AQUATIC ECOLOGY MONITORING: METROPOLITAN COAL LONGWALLS 20-27

SPRING 2020 SURVEYS

Prepared for

METROPOLITAN COAL

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1.0 INTRODUCTION

Metropolitan Coal is wholly owned by Peabody Energy Australia Pty Ltd and is located approximately 30 kilometres (km) north of Wollongong in NSW. Metropolitan Coal was granted approval for the Metropolitan Coal Project (the Project) under the NSW *Environmental Planning and Assessment Act, 1979* in June 2009.

The Project comprises the continuation, upgrade and extension of underground coal mining operations (Longwalls 20-27 and Longwalls 301-317) and surface facilities at the Metropolitan Coal Mine. Longwalls 305-307 are situated to the west of Longwalls 301-304, and define the current mining sub-domain within the Project underground mining area (Metropolitan Coal, 2019).

BIO-ANALYSIS Pty Ltd (BA) was commissioned by Metropolitan Coal to develop an aquatic ecology monitoring programme for the Longwalls 20-22 and Longwalls 23-27 Extraction Plan's to: i) Monitor subsidence-induced impacts (if any) on aquatic ecology (referred to as stream monitoring); and ii) Monitor the response of aquatic ecosystems to the implementation of stream remediation works (referred to as pool monitoring).

The design of the monitoring programmes uses the current best practice approach for monitoring impacts on aquatic habitats "Beyond BACI" and focused on representative sampling of selected locations within streams in the Longwalls 20-22 and Longwalls 23-27 mining area's and in suitable control streams (i.e. not subject to mine subsidence).

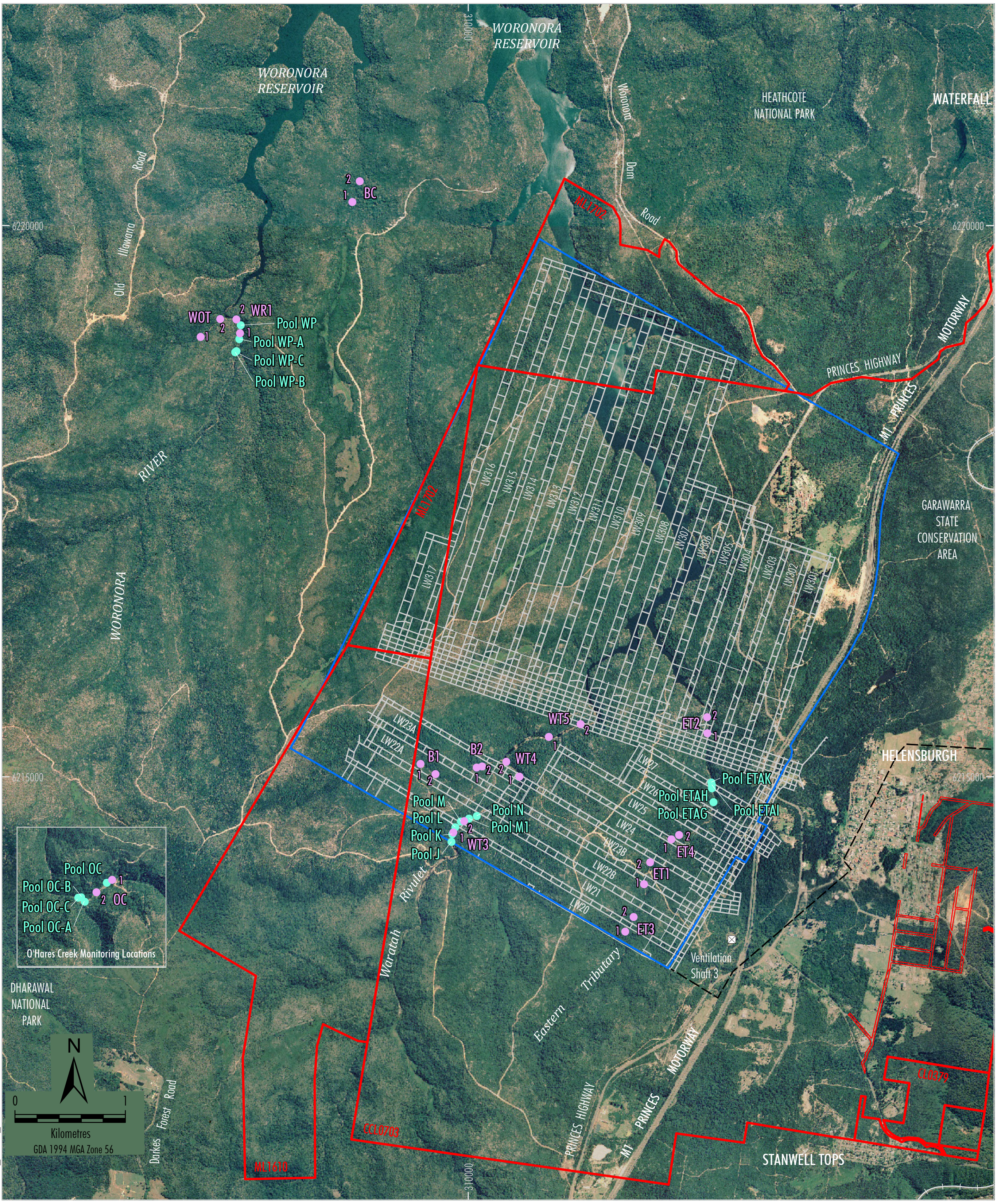
The primary objective of monitoring was to determine whether the extent and nature of any impacts, primarily associated with subsidence-induced fracturing of bedrock and diversion and loss of aquatic habitat, are consistent with the predictions made in the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan* (Longwalls 20-22 BMP) (Metropolitan Coal, 2015a) and the *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan* (Longwalls 23-27 BMP) (Metropolitan Coal, 2015b) [1].

[1] The Longwalls 20-22 BMP and the Longwalls 23-27 BMP have been superseded by the *Metropolitan Coal Longwalls 305-307 Biodiversity Management Plan* (Metropolitan Coal, 2020).

Mining of the Longwalls 20-22 area commenced in May 2010 and was completed in April 2014. Subsequently, mining of the Longwalls 23-27 area commenced in May 2014 and was completed in March 2017. Longwalls 301-303 area commenced in April 2017 and was completed in June 2019. Longwall 304 commenced in July 2019 and was completed in January 2020. Longwall 305 commenced in April 2020 and was completed in November 2020. Longwall 306 commenced in June 2021.

The Spring 2020 post-mining aquatic ecology monitoring programme for the Longwalls 20-27 sub-domain, as outlined in this report, was conducted in accordance with the currently approved Longwalls 305-307 Biodiversity Management Plan, which includes post-mining monitoring and management of aquatic flora and fauna for Longwalls 20-22, 23-27, 301-303 and 304 (subject to the respective previously approved Extraction Plans).

This report presents the results of: i) monitoring undertaken in spring 2020 (Section 3); and ii) comparisons of the findings of the spring 2020 monitoring survey with previous surveys to determine whether any changes have occurred to aquatic habitat or biota (Section 4). A reconciliation against the Trigger Action Response Plan in the Metropolitan Coal Longwalls 305-307 BMP (Appendix 1) has also been completed in Section 5.3.



LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Existing Underground Access Drive (Main Drift)

Monitoring

- Pool Aquatic Ecology Sampling Site
- Stream Aquatic Ecology Sampling Site

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2020)

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Aquatic Ecology Monitoring Locations

Figure 1

2.0 METHODS

2.1 Study Area

The Project underground mining area and surrounds are located within the Woronora Special Area (WSA) (Figure 1). The WSA is largely undeveloped, covered predominantly by native vegetation and public access is restricted and managed by WaterNSW (previously the Sydney Catchment Authority [SCA]). The WSA drains to the Woronora Reservoir, which supplies water to residents in the areas south of the Georges River including Sutherland, Helensburgh, Stanwell Park, Lucas Heights and Bundeena.

Longwalls 20-27 extend below a tributary of the Woronora Reservoir in the east of the study area (Tributary C/Eastern Tributary), the Waratah Rivulet and an un-named tributary of the Waratah Rivulet (Tributary B) (Figure 1).

The headwaters of Tributary C/Eastern Tributary and the Waratah Rivulet are located in the Darkes Forest area at approximately 300 m AHD and 380 m AHD, respectively. Tributary C/Eastern Tributary and the Waratah Rivulet flow through relatively steep valleys in a northerly direction into the Woronora Reservoir. The upper reaches of Tributary C/Eastern Tributary traverse the completed Longwalls 1-13 underground mining area (Figure 1). The mid to upper reaches of the Waratah Rivulet traverse the completed Longwalls 14-17 (middle reach) and Longwalls 12 and 13 (upper reach) underground mining areas (Figure 1).

The Woronora River occurs within the WSA but outside the area potentially affected by past and current mining activities at Metropolitan Coal. As such, this system in addition to O'Hares Creek, which lies outside the mining area in the Dharawal Nature Conservation Area to the south-west of the WSA, represent the control systems for this study.

2.2 Sampling Design

The current best practice approach for monitoring impacts on aquatic habitats is termed "Beyond BACI" (Underwood, 1992; 1993; 1994) and this approach has been used in order to assess potential impacts on aquatic ecology. The programme has been designed to monitor subsidence-induced impacts on aquatic ecology.

2.2.1 Longwalls 20-22 Monitoring Program

In accordance with the Longwalls 20-22 BMP, the aquatic ecology along Waratah Rivulet and Tributary C/Eastern Tributary as well as in appropriate control systems (i.e. Woronora River and O'Hares Creek) are monitored annually in spring (September 15 to December 15) and autumn (March 15 to June 15), consistent with the timing required by the Australian River Assessment System (AUSRIVAS) protocol. The control systems lie outside the area potentially affected by past and current Metropolitan Coal mining activities (Figure 1).

The spatial design for the Longwalls 20-22 program includes sampling two random sites (approximately 100 m in length) at the following stream locations (Appendix 2):

- Locations WT3 on Waratah Rivulet, C1 and C3[2] on Tributary C/Eastern Tributary overlying Longwalls 20-22.
- Locations WT4 and WT5 on Waratah Rivulet and C2 on Tributary C/Eastern Tributary, downstream of Longwalls 20-22.
- Control locations: WR1 on Woronora River and OC on O'Hares Creek.

The approximate locations of the sampling sites are shown on Figure 1.

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[2] Locations C1, C2 and C3 are referred to as ET1, ET3 and ET2 in the Longwalls 305-307 BMP (and previously in the Longwalls 20-22 BMP).

2.2.2 Longwalls 23-27 Monitoring Program

In accordance with the Longwalls 23-27 BMP, the aquatic ecology along Tributary C/Eastern Tributary as well as in appropriate control systems (i.e. Woronora River and O'Hares Creek) are monitored annually in spring (September 15 to December 15) and autumn (March 15 to June 15), consistent with the timing required by the Australian River Assessment System (AUSRIVAS) protocol. The control systems lie outside the area potentially affected by past and current Metropolitan Coal mining activities (Figure 1).

The spatial design for Longwalls 23-27 includes sampling two random sites (approximately 100 m in length) at the following stream locations (Appendix 2)[3]:

- Locations C1 and C4 on Tributary C/Eastern Tributary overlying Longwalls 23-27.
- Location C2 on Tributary C/Eastern Tributary, downstream of Longwalls 23-27.
- Control locations: WR1 on Woronora River and OC on O'Hares Creek.

The approximate locations of the sampling sites are shown on Figure 1.

Location C2 on Tributary C/Eastern Tributary is located downstream of Longwalls 23-27 and will assist in determining the spatial extent of any impacts on aquatic ecology over time as mining progresses and determine whether any such impacts were attributable to mining.

Information on stream characteristics was recorded at each site in accordance with the Australian River Assessment System (AUSRIVAS) protocol (Turak et al., 2004). Characteristics recorded included a visual assessment of stream width and depth, riparian conditions, signs of disturbance, water quality and percentage cover of the substratum by algae. Samples of assemblages of aquatic macroinvertebrates, aquatic macrophytes and physico-chemical water quality were collected at sites within each of the locations.

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[3] Location C1 on Tributary C/Eastern Tributary is situated over Longwalls 22 and 23. Consequently, it has also been monitored as a component of the Longwalls 20-22 aquatic ecology monitoring program. Location C4 is situated on Tributary C/Eastern Tributary overlying Longwalls 23-27, downstream of mining activities undertaken within the Longwalls 20-22 mining area. Location C2 on Tributary C/Eastern Tributary is situated downstream of Longwalls 23-27 and has also been monitored as a component of the Longwalls 20-22 aquatic ecology monitoring program.

2.3 Timing of Aquatic Ecology Surveys

Timing of aquatic ecology surveys relative to extraction of the Longwalls 20-27 underground coal mining areas are outlined in Table 1.

Table 1. Timing of aquatic ecology surveys relative to extraction of Longwalls 20-22 and Longwalls 23-27. (Before-, During- and After- indicate whether surveys were done before-, during- or after-mining of each area).

Survey	Mining Area		Comments
	LW20-22	LW23-27	
Spring 2008	Before-		
Autumn 2009	Before-		
Spring 2009	Before-	Before-	
Autumn 2010	Before-	Before-	LW20 commenced May 2010/completed August 2011
Spring 2010	During-	Before-	
Autumn 2011	During-	Before-	
Spring 2011	During-	Before-	LW21 commenced Sept 2011/completed January 2013
Autumn 2012	During-	Before-	
Spring 2012	During-	Before-	
Autumn 2013	During-	Before-	LW22A commenced January 2013/completed August 2013
Spring 2013	During-	Before-	LW22B commenced August 2013/completed April 2014
Autumn 2014	After-	During-	LW23 commenced May 2014/completed March 2015
Spring 2014	After-	During-	
Autumn 2015	After-	During-	LW24 commenced April 2015/completed September 2015
Spring 2015	After-	During-	LW25 commenced October 2015/completed April 2016
Autumn 2016	After-	During-	LW26 commenced May 2016/August 2016
Spring 2016	After-	During-	LW27 commenced September 2016/completed March 2017
Autumn 2017	After-	During-	
Spring 2017	After-	During-	LW301 commenced June 2017/completed February 2018
Autumn 2018	After-	After-	LW302 commenced March 2018/completed October 2018
Spring 2018	After-	After-	LW302 completed/LW303 commenced November 2018
Autumn 2019	After-	After-	LW303 completed June 2019
Spring 2019	After-	After-	LW304 commenced July 2019/completed January 2020
Autumn 2020	After-	After-	LW305 commenced April 2020
Spring 2020	After-	After-	LW305 completed November 2020
			LW306 commenced June 2021

2.4 Sampling Techniques

2.4.1 Habitat Assessment

Information on stream characteristics was recorded at each site in accordance with the Australian River Assessment System (AUSRIVAS) protocol (Turak et al., 2004). Characteristics recorded included a visual assessment of stream width and depth, sequence of pools, runs and riffles (shallow areas with broken water) riparian conditions, signs of disturbance, water quality and percentage cover of the substratum by algae.

Photographs were taken at each site to assist in descriptions.

2.4.2 Water Quality

A number of water quality variables were measured at each of the sampling sites prior to undertaking the biological sampling. Measurements of physico-chemical water quality were determined using a YEOKAL 611 submersible data logger. Variables included conductivity (µS/cm), dissolved oxygen (% Saturation and mg/L), pH, temperature (ºC), turbidity (NTU) and oxygen reduction potential (mV).

Two replicate samples of water were also collected to be analysed for alkalinity (mg/L $CaCO_3$), total nitrogen (mg/L) and total phosphorous (mg/L). Alkalinity was determined in the field using a CHEMetrics' total alkalinity field kit. For analysis of total nitrogen and total phosphorous, samples were sent to the National Measurement Institute (NMI) laboratory (a NATA accredited laboratory). For the purpose of calculating summary statistics (e.g. mean concentration), any results that were recorded less than the detection limit were assigned a concentration value of half the detection limit, except in instances of zero alkalinity. It should be noted that water quality measurements are intended to provide information relevant to the times of sampling only.

2.4.3 Aquatic Macroinvertebrates

Two methods were used to collect aquatic macroinvertebrates at locations sampled as part of the Stream Monitoring Programme: sampling using the AUSRIVAS protocol and quantitative sampling.

AUSRIVAS

To sample assemblages of macroinvertebrates in accordance with the Rapid Assessment Method (RAM), which is based on the AUSRIVAS protocol (Turak et al., 2004), samples of stream edge habitats were collected using a 250 µm mesh dip net. Edge habitat was defined as areas along stream banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, beds of macrophytes, overhanging banks and areas with trailing vegetation (Turak et al., 2004).

At each site (approximately 100 m long), samples were collected over a total length of 10 m, usually in 1-2 m sections, ensuring all significant edge sub-habitats within a site (i.e. macrophytes, over-hanging bank and vegetation, leaf-litter, pool rocks, logs) were included in the sample (Turak et al., 2004). The contents of each net sample were placed into a white sorting tray and animals were collected for a minimum period of 30 minutes. Thereafter, removals were carried out in 10-minute periods, up to a total of one hour (Turak et al., 2004). If no new taxa were found within a 10-minute period, removals would cease (Turak et al., 2004). The animals collected were placed inside a labelled container and preserved with 70% alcohol.

Samples were identified using an ISSCO M400 stereomicroscope. Taxa were identified to family level with the exception of Acarina (to order), Chironomidae (to sub-family), Nematoda (to phylum), Nemertea (to phylum), Oligochaeta (to class), Ostracoda (to subclass) and Polychaeta (to class). Some families of Anisoptera (dragonfly larvae) were identified to species, because they could potentially include threatened aquatic species.

Quantitative Sampling

Within each site, three replicate macroinvertebrate samples were collected using timed 1-minute sweeps of all habitats (edge, riffle, pools, etc.) using a 250 μm mesh dip net. For each replicate sample, the contents of the net were placed into white plastic trays filled with fresh water and then placed into pre-labelled plastic sample containers filled with 70 % alcohol. In the laboratory, animals were identified to family level with the exception of some families of Anisoptera (dragonfly larvae), which were identified to species, because they could potentially include threatened aquatic species.

2.4.4 Aquatic Macrophytes

The distribution of floating-attached, submerged and emergent (occurring in-stream and in the riparian zone) macrophytes was estimated along each sampling location by assigning a cover class to each species. The cover classes were: (1) one plant or small patch (i.e. few), (2) not common, growing in a few places (i.e. scattered), and (3) widespread (i.e. common). Cover class information was used to help provide a qualitative assessment of the structure of assemblages of plants found at each location.

Within each site, an assessment of floating-attached, submerged and emergent macrophytes was undertaken by estimating the relative abundance (i.e. percentage cover) of species within five haphazardly placed 0.25 square metres (m^2) quadrats, using a stratified sampling technique. This information provided a quantitative measure of aquatic macrophytes within each site at each location.

2.5 Data Analyses

AUSRIVAS Model Analysis

Data collected using the AUSRIVAS sampling protocol for the Stream Monitoring Programme were analysed using the New South Wales/Spring/Edge model (see Turak et al., 2004). This predictive model was developed from sampling edge habitat at a number of sites across NSW, which had been determined to be unaffected by human disturbances, between 1994 and 1999 (Turak et al., 2004).

Physical and chemical data (see Ransom et al., 2004) are used by the model to determine the predicted (i.e. Expected) composition of macroinvertebrate fauna if the site is undisturbed (Turak et al., 2004). Thus, an AUSRIVAS assessment represents a comparison of the macroinvertebrates collected at a site (i.e. Observed) to those predicted to occur (Expected) if the site is in an undisturbed or 'reference' condition.

The principal outputs of the AUSRIVAS model include:

- Observed to Expected ratio (OE50): the ratio of the number of macroinvertebrate families collected at a site which had a predicted probability of occurrence of greater than 50 % (i.e. Observed) to the sum of the probabilities of all of the families predicted with greater than a 50 % chance of occurrence (i.e. Expected) (Ransom et al., 2004).
- BAND: for each model, the OE50 taxa ratios are divided into bands representing different levels of impairment. Band X represents a more diverse assemblage of macroinvertebrates than reference sites; Band A is considered equivalent to reference condition; Band B represents sites below reference condition (i.e. significantly impaired); Band C represents sites well below reference condition (i.e. severely impaired); and Band D represents impoverished sites (i.e. extremely impaired) (Ransom et al., 2004).

Quantitative Analyses

Multivariate and univariate statistical procedures were done using Permutational Multivariate Analyses of Variance (PERMANOVA, Anderson 2001; Anderson et al, 2008) and Plymouth Routines in Multivariate Ecological research (PRIMER, Clarke and Warwick, 1994) software packages to examine temporal and spatial patterns in macroinvertebrates and macrophytes sampled within the study area. Multivariate methods allow comparisons of two (or more) samples based on the degree to which these samples share particular species, at comparable levels of abundance (Clarke and Warwick, 1994).

Multivariate analysis was done on Bray Curtis dissimilarities of the macroinvertebrate and macrophyte assemblage (non-transformed) data. A graphical representation of relationships among samples (i.e. the centroids for each location per time) was produced using Principal Coordinates Analyses (PCoA). The amount of variation "explained" by the principle factors is indicated by each axis and the dissimilarity between data points can be determined from their distance apart on the axes (Anderson et al., 2008). Similarity of percentages (SIMPER) was then used to determine those taxa primarily responsible for the observed similarities (or dissimilarities) (Clarke, 1993).

PERMANOVA analyses on selected univariate estimates (e.g. total number of taxa, total abundance and abundances of the most important taxonomic groups identified from the samples) were done on Euclidean Distances. Each analysis was based on 999 permutations of residuals under a reduced model.

Specifically, PERMANOVA were done to test hypotheses related to differential changes occurring in multivariate and univariate estimates for streams within the Longwalls 20-22 mining area (Section 4.1) and the Longwalls 23-27 mining area (Section 4.2) in comparison to independent locations that are not subject to mine subsidence.

The analytical design for each mining area was:

- **Period:** A fixed factor with two levels: Before (commencement of extraction) and After (commencement of extraction);
- **Treatment:** A fixed factor with two levels, Control and Impact;
- **Time**: A random factor representing surveys carried out within Period;
- **Location**: A random factor nested within Treatment; and
- **Site**: A random factor nested within Treatment and Location.

A potential impact could be expected to affect the magnitude and/or dispersion of an indicator (e.g. total number of individuals, percentage cover). If a statistically significant difference between sample groups is detected that could be attributed to mining impact, the difference in variance between groups would be explored using the Index of Multivariate Dispersion (IMD) and PERMDISP procedure's (Anderson et al, 2008).

If there is no statistical difference between variances, the statistical difference between groups is most likely due to differences between group means. Pair-wise tests would be used to explore the different possible combinations of the groups of interest, to determine where significant differences occur. Only statistical differences with a significance level of $P \leq 0.05$ were considered.

Significant main effects (e.g. Period or Impact) are not indicative of a mining-related impact, and, as such, are not described in detail. The Period x Impact interaction is the scale that would indicate that differences or changes could be attributable to mining.

3.0 RESULTS

3.1 Aquatic Habitat & General Observations

Since 2006 (but excluding 2007, 2014, 2018 and 2020), annual rainfall recorded at Darkes Forest (Station 68024), ranged from 752.4 mm (2019) to 1,747.8 mm (2013) (Figure 2).

For the spring 2020 survey, sites were sampled on 12 November, 23 November and 2 December 2020. Within the two months prior to the 2020 spring survey (i.e. 12 September – 12 November 2020), a total of 251 mm of rain was recorded.

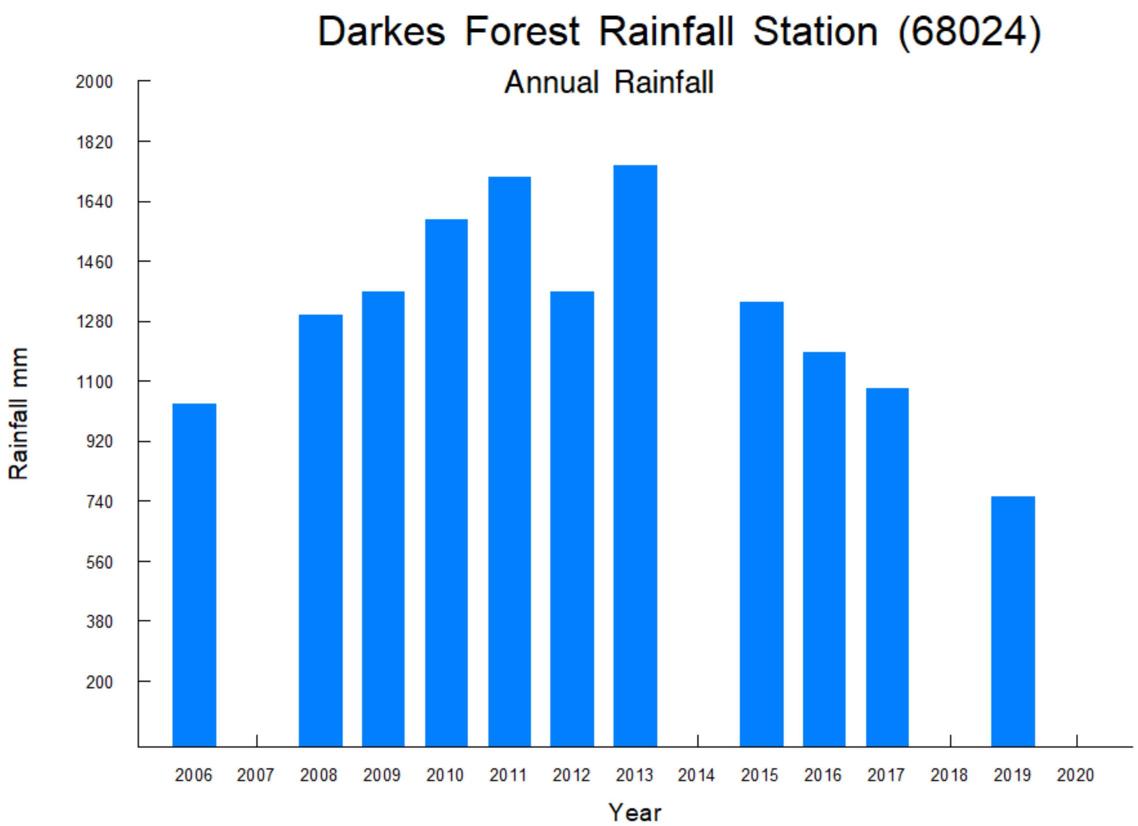

Figure 2. Annual rainfall (mm) measured at Darkes Forest from 1 January 2006 to 31 December 2020. NB Rainfall data were not available for several months within 2007, 2014, 2018 and 2020

3.1.1 Stream Characteristics

A summary of findings from surveys of stream characteristics done at stream monitoring locations sampled on Tributary C/Eastern Tributary (Locations C1, C2, C3 and C4), Waratah Rivulet (Locations WT3, WT4 and WT5) and at two control locations (Woronora River, O'Hares Creek) (Figure 1), undertaken between spring 2008 or spring 2009[4] and spring 2020, is presented below.

