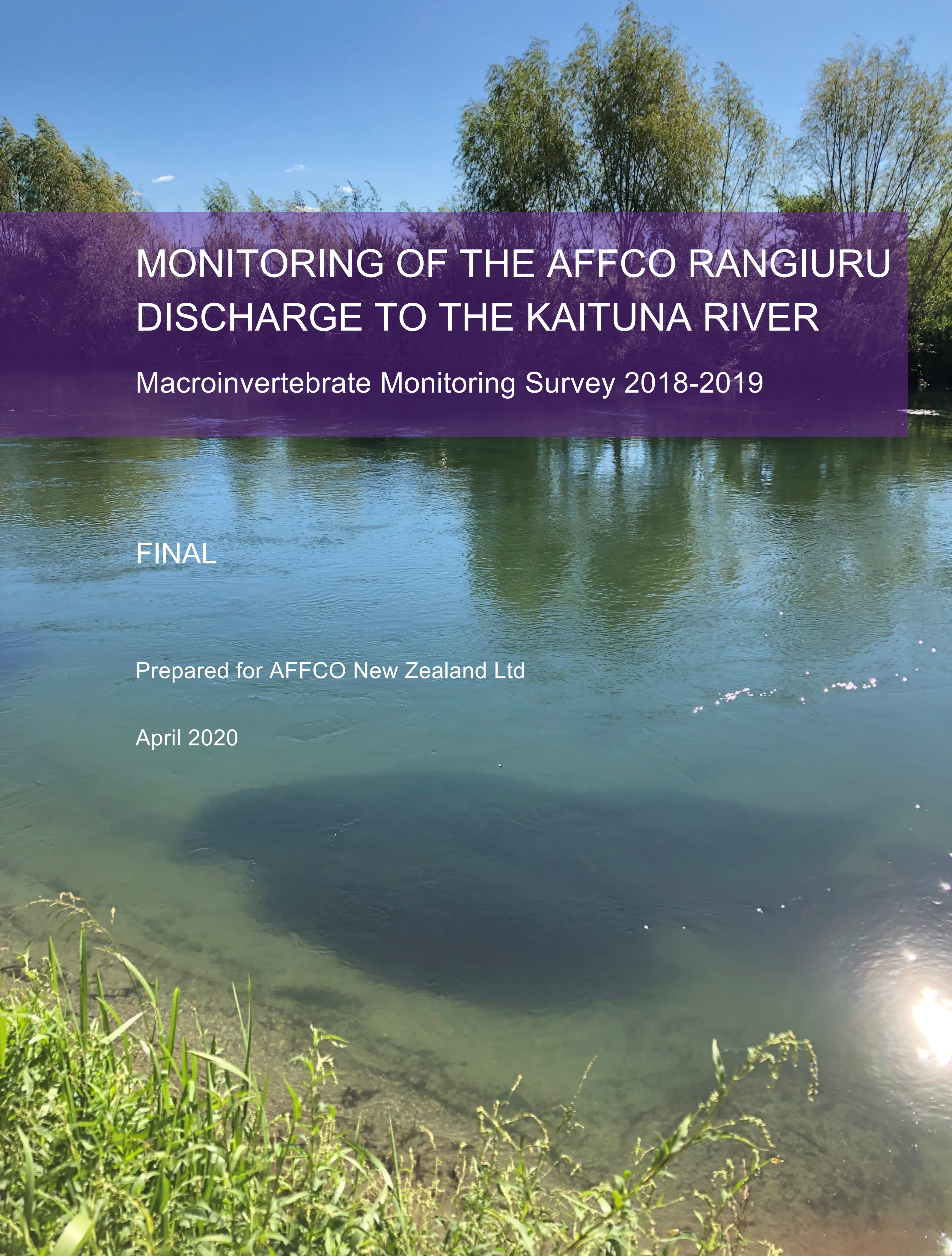

MONITORING OF THE AFFCO RANGIURU DISCHARGE TO THE KAITUNA RIVER

Macroinvertebrate Monitoring Survey 2018-2019

FINAL

Prepared for AFFCO New Zealand Ltd

April 2020

argoenvironmental

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By

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ENVIRONMENTAL CONSULTANTS

DOCUMENT REVISION SCHEDULE

Revision Status / Number	Revision Date	Description of Revision	Approved By
Rev0	July 2019	Draft	Luke Gowing (Director)
Rev1	April 2020	Final	Luke Gowing (Director)

Statement of Limitations

This report is not to be used for purposes other than those for which it was intended.

This document has been prepared based on site observations, assessments and data collection undertaken by Argo Environmental Ltd and the information provided by the Client regarding the activities associated with the proposed Project.

Environmental conditions change with time. Argo Environmental Ltd do not imply that the site conditions described in this report are representative of past or future conditions.

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EXECUTIVE SUMMARY

Aquatic macroinvertebrate surveys have been undertaken to supplement the AEE and consent application for the continuation of the treated wastewater discharge to the Kaituna River from the AFFCO Rangiuru facility, on the request of BoPRC.

These additional surveys, carried out between March 2018 to April 2019, focused on the macroinvertebrate assemblages within the Kaituna River directly upstream and downstream of the discharge, using artificial substrates. This work is not intended to be a standalone assessment on the ecological health of the Kaituna River, as the AEE sets out a more comprehensive assessment, based on a number of other ecological surveys that have already been undertaken in the Kaituna River associated with the discharge.

Overall, the results of these macroinvertebrate surveys indicate that the treated wastewater discharge from the AFFCO facility is currently resulting in a no more than minor adverse effect on the ecological health of the Kaituna River.

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1. Introduction

1.1 Background

AFFCO New Zealand Limited (AFFCO) submitted a resource consent application to Bay of Plenty Regional Council (BoPRC) in February 2017 for the continued discharge of treated wastewater from the Rangiuru meat processing facility into the Kaituna River, in advance of the expiring resource for the discharge (Consent No. 24932). Under Section 92 of the Resource Management Act 1991 (RMA) BoPRC requested that further aquatic ecological monitoring be undertaken by AFFCO to support the consent application.

Argo Environmental Limited (ARGO) were commissioned by AFFCO to undertake this additional monitoring, which includes further aquatic macroinvertebrate surveys which would then inform a further assessment of the effects of the discharge of treated wastewater from the AFFCO facility on the macroinvertebrate assemblages within the Kaituna River.

This additional macroinvertebrate survey work was undertaken over a 15-month period from January 2018 to April 2019. The scope of this survey was determined based on discussions between ARGO, acting on behalf of AFFCO, and BoPRC, as detailed in Section 2 of this Report.

1.2 Scope of Report

This Report describes a survey undertaken to provide further assessment of the effects of the discharge of treated wastewater from the AFFCO facility on the macroinvertebrate assemblages within the Kaituna River directly upstream and downstream of the point of discharge.

As broader aquatic ecology information on the effects of the discharge on the Kaituna River was assessed as part of the Assessment of Environmental Effects (AEE) (Argo, 2017) which supported the resource consent application, this additional survey work requested by BoPRC focuses specifically on aquatic macroinvertebrate communities to supplement previous studies undertaken in 2005 (Bioresearches), 2007, 2012 and 2016 (ARGO) related to the discharge to the River.

