Final Environmental Evaluation Report

Sealord King Reef Pty Ltd

Cowley Creek farm operation

Lot/Plan: 1/RP721954; 2/CP886368; 1/NR5347; and 295/RP814124

Environmental authority (EA): EPPR00390913



Nautilus Collaboration and Aquenal Pty Ltd

March 2023

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2 Executive summary

Department of Environment and Sustainability (DES) under the *Environmental Protection Act 1994* (the Act) have requested Sealord King Reef (SKR) undertake an Environmental Evaluation (EE) in accordance with section 326B(1)(b) of the Act until June 2022, or the Department is satisfied that the farming activity at Sealord King Reef is not causing or likely to not cause environmental harm". Two extensions have been requested by SKR and granted by DES. The submission of the final Environmental Investigation report is now due on 31st March 2023.



Figure 1. Schematic of timeline and processes under the environmental evaluation notice

This report builds on the "6-month and 12-month reports", and present 17-months of data covering the September 2021 to February 2023 period. A summary of the findings and recommendations are as follows:

- On-farm management has seen improvements to the discharge waters
- Several on-farm management actions have improved (and continue to improve) water quality into the receiving water from W2 discharge where water treatment was focused
- Passive sludge removal ongoing appears to be the most effective and economical management approach to long term health of the bioremediation ponds and thus the receiving waters
- The intake water quality (WQ) parameters are frequently higher than the farms discharge limits, so the farm is having to treat for high amounts of nitrogen and ammonia within the system it takes from prior to discharge
- Monitoring for water quality in an ephemeral environment coupled with surrounding agricultural inputs that are considered radiant polluters attributing to near, mid and far field receiving waters it is misleading to draw any conclusion from the current water quality dataset with any confidence beyond the near field release point
- Consideration into the relationship between physicochemical parameters and how these influence nutrients in the tropical water context needs to be considered to make more representative water quality regulations for barramundi farming that accurately reflect the reality of farming fish in a tropical setting but do not compromise the receiving waters
- Cowley creek – farm discharge levels currently supply water to this creek, ensuring the freshwater ecosystem is maintained and water is drawn downstream for agricultural use.
- Water quality objectives (WQOs) for Cowley Creek should be reviewed because the macroinvertebrate results, upstream and downstream receiving WQ results and receiving waters WQ results indicate that the catchment is already highly disturbed irrespective of the farm inputs
- Once the WQOs are reviewed for this catchment, then it is recommended that the water quality limits for the farm is also revised

Sealord King Reef has made a commitment to implement several new water quality management actions and continue existing strategies for managing water quality within the ponds and

bioremediation systems. The company has demonstrated significant improvements in the EE period mainly driven by farm management and is committed to environmental stewardship of the area within which it farms barramundi. The company has plans for the next 24 months to continuously improve operations including committed capital investment into managing the receiving waters. An adaptive management approach would benefit all stakeholders due to the challenges of regulating in a tropical ephemeral aquatic environment that is already disturbed by surrounding agricultural land-use.

3 Operational Summary

This report has been prepared by Nautilus Collaboration, but a number of parties have had a part to play in the fieldwork and data analysis and they are as follows:

Task owner	Task
Nautilus Collaboration	Analysis of water quality data, review REMP design, report compilation.
Aquenal	Analysis of the macroinvertebrate study
C&R Consulting	Fieldwork macroinvertebrate study
Sealord King Reef	In-house testing and sample collection for laboratory analysis
ALS Environmental Laboratories in Townsville	Analysis of collected samples

4 Abbreviations

BP: Bioremediation Pond

DES: Department of Environment and Sustainability

EA: Environmental Authority

EE: Environmental Evaluation

IP: Implementation Program

REMP: Receiving Environmental Monitoring Plan

SKR: Sealord King Reef

SP: Settlement Pond

The Act: *Environmental Protection Act 1994*

WQMP: Water Quality Management Plan

WQO: water quality objective

ZZ: Zig Zag

5 Introduction and Background

5.1 Project Extension

During the lifetime of the project, two project extensions were requested by SKR and granted by DES. Initial technical issues caused delays, which instigated the first request for an extension (Appendix 1). The request was granted on 1st of December 2021, and the project was extended to 17th of November 2022. Extended rainfalls during the dry season, which caused delays in the completion of earthworks in bioremediation system 2 and the commencement of a new trial (EcoTabs™ trial), initiated the second request for an extension. The request was granted on 8th of November 2022 and the project extended to 31st of March 2023.

5.2 Previous and current report

The approved Environmental Evaluation provides the framework for the water quality monitoring requirements which ensued from the environmental evaluation notice EPPR00390913 issued on the 3rd of March 2021. These requirements are detailed in an 'Investigation Scope' (Nautilus Collaboration and Aquenal, 2021), which includes: (a) guidelines for assessments of environmental values, WQOs and management goals and (b) monitoring and measurement of water quality and water flow within the farm operation and in adjacent waterways.

The Investigation Scope is organised around the seven key points identified in the Environmental Evaluation Notice – "EE Requirement 2a-g":

"2. The investigation scope must:

> *a) assess the farm operation against a detailed assessment of environmental values, WQOs and management goals of Cowley Creek (the waters) as specified in Schedule 1 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 "Johnstone River Basin Environmental Values and WQOs, Basin 112"; and*
>
> *b) evaluate aquaculture wastewater releases against limits within EA EPPR00390913; and*
>
> *c) monitor and measure water quality at a representative number of sites within Cowley Creek, both upstream and downstream of the release points (including mixing zones), during the wet season, during the dry season and during intermittent high flow events, in order to determine any changes in water quality for the entire creek system from the upstream sample points to the confluence with Liverpool Creek; and*
>
> *d) monitor and measure water quality observations and critical water quality changes through the farm operation from supply water intake to aquaculture wastewater releases, including in production ponds, drains, settlement areas, bioremediation areas and zig-zag wetland (polishing) areas; and*
>
> *e) conduct a minimum of fortnightly nutrient monitoring and daily flow monitoring of both the water supply intake and the aquaculture wastewater releases; and*
>
> *f) conduct a robust estimate of flows in Cowley Creek at the time of each sampling event; and*
>
> *g) include the planned operational measures for monitoring events that will be implemented to overcome and control both the Saltwater Crocodile risk and biosecurity risk involving access to monitoring sites in consideration of Panama Disease*

The requirements for this report are listed under requirement 7a-g in the Environmental Evaluation Notice:

"7. By 31 March 2023 you must provide an Environmental Report about the environmental investigation that:

- *a) reviews and assesses the environmental impact of the release of aquaculture wastewater into Cowley Creek from the farm operation, and*
- *b) reviews and assesses your compliance with relevant water quality and quantity limits in the EA, and*
- *c) reviews and assesses your ability to secure releases that support the WQOs in the EPP Water, and*
- *d) reviews and assesses the current infrastructure of the farm operation, and makes any necessary recommendations in order to:*
  - *comply with EA water quality and quantity limits, and*
  - *minimise impact on the receiving environment, and*
- *e) identifies a timeframe for an implementation program for 7. part (d) above,*
- *f) documents the process for managing water quality at the farm operation to be incorporated into operational plans for water quality management. The documented process is to include a Risk Assessment (including mitigation actions) for potential impacts to water quality,*
- *g) identifies any required changes to your Receiving Environment Monitoring Program required under your EA Part 2 condition H9, including timeframes for implementation.*

This report builds on the 6-month and 12-month reports, and present 17-months of monitoring data. Unlike previous reports, this report assesses monitoring data against relevant WQOs as well as EA water quality and quantity limits. In accordance with requirement 7d-g, it also contains an Implementation Program (IP), Water Quality Management Plan (WQMP) and a review of the current Receiving Environment Monitoring Program (Wild Environmental Consultants, 2020).

The report is structured to discuss the water quality results, the treatment of the water and subsequent trends and potential attribution of nutrients from land-based sources (radiant polluters). It is intended to relay the results and summarise findings on water quality that is treated as it moves throughout the farm, from the pond water management within the farm to discharge (and intake) and subsequently the receiving environment (Cowley Creek). The water quality is discussed throughout the process as follows:

- on-farm management
- government regulation of discharge; therefore, Section 7 analysis of discharge data discusses the results with respect to the EA water quality limits
- Following from that monitoring results from the receiving environment are discussed with respect to the WQOs for the farm respective catchment (Johnstone River Basin)

Structuring the report in this manner allows for more meaningful interpretation of the water quality results. Each step builds on the other to reflect where possible which physico-chemical patterns may be influencing the receiving environment (pond➔bioremediation➔discharge➔receiving waters).

Consequently, the report is structured into the following sections:

- On-farm monitoring – bioremediation systems and production ponds (Section 6);
- Discharge and inlet points (Section 7);
- Receiving Environment (Section 8);

- Macroinvertebrate Study (Section 9)
- Summary of results (Section 12);
- Recommendations and implementation program (Section 10); and
- Water Quality Management Plan and review of the Receiving Environmental Monitoring Program (Section 11).

An overall summary brings together the sub-summaries of each section for an overarching discussion on the trends in water quality discharged and the receiving environment which is followed by recommendations regarding future compliance (Section 12 and 10).

6 On-Farm Monitoring

6.1 Sampling design

Fortnightly sampling of sites located in drains, settlement ponds, zig zags and bioremediation ponds were conducted according to the specifications in Table 1 (Figure 2). The methodology is outlined in detail in the investigation scope (Nautilus Collaboration and Aquenal 2021) and outlined briefly here.

The monitoring program is designed to measure water quality as it moves through the bioremediation system. At SKR, there are two bioremediation systems: (1) Bioremediation System 1 encompasses rows C & D and is currently under construction (Box 1a) (2) Bioremediation System 2 encompasses rows A & B and the direction of flow is described in Box 1b. The monitoring program samples within each of the four components of each bioremediation system: (1) Drain (1 sample); (2) Settlement Pond (1 sample); (3) Bioremediation Ponds (2 samples; intake and discharge); and (4) Zig Zag (2 samples; intake and discharge). Data is presented according to the order of flow through the system (see green and purple flow charts below).

The purpose of this monitoring is to evaluate the effectiveness of each bioremediation system and determine whether improvements in discharge water quality can be made by improving the functionality of these systems.

Data was also collected from production ponds and summarised by pond row. Rows A & B discharge water into bioremediation system 2, whilst rows C & D discharge into bioremediation system 1.

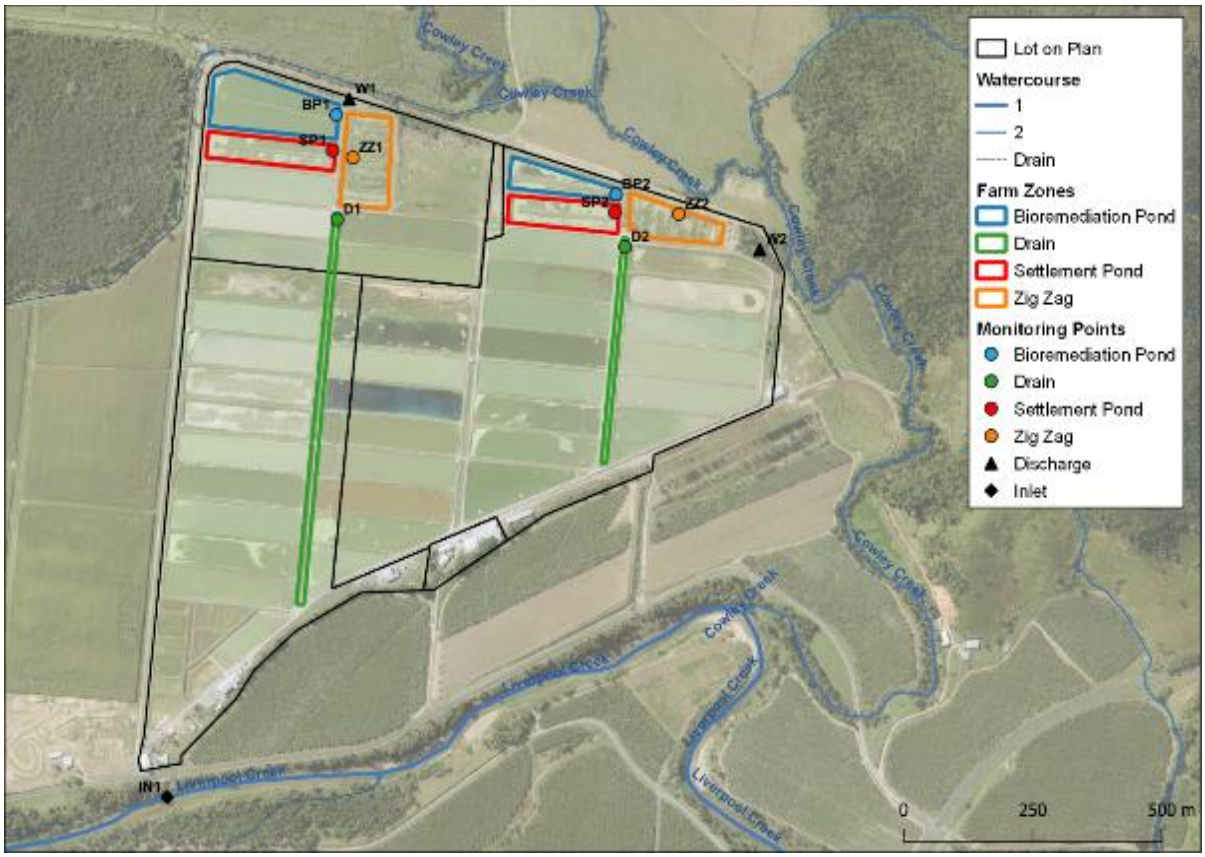


Figure 2. Schematic of fortnightly monitoring on farm monitoring sites.

6.2 Methods

Analysis of water quality at on-farm sites utilises in-house laboratory equipment and included monitoring of ammonia, nitrite, nitrate, total nitrogen and total phosphorous, in addition to field probe monitoring of temperature, pH, dissolved oxygen and turbidity. The sites sampled four components of the bioremediation system.

- Drain 1 & 2: single monitoring point from each
- Settlement pond 1 & 2: single monitoring point from each
- Bioremediation pond 1 & 2: Intake and discharge monitoring point from each
- Zig zag 1 & 2: Intake and discharge monitoring point from each

For most sites, water was <1m depth. Therefore, all data shown in this section of the report is from surface water samples. All in-house testing is labelled "I-H" (Figure 4 and Figure 6). Additionally, monthly samples were collected from drains, settlement, zig zags, and bioremediation ponds and sent to a third-party laboratory for analysis (ALS Environmental, Townsville) (Figure 3, Figure 5 and Figure 7).

6.2.1 Bioremediation System 1

System 1 is still currently under construction. The zig zag pond in this system has been temporarily blocked off to dry out the ponds for excavation, which occurred during this reporting period of the EE. Removal of organic matter and deepening of these ponds will allow more water to move through the system with a higher retention time. This measure aims to reduce the nutrient loads being discharged into the receiving environment. Due to these construction works; the system currently operates as follows:



6.2.2 Bioremediation System 2

Bioremediation system 2 is operating as per normal. The system therefore operates as follows:

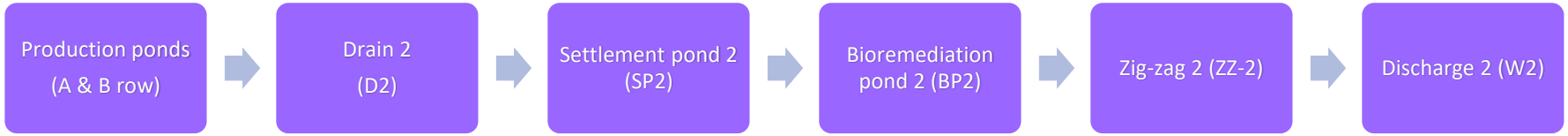


Table 1. List of monitoring parameters, frequencies and sampling methods at bioremediation sites System 1 sites = D1, D2, SP1, SP2, BP1-I, BP1-O. System 2 sites = BP2-I, BP2-O, ZZ1-I, ZZ1-O, ZZ2-I, ZZ2-O.

Parameter	Symbol	Units	Sampling Locations**	Sampling Frequency*	Sampling Method
Physico-chemical					
Dissolved Oxygen	DO	mg/L, %	System 1 sites; System 2 sites	Fortnightly	Field probe
pH	pH		System 1 sites; System 2 sites	Fortnightly	Field probe
Electrical Conductivity	EC	uS/cm	System 1 sites; System 2 sites	Fortnightly	Field probe
Temperature		^{o}C	System 1 sites; System 2 sites	Fortnightly	Field probe
Turbidity	Turb	NTU	System 1 sites; System 2 sites	Monthly	Field probe
Total Suspended Solids	TSS	mg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Nutrients					
Ammonia - Nitrogen	NH3-N	mg/L	System 1 sites; System 2 sites	Fortnightly	1 grab sample
Oxidised N (Nitrate + Nitrite)	NOx	mg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Total Nitrogen	TN	mg/L	System 1 sites; System 2 sites	Fortnightly	1 grab sample
Filterable Reactive Phosphorous	DRP	mg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Total Phosphorous	TP	mg/L	System 1 sites; System 2 sites	Fortnightly	1 grab sample
Biochemical oxygen demand	BAD	mg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Nitrate – Nitrogen	NO2-N	mg/L	System 1 sites; System 2 sites	Fortnightly	1 grab sample
Nitrite – Nitrogen	NO3-N	mg/L	System 1 sites; System 2 sites	Fortnightly	1 grab sample
Total Kjeldahl Nitrogen	TKN	mg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Algal Growth					
Chlorophyll *a*	Chla	µg/L	System 1 sites; System 2 sites	Monthly	1 grab sample
Cyanophyte Enumeration	Cyano	Cells/ml	System 1 sites; System 2 sites	Monthly	1 grab sample

*Note that all parameters are analysed monthly by an external laboratory (ALS), and parameters labelled “fortnightly” are monitored in house in the in the intervening fortnight (when samples are not sent to ALS for analysis).

**Only one sample is sent from each ziz-zag (ZZ) and bioremediation pond (BP) at a monthly external analysis interval.

6.3 Results

6.3.1 Production Ponds

Ammonia, nitrite, temperature, pH and dissolved oxygen showed fairly similar trends across all pond rows (Figure 8). Ammonia fluctuated significantly, with high temporal variation evident in all pond rows. Dissolved oxygen also showed high amounts of temporal variation, and appears to be inversely correlated with temperature, as is expected in pond culture conditions.

From a production stand-point, nutrient load is affected by:

- Feed input: total amount of feed that is placed into the production system and digested and metabolised by stock;
- Feed wastage: uneaten feed in ponds will continue to leach ammonia;
- Biomass: standing biomass for ponds and the size of fish;
- Biofloc: availability of aerobic bacteria to facilitate nitrification and annamox reactions;
- Benthic health of ponds: microorganisms on the pond bottom will digest and utilise sludge;
- Stratification of pond dissolved oxygen and temperature: pond flow and limiting stratification will improve and stabilise the environment for beneficial microorganisms;
- Algal biomass: consistency of the algal bloom. A healthy and consistent algal bloom will be able to convert and utilise N, P and C in pond;
- Mortalities: mortalities are removed regularly for this reason, as decaying biomass will contribute to the nutrient load of the system; and
- Fish health: optimising fish health and performance will improve feed utilisation and reduce the numbers of mortalities.

6.3.2 Bioremediation System 1

Bioremediation system 1 (System 1) showed similar levels and trends in water temperature, conductivity, dissolved oxygen, and pH as water moves through the system. Generally, the trend for water temperature is to inversely effect DO but this was not always the case in this system. Where dissolved oxygen occasionally showed low levels (in both % saturation and mg/L) this coincided with relatively low temperatures suggesting that DO depletion was not driven by high temperatures but may instead be due to increased oxygen demand by oxygen-consuming microbiota in the ponds, which is a trend consistent with the throughout the duration of the EE.

This 17-month dataset continues to show nutrient loads and physical parameters (i.e. TSS, turbidity, BOD and chlorophyll-*a*) measured by the third-party laboratory in a decreasing trend as they moved through System 1 (Figure 3 and Figure 5). This pattern was not as apparent when the in-house (I-H) data was considered (Figure 4 and Figure 6).

Ammonia, TKN, Total N and nitrite were shown to reduce throughout the system. However, nitrate, Total P and Reactive P all showed only slight decreasing trends towards the end of the system in BP1 (the final ponds before discharge into Cowley Creek via W1) compared to drain (D1) levels.

Cyanophytes peaked and troughed throughout the 17-month period, where they were at their highest in the system in October 2021 through to February 2022 but certainly reduced throughout this period in BP1 (Figure 7). There were peaks of cyanophytes in later months of 2022 but they reduced dramatically towards the end of the sampling period in February 2023. It is notable that the cyanophytes in late 2022 were predominately “non-toxic” taxa.

Overall, with the exception of dissolved oxygen, nitrate and phosphorus, water quality in bioremediation System 1 generally improves as water moves through the system.

6.3.3 Bioremediation System 2

Bioremediation system 2 (System 2) also showed a decreasing DO trend through the monitoring period, with levels peaking November 2022 and quickly troughing thereafter – this coincides with the introduction of the EcoTabs™ trial commencing in the system (see section 10.1.2 for more detail).

Conductivity, temperature, and pH showed relatively similar levels across all System 2 sites, except for a few isolated peaks. Turbidity and total suspended solids peaked in March 2022 but thereafter the trending appeared the same throughout the system. Chlorophyll *a* also showed a decreasing trend throughout monitoring period as the water moves through the system.

Total phosphorus, reactive phosphorus and total nitrogen were relatively similar throughout the sites in System 2 but appear to have decreased over time except for the Total P peak in September 2022. All nitrogenous parameters generally showed a decreasing trend as the water moved through System 2. Unlike the 12-month report results, this 18-month dataset was able to show ammonia lowered at the end (ZZ-2) than at the start of System 2 (D-2) signifying an improvement in System 2.

Cyanophyte numbers were significantly elevated in the earlier months of sampling System 2, particularly at the drain (D2) site, where a significant proportion of these were “potentially toxic” taxa. This proportion has decreased significantly at all sites since Jan-2022, and overall cyanophyte presence has significantly decreased in this time. In addition, cyanophyte counts appear to reduce as the water moves throughout the system, minimising the number of cells that are discharged from W2.

6.4 Summary of bioremediation systems

A healthy bioremediation system is one of the key elements to maintaining good water quality before it enters the receiving environment. Retention times for adequate treatment and a good microbiome for processing nitrogenous waste play a role in the health of the system. Sealord King Reef’s two bioremediation systems were treated differently which showed that active management can improve the effectiveness of bioremediation at SKR. Even with differing biomass waters feeding into the different bioremediation systems there was overall improvement by February 2023 in most cases for both Systems.

The results show neatly that the system with no treatment and a higher biomass in ponds that feed into System 1 lead in most instances to poorer water quality than System 2, especially phosphorus and nitrogenous parameters (Figure 3 and Figure 9). Bioremediation system 2 has received water from ponds with less biomass and treatments to improve the water quality discharged from W2. Consequently, there is an improvement in the water quality discharge which will be discussed in the next section. The on farm management that has led to improvements in System 2 such as the EcoTab™ trial and biosolids removal is discussed in detail in Section 10.

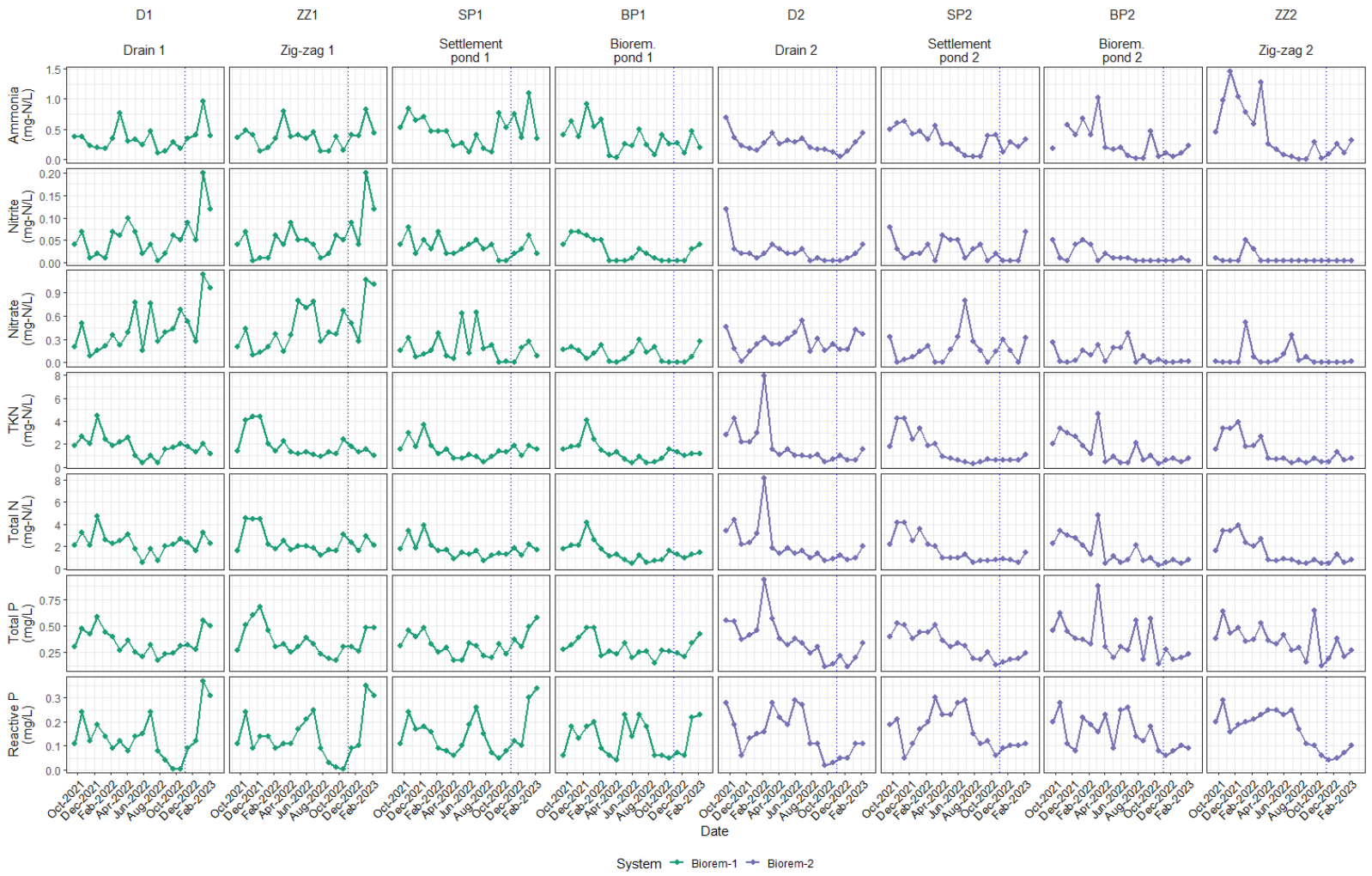


Figure 3. Monthly observations of ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total nitrogen (mg/L), and total phosphorus (mg/L) (analysed by ALS) at sites in bioremediation system 1 (green) and 2 (purple). Sites within each system are arranged left to right in direction of water flow. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

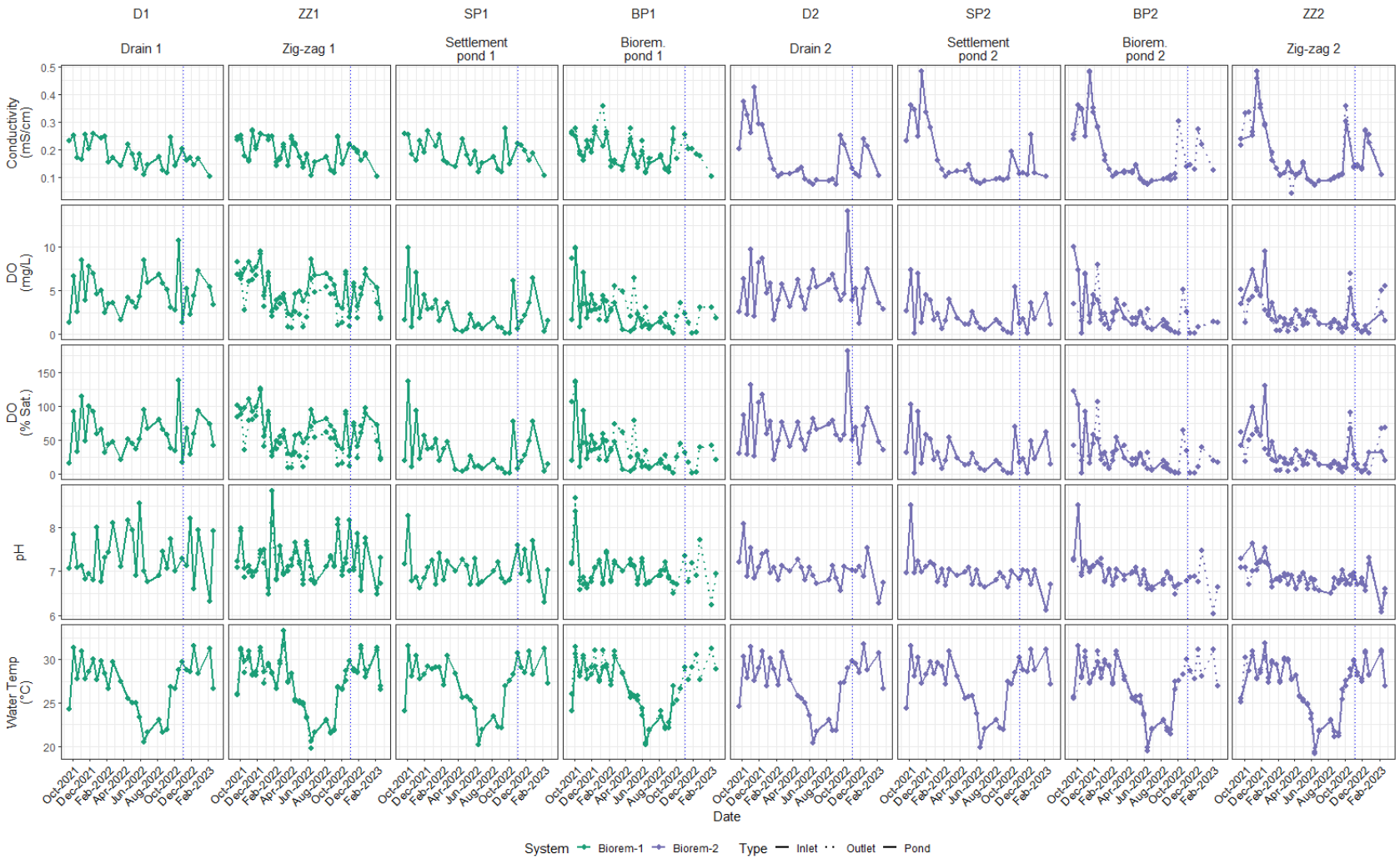


Figure 4. Fortnightly in-house (I-H) observations of conductivity (mS/cm), dissolved oxygen (mg/L & %sat.), pH and water temperature (°C) at sites in bioremediation system 1 (green) and 2 (purple). Sites within each system are arranged left to right in direction of water flow. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

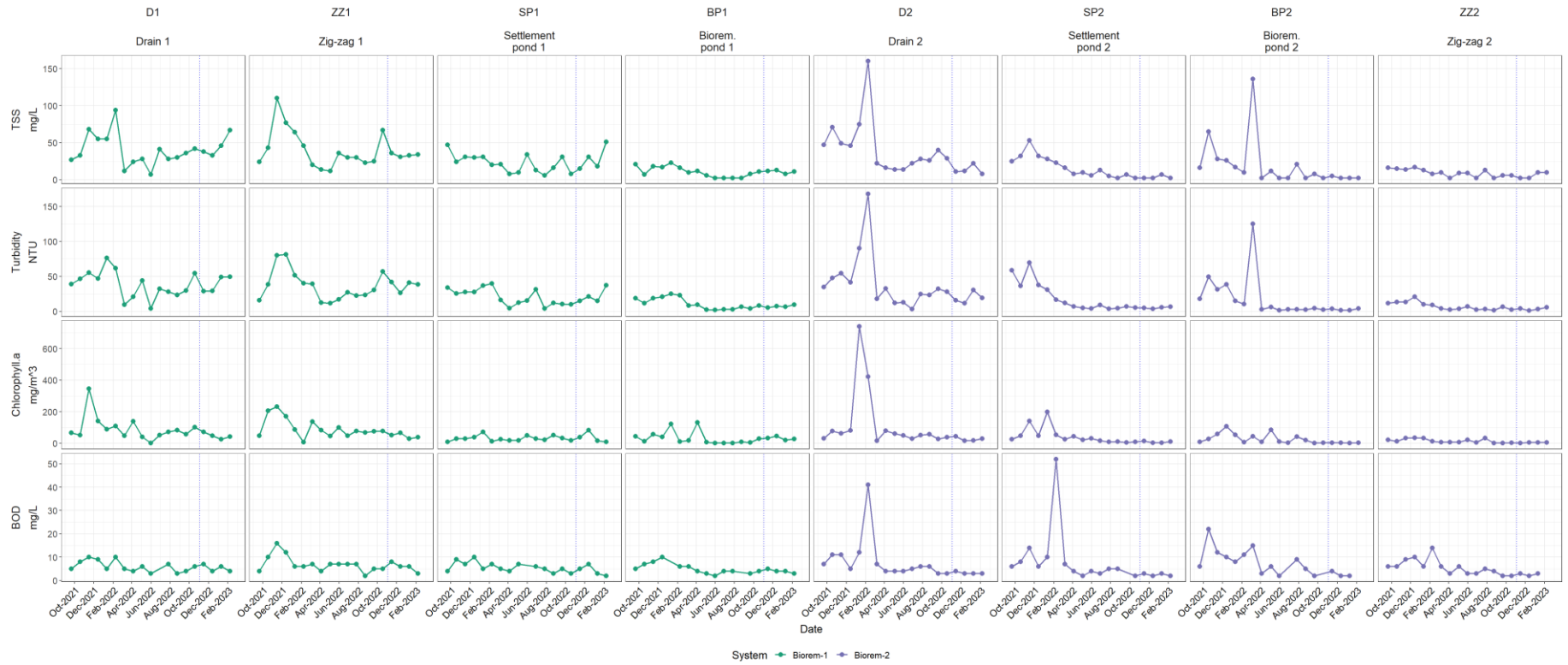


Figure 5. Monthly observations of total suspended solids - TSS (mg/L), turbidity (NTU), Chlorophyll α (mg/m^3), and biological oxygen demand – BOD (mg/L) (analysed by ALS) at sites in bioremediation system 1 (green) and 2 (purple). The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

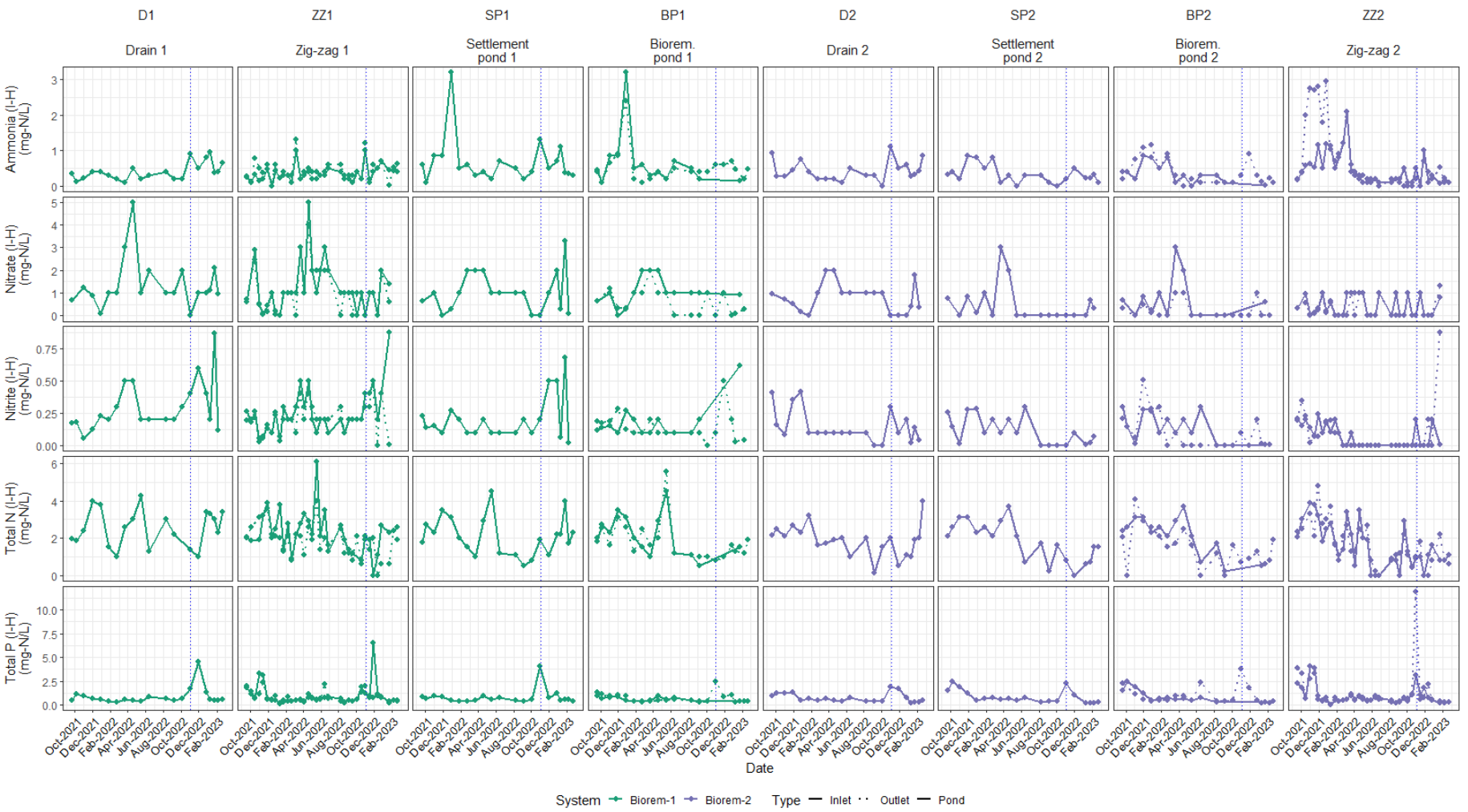


Figure 6. Fortnightly in-house (I-H) observations of ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total nitrogen (mg/L), and total phosphorus (mg/L) at sites in bioremediation system 1 (green) and 2 (purple). Sites within each system are arranged left to right in direction of water flow. The vertical blue dotted line (blue) indicates the commencement of the EcoTabsTM trial.

