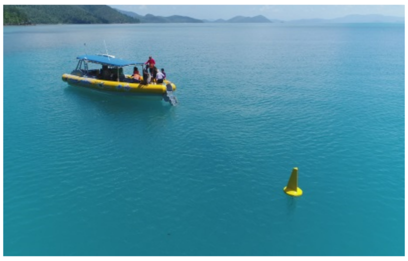
Whitsunday Water Quality Monitoring Blueprint for Tourism Operators: Annual report 2019-2020

Jordan Iles and Nathan Waltham

Report No. 20/22

May 2020



Whitsunday Water Quality Monitoring Blueprint for Tourism Operators: Annual report 2019-2020

A Report for Reef Catchments (Mackay Whitsunday Isaac) Limited

Report No. 20/22

May 2020

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1 INTRODUCTION

1.1 Background

The Whitsunday region of the Queensland coast encompasses numerous islands, bays, and inshore reef and is an important gateway to the outer barrier reef. Of concern in the region is an apparent decline in the water quality, demonstrated in water quality monitoring results (Gruber et al., 2019) and supported by anecdotal evidence from local residents and tourism operators. For example, the GBRMPA marine monitoring program (MMP) long-term water quality index for the Whitsundays region has been in decline since monitoring started in 2007, with water quality in the region currently assessed to be 'moderate' (Figure 1). The rate of decline in water quality has also been more rapid in the Mackay-Whitsunday region compared to other regions to the north (Figure 1). However, the annual condition index instigated in 2015 which is sensitive to year-to-year variability indicates some improvement in water quality has been made. The tourism industry have expressed that they often feel in the dark, regarding reef or marine monitoring and its outcomes.

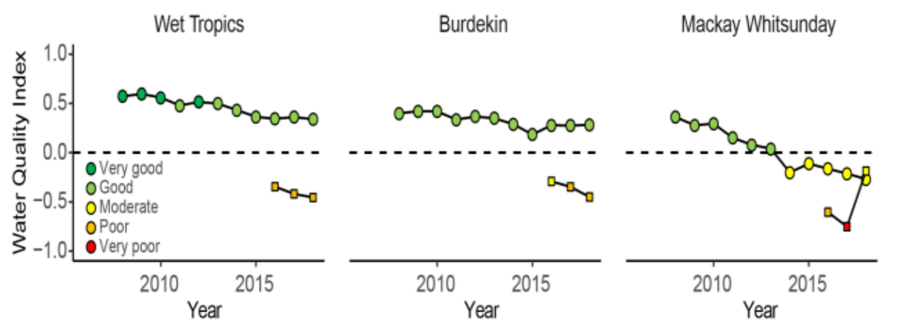

Figure 5. *In situ* **water quality index for the Wet Tropics, Burdekin and Mackay Whitsunday regions from 2007-2008 to 2017-2018 circle symbols indicate the 'long-term' trend since the start of monitoring based on an initial program design. From 2015 a revised program design was implemented that includes increased temporal and spatial sampling and compares water quality values to wet and dry season water quality guidelines where available (squares). Colour coding: ■ = very good (> 0.5 to 1), ■ = good (> 0 to 0.5), ■ = moderate (<0 to -0.33), ■ = poor (< -0.33 to -0.66), ■ = very poor (< -0.66 to -1). Data source: (Gruber et al. 2019).**

Figure 1. Water quality index. Figure and caption reproduced from the 'Reef water quality report card 2017 and 2018' (GBRMPA, 2019).

1.2 Citizen science project

TropWATER (Centre for Tropical Water and Aquatic Ecosystem Research), James Cook University, has been commissioned to assist Reef Catchments (Mackay Whitsunday Isaac) and Whitsunday Tourism Operators establish an ambient marine water quality program for the Whitsunday region as part of the Whitsunday Water Quality Monitoring Blueprint for Tourism Operators program. The Whitsunday Water Quality Monitoring Blueprint for Tourism Operators is funded by the partnership between the Australian Government's Reef Trust and the Great Barrier Reef Foundation.

This citizen science project has brought together partners from a cross section of the Whitsunday community, the Partners include Reef Catchments, the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership, North Queensland Bulk Ports, TropWATER (Centre for Tropical Water and Aquatic Ecosystem Research) at James Cook University (JCU), and Whitsunday Tourism Operators — Whitsunday Bareboat Operators Association (WBOA), Whitsunday Charter Boat Industry Association (WCBIA).

The project aims to link together citizen science and research initiatives for reef health with water quality to collaboratively develop a framework for connecting citizen science work with the regional report card partnership hosted by Reef Catchments. This project focuses on utilising proven research, science experience and methodology to train Whitsunday tourism operators to collect marine monitoring data at key locations. The tourism community has a vested interest in the long term health and functionality of the Great Barrier Reef (GBR), and are well positioned to lead solution based monitoring, evaluation, and effective communication.

1.3 Project aims and objectives

The aim of the citizen science program is to establish two new water quality monitoring sites in the Whitsunday region which are then regularly sampled and maintained by Tourism Operators during their day-to-day activities. The objective of the program is to give Tourism Operators the direct opportunity to engage in the collection of water quality data throughout the region.

2 METHODOLOGY

2.1 Water quality monitoring sites

Two water quality monitoring sites were established in the Whitsunday region in February 2020. Sites were selected at Cairn Beach (WH1) and Tongue bay (WH2) with input from tourism operators (Figure 2, Table 1). A third site at Blue Pearl Bay (WH3) has also been identified for future expansion of the program. An instrument (data logger) was deployed at each site to continuously collect high frequency data. Water sampling was conducted at the two sites approximately every 4 weeks coinciding with site maintenance and instrument swap-outs. The Fieldwork component of the monitoring program was performed by tourism operators following a schedule (Table 2).

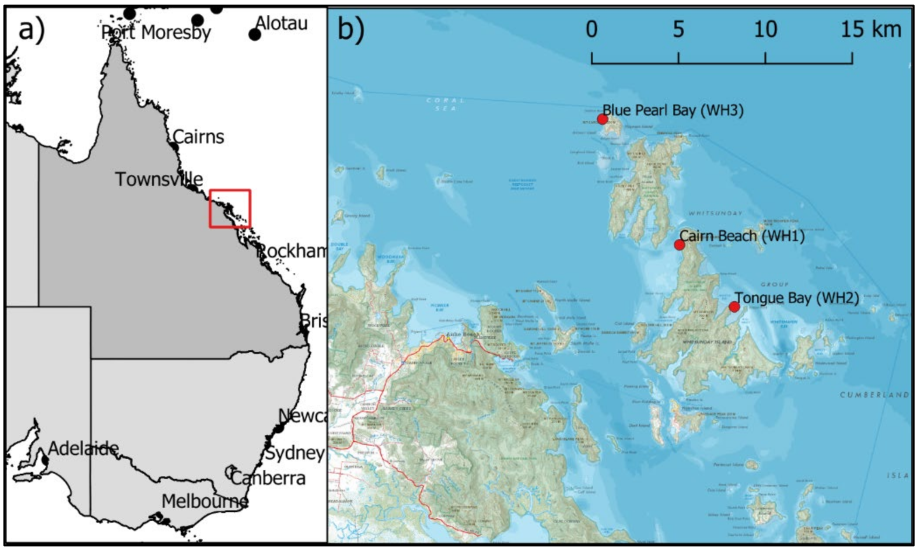

Figure 2. a) The Whitsunday region (red bounding box) is located on the Queensland coast, b) Location of monitoring sites as part of this project in the Whitsunday region. The sites are Cairn Beach (WH1), Tongue Bay (WH2), and Blue Pearl Bay (WH3). Note Blue Pearl Bay may be included as a third site in the future but is currently not monitored. The three monitoring sites are located in 'open coastal' waters.

Table 1. Water quality monitoring site locations selected for the Whitsunday Water Quality Monitoring Blueprint for Tourism Operators program. Note Blue Pearl Bay has been identified as part of a future expansion of the program

Site name	Site code	Depth (m)	Lat	Long	Date established
Cairn Beach	WH1	10.4	-20.233633	149.017825	4/02/2020
Tongue Bay	WH2	7.7	-20.161447	148.955416	4/02/2020
Blue Pearl Bay	WH3	-	-20.233633	149.017825	-

Table 2. Monitoring schedule for the first quarter of 2020.

Event	Date scheduled	Cairn Beach (WH1)	Tongue Bay (WH2)
a	04/02/2020	Ocean Rafting / TropWATER	Ocean Rafting / TropWATER
b	04/03/2020	True Blue	Red Cat
-	31/03/2020*	Southern Cross	Southern Cross (Bullet Boats)
-	28/04/2020*	Tallship adventures	Ocean Rafting
c	11/05/2020	Ocean Rafting	Ocean Rafting

*Note: The March and April monitoring events were postponed due to COVID-19 restrictions.

Training was provided to tourism operators over two days in February and March 2020 by TropWater staff. Operators were trained in how to perform instrument maintenance, collect water samples and complete field datasheets (Figure 3). All measurements and samples were collected by tourism operators.

