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MYRTLE CREEK AQUATIC MONITORING REPORT
TAHMOOR NORTH

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Document control

Project number	Client	Project manager	LGA
5750	Tahmoor Coal	Matthew Russell	Wollondilly

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Enquiries should be addressed to:

Sydney Head Office
Niche Environment and Heritage
02 9630 5658
info@niche-eh.com
PO Box 2443 North Parramatta
NSW 1750 Australia

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1. Introduction

1.1 Context

The Tahmoor Coal Mine (Tahmoor Mine) is an underground coal mine located approximately 80 kilometres (km) south-west of Sydney between the towns of Tahmoor and Bargo, New South Wales (NSW). Tahmoor Mine produces up to three million tonnes of Run of Mine (ROM) coal per annum from the Bulli Coal Seam. Tahmoor Mine produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for coke manufacture for steel production. Product coal is transported via rail to Port Kembla and Newcastle for Australian domestic customers and export customers.

Mining related subsidence in Myrtle Creek has resulted in reduced pool holding capacity. Water flow in affected pools is diverted through the subsurface via cracks and fissures in the bedrock. This has resulted in a reduced pool holding capacity and subsequent reduced aquatic habitat at Pool 23. Prior to remediation, Pool 23 has been effectively dry post mining.

Remediation works at Pool 23 consisted of a Polyurethane Injection Resin (PUR) grout curtain wall, which involved drilling holes to 7 metres (m) deep and infilling fractures with PUR. Works were completed on 5 February 2020. Autumn 2020 monitoring was undertaken in March 2020, approximately one month after remediation was completed.

Niche Environment Heritage Pty Ltd (Niche) was engaged by Tahmoor Coal to conduct monitoring of aquatic ecology within Myrtle Creek to identify impacts from longwall mining and to monitor the outcome of efforts to rehabilitate and restore water holding capacity within the waterway.

1.2 Objectives of this report

The primary objective of this report is to describe the outcomes of monitoring surveys of stream health post mining beneath Myrtle Creek and before and after creek remediation. Monitoring was conducted using standard Australian River Assessment System (AUSRIVAS) methods and quantitative macroinvertebrate surveys.

This report presents the results of monitoring undertaken in autumn and spring 2019, before remediation commenced, and autumn 2020, after remediation was complete. Aquatic ecology before and after remediation was investigated through temporal and spatial observations of aquatic habitat, water quality and macroinvertebrate community and compared to AUSRIVAS modelled, and quantitatively surveyed, References sites. This process informs remediation and adaptive management of the waterway.

Figure 1: Monitoring sites

2. Methods

2.1 Location of sampling sites

Monitoring data from four Impact sites and three Reference sites were used for the analysis (

Figure 1, Table 1). Monitoring of Impact and Reference sites was undertaken as follows:

- Impacts sites: AUSRIVAS and quantitative sampling at four Impact sites: Pool 22, Pool 23, Pool 24 and Pool 30.
- Reference sites: Quantitative sampling at three Reference sites: Site 9, Site 12 and Site 16. Monitoring of Reference sites occurred in association with Tahmoor Coal monitoring Program for the Western Domain. These Reference sites were selected as the sampling methods and time periods matched the Impact site monitoring, the sites are not impacted by mining subsidence and are located close to Myrtle Creek.

Table 1: Sampling sites

Site name	Site type	Easting	Northing	Details
Pool 22	Impact	278868	6211773	Upstream of Pool 23 remediation
Pool 23	Impact	278880	6211781	Remediation site
Pool 24	Impact	278911	6211775	Approximately 30 m downstream of Pool 22
Pool 30	Impact	279152	6211736	Approximately 270 m downstream of Pool 23 remediation
Site 9	Reference	275401	6214851	Cedar Creek
Site 12	Reference	276643	6215875	Cedar Creek
Site 16	Reference	273744	6214122	Cedar Creek

2.2 Survey timing

Remediation was completed on 5 February 2020. Monitoring was undertaken on three occasions:

- Autumn 2019: Before remediation (May 2019)
- Spring 2019: Before remediation (October 2019)
- Autumn 2020: After remediation (March 2020).

2.3 Survey methods

The monitoring program employed the following survey methods:

- Aquatic habitat assessment comprising:
  - AUSRIVAS
- Macroinvertebrate survey comprising:
  - AUSRIVAS macroinvertebrate sampling
  - A quantitative benthic macroinvertebrate monitoring program
- Water quality sampling.

The monitoring is primarily focused on macroinvertebrate monitoring regimes including AUSRIVAS and quantitative sampling. AUSRIVAS is a rapid assessment based on presence/absence of invertebrates, where macroinvertebrate samples are compared to modelled reference sites. The quantitative macroinvertebrate program compares monitoring sites and the communities present in each location to Reference sites on Cedar Creek.

Detailed descriptions of survey methods, laboratory methods and data analysis are provided below.

2.3.1 Aquatic habitat assessment

Visual assessment of aquatic habitat was conducted using the AUSRIVAS method. The survey is a rapid assessment to describe habitat based on the following parameters:

- Geomorphology
- Channel diversity
- Bank stability
- Riparian vegetation and adjacent land use
- Water quality
- Macrophytes
- Local impacts and land use practices.

2.3.2 Macroinvertebrate survey

AUSRIVAS

The AUSRIVAS method of sampling both pools and riffles was modified to suit site conditions as no suitable in-stream riffle features were present. Samples were collected from pool edges for a length of 10 m either side as a continuous line or in disconnected segments. Sampling in segments was undertaken to ensure the sampling of sub-habitats such as macrophyte beds, bank overhangs, submerged branches and root mats. Segmented sampling was also employed where pool length was short and it was logistically difficult to sample in a continuous line (e.g. due to the presence of in-stream logs). A 250 micrometre (μ/m) dip net was drawn through the water with short sweeps towards the bank to dislodge benthic fauna while scraping submerged rocks and debris, sides of the stream bank and the bed substrate. Further sweeps in the water column targeted suspended fauna.

Each sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps, pipettes and/or paint brushes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. The animals collected at each site were placed into a labelled jar containing 70% ethanol.

The chemical and physical variables required for running the AUSRIVAS predictive model were also recorded: i.e. alkalinity, modal depth and width of the stream, percentage bedrock, boulder or cobble along with latitude and longitude. Distance from stream source, altitude, land-slope and rainfall were also calculated.

Quantitative benthic macroinvertebrate sampling

Macroinvertebrates were sampled from three random pool edges at each site. Pool-edge samples were collected from depths of 0.2 - 0.5 m within 2 m of the bank. A suction sampler described by Brooks (1994) was placed over the substrate and operated for one minute at each sampling location. The sample was washed thoroughly over a 500 μm mesh sieve. All material retained on the 500 μm mesh sieve was preserved in 70% ethanol for laboratory sorting and identification.

2.3.3 Water quality

Surface water quality was measured in situ using a Yeokal 611 water quality probe at each site. The following variables were measured:

- Temperature (°C)
- Conductivity (μS/cm)

- pH
- Alkalinity measured with a standard titration kit (mg $CaCO_3$/L)
- Dissolved Oxygen (DO) (% saturation and mg/L)
- Turbidity (NTU).

2.3.4 Laboratory methods invertebrate identification - AUSRIVAS and quantitative

Macroinvertebrate samples were identified to family level with the exception of Oligochaeta (to class), Polychaeta (to class), Ostracoda (to subclass), Nematoda (to phylum), Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Small crustaceans Ostrocoda, Copapoda and Cladocera were not included as part of the analysis. Identification keys used included:

- Dean, J., Rosalind, M., St Clair, M., and Cartwright, D. (2004). Identification keys to Australian families and genera of caddis-fly larvae (Trichoptera) Cooperative Research Centre for Freshwater Ecology
- Gooderham, J. and Tsyrlin, E. (2002). The Waterbug Book: A guide to the Freshwater Macroinvertebrates of Temperate Australia, CSIRO Publishing
- Hawking and Theischinger (1999). A guide to the identification of larvae of Australian families and to the identification of ecology of larvae from NSW
- Madden, C. (2010). Key to genera of Australian Chironomidae. Museum Victoria Science Reports 12,1-31
- Madden, C. (2011). Draft identification key to families of Diptera larvae of Australian inland waters La Trobe University
- Smith, B. (1996). Identification keys to the families and genera of bivalve and gastropod molluscs found in Australian inland waters Murray Darling Freshwater Research Centre
- Website - http://www.mdfrc.org.au/bugguide/.

