed to collect high frequency data over consecutive years at a single site (Aquilla; MKY_CAM1). Regular maintenance visits occurred in parallel with water quality monitoring to perform sensor maintenance and download data from the instrument, as part of a broader regional program (see Waltham et al., 2018).

2.2 Ambient water quality

2.2.1 Physicochemical parameters

Spot water quality samples were collected from a research vessel at three sites approximately on a 6 week basis. Water temperature, electrical conductivity (EC), dissolved oxygen (DO), and pH were measured with a water quality multiprobe (Hydrolab Quanta) at each site (Figure 2.1). Parameters were recorded at three depth horizons: a) surface (0.25 m); b) mid-depth; and c) bottom. Secchi disk depth (Z_{sd}) and light (PAR) intensity were recorded as a measure of the optical clarity of the water column and to profile light attenuation. Light intensity was measured at the three depths with a PAR sensor (Li-Cor LI-192 Underwater Quantum Sensor).

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

- Particulate nitrogen and phosphorus;
- Nitrate/Nitrite (N_{ox});
- Total suspended solids; and
- Chlorophyll-*a*


Figure 2.1 TropWATER staff measuring and recording water quality parameters with a multiprobe (left) and collecting a water sample for laboratory analysis (right) during water quality sampling trips.

2.2.2 Nutrients and Chlorophyll *a*

Sampling methodology, sample bottles, preservation techniques and analytical methodology (NATA accredited) were in accordance with standard methods (i.e., DERM 2009b; Standards Australia 1998). Field collected water samples were stored on ice in eskies immediately during field trips aboard the vessel, and transported back to refrigeration, before delivery to the TropWATER laboratory. For chlorophyll analysis, water was placed into a 1L dark plastic bottle and placed on ice for transportation back to refrigeration.

Water was passed through a 0.45 µm disposable membrane filter (Sartorius), fitted to a sterile 60 mL syringe (Livingstone), and placed into a 10 mL sample tubes for nutrient 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-*a* 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 defined analysis methods and detection limits (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'. Herbicides and pesticides were analysed using passive samplers deployed for several weeks at a time as per instructions provided by QAEHS centre, University of Queensland.

Table 2.1 Water analyses performed during the ambient marine water quality monitoring program. The method used and limit of reporting (LOR) is provided for each parameter.

Group	Parameter	APHA method number	LOR
Routine water quality analyses			
	pH	4500-H^+ B	-
	Conductivity (EC)	2510 B	5 µS cm^{-1}
	Total Suspended Solids (TSS)	2540 D @ 103 - 105°C	0.2 mg L^{-1}
	Turbidity	2130 B	0.1 NTU
Nutrients			
	Nitrogen and Phosphorus (TN, TP)	Simultaneous 4500-NO_3^- F and 4500-P F analyses after alkaline persulphate digestion	25 µg N L^{-1}, 5 µg P L^{-1}
	Filterable nutrients (nitrate, nitrite, ammonia, NO_x)	4500-NO_3^- F	1 µg N L^{-1}
	Ammonia	4500- NH_3 G	1 mg N L^{-1}
	Filterable Reactive Phosphorus (FRP)	4500-P F	1 µg P L^{-1}
Chlorophyll			
	Chlorophyll-*a*	10200-H	0.1 µg L^{-1}
	Phaeophytin-*a*	10200-H	0.2 µg L^{-1}

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 one site (MKY_CAM1) using a purpose built multiparameter water quality instrument manufactured at the Marine Geophysics Laboratory, School of Engineering and Physical Sciences, James Cook University (Figure 2.2). These instruments are programmed to measure these marine physical parameters using specifically designed sensors and store the data on a Campbell's Scientific 1000 data logger housed inside.

a) b)

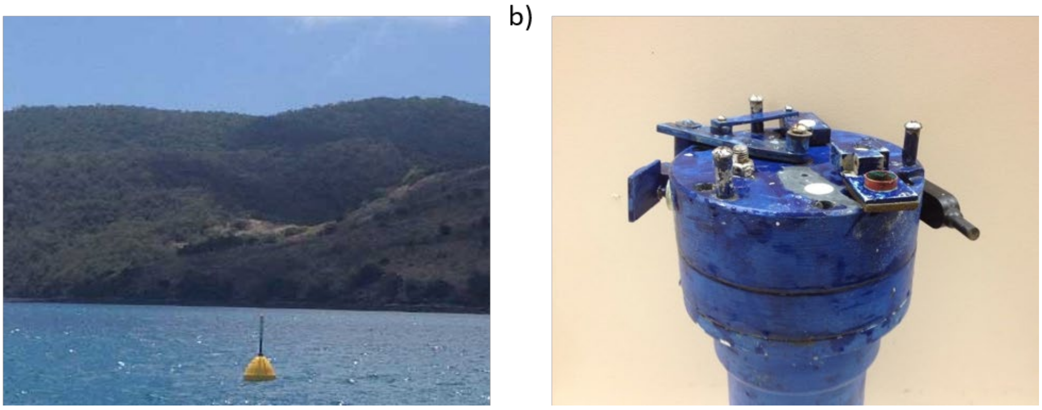

Figure 2.2 Example coastal multiparameter water quality instrument: a) site navigation beacon for safety and instrument retrieval; b) instrument showing sensors and wiping mechanisms

2.3.1 Turbidity

The turbidity sensor provides data in backscatter units (BU), reported by Ridd et al. (2001) as NTU 'equivalents'. The sensor is calibrated against sediments collected from the site to report Suspended Sediment Concentration (SSC) in mg L^{-1} (Larcombe et al., 1995). The sensor is located on the side of the logger, pointing parallel light-emitting diodes (LED) and transmitted through a fibre optic bundle. The backscatter probe takes 250 samples in an eight second period to attain a 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 one hour interval allowing for long deployment periods where bio-fouling would otherwise seriously affect readings.

The international turbidity standard ISO7027 defines NTU only for 90 degree scatter, however, the Marine Geophysics Laboratory instruments used throughout this monitoring program 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. Suspended sediment concentrations (SSC) (mg L^{-1}) was calculated from turbidity measurements based on an established relationship between measured turbidity and suspended sediment concentration measured from discreet water samples.

2.3.2 Sediment deposition

Deposition is recorded as 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:

$$D_{rms} = \sqrt{\sum_{n=1}^{10} (D_n - \bar{D})^2 / n} \qquad \text{[Equation 1]}$$

Where:

D_n is the nth of the 10 readings,

$\bar{D}$ is the mean water depth (m) 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, two sites both have the same surface wave height, site one is 10 m deep and has a measurement of 0.01 RMS water height and site two is 1 m deep and has a measurement of 0.08 RMS water height. Even though the surface wave height is the same at both sites, the RMS water height is greater at the shallower site and we would expect more re-suspension due to wave shear stress at this site.

2.3.4 Water temperature

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

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 of PAR for a 10 minute period and then summed for each day.

3 RESULTS

Event sampling was conducted on trips coinciding with logger replacements. For each site water temperature, electrical conductivity, pH, and dissolved oxygen were measured at three depths in the water column. Secchi disk depth was also recorded. Water samples were collected for laboratory analysis. There were seven sampling events during the 2020-2021 reporting period (**Table 3.1**).

Table 3.1 Summary of instrument maintenance and water quality surveys completed during the 2020-2021 reporting period.