This Report presents the results of the January 2018 to April 2019 macroinvertebrate surveys undertaken to satisfy BoPRC request for further information to support the resource consent application.

2. Methodology

2.1 Sampling Site Locations and Dates

This survey included sampling sites both upstream and downstream of the point of discharge to the Kaituna River. The locations of the sampling sites are outlined in Table 2-1, and shown in Figure 2-1.

Table 2-1: Locations of macroinvertebrate sampling sites in the Kaituna River.

Site ID	Site Description	Location coordinates (NZTM)	
		Easting	Northing
US1	**Upstream Site 1:** Attached to a waratah installed in the river bank beneath a stand of willow trees, approximately 850 m upstream of the discharge point.	1897569	5811308
US2	**Upstream Site 2:** Attached to a floating pontoon for the intake structure, approximately 680 m upstream of the discharge point	1897627	5811471
DS1	**Downstream Site 1:** Attached to a branch of a willow tree, approximately 500 m downstream of the discharge point.	1896843	5811920
DS2	**Downstream Site 2:** Attached to a waratah installed in the river bank, approximately 1,150 m downstream of the discharge point.	1896741	5811865

All of the sites are located on the true right bank of the Kaituna River. The upstream and downstream sites closest to the discharge (US2 and DS1) were installed in January 2018 and sampled on eight occasions from March 2018 to April 2019. The additional sites (US1 and DS2) were included in January 2019, at the request of BoPRC (December 2018), and were sampled on two further occasions in March 2019 and April 2019.

The locations were selected following extensive reconnaissance of the River to determine the most stable and safely accessible sites. The direct downstream location selected (DS1), in particular, is the closest to the point of discharge where bank the banks are relatively stable and flat enough to allow a waratah to be installed.

At these locations, due to the lack of easily sampleable (e.g. wadable) instream habitat in the River, artificial substrates were installed as agreed with BoPRC. The artificial substrates, consist of 400 mm long (by 20 mm diameter) lengths of polyproplylene rope that float tied to submerged waratahs secured to the River bank (downstream site) and the water intake structure (upstream site). Photographs of the artificial substrates at each site are provided in Figure 2-2 to Figure 2-5.

It was originally envisaged that these ropes would be attached to concrete pavers as has been traditionally used. However, the ropes attached to pavers and placed in the River in November 2017 were lost as a result of the large flood event that occurred in late December 2017. To ensure security of the ropes it was decided that they would be attached to waratahs installed in the stream bank, and in the case of US2 to the intake structure (floating pontoon) and DS1 attached to a branch of a willow tree.

Figure 2-1: Location of macroinvertebrate sampling sites

Figure 2-2: US1 – artificial substrate attached to waratah installed in river bank.

Figure 2-3: US2 – artificial substrate attached to floating ponton for intake structure at closest upstream site.

Figure 2-4: DS1 – artificial substrate attached to branch of willow tree at closest downstream site.

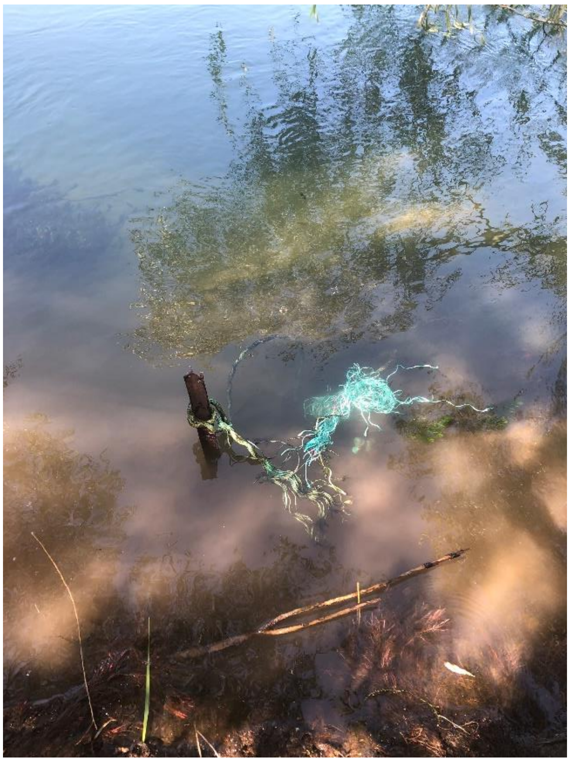

Figure 2-5: DS2 – artificial substrate attached to waratah installed in river bank.

The ropes at sites US2 and DS1 were first successfully installed in January 2018, while the additional sites (US1 and DS2) were first installed in January 2019. The ropes were left to soak for approximately nine weeks on average prior to sampling to provide sufficient time for macroinvertebrate colonisation.

The ropes were left slightly longer (12 weeks) for the May 2018 survey due to the difficulties associated with accessing the River during consistently higher flows that occurred during this period. In addition, the duration between the January, February and April 2019 survey dates was only six weeks to allow two sampling events during warmer weather of the newly installed sites (US1 and DS2).

A summary of the frequency of sampling at each site, survey dates and duration between surveys is provided in Table 2-2 and Table 2-3.

Table 2-2: Number of sampling events for each site.

Site ID	No. of events	Date first installed	Survey Dates							
			Mar-18	Jun-18	Aug-18	Oct-18	Nov-18	Jan-19	Mar-19	Apr-19
US1	2	Jan-19	-	-	-	-	-	-	✓	✓
US2	8	Jan-18	✓	✓	✓	✓	✓	✓	✓	✓
DS1	8	Jan-18	✓	✓	✓	✓	✓	✓	✓	✓
DS2	2	Jan-19	-	-	-	-	-	-	✓	✓

Table 2-3: Duration between surveys

Survey	Date Ropes in	Date Ropes Out	Duration
1	16 January 2018	10 March 2018	8 weeks
2	10 March 2018	11 May 2018	9 weeks
3	11 May 2018	2 August 2018	12 weeks
4	2 August 2018	11 October 2018	10 weeks
5	11 October 2018	21 November 2018	6 weeks
6	21 November 2018	14 January 2019	8 weeks
7	14 January 2019	27 February 2019	6 weeks
8	27 February 2019	3 April 2019	6 weeks

2.2 Macroinvertebrate Indices

At all sites three replicate samples were collected of artificial substrates during each monitoring event. Sample collection consisted of placing the artificial substrates (polyproplylene ropes) into a sample container, being careful not to dislodge colonised macroinvertebrates, and preserved in 70% methylated spirits. The samples were then analysed in the laboratory, where macroinvertebrates were identified to the lowest practicable level using 'Protocol P2: 200 Fixed Count + Scan for rare taxa' (Stark *et. al.* 2001).

The following indices were calculated for each sample:

- **Taxa Abundance (i.e. Number of Individuals).** Measures the total number of animals found in each sample (highly variable in the natural environment). Number of individuals is associated with in-stream health; extremely degraded and pristine environments tend to have lower abundance than intermediate levels of enrichment. However, abundance does depend to a large degree on the type of species in the community.