2.3.5 Data analysis

AUSRIVAS

Samples collected using AUSRIVAS protocol were analysed using the predictive models for NSW pool edge habitats (Turak *et al*. 2004). The AUSRIVAS model predicts the aquatic macroinvertebrate fauna expected to occur at a site in the absence of environmental stress, such as pollution or habitat degradation. The AUSRIVAS NSW autumn and spring models were used for the data collected. Observed to expected ratio (OE50), SIGNAL (Stream Invertebrate Grade Number Average Level), and number of taxa were the indices used to interpret stream health.

OE50

The Observed to Expected ratio is the ratio of the number of invertebrate families observed at a site (NTC50) to the number of families expected (NTE50) at that site. Only macroinvertebrate families with a greater than 50% predicted probability of occurrences are used by the model. OE50 provides a measure of biological impairment at the test site. Bands derived from the OE50 indicate the level of impairment of the assemblage. The OE50 ratios are divided into bands representing different levels of impairment (Table 2).

Table 2: AUSRIVAS band interpretation

Band	Interpretation
Band X	Represents a more biologically diverse community than reference
Band A	Is considered similar to reference condition
Band B	Represents sites significantly impaired
Band C	Represents sites in a severely impaired condition
Band D	Represents sites that are extremely impaired

SIGNAL (Stream Invertebrate Grade Number Average Level) scores

The revised SIGNAL2 biotic index developed by Chessman (2003) was also used to determine the "environmental quality" of sites. This method assigns grade numbers to each macroinvertebrate family or taxa found, based largely on their response to a range of environmental conditions (Table 3). The sum of all grade numbers for that habitat is then divided by the total number of families recorded in each habitat to calculate the SIGNAL2 index. The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site.

Table 3: SIGNAL Grade and the Level of Pollution Tolerance

SIGNAL Grade	Pollution Tolerance
10-8	Indicates a greater sensitivity to pollution
7-5	Indicates a sensitivity to pollution
4-3	Indicates a tolerance to pollution
2-1	Indicates a greater tolerance to pollution

Table 4 provides a broad guide for interpreting the health of the site according to the SIGNAL2 score of the site.

Table 4: Guide to interpreting the SIGNAL2 scores

SIGNAL2 Score	Habitat quality
Greater than 6	Healthy habitat
Between 5 and 6	Mild pollution
Between 4 and 5	Moderate pollution
Less than 4	Severe pollution

*Note that SIGNAL2 scores are indicative only and that pollution does not refer to just anthropogenic pollution. Environmental stress may result in poor water quality occurring naturally in waterways. Low family richness and the occurrence of pollution tolerant invertebrates can give a low SIGNAL score even though they are in natural condition.

Taxa Richness

The richness of macroinvertebrate families (or class/orders if not identified to family level) was calculated as an indicator of stream health. The higher the number, the healthier the aquatic ecosystem.

EPT Index

The EPT (Ephemeroptera, Plecoptera and Tricoptera) index is based on the insect orders that contain a majority of pollution sensitive taxa (Lenat 1988). All genera of Ephemeroptera, Plecoptera and Tricoptera were identified and the number of distinct taxa were counted as an indicator of ecosystem health. The higher the number, the healthier the aquatic ecosystem.

Statistical Analysis

Statistical analysis was performed on the macroinvertebrate assemblage data collected using the suction sampler with the PERMANOVA+ for Primer statistical software package (Anderson *et al*. 2008). A three-factor design was used to investigate and explore changes and stream responses in Myrtle Creek before and after completion of remediation of Pool 23.

- Treatment: A fixed factor with two levels:
    - Impact: Sites on Myrtle Creek with potential to have been impacted by the project.
    - Reference: Sites on nearby creeks outside the influence of this and other similar projects. Additionally, these sites were selected as they were surveyed using the same techniques and over similar times periods.
- Survey: A fixed factor combining Year and Season and with three levels:
    - Autumn 2019 (Before remediation)
    - Spring 2019 (Before Remediation)
    - Autumn 2020 (After Remediation)
- Site: A random factor nested within Treatment with various sites
    - Myrtle Creek (Sites 1, 2 and 3) nested within Impact
    - Cedar Creek (Site 9, 12, and 16) nested within Reference.

The interaction term of 'Treatment x Survey' was investigated in detail to detect changes in the assemblage at a spatial scale considered reflective of the action at the remediation site. Although smaller scale temporal changes in the assemblage at the Site level may also be detected within the 'Survey x Site (Treatment)' interaction. Pairwise comparisons were performed to further investigate significant factors identified in the PERMANOVA for comparisons of interest. In the case where the number of unique permutations for a particular test was less than 100, Monte Carlo probability values were used to assess the significance of the test as outlined in Anderson *et al.* (2008).

To test and describe the multivariate differences PERMANOVA+ in PRIMER v6 (Anderson *et al*. 2008) was also used to undertake a multivariate PERMANOVA to compare the assemblages and Principles Coordinates Analysis (PCO) to depict and identify the drivers of these differences. Multivariate data was log transformed to reduce the effects of taxa with high abundances on the normality of the data, and the Bray-Curtis similarity measure was used to generate the resemblance matrix based on the centroids. Results of the PCO were depicted graphically displaying variation explained by the first two axes. In addition, vector overlays derived using Spearman correlations were superimposed on the PCO graph (where $r > 0.5$) to show the strength (length of vector) and direction (presence of taxa) driving differences in the assemblage. A PCO analysis was also performed on data limited to just the Impact sites to investigate and determine the strongest drivers of assemblage differences through time and occurring independently of the Reference sites.

A SIMPER analysis was used to explore the macroinvertebrate families that contribute to overall differences of factor Treatment between Impact and Reference groups. Additionally, a SIMPER analysis was performed on Site to explore macroinvertebrate families that contribute to differences at the Site level explore what family densities within Sites are driving differences between Impact and Reference sites.

For the univariate analysis the following parameters were investigated with PERMANOVA using the same procedure for assemblages, however the resemblance matrix was based on the Euclidean distance. Univariate analysis was performed for the following two indices:

- Taxonomic Richness
- Density

3. Results

3.1 Rainfall

In general, the water level was low on each sampling occasion in 2019, however a small storm event did provide some water in pools in Myrtle Creek in spring 2019, which allowed Pool 24 (immediately downstream of Pool 23) to be sampled (Figure 2). Pool 23 receded rapidly after this event and could not be sampled in spring 2019 surveys. In autumn 2020 there was one major rainfall event on 10 February 2020 of 260 mm and a moderate event on 6 March 2020 of 47.8 mm.

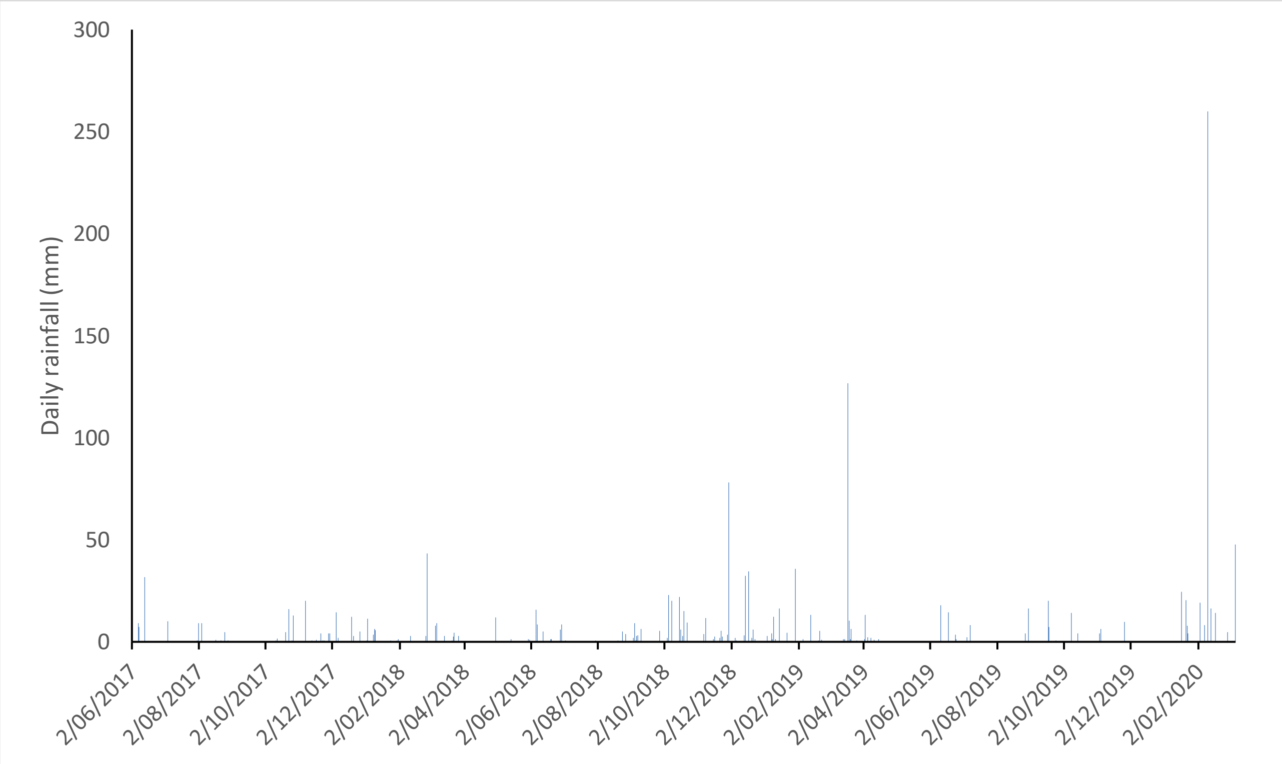

Figure 2: Daily rainfall Jan-November 2019 (source - Bureau of Meteorology (BOM))