Date	Field measurements	Water sampling	Pesticides	Logger
04/09/2020	Yes	Yes	-	Yes
31/10/2020	Yes	Yes	-	Yes
01/12/2020	Yes	Yes	Yes	Yes
27/01/2021	Yes	Yes	Yes	Yes
11/03/2021	Yes	Yes	Yes	Yes
21/04/2021	Yes	Yes	-	Yes
15/06/2021	Yes	Yes	-	Yes

3.1 Field water quality measurements

3.1.1 Temperature

Water temperature ranged between 20.4 and 28.33 °C during the 2020-2021 reporting period (Figure 3.1). The January 2020 survey was the warmest period sampled. These patterns are consistent throughout the water column, indicating that the water column profile is vertically well mixed. Temperature is an essential interpretative aid for ecological assessment in environments. For example, species such as fish and other animals have thermal stress point which causes discomfort.

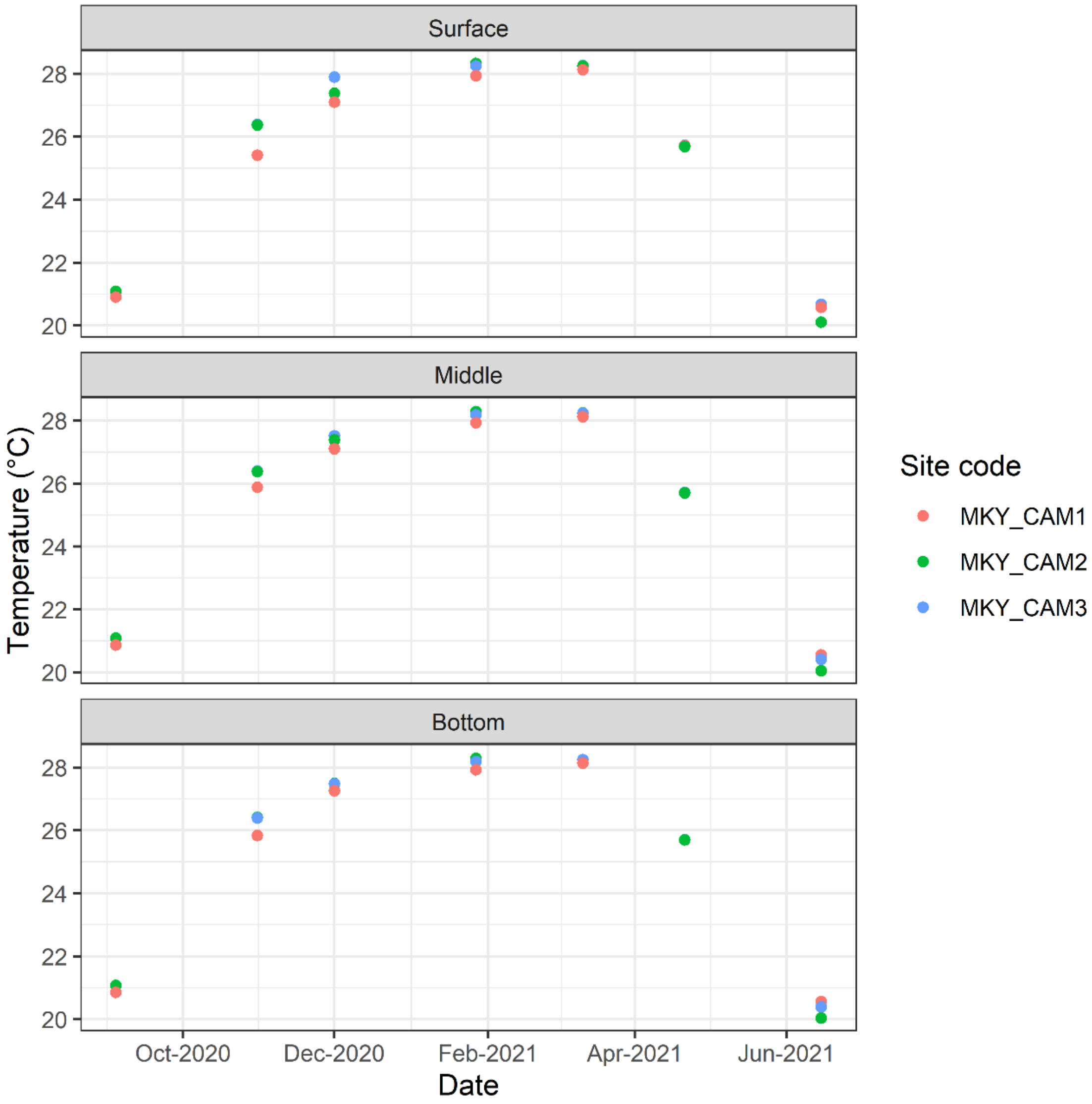

Figure 3.1 Water temperature (°C) measured at surface, mid, and bottom depths pooled across all sampling events

3.1.2 Electrical Conductivity

Electrical conductivity ranged from 52.5 to 56.1 mS cm^{-1} and generally indicate oceanic conditions (Figure 3.2). Electrical conductivity was similar across all sites during each sampling event.

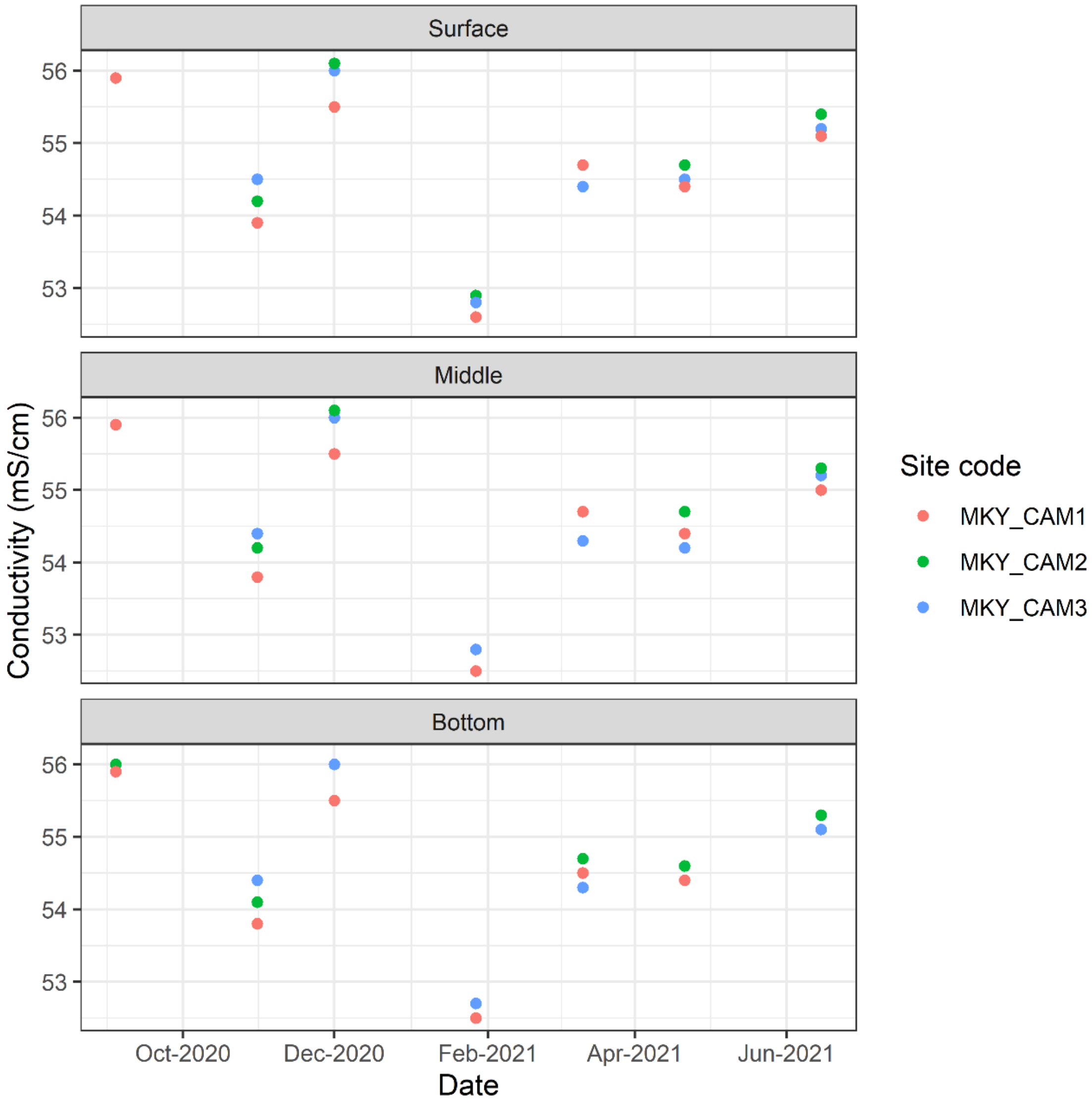

Figure 3.2 Electrical conductivity (mS cm^{-1}) measured at surface, mid, and bottom depths pooled across all sampling events