Figure 3. Tourism operators receiving training out on the water and in a class environment. Photos courtesy of Reef Catchments.

2.1.1 Loggers

A calibrated nephelometer was deployed on the seafloor at each site to record water quality measurements over the deployment period (Figure 4). The instrument measures water temperature, pressure (depth), photosynthetically active radiation (PAR), and turbidity at a 10 min interval. The nephelometer was retrieved and a replacement instrument installed at a 4 week period.

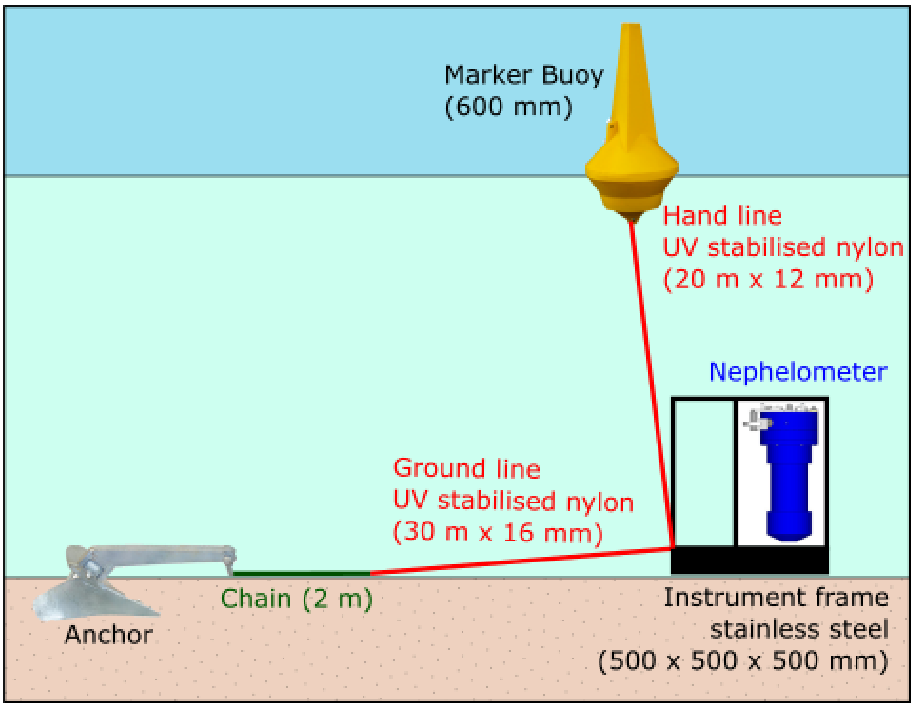

Figure 4. Diagram showing instrument deployments

Water temperature

Water temperature values are obtained with a thermistor that records measurements every 10 minutes. The sensor is installed in a bolt that protrudes from the instrument and gives sensitive temperature measurements. Collecting temperature data is useful for examining changes in water temperature in relation to time of day, tidal movements, seasonal patterns, and in response to weather events. Temperature gives an indication of these physical processes occurring, and is useful for assessing environmental conditions. Temperature regulates the rate that biological processes occur and is an especially useful parameter to observe in parallel with monitoring for coral bleaching.

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 suspended sediment concentration (SSC) for sites where a relationship has been established between turbidity 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.

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 the daily light integral (DLI) the sum of 10 min PAR measurements (µmol m^{-2} s^{-1}) is multiplied by the measurement interval in seconds (10 min × 60 sec = 600 sec) and divided by 1,000,000 to give DLI (mol m^2 d^{-1}). PAR indicates the amount of light reaching benthic communities where the logger is located and may reflect either weather conditions (i.e. cloud cover, haze), water clarity, or both. Elevated turbidity, algal blooms, or suspended sediment in the water column will cause an increase in the amount of light attenuated through the water column, and hence a reduction in PAR.

Turbidity

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 hourly by a mechanical wiper allowing for long deployment periods where bio-fouling would otherwise compromise measurements.

Turbidity is an indicator of water clarity, with higher turbidity readings indicating lower water clarity, while readings approaching zero indicate clear water. The international turbidity standard ISO7027 defines NTU for 90 degree scatter, however, the Marine Geophysics Laboratory instruments used throughout this monitoring program obtain an NTU equivalent value (NTUe) using 180 degree backscatter to allow for more effective cleaning (Larcombe et al., 1995). Because particle size influences the angular scattering functions of incident light (Bunt et al., 1999; Conner & De Visser, 1992; Ludwig & Hanes, 1990; Wolanski et al., 1994), instruments using different scattering angles may provide different units of turbidity. Hence, direct comparison between instruments obtaining turbidity in different units is not possible. Nonetheless turbidity is useful in observing relative changes in water clarity.

2.1.2 Analysis of water samples

Sampling methodology, sample bottles, preservation techniques and analytical methodology (NATA accredited) were in accordance with standard methods (i.e. DES, 2018; 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. Water was passed through a 0.45 µm disposable membrane filter (Sartorius), fitted to a sterile 60 mL syringe (Livingstone), and placed into 10 mL sample tubes for nutrient analysis in the laboratory. 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'. The concentration of Chlorophyll *a* in the water column is used as an indicator of the amount of phytoplankton (algae) present.

Water samples are analysed using defined analysis methods and detection limits (Table 3). In summary, all nutrients were analysed using colorimetric method on OI Analytical Flow IV Segmented Flow Analysers. Total nitrogen (TN), total phosphorus (TP), total dissolved nitrogen (TDN) and total dissolved phosphorus (TP) 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 (NO_x) was analysed using the methods 'Standard Methods for the Examination of Water and Wastewater, 4500-NO3- F. Automated Cadmium Reduction Method'.

Table 3. 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}
Nutrients			
	Total nitrogen (TN), total dissolved nitrogen (TDN), total phosphorus (TP), and total dissolved phosphorus (TDP)	Simultaneous 4500-NO_3^- F and 4500-P F analyses after alkaline persulphate digestion	25 µg N L^{-1}, 5 µg P L^{-1}
	Nitrate-nitrite (NO_x)	4500-NO_3^- F	1 µg N L^{-1}
Chlorophyll			
	Chlorophyll-*a*	10200-H	0.1 µg L^{-1}
	Phaeophytin-*a*	10200-H	0.2 µg L^{-1}

pH and electrical conductivity (EC) were measured in the laboratory with a benchtop meter. pH is a measure of how acidic or basic a solution is. pH < 7 indicating more acidic conditions, and pH > 7 more basic conditions. Seawater typically has a pH of 8.2 but ranges pH 7.5 to 8.5. A decrease in pH in the coastal marine environment may be an indication of freshwater mixing (i.e. short term events), changes in dissolved carbon dioxide concentrations causing ocean acidification (longer term changes in water chemistry), or to a lesser extent changes in temperature or salinity. Electrical conductivity (EC) is a measure of the electrical conductance of as solution and is reported in millisiemens per centimeter (mS cm^{-1}) in marine settings, but may sometimes be seen reported in microsiemens per centimeter (µS cm^{-1}) – generally for freshwater settings. An increase in the amount of salts in solution results in an increase in EC. Therefore EC generally correlates with salinity. EC is reported in place of salinity as it is a much more straightforward parameter to measure and is not affected by the types of salts present in the seawater. Total suspended solids (TSS) is a measure of the total amount of solid material in the water. TSS was determined gravimetrically by filtering a known amount of seawater with a glass fibre filter and weighing the residual solids retained on the filter following oven drying. TSS in marine settings mostly consists of sediment particles, although a proportion of TSS may also be made up of organic particles of biological origin (e.g. algae, bacteria, detrital material).

2.2 Regional climate

Air temperature (Figure 5) and rainfall observations were obtained from the Bureau of Meteorology Weather station Hamilton Island Airport (station 033106) for the first quarter of 2020 (Figure 6) and total rainfall calculated for each wet season from 2002 to present (Figure 7). The 2019-2020 wet season was an average year with 1040 mm rainfall. There was a period of cool weather and rainfall in late February, and anecdotal evidence of a marine heatwave in early February. Cyclone Gretel influenced local weather in mid-March (Figure 8) with TC Gretel being the most significant event during the current monitoring period. Tide data was obtained from the Transport and Main Roads Shute Harbour tidal station (P030003A) (Figure 9).