3.2 Aquatic habitat

The aquatic habitat at impact sites were similar in autumn 2020 to previous sampling in spring and autumn 2019 and consisted predominately of pools with little to no riffles present (Plate 1-Plate 3). The streams were controlled by the sandstone geology, with bedrock a common component of the stream's morphology. The stream benthos was dominated by bedrock and boulders at all sites. Macrophyte occurrence varied among sites. Species present at Pool 22 include: *Myriophyllum aquaticum*, *Potomogoton sulcatus*, *Persicaria decipiens*, *Typha* sp. and *Cyprus* sp. Pool 30 contained primarily *Typha* sp. There was aquatic habitat available at Pool 23 (Plate 2) however no macrophytes were present.

Plate 1 Myrtle Creek at Pool 22 autumn 2020

Plate 2 Myrtle Creek at Pool 23 autumn 2020

Plate 3: Myrtle creek Pool 30 autumn 2020

3.3 Water quality

Water quality was not sampled in autumn 2019 due to equipment failure. The water quality results show electrical conductivity, turbidity and pH to be within ANZECC trigger values (DTVs) at all sites in autumn 2020. Dissolved oxygen (DO) was below DTVs at all sites with alkalinity consistently measuring 40 mg$CaCO_3$/L at Pool 22, 23 and Pool 30 (Table 5). Note that Pool 23 was not sampled in spring 2019 as it was dry and Pool 24 was not sampled in autumn 2020 as was only sampled in place of Pool 23 which was dry at the time in spring 2019.

Table 5: Water quality results spring 2019 and autumn 2020

	Site	Temp (C°)	Conductivity (µS/cm)	Turbidity (NTU)	Dissolved Oxygen (% sat)	pH*	Alkalinity (mg $CaCO_3$/L)
Spring 2019	Pool 22	13.75	185	17.6	**83.4**	7.56	60
	Pool 24	14.75	**424**	**146.6**	**72.4**	7.17	60
	Pool 30	15.6	**575**	5.4	100.3	6.86	80
Autumn 2020	Pool 22	19.36	57	9.3	**48.6**	7.05	40
	Pool 23	19.83	56	7.6	**60.6**	7.74	40
	Pool 30	19.96	71	8.4	**57.2**	7.7	40

NOTES: ANZECC guidelines for upland streams: Electrical conductivity (30-350µS/cm), Turbidity (2-25 NTU), pH (6.5-8.0), Dissolved Oxygen (90-110%). Text in bold indicate those variables that exceed the default trigger values.

3.4 AUSRIVAS and SIGNAL

AUSRIVAS results for autumn 2020 are presented in Table 6, with raw data provided in Annex 1.

Overall, 43 different taxa were collected from all sampling occasions, with the most taxa (19) found at Pool 23 in autumn 2020 and the least at Pool 24 (9) in spring 2019 (Table 6).

AUSRIVAS scores improved in autumn 2020 from the spring 2019 survey with Pool 22 and Pool 30 scoring in Band B and with increased O/E 50 scores (Table 6). This indicates that sites have fewer families than expected and are categorised as significantly to severely impaired (Table 4). Pool 23 (remediation site) scored in Band A in autumn 2020, which indicates that the site has similar families present to AUSRIVAS reference streams.

The SIGNAL scores for all sites and seasons are less than 4, which may indicate severe pollution in Myrtle Creek (Table 6). This low score reflects the dominance of pollution tolerant macroinvertebrates and presence of few pollution sensitive taxa (Table 3).

The low scores corresponded with the low EPT index, which showed that few sensitive families of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) were represented at most sites. Two EPT families were recorded in Pool 22 and Pool 24 and four were recorded in Pool 23 and Pool 30 in autumn 2020.

Sensitive families (SIGNAL ≥6) observed in Myrtle Creek include mayfly Leptophlebiidae (SIGNAL 8), beetles Elmidae (SIGNAL 7), Scirtidae (SIGNAL 6) and caddis fly Leptoceridae (SIGNAL 6).

Table 6: AUSRIVAS results autumn and spring 2019

Season	Autumn 2019			Spring 2019				Autumn 2020		
Site	Pool 22	Pool 23	Pool 30	Pool 22	Pool 23	Pool 24	Pool 30	Pool 22	Pool 23	Pool 30
No of taxa	13	dry	13	11	dry	9	17	16	19	16
OE 50	0.44	dry	0.55	0.34	dry	*	0.61	0.65	0.83	0.64
SIGNAL	3.09	dry	3.50	2.82	dry	2.11	3.47	3.47	3.83	3.4
Band	C	dry	B	C	dry	*	B	B	A	B
EPT	1	dry	4	0	dry	0	5	2	4	4

*Outside of experience of model.

3.5 Macroinvertebrate assemblages

Raw quantitative data is provided in Attachment 1. Data analysis is provided in Annex 2.

3.5.1 Multivariate analysis

The PCO analysis found that the first two-axes explain 47.2% of the variation in the data, with PCO1 the marginally higher at 26.1% (Figure 3). Graphical review of the assemblage based on ‘Site’ analysis shows some grouping of subset of Reference sites in the lower portion of the graph, however there are overlaps of the Impact and Reference sites in the upper portion. The Spearman correlations show a visual representation of a potential monotonic relationship between family densities and ordination axes. In this case, Ceratopognidae has a strong negative correlation with PCO2 and to a lesser extent Chironominae, Tanypodinae, Coengrionidae and EPT taxa Leptoceridae. Baetidae has negative relationship with PCO2. Oligochaeta a positive relationship with PCO1. While not causative, these overlays of taxa indicate potential monotonic relationships between these families and sites and are potentially important in driving differences between sites.

The SIMPER analysis of Treatment factor also showed differences between Impact and Reference sites are driven by differences in mostly common pollution tolerant taxa; Chironominae, Tanipodinae, Oligochaeta, and Ceratopognidae being higher at Reference sites. Additionally, EPT taxa that contributed to differences include Baetidae, Leptophlebiidae and Ecnomidae, which were higher at Impacts sites and Leptoceridae, which had high densities at Reference sites. SIMPER analysis based on Site showed that higher abundances in Pool 30 and Pool 23 were important in driving these overall family density differences in Leptophlebiidae, Baetidae and Ecnomidae EPT taxa between Impact and Reference sites (Annex 2).