3.1.3 pH

Field pH measurements were stable across sites and depths primarily ranging between 7.71 and 8.33 (Figure 3.3).

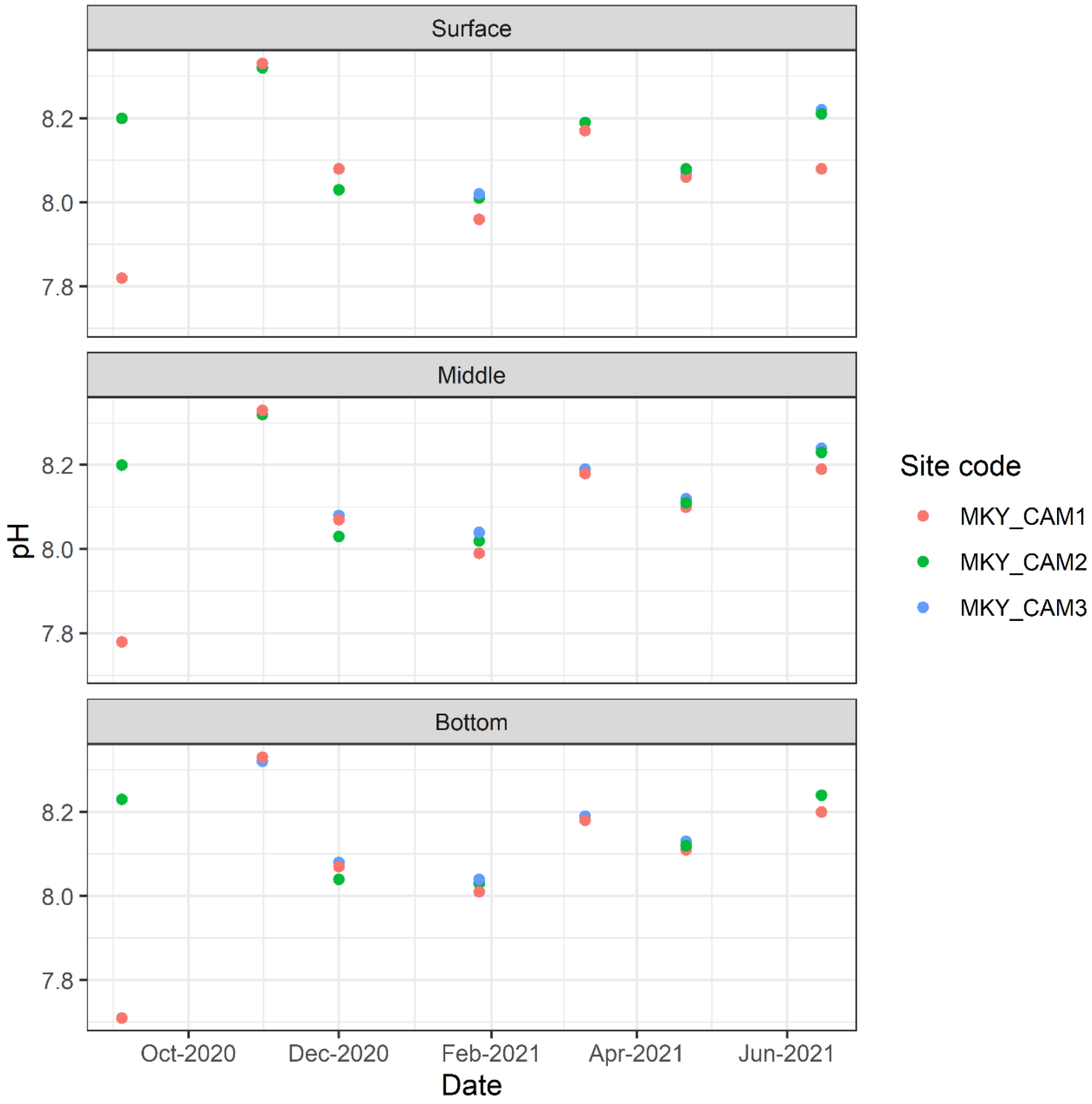

Figure 3.3 pH measured at surface, mid, and bottom depths pooled across all sampling events

3.1.4 Dissolved oxygen

Dissolved oxygen ranged between 85.3 to 107.7 % sat (Figure 3.4). There was no evidence of an oxycline in the waters at sites, with available oxygen generally the same at the surface and bottom waters. This highlights that the waters in the region are generally well mixed, which is expected in these coastal areas.