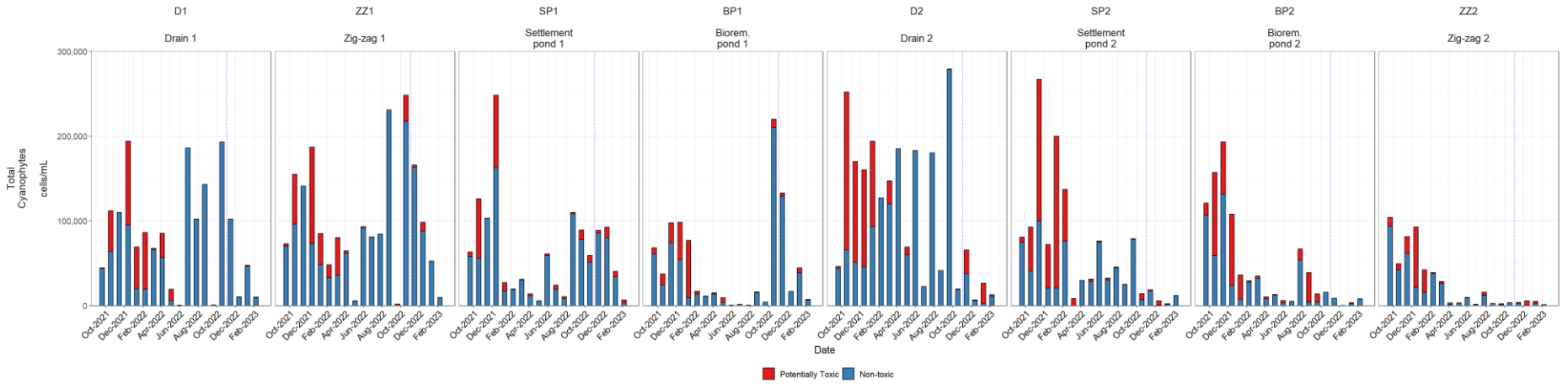


Figure 7. Monthly count (analysed by ALS) of total cyanophytes (cells/mL) classified into "Potentially toxic" and "Non-toxic" taxa at sites in bioremediation system 1 and 2. Sites within each system are arranged left to right in direction of water flow.

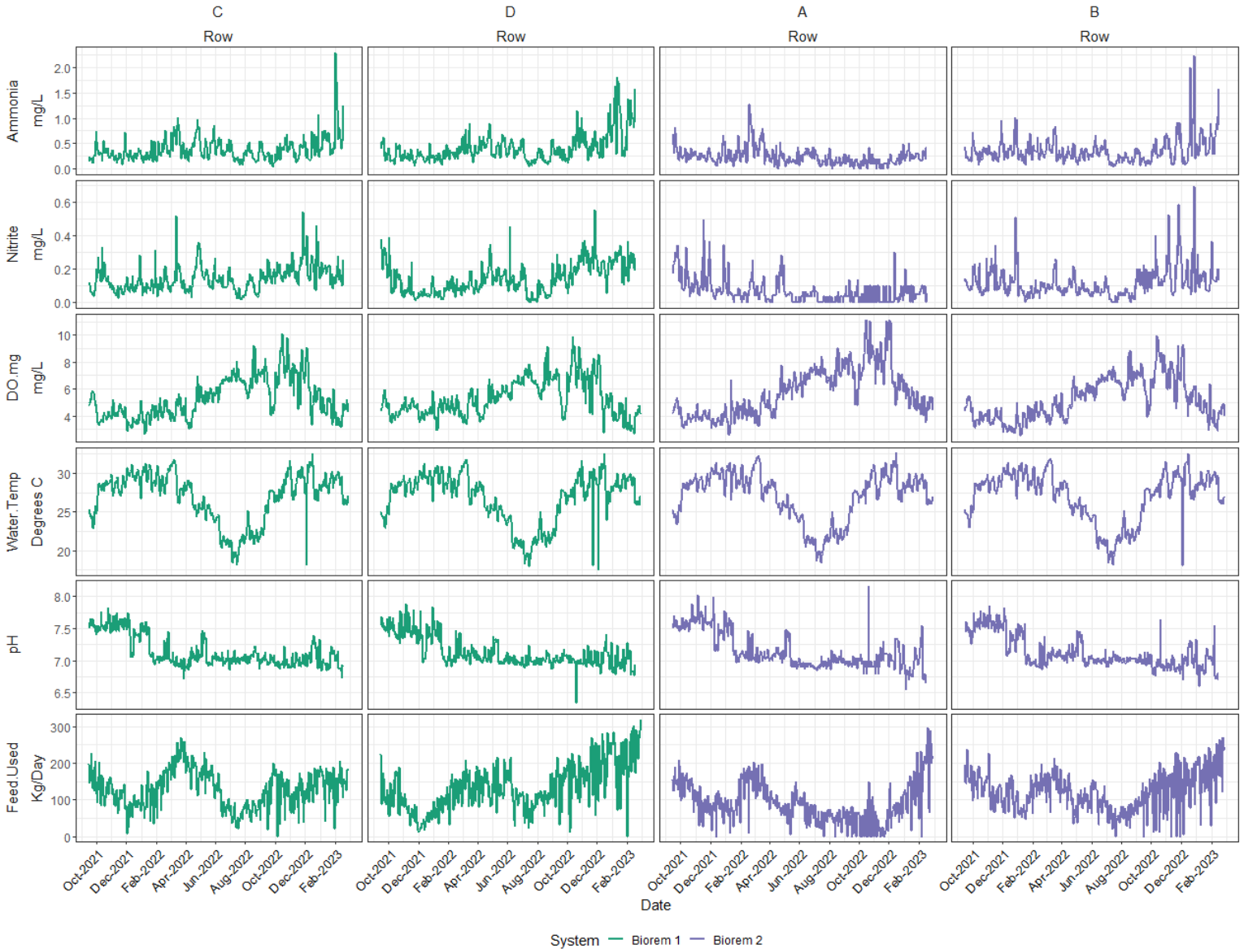


Figure 8. Mean ammonia (mg/L), nitrite (mg/L), dissolved oxygen (mg/L), water temperature (°C), pH and feed used (kg/day) in the production ponds, summarised by row. Pond corresponding to bioremediation system 1 (green) and 2 (purple).

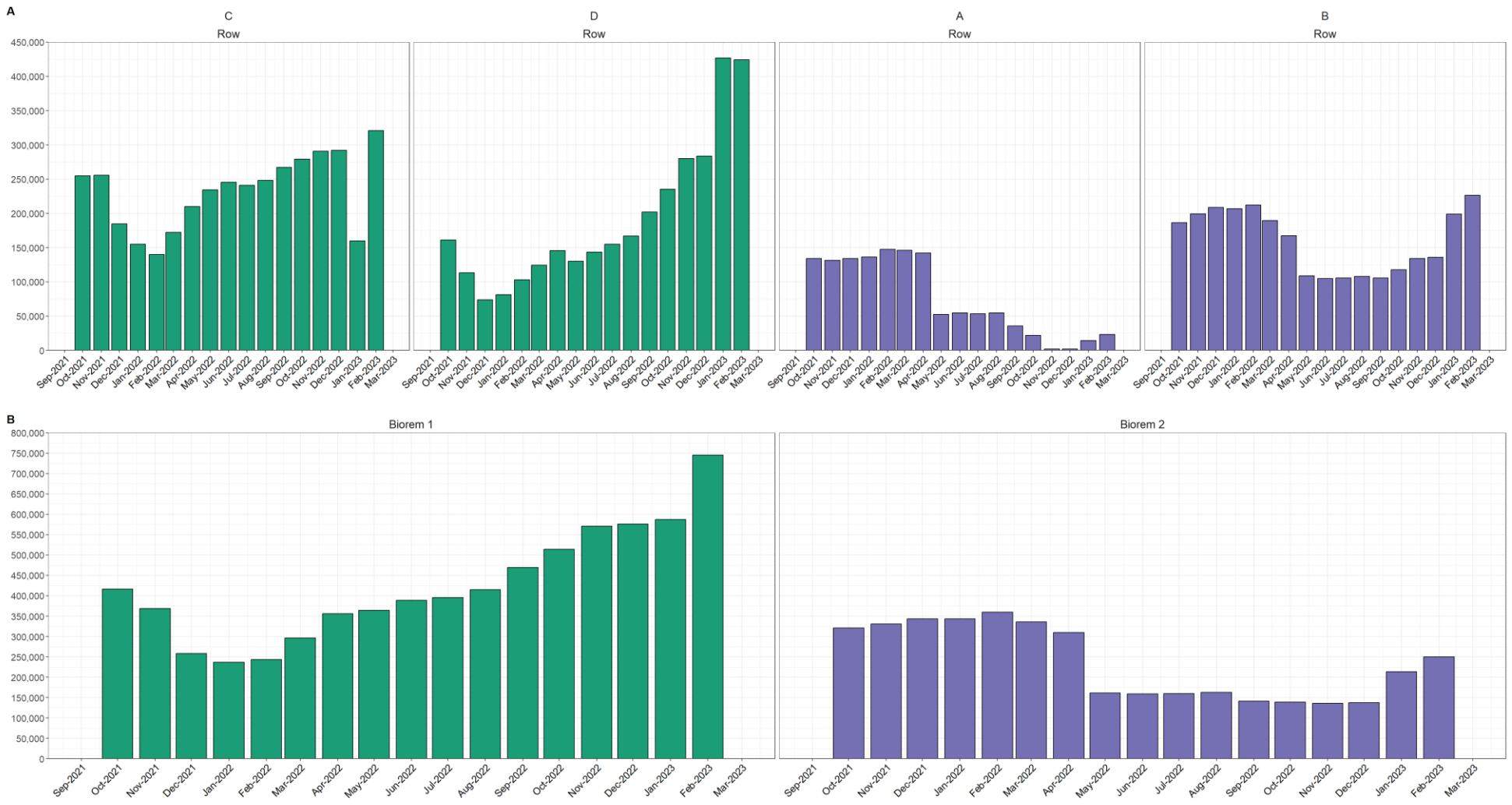


Figure 9. Total on-farm biomass by Row (A) and System (B) from September 2021 to May 2021. Note that "C row" and "D row" drain into system 1 (green), and "A row" and "B row" drain into bioremediation system 2 (purple).

7 Water Quality Monitoring of Inlet and Discharge Points

7.1 Location of discharge points

Water quality monitoring data, collected at the Liverpool Creek inlet and Cowley Creek discharge points, are presented in this section. The EA permits SKR to discharge aquaculture wastewater generated from the Cowley Creek farm operation, from three approved release points: W1, W2, and W3. Wastewater is permitted to be discharged to Cowley Creek from W1 and W2, and Liverpool Creek from W3. However, only discharge points W1 and W2 are currently in operation (Figure 2). W3 is currently unused due to it requiring some earthworks but if this was in use it is licenced to discharge into Liverpool Creek.

7.1.1 Discharge flow calculations

Discharge flow was calculated using the Kindsvater-Shen equation (UBSM, 1993). Head height was recorded at daily at discharge weirs (W1 and W2), and then flow was calculated using the following V-notch weir calculation:

$$\mathbf{Q = 4.28 \times C \times \tan(90°/2) \times (H/10 + K)^{2.5}/SQRT(3.28084)/100000 \times 60 \times 60}$$

Where Q = Discharge (m^3/h)

C = Discharge Coefficient (0.57790489)

K = Head Correction (0.088468713)

H = Head Height (mm)

Source: https://www.lmnoeng.com/Weirs/vweir.php.

*Note that equation has been adjusted for metric measurements.

7.2 Methods

7.2.1 Field methods

The methodology for collecting data in the field and the laboratory are outlined in detail in the Sealord King Reef Environmental Investigation Scope document (Nautilus Collaboration and Aquenal, 2021). A summary of sites is included in Figure 2. A summary of monitoring parameters, and sampling frequency can be found in Table 2 (Inlet/discharge sites).

All water quality samples and measurements were collected by suitably trained technical officers at Sealord King Reef, and water samples were sent by same-day or overnight courier to ALS Environmental Laboratories in Townsville for analysis. At each monitoring site, field measurements were taken using a calibrated YSI multi-parameter probe. Water samples were collected in containers provided by ALS Environmental (Townsville), and the ALS compass App was used to electronically populate the submission paperwork. Each sample bottle is scanned into the App as the sample is collected, reducing the risk of labelling or submission paperwork errors during the collection. Samples were transported by express courier to the laboratory, and sensitive parameters (such as BOD) were analysed within 48 hrs of being collected. One laboratory blank per sample collection and 1x field replicate per 10 sites were also collected and sent to the laboratory for analysis as per the QA/QC methodology outlined in the EE Investigation Scope Document (Nautilus Collaboration 2021).

Table 2. List of monitoring parameters, frequencies and sampling methods at SKR Inlet and Discharge sites.

Parameter	Symbol	Units	Sampling Locations	Sampling Frequency	Sampling Method
Physico-chemical					
Dissolved Oxygen	DO	mg/L, %	Inlet, W1, W2	Fortnightly	Field probe
pH	pH		Inlet, W1, W2	Fortnightly	Field probe
Electrical Conductivity	EC	uS/cm	Inlet, W1, W2	Fortnightly	Field probe
Temperature		^{o}C	Inlet, W1, W2	Fortnightly	Field probe
Turbidity	Turb	NTU	Inlet, W1, W2	Fortnightly	Field probe
Total Suspended Solids	TSS	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Inlet flow	IF	M^3/Hr	Inlet	Daily	Ultrasonic flow meter
Discharge flow	DF	M^3/Hr	W1, W2	Daily	Calculation based on weir head height
Nutrients				Fortnightly	
Ammonia - Nitrogen	NH3-N	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Oxidised N (Nitrate + Nitrite)	NOx	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Total Nitrogen	TN	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Filterable Reactive Phosphorous	DRP	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Total Phosphorous	TP	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Biochemical oxygen demand	BAD	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Nitrate – Nitrogen	NO2-N	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Nitrite – Nitrogen	NO3-N	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Total Kjeldahl Nitrogen	TKN	mg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Algal Growth					
Chlorophyll α	Chla	µg/L	Inlet, W1, W2	Fortnightly	1 grab sample
Cyanophyte Enumeration	Cyano	Cells/ml	Inlet, W1, W2	Fortnightly	1 grab sample

7.2.2 Analysis of data

As required by "EE Requirement 7b", this section reviews and assesses compliance with relevant water quality and quantity limits in the EA.

Table 3 presents the Release Quality Characteristic Limits, including the quality characteristics (i.e. parameters), release limit, and the limit type. In accordance with the note under EA condition C5, a rolling 5-month 80th percentiles were calculated for each parameter. Monitoring of release water quality began in October 2021, so the first instance in which 5-months of data was available to calculate rolling 5-month 80th percentiles was February 2022.

Table 4 presents the maximum daily discharge volumes permitted for July to November and December to June periods. According to EA condition C4, the total quantity of contaminants released via the discharge points (i.e. W1, W2 and W3) must not exceed these limits, exception of periods when excessive rainfall causes aquaculture ponds to overflow.

Table 3. Release Quality Characteristic Limits relating to discharge point W1 and W2 (adapted from Environmental Authority, pp 14).

Quality Characteristics	Units	Release Point	Release Limit	Limit Type
Suspended solids	mg/L	W1, W2	15-25	80th percentile-maximum
pH		W1, W2	6.5-8.7	range
Dissolved Oxygen	mg/L	W1, W2	4.0	minimum
Total Nitrogen	mg/L	W1, W2	0.6-0.8	80th percentile-maximum
Chlorophyll a	ug/L	W1, W2	30-50	80th percentile-maximum
Total Phosphorus	mg/L	W1, W2	0.05-0.08	80th percentile-maximum

Note: the 80th percentile and maximum values are to be calculated using consecutive results for the previous five months for the characteristic.

Table 4. Quantity limits currently permitted (adapted from Environmental Authority, pp 14).

		Maximum daily discharge (m3/day)		
Season	**Discharge Type**	**W1**	**W2**	**W3**
July to November inclusive	exchange	1155	1913	5955
	exchange + drainage	1155	1913	10925
December to June inclusive	exchange	2130	3825	5955
	exchange + drainage	6435	7013	10925

7.3 Results

7.3.1 Performance against relevant EA quality and quantity limits

7.3.1.1 Discharge point W1

In general, no apparent improvements of the water quality discharged from discharge point W1, were observed. As a consequence, no profound improvement was observed when comparing the data against relevant EA quality and quantity limits (Table 3 and Table 4). The results presented in Figure 10, Figure 11, and Figure 12 and Figure 14, are summarised below.

There was no apparent improvement regarding compliance with the EA limits for total nitrogen, total phosphorus, and dissolved oxygen. The 80th percentile-maximum limit for both total nitrogen, total phosphorus were exceeded on all occasions. Maximum limits were exceeded on all occasions for total phosphorus and on most occasions for total nitrogen. Dissolved oxygen was variable, but under the minimum EA limit, on several occasions. pH was within the permitted range, except from one low reading recorded in 2023; however, this was also seen at the intake point. In recent time, TSS and turbidity appear to be under or hovering just over the EA limits, signifying a marginal improvement.

The discharged volumes released from W1 were frequently over the maximum daily release limits (Figure 14). This appears to be the case even when Figure 25 indicate low or no daily rainfalls, signifying an exceedance of the EA release limit.

7.3.1.2 Discharge point W2

In general, water quality discharged from discharge point W2 appears to have improved over the course of the EE. When comparing recent data against the relevant EA release limits (Table 3 and Table 4), a larger number of parameters seem to either meet or approach the EA limits. The results presented in Figure 10, Figure 11, Figure 12 and Figure 14, are summarised below.

Total nitrogen was consistently over the permitted EA limit up to April 2022. The maximum limit has only been exceeded once since then, and the concentrations are hovering around the 80th percentile-maximum limit. For total phosphorous no improvement was evident, when comparing concentrations against the maximum limit. However, for the 80th percentile-maximum limit for total phosphorous, there appears to be an improvement in more recent time. Even so, total phosphorous was close to the EA limit on every occasion. Total suspended solids were within or at the maximum EA limits, and compliant with the 80th percentile-maximum limits for the more recent data.

Dissolved oxygen was variable, but under the minimum EA limit, on several occasions. pH was within the permitted range, except from one low reading recorded in 2023; however, this was also seen at the intake point.

The discharged volumes released from W2 were frequently over the maximum daily release limits (Figure 14). This appears to be the case even when Figure 25 indicate low or no daily rainfalls, signifying an exceedance of the EA release limit.

7.3.1.3 Discharge volumes

Discharge flow volume showed variable flow throughout the reporting period, with discharge volume (m^3/day) exceeding the maximum discharge limit (exchange + drainage) on many occasions (Figure 14). Most of these exceedances were associated high flow/rainfall events but exceedances happened also in the dry season (Figure 25). This appears to be compensated by a reduced inflow between February-April ’22.

7.4 Summary

Across the monitoring period, nutrient concentrations were consistently lower and less variable at the inlet compared to the two discharge points. This indicates a clear (and unsurprising/predictable) impact of farm operations on water quality as it moves through the production system. It should be noted though that there were times throughout the 17-months of the EE where physico-chemical parameters were above EA limits at intake such as Total P, Total Suspended Solids and Total N (Figure 10 - Figure 12).

Temporal patterns in nutrient concentrations at W1 were erratic with a distinct lack of consistency between parameters. There was little sign of improvement (i.e. a decrease in nutrient concentrations) over time at W1. In contrast, nutrient concentrations at W2 showed a broadly declining trend for ammonia, nitrate, TKN, Total N, Total P and Reactive P. This indicates a clear improvement of water quality due to management interventions (see Section 10 for detail).

Dissolved oxygen was consistently lower and chlorophyll *a* was consistently higher at the discharge sites compared to the inlet. In contrast, pH, conductivity, and BOD were relatively similar between the inlet and discharge. With the possible exception of chlorophyll *a* and BOD, there was little evidence of an improvement in these water quality characteristics at discharge sites over time.

Dissolved oxygen in both W1 and W2 was lower than in the inlet water and was below the minimum EA release limit on several occasions (Figure 11). Conductivity and pH levels were similar in inlet and discharge waters. Total suspended solids, turbidity, and BOD generally showed a decreasing trend to levels similar to those of the inlet water. The majority of these were below the maximum discharge release limit. Samples collected at discharge W2 showed low chlorophyll *α* levels below the EA release limits and like those of the inlet water. W1 showed a few high spikes in chlorophyll *α* between December ’21-June ’22 that exceeded maximum discharge limits, but then decreased to levels below the maximum limits thereafter.

The nutrient, biological (including cyanophytes) and physico-chemical parameters were better at the intake than at the discharge points (W1 and W2). Cyanophytes were reduced in W2 due to improvements of the pond system and bioremediation. Water quality characteristics at discharge point W1 appear to be similar throughout the collection period. However, even though biomass and feed use were high, water quality at discharge point W2 appears to have improved in recent time, with total nitrogen, Chlorophyll-*a* and TSS meeting or approaching EA limits. Dissolved oxygen on the other hand seem to be variable and at times low.

Key points from the compliance data are summarised below:

- Over the monitoring period, there was a noticeable decrease in nutrient concentrations and cyanophyte counts at discharge W2, which indicates a significant improvement in water quality
- Improvements were not as apparent at discharge W1; however, applying treatment to this system in the same manner as W2 should improve water quality
- In recent times (November 2022), a probiotic has been trialled (EcoTabs^{TM} trial) in the bioremediation system associated with discharge point W2, which appears now effective after a short spike in nitrogen and phosphorous due to the altering of the microbiome in System 2.
- The sludge removal undertaken in the bioremediation system linked to discharge point W1, has only recently been completed and has not yet been put to the test

- There was a high presence of potentially toxic (and non-toxic) cyanophytes in water sampled from both discharge sites between October ’21 and April ’22 (Figure 13). Cyanophyte counts remained low throughout the remainder of the reporting period in W2. However, W1 saw a marked increase again between September ’22 to February ’23, although the proportion taxa that were classified as potentially toxic was very low. Cyanophytes were not present in the intake water
- Water from W2 showed significant improvement throughout the monitoring period based on nitrogen outputs, only exceeding the EA release limit once since April 2022. This points to significant improvement of on-farm management practices, as these low total nitrogen levels continued into the end of 2022, despite nearly double the feed input and biomass during this period when compared to the same time the previous year

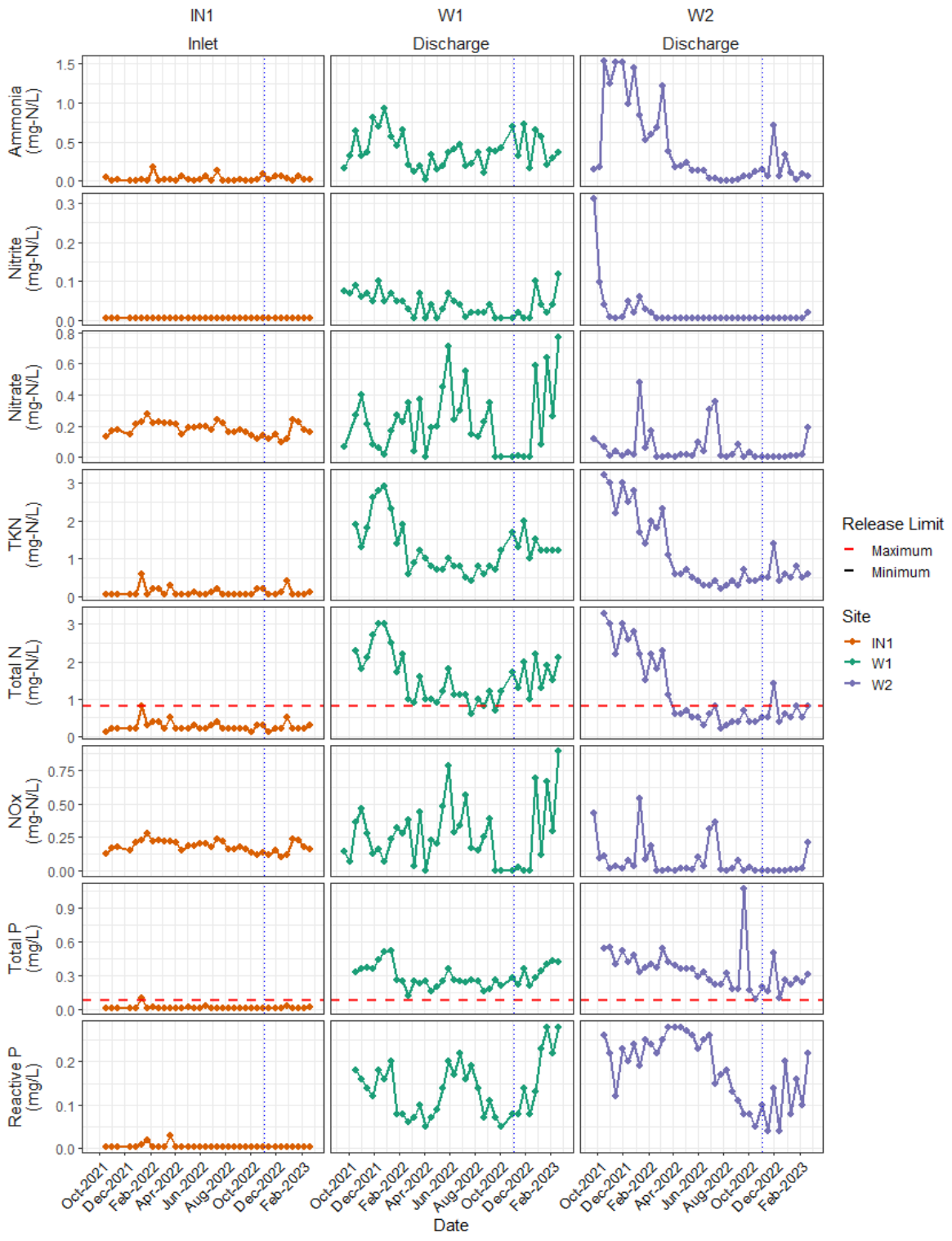


Figure 10. Monthly observations of ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total Kjeldahl nitrogen - TKN (mg/L), total nitrogen (mg/L), oxidised nitrogen (NOx) (mg/L), total phosphorus (mg/L) and reactive phosphorus (mg/L) at inlet (orange), discharge W1 (green) and discharge W2 (purple). EA water quality limits are shown as horizontal dashed lines. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

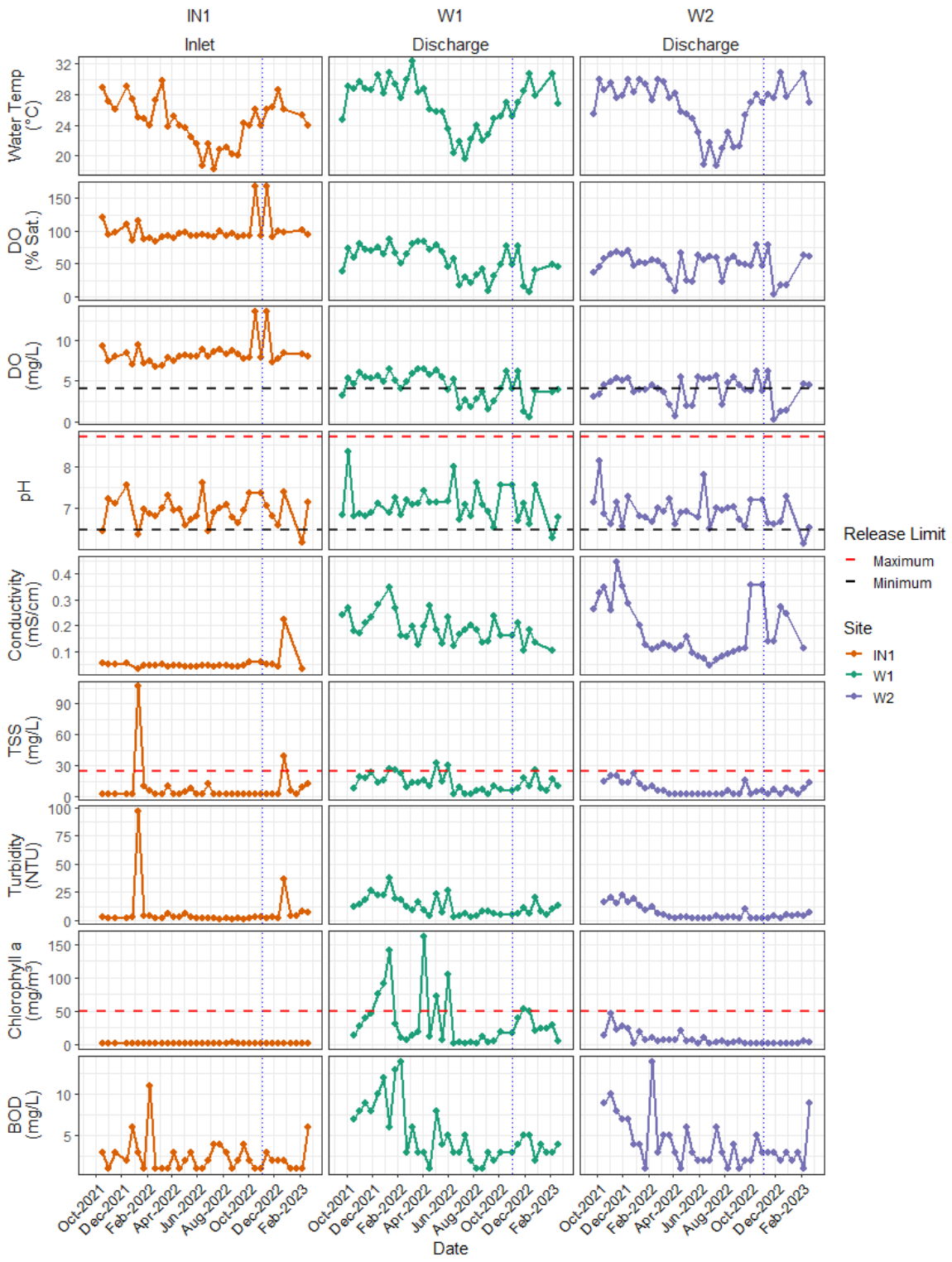


Figure 11. Monthly observations of water temperature (°C), dissolved oxygen (% sat level), dissolved oxygen (mg/L), pH, conductivity (mS/cm), total suspended solids – TSS (mg/L), turbidity (NTU), chlorophyll α (mg/m3) and BOD (mg/L) at inlet (orange), discharge W1 (green) and discharge W2 (purple). EA water quality limits are shown as horizontal dashed lines. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

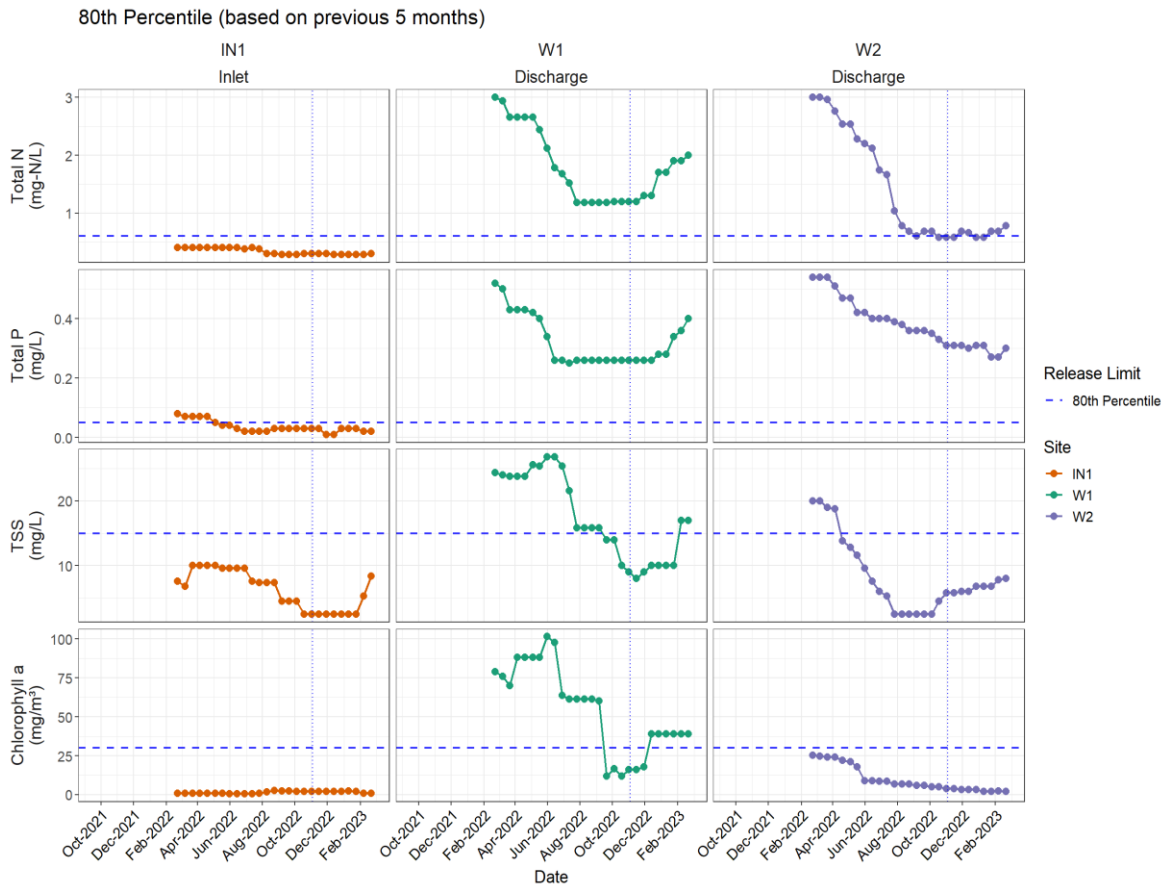


Figure 12. Comparison of 5-month rolling 80th percentiles for Total N, Total P, TSS and Chlorophyll-a at inlet (orange), discharge W1 (green) and discharge W2 (purple). EA water quality limits (80th percentile) are shown as horizontal dashed lines. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial

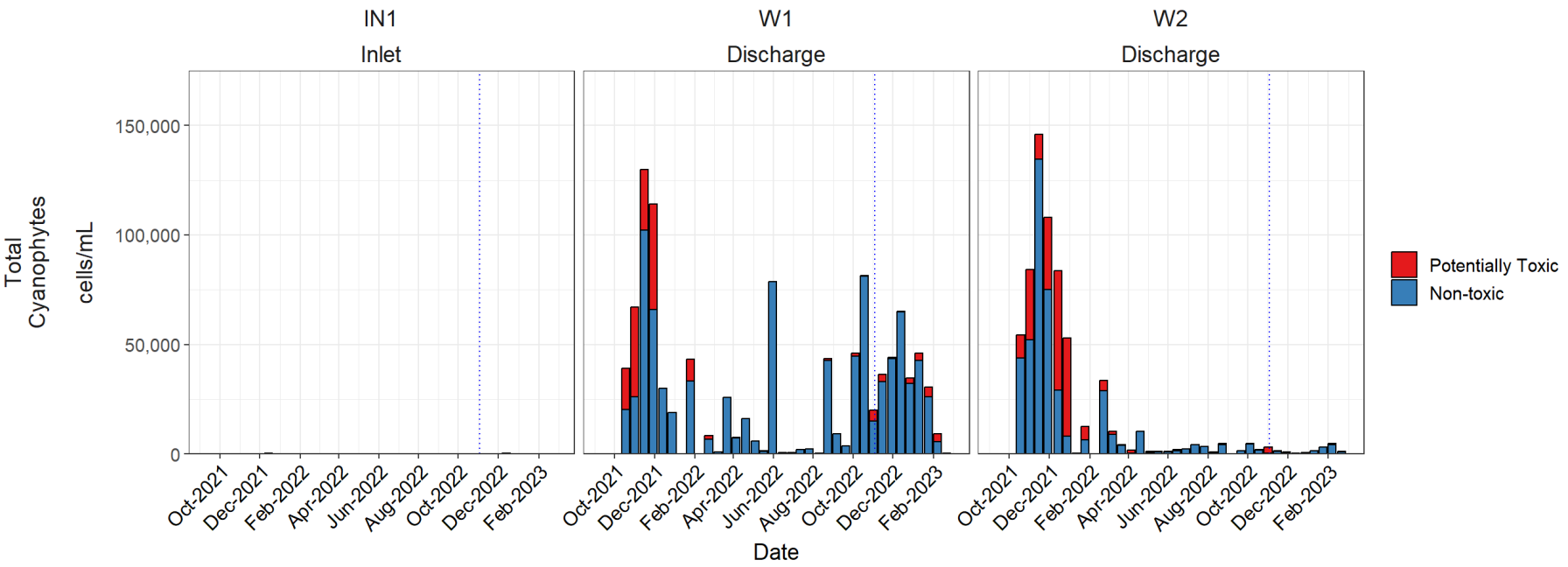


Figure 13. Fortnightly counts of total cyanophytes (cells/mL) classified into "Potentially toxic" and "Non-toxic" taxa at the inlet and at discharge points W1 and W2. The vertical dotted line (blue) indicates the commencement of the Eco Tabs™ trial.

