HEALTHY RIVERS TO REEF PARTNERSHIP
MACKAY-WHITSUNDAY-ISAAC

Carmila Creek Estuary Pilot Study

Water Quality Report

September 2022

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Introduction

CQUniversity, the Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership (HR2RP) and Catchment Solutions collaborated to investigate water quality and estuarine fish populations in the estuary of a cane growing catchment of the Great Barrier Reef (GBR), south of Mackay. The Queensland Department of Environment and Science (DES) estuary water quality monitoring program had showed intermittent periods of elevated dissolved oxygen saturation and chlorophyll-*a* (Chl-*a*) in Carmila Creek from 2016 to 2018. These are usually indications of high nutrient runoff, however nutrient concentrations in Carmila Creek during the same period were comparable to similar estuaries in the region.

CQUniversity ran a brief data comparison in 2019 to assist with interpretation of the report card results (Flint and Wake, 2019). The study identified a pattern in which Chl-*a* appeared to respond to increases in concentrations of dissolved inorganic nitrogen (DIN), but with a time lag of 1-2 months. Lower salinity was recorded on dates corresponding with higher DIN concentrations, suggesting runoff following rainfall was contributing to nutrient loads in the estuary, and Chl-*a* and dissolved oxygen (DO) followed similar patterns through time. Chlorophyll-*a* is the most abundant photosynthetic pigment, occurring in all photosynthetic organisms including the cyanobacteria. It is the primary electron donor in the electron transport chain that has oxygen as its product. Therefore, there is a strong link between Chl-*a* concentration, phytoplankton abundance and dissolved oxygen (DO).

Phytoplankton populations in estuaries respond rapidly to bio-available nutrients and Chl-*a* can provide a reliable proxy for the nutrient status, particularly where inputs may occur in irregular pulses of inorganic nitrogen and phosphorus. Actively photosynthesising phytoplankton populations provide the main contribution to dissolved oxygen concentrations in estuarine waters. In nutrient enriched waters, this can lead to hypersaturation of DO during the day but critically low levels during hours of darkness. Low DO concentrations (hypoxia) can be dangerous for water-breathing animals, causing both sublethal and lethal effects with consequences for ecosystem function.

This preliminary study was developed to investigate water quality patterns in Carmila Creek, using continuous logging of water quality parameters for 24 hours, once a month, for six months, to better understand the natural range. In particular, overnight DO concentrations were monitored to determine whether the estuary was experiencing nocturnal hypoxia. The results provide a temporal representation of ambient water quality conditions from late spring to early autumn (November 2021 to April 2022). Fish assemblages were also investigated using baited remote underwater video stations (BRUVS), and the results are provided in a separate report.

Sampling methodology

Water quality was monitored at the same site each month, ~0.9km from the mouth of Carmila Creek estuary. This site was selected as one of the only parts of the estuary that was deep enough to house the monitoring buoy at low tide. A YSI EXO2 sonde housed in an EMM65 monitoring buoy was deployed and anchored *in situ* to continuously log physicochemical parameters (including temperature, dissolved oxygen concentration and saturation, total algae, Chl-*a*, conductivity, salinity and pH) over a 24-hour period each month (Figure 1). As the boat ramp access is tide-dependent, the deployment of the buoy on one day and retrieval the next day was timed to allow for boat access. Catchment Solutions provided the vessel and skipper for sampling, and CQUniversity researchers collected data. Data was transmitted and downloaded automatically via YSI software.

The team attempted to align sampling dates with DES monitoring in Carmila Creek, though this wasn't always possible. Sampling dates and collection methods are provided in Table 1.

Table 1: Sampling dates at Carmila Creek from November 2021 to April 2022

DES monitoring date	Water monitoring buoy deployed	BRUVS deployed (fish assemblages)
15 November 2021	23-24 November 2021	NA
14 December 2021	9-10 December 2021	NA
Not sampled (travel restrictions)	24-25 January 2022	24 and 25 January 2022
18 February 2022	8-9 February 2022	8 and 9 February 2022
25 March 2022	23-24 March 2022	23 and 24 March 2022
22 April 2022	5-6 April 2022	5 and 6 April 2022

Figure 1: YSI EXO2 sonde and EMM65 monitoring buoy, deployed at Carmila Creek estuary in January 2022.