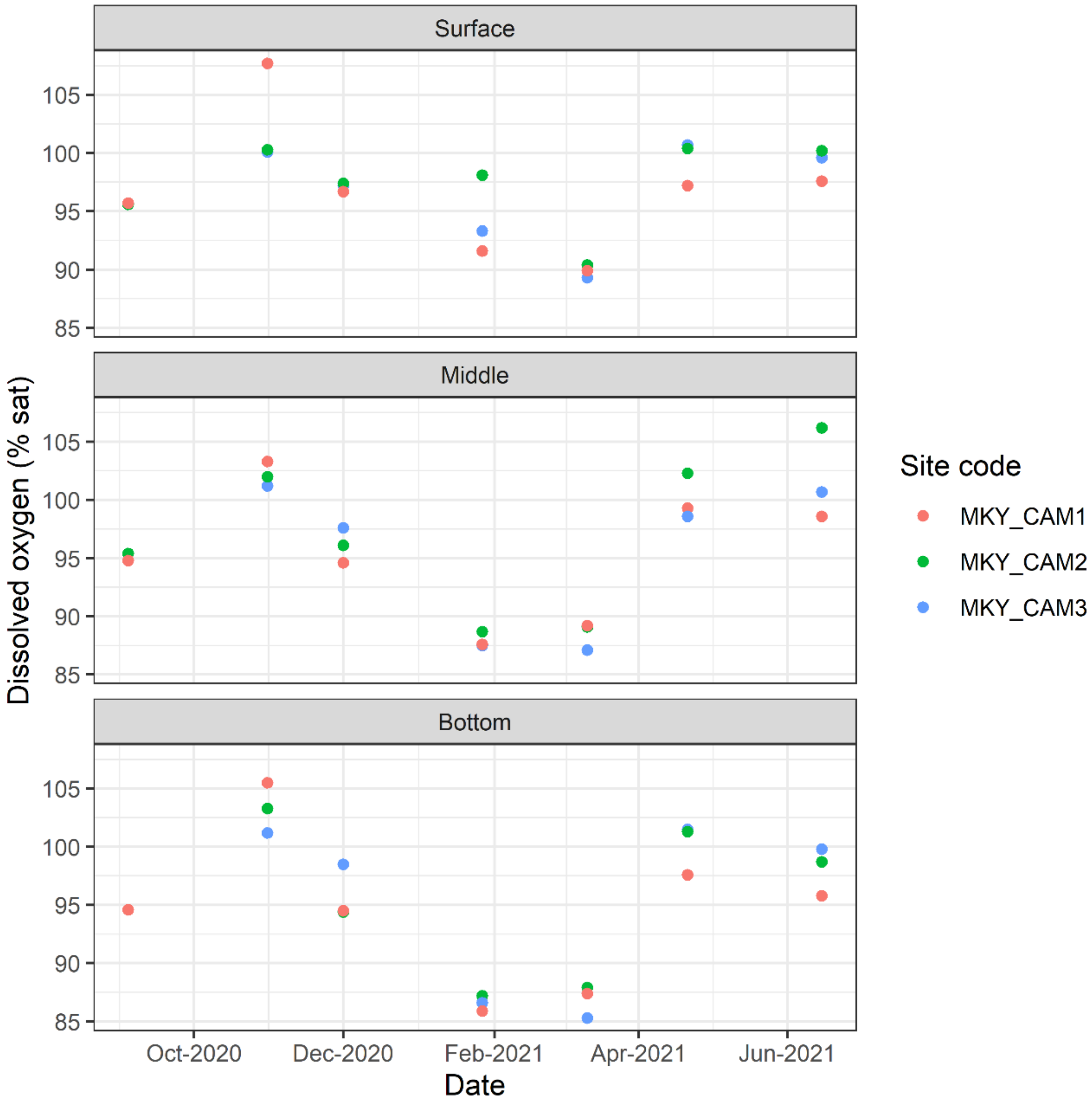

Figure 3.4 Dissolved oxygen percent saturation measured at surface, mid, and bottom depths pooled across all sampling events

3.2 Water sample analysis

3.2.1 Nutrients, water clarity and chlorophyll-*a*

For the purposes of this report, we only focus on particulate nitrogen (PN) and particulate phosphorus (PP) as these nutrient components are measured in the region more broadly (see Waltham et al., 2018). Total nitrogen, total phosphorus, total dissolved nitrogen, total dissolved phosphorus and nitrogen oxide (NOx) are also included in the full dataset. Particulate nitrogen (PN) concentrations ranged from 2 to 61 µg L^{-1} (Figure 3.5). Mean PN across the sites exceeded the GBRMPA guideline trigger value of 20 µg L^{-1} for all sampling events with the exception of December 2020 to March 2021, and June 2021. Particulate phosphorus (PP) concentrations ranged from <1 to 6 µg L^{-1} (Figure 3.6). Mean PP exceeded the GBRMPA guideline trigger value of 2.8 µg L^{-1} during September and December 2020, and March 2021.

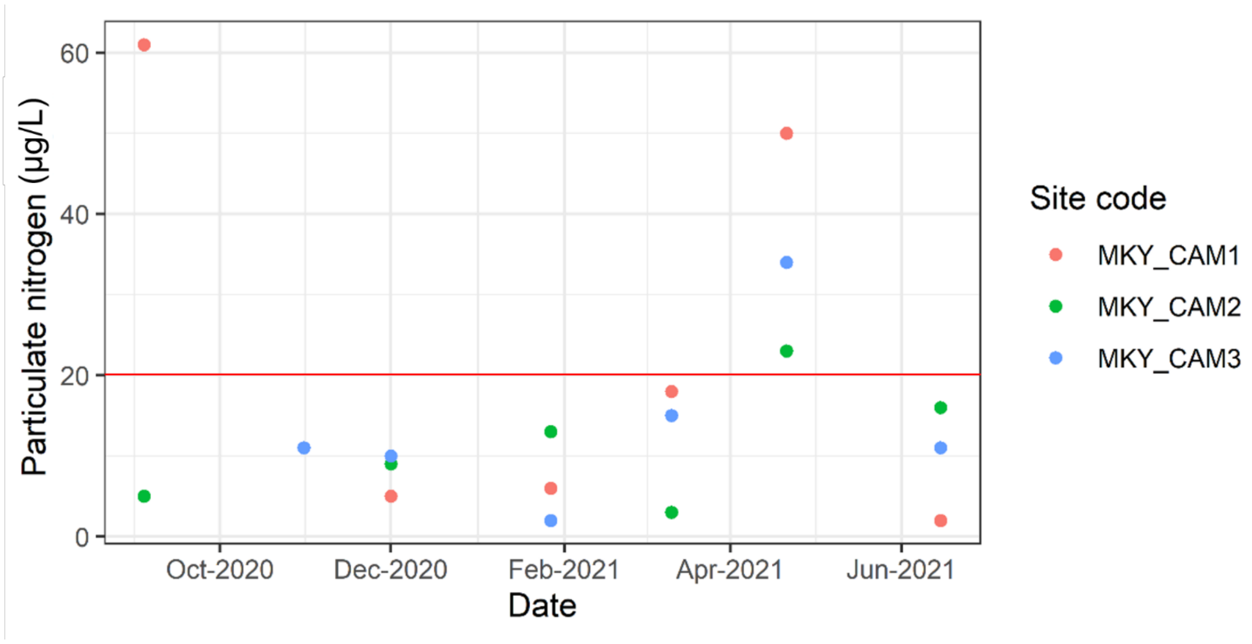

Figure 3.5 Particulate nitrogen (PN) concentrations measured in water samples collected from the three water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

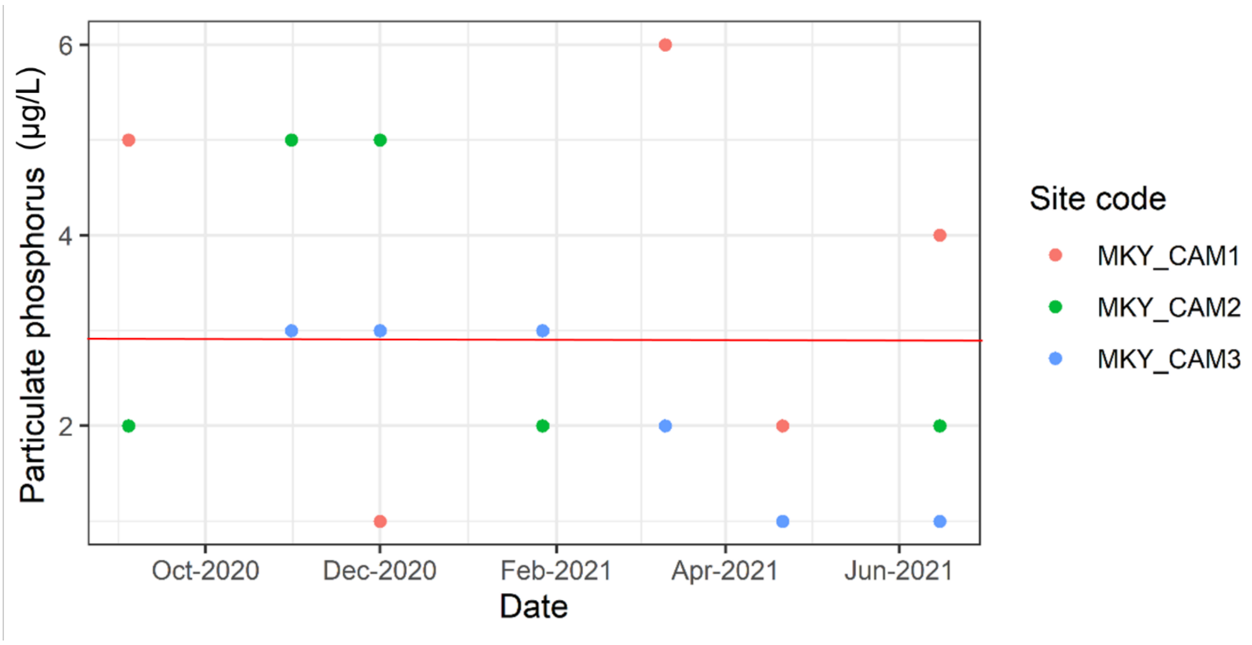

Figure 3.6 Particulate phosphorus (PP) concentrations measured in water samples collected from the water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

Total suspended solids ranged from 1.0 to 15 mg L^{-1} (Figure 3.7). Mean TSS across the sites exceeded the GBRMPA guideline trigger value of 2.0 mg L^{-1} for all sampling events. Secchi disk depth ranged from 1.1 to 3.5 m over the reporting period (Figure 3.8). Chlorophyll-*a* concentrations ranged from 0.22 to 13.27 µg L^{-1} (Figure 3.9). Chl-*a* concentrations were highest in December 2021.