Tributary C/Eastern Tributary

Tributary C/Eastern Tributary is a third order stream located in the east of the Project area and is approximately 5.4 km in length (Figure 1). The stream is situated in a moderately steep incised valley with numerous in-stream pools. Observations of sections of Tributary C/Eastern Tributary not subject to mine subsidence indicate that stream sections between pools during dry periods cease to flow and pools may dry up. Four locations were sampled on this tributary (Figure 1).

Location C1

Sampling location C1 is comprised of pools up to approximately 6 m wide and 1.0 m deep connected by sections of shallow flow over bedrock. The dominant riparian vegetation was reported to include *Gleichenia dicarpa*, *Leptospermum polygalifolium*, *Acacia binervia*, *Acacia floribunda*, *Acacia longifolia*, *Acacia parramattensis*, *Banksia marginata*, *Eucalyptus* sp. and *Grevillea buxifolia* (Bio-Analysis Pty Ltd, 2008).

Pool water at Location C1 has commonly had a green tinge since sampling commenced in spring 2008. Iron staining has commonly been noted at this location since the autumn 2014 survey. Fracturing of the streambed (predominantly bedrock) and a decline in pool water level (by up to 0.8 m) were first noted by the spring 2015 survey, at Site C1-1.

[4] The sampling of Location C3 and Location C4 on the Eastern Tributary commenced in spring 2009.

Since then, pool water level at Site C1-1 appeared to be below pre-mining levels in autumn 2016, spring 2017, autumn 2018, autumn 2019 and spring 2019.

At Site C1-2, which has a predominantly sandy substratum, pool water level appeared lower than pre-mining levels at the time of the autumn 2016 survey but not subsequently.

The main findings from the current survey (spring 2020) are summarised below:

- Pool water level at Site C1-1 and C1-2 appeared similar to pre-mining levels (Plates 1&2) and there was flow over the rock-bar in the middle of the study reach;
- The iron precipitate/micro-organism complex commonly observed covering the substratum at both sites was greatly reduced since the previous survey, most likely due to recent high flows (Plates 1&2);
- Areas of desiccated riparian vegetation (mostly *Gleichenia dicarpa* and *Empodisma minus*) reported in spring 2018 (BIO-ANALYSIS, 2019), autumn and spring 2019 (BIO-ANALYSIS, 2020a&b), showed some signs of regeneration, most likely due to increased rainfall since late January/February 2020 and increased pool water levels (Plate 1);
- *Baumea juncea*, *Lepidosperma filiforme* and *Empodisma minus* were relatively abundant at the time of this survey (Appendix 3a); and
- Submerged aquatic macrophytes have consistently not been recorded at this location (Appendices 3a&b).

Plate 1: Tributary C – Location C1 (C1-1) (sp-20)
Looking upstream

Plate 2: Tributary C – Location C1 (C1-2) (sp-20)
Looking downstream

Location C2

Location C2 has commonly consisted of pools up to approximately 8 m wide and 1.3 m deep with a predominantly bedrock and sand substratum (Plates 3 and 4). Previously, riparian vegetation was reported to include *Acacia binervia, Acacia floribunda, Acacia longifolia, Acacia parramattensis, Bauera rubioides, Baumea rubiginosa, Chorizandra cymbaria, Juncus prismatocarpus* and *Lepidosperma filiforme* (Bio-Analysis Pty Ltd, 2008).

Since the autumn 2013 survey, water in pools at Location C2 has occasionally been noted to have a pale-green milky tinge. Iron staining/iron flocculent was first observed at Location C2 in spring 2016[5]. Iron staining/iron flocculent has been observed to cover the stream substratum from the top of Site C2-1 to the bottom of Site C2-2 since spring 2016[6]. In spring 2017, pool water level at Site C2-1 appeared to be approximately 0.5 m below pre-mining levels but similar to pre-mining levels subsequently.

The main findings from the current survey (spring 2020) are summarised below:

- Heavy iron staining/iron flocculent was observed at Site C2-1 and Site C2-2 and pool water was pale-green milky in appearance (Plates 3&4);
- Pool water levels appeared to be similar to pre-mining levels and there was flow along the study reach (Plates 3&4);
- *Baumea juncea, Lepidosperma filiforme* and *Empodisma minus* were abundant components of the riparian assemblage at the time of this survey (Appendix 3a); and
- Similar to Location C1, submerged aquatic macrophytes have consistently not been present (Appendices 3a&b).

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5 In spring 2016, Location C2 was sampled on 24 October 2016.

6 Pools were impacted by the 'Eastern Tributary Incident' (exceedance of the Eastern Tributary performance measure) in spring 2016.

Plate 3: Tributary C – Location C2 (C2-1) (sp-20)
Looking upstream

Plate 4: Tributary C – Location C2 (C2-2) (spt-20)
Looking downstream

Location C3

Location C3 is situated within the Longwalls 20-22 mining area and is approximately 300 m upstream of Location C1. In general, the study reach has consisted of pools up to approximately 12 m wide and up to 1.8 m deep, interrupted by a braided channel with large boulders in places. The substratum is predominantly bedrock and sand with large boulders in several places. Submerged aquatic macrophytes have consistently not been present (Appendices 3a&b).

A milky-green tinge to pool water was noted at Location C3 when sampling commenced in spring 2009. In autumn 2013, dieback of riparian vegetation was noted at Site C3-2, thought to be associated with tilting of the stream bank by mine subsidence. Further desiccation and dieback of riparian vegetation was noted at Site C3-2 in autumn 2014.

Cover of the stream substratum by an iron precipitate/micro-organism complex was first noted at Sites C3-1 and C3-2 in autumn 2014. A considerable decline in pool water levels was observed at both sites between autumn 2015 and autumn 2017, particularly at the downstream site (Site C3-2). Subsequently, pool levels at Site C3-1 have appeared similar to pre-mining levels, but commonly well below pre-mining levels at Site C3-2 up until spring 2019.

The main findings from the spring 2020 survey are summarised below:

- Pool water level at Site C3-1 and Site C3-2 was similar to pre-mining levels (Plates 5&6);
- Riparian health at Site C3-2 appears to have continued to improve since obvious signs of desiccation in spring 2018; and
- *Lepidosperma filiforme*, *Empodisma minus*, *Gleichenia dicarpa* and *Gahnia clarkei* were amongst the most abundant components of the riparian macrophyte vegetation (Appendix 3a).

Plate 5: Tributary C – Location C3 (C3-1) (sp-20)
Looking upstream

Plate 6: Tributary C – Location C3 (C3-2) (sp-20)
Looking downstream

Location C4

Location C4 is situated approximately 500 m downstream of Location C1, above Longwalls 24-25. The study reach was previously comprised by pools (up to approximately 25 m long, 8 m wide and 1.0 m deep) interrupted by runs and steep (up to approximately 10 m) cascades in places.

Mining related disturbances (i.e. iron staining) were first noted at this location in autumn 2014. At the time of the spring 2015 survey, rock fractures, flow diversions and low water levels were noted at the upstream site (i.e. Site C4-1) and within a relatively steep boulder field between sites C4-1 and C4-2. An iron complex covered up to approximately 95% of the remaining submerged substratum. Desiccation of the riparian assemblage was evident in some places. Water reappeared near the top of the reach at Site C4-2, providing some flow to that section of the stream.

Large proportions of the study reach at Site C4-1 have commonly been found to be dry since the time of the spring 2015 survey, but flow has consistently been present along the study reach at Site C4-2.

The main findings from the spring 2020 survey are summarised below:

- Pool water level appeared similar to baseline levels at both sites and surface flow was apparent along the study reaches (Plates 7&8);
- Although thinner than observed by the autumn 2020 survey, an iron complex covered a large proportion of the submerged substratum at both sites (Plates 7&8);
- *Lepidosperma filiformis, Baumea juncea, Viminaria juncea* and *Empodisma minus* were amongst the most common emergent macrophytes (Appendix 3a); and
- Submerged aquatic macrophytes have consistently been absent (Appendix 3a&b).

Plate 7: Tributary C – Location C4 (C4-1) (sp-20)
Looking downstream

Plate 8: Tributary C – Location C4 (C4-2) (sp-20)
Looking downstream

<u>Waratah Rivulet</u>

The Waratah Rivulet is some 9 km in length from its headwaters to the point where it flows into the Woronora Reservoir. The Waratah Rivulet starts as a third order stream and becomes a fourth order stream downstream of the Waratah Tributary 1 (also known as Unnamed Tributary and Tributary D in some assessments) confluence (Figure 1).

The Waratah Rivulet flows through a relatively steep valley, sourcing at around 380 m AHD with the full supply level (FSL) of the Woronora Reservoir at about 165 m AHD. The catchment area above the inundation limits (FSL) of the reservoir is about 30 km^2 and the sub-catchment areas vary from 1.6 km^2 to 6.7 km^2 (Gilbert and Associates, 2006). The mean annual flow for the rivulet (based on modeled flows between 1976 and 2006) is 7,300 ML (Gilbert and Associates, 2006).

The stream channel in Waratah Rivulet downstream of Flat Rock Crossing is characterised by a gently meandering, relatively shallow, wide channel with a sandstone bed (Gilbert and Associates, 2006). The channel contains a series of in-stream pools that have formed in local depressions in the bedrock and behind rock bars.

Three locations (i.e. WT3, WT4 and WT5) were sampled on Waratah Rivulet (Figure 1).

Location WT3

At the most upstream sampling location (i.e. WT3: approximately 300 m downstream of Flat Rock Crossing and approximately 6 km downstream from its source at 380 m AHD), the rivulet was a broad stream (approximately 4 to 15 m wide) with mostly shallow pools (up to approximately 1.5 m deep in places) interspersed between exposed bedrock shelves (Plates 9&10). Cummins et al. (2007) reported that the dominant riparian vegetation included *Banksia integrifolia, Bauera rubioides, Centrolepis strigose, Hakea sericea* and *Leptospermum polygalifolium*.

The stream channel has commonly been observed to be covered by an iron precipitate/micro-organism complex since autumn 2008, and the water has had a milky green tinge (Cummins et al., 2008). Evidence of fracturing of the sandstone substratum of the stream channel due to subsidence was first noted at Location WT3 in spring 2013.

The main findings from the current survey (spring 2020) are summarised below:

- Similar to previous surveys, riparian vegetation present in this reach of the Waratah Rivulet appeared healthy and relatively undisturbed;
- The emergent species, *Gleichenia dicarpa* and *Lepidosperma filiformis* have consistently been amongst the most common components of assemblages of aquatic macrophytes (Appendix 3a&b);
- Although thinner than in the previous survey, mostly likely die to recent high flows, iron staining continues to be present along the study reach (Plates 9&10); and
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 9&10).

Plate 9: Waratah Rivulet – Location WT3 (WT3-1) (sp-20)
Looking upstream

Plate 10: Waratah Rivulet – Location WT3 (WT3-2) (sp-20)
Looking upstream

Location WT4

The pool sampled in the upstream section of the study reach at Location WT4 (i.e. Site WT4-1) is approximately 35 m long and 14 m wide. Further downstream (Site WT4-2), pool width varied from approximately 12 to 16 m and 185 m long. Pool water has been commonly observed to have a milky-green tinge. The base of both pools was sandstone with several boulders and sand. The submerged aquatic macrophyte, *Triglochin procerum*, has consistently been relatively abundant at this location (Appendices 3a&b). The Charophyte, *Chara/Nitella* spp., has often been present.

The main findings from the current survey (autumn 2020) are summarised below:

- Pool water levels were at or above baseline levels (Plates 11&12). Reduced pool water levels were noted by the spring 2019, autumn 2019, spring 2018, autumn 2018, spring 2017, autumn 2016 and spring 2015 surveys;
- Flow was apparent into and out of the study reach at each site;
- To date, there has been no evidence of mining related fracturing of the stream substratum;
- Iron precipitate previously observed covering up to approximately 80% of the stream substratum was not apparent;
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 11&12);
- Emergent species within the riparian strip were mostly comprised by *Lomandra fluviatilis* and *Lepidosperma filiforme* (Appendix 3a&b); and
- *Triglochin procerum* was present at both sites, particularly at Site WT2. *Chara/Nitella* spp. was not observed by this or the autumn 2020 survey, most likely due to recent (since late January/February 2020) high flows along the study reach (Plates 11&12).

Plate 11: Waratah Rivulet – Location WT4 (WT4-1) (sp-20)
Looking across-stream

Plate 12: Waratah Rivulet – Location WT4 (WT4-2) (sp-20)
Looking downstream

Location WT5

At Location WT5, a gauging station operated by WaterNSW is situated between the two sampling sites (WT5-1 and WT5-2). The in-stream habitat was predominantly bedrock and sand. Pools have consistently been up to approximately 110 m long, 30 m wide and 2.0 m deep at their deepest point (Plates 13&14).

Previously, the dominant riparian vegetation was reported to include *Acacia binervia, Acacia floribunda, Acacia longifolia, Acacia parramattensis, Epacris calvertiana, Gleichenia dicarpa, Leptospermum polygalifolium* and *Tristaniopsis laurina* (Bio-Analysis Pty Ltd, 2008). The submerged aquatic macrophyte, *Triglochin procerum*, has been relatively abundant at this location.

The main findings from the current survey (spring 2020) are summarised below:

- Flow was apparent along the study reach (Plates 13&14);
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 13&14);
- The riparian strip appeared relatively healthy, with *Gleichenia dicarpa, Eurychorda complanata* and *Lepidosperma filiforme* amongst the most common components of the assemblage of aquatic macrophytes (Appendix 3a&b);
- *Triglochin procerum* was observed in the deeper pools at the upstream site (Site WT5).

Plate 13: Waratah Rivulet – Location WT5 (WT5-1) (sp-20)
Looking upstream

Plate 14: Waratah Rivulet – Location WT5 (WT5-2) (sp-20)
Looking upstream

Control Locations

Woronora River

Sites were chosen on the Woronora River approximately 7 km from its headwaters (Appendix 2). The river flows through a steep valley into the Woronora Reservoir. The sites sampled were characterised by interconnected pools (up to approximately 1.4 m deep) approximately 1.5 to 11.7 m wide with predominantly sandy bottoms interspersed with large boulders and beds of the native aquatic macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum* (Appendix 3). Cummins et al. (2007a) reported that the riparian vegetation was dominated by the species *Acacia parramattensis, Banksia integrifolia, Juncus prismatocarpus* and *Viminaria juncea*.

At the time of the spring 2020 survey, the emergent macrophyte assemblage was relatively diverse and included the species *Lepidosperma filiforme, Chorizandra cymbaria, Empodisma minus* and *Gleichenia dicarpa* (Appendix 3). *Triglochin procerum* and *Myriophyllum pedunculatum* were also abundant. No exotic plants or animals were observed (Appendices 3, 4 and 5). Pool water levels were at or above baseline levels and flow was apparent along the study reaches (Plates 15&16). Visibility of the water was considered excellent.

Plate 15: Woronora River (WR1) (sp-20)
Looking across-stream

Plate 16: Woronora River (WR2) (sp-20)
Looking downstream

O'Hares Creek

The headwaters of this 4th order stream originate in an upland swamp. The creek is set in a sandstone gorge and natural rock-bars and waterfalls are common along the watercourse. The sandstone bedrock provided for short, infrequent riffle separating long reaching pools. The substratum was predominantly bedrock with some boulders and deposits of sand in areas of low flow. The immediate catchment is the Dharawal National Park.

At the sampling location, the creek consisted of a series of relatively large (approximately 4 to 18 m wide), interconnected pools to a depth of up to approximately 1.0 m (Plates 17&18). The substratum was predominantly bedrock with some boulders and deposits of sand in areas of low flow. With the exception of where Fire Road 10C crosses the creek, there was little evidence of disturbance.

Dominant riparian vegetation has consistently included *Gleichenia dicarpa, Empodisma minus* and *Baumea* spp. (Appendix 3a). Notably, there appears to have been a considerable decline in cover of *Triglochin procerum* at the upstream site (Site OH1) since the spring 2019 survey, and *Chara/Nitella* spp. was not recorded by this or the autumn 2020 survey (Appendix 3a).

The exotic macrophyte, *Isolepis prolifera*, observed at Site OC1 by the autumn 2020 and many previous survey's was absent, most likely due to occasional high flows since late January/February 2020 (Appendix 3a). Stream water visibility was excellent.

Plate 17: O'Hares Creek (OC1) (sp-20)
Looking across stream

Plate 18: O'Hares Creek (OC2) (sp-20)
Looking downstream

3.1.2 Water Quality

Physico-chemical water quality, alkalinity, total phosphorous and total nitrogen measurements are summarised in Table 1 with values highlighted in bold type indicating where mean values were outside the ANZECC/ARMCANZ (2000) guidelines.

In general, mean water temperature within the four creeks ranged from 16.8 to 23.1 ° C (Table 1), which is typical for the time of year the samples were collected. Mean pH (range = 6.3 – 8.1) was once again below the lower Default Trigger Values (DTV) (i.e. pH 6.5-8.0; ANZECC/ARMCANZ, 2000) for upland rivers at the sites sampled within the Woronora River (Table 1). Relatively low pH values are common in areas with a sandstone substratum. Mean pH exceeded the upper DTV at C1-2 and WT5-2 in spring 2020 (Table 2).

Mean conductivity (range = 125 – 198 µS/cm) was within the recommended DTV's at all of the sites sampled (Table 2). Mean dissolved oxygen levels (range = 21.9 – 104 %) were below the lower DTV at sites C1-1, C2-1, C2-2, C3-1, C3-2, C4-1, C4-2, WT4-2, WR1-2 and OH-1 (Table 2).

Mean turbidity (range = 2.6 – 31.7 NTU) levels were above the upper DTV at Site C2-1 and C2-2 while mean oxidation-reduction potential ranged from 559 to 669 mV (Table 2). Alkalinity ranged from 5 to 35 mg/L $CaCO_3$ (Table 2). For nutrients, mean concentrations of total phosphorous (0.004 to 0.015 mg/L) and total nitrogen (range = 0.09 to 0.21 mg/L) were within the DTVs (Table 2). The raw water quality data are provided in Appendix 6.

Table 2. Mean (+ SE) measurements of water quality variables recorded at each site (spring 2020). Values in bold are outside the guideline values recommended by ANZECC (2000). N/R = not recorded.

Watercourse	**Tributary C/Eastern Tributary**					
Location/Site	**C1-1**	**C1-2**	**C2-1**	**C2-2**	**C3-1**	**C3-2**
Temperature °C (*n* =3)	18.8 (0.0)	19.9 (0.0)	17.1 (0.0)	17.2 (0.0)	18.2 (0.0)	18.6 (0.0)
pH (*n* =3)	7.7 (0.0)	**8.1** (0.0)	7.9 (0.0)	7.9 (0.0)	7.7 (0.0)	7.8 (0.0)
Conductivity (µS/cm) (*n* = 3)	155.0 (0.0)	154.0 (0.6)	198.0 (0.0)	181.0 (0.0)	166.0 (0.0)	164.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	**65.1** (0.1)	89.9 (0.0)	**21.9** (0.1)	**53.0** (0.1)	**77.9** (0.0)	**84.2** (0.0)
Turbidity (NTU) (*n* = 3)	5.7 (0.1)	7.3 (0.1)	**28.6** (0.0)	**31.7** (1.0)	8.1 (0.1)	16.8 (0.0)
ORP (mV) (*n* = 3)	612.7 (0.3)	575.7 (0.3)	609.0 (0.0)	599.0 (0.0)	623.0 (0.0)	616.0 (0.0)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	18	23	25	30	21	20
Total phosphorous (mg/L) (*n* = 2)	0.015 (0.009)	0.006 (0.001)	0.011 (0.001)	0.010 (0.000)	0.013 (0.007)	0.008 (0.001)
Total nitrogen (mg/L) (*n* = 2)	0.170 (0.040)	0.090 (0.010)	0.110 (0.010)	0.145 (0.005)	0.105 (0.045)	0.115 (0.015)
Watercourse	**Tributary C/Eastern Tributary**		**Waratah Rivulet**			
Location/Site	**C4-1**	**C4-2**	**WT3-1**	**WT3-2**	**WT4-1**	**WT4-2**
Temperature °C (*n* =3)	18.5 (0.0)	18.7 (0.0)	23.0 (0.0)	23.1 (0.0)	19.8 (0.0)	19.5 (0.0)
pH (*n* =3)	7.7 (0.0)	7.8 (0.0)	7.7 (0.0)	8.0 (0.0)	7.9 (0.0)	7.9 (0.0)
Conductivity (µS/cm) (*n* =3)	156.0 (0.0)	159.0 (0.0)	183.0 (0.0)	184.0 (0.0)	155.0 (0.0)	156.3 (0.3)
Dissolved Oxygen (% Saturation) (*n* = 3)	**77.4** (0.0)	**81.8** (0.0)	102.4 (0.0)	104.0 (0.0)	94.4 (0.0)	**87.1** (0.0)
Turbidity (NTU) (*n* =3)	18.6 (0.1)	14.9 (0.1)	10.3 (0.1)	9.7 (0.1)	5.5 (0.2)	4.3 (0.0)
ORP (mV) (*n* = 3)	606.0 (0.0)	606.0 (0.0)	584.0 (0.0)	569.0 (0.0)	619.0 (0.0)	614.0
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	20	23	35	30	25	23
Total phosphorous (mg/L) (*n* = 2)	0.007 (0.001)	0.007 (0.001)	0.005 (0.001)	0.007 (0.000)	0.006 (0.000)	0.006
Total nitrogen (mg/L) (*n* = 2)	0.210 (0.110)	0.135 (0.065)	0.090 (0.000)	0.135 (0.005)	0.165 (0.035)	0.175

NB[1]: ANZECC (2000) guideline values for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 µS/cm); Turbidity (2 – 25 NTU); Dissolved Oxygen (90–110 % Saturation); Total phosphorous (0.02 mg/L); Total nitrogen (0.25 mg/L). There are no ANZECC (2000) guideline values for Temperature, ORP or Alkalinity.
NB[2]: *For any site where a value has been recorded as less than the detection limit, it was assigned a value of half the detection limit in order to calculate the mean (e.g. <0.02 taken as 0.01).

Table 2 (Continued)

Watercourse	Waratah Rivulet		Woronora River		O'Hares Creek	
Location/Site	**WT5-1**	**WT5-2**	**WR1-1**	**WR1-2**	**OC-1**	**OC-2**
Temperature °C (*n* =3)	19.4 (0.0)	21.0 (0.0)	16.9 (0.0)	16.8 (0.0)	22.2 (0.0)	22.3 (0.0)
pH (*n* =3)	8.0 (0.0)	**8.1** (0.0)	6.3 (0.0)	6.3 (0.0)	7.1 (0.0)	7.6 (0.0)
Conductivity (µS/cm) (*n* = 3)	158.0 (0.0)	157.7 (0.3)	137.0 (0.0)	138.0 (0.0)	125.0 (0.0)	128.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	93.2 (0.2)	98.0 (0.0)	91.7 (0.1)	**89.0** (0.1)	**84.7** (0.0)	99.3 (0.0)
Turbidity (NTU) (*n* = 3)	3.8 (0.0)	8.0 (0.0)	2.6 (0.1)	15.4 (0.0)	3.3 (0.0)	3.0 (0.0)
ORP (mV) (*n* = 3)	612.0 (0.0)	602.0 (0.6)	668.0 (0.0)	669.0 (0.0)	585.0 (0.0)	559.0 (0.0)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	21	19	5	5	11.5	11.5
Total phosphorous (mg/L) (*n* = 2)	0.005 (0.000)	0.006 (0.001)	0.004 (0.000)	0.004 (0.001)	0.010 (0.001)	0.007 (0.000)
Total nitrogen (mg/L) (*n* = 2)	0.115 (0.025)	0.140 (0.03)	0.190 (0.04)	0.105 (0.005)	0.185 (0.005)	0.190 (0.020)

NB[1]: ANZECC (2000) guideline values for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 µS/cm); Turbidity (2 – 25 NTU); Dissolved Oxygen (90–110 % Saturation); Total phosphorous (0.02 mg/L); Total nitrogen (0.25 mg/L). There are no ANZECC (2000) guideline values for Temperature, ORP or Alkalinity.
NB[2]: *For any site where a value has been recorded as less than the detection limit, it was assigned a value of half the detection limit in order to calculate the mean (e.g. <0.02 taken as 0.01).