Data collected by the DES estuary water quality monitoring program at Carmila Creek was made available for comparison to the results of the study, including: dissolved oxygen, Chlorophyll-*a*, filterable reactive phosphorous, dissolved inorganic nitrogen, turbidity, and secchi depth. Publicly available government datasets for climate, rainfall and stream level (gauging station) at Carmila Creek, were also accessed for comparison. Note that long term monitoring data provided by DES suggest a seawater salinity range of 35.3-36.1 ppt, lower than recorded by the probe (Figure 3)

Results and Discussion

There were clear diel and tidal patterns in water quality across all six months of the study (e.g., Figures 2-5; see also Appendices). The results suggest Carmila Creek is a tide-dominated estuary, which is sometimes also influenced by water quality in the upper estuary. Two discharge events occurred during the study period, one from 29 November to 2 December 2021, which may have influenced December results, and a second smaller event on 27 March 2022, which may have contributed to the higher Chl-*a* concentrations recorded in April.

On the monitoring dates in 2021 and 2022, the median values for DO were all within the report card guideline values for Carmila (lower 70%; upper 105%; Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership, 2022) (Figure 7), though saturations that exceeded the lower and upper limits were recorded at some times of the day/tide (e.g., Figure 2; see also Appendices). The variations in DO concentrations show an interaction between a diel cycle of high DO from photosynthesis in daylight hours (and low DO driven by respiration in dark hours), and a tidal cycle of lower oxygen, lower salinity water moving down from the upper estuary (Figure 3), and oxygenated ocean water and absorption of DO with the increased water movement associated with incoming tide (Figure 2).

The median Chl-*a* concentration exceeded the Carmila guideline value (5 µg/L) in January and April 2022 (Figure 7). The highest concentrations coincided with low tide in the estuary. This result, in combination with the observed pattern of increasing Chl-*a* as the tide dropped indicates the source of Chl-*a* during monitoring was upstream of the estuary and likely associated with freshwater inputs. In November, and to a lesser extent in December, there was also a peak in concentration as the tide turned, which may have been a result of resuspended benthic algae/algae fragments. Concentrations recorded by the DES estuary water quality monitoring program at the 0.9km site were also higher than the guideline value (Figure 7, 8). Similar results were seen for phytoerythrin (PE), but two very sharp peaks in PE recorded in January could have been caused by a patch of marine cyanobacterium such as *Trichodesmium,* or a detached segment of marine algae.

Periodic turbidity peaks during logging each month indicated that the elevated levels observed were most likely due to resuspension of fine particles by tidal movements especially on the incoming tide (e.g., Figure 6). The median turbidity recorded in each sampling month was relatively low, at around 10 NTU (Figure 7).

The DES estuary monitoring program recorded a high NOx concentration in the upper part of the estuary in March 2022 of 0.26 mg/L, giving a DIN concentration of 0.262 mg/L when summed with ammonia-N, and exceeding the DIN guideline value of 0.018 mg/L. This nutrient pulse was not reflected in Chl-*a* concentrations from March; however, Chl-*a* concentrations in April were higher than the guideline value (Figure 7, 8), suggesting a time lag between nutrient inputs to Carmila Creek and algal growth. The poor correlation between Chl-*a* concentrations recorded by the probe and DES lab results suggest that the probe data, while useful for assessing cycles, is not highly accurate in terms of absolute values.