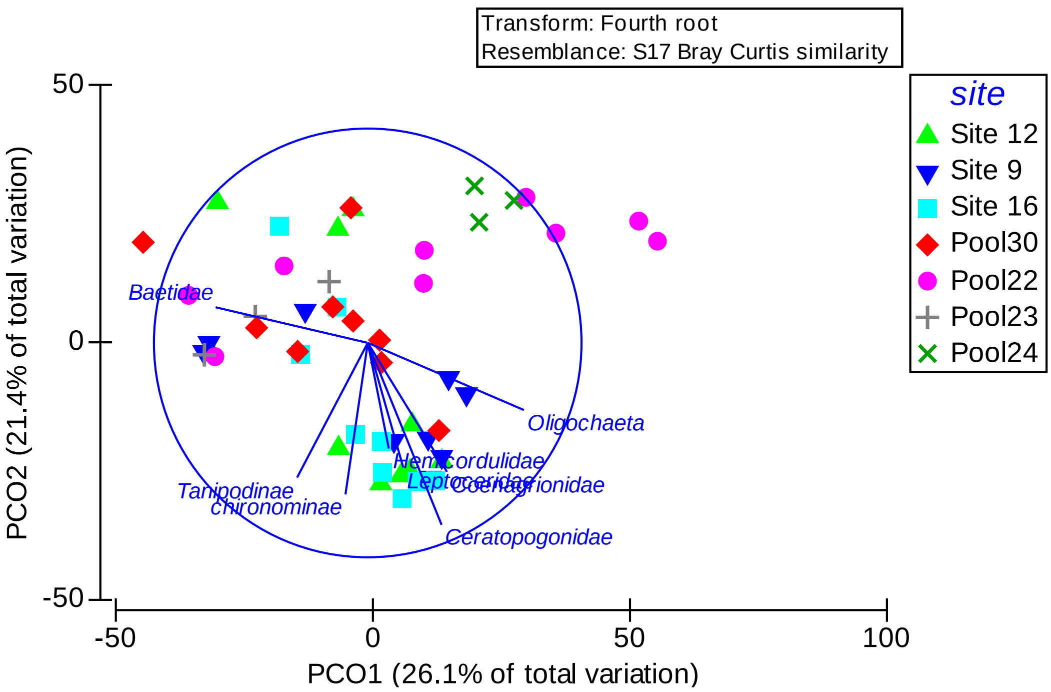

Figure 3: Principle Component Analysis of Survey (autumn2019-autumn 2020) and vector overlays derived from Spearman correlations.

Analysis of the differences within the macroinvertebrate assemblage using PERMANOVA detected a statistically significant difference for the 'Treatment x Survey' interaction term (Table 7). Further investigation of the 'Survey x Site' interaction found that there were some significant differences between factor 'Treatment' for each survey period indicating a difference between Impact and Reference sites irrespective of 'Survey'. Analysis of the factor 'Survey' showed a significant difference between all Surveys for Reference sites; however, Impact site differences were significant between autumn 2020 and autumn 2019, autumn 2020 and spring 2019 and not significantly different between autumn 2019 and spring 2019. This indicates that there are temporal differences also occurring within Impact sites and Reference sites.

3.5.2 Univariate analysis

Density

Analysis of density data detected no significant difference for 'Survey x Treatment' however a significant difference was detected for 'Survey x Site (Treatment)' (Table 8, Figure 4). Further investigation of the 'Survey x Site (Treatment)' for 'Survey' showed no statistical temporal difference between sites at Impact sites, however these temporal and spatial differences were observed at the Reference sites. This result suggests that Impact sites (Pool 30 and Pool 22) were more similar through time in comparison to Reference sites (Site 9, Site 13 and Site 14), which are temporally more variable.

For factor 'Site' there were several significant and non-significant results depending on 'Survey' and no ecologically meaningful patterns were observed.

Analysis of family richness data detected no significant difference for 'Survey x Treatment', however a significant difference was detected for 'Survey x Site (Treatment)' (Table 9, Figure 5). Further investigation of the 'Survey x Site (Treatment)' for 'Survey' showed significant differences between some sites within Impact sites and sites within Reference sites, however no clear temporal patterns are evident. Similarly, for factor 'Site' there were several significant and non-significant results depending on 'Survey' and no ecologically meaningful patterns were observed. These differences are likely to reflect the expected spatial and temporal variability between sites within Treatment groups.

Table 7: Macroinvertebrate assemblage PERMANOVA results

Source	Degrees of Freedom (df)	Sum of Squares (SS)	Mean sum of squares (MS)	Pseudo-F	P(perm)	Unique Permutations
Treatment	1	8312	8312	9.8736	0.043	20
Survey	2	16803	8401.3	11.617	0.001	998
Site (Treatment)	4	3357.9	839.48	0.67753	0.906	997
Treatment x Survey	2	9791.5	4895.7	6.7695	**0.001**	998
Survey x Site (Treatment)	8	5745.9	718.24	0.57968	0.99	998
Residual	33	40888	1239			
Total	50	85408				

Table 8: Density PERMANOVA results

Source	Degrees of Freedom (df)	Sum of Squares (SS)	Mean sum of squares (MS)	Pseudo-F	P(perm)	Unique Permutations
Treatment	1	10.26	10.26	47.017	0.008	209
Survey	2	5.0685	2.5343	2.9787	0.125	999
Site (Treatment)	5	1.1185	0.2237	1.2803	0.298	998
Treatment x Survey	2	4.1329	2.0665	2.4288	0.178	998
Survey x Site (Treatment)	6	5.1048	0.85081	4.8694	**0.001**	999
Residual	34	5.9406	0.17472			
Total	50	38.674				

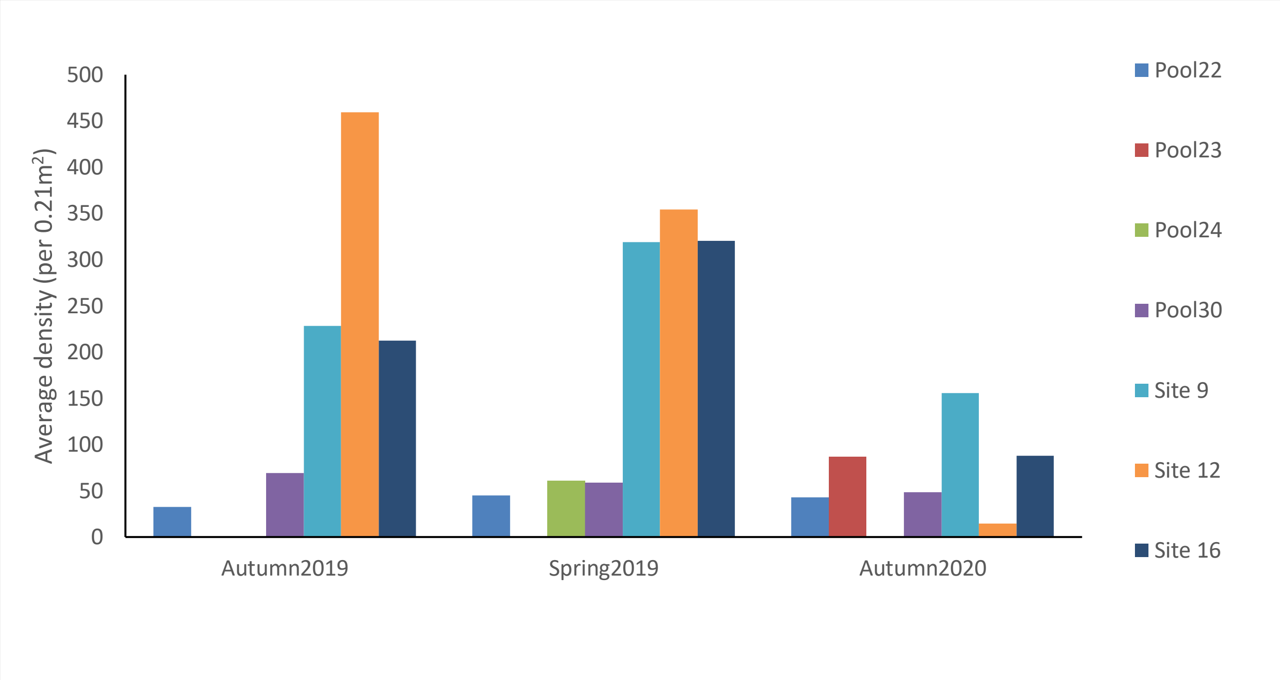

Figure 4: Average macroinvertebrate density of Impact and Reference sites for each survey

Table 9: Density PERMANOVA results

Source	Degrees of Freedom (df)	Sum of Squares (SS)	Mean sum of squares (MS)	Pseudo-F	P(perm)	Unique Permutations
Treatment	1	27.598	27.598	1.4514	0.302	210
Survey	2	60.052	30.026	2.4855	0.134	997
Site (Treatment)	5	104.8	20.959	5.8094	0.001	999
Treatment x Survey	2	74.274	37.137	3.0742	0.115	998
Survey x Site (Treatment)	6	72.481	12.08	3.3483	**0.015**	998
Residual	34	122.67	3.6078			
Total	50	507.29				