3.1.3 Aquatic Macroinvertebrates

AUSRIVAS Assessment

A total of 35 taxa were collected from the 18 sites sampled using the AUSRIVAS sampling protocol (Appendix 4). No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007), were found. *Gambusia* were collected at Location WT5 (3 individuals) on the Waratah Rivulet using the AUSRIVAS technique.

For the sites sampled, the OE50 scores ranged between 0.35 (C5-1) and 0.96 (C1-2) (Table 3). Two sites were grouped within Band A (C1-2 and C4-1), eleven sites were grouped in Band B (C2-2, C3-2, C4-2, WT3-1, WT3-2, WT4-2, WT5-2, WR1-1, WR1-2, OC1 and OC2) and five were grouped in Band C (C1-1, C2-1, C3-1, WT4-1 and WT5-1) (Table 3). Thus, fewer families of macroinvertebrates than expected were collected from sites sampled (including reference sites) in spring 2020, compared to reference sites selected by the AUSRIVAS model (Table 3).

Taxon with > 0.86 probability of occurrence but not collected included the water mite family, Acarina, at sites C1-1, C2-1, C4-1, C4-2, WT3-2, WT4-1, WT4-2, WT5-1, WT5-2 and WR1-1. Also expected but not collected was the caddis fly family, Leptoceridae, at C3-1, WT5-1 and WT5-2, and the aquatic beetle families, Gyrinidae (at C1-1, C2-2, C3-1, C3-2, C4-2, WT5-1, WR1-2, OC1 and OC2) and Hydrophilidae (C1-1, C3-1, C3-2, and C4-1). The aquatic bug family, Veliidae, was expected but not collected at all sites except C1-2, WR1-2, OC1 and OC2.

Table 3. AUSRIVAS outputs for sites sampled in Tributary C/Eastern Tributary (C), Waratah Rivulet (WT), Woronora River (WR) and O'Hares Creek (OC) (spring 2020) (*n* = 1).

System	Location	Site	Site Code	OE50	Band
Tributary C	1	1	C1-1	0.48	C
	1	2	C1-2	0.96	A
	2	1	C2-1	0.38	C
	2	2	C2-2	0.67	B
	3	1	C3-1	0.48	C
	3	2	C3-2	0.57	B
	4	1	C4-1	0.86	A
	4	2	C4-2	0.57	B
Waratah Rivulet	3	1	WT3-1	0.79	B
	3	2	WT3-2	0.82	B
	4	1	WT4-1	0.48	C
	4	2	WT4-2	0.73	B
	5	1	WT5-1	0.35	C
	5	2	WT5-2	0.59	B
Woronora River	1	1	WR1-1	0.59	B
	1	2	WR1-2	0.67	B
O'Hares Creek	1	1	OC1	0.73	B
	1	2	OC2	0.62	B

Quantitative Assessment

A total of 2,723 individuals from 46 macroinvertebrate taxon were collected from sites using the quantitative sampling technique (Appendix 5). The most abundant macroinvertebrate taxon was the Leptophlebiidae (1,601 individuals) followed by the Chironomidae (175 individuals), Dytiscidae (161 individuals), Caenidae (137 individuals) and the Notonectidae (104 individuals) (Appendix 5). The native freshwater crayfish (*Euastacus* sp.) was not collected by either the AUSRIVAS or quantitative sampling techniques during the survey period (Appendices 4&5). *Gambusia* were collected at Location C1 (1 individual) on this sampling occasion.

No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007), were found. Confirmation of the presence of the Adams emerald dragonfly or Sydney hawk dragonfly would have triggered a response for further investigations of this species.

Of the sites sampled, mean diversity was greatest at the O'Hares Creek location followed by Location 3 sampled on Tributary C (Figure 3). The total abundance of macroinvertebrates was greatest at the O'Hares Creek location, followed by Location 3 sampled on the Waratah Rivulet (Figure 4). Diversity and abundance of aquatic macroinvertebrates was smallest at Location 4 sampled on Tributary C (Figures 3&4).

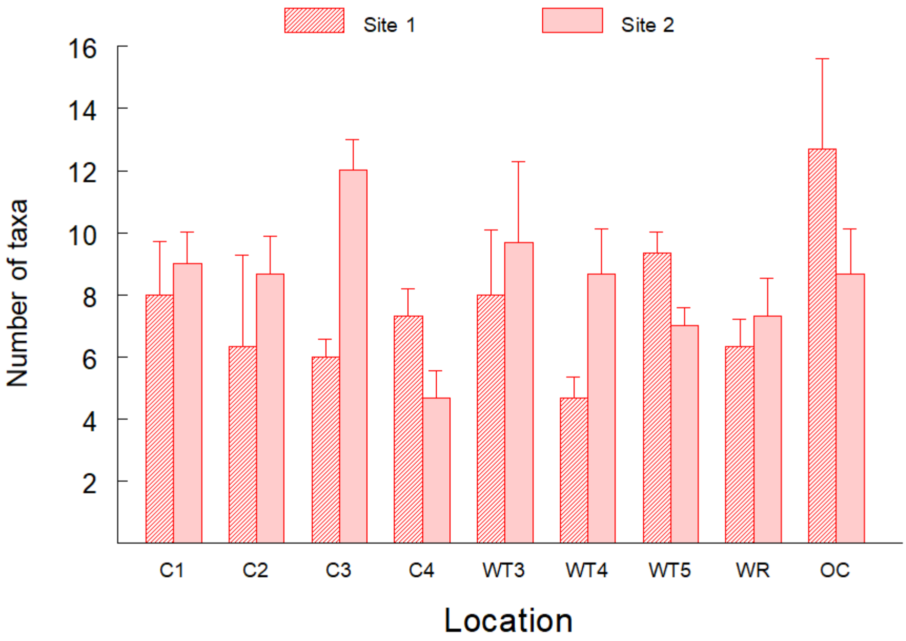


Figure 3. Mean (+SE) diversity of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

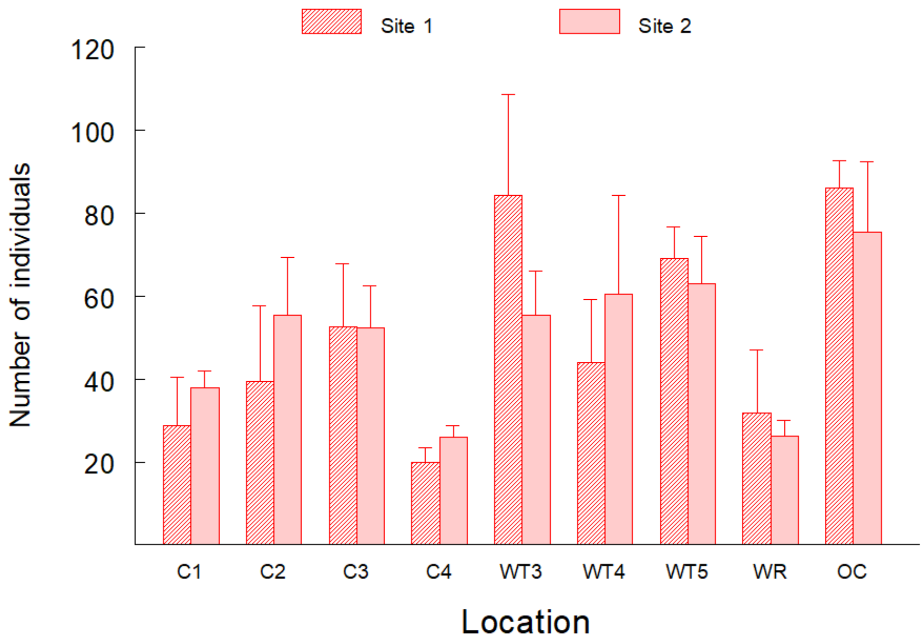


Figure 4. Mean (+SE) abundance of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

3.1.4 Aquatic Macrophytes

A total of 22 aquatic macrophyte species were found in quantitative samples at sites on Tributary C/Eastern Tributary (C1: 7 species, C2: 8 species, C3: 10 species, C4: 9 species), Waratah Rivulet (WT3: 9 species, WT4: 6 species, WT5: 9 species), Woronora River (8 species) and O'Hares Creek (14 species) (Appendix 3b).

In general, mean percentage cover of macrophytes was greatest at Location C3 situated on Tributary C, followed by the O'Hares Creek location (Figure 5). The mean diversity of macrophytes recorded in the 0.25 m^2 quadrats at any one location was generally low (i.e. < 4 species) (Figure 6).

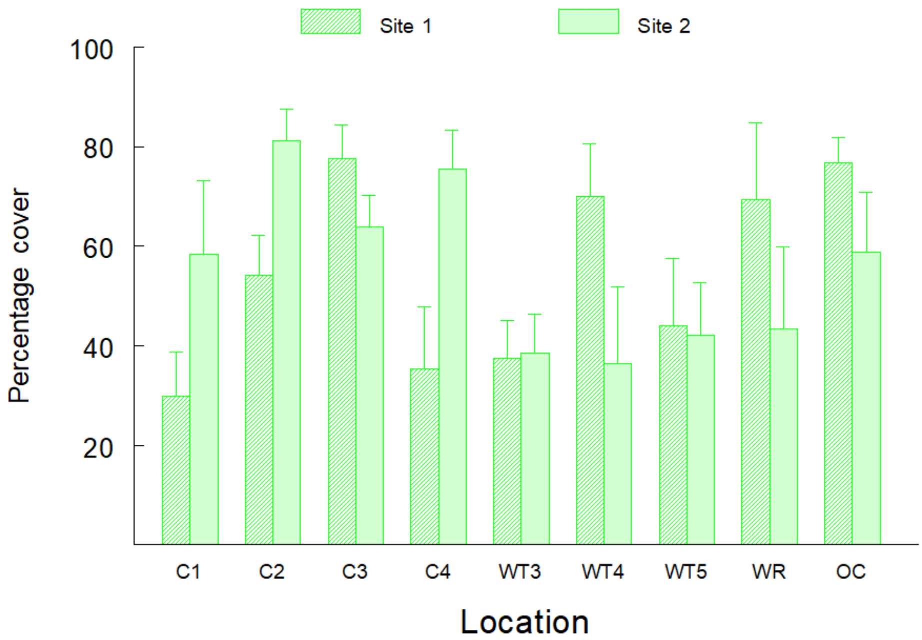


Figure 5. Mean (+SE) percentage cover of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

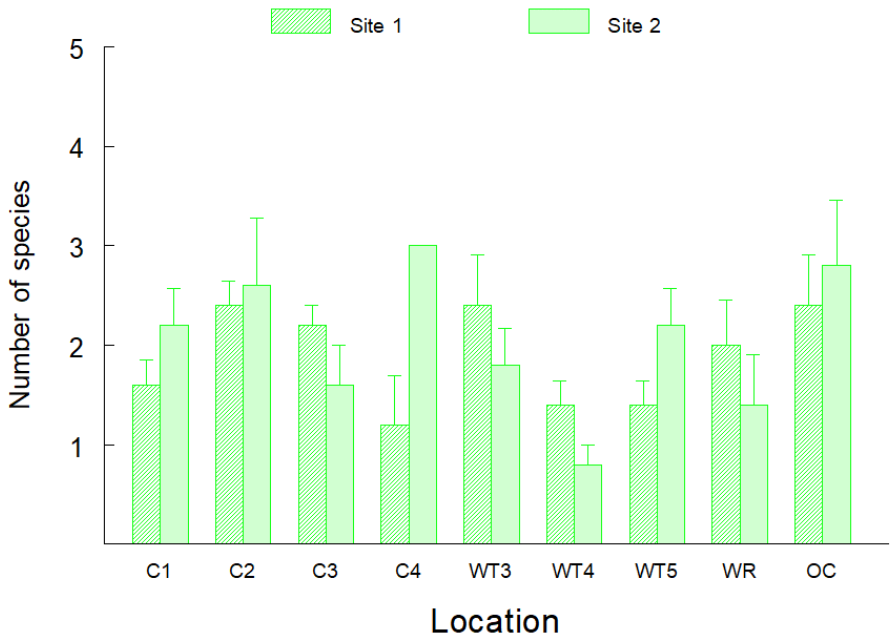


Figure 6. Mean (+SE) diversity of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

4.0 TEMPORAL ANALYSES

A temporal comparison of the aquatic macroinvertebrate and macrophyte data was carried out for the post-mining of Longwalls 20-22 (Section 4.1) and Longwalls 23-27 (Section 4.2) periods. The quantitative data from the surveys done between spring 2008 or spring 2009 and spring 2020 were analysed using both multivariate and univariate techniques. AUSRIVAS data collected from the stream monitoring locations are also presented.

4.1 Post-mining of Longwalls 20-22

The following comparisons consider any ongoing effects of mining within the Longwalls 20-22 area on aquatic indicators at selected sampling locations within Tributary C/Eastern Tributary (Locations C1, C2 and C3) and the Waratah Rivulet (Locations WT3, WT4 and WT5), and any changes that may have occurred following the commencement of extraction of Longwalls 23-27 (May 2014), Longwalls 301-303 (June 2017), Longwall 304 (July 2019) and Longwall 305 (April 2020).

Two to four replicate times (spring 2008 or spring 2009[7] to autumn 2010) have been sampled at the Tributary C/Eastern Tributary, Waratah Rivulet and Control (Woronora River and O'Hares Creek) locations within the pre-mining of Longwalls 20-22 period and 21 replicate times (spring 2010 to spring 2020) have been sampled within the post-mining period.

4.1.1 Tributary C/Eastern Tributary

PERMANOVA was used to test the null hypothesis of no significant change in aquatic macroinvertebrate or macrophyte indicators at Tributary C/Eastern Tributary locations (Locations C1, C2 and C3) Before- vs After-commencement of mining within the Longwalls 20-22 mining area in relation to Control locations (Woronora River and O'Hares Creek).

7 The sampling of Location C3 (ET3) on the Eastern Tributary commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

Significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (variance) among groups or a combination of both. Significant main effects (e.g. Period or Impact) are not indicative of a mining-related impact, and, as such, are not described in detail. The Period x Impact interaction is the scale that would indicate that differences or changes could be attributable to mining.

4.1.1.1 Aquatic Macroinvertebrates

Quantitative Assessment

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2020)

There has been no evidence of any significant impact to aquatic macroinvertebrate fauna at Location C1 within the during- or after-mining periods for the Longwalls 20-22 mining area (Tables 4&5, Figures 7a&8a-d).

Current Survey (Spring 2020)

At the time of the spring 2020 survey, multivariate analyses did not detect a significant before-after mining difference in the structure of assemblages of aquatic macroinvertebrates at Location C1 in relation to the Control group (Table 4, Figure 7a). With the exception of the factor ‘Impact’, each of the main factors appeared to have significant effects ($P < 0.05$), particularly ‘Location’, which contributed 17 % to the components of variation (Table 4).

These results are reflected in the patterns seen in the PCoA, which shows that there is a tendency for samples from the Woronora River location to occur in the upper left of the diagram, compared to those from O’Hares Creek, which occur on the upper right (Figure 7a).

There does appear to be greater dispersion among centroids representing the assemblage at Location C1 than for the Control group (Figure 7a). Analyses indicate that any changes in composition have been within the range of natural variability in these assemblages as measured by the controls.

SIMPER analyses indicated that mayflies (Leptophlebiidae) and freshwater shrimp (Atyidae) have consistently contributed to the structure of assemblages of macroinvertebrates at Location C1 and the control locations and to differences over time.

To date, Leptophlebiidae has increased its contribution to assemblages between Periods at Location C1 (Before: 5.5 %; After: 55.3 %) and O'Hares Creek (Before: 8.8 %, After: 38.2 %) but changed little at the Woronora River location (Before: 16.1 %, After: 25.2 %).

Atyid shrimps made a larger contribution to the structure of assemblages at Location C1 within the Before (59.6 %) than After-period (9.6 %) but changed little at the Woronora River (Before: 72.8 %; After: 61.3 %) and O'Hares Creek (Before: 4.9 %; After: 4.3 %) locations.

Univariate analyses found no evidence of significant change in mean diversity, abundance, numbers of Leptophlebiidae or Atyidae at Location C1 that could be related to mining activities (Table 5, Figure 8a-d). In general, macroinvertebrate diversity at Location C1 was comparable to diversity at the control locations in spring 2020 (T25) (Figure 8a). Mean abundance and numbers of Leptophlebiidae increased at Location C1 and the control locations between the autumn 2020 (T24) and spring 2020 (T25) surveys (Figure 8b&c). Atyidae have rarely been collected at Location C1 since autumn 2018 (T20) (Figure 8d).

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2020)

Analyses of the aquatic macroinvertebrate data have consistently found no significant changes in the structure of assemblages, diversity, abundance or mean numbers of Leptophlebiidae at Location C2 that would indicate an impact during or after mining of the Longwalls 20-22 area (Figure 7b). There has been evidence of significant mining-related changes to mean numbers of Atyidae at Location C2 within the After-mining period, in spring 2015 (T15), but not subsequently[8] (Figure 8d).

[8] A significant change in relation to mean numbers of Atyidae was reported for the autumn (2017) (T18) survey however, this result was later found to be incorrect.

Current Survey (Spring 2020)

There were no detectable impacts to assemblages of aquatic macroinvertebrates at Location C2 in relation to the control locations that could be associated with mining (Table 4, Figure 7b). Similar to the findings for Location C1, the 'Location' factor contributed most (18.5 %) to the components of variation (Table 4, Figure 7b).

Although not significant, the PCoA indicates greater variability in the structure of the assemblage at Location C2 over time, than the Control group (Figure 7b). Notably, the centroid for the spring 2019 (T23), autumn 2020 (T24) and spring 2020 (T25) surveys done at C2 plot separately from all other times of sampling (Figure 7b). This pattern coincides with the finding that Leptophlebiidae contributed as much as 93 %, 92 % and 75 % to the structure of the assemblage at Location C2 in spring 2019, autumn 2020 and spring 2020 (SIMPER), respectively. SIMPER ranked Atyidae as contributing most to the assemblage at Location C2 (71%) prior to the commencement of mining of the Longwalls 20-22 area, followed by the Leptophlebiidae (12%).

Similar to the findings of previous surveys, univariate analyses found no evidence of significant change in mean diversity, abundance or numbers of individuals of Leptophlebiidae at Location C2 in relation to the Control group (Table 5, Figure 8a-c). Graphically, it can be seen that spikes in mean abundance and numbers of Leptophlebiidae have been common at Location C2 and at the control locations throughout the study period (Figures 8b&c). Similar numbers of individuals, taxa and Leptophlebiidae were collected at Location C2 and the control locations in spring 2020 (Figures 8b&c).

Similar to the findings of surveys done since autumn 2016 (T16), analyses found no evidence of a significant impact to mean numbers of Atyidae that may have resulted from mining (Table 5, Figure 8d). Atyidae have rarely been collected at Location C2 since spring 2017 (T19) (Figure 8d).

Location C3 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

There has been no evidence of any significant impact to the assemblage of aquatic macroinvertebrate fauna at Location C3 that may have resulted during or after mining of the Longwalls 20-22 area (Tables 4&5, Figures 7c&8a-d).

Current Survey (Spring 2020)

Similar to the findings of previous surveys, there was no evidence of any significant impact to the assemblage of aquatic macroinvertebrate fauna at Location C3 that may have resulted during or after mining of the Longwalls 20-22 area (Tables 4&5, Figures 7c&8a-d).

SIMPER ranked Atyidae as contributing most to the assemblage at Location C3 within the Before-period (48 %), followed by the Leptophlebiidae (35 %). At the time of the spring 2020 survey, Leptophlebiidae contributed the most (69 %) within the After-period, followed by the Atyidae (11 %).

Graphically, diversity has steadily increased at C3 since the autumn 2021 (T24) survey, to become similar to diversity at the Woronora River location (Figure 8a). Similar to the control locations, mean abundance and numbers of Leptophlebiidae increased at Location C3 between the autumn 2020 (T24) and spring 2020 (T25) surveys (Figure 8b&c). Very few Atyidae have been collected at Location C3 since spring 2016 (T17) (Figure 8d).

Table 4. PERMANOVA on macroinvertebrate assemblage data to compare locations C1, C2 and C3 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek) Before- versus After-mining of Longwalls 20-22. Percentages of Components of Variation (% CV) are shown.

C1					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**37671**	**2.60**	**0.01**	**8.88**
Impact = Im	1	16960	0.26	1.00	0.00
Time (Pe) = Ti(Pe)	**23**	**7670**	**1.83**	**0.00**	**8.45**
Location (Im) = Lo(Im)	**1**	**77228**	**8.61**	**0.00**	**16.99**
Pe x Im	1	12335	1.18	0.30	3.90
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5113**	**1.75**	**0.01**	**4.23**
Pe x Lo(Im)	**1**	**8415**	**1.71**	**0.02**	**6.18**
Ti(Pe) x Im	**23**	**5623**	**1.34**	**0.01**	**7.66**
Pe x Si(Lo(Im))	3	2452	0.84	0.72	0.00
Ti(Pe) x Lo(Im)	**23**	**4195**	**1.44**	**0.00**	**8.35**
Ti(Pe) x Si(Lo(Im))	**69**	**2921**	**1.64**	**0.00**	**11.16**
Residual	300	1784			24.21
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	27676	1.81	0.05	7.22
Impact = Im	1	18955	0.28	1.00	0.00
Time (Pe) = Ti(Pe)	23	**9196**	**2.19**	**0.00**	**11.09**
Location (Im) = Lo(Im)	1	**77234**	**8.47**	**0.00**	**18.53**
Pe x Im	1	7906	0.93	0.61	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**5225**	**2.03**	**0.00**	**5.08**
Pe x Lo(Im)	1	**8407**	**1.69**	**0.02**	**6.61**
Ti(Pe) x Im	23	4633	1.10	0.24	4.64
Pe x Si(Lo(Im))	3	2311	0.90	0.63	0.00
Ti(Pe) x Lo(Im)	23	**4195**	**1.63**	**0.00**	**10.30**
Ti(Pe) x Si(Lo(Im))	69	**2576**	**1.55**	**0.00**	**10.92**
Residual	300	1667			25.60
C3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	11863	1.39	0.18	5.79
Impact = Im	1	14960	0.37	0.99	0.00
Time (Pe) = Ti(Pe)	**21**	**7638**	**2.04**	**0.00**	**10.42**
Location (Im) = Lo(Im)	**1**	**45450**	**6.55**	**0.00**	**20.42**
Pe x Im	1	4018	0.95	0.55	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	3621	1.27	0.18	3.95
Pe x Lo(Im)	1	3592	1.19	0.23	4.59
Ti(Pe) x Im	21	4561	1.22	0.09	6.72
Pe x Si(Lo(Im))	3	1661	0.58	0.95	0.00
Ti(Pe) x Lo(Im)	**21**	**3751**	**1.31**	**0.01**	**8.17**
Ti(Pe) x Si(Lo(Im))	**63**	**2855**	**1.96**	**0.00**	**14.43**
Residual	276	1457			25.51

Bold numbers indicate significant results at $P < 0.05$.

Table 5. PERMANOVA analysis of diversity and abundance of aquatic macroinvertebrates, and of numbers of Leptophlebiidae and Atyidae collected from three locations within Tributary C and at two control locations.