- **Taxa Richness (i.e. Number of Species).** This is a measure of diversity by the types of invertebrate taxa present in each sample. Typically, the more species present the higher the quality of the environment.

- **% EPT individuals.** This is the percentage of the sample that are the three generally pollution-sensitive orders of insects of *ephemeroptera* (mayflies); *plecoptera* (stoneflies); and *trichoptera* (caddisflies).

- **Macroinvertebrate Community Index (MCI).** A biotic index of stream health calculated from the sensitivity of macroinvertebrate taxa present in the sample (Stark JD M. J., 2004). The MCI is a measure of waterway eutrophication. Taxa are allocated sensitivity scores between 1 and 10 based on their tolerance to pollution. MCI scores can be used to describe the 'health' of a stream by averaging the assigned scores for presence/absence of taxa. The scores are calculated as:

$$\mathrm{MCI} = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

  where ***S*** is the total number of taxa in a sample and a_i is the score for the ***i***-th taxa.

- **Quantitative Macroinvertebrate Community Index (QMCI).** A biotic index of stream health calculated from macroinvertebrate taxa presence and abundance and is based on the relative sensitivity of the different taxa to changes in water quality (Stark JD M. J., 2004). As water quality decreases certain taxa generally decline in abundance in the community and this is reflected in the index values. The QMCI score represents a community-based index of environmental quality and like MCI scores show increasing eutrophication with declining QMCI scores. The QMCI is calculated as:

$$\mathrm{QMCI} = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

  where ***S*** is the total number of taxa in a sample, n_i is the abundance for the ***i***-th scoring taxon, a_i is the score for the ***i***-th taxon, and N is the total abundance for the entire sample.

The MCI and QMCI can be used to determine the health of the stream and the degree of organic enrichment. Generally accepted quality classes and description and index scores are shown in Table 2-4.

Table 2-4: Estimates of eutrophication using MCI and QMCI scores.

Water Quality Class (Stark and Maxted, 2007)	Description (Stark, 1998)	MCI	QMCI
Excellent	Clean Water	> 120	> 6
Good	Doubtful quality or possible mild enrichment	100 - 120	5 – 6
Fair	Probable moderate enrichment	80 – 100	4 – 5
Poor	Probable severe enrichment	< 80	< 4

2.3 Statistical Analysis

Statistical analyses were performed on the following indices: total abundance, number of taxa, percentage EPT, percentage EPT taxa, and both MCI and QMCI scores. All variables were checked for normality using a Shapiro Wilks W-test prior to formal comparisons. Where data was determined to depart from expected normality they were checked for lognormal distribution and transformed using natural log (x+1) where appropriate.

For this analysis the two upstream and downstream locations for March and April 2019 were grouped for the purposes of a single upstream and downstream comparison (i.e., with six replicates instead of three).

Only the number of taxa index was determined to be normally distributed and was analysed at the raw scale. Total abundance and QMCI were determined to fit a lognormal distribution and were therefore analysed using a natural-log(x+1) transformation. MCI, EPT, and percentage EPT taxa were determined to not fit either the normal or lognormal distributions and were analysed using nonparametric methods (e.g., Wilcoxon/Kruskal Wallis tests).

For all analyses differences between locations across time were analysed using ANOVA techniques. Where an interaction effect was determined, differences between sampling locations and surveys were analysed independently to look for trends.

When significant statistical differences could be determined Tukey's HSD mean comparison methods were employed to determine where the differences lay. All statistical significance was determined at the 0.05 level. Where interaction terms were determined to fall below the statistical significance threshold these terms were removed from the analytical model and re-analysed. All analyses were undertaken using JMP statistical software (SAS Institute 2003, vers. 5.0.1.2).

In addition, a Principal Component Analysis (PCA) was conducted on the dataset to see whether there are any trends occurring in individual species present. To allow the analysis the dataset was transformed by the following method: any species that was not present in at least three sampling occasions was removed, and all data was natural log (x+1) transformed. This was done to ensure any trends were not influenced by "one off" high density counts enabling differences to be compared at the population level.

A total of 37 recorded species were able to be used for ordination analyses (from a total of 64).

3. Results

3.1 Macroinvertebrate Indices

Table 3-1 summarises the data for all surveys combined. Figure 3-1 shows the average species distribution at each site while Figure 3-2 presents the key indices for all each site.

The analytical results for surveys between March 2018 and April 2019 are summarised in Appendix A and the raw count data is provided in Appendix B.

Table 3-1: Summary of macroinvertebrate metrics data (mean ± st. dev presented) and statistical analysis results for all surveys and reps combined (US2 & DS1 n = 24; US 1 & DS2 n = 6)

Parameter	All Surveys				
	Upstream 1 (US1)	Upstream 2 (US2)	Downstream 1 (DS1)	Downstream 2 (DS2)	P-value[1]
Taxa Abundance	348.8 ± 45.9	347.7 ± 262.8	398.8 ± 398.3	43.8 ± 33.8	0.678
Taxa Richness	12.7 ± 2.8	12.6 ± 3.6	14.2 ± 4.5	8.3 ± 2.9	0.234
% EPT Individuals	2.3%	28.7%	27.5%	41.8%	-
MCI score	88.7 ± 15.0	99.2 ± 9.1	94.1 ± 11.5	89.1 ± 15.9	0.806
QMCI score	2.8 ± 0.5	3.9 ± 1.4	4.1 ± 1.4	4.5 ± 1.0	0.069

The key points to note regarding the data are as follows:

- An average of 348.8 and 347.7 individuals representing 12.7 and 12.6 taxa from the upstream sites (US1 and US2 respectively), and 398.8 and 43.8 individuals representing 14.2 and 8.3 taxa from the downstream sites (DS1 and DS2 respectively) were collected and identified during each survey.
- The species identified during surveys includes species from the following orders: 16 species of trichoptera (caddisflies); 15 species of diptera (two-winged flies); 8 species of ephemeroptera (mayflies); 6 species each of gastropod molluscs (snails), and crustacea (shrimps and amphipods); 4 species of plecopteran (stoneflies); 3 species of odonata (dragonflies or damselflies); and 1 species each of megaloptera (dobsonflies), coleoptera (beetles), oligochaete (bristle worm), hirudinea (leech), platyhelminthes (flat worm), nemertea (ribbon worm) and dolomedes (water spider).
- The taxa present in the greatest proportion at US1 upstream are oligochaetae worms (43%) followed by molluscs and diptera (refer Figure 3-1). Very few EPT species (2.3%) were identified at this site. Comparatively the other upstream site US2 is dominated by diptera (71%). EPT species made up 28.7% of samples from this site. This difference in species assemblage between the two upstream sites may partly be explained due to the artificial substrates (ropes) at Site US2 hanging off a floating pontoon in slightly deeper water away from the river bank, while at US1 the artificial substrates was installed close to the river bank in shallower water and occasionally experiencing sediment disturbance after flushing events.

[1] P-value based on single factor ANOVA for comparison of upstream and downstream significance. The two upstream and two downstream sites for March and April 2019 were grouped as a single upstream and downstream comparison (i.e., with six replicates instead of three).