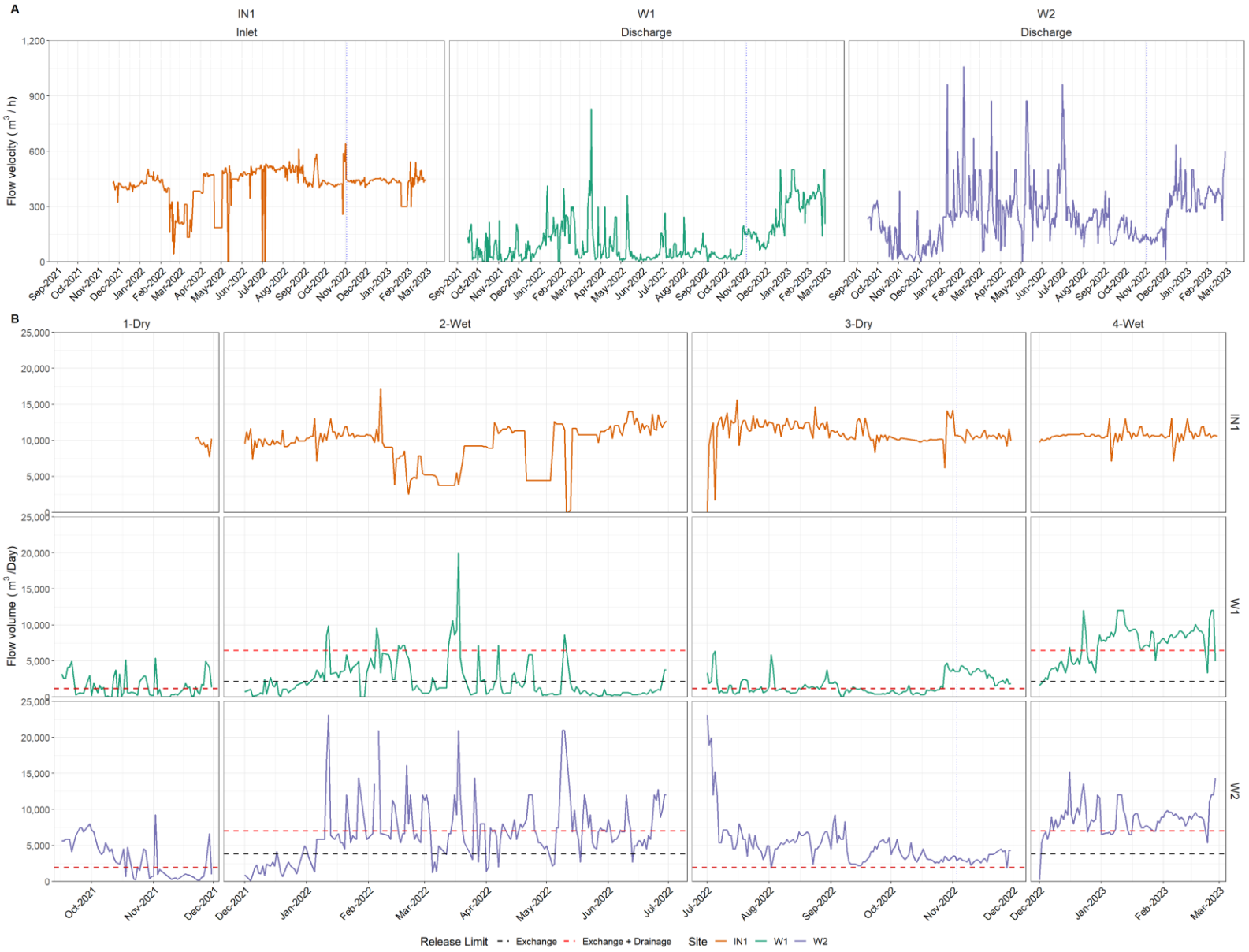


Figure 14. Discharge flow velocity and flow volume at farm inlet (orange), discharge W1 (green) and discharge W2 (purple). Horizontal dashed lines represent release limits as per Environmental Authority.

8 Water Quality Monitoring of the Receiving Environment (Cowley Creek)

8.1 Sampling Design

When assessing potential environmental impacts, it is necessary to measure one or more indicators that will provide information (generally numerical quantities or qualitative ranks) about the environmental condition at the potentially impacted site, or test site, and compare these measurements against similar measurements collected in the absence of impact or disturbance according to QLD's Monitoring and Sampling Manual 2008 (pp. 24, DES 2008). Consequently, the location of sampling sites at Cowley Creek was designed around control sites upstream of the discharge points and impact/test sites downstream of the discharge points.

The location of sampling sites considers previous monitoring locations, the location of discharge points and elements of site accessibility (including biosecurity considerations) (Figure 15, Figure 16 and Figure 17Figure 2). The four monitoring locations for the REMP 2020 have been adopted and an additional three locations (one upstream and two downstream) aded to increase spatial coverage and meet the requirements of the EE (i.e. "…….*to determine any changes in water quality for the entire creek system from the upstream sample points to the confluence with Liverpool Creek*"). Adopting previous sites ensures the continuity of historical sampling and - given their ongoing sampling as part of the REMP - ensures the most efficient use of time and resources.

Given the branching nature of Cowley Creek, waters flowing through the current control site (CC-1) do not flow past 'impact site' CC-2. The remaining two sites (CC-4, CC-5) sites have been placed at locations that ensure that Cowley Creek is sampled at systematic intervals, where practicable, to the confluence with Liverpool Creek. The proposed gradient of sampling sites will enable tracking of nutrients downstream from the SKR discharges and for identifying other potential sources of impacts (e.g. run off from agriculture).

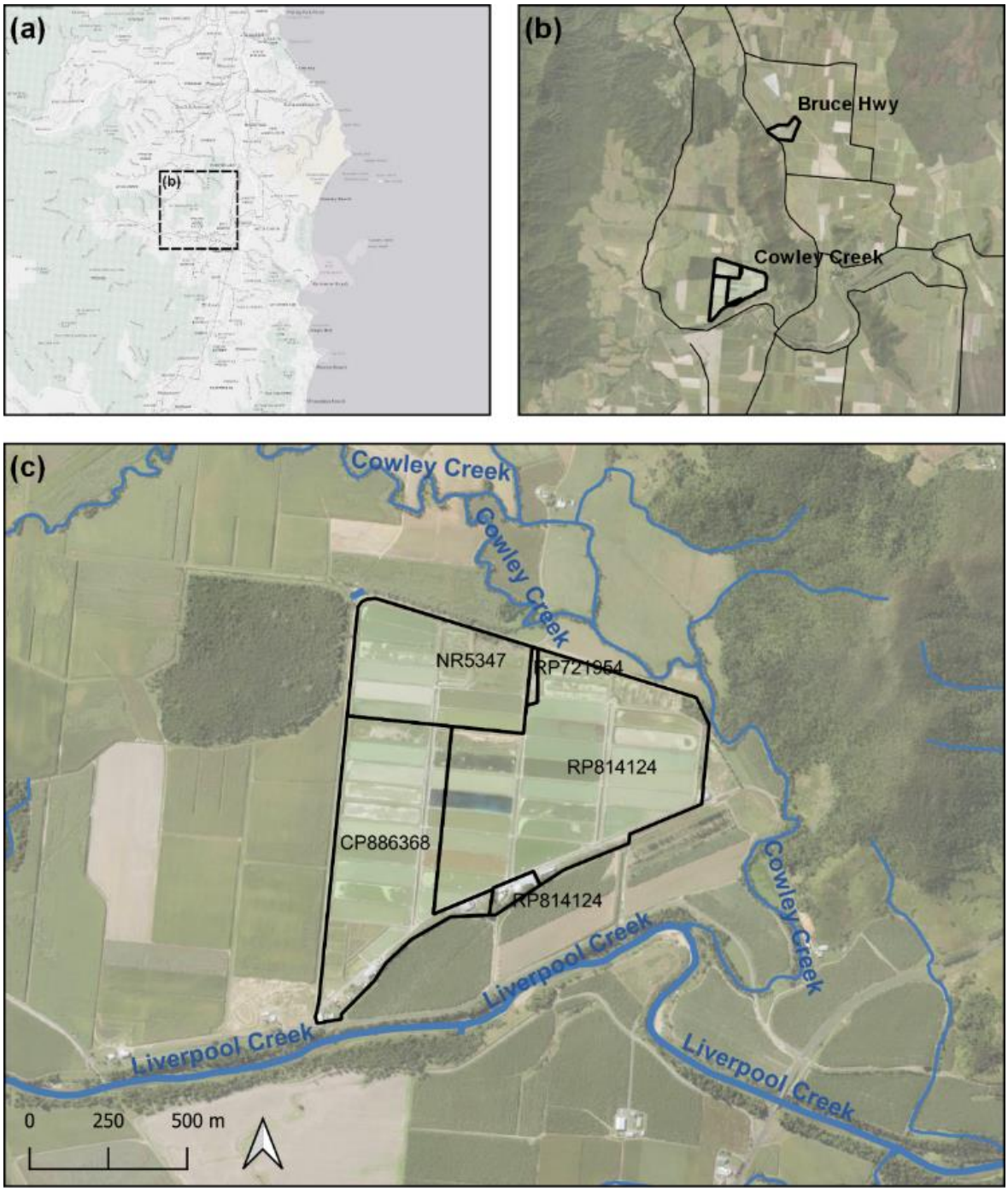


Figure 15. (a) Location of SKR operations south of Innisfail in Northern Queensland. (b) location of barramundi farm facility at Cowley Creek and a barramundi nursery facility on the Bruce Highway. (c) lot plan for the barramundi farm facility at Cowley Creek and adjacent waterways.

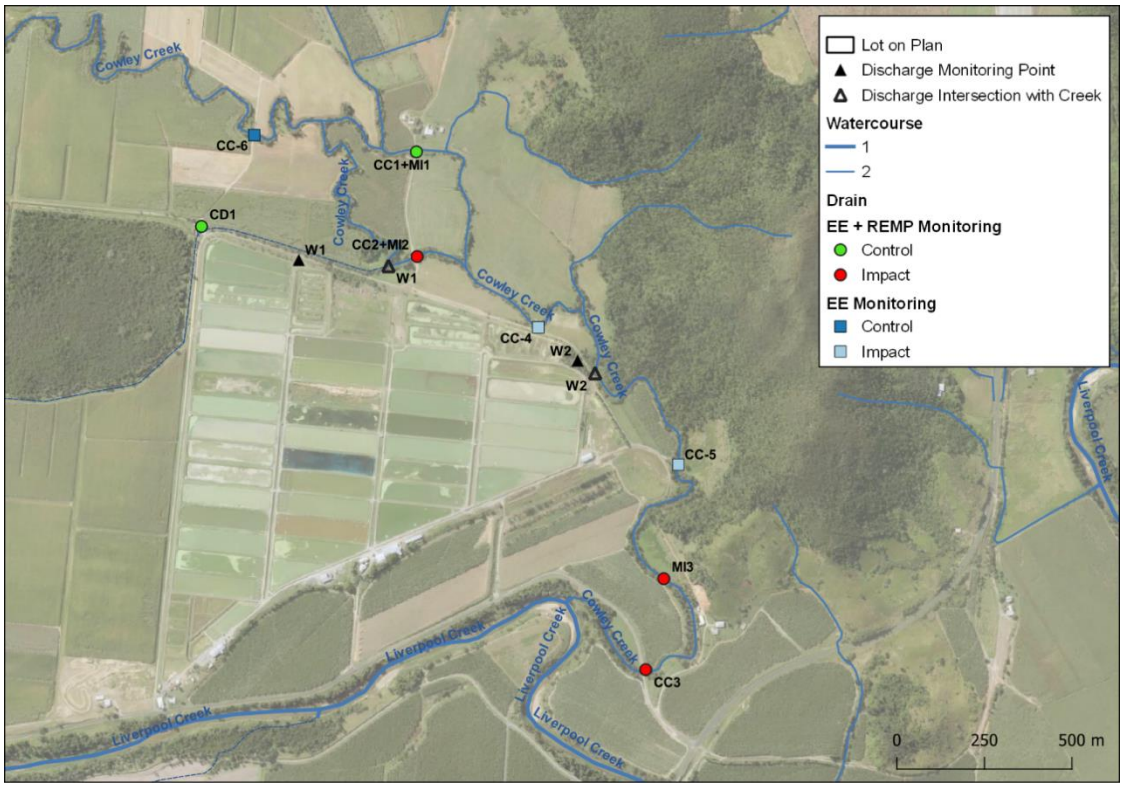


Figure 16. Discharge points (W1 and W2) and Environmental Evaluation (EE) monitoring sites along Cowley Creek adjacent to Sealord King Reef.

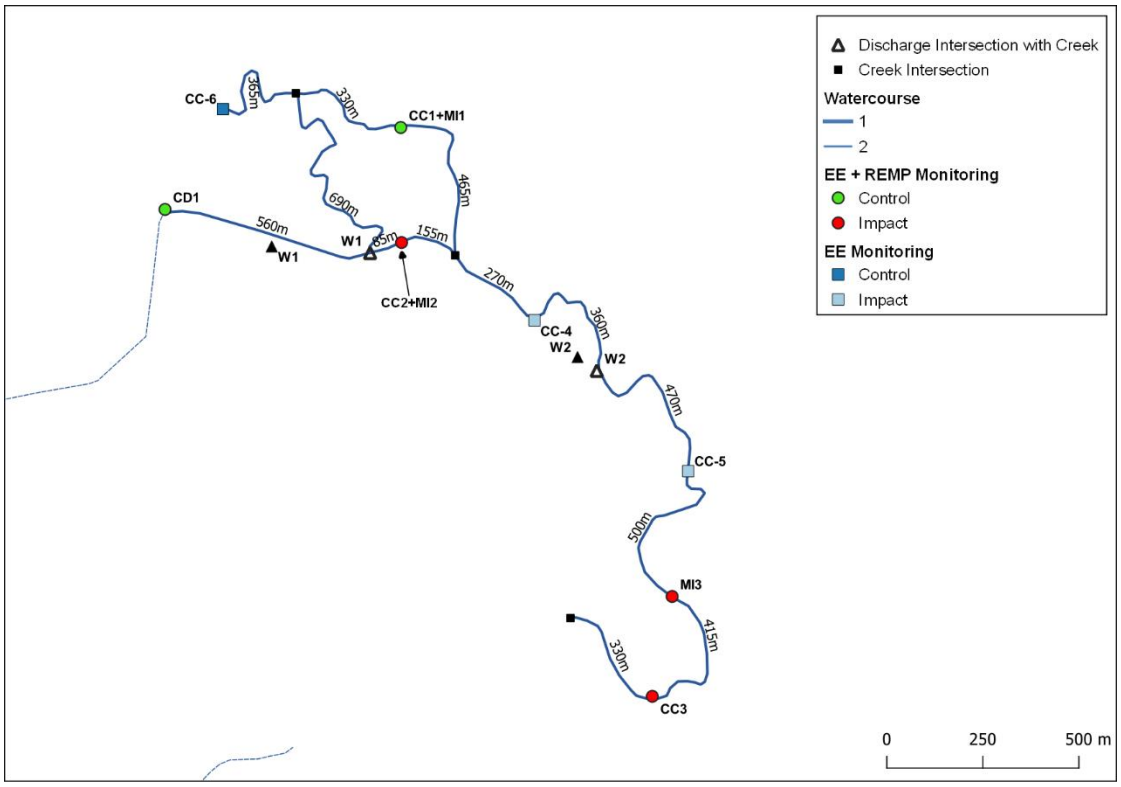


Figure 17. Schematic diagram of sample sites and distances between each landmark along Cowley Creek.

8.2 Methods

8.2.1 Field methods

The methodology for collecting data in the field and the laboratory are outlined in detail in the Sealord King Reef Environmental Investigation Scope document (Nautilus Collaboration and Aquenal, 2021). Figure 15Figure 16Figure 17Monitoring parameters and sampling frequency can be found in Table 5. All water quality samples and measurements were collected by suitably trained technical officers at Sealord King Reef, and water samples were sent by same-day or overnight courier to ALS Environmental Laboratories in Townsville for analysis. At each monitoring site, field measurements were taken using a calibrated YSI multi-parameter probe. Water samples were collected in containers provided by ALS Environmental (Townsville), and the ALS compass App was used to electronically populate the submission paperwork. Each sample bottle is scanned into the App as the sample is collected, reducing the risk of labelling or submission paperwork errors during the collection. Samples were transported by express courier to the laboratory, and sensitive parameters (such as BOD) were analysed within 48 hrs of being collected. One laboratory blank per sample collection and 1x field replicate per 10 sites were also collected and sent to the laboratory for analysis as per the QA/QC methodology outlined in the EE Investigation Scope Document (Nautilus Collaboration and Aquenal, 2021).

Table 5. List of monitoring parameters including measured at Cowley Creek EE sites.

Parameter	Symbol	Units	Sampling Locations	Sampling* Frequency	Sampling Method
Physico-chemical					
Dissolved Oxygen	DO	mg/L, %	CD1;CC1-6	Monthly	Field probe
pH	pH		CD1;CC1-6	Monthly	Field probe
Electrical Conductivity	EC	uS/cm	CD1;CC1-6	Monthly	Field probe
Temperature		°C	CD1;CC1-6	Monthly	Field probe
Turbidity	Turb	NTU	CD1;CC1-6	Monthly	Field probe
Total Suspended Solids	TSS	mg/L	CD1;CC1-6	Monthly	1 grab sample
Nutrients					
Ammonia - Nitrogen	NH3-N	mg/L	CD1;CC1-6	Monthly	1 grab sample
Oxidised N (Nitrate + Nitrite)	NOx	mg/L	CD1;CC1-6	Monthly	1 grab sample
Total Nitrogen	TN	mg/L	CD1;CC1-6	Monthly	1 grab sample
Filterable Reactive Phosphorous	DRP	mg/L	CD1;CC1-6	Monthly	1 grab sample
Total Phosphorous	TP	mg/L	CD1;CC1-6	Monthly	1 grab sample
Biochemical oxygen demand	BAD	mg/L	CD1;CC1-6	Monthly	1 grab sample
Nitrate – Nitrogen	NO2-N	mg/L	CD1;CC1-6	Monthly	1 grab sample
Nitrite – Nitrogen	NO3-N	mg/L	CD1;CC1-6	Monthly	1 grab sample
Total Kjeldahl Nitrogen	TKN	mg/L	CD1;CC1-6	Monthly	1 grab sample
Algal Growth					
Chlorophyll *a*	Chla	µg/L	CD1;CC1-6	Monthly	1 grab sample
Cyanophyte Enumeration	Cyano	Cells/ml	CD1;CC1-6	Monthly	1 grab sample
Macroinvertebrates					
Signal index	SI		MI-1-MI-2-MI-3	Wet/Dry	AUSRIVAS protocol
Taxa richness	TR	N	MI-1-MI-2-MI-3	Wet/Dry	AUSRIVAS protocol
PET taxa richness	TR-PET	N	MI-1-MI-2-MI-3	Wet/Dry	AUSRIVAS protocol
% sensitive taxa	%ST	%	MI-1-MI-2-MI-3	Wet/Dry	AUSRIVAS protocol
% tolerant taxa	%TT	%	MI-1-MI-2-MI-3	Wet/Dry	AUSRIVAS protocol

*Note that for water quality monitoring, fortnightly sampling occurs in the September – November period when creek flows are expected to be low. Macroinvertebrate sampling occurs bi-annually, with the first monitoring event encompassing dry season conditions, and the second in the wet season.

8.2.2 Analysis of data and comparison against relevant WQOs

For each parameter concentrations were graphically depicted over time for the duration of the EE. Plots were arranged from upstream 'control' locations to downstream 'impact'' locations to allow potential impacts from fish farm discharges to be assessed. A detailed description of the methodology for identifying and selecting relevant environmental values, WQOs and management goals are outlined in Section 3 in the Sealord King Reef Environmental Investigation Scope document (Nautilus Collaboration and Aquenal, 2021). In short, the methodology was developed in accordance with EE requirement 2a.

"2. The investigation scope must a) assess the farm operation against a detailed assessment of environmental values, WQOs and management goals of Cowley Creek (the waters) as specified in Schedule 1 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 "Johnstone River Basin Environmental Values and WQOs, Basin 112".

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019 Schedule 1* mapping outputs available on Queensland Globe, identifies Cowley Creek and Liverpool Creek as "moderately disturbed surface fresh waters (rivers, creeks, streams) in developed areas (e.g. urban, industrial, rural residential, agriculture, farmlands)". The *"Johnstone River Basin Environmental Values and WQOs, Basin 112"* (DES 2020) links ten environmental values relevant to site, which are presented in the Environmental Investigation Scope (Nautilus Collaboration and Aquenal, 2021). The water quality objective adopted in this report, are derived from table 2.1 DES 2020 (see Table 6). These objectives are based on data from reference sites in the Johnstone River Catchment and are developed to protect the aquatic ecosystem environmental values relevant to the catchment.

According to Section 3.2 of DES 2020, for the comparison of test site monitoring data against the WQOs, the median water quality value (e.g. concentration) of a number (preferably five or more) of independent samples at a particular monitoring ('test') site should be compared against the water quality objective of the same indicator, water type and level of aquatic ecosystem protection". "For concentration-based indicators (e.g. nutrients) and turbidity (NTU), the intent is for test site water quality value to be less than or equal to the corresponding water quality objective. For indicators where a range is specified (e.g. pH, DO), the intent is that the test site water quality median value falls within the specified WQOs range" (pp 16 DES 2020).

Analysis in this report focused on (a) comparisons of downstream 'impact' sites with upstream 'control' sites to determine potential impacts from discharge from farm operations; and (b) assessment of the performance of each site against WQOs.

In order to compare longer-term medians across the different sites to the water quality objective, the data was divided up into two groups: Winter 2021 to Autumn 2022 (beginning of monitoring period until June 30th 2022), and Winter 2022-Autumn 2023 (July 1st 2022 until most recent data collection: February 2022). The purpose of this was to avoid seasonal bias in any calculated statistics. Boxplots were constructed that compare median, Q1, Q3 and outliers within each of these time periods against the default approach or match the WQOs (Figure 21 and Figure 22). These plots show median (black line), 25th percentile (bottom of box) and 75th percentile (top of box) of aggregated data.

Table 6. WQOs for moderately disturbed surface fresh waters in developed areas of the Johnstone River Basin under baseflow conditions (adapted from Table 2.1, DES 2020).

Water Quality Indicator	Units	Objectives[%]
Physico-chemical		
Dissolved Oxygen	% Saturation	85–120*
pH		6.0–8.0*
Nutrients		
Ammonia Nitrogen	µg/L	<10[#]
Oxidised Nitrogen	µg/L	<50[#]
Total Nitrogen	µg/L	<340[#]
Filterable Reactive Phosphorous	µg/L	<8[#]
Total Phosphorous	µg/L	<25[#]
Algal Growth		
Chlorophyll *a*	µg/L	<1.5*
Water Clarity		
Turbidity	NTU	<15*
Total Suspended Solids	mg/L	<8[#]

*Queensland Water Quality Guidelines 2009.

[#]Analysis of DSITIA water quality monitoring data and Great Barrier Reef Catchment Loads Monitoring Program.

[%]WQOs shown as 20th, 50th and 80th percentiles (i.e. 3-4-5) or as a single value of median or 80th percentile (i.e. 15). DO and pH may be shown as a range of 20th and 80th percentiles (i.e. 85–105).

8.3 Results

8.3.1 Comparison of upstream (control) and downstream (impact) sites

Each of the three control sites (CD-1, CC-6, CC-1) had low concentrations of nitrogen and phosphorus parameters with some short-lived instances of relatively high NOx, total N, TKN and nitrate that may have been associated with rainfall events (Figure 19 and Figure 25). Concentrations of all nitrogen and phosphorus parameters increased at the monitoring site 85 m below discharge point W1 (CC-2) (Figure 19). Compared to CC-2, nutrient concentrations showed a similar temporal trend but were comparatively lower at sites located further downstream (i.e. CC-3; CC-4; CC-5) indicating the dilution of nutrients as water moves through the system. Impact site CC-2 has also the lowest water depth. There was little evidence of an additive impact downstream of discharge point W2, with nutrient concentrations and physical parameters upstream (CC-4) and downstream (CC-5; C-3) of this point being similar in magnitude.

The monitoring sites further downstream (i.e. CC-3; CC-4; CC-5) showed similar temporal patterns, which showed the following features: (a) an increase in nutrients between October/November and December/January before declining to relatively low concentrations in March/April; and (b) a period of relatively low and stable nutrient concentrations between March/April and October/November (in 2022), which approach or match the WQOs for the Johnson River Catchment. Site CC-2 followed this pattern to some extent for some parameters; for example, ammonia, TKN but by contrast concentrations were both higher and more erratic at this site.

Importantly, the peak in nutrients (i.e. (a), above) in 2022/23 was lower than the peak in 2021/22. This may indicate either (i) an improvement in discharge water quality from due to management interventions (e.g. EcoTabs, see vertical blue line on figures); or (ii) the effect of changes in other environmental conditions in Cowley Creek (e.g. flow, runoff, catchment hydrology).

The box plots (Figure 21 and Figure 22) help to further demonstrate that nutrient concentrations were higher in downstream sites compared to upstream sites and that downstream sites exceeded WQO limits on most occasions. The CD-1 (cane drain) shows poorer water quality compared to other control sites – and exceeded WQO limits for most parameters. There was an improvement in water quality at downstream sites over the 2022-23 timeframe, compared to the 2021-22 timeframe. This includes lower median values in most nutrients, less variation within each site across time, and fewer instances of extreme values (represented by outliers). Long term median data from the box plots shows nutrient contribution from W1 appears to be more significant than W2 in the most recent data. W2 appears to be having a negligible effect on nutrient loads at sites CC-5 and CC-3, which are downstream from both discharge outlets. Box plots indicate that phosphorus is one of the most concerning parameters in the more recent data due to high levels and frequency of phosphorous spikes.

Log-term median data from the box plots shows physico-chemical data parameters improved from 2021-22 to 2022-23. Total suspended solids, turbidity and BOD were all lower in 2022-23, with less variation and outliers. Long-term median data for 2022-23 was below WQO limits for turbidity and TSS at most sites. . Dissolved oxygen was generally lower in discharge water than receiving environment, but this appears to recover quickly to similar levels to control sites in all impact sites. Dissolved oxygen in the whole system (all sites) is below the minimum WQOs. pH appears unaffected by farm discharge and was within the WQO limits.

Patterns of chlorophyll *a* mirrored those described for the suite of nutrients above. Accordingly, chlorophyll *a* concentrations were the lowest at the upstream control sites and the highest at the monitoring site 85m below discharge point W1 (CC-2). Chlorophyll *a* concentration tended to decrease with increasing distance downstream; however, it remained higher at the downstream sites compared to upstream controls. There was a marked increase in chlorophyll *a* concentration in April 2022, with an exceptionally high concentration recorded at the site 85m below discharge point W1 (CC-2). The reason for this spike appears to be linked to high chlorophyll *a* levels in the farm discharge from W1 in April 2022 (Figure 11). Patterns of chlorophyll a concentration were also lower in 2022-23, indicating a potential improvement in water quality.

Differences in physicochemical parameters between upstream and downstream sites were variable. Dissolved oxygen, and pH were of a similar magnitude upstream and downstream of the discharge discharges (Figure 20). Impact site CC-2 has the lowest water depth of all sites (Figure 24), which may be why it generally displays slightly higher water temperature and lower DO, than the other impact sites. Conductivity was higher at the downstream sites. Total suspended solids (TSS) and turbidity collected at the downstream sites were high and erratic in the early monitoring period, but low and stable toward the end of the monitoring period. This pattern is likely a reflection of monitoring in ephemeral conditions where much is influenced by rainfall and dilution in receiving waters.

Downstream sites showed a significantly higher density of cyanophytes than the upstream control sites, where cyanophytes were effectively non-existent (Figure 23). At downstream sites, cyanophytes were most common in the September to March period. There were significantly less cyanophytes in 2022/23 compared to 2021/22. This reduction in cyanophytes is largely due to the loss of potentially toxic cyanophytes from the system after March 2022. Whilst seasonal water levels in Cowley Creek may play some role, this marked decrease in cyanophytes can be attributed to farm management strategies such as additional carbon input and lysine treatment of ponds in addition to SKR introducing cyanophyte slick mitigation in production and bioremediation ponds (Table 10).

8.3.2 Performance against relevant WQOs

As described in greater detail in Section 8.2.2, the data has been divided into two groups: winter 2021 to autumn 2022; and winter 2022 to autumn 2023, in order to compare the longer-term medians across the different sites against the WQOs for moderately disturbed waters in the Johnstone River Catchment presented in

Table 6. The results presented in Figure 19, Figure 20, Figure 21, Figure 22 and Table 7, are summarised below.

The control sites met the WQOs for reactive phosphorus, TSS and turbidity throughout both periods. The water quality objective for total nitrogen was met at two out of three control sites (i.e. CC-6 and CC-1, not CD-1). Control site CD-1, failed to meet the water quality objective for total phosphorus, but was met at CC-6 during the 2022-2023 period and CC-1 over both periods. All control sites, except from CD-1 during the 2022-2023 period, failed to meet the objectives for oxidised nitrogen (NOx).

All impact sites (i.e. CC-2, CC-4, CC-5 and CC-3) failed to meet the objectives for total nitrogen, oxidised nitrogen (NOx), total phosphorus and reactive phosphorus. Impact site CC-2 failed to meet the objective for TSS, but CC-4, CC-5 and CC-3 met the objective over the 2022-2023 period. All impact sites, failed to meet the objective for turbidity over the 2021-2022 period, but met the objective in 2022-2023.

All sites (i.e. control and impact sites), failed to meet the WQOs for ammonia, dissolved oxygen and chlorophyll *a.* For pH the water quality objective was met throughout both periods.

8.4 Summary

The discharge sites W1 and W2 showed negligible impact on downstream sites in the most recent data, a considerable improvement from 2021-2022 (Figure 19 and Figure 20); however, observed patterns for nutrients, biological and physico-chemical parameters between control and impact sites with increasing distance downstream of the discharge points reflect a clear and persistent initial impact of emissions from the farm, particularly at the sites closest to the discharge points.

With increasing distance downstream, dilution of emissions was apparent, but nutrient concentrations at sites further downstream generally remained higher than those at the upstream sites. For some nutrients, periods of high concentrations were observed between December and March. During this peak period, nutrient concentrations in 2022/23 were lower than during the corresponding period in 2021/22. Cyanophytes – particularly potentially toxic cyanophytes, decreased across the monitoring period at sites downstream from the discharge points, particularly W2. The notable improvements to the water quality from W2 in comparison to W1 (less management action taken) indicate that the management actions SKR applied for the duration of the EE (and continuing) have been useful in improving the discharge water quality from W2. These on-farm water quality management strategies which are discussed in more detail in Section 10 may have also contributed to these recent improvements in water quality in Cowley Creek, but it is difficult to partition the magnitude of seasonal vs management effects with only 17 months of data.

With the exception of turbidity and total suspended solids the spatial-temporal graphs in Figure 19 and Figure 20 indicate the WQOs level for most parameters have been regularly exceeded over the lifetime of the EE; however, the WQOs for some parameters also exceeded at the upstream control sites.

The control sites failed to meet the WQOs on numerous occasions for ammonia, total nitrogen, dissolved oxygen, and chlorophyll a. These upstream sites are reference sites for water quality under the REMP for SKR and the best available sites for the purpose of providing a reference for water quality upstream and uninfluenced by SKR. Given all the upstream sites do not meet the WQOs then it can be argued that they are likely not the correct appropriate WQOs for the Johnston River Basin catchment

Cowley Creek System. Therefore, regardless of farm emissions Cowley Creek is already impacted and will not be able to achieve the designated WQOs.

Given that QWDG states application of most objectives are inappropriate during times of low/no-flows and given that QLD Globe mapping (MSES regulated vegetation, defined water course mapping layer) identifies Cowley Creek as a non-perennial watercourse then it is also questionable that WQOs should apply for this ephemeral system.

Potential impacts from surrounding land use in the vicinity of the SKR farm are also likely to be affecting water quality patterns. Variation in river physico-chemical and nutrient parameters downstream of the discharge cannot be solely attributable to the fish farm given that some parameters downstream were higher for the impact sites than the discharge (e.g. Total N and nitrate). It is likely the relatively high nutrient levels at mid and far field sites downstream of the discharge points are also being impacted from other inputs such as agriculture which is prevalent in the area (Figure 18).

There are a number of influences upstream and downstream that suggest agricultural runoff may be influencing this catchment. Cowley Creek downstream far-field sites have high water temperatures. Because water temperature affects all chemical and biological processes for example the solubility of oxygen decreases with increasing temperature, and so concentrations are usually lower in summer which is a pattern that is demonstrated in control and impact sites where temperature and DO % sat are inverse (Figure 20). Prolonged exposure to low, nonlethal levels of DO constitutes a stress to the system which can be seen as far away from the farm as 2.25km (CC-3) where farm influence based on the data is unlikely to be of a degree to have any impact. Towards the end of the sampling timeframe of the EE there is a rise in total phosphorous from June 2022 to October 2022 in the far field impact sites (CC 2 and CC 3) conductivity of Cowley Creek at this distance also increases. This steadily rising electrical conductivity can indicate that pollution has entered the river. Agricultural runoff or a sewage leak will increase conductivity due to the additional chloride, phosphate, and nitrate ions. An addition of other organic compounds would decrease conductivity as these elements do not break down into ions. The additional dissolved solids will have a negative impact on water quality. While there is a plateauing out of most nutrients since initial sampling in October 2021, there is still occasional spikes e.g. ammonia at CC5 and total phosphorous at CC 3 which may be indicative of agricultural run-off, especially the presence of P and Total N which suggests fertiliser application of surrounding land (Figure 19).



Figure 18. Map of Sealord King Reef and surrounding matrix of agricultural use. To the upper west of Cowley Creek there is cattle farming the rest of the surrounds include cane and banana plantations

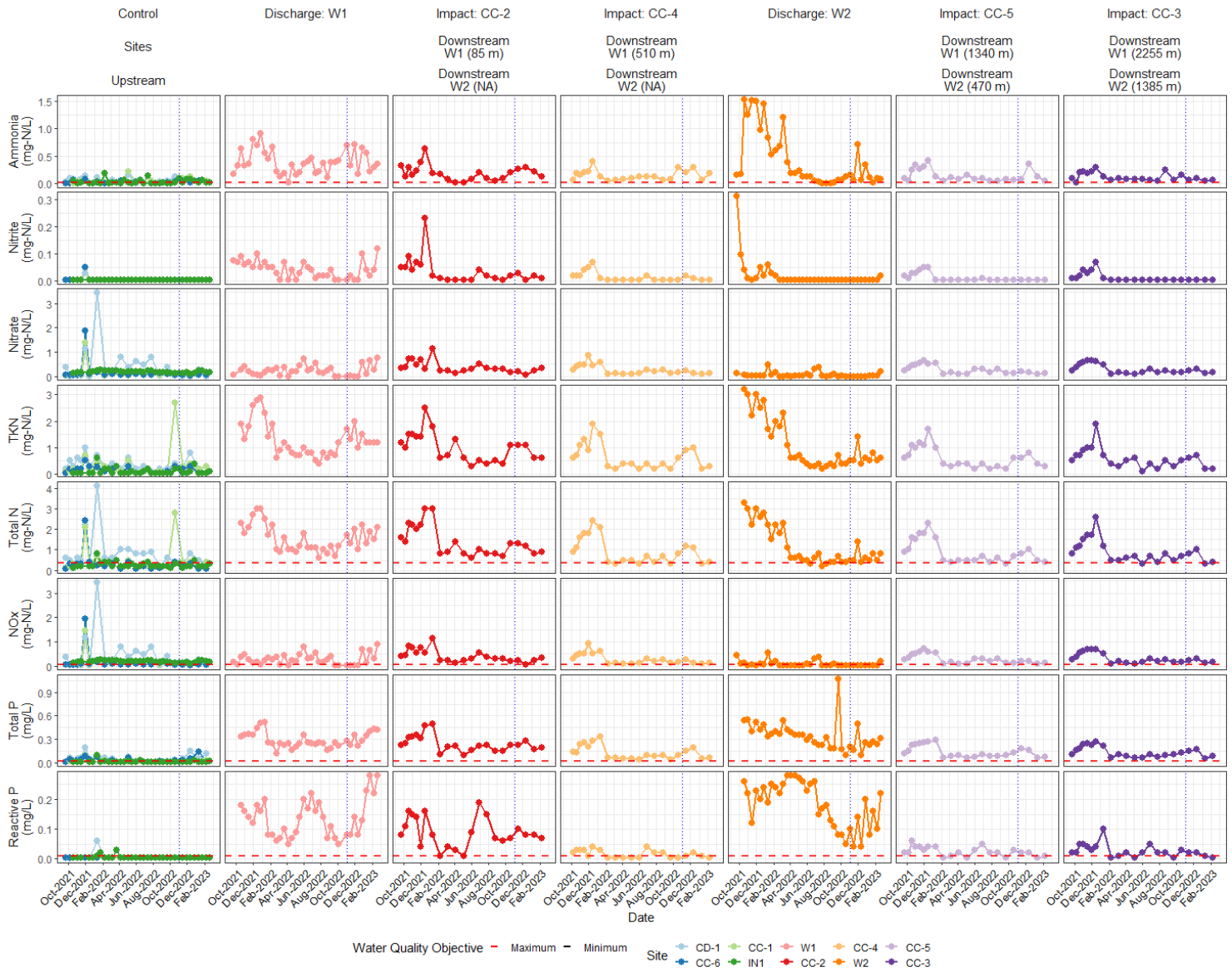


Figure 19. Monthly observations of ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total Kjeldahl nitrogen - TKN (mg/L), total nitrogen (mg/L), oxidised nitrogen (NOx) (mg/L), total phosphorus (mg/L) and reactive phosphorus (mg/L) measured at control sites (CD-1, CC-6, CC-1, IN1), discharge sites (W1, W2) and impact sites (CC-2, CC-4, CC-5 and CC-3). Downstream sites are in order (left to right) of distance from W1 and W2 outfalls. Water quality objectives (Table 6) are shown as horizontal dashed lines. The vertical blue dotted line (blue) indicates the commencement of the Eco Tabs ™ trial.