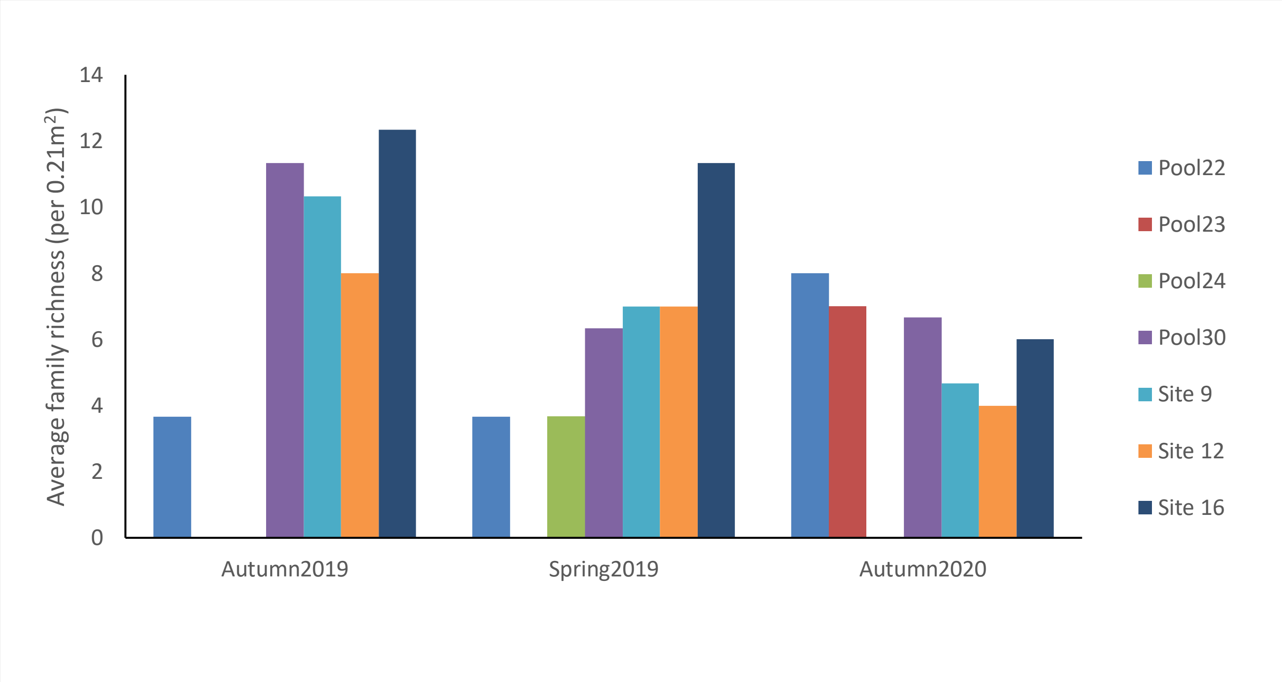

Figure 5: Average family richness of Impact and Reference sites for each survey

4. Discussion

Remediation work on Pool 23 was completed in February 2020. After being dry during autumn and spring 2019 monitoring, Pool 23 was holding water in autumn 2020 and was able to be sampled. Autumn 2020 was considerably wetter than previous years with one high rainfall event and one moderate rainfall event occurring in the month before sampling. There was evidence of high flows with reduction in aquatic macrophytes and benthic organic matter and flood debris. All sites had similar riparian and channel condition prior to sampling however there was reduced macrophyte coverage in Pool 22 in autumn 2020. The higher water levels have resulted in surface flow, pool connectivity and, in general, good water quality with EC, turbidity and pH physio-chemical measurements within ANZECC DTVs.

The previous monitoring report (Niche 2019), which considered autumn 2019 and spring 2019, identified the following targets that may indicate improved stream health:

- Increases in EPT taxa such as Baetidae, Leptophlebidae, Canidae, Leptoceridae and Ecnomidae in Pool 23.
- Increase in SIGNAL score to approximately 3.5 or above.
- Increase in AUSRIVAS score to Band B or above.

The AUSRIVAS data indicates that there has been an improvement overall in stream health at Pool 22 and Pool 30 with SIGNAL, Number of families and OE50 scores highest in Autumn 2020. EPT decreased slightly for Pool 30 compared to Spring 2019 but was similar to autumn 2019. EPT taxa in Pool 22 increased in autumn 2020. Pool 23, only sampled in autumn 2020 (previously dry), scored in Band A, which indicated it is close to reference condition based on the AUSRIVAS autumn pool edge model. Pool 23 also supported habitat for pollution sensitive fauna including Leptophlebiidae (SIGNAL 8), Elmidae (SIGNAL 7), Scirtidae (SIGNAL 6) and Leptoceridae (SIGNAL 6) as well as other EPT taxa – Baetidae and Ecnomidae.

While the multivariate analysis was limited in temporal replication, it also supports improved stream health and showed that, with the exception of Leptoceridae, Myrtle Creek has higher densities of EPT taxa including Baetidae, Leptophlebiidae, and Ecnomidae than Reference sites. These families were present in Pool 23, which contributed to these overall differences between Impact and Reference sites. Common pollution tolerant taxa Oligochaeta, Ceratopognidae, Chironominae and Tanipodinae also drove these differences, however these taxa had a greater representation at Reference sites. While it is difficult to determine what recovery of Pool 23 should look like with no pre-mining macroinvertebrate surveys, the AUSRIVAS and benthic quantitative data suggests that Pool 23 is close to reference condition and has ecology reflective of good stream health. In addition, the targets identified in Niche (2019) have been met.

5. Conclusion and recommendations

The ecology of intermittent waterways is driven by natural fluctuations in flow, resulting in changes to water quality and ecological processes, which need to be taken into consideration when interpreting ecological recovery. Monitoring results indicate that Myrtle Creek has improved in stream health. The improvement in stream health occurred in part due to overall wetter conditions in February 2020, however remediation of Pool 23 has enabled the pool to store water. This has resulted in a rapid response from aquatic macroinvertebrates (approximately one month) that have colonised this habitat.

The following targeted improvements identified in Niche (2019) monitoring report have been met:

- Increases in EPT taxa such as Baetidae, Leptophlebidae, Canidae, Leptoceridae and Ecnomidae in Pool 23.
- Increase in SIGNAL score to approximately 3.5 or above.
- Increase in AUSRIVAS score to Band B or above.

It is recommended that biannual monitoring continue in order to gauge the longevity of these stream health improvements

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Annex 1: AUSRIVAS - Myrtle Creek

AUSRIVAS 2019

Note: Pool24 only sampled in spring 2019. Pool23 was only sample in autumn 2020.

Monitoring period	Autumn 2019		Spring 2019			Autumn 2020		
Site	Pool 22	Pool 30	Pool 22	Pool 24	Pool 30	Pool 22	Pool 23	Pool 30
Nematoda			29					
Turbellaria	1	0						
Ancylidae	1	0						
Pyralidae	0	1		1				
Physidae	3	0	4				3	1
Corbiculidae			20			1		
Oligochaeta	3	0	9		3			2
Acarina	1	0				1		
Ostracoda	2	0						
Atyidae	0	22	25		22		3	3
Parastacidae					2	1	1	
Dytiscidae	0	1	2	4	4	6	14	9
Elmidae							1	
Gyrinidae							2	
Hydrophilidae				1				
Scirtidae							1	
Stratiomyidae				2	1	1		
Culicidae				6		1		
Dixidae							1	
Ceratopogonidae					1			
Tanypodinae						5		7
Orthocladinidae								2
Chironominae	4	17	32	8	23	29	16	11
Choarboridae							2	
Baetidae					16	10	37	52
Leptophlebiidae	0	5			43	20	10	4
Caenidae	0	1			2			
Veliidae	2	0		1			1	
Gerridae						1		
Corixidae	2	2			1	2	7	2
Notonectidae	13	8	3	1	9	1	2	4
Coenagrionidae	12	2	6	1	2		3	1
Isostictidae					1			
Lestidae						3		
Megapodagrionidae			5					

Monitoring period	Autumn 2019		Spring 2019			Autumn 2020		
Site	Pool 22	Pool 30	Pool 22	Pool 24	Pool 30	Pool 22	Pool 23	Pool 30
Aeshnidae	1	0						
Gomphidae						1		
Hemicorduliidae	1	3	1			1		1
Libellulidae	0	5			1			2
Ecnomidae	0	2			6		2	1
Leptoceridae	0	7			2		5	10

Annex 2: Macroinvertebrate quantitative analysis

Multivariate analysis

PAIR-WISE TESTS

Term 'Tr'

Groups	t	P(perm)	Unique perms	P(MC)
Reference, Impact	3.1422	0.051	20	0.001

Denominators

Groups	Denominator	Den.df
Reference, Impact	0.99408*re(Tr) + 5.9172E-3*Res	4.07

Average Similarity between/within groups

	Reference	Impact
Reference	52.361	
Impact	40.415	40.335

PAIR-WISE TESTS

Term 'su'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Autumn2020	3.3656	0.009	999	0.001
Autumn2019, Spring2019	1.9838	0.036	998	0.016
Autumn2020, Spring2019	4.4542	0.007	971	0.001