C1		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	36.8	1.28	10312	1.72	5187	2.28	110	0.96
Impact = Im	1	301.9	0.57	13619	1.76	1	0.15	971	0.16
Time (Pe) = Ti(Pe)	23	**44.9**	**2.14**	5926	3.06	**1730**	**7.10**	376	1.04
Location (Im)	1	**553.6**	**15.87**	**6737**	**2.85**	258	2.04	**8119**	**12.72**
Pe x Im	1	25.0	2.71	245	0.66	243	0.24	497	2.74
Site (Lo(Im))	3	14.5	1.38	964	0.63	101	0.23	293	1.49
Pe x Lo(Im)	1	0.3	0.46	1196	1.24	**655**	**3.57**	115	0.84
Ti(Pe) x Im	23	16.7	0.80	2108	1.09	**1396**	**5.73**	197	0.55
Pe x Si(Lo(Im))	3	2.4	0.23	260	0.17	65	0.15	10	0.05
Ti(Pe) x Lo(Im)	23	**21.0**	**2.00**	1936	1.27	244	0.55	**360**	**1.83**
Ti(Pe) x Si(Lo(Im))	69	10.5	1.24	**1526**	**2.51**	**444**	**2.43**	**196**	**1.65**
Residual	300	8.5		609		183		119	
C2		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	134.2	3.28	7916	2.60	3072	2.20	107.7	0.70
Impact = Im	1	454.7	0.83	15702	2.26	103	0.79	117.9	0.06
Time (Pe) = Ti(Pe)	23	**47.0**	**2.24**	2592	1.34	**853**	**3.50**	554.1	1.54
Location (Im)	1	**553.6**	**15.57**	6737	2.57	258	1.27	**8119.2**	**12.96**
Pe x Im	1	0.3	1.29	797	1.21	1	0.29	491.2	3.37
Site (Lo(Im))	3	15.1	1.71	1059	1.10	94	0.55	279.0	1.70
Pe x Lo(Im)	1	0.3	0.35	1196	0.98	**655**	**3.02**	115.2	0.71
Ti(Pe) x Im	23	16.2	0.77	1067	0.55	180	0.74	137.3	0.38
Pe x Si(Lo(Im))	3	4.8	0.54	258	0.27	30	0.18	31.8	0.19
Ti(Pe) x Lo(Im)	23	**21.0**	**2.37**	**1936**	**2.01**	244	1.42	**360.3**	**2.19**
Ti(Pe) x Si(Lo(Im))	69	8.9	1.07	**965**	**1.90**	**171**	**1.93**	**164.6**	**1.58**
Residual	300	8.3		507		89		104.2	
C3		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	0.0	0.35	993	0.78	1904	1.54	**734**	**6.92**
Impact = Im	1	139.1	0.38	7377	1.50	440	0.91	1006	0.23
Time (Pe) = Ti(Pe)	21	**59.6**	**2.67**	3644	1.75	**1180**	**4.53**	157	0.41
Location (Im)	1	**402.1**	**7.20**	4766	1.95	248	1.44	**5833**	**8.46**
Pe x Im	1	27.7	2.11	53	1.15	43	0.41	158	1.89
Site (Lo(Im))	3	**35.1**	**2.94**	995	0.79	207	0.49	323	2.16
Pe x Lo(Im)	1	4.8	0.57	294	0.64	224	2.22	4	0.33
Ti(Pe) x Im	21	18.9	0.85	1561	0.75	524	2.01	282	0.74
Pe x Si(Lo(Im))	3	6.8	0.57	353	0.28	31	0.07	85	0.57
Ti(Pe) x Lo(Im)	21	**22.3**	**1.87**	2087	1.66	261	0.62	**384**	**2.56**
Ti(Pe) x Si(Lo(Im))	63	**11.9**	**1.45**	**1259**	**2.15**	**423**	**2.79**	**150**	**1.76**
Residual	276	8.2		586		152		85	

Bold numbers indicate significant results at $P < 0.05$.

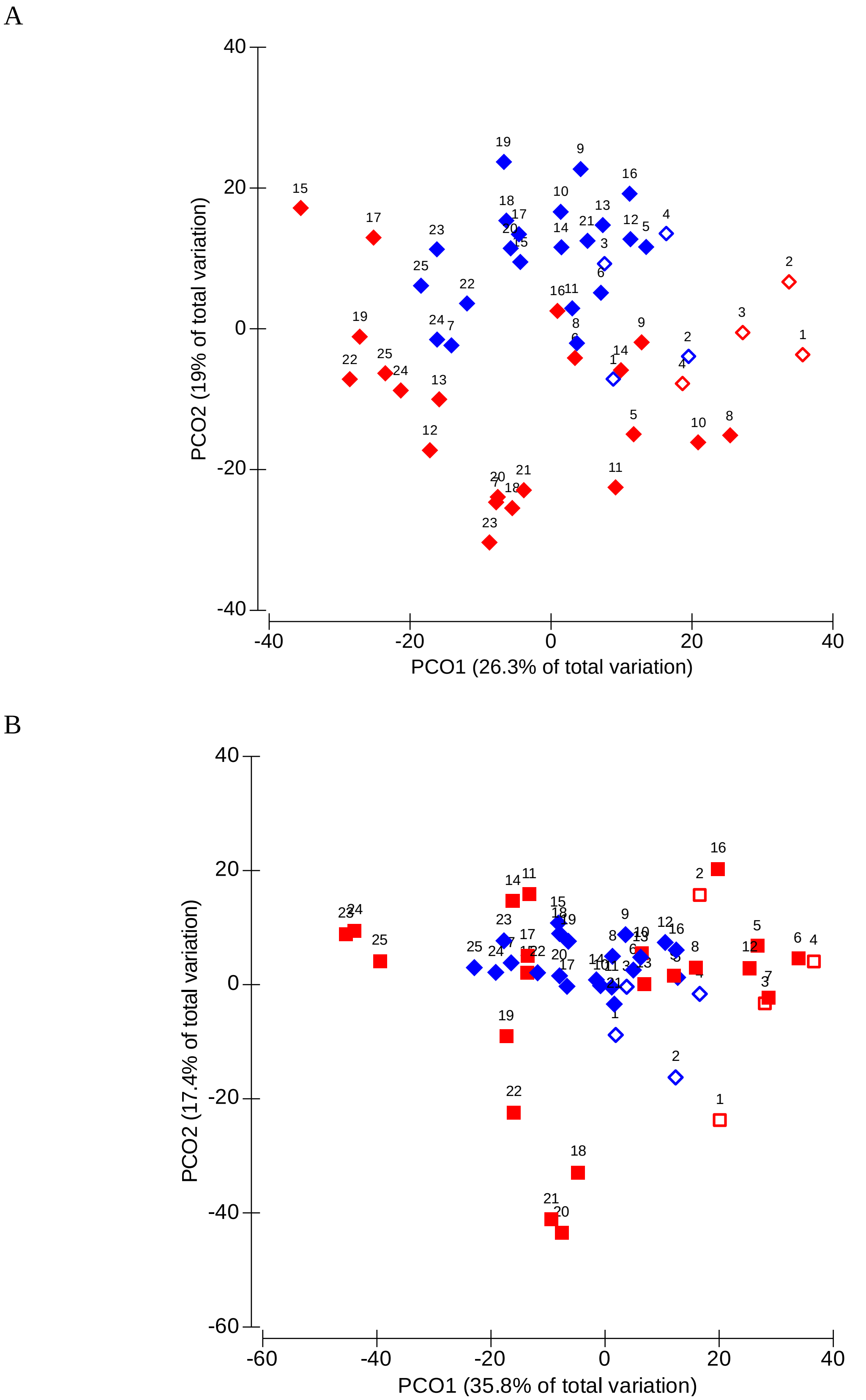


Figure 7. PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at locations a) C1 and b) C2 (red symbols) and the Control group (blue diamonds) between spring 2008 (T1) and spring 2020 (T25). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 20-22.

C

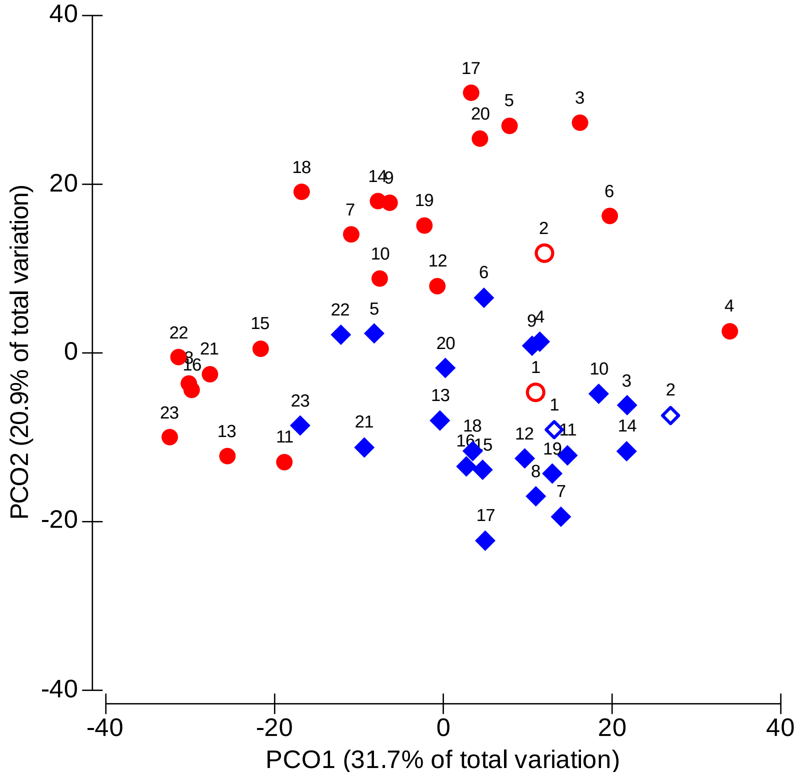
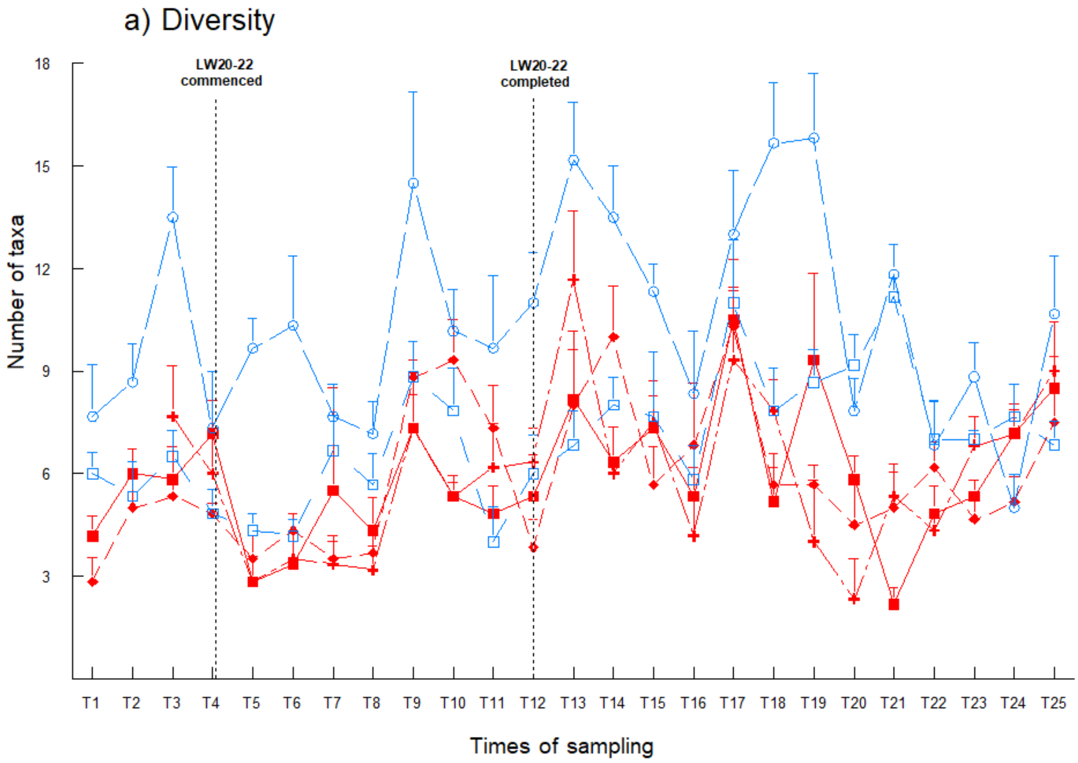


Figure 7 (Cont'd). c) Location C3 (red circles) and the Control group (blue diamonds) for each time of sampling (*n* = 6), between spring 2009 (T1) and spring 2020 (T23). Empty symbols: Before-commencement of mining; Filled symbols: After-mining. Numbers indicate sampling time.



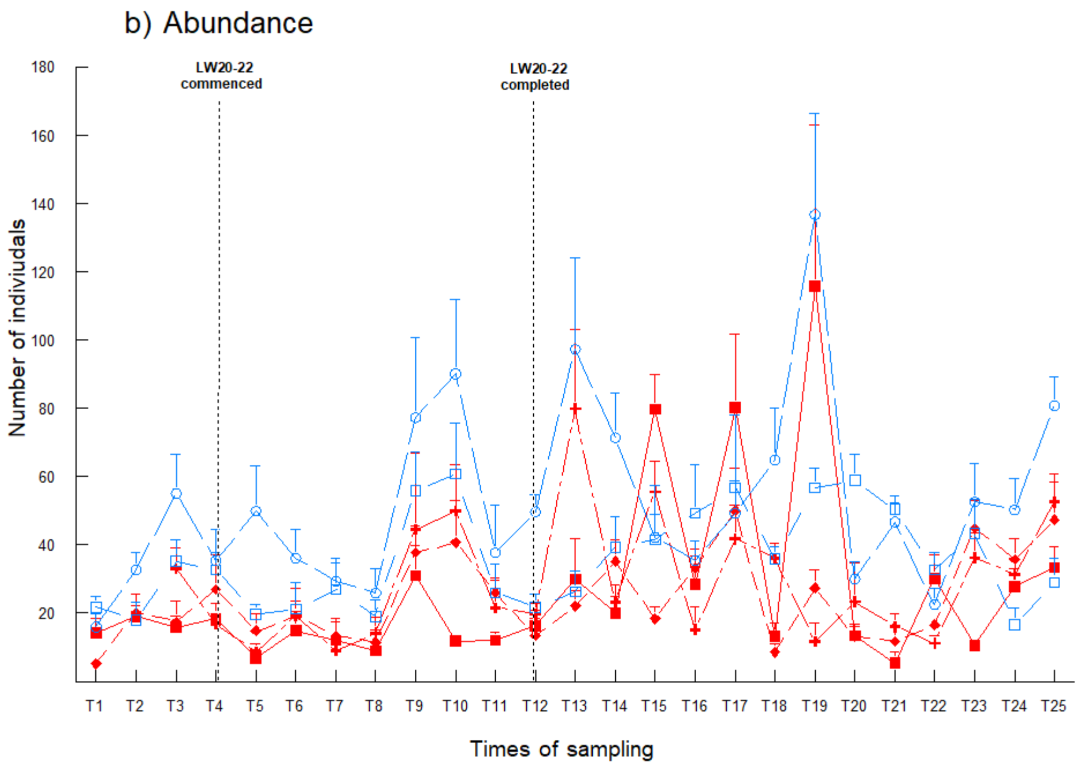


Figure 8. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).

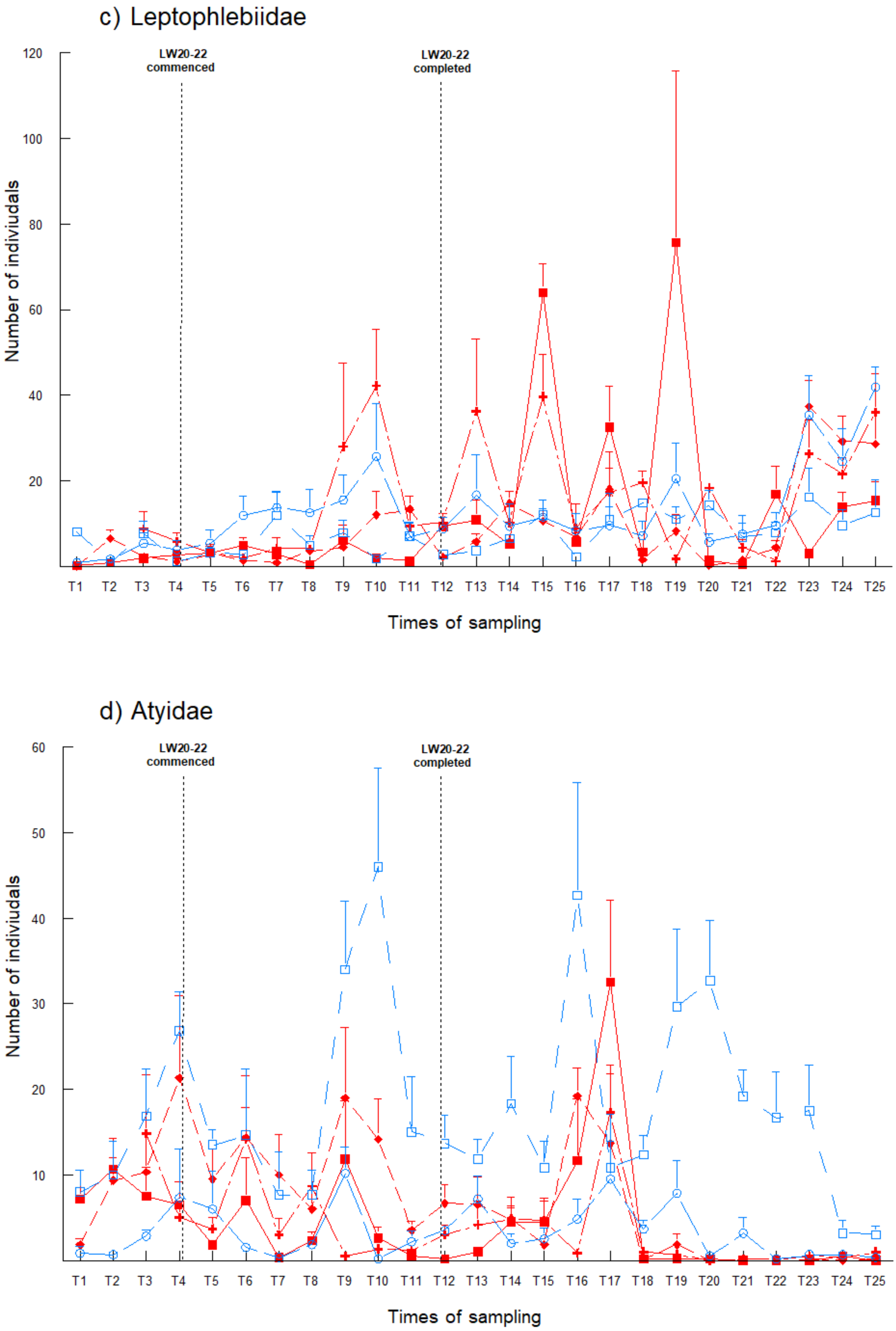


Figure 8 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.10 (Location C1 in spring 2018) and 1.015 (Location C3 in spring 2014) (Figure 9a). OE50 Taxa Scores for samples collected in autumn ranged from 0.30 (Location C3 in autumn 2014) to 0.88 (Location OC in autumn 2017) (Figure 9b). With the exception of one sample (i.e. Location C3 in spring 2014), all of the OE50 Taxa scores were below 1.00 (Figure 9a&b), indicating that the number of taxa observed was less than would be expected relative to the AUSRIVAS reference watercourses.

Only one location achieved a Band A score (equivalent to AUSRIVAS reference condition) in autumn (OC in autumn 2017) (Figure 9a). Four Band A scores have been obtained in spring (Locations C3, WR and OC in spring 2014 and Location OC in spring 2017) (Figure 9a&b).

The results from this sampling occasion (spring 2020) indicated that the condition of aquatic macroinvertebrate fauna at the Woronora River location increased by one AUSRIVAS Band level, from Band C (severely impaired) to Band B (significantly impaired), between the autumn 2020 and spring 2020 surveys (Figure 9a&b).

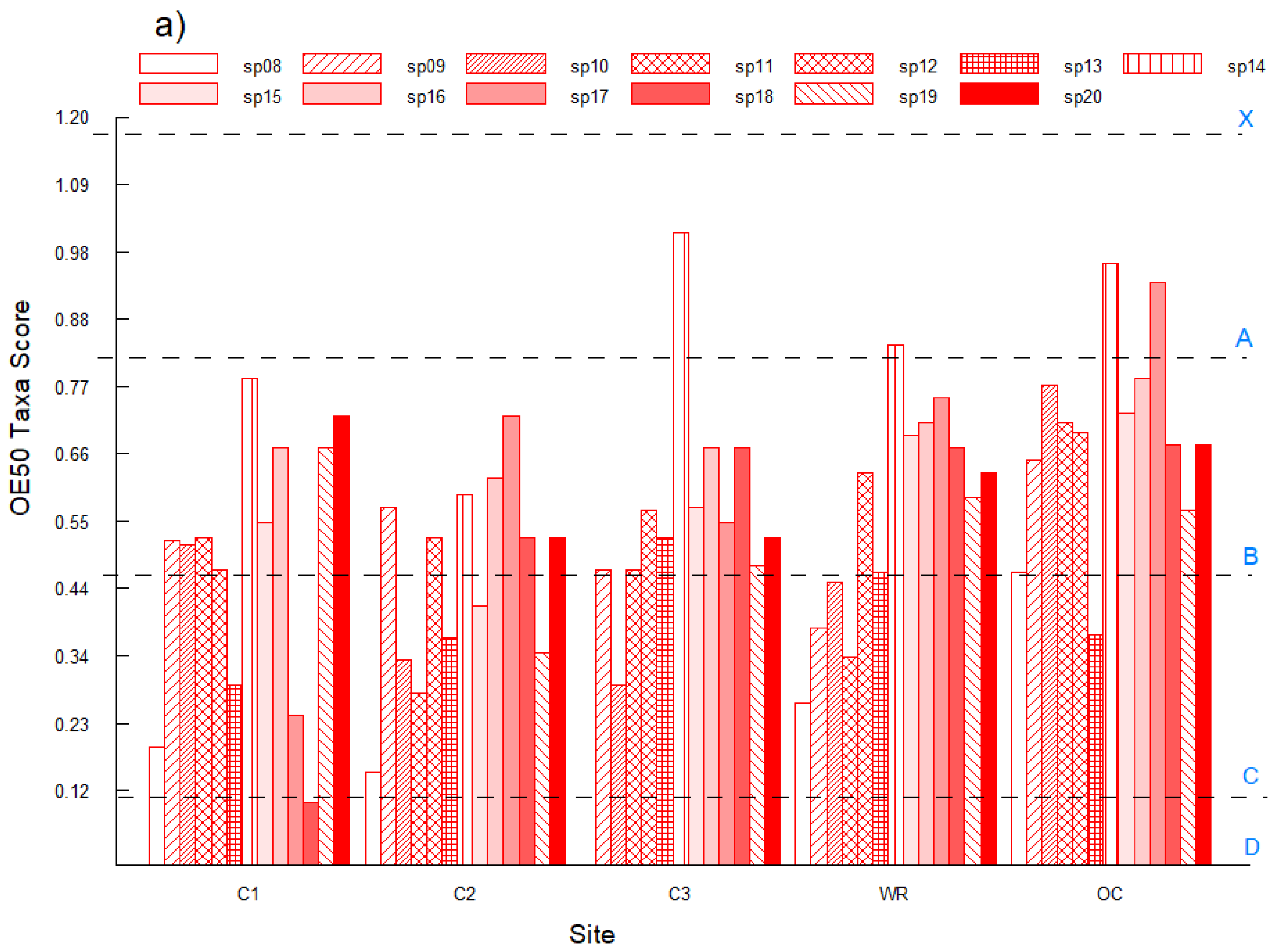


Figure 9a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2008 and 2020 (*n* = 2).

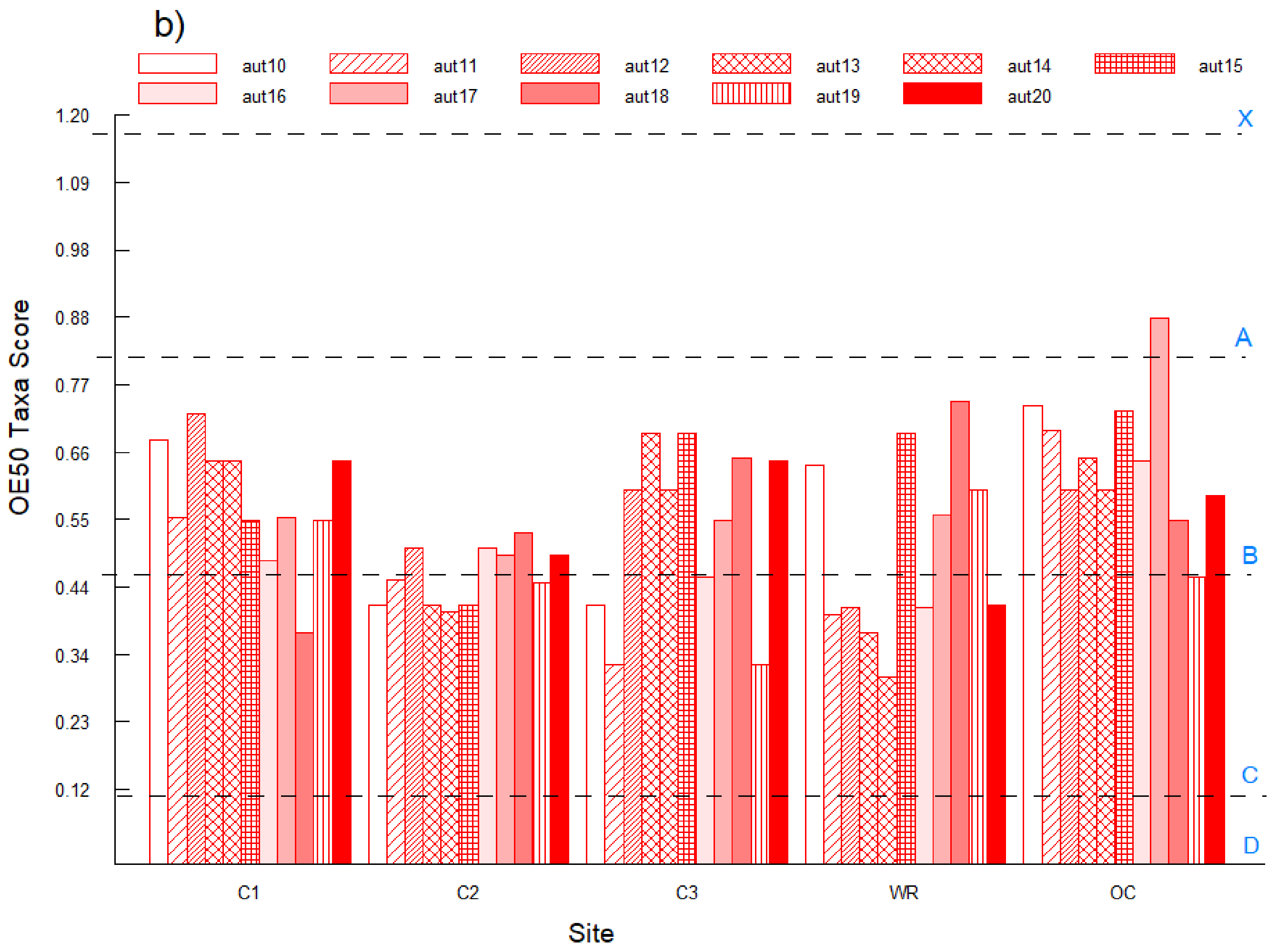


Figure 9b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2008 and 2020 (*n* = 2).