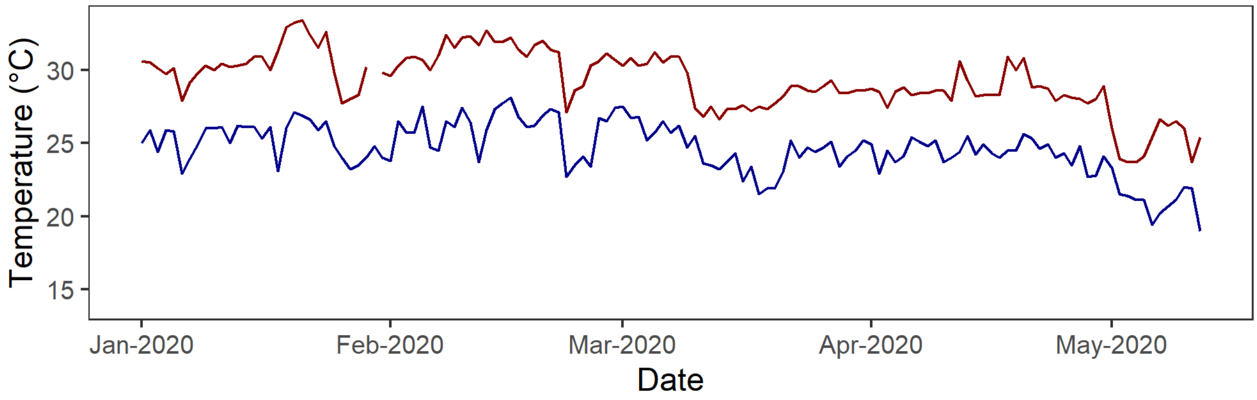

Figure 5. Daily maximum (red) and minimum (blue) temperature observations at Hamilton Island. Observations were drawn from the Bureau of Meteorology weather station at Hamilton Island Airport (station 033106)

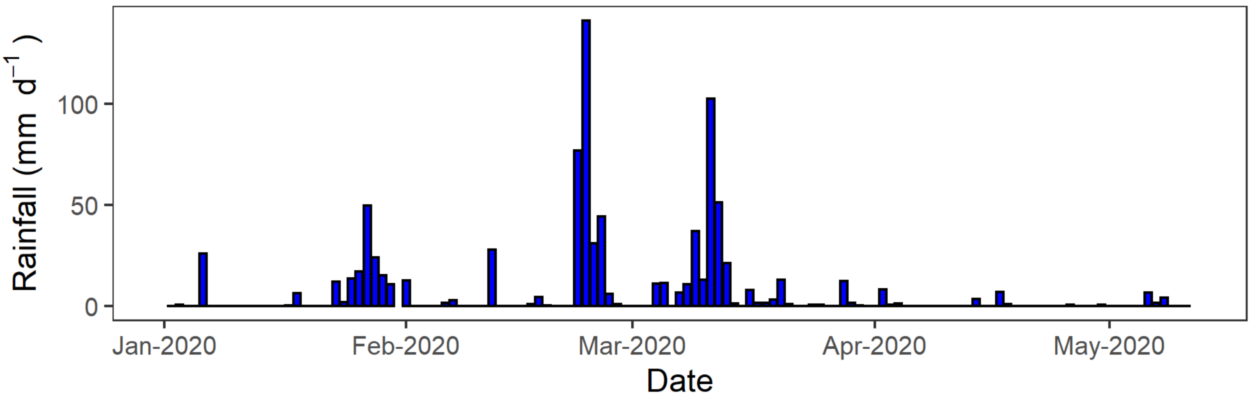

Figure 6. Daily rainfall amount at Hamilton Island. Observations were drawn from the Bureau of Meteorology weather station at Hamilton Island Airport (station 033106)

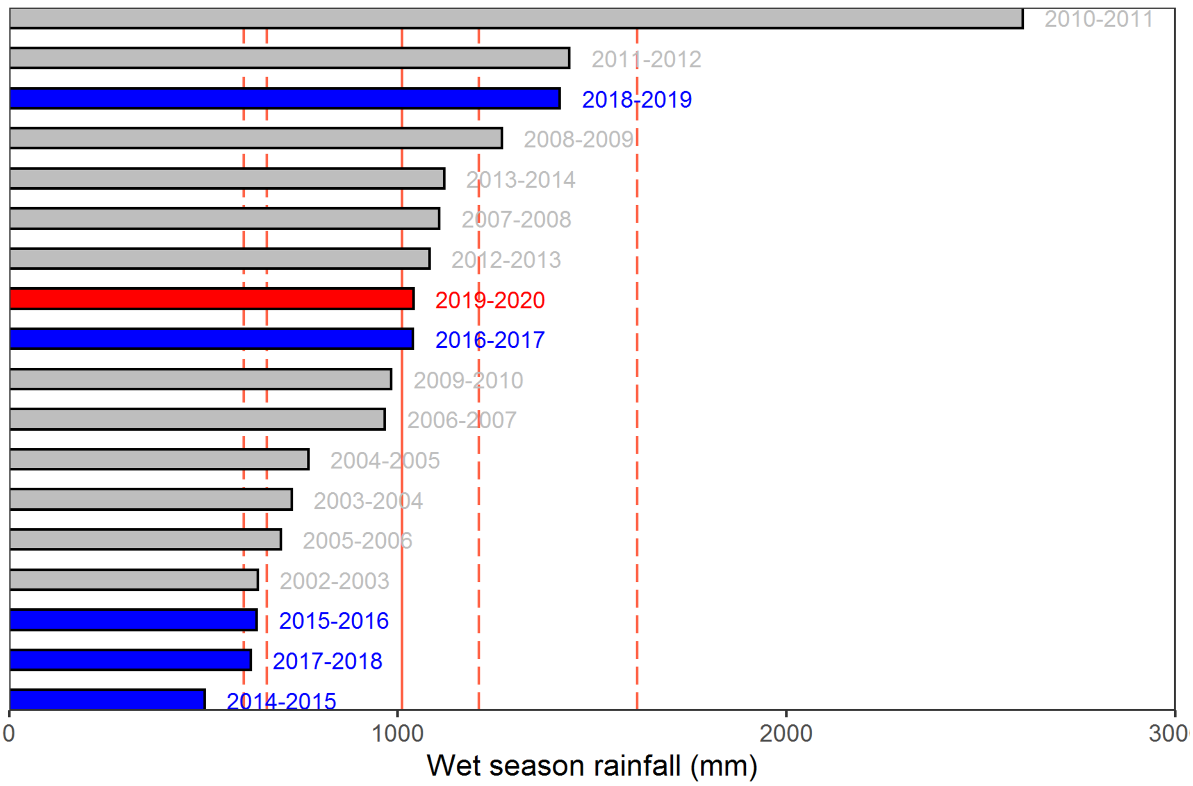

Figure 7. Wet season rainfall for the Whitsunday region ranked in order of decreasing total wet season rainfall (mm). Daily rainfall data was obtained from the Bureau of Meteorology Hamilton Island Airport weather station (Station number 033106). Totals were calculated for the wet season period 1st November to 31st March for each reporting year. Red bar represents the 2019/20 wet season, blue bars show total rainfall over the previous five wet seasons. Solid red line represents median wet season rainfall 2002-03 to 2019-20 and dashed red lines represent 5th, 20th, 80th, and 95th percentiles.

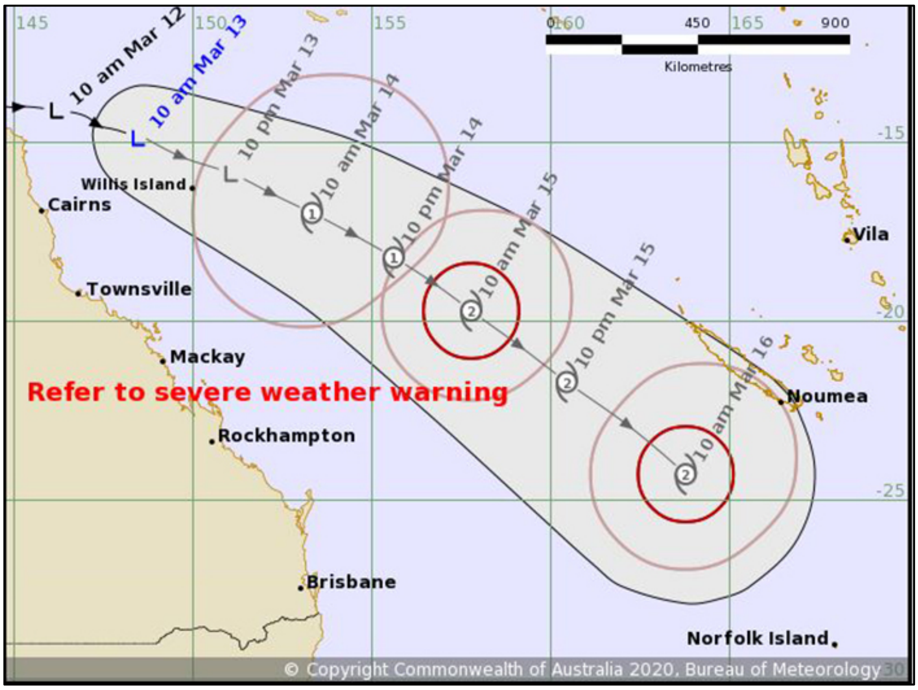

Figure 8. Tropical cyclone Gretel was a major influence for weather in the Whitsunday region in March 2020. While the cyclone remained well offshore it did cause local increased wind and wave activity.