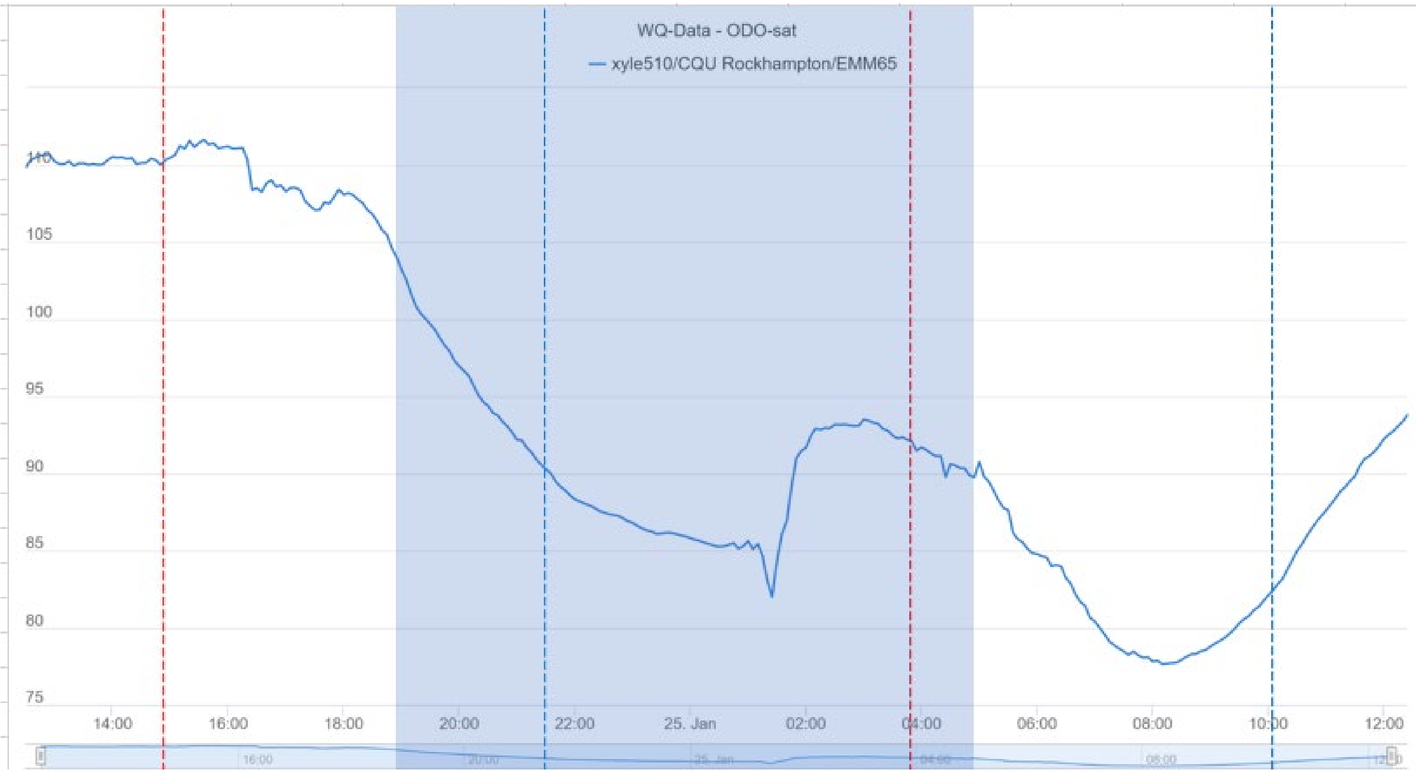

Figure 2: Continuous dissolved oxygen (% saturation) from monitoring buoy deployed on 24-25 January 2022. The blue dashed line represents low tide time, red dashed line is high tide time and blue shading is the time between sunset and sunrise.