4.1.1.2 Aquatic Macrophytes

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2020)

A significant Before- vs After-mining change in the structure of the assemblage of aquatic macrophytes was detected at Location C1 in spring 2014 (T13) in relation to the control locations, but not subsequently. This result did not appear to be related to mining activities.

Analyses of univariate estimates of total cover and species diversity at Location C1 have consistently found no significant changes in relation to control locations that would indicate an impact from mining.

Current Survey (Spring 2020)

Similar to the findings of past surveys, results from the multivariate analysis examining patterns in assemblages of macrophytes at Location C1 in relation to the control locations indicated that differences in the structure of assemblages of macrophytes were not related to mining activities within the Longwalls 20-22 area, evidenced by the non-significant result for the Period x Impact term (Table 6, Figure 10a).

Notable from the PCoA ordination was that assemblages at Location C1 and the control locations (Woronora River and O'Hares Creek) mostly group separately from each other (Figure 10a). The presence of the floating-attached species, *Triglochin procerum,* at the control locations but not at Location C1 contributed greatly to observed differences. In addition, *Baumea juncea* is a relatively abundant component of the riparian strip adjacent to Tributary C but has not been recorded at either of the control locations.

Analyses of univariate estimates of total cover and species diversity of aquatic macrophytes have consistently found no significant differences between the factors of interest (i.e. Pe x Im), indicating that to date, any changes observed throughout the study period are unlikely to be related to mining activities within the Longwalls 20-22 area (Table 7, Figures 11a&b).

Graphically there appears to have been a considerable increase in cover of macrophytes at Location C1 between autumn 2020 (T24) and spring 2020 (T25) (Figure 11b), most likely related to recovery after the end of the recent drought and mining related drops in pool water level.

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2020)

Similar to the findings for Location C1, analyses detected a significant Before- vs After-mining change in the structure of the assemblage of aquatic macrophytes at Location C2 in spring 2014 (T13), in relation to the Control group (Figure 10b). There were no apparent physical changes to the riparian strip that might be associated with mining activities and analyses of data from subsequent surveys have not detected a significant change in relation to assemblages at the control locations.

Analyses of species diversity and total cover of aquatic macrophytes have consistently found no significant differences between the factors of interest (i.e. Pe x Im) (Figure 11a&b).

Current Survey (Spring 2020)

Analyses of temporal changes in the structure of assemblages of aquatic macrophytes (Table 6, Figure 10b) and univariate estimates of total cover and species diversity (Table 7, Figures 11a&b) at Location C2 found no significant changes in relation to control locations that would indicate an impact from mining. In spring 2020, *Baumea juncea* contributed most (44 %) to the structure of the assemblage at Location C2, followed by *Lepidosperma filiforme* (37 %) (SIMPER).

Graphically, it can be seen that there was a small decrease in percentage cover of macrophytes at Location C2 between autumn 2020 (T24) and spring 2020 (T25) (Figures 11a&b).

Location C3 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

Analyses of Before- (spring 2009 – autumn 2010) vs After- (spring 2010 – spring 2019) mining changes in the structure of assemblages of aquatic macrophytes (Figure 10c) and univariate estimates of total cover and species diversity (Figures 11a&b) have consistently found no significant changes at Location C3 in relation to control locations that would indicate an impact from mining.

Current Survey (Spring 2020)

Consistent with the findings of the previous surveys, multivariate analyses found no significant changes in relation to control locations that would indicate an impact from mining (Table 6, Figure 10c). In spring 2020, *Empodisma minus* contributed most to the structure of the assemblage (34 %) at Location C3, followed by *Gleichenia dicarpa* (32 %) and *Lomandra fluviatilis* (17 %) (SIMPER).

Univariate analyses of total diversity found no significant difference at any of the scales examined (Table 7, Figure 11a). Total cover of macrophytes differed significantly between the scales of Time nested in Period and Locations nested within type of Creek (i.e. Ti(Pe) x Lo(Im)), indicating that differences in cover among locations depended on the time of sampling not mining related activities (Table 7, Figure 11b). Graphically, it can be seen that cover of macrophytes in the riparian zone at Location C3 decreased between autumn 2020 (T22) and spring 2020 (T23), but increased at each of the control locations (Figure 11b).

Table 6. PERMANOVA on macrophyte assemblage data to compare locations C1, C2 and C3 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown.

C1					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	23810	1.26	0.23	3.76
Impact = Im	1	50527	1.60	0.10	7.06
Time (Pe) = Ti(Pe)	**23**	**6451**	**1.61**	**0.00**	**6.31**
Location (Im) = Lo(Im)	**1**	**28648**	**1.56**	**0.03**	**6.03**
Pe x Im	1	14818	0.90	0.63	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**16162**	**5.85**	**0.00**	**9.31**
Pe x Lo(Im)	**1**	**15540**	**1.54**	**0.03**	**6.45**
Ti(Pe) x Im	**23**	**5337**	**1.33**	**0.01**	**6.59**
Pe x Si(Lo(Im))	**3**	**7867**	**2.85**	**0.00**	**8.12**
Ti(Pe) x Lo(Im)	**23**	**4003**	**1.45**	**0.00**	**7.34**
Ti(Pe) x Si(Lo(Im))	69	2763	0.79	1.00	0.00
Residual	600	3510			39.04
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	21940	1.27	0.23	3.81
Impact = Im	1	47270	1.45	0.16	6.45
Time (Pe) = Ti(Pe)	**23**	**5076**	**1.32**	**0.01**	**4.69**
Location (Im) = Lo(Im)	**1**	**31031**	**1.69**	**0.02**	**6.99**
Pe x Im	1	17017	1.07	0.42	2.67
Site (Lo(Im)) = Si(Lo(Im))	**3**	**16322**	**5.41**	**0.00**	**9.67**
Pe x Lo(Im)	**1**	**15209**	**1.74**	**0.01**	**7.37**
Ti(Pe) x Im	23	4291	1.12	0.16	4.02
Pe x Si(Lo(Im))	**3**	**6666**	**2.21**	**0.00**	**7.17**
Ti(Pe) x Lo(Im)	**23**	**3836**	**1.27**	**0.00**	**6.22**
Ti(Pe) x Si(Lo(Im))	69	3017	0.85	1.00	0.00
Residual	600	3545			
C3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	14360	1.45	0.14	5.78
Impact = Im	1	24711	1.39	0.19	6.88
Time (Pe) = Ti(Pe)	21	4468	1.13	0.21	3.28
Location (Im) = Lo(Im)	**1**	**16649**	**1.64**	**0.02**	**7.77**
Pe x Im	1	6445	0.85	0.68	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**8066**	**2.63**	**0.00**	**8.87**
Pe x Lo(Im)	1	8182	1.30	0.13	6.37
Ti(Pe) x Im	21	4003	1.01	0.48	1.24
Pe x Si(Lo(Im))	3	4704	1.53	0.06	7.17
Ti(Pe) x Lo(Im)	**21**	**3967**	**1.29**	**0.01**	**7.19**
Ti(Pe) x Si(Lo(Im))	63	3067	0.85	1.00	0.00
Residual	552	3597			45.44

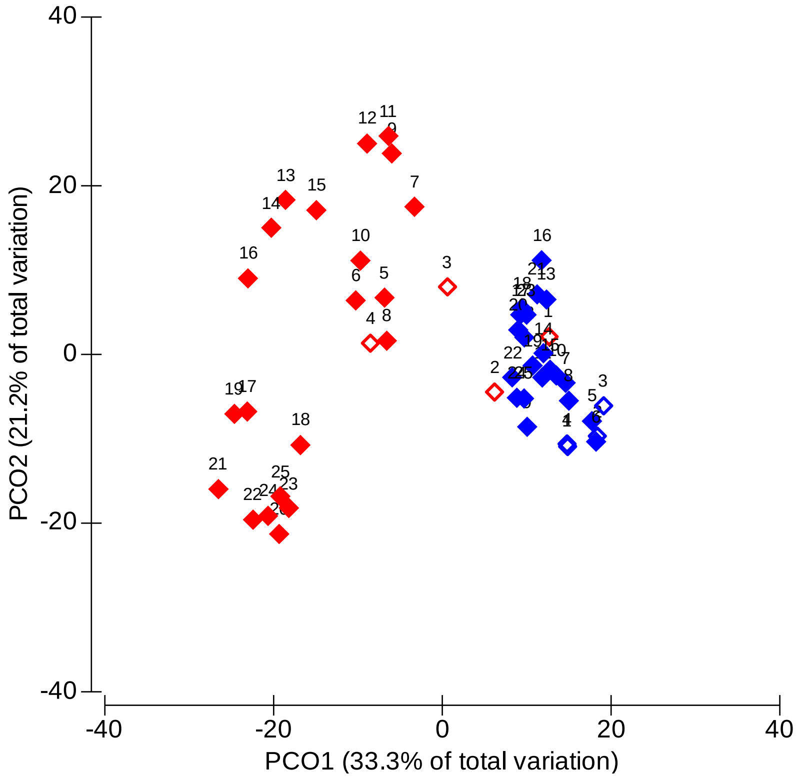
Bold numbers indicate significant results at $P < 0.05$.

Table 7. PERMANOVA on estimates of diversity and cover of aquatic macrophytes.

C1		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	22.37	3.42	986	0.36
Impact = Im	1	0.03	0.59	418	0.41
Time (Pe) = Ti(Pe)	23	**5.10**	**2.33**	**3427**	**3.02**
Location (Im) = Lo(Im)	1	0.00	0.39	1224	0.63
Pe x Im	1	0.09	0.39	1327	0.48
Site (Lo(Im)) = Si(Lo(Im))	3	1.17	0.91	**1845**	**2.86**
Pe x Lo(Im)	1	2.07	1.32	2535	0.93
Ti(Pe) x Im	23	3.78	1.73	**2562**	**2.26**
Pe x Si(Lo(Im))	3	0.36	0.27	**2300**	**3.57**
Ti(Pe) x Lo(Im)	23	2.19	1.69	**1135**	**1.76**
Ti(Pe) x Si(Lo(Im))	69	1.29	0.98	645	1.07
Residual	600	1.32		604	
C2		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	**35.30**	**4.69**	1282	0.88
Impact = Im	1	2.09	1.84	0	0.74
Time (Pe) = Ti(Pe)	23	**6.65**	**3.15**	1368	1.02
Location (Im) = Lo(Im)	1	0.08	0.48	611	0.46
Pe x Im	1	0.73	0.81	202	0.55
Site (Lo(Im)) = Si(Lo(Im))	3	0.72	0.56	1793	2.16
Pe x Lo(Im)	1	1.31	1.03	1607	0.81
Ti(Pe) x Im	23	2.20	1.04	1192	0.89
Pe x Si(Lo(Im))	3	0.41	0.32	1687	2.03
Ti(Pe) x Lo(Im)	23	2.11	1.66	1338	1.61
Ti(Pe) x Si(Lo(Im))	69	1.28	0.95	**829**	**1.69**
Residual	600	1.34		491	
C3		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	5.57	1.13	12	0.67
Impact = Im	1	0.20	0.86	14	1.43
Time (Pe) = Ti(Pe)	21	3.40	1.64	1440	0.99
Location (Im) = Lo(Im)	1	1.39	0.70	405	0.44
Pe x Im	1	0.01	0.45	390	1.33
Site (Lo(Im)) = Si(Lo(Im))	3	1.77	1.35	883	1.41
Pe x Lo(Im)	1	3.39	2.06	766	0.51
Ti(Pe) x Im	21	1.27	0.61	624	0.43
Pe x Si(Lo(Im))	3	0.21	0.16	1261	2.02
Ti(Pe) x Lo(Im)	21	2.08	1.58	**1456**	**2.33**
Ti(Pe) x Si(Lo(Im))	63	1.31	0.95	624	1.20
Residual	552	1.38		521	

Bold numbers indicate significant results at $P < 0.05$.

A



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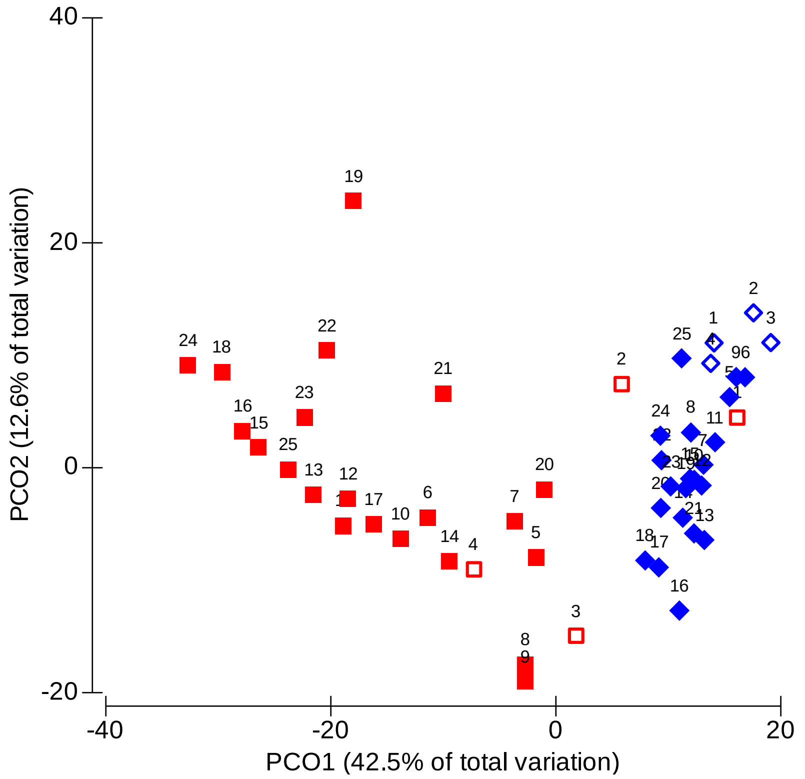


Figure 10. PCoA of centroids for macrophyte data for a) Location C1 and b) Location C2 and two control locations (Woronora River and O'Hares Creek) for each time of sampling (*n*= 10). Red symbols: Potential 'impact' locations; Blue symbols: Control group. Empty symbols: Before-mining; Filled symbols: After-mining. Numbers indicate sampling time. NB Sampling of locations C1 and C2 commenced in spring 2008 (T1).

C

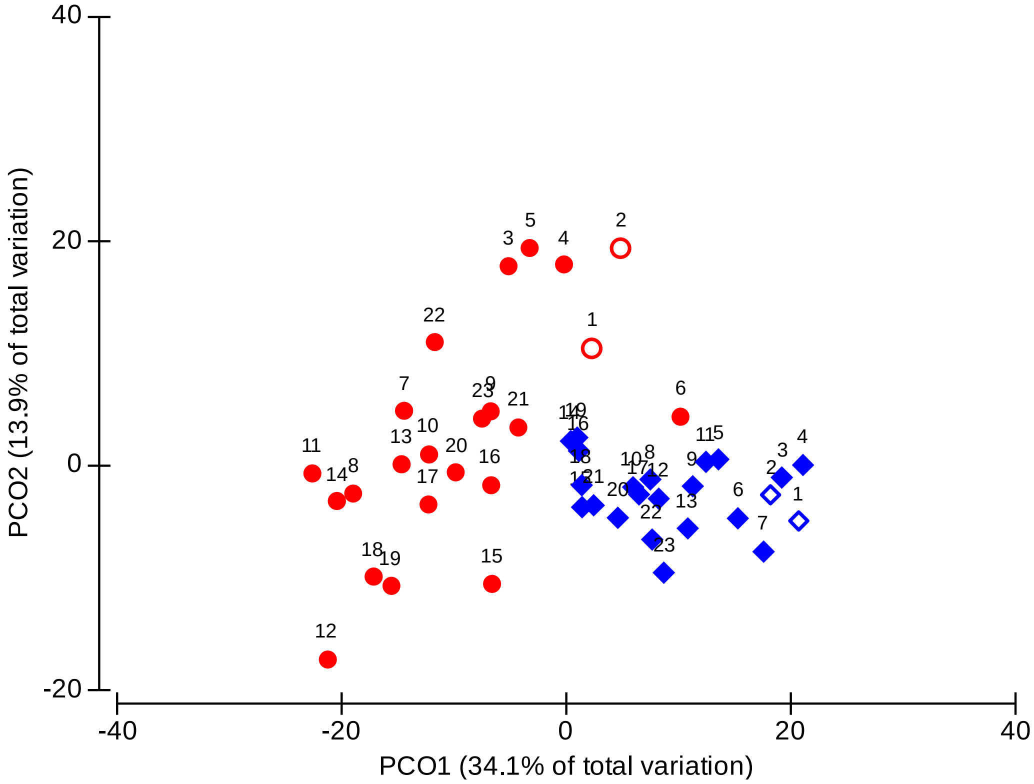


Figure 10 (Cont'd). PCoA of centroids for macrophyte data for c) Location C3. Red symbols: Potential 'impact' location; Blue diamonds: Control group. Empty symbols: Before-mining; Filled symbols: After-mining. Numbers indicate sampling time. NB sampling of location C3 commenced in spring 2009.

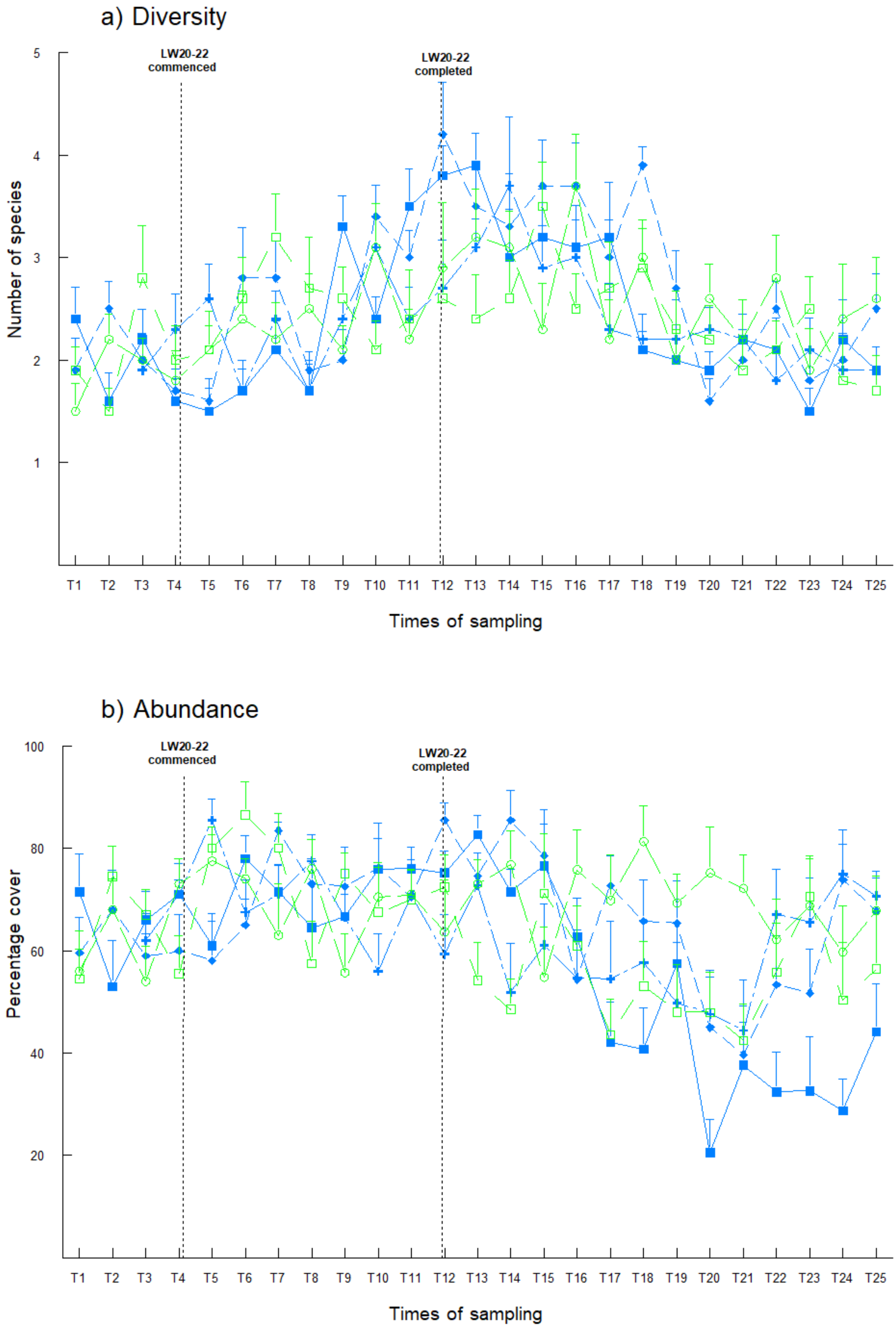


Figure 11. Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 10). NB Sampling of location C3 commenced in spring 2009.

4.1.2 Waratah Rivulet

4.1.2.1 Aquatic Macroinvertebrates

Quantitative Assessment

Prior Surveys (Spring 2008 – Autumn 2020)

To date, analyses comparing temporal changes in components of assemblages of macroinvertebrates at Locations WT3, WT4 and WT5 in relation to control locations have not detected significant changes from Before- vs After-commencement of mining of the Longwalls 20-22 underground mining area.

Univariate analyses detected a significant decrease in mean diversity at Location WT3 within the after-period in spring 2016 (T15), autumn 2018 (T20) and subsequent surveys.

Current Survey (Spring 2020)

Consistent with previous surveys, multivariate analyses did not yield any significant interaction of the factors Period and Impact (Table 8, Figures 12a-c). SIMPER analyses indicate that throughout the survey period, temporal differences at the Waratah Rivulet locations in relation to the control group have been mostly due to differences in abundances of the macroinvertebrate taxa, particularly Atyidae and Leptophlebiidae, rather than the presence or absence of species.

SIMPER indicates that the contribution that Atyidae has made to each of the rivulet locations has declined considerably between the Before- (WT3: 25.9 %; WT4: 33 %; WT5: 52.8 %) and After-mining (WT3: 5.2 %; WT4: 7.9 %; WT5: 13.2 %) periods. In contrast, Atyidae differed little in its contribution to assemblages at the control locations (Before- WR: 72.5 %, OH: 4.9 %; After - WR: 61.4 %, OH: 4.4 %).

Leptophlebiidae increased its contribution at the rivulet and Control location between the Before (WT3: 23.1 %; WT4: 43.7 %; WT5: 12.3 %; WR: 15.8; OH: 8.8 %) and After (WT3: 64.3 %; WT4: 49.9 %; WT5: 37.6 %; WR: 40.6; OH: 73.3 %) period.

Similar to the findings of the spring 2016 (T15), autumn 2018 (T20) and subsequent surveys, univariate analyses detected a significant change in mean diversity at Location WT3 within the after-period, in relation to the control locations (Table 9, Figure 13a). When PERMDISP was used to formally compare the apparent variability (dispersion), a non-significant result was obtained ($P = 0.409$). Similarly, pair-wise tests were unable to determine differences among means ($P > 0.05$). Differences appear to be related to small differences in the direction of change in mean diversity at WT3 (Before: 9.5; After: 8.0) compared to the control treatment (Before: 8.0; After: 9.0) between periods (Figure 13a).

Mean diversity did not differ significantly between periods at Location WT4 and Location WT5 in relation to the controls (Table 9, Figure 13a). Graphically, it can be seen that diversity changed little at the rivulet and control locations between the autumn 2020 (T24) and spring 2020 (T25) surveys (Figure 13a).

Mean abundance and numbers of Leptophlebiidae and Atyidae collected at Locations WT3, WT4 and WT5 showed no significant interactions at the level of interest (i.e. Period x Impact) (Table 9, Figures 13b-d). In general, mean abundance of macroinvertebrates measured at the rivulet locations appeared to be within the range of variability as displayed by the control locations (Figure 13b). Mean abundance of Leptophlebiidae increased considerably at Location WT5 between the autumn 2020 (T24) and spring 2020 (T25) surveys (Figure 13c).

Atyidae have consistently been most abundant at the Woronora River location, although numbers have varied considerably and fewer individuals were collected in autumn and spring 2020 than prior surveys (Figure 13d). In spring 2020 (T25), Atyidae were not collected at Location WT3 or WT5, while fewer than 4 individuals were collected at Location WT4 and OC (Figure 13d).

Table 8. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate assemblage data (non-transformed) to compare locations WT3, WT4 and WT5 sampled on Waratah Rivulet with control locations (Woronora River and O'Hares Creek) Before- vs After-commencement of mining. Percentages of Components of Variation (% CV) are shown.