- The two downstream sites (DS1 and DS2) had similar species assemblages both being dominated by molluscs (43% and 36%) followed by diptera, trichopteran, and ephemeroptera (refer Figure 3-1). EPT species contributed 27.5% and 41.8% of samples, respectively.
- Both the upstream and downstream macroinvertebrate indices (MCI and QMCI) indicate at least probable moderate instream enrichment, while the upstream QMCI score indicated probable severe enrichment (refer Figure 3-2).
- There is no statistically significant ($p>0.05$) difference in mean macroinvertebrate abundances and numbers of species or in the difference in mean macroinvertebrate community index (MCI and QMCI) scores between the upstream and downstream sites (as shown in Table 3-1).

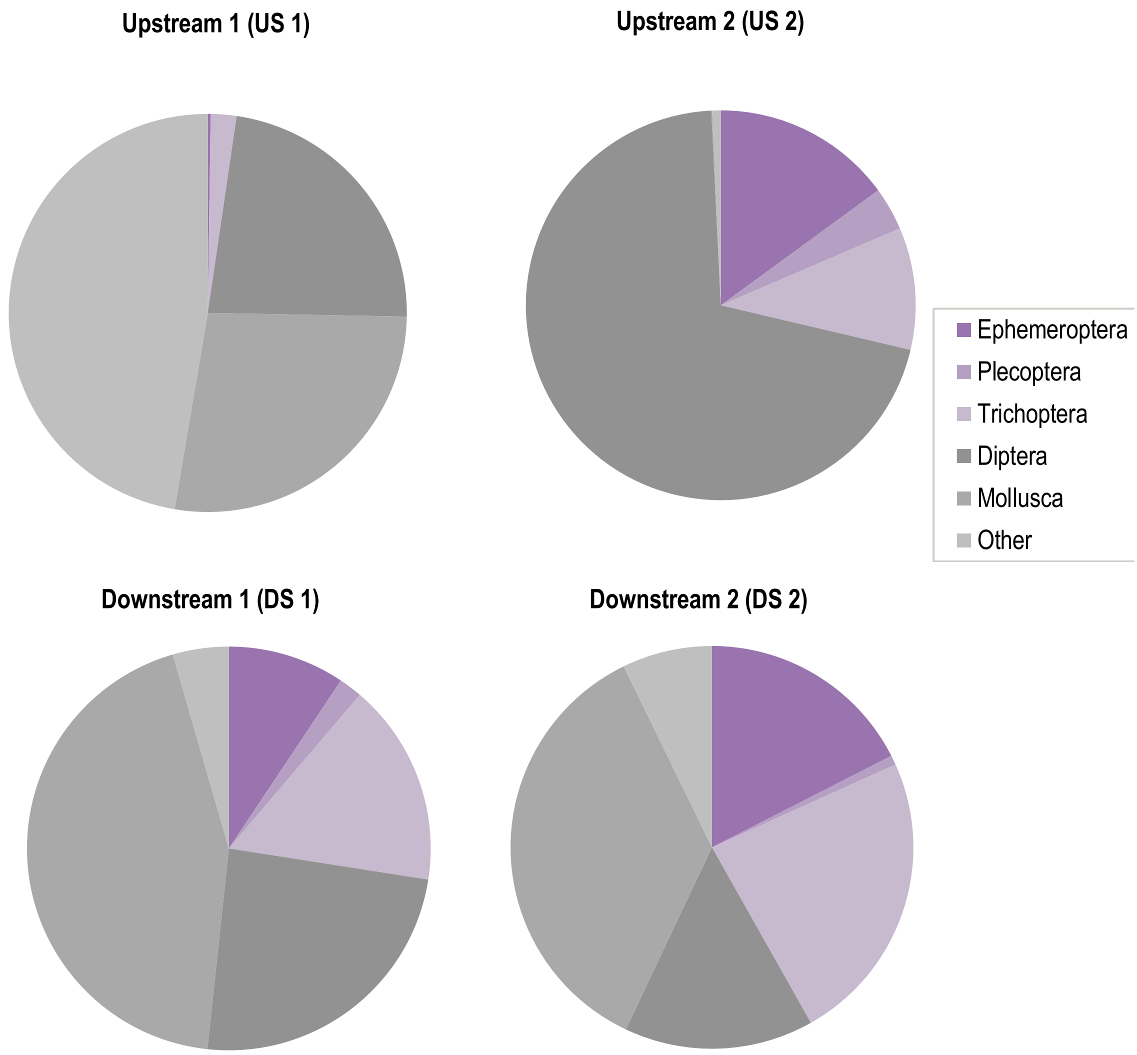

Figure 3-1: Percentage distribution of species taxa across upstream and downstream sites

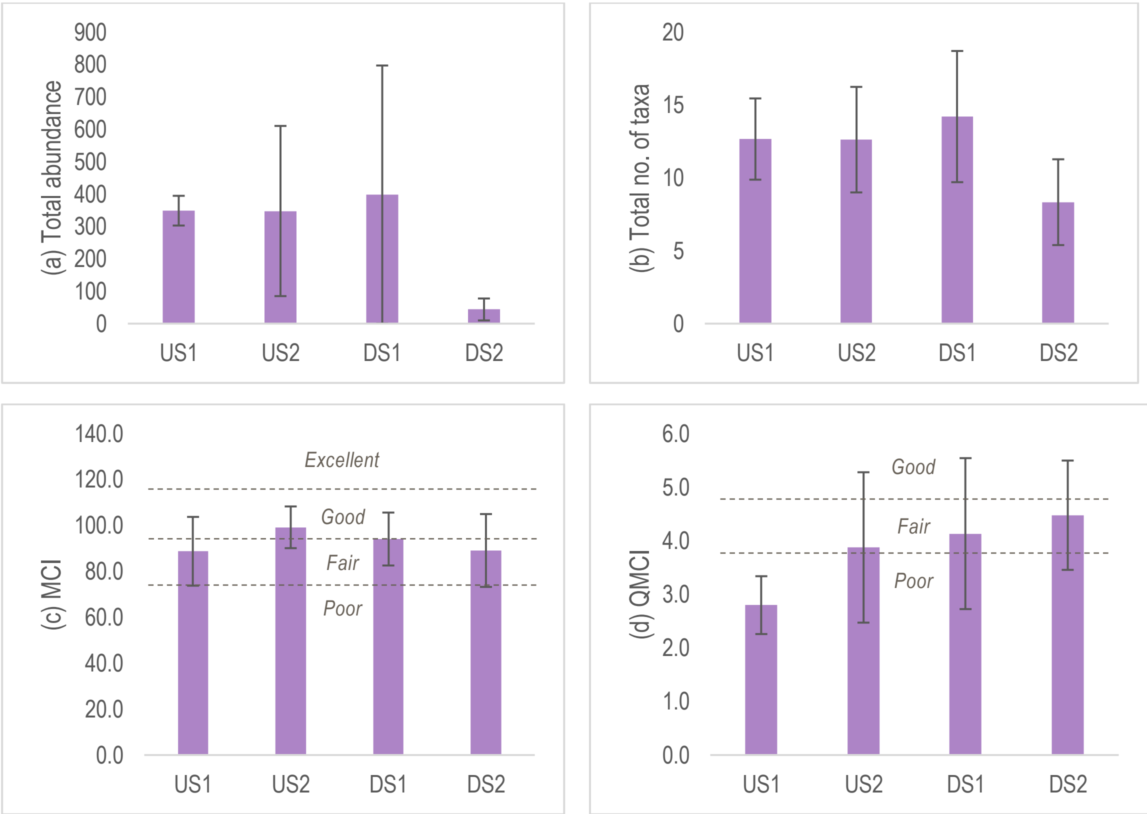

Figure 3-2: Average macroinvertebrate indices across sites for all surveys, including (a) total abundance, (b) Total no. of Taxa, (c) MCI scores and (d) QMCI scores.