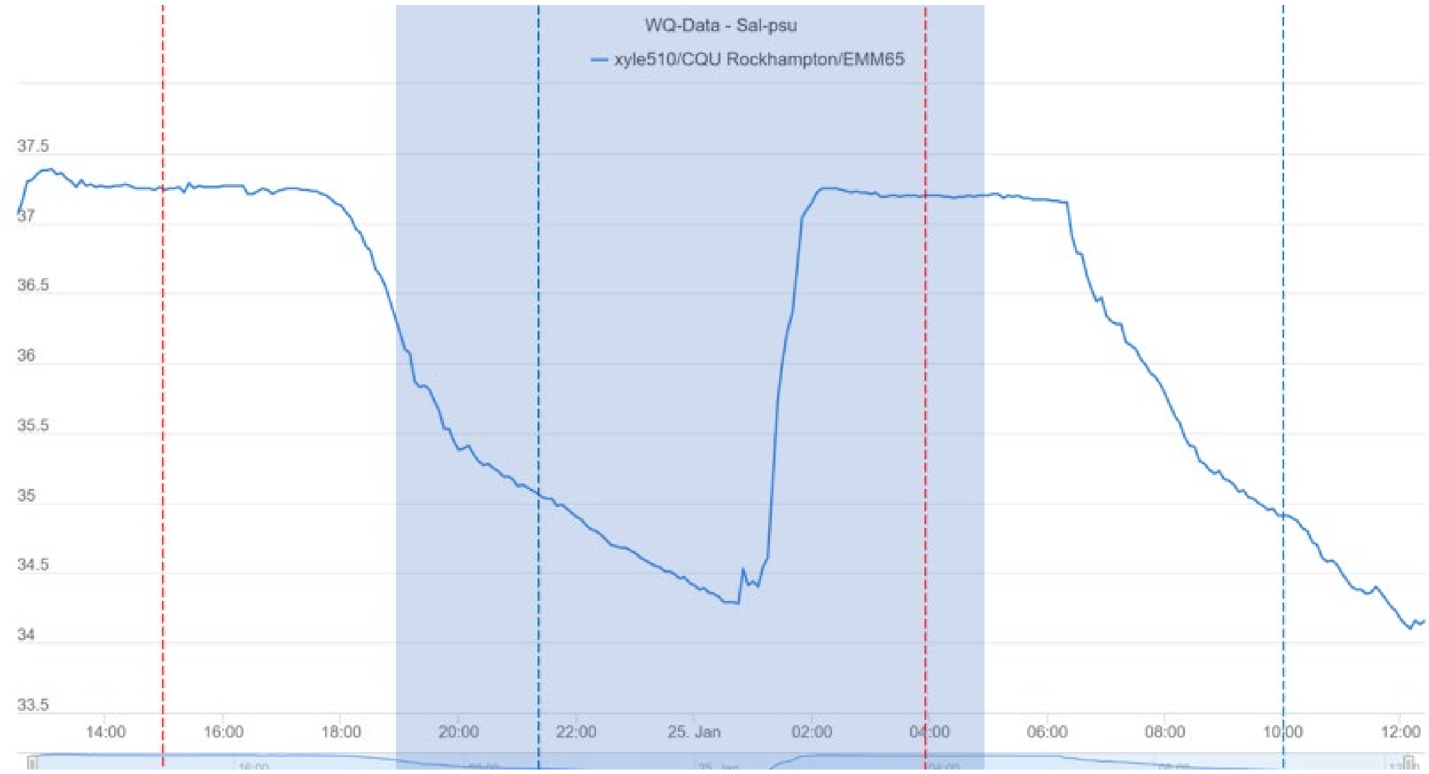

Figure 3: Continuous salinity data from monitoring buoy deployed on 24-25 January 2022. The blue dashed line represents low tide time, red dashed line is high tide time and blue shading is the time between sunset and sunrise.