WT3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	15501	1.27	0.24	4.04
Impact = Im	1	26407	0.40	0.99	0.00
Time (Pe) = Ti(Pe)	**23**	**7778**	**1.98**	**0.00**	**10.17**
Location (Im) = Lo(Im)	**1**	**71760**	**8.28**	**0.00**	**18.65**
Pe x Im	1	6700	0.88	0.67	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5057**	**1.97**	**0.00**	**5.15**
Pe x Lo(Im)	**1**	**7558**	**1.50**	**0.04**	**6.01**
Ti(Pe) x Im	23	4575	1.17	0.11	5.92
Pe x Si(Lo(Im))	3	2806	1.09	0.31	2.27
Ti(Pe) x Lo(Im)	**23**	**3923**	**1.53**	**0.00**	**9.86**
Ti(Pe) x Si(Lo(Im))	**69**	**2563**	**1.62**	**0.00**	**11.83**
Residual	300	1586			
WT4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	14320	1.23	0.27	3.69
Impact = Im	1	26656	0.40	0.99	0.00
Time (Pe) = Ti(Pe)	23	**7633**	**2.00**	**0.00**	**10.12**
Location (Im) = Lo(Im)	1	**72383**	**8.47**	**0.00**	**18.85**
Pe x Im	1	6680	0.89	0.65	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**5028**	**1.94**	**0.00**	**5.11**
Pe x Lo(Im)	1	7145	1.47	0.06	5.78
Ti(Pe) x Im	23	4684	1.22	0.06	6.79
Pe x Si(Lo(Im))	3	2805	1.08	0.34	2.11
Ti(Pe) x Lo(Im)	23	**3826**	**1.47**	**0.00**	**9.38**
Ti(Pe) x Si(Lo(Im))	69	**2598**	**1.63**	**0.00**	**12.03**
Residual	300	1589			26.14
WT5					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	21744	1.62	0.08	6.10
Impact = Im	1	21109	0.31	1.00	0.00
Time (Pe) = Ti(Pe)	**23**	**7916**	**1.91**	**0.00**	**9.74**
Location (Im) = Lo(Im)	**1**	**76706**	**7.79**	**0.00**	**18.57**
Pe x Im	1	6827	0.88	0.67	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**6027**	**2.33**	**0.00**	**5.86**
Pe x Lo(Im)	**1**	**8025**	**1.53**	**0.04**	**6.06**
Ti(Pe) x Im	23	4511	1.09	0.24	4.28
Pe x Si(Lo(Im))	3	2780	1.08	0.35	1.98
Ti(Pe) x Lo(Im)	**23**	**4146**	**1.60**	**0.00**	**10.24**
Ti(Pe) x Si(Lo(Im))	**69**	**2584**	**1.44**	**0.00**	**10.33**
Residual	300	1789			26.83

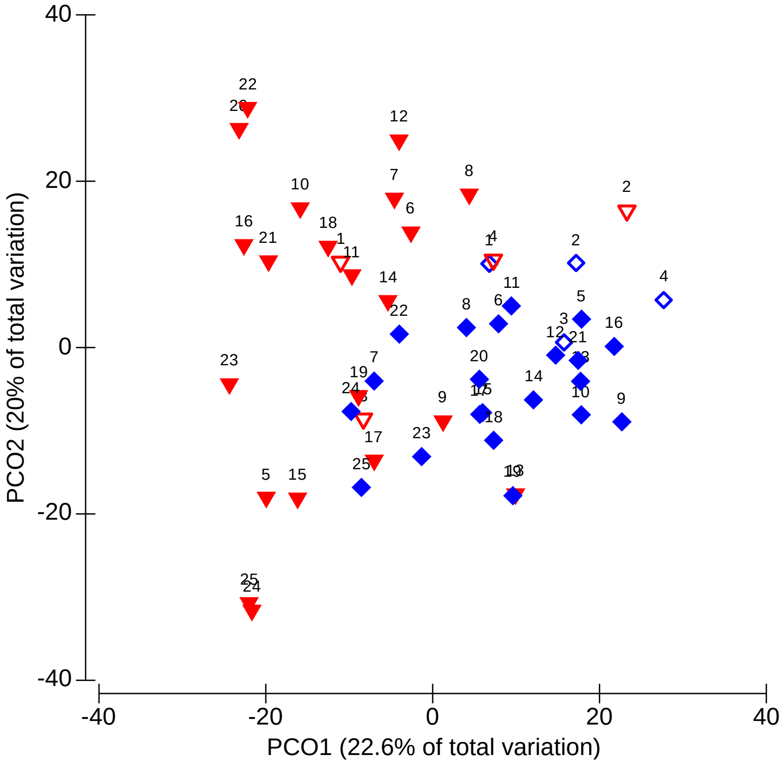
Bold numbers indicate significant results at $P < 0.05$.

Table 9. PERMANOVA analysis on Euclidean Distances of four univariate estimates (i.e. non-transformed) (total diversity and abundance and abundances of Leptophlebiidae and Atyidae) of the macroinvertebrate data collected to compare three locations within Waratah Rivulet with two control locations Before- vs After-commencement of mining.

WT3		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	0.4	0.32	2868	0.86	1079	0.75	115	1.42
Impact = Im	1	6.0	0.05	667	0.28	672	1.20	1719	0.25
Time (Pe) = Ti(Pe)	23	**70.0**	**3.22**	**4479**	**2.31**	**1101**	**4.52**	220	0.61
Location (Im) = Lo(Im)	1	**580.9**	**16.28**	6972	2.62	258	1.40	**8119**	**12.93**
Pe x Im	1	**95.6**	**5.97**	3707	1.58	555	0.69	507	3.00
Site (Lo(Im)) = Si(Lo(Im))	3	14.5	1.52	1110	1.09	108	0.46	279	1.87
Pe x Lo(Im)	1	0.1	0.28	1131	0.70	655	1.04	115	0.71
Ti(Pe) x Im	23	19.6	0.90	2448	1.26	503	2.07	174	0.48
Pe x Si(Lo(Im))	3	12.3	1.29	1145	1.12	607	2.61	14	0.09
Ti(Pe) x Lo(Im)	23	**21.8**	**2.28**	**1941**	**1.90**	244	1.05	**360**	**2.41**
Ti(Pe) x Si(Lo(Im))	69	9.6	1.02	**1023**	**1.59**	**232**	**1.49**	**150**	**1.89**
Residual	300	9.4		643		156		79	
WT4		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	98.4	2.3	11389	2.28	1880	1.01	120	0.77
Impact = Im	1	92.5	0.2	2058	0.43	2338	2.38	1821	0.26
Time (Pe) = Ti(Pe)	23	**52.6**	**2.4**	**4710**	**2.43**	**1449**	**5.95**	507	1.41
Location (Im) = Lo(Im)	1	**580.9**	**15.0**	6972	2.75	258	1.48	**8119**	**12.00**
Pe x Im	1	0.6	0.9	59	0.58	170	0.28	1	0.87
Site (Lo(Im)) = Si(Lo(Im))	3	17.6	1.7	975	0.92	77	0.36	336	1.41
Pe x Lo(Im)	1	0.1	0.4	1131	0.72	655	2.31	115	0.81
Ti(Pe) x Im	23	23.6	1.1	2334	1.20	**825**	**3.39**	299	0.83
Pe x Si(Lo(Im))	3	1.9	0.2	1095	1.03	135	0.62	77	0.32
Ti(Pe) x Lo(Im)	23	**21.8**	**2.2**	**1941**	**1.83**	244	1.12	360	1.51
Ti(Pe) x Si(Lo(Im))	69	10.1	1.2	**1060**	**1.65**	217	1.34	**239**	**2.04**
Residual	300	8.7		641		161		117	
WT5		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	86.6	2.21	13280	3.05	3540	2.42	78	0.72
Impact = Im	1	153.1	0.29	8603	1.19	131	0.60	707	0.13
Time (Pe) = Ti(Pe)	23	**49.0**	**2.25**	3858	1.99	**907**	**3.72**	490	1.36
Location (Im) = Lo(Im)	1	**580.9**	**15.91**	6972	2.70	258	1.22	**8119**	**12.04**
Pe x Im	1	0.0	1.12	1	0.65	9	0.25	426	2.33
Site (Lo(Im)) = Si(Lo(Im))	3	15.4	1.56	1012	1.02	108	0.63	327	2.16
Pe x Lo(Im)	1	0.1	0.42	1131	0.96	655	3.03	115	0.69
Ti(Pe) x Im	23	19.4	0.89	1869	0.96	370	1.52	221	0.61
Pe x Si(Lo(Im))	3	1.9	0.20	272	0.27	29	0.17	23	0.15
Ti(Pe) x Lo(Im)	23	**21.8**	**2.21**	**1941**	**1.96**	244	1.41	**360**	**2.38**
Ti(Pe) x Si(Lo(Im))	69	9.9	1.06	**990**	**1.62**	**172**	**1.69**	**151**	**1.67**
Residual	300	9.3		612		102		91	

Bold numbers indicate significant results at $P < 0.05$.

A



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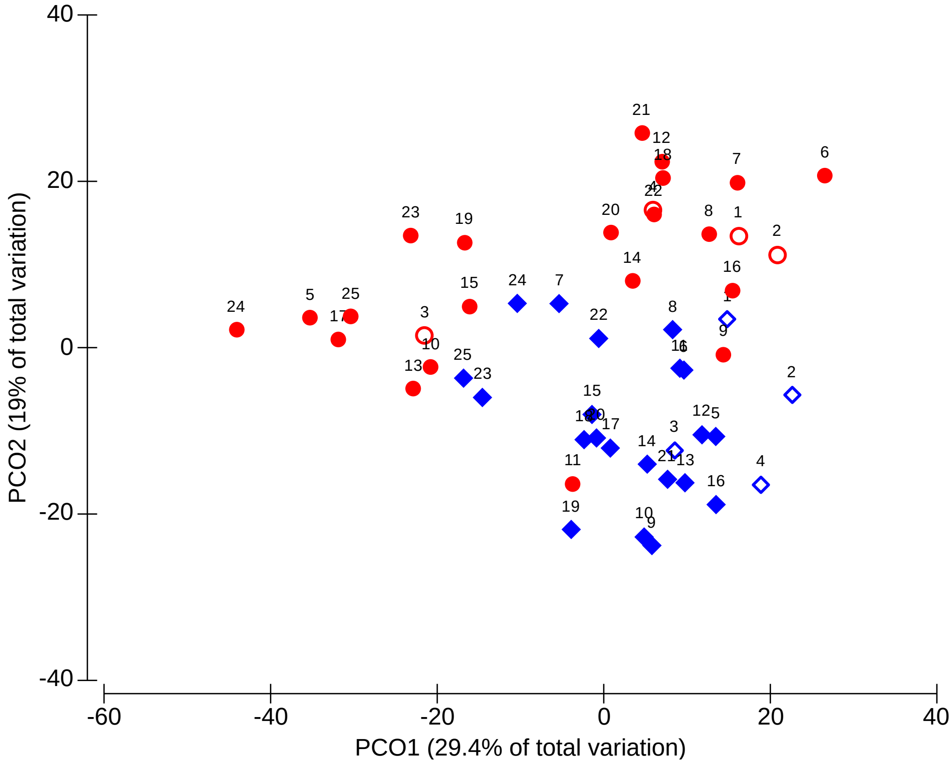


Figure 12. PCoA of centroids for macroinvertebrate data for locations a) WT3 and b) WT4 (red symbols) and the Control group (blue symbols) for each time of sampling (*n* = 6). Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.

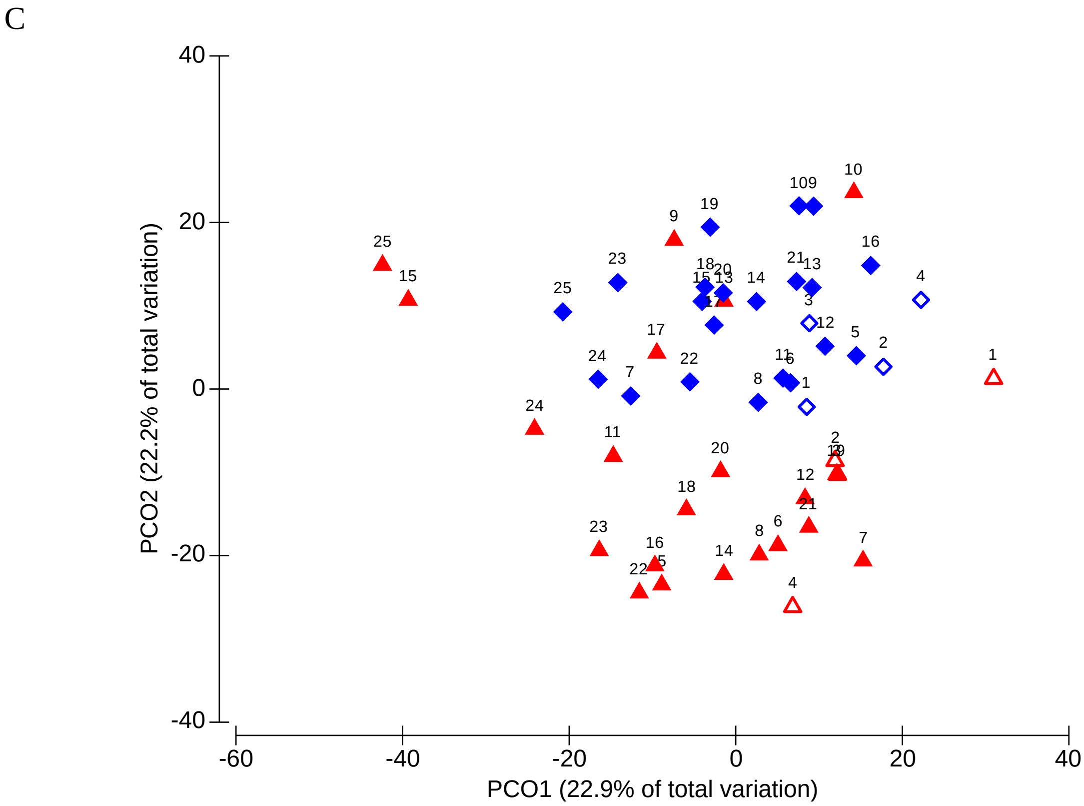
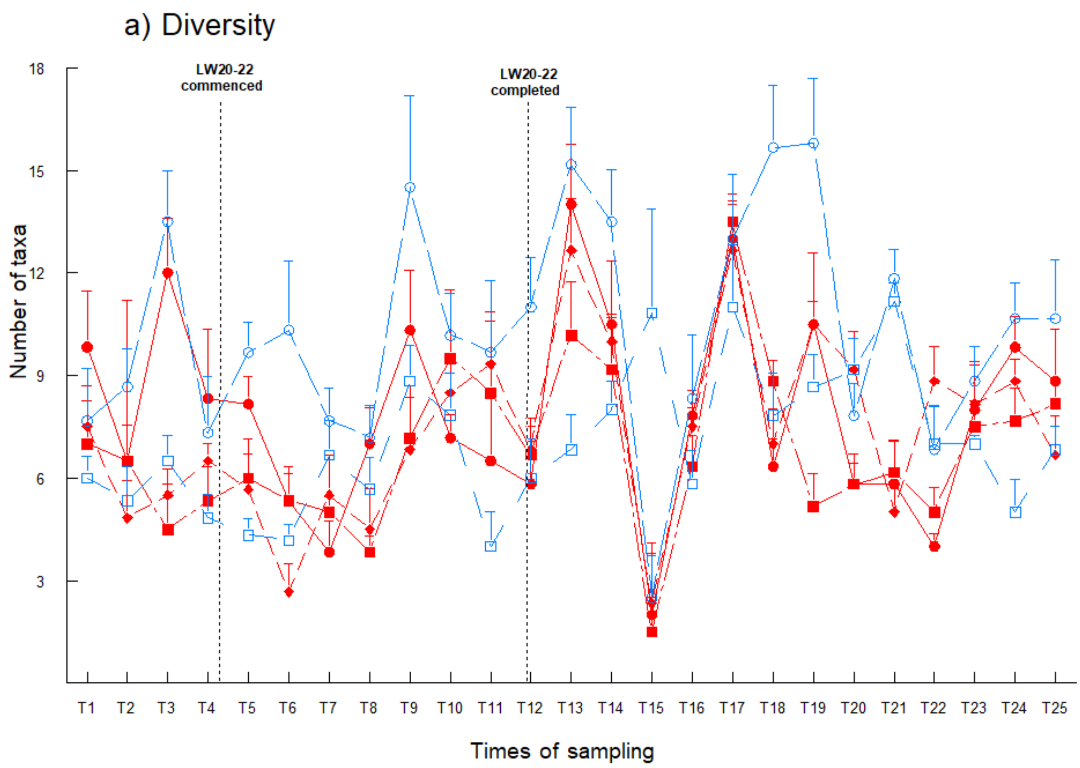


Figure 12 (Cont'd). PCoA of centroids for macroinvertebrate data for c) Location WT5 (Red symbols) and the Control group (blue symbols) for each time of sampling (n = 6); Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.



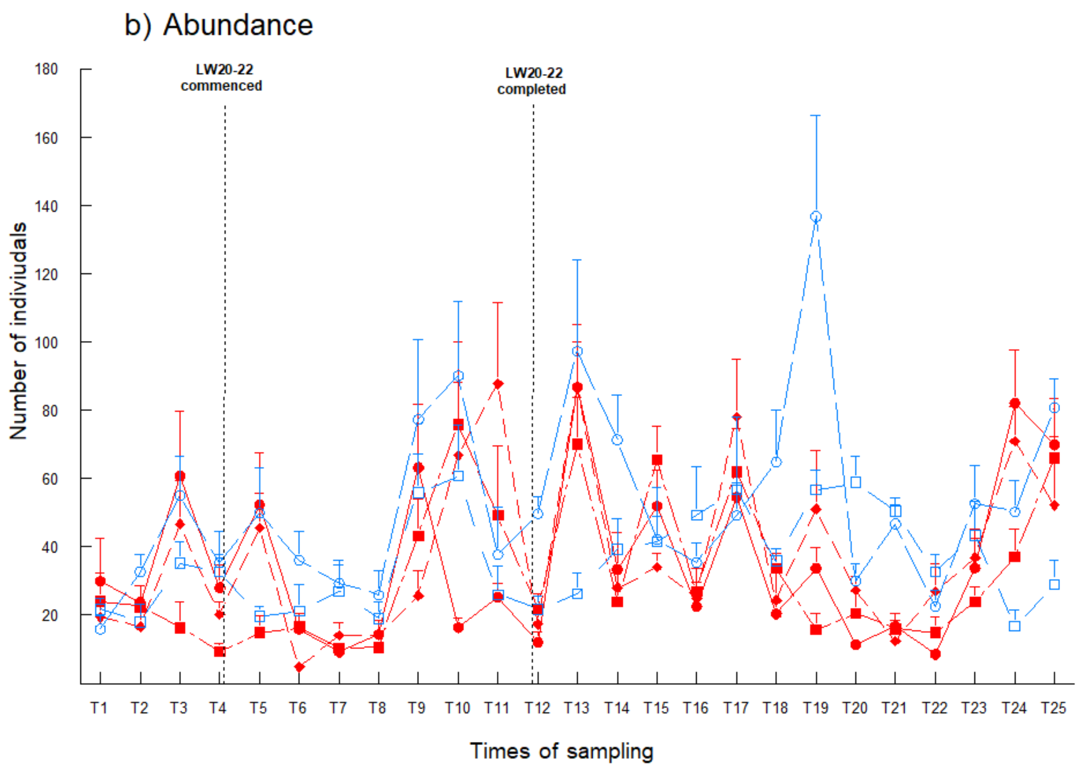
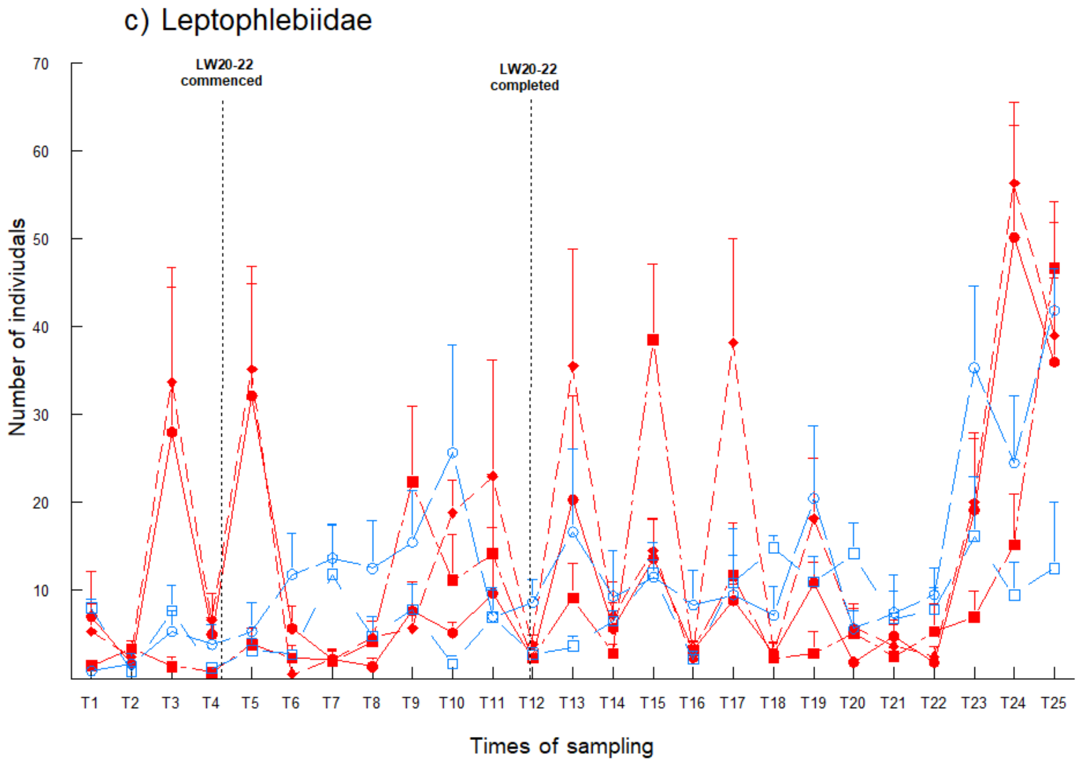


Figure 13. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the control locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc.



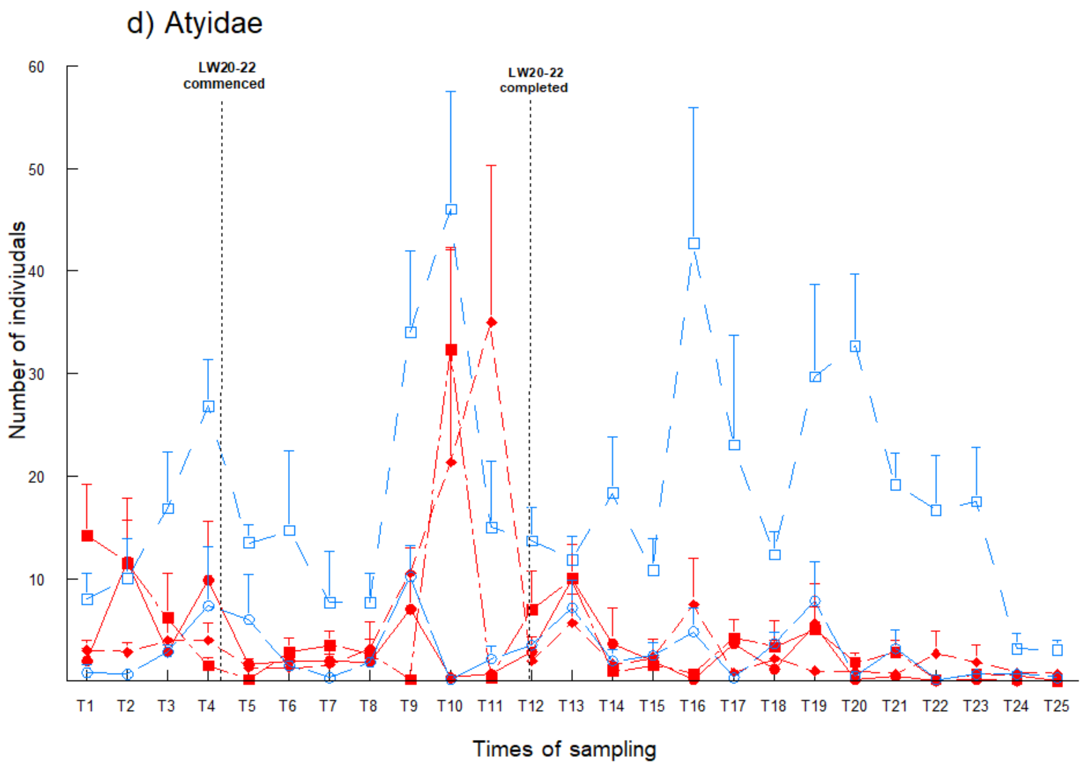


Figure 13 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the control locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc.

AUSRIVAS Analyses

For AUSRIVAS surveys done in the Waratah Rivulet and the control locations in spring, OE50 scores ranged between 0.26 (Site WR in spring 2008) and 0.97 (Site OH in spring 2014) (Figure 14a). OE50 Taxa Scores for samples collected in autumn ranged from 0.26 (Site WR in autumn 2014) to 0.91 (Site WT5 in autumn 2015) (Figure 13b). All of the OE50 Taxa scores were below 1.00 (Figure 14a&b), indicating that the number of taxa observed was less than would be expected relative to the AUSRIVAS reference watercourses.