3.2 Statistical Analysis

No interaction terms of significance could be determined for number of taxa or the transformed abundance and QMCI data. These were removed from the analytical model and differences over time and between sampling locations, analysed independently.

No statistically significant differences could be determined between surveys or sampling locations for number of taxa (p=0.1910 and p=0.2219, respectively). Similarly, no statistical differences could be determined between surveys for taxa abundance (p=0.1446 and p=0.6696, respectively).

For QMCI statistical differences could be determined independently between surveys and sampling locations (p=0.0074 and p=0.0302, respectively). For surveys, the differences are due to higher mean QMCI results in August 2018 compared to March 2019. All other QMCI results were similar. For sampling locations, mean QMCI results were greater downstream compared to upstream sampling locations.

Percentage EPT, Percentage EPT taxa and MCI scores were all analysed using non-parametric techniques. Percentage EPT showed no statistical differences between sampling locations (p=0.81) but did show differences across surveys (p<0.0001). On average, percentage EPT was greater in August 2018, June 2018, March 2018, and October 2018 compared to other surveys. Percentage EPT taxa is similar with mean percentage EPT taxa being greater in August 2018, June 2018, March 2018, and October 2018 compared to other surveys (p<0.0001), and no discernible difference between sampling locations (p=0.47).

MCI scores recorded no statistical difference between sampling locations (p=0.76), whereas differences were recorded between surveys (p=0.002).

In addition, a Principal Component Analysis (PCA) was conducted on the correlation matrix between species observed across time to look at how all species varied relative to each other. Figure 3-3 shows the full plot which explains 40.9% of all variation in the dataset. To simplify the output, only the 6 strongest vectors of species are plotted.

Figure 3-4 shows that there is somewhat of a dichotomy between the Mollusc *Potamopyrgus*, the Tricopteran *Triplectides* and three other Trichoptera species (*Hudsonema*, *Psilochorema*, and *Aoteapsyche*) and the Ephemeropteran *Zephlebia*.

In addition, the Mollusc *Potamopyrgus* and Tricopteran *Triplectides* typically recorded higher population levels in 2019 compared to 2018 on average (Figure 3-5 provides a plot of *Potamopyrgus* vs sampling times/locations as an example).

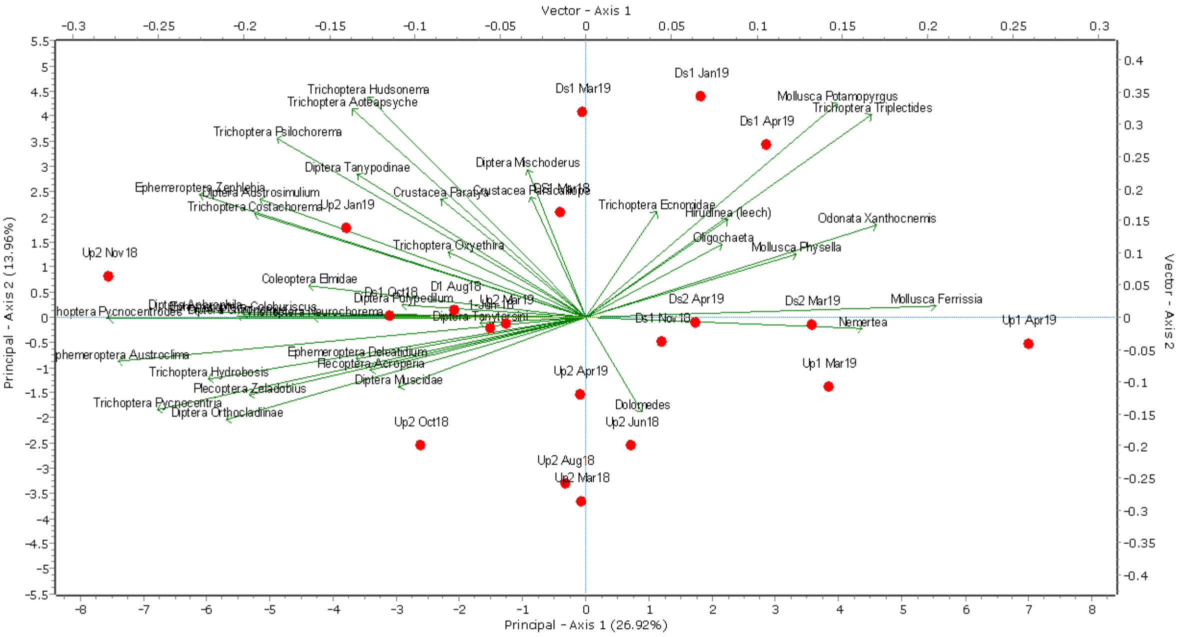

Figure 3-3: PCA plot n the correlation matrix for species observed across time.

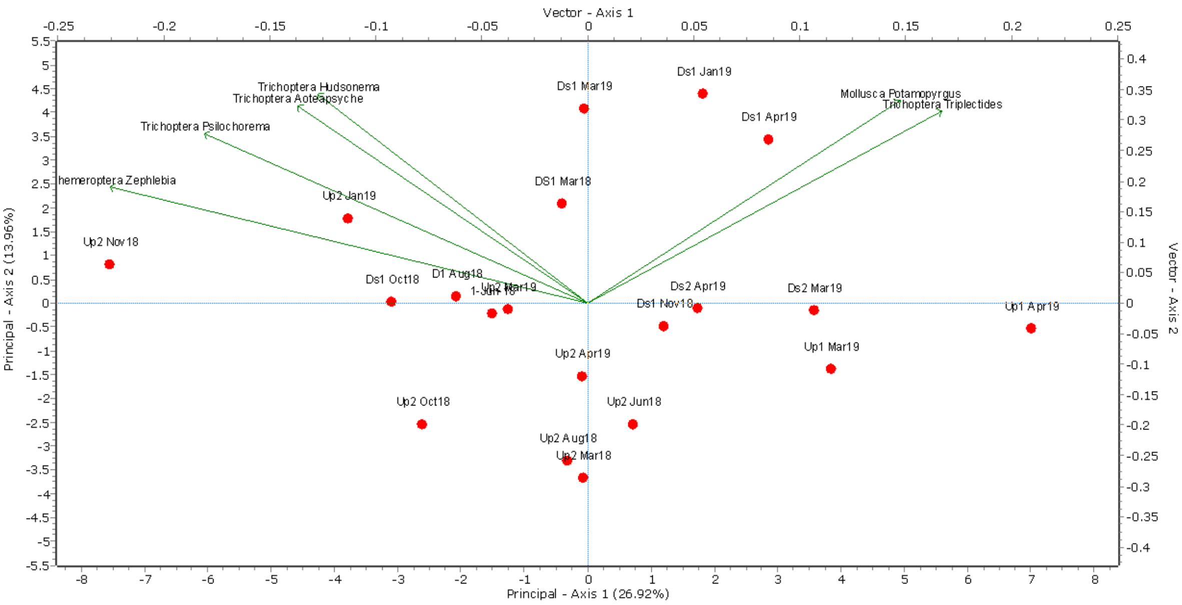

Figure 3-4: Six strongest species vectors.