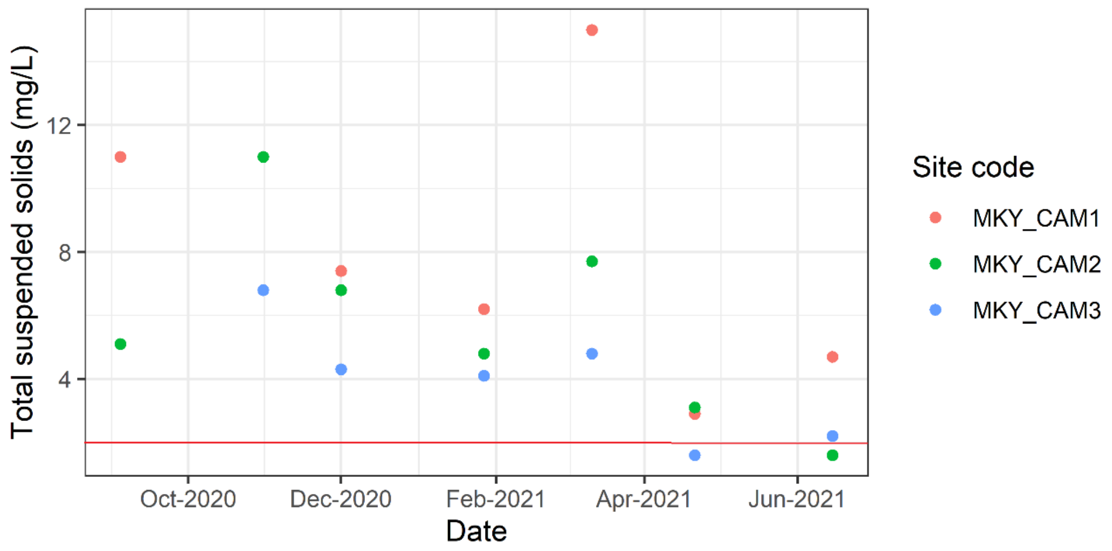

Figure 3.7 Total suspended solids (TSS) measured in water samples at the three water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

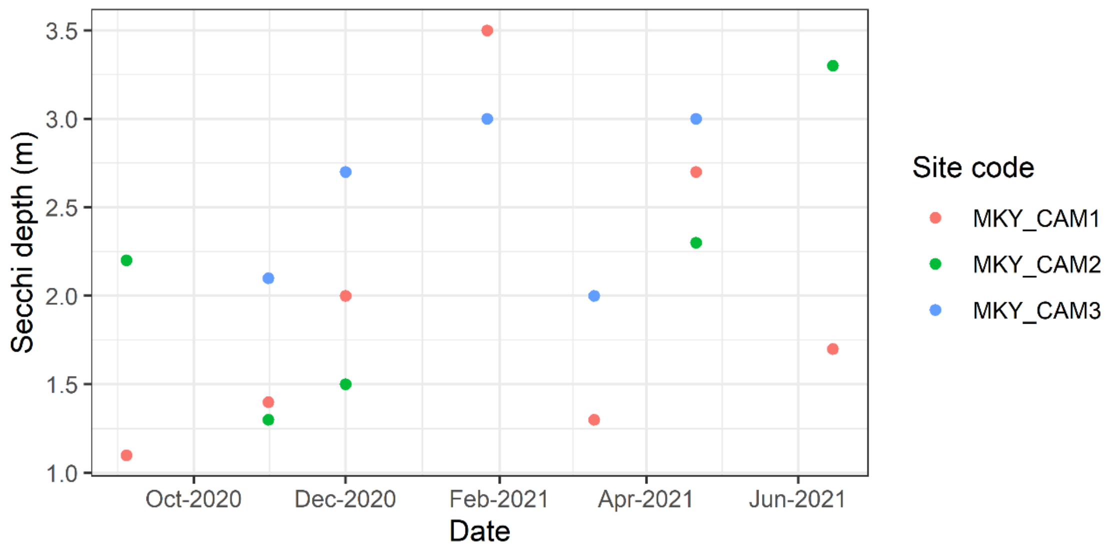

Figure 3.8 Secchi disk depth recorded at the three water quality sites throughout the reporting period.

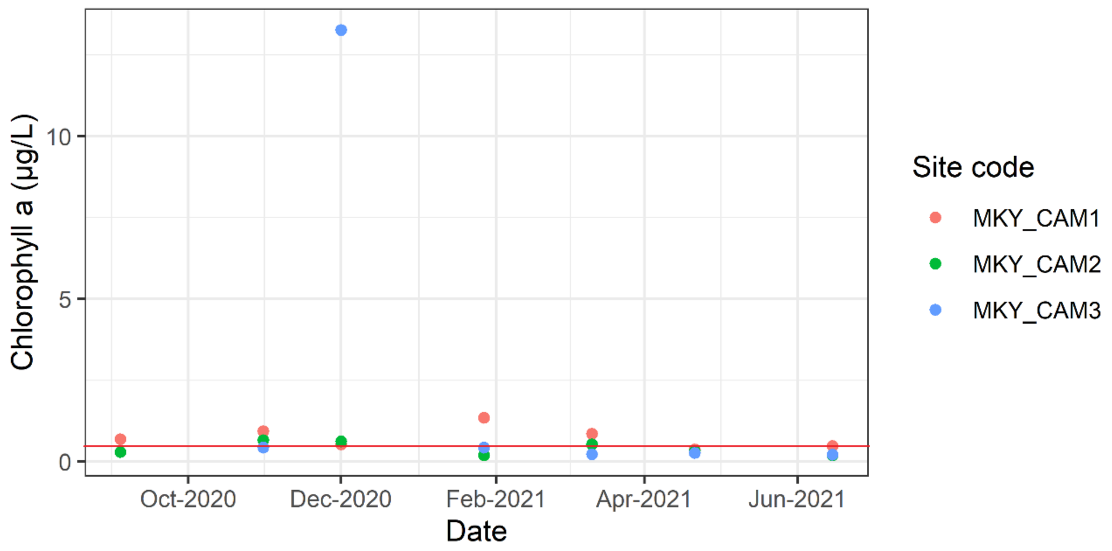

Figure 3.9 Chlorophyll-*a* concentrations measured in water samples collected from the three water quality sites throughout the reporting period. Horizontal red line indicates the GBRMPA open coastal guideline trigger value.

3.2.2 Pesticides

Pesticide concentrations are presented in Table 3.2. 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 Diuron, and Ametryn were below guidelines. The insecticide Simazine was below the guideline, however, Atrazine was above the guideline.