Denominators

Groups	Denominator	Den.df
Autumn2019, Autumn2020	0.98765*suxre(Tr) + 1.2346E-2*Res	4.13
Autumn2019, Spring2019	0.98765*suxre(Tr) + 1.2346E-2*Res	4.18
Autumn2020, Spring2019	1*suxre(Tr)	4

Average Similarity between/within groups

	Autumn2019	Autumn2020	Spring2019
Autumn2019	51.54		
Autumn2020	40.217	51.747	
Spring2019	46.191	37.644	44.732

SIMPER

Group Reference
Average similarity: 52.36

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.92	19.16	3.24	36.59	36.59
Tanipodinae	2.16	12.50	2.56	23.88	60.47
Oligochaeta	2.03	8.56	1.35	16.34	76.81
Ceratopogonidae	1.33	4.96	0.90	9.47	86.28
Dytiscidae	0.60	1.90	0.56	3.63	89.92
Baetidae	0.41	1.07	0.32	2.04	91.96

Group Impact
Average similarity: 40.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	1.60	12.65	1.54	31.36	31.36
Oligochaeta	1.51	12.07	0.99	29.92	61.27

Tanipodinae	1.12	6.16	0.81	15.27	76.54
Baetidae	0.85	3.20	0.54	7.93	84.47
Leptophlebiidae	0.69	2.95	0.61	7.31	91.78

Groups Reference & Impact
Average dissimilarity = 59.59

	Group Reference	Group Impact				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.92	1.60	6.80	1.26	11.40	11.40
Oligochaeta	2.03	1.51	6.54	1.20	10.97	22.38
Tanipodinae	2.16	1.12	6.32	1.19	10.60	32.98
Ceratopogonidae	1.33	0.22	5.27	1.32	8.84	41.82
Baetidae	0.41	0.85	3.93	1.06	6.59	48.41
Leptophlebiidae	0.48	0.69	3.17	1.07	5.32	53.73
Dytiscidae	0.60	0.37	2.91	1.00	4.88	58.61
Ecnomidae	0.23	0.41	2.25	0.74	3.77	62.38
Coenagrionidae	0.47	0.13	2.04	0.84	3.43	65.81
Leptoceridae	0.43	0.10	1.77	0.74	2.98	68.79
Sphaeridae	0.37	0.08	1.76	0.57	2.95	71.74
Gomphidae	0.18	0.17	1.44	0.57	2.41	74.15
Hemicordulidae	0.36	0.00	1.36	0.57	2.28	76.43
Megapodagrionidae	0.32	0.08	1.35	0.64	2.26	78.69
Physidae	0.00	0.24	1.05	0.48	1.77	80.46
Culicidae	0.07	0.13	0.96	0.44	1.61	82.07
Corixidae	0.07	0.12	0.79	0.40	1.33	83.40
Atyidae	0.07	0.13	0.77	0.43	1.29	84.69
Scirtidae	0.04	0.14	0.66	0.41	1.11	85.80
Micronectidae	0.08	0.08	0.66	0.39	1.10	86.90
Paratascidae	0.00	0.13	0.64	0.35	1.08	87.98
Orthocladinae	0.00	0.15	0.62	0.35	1.05	89.03
Tricladida	0.08	0.08	0.62	0.32	1.03	90.06

Group Site 12
Average similarity: 51.62

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.68	18.93	3.33	36.67	36.67
Tanipodinae	2.71	16.59	3.02	32.13	68.80
Oligochaeta	1.71	6.38	1.00	12.37	81.17
Ceratopogonidae	1.38	5.44	0.82	10.54	91.71

Group Site 9
Average similarity: 56.35

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.84	19.51	2.64	34.63	34.63
Tanipodinae	1.86	12.23	2.06	21.71	56.34
Oligochaeta	2.39	9.76	1.06	17.31	73.65
Ceratopogonidae	1.34	5.12	0.83	9.08	82.73
Sphaeridae	1.01	3.05	0.60	5.42	88.15
Dytiscidae	0.78	3.05	0.81	5.41	93.55

Group Site 16
Average similarity: 55.91

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.25	19.16	4.54	34.27	34.27
Oligochaeta	1.98	9.83	5.45	17.59	51.86
Tanipodinae	1.90	9.43	3.95	16.86	68.72
Ceratopogonidae	1.28	4.01	1.07	7.17	75.90
Dytiscidae	0.73	3.26	0.76	5.84	81.73
Leptophlebiidae	0.98	2.78	0.82	4.97	86.71
Leptoceridae	0.75	1.80	0.61	3.22	89.92
Megapodagrionidae	0.70	1.72	0.60	3.08	93.00

Group Pool30
Average similarity: 42.89

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	1.66	10.19	1.55	23.76	23.76
Tanipodinae	1.23	6.86	1.04	16.00	39.76
Oligochaeta	1.31	6.36	1.06	14.83	54.59
Ecnomidae	1.10	5.59	1.11	13.04	67.64
Baetidae	1.17	5.45	0.78	12.70	80.34
Leptophlebiidae	1.01	5.39	1.12	12.58	92.92

Group Pool22
Average similarity: 37.18

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oligochaeta	1.59	17.05	1.02	45.86	45.86
Chironominae	1.21	10.20	1.11	27.44	73.30
Tanipodinae	0.96	4.96	0.60	13.33	86.63
Gomphidae	0.33	1.57	0.30	4.21	90.85

Group Pool24
Average similarity: 74.27

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oligochaeta	2.36	30.75	4.97	41.40	41.40
Chironominae	1.66	25.84	13.74	34.79	76.19
Culicidae	1.00	17.69	10.38	23.81	100.00

Group Pool23
Average similarity: 65.16

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.55	21.75	12.16	33.37	33.37
Tanipodinae	2.02	15.90	3.06	24.40	57.78
Baetidae	1.80	15.54	8.68	23.85	81.62
Oligochaeta	1.02	3.30	0.58	5.06	86.68
Leptophlebiidae	0.88	2.93	0.58	4.49	91.17

Groups Site 12 & Pool30
Average dissimilarity = 59.15

	Group Site 12	Group Pool30				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanipodinae	2.71	1.23	7.14	1.45	12.06	12.06
Oligochaeta	1.71	1.31	6.03	1.35	10.20	22.26
Chironominae	2.68	1.66	5.50	1.05	9.30	31.56
Ceratopogonidae	1.38	0.43	5.11	1.29	8.64	40.20
Baetidae	0.11	1.17	5.11	1.29	8.63	48.83
Ecnomidae	0.57	1.10	3.98	1.20	6.73	55.56
Leptophlebiidae	0.35	1.01	3.85	1.23	6.50	62.06
Hemicordulidae	0.61	0.00	2.20	0.85	3.72	65.78
Dytiscidae	0.29	0.35	2.11	0.82	3.57	69.36
Coenagrionidae	0.35	0.22	1.78	0.80	3.02	72.37
Megapodagrionidae	0.26	0.22	1.43	0.72	2.41	74.78
Leptoceridae	0.15	0.28	1.41	0.61	2.39	77.17
Gomphidae	0.26	0.11	1.40	0.61	2.37	79.54
Paratascidae	0.00	0.24	1.40	0.48	2.37	81.91
Tricladida	0.11	0.23	1.31	0.44	2.21	84.12
Corixidae	0.11	0.20	1.25	0.49	2.12	86.24
Orthocladinae	0.00	0.28	1.25	0.48	2.10	88.35
Micronectidae	0.00	0.22	0.90	0.51	1.52	89.87
Atyidae	0.00	0.22	0.86	0.52	1.46	91.33

Groups Site 9 & Pool30
Average dissimilarity = 60.12

	Group Site 9	Group Pool30				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%

Oligochaeta	2.39	1.31	7.35	1.32	12.23	12.23
Chironominae	2.84	1.66	6.00	1.06	9.98	22.21
Ceratopogonidae	1.34	0.43	4.79	1.30	7.97	30.17
Ecnomidae	0.00	1.10	4.40	1.59	7.32	37.49
Baetidae	0.56	1.17	4.10	1.40	6.82	44.31
Tanipodinae	1.86	1.23	4.09	1.09	6.81	51.12
Leptophlebiidae	0.11	1.01	3.88	1.53	6.46	57.58
Sphaeridae	1.01	0.00	3.84	1.05	6.39	63.97
Dytiscidae	0.78	0.35	2.76	1.14	4.58	68.56
Coenagrionidae	0.53	0.22	2.15	0.94	3.58	72.14
Leptoceridae	0.39	0.28	1.86	0.82	3.09	75.23
Micronectidae	0.24	0.22	1.50	0.69	2.50	77.73
Atyidae	0.22	0.22	1.25	0.71	2.09	79.82
Tricladida	0.13	0.23	1.25	0.46	2.08	81.90
Paratascidae	0.00	0.24	1.22	0.51	2.04	83.94
Orthocladinae	0.00	0.28	1.14	0.49	1.90	85.83
Scirtidae	0.11	0.15	0.88	0.47	1.46	87.29
Gomphidae	0.11	0.11	0.81	0.48	1.35	88.64
Megapodagrionidae	0.00	0.22	0.77	0.52	1.29	89.93
Aeshnidae	0.00	0.22	0.77	0.52	1.29	91.21