Figure 20. Monthly observations of water temperature (°C), dissolved oxygen (% sat level), dissolved oxygen (mg/L), pH, conductivity (mS/cm), total suspended solids – TSS (mg/L), turbidity (NTU), chlorophyll α (mg/m^3) and BOD (mg/L) measured at control sites (CD-1, CC-6, CC-1, IN1), discharge sites (W1, W2) and impact sites (CC-2, CC-4, CC-5 and CC-3). Downstream sites are in order (left to right) of distance from W1 and W2 outfalls. Water quality objectives (Table 6) are shown as horizontal dashed lines. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

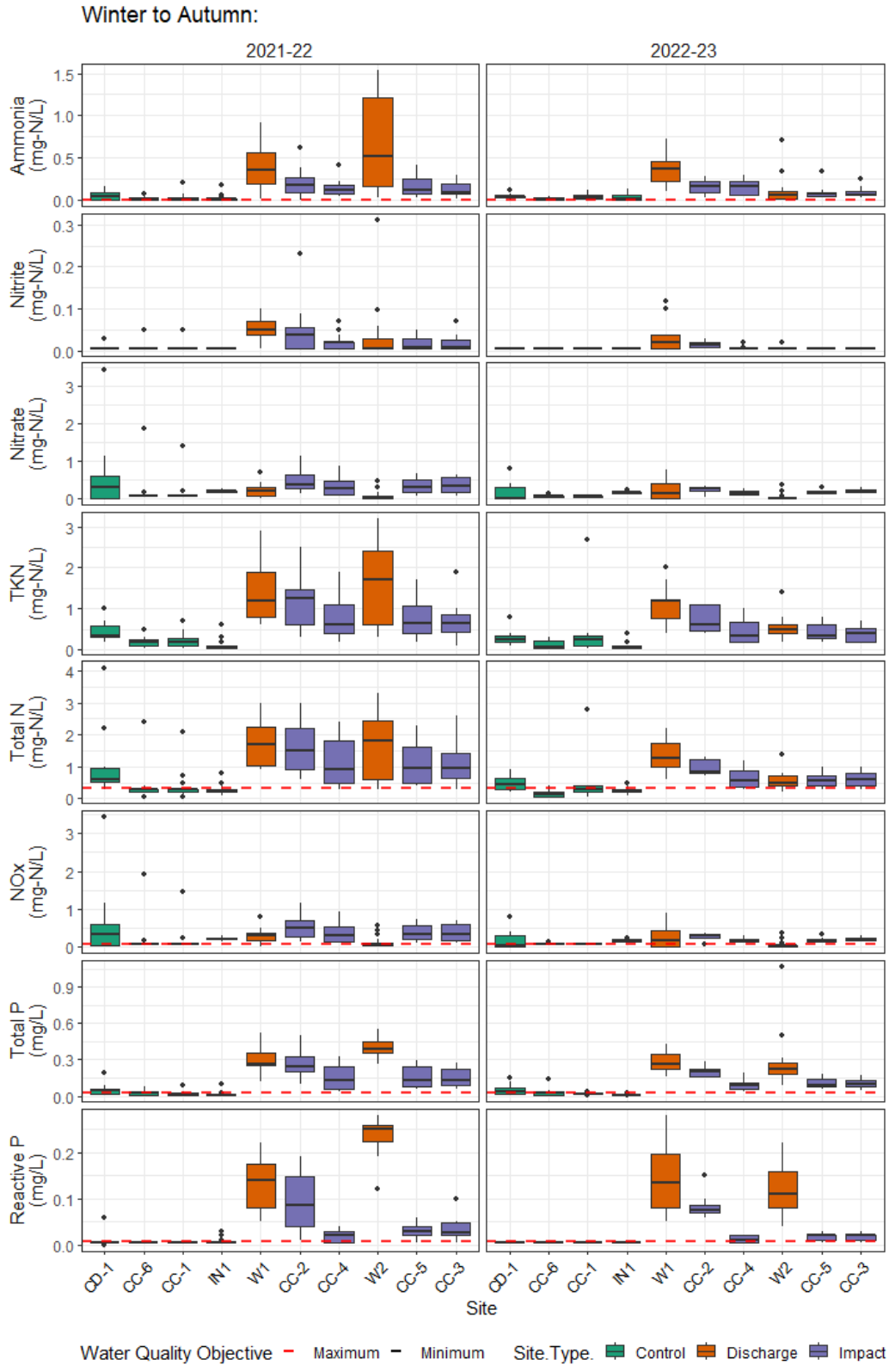


Figure 21. Boxplots representing aggregate water quality data (Winter 2021 to Autumn 2022, and Winter 2022 to Autumn 2023) for ammonia (mg/L), nitrite (mg/L), nitrate (mg/L), total Kjeldahl nitrogen - TKN (mg/L), total nitrogen (mg/L), oxidised nitrogen (NOx) (mg/L), total phosphorus (mg/L) and reactive phosphorus (mg/L) measured at control sites (CD-1, CC-6, CC-1, IN1), discharge sites (W1, W2) and impact sites (CC-2, CC-4, CC-5 and CC-3). WQOs (Table 6) are shown as horizontal dashed lines.

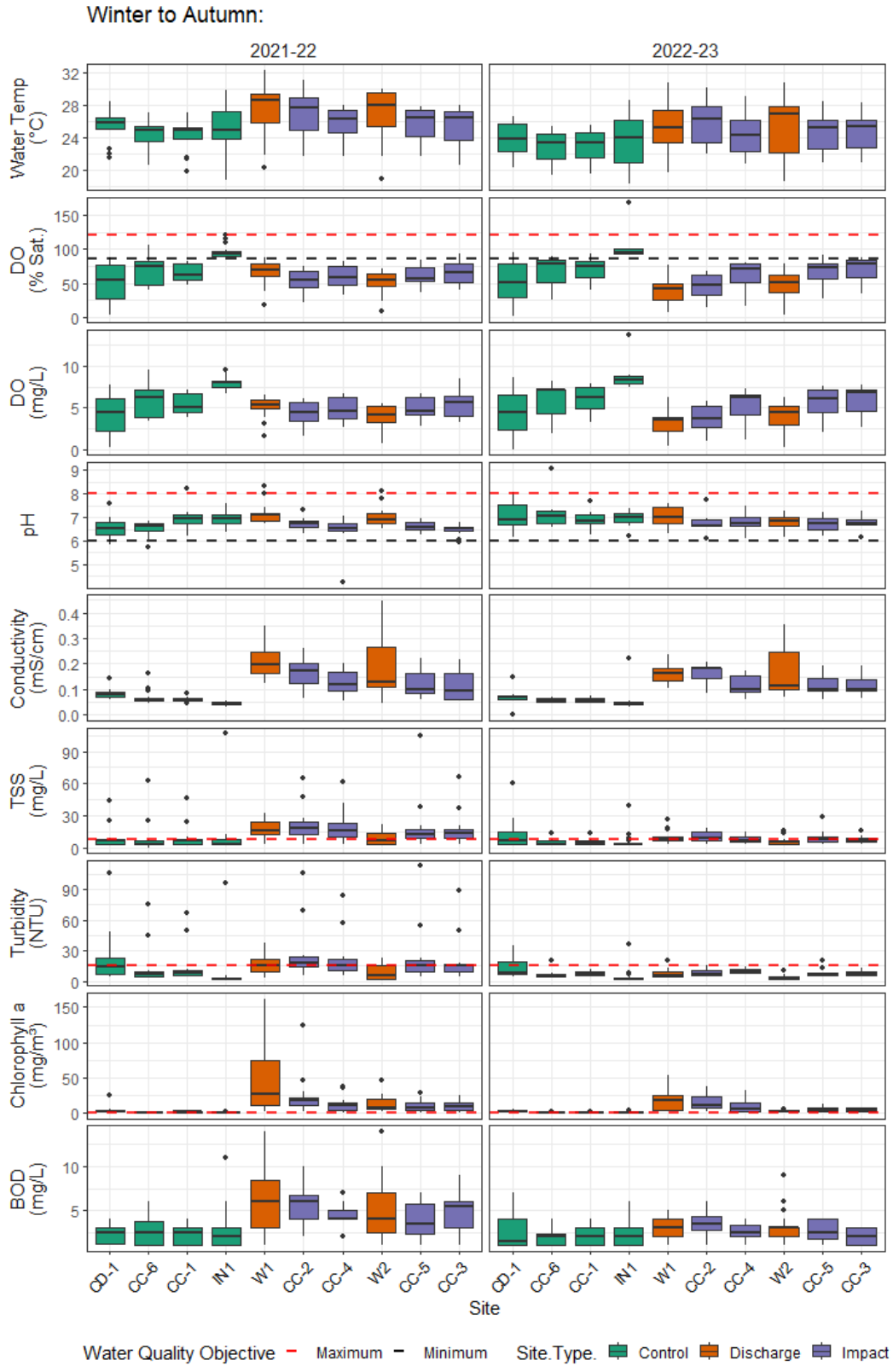


Figure 22. Boxplots representing aggregate water quality data (Winter 2021 to Autumn 2022, and Winter 2022 to Autumn 2023) for water temperature (°C), dissolved oxygen (% sat level), dissolved oxygen (mg/L), pH, conductivity (mS/cm), total suspended solids – TSS (mg/L), turbidity (NTU), chlorophyll α (mg/m^3) and BOD (mg/L) measured at control sites (CD-1, CC-6, CC-1, IN1), discharge sites (W1, W2) and impact sites (CC-2, CC-4, CC-5 and CC-3). WQOs (Table 6) are shown as horizontal dashed lines.

Table 7. Median value of all measured water quality parameters (aggregated into two groups: Winter 2021 to Autumn 2022, and Winter 2022 to Autumn 2023) measured at control sites (CD-1, CC-6, CC-1, IN1) and impact sites (CC-2, CC-4, CC-5 and CC-3). Values highlighted in red are in exceedance of the water quality objective for the respective parameter, whilst values highlighted in green are within compliance of the water quality objective for the respective parameter. Values highlighted in amber are right on the limit of the respective water quality objective.

				Control						Impact							
				CD-1		CC-6		CC-1		CC-2		CC-4		CC-5		CC-3	
Analyte	**Unit**	**WQO (20th %ile)**	**WQO (80th %ile)**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
Ammonia	**mg-N/L**	**0**	**0.01**	0.050	0.045	0.020	0.020	0.025	0.040	0.175	0.160	0.120	0.160	0.115	0.070	0.095	0.060
Nitrite	**mg-N/L**	**N/A**	**N/A**	0.005	0.005	0.005	0.005	0.005	0.005	0.040	0.015	0.020	0.005	0.010	0.005	0.010	0.005
Nitrate	**mg-N/L**	**N/A**	**N/A**	0.310	0.015	0.070	0.060	0.070	0.060	0.365	0.260	0.270	0.140	0.310	0.160	0.335	0.170
TKN	**mg-N/L**	**N/A**	**N/A**	0.350	0.250	0.200	0.075	0.200	0.250	1.250	0.600	0.600	0.350	0.650	0.350	0.650	0.400
Total N	**mg-N/L**	**0**	**0.34**	0.600	0.450	0.275	0.150	0.300	0.300	1.500	0.850	0.900	0.550	0.950	0.550	0.950	0.600
NOx	**mg-N/L**	**0**	**0.05**	0.310	0.015	0.070	0.060	0.070	0.060	0.490	0.275	0.290	0.140	0.320	0.160	0.340	0.170
Total P	**mg-P/L**	**0**	**0.025**	0.050	0.040	0.030	0.025	0.020	0.020	0.240	0.205	0.130	0.085	0.135	0.090	0.135	0.100
Reactive P	**mg-P/L**	**0**	**0.008**	0.005	0.005	0.005	0.005	0.005	0.005	0.085	0.075	0.020	0.010	0.030	0.020	0.025	0.020
Temperature	**°C**	**N/A**	**N/A**	25.9	23.8	24.9	23.4	24.9	23.3	27.6	26.2	26.3	24.3	26.4	25.2	26.5	25.3
Dissolved O_2	**% Sat.**	**85**	**120**	54.25	50.20	75.05	79.00	61.55	75.10	53.90	47.90	57.90	70.90	57.15	72.60	65.80	77.90
Dissolved O_2	**mg-N/L**	**N/A**	**N/A**	4.42	4.54	6.20	7.07	5.08	6.18	4.52	3.74	4.67	6.32	4.68	6.10	5.63	6.82
pH	**-**	**6**	**8**	6.56	6.92	6.62	7.08	6.95	6.83	6.76	6.64	6.52	6.73	6.59	6.75	6.56	6.75
Conductivity	**mS/cm**	**N/A**	**N/A**	0.078	0.070	0.061	0.056	0.063	0.057	0.172	0.183	0.117	0.100	0.101	0.100	0.096	0.102
TSS	**mg/L**	**0**	**8**	7.0	7.0	2.5	2.5	6.0	4.3	18.5	8.5	16.0	6.0	12.5	8.0	14.0	6.0
Turbidity	**NTU**	**0**	**15**	14.3	8.2	7.0	5.7	7.9	7.4	18.0	6.9	16.2	10.0	15.1	6.6	15.4	7.5
Chlorophyll *a*	**mg/m³**	**0**	**0.002**	2.0	2.0	0.5	0.5	1.0	0.5	18.5	11.0	11.0	4.5	7.5	4.0	9.0	4.0
BOD	**mg/L**	**N/A**	**N/A**	2.5	1.5	2.5	2.0	2.5	2.0	6.0	3.5	4.0	2.5	3.5	2.5	5.5	2.0

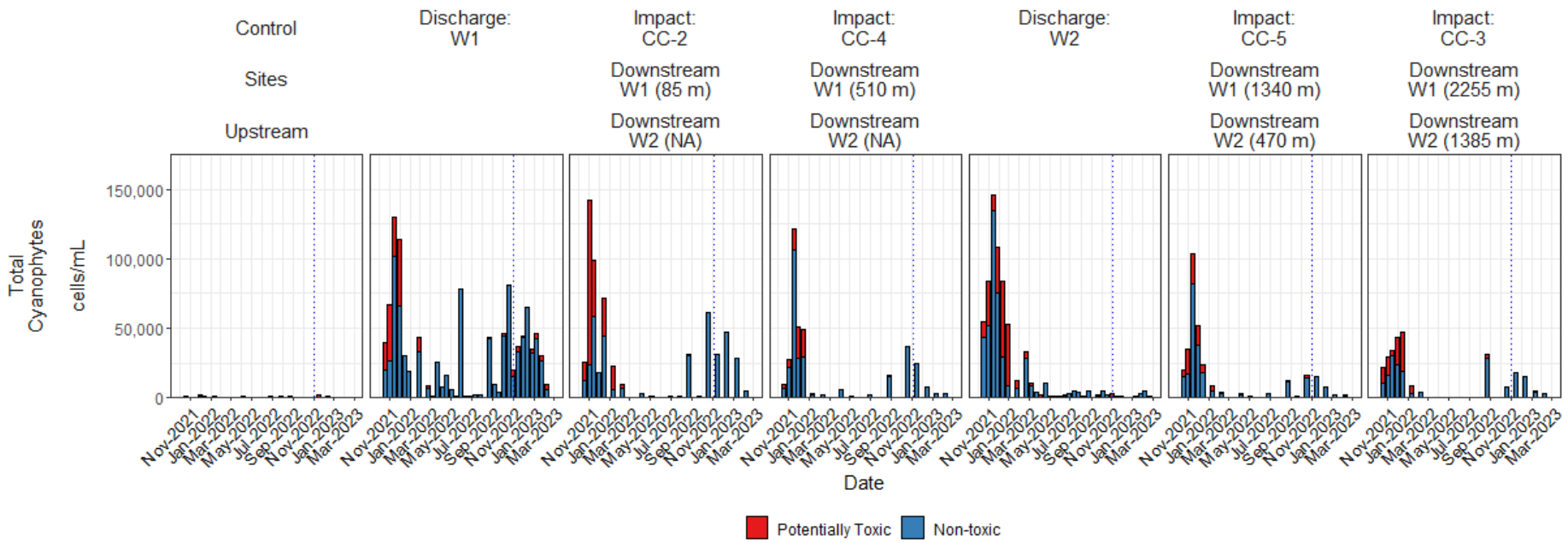


Figure 23. Total cyanophytes (cells/mL) classified into "Potentially toxic" and "Non-toxic" taxa at control sites (CD-1, CC-6, CC-1, IN1), discharge sites (W1, W2) and impact sites (CC-2, CC-4, CC-5 and CC-3). Downstream sites are in order (left to right) of distance from W1 and W2 outfalls. The vertical dotted line (blue) indicates the commencement of the Eco Tabs™ trial.

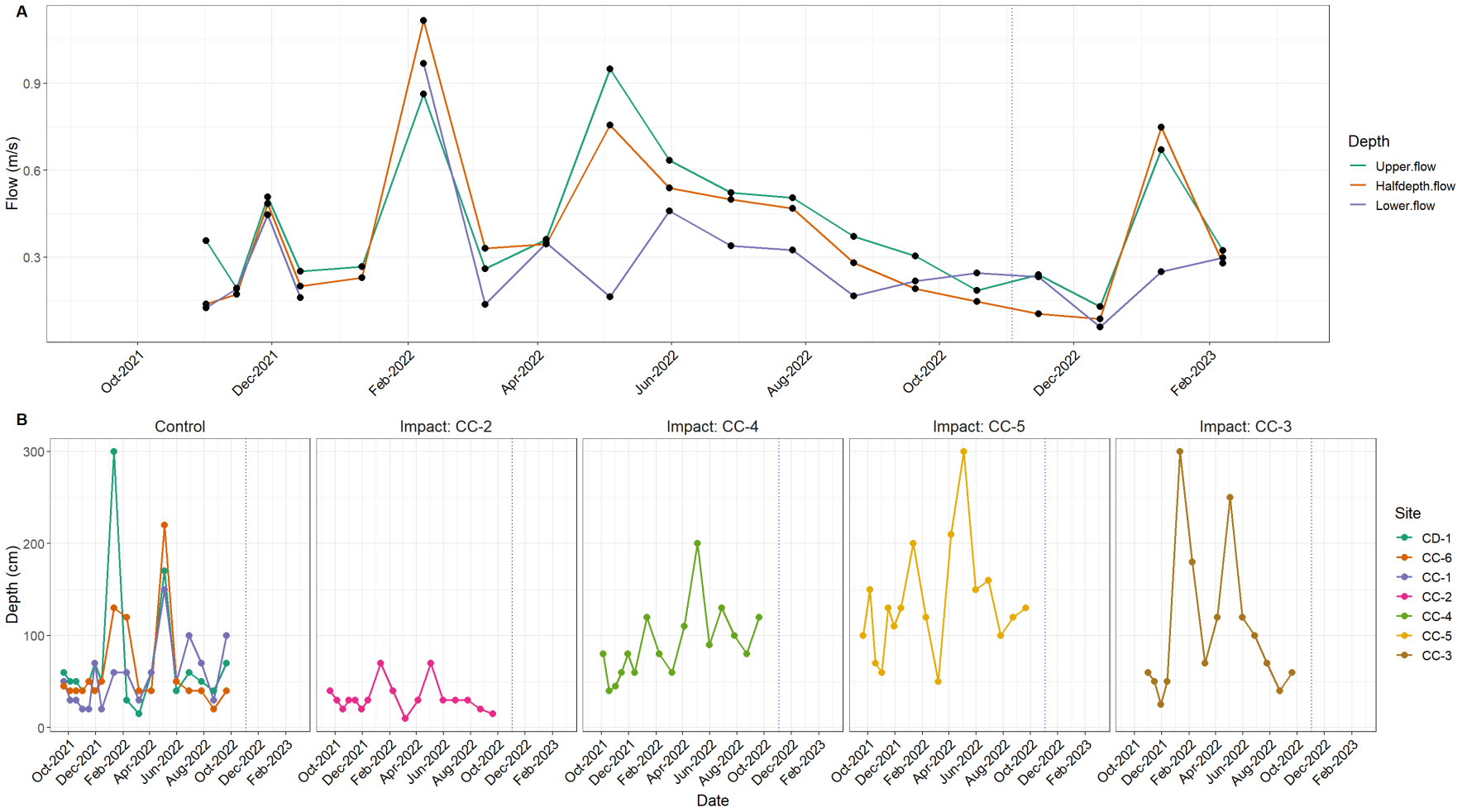


Figure 24. (A) Stream flow (metres/second) measured at CC-3 control site at upper, half-depth and lower portion of water column at Cowley Creek Site 3 (CC-3) with Swoffer handheld flowmeter. Datapoint missing in lower flow section is due to high water level. Telescopic flow meter wand was not long enough to reach lower depth from bridge access point; and (B) Depth (cm) measured at each EE site. The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial. Due to operational factors, depth was not recorded between October 2022-Feb 2023. This has been rectified and this data will be collected in the ongoing monitoring program.

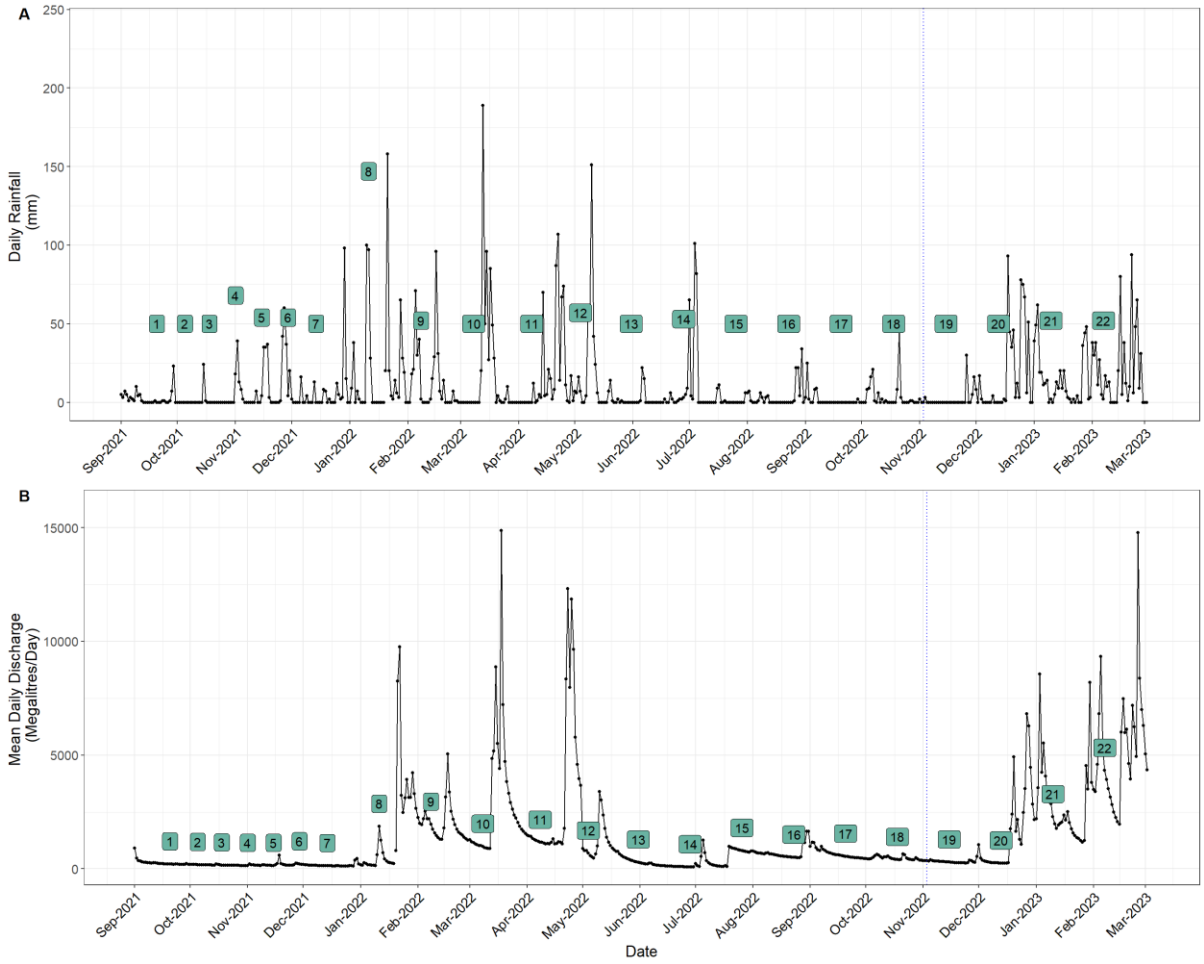


Figure 25. (A) Total daily rainfall and (B) mean daily discharge of Liverpool Creek (at Silkwood: station no. 112103B), located 5.5km upstream from SKR intake. Numbered labels denote EE site sampling iterations. Data from Queensland Government Water Monitoring Information Portal: (https://water-monitoring.information.qld.gov.au/). The vertical blue dotted line (blue) indicates the commencement of the EcoTabs™ trial.

9 Macroinvertebrates in the Receiving Environment (Cowley Creek)

9.1 Methods

9.1.1 Field and laboratory

Field and laboratory methodologies were based on the AUSRIVAS protocols outlined in detail in the water quality guidelines documentation (DNRM 2001) and the investigation scope (Nautilus 2021). Local macroinvertebrate specialists C&R Consulting were engaged to undertake the macroinvertebrate sampling and taxonomic identification.

To date, two sampling events have been undertaken in Cowley Creek: one in October 2021 during the dry season and one in June 2022 at the end of an unusually long wet season. Wet season samples are traditionally sampled in the January-April period, but an exceptionally long 2022 wet season characterised by heavy rainfalls and a series of large flow events in Cowley Creek precluded sampling during these months. The June 2022 sample was collected after a particularly large flow event lasting approximately five weeks.

Sampling was undertaken at one upstream site (MI1) and two downstream sites (MI2 below discharge point W1; MI-3 below discharge point W2) (Figure 16). The location for MI3 was initially proposed to be co-located with CC-3. However, safety concerns prohibited macroinvertebrate sampling at this site (detailed in Appendix 1). An alternative location for MI3 was established at a safer location upstream and will be used in future sampling events (Appendix 1: Figure 29).

Bed/riffle habitats were sampled according to standardised field protocols (DNRM 2001). Edge habitats were not sampled due to insufficient edge habitat at each monitoring site during the dry season October 2021 sampling event (Appendix 2). To maintain consistency and allow comparison across sampling rounds only bed habitats were sampled during the subsequent June 2022 wet season sampling event (see Appendix 3).

Samples for macroinvertebrate objectives were identified in the laboratory to family level, except Chironomidae (non-biting midges) that were identified to sub-family, and lower Phyla (Porifera, Nematoda, Nemertea, etc.), Oligochaeta (freshwater worms), Acarina (mites), and microcrustacea (Ostracoda, Copepoda, Cladocera) that were not identified further. The taxonomy used to calculate macroinvertebrate indices were based on those used in SIGNAL version 2.iv (Chessman 2003, available at www.environment.gov.au). Raw data from the macroinvertebrate surveys is included in Appendix 2 and Appendix 3.

9.1.2 Analysis

Analysis of macroinvertebrate communities in Cowley Creek focused on five macroinvertebrate indices, including:

(1) Taxa richness is the number of different aquatic macroinvertebrate taxa collected in a sample.
(2) PET taxa richness is the number of aquatic macroinvertebrate families collected from three orders of aquatic insects; Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). These orders are considered to be sensitive to changes in their environment and therefore useful indicators to assess stream condition
(3) SIGNAL index (Stream Invertebrate Grade Number – Average Level) was developed for the bioassessment of water quality in rivers in Australia. A SIGNAL score is calculated by grading each detected macroinvertebrate family based upon its sensitivity to pollutants from 1

(tolerant) to 10 (sensitive) and averaging the grades. These guidelines used SIGNAL version 2.iv

(4) % sensitive taxa in an index based on the proportion of taxa with 'sensitive' SIGNAL grades of 8-10 (SIGNAL version 2.iv)

(5) % tolerant taxa in an index based on the proportion of taxa with 'tolerant' SIGNAL grades of 1-3 (SIGNAL version 2.iv)

Locally derived WQOs for these five freshwater macroinvertebrate indices are listed in Table 8. These objectives were based on reference sites in the Johnstone River Catchment in which Cowley Creek is situated.

Analysis focused on (a) comparisons of downstream 'impact' sites with upstream 'control' sites to determine potential impacts from discharge from farm operations; and (b) assessment of the performance of each site against macroinvertebrate WQOs.

Analysis of changes in macroinvertebrate indices between October 2021 and June 2022 were not included due to the overarching effects of seasonality on macroinvertebrate communities.

9.2 Results

9.2.1 Comparison of upstream (control) and downstream (impact) sites

In October 2021, mean taxonomic richness increased with increasing distance downstream with the control site (MI1) having a lower mean taxonomic richness than the two impact sites (MI2,MI3; Figure 26). In June 2022, mean taxonomic richness was relatively stable with distance downstream (Figure 26), with the control site (MI1) having an equivalent (MI2) or higher (MI3) taxonomic richness to impact sites (Figure 26). For the taxonomic richness metric, higher values are associated with better stream condition (see grey box in Figure 26). As such, this metric implies that the control sites had a poorer stream condition than impact sites in October 2021 and equivalent stream condition to impact sites in June 2022 (Figure 26).

In both October 2021 and June 2022, the mean values for PET richness, signal index and percent sensitive taxa at the control site (MI1) were consistently higher than those recorded at downstream sites (MI2, MI3; Figure 26). Differences between control sites and impact sites were most pronounced for signal index and percent sensitive taxa in June 2022 and least pronounced for PET richness in October 2021. For these three metrics, higher values are associated with better stream condition (see grey box in Figure 26). As such, these metrics imply that the control sites were in better condition than impact sites in both sampling events (Figure 26).

In both October 2021 and June 2022, the mean value for percent tolerant taxa was lower at the control site compared to the impact sites (MI2, MI3; Figure 26). For the percent tolerant taxa metric, lower values are associated with better stream condition (see grey box in Figure 26). As such, this metric implies that the control sites had a better stream condition than impact sites in both sampling events (Figure 26).

9.2.2 Performance against macroinvertebrate WQOs

The mean values across three replicates sampled at each site (Table 9; Figure 26) were used to test performance against macroinvertebrate WQOs for moderately disturbed waters in the Johnstone River Catchment (Table 8).

In October 2021, the upstream control site met the objectives for taxonomic richness and percent tolerant taxa (Table 9; Figure 26). In June 2022, the upstream control site met the objectives for signal

index, percent tolerant taxa and percent sensitive taxa (Table 9; Figure 26). The downstream sites only met the WQOs for taxonomic richness in October 2021 (Table 9; Figure 26). Downstream sites failed to meet the WQOs for all other metrics in both survey events (Table 9; Figure 26).

The failure of the upstream control site to meet selected WQOs suggests that macroinvertebrate communities at the upstream site are showing the effects of reduced water quality, most likely derived from intensive agricultural and horticultural activities operating within the catchment. The reduction in water quality from these activities would also have an impact on the macroinvertebrate communities at the downstream sites. However, the results also suggest and additional impact from discharge from fish farm operations in both sampling events with downstream sites not meeting most objectives and tending to be further away from the water quality objective range for all indices except taxonomic richness (Figure 26).

9.3 Summary

Analysis of macroinvertebrate communities at the upstream control site showed that some metrics failed to meet WQOs in October 2021 and June 2022. This suggests that the water quality of Cowley Creek both upstream and downstream of the fish farm outfall is affected by the impacts of agricultural and horticultural activities in the upper catchment.

Apart from taxonomic richness, metrics at downstream impact sites indicated (a) poorer stream condition compared to the upstream control site and (b) failed to meet WQOs. In general, there were a higher number of pollution tolerant taxa and a lower number of pollution sensitive taxa at the downstream sites compared to the upstream site. This suggests an impact on macroinvertebrate communities and stream condition from fish farm discharges into Cowley Creek that is additional to impacts from agricultural and horticultural activities in the upper catchment.

These patterns were evident in both survey events but were most pronounced in the June 2022 where differences in several metrics between the upstream control site and downstream impact sites were greater. The June 2022 sampling event occurred five weeks after a period of high rainfall and a series of large flow events, with field observations of bank scouring. When systems are impacted by high flows, it can take up to six weeks for macroinvertebrate communities to recolonise the reaches (DNRM, 2001). The potential impact of high flow events on the June 2022 survey event should be considered when interpreting results.

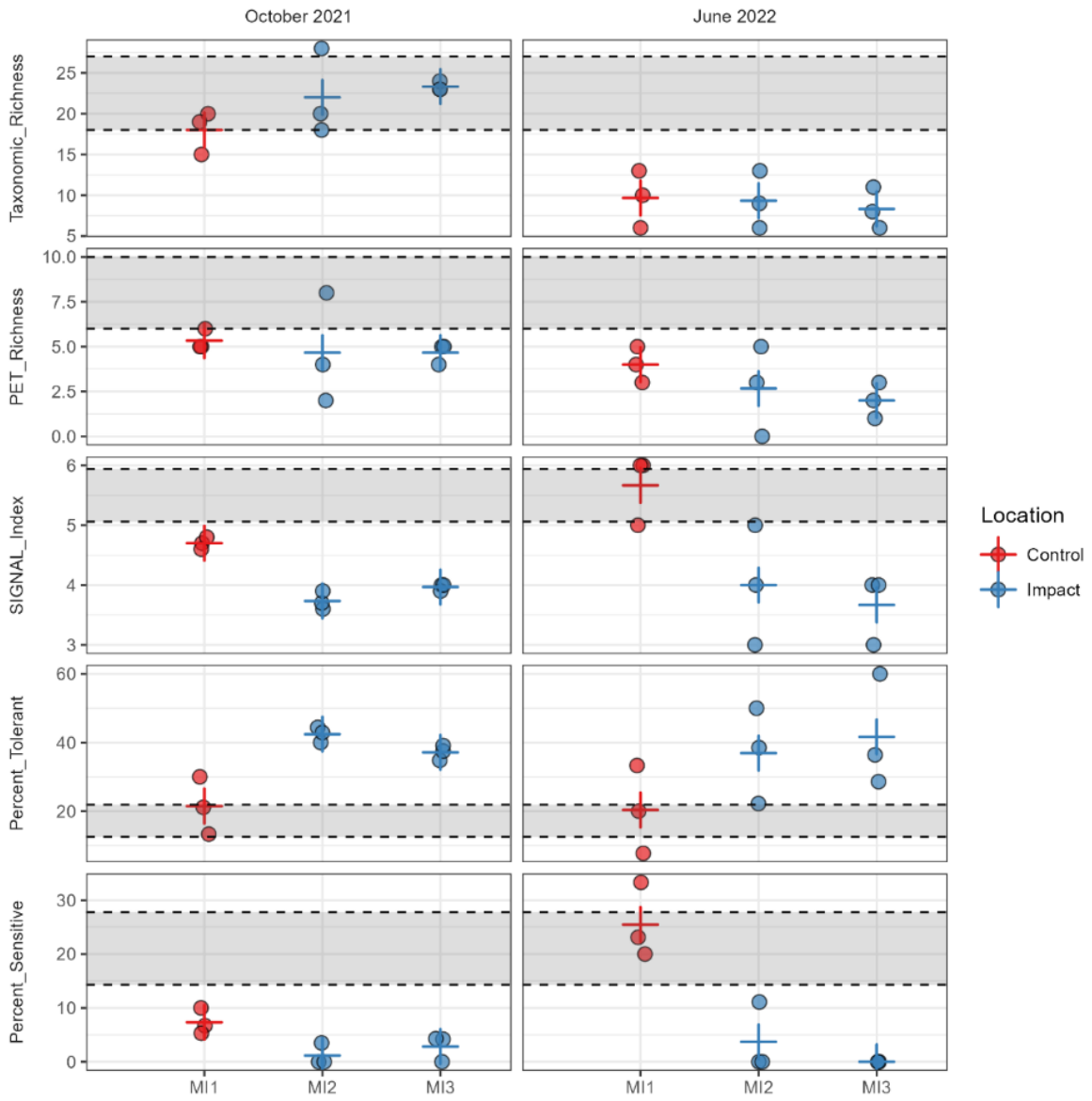


Figure 26. Replicate values (dots) and mean values (crosshairs) for five macroinvertebrate indices (see text for details) calculated for three replicates sampled in October 2021 (dry season) and June 2022 (wet season) from bed habitat at three sites on Cowley Creek: MI1 (upstream W1), MI2 (downstream W1) and MI3 (downstream W1 and W2). Lower (20th percentile) and upper (80th percentile) limits for macroinvertebrate WQOs for moderately disturbed waters of the Johnstone River Basin (Table 8) are indicated with dashed lines.

Table 8. Freshwater macroinvertebrate WQOs (WQO) for moderately (MD) disturbed waters of the Johnstone River Basin.