Table 3.2 Pesticide concentrations measured in water samples collected from the three 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).

ED PPCP Water Concentration (ng/L)			
Site Name	Aquila Island	Aquila Island	Aquila Island
Deployment Date	1/12/2020	27/01/2021	11/03/2021
Retrieval Date	27/01/2021	11/03/2021	21/04/2021
Days Deployed	57	43	41
Flow Rate (m/s)	0.2	0.268	0.285
Sample Name	AQ1220_ED_AQA	AQ0121_ED_AQA	AQ0321_ED_AQA
2,4-D	*<0.570*	*<0.670*	*<0.690*
Ametryn	*<1.03*	*<1.21*	*<1.24*
Atrazine	**0.250**	**0.460**	**0.180**
Atrazine desethyl	*<0.160*	*<0.190*	*<0.200*
Atrazine desisopropyl	*<0.140*	*<0.160*	*<0.160*
Bromacil	*<0.090*	*<0.110*	*<0.110*
Diuron	*<0.160*	*<0.190*	*<0.200*
Fluazifop	*<0.010*	*<0.020*	*<0.020*
Fluometuron	*<0.100*	*<0.120*	*<0.120*
Fluroxypyr	*<0.140*	*<0.160*	*<0.160*
Haloxyfop	*<0.070*	*<0.080*	*<0.090*
Hexazinone	*<0.130*	*<0.160*	*<0.160*
Imazapic	*<0.140*	*<0.160*	*<0.160*
Imidacloprid	*<0.140*	*<0.160*	*<0.160*
MCPA	*<0.410*	*<0.490*	*<0.500*
Metolachlor (S+R)	*<0.130*	*<0.160*	*<0.160*
Metribuzin	*<0.140*	*<0.160*	*<0.160*
Metsulfuron methyl	*<0.140*	*<0.160*	*<0.160*
Prometryn	*<0.220*	*<0.260*	*<0.270*
Propazine	*<0.140*	*<0.160*	*<0.160*
Simazine	*<0.090*	*<0.110*	*<0.110*
Tebuconazole	*<0.140*	*<0.160*	*<0.160*
Terbuthylazine	*<0.130*	*<0.150*	*<0.150*
Terbutryn	*<0.880*	*<1.03*	*<1.06*

3.3 Multiparameter water quality

The multiparameter instrument deployed at the Aquila site (MKY_CAM1) measured water temperature, depth, RMS water depth, photosynthetically active radiation, and turbidity. Suspended sediment concentration and depositional rate were calculated from turbidity values. An instrument was unable to be recovered from the December 2020 deployment so there is a gap in data from 06/12/2020 to 11/01/2020. Instruments were removed from the water during initial response to COVID-19 travel restrictions leaving a gap in the dataset from 03/04/2020 to 27/05/2020.

3.3.1 Temperature

Water temperature ranged from 18.76 to 29.36 °C (median 24.98 °C) and primarily had a seasonal component, but also shorter term fluctuations most probably due to local oceanological conditions (i.e. upwelling, tides, currents, weather) (Figure 3.10). The coolest month was July 2020 with a mean temperature of 19.6 °C, warmest month was March 2021 with a mean temperature of 28.1 °C.

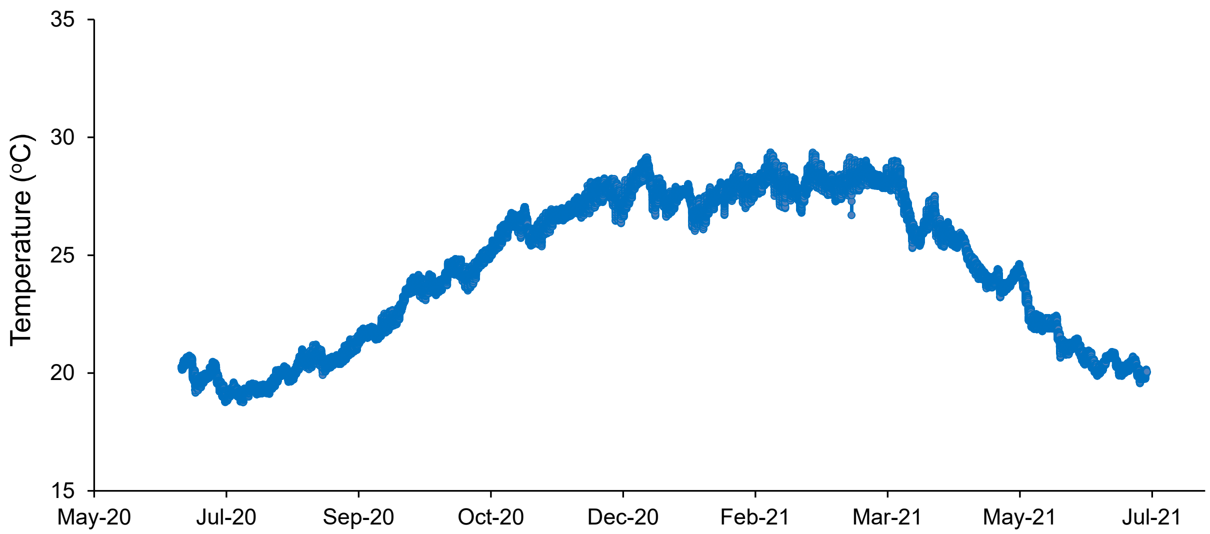

Figure 3.10 Water temperature (°C) measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

3.3.2 Water depth and wave height

The water depth ranged from 2.35 to 12.84 m (median 5.89 m) (Figure 3.11). Water depth was primarily driven by tidal components, with the Mackay region experiencing macro-tidal conditions. Step changes in water depth Root mean square water height ranged from 0 to 0.26 m (median 0.01 m) (Figure 3.12)

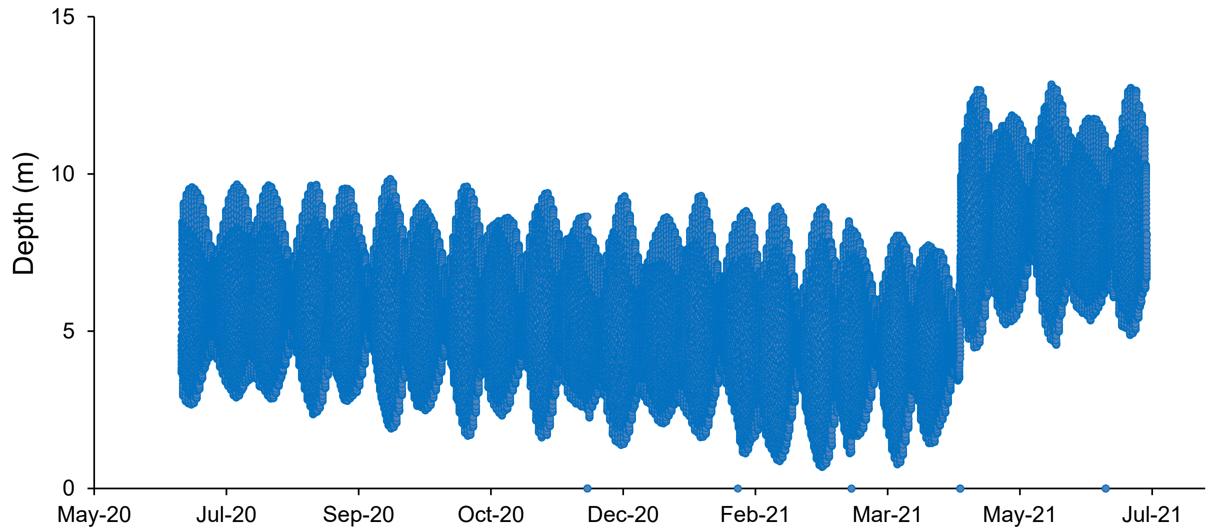

Figure 3.11 Water height (m) measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