Groups Site 16 & Pool30
Average dissimilarity = 56.79

	Group Site 16	Group Pool30				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.25	1.66	6.35	1.35	11.18	11.18
Ceratopogonidae	1.28	0.43	4.04	1.29	7.11	18.30
Oligochaeta	1.98	1.31	3.92	1.25	6.90	25.20
Ecnomidae	0.11	1.10	3.87	1.42	6.82	32.02
Baetidae	0.57	1.17	3.78	1.24	6.66	38.68
Tanipodinae	1.90	1.23	3.60	1.24	6.34	45.02
Leptophlebiidae	0.98	1.01	2.98	1.07	5.25	50.27
Dytiscidae	0.73	0.35	2.58	1.01	4.55	54.82
Leptoceridae	0.75	0.28	2.55	1.05	4.48	59.30
Megapodagrionidae	0.70	0.22	2.38	1.09	4.20	63.50
Coenagrionidae	0.53	0.22	1.94	0.94	3.41	66.91
Hemicordulidae	0.46	0.00	1.54	0.67	2.71	69.63
Libellulidae	0.45	0.00	1.46	0.68	2.58	72.20
Aeshnidae	0.22	0.22	1.20	0.70	2.11	74.32
Paratascidae	0.00	0.24	1.12	0.49	1.97	76.29
Orthocladinae	0.00	0.28	1.05	0.48	1.85	78.14
Corixidae	0.11	0.20	1.01	0.49	1.77	79.91
Sialidae	0.29	0.00	0.96	0.52	1.69	81.61
Gomphidae	0.18	0.11	0.89	0.49	1.57	83.18
Tricladida	0.00	0.23	0.85	0.34	1.50	84.69
Simuliidae	0.22	0.00	0.79	0.51	1.40	86.08
Micronectidae	0.00	0.22	0.77	0.51	1.36	87.45
Atyidae	0.00	0.22	0.75	0.52	1.31	88.76
Physidae	0.00	0.19	0.71	0.34	1.25	90.01

Groups Site 12 & Pool22
Average dissimilarity = 63.79

	Group Site 12	Group Pool22				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanipodinae	2.71	0.96	10.37	1.62	16.26	16.26
Oligochaeta	1.71	1.59	8.45	1.28	13.25	29.52
Chironominae	2.68	1.21	8.14	1.38	12.76	42.27
Ceratopogonidae	1.38	0.15	6.30	1.36	9.88	52.15
Ecnomidae	0.57	0.00	3.06	0.84	4.79	56.95
Baetidae	0.11	0.49	2.89	0.72	4.54	61.49
Gomphidae	0.26	0.33	2.69	0.76	4.21	65.70
Leptophlebiidae	0.35	0.41	2.68	0.86	4.20	69.90
Hemicordulidae	0.61	0.00	2.57	0.86	4.03	73.93
Dytiscidae	0.29	0.37	2.37	0.70	3.72	77.64
Coenagrionidae	0.35	0.11	2.01	0.71	3.15	80.80
Corbiculidae	0.00	0.28	1.75	0.49	2.74	83.54
Physidae	0.00	0.24	1.23	0.50	1.94	85.47
Corixidae	0.11	0.11	1.19	0.46	1.86	87.34
Nematoda	0.11	0.11	1.17	0.46	1.83	89.16

Sphaeridae	0.00	0.22	1.05	0.50	1.65	90.82

Groups Site 9 & Pool22
Average dissimilarity = 62.14

Species	Group Site 9 Av.Abund	Group Pool22 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.84	1.21	9.20	1.38	14.81	14.81
Oligochaeta	2.39	1.59	8.46	1.35	13.62	28.42
Tanipodinae	1.86	0.96	6.46	1.13	10.40	38.83
Ceratopogonidae	1.34	0.15	5.91	1.38	9.51	48.34
Sphaeridae	1.01	0.22	4.55	1.15	7.32	55.65
Dytiscidae	0.78	0.37	3.81	1.33	6.14	61.79
Baetidae	0.56	0.49	3.72	0.99	5.99	67.78
Coenagrionidae	0.53	0.11	2.48	0.89	3.98	71.77
Leptophlebiidae	0.11	0.41	2.05	0.75	3.30	75.07
Gomphidae	0.11	0.33	2.05	0.73	3.29	78.36
Leptoceridae	0.39	0.00	1.60	0.68	2.58	80.94
Corbiculidae	0.00	0.28	1.53	0.51	2.46	83.39
Atyidae	0.22	0.11	1.32	0.58	2.13	85.52
Micronectidae	0.24	0.00	1.27	0.50	2.04	87.56
Physidae	0.00	0.24	1.11	0.52	1.79	89.35
Nematoda	0.11	0.11	0.90	0.48	1.44	90.79

Groups Site 16 & Pool22
Average dissimilarity = 63.37

Species	Group Site 16 Av.Abund	Group Pool22 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.25	1.21	9.42	1.83	14.86	14.86
Tanipodinae	1.90	0.96	5.52	1.42	8.72	23.57
Ceratopogonidae	1.28	0.15	4.92	1.39	7.77	31.34
Oligochaeta	1.98	1.59	4.54	1.27	7.16	38.50
Dytiscidae	0.73	0.37	3.86	1.24	6.10	44.60
Leptophlebiidae	0.98	0.41	3.61	1.21	5.70	50.30
Baetidae	0.57	0.49	3.39	0.91	5.34	55.64
Leptoceridae	0.75	0.00	2.89	1.07	4.56	60.20
Megapodagrionidae	0.70	0.00	2.74	1.07	4.33	64.53
Coenagrionidae	0.53	0.11	2.19	0.89	3.46	67.99
Gomphidae	0.18	0.33	2.08	0.75	3.28	71.26
Hemicordulidae	0.46	0.00	1.78	0.67	2.81	74.07
Libellulidae	0.45	0.00	1.68	0.69	2.66	76.73
Corbiculidae	0.00	0.28	1.39	0.49	2.19	78.92
Sphaeridae	0.11	0.22	1.14	0.60	1.79	80.71
Sialidae	0.29	0.00	1.11	0.52	1.75	82.46
Physidae	0.00	0.24	1.02	0.50	1.61	84.07
Simuliidae	0.22	0.00	0.93	0.52	1.47	85.54
Aeshnidae	0.22	0.00	0.90	0.53	1.41	86.95
Corixidae	0.11	0.11	0.88	0.48	1.38	88.33
Notonectidae	0.22	0.00	0.81	0.53	1.27	89.61
Caenidae	0.11	0.11	0.72	0.48	1.13	90.74

Groups Site 12 & Pool24
Average dissimilarity = 60.62

Species	Group Site 12 Av.Abund	Group Pool24 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanipodinae	2.71	0.33	13.23	2.15	21.82	21.82
Oligochaeta	1.71	2.36	9.83	1.27	16.21	38.03
Ceratopogonidae	1.38	0.00	6.68	1.35	11.02	49.06
Culicidae	0.00	1.00	6.42	2.59	10.59	59.64
Chironominae	2.68	1.66	5.66	1.63	9.34	68.98
Ecnomidae	0.57	0.00	3.28	0.84	5.41	74.39
Leptophlebiidae	0.35	0.33	2.79	0.79	4.61	79.00
Hemicordulidae	0.61	0.00	2.72	0.86	4.48	83.48
Coenagrionidae	0.35	0.00	1.73	0.69	2.85	86.33
Gomphidae	0.26	0.00	1.42	0.52	2.35	88.68
Dytiscidae	0.29	0.00	1.23	0.51	2.03	90.71