Site	Riffle/Bed Habitat	
	20th percentile	80th percentile
Taxa Richness	18	27
PET Richness	6	10
SIGNAL Index	5.06	5.94
% Tolerant Taxa	12.50	21.88
% Sensitive Taxa	14.29	27.78

Table 9. Performance of the mean score from three replicates at each site for five macroinvertebrate indices against the freshwater macroinvertebrate WQOs (WQO) for samples taken in October 2021 (dry season) and June 2022 (wet season). WQOs are based upon moderately disturbed waters of the Johnstone River Basin (see Table 8. Freshwater macroinvertebrate WQOs (WQO) for moderately (MD) disturbed waters of the Johnstone River Basin.Table 8). Raw data for each replicate is presented in Figure 26. Green = Within WQO. Red = Outside WQO.

Date Sampled	Metric	WQO Bed/Riffle	Mean value across replicates			Within WQO? (Y/N)		
			MI1	MI2	MI3	MI1	MI2	MI3
			Upstream	Downstream W1	Downstream W1+W2	Upstream	Downstream W1	Downstream W1+W2
October 2021	Taxa Richness	18-27	18	22	23.3	Y	Y	Y
October 2021	PET Richness	6-10	5.3	4.7	4.7	N	N	N
October 2021	SIGNAL Index	5.06-5.94	4.7	3.7	3.9	N	N	N
October 2021	% Tolerant	12.50-21.88	21.3	42.3	37.0	Y	N	N
October 2021	% Sensitive	14.29-27.78	7.3	1.2	2.8	N	N	N
June 2022	Taxa Richness	18-27	9.6	9.3	8.3	N	N	N
June 2022	PET Richness	6-10	4.0	2.7	2.0	N	N	N
June 2022	SIGNAL Index	5.06-5.94	5.6	4.0	3.7	Y	N	N
June 2022	% Tolerant	12.50-21.88	20.3	36.9	41.7	Y	N	N
June 2022	% Sensitive	14.29-27.78	25.5	3.7	0.0	Y	N	N

10 Recommendations and Implementation Program

10.1 On-farm Management Improvements

The on-farm improvements implemented in the past 17-months are presented in Table 10. The strategies implemented in the first 12 months, are on-going.

Table 10 Management improvements that have been implemented on site, in the last 17-months.

Implemented Improvement Strategies	Goal	Location on farm	Timeframe
Vaccination trial	Reduce mortalities	All fish stocked on farm since implemented in June 2022	**Implemented in the first 12 months**
Preventative fish health measures	Reduce mortalities	Production ponds	
Spray hydrogen peroxide on slicks	Manage Microcystis	Production ponds, drains and remediation systems	
Azolla harvesting	Reduce nutrient loads		
Feed management	Reduce nutrient loads	Production ponds	
Dosing of Lysine	Manage *Microcystis*		
Dosing of Molasses	Increase bacterial floc		
Reduction of maximum pond biomass from 80T to 60T	Manage nutrient loads	Production ponds	
Duckweed suckers/Azola suckers	Reduce nutrient loads	Bioremediation system 1 and 2 (SP-1 and SP-2)	**Implemented/trialled in the last 5 months**
Paddle wheels	Improve oxygen levels	Bioremediation system 1 and 2 (SP-1 and SP-2 in)	
Remove sludge	Increase retention time and decrease leakage from sediments	Bioremediation system 1 (ZZ-1)	
Dosing of EcoTabs™	Decrease sediments and nutrient loads and increase oxygen levels	Bioremediation system 2 (SP-2 and BP-2)	

10.1.1 Earthworks

Earthworks to remove sludge from zig zag (ZZ-1) in bioremediation system 1, commenced in October/November 2022, but has only recently been completed due to persistent rainfalls during the dry season. The zig zag has been bypassed during this period but is due to be put back in use in March 2023. consequently, it is too early to draw any conclusions on whether this strategy has been effective or not.

10.1.2 Eco-Tab Trial

A new probiotic (Eco Tabs™) has been trialled since 3rd of November 2022 in bioremediation system 2 (SP-2 and BP-2). Based on the volume and retention time of the ponds, a high initial dosage of Eco Tabs™ were applied to kickstart the process. Water samples were collected, and the dosage adjusted. The target readings for the trial, were set to: 1.2625 mg/L total nitrogen and 0.237 mg/L total phosphorus at the discharge of bioremediation pond BP-2.

Eco Tabs™ contains a blend of specifically selected strains of bacteria that are both sludge reducing and capable of fixating nitrogen (i.e. *Bacillus* strains). The sodium percarbonate compound in the

product, is in a granulated form of hydrogen peroxide, which during enzymatic breakdown forms oxygen. The expected outcome, by applying Eco Tabs™ to bioremediation system 2, was to:

- reduce sludge;
- increase oxygen levels;
- decrease nitrogen and phosphorus levels discharged from point W2, and
- minimise impact on the receiving environment (Cowley Creek)

The targeted readings for total nitrogen and total phosphorus set for the trial was achieved, despite high feed input and biomass during this period (Figure 27).

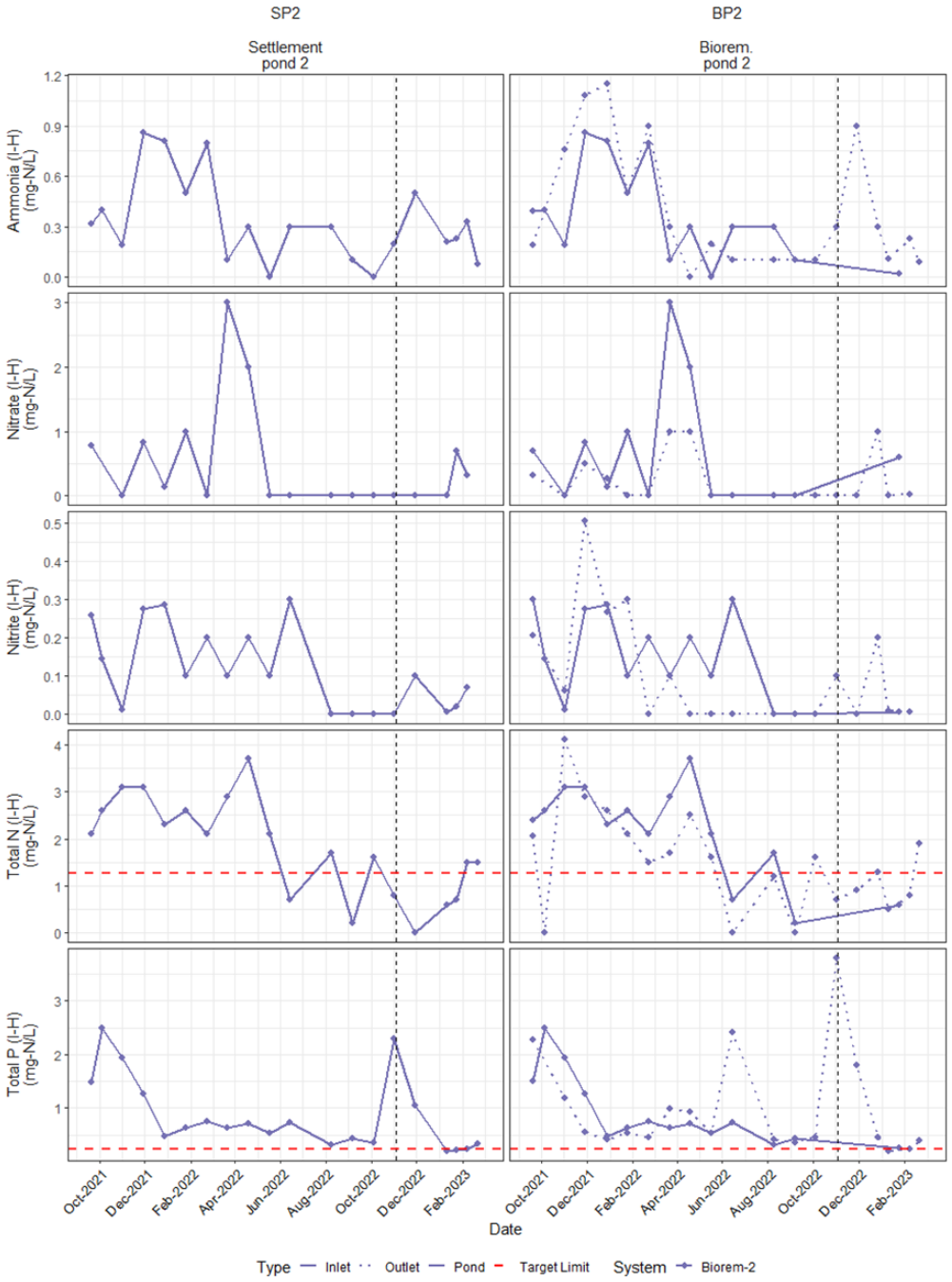


Figure 27. Fortnightly in-house (I-H) observations of ammonia (mg/L), nitrate (mg/L), nitrite (mg/L), total nitrogen (mg/L) and total phosphorus (mg/L) at settlement pond SP-2 and bioremediation pond BP-2 in bioremediation system 2 (purple).

10.2 On-farm recommendations and implementation program

As the previous sections have highlighted and EE requirement 7d entail, further actions are required to:

- comply with EA water quality and quantity limits, and
- minimise impact on the receiving environment

Moving forward, a combination of different actions is recommended to ensure that SKR's farm operation at Cowley Creek meet this requirement. In accordance with EE requirement 7d-e, the actions recommended and timeframes for implementing them, are presented in an Implementation program (Table 11).

The objective of the Implementation program is to comply with EE requirement 7d. The program has been divided into three steps, where:

- Step 1 – presents actions that are currently in place (ongoing) or recommended to be implemented in the near future (i.e. within 2023). A 6-month review is recommended to assess the results, against the program's objective
- Step 2 – presents actions, which are only recommended to be implemented if the program's objective has not been meet in step 1
- Step 3 – presents actions, which are only recommended to be implemented if the program's objective has not been meet in step 2. These actions involve major amendments to the farm's current infrastructure and would require regulatory and internal approvals. As such, the time for implementing these actions, will be lengthy

The following sections provides further details to the actions and steps, recommended in the Implementation program in Table 11.

10.2.1 Step 1

10.2.1.1 General on-farm management

The improvements strategies that have been implemented in the past 17 months, are recommended to be continued (Table 10).

10.2.1.2 EcoTabs™

The application of EcoTabs ™ to bioremediations system 2, are recommended to be continued, as the review suggests that the implementation of this action, has been effective (Section 10.1.2).

However, to further improve water quality released from discharge point W2, it is recommended that the probiotic is applied not only in settlement pond (SP-2) and bioremediation pond (BP-2), but also in and zig zag (ZZ-2) in bioremediation system 2.

Furthermore, for this action to become viable as a potential long-term option, it is recommended that further actions are implemented to reduce sludge in the bioremediation systems, so that the probiotic

is treating the water column rather than the bottom sediment. This would also increase the retention time and improve the treatment of wastewater in the bioremediation systems, in general.

10.2.1.3 Sludge management

The sludge removal at zig zag (ZZ-1) in bioremediation system 1 has not yet been reviewed, as ZZ-1 has not been put back in use since work commenced in late 2022. ZZ-1 is scheduled to be back in use by March 2023. A 6-month review of the results against the program's objective, is recommended.

10.2.2 Step 2

10.2.2.1 Sludge management

Step 2 lists several different options relating to further sludge management at site, including:

- undertaking additional earthworks;
- installing drum filter; or
- installing sludge removal system.

SKR are currently considering trialling a sludge removal system from Avantaqua™, consisting of:

- AirRat®;
- Water Deflector Panel™ / Baffles
- Tri-Blade Diffuser

The AirRat® lifts and removes sludge from the bottom sediments and transfer it to a floating tank for resettling the lifted solids. The task of the additional equipment proposed, are to produces directional currents, increases aeration, detention time and sedimentations (Figure 28).

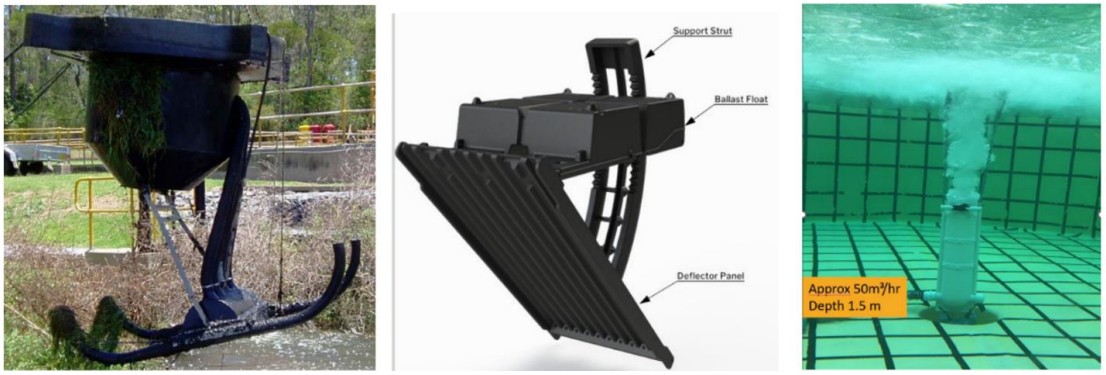


Figure 28. Pictures showing (from left to right) AirRat®, Water Deflector Panel™ / Baffles and Tri-Blade Diffuser (pictures sourced from Avantaqua™).

10.2.3 Step 3

10.2.3.1 Reinstate discharge point W3

One potential action recommended in step 3, is to reinstate discharge point W3. Current EA permits wastewater to be discharged from three different discharge points; W1, W2 and W3 (condition C1, part 2 in EA), however only two are currently in operation (i.e. W1 and W2). The receiving waters differ

between the discharge points, as W1 and W2 are permitted to discharge to Cowley Creek (W1 and W2) while W3 to Liverpool Creek. The EA quantity limits (i.e. the maximum daily discharge limit) that are permitted to be discharged from W3, are also far greater than what are permitted for W1 and W2 (Table 4). QLD Globe mapping, identifies Cowley Creek as non-perennial, while Liverpool Creek has been identified as a perennial watercourse (QLD Globe, MSES regulated vegetation, defined water course mapping layer). All of this combined, suggests that the implementation of this action would presumably minimise impact on Cowley Creek and comply with relevant EA quality and quantity limits.

10.2.3.2 Recirculating aquaculture systems (RAS)

Another potential action recommended in step 3, is to convert current farm operations to a pond-based RAS system with net Zero Discharge. As this action would require major amendments to the farm's current infrastructure as well as regulatory and internal approvals, the time for implementing these actions will presumably be lengthy.

Table 11. Implementation program.

									2023										2024	2025-2026	2026-2028
									March	April	May	June	July	August	September	October	November	December			
Task ID	Step	Aim	Target of task	Task title	Task location on farm	Taks description	Task owner	Due date	1/03/2023	1/04/2023	1/05/2023	1/06/2023	1/07/2023	1/08/2023	1/09/2023	1/10/2023	1/11/2023	1/12/2023			
1.0	Step 1	Improve water quality																			
1.1			Ongoing on-farm management strategies to improve water quality	On-farm management	Bioremediation System 1 and 2	Apply lysine, molasses and spray hydrogen peroxide when required. Harvest Azolla on a regular basis and operate paddle wheels. Take preventative fish health measures (incl vaccination) and regularly review feeding practices.	RM	Currently in place - ongoing													
1.2			Sludge Reduction and Treatment of Water Column	EcoTabs™	Bioremediation System 2 (SP-2, BP-2 and ZZ-2)	Apply EcoTabs™ to bioremediation pond SP-2, BP-2 and ZZ-2	DR														
1.2.1						Review outcome	RM/CH														
1.3			Sludge Removal	Earthworks	Bioremediation System 1 (ZZ-1)	Take ZZ-1 back in use, post earthworks		31/03/2023													
1.3.1						Review outcome	RM	31/08/2023													
1.3.2						Review outcome		31/9/2023													
1.4						Review actions implemented in Step 1 against the objective, prior of moving to step 2															

2.0	Step 2	Improve water quality																		
2.1			Sludge Removal and aeration	Avantaqua™	Bioremediation System 1	Meet with Avantaqua™ and complete sludge survey	RM	31/4/2023												
2.1.2						Review option		31/05/2023												
2.1.3						If viable, sign contract		30/06/2023												
2.1.4						Implement equipment		31/08/2023												
2.1.5						Review outcome		31/9/2023												
2.2			Sludge Removal	Drum filter	Bioremediation System 2	If required, to achieve the objective, review as an option														
2.2.1						Review option														
2.2.2						If viable, sign contract														
2.2.3						Implement equipment														
2.2.4						Review outcome														
2,3						Review actions implemented in Step 2 against the objective, prior of moving to step 3														
3.0	Step 3	Improve water quality and manage discharge volumes																		

3.1			Distribute wastewater to both Cowley and Liverpool Creeks	Reinstate discharge point W3	Bioremediation System 1 and 2	If required, to achieve the objective, review as an option														
3.1.1						Seek regulatory and internal approvals														
3.1.2						Investigate amendments required to infrastructure on-farm and beyond														
3.1.3						Execute amendments required to infrastructure on-farm and beyond														
3.1.4						Review outcome														
3.2			Net zero discharge by recycling water	Recirculating aquaculture systems (RAS)	Bioremediation System 1 and 2	If required, to achieve the objective, review as an option														
3.2.1						If viable, sign contract														
3.2.2						Implement equipment														
3.2.3						Review outcome														

11 Water Quality Management Plan and review of the Receiving Environmental Monitoring Program

11.1 Water Quality Management Plan

In agreement with EE requirement 7f, a Water Quality Management Plan (WQMP) has been prepared, which:

- documents the process for managing water quality
- lists operational procedures and plans required for managing water quality
- includes a risk assessment (including mitigation actions) for potential impacts to water quality

The Water Quality Management Plan is presented in a separate document in Appendix 5.

11.2 Review of the Receiving Environmental Monitoring Program

In agreement with EE requirement 7g, the Receiving Environmental Monitoring Program (REMP) design program, prepared by Wild Environmental Consultants Pty Ltd in October 2020 (Wild Environmental Consultants, 2020) has been reviewed, to identify potential changes and timeframes for implementing changes if required. The review of the REMP document, suggest that it is a comprehensive document, which:

- Includes control and impact sites, relevant to sites. These sites were also adopted in the EE investigation scope
- Selects appropriate environmental values and corresponding WQOs, in order to protect these values as specified in *Schedule 1 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019* "Johnstone River Basin Environmental Values and WQOs, Basin 112" (DES 2020)
- Selects both physicochemical and biological indicators in the monitoring program
- Includes and addresses the requirements in the EA, e.g. biannual macroinvertebrate surveys
- Provides an appropriate sampling frequency for all parameters involved
- Refers to standard methods and appropriate guidelines

The receiving waters have been monitored for 17 months in a comprehensive manner indicating that there have been some overall improvements but that the catchment upstream and downstream is not meeting the WQOs. SKR request a new REMP be structured to better capture an adaptive management approach that is reflective of the conditions in which they farm.

12 Overall Summary

Water quality has now been thoroughly assessed for 17 months at SKR and the results discussed in this document as the water flows through the arm: ➔pond➔discharge➔receiving environment. Additional requirements including an implementation program and water quality management plan (includes risk assessment) support the current and future actions SKR will take in managing water quality within the farm and receiving waters.

Comparison of the intake with the discharge indicates that there is clear and predictable impact of the production system on water quality as it moves from the inlet to the discharge. However, there have

been significant changes and improvement in production pond water quality management (Section 10), including targeted treatment of W2 bioremediation system, which will continue beyond the life of the EE. The bioremediation treatment resulted in overall water quality improvements; however, water quality in bioremediation System 1 and 2 improved as water moved through the system. These enhancements for W2 may be due to on-farm management actions and trials e.g., the application of EcoTabs™ to settlement pond 2 (SP2) and bioremediation pond 2 (BP2), seem to have improved nutrient parameters despite biomass and feed use being high. Throughout this EE SKR has managed to maintain production while taking measures to improve water quality. This is an important observation because water quality at discharge points is largely influenced by the effectiveness of water quality management in the ponds throughout the production cycle (fallowing, feed and faecal inputs).

The receiving environment water quality and macroinvertebrate monitoring delivered some interesting results. While there were clear differences between upstream and downstream sites, both control and impact sites failed to meet the WQOs for the Johnson River Basin. Given the upstream sites do not meet all the WQOs then it can be argued that they are likely not appropriate for the Cowley Creek system. Equally the macroinvertebrate study demonstrated that while sites downstream of the fish farm discharge were of poorer condition than upstream, upstream control sites also showed evidence of biological impact. These patterns indicate that the water quality of Cowley Creek both upstream and downstream of the fish farm outfall is affected not only by fish farm discharge but also the impacts of agricultural and horticultural activities in the upper catchment.

The EE has driven the investigation into water quality on-farm (bioremediation), discharge and receiving waters. This data has revealed that the Cowley Creek catchment surrounding the farm is disturbed irrespective of the farms input. Variation in river physico-chemical and nutrient parameters downstream of the discharge cannot be solely attributable to the fish farm given that some parameters downstream such as total nitrogen and nitrate were higher for the impact sites than the discharge and these plus other indicators such as phosphorus were not meeting the WQOs. Evidence of impacts on water quality and biological communities at upstream sites provides clear evidence of catchment impacts in Cowley Creek unrelated to fish farm discharges.

Sealord King Reef has made a commitment to implement several new water quality management actions and continue with some existing ones to further treat the water prior to discharge. While SKR applies its water quality improvements on the farm, a long-term recommendation is an adaptive management approach. Such adaptive management allows for production while monitoring of the receiving waters is revisited and monitored to reflect a staged approach without irreversible environmental impact. SKR are committed to work with DES to further understand the water quality of this ephemeral environmental within which they farm and build on more appropriate conditions of pond water quality that SKR can meet without further impact to an already disturbed catchment.

13 References

1. DES (2020) Johnstone River Basin Environmental Values and WQOs. Environmental Protection (Water and Wetland Biodiversity) Policy 2019. State of Queensland, 2020.

2. DES 2018. Monitoring and Sampling Manual: Environmental Protection (Water) Policy, 2008. Brisbane: Department of Environment and Science Government.

3. Queensland Water Quality Guidelines 2009, State of Queensland, version 3 reviewed July 2013.

4. Nautilus Collaboration and Aquenal, 2021, Environmental Evaluation for Sealord King Reef Pty Ltd Cowley Creek farm operation - Draft Investigation Scope V5.0, prepared by Nautilus Collaboration and Aquenal for Sealord King Reef Pty Ltd.

5. Wild Environmental Consultants, 2020, Receiving Environment Monitoring Program Design Report, prepared by Wild Environmental Consultants for King Reef Seafood Pty Ltd.

6. BioTech Water, Eco Tabs™, product information, https://www.biotechwater.com.au/about-eco-tabs

7. Avantaqua, equipment for sludge removal and aeration, https://avantaqua.com

8. C&R Dry Season Report (October 2021)

9. C&R Wet Season Report (June 2022)

10. QLD Globe mapping, available on: https://qldglobe.information.qld.gov.au, accessed: March 2023.

11. EA permit EPPR00390913, issued on: 17 January 2023.

12. DNRM (2001). Queensland Australian River Assessment System (AusRivAS) Sampling and Processing Manual. Queensland Department of Natural Resources and Mines, Rocklea, QLD

Appendix 1 – Project Delays

Equipment Delays

YSI multi-parameter probe

To ensure reliability of in-situ field measurements, a YSI ProDSS handheld multi-parameter probe has been ordered from a third-party supplier. Due to COVID-19 related manufacturing delays, delivery of this unit is currently scheduled for mid-December 2021. In the meantime, a slightly older (but well calibrated) YSI unit is being used for most field measurements, while turbidity is being analysed as part of the water quality panel at a third-party laboratory (ALS Environmental, Townsville.

Swoffer handheld flow/velocity meter

For in-situ flow measurements, a Swoffer handheld meter has been procured. This meter only arrived on site in early November, and flow velocity data will be collected herein. Since only one measurement has been taken, it will not be included in this 6-monthly report.

Inlet flow meter

An ultrasonic flowmeter was installed in 2021 to monitor the inlet flow on site.

In-house water quality testing kits

Stock of certain water quality test kits for in-house testing was depleted. Although replacement kits were ordered early, significantly longer-than-average lead times due to COVID-19 resulted in some in-house testing to be incomplete. The availability of these kits has been a significant issue throughout the EE monitoring period, and subsequently, on-farm measurements are missing intermittently throughout. The farm is now sending samples for lab analysis if there are no kits available for on-farm testing.

Site access difficulties

Water quality monitoring: Site CC-4

Water quality monitoring sites were selected based on a REMP design report produced by consultants that are no longer engaged by Sealord King Reef. One of the sites (CC-4) was deemed "inaccessible" due to being steep and overgrown. In order to ensure occupational safety for field technicians, this site was moved to a new location approximately 400 m upstream from the original site (Figure 29). This amendment to the EE scope was submitted to DES. Since this site was not accessible during the first sampling iteration, water quality data from this site was not collected. Data reported thereafter refers to samples collected from the amended CC-4 site.

Macro-invertebrate sampling: Site MI-3

Downstream impact site MI-3 was moved slightly upstream from its original location (adjacent to CC-3) due to inappropriate habitat and hazardous access conditions. Third-party consultants (C & R Consulting) conducting the macroinvertebrate surveys reported that safety concerns (from potential crocodile encounters) restricted macroinvertebrate sampling at CC-3. The following is an excerpt from the macroinvertebrate report (Appendix 2):

> "*CC-3 which is located at the Cowley Creek road crossing where there are two large, deep turbid pools immediately upstream and downstream of a short (~10m long) artificial riffle zone (created by the rock protection around the bridge foundations). Further, the channel through this reach has very steep banks inhibiting a fast exit by field personnel, if required. Therefore, an additional sample site (MI-3) was established at a safer location slightly upstream of CC3 (Map 1). This new site is located approximately 300 m upstream of the already established*

CC3, while still downstream of both licenced release points associated with the barramundi farm."

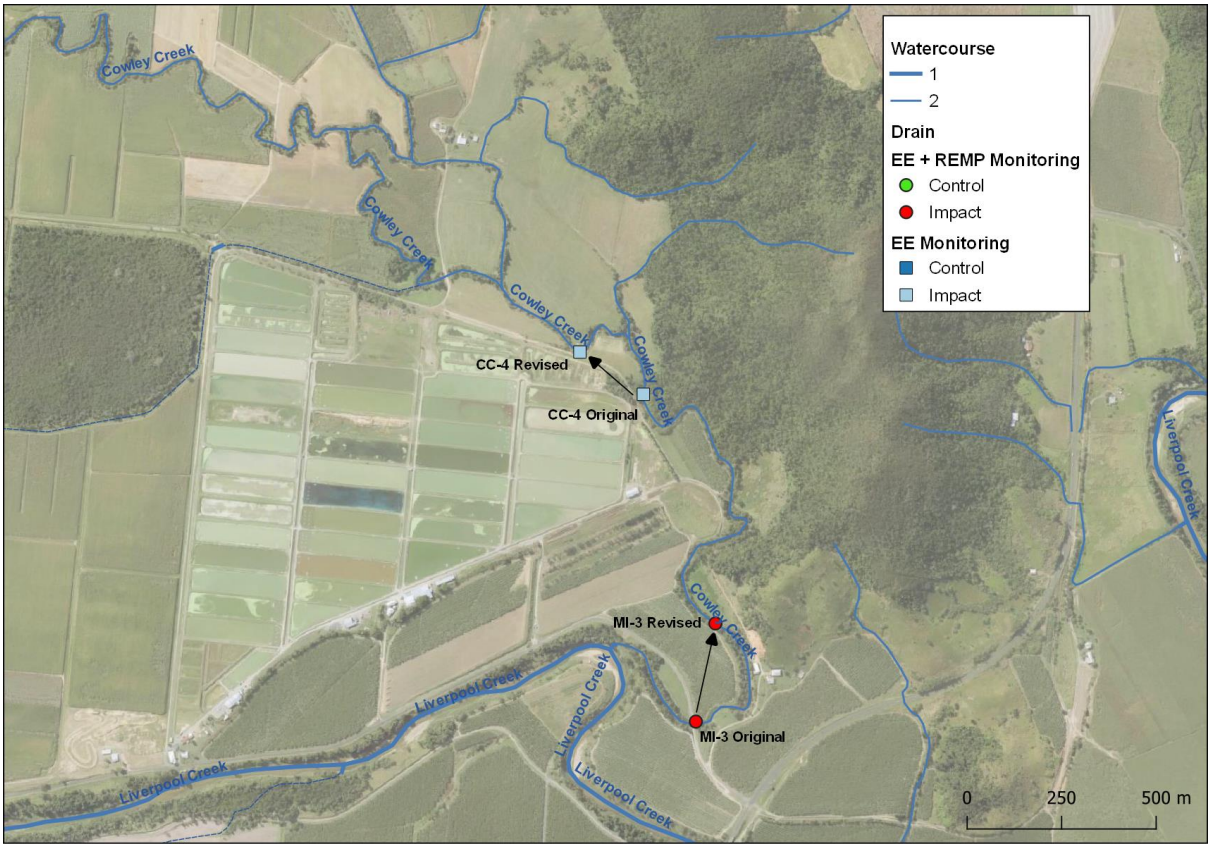


Figure 29. Original and revised locations for CC-4 (water quality site) and MI-3 (macroinvertebrate survey site).

Clerical Error

Inlet and Discharge samples mistakenly tested in-house for initial sampling events rather than sent to third party laboratory. This mistake was rectified and Inlet/W1/W2 samples were sent to ALS fortnightly for analysis as of the 18th October and thereafter. Consequently, data for some analytes is missing at the first two sampling iterations.

Weather events

Prolonged and heavy rainfalls have caused delays in the completion of earthwork undertaken at the zig zag (ZZ-1) in bioremediation system 1 and undertake macroinvertebrate surveys at site.

Appendix 2 – Macroinvertebrate Survey Report 1

C&R CONSULTING
Geochemical & Hydrobiological Solutions Pty Ltd
ABN 72 077 518 784

Underground Coal Gasification / Coal Seam Gas Investigations
Mineralogical, Geological, Petrographic and Soils Services
Hydrogeomorphic and Palaeogeomorphic Evaluations
Terrestrial and Aquatic Fauna and Flora Surveys
Climate History and Extreme Events Analysis
Contaminated Site and Mine Water Analysis
Environmental Compliance and Monitoring
Estuarine and Marine Water Assessments
Registered Research and Development
Surface and Groundwater Hydrology

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8 November 2021

Dr. Christian van Rijn
Research and Development Scientist
Nautilus Collaboration Aquaculture Consultants

Re: Macroinvertebrate sampling results

Dear Dr. van Rijn,

C&R undertook macroinvertebrate sampling within the receiving environment of the Sealord barramundi farm at Cowley Creek, north Queensland in October 2021. The sampling was undertaken in accordance with AusRivAS methods for Queensland (DNRM, 2001[1]), except that three bed habitat replicate samples were collected from each site instead of one bed and one edge habitat sample. Thelow water level along the banks limited the availability of sufficient edge habitat to gain three replicatesfrom each site. Hence, only bed habitats were targeted.

Three separate established monitoring sites were targeted (MI-1, MI-2 and MI-3; refer to Map 1 attached). MI-1 is located upstream of any potential influence from the barramundi farm (at the already established site of CC1), MI-2 is located downstream of release point WW1 (adjacent to the already established site of CC2) and MI-3 is located downstream of both licenced release points (i.e. WW1 and WW2). Safety concerns (from potential crocodile encounters) restricted macroinvertebrate sampling at CC3. CC3 is located at the Cowley Creek road crossing where there are two large, deep turbid pools immediately upstream and downstream of a short (~10m long) artificial riffle zone (created by the rock protection around the bridge foundations). Further, the channel through this reach has very steep banks inhibiting a fast exit by field personnel, if required. Therefore, an additional sample site (MI-3) was established at a safer location slightly upstream of CC3 (Map 1). This new site is located approximately 300 m upstream of the already established CC3, while still downstream of both licenced release points associated with the barramundi farm.

Results

The habitat condition assessment undertaken at the three sites found all sites to be in good condition, with MI-3 in the best condition (Figure 1). MI-3 was comprised of diverse habitats that included deeper pools, shallow and deep riffle and run habitats, as well as macrophyte beds.

[1] DNRM (2001). *Queensland Australian River Assessment System (AusRivAS) Sampling andProcessing Manual.* Queensland Department of Natural Resources and Mines, Rocklea, QLD.

In-situ water quality results were recorded during macroinvertebrate monitoring. Evidence of the influence of released waters could be observed in most quality characteristics, although only dissolved oxygen levels displayed a uniform trend, decreasing with increasing distance downstream (Table 1). Spikes in pH, turbidity and electrical conductivity were all observed downstream of WW1, with electrical conductivity recorded at levels four times higher immediately downstream of the release point (Table 1).

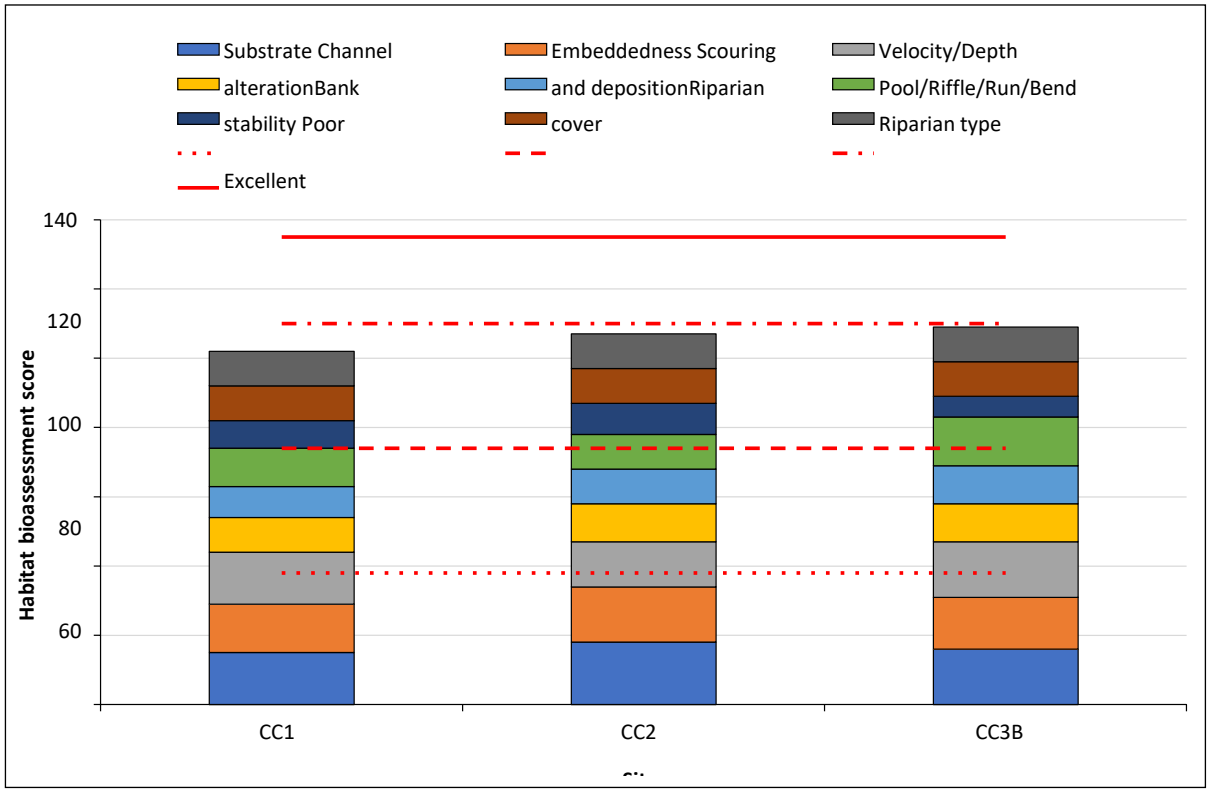


Figure 1: Habitat condition assessment results.

Table 1: In-situ water quality results.

Quality characteristic	Unit	LOR	WI-1	WI-2	WI-3
Temperature	°C	0.01	24.46	28.26	27.71
Electrical conductivity	µS/cm	0.01	60.66	274	166.9
pH	units	0.01	6.64	7.04	6.19
DO	mg/L	0.01	5.7	4.6	4.39
DO	% sat	0.01	67.69	59.05	55.8
Turbidity	NTU	0.01	4.94	20.38	NA
ORP	mV	0.1	182	109.8	NA

DO = Dissolved oxygen.
LOR = Limit of reporting.
ORP = Oxidation reduction potential.
NA = Not available (probe issues).

The influence of release waters on in-situ water quality characteristics corresponded with marginal differences in the macroinvertebrate communities inhabiting the various sites. The taxonomic richness was greater within replicates downstream of the release points when compared to the upstream site (Figure 2), with MI-1, MI-2 and MI-3 averaging 18, 22 and 23.33, respectively. This trend was reversed in PET richness (number of Plecoptera, Ephemeroptera and Trichoptera families present; Figure 3) results with MI-1 generally recording greater PET richness (averaging 5.33) than the downstream sites (MI-2 and MI-3 both averaged 4.67), despite replicate C of CC2 recording the highest PET richness of any sample.

The PET richness results were mirrored in the SIGNAL index values as well as the percent tolerant and percent sensitive taxa recorded which all found the upstream community of MI-1 to be more sensitive to environmental change than the downstream communities (Figure 3, Figure 4, Figure 5 and Figure 6). These sensitivity indices suggest that releases from the barramundi farm may be influencing the downstream macroinvertebrate communities, increasing the dominance of families tolerant to environmental change downstream of the operations when compared to upstream.