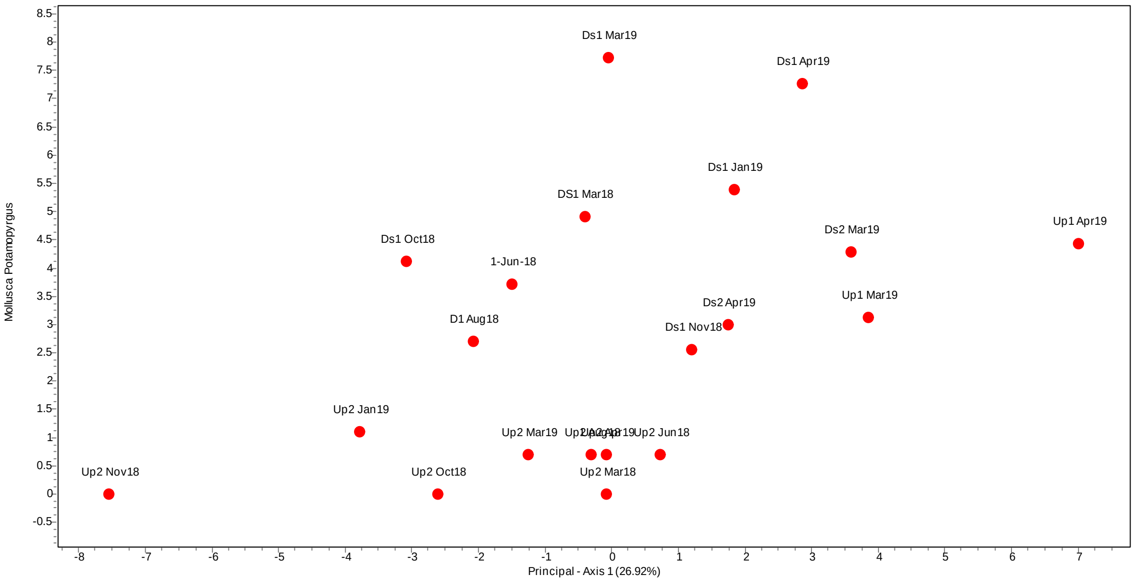

Figure 3-5: Potamopyrgus vs sampling times / locations.

4. Summary

The aquatic ecological communities present within the Kaituna River, both upstream and downstream, of the discharge are considered to be 'robust' having adapted to 'moderate' to 'serve' levels of organic enrichment due to activities in catchment upstream of the AFFCO facility.

A comparison of the upstream and downstream sites, while not statistically significant, appears to indicate a general trend for the downstream site to have slightly higher macroinvertebrate taxa richness than the upstream site.

The Principal Component Analysis (PCA) indicates that there is a dichotomy between the Mollusc *Potamopyrgus*, and four key Trichoptera species and that the Mollusc *Potamopyrgus* and Tricopteran *Triplectides* on average typically recorded higher population levels in 2019 compared to 2018.

5. References

Argo. (2007). An assessment of the environmental effects of the AFFCO Rangiuru discharge on the Kaituna River. Auckland: Report prepared by Argo Environmental Ltd for AFFCO NZ Ltd. July 2007.

Argo. (2017). *Rangiuru Processing Plant Discharges to Kaituna River Resource Consent Applications - Assessment of Effects on the Environment.* Auckland: Report prepared by Argo Environmental Ltd for AFFCO NZ Ltd. February 2017.

Bioresearches (2005). An assessment of the environmental effects of the AFFCO Rangiuru discharge on the Kaituna River. Report prepared by Bioresearches on behalf of AFFCO New Zealand Ltd Rangiuru Plant. November 2005.

Collier, K. &. (2005). *Regional Guidelines for Ecological Assessments of Freshwater Environments: Macroinvertebrate Sampling in Wadeable Streams. .* Hamilton: Environment Waikato.

Stark JD, B. I. (2001). *Protocols for Sampling Macroinvertebrates in Wadeable Streams.* New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103, 57 p.

Stark JD, M. J. (2004). *Macroinvertebrate community indices for Auckland's soft-bottomed streams and applications to SOE reporting. .* Auckland: Prepared for Auckland Regional Council. Cawthron Report No. 970. Nelson: Cawthron Institute. ARC Technical Publication 303, 59 p.

Stark JD, M. J. (2007). A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research 41(1).*

Stark, J. (1998). SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32*, 55-66.

Appendix A Summary of Aquatic Macroinvertebrate Survey Data for all Surveys

Summary of macroinvertebrate data and statistical analysis results (mean of 3 replicates ± st dev) for each survey from March 2018 to April 2019.