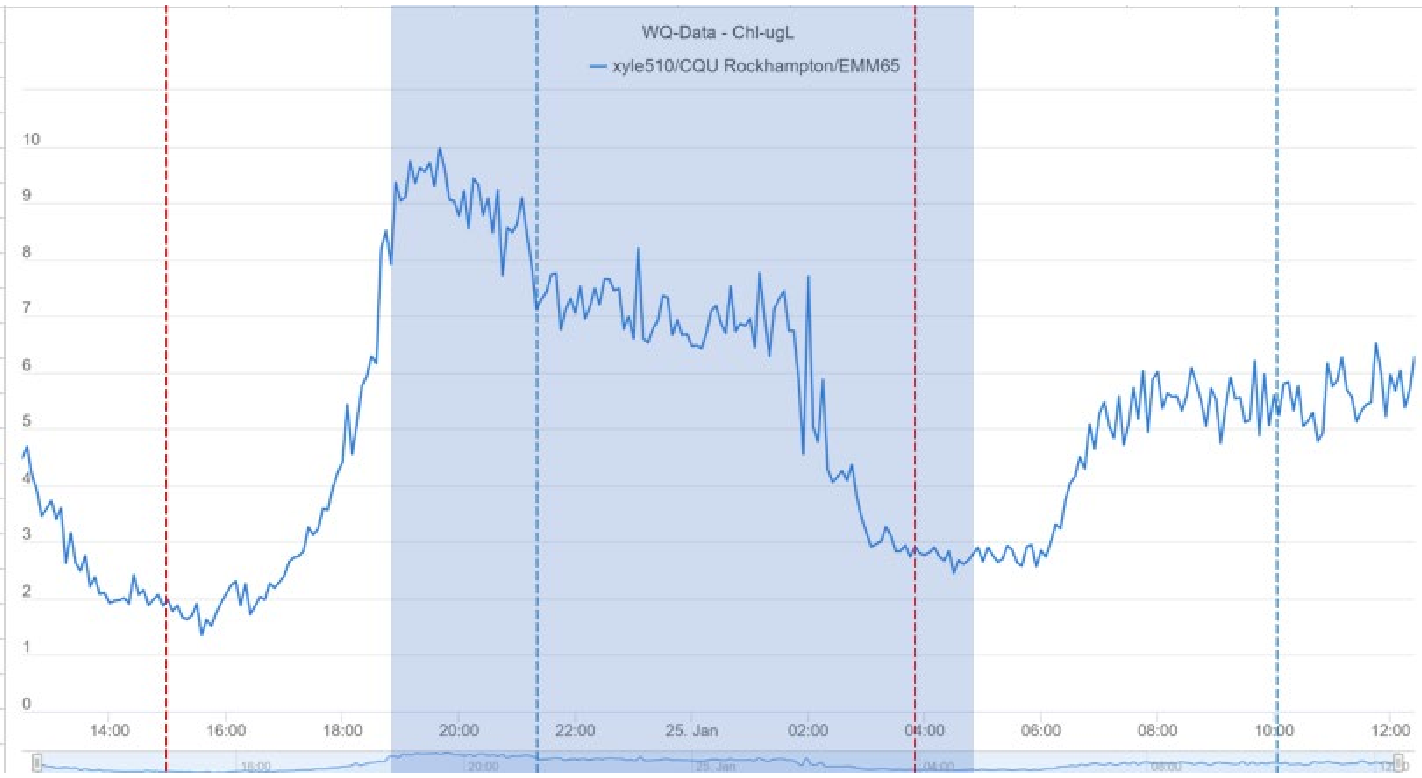

Figure 4: Continuous chlorophyll-*a* (µg/L) concentrations from monitoring buoy deployed on 24-25 January 2022. The blue dashed line represents low tide time, red dashed line is high tide time and blue shading is the time between sunset and sunrise.

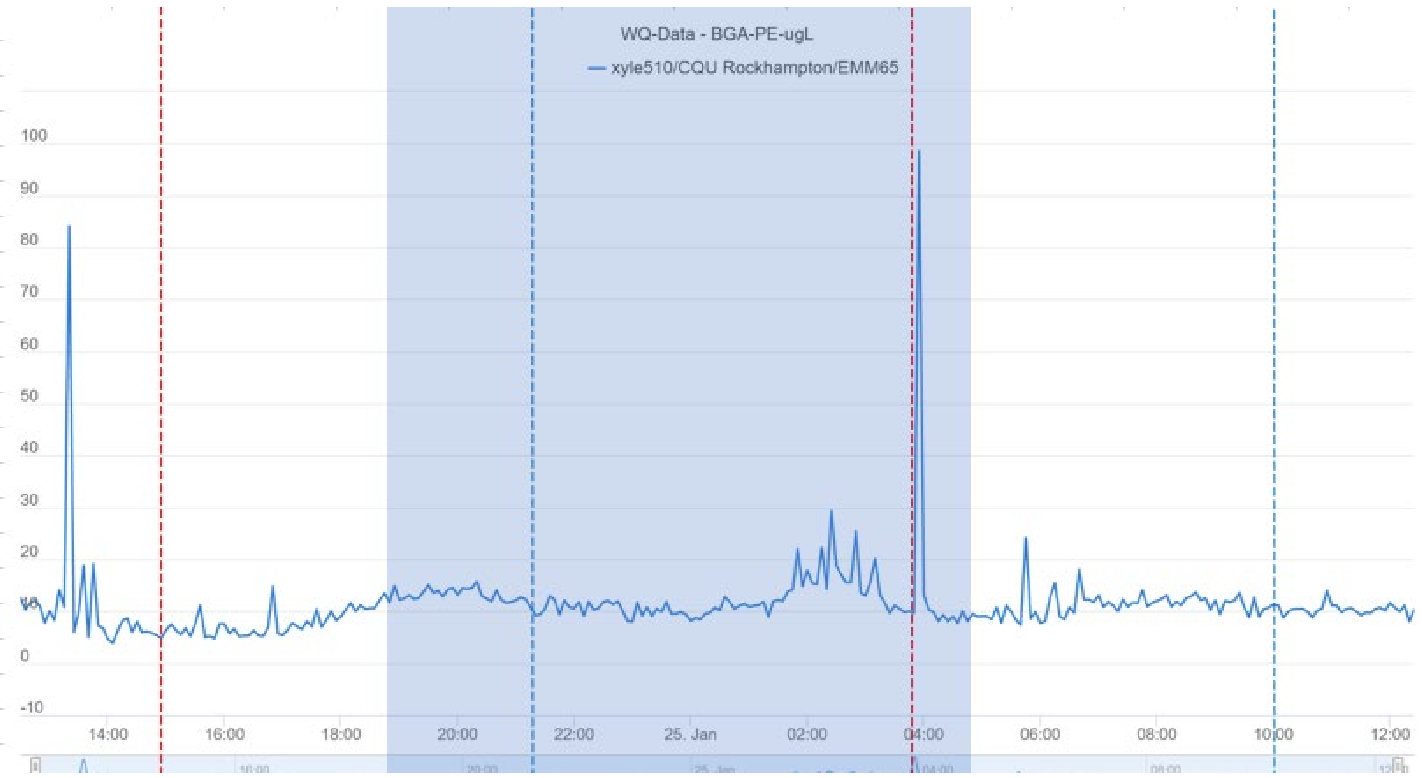

Figure 5: Continuous phytoerythrin (µg/L) concentrations from monitoring buoy deployed on 24-25 January 2022. The blue dashed line represents low tide time, red dashed line is high tide time and blue shading is the time between sunset and sunrise.