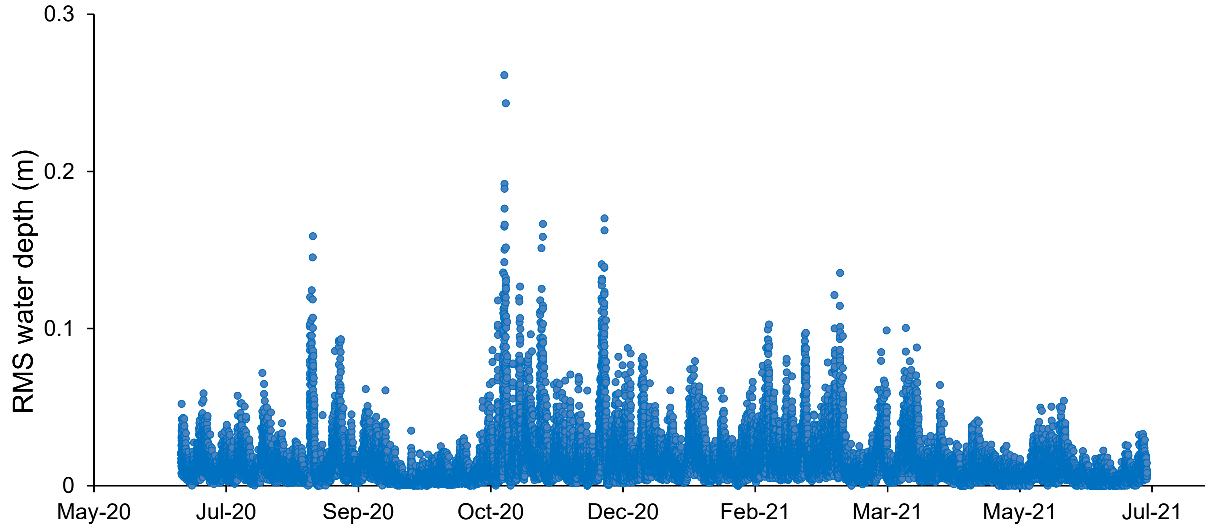

Figure 3.12 Root mean square water height (m) measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

3.3.3 Photosynthetically active radiation

Photosynthetically active radiation ranged from 0 (i.e. night-time) to 792 µmol m^{-2} s^{-1} (Figure 3.13). The highest ambient light conditions in the benthic environment occurred during December 2020 and January 2021. The PAR measured in the benthic environment is influenced by time of day, weather conditions, and water attenuation which in turn is influenced by turbidity, suspended sediment concentration and the water depth at the time of measurement (which is heavily influenced by the stage in the tidal cycle). In general benthic PAR levels are higher during neap tides, and lower during spring tides.

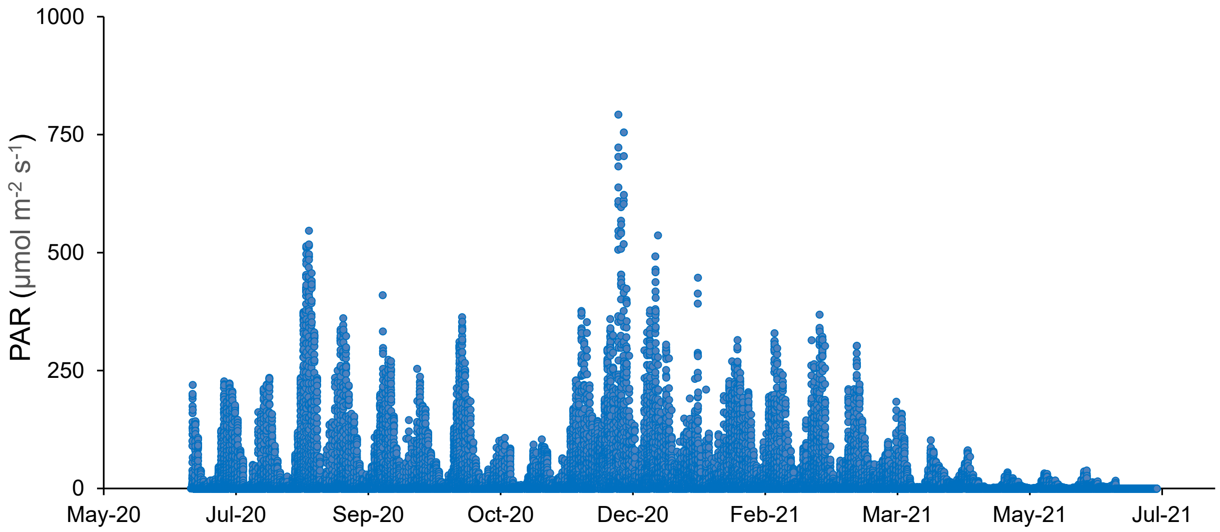

Figure 3.13 Photosynthetically active radiation (µmol m^{-2} s^{-1}) measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

3.3.4 Turbidity, suspended sediments, and sediment deposition

Turbidity measured at the seafloor had a median value of 7.0 NTUe equivalents (Figure 3.14). There was a certain amount of periodicity in turbidity values at MKY_CAM1 (Aquila Island), which we attribute to primarily a physical response to water depth throughout the tidal cycle (i.e. resuspension in shallow water). In general turbidity values are higher during spring tides, and lower during neap tides. Suspended sediment concentration at MKY_CAM1 (Aquila Island) derived from turbidity measurements is presented in Figure 3.15. Note that the turbidity sensor fouled in October 2020, February 2021, and June 2021, coinciding with high RMS values. It is probable that turbidity would have been higher than surrounding calm periods during those periods of missing data. The quantity of deposited sediment per 10 minute interval is presented in Figure 3.16. The maximum deposited sediment over a 10 minute period was 19.1 mg cm^{-2}, which is lower than the previous reporting period (38.7 mg cm^{-2}).

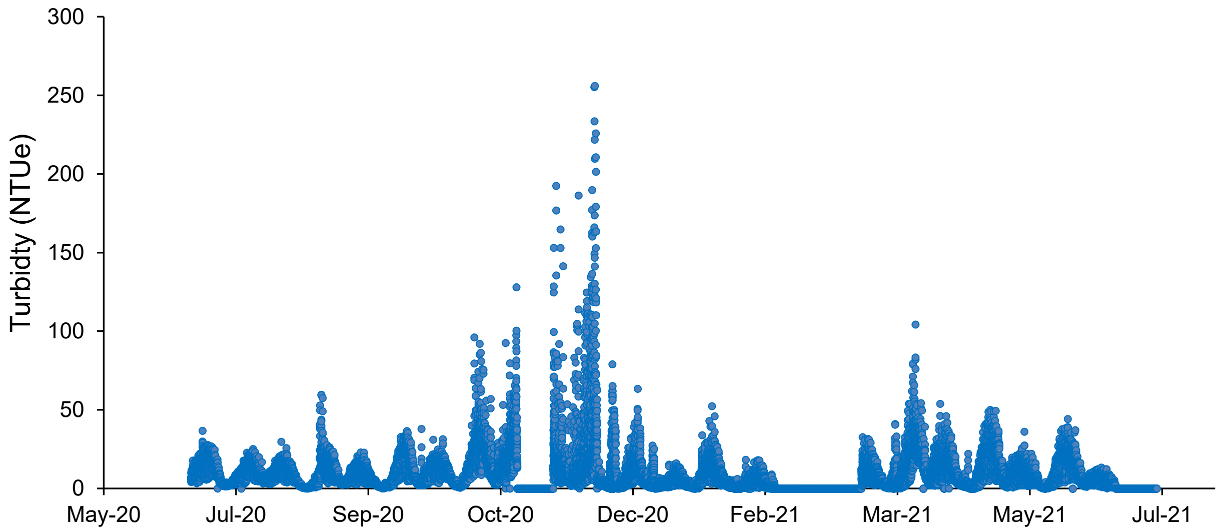

Figure 3.14. Turbidity (NTUe) measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