Parameter	March 2018			June 2018			August 2018			October 2018			November 2018			January 2019			February 2019					April 2019				
	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 2 (US2)	Downstream 1 (DS1)	p-value	Upstream 1 (US1)	Upstream 2 (US2)	Downstream 1 (DS1)	Downstream 2 (DS2)	p-value	Upstream 1 (US1)	Upstream 2 (US2)	Downstream 1 (DS1)	Downstream 2 (DS2)	p-value
Taxa Abundance	235.3 ±111.0	150.0 ±207.3	0.564	114.0 ±22.9	149.7 ±82.4	0.510	96.7 ±39.3	247.7 ±130.1	0.127	665.7 ±129.1	839.7 ±623.4	0.661	663.2 ±229.3	115.0 ±120.4	0.023	372.7 ±59.8	218.7 ±122.9	0.123	54.7 ±60.1	545.0 ±188.1	956.7 ±327.8	41.0 ±26.5	0.449	89.0 ±27.9	99.3 ±44.4	555.3 ±226.5	46.7 ±46.2	0.140
Taxa Richness	10.3 ±7.2	15.0 ±1.5	0.334	9.3 ±2.9	14.0 ±8.7	0.428	12.0 ±0.0	16.0 ±2.0	0.026	12.0 ±2.0	14.0 ±3.6	0.448	15.7 ±4.0	13.0 ±1.0	0.329	19.0 ±2.6	12.3 ±7.6	0.226	8.3 ±3.8	12.3 ±0.6	15.0 ±0.0	7.3 ±2.5	0.721	7.3 ±2.1	10.3 ±2.1	14.3 ±3.8	9.3 ±3.5	0.167
% EPT	23.1% ±34.9	33.7% ±12.0	-	48.6% ±18.3	52.2% ±44.4	-	82.2% ±4.5	61.9% ±34.2	-	29.6% ±11.4	18.0% 5.3	-	25.8% ±10.7	45.1% ±39.2	-	38.8% ±19.3	31.5% ±41.5	-	0.0% ±0.1	0.2% ±0.1	0.2% ±0.1	0.2% ±0.1	-	0.0% ±0.0	0.5% ±0.1	0.1% ±0.2	0.5% ±0.1	-
MCI score	87.2 ±15.4	89.1 ±7.5	0.856	106.0 ±2.3	88.0 ±28.9	0.343	95.0 ±1.7	100.1 ±8.7	0.377	108.1 ±11.0	102.5 ±2.4	0.433	109.2 ±4.5	96.1 ±6.9	0.050	98.4 ±1.9	89.1 ±3.9	0.021	63.1 ±23.7	92.7 ±9.3	94.2 ±4.3	79.9 ±17.7	0.421	64.5 ±0.5	96.8 ±0.6	93.6 ±0.6	98.3 ±7.8	0.072
QMCI score	3.1 ±1.1	4.6 ±0.9	0.139	4.7 ±0.9	4.3 ±2.0	0.799	6.3 ±0.3	5.2 ±2.1	0.394	3.1 ±0.6	2.7 ±0.2	0.284	3.2 ±0.8	4.2 ±2.9	0.565	3.7 ±0.6	3.6 ±1.4	0.940	2.0 ±0.6	2.1 ±0.7	4.1 ±0.1	3.6 ±0.6	<0.001	2.4 ±0.6	4.8 ±1.1	4.1 ±0.2	5.3 ±0.3	0.133

Appendix B Aquatic Macroinvertebrate Count Data

		Mar-18						Jun-18						Aug-18					
	MCI Sensitivity	Upstream 2 (US2)			Downstream 1 (DS1)			Upstream 2 (US2)			Downstream 1 (DS1)			Upstream 2 (US2)			Downstream 1 (DS1)		
Species Taxa	**Score**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 1**	**Rep 2**	**Rep 3**
Odonata Antipodochlora	6																		
Odonata Ischnura	6																		
Odonata Xanthocnemis	5																		
Ephemeroptera Acanthophlebia	7																		
Ephemeroptera Ameletopsis	10																		
Ephemeroptera Austroclima	9	28	37	12	3		85	15	12	19	11	51		17	51	24	137	1	80
Ephemeroptera Coloburiscus	9																		1
Ephemeroptera Deleatidium	8			1							1								
Ephemeroptera Mauiulus	5																		
Ephemeroptera Nesameletus	9																		
Ephemeroptera Zephlebia	7				12		12	4		6	12	11		2	1	2	29	5	5
Plecoptera Acroperia	5													1	2	1	3		
Plecoptera Megaleptoperla	9																		
Plecoptera Spaniocerca	8							1		3	3	2							
Plecoptera Zeladobius	5						3		2		2	1		12	26	13	21	3	7
Megaloptera Archichauliodes	7																		
Trichoptera Aoteapsyche	4	6	1	2	4		46	4		1	38	83	1	1	1	1	22	4	72
Trichoptera Confluens	5							1											
Trichoptera Costachorema	7						1												
Trichoptera Edpercivalia	9																		
Trichoptera Ecnomidae	8							1			1						2		
Trichoptera Hudsonema	6				2						1								1
Trichoptera Hydrobosis	5	2	5	3	3		1		2		2	2		2	2	2	2		1
Trichoptera Neurochorema	6											1					3		2
Trichoptera Olinga	9																		
Trichoptera Orthopsythe	9						3												1
Trichoptera Oxyethira	2						3			1									
Trichoptera Plectrocnemia	8																		
Trichoptera Psilochorema	8				1		3			1	1	2					3	2	
Trichoptera Pycnocentria	7	12	4	3	8	1	21	66	17	14	44	31		19	36	17	40	6	80
Trichoptera Pycnocentrodes	5	7		1	1		11	3		1	3	3		3	1	3	2		11
Trichoptera Triplectides	5				1	1											1	1	
Coleoptera Elmidae	6				1														
Diptera Aphrophila	5										1	1							
Diptera Austrosimulium	3			2	1		3				19	11		2	3		34	13	3
Diptera Chironomus	1	200	46	16	4		22				2	2		1		1	4	1	
Diptera Empididae	3														1				2
Diptera Eriopterini	9																		
Diptera Lobodiamesa	5		1	2	1														
Diptera Mischoderus	4				1														
Diptera Molophilus	5																	1	
Diptera Muscidae	3	1	3	2															
Diptera Orthocladiinae	2	212	34	55	3	2	30	43	70	46	11	8	4	3	13	5	4	1	1
Diptera Paradixa	4																		
Diptera Polypedilum	3		1				1				1	1							
Diptera Tabanidae	3																1		
Diptera Tanypodinae	5				1														
Diptera Tanytersini	3						2	1	2	4		2		11	5	4	20	7	41
Crustacea Isopoda	5																		
Crustacea Ostracoda	3																		
Crustacea Paracalliope	5																		
Crustacea Paraleptamphopus	5				4														
Crustacea Paratya	5				1							1							
Crustacea Phreatogammarus	4											1							
Mollusca Ferrissia	3																		
Mollusca Latia	3																		
Mollusca Lymnaeidae	3																		
Mollusca Physella	3				3														
Mollusca Potamopyrgus	4				96	27	13			1	17	5	18			1	6	5	3
Mollusca Sphaeriidae	3																		
Oligochaeta	1	3				5		1					36					48	
Hirudinea (leech)	3	3			1	1													
Platyhelminthes	3																		
Nemertea	3					1													
Dolomedes	5			1								1							