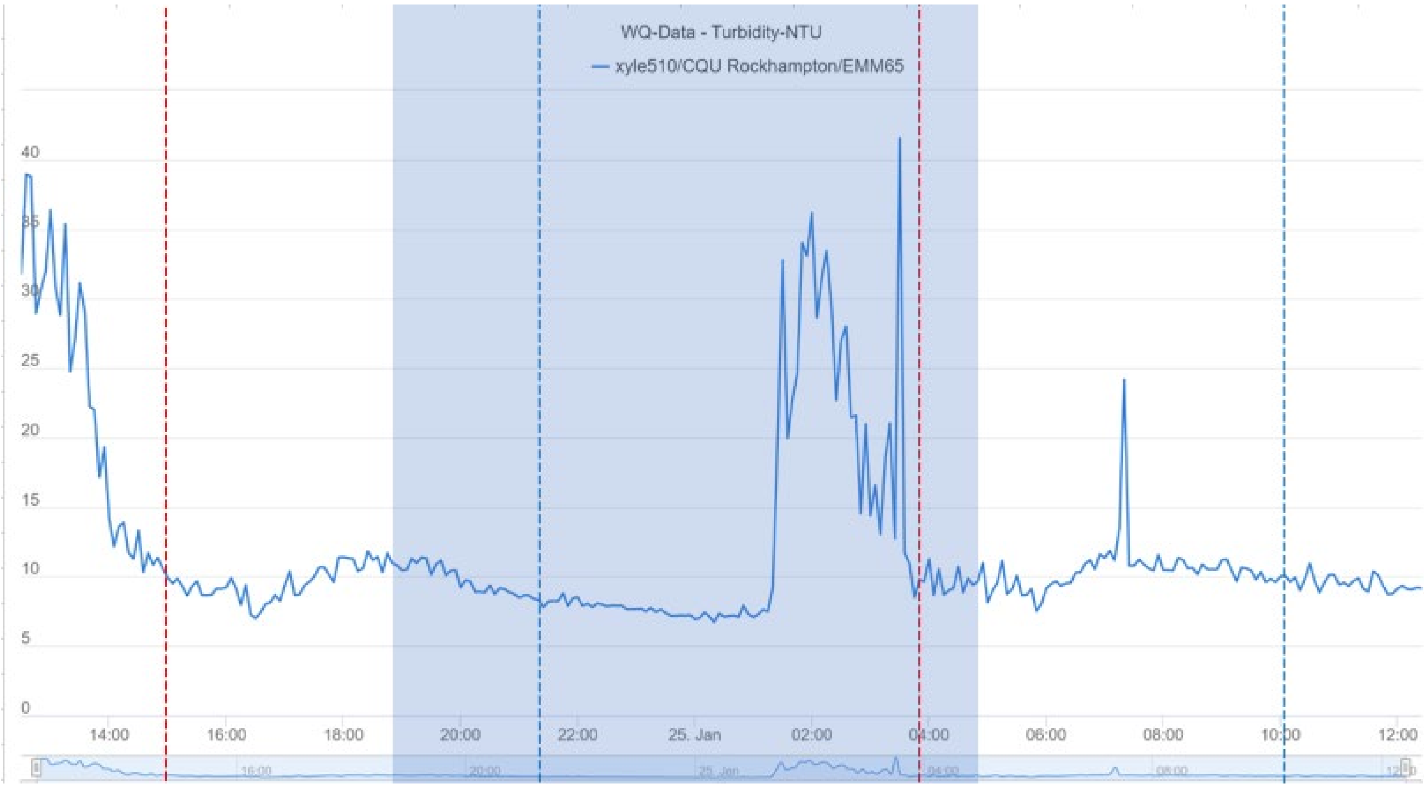

Figure 6: Continuous turbidity (NTU) from monitoring buoy deployed on 24-25 January 2022. The blue dashed line represents low tide time, red dashed line is high tide time and blue shading is the time between sunset and sunrise.

