



HEALTHY RIVERS TO
REEF PARTNERSHIP
MACKAY-WHITSUNDAY-ISAAC



Southern Inshore Program (SIP) Ambient Marine Water Quality: Annual Report 2024–2025



Southern Inshore Program (SIP) Ambient Marine Water Quality: Annual Report 2024–2025

A Report for Healthy Rivers to Reef Partnership

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Executive Summary

This report presents the results of monitoring undertaken in 2024–2025 for the marine water quality component of the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership’s Isaac Coastal Monitoring Program, funded by Dalrymple Bay Coal Terminal Pty Ltd and Dalrymple Bay Infrastructure. Monitoring was undertaken by the Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University as part of the Partnership’s long-term ambient water quality program.

The Isaac Coastal Ambient Marine Water Quality Monitoring Program provides long-term, high-quality data to characterise environmental conditions in a dynamic inshore coastal region of the Great Barrier Reef. The program integrates routine water sampling, continuous in situ logger measurements, and pesticide monitoring to assess variability in water quality and the environmental drivers influencing coastal ecosystem condition.

Monitoring during the 2024–2025 reporting period captured typical wet–dry tropical seasonal patterns. Rainfall and river discharge were highly episodic, with major flow events occurring during the wet season, particularly in early 2025. These events influenced short-term variability in water quality, including elevated suspended sediments and particulate nutrients during peak runoff periods.

Physicochemical conditions across all sites remained within expected ranges for coastal marine waters, with no evidence of hypoxia or persistent stratification. Nutrient concentrations were generally low to moderate, with a single elevated event at Aquila Island in November 2024 driven by particulate fractions rather than dissolved nutrients. Chlorophyll-a concentrations were typically low, indicating low phytoplankton biomass throughout most of the year.

Water clarity exhibited seasonal variability, with reduced transparency during late dry-season and peak wet-season conditions associated with increased suspended sediments. In contrast, clearer conditions were observed during transitional periods, particularly in autumn. These patterns are consistent with the influence of tidal resuspension and episodic river inputs in this highly dynamic coastal environment.

Pesticides were detected intermittently during the wet season, coinciding with rainfall-driven discharge events. Detected concentrations of key herbicides remained below relevant guideline values, indicating low risk during the monitoring period.

Continuous logger data provided high-resolution insights into environmental variability. Water temperature followed a strong seasonal cycle, with sustained elevated temperatures during the wet season. Turbidity and light availability (PAR) showed variability linked to tidal processes and sediment resuspension, reinforcing the importance of hydrodynamic drivers in controlling benthic light environments.

Overall, results indicate that water quality in the Isaac Coastal region during 2024–2025 was consistent with expected seasonal and environmental variability for an inshore Great Barrier Reef system. Short-term changes in water quality were primarily driven by rainfall and hydrological events, rather than persistent degradation.

The continuation of long-term monitoring is critical for distinguishing natural variability from emerging trends, supporting adaptive management, and informing regional report cards and water quality improvement initiatives.

Table of Contents

1	Introduction	1
1.1	Program outline	1
1.2	Background	1
1.3	Program objectives	2
2	Methods.....	3
2.1	Regional Description	3
2.2	Characterisation of weather, hydrological status, and oceanographic conditions	4
2.3	Monitoring and sampling design	4
2.4	Pesticide monitoring	7
2.5	Seafloor mounted continuous dataloggers	9
3	Results and Discussion	12
3.1	Rainfall and river flows.....	12
3.2	Oceanographic conditions	15
3.3	Water quality	16
3.3.1	Physicochemical.....	16
3.3.2	Nutrients	20
3.3.3	Water clarity	23
3.3.4	Pesticides	25
3.4	In-situ loggers.....	29
3.4.1	Water temperature.....	29
3.4.2	Water depth.....	30
3.4.3	Wave activity.....	31
3.4.4	Turbidity	32
3.4.5	Photosynthetically active radiation (PAR).....	33
3.4.6	Water quality logger data	36
3.4.7	Data Recovery	37
4	Conclusions and Recommendations	38
4.1	Conclusions	38
4.1.1	Climatic conditions.....	38
4.1.2	Ambient water quality	38
4.1.3	Turbidity	39
4.1.4	Photosynthetically active radiation (PAR).....	39
4.2	Recommendations	39
5	References	40
	Appendix 1. Quality control procedures.....	42

Table of Figures

Figure 1-1: James Cook University research vessel ‘Kasmira’ enroute to Aquila Island ready to conduct water quality monitoring in the Isaac coastal region.	1
Figure 2-1. Map of the Isaac coastal region where water quality monitoring locations (yellow circles), monitoring locations with loggers (yellow/black circle), and the stream gauge (purple triangle) referred to in this report, are located.....	3
Figure 2-2. Pesticide monitoring passive samplers such as these were retrieved from Aquila Island (MKY_CAM1) over the reporting period (Table 2-5). Note: biological growth on the samplers.....	8
Figure 2-3. Water quality loggers attached to instrument frames ready for deployment to the seabed. The horizontally orientated logger is an NTU-LPT turbidity logger, and the vertically orientated logger is a MS9-LPT multispectral light logger manufactured by Insitu Marine Optics.	9
Figure 3-1. Rainfall recorded at Plane Creek Sugar Mill (station 033059) for the 2024-2025 water year. The nominal wet season period is shaded grey. Green vertical dash indicates northern rainfall onset. Data source: http://www.bom.gov.au/climate/data/	12
Figure 3-2: Annual rainfall by water year for the Mackay region during wet season (blue) and dry season (light blue). Totals were calculated for the wet season period 1st November to 31st March for each water year. Water year runs from 1 st July to 30 th June. Solid red line represents median annual rainfall by water year, dashed lines represent 10 th , 25 th , 75 th , and 90 th percentiles. Daily rainfall data was obtained from the Plane Creek Sugar Mill (station 033059). Data source: http://www.bom.gov.au/climate/data/	13
Figure 3-3: Daily discharge in Carmila Creek (blue line; GL day ⁻¹) and daily rainfall at Plane Creek (pink bars; mm) from July 2024 to June 2025. Flow remained negligible for much of the dry season, with short-lived discharge events occurring during the wet season in response to rainfall pulses, particularly in January–February 2025.	14
Figure 3-4 Daily discharge (blue line; GL day ⁻¹) and rainfall (pink bars; mm) for Carmila Creek (top), Pioneer River (middle) and Sandy Creek (bottom) from July 2024 to June 2025. Carmila Creek is the primary freshwater input to the Isaac coastal zone and exhibited low, short-lived flow responses. In contrast, the Pioneer River and Sandy Creek— which influence coastal waters further north in the Mackay region—recorded substantially higher peak discharges during wet-season rainfall events, particularly between January and April 2025. This comparison highlights the relatively smaller hydrological contribution of river catchments to the Isaac coastal zone.....	14
Figure 3-5. Frequency of counts by wave direction (%), and significant wave height (m) at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025. Data source: https://www.qld.gov.au/environment/coasts-waterways/beach/monitoring	15
Figure 3-6. Frequency of counts by wave direction (%), and significant wave height (m) at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025. Values shown in this plot for those months are good for wave height information only. Data source: https://www.qld.gov.au/environment/coasts-waterways/beach/monitoring	16
Figure 3-7. Dissolved oxygen concentration (mg/L) at three water quality monitoring sites in the Isaac coastal region showing results for the top, middle, and bottom water.	17
Figure 3-8. Electrical conductivity recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.	18

Figure 3-9. Water temperature recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.	19
Figure 3-10. pH recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.	20
Figure 3-11 Chlorophyll-a concentrations measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), throughout the reporting period. Horizontal red lines represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means.	21
Figure 3-12. Particulate Nitrogen (PN), Total Dissolved Nitrogen (TDN), Total Nitrogen (TN), and oxidised nitrogen (NOx) concentrations measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal lines represent EPP 2019 WQO 20 th (orange), 50 th (red) and 80 th (dark red) percentiles. Horizontal red lines on PN panel represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means. Note unequal y-axis.	22
Figure 3-13. Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), and Particulate Phosphorus (PP) concentrations measured in water samples collected from the three Isaac coastal water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal lines represent EPP 2019 WQO 20 th (orange), 50 th (red) and 80 th (dark red) percentiles. Horizontal red lines on PP panel represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means. Note unequal y-axis.	23
Figure 3-14 Total suspended solids (TSS) measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal red lines represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means.	24
Figure 3-15. Secchi disk depth recorded at the three water quality sites throughout the reporting period. Horizontal red line represents EPP 2019 WQO annual mean.	24
Figure 3-16. Passive sampler deployment periods (green numbers and dashed lines) overlaid on the stream discharge plot (GL d-1) recorded for Carmila Creek (station 126 003A) during the 2024-2025 reporting period. The nominal wet season period is shaded grey. Rainfall data from the Carmila gauging station is also shown in pink. Data source: https://water-monitoring.information.qld.gov.au/	25
Figure 3-17. Daily mean water temperature (blue) and daily minimum and maximum (light blue) measured at water quality monitoring sites in the Isaac coastal region.	29
Figure 3-18. Daily tidal range measured by insitu loggers at Aquila Island (MKY_CAM1).	30
Figure 3-19. RMS depth measured at Aquila Island (MKY_CAM1). Values presented are daily mean (blue line) +/- standard deviation (light blue).	31
Figure 3-20. Turbidity measured at measured at Aquila Island (MKY_CAM1). Values presented are daily mean (blue line) +/- standard deviation (light blue). Y-axis is in log scale.	33
Figure 3-21 Daily light integral (mol photons m ⁻² d ⁻¹) of benthic photosynthetically active radiation measured at Aquila Island. Periods of missing or QC-removed data are indicated by the orange bar.	34
Figure 3-23. Data collected at Aquila Island with In-situ Marine Optics (IMO) dataloggers. Data presented excludes data flagged as flag 4 (Bad data). For more information on Quality Control Procedures see Appendix 1.	36

Figure 3-24. Data recovery and qc flags at the Aquila Island (MKY_CAM1) logger site over the reporting period. Flag 1 (green) indicates a 'good value'; flag 2 (blue) indicates a 'probably good value'; flag 3 (yellow) indicates 'probably bad value', flag 4 (red) indicates a 'bad value' and flag 9 (grey) indicates data that is missing. 37

1 Introduction

1.1 Program outline

The Centre for Tropical Water and Aquatic Ecosystem Research (TropWATER) at James Cook University (JCU) has been commissioned to assist the Healthy Rivers to Reef Partnership to collect marine water quality data for the Isaac coastal region as part of the Mackay-Whitsunday-Isaac regional report card. The report card is released biennially, providing an overview of the health and condition of regional catchments, rivers, creeks, and nearshore habitats along this section of the Great Barrier Reef (GBR) coastline. The information will be used to set strategic and collaborative management action plans to protect the regions marine, freshwater, and estuarine ecosystems. This report has been prepared for the 2024-2025 water quality monitoring period.



Figure 1-1: James Cook University research vessel 'Kasmira' enroute to Aquila Island ready to conduct water quality monitoring in the Isaac coastal region.

1.2 Background

Declining water quality remains a major pressure on the GBR, with elevated fine sediments, nutrients, and pesticides from catchments reducing the resilience of ecosystems to extreme events such as cyclones and marine heatwaves (Brodie et al., 2019; Waterhouse et al., 2017, 2022; Lam et al., 2018). Despite sustained investment in land-based pollution reduction, recent assessments show that progress towards Reef 2050 water quality targets remains limited, with reductions in nutrients, fine sediments and pesticides still falling short of required trajectories (Moran et al., 2025; Waterhouse et al., 2022; Reef Water Quality Report Card, 2024). Maintaining high water quality is crucial for protecting the ecological health of the GBR and sustaining its substantial economic,

cultural, and social value; recent assessments estimate the Reef contributes \$9 billion annually and supports ~77,000 jobs (GBRF, 2025).

The Isaac coastal region is a dynamic coastal environment influenced by strong tidal processes, episodic freshwater flows, and seasonal climate variability. Long-term environmental monitoring provides the high-quality evidence needed to understand natural variability, detect emerging trends, and support adaptive management responses under a changing climate.

1.3 Program objectives

As the Isaac coast lies within the Great Barrier Reef region, the primary objective of the program is to characterise variability in water quality by monitoring a suite of key parameters to better define potential impacts to water quality. Along with regular monitoring of water quality parameters, an understanding of the meteorological and oceanographic (metocean) conditions that affect the regions coastal ecosystems is important in understanding seasonal and interannual variability in water quality. The extensive marine monitoring program implemented by TropWATER is designed to characterise the ambient water quality so that potential impacts to habitats can be identified. The partnership's objective also moves beyond basic environmental stewardship and incorporates robust scientific research initiatives undertaken by leading researchers and specialists in marine water quality, coastal habitat, seagrass, coral ecology, and natural resource management. The long-term acquisition of data under the partnership presents an invaluable resource for understanding the interannual variability and climatic influences that drive water quality and ecological processes along coastal Queensland.

2 Methods

2.1 Regional Description

The Isaac coastal region is situated on the central Queensland Coast between Mackay and St Lawrence (Figure 2-1). There is an extensive agricultural presence along the coastal plain, interspersed by several creek systems that link to the marine environment. This section of the Queensland coastline is characterised by large tidal ranges (up to 8 metres) with the adjacent (to the south) Broad Sound and Shoalwater Bay marine areas being the largest shallow macro-tidal bays on Australia’s east coast. Strong tidal currents are therefore a feature across this inshore region, often resulting in highly turbid water due to tidal resuspension of bottom sediments (Kleypas 1996). Despite the sediment load, the Northumberland Islands group within this region support a high cover of coral in both incipient (lacking a reef flat) and fringing reef systems (Cheal et al., 2001).

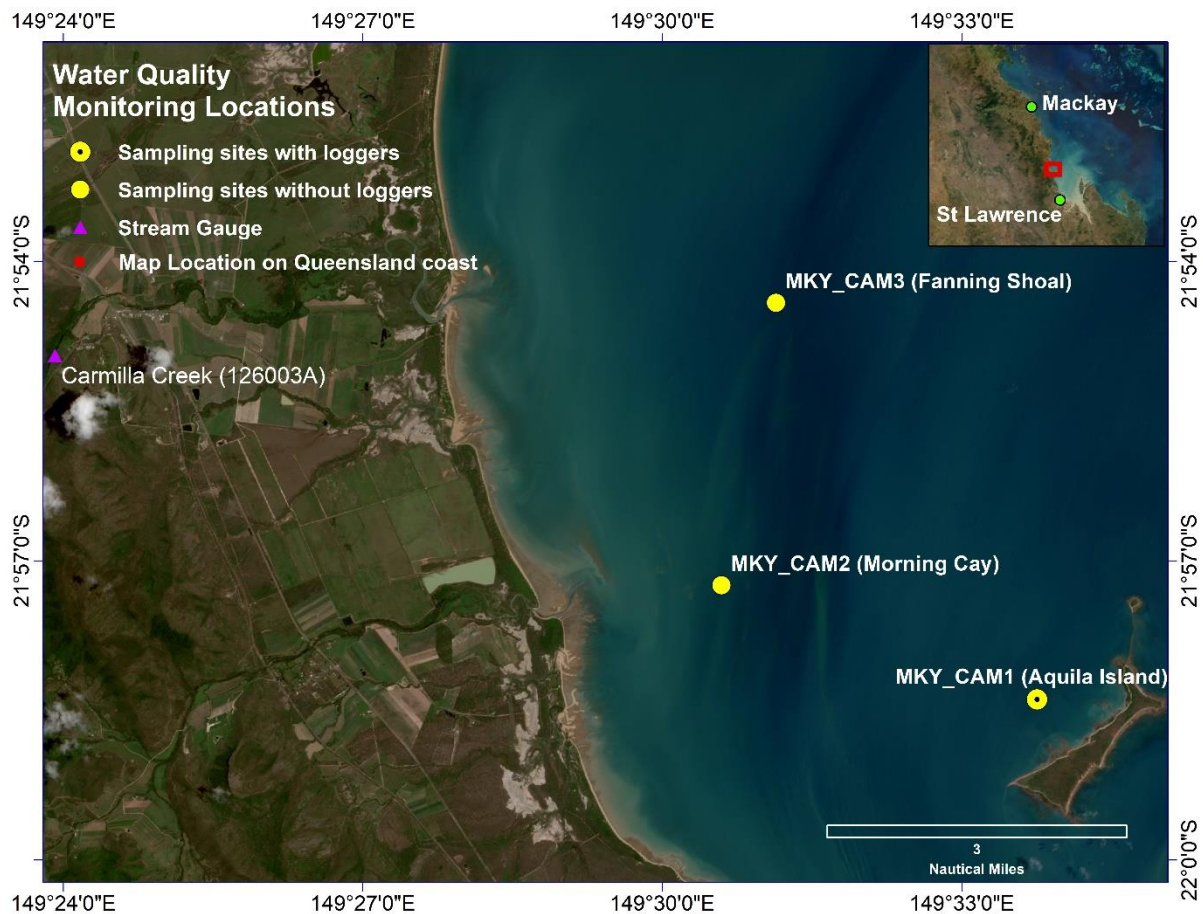


Figure 2-1. Map of the Isaac coastal region where water quality monitoring locations (yellow circles), monitoring locations with loggers (yellow/black circle), and the stream gauge (purple triangle) referred to in this report, are located.