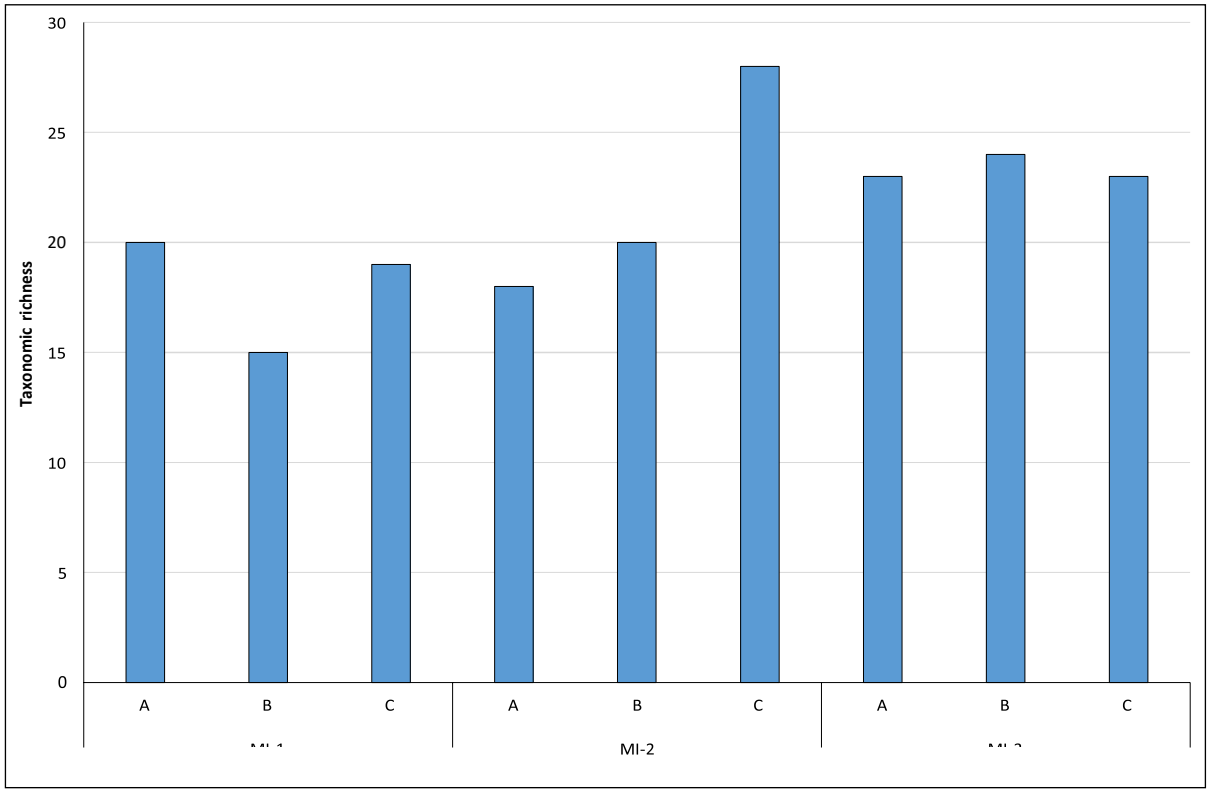


Figure 2: Taxonomic richness recorded within the bed habitat at each site.

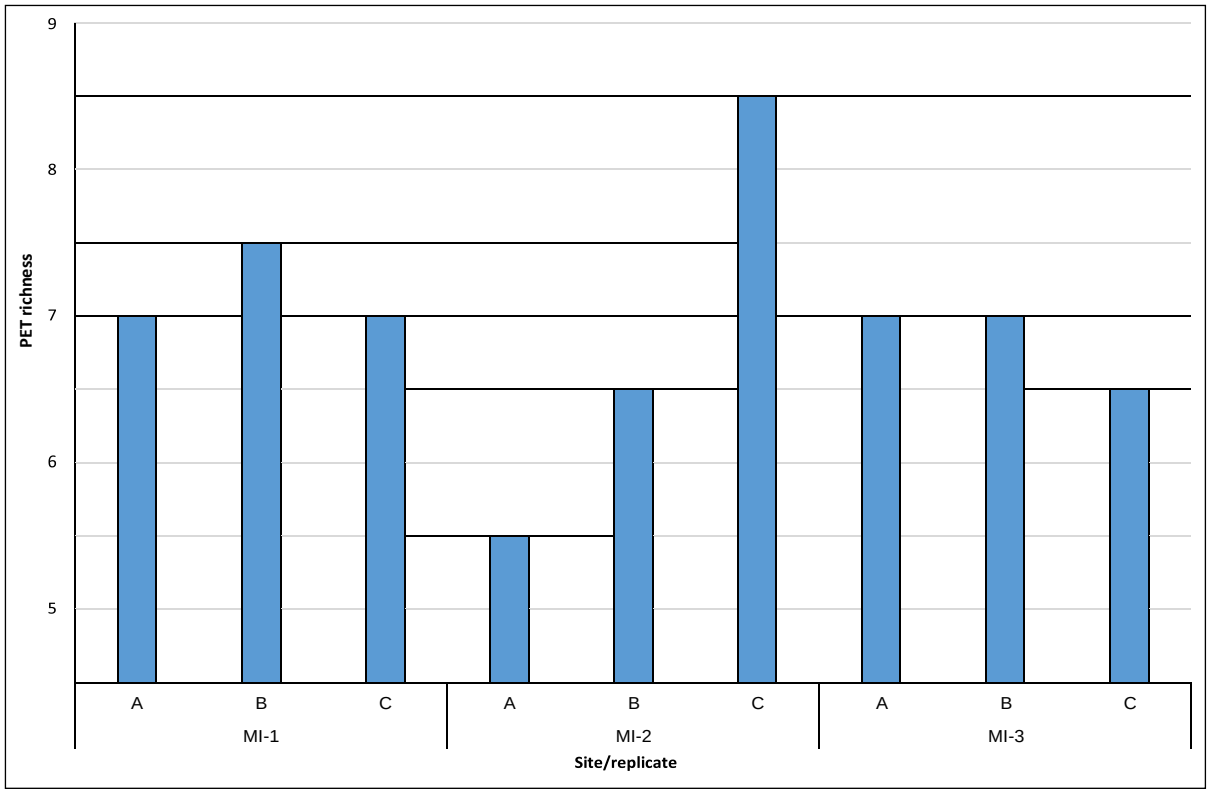


Figure 3: PET richness recorded within the bed habitat at each site.

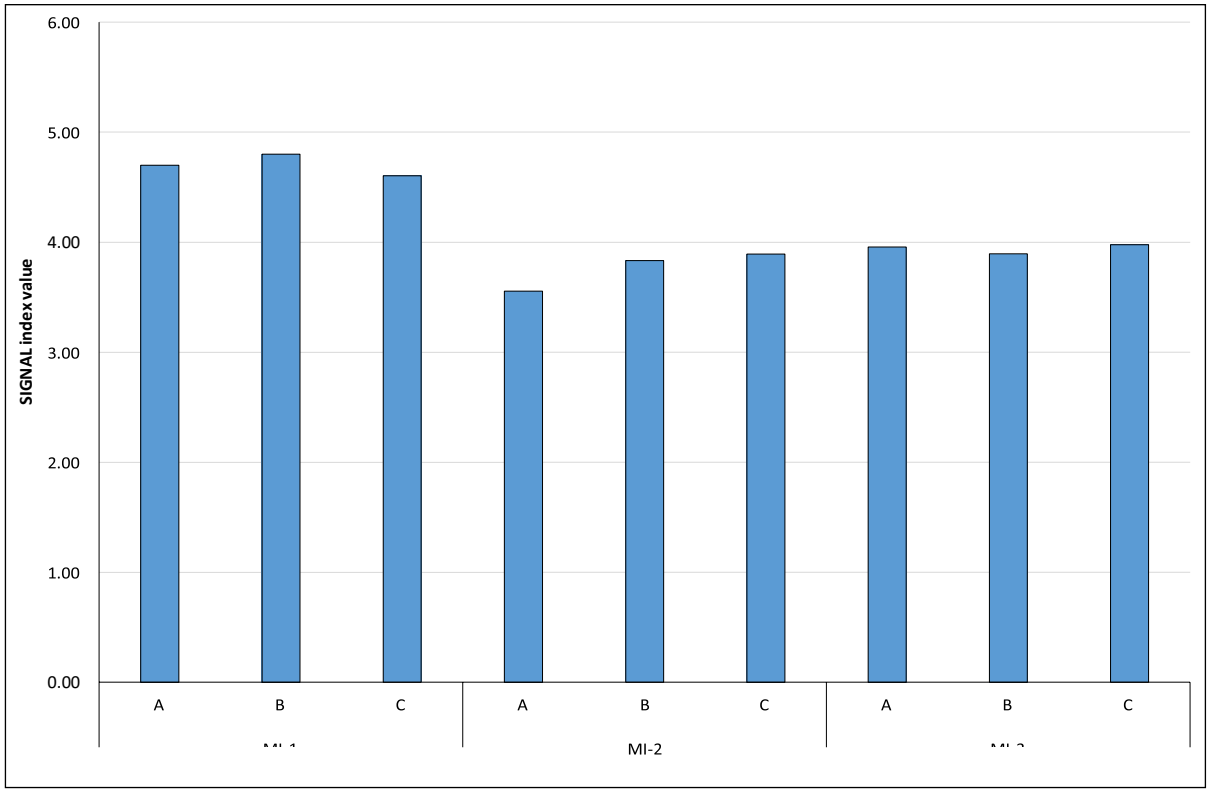


Figure 4: SIGNAL index value recorded at each site.

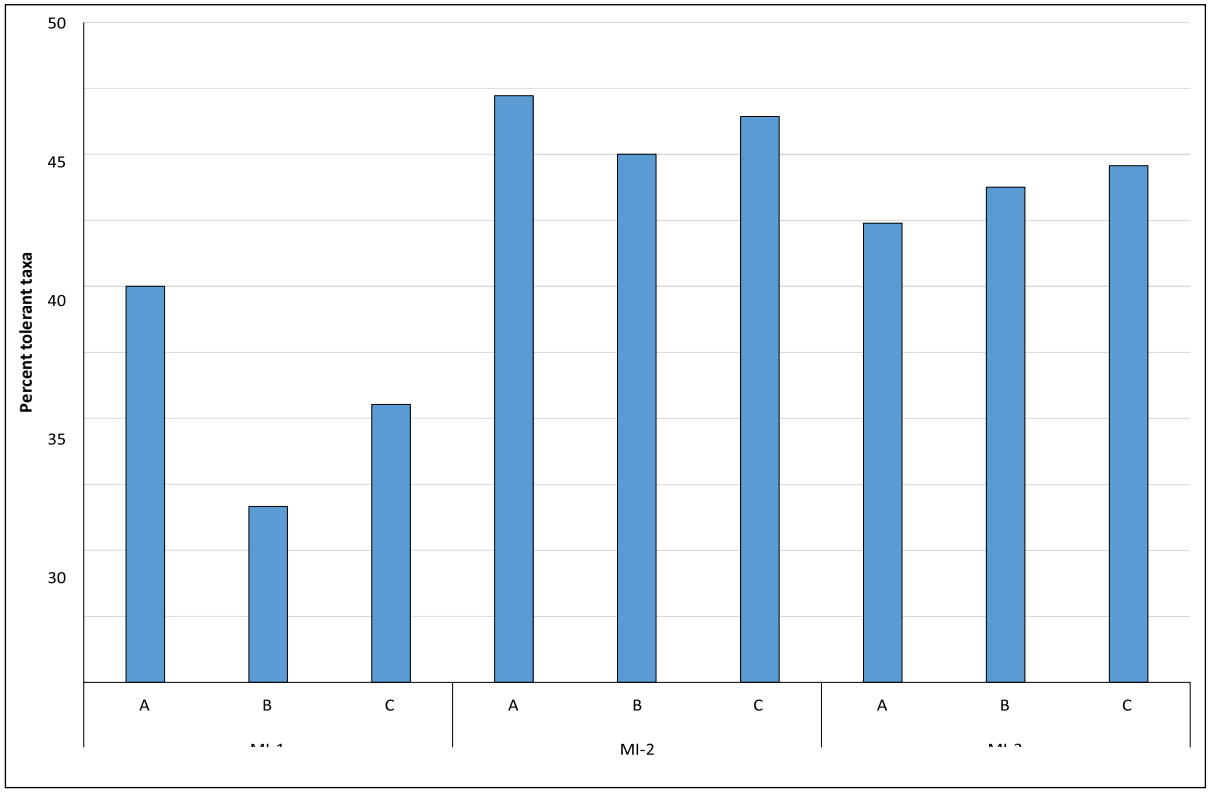


Figure 5: Percent tolerant (i.e. SIGNAL grade ≤3) taxa within the bed habitat at each site.

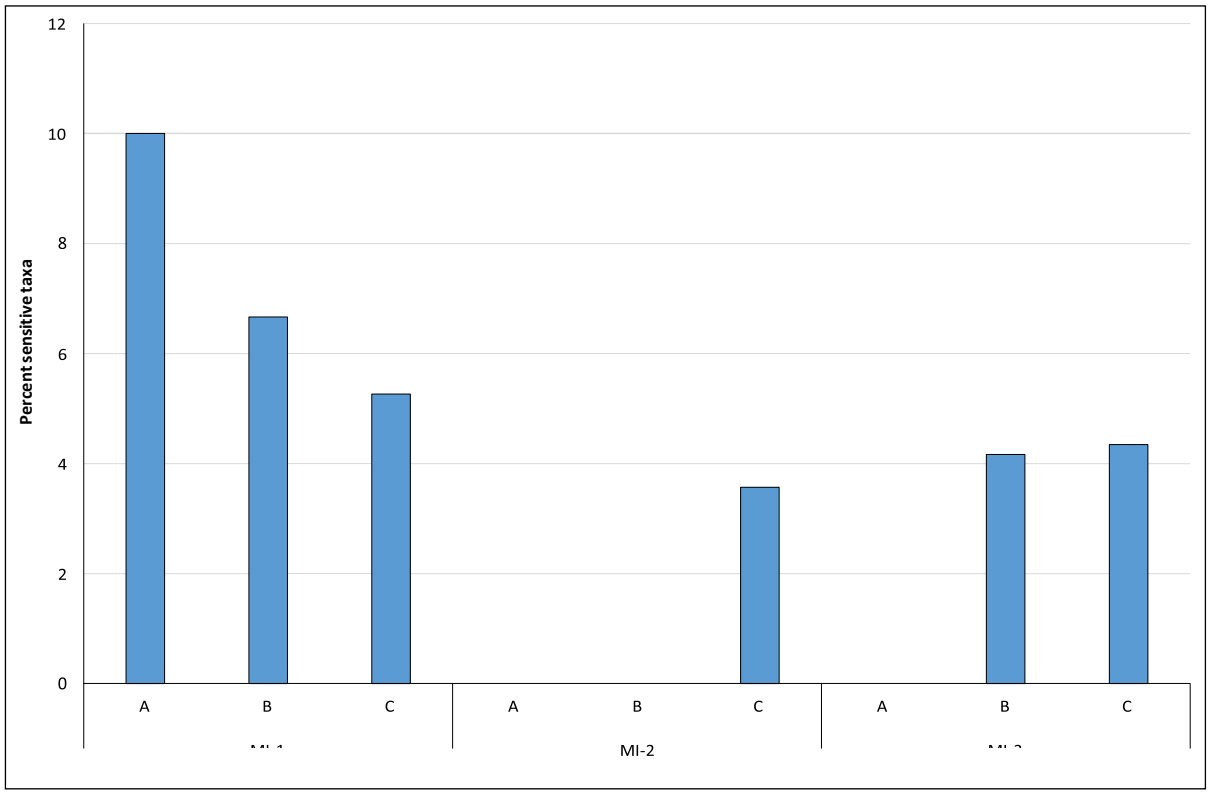


Figure 6: Percent sensitive (SIGNAL grade ≥8) taxa within the bed habitat at each site.

An assessment of the macroinvertebrate data using the AusRivAS modelling program found all sites – both upstream and downstream of the barramundi farm's release points – to be classed as 'Band B' (*Significantly impaired*; Table 2).

The bandwidth shows the range O/E score (50%) for each model output Band allocated (refer to Table 2). Band B has a bandwidth of 0.38 to 0.78. When this band width is compared to the results in Table2, it can be seen that replicates (a) and (b) from site MI-2 are both at the lower end of Band B (i.e. almost classed as Band C). The remaining replicates from each site generally occurred within the mid-range of the band width.

Interestingly, despite other sensitivity indices suggesting the downstream sites may be impacted, the observed SIGNAL scores compared to the expected SIGNAL scores (with >50% probability of occurring) for each replicate were similar both upstream and downstream of the project site and close to the expected SIGNAL scores (i.e. close to 1; Table 2).

These modelling results suggests that all sites display signs of impacts from upstream anthropogenic disturbances and, while there is some discernible influence from the barramundi farm immediately downstream of the release points, there is negligible difference between upstream communities (observed at MI-1) and further a-field downstream (observed at MI-3) communities.

Table 2: Observed taxa results compared to those expected each site with greater than 50%probability of occurrence

Site/rep	Number of taxa collected (50%)	O/E score (50%)	O/E SIGNAL score (50%)	Band
MI-1 (a)	11	0.69	1.05	B
MI-1 (b)	9	0.57	0.95	B
MI-1 (c)	10	0.63	0.95	B
MI-2 (a)	6	0.38	0.87	B
MI-2 (b)	7	0.44	0.90	B
MI-2 (c)	9	0.57	0.97	B
MI-3 (a)	9	0.57	0.93	B
MI-3 (b)	8	0.50	0.95	B
MI-3 (c)	10	0.63	0.95	B

QA/QC of the laboratory identified taxa was undertaken in accordance with the relevant Queensland guidelines[2]. Ten percent of the samples identified were randomly selected for re-identification by a suitably qualified person. The ratio of taxonomic richness of the original identification compared to the QA identification was found to be 1, compliant with the guideline value of >0.90. Further, the number of correct identifications was found to be 96.5%, compliant with the guideline requirement of >90%. Based on these results, the macroinvertebrate samples meet all relevant QA/QC requirements.

The full set of raw macroinvertebrate data collected during the October 2021 sampling events is provided in Table 3.

[2] DES (2018). *Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual:Biological assessment.* The Department of Environment and Science, Queensland Government.

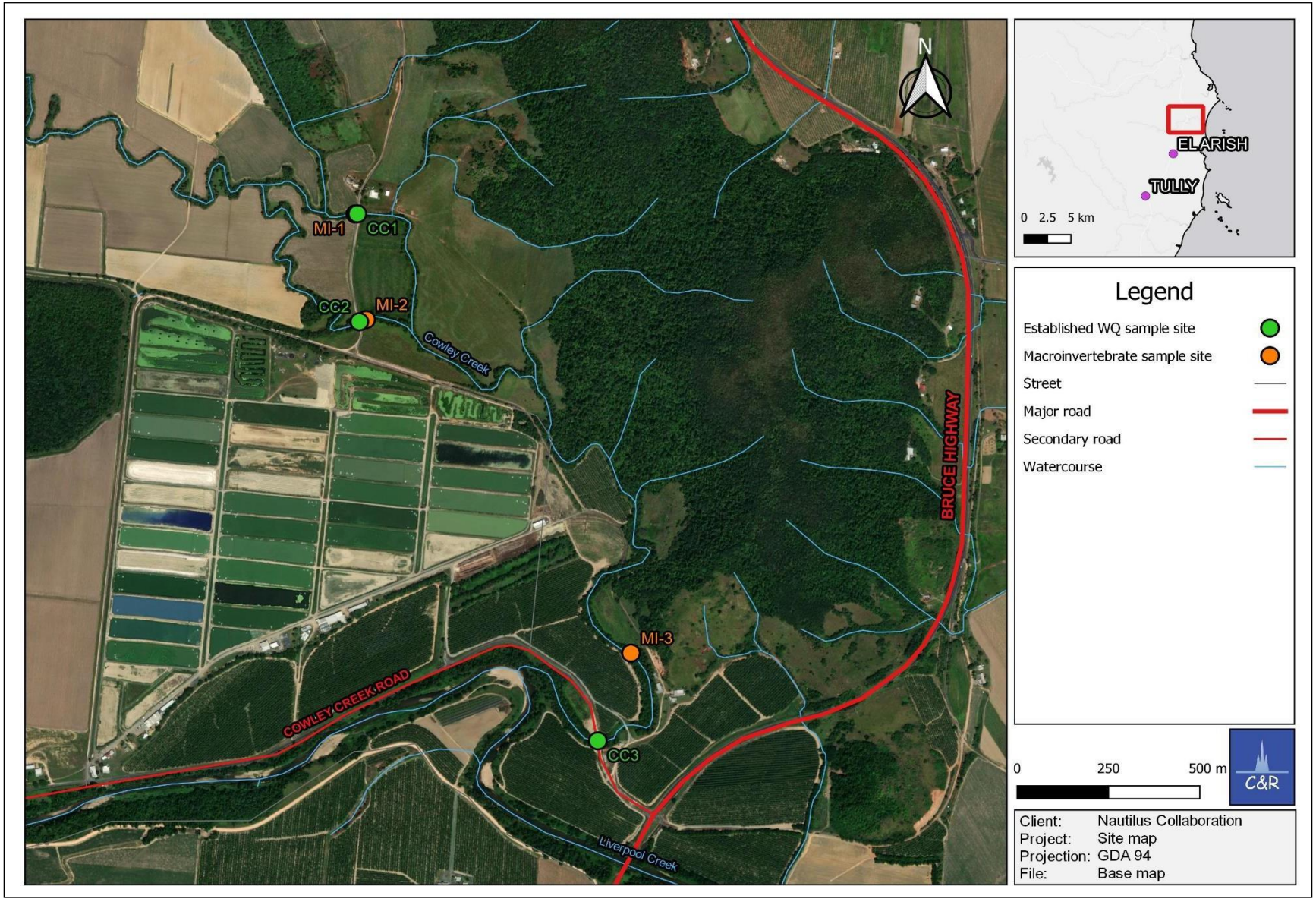
If you have any questions regarding the outcomes of this assessment, please do not hesitate to contact me on the details below.

Regards,



Matt Knott

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Email: matt@candrconsulting.com.au
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Map 1: Site map.

Table 3: October 2021 macroinvertebrate dataset

Major group	Order	Family	Sub-family	AUSRIVAS code	SIGNAL grade	MI-1			MI-2			MI-3			MI-1 (B)
						A	B	C	A	B	C	A	B	C	QA/QC
Nematoda				II999999	3						1				
Oligochaeta				LO999999	2				72	47	38	3	4	6	
Hirudinea	Glossiphoniidae			LH019999	1				4	27	13			1	
	Arhynchobdellida			LH039999	4			3	17	15	14		2	9	
Gastropoda	Hygrophila	Planorbidae		KG079999	2									1	
	Cerithimorpha	Thiaridae		KG049999	4	3	3	8	20	20	14	12	8	7	3
Crustacea	Cladocera			OG999999	5.5					1	1				
	Copepoda			OJ999999	5.5				4			2			
	Ostracoda			OH999999	5.5			3	7	2	11	10	8	16	
	Conchostraca			OF999999	1				1	2	2				
	Decapoda	Atyidae		OT019999	3	5		7	6	2	3	21	11	28	
Acarina	Hydracarina			MM999999	6	7	7	10	10	8	18	2		3	7
Insecta	Coleoptera	Carabidae		QC059999	3	17	6	3							6
		Dytiscidae		QC099999	2	3				2	9	2			
		Elmidae		QC349999	7							4	7	8	
		Gyrinidae		QC109999	4			1					2	1	
		Hydrochidae		QCAO9999	4							2			
		Hydrophilidae		QC119999	2									4	
		Ptilodactylidae		QC399999	10	4									
		Scirtidae		QC209999	6	4	1	1						1	1
	Diptera	Ceratopogonidae		QD099999	4	1						1	2		
		Chironomidae	Chironominae	QDAJ9999	3	12	14	7	6	1	2	27	16	25	13
			Orthocladiinae	QDAF9999	4		1	2	3	5	4			4	2
			Tanypodiinae	QDAE9999	4	2	2	7	3	2		8	4	6	2
		Simuliidae		QD109999	5	2		2	3		1				
		Tabanidae		QD239999	3							1	2		
	Ephemeroptera	Baetidae		QE029999	5	10	7	9		2	1	6	15	5	7
		Caenidae		QE089999	4	1	1	7			1	5	4	6	1
		Leptophlebiidae		QE069999	8	35	4	8			1		1	1	4

Major group	Order	Family	Sub-family	AUSRIVAS code	SIGNAL grade	MI-1			MI-2			MI-3			MI-1 (B)
						A	B	C	A	B	C	A	B	C	QA/QC
	Hemiptera	Corixidae		QH659999	2						1				
		Mesoveliidae		QH529999	2				1						
		Micronectidae		-	2						2		1		
		Saldidae		QH609999	1						1	1	1		
		Veliidae		QH569999	3	1							3	2	
		Corduliidae		QO169999	5	7	4	3					1		4
		Gomphidae		QO139999	5	2									
		Libellulidae		QO179999	4							2	6	1	
	Zygoptera	Coenagrionidae		QO029999	2				1	10	5	1	2	3	
		Platycnemidae		QO049999	4		1			20	2	7	4		1
	Trichoptera	Calamoceratidae		QT249999	7						1				
		Conoesucidae		QT159999	7						2				
		Ecnomidae		QT089999	4		2		3	3	4	3	12		1
		Hydropsychidae		QT069999	6	13	2	1	5	1	2	86	57	40	2
		Leptoceridae		QT259999	6	8	3	18		2	1	1			3
	Lepidoptera	Crambidae		QL999999	2	1		1	14	8	9	5	7	2	
	Other														
	Diptera	Chironomidae (empty cases)^				4									
	Diptera	Pupae^						2					1		
	Coleoptera	terrestrial (wings)^				1	1	1				1	1	4	
	Arachnida	terrestrial spider (exoskelton)^				1								1	

^ excluded form richness and abundance

Appendix 3 – Macroinvertebrate Survey Report 2

C&R CONSULTING
Geochemical & Hydrobiological Solutions Pty Ltd
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Underground Coal Gasification / Coal Seam Gas Investigations
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3 August 2022

Dr. Christian van Rijn
Research and Development Scientist
Nautilus Collaboration Aquaculture Consultants

Re: Macroinvertebrate sampling results

Dear Dr. van Rijn,

C&R Consulting undertook macroinvertebrate sampling within the receiving environment of the Sealord barramundi farm at Cowley Creek, North Queensland in June 2022. The sampling was undertaken in accordance with AusRivAS methods for Queensland (DNRM, 2001[1]), except that three bed habitat replicate samples were collected from each site instead of one bed and one edge habitat sample. This is in-accordance with previous methods utilised in October 2021. Insufficient edge habitat was present at each monitoring site to collect three replicates during the October 2021 sampling event and, therefore, to maintain consistency across sampling rounds only bed habitats were again sampled during the June 2022 sampling event.

Three separate established monitoring sites were targeted (MI-1, MI-2 and MI-3; refer to Map 1 attached). MI-1 is located upstream of any potential influence from the barramundi farm (at the established CC1 surface water quality monitoring site), MI-2 is located downstream of release point WW1 (adjacent to the established CC2) and MI-3 is located downstream of both licenced release points (i.e. WW1 and WW2), and approximately 300 m upstream of the established surface water quality monitoring site of CC3.

Results

The habitat condition assessment undertaken at the three sites found all sites to be in good condition, with MI-3 in the best condition (Figure 1). MI-3 was comprised of diverse habitats that included deeper pools, shallow and deep riffle and run habitats, as well as macrophyte beds. Compared to previous results in October 2021, all sites returned lower habitat scores, however, maintain their overall good rating (Figure 1). The habitat indices that scored lower this sampling round compared to the October 2021 results included bank stability, scouring and deposition as well as embeddedness (Figure 1). This

[1] DNRM (2001). *Queensland Australian River Assessment System (AusRivAS) Sampling andProcessing Manual.* Queensland Department of Natural Resources and Mines, Rocklea, QLD.

is potentially the result of the large flow events experienced over the 2021-2022 wet season impacting the stability of the habitats present and the levels of scouring and erosion observed.

In-situ water quality results were recorded during macroinvertebrate monitoring. Evidence of the influence of released waters could be observed in some quality characteristics, with electrical conductivity increasing and pH and dissolved oxygen decreasing downstream of the initial release point (i.e. WW1; Table 1). The highest electrical conductivity was observed directly downstream of WW1, with MI-2 recording a level more than three times higher than MI-1. Similarly, the highest dissolved oxygen concentration was observed upstream of the release points at MI-1, with MI-2 recording the lowest oxygen levels (Table 1).

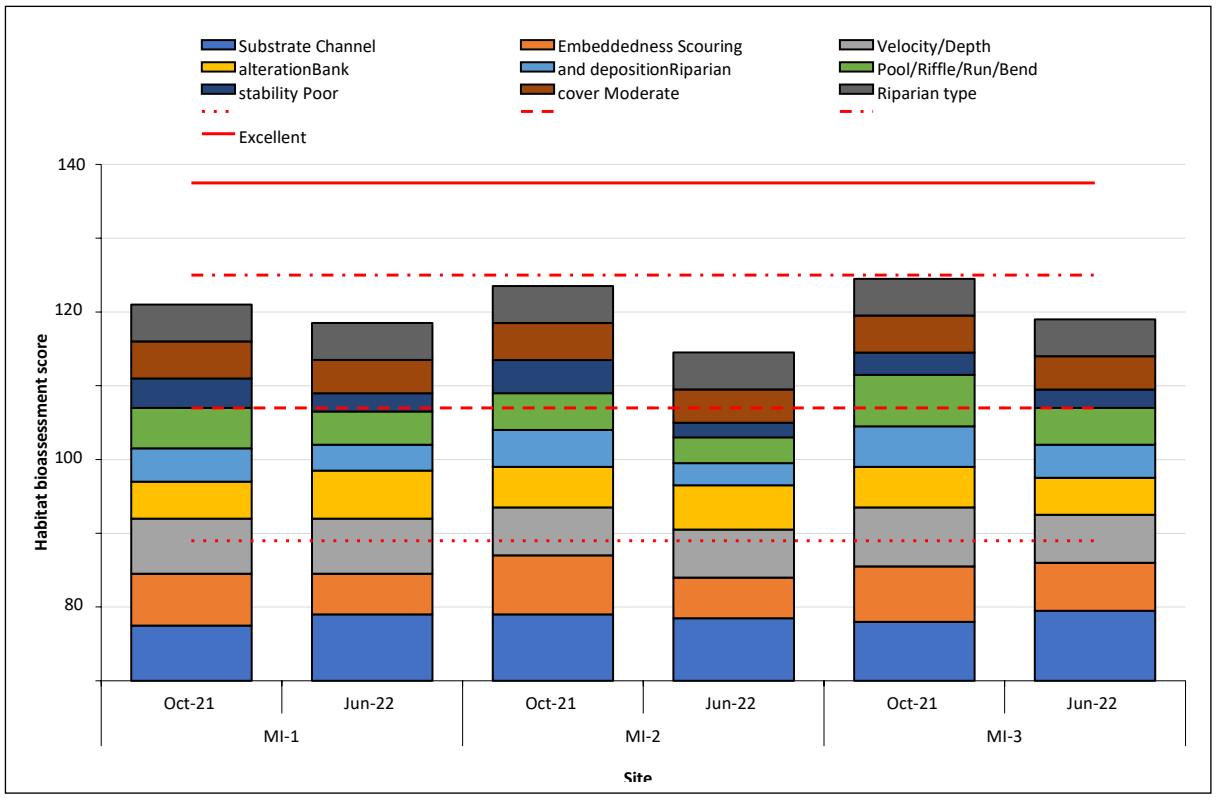


Figure 1: Habitat condition assessment results.

Table 1: In-situ water quality results.

Quality characteristic	Unit	LOR	MI-1	MI-2	MI-3
Temperature	°C	0.01	20.95	23.16	22.13
Electrical conductivity	µS/cm	0.01	51.6	174.92	87.48
pH	units	0.01	7.43	6.52	6.41
DO	mg/L	0.01	7.78	6.36	7.54
DO	% sat	0.01	86.98	74.18	86.19
Turbidity	NTU	0.01	9.52	10.23	10.32
ORP	mV	0.1	172.32	189.79	193.8

DO = Dissolved oxygen.
LOR = Limit of reporting.
ORP = Oxidation reduction potential.
NA = Not available (probe issues).

The influence of release waters on in-situ water quality characteristics corresponded with marginal differences in the macroinvertebrate communities inhabiting the various sites. The taxonomic richness was greatest immediately downstream of the release point WW1 (i.e. MI-2), and lowest at the furthest downstream site, with MI-1, MI-2 and MI-3 recorded total site taxonomic richness at 16, 19 and 13, respectively (Figure 2). Individual replicate richness ranged from 6 to 13 taxa per site (Figure 3). These results show a reduction in richness at each site compared to the October 2021 results (Figure 2). As this reduction is experienced at all sites, this result is likely attributed to either seasonal differences in community assemblages or insufficient time allowed prior to sampling following the previous large flow event (~5 weeks). Habitat condition was noted to be impacted by scouring. When systems are impacted by high flows like this, it can take greater than six weeks for macroinvertebrate communities to recolonise the reaches (DNRM, 2001). *Note: macroinvertebrate data is not generally compared across seasons as significant differences between seasons is expected/predicted in mostmacroinvertebrate communities.*

The furthest downstream site MI-3 also recorded the lowest PET richness (number of Plecoptera, Ephemeroptera and Trichoptera families present; Figure 4), with sites MI-1 and MI-2 attaining an equal score of 5 for PET richness. PET richness from individual results at each site ranged from 0 to 6 (Figure 5). Similar to the total taxonomic richness results, the PET richness was found to be reduced at each site compared to last year's dry season results (Figure 4).

Similar to the October 2021 results, the SIGNAL index values as well as the percent tolerant and percent sensitive taxa values all found the upstream community of MI-1 to be more sensitive to environmental change than the downstream communities (Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 10 and Figure 11). These sensitivity indices suggest that releases from the barramundi farm may be influencing the downstream macroinvertebrate communities, increasing the dominance of families tolerant to environmental change downstream of the operations when compared to upstream.

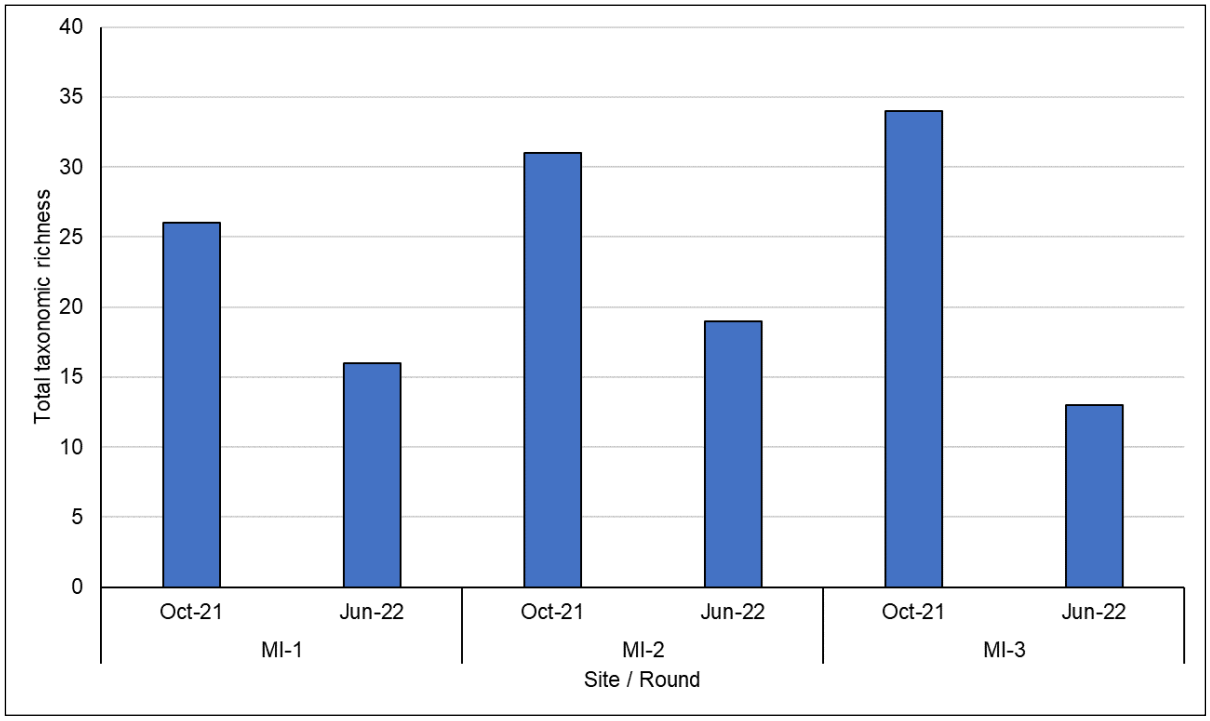


Figure 2: Total taxonomic richness recorded at each site compared to the 2021 dry seasonresults.