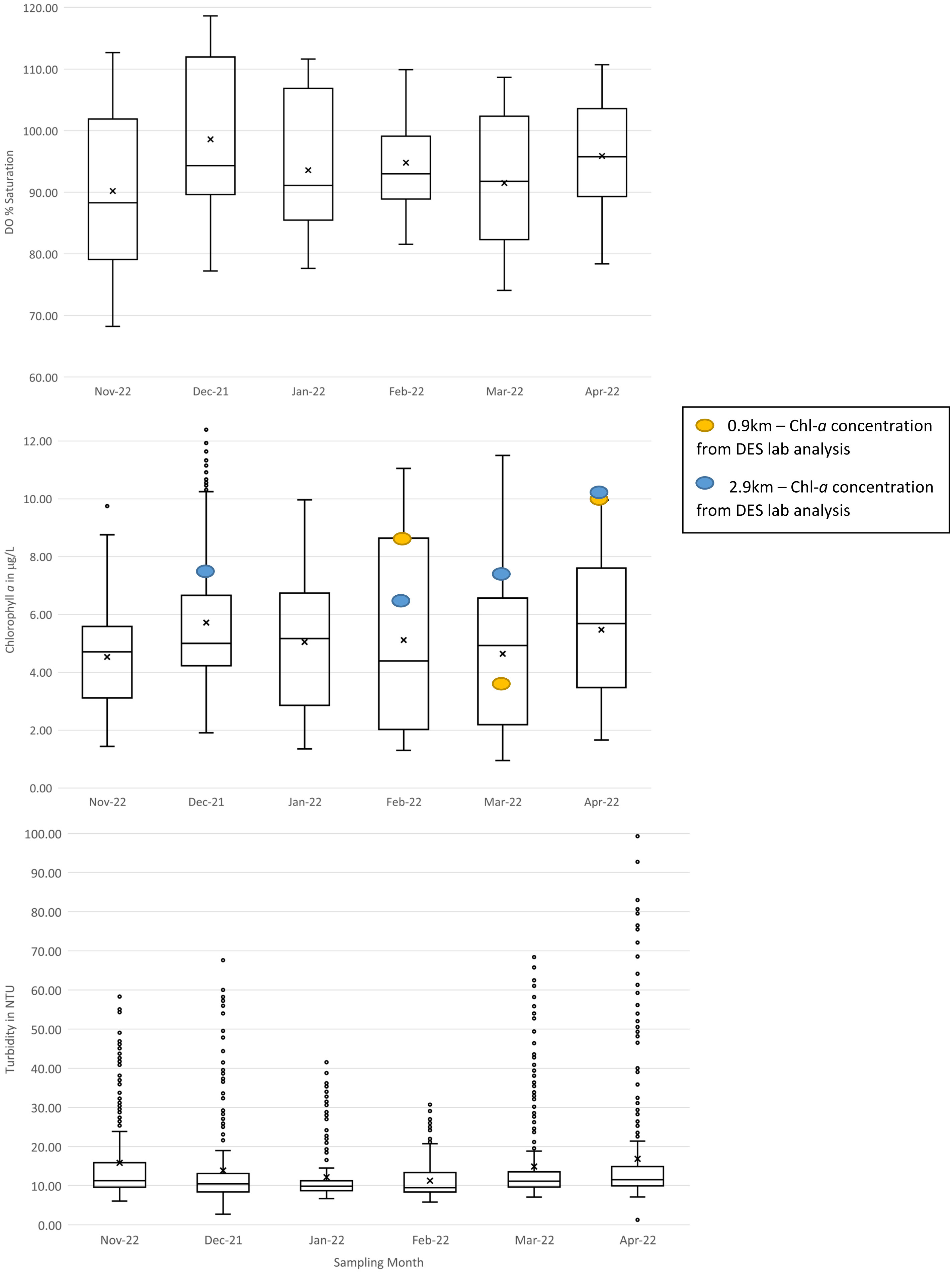

Figure 7: Box plots of dissolved oxygen (% saturation), chlorophyll-*a* (ug/L) and turbidity (NTU) each sampling month (sample numbers per month: Nov = 287; Dec = 313; Jan = 288; Feb = 290; Mar = 313; Apr = 316).