2.2 Characterisation of weather, hydrological status, and oceanographic conditions

Climate data for the region was extracted from the Australian Bureau of Meteorology climate data online tool (<http://www.bom.gov.au/climate/data/>). Total rainfall, rainfall onset date, along with wet season rainfall totals were calculated. The nominal wet season is defined as 1st November to 31st March. The rainfall onset is calculated as the date when the rainfall total reaches 50 mm since 1st September. Stream discharge data for streams discharging into the coastal waters of the region was extracted from the Queensland Government water monitoring information portal (<https://water-monitoring.information.qld.gov.au/>). Total discharge and date of first significant discharge event were calculated. The water year reported throughout is defined as 1st July to 30th June. Wave data for the region was extracted from Queensland Government open data portal (<https://www.data.qld.gov.au/>) comprising of the significant wave height (H_s), calculated as the average of the highest third of the waves in a recorded period (26.6 minutes), and the Peak Direction (which the waves are coming from), as recorded by the wave buoy located at Bailey Reef, 19 nautical miles offshore from Mackay Harbour. Note that this wave buoy is approximately 50 nautical miles north of the Isaac coastal monitoring sites and may not be representative of the wave energy experienced at these sites, particularly when the wave direction is from a south-easterly direction, as the Isaac coastal monitoring locations are somewhat protected from this aspect by Cape Townshend and Stanage Point.

2.3 Monitoring and sampling design

The Isaac coastal region has three active ambient marine water quality monitoring sites (Figure 2-1) that were established in September 2017 as part of a broader regional program (see Cartwright et al., 2025). Ambient water quality monitoring consisting of water samples that are laboratory analysed and spot measurements with a multiparameter instrument were conducted at all three sites approximately every 6-8 weeks (Table 2-2). One site (Aquila Island) also has a pair of data loggers deployed on the seafloor to continuously record environmental data. Regular change-out of loggers to perform sensor maintenance and download data from the instruments occurred in parallel with the water sampling. The sites were chosen to align with key sensitive receptor habitats (e.g., corals or seagrass), and key features in the study region (e.g. river flow points). Coral and seagrass receptor habitat assessments are available in companion reports on the TropWATER website (www.tropwater.com).

Water samples were collected from 0.2 m below water surface by hand. Samples were collected for analytical determination of total nitrogen, total phosphorus, total dissolved nitrogen, total dissolved phosphorus, pH, salinity, electrical conductivity, total suspended solids, chlorophyll-*a* and phaeophytin-*a* (Table 2-3). Dissolved nutrient samples were filtered onsite with a 0.45 µm syringe filter (Sartorius minisart PES 0.45). TSS samples were collected in a 1 L bottle, Chlorophyll-*a* was collected in a dark 1 L bottle, pH and salinity were collected in a 60 mL vial. Water samples were stored on ice immediately and transported to the laboratory for analysis.

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 were then wrapped in aluminum foil and frozen. Pigment determinations from acetone extracts of the filters were completed using spectrophotometry, following the methodology described in 'Standard Methods for the Examination of Water and Wastewater, 10200 H. Chlorophyll'.

Table 2-1. Location of water quality monitoring sites in the Isaac coastal region.

Site name	Site code	Latitude	Longitude	Av Depth (m)	Loggers deployed
Aquila Island	MKY_CAM1	-21.97	149.55	9	Yes
Morning Cay	MKY_CAM2	-21.95	149.50	10	No
Fanning Shoal	MKY_CAM3	-21.90	149.52	11	No

Table 2-2. Field dates in the 2024-25 reporting period for water sampling, logger maintenance and pesticide sampling at the Isaac coastal monitoring locations. Note that pesticide sampling and logger maintenance was only undertaken at Aquila Island.

Date	Water sampling	Logger maintenance	Pesticides
2024-07-31	Yes	Yes	No
2024-10-02	Yes	Yes	No
2024-11-28	Yes	Yes	Yes
2025-03-04	Yes	Yes	Yes
2025-04-07	Yes	Yes	Yes
2025-06-05	Yes	Yes	Yes

Physiochemical parameters were measured at three depths in the water column with a multiparameter water quality meter (Hydrolab Quanta, Hydrolab CO, USA). The water quality meter records water temperature, electrical conductivity, pH, % saturation oxygen, and dissolved oxygen (Table 2-4). The three measurement depths were surface (0.25 m below surface), mid-water, and bottom (1 m above seafloor). Photosynthetically active radiation (PAR) was measured at the three depths, and above water with an underwater quantum sensor (LI-192) and light meter (LI-250A) (Licor Biosciences, Nebraska USA). Care was taken to measure PAR without interference of sporadic cloud cover or boat shadow, though occasionally this was unavoidable.

Water clarity as measured with a Secchi disk was recorded at each site at the time of water sampling. A Secchi disk was lowered to a depth where it is no longer visible then raised back to depth where it becomes visible again. The mean depth between those two points was then recorded as Secchi disk depth.

Table 2-3. Water quality parameters that were analysed using water samples collected at three locations, Aquila Island, Morning Cay and Fanning Shoal, and the methods and reporting limits of the laboratory analysis.

Parameter	APHA method number	Reporting limit
Routine water quality analysis		
pH	4500-H+ B	-
Salinity	2520 B	0.1 PSU
Electrical conductivity (EC)	2510 B	5 μ S cm ⁻¹
Total Suspended Solids (TSS)	2540 D @ 103 - 105°C	0.2 mg L ⁻¹
Nutrients		
Total nitrogen (TN)	Simultaneous 4500-NO ₃ - F and 4500-P F analyses after alkaline persulphate digestion	10 μ g N L ⁻¹
Total dissolved nitrogen (TDN)		
Total phosphorus (TP)		1 μ g P L ⁻¹
Total Dissolved phosphorus (TDP)		
Particulate nitrogen (PN)	Calculated as PN = TN - TDN	-
Particulate phosphorus (PP)	Calculated as PP = TP - TDP	-
Nitrogen oxides (NO _x)	AIMS laboratory, Townsville	0.2 μ g L ⁻¹
Chlorophyll		
Chlorophyll-a	10200-H	0.2 μ g L ⁻¹
Phaeophytin-a		

Table 2-4. Physiochemical measurements that were collected at three locations, Aquila Island, Morning Cay, and Fanning Shoal.

Parameter	Units
Multiparameter water quality meter	
Water temperature	Degrees Celsius (°C)
Electrical conductivity (SpC)	mS cm ⁻¹
pH	
Dissolved Oxygen	%sat
Dissolved Oxygen	mg L ⁻¹
Turbidity	FNU
Light meter	
Photosynthetically active radiation (PAR)	μmol m ⁻² s ⁻¹
Water clarity	
Secchi disk depth	Meters (m)

2.4 Pesticide monitoring

Passive samplers were deployed at Aquila Island (MKY_CAM1) for pesticide monitoring over the wet season (Figure 2-2). Each set of passive samplers contained an Empore™ SPE disk (ED), and a passive flow monitor (PFM). Passive samplers were supplied and analysed by Queensland Alliance for Environmental Health Sciences (QAEHS) at The University of Queensland. Samplers were extracted and the extract then analysed by liquid chromatography mass spectrometry (LCMS) for polar pesticides. An additional 10% samplers were deployed, extracted, and analysed for QA/QC purposes, which also included lab and field blanks, duplicates, and matrix recovery spikes. Water concentration estimates (either time weighted average or point in time) were calculated where possible, otherwise mass loads per sampler are given. Water concentration estimates are derived by applying sampling rates from calibration studies to the amount of analyte accumulated by the sampler. The twenty-two herbicides and insecticides used to calculate pesticide risk metrics (ms-PAF) are listed in Table 2-6.

Pesticide deployments during the 2024–2025 program were affected by severe weather, which prevented site access on two occasions in January and February 2025. As a result, the second deployment remained in the field longer than planned.



Figure 2-2. Pesticide monitoring passive samplers such as these were retrieved from Aquila Island (MKY_CAM1) over the reporting period (Table 2-5). Note: biological growth on the samplers.

Table 2-5. Pesticide passive samplers deployed at Aquila Island (MKY_CAM1) during the 2024-2025 wet season.

Site name	Site code	Start date	End date	Duration (days)
Aquila Island	MKY_CAM1	2024-10-02	2024-11-28	57
Aquila Island	MKY_CAM1	2024-11-28	2025-04-03	94
Aquila Island	MKY_CAM1	2025-03-04	2025-04-07	34
Aquila Island	MKY_CAM1	2025-04-07	2025-06-06	60

Table 2-6. Pesticide analytes used for ms-PAF calculations to determine the pesticide risk baseline. Column two shows the type of pesticide - photosystem-two inhibiting herbicide (PSII), other herbicide (OH), and insecticide (I). Note: A full list of pesticides monitored via passive samplers is included in Appendix 1

Analyte	Type	Detection method	Limit of reporting (LOR)
2,4-D	OH	ED	5 ng sampler-1
Ametryn	PSII	ED	5 ng sampler-1
Atrazine	PSII	ED	1 ng sampler-1
Diuron	PSII	ED	1 ng sampler-1
Fipronil	I	ED	5 ng sampler-1
Fluroxypyr	OH	ED	1 ng sampler-1
Haloxypop	OH	ED	1 ng sampler-1
Hexazinone	PSII	ED	1 ng sampler-1
Imidacloprid	I	ED	1 ng sampler-1

MCPA	OH	ED	5 ng sampler-1
Metolachlor	OH	ED	1 ng sampler-1
Metribuzin	PSII	ED	1 ng sampler-1
Metsulfuron-methyl	OH	ED	1 ng sampler-1
Pendimethalin	OH	ED	5 ng sampler-1
Prometryn	PSII	ED	1 ng sampler-1
Simazine	PSII	ED	1 ng sampler-1
Tebuthiuron	PSII	ED	1 ng sampler-1
Terbutylazine	PSII	ED	1 ng sampler-1

2.5 Seafloor mounted continuous dataloggers

A pair of water quality loggers were deployed at Aquila Island (MKY_CAM1) to measure water temperature, water depth, turbidity, and light. The loggers were attached to stainless steel frame to be placed on the seafloor (Figure 2-3). The loggers used are NTU-LPT and MS9-LPT loggers manufactured by In-situ Marine Optics, Perth WA (<https://insitumarineoptics.com>). The loggers record a burst of 50 measurements of water temperature (°C), water depth (m), turbidity (NTU), and light (PAR, $\mu\text{mol m}^{-2} \text{s}^{-1}$) at a frequency of 5 Hz every 10-minutes.



Figure 2-3. Water quality loggers attached to instrument frames ready for deployment to the seabed. The horizontally orientated logger is an NTU-LPT turbidity logger, and the vertically orientated logger is a MS9-LPT multispectral light logger manufactured by Insitu Marine Optics.

Table 2-7. Specifications of NTU-LPT turbidity logger and MS9-LPT multispectral light loggers.

Parameter	Units	Sensor range	Accuracy / Resolution
Water temperature	Degrees Celsius (°C)	-55 to 125 °C	+/- 1.0 °C
Water depth	Meters (m)	0 – 90 m	+/- 1.0 %
Turbidity	Nephelometric turbidity units (NTU)	0 – 400/1000 NTU	0.05 NTU
Irradiance	$\mu\text{W cm}^{-2} \text{ nm}^{-1}$	0 – 400 $\mu\text{W cm}^{-2} \text{ nm}^{-1}$	$2.5 \times 10^{-3} \text{ W cm}^{-2} \text{ nm}^{-1}$

Logger data processing

After each deployment, dataloggers are returned to the laboratory and their logfiles downloaded. The mean values for water temperature, water depth, turbidity and irradiance were calculated for each 10-minute burst interval.

RMS Depth

A pressure sensor is located on the MS9-LPT 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. The average water depth and Root Mean Square (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.

Each time a pressure measurement is made the pressure sensor takes 50 measurements over a period of 10 seconds. From these 50 measurements, average water depth (m) and Root Mean Square (RMS) water height are calculated.

RMS water height, D_{rms} , is calculated as follows:

$$RMS_{depth} = \sqrt{\frac{\sum_{n=1}^N (D_n - \bar{D})^2}{N}} \quad \text{[Equation 1]}$$

Where D_n is the n^{th} of the 50 readings and \bar{D} is the mean water depth of the n readings.

Photosynthetically Active Radiation (Daily Light Integral)

While turbidity is a primary indicator of water quality (Erftemeijer et al., 2012), the relationship between turbidity and benthic light is not always strong (Sofonia and Unsworth, 2010; Kirk, 1985). As benthic photosynthetically active radiation (bPAR) is more biologically relevant to the health of photosynthetic benthic habitats such as seagrass, algae, and corals it is becoming more useful as a management response tool when used in conjunction with known thresholds for healthy growth for these habitats (e.g., Chartrand et al., 2012). For this reason, it is important to include bPAR in the suite of water quality variables when capturing local baseline conditions of ambient water quality.

This may be especially relevant in the Isaac coastal region due to the naturally variable turbidity to which habitats are adapted.

Photosynthetically active radiation (bPAR) was calculated from the response of the nine individual irradiance channels on the MS9 logger. Light data between 400 and 700 nm was interpolated and integrated internally. The mean value for PAR was calculated for each 10-minute burst interval.

Daily light integral (DLI) describes the number of photosynthetically active photons that are delivered to a specific area over a 24-hour period.

Daily light integral (DLI) was calculated as follows:

$$DLI = \sum_i PAR_i * \frac{600}{1000000} \quad \text{[Equation 2]}$$

Where:

DLI is the daily light integral in mol photons m⁻² d⁻¹

i is each PAR reading during the day

PAR is the photosynthetically active radiation in μmol photons m⁻² s⁻¹

600 is the time interval between readings

1,000,000 is the unit conversion

Suspended Sediment Concentration

Suspended sediment concentration was calculated from turbidity data after establishing a relationship with each site. Full methods are provided in Cartwright et al. (2022).

The following equation may be used to calculate suspended sediment concentration from logger data acquired from IMO-NTU turbidity loggers at each site:

$$SSC = Turb * C_f \pm e \quad \text{[Equation 3]}$$

Where:

SSC is the calculated suspended sediment concentration in mg L⁻¹

Turb is the measured turbidity value in NTU

C_f is the conversion factor (unique for each site)

e is the root mean square error value

Note that error values are not presented in the converted data values.

Quality control

During logger processing the data is passed through automatic and manual quality control steps to flag data. The automated QC steps are rule-based tests. Manual QC follows the automated steps to catch anything missed or which is difficult for machine to detect. A concise description of rules for flagging data is in Appendix 1. More detail of the data processing workflow and quality control procedures is contained in a separate document (Iles et al., 2023).

Statistical summaries for each water quality parameter measured are provided in the results section. Annual values (mean, median, minimum, maximum) are calculated over the twelve-month period corresponding to both the water year and reporting period (July 2024 to June 2025). Data collected over the monitoring period has been compared to the Pioneer River and Plane Creek Basins Environmental Values and Water quality objectives (EPP, 2019). The three Isaac coastal sites are in

water area/type SD2383 open coastal waters (including macrotidal) landward of the plume line, shown in WQ1222 (s3, s4).

3 Results and Discussion

3.1 Rainfall and river flows

Daily rainfall for the Mackay region is shown in Figure 3.1. The northern wet season is defined as between 1st November and 30th April, whereas the annual rainfall onset is calculated as the date when the rainfall total reaches 50 mm since 1st September, and hence is a better indication of the start of the wet season. Comparatively, this year’s onset was later than average for Mackay, occurring on 7th October 2024, with total wet season rainfall of 1361 mm.