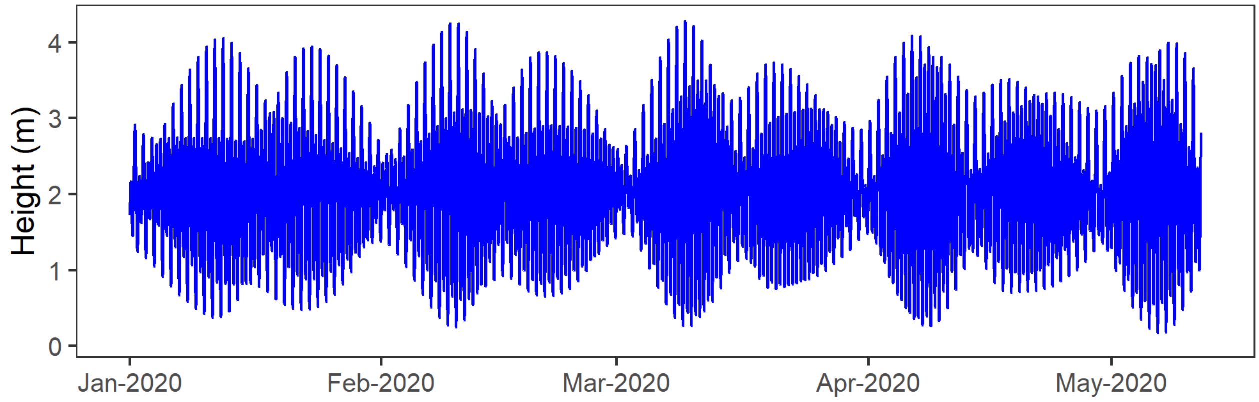

Figure 9. Tide height predictions at Shute Harbour (Station P030003A)

3 RESULTS

Note: Instruments were deployed and began logging water quality data on 4 February 2020. Instrument maintenance and water sampling was suspended at the end of March 2020 due to the COVID-19 pandemic. It was re-started on 11th of May 2020. Results from loggers have been included up to 11th of May but results from water samples from 11th of May were not available at the time of writing due to time taken for laboratory analysis.

3.1 Logger data

3.1.1 Water temperature

Water temperature ranged from 24.2 to 30.3 °C during the deployment period (Figure 10). Warmer water temperatures were measured at Tongue bay compared to Cairn Beach for the first week of deployment (approx. 0.5 °C difference), although temperatures became more similar between the two monitoring sites for the remainder of the deployment period. Sub-daily fluctuations in water temperature were likely attributed to a combination of both diel and tidal influences. There was an overall decrease in water temperature aligning with cooler weather and rainfall towards the end of February and again in early March.

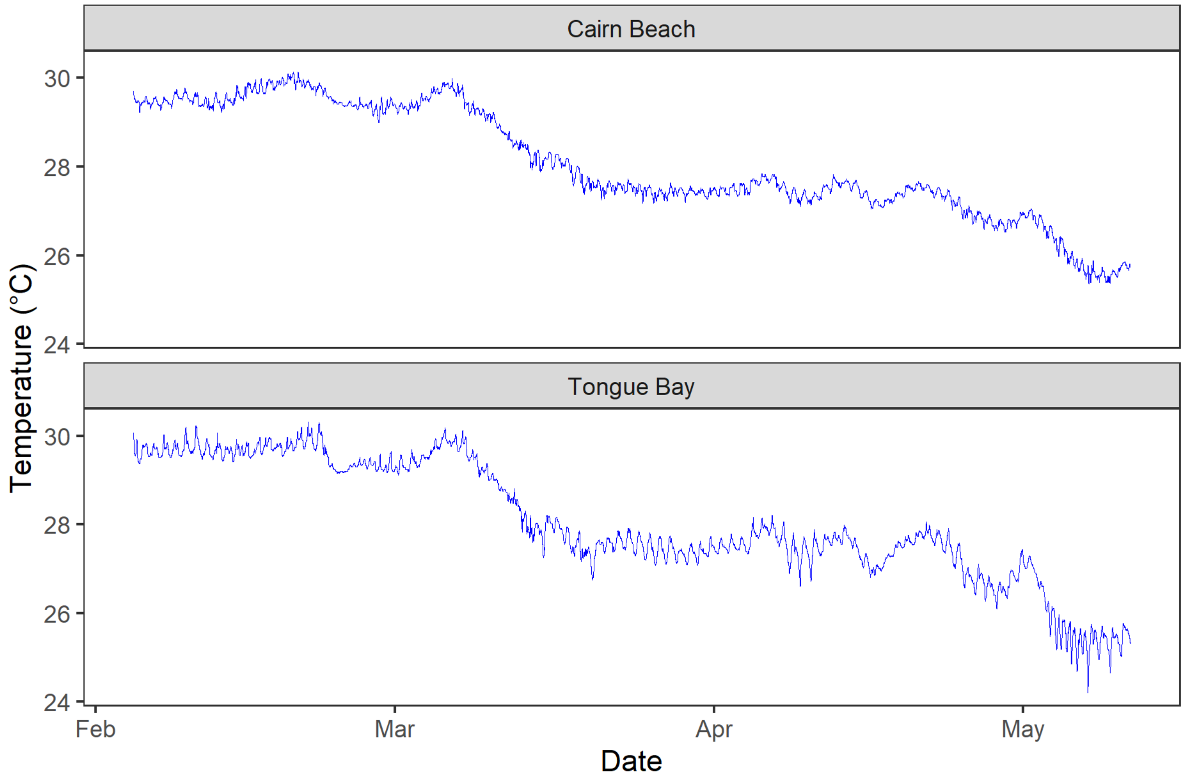

Figure 10. Water temperature measured at Cairn Beach and Tongue Bay

3.1.2 Water depth and wave height

The average water depth of the deployed logger was 10.4 m at Cairn Beach and 8.09 m at Tongue Bay (Figure 11). There was a slight change in the location and depth that the loggers were sitting between the two deployments, with the Cairn beach logger sitting in slightly shallower water during the second deployment, and the Tongue bay logger sitting in slightly deeper water. This can be seen in the figure as a small step occurring on 09/03/2020. Water depth at the two sites fluctuated by up to 3.8 m due to tides. The root means square (RMS) depth is shown in Figure 12. There was very little wave activity at the Cairn Beach site with RMS depth generally less than 0.005 m throughout the deployment period (average = 0.003 m). Tongue Bay was more exposed to wave energy with a mean RMS wave height of 0.0219 m. The most active period saw RMS wave height of up to 0.4 m and aligning with cooler weather and rainfall mid-March. Tropical cyclone Gretel was a major influence for weather in the Whitsunday region in March 2020. While the cyclone remained well offshore it did cause local increased wind and wave activity.