Five mean Band A scores (equivalent to AUSRIVAS reference condition) were obtained in spring (Site WT3 in 2016, WT4 in 2012, WR and OC in spring 2014 and Site OC in spring 2017) (Figure 14a). Four locations have achieved a Band A score in autumn (WT3 in autumn 2013, WT4 in 2012, WT5 in 2015 and OC in autumn 2017) (Figure 14b).

On this sampling occasion (spring 2020), the OE50 Taxa scores ranged from 0.40 at Location WT3 and 0.59 at Location WR (Figure 14b). Location’s WT3 and WR increased by one AUSRIVAS band level between the autumn 2020 and spring 2020 surveys, from Band C to Band B (Figure 14b).

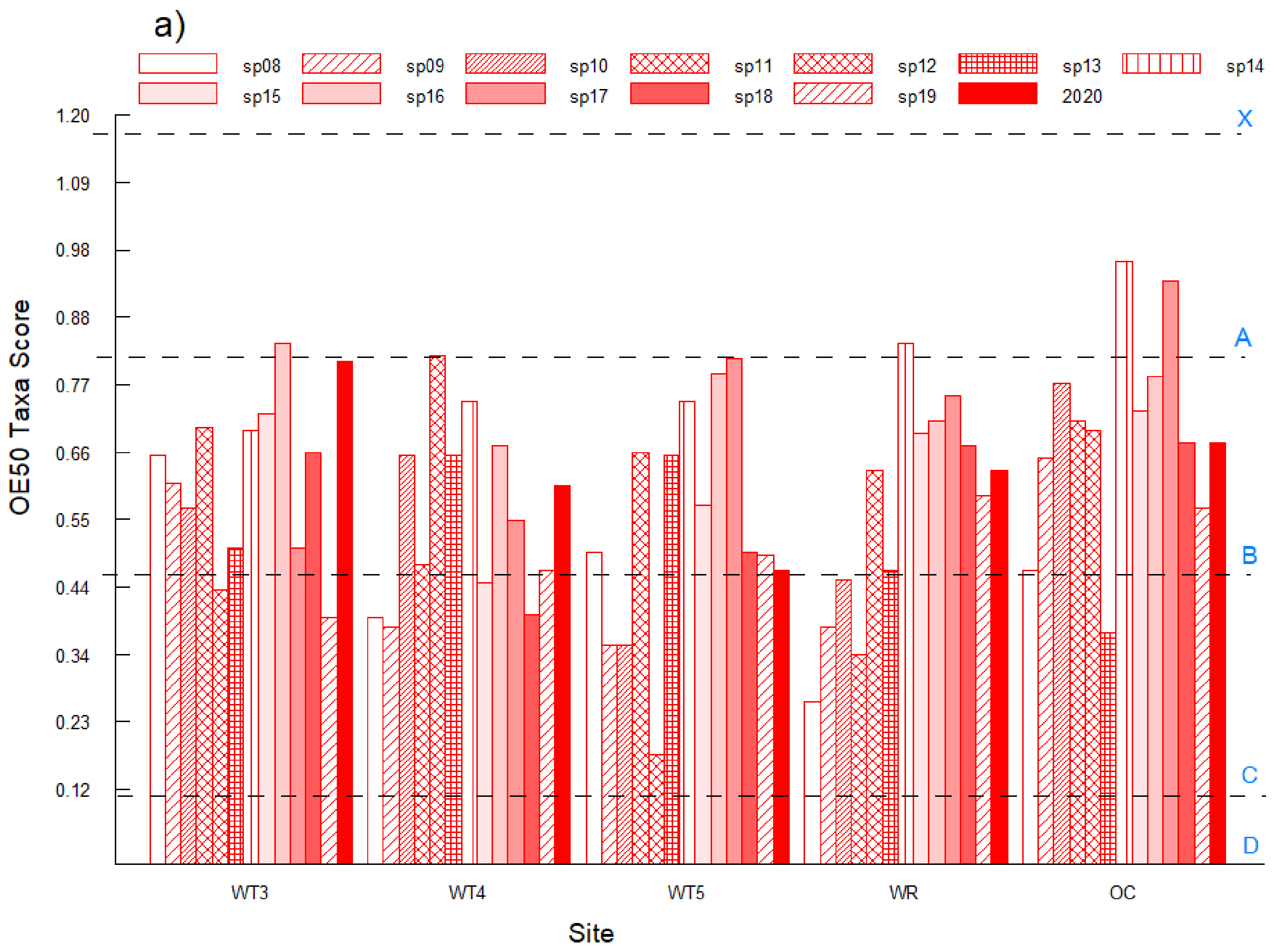


Figure 14a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2008 and 2020 (n = 2).

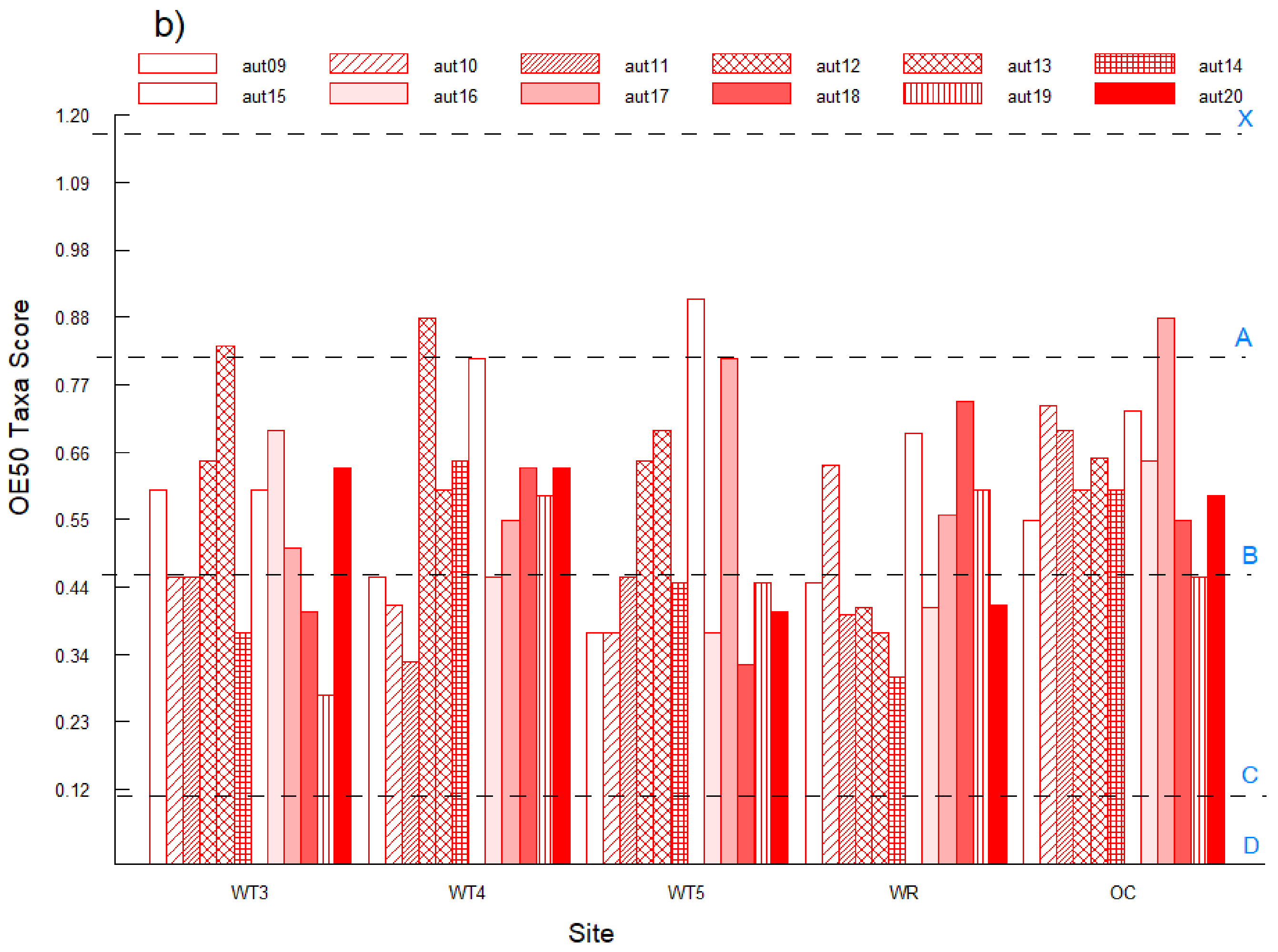


Figure 14b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2008 and 2020 (*n* = 2).

4.1.2.2 Aquatic Macrophytes

Waratah Rivulet v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

To date, there have been no detectable impacts to macrophytes at the Waratah Rivulet locations (i.e. Locations WT3, WT4 and WT5) in relation to the control locations that could be associated with mining of the Longwalls 20-22 mining area.

Current Survey (Spring 2020)

Consistent with previous surveys, multivariate analyses did not yield any significant interaction of the factors Period and Impact (Table 10, Figures 15a-b).

The PCoA indicates that the structure of assemblages of aquatic macrophytes sampled at the Waratah Rivulet locations have been more variable among times than the Control group (Figures 15a-c). SIMPER has consistently indicated differences between the rivulet and Control group have largely been due to the presence of *Myriophyllum pedunculatum*, which has only occurred at the Woronora River location, and the floating-attached species, *Triglochin procerum,* which has commonly been more widespread at the Woronora River location than at the other locations sampled.

There were no conspicuous differences in mean total diversity or percentage cover of macrophytes at locations WT3, WT4 or WT5 in relation to the control locations between the 'Before' and 'After' mining periods (Table 11, Figures 16a&b). Fewer species of macrophytes have commonly been observed at Location WT4 than at the other locations sampled, most likely due to dominance of the riparian strip at the upstream site (i.e. Site WT4-1) by *Lomandra fluviatilis* (Figure 16a). There was a notable increase in cover at WT3 between the autumn 2020 (T24) and spring 2020 surveys (Figure 16b).

Table 10. PERMANOVA on macrophyte assemblage data to compare locations on Waratah Rivulet (WT3, WT4 and WT5) with control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown.

WT3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	35973	1.78	0.06	7.02
Impact = Im	1	41086	1.33	0.22	5.62
Time (Pe) = Ti(Pe)	23	**7.02**	**7.02**	**7.02**	**7.02**
Location (Im) = Lo(Im)	1	**5.62**	**5.62**	**5.62**	**5.62**
Pe x Im	1	13638	0.90	0.63	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**12396**	**4.16**	**0.00**	**8.39**
Pe x Lo(Im)	1	**16134**	**1.94**	**0.00**	**8.31**
Ti(Pe) x Im	23	3668	0.87	0.84	0.00
Pe x Si(Lo(Im))	3	**5636**	**1.89**	**0.00**	**6.30**
Ti(Pe) x Lo(Im)	23	**4224**	**1.42**	**0.00**	**7.91**
Ti(Pe) x Si(Lo(Im))	69	2977	0.85	1.00	0.00
Residual	600	3522			42.05
WT4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	28923	1.64	0.08	6.47
Impact = Im	1	30762	1.06	0.44	2.48
Time (Pe) = Ti(Pe)	23	4395	1.03	0.40	1.78
Location (Im) = Lo(Im)	1	**30215**	**1.52**	**0.04**	**6.98**
Pe x Im	1	10799	0.80	0.76	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**17580**	**6.01**	**0.00**	**11.24**
Pe x Lo(Im)	1	**15808**	**1.85**	**0.01**	**8.62**
Ti(Pe) x Im	23	2897	0.68	1.00	0.00
Pe x Si(Lo(Im))	3	**5854**	**2.00**	**0.00**	**7.11**
Ti(Pe) x Lo(Im)	23	**4249**	**1.45**	**0.00**	**8.76**
Ti(Pe) x Si(Lo(Im))	69	2923	0.78	1.00	0.00
Residual	600	3740			46.55
WT5					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	45958	1.89	0.05	8.37
Impact = Im	1	17687	0.66	0.90	0.00
Time (Pe) = Ti(Pe)	23	5250	1.26	0.07	4.63
Location (Im) = Lo(Im)	1	**29887**	**1.53**	**0.04**	**6.72**
Pe x Im	1	8019	0.50	0.98	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**17309**	**5.74**	**0.00**	**10.63**
Pe x Lo(Im)	1	**21247**	**2.18**	**0.00**	**10.19**
Ti(Pe) x Im	23	3352	0.80	0.91	0.00
Pe x Si(Lo(Im))	3	**6949**	**2.31**	**0.00**	**7.89**
Ti(Pe) x Lo(Im)	23	**4174**	**1.39**	**0.00**	**7.85**
Ti(Pe) x Si(Lo(Im))	69	3014	0.84	1.00	0.00
Residual	600	3604			43.74

Bold numbers indicate significant results at $P < 0.05$.

Table 11. PERMANOVA on diversity and cover of aquatic macrophytes.

WT3		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	16.53	3.43	2277	1.27
Impact = Im	1	**3.06**	**4.71**	**9274**	**4.59**
Time (Pe) = Ti(Pe)	23	3.40	1.65	1081	0.82
Location (Im) = Lo(Im)	1	0.00	0.38	694	0.40
Pe x Im	1	1.46	1.14	1106	0.72
Site (Lo(Im)) = Si(Lo(Im))	3	1.20	0.98	**1749**	**3.35**
Pe x Lo(Im)	1	2.02	1.29	1739	0.76
Ti(Pe) x Im	23	1.09	0.53	1615	1.23
Pe x Si(Lo(Im))	3	0.44	0.36	**1652**	**3.17**
Ti(Pe) x Lo(Im)	23	2.07	1.68	**1316**	**2.52**
Ti(Pe) x Si(Lo(Im))	69	1.23	0.93	522	1.01
Residual	600	1.33		518	
WT4		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	0.37	0.74	286	0.58
Impact = Im	1	**28.38**	**32.38**	3	1.05
Time (Pe) = Ti(Pe)	23	2.01	0.95	1206	0.90
Location (Im) = Lo(Im)	1	0.07	0.41	612	0.36
Pe x Im	1	4.55	2.99	5	0.59
Site (Lo(Im)) = Si(Lo(Im))	3	0.72	0.65	**2171**	**3.36**
Pe x Lo(Im)	1	1.36	1.00	1608	1.01
Ti(Pe) x Im	23	0.87	0.41	662	0.50
Pe x Si(Lo(Im))	3	0.35	0.32	901	1.40
Ti(Pe) x Lo(Im)	23	**2.12**	**1.93**	**1337**	**2.07**
Ti(Pe) x Si(Lo(Im))	69	1.10	0.89	646	1.16
Residual	600	1.23		558	
WT5		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	19.69	4.04	5589	0.95
Impact = Im	1	**8.53**	**5.51**	**6392**	**7.96**
Time (Pe) = Ti(Pe)	23	2.24	1.02	1057	0.85
Location (Im) = Lo(Im)	1	0.78	0.70	187	0.23
Pe x Im	1	0.26	0.56	2288	0.51
Site (Lo(Im)) = Si(Lo(Im))	3	0.86	0.64	**2306**	**3.60**
Pe x Lo(Im)	1	3.17	0.59	6167	1.90
Ti(Pe) x Im	23	1.17	0.53	773	0.62
Pe x Si(Lo(Im))	3	**5.49**	**4.05**	**2333**	**3.64**
Ti(Pe) x Lo(Im)	23	2.18	1.61	**1250**	**1.95**
Ti(Pe) x Si(Lo(Im))	69	1.35	1.04	641	1.16
Residual	600	1.30		552	

Bold numbers indicate significant results at $P < 0.05$.

A

B

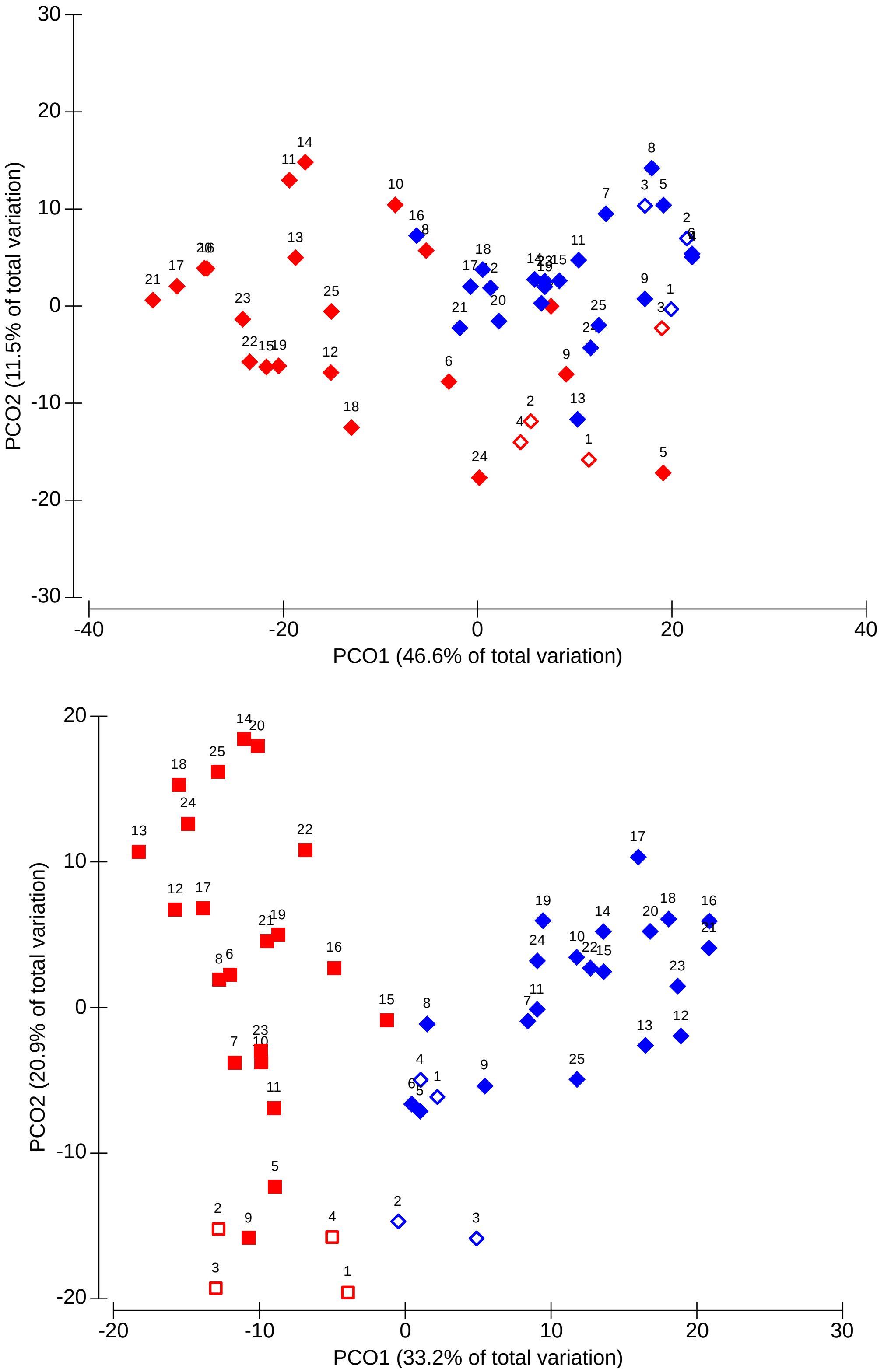


Figure 15. PCoA of centroids for macrophyte data for a) Location WT3 and b) Location WT4 and the Control group for each time of sampling. Red symbols: Potential 'impact' locations; Control group (Blue symbols. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.

C

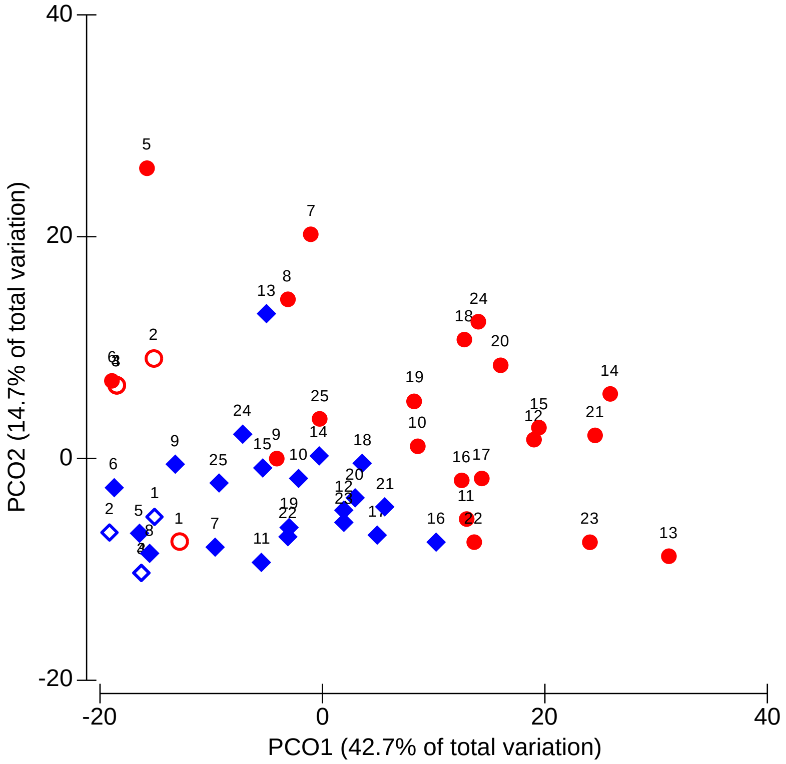
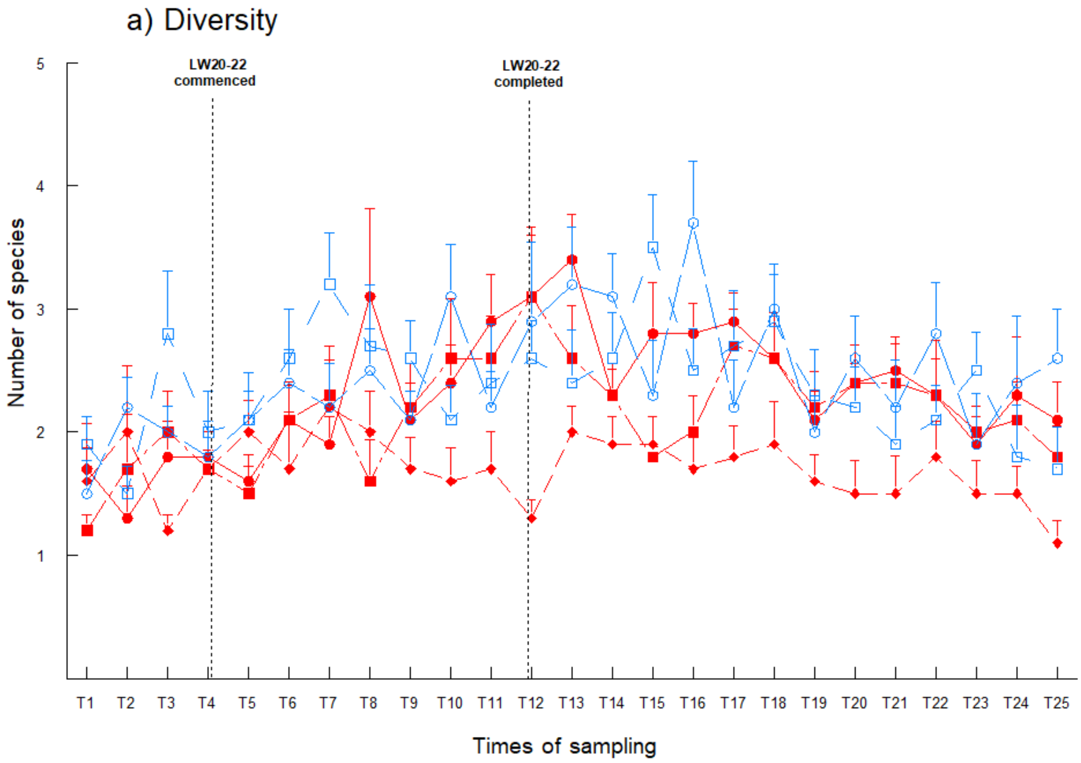


Figure 15 (Cont'd). PCoA of centroids for macrophyte data for c) Location WT5. Red triangles: Potential 'impact' location; Blue symbols: Control group. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.