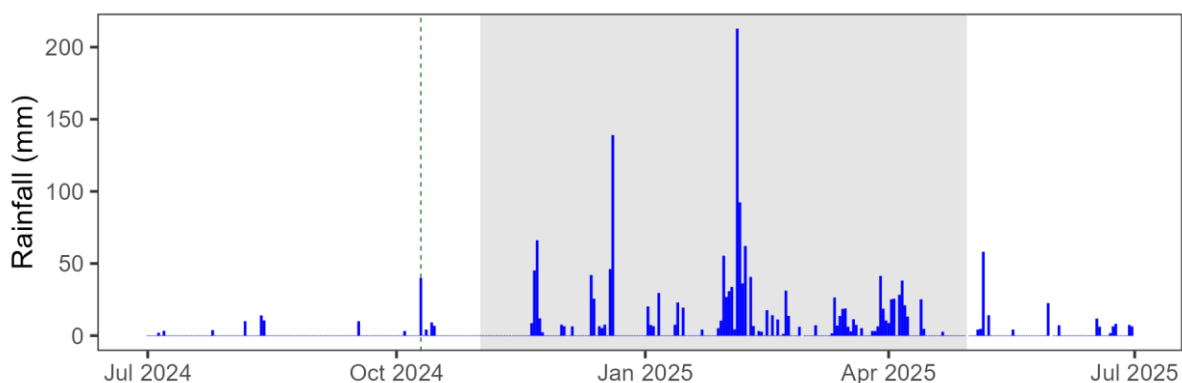


Figure 3-1. Rainfall recorded at Plane Creek Sugar Mill (station 033059) for the 2024-2025 water year. The nominal wet season period is shaded grey. Green vertical dash indicates northern rainfall onset. Data source: <http://www.bom.gov.au/climate/data/>

Rainfall during the 2024–2025 monitoring period followed typical seasonal patterns, with low dry-season totals and a marked increase from late December (Figure 3-1). However, several extreme wet-season events were recorded. The most significant occurred in early February 2025, when 212.6 mm was recorded on 4 February, with multiple additional days exceeding 30–90 mm between late January and early February. Cumulative rainfall during this period was well above average daily totals for the long-term climate record shown in Figure 3-2, with peak daily values exceeding typical wet-season event magnitudes. While annual rainfall remains within the historical range (1928 mm), the intensity and clustering of rainfall events in early 2025 were high relative to long-term patterns.

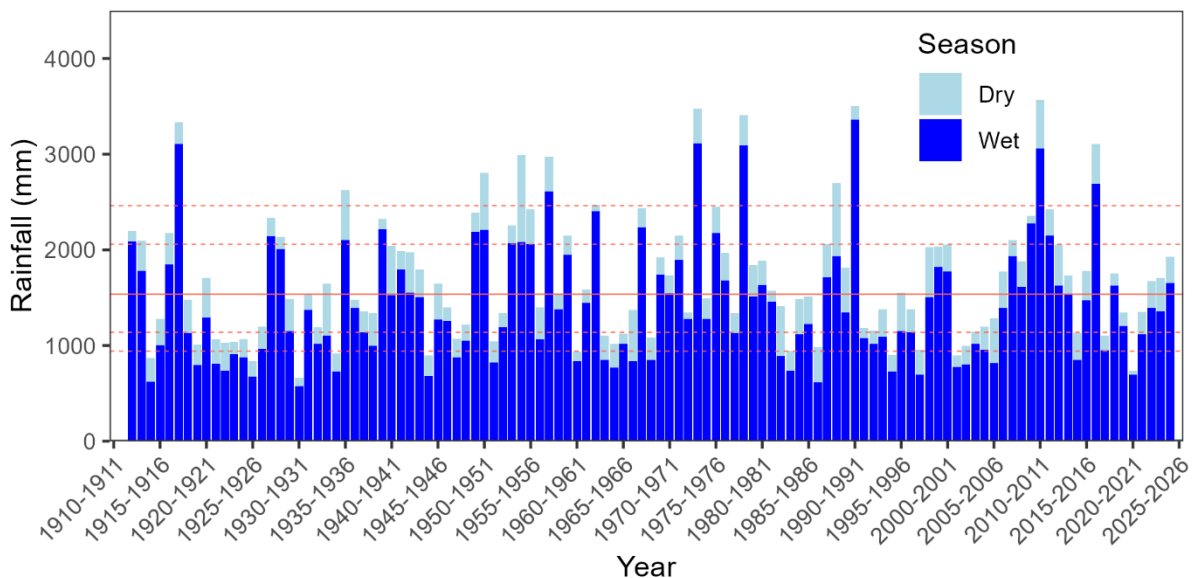


Figure 3-2: Annual rainfall by water year for the Mackay region during wet season (blue) and dry season (light blue). Totals were calculated for the wet season period 1st November to 31st March for each water year. Water year runs from 1st July to 30th June. Solid red line represents median annual rainfall by water year, dashed lines represent 10th, 25th, 75th, and 90th percentiles. Daily rainfall data was obtained from the Plane Creek Sugar Mill (station 033059). Data source: <http://www.bom.gov.au/climate/data/>

Streamflow during the 2024–2025 reporting period was strongly seasonal, with discharge dominated by wet-season rainfall events and minimal flow during the dry season (Figure 3-3). Carmila Creek exhibited negligible or zero flow throughout much of the dry season (July–November 2024), consistent with long-term hydrological behaviour for this system.

Flow commenced in response to early wet-season rainfall in late December 2024, with multiple discharge pulses recorded between January and March 2025. The most significant event occurred in early February 2025, coinciding with extreme rainfall across the catchment (including >200 mm recorded on 4 February). This event generated the highest discharge of the reporting year in Carmila Creek, followed by several smaller but sustained flow pulses through mid-February. Additional moderate flow events occurred in March and early April, before discharge declined rapidly toward late autumn.

Overall, the 2024–2025 hydrograph for Carmila Creek reflects a typical wet–dry tropical regime, characterised by episodic, rainfall-driven runoff rather than sustained baseflow. Flow events were short-lived but high magnitude, indicating rapid catchment response to intense rainfall.

For context, the larger northern systems (Pioneer River and Sandy Creek) exhibited similar seasonal timing, with peak discharge occurring during the January–March wet season (Figure 3-4). However, as perennial or larger catchment systems, these rivers maintained greater discharge volumes and more prolonged flow periods relative to Carmila Creek. No atypical flow timing or out-of-season events were observed in any of the monitored systems during the reporting year.

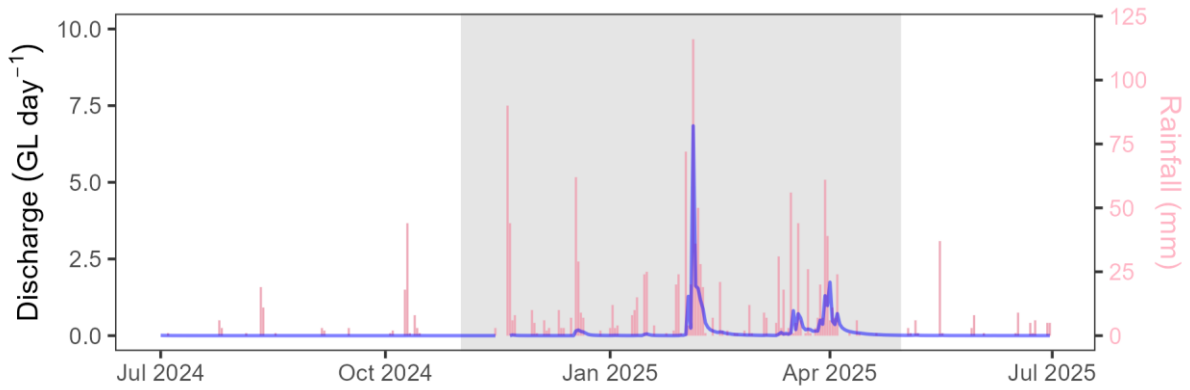


Figure 3-3: Daily discharge in Carmila Creek (blue line; GL day^{-1}) and daily rainfall at Plane Creek (pink bars; mm) from July 2024 to June 2025. Flow remained negligible for much of the dry season, with short-lived discharge events occurring during the wet season in response to rainfall pulses, particularly in January–February 2025.

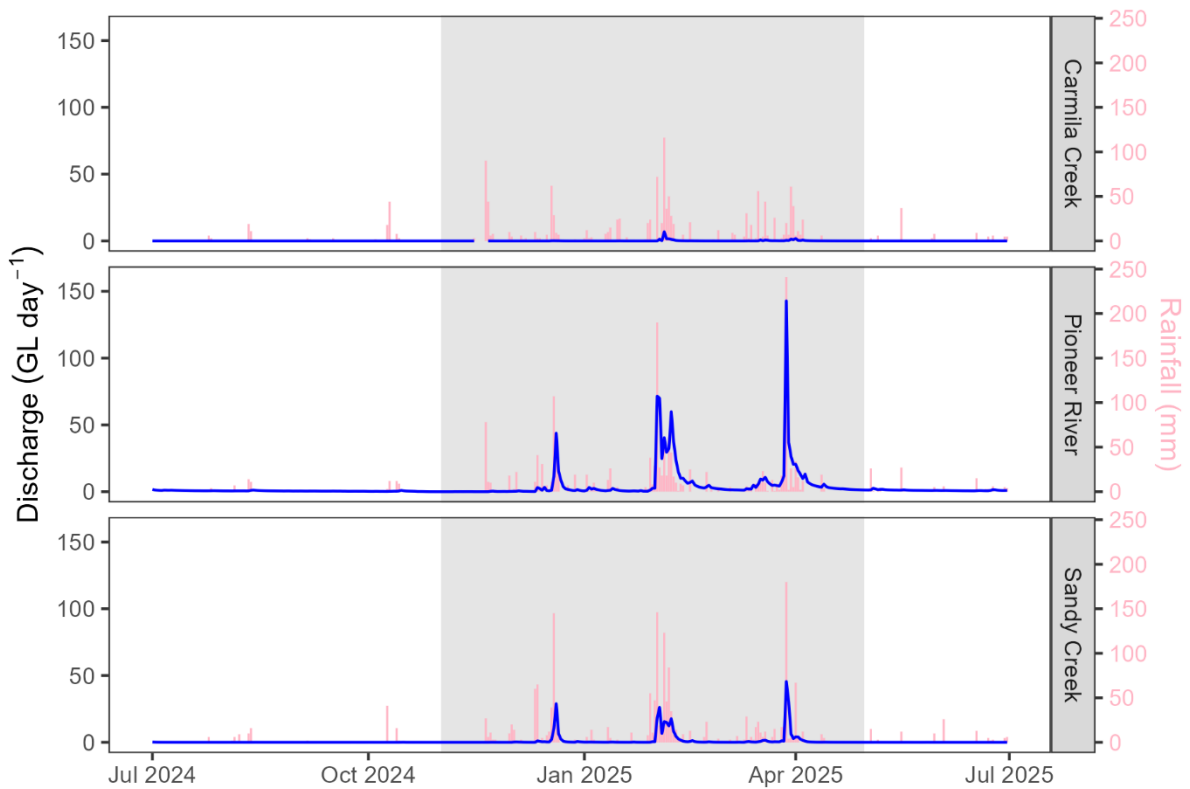


Figure 3-4 Daily discharge (blue line; GL day^{-1}) and rainfall (pink bars; mm) for Carmila Creek (top), Pioneer River (middle) and Sandy Creek (bottom) from July 2024 to June 2025. Carmila Creek is the primary freshwater input to the Isaac coastal zone and exhibited low, short-lived flow responses. In contrast, the Pioneer River and Sandy Creek— which influence coastal waters further north in the Mackay region— recorded substantially higher peak discharges during wet-season rainfall events, particularly between January and April 2025. This comparison highlights the relatively smaller hydrological contribution of river catchments to the Isaac coastal zone.

3.2 Oceanographic conditions

During the 2024–2025 reporting year, wave conditions were characteristic of an inshore, trade-wind-dominated environment (Figure 3-5).

Significant wave height (H_s) ranged from approximately 0.1 to 2.3 m, with most observations below 1 m (Figure 3-5, Figure 3-6). Higher wave heights (>2 m) were infrequent and associated with short-lived periods of stronger southeasterly winds or offshore weather systems. Wave direction was dominated by the southeast to east–southeast sector throughout the year, consistent with prevailing trade-wind conditions.

Seasonal variability was modest (Figure 3-5). Winter months (June to August) were characterised by lower wave heights, commonly below 0.5 m, and a strongly constrained southeast direction. During summer and early wet-season months (December to March), wave direction broadened slightly and typical wave heights increased modestly, with most higher-energy events occurring during this period.

Overall, the 2024–2025 wave climate reflects stable, trade-wind-driven conditions with moderate seasonal variation, providing context for sediment resuspension and turbidity dynamics in the Isaac coastal zone.

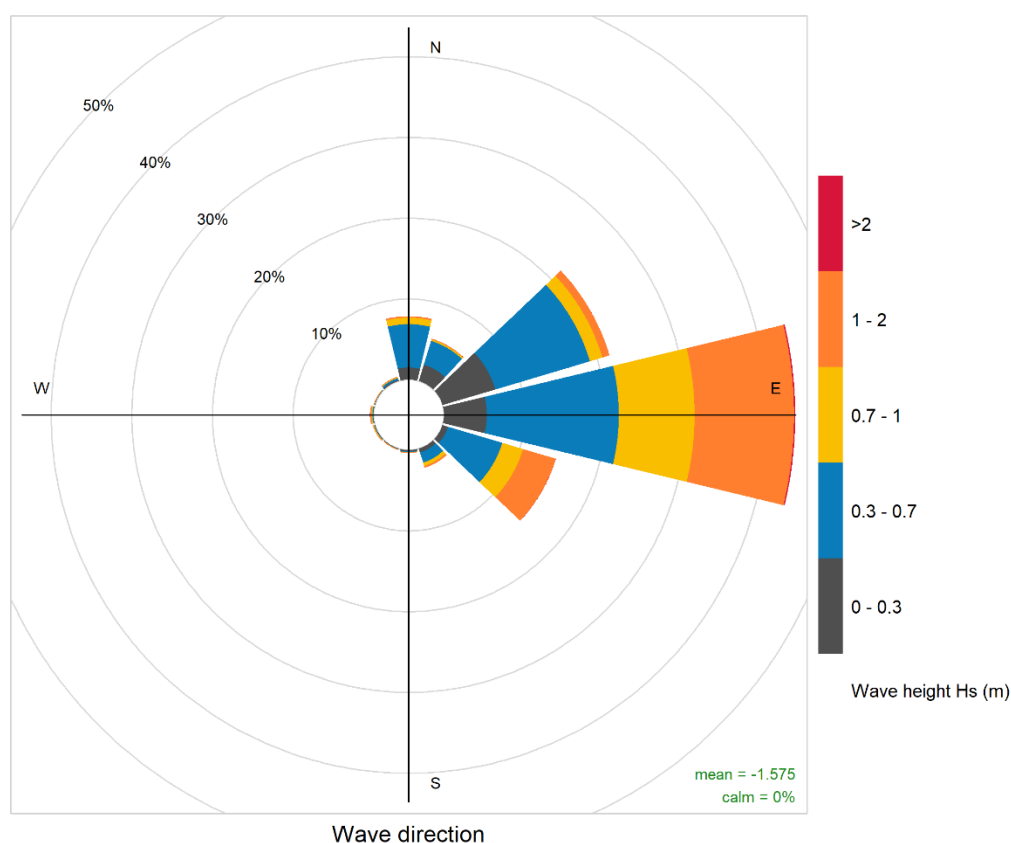


Figure 3-5. Frequency of counts by wave direction (%), and significant wave height (m) at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025. Data source: <https://www.qld.gov.au/environment/coasts-waterways/beach/monitoring>

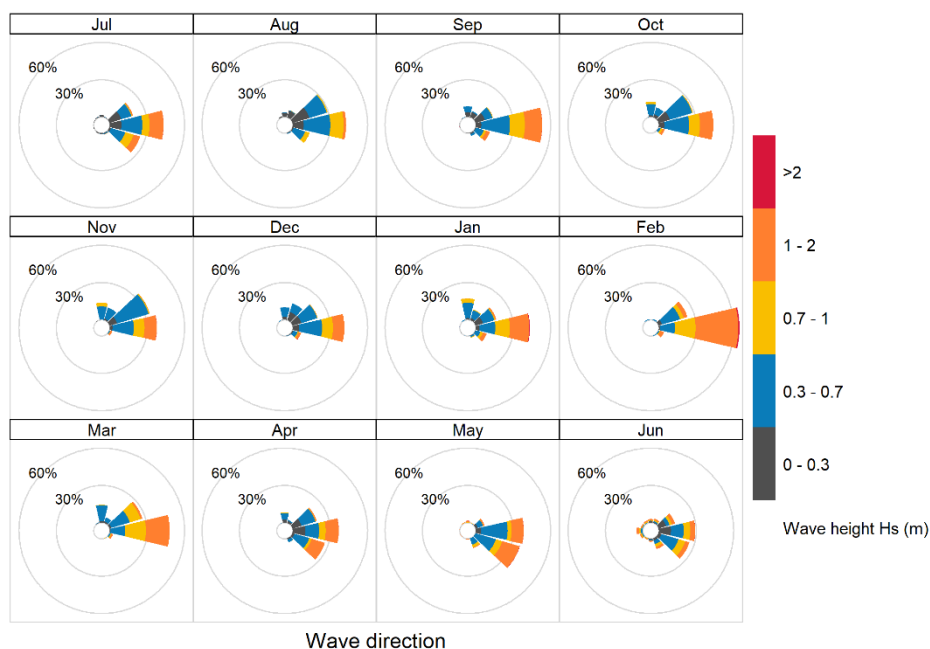


Figure 3-6. Frequency of counts by wave direction (%), and significant wave height (m) at the Hay Point wave buoy station between July 1, 2024, and June 30, 2025. Values shown in this plot for those months are good for wave height information only. Data source: <https://www.qld.gov.au/environment/coasts-waterways/beach/monitoring>.