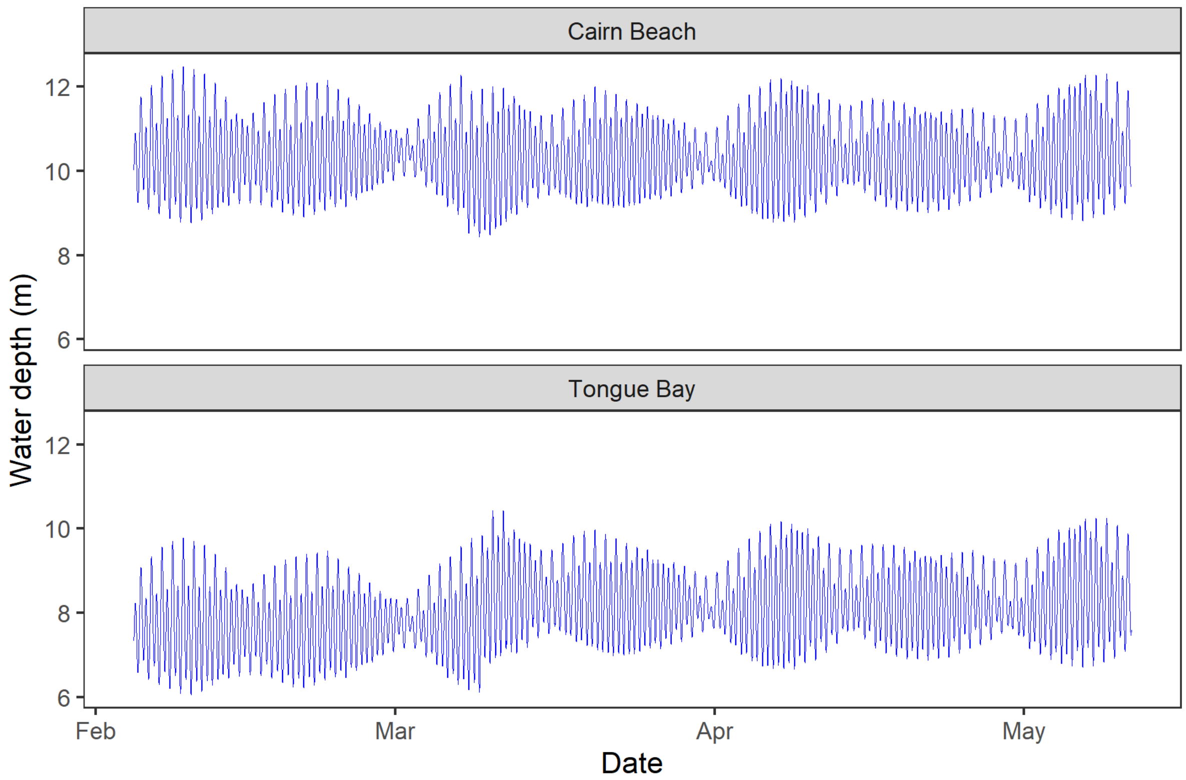

Figure 11. Water depth measured at Cairn Beach and Tongue Bay

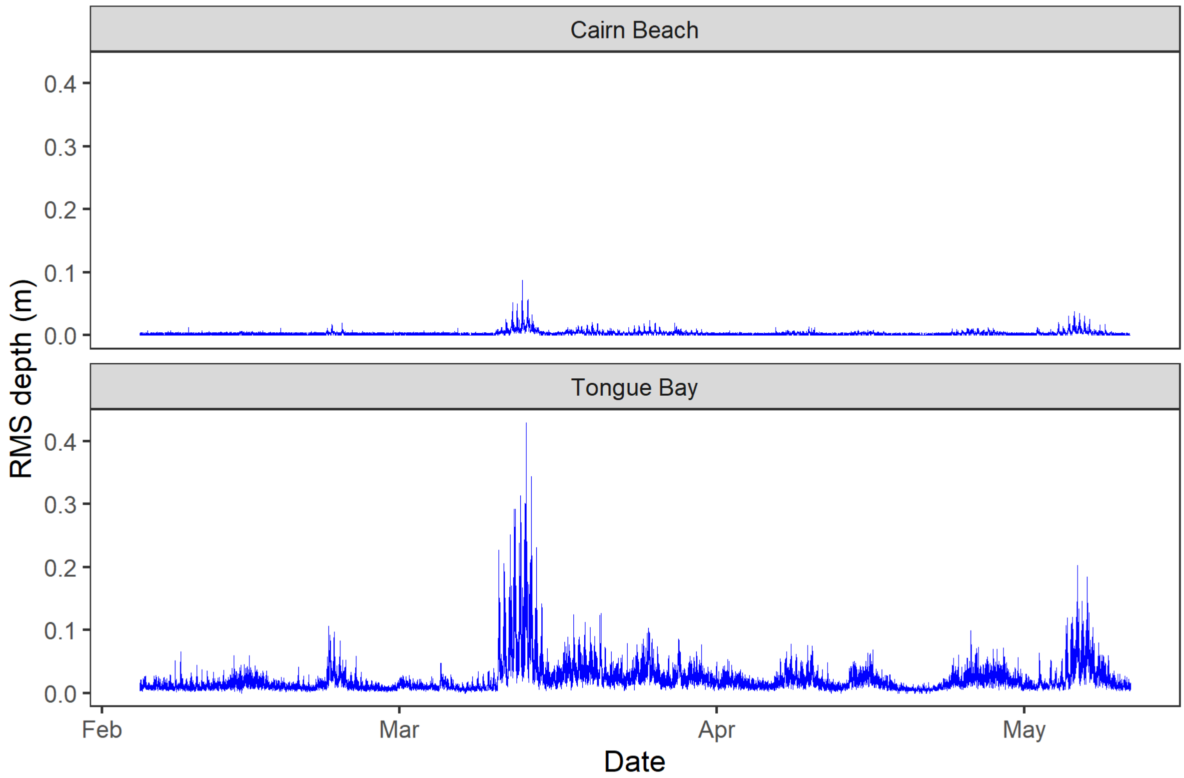

Figure 12. Root mean squared (RMS) water depth measured at Cairn Beach and Tongue Bay

3.1.3 Photosynthetically active radiation (PAR)

Photosynthetically active radiation (PAR) measured at depth followed a typical diel cycle with higher values during the day, decreasing to zero overnight (Figure 13). The longer term day- to week-long cycles were primarily associated with spring-neap tidal range and ambient weather conditions. PAR levels were generally lower at Cairn Beach (measured at 10.4 m depth) than at the shallower Tongue bay site (measured at 8.1 m depth). Daily photosynthetically active radiation is shown in Figure 14. Mean daily PAR was 1.41 mol m^{-2} d^{-1} at Cairn Beach, and 1.85 mol m^{-2} d^{-1} at Tongue Bay.

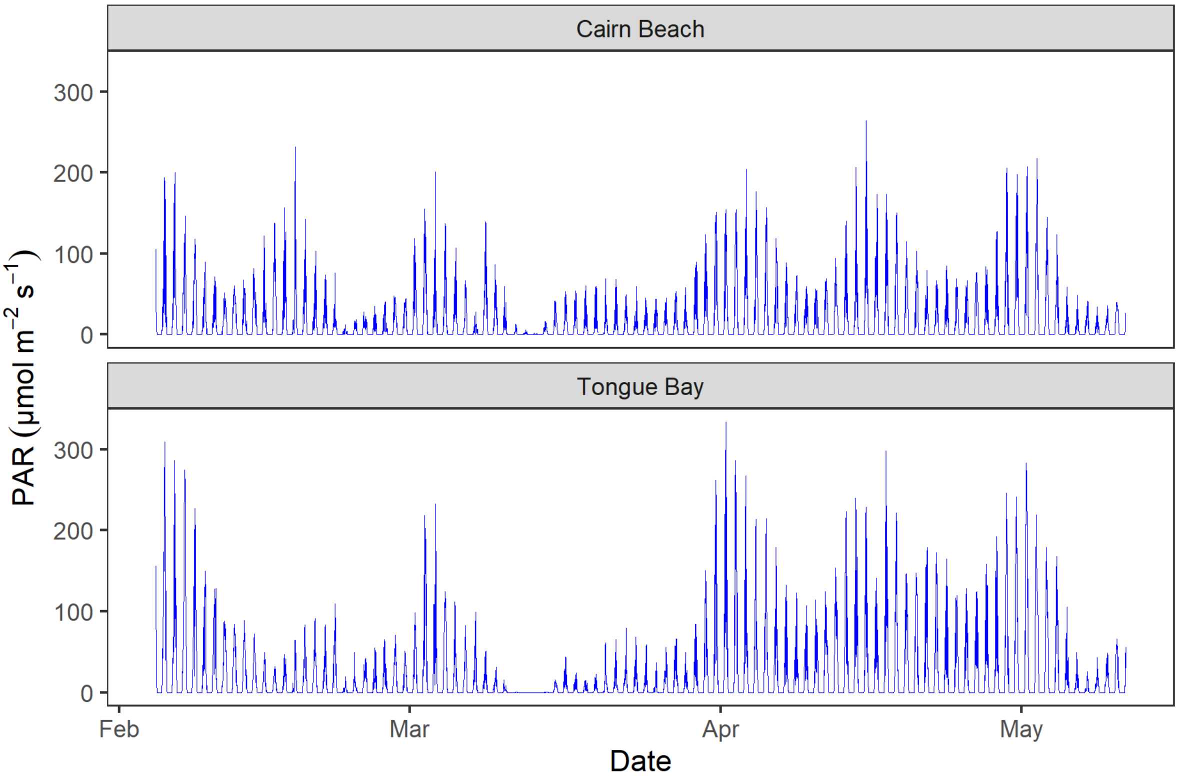

Figure 13. Photosynthetically active radiation (PAR) measured at 10 min intervals at Cairn Beach and Tongue Bay