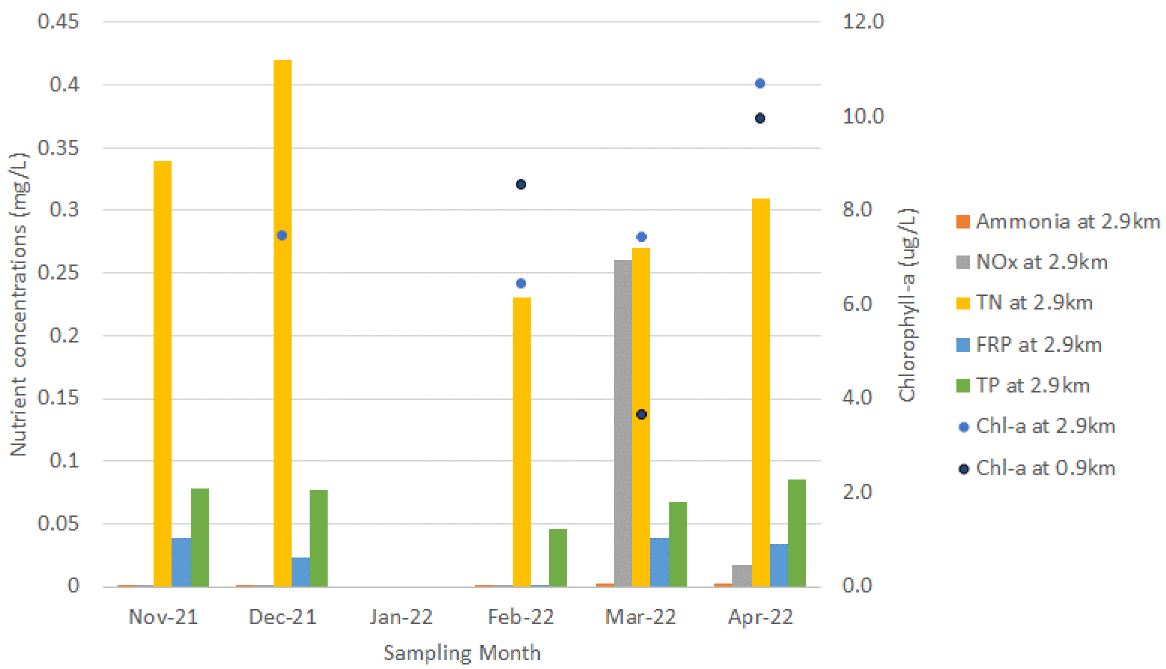

Figure 8: Nutrient (mg/L) and chlorophyll-*a* (µg/L) concentrations from laboratory analyses conducted by the Department of Environment and Science estuary monitoring program.

Conclusions

The results of the six-month pilot study showed clear diel and tidal patterns in water quality at Carmila Creek estuary, indicating a tide-dominated estuary that is, at times, influenced by water quality and nutrient inputs in the upper reaches. No major water quality issues were identified during the period studied, though DO saturations did sometimes fall outside of the recommended range of 70-105%, and Chl-*a* also exceeded the report card guideline values in January and April 2022. Chlorophyll-*a* appeared to be derived from upstream sources and influenced by catchment activities, rather than by ocean sources such as marine cyanobacteria.

Unlike in previous years, no very high flow events were recorded during the 2021-22 wet season, and there had been some smaller events in the weeks preceding sampling, which may have reduced the first flush effect of the November/December discharge event. During high flows, high nutrient inputs from catchment areas are more likely, driving higher Chl-*a* concentrations and lower DO saturations during the night and on the low tide.

The complex temporal patterns and interactions between nutrients, algae and physicochemical parameters mean that one-off sampling of each parameter conducted each month at different times of the day and on different tidal cycles may not fully represent the potential impacts of water quality on biological communities at Carmila Creek. The timing of sampling within the tidal and diel cycles would likely affect results and the report card scores and grades. However, the full suite of monitored water quality parameters including nutrients, Chl-*a* and DO, combined with explanatory parameters such as salinity, flow, sampling time and the new knowledge of temporal variations provided by this study, can provide for an overall assessment of water quality in the estuary. Monitoring of toxicants such as pesticides is also important for condition assessment but was not included in this study.

This preliminary study suggests it is unlikely that Carmila Creek estuary experiences unusual water quality patterns in comparison to other estuaries with large tidal ranges. The Carmila Creek estuary is influenced by a smaller catchment area and has a lower proportion of sugar cane production (12,742 ha; 20% sugar cane) than other estuaries in the Plane Basin, including Plane Creek (15,975 ha; 21% sugar cane), Sandy Creek (49,864 ha; 51% sugar cane) and Rocky Dam Creek (51,901 ha; 23% sugar cane) (Drewry et al., 2008; Folkers et al., 2014). Different catchment areas and land uses can influence downstream water quality and these effects may be more pronounced in smaller systems; however, all estuaries in the region experience high tidal ranges and are likely to be similarly influenced by temporal variation. A longer-term study including multiple estuaries would aid in assessing the range of temporal variation influencing water quality in estuaries of the Mackay-Whitsunday-Isaac region.

References

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Appendices

The following data files were provided to the Healthy Rivers to Reef Partnership, as Appendices:

November 2021 water quality data

December 2021 water quality data

January 2022 water quality data

February 2022 water quality data

March 2022 water quality data

April 2022 water quality data

Thank you to our partners

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ABOUT US

The Mackay-Whitsunday-Isaac Healthy Rivers to Reef Partnership is a collaboration between community, Traditional Owners, farmers and fishers, industry, science, tourism, and government who recognise that more can be achieved by working together.

Contact us to learn more about how we help build and shape our community's understanding of waterway health and inform management actions.

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