3.3 Water quality

3.3.1 Physicochemical

Physicochemical conditions across the six sampling events during 2024–2025 were consistent with marine coastal waters and showed expected seasonal variability.

Dissolved oxygen (DO) concentrations ranged from 6.34 to 9.41 mg L⁻¹, corresponding to 88–135% saturation (Figure 3-7). Most measurements were near or slightly above 100% saturation, indicating well-oxygenated conditions at the time of sampling. Occasional supersaturation (>110%) is consistent with daytime photosynthetic activity and physical mixing in shallow coastal environments. No hypoxic conditions were observed.

Electrical conductivity varied between 46.3 and 56.2 mS cm⁻¹, with corresponding salinity values ranging from 35.4 to 37.5 PSU (Figure 3-8). Most observations were within the range expected for fully marine waters. Lower conductivity values were recorded during the August sampling event (~46–48 mS cm⁻¹), which likely reflects the influence of cooler winter water temperatures (which reduce conductivity) and/or short-term mixing effects prior to sampling. Conductivity and salinity returned to typical marine values during subsequent sampling events.

Water temperature ranged from 18.1 to 28.2 °C (Figure 3-9). The lowest temperatures were recorded during the winter (August) sampling event (~18–19 °C), increasing to approximately 27–28 °C during summer months. This pattern reflects normal seasonal warming and cooling of shallow inshore waters.

pH ranged from 8.05 to 8.55 across sampling events, remaining within the expected range for marine waters (Figure 3-10). Variability between sampling occasions was modest and did not indicate abnormal carbonate system conditions.

Overall, the in-situ sampling events (whilst limited to six over the year) indicates seasonal variability consistent with an open coastal marine setting, with no evidence of stratification or oxygen depletion during field observations.

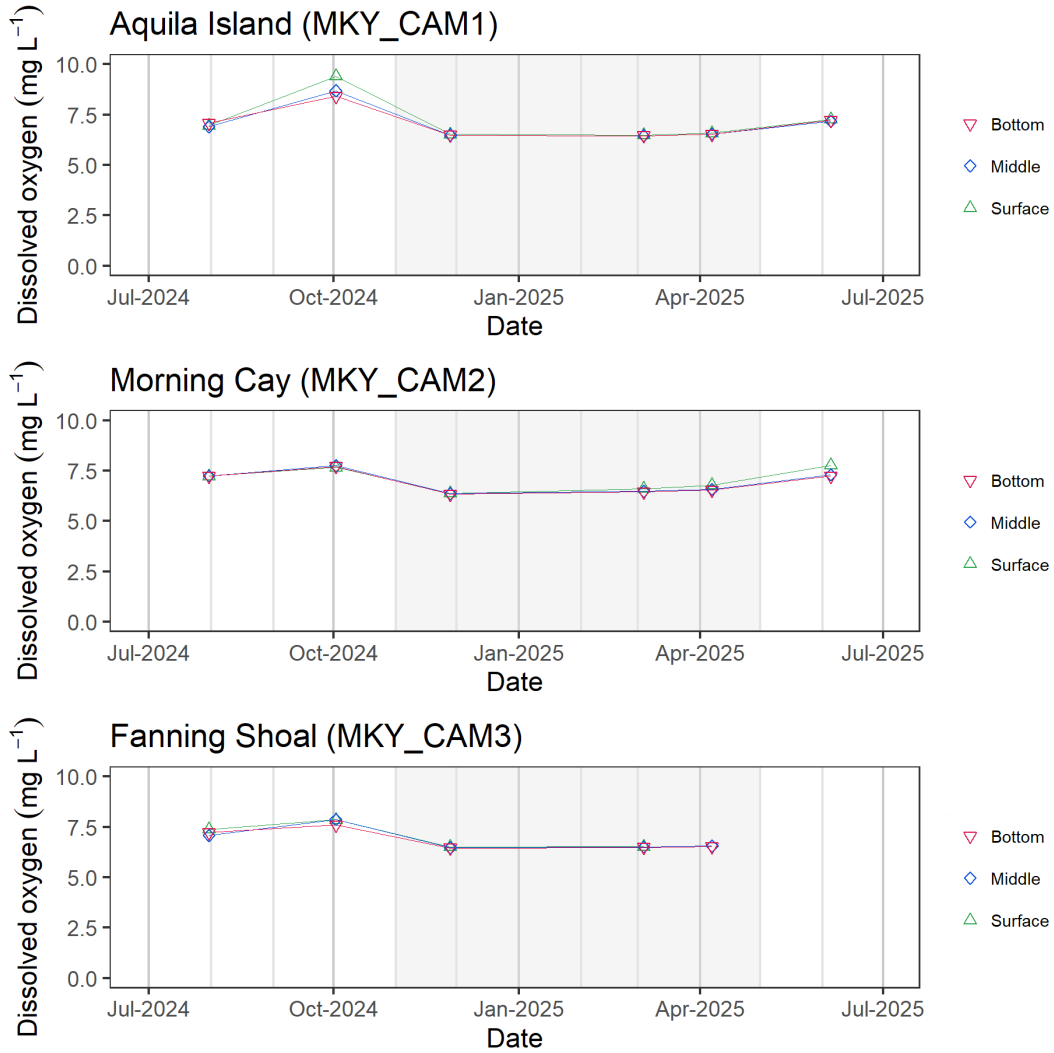


Figure 3-7. Dissolved oxygen concentration (mg/L) at three water quality monitoring sites in the Isaac coastal region showing results for the top, middle, and bottom water.

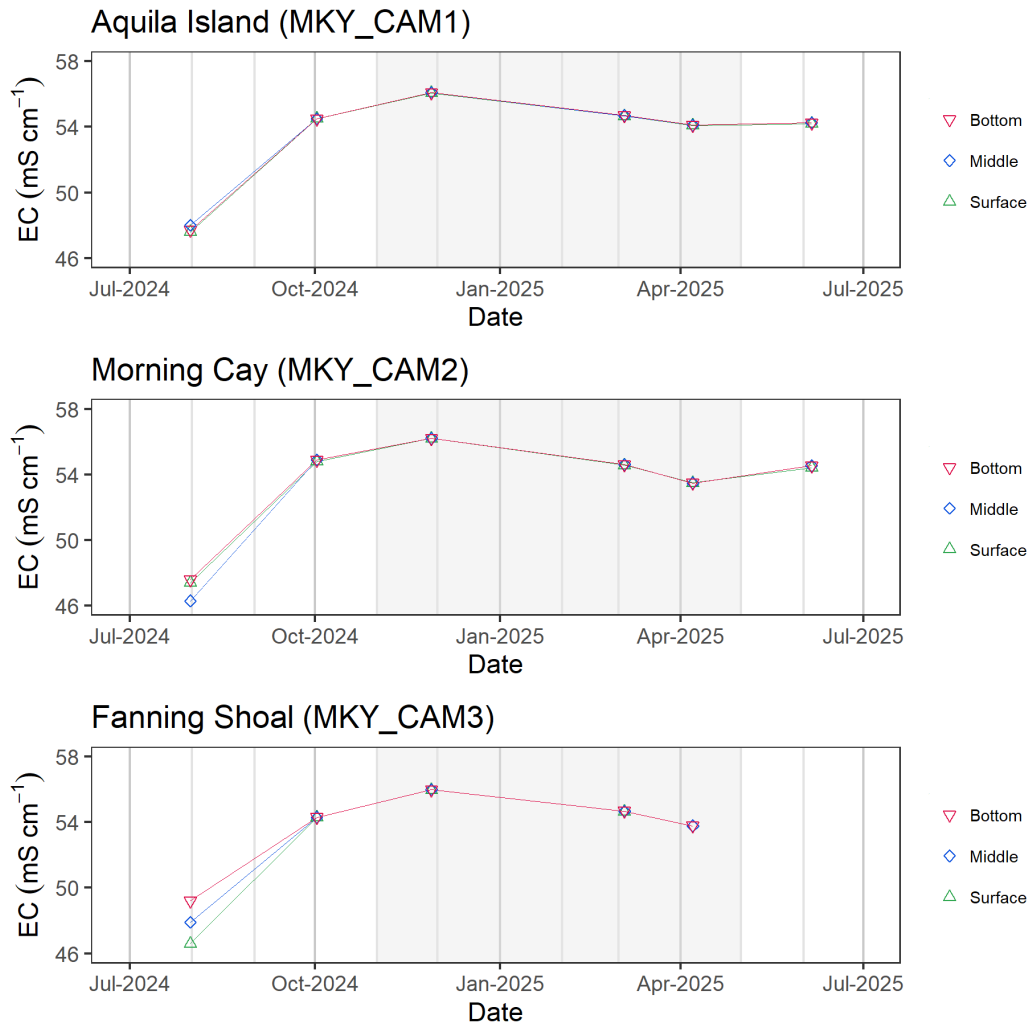


Figure 3-8. Electrical conductivity recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.

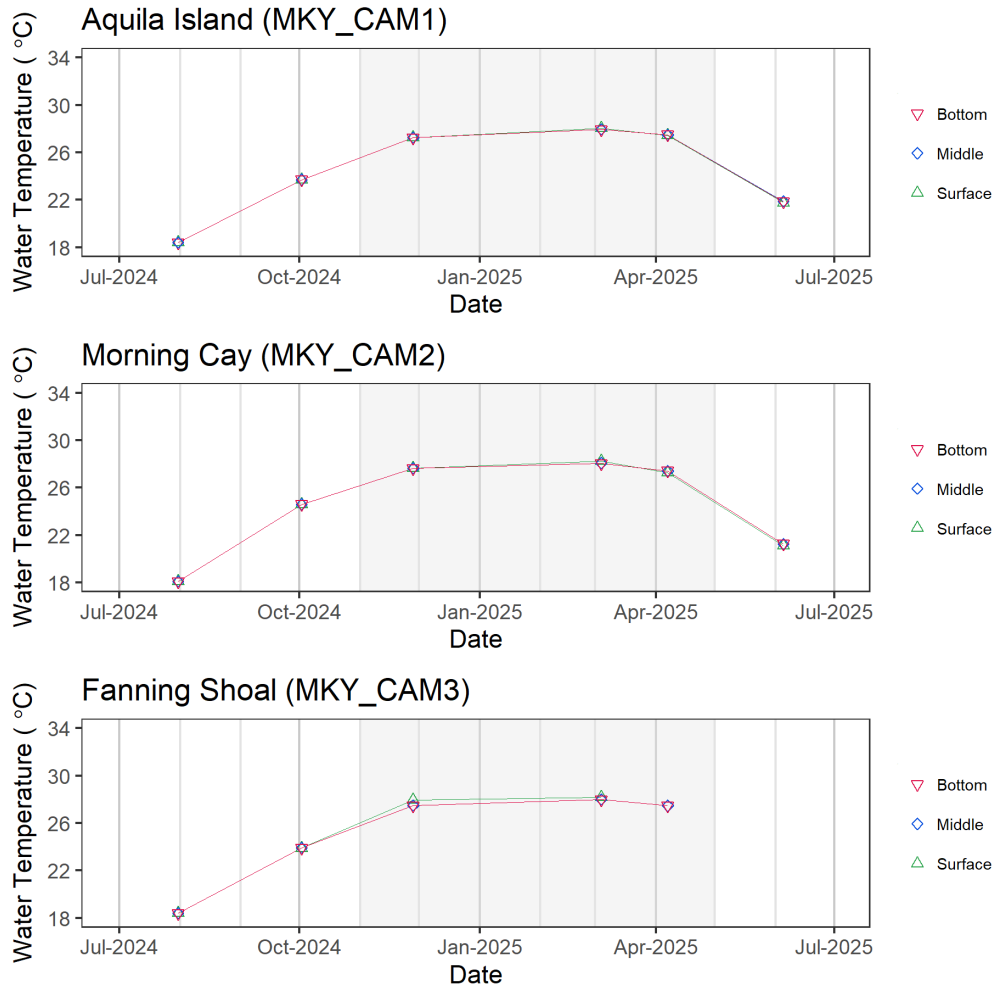


Figure 3-9. Water temperature recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.

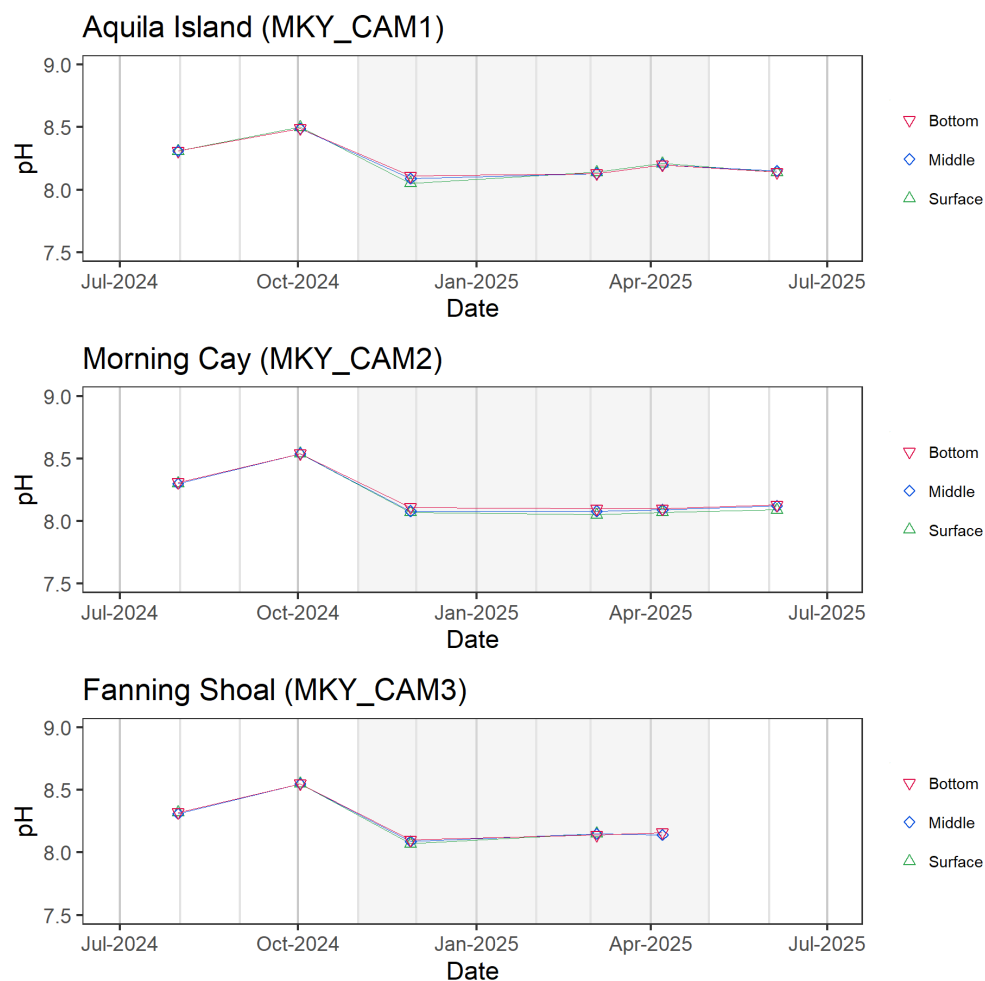


Figure 3-10. pH recorded at three water quality sites in the Isaac coastal region showing results for the top, middle, and bottom water.