		Oct-18						Nov-18						Jan-19					
	MCI Sensitivity	Upstream 2 (US2)			Downstream 1 (DS1)			Upstream 2 (US2)			Downstream 1 (DS1)			Upstream 2 (US2)			Downstream 1 (DS1)		
Species Taxa	Score	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Odonata Antipodochlora	6																	1	
Odonata Ischnura	6																		
Odonata Xanthocnemis	5											1	1						1
Ephemeroptera Acanthophlebia	7																		
Ephemeroptera Ameletopsis	10				1			9	4	10									
Ephemeroptera Austroclima	9	42	66	120	100	22	3	79	48	41	2	9	15	20	110	40	22		
Ephemeroptera Coloburiscus	9		1							10									
Ephemeroptera Deleatidium	8									2		1							
Ephemeroptera Mauiulus	5																		
Ephemeroptera Nesameletus	9																		
Ephemeroptera Zephlebia	7	21	17	10	17	130	4	29	18	8		2	5	24	25	15	26		4
Plecoptera Acroperia	5							3				1							
Plecoptera Megaleptoperla	9	1	7			4													
Plecoptera Spaniocerca	8																		
Plecoptera Zeladobius	5	37	53	108	100	22	6		9	14			1		1	3			
Megaloptera Archichauliodes	7																		1
Trichoptera Aoteapsyche	4			5	22	6	1	9		12	4		1	100	10		162		13
Trichoptera Confluens	5																		
Trichoptera Costachorema	7						1	9		8					1				
Trichoptera Edpercivalia	9													1	1	1			
Trichoptera Ecnomidae	8																		12
Trichoptera Hudsonema	6							3						1	1			1	2
Trichoptera Hydrobosis	5		1	1	1			12	4						1	1			
Trichoptera Neurochorema	6							3								1			
Trichoptera Olinga	9		1																
Trichoptera Orthopsythe	9																		
Trichoptera Oxyethira	2							3					1	2	1	1			
Trichoptera Plectrocnemia	8																		
Trichoptera Psilochorema	8		1	2	3	1		3	4		3		2	3	8	4	4		2
Trichoptera Pycnocentria	7	38	16	9	26	28	2	26	26	25	3	7	9	30	2	3	4		
Trichoptera Pycnocentrodes	5	6	9	2	11	7		18	9	4			3	8	3	3	4		
Trichoptera Triplectides	5											1	2	1			1		10
Coleoptera Elmidae	6				3			3		2	1								
Diptera Aphrophila	5		1		1			3								1			
Diptera Austrosimulium	3	2		1	4	6		15		14	1	1	1	6	3	1	7		4
Diptera Chironomus	1	234	320	180	640	480	30	58	481	115	2			90	100	100	10		
Diptera Empididae	3																		
Diptera Eriopterini	9																		
Diptera Lobodiamesa	5																		
Diptera Mischoderus	4													1			1		
Diptera Molophilus	5																		
Diptera Muscidae	3		1	1	1	1									4	1			
Diptera Orthocladiinae	2	195	320	165	408	320		318	267	156	10	13	3	30	130	150	8		4
Diptera Paradixa	4														1				1
Diptera Polypedilum	3								13			1			1				
Diptera Tabanidae	3																		
Diptera Tanypodinae	5	3					4	3	18			1		1	4		1		8
Diptera Tanytersini	3													1	30	30			2
Crustacea Isopoda	5										3		2						
Crustacea Ostracoda	3														1				
Crustacea Paracalliope	5				2	1										1			
Crustacea Paraleptamphopus	5																		
Crustacea Paratya	5					1								2	1				
Crustacea Phreatogammarus	4																		60
Mollusca Ferrissia	3																		1
Mollusca Latia	3																		
Mollusca Lymnaeidae	3																		
Mollusca Physella	3																		1
Mollusca Potamopyrgus	4				5	2	54				6	5	1	2			30	24	164
Mollusca Sphaeriidae	3																		
Oligochaeta	1						38	6		25	89	1					3	51	3
Hirudinea (leech)	3									3									3
Platyhelminthes	3																		
Nemertea	3																		
Dolomedes	5																		

		Mar-19												Apr-19											
	MCI Sensitivity	Upstream 1 (US1)			Upstream 2 (US2)			Downstream 1 (DS1)			Downstream 2 (DS2)			Upstream 1 (US1)			Upstream 2 (US2)			Downstream 1 (DS1)			Downstream 2 (DS2)		
Species Taxa	Score	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Odonata Antipodochlora	6																								
Odonata Ischnura	6															1									
Odonata Xanthocnemis	5						1							1	1	1					1	4		1	
Ephemeroptera Acanthophlebia	7									3															
Ephemeroptera Ameletopsis	10																								
Ephemeroptera Austroclima	9	1			8	7	90		8		2						24	56	3	14	1			2	13
Ephemeroptera Coloburiscus	9																								
Ephemeroptera Deleatidium	8																								
Ephemeroptera Mauiulus	5																			5					
Ephemeroptera Nesameletus	9																								
Ephemeroptera Zephlebia	7					2	38		22	7		2	1				3	8	10	14	3		5	7	14
Plecoptera Acroperla	5																								
Plecoptera Megaleptoperla	9																								
Plecoptera Spaniocerca	8																								
Plecoptera Zeladobius	5					1					2								1	1					
Megaloptera Archichauliodes	7																								
Trichoptera Aoteapsyche	4			1	41		2		280	160	3							1	6	65	3			1	18
Trichoptera Confluens	5																	1							
Trichoptera Costachorema	7							4																	
Trichoptera Edpercivalia	9						1																		
Trichoptera Ecnomidae	8																4			2	1				
Trichoptera Hudsonema	6							1		1												1			
Trichoptera Hydrobosis	5						5	3	1	1								2							3
Trichoptera Neurochorema	6																	4							
Trichoptera Olinga	9																								
Trichoptera Orthopsythe	9																								
Trichoptera Oxyethira	2				7			1		1							5	16		3					1
Trichoptera Plectrocnemia	8																				1				
Trichoptera Psilochorema	8	1			2	7	2	4	1	1									1	3		1		2	
Trichoptera Pycnocentria	7	1			5	1	4	5	2				1				5	5	10			1	1		17
Trichoptera Pycnocentrodes	5					2		1	3	1								4		1					
Trichoptera Triplectides	5	2		1				14	6	7	10		3	3						3	17	12	1	1	
Coleoptera Elmidae	6																								1
Diptera Aphrophila	5																								
Diptera Austrosimulium	3				1		2		4	2							1	2	1	15		1			16
Diptera Chironomus	1	22	4	5	240	400	288		13	12		2	2			1	3		17	6	1			1	
Diptera Empididae	3																								
Diptera Eriopterini	9																				1				
Diptera Lobodiamesa	5																								
Diptera Mischoderus	4																								
Diptera Molophilus	5																								
Diptera Muscidae	3																								
Diptera Orthocladiinae	2	45	2	3	20	264	172	1	3	1	3	1		6			22	43	30	9	1				8
Diptera Paradixa	4																								
Diptera Polypedilum	3	2		4		3			1																3
Diptera Tabanidae	3																								
Diptera Tanypodinae	5	2			2	3		1	1		2		1							1		1	1		
Diptera Tanytersini	3	2			5	3				1						1		8		1					
Crustacea Isopoda	5																								
Crustacea Ostracoda	3																								
Crustacea Paracalliope	5							18	3		1														
Crustacea Paraleptamphopus	5							4																	
Crustacea Paratya	5				1			1		1	1														
Crustacea Phreatogammarus	4																								
Mollusca Ferrissia	3			1										2		5									1
Mollusca Latia	3																				1			1	
Mollusca Lymnaeidae	3													2											
Mollusca Physella	3			2										1											
Mollusca Potamopyrgus	4	19	2	1	1			600	960	704	42	6	24	38	21	24			1	148	644	648	9	6	4
Mollusca Sphaeriidae	3										1										2				
Oligochaeta	1	27	11	2	1	2	1	1				3	10	24	88	32					10	8			
Hirudinea (leech)	3													4		1				3	5	1			1
Platyhelminthes	3														2						2				
Nemertea	3														8				1				1		
Dolomedes	5			1																					

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