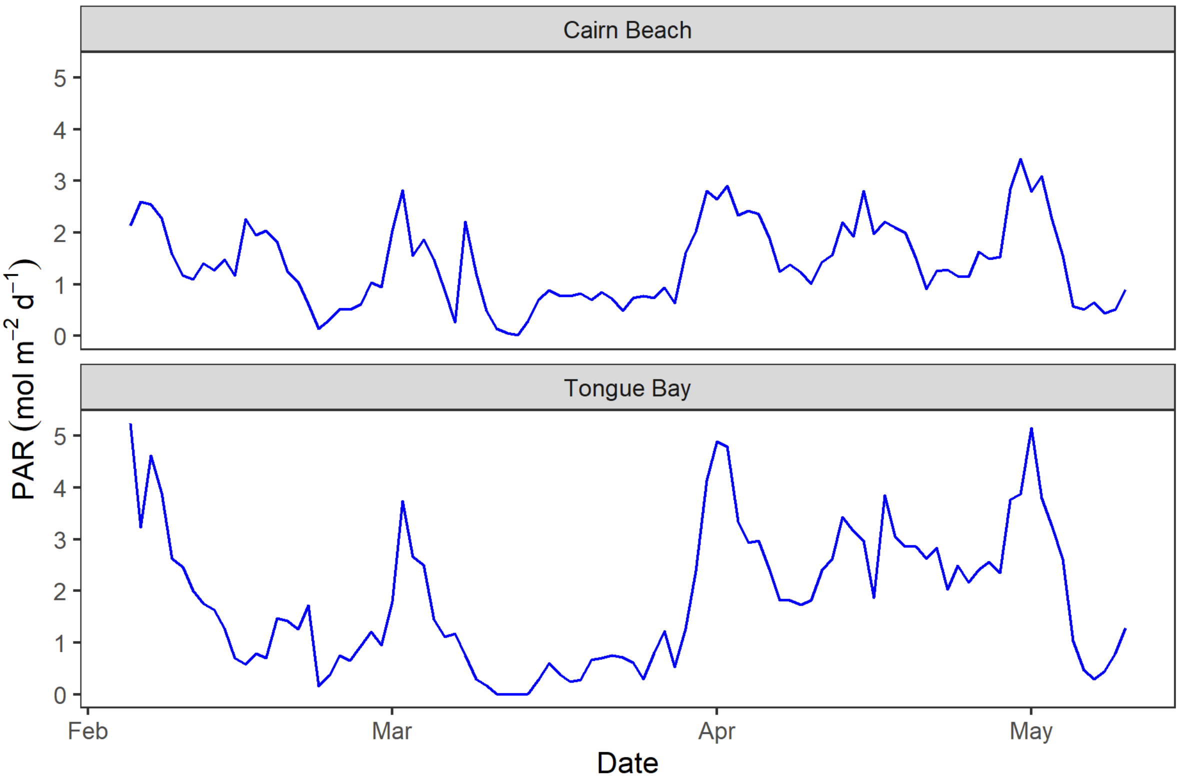

Figure 14. Daily photosynthetically active radiation at Cairn Beach and Tongue Bay

3.1.4 Turbidity

Turbidity ranged from 0 to 16.7 NTUe at the Cairn Beach monitoring site, with an average value of 1.91 NTUe over the deployment period (Figure 15). Turbidity ranged from 0 to 261.7 NTUe at the Tongue Bay monitoring site, with an average value of 6.0 NTUe over the deployment period. The Tongue Bay instrument had continuous problems with sensor fouling during the first deployment – possibly due to wiper malfunction – with data after 12th February deemed unreliable and removed during the data QC process. The first eight days of that deployment have been presented in Figure 15 but should be viewed with caution. The most significant event over the monitoring period was in mid-March and coincides with the passing of TC Gretel. This period of high turbidity also aligns with increased RMS water depth and decreased PAR (light conditions).

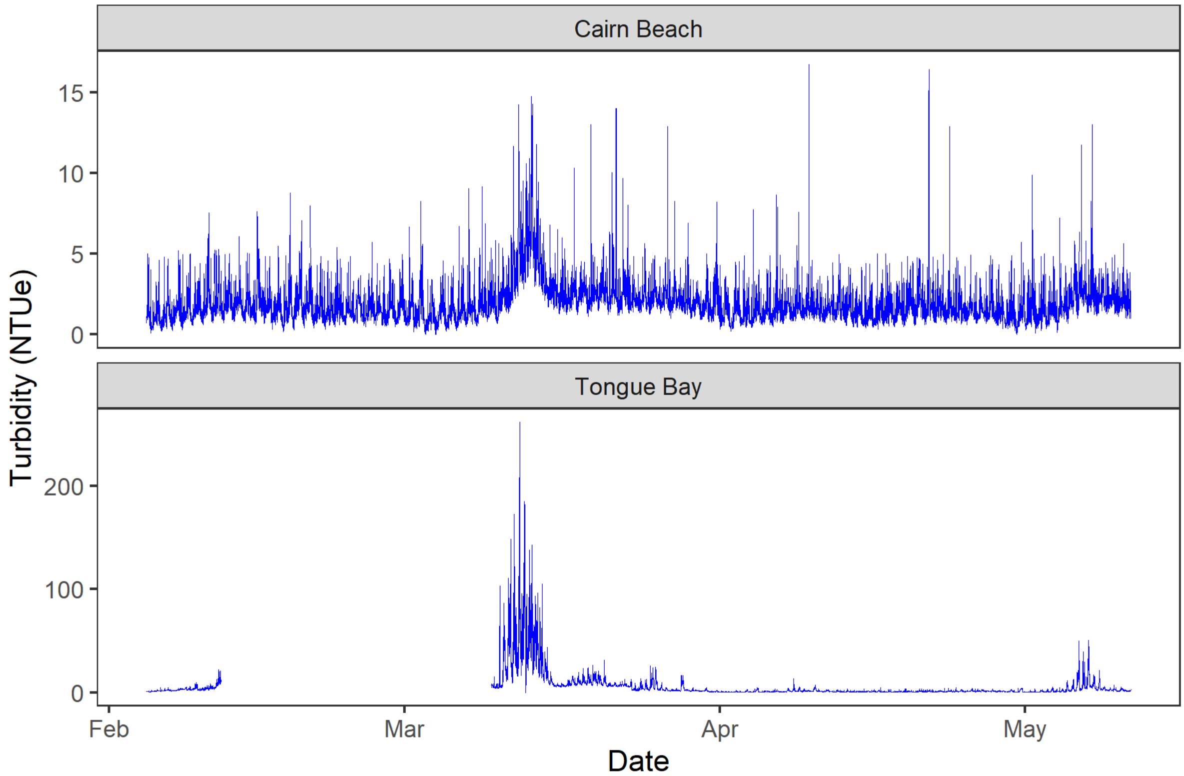

Figure 15. Turbidity measured at Cairn Beach and Tongue Bay. Note different y-axis scale to accommodate for high turbidity event at Tongue Bay in March 2020. Data has been removed during the QC process from 12th February to the end of first deployment period for Tongue Bay due to sensor fouling.

3.2 Water samples

3.2.1 Field observations

The tourism operators recorded observations of conditions on the water at the time of each sampling and maintenance event (Table 4). The conditions at the time of sampling for the first two events were calm with little wind, while on-water conditions were a little rougher in May. There were no surface scums or slicks present at the time of any of the sampling events. Secchi depths ranged from 3 to 6.5 m.

Table 4. Water quality measurements and observations recorded from Cairn Beach and Tongue Bay.

Site Name	Site Code	Date	Time	Secchi depth m	Cloud cover %	Wind knots	Sea surface	Surface scum/slick

Cairn Beach	WH1	04/02/2020	13:45	4.5	15	5 - 10	Calm	Nil
		07/03/2020	17:15	4	80	0 - 5	Flat	Nil
		11/05/2020	08:05	3	75	21 - 25	Light surface chop	Nil
Tongue Bay	WH2	04/02/2020	15:00	6.5	10	5 - 10	Calm	Nil
		09/03/2020	10:30	0.3#	80	5	Glass	Nil
		11/05/2020	10:20	3*	5	25	Chop	Nil

Note: Likely erroneous measurement, * Note: Secchi depth estimated

3.2.2 Physico-chemical parameters

Water samples collected from the monitoring sites were measured in the laboratory for electrical conductivity, total suspended solids (TSS), and pH (Table 5). Conductivity ranged from 52.95 to 54.02 $\mu S\ cm^{-1}$ and was within expected range of seawater with limited freshwater inputs. TSS ranged from 1.9 to 9.8 $mg\ L^{-1}$. The high TSS concentration measured at Cairn Beach in March 2020 corresponded with elevated particulate nutrient concentrations. pH ranged from 8.29 to 8.33.

Table 5. Electrical conductivity (Cond, $mS\ cm^{-1}$), Total suspended solids (TSS, $mg\ L^{-1}$) and pH of surface water samples collected from Cairn Beach and Tongue Bay.

Site name	Site code	Sample Date	Cond $mS\ cm^{-1}$	TSS $mg\ L^{-1}$	pH
Cairn Beach	WH1	04/02/20	54.02	1.9	8.29
		09/03/20	52.95	9.3	8.33
Tongue Bay	WH2	04/02/20	53.92	2.8	8.31
		08/03/20	53.14	3.0	8.29

3.2.3 Nutrients

Nitrogen and phosphorus concentrations are presented in Table 6. Total nitrogen concentrations ranged from 126 to 227 $\mu g\ N\ L^{-1}$. Total phosphorus concentrations ranged from 8 to 17 $\mu g\ P\ L^{-1}$. With the exception of Cairn Beach March 2020 the bulk of nutrients were present in the dissolved fraction with 84 to 95% nitrogen dissolved, and 88 % phosphorus dissolved. Particulate nutrient concentrations at Cairn Beach in March 2020 were elevated, and corresponded with high TSS concentrations. Nitrate-nitrite concentrations (indicating directly bioavailable N) were approximately double at Cairn Beach than Tongue Bay.

Table 6. Nutrient concentrations measured in surface water samples collected from Cairn Beach and Tongue Bay. Total nitrogen (TN, total dissolved nitrogen (TDN), oxidised nitrogen (NO_x), particulate nitrogen (PN), total phosphorus (TP), total dissolved phosphorus (TDP), and particulate phosphorus (PP). All concentrations reported in micrograms per litre ($\mu g\ L^{-1}$).