3.3.2 Nutrients

Nutrient concentrations across the six sampling events (July 2024 to June 2025) were generally low to moderate at all three Isaac coastal sites, with one pronounced late-November event.

Chlorophyll-a concentrations were generally low ($0.23\text{--}2.87\ \mu\text{g L}^{-1}$), indicating low phytoplankton biomass across most sampling events (Figure 3-11). A single elevated value ($7.98\ \mu\text{g L}^{-1}$) was recorded at Aquila Island (MKY_CAM1) in late November 2024, coincident with elevated particulate nutrients.

Total nitrogen (TN) concentrations ranged from 93 to $1,345\ \mu\text{g L}^{-1}$ (Figure 3-12). For most sampling events and sites, TN was between 107 and $188\ \mu\text{g L}^{-1}$. A marked elevation was recorded at Aquila Island (MKY_CAM1) on 28 November 2024 ($1,345\ \mu\text{g L}^{-1}$), substantially higher than all other observations.

Total dissolved nitrogen (TDN) ranged from 83 to $129\ \mu\text{g L}^{-1}$ and showed relatively little variability among sites or sampling rounds (Figure 3-12). Dissolved nitrogen remained within a narrow band across the year, including during the November event.

The elevated TN in late November was driven primarily by the particulate fraction. **Particulate nitrogen (PN)** ranged from 3 to $1,230\ \mu\text{g L}^{-1}$, with most observations below $50\ \mu\text{g L}^{-1}$ (Figure 3-12).

On 28 November 2024 at Aquila Island (MKY_CAM1), PN reached 1,230 $\mu\text{g L}^{-1}$, accounting for the majority of total nitrogen at that time.

Total phosphorus (TP) ranged from 7 to 112 $\mu\text{g L}^{-1}$ (Figure 3-13). For most samples, TP was between 7 and 13 $\mu\text{g L}^{-1}$. An elevated TP concentration (112 $\mu\text{g L}^{-1}$) was recorded at Aquila Island (MKY_CAM1) in late November 2024. As with nitrogen, this increase was associated with the particulate fraction.

Total dissolved phosphorus (TDP) remained consistently low across all sites and dates, ranging from 5 to 8 $\mu\text{g L}^{-1}$ (Figure 3-13). In contrast, particulate phosphorus (PP) ranged from 1 to 105 $\mu\text{g L}^{-1}$, with the highest value (105 $\mu\text{g L}^{-1}$) recorded at Aquila Island (MKY_CAM1) on 28 November 2024 (Figure 3-12).

Overall, nutrient concentrations were comparable among sites for most of the year. The late-November 2024 sampling event at Aquila Island (MKY_CAM1) was characterised by elevated particulate nitrogen and phosphorus, and increased chlorophyll-a, while dissolved nutrient fractions remained relatively stable.

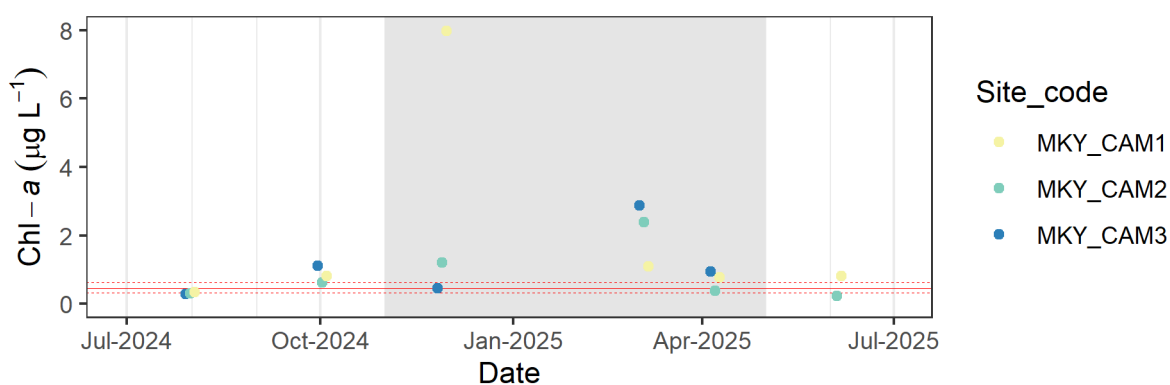


Figure 3-11 Chlorophyll-a concentrations measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), throughout the reporting period. Horizontal red lines represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means.

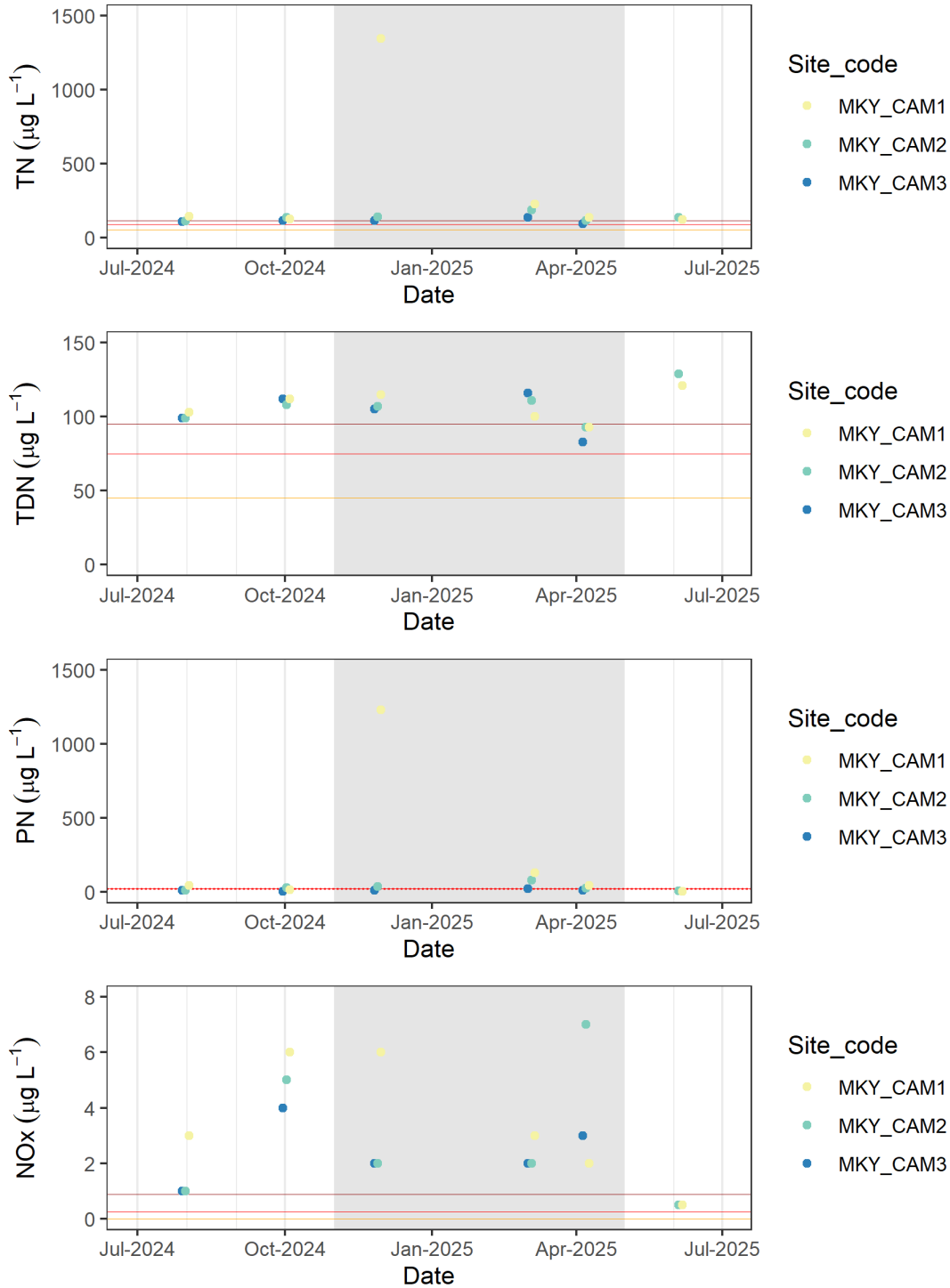


Figure 3-12. Particulate Nitrogen (PN), Total Dissolved Nitrogen (TDN), Total Nitrogen (TN), and oxidised nitrogen (NOx) concentrations measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal lines represent EPP 2019 WQO 20th (orange), 50th (red) and 80th (dark red) percentiles. Horizontal red lines on PN panel represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means. Note unequal y-axis.

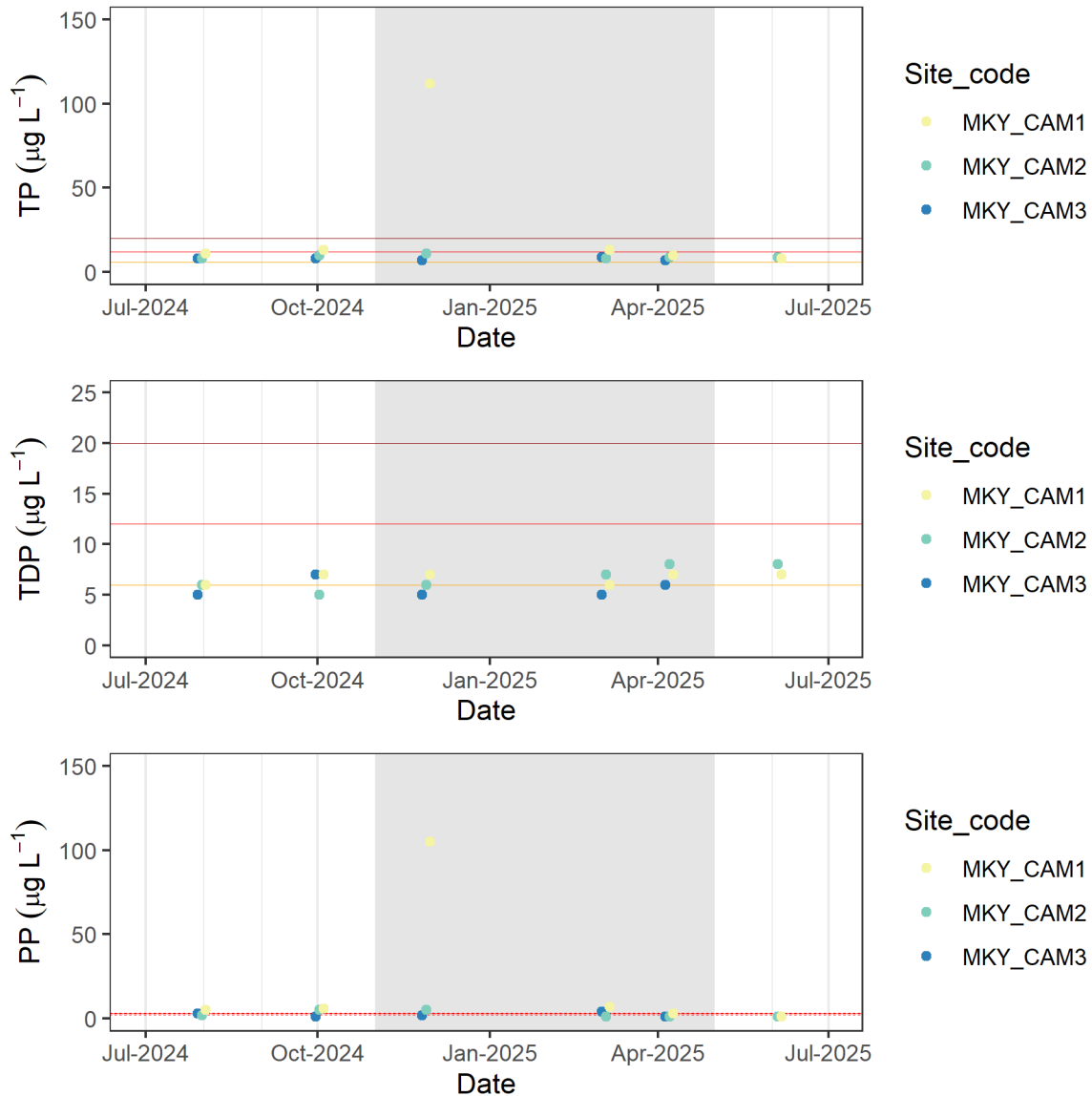


Figure 3-13. Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), and Particulate Phosphorus (PP) concentrations measured in water samples collected from the three Isaac coastal water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal lines represent EPP 2019 WQO 20th (orange), 50th (red) and 80th (dark red) percentiles. Horizontal red lines on PP panel represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means. Note unequal y-axis.

3.3.3 Water clarity

Total suspended solids (TSS) and Secchi depth measurements indicate moderate seasonal variability in water clarity across Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3) during 2024–2025.

TSS concentrations ranged from 0.6 to 21 mg L⁻¹ across the reporting period (Figure 3-14). The lowest values were recorded at Fanning Shoal in July and November 2024 (0.6–2.0 mg L⁻¹), while the highest concentration (21 mg L⁻¹) occurred at Aquila Island in early March 2025. Elevated TSS was

also observed at Aquila Island in October 2024 (14 mg L⁻¹). For most sampling events and sites, TSS remained below 8 mg L⁻¹.

Secchi depths ranged from 1.0 to 4.0 m and showed a clear inverse relationship with TSS (Figure 3-15). Reduced water clarity was observed in October 2024 (1.5–2.0 m across sites) and early March 2025 (1.0–2.0 m), corresponding with higher suspended sediment concentrations. In contrast, clarity improved in April 2025, reaching 3.0 m at Aquila Island and 4.0 m at both Morning Cay and Fanning Shoal, coinciding with lower TSS values (1.9–6.8 mg L⁻¹). July 2024 conditions were also relatively clear (2.0–3.5 m) and associated with low TSS (1.2–3.9 mg L⁻¹).

The highest turbidity conditions were recorded at Aquila Island in March 2025, when TSS reached 21 mg L⁻¹ and Secchi depth was reduced to 1.0 m. In contrast, the late-November 2024 sampling event showed relatively low TSS at Aquila Island (3.7 mg L⁻¹) and moderate water clarity (2.5 m), despite elevated particulate nutrient concentrations at that time.

Overall, suspended sediment concentrations and water clarity exhibited short-term variability between sampling events, with reduced transparency during late dry-season (October) and late wet-season (March) conditions, and improved clarity during autumn (April).

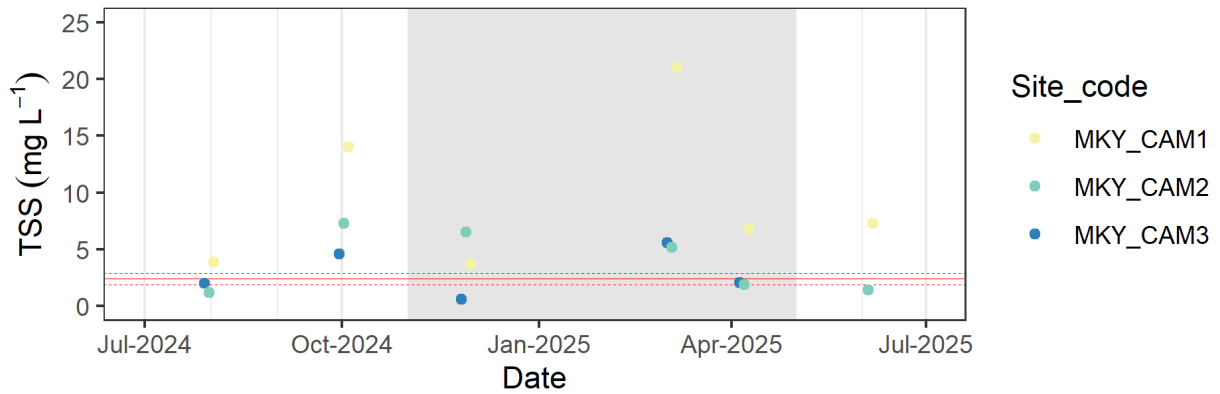


Figure 3-14 Total suspended solids (TSS) measured in water samples collected from the three water quality sites, Aquila Island (MKY_CAM1), Morning Cay (MKY_CAM2), and Fanning Shoal (MKY_CAM3), over the reporting period. Horizontal red lines represent EPP 2019 WQO annual (solid red line), dry and wet season (dashed red line) means.