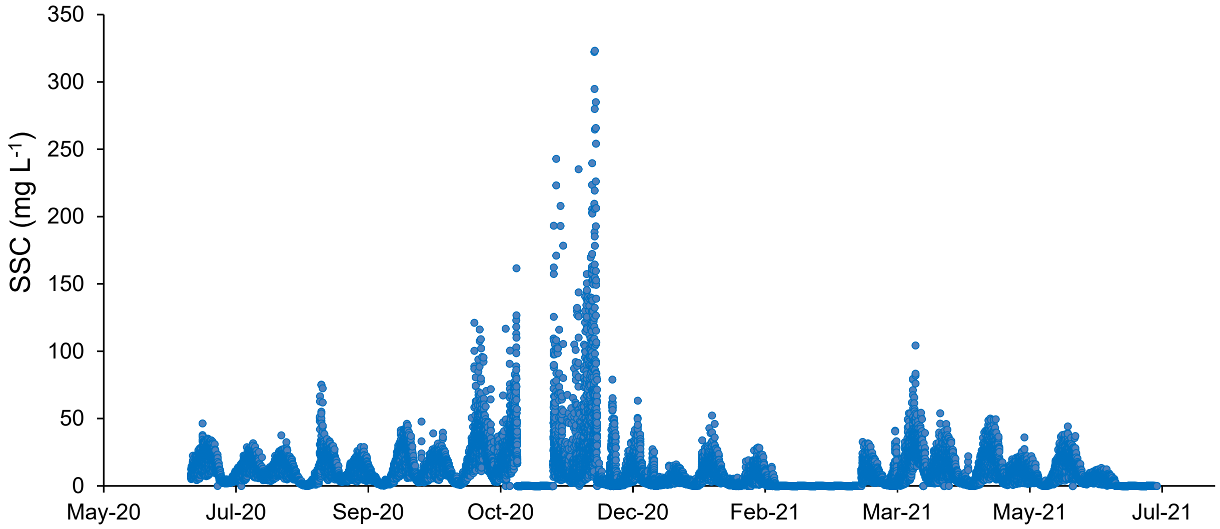

Figure 3.15 Suspended sediment concentration (mg L^{-1}) calculated from turbidity measurements at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

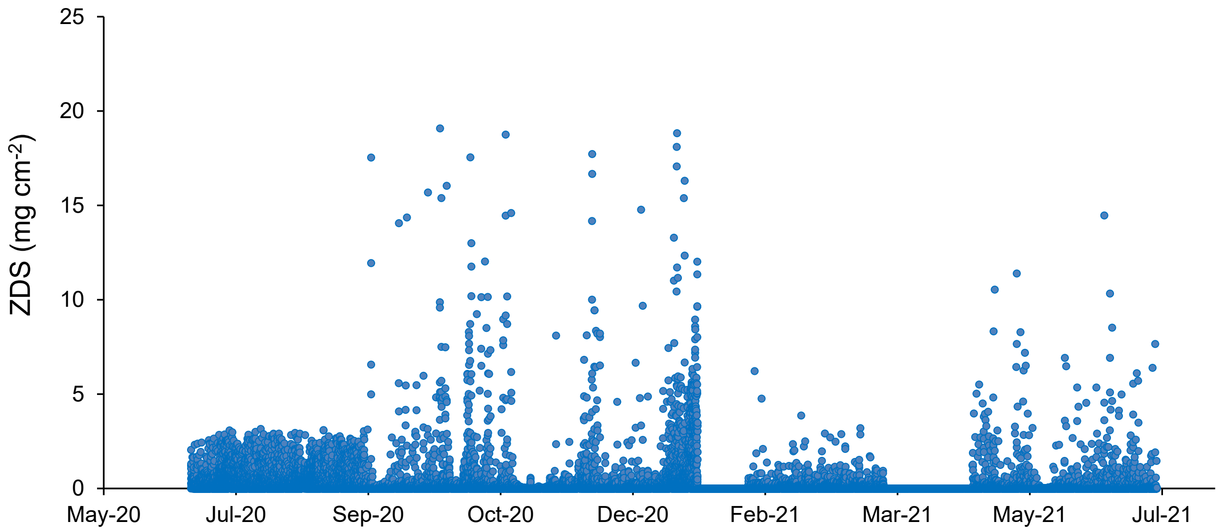

Figure 3.16 Sediment deposition (ZDS) (mg cm^{-2}) per 10 minute interval at MKY_CAM1 (Aquila Island) for the 2020-2021 period.

4 GENERAL CONCLUSIONS

4.1.1 Climatic conditions

- The 2020-2021 survey period covered an average wet season for the region; future years could see lower or higher rainfall patterns which could contribute to very different results compared to these data here.

4.1.2 Ambient water quality

- The water column profile is well mixed for dissolved oxygen, temperature, electrical conductivity and pH. There is a seasonal pattern for water temperature, with highest temperatures recorded during the summer months, while winter months had much cooler conditions. This is expected in the region. Dissolved oxygen levels were also within the expected range, as was pH and electrical conductivity during this reporting period.
- Particulate nitrogen and phosphorus were elevated above guideline values during summer months
- Chlorophyll-*a* concentrations were highest in summer months and coincided with when nutrient concentrations are also high.

4.1.3 Turbidity

- In general turbidity values measured at Aquila Island were higher during spring tides, and lower during neap tides. Turbidity also increased during periods of heightened wave activity.

4.1.4 Photosynthetically active radiation (PAR)

- PAR levels are primarily driven by tidal cycles with fortnightly increases in PAR coinciding with neap tides and lower tidal flows. Larger episodic events which lead to extended periods of low light conditions are driven by a combination of strong winds leading to increases in wave height and resuspension of particles, and rainfall events resulting from storms leading to increased catchment flows, and an input of suspended solids. This summary seems to follow patterns in the previous reporting period (2019-2020).

4.1.5 Pesticides and herbicides

- Atrazine was the only herbicide that was detected during the reporting period using passive samplers.

5 REFERENCES

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

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

DEHP (2013) Monitoring and Sampling Manual 2009. Environmental Protection (Water) Policy 2009. Version 1 September 2009. Queensland, Department of Environment and Resource Management, Queensland Government.

GBRMPA (2013) Great Barrier Reef Region Strategic Assessment Report. Australian Government, Great Barrier Reef Marine Park Authority. pp. 636.

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

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

Ridd, P.V., Day, G., Thomas, S., Harradence, J., Renagi, O., Fox, D., Bunt, J., Renagi, O., Jago, C. (2001) Measurement of sediment deposition rates using an Optical Backscatter Sensor. Estuarine Coastal and Shelf Science, 52, 155-163.

Standards Australia (1998) Water Quality – Sampling. Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples. AS/NZS 5667. 1:1998. Standards Australia, Homebush.

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

Waltham, N., Buelow, C., Whinney, J., Macdonald, R., Olsen, A., (2018) 'Port of Mackay and Hay Point Ambient Marine Water Quality Monitoring Program (July 2017 – July 2018)', Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 18/18, James Cook University, Townsville, Australia, 121 pp.

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

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