Groups Site 9 & Pool24
Average dissimilarity = 60.32

Species	Group Site 9 Av.Abund	Group Pool24 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanipodinae	1.86	0.33	9.06	1.57	15.01	15.01
Oligochaeta	2.39	2.36	8.47	1.22	14.04	29.05
Chironominae	2.84	1.66	7.10	1.59	11.78	40.82
Ceratopogonidae	1.34	0.00	6.41	1.37	10.63	51.45
Culicidae	0.11	1.00	4.94	2.23	8.19	59.64
Sphaeridae	1.01	0.00	4.81	1.06	7.98	67.62
Dytiscidae	0.78	0.00	3.84	1.33	6.36	73.98
Baetidae	0.56	0.00	3.51	0.84	5.82	79.80
Coenagrionidae	0.53	0.00	2.42	0.85	4.02	83.82
Leptophlebiidae	0.11	0.33	2.08	0.71	3.44	87.26
Leptoceridae	0.39	0.00	1.69	0.68	2.81	90.06

Groups Site 16 & Pool24
Average dissimilarity = 60.68

Species	Group Site 16 Av.Abund	Group Pool24 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.25	1.66	7.38	2.65	12.16	12.16
Tanipodinae	1.90	0.33	7.35	2.02	12.11	24.27
Ceratopogonidae	1.28	0.00	5.34	1.46	8.80	33.07
Oligochaeta	1.98	2.36	4.64	1.06	7.65	40.72
Culicidae	0.11	1.00	4.50	1.87	7.41	48.13
Dytiscidae	0.73	0.00	4.06	1.17	6.69	54.82
Leptophlebiidae	0.98	0.33	3.85	1.29	6.35	61.17
Baetidae	0.57	0.00	3.16	0.77	5.21	66.38
Leptoceridae	0.75	0.00	3.05	1.07	5.02	71.39
Megapodagrionidae	0.70	0.00	2.89	1.07	4.76	76.16
Coenagrionidae	0.53	0.00	2.11	0.87	3.48	79.64
Hemicordulidae	0.46	0.00	1.87	0.67	3.09	82.73
Libellulidae	0.45	0.00	1.77	0.68	2.92	85.65
Sialidae	0.29	0.00	1.17	0.52	1.92	87.57
Simuliidae	0.22	0.00	0.98	0.51	1.62	89.19
Aeshnidae	0.22	0.00	0.95	0.52	1.56	90.75

Univariate -Density

PAIR-WISE TESTS

Term 'suxsi(Tr)' for pairs of levels of factor 'survey'

Within level 'Impact' of factor 'Treatment'
Within level 'Pool30' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	0.71703	0.487	10	0.502
Autumn2019, Autumn2020	1.0033	0.525	10	0.378
Spring2019, Autumn2020	0.36734	0.684	10	0.716

Within level 'Impact' of factor 'Treatment'
Within level 'Pool22' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	0.39886	0.705	10	0.692
Autumn2019, Autumn2020	0.82676	0.521	10	0.465
Spring2019, Autumn2020	0.20331	0.899	10	0.827

Within level 'Reference' of factor 'Treatment'
Within level 'Site 12' of factor 'site'
Unique

Groups	t	P(perm)	perms	P(MC)
Autumn2019, Spring2019	3.0374	0.113	10	0.037
Autumn2019, Autumn2020	24.688	0.123	10	0.001
Spring2019, Autumn2020	35.872	0.099	10	0.001

Within level 'Reference' of factor 'Treatment'
Within level 'Site 9' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	1.1644	0.415	10	0.29
Autumn2019, Autumn2020	1.4107	0.328	10	0.22
Spring2019, Autumn2020	2.4236	0.098	10	0.074

Within level 'Reference' of factor 'Treatment'
Within level 'Site 16' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	1.4068	0.22	10	0.24
Autumn2019, Autumn2020	2.02	0.121	10	0.109
Spring2019, Autumn2020	2.8636	0.089	10	0.038

PAIR-WISE TESTS

Term 'suxsi(Tr)' for pairs of levels of factor 'site'

Within level 'Impact' of factor 'Treatment'
Within level 'Autumn2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	2.244	0.111	10	0.101

Within level 'Impact' of factor 'Treatment'
Within level 'Spring2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	0.43724	0.51	10	0.7
Pool30, Pool24	0.14163	1	10	0.898
Pool22, Pool24	0.21235	0.899	10	0.84

Within level 'Impact' of factor 'Treatment'
Within level 'Autumn2020' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	0.1477	1	7	0.903
Pool30, Pool23	1.4217	0.087	10	0.241
Pool22, Pool23	4.3462	0.102	10	0.01

Within level 'Reference' of factor 'Treatment'
Within level 'Autumn2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Site 12, Site 9	3.8073	0.108	10	0.025
Site 12, Site 16	4.0293	0.09	10	0.021
Site 9, Site 16	0.27406	0.676	10	0.799

Average Distance between/within groups

	Site 12	Site 9	Site 16
Site 12	6.3402E-2		

Site 9	0.3407	0.44552	
Site 16	0.26167	0.38125	0.49257

Within level 'Reference' of factor 'Treatment'
Within level 'Autumn2020' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Site 12, Site 9	8.2154	0.098	10	0.001
Site 12, Site 16	2.5417	0.096	10	0.047
Site 9, Site 16	1.3544	0.313	10	0.24

Univariate – Family Richness

PAIR-WISE TESTS

Term 'suxsi(Tr)' for pairs of levels of factor 'survey'

Within level 'Impact' of factor 'Treatment'
Within level 'Pool30' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	4.5227	0.092	6	0.011
Autumn2019, Autumn2020	2.2711	0.108	8	0.089
Spring2019, Autumn2020	0.16903	1	5	0.867

Within level 'Impact' of factor 'Treatment'
Within level 'Pool22' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	9.996E-9	1	3	1
Autumn2019, Autumn2020	4.111	0.107	5	0.016
Spring2019, Autumn2020	3.6056	0.114	5	0.022

Within level 'Reference' of factor 'Treatment'
Within level 'Site 12' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	0.61237	0.709	5	0.591
Autumn2019, Autumn2020	2.6186	0.206	5	0.05
Spring2019, Autumn2020	1.964	0.209	6	0.133

Within level 'Reference' of factor 'Treatment'
Within level 'Site 9' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	1.5811	0.287	6	0.199
Autumn2019, Autumn2020	2.4042	0.208	5	0.065
Spring2019, Autumn2020	1.75	0.303	5	0.15

Within level 'Reference' of factor 'Treatment'
Within level 'Site 16' of factor 'site'

Groups	t	P(perm)	Unique perms	P(MC)
Autumn2019, Spring2019	0.90453	0.719	3	0.401
Autumn2019, Autumn2020	3.8	0.106	7	0.016
Spring2019, Autumn2020	3.0237	0.089	8	0.045

PAIR-WISE TESTS

Term 'suxsi(Tr)' for pairs of levels of factor 'site'

Within level 'Impact' of factor 'Treatment'
Within level 'Autumn2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	8.1317	0.106	6	0.002

Within level 'Impact' of factor 'Treatment'
Within level 'Spring2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	2.8284	0.17	3	0.06
Pool30, Pool24	3.5777	0.094	5	0.022
Pool22, Pool24	7.0682E-9	1	3	1

Within level 'Impact' of factor 'Treatment'
Within level 'Autumn2020' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Pool30, Pool22	0.63246	0.666	4	0.562
Pool30, Pool23	0.15811	1	4	0.887
Pool22, Pool23	0.70711	1	1	0.538

Within level 'Reference' of factor 'Treatment'
Within level 'Autumn2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Site 12, Site 9	1	0.483	6	0.375
Site 12, Site 16	3.25	0.093	5	0.035
Site 9, Site 16	0.93704	0.586	6	0.39

Within level 'Reference' of factor 'Treatment'
Within level 'Spring2019' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Site 12, Site 9	Negative			
Site 12, Site 16	2.9824	0.108	7	0.037
Site 9, Site 16	4.111	0.09	6	0.017

Within level 'Reference' of factor 'Treatment'
Within level 'Autumn2020' of factor 'survey'

Groups	t	P(perm)	Unique perms	P(MC)
Site 12, Site 9	0.4264	0.709	4	0.69
Site 12, Site 16	1.0954	0.494	6	0.323
Site 9, Site 16	0.68599	0.589	6	0.52

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Contact Us

Niche Environment and Heritage
02 9630 5658
info@niche-eh.com

NSW Head Office – Sydney
PO Box 2443 North Parramatta
NSW 1750 Australia

QLD Head Office – Brisbane
PO Box 540 Sandgate
QLD 4017 Australia

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Our services

Ecology and biodiversity
Terrestrial
Freshwater
Marine and coastal
Research and monitoring
Wildlife Schools and training

Heritage management
Aboriginal heritage
Historical heritage
Conservation management
Community consultation
Archaeological, built and landscape values

Environmental management and approvals
Impact assessments
Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)