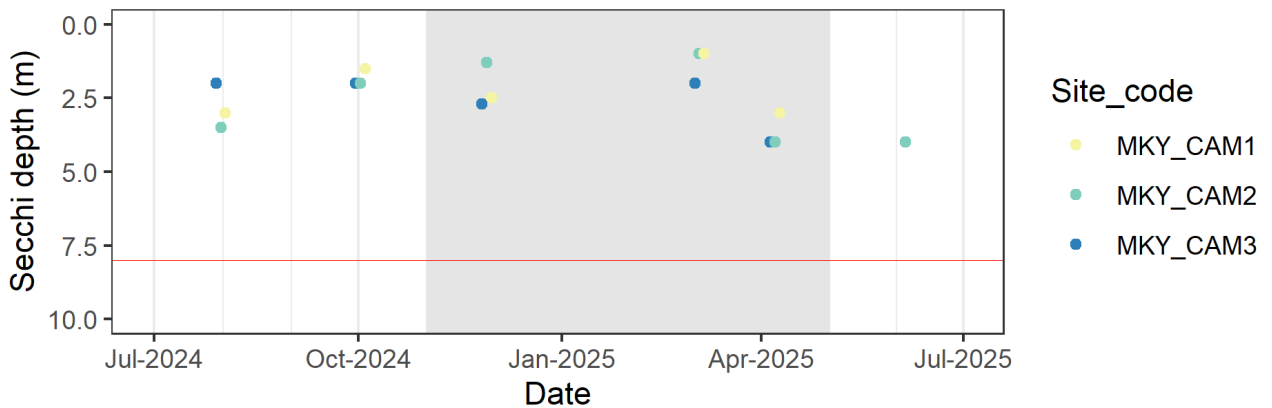


Figure 3-15. Secchi disk depth recorded at the three water quality sites throughout the reporting period. Horizontal red line represents EPP 2019 WQO annual mean.

3.3.4 Pesticides

Pesticides detected at Aquila Island (MKY_CAM1) are presented in Table 3-1. Photosystem-II inhibiting herbicides (PSII) were present in three of the four sampling windows, Atrazine detected in the third window, Diuron detected in the second and third, Hexazinone detected in the second, and Tebuthiuron detected in the third and fourth windows. Atrazine concentrations were below GBRMPA 2010 default guideline values (GBRMPA, 2010), as were concentrations of Diuron, Hexazinone, and Tebuthiuron. The rainfall event during the first sampling window, at the end of November 2024, was not recorded in the stream discharge data and no pesticides were detected during that sampling window. However, rainfall events in January 2025 were recorded in stream discharge data during the second and third sampling windows, when pesticides were detected.

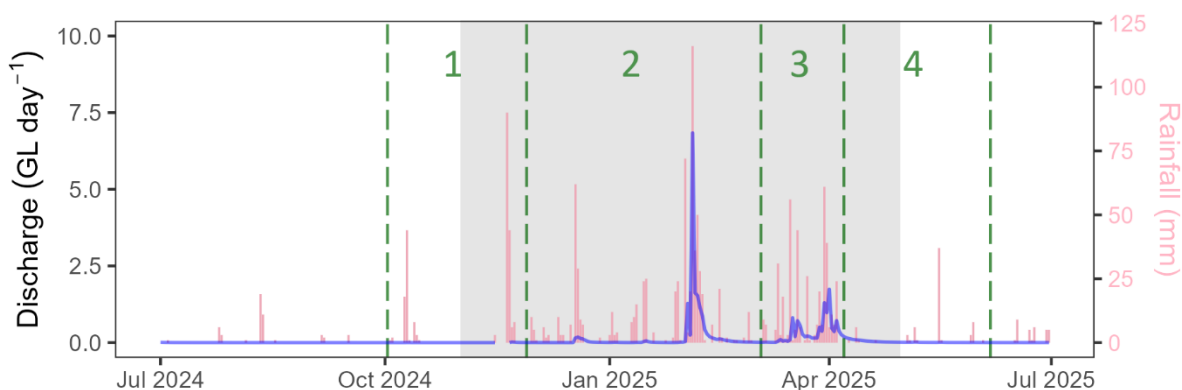


Figure 3-16. Passive sampler deployment periods (green numbers and dashed lines) overlaid on the stream discharge plot (GL d⁻¹) recorded for Carmila Creek (station 126 003A) during the 2024-2025 reporting period. The nominal wet season period is shaded grey. Rainfall data from the Carmila gauging station is also shown in pink. Data source: <https://water-monitoring.information.qld.gov.au/>

Table 3-1. Pesticide mass per sampler recovered from passive samplers deployed at Aquila Island (MKY_CAM1).

Site Name	Aquila Island		Aquila Island		Aquila Island		Aquila Island	
Deployed Date	02/10/2024		28/11/2024		04/03/2025		04/03/2025	
Retrieved Date	28/11/2024		04/03/2025		07/04/2025		07/04/2025	
Days Deployed	57		96		34		34	
Flow Rate (cm/s)	28.2		28.2		28.2		28.2	
Site Code	1		1		1		1	
Sample Name	AQD125_ED_AQA		AQD225_ED_AQA		AQD325_ED_AQA		AQD325_ED_AQA DUP	
Analyte	LOQ							
2,4-D	5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Ametryn	5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Atrazine	1.00	<1.00	2.81	<1.00	<1.00	1.11	<1.00	<1.00
Atrazine desethyl	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Atrazine desisopropyl	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Bromacil	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Diuron	0.500	<0.500	1.21	<0.500	<0.500	0.950	<0.500	<0.500
Fluazifop	0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Fluometuron	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Fluroxypyr	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Haloxyfop	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Hexazinone	1.00	<1.00	1.52	<1.00	<1.00	<1.00	<1.00	<1.00
Imazapic	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Imidacloprid	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
MCPA	5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Metolachlor (S+R)	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Metribuzin	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Metsulfuron methyl	1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00

Prometryn	1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Propazine	1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Simazine	1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Tebuconazole	1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Tebuthiuron	1.00	<1.00	1.32	1.71	2.20	6.20
Terbuthylazine	1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Terbutryn	5.00	<5.00	<5.00	<5.00	<5.00	<5.00

Table 3-2. Pesticide water concentration recovered from passive samplers deployed at Aquila Island (MKY_CAM1).

Site Name	Aquila Island	Aquila Island	Aquila Island	Aquila Island	Aquila Island
Deployed Date	02/10/2024	28/11/2024	04/03/2025	04/03/2025	07/04/2025
Retrieved Date	28/11/2024	04/03/2025	07/04/2025	07/04/2025	06/06/2025
Days Deployed	57	96	34	34	60
Flow Rate (cm/s)	28.2	28.2	28.2	28.2	28.2
Site Code	1	1	1	1	1
Sample Name	AQD125_ED_AQA	AQD225_ED_AQA	AQD325_ED_AQA	AQD325_ED_AQA DUP	AQD425_ED_AQA
Analyte					
2,4-D	<0.499	<0.296	<0.836	<0.836	<0.474
Ametryn	<0.898	<0.533	<1.51	<1.51	<0.853
Atrazine	<0.119	0.198	<0.199	0.221	<0.113
Atrazine desethyl	<0.142	<0.084	<0.239	<0.239	<0.135
Atrazine desisopropyl	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Bromacil	<0.081	<0.048	<0.135	<0.135	<0.077
Diuron	<0.071	0.103	<0.120	0.227	<0.068
Fluazifop	*<0.012	*<0.007	*<0.020	*<0.020	*<0.011
Fluometuron	<0.086	<0.051	<0.144	<0.144	<0.082
Fluroxypyr	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Haloxypop	<0.062	<0.037	<0.103	<0.103	<0.059
Hexazinone	<0.116	0.105	<0.195	<0.195	<0.111

Imazapic	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Imidacloprid	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
MCPA	<0.361	<0.214	<0.605	<0.605	<0.343
Metolachlor (S+R)	<0.116	<0.069	<0.195	<0.195	<0.111
Metribuzin	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Metsulfuron methyl	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Prometryn	<0.196	<0.117	<0.329	<0.329	<0.187
Propazine	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Simazine	<0.081	<0.048	<0.135	<0.135	<0.077
Tebuconazole	*<0.119	*<0.070	*<0.199	*<0.199	*<0.113
Tebuthiuron	<0.091	0.071	0.261	0.336	0.536
Terbutylazine	<0.109	<0.065	<0.183	<0.183	<0.104
Terbutryn	<0.766	<0.455	<1.28	<1.28	<0.728

[^] - Limit of Reporting (LOR) raised by blank level: Where an analyte is detected in field or lab blanks above the Limit of Quantification (LOQ), the effective LOR is raised to the average blank value plus three times the standard deviation

Data reported as <LOR where applicable, and expressed as a water concentration estimate

N/R - Not Reportable: Where a data point is not able to be reliably reported due to unavoidable analytical issues such as matrix interference or unacceptable analyte performance/recovery

Water concentration estimates provided here are derived by applying sampling rates from calibration studies to the amount of analyte accumulated by the sampler

* - Sampling rate for analyte not available: Water concentration estimate provided using the atrazine as the surrogate sampling rate for comparison purposes only

3.4 In-situ loggers

3.4.1 Water temperature

Water temperature at Aquila Island followed a clear seasonal cycle consistent with a tropical inshore marine environment (Figure 3-17; Table 3-3). Monthly mean temperatures increased progressively from winter minima in July (mean 19.9 °C; minimum 18.1 °C) through spring, reaching peak summer conditions in January (mean 28.8 °C; maximum 30.1 °C). Temperatures remained elevated throughout the wet season (December–March), with monthly means consistently above 27.8 °C.

Cooling commenced in April (mean 26.6 °C) and accelerated through May (23.8 °C), returning to winter conditions by June (mean 20.8 °C). The annual temperature range was 18.1–30.1 °C.

Seasonally, the dry season (May–October) was characterised by lower and more variable temperatures (mean 22.2 °C; SD 2.08 °C), reflecting transitional warming and cooling periods. In contrast, the wet season (November–April) exhibited consistently high temperatures with reduced variability (mean 27.8 °C; SD 0.94 °C), indicative of sustained summer conditions.

Overall, mean daily water temperature across the reporting period was 25.0 °C (median 25.8 °C), with variability driven primarily by the strong seasonal transition between winter minima and summer maxima rather than short-term fluctuations.

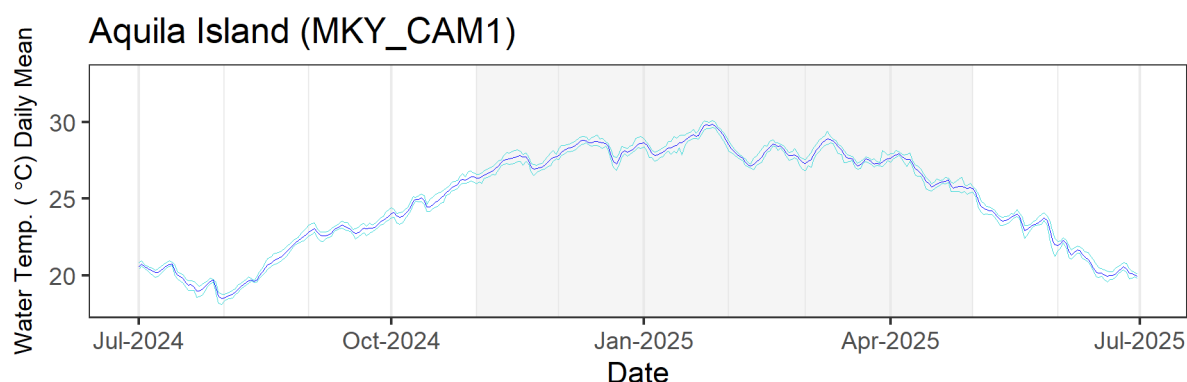


Figure 3-17. Daily mean water temperature (blue) and daily minimum and maximum (light blue) measured at water quality monitoring sites in the Isaac coastal region.

Table 3-3. Monthly summary statistics for water temperature (°C) measured by continuous dataloggers at the Aquila Island (MKY_CAM1) ambient water quality monitoring site. SD = standard deviation, Min = minimum, Max = maximum, Q1 = 1st quartile (25th percentile), Q3 = 3rd quartile (75th percentile), n = sample size (number of measurements). Wet season 1st November to 30th April.

Period	Mean	Median	SD	Min	Max	Q1	Q3	n
Jul-2024	19.86	19.91	0.67	18.10	20.95	19.32	20.46	4461
Aug-2024	20.48	20.48	1.29	18.31	23.08	19.46	21.57	4464
Sep-2024	23.05	23.04	0.34	22.20	24.29	22.82	23.23	4320
Oct-2024	25.06	24.96	0.85	23.34	26.82	24.38	25.82	4462
Nov-2024	27.22	27.28	0.48	25.98	28.18	26.89	27.63	4317

Dec-2024	28.32	28.41	0.44	26.86	29.15	28.05	28.66	4464
Jan-2025	28.83	28.82	0.65	27.43	30.10	28.30	29.34	4464
Feb-2025	27.89	27.87	0.44	26.89	28.86	27.56	28.24	4032
Mar-2025	27.84	27.63	0.57	26.86	29.41	27.38	28.32	4461
Apr-2025	26.55	26.18	0.82	25.31	28.16	25.85	27.48	4317
May-2025	23.76	23.72	0.77	21.24	25.82	23.33	24.11	4464
Jun-2025	20.79	20.45	0.77	19.57	22.47	20.12	21.48	4316
Dry season	22.17	22.46	2.08	18.10	26.82	20.27	23.75	26487
Wet season	27.78	27.79	0.94	25.31	30.10	27.29	28.47	26055
Overall	24.95	25.81	3.24	18.10	30.10	22.42	27.78	52542

3.4.2 Water depth

The Isaac coastal region is characterised by a mixed semidiurnal, macrotidal regime. Daily tidal range at Aquila Island during the reporting period varied from 1.78 to 7.94 m, with an overall mean daily range of 5.52 m (median 5.67 m) (Figure 3-18). Tidal range exhibited consistent fortnightly spring–neap cycling throughout the year, with spring tides approaching 8 m and neap ranges near 2 m. Seasonal differences in tidal amplitude were minor relative to the dominant astronomical signal.

Absolute water depth measured at the logger varied from 3.78 to 12.91 m over the reporting period (Table 3-4), with an overall mean depth of 8.33 m (median 8.31 m; SD 1.83 m). Mean depth during the dry season (May–October) was slightly higher (8.51 m) than during the wet season (November–April; 8.15 m), though variability was similar between seasons (SD 1.83 m). Monthly mean depths ranged from 7.78 to 8.79 m, indicating limited seasonal variation beyond normal tidal forcing.

The persistence of large tidal amplitudes and substantial water depth variability reinforces the highly energetic hydrodynamic setting of the Isaac coastal zone, with tidal processes likely to play a dominant role in sediment resuspension, mixing and nearshore water column dynamics.

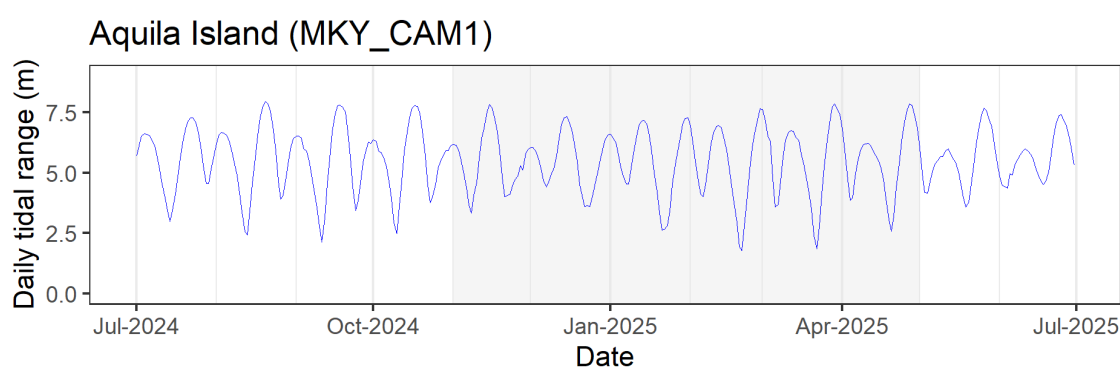


Figure 3-18. Daily tidal range measured by insitu loggers at Aquila Island (MKY_CAM1).