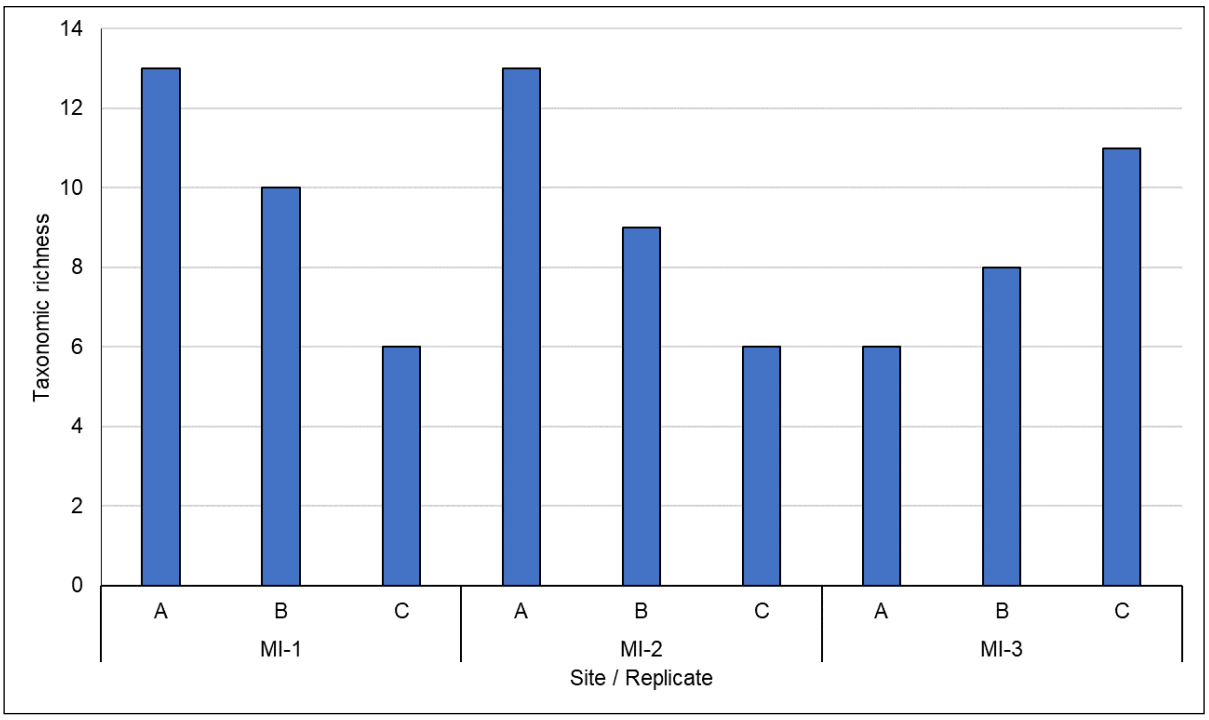


Figure 3: **Taxonomic richness recorded within each replicate in the bed habitat at each site.**

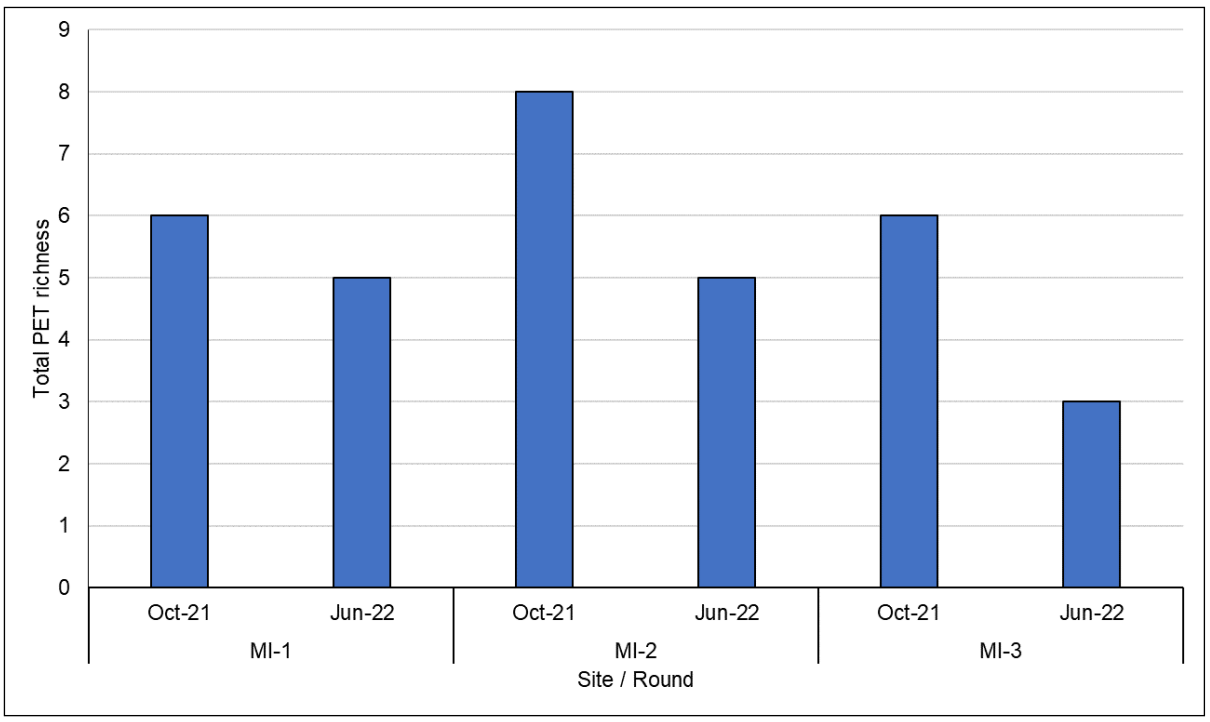


Figure 4: **Total PET richness recorded at each site compared to the 2021 dry season results.**

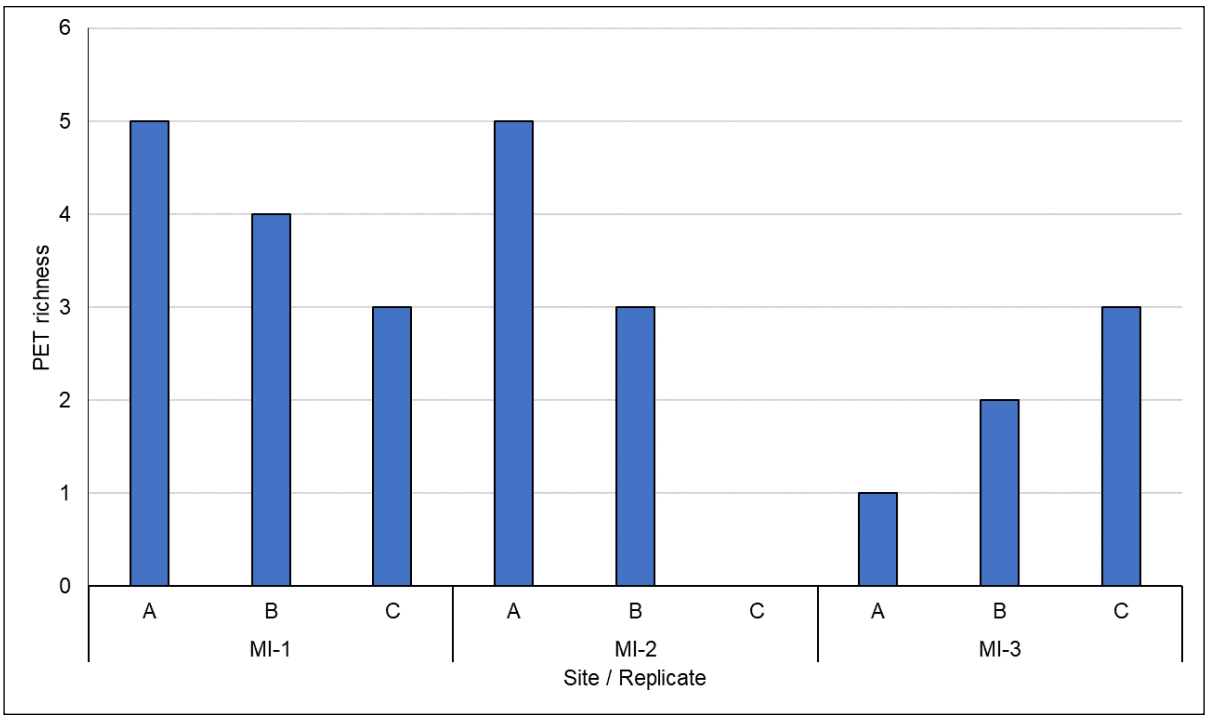


Figure 5: **PET richness recorded within each replicate in the bed habitat at each site.**

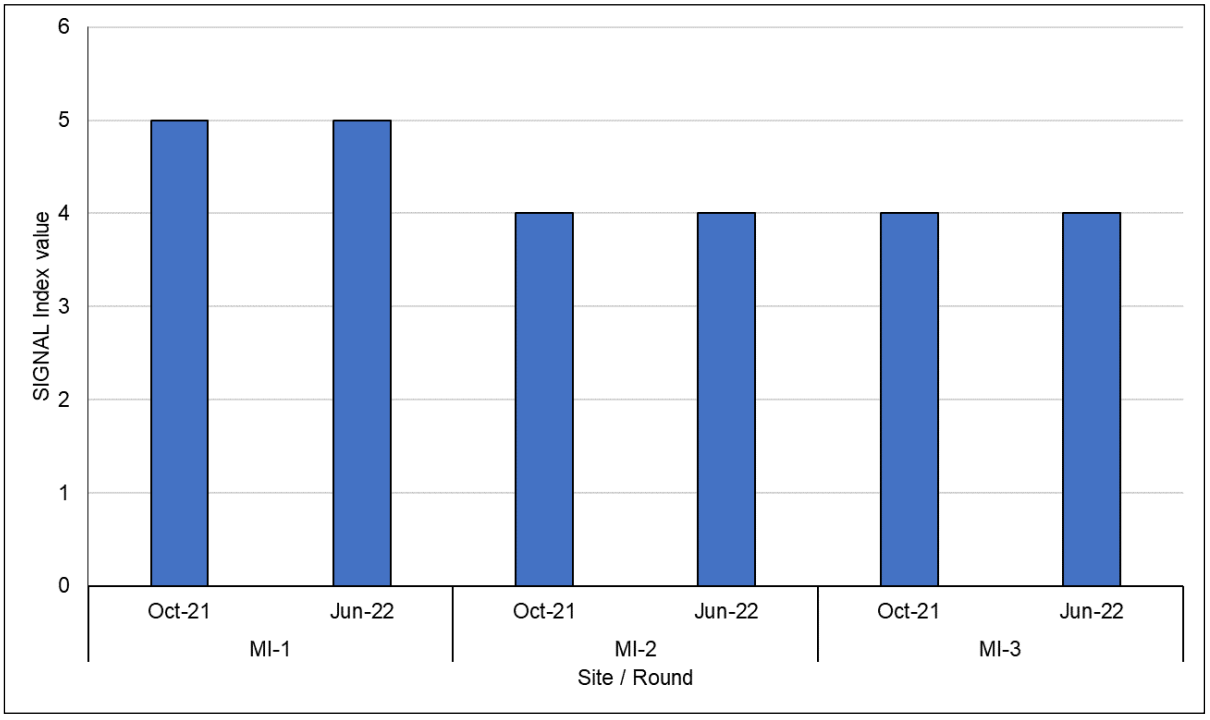


Figure 6: **SIGNAL index value calculated on the total taxonomic richness data from each sitecompared against the 2021 dry season results.**

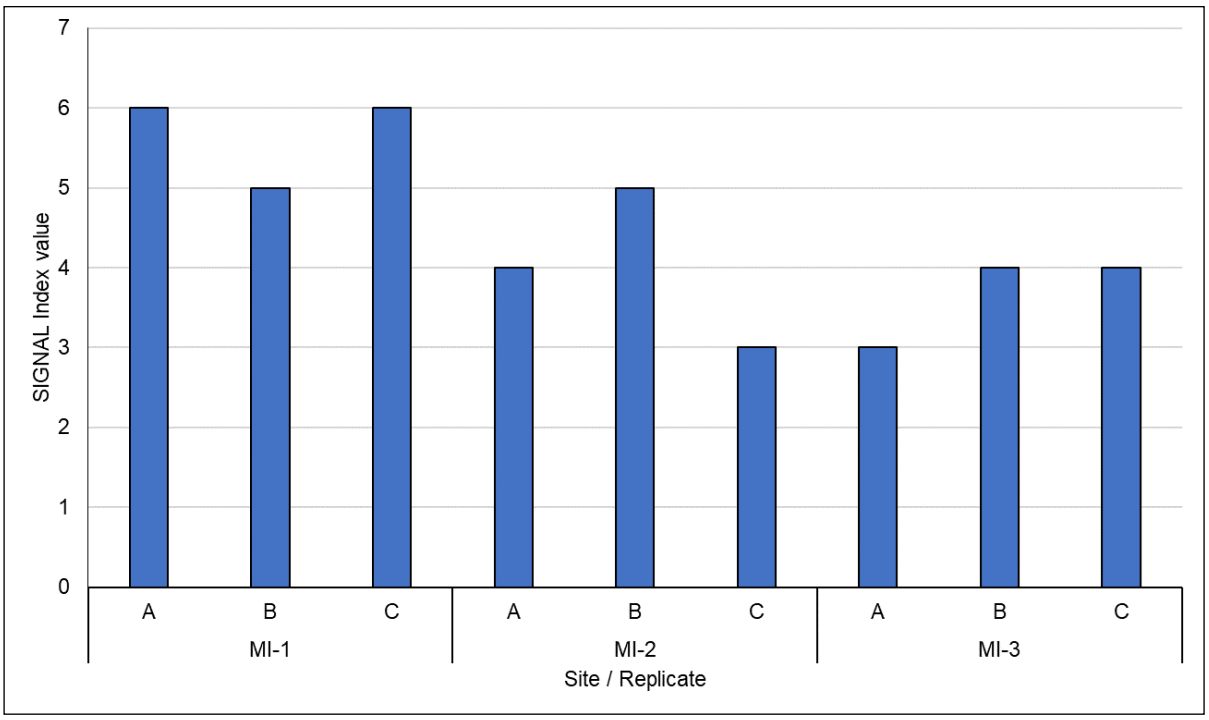


Figure 7: **SIGNAL index value recorded for each replicate at each site.**

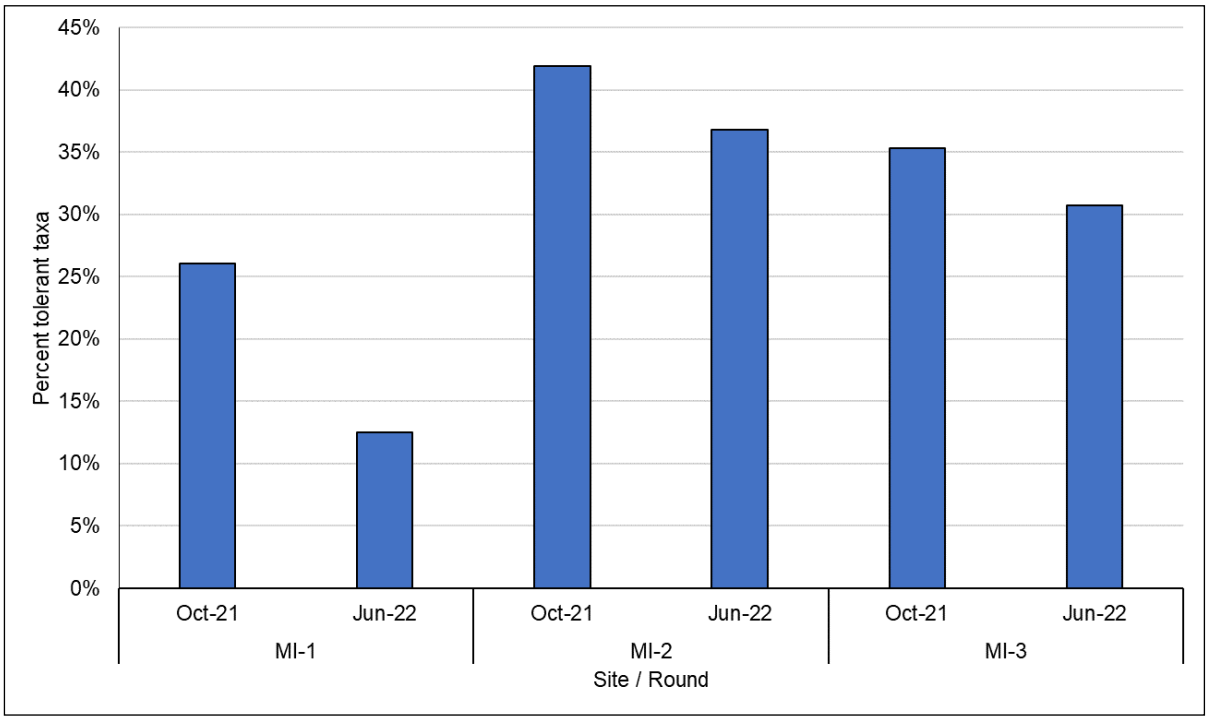


Figure 8: **Percent tolerant (i.e. SIGNAL grade ≤3) taxa calculated on the total taxonomicrichness data from each site compared against the 2021 dry season results.**

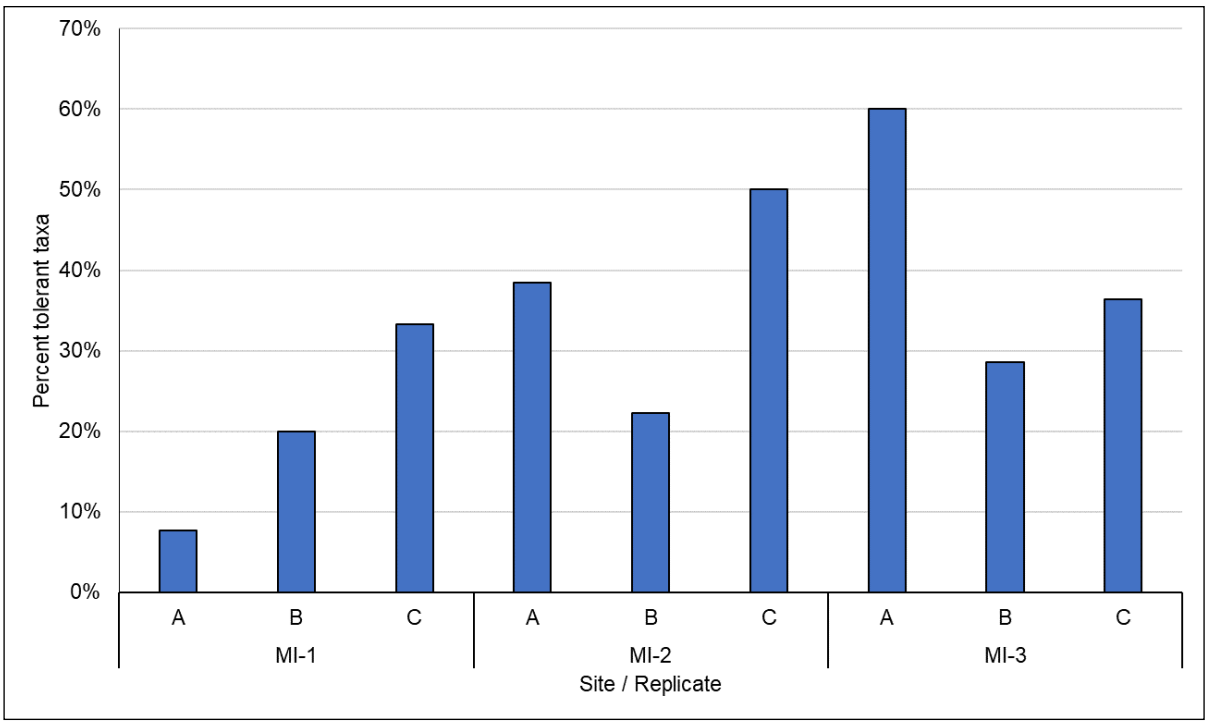


Figure 9: **Percent tolerant (i.e. SIGNAL grade ≤3) taxa within each replicate in the bed habitatat each site.**

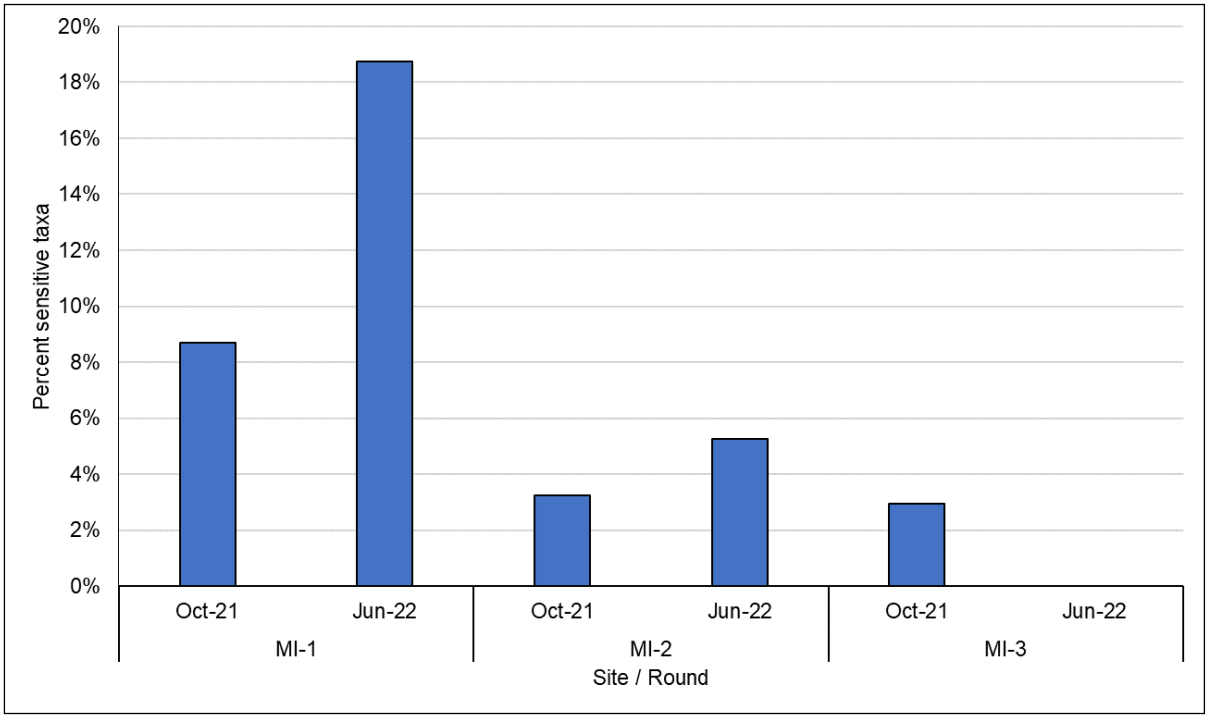


Figure 10: Percent sensitive (i.e. SIGNAL grade ≤8) taxa calculated on the total taxonomicrichness data from each site compared against the 2021 dry season results.

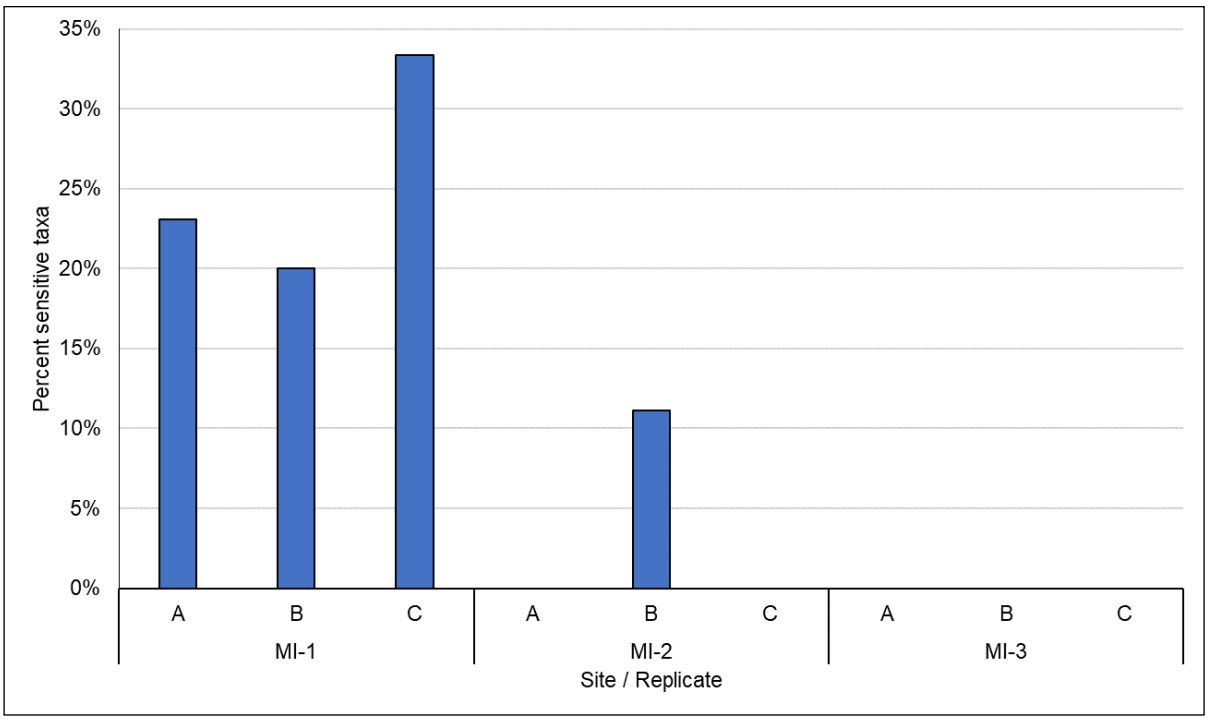


Figure 11: Percent sensitive (SIGNAL grade ≥8) taxa within each replicate of the bed habitatat each site.

An assessment of the macroinvertebrate data using the AusRivAS modelling program found the average condition of sites upstream of the barramundi farm's release points to be in better condition classed as 'Band B' (*Significantly impaired*) compared to downstream sites that averaged 'Band C' (*Severely impaired*; Table 2).

The bandwidth shows the range O/E score (50%) for each model output Band allocated (refer to Table 2). Band B has a bandwidth of 0.5 to 0.83, while Band C had a bandwidth of 0.17 to 0.5. When this bandwidth is compared to the results in Table 2, it can be seen that replicates MI-2(b) was at the high end of Band C (i.e. almost classed as Band B), while MI-3(a) was also at the upper end of Band D (i.e. almost classed as Band C). The remaining replicates from each site generally occurred within the mid-range of the band width, except for MI-2(c) which did not record any of the expected (with greater than 50% probability) taxa.

These results correlate with the other sensitivity indices in suggesting the downstream sites may be impacted (Table 2).

Table 2: Observed taxa results compared to those expected each site with greater than 50%probability of occurrence

Site/rep	Number of taxa collected (50%)	O/E score (50%)	O/E SIGNAL score (50%)	Band
MI-1 (a)	8	0.62	1.06	B
MI-1 (b)	7	0.54	0.99	B
MI-1 (c)	4	0.31	1.13	C
MI-2 (a)	4	0.31	1.03	C

Site/rep	Number of taxa collected (50%)	O/E score (50%)	O/E SIGNAL score (50%)	Band
MI-2 (b)	6	0.47	1.08	C
MI-2 (c)	0	0	0	D
MI-3 (a)	2	0.16	0.77	D
MI-3 (b)	3	0.25	0.77	C
MI-3 (c)	7	0.57	0.96	B

QA/QC of the laboratory identified taxa was undertaken in accordance with the relevant Queensland guidelines[2]. Ten percent of the samples identified were randomly selected for re-identification by a suitably qualified person. The ratio of taxonomic richness of the original identification compared to the QA identification was found to be 1, compliant with the guideline value of >0.90. Further, the number of correct identifications was found to be 97.5%, compliant with the guideline requirement of >90%. Based on these results, the macroinvertebrate samples meet all relevant QA/QC requirements.

The full set of raw macroinvertebrate data collected during the June 2022 sampling event is provided in Table 3.

If you have any questions regarding the outcomes of this assessment, please do not hesitate to contact me on the details below.

Regards,



Matt Knott

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Mob: 0431 558 675

[2] DES (2018). *Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual:Biological assessment.* The Department of Environment and Science, Queensland Government.

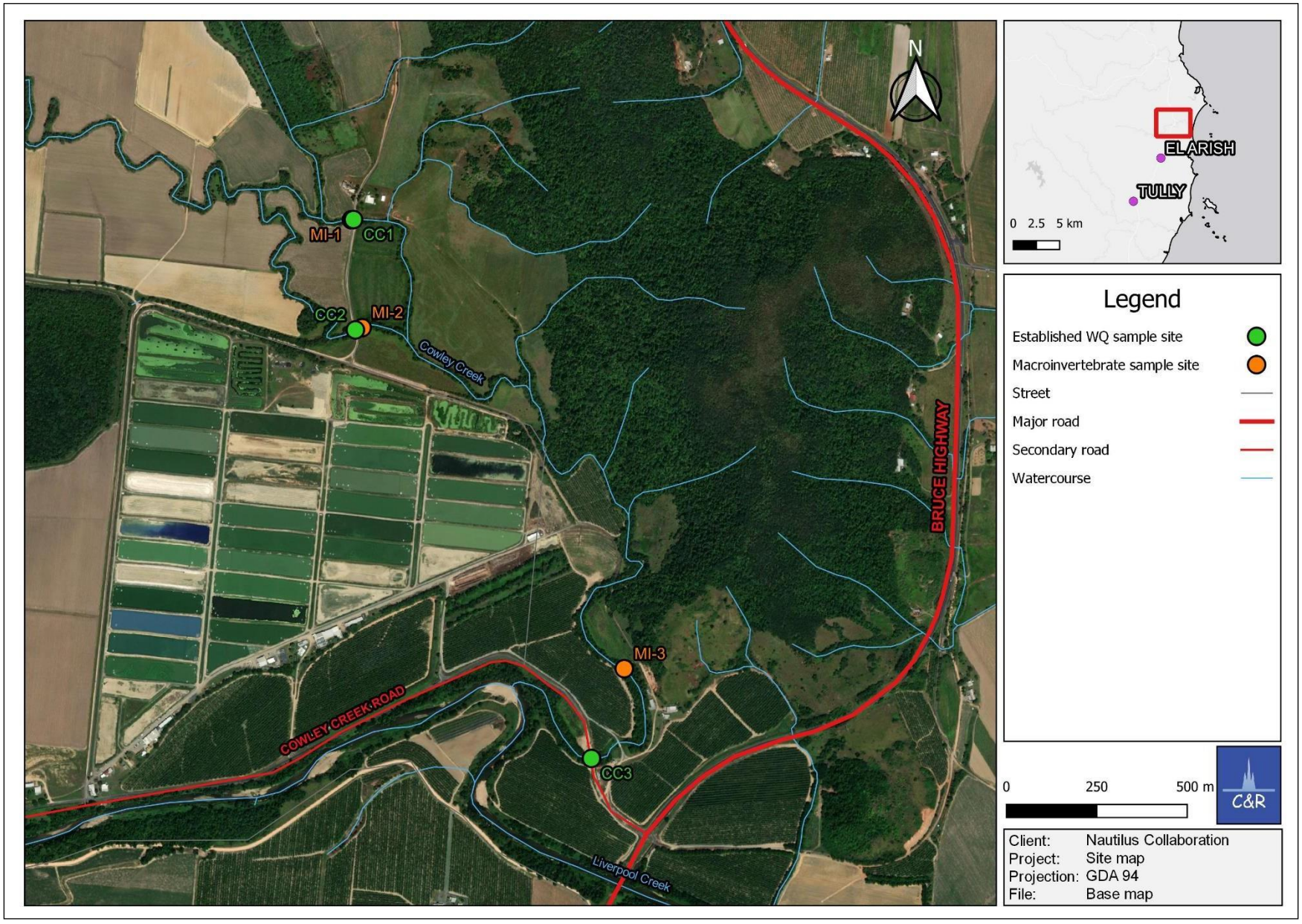

N
MI-1
CC1
CC2
MI-2
Cowley Creek
BRUCE HIGHWAY
MI-3
COWLEY CREEK ROAD
CC3
Liverpool Creek
ELARISH
TULLY
0 2.5 5 km
Legend
Established WQ sample site
Macroinvertebrate sample site
Street
Major road
Secondary road
Watercourse
0 250 500 m
C&R
Client: Nautilus Collaboration
Project: Site map
Projection: GDA 94
File: Base map

Figure 30: Site map

Table 12: June 2022 macroinvertebrate dataset

Order	Family	Sub-family	SIGNAL GRADE	MI-1(A)	MI-1(B)	MI-1(C)	MI-2(A)	MI-2(B)	MI-2(C)	MI-3(A)	MI-3(B)	MI-3(C)
Annelida	Oligochaeta		2		5	1	5	6	2	1	1	4
Hirudinea	Arhynchobdellida		4						1		1	
Cnidaria	Hydridae		2						1			
	Thiaridae		4	2	2		14	20	34	5	15	11
Ostracoda	Ostracoda		5.5				18	5	1		1	
Decapoda	Atyidae		3				3		1	1		1
Isopoda	Corallanidae		2				1					
Acarina	Hydracarina		6	3								1
Coleoptera	Dytiscidae		2									1
	Elmidae		7	3	11	1		4				1
Diptera	Ceratopogonidae		4	1								
	Chironomidae	Chironominae	3	2	5	1		2		1	2	1
		Orthocladiinae	4		1							1
		Tanypodiinae	4		1			1				
Ephemeroptera	Baetidae		5	32	40	64	4	2		8	3	29
	Caenidae		4	1	1		1				1	1
	Leptophlebiidae		8	6	1	1		3				
Hemiptera	Gelastocoridae		5	1								
Neuroptera	Nevrorthidae		9	1								
Odonata	Libellulidae		4	1								
	Lindeniidae		3				1					
Zygoptera	Coenagrionidae		2				3					
	Platycnemidae		4				1					

Plecoptera	Gripopterygidae		8	7	1	1						
	Calamoceratidae		7									
	Calocidae		9									
	Conoesucidae		7									
Trichoptera	Ecnomidae		4				1					
	Hydropsychidae		6	3			1	1				
	Hydroptilidae		4									
	Leptoceridae		6				1					1

Order	**Family**	**Sub-family**	**SIGNAL GRADE**	**MI-1(A)**	**MI-1(B)**	**MI-1(C)**	**MI-2(A)**	**MI-2(B)**	**MI-2(C)**	**MI-3(A)**	**MI-3(B)**	**MI-3(C)**
Other												
Diptera	Chironomidae (damaged orpupa)^									1	3	
Diptera	terrestrial (wings)^				1	1						
Coleoptera	terrestrial (wings)^									1		
Arachnida	terrestrial spider^					1						
Trichoptera	Empty sand/veg case						1			1		

^ excluded form richness and abundance

* excluded from richness only

Appendix 4 – Quality Control and Quality Assurance

Quality Control and Quality Assurance

Methods

Quality assurance and quality control procedures are necessary to ensure that samples and monitoring data are collected in a scientifically robust manner.

Field QA/ QC

Quality assurance and quality control measures should be generally in accordance with the DES Monitoring and Sampling Manual (DES 2018) and Australian Standard for water quality sampling – AS/NZS 5667.1:199812. The following specific methods shall be employed during field sampling to ensure quality assurance and quality control (QA/QC) measures are correctly implemented.

(1) sampling will be conducted by suitably qualified and experienced environmental staff who are competent in sampling and making field measurements (e.g. experience undertaking field tests);

(2) prior to sampling, sample containers (if reused) and equipment will be cleaned;

(3) all equipment and field instruments will be appropriately maintained, with calibrations and preventative maintenance recorded;

(4) samples will be collected in appropriately clean, pre-treated (if required), and labelled sample containers that are provided by the analytical laboratory;

(5) during field sampling, the following information will be recorded: (a) sample number; (b) sample site; (c) sample technique; (d) time; (e) weather; (f) any issues with sample; (g) any potential contamination; (h) sample date; and (i) technician.

(6) transportation of samples will occur under a chain of custody (COC) documentation procedure;

(7) COC forms that list all sample numbers and locations will accompany each sample to the laboratory.

Samples are to be checked against the COC forms at each stage of handling;

(1) Where sample holding times are breached, these instances will be documented.

Field quality control samples

Replicates, and quality control samples will be collected in accordance with the Australian Standard for water quality sampling – AS/NZS 5667.1:1998.

Field replicate

A field replicate will be collected for every 10 samples per field collection. These samples assist in the determination of sample variability, which includes environmental heterogeneity, sampling error/ contamination and laboratory analytical errors. However, a dynamic environment is expected to show a varying degree of natural environmental heterogeneity.

Sample contamination blanks

Field and laboratory blanks will be collected with each sampling round to assess sample contamination that may occur during the collection, transportation, or storage of the sample. If sample contamination is identified, additional sample contamination assessment will be conducted. These

samples consist of pure or ultrapure water (e.g., Milli-Q) added to each sampling container in a controlled environment (laboratory blank) and during field sampling (field blank).

Laboratory QA/ QC

Samples were submitted to a NATA accredited laboratory or a laboratory of equivalent qualification for analysis. All samples will be analysed in accordance with relevant the NATA (or equivalent) standards, and the laboratory's internal QA/QC procedures.

Results

Laboratory and field blanks showed that lab and field-sourced contamination was minimal throughout the reporting period. There were some low levels of ammonia detected in both lab and field blanks throughout the reporting period. With the exception of these samples, and low levels of BOD detected in some samples, the majority of blanks contained undetectable levels of each analyte (**Table 13**). As expected, field replicates showed some inherent variability between sample and replicate, however most analytes showed the same or similar values (Figure 31).