Site name	Site code	Sample Date	TN $\mu g\ N\ L^{-1}$	TDN $\mu g\ N\ L^{-1}$	NO_x $\mu g\ N\ L^{-1}$	PN $\mu g\ P\ L^{-1}$	TP $\mu g\ P\ L^{-1}$	TDP $\mu g\ P\ L^{-1}$	PP $\mu g\ P\ L^{-1}$
Cairn Beach	WH1	04/02/20	142	136	6	6	9	8	1

		09/03/20	227	111	7	116	17	7	10
Tongue Bay	WH2	04/02/20	130	109	3	21	8	7	1
		08/03/20	126	118	3	8	9	8	1

3.2.4 Chlorophyll *a*

Chlorophyll *a* values were consistently 0.4 µg L^{-1} between sites and sampling events (Table 7). Chlorophyll a was not elevated at Cairn Beach in March 2020 indicating that elevated particulate nutrient concentrations were likely associated with suspended sediments rather than a phytoplankton bloom.

Table 7. Chlorophyll-*a* and Phaeophytin-*a* concentrations measured in surface water samples collected from Cairn Beach and Tongue Bay. All concentrations reported in micrograms per litre (µg L^{-1}).

Site name	Site code	Sample Date	Chl-*a* µg L^{-1}	Phaeo-*a* µg L^{-1}
Cairn Beach	WH1	04/02/20	0.41	<0.2
		09/03/20	0.38	<0.2
Tongue Bay	WH2	04/02/20	0.40	0.22
		08/03/20	0.40	0.21

4 DISCUSSION

4.1 Water quality at Whitsunday sites

Results from the first two monitoring periods have been compared to water quality guideline trigger values. The Great Barrier Reef Marine Park Authority (GBRMPA) produce water quality guideline trigger levels (GBRMPA, 2010). These guidelines are based on annual mean values. It is not possible to calculate annual mean values from the data collected to date by Whitsunday Water Quality Monitoring Blueprint for Tourism Operators at this point in time but nonetheless it may be useful to cautiously compare the measurements made at the sampling events to date to these guideline trigger values.

4.1.1 Water clarity

The Secchi disk depth mean annual trigger level is 10 m for open coastal, hence the values reported in this study (4 – 6.5 m) exceed this trigger level. The turbidity mean annual guideline value is 1.5 NTU. The mean turbidity value during the first monitoring period was 1.61 NTUe at Cairn Beach and 2.18 NTUe at Tongue Bay, slightly exceeding the mean annual guideline value. The total suspended solids (TSS) mean annual guideline value is 2 mg L^{-1} for open coastal settings. The mean TSS concentration measured was 5.6 mg L^{-1} at Cairn Beach and 2.9 mg L^{-1} at Tongue Bay.

The dominant event relating to water clarity throughout this monitoring period was in mid-March while TC Gretel was offshore. The mean values mentioned above which were calculated for this monitoring period are heavily weighted by this one event. Cyclones create wind and wave energy which propagates away from the low pressure system. As these waves reach shallow coastal waters they can then drive sediment resuspension which reduces water clarity. The increase in wave energy measured at the two Whitsunday monitoring sites (RMS water depth) coincides with an increase in measured turbidity, and a decrease in the amount of photosynthetically active radiation (PAR) reaching the seafloor where the logger was situated. As the wave event passed, so too does the turbidity decrease back to low levels, and PAR returns to normal diel fluctuations. The Tongue Bay site saw a much larger increase in RMS water depth and turbidity due to it being more exposed to wind and wave energy coming from the east, in comparison to the relatively sheltered Cairn Beach site.

4.1.2 Water temperature

The GBRMPA water quality guideline trigger level for sea temperature is set at increases of no more than 1 °C above the long-term average maximum (GBRMPA, 2010). There is no long-term (20 year) data for the two sites in this study so we are unable to directly assess how measured water temperature compares to the guidelines. Nonetheless it was evident that water temp was high at both Cairn Beach and Tongue Bay during February 2020 with an average temperature of 29.6 °C during the monitoring period. The Australian Institute of Marine Science (AIMS) has been monitoring water temperature at nearby sites dating back multiple years as part of their Sea Water Temperature Observing System (Figure 16). The temperatures measured in this study are comparable to maximum mean monthly temperatures recorded by AIMS over previous years.

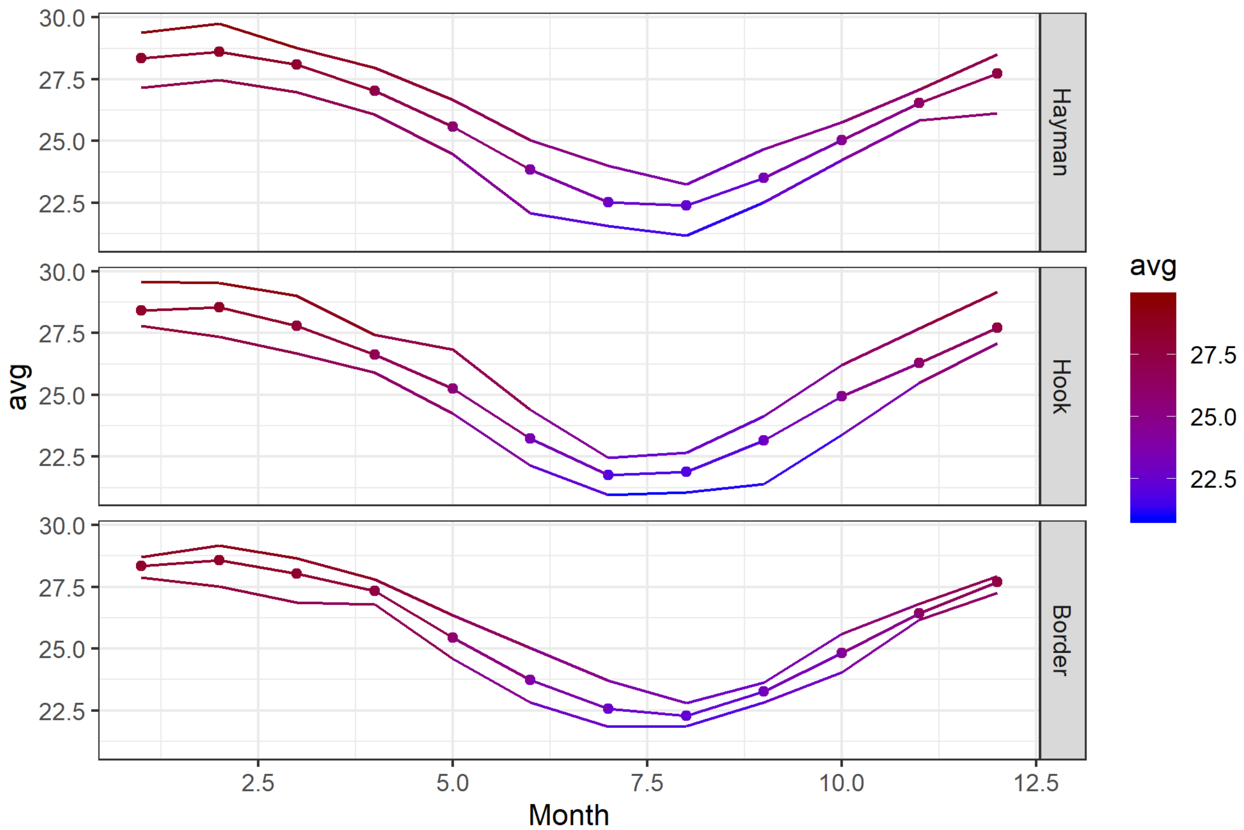

Figure 16. Month averaged sea temperature at Hayman Island @ 2 m (1996 to 2017), Hook Island @ 6.8 m (2007 to 2014), and Border Island @ 1.6 m (2011 to 2017). Data sourced from the AIMS Sea Water Temperature Observing System.

4.1.3 Nutrients and Chlorophyll *a*

Only a few water samples have been collected under the current program which limits our ability to provide any meaningful assessment of the data. The GBRMPA mean annual guideline trigger values for nutrients are 20 µg N L^{-1} for particulate nitrogen (PN) and 2.8 µg P L^{-1} for particulate phosphorus (PP) with a ±20 % seasonal adjustment (GBRMPA, 2010). The mean particulate nitrogen concentration measured was 61 µg N L^{-1} at Cairn Beach and 14.5 µg N L^{-1} at Tongue Bay. The mean particulate phosphorus concentration measured was 5.5 µg P L^{-1} at Cairn Beach and 1 µg P L^{-1} at Tongue Bay. Mean nutrient concentrations at Cairn Beach were heavily influenced by high PN and PP concentrations measured in March 2020.

Chlorophyll *a* values measured in the Whitsunday were consistently 0.4 µg L^{-1} across sites and sampling events. The GBRMPA guideline trigger value for Chlorophyll *a* is 0.45 µg L^{-1} calculated as mean annual value. The Chlorophyll guideline values are adjusted for season with the value being ~40% higher in summer (~0.63 µg L^{-1}) and ~30% lower in winter (~0.32 µg L^{-1}) than mean annual values (GBRMPA, 2010). Hence, the Chlorophyll *a* values during the monitoring period were not considered elevated in relation to the guideline trigger values.