Table 3-4. Monthly summary statistics for water depth (m) measured by continuous dataloggers at the Aquila Island (MKY_CAM1) ambient water quality monitoring site. SD = standard deviation, Min = minimum, Max = maximum, Q1 = 1st quartile (25th percentile), Q3 = 3rd quartile (75th percentile), n = sample size (number of measurements). Wet season 1st November to 30th April.

Period	Mean	Median	SD	Min	Max	Q1	Q3	n
Jul-2024	8.57	8.54	1.76	5.20	12.51	7.06	9.96	4461
Aug-2024	8.54	8.51	1.80	4.74	12.68	7.05	9.96	4464

Sep-2024	8.64	8.63	1.82	4.76	12.81	7.19	10.11	4320
Oct-2024	8.79	8.74	1.82	4.80	12.66	7.32	10.27	4462
Nov-2024	8.75	8.73	1.77	4.98	12.86	7.33	10.18	4317
Dec-2024	8.09	8.06	1.73	4.68	12.06	6.60	9.53	4464
Jan-2025	8.20	8.18	1.78	4.80	12.18	6.72	9.62	4464
Feb-2025	8.30	8.29	1.77	4.86	12.50	6.86	9.68	4032
Mar-2025	7.81	7.76	1.90	3.84	12.41	6.29	9.29	4461
Apr-2025	7.78	7.76	1.82	3.78	11.72	6.30	9.29	4317
May-2025	7.80	7.78	1.77	4.01	11.67	6.29	9.27	4464
Jun-2025	8.75	8.69	1.79	5.50	12.91	7.15	10.27	4316
								4461
Dry season	8.51	8.48	1.83	4.01	12.91	7.00	9.97	26487
Wet season	8.15	8.12	1.83	3.78	12.86	6.67	9.62	26055
Overall	8.33	8.31	1.83	3.78	12.91	6.85	9.79	52542

3.4.3 Wave activity

The Wave activity, expressed as daily mean RMS depth (m), remained low throughout the reporting period, consistent with a sheltered inshore setting (Figure 3-19; Table 3-5). Overall RMS depth averaged 0.013 m (median 0.012 m; SD 0.007 m), with values ranging from 0.000 to 0.126 m.

Seasonal differences were modest. Mean RMS depth during the wet season (November–April) was slightly higher (0.014 m) than during the dry season (May–October; 0.012 m). The highest individual daily values (up to 0.124–0.126 m) occurred during January and March, coinciding with episodic higher-energy events during the summer wet season.

Monthly means were relatively consistent (0.010–0.016 m), with slightly elevated averages during late summer (January–March). Variability (SD) was also greater during the wet season (0.008 m) compared to the dry season (0.006 m), reflecting short-lived increases in wave energy associated with stronger winds or offshore weather systems.

Overall, wave activity at Aquila Island was characterised by generally low background energy punctuated by occasional higher-energy events during the wet season, suggesting that wave-driven resuspension is episodic rather than persistent in this Isaac coastal location.

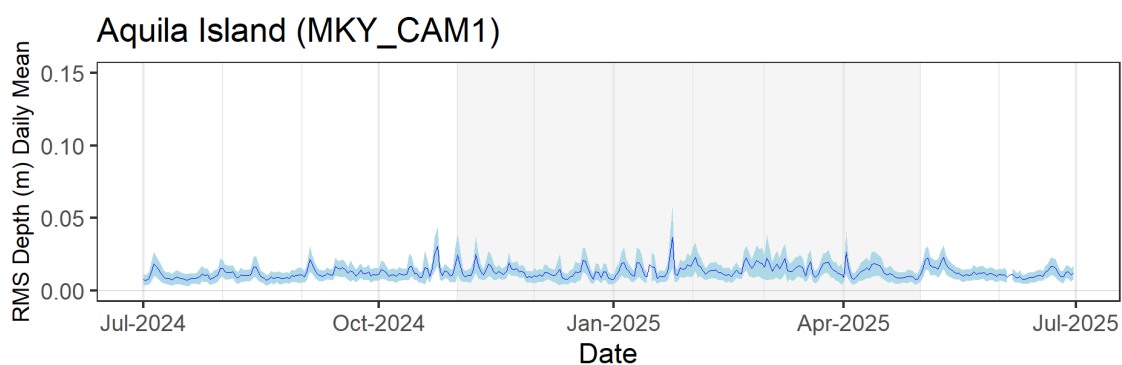


Figure 3-19. RMS depth measured at Aquila Island (MKY_CAM1). Values presented are daily mean (blue line) +/- standard deviation (light blue).

Table 3-5. Monthly summary statistics for wave activity (Depth RMS) measured by continuous dataloggers at the Aquila Island (MKY_CAM1) ambient water quality monitoring site. SD = standard

deviation, Min = minimum, Max = maximum, Q1 = 1st quartile (25th percentile), Q3 = 3rd quartile (75th percentile), n = sample size (number of measurements). Wet season 1st November to 30th April.

Period	Mean	Median	SD	Min	Max	Q1	Q3	n
Jul-2024	0.010	0.009	0.006	0.000	0.048	0.006	0.012	4461
Aug-2024	0.011	0.010	0.005	0.000	0.046	0.007	0.013	4464
Sep-2024	0.013	0.012	0.006	0.000	0.056	0.009	0.015	4320
Oct-2024	0.013	0.012	0.008	0.000	0.073	0.009	0.015	4462
Nov-2024	0.014	0.013	0.007	0.000	0.080	0.009	0.017	4317
Dec-2024	0.012	0.011	0.006	0.000	0.069	0.008	0.014	4464
Jan-2025	0.015	0.012	0.010	0.000	0.124	0.009	0.017	4464
Feb-2025	0.015	0.013	0.008	0.000	0.070	0.010	0.019	4032
Mar-2025	0.016	0.014	0.008	0.000	0.126	0.010	0.019	4461
Apr-2025	0.012	0.011	0.007	0.000	0.085	0.008	0.015	4317
May-2025	0.014	0.013	0.006	0.000	0.048	0.010	0.017	4464
Jun-2025	0.011	0.011	0.005	0.000	0.039	0.008	0.013	4316
Dry season	0.012	0.011	0.006	0.000	0.073	0.008	0.014	26487
Wet season	0.014	0.012	0.008	0.000	0.126	0.009	0.017	26055
Overall	0.013	0.012	0.007	0.000	0.126	0.008	0.015	52542

3.4.4 Turbidity

Turbidity at Aquila Island exhibited pronounced short-term variability superimposed on a moderate seasonal pattern (Figure 3-19; Table 3-6). Across the reporting period, mean daily turbidity was 10.08 NTU (median 7.09 NTU; SD 9.14 NTU), with values ranging from 0.25 to 164.24 NTU.

Monthly mean turbidity increased from winter through spring, rising from 6.73 NTU in July to 12.25 NTU in October. Following lower means in November (6.50 NTU) and December (5.70 NTU), turbidity increased again during late summer and early autumn, peaking in March (15.97 NTU) and April (15.23 NTU). Elevated variability during these months (SD up to 13.45 NTU) reflects episodic high-turbidity events, with maximum daily values exceeding 120 NTU in October, March, and April.

Seasonal averages were comparable between dry (9.93 NTU) and wet (10.23 NTU) seasons; however, the wet season exhibited greater variability (SD 9.96 NTU) and higher extreme values (maximum 164.24 NTU), indicating that short-lived high-turbidity events were more pronounced during this period.

Overall, turbidity dynamics at Aquila Island were characterised by strong episodic peaks rather than sustained elevation, consistent with a tidally energetic system where resuspension events drive short-term increases in suspended sediment concentrations.

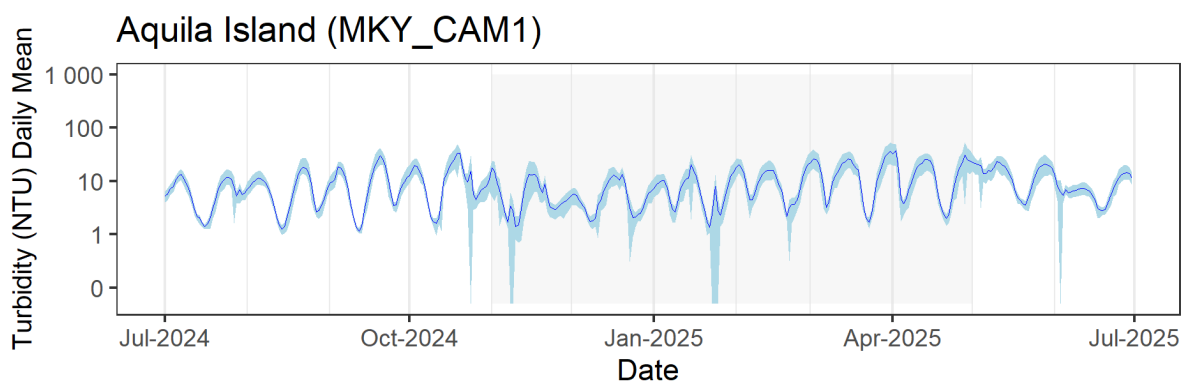


Figure 3-20. Turbidity measured at measured at Aquila Island (MKY_CAM1). Values presented are daily mean (blue line) +/- standard deviation (light blue). Y-axis is in log scale.

Table 3-6. Monthly mean, median (Med), and standard deviation (SD) for turbidity (NTU) measured by in-situ loggers at Aquila Island in the Isaac coastal region.

Period	Mean	Median	SD	Min	Max	Q1	Q3	n
Jul-2024	6.73	5.85	4.32	1.10	67.48	3.20	9.52	4460
Aug-2024	7.51	5.80	5.78	0.74	34.31	2.92	10.67	4464
Sep-2024	10.53	7.75	9.04	0.79	65.61	3.59	14.83	4320
Oct-2024	12.25	8.86	11.17	0.96	128.86	4.22	17.15	4461
Nov-2024	6.50	4.12	6.47	0.25	56.47	2.49	8.00	4317
Dec-2024	5.70	3.99	4.43	0.87	29.84	2.44	7.63	4464
Jan-2025	7.51	5.68	6.37	0.70	82.80	2.84	10.59	4463
Feb-2025	10.54	8.44	7.34	1.37	44.13	4.48	15.68	4031
Mar-2025	15.97	12.90	12.49	1.09	127.94	5.46	24.59	4459
Apr-2025	15.23	10.85	13.45	1.37	164.24	4.28	23.15	4317
May-2025	14.97	14.13	8.82	2.43	78.54	7.50	20.81	4459
Jun-2025	7.55	6.58	4.35	1.58	48.87	4.37	9.20	4316
Dry season	9.93	7.50	8.26	0.74	128.86	4.06	13.48	26480
Wet season	10.23	6.55	9.96	0.25	164.24	3.17	14.10	26051
Overall	10.08	7.09	9.14	0.25	164.24	3.58	13.77	52531

3.4.5 Photosynthetically active radiation (PAR)

Daily Light Integral (DLI) at Aquila Island showed high short-term variability and strong seasonal contrasts (Figure 3-21; Table 3-7). Across the reporting period, mean DLI was $12.57 \text{ mol m}^{-2} \text{ d}^{-1}$; however, the median was substantially lower ($0.08 \text{ mol m}^{-2} \text{ d}^{-1}$), indicating a highly skewed distribution dominated by episodic high-light days interspersed with frequent low-light conditions. Values ranged from 0 to $401.53 \text{ mol m}^{-2} \text{ d}^{-1}$.

Dry season DLI averaged $9.77 \text{ mol m}^{-2} \text{ d}^{-1}$ (median $0.11 \text{ mol m}^{-2} \text{ d}^{-1}$), while the wet season exhibited a higher mean ($16.08 \text{ mol m}^{-2} \text{ d}^{-1}$) and greater variability (SD $42.05 \text{ mol m}^{-2} \text{ d}^{-1}$), reflecting occasional high-irradiance events. The highest monthly means occurred in November ($24.35 \text{ mol m}^{-2} \text{ d}^{-1}$) and December ($24.07 \text{ mol m}^{-2} \text{ d}^{-1}$), with maximum daily values exceeding $370\text{--}400 \text{ mol m}^{-2} \text{ d}^{-1}$ during late spring and early summer.

February and March exhibited reduced light availability; however, most March PAR data were removed during quality control due to the logger frame being displaced and resting laterally on the seabed. This resulted in substantially reduced data coverage for March (n = 510 compared with >4,000 samples in most other months), and the very low March mean ($0.61 \text{ mol m}^{-2} \text{ d}^{-1}$) should therefore be interpreted with caution. Periods of reduced DLI during February were more consistent with elevated turbidity and increased cloud cover during the wet season.

Overall, light availability at Aquila Island was characterised by episodic high-light events superimposed on generally low median daily conditions, consistent with a turbid, tidally energetic inshore environment where suspended sediments, tidal resuspension and weather variability strongly influence the benthic light climate.

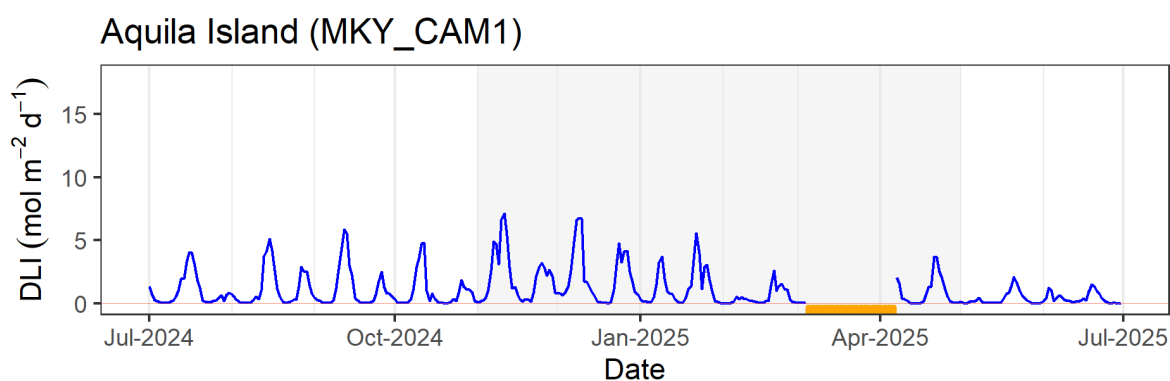


Figure 3-21 Daily light integral ($\text{mol photons m}^{-2} \text{ d}^{-1}$) of benthic photosynthetically active radiation measured at Aquila Island. Periods of missing or QC-removed data are indicated by the orange bar.

Table 3-7. Monthly summary statistics for Daily Light Integral (DLI: mol photons $m^{-2} d^{-1}$) measured by continuous dataloggers at the Aquila Island (MKY_CAM1) ambient water quality monitoring site. SD = standard deviation, Min = minimum, Max = maximum, Q1 = 1st quartile (25th percentile), Q3 = 3rd quartile (75th percentile), n = sample size (number of measurements). Wet season 1st November to 30th April. Note: PAR data was removed during QC during March/April 2025, when the logger frame became displaced and rested laterally on the seabed.

Period	Mean	Median	SD	Min	Max	Q1	Q3	n
Jul-2024	11.18	0.25	31.32	0.03	249.09	0.22	3.71	4461
Aug-2024	14.06	0.07	38.67	0.02	375.95	0.05	4.51	4464
Sep-2024	13.72	0.07	38.83	0.04	318.88	0.06	3.22	4320
Oct-2024	10.61	0.04	30.91	0	261.80	0.03	2.77	4462
Nov-2024	24.35	0.39	53.93	0	374.02	0.04	15.68	4317
Dec-2024	24.07	0.31	53.56	0	401.53	0	18.91	4464
Jan-2025	15.22	0.22	36.71	0	260.41	0	7.53	4464
Feb-2025	5.75	0	15.93	0	119.14	0	1.74	4032
Mar-2025	0.61	0	2.31	0	21.52	0	0.01	510
Apr-2025	10.77	0.05	33.59	0	227.28	0	1.14	3409
May-2025	4.16	0.01	14.93	0	139.27	0	0.27	4464
Jun-2025	4.88	0	13.84	0	167.34	0	2.21	4316
Dry season	9.77	0.11	30.13	0	375.95	0.03	2.45	26487
Wet season	16.08	0.06	42.05	0	401.53	0	6.89	21196
Overall	12.57	0.08	36.06	0	401.53	0.01	3.84	47683

3.4.6 Water quality logger data

Logger data collected at 10-minute intervals which has passed through the quality control process is presented in Figure 3-22.