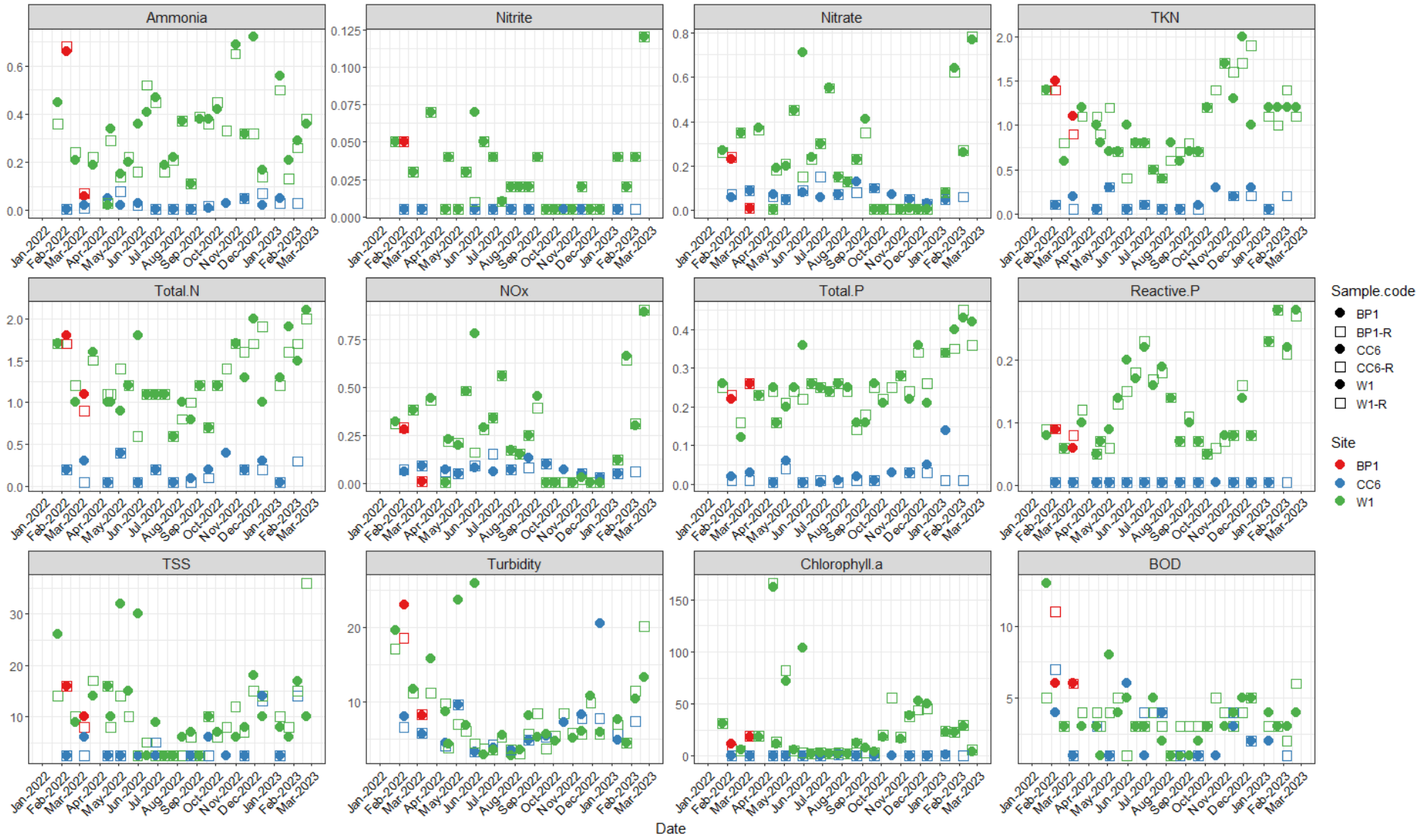


Figure 31 Field replicates (open square) and their corresponding samples (closed circles) for each lab analyte.

Table 13. Analytical results for laboratory blanks and field blanks.

Sample date	Sample type	Report Date	Report No	TSS	Turbidity	Ammonia	Nitrite	Nitrate	NOx	TKN	Total.N	Total.P	Reactive.P	BOD
11/01/2022	Field blank	25/01/2022	ET2200139	<5	0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
11/01/2022	Field blank	25/01/2022	ET2200139	<5	0.1	<0.01	<0.01	0.01	0.01	<0.1	<0.1	<0.01	<0.01	<2
11/01/2022	Lab blank	25/01/2022	ET2200139	<5	<0.1	<0.01	<0.01	0.03	0.03	<0.1	<0.1	<0.01	<0.01	<2
25/01/2022	Field blank	3/02/2022	ET2200471	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
25/01/2022	Lab blank	3/02/2022	ET2200471	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
8/02/2022	Field blank	18/02/2022	ET2200794	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	13
8/02/2022	Lab blank	18/02/2022	ET2200794	<5	<0.1	<0.01	<0.01	0.05	0.05	<0.1	<0.1	<0.01	<0.01	9
22/02/2022	Field blank	7/03/2022	ET2201098	<5	<0.1	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
22/02/2022	Lab blank	7/03/2022	ET2201098	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
8/03/2022	Field blank	17/03/2022	ET2201406	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
8/03/2022	Lab blank	17/03/2022	ET2201406	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
22/03/2022	Field blank	31/03/2022	ET2201648	<5	<0.1	0.05	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
22/03/2022	Lab blank	31/03/2022	ET2201648	<5	<0.1	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
14/04/2022	Field blank	5/04/2022	ET2201897	<5	<0.1	0.04	<0.01	0.02	0.02	<0.1	<0.1	<0.01	<0.01	<2
14/04/2022	Lab blank	5/04/2022	ET2201897	<5	<0.1	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
19/04/2022	Field blank	4/05/2022	ET2202136	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	0.01	<2
19/04/2022	Lab blank	4/05/2022	ET2202136	<5	<0.1	0.06	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
4/05/2022	Field blank	19/05/2022	ET2202452	<5	0.2	0.05	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	2
4/05/2022	Lab blank	19/05/2022	ET2202452	<5	0.6	0.12	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	3
17/05/2022	Field blank	27/05/2022	ET2202755	<5	<0.1	0.05	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	2
17/05/2022	Lab blank	27/05/2022	ET2202755	<5	<0.1	0.17	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.01	2
31/05/2022	Field blank	13/06/2022	ET2203019	<5	<0.1	<0.01	<0.01	0.04	0.04	<0.1	<0.1	<0.01	<0.01	<2
31/05/2022	Lab blank	13/06/2022	ET2203019	<5	<0.1	0.02	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
14/06/2022	Field blank	24/06/2022	ET2203231	<5	0.2	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
14/06/2022	Lab blank	24/06/2022	ET2203231	<5	0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
28/06/2022	Field blank	11/07/2022	ET2203515	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
28/06/2022	Lab blank	11/07/2022	ET2203515	<5	<0.1	0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2

9/08/2022	Field blank	18/08/2022	ET2204250	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
9/08/2022	Lab blank	18/08/2022	ET2204250	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
12/07/2022	Lab blank	20/07/2022	ET2203747	<5	0.2	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
12/07/2022	Field blank	20/07/2022	ET2203747	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
26/07/2022	Field blank	3/08/2022	ET2204013	<5	0.4	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	3
26/07/2022	Lab blank	3/08/2022	ET2204013	<5	0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
23/08/2022	Field blank	1/09/2022	ET2204535	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
23/08/2022	Lab blank	1/09/2022	ET2204535	<5	0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
6/09/2022	Field blank	15/09/2022	ET2204747	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	4
6/09/2022	Lab blank	15/09/2022	ET2204747	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
20/09/2022	Field blank	4/10/2022	ET2204982	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	4
20/09/2022	Lab blank	4/10/2022	ET2204982	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	4
4/10/2022	Field blank	13/10/2022	ET2205171	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
4/10/2022	Lab blank	13/10/2022	ET2205171	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
18/10/2022	Field blank	28/10/2022	ET2205450	<5	0.4	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	3
18/10/2022	Lab blank	28/10/2022	ET2205450	<5	0.3	0.06	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	2
1/11/2022	Field blank	9/11/2022	ET2205705	<5	<0.1	0.07	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
1/11/2022	Lab blank	9/11/2022	ET2205705	<5	<0.1	0.08	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	3
15/11/2022	Field blank	25/11/2022	ET2205977	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
15/11/2022	Lab blank	25/11/2022	ET2205977	<5	<0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
29/11/2022	Field blank	8/12/2022	ET2206270	<5	0.2	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
29/11/2022	Lab blank	8/12/2022	ET2206270	<5	0.1	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
13/12/2022	Field blank	22/12/2022	ET2206602	<5	<0.1	0.05	<0.01	0.02	0.02	0.1	0.1	0.02	<0.01	<2
13/12/2022	Lab blank	22/12/2022	ET2206602	<5	<0.1	0.05	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.01	<2
10/01/2023	Field blank	19/01/2023	ET2300117	<5	0.3	0.08	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
10/01/2023	Lab blank	19/01/2023	ET2300117	<5	0.4	0.05	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
24/01/2023	Field blank	6/02/2023	ET2300377	<5	0.3	0.08	<0.01	0.01	0.01	<0.1	<0.1	<0.01	<0.01	<2
24/01/2023	Lab blank	6/02/2023	ET2300377	<5	0.4	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
21/02/2023	Field blank	2/03/2023	ET2300996	<5	<0.1	0.04	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
21/02/2023	Lab blank	2/03/2023	ET2300996	<5	<0.1	0.03	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2

7/02/2023	Field blank	23/02/2023	ET2300660	<5	0.4	0.06	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01	<2
7/02/2023	Lab blank	23/02/2023	ET2300660	<5	0.3	0.05	<0.01	<0.01	<0.01	0.2	0.2	<0.01	<0.01	<2

Appendix 5 – Water Quality Management Plan

Water Quality Management Plan

Sealord King Reef Pty Ltd

Cowley Creek farm operation

Lot/Plan: 1/RP721954; 2/CP886368; 1/NR5347; and 295/RP814124
Environmental authority (EA): EPPR00390913

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1 Background

Sealord King Reef Pty Ltd (SKR) currently owns and operates Sealord's Barramundi Aquaculture Operations located on Cowley Creek Road and an additional nursery facility on Bruce Highway. The farm was issued an Environmental Authority (EA) EPPR00390913, which authorises the operation and maintenance of:

1. Twenty (20) nursery ponds with a total combined area of not more than 2.25 hectares, for the production of barramundi fingerlings;
2. Forty-three (43) barramundi grow out ponds with a total combined area of not more than 38.5 hectares for the production of barramundi; and
3. An on-farm wastewater retention and treatment system consisting of at least four (4) settlement ponds with a total combined area of not less than 5.7 ha associated with the **Cowley Creek Road location**, and:
4. Operation of not more than eight (8) barramundi ponds, and a hatchery and rearing facility having a combined area of not greater than seventeen (17) hectares associated with the **Bruce Highway facility**.

2 Purpose

The purpose of this plan is to outline the water quality (WQ) procedures that the farm implements to manage water quality within the farm and at discharge. By effectively monitoring the water quality in and around SKR's farm operation at Cowley Creek, risks to fish health and the receiving environment can be mitigated. This plan is an important component of SKRs Environmental Management System and falls under the farms environmental management planning.

3 Managing Water Quality

Water quality monitoring occurs at different spatial and temporal scales. This section of the plan outlines these scales and the associated water quality monitoring programs (see **Table 4**).

3.1 Daily and monthly water quality monitoring on farm

Daily monitoring of the operation's waters is two-fold, it acts as a preventative measure for understanding pond health/health of the pond system and how the physicochemical and nutrients all interact with one another to influence water quality which can impact the health and welfare of the farmed barramundi. Understanding the water quality on a daily basis can also help the farm manage for any impacts at discharge, especially in the bioremediation system prior to release.

Sealord King Reef has a daily water quality monitoring program which entails frequent monitoring of dissolved-oxygen, pH and daily volume, released from discharge point W1 and W2. Monitoring is undertaken by using a handheld YSI meter, a multiparameter measuring instrument which is calibrated according to manufacturer's instructions (calibration with each use)

For monthly monitoring, which is a licence requirement, total suspended solids, turbidity, Ammonia as N, Nitrite as N, Nitrate as N, NOx, Total Kjeldahl Nitrogen, TKN+NOx, Reactive Phosphorous, Total Phosphorus, Biochemical oxygen demand, chlorophyll-*a* and Cyanophytes are measured at discharge point W1 and W2. Water samples are collected and sent for analyses of these nutrients at ALS laboratory in Townsville, QLD, a third-party independent NATA accredited laboratory.

All results are kept on file and any exceeding that of the licence from the discharge points are reported to the DES following the *SKREM2 - Environmental Incident Notification and Reporting Procedure*.

3.2 Monitoring of the Receiving Environment (Cowley Creek and Liverpool Creek)

A revised *Receiving Environment Monitoring Program* (REMP) was developed and implemented in 2020. The aim of the program is to determine and understand the extent and concentration of potential impacts relating to the operation of SKR's facilities to ensure that environmental values of the receiving environment are protected and maintained.

Water quality is monitored monthly at three (3) control sites (two at Cowley Creek and one at Liverpool Creek) and four (4) impact sites (two sites for each creek). Temperature, pH, conductivity, dissolved oxygen, turbidity, Chlorophyll-a, total suspended solids, total Kjeldahl nitrogen, total nitrogen, and total phosphorus are monitored at these sites (**Figure 1**).

In addition to this, macroinvertebrates are surveyed on a biannual basis (i.e., 6 monthly) at three sites (one control and two impact sites) at Cowley Creek (**Figure 1**).

3.3 Additional Monitoring Required by the Environmental Evaluation Notice

Additional monitoring has been and are currently undertaken as required by the Environmental Evaluation (EE) Notice issued by DES. Three sites (one upstream and two downstream) were added in addition to the REMP sites, to increase spatial coverage and meet the requirements of the EE notice.

The production ponds and the bioremediation ponds, associated with discharge point W1 and W2 the bioremediation systems, were also monitored (**Figure 1**).

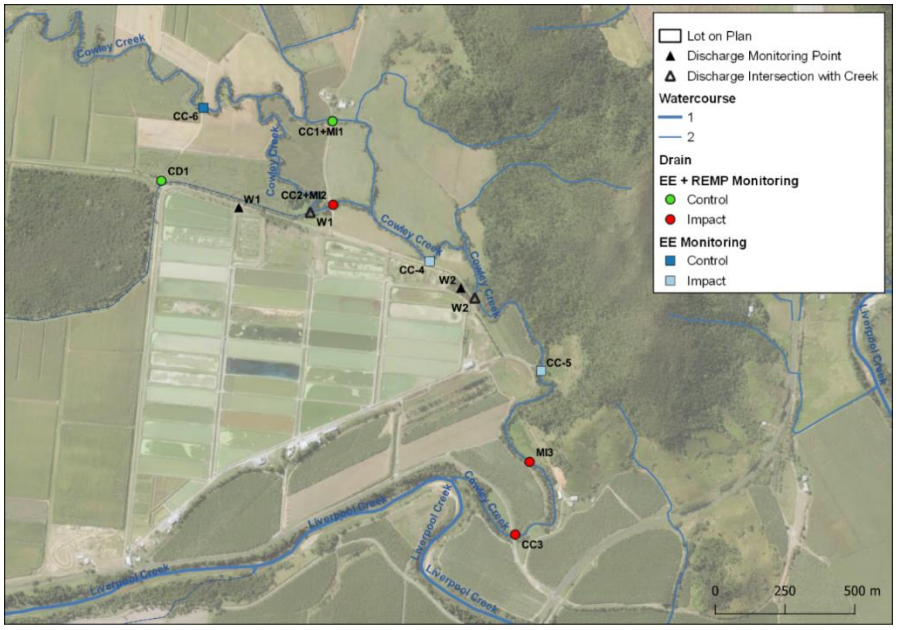


Figure 1. Environmental Evaluation (EE) and REMP monitoring sites at SKR farm operation at Cowley Creek

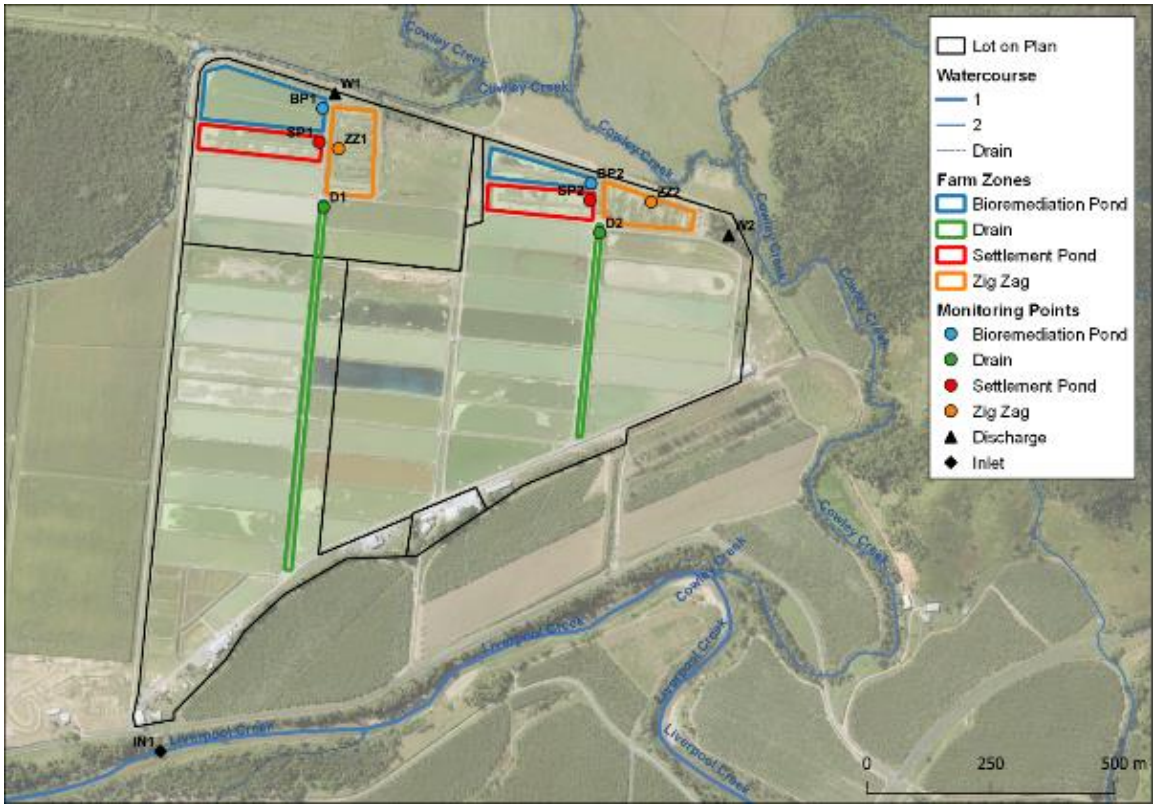


Figure 2. Figure Schematic of fortnightly monitoring on farm monitoring sites

Bioremediation System 1:

Production ponds (C & D row) → Drain 1 (D1) → Zig-zag 1 (ZZ-1: two sections only) → Settlement pond 1 (SP1) → Bioremediation pond 1 (BP1) → Zig-zag 1 (ZZ-1) → Discharge 1 (W1)

Bioremediation System 2:


Production ponds
(A & B row)
Drain 2
(D2)
Settlement pond 2
(SP2)
Bioremediation
pond 2 (BP2)
Zig-zag 2 (ZZ-2)
Discharge 2 (W2)

3.4 Additional monitoring

SKR takes photos of discharge and intake areas every six months to get a catalogue of visual data ensuring erosion, weeds and surrounding environment are all improving or without negative impact (Environmental Management Plan). Additional monitoring is also required when the farm may experience algal issues or ay fish health issues, such monitoring includes physicochemical and nutrient in addition to algal sampling of ponds, increase and frequency is at company discretion and in consultation with experts as required e.g. company veterinarian.

4 Staff Training

Training is one of the most important components to managing water quality at SKR. Sealord King Reef has a written procedure for checking water quality on a daily and monthly basis (*054 - SOP Water Quality Monitoring and Sampling*) and recording the results in a diary before being transferred into the farms online records. The Farm Manager, Fish Health & WQ Co-ordinator and Feed Team leader train staff to do daily water quality checks which are then signed off as competent and this is evidenced in the staff training matrix. Due to some testing errors and trouble sourcing equipment/materials, some testing that was performed in house is now being sent for analysis at ALS, this is consistent with samples taken from Control and Impact sites off the farm. (REMP and discharge point).

Farm staff will attend special training sessions on identifying algae where applicable but currently training is in-house. Identifying phytoplankton can be difficult, so when necessary samples are sent to Analytical Services Tasmania (AST) for accurate identification.

5 Measures

In the event of water quality problems SKR will take practical mitigation measures such as:

- Stop feeding if dissolved oxygen, temperatures and salinity are too high or too low and continue to monitor until these parameters return to an acceptable level;
- Elevated ammonia levels in pond are managed both pro and re-actively through water exchange levels and the addition of molasses.
- If the event is broadscale, then seek expert advice and continue to monitor; and
- In case of any emergencies or incidents which results in or are reasonable expected to result in an exceedance of the conditions of the EA, must be reported to the administering authority (i.e., DES) (*SKREM2 - Environmental Incident Notification and Reporting Procedure*).

6 Risk Assessment

A risk assessment of the water quality impacts is required as a part o SKR environmental management system which supports the environmental management plan (see Table 2). The risk assessment is an important exercise which identifies what the risks to water quality are within the farm and onto receiving waters and how the farm manages for these to reduce impact. Recognising the environmental values of the surrounding catchment and the farm's role it plays in acting as a steward for water quality is a commitment SKR makes. Such values are described below and a formal risk assessment follows (Table 2).

6.1 Environmental values

6.1.1 Johnstone River Basin

The farm operation is located within the South Johnstone River sub-basin (sub-basin 1121) of the Johnstone River Basin (Basin 112). Locally relevant environmental values and water quality objectives have been set, as specified in Schedule 1 of the *Environmental Protection (Water and Wetland*

Biodiversity) Policy 2019 "Johnstone River Basin Environmental Values and Water Quality Objectives, Basin 112" (DES 2020).

The Environmental Values relevant to site are presented in **Table 1**.

Table 1. Relevant Environmental Values for site (adapted from DES 2020)

Environmental Values	Description.
Aquatic ecosystems:	The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas, for example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation:	Suitability of water supply for production of healthy livestock.
Farm Supply:	Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.
Aquaculture:	Health of aquaculture species and humans consuming aquatic foods (such as fish, molluscs and crustaceans) from commercial ventures.
Human consumer	Health of humans consuming aquatic foods, such as fish, crustaceans and shellfish from natural waterways. Note that in some areas oystering is a more specific goal identified under the human consumer environmental value.
Primary recreation:	Health of humans during recreation which involves direct contact and a high probability of water being swallowed, for examples, swimming, surfing, windsurfing, diving and waterskiing. Primary recreational use of water means full body contact with the water.
Secondary recreation:	Health of humans during recreation which involves indirect contact and a low probability of water being swallowed, for example, wading, boating, rowing and fishing. Secondary recreational use, of water, means contact other than full body contact with the water, for example, boating and fishing.
Visual recreation:	Amenity of waterways for recreation which does not involve any contact with water—for example, walking and picnicking adjacent to a waterway. Visual recreational use of water means viewing the water without contact with it.
Industrial Use:	Suitability of water supply for industrial use, for example, food, beverage, paper, petroleum and power industries, mining and minerals refining/ processing. Industries usually treat water supplies to meet their needs.
Cultural and spiritual values:	Indigenous and non-indigenous cultural heritage, for example: (1) custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities; (2) symbols, landmarks and icons (such as waterways, turtles and frogs); and (3) lifestyles (such as agriculture and fishing). Cultural and spiritual values, of water, means its aesthetic, historical, scientific, social or other significance, to the present generation or past or future generations.

Relevant water quality objectives for moderately disturbed surface fresh waters in developed areas of the Johnstone River Basin (DES 2020) to protect identified environmental values, have been adopted by the Receiving Environmental Monitoring Program (REMP) (**Table 2**).

According to DES *Technical guideline Wastewater release to Queensland waters* (DES Technical guideline), a "sustainable load of a particular contaminant is the maximum amount that a water body can receive without failing to meet the WQOs and therefore adversely affecting EVs. The concept of sustainable load is particularly important for oxygen demanding substances, nutrients, sediments and toxicants". Furthermore ,"for wastewater release to slightly-to-moderately disturbed (SMD) receiving waters: either maintain (use some assimilative capacity) or improve (over time)".

Table 2. Water quality objectives for moderately disturbed surface fresh waters in developed areas of the Johnstone River Basin under baseflow conditions (adapted from Table 2.1, DES 2020)

Water Quality Indicator	Units	Objectives[%]
Physico-chemical		
Dissolved Oxygen	% Saturation	85–120*
pH		6.0–8.0*
Nutrients		
Ammonia Nitrogen	µg/L	<10[#]
Oxidised Nitrogen	µg/L	<50[#]
Total Nitrogen	µg/L	<340[#]
Filterable Reactive Phosphorous	µg/L	<8[#]
Total Phosphorous	µg/L	<25[#]
Algal Growth		
Chlorophyll *a*	µg/L	<1.5*
Water Clarity		
Turbidity	NTU	<15*
Total Suspended Solids	mg/L	<8[#]

*Queensland Water Quality Guidelines 2009.

[#]Analysis of DSITIA water quality monitoring data and Great Barrier Reef Catchment Loads Mon

[%]Water quality objectives shown as 20th, 50th and 80th percentiles (i.e. 3-4-5) or as a single valu and pH may be shown as a range of 20th and 80th percentiles (i.e. 85–105).

6.1.2 Matters of State Environmental Significance

Matters of State Environmental Significance (MSES) in the vicinity of the SKR farm were mapped and reported by Wild Environmental Consultants in 2020, during the design of the ongoing REMP. The assessment identified a range of regulated communities and habitat, wildlife habitat and wetlands around the SKR. The waterways of Cowley Creek and Liverpool Creek are fringed with regulated vegetation (Category R, GBR Riverine). This is likely to be the most directly impacted component of the MSES in the vicinity of the SKR Barramundi Farm **Figure 3**.

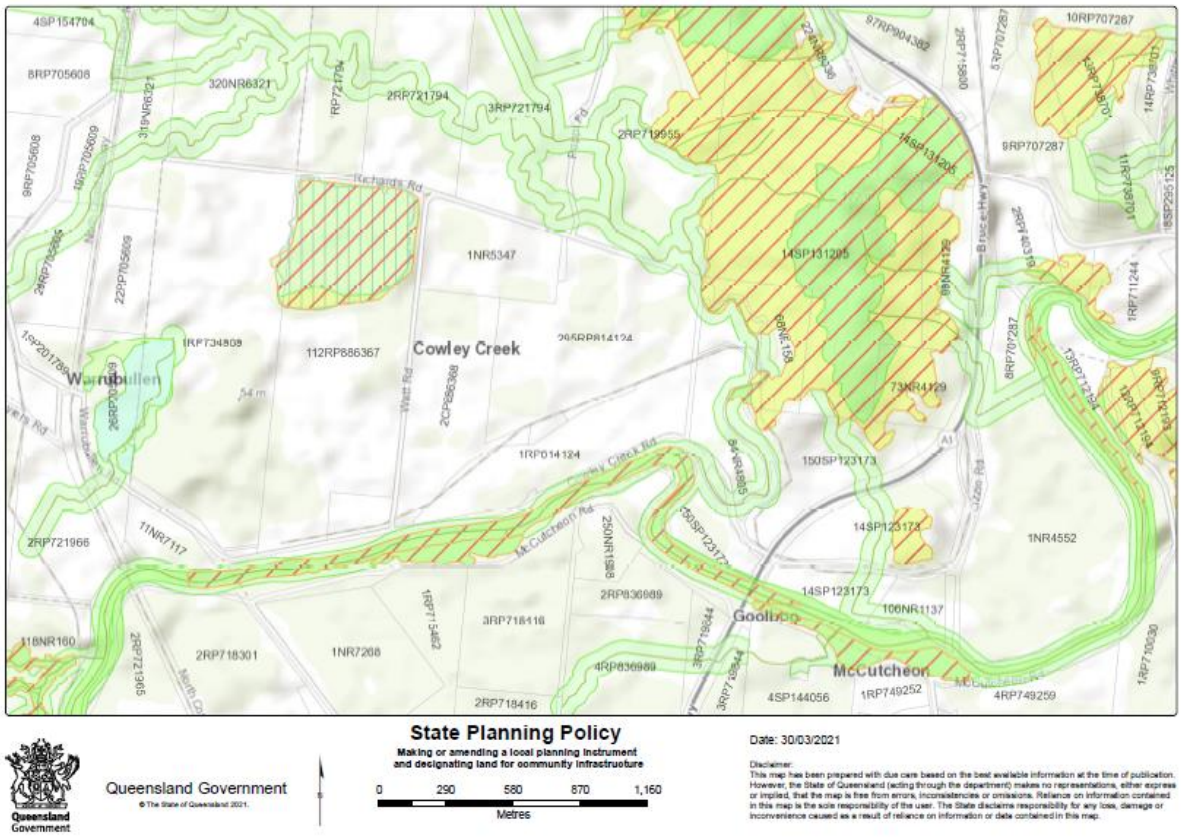


Figure 3. Matters of State Environmental Significance (MSES) in the vicinity of the Cowley Creek SKR Barramundi Farm (State Planning's online tool) (March 2021)

6.2 Mitigation of Risk

The farm manages the potential impacts by regularly monitoring of water quality and quantity as well as benthic macroinvertebrate monitoring at Cowley Creek in line with EA requirements (**Table 4**). Operational procedures (**Table 3**) and an Environmental Management Plan have been developed and implemented to mitigate risk for environmental harm. SKR facilities have also been independently certified by the Best Aquaculture Practices (BAP).

Table 3. List of procedures developed and implemented at site

SOP Number	Description
002	SOP Chemical Treatment of Ponds Potassium Permanganate (Condies)
005	SOP for Applying Molasses to Ponds
008	SOP for Loading Feed into Feed Hoppers
010	SOP for Chemical Storage and Handling
011	SOP for Aerators and Paddlewheels
015	SOP Harvest
018	SOP for Using and Calibrating Thermometers
022	SOP for Cyclone Preparedness
036	SOP for Emergency Oxygen Crash
037	Fish Health Management Plan
039	SOP for Aeration Workshop
045	Our Environmental Responsibility – PowerPoint Presentation
049	SOP for Disinfection of Harvest Net and Mort Scoops

054	SOP Water Quality Monitoring and Sampling
059	SOP for Routine Dead Fish Collection
061	SOP for Pond Preparation
063	SOP Mixing Molasses from Shuttle

Applied consistently under close supervision of the Manager responsible, but not yet documented in SOPs, the following practices assist in maintaining good water quality on the farm:

- Significant tightening up and increased consistency in feed practices. This has been done through a reduction in feed crew size and increased focus of the farms feed team leader
- Implementation of a 60T maximum biomass per pond- demonstrated through harvest records over the last 12 months and production planning through to the end of 2024.
- Regular removal of Duckweed from the farms remediation systems. Ownership of this task is being transferred to the farms aeration co-ordinator
- Increased focus on operation and placement of aeration in the farms bio-remediation systems
- Application of EcoTabs™ to the Bioremediation system 1following the manufacturers recommendation.
- This trial was successful and is being extended to a production pond on a trial basis- if successful/economically viable it will be rolled out farm wide.
- Application of EcoTabs™
- Settlement pond health – Sludge reduction. In the AB remediation system this has been achieved with EcoTabs™, in the CD remediation system it is being achieved mechanically with an excavator. Wet weather has hampered Excavator operation, we are currently reviewing dredge options.
- Calibration of instruments

Table 4. Lists the programs which monitor WQ for SKR's farm operation at Cowley Creek

Monitoring Program	Requirement	Parameter measured	Frequency	Spatial Scale
Discharge points Daily	EA Part 2 condition C4, C5 and H7	Dissolved-oxygen, pH and daily volume	Daily monitoring	Discharge point W1 and W2
Discharge points Monthly	EA Part 2 condition H7	Total suspended solids, total nitrogen, chlorophyll-*a* and total phosphorous	Monthly monitoring	Discharge point W1 and W2
REMP	EA Part 2 condition H9	Temperature, pH, conductivity, dissolved oxygen, turbidity, Chlorophyll-a, total suspended solids, total Kjeldahl nitrogen, total nitrogen, and total phosphorus	Monthly monitoring	Cowley Creek and Liverpool Creek
REMP	EA Part 2 condition H8 and H9	Macroinvertebrates	Biannual (6 monthly)	Cowley Creek
EE notice		Dissolved oxygen, pH, conductivity, temperature, turbidity, total suspended solids, total nitrogen, NOx, ammonia, nitrate, nitrite, Total Kjeldahl Nitrogen, filterable reactive phosphorous, total	Fortnightly and monthly	Production ponds, Bioremediation ponds and Cowley Creek and Liverpool Creek

		phosphorous, biochemical oxygen demand, chlorophyll-*a* and Cyanophyte enumeration.		

6.2.1 Water Quality Risk Assessment

The following is a table outlining the risk to water quality within the farm and the receiving waters and how the water quality is managed to prevent any risk to the pond system and the receiving waters. A risk matrix to include environmental risks has been applied to calculating the WQ risk management. A residual risk rating is also calculated because this is an important step to identifying the effectiveness of on-farm management of water quality.

Permanent or long-term serious environmental harm / life threatening or long-term harm to health and wellbeing.	Consequence	Severe	Medium	High	High	Extreme	Extreme
Serious environment harm / high-level harm to health and wellbeing.		Major	Medium	Medium	High	High	Extreme
Medium level of harm to health and wellbeing or the environment over an extended period of time.		Moderate	Low	Medium	Medium	High	High
Low environmental impact / low potential for health and wellbeing impacts.		Minor	Low	Low	Medium	Medium	High
No or minimal environmental impact, or no health and wellbeing impacts.		Low	Low	Low	Low	Medium	Medium
			Rare	Unlikely	Possible	Likely	Certain
			Likelihood				
			Could happen but probably never will	Not likely to happen in normal circumst-ances	May happen at some time	Expected to happen at some time	Expected to happen regularly under normal circumst-ances

Description of risk ratings

Risk level	Description
Extreme	Totally unacceptable level of risk. Stop work and/or take action immediately.
High	Unacceptable level of risk. Controls must be put in place to reduce to lower levels.
Medium	Can be acceptable if controls are in place. Attempt to reduce to *low*.
Low	Acceptable level or risk. Attempt to eliminate risk but higher risk levels take priority.

Figure 4. Risk matrix and description of risk rating used in this repor*t*

Table 5. Risk assessment (including mitigation actions) for potential impacts to water quality.

Identification				Unmitigated Risk			Control Strategies	Residual Risk		
Hazard / Risk Event	**Relevant EV**	**Aspects / Risk factors to consider**	**Potential impact(s)**	**Pre-control Likelihood**	**Pre-control Consequence**	**Pre-control Risk Rating**	**Risk Minimisation / Mitigation Strategies and Additional Comments**	**Post- control Likelihood**	**Post-Control Consequence**	**Residual Risk Rating**
Poor water quality coming from W1 and W2	Water (section 6.1)	**Staff Training and Environmental Awareness** Risk factors: Poor training Degree of supervision, staff turnover and experience. Farm operations such as poor bioremediation or over feeding	Staff could cause incident leading to environmental harm. Staff may not recognise and report environmental harm Breach of licence conditions – loss of farming capacity	Likely	High	Moderate	Environmental awareness as part of company induction. Competency training sign off. Annual training refresher on environmental management plan. Important documents are posted in high staff traffic areas. Water quality monitoring programs (in-house and regulatory) Standard Operating Procedures	Unlikely	Medium	Moderate
Discharge infrastructure failure		**Unplanned discharge** Risk factors: Non-compliant discharge volumes Inaccurate discharge volume records Impact to river system	Environmental harm to receiving waters	Likely	High	Moderate	Maintenance program to ensure integrity of infrastructure Daily/weekly checks of infrastructure	Rare	Low	Moderate
Algal bloom		**Receiving waters and pond system** Risk factors: Management of water on farm and	Fish morbidity and/or mortality on farm Harm to the aquatic environment of the receiving waters	Possible	Medium	Moderate	Algal monitoring program Adequate bioremediation system	Unlikely	Low	Minor

		subsequent discharge water quality								
Cyclones		**Water addition and movement** Risk factors: Major flooding outside and inside farm, debris across area. **Altering water quality parameters such as conductivity and**	Fish escapes and debris into river basin and washed into ocean	Possible	Medium	Moderate	Farm wall above highest flood on record. Adjustable discharge levels to control outflow. Water management procedures include extreme weather events. Cyclone preparedness plan reviewed annually.	Unlikely	Low	Minor
Aerators		**Pump/aerator or power failure** Risk factors: Wastewater not meeting EA limits leading to environmental harm and fish kill.	Fish death High eutrophication/nutrification of the pond water	Likely	High	Major	Maintenance program to ensure integrity of aerators	Unlikely	High	Moderate
Overfeeding		**Excess nutrient input** Risk factors: Wastewater not meeting EA limits leading to environmental harm and fish kill.	Eutrophication of pond water Excessive nutrient input into pond leading to stress on bioremediation system	Likely	Medium	Moderate	Staff training and education on feeding fish	Unlikely	Medium	Moderate
Intake water		**Excess nutrient is intake water** Risk factors: Fish deaths and poor water quality	Fish deaths and pressure on pond system to treat excess nutrients. Stress on bioremediation system and potential licence breaches	Likely	High	Major	Water quality monitoring	Unlikely	High	Moderate

Reference

REMP - Receiving Environmental Monitoring Program design report, Wild Environmental Consultants 2020.

DES 2020 - Johnstone River Basin Environmental Values and Water Quality Objectives, DES October 2020

DES Technical guideline - Technical guideline Wastewater release to Queensland waters, ESR/2015/1654, Version 2.04, DES last reviewed April 2022