4.2 Monitoring and Evaluation

As part of ongoing monitoring and evaluation of the Whitsunday Water Quality Monitoring Blueprint for Tourism Operators, the program to date has been assessed against the following three criteria:

1. *What is the percentage data recovery from the logger instruments for each deployment? Were there any technical issues with data acquisition (i.e. sensor fouling, instrument malfunction)?*

2. *Is the quality of data collected at each site sufficient? (i.e. all required measurement parameters have been recorded in the field, water samples have been collected and transported correctly, identification and removal of erroneous logger data and outliers, frequency of measurements is sufficient)*
3. *Is the monitoring data collected at the sites sufficient for providing additional water quality information for the region (long term comparison to each other and MMP sites)?*

4.2.1 Data recovery

Data recovery for the first three months of the program was good with 100% recovery for the Cairn Beach (WH1) site, while 100% recovery was achieved for all sensors except for turbidity on the Tongue Bay (WH2) instrument (Table 8). 25 days of turbidity measurements were excluded from the Tongue Bay due to sensor fouling. Hence, data recovery for the turbidity sensor was 20.4%. There were no other instrument malfunctions over the period.

Table 8. Summary of data recoveries for each nephelometer logger deployment

Site	Code	Deployment	Start	End	Days	% recovery
Cairn Beach	WH1	a	4/02/2020	7/03/2020	32	100[#]
Cairn Beach	WH1	b	7/03/2020	11/05/2020	64	100
Tongue Bay	WH2	a	4/02/2020	9/03/2020	34	100
Tongue Bay	WH2	b	9/03/2020	11/05/2020	62	100

[#] Note: Data recovery for the turbidity sensor was 20.4% while recovery for all other sensors was 100%.

4.2.2 Data quality

Water samples

Analysis of water samples was conducted in the TropWATER laboratory at the JCU Townsville campus. The laboratory has QA/QC procedures in place which cover sampling handling and analysis once the samples are received by the laboratory. The values reported for all parameters fell within expected natural range (i.e. no obvious contamination).

Tourism operators

The Secchi disk depth of 0.3 m at Tongue bay WH2 on 09/03/2020 seems unlikely as the comment below says "Perfect conditions, good vis". We would expect the Secchi disk depth to be deeper than 0.3 m considering the visibility was good. This entry has been flagged as a measurement error.

Datasheets are being returned by the operators incomplete. It is important that these data sheets are fully completed on the day that the instruments are retrieved and redeployed, and the water samples are collected. Missing information included the GPS coordinates of the redeployed instruments. The recording of the location of the instrument frame and anchor is critical, particularly in a situation where the surface marker buoy goes missing. The GPS coordinates are then used to begin searching the last know location of the instrument with a grappling hook. If the instrument cannot be found after searching with the grappling hook, additional efforts to retrieve the instrument will be necessary.

The information of the new logger deployment was missing from the datasheets. Recording the logger serial number is critical. Without knowing the serial number of the logger deployed at the site reduces our ability to know which data relates to which site during the downloading stage.

The bottle label was not recorded on the field datasheets. It is important that this information is included on the datasheets, particularly when the laboratory processes the samples. In addition, information was not recorded on the datasheet when the Chlorophyll samples were filtered at the end of the day on one occasion (WH1b). Missing information for the sample were date and time filtered, and the volume filtered. The information was recorded on the envelope which the filter was stored in, but not on the datasheet.

Transport of samples

There was a problem with sample transport for the March sampling event. Samples arrived at the laboratory at ambient temperature (approx. 25°C). It was determined that this may be due to the samples being transported over 4 legs (Airlie > Proserpine, Proserpine > Mackay, Mackay > Townsville, Townsville > JCU TropWATER) meaning that the time in transit is 8+ hours rather than being directly transported (3.5 hours). The small 10 L eskies are unable to keep the nutrient samples and chlorophyll filters frozen under those conditions. This has been rectified by placing additional ice blocks inside the two 10 L eskies, and transporting the samples between Airlie Beach and Townsville laboratory in a larger esky with additional ice blocks.

4.2.3 Data sufficiency

The two newly established water quality monitoring sites from this project fill in gaps between other monitoring sites throughout the region (Figure 17). There are numerous water quality monitoring sites, including instruments which log data, throughout the Whitsunday region. The marine monitoring program (MMP) coordinated by the Australian Institute of Marine Science (AIMS) has 11 water quality sites, of which 4 are moorings with instrumentation. The data from these AIMS sites are released on an annual basis following extensive quality control and reporting. North Queensland Bulk Ports (NQBP) have established ambient marine water quality monitoring sites adjacent to port facilities to the north and south of the Whitsunday region. As this project matures we will be able to compare the data from the two sites in this project to the nearby MMP and NQBP sites. Long term water temperature data was sourced from the AIMS Sea Water Temperature Observing System which has been used here to calculate the 20 year average temperatures for guideline exceedances (AIMS, 2017). Waverider buoys are located to the north (Abbot Point) and south (Mackay Inner, Mackay Outer, Hay Point) of the Whitsunday region. These buoys provide wave height and water temperature data which may be compared to water temperatures measured at the Whitsunday sites to assess whether trends and anomalies in water temperature are due to local or regional patterns.

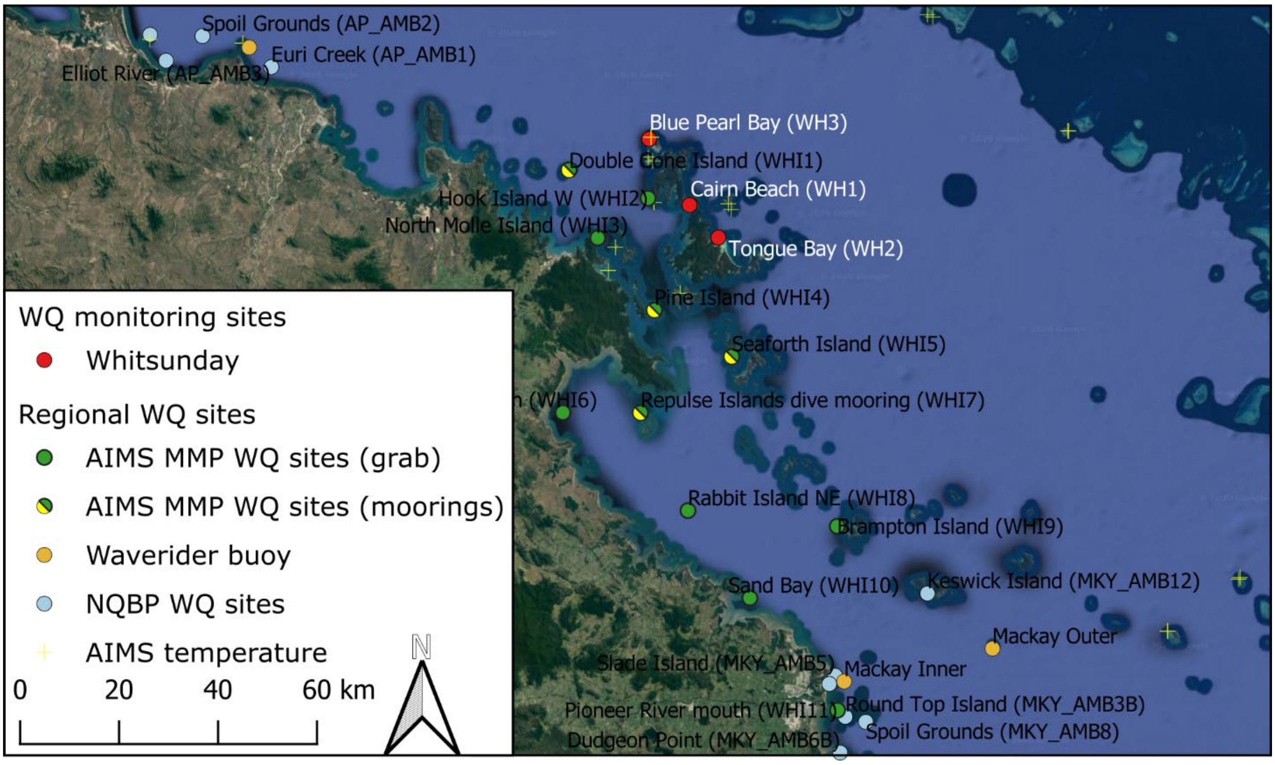

Figure 17. Monitoring sites from other water quality programs operating in and adjacent to the Whitsunday region

4.3 Concluding remarks

The Whitsunday Water Quality Monitoring Blueprint for Tourism Operators has commenced and will continue to generate useful data for the region, including potentially for use in regional report cards. Tourism operator's eagerness to participate in the program will continue to be a strength of the program. It is recommended that water sampling teams be reminded of the need to fill out field data sheets in full, in order to reduce any problems with the post processing of data in the laboratory and office. The process of completing the field data sheets was covered during the training, however, additional follow up checks might be necessary in order to prevent these problems occurring in the future.

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