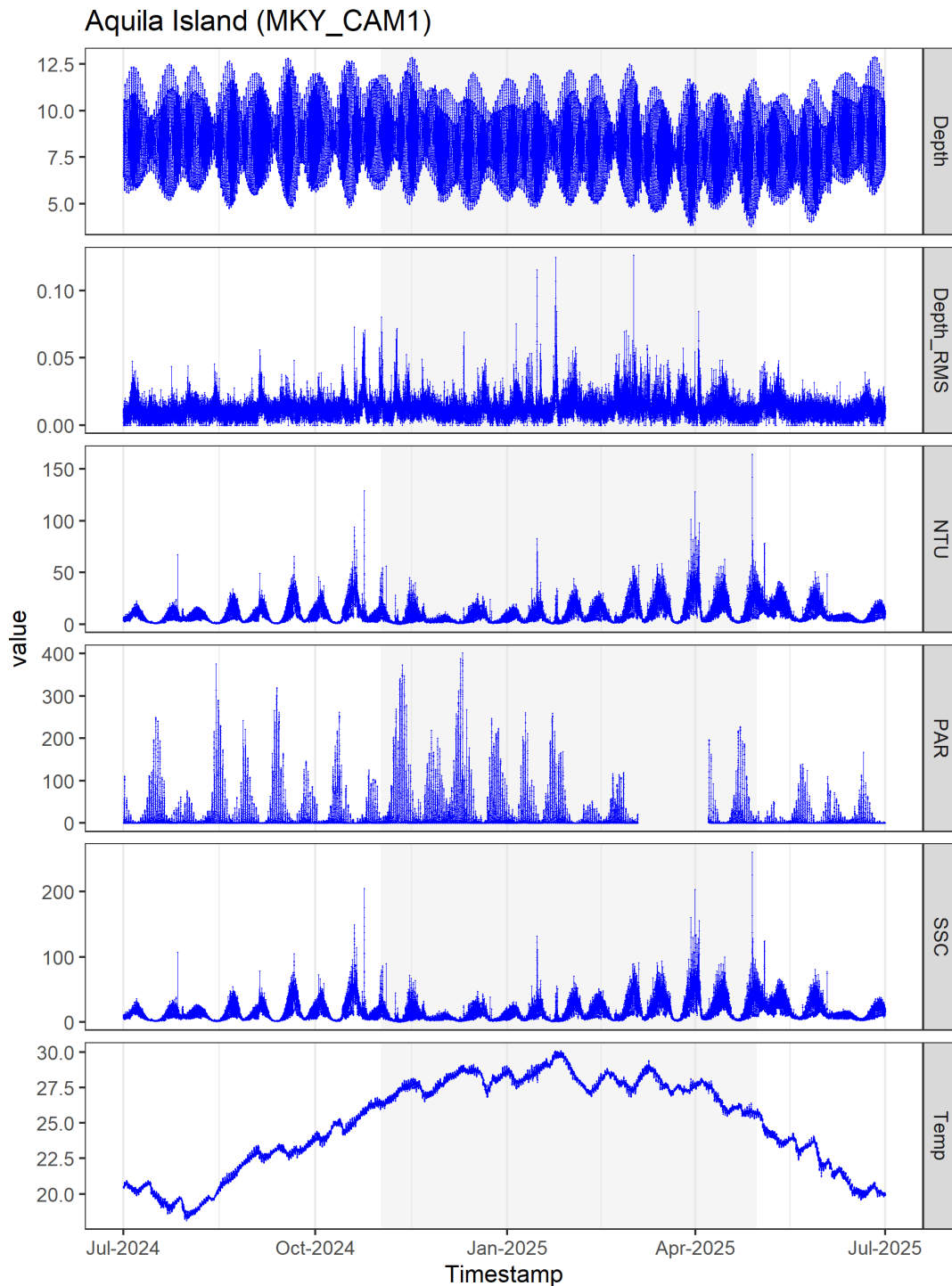


Figure 3-22. Data collected at Aquila Island with In-situ Marine Optics (IMO) dataloggers. Data presented excludes data flagged as flag 4 (Bad data). For more information on Quality Control Procedures see Appendix 1.

3.4.7 Data Recovery

Data recovery and quality control flagging for in situ loggers varied across the sites (Figure 3-24). Overall, data recovery for the reporting period was near 100 % with the exception of some flagged and missing data for the PAR sensor. Data flagged as bad data (QC flag 4 – red) was removed prior to preparing figures and tables for this report. A brief description of the quality control process and QC flags is provided in Appendix 1 while more substantive outline of the quality control process undertaken on the logger data is outlined in Iles et al. (2023).

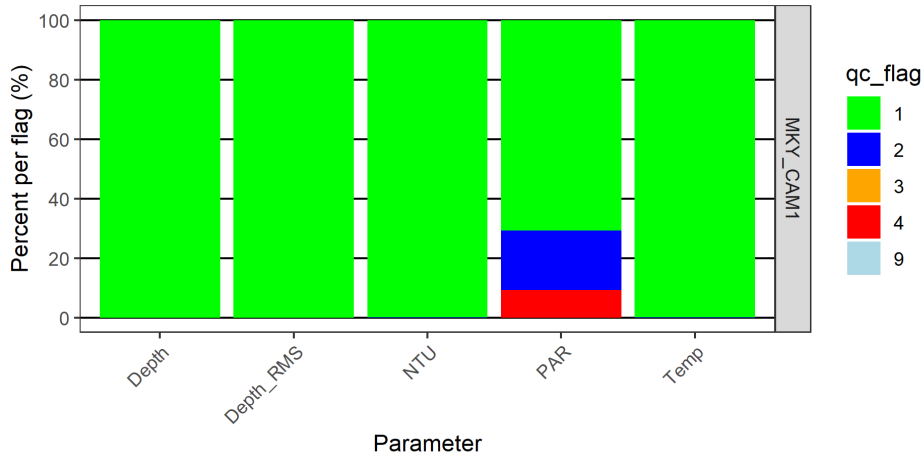


Figure 3-23. Data recovery and qc flags at the Aquila Island (MKY_CAM1) logger site over the reporting period. Flag 1 (green) indicates a ‘good value’; flag 2 (blue) indicates a ‘probably good value’; flag 3 (yellow) indicates ‘probably bad value’, flag 4 (red) indicates a ‘bad value’ and flag 9 (grey) indicates data that is missing.

4 Conclusions and Recommendations

4.1 Conclusions

4.1.1 Climatic conditions

1. Rainfall during the 2024–2025 monitoring period followed the expected dry–wet tropical seasonal pattern, with low rainfall through the dry season (July–November 2024) and a marked increase from late December. Several high-intensity wet-season events were recorded, most notably in early February 2025 when 212.6 mm was recorded on 4 February. Multiple additional days exceeding 30–90 mm occurred between late January and early February. Although total annual rainfall (1928 mm) remained within the long-term historical range for Mackay, the intensity and clustering of rainfall events in early 2025 were elevated relative to typical wet-season patterns shown in the long-term climate record.
2. Streamflow in Carmila Creek reflected this strongly seasonal rainfall pattern. Flow was negligible or absent throughout much of the dry season, with discharge commencing in response to late-December rainfall. The early February 2025 extreme rainfall event generated the highest discharge of the reporting year, followed by several smaller pulses through February and March before declining rapidly in late autumn. This hydrograph is consistent with a rainfall-driven, episodic wet–dry tropical system characterised by rapid catchment response and limited sustained baseflow.
3. Wave conditions during 2024–2025 were typical of an inshore, trade-wind–dominated environment. Significant wave heights were generally low to moderate (mostly <1 m), with infrequent higher-energy events (>2 m) associated with stronger southeasterly winds or offshore weather systems. Seasonal variability was modest, with slightly higher and more variable wave conditions during summer and the wet season. These metocean conditions provide important context for understanding sediment resuspension, turbidity variability and light availability across the Isaac coastal zone.

4.1.2 Ambient water quality

1. Water temperature followed a clear seasonal cycle, with dry-season minima (~19–21 °C) and wet-season maxima (~29–30 °C). Minor intra-season variability corresponded with rainfall and short-term weather patterns.
2. The water column remained generally well mixed, consistent with the mixed semidiurnal macrotidal regime of the region. Dissolved oxygen and pH were stable throughout the reporting year, and salinity and electrical conductivity indicated predominantly marine conditions across sampling events.
3. Dissolved nutrient fractions were generally stable across the reporting year; however, oxidised nitrogen (NO_x) concentrations were frequently elevated relative to WQO percentile values and represent the primary nutrient parameter of concern. Total nitrogen (TN), particulate nitrogen (PN), total phosphorus (TP) and particulate phosphorus (PP) were typically below WQO 80th percentile values, with the exception of a single particulate-driven event at Aquila Island (MKY_CAM1) in late November 2024. Outside of elevated NO_x and this short-lived event, there was no evidence of sustained nutrient enrichment across the Isaac coastal sites.

4.1.3 Turbidity

1. Continuous benthic turbidity data demonstrated strong tidal modulation, with fortnightly variability associated with spring–neap cycles and additional increases during periods of rainfall and elevated catchment discharge. The mixed semidiurnal macrotidal regime and sand–mud substrate contribute to frequent sediment resuspension under strong tidal currents.
2. Guideline values for turbidity in the Isaac coastal region should take into consideration the natural variability of suspended sediment that is due to the strong tidal currents that are a feature of the region. This natural variability in turbidity supports many turbid reefs, both insipid and fringing, that are adapted to these conditions.
3. Total suspended solids (surface) were generally low to moderate, with elevated concentrations recorded at Aquila Island in October 2024 and March 2025 corresponding with rainfall and runoff events.
4. As the long-term dataset continues to expand, further analysis of rainfall frequency, streamflow magnitude, tidal energy and wave conditions will improve understanding of the relationships between climatic drivers and suspended sediment dynamics in the Isaac coastal region.

4.1.4 Photosynthetically active radiation (PAR)

1. Fine-scale patterns of PAR were strongly influenced by tidal cycles, with higher daily light integral (DLI) values typically associated with neap tides and weaker tidal flows. Periods of elevated turbidity during wet-season events corresponded with reduced light availability at the seabed.
2. Larger episodic weather systems contributed to short periods of reduced light conditions through increased cloud cover, wind-driven resuspension and rainfall-driven sediment inputs.
3. Including PAR in the suite of monitored variables remains important for capturing baseline ambient conditions, particularly in this naturally turbid and tidally dynamic environment where benthic habitats are adapted to variable light regimes.

4.2 Recommendations

This monitoring program has been underway since 2017 and should remain in place to continue characterising and building a robust long-term understanding of water quality dynamics in the Isaac coastal region. Maintaining continuous datasets across varying climatic conditions will strengthen interpretation of event-driven variability and support informed coastal management and strategic planning in this important section of the Great Barrier Reef coastline.

5 References

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Appendix 1. Quality control procedures

To complement the new loggers that were introduced into the program in the 2021-22 reporting year, a new quality control (QC) process for water quality data has been implemented. The QC process is science-based, sourced from public documentation, and based on the quality assurance of Real Time Oceanographic (QARTOD) program (NOAA, 2020), which is adopted by CSIRO, IMOS, and AIMS. Data goes through both automated and manual quality control steps. The 12 automated control tests are outlined in Table A5.

Table A 1. Quality Control rules applied to the logger data in the automated process.

QC rule 1: Syntax test	QC rule 7: Spike test
QC rule 2: Impossible date test	QC rule 8: Rate of change test
QC rule 3: In/out-water test	QC rule 9: Stationary test
QC rule 4: Global range test	QC rule 10: Standard deviation test
QC rule 5: Regional range tests	QC rule 11: Burst count test
QC rule 6: Impossible depth test	QC rule 12: Orientation test

Dependent on the outcome of these QA tests, data may be flagged ‘good data’ (green), ‘probably good data’ (blue), ‘probably bad data’ (orange) and ‘bad data’ (red). There are four sensors on each logger: Temperature, Depth, Tilt, and either turbidity (NTU) or photosynthetically active radiation (PAR). For each sensor on the logger the ‘worst’ flag from QC rules 1 to 12 is reported for each 10-minute time interval (Figure A-1). End user decides what level of data ‘quality’ they wish to use for their application. For example, for most applications ‘good data’ and ‘probably good data’ is considered acceptable, ‘probably bad data’ could be used with caveats, and ‘bad data’ should be discarded. Unwanted data can easily be masked in excel or other data management programs by filtering by ‘QC flag’. A full technical report with detailed descriptions of the quality control procedures and tests as applied to the data in this project is available on the TropWATER website (Iles et al., 2023).

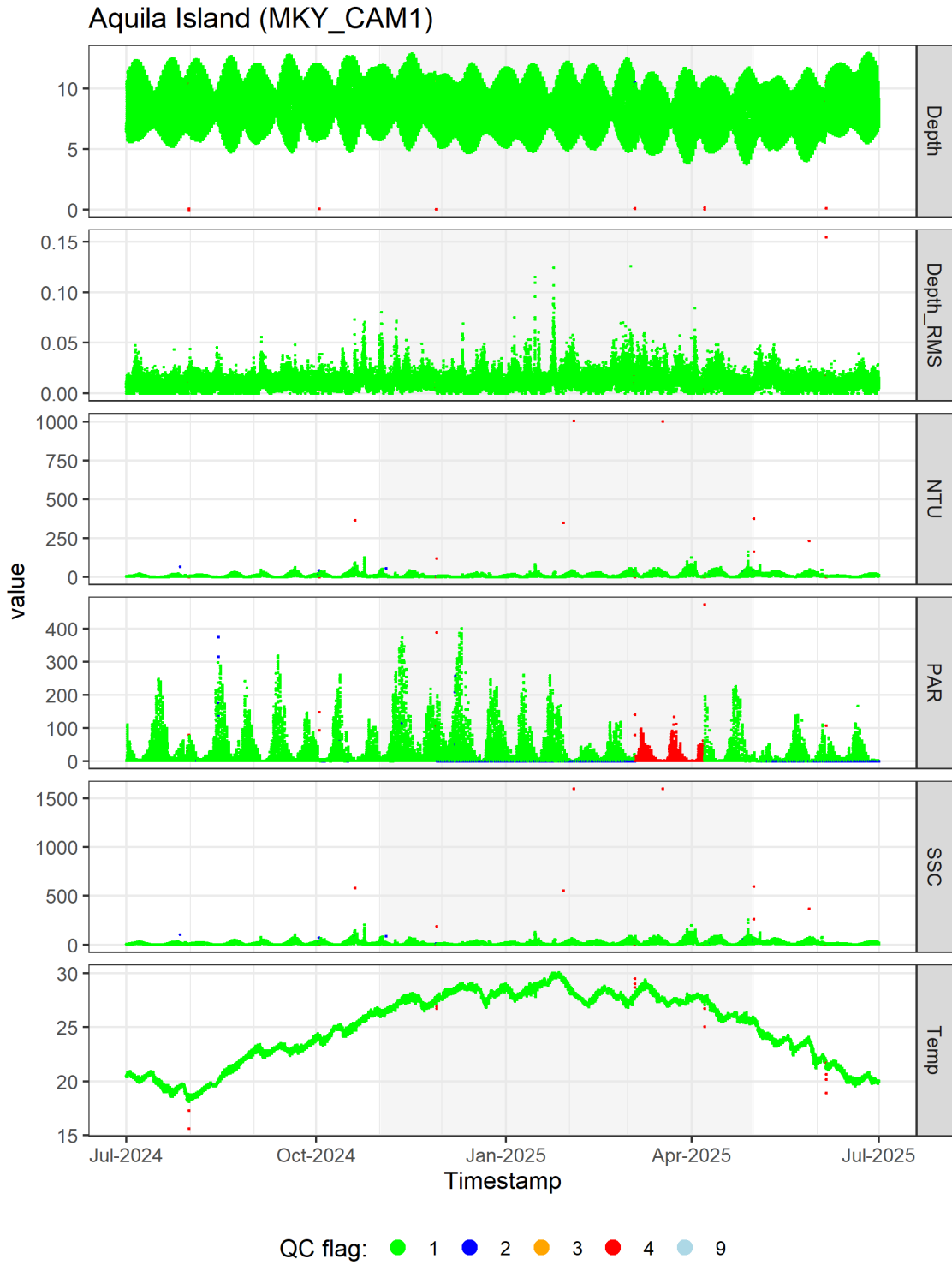


Figure A 1. Raw data collected at Aquila Island with IMO loggers, passed through automated and manual quality control (QC) steps. Symbol colour indicates QC flag designation where: 1 (green) = Good data, 2 (blue) = Probably good data, 3 (orange) = Suspect data, 4 (red) = Bad data, 9 (light blue) = Missing data.