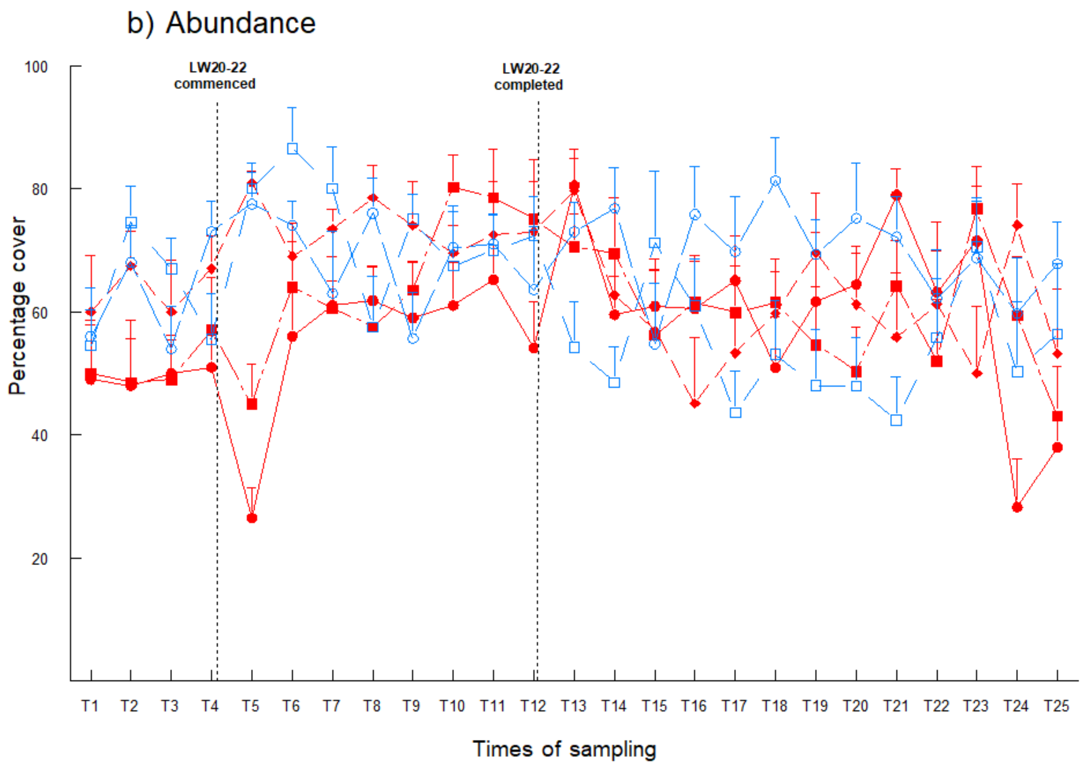


Figure 16. **Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Waratah Rivulet (WT3: circle; WT4: diamond; WT5: solid square) and the control locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 10). Time 1 = spring 2008, T2 = autumn 2009, etc.**

4.2 Post-mining of Longwalls 23-27

The following comparisons consider any ongoing effects of extraction of Longwalls 23-27 (May 2014 to March 2017) on aquatic indicators at selected sampling locations within Tributary C/Eastern Tributary (Locations C2 and C4) and any changes that may have occurred following the commencement of extraction of Longwalls 301-303 (June 2017 to July 2019), Longwall 304 (July 2019 to January 2020) and Longwall 305 (April 2020 to November 2020).

The analyses were undertaken on data collected nine replicate times (spring 2009 to spring 2013) within the pre-mining period and fourteen replicate times (autumn 2014 to spring 2020) within the post-mining period.

4.2.1 Aquatic Macroinvertebrates

<u>Quantitative Assessment</u>

Location C2 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

To date, multivariate analysis of the aquatic macroinvertebrate data has detected a significant interaction of the factors Period x Impact since spring 2019 (T21). This result indicates that a measurable impact to aquatic macroinvertebrates occurred at Location C2 after completion of mining within the Longwalls 23-27 area. Mining of Longwall 27 was completed in March 2017.

Univariate analyses detected a significant before-after mining change in mean numbers of Atyidae at Location C2 in relation to the control locations, between autumn 2016 (T14) and autumn 2018 (T18) and in autumn 2020 (T22). Mining of Longwall 26 commenced in May 2016.

Analyses of the macroinvertebrate data collected between spring 2009 and autumn 2020 found no significant change in mean numbers of species, individuals or Leptophlebiidae at Location C2 in relation to the Control group.

Current Survey (Spring 2020)

Similar to the findings from surveys done since spring 2019 survey, multivariate analysis of the aquatic macroinvertebrate data detected a significant interaction of the factors Period x Impact, which indicates an impact from mining (Table 12, Figure 17b). *Post hoc* tests indicated that statistical differences between the Period and Impact groups were due to a difference in the variance (PERMDISP: $P = 0.001$) and the mean between groups. In particular, the mean structure of the assemblage at Location C2 differed significantly between the Before- and After-period ($t = 1.88$, $P = 0.007$) but not at the Control group ($t = 1.20$, $P = 0.12$). SIMPER indicated that changes in the contribution that Atyidae (Before: 67.5 %; After: 10.8 %) and Leptophlebiidae (Before: 18.5 %; After: 56.9 %) made to the assemblage at C2 contributed greatly to this result.

Analyses have detected evidence of a mining related change in mean numbers of Atyidae at Location C2, between autumn 2016 (T14) and autumn 2018 (T18), in autumn 2020 (T22) and on this sampling occasion, spring 2020 (T23) (Table 13, Figure 18d). Atyidae have rarely been collected at Location C2 by surveys done since spring 2017 (T17) (Figure 18d).

Analyses of the macroinvertebrate data collected between spring 2009 and autumn 2020 found no significant change in mean numbers of species, individuals or Leptophlebiidae at Location C2 in relation to the Control group (Table 13, Figure 18a, b&c).

Location C4 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

PERMANOVA has detected a significant Period x Impact interaction in the structure of assemblages at Location C4 in spring 2019 and autumn 2020, which indicates an impact from mining at Location C4. There has also been evidence of mining related changes to mean diversity of macroinvertebrates at Location C4 (between autumn 2018 and autumn 2020), and abundance of Atyidae (autumn 2016, spring 2018, spring 2019 and autumn 2020).

Temporal patterns of change in mean total abundance of macroinvertebrates and Leptophlebiidae at Location C4 have remained similar to those displayed by the Control group.

Current Survey (Spring 2020)

Similar to the findings of the spring 2019 (T21) and autumn 2020 (T22) surveys, PERMANOVA detected a significant change in the structure of the assemblage of macroinvertebrates at Location C4 in relation to the control locations (Table 12, Figure 17c).

The PCoA and PERMDISP indicated that the structure of the assemblage of macroinvertebrates has become significantly more variable at Location C4 After-commencement of mining (t = 3.75, P = 0.002), but not at the Control group (PERMDISP: t = 1.13, P = 0.315) (Figure 17c). The mean structure of the assemblage at C4 has also changed significantly between periods (Pair-wise test: t = 1.77, P = 0.003) but not the Control group (t = 1.21, P = 0.116).

Similar to the findings for Location C2, SIMPER indicates that changes in the contribution that Atyidae have made to the assemblage at Location C4 (Before: 39.6 %; After: 5.8 %) contributed greatly to this result. Atyidae have consistently been ranked highest for the Control treatment (Before: 42.4 %; After: 39.2 %). Leptophlebiidae contributed most (44.2 %) to the structure of the assemblage at Location C4 within the 'after' period, followed by the family, Chironomidae (29.1 %), and the Dytiscidae (8.7 %) (SIMPER).

Considerable spikes in mean abundance of macroinvertebrates and numbers of Leptophlebiidae were observed at C4 between spring 2015 (T13) and autumn 2018 (T18), coinciding with declines in pool water level at the most upstream site (i.e. Site C41) (Figures 18b&c). Nevertheless, observed patterns of change did not differ significantly in relation to the control locations (Table 13, Figure 18b&c). In autumn 2020, mean numbers of macroinvertebrates and Leptophlebiidae collected at C4 and the control locations were comparable to surveys done prior to mining of the Longwall 20-22 and Longwall 23-27 areas (Figures 18b&c).

Similar to the findings of surveys done since spring 2018 (T19), a significant 'before' to 'after' change in mean diversity was detected at Location C4 on this occasion (spring 2020) (Table 13, Figure 18a). *Post-hoc* tests indicated that this result was due to a combination of differences in dispersion (P = 0.001) and the group means (Location C4: t = 0.68, P = 0.85 ns; Control: t = 2.32, P = 0.02).

Unlike surveys done in autumn 2016 (T15), spring 2018 (T19), spring 2019 (T21) and autumn 2020 (T22), there was no statistically significant difference in mean numbers of Atyidae collected at Location C4 compared to the Control group on this sampling occasion (Table 13, Figure 18d). An 82% decline in abundance of Atyidae at the Woronora River location between autumn 2019 (T20) and spring 2019 (T21) is likely to have contributed to this result (Figure 18d).

Table 12. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate assemblage data (non-transformed) to compare locations C2 and C4 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek) Before- vs After-commencement of mining of Longwalls 23-27. Percentages of Components of Variation (% CV) are shown.

C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**40628**	**3.45**	**0.00**	**8.29**
Impact = Im	1	22696	0.19	1.00	0.00
Time (Pe) = Ti(Pe)	**21**	**8501**	**2.17**	**0.00**	**10.43**
Location (Im) = Lo(Im)	**1**	**133150**	**13.38**	**0.00**	**19.05**
Pe x Im	**1**	**17365**	**2.56**	**0.00**	**7.51**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**6206**	**2.60**	**0.00**	**4.70**
Pe x Lo(Im)	1	4406	0.77	0.85	0.00
Ti(Pe) x Im	21	3907	1.00	0.52	0.00
Pe x Si(Lo(Im))	**3**	**4909**	**2.05**	**0.00**	**5.40**
Ti(Pe) x Lo(Im)	**21**	**3925**	**1.64**	**0.00**	**9.86**
Ti(Pe) x Si(Lo(Im))	**63**	**2391**	**1.46**	**0.00**	**9.75**
Residual	276	1642			25.00
C4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**31727**	**3.23**	**0.00**	**7.42**
Impact = Im	1	47898	0.40	0.98	0.00
Time (Pe) = Ti(Pe)	**21**	**6798**	**1.80**	**0.00**	**8.64**
Location (Im) = Lo(Im)	**1**	**123880**	**11.78**	**0.00**	**18.62**
Pe x Im	**1**	**12390**	**1.94**	**0.02**	**5.94**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**6972**	**2.84**	**0.00**	**5.20**
Pe x Lo(Im)	1	4170	0.81	0.80	0.00
Ti(Pe) x Im	21	4132	1.10	0.23	4.25
Pe x Si(Lo(Im))	**3**	**4453**	**1.81**	**0.01**	**4.89**
Ti(Pe) x Lo(Im)	**21**	**3759**	**1.53**	**0.00**	**9.26**
Ti(Pe) x Si(Lo(Im))	**63**	**2458**	**1.48**	**0.00**	**10.22**
Residual	275	1662			25.56

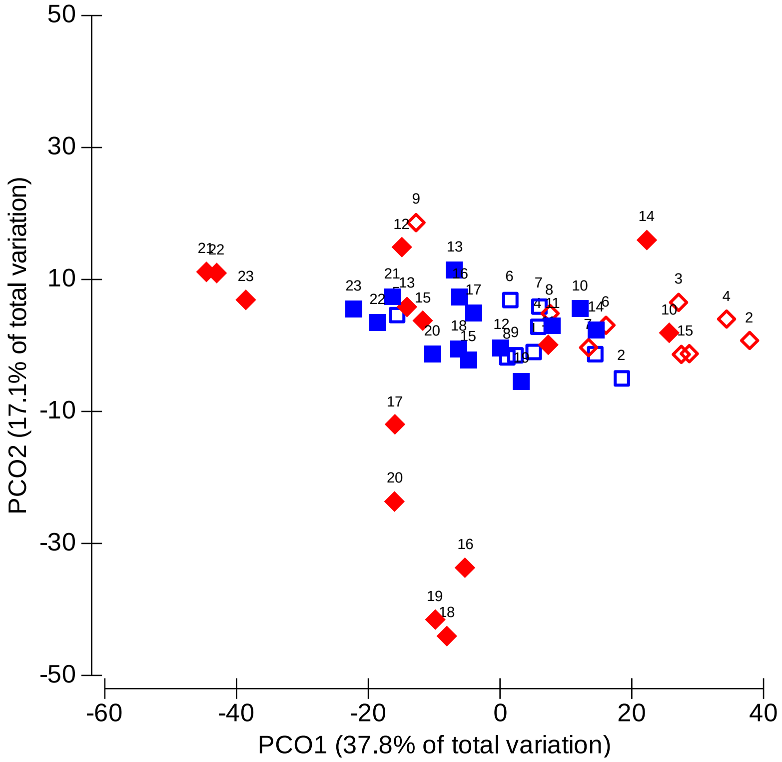
Bold numbers indicate significant results at $P < 0.05$.

Table 13. PERMANOVA analysis on Euclidean Distances of four univariate estimates (i.e. non-transformed) (total diversity and abundance and abundances of Leptophlebiidae and Atyidae) of the macroinvertebrate data collected to compare locations C2 and C4 within Tributary C with two control locations, Before- vs After-commencement of mining.

C2		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	137	3.47	3583	2.03	2920	3.65	**2008**	**4.68**
Impact = Im	1	661	0.67	35375	1.80	350	0.25	892	0.07
Time (Pe) = Ti(Pe)	21	45	2.02	2527	1.21	**874**	**3.22**	489	1.28
Location (Im) = Lo(Im)	1	**1003**	**14.74**	**19688**	**6.29**	**2353**	**5.89**	**16998**	**19.38**
Pe x Im	1	21	2.44	550	1.89	236	2.88	**950**	**9.65**
Site (Lo(Im)) = Si(Lo(Im))	3	**46**	**5.84**	1200	1.21	157	0.94	**503**	**2.90**
Pe x Lo(Im)	1	1	0.19	270	0.37	1	0.24	21	0.38
Ti(Pe) x Im	21	16	0.74	1126	0.54	175	0.65	117	0.31
Pe x Si(Lo(Im))	3	**26**	**3.32**	1323	1.34	425	2.55	128	0.74
Ti(Pe) x Lo(Im)	21	**22**	**2.79**	**2087**	**2.11**	271	1.62	**383**	**2.21**
Ti(Pe) x Si(Lo(Im))	63	8	0.94	**988**	**1.82**	**167**	**1.74**	**174**	**1.57**
Residual	276	8		544		96		110	
C4		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	48	2.29	11382	2.50	2651	3.14	597	2.44
Impact = Im	1	972	0.96	34571	1.74	372	0.22	4156	0.27
Time (Pe) = Ti(Pe)	21	30	1.37	5115	2.43	**929**	**3.39**	377	0.98
Location (Im) = Lo(Im)	1	**1019**	**16.58**	**19606**	**6.36**	**2292**	**5.42**	**16857**	**16.79**
Pe x Im	1	**87**	**6.24**	551	1.59	170	0.68	103	3.49
Site (Lo(Im)) = Si(Lo(Im))	3	**40**	**4.37**	1165	1.00	202	0.71	**631**	**3.87**
Pe x Lo(Im)	1	1	0.31	268	0.45	0	0.39	24	0.35
Ti(Pe) x Im	21	17	0.77	1401	0.67	656	2.39	115	0.30
Pe x Si(Lo(Im))	3	10	1.04	1099	0.95	456	1.61	145	0.89
Ti(Pe) x Lo(Im)	21	**22**	**2.38**	**2100**	**1.81**	273	0.97	**383**	**2.35**
Ti(Pe) x Si(Lo(Im))	63	9	1.16	**1162**	**1.50**	283	1.13	163	1.41
Residual	275	8		773		250		115	

Bold numbers indicate significant results at $P < 0.05$.

A. C2 v Controls



B. C4 v Controls

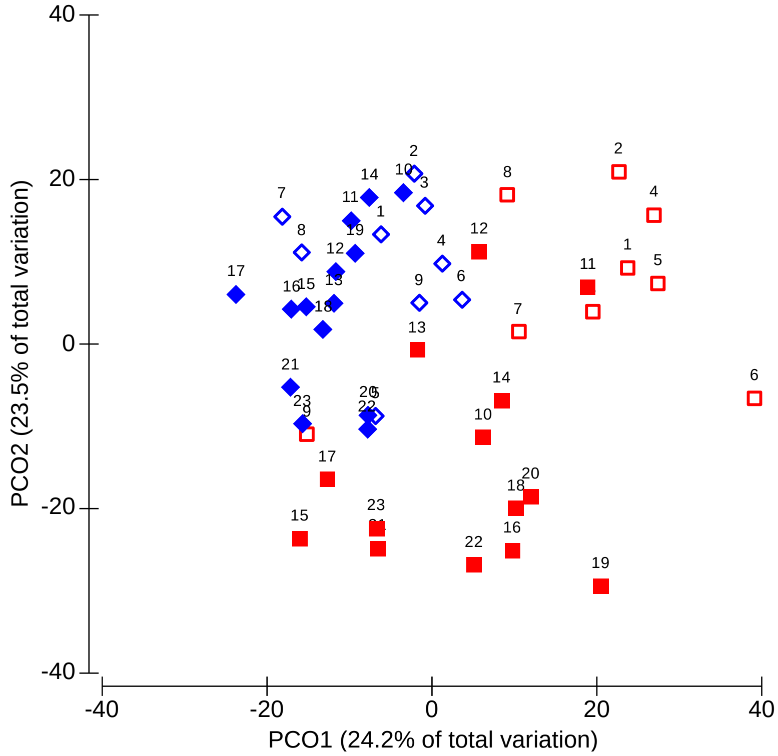
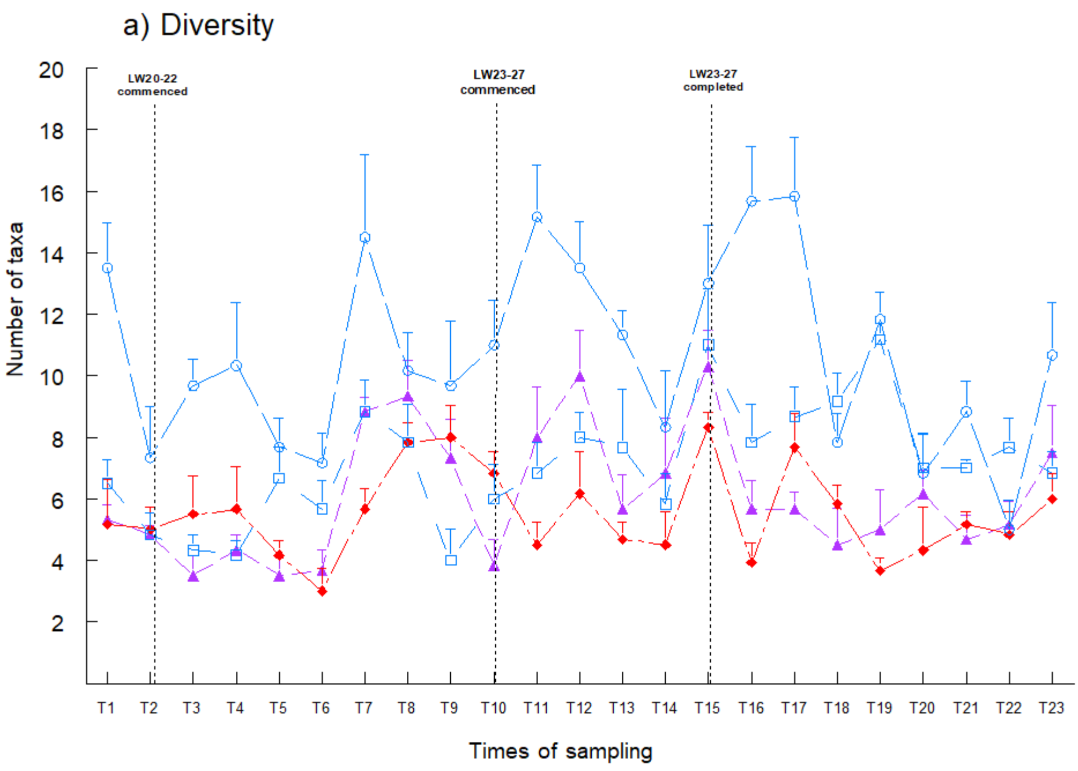


Figure 17. PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at location a) C2 (red diamonds) and b) C4 (red squares) and the Control group (blue diamonds) between spring 2009 (T1) and spring 2020 (T23). Empty symbols: 'Before'; Filled symbols: 'After' commencement of mining Longwalls 23-27.



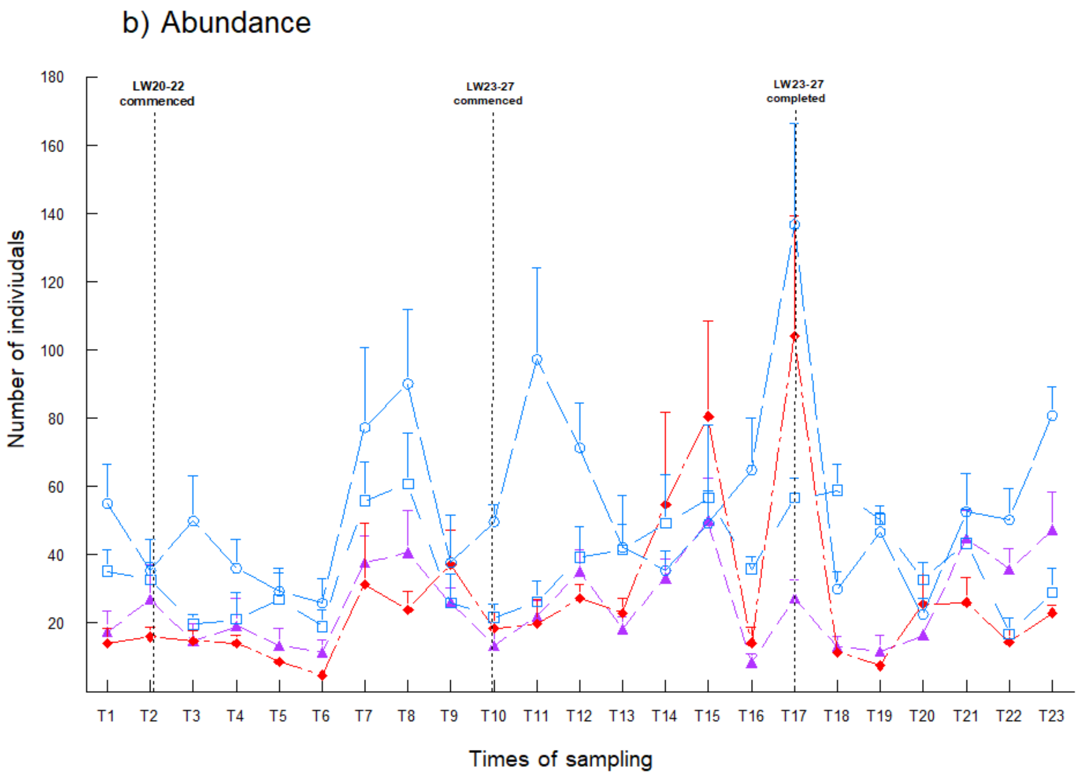
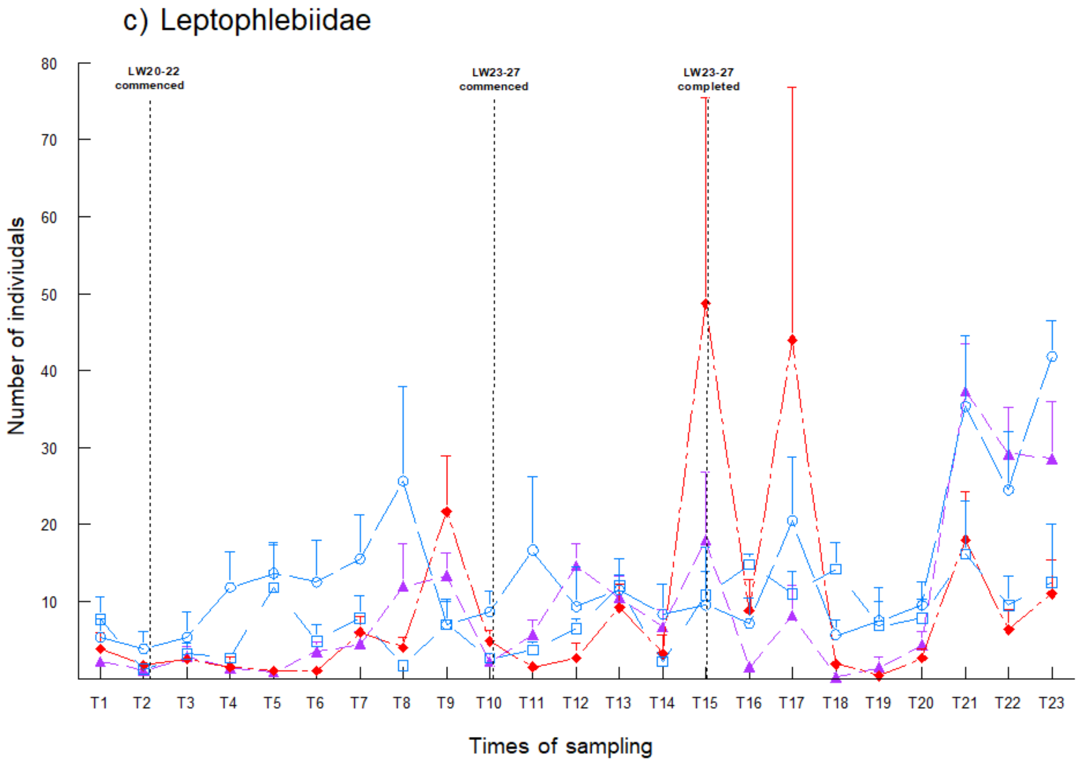


Figure 17. Mean number (+SE) of a) Taxa and b) Individuals of aquatic macroinvertebrates at locations on Tributary C/Eastern Tributary (C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles), between spring 2009 (T1) and spring 2020 (T23) (*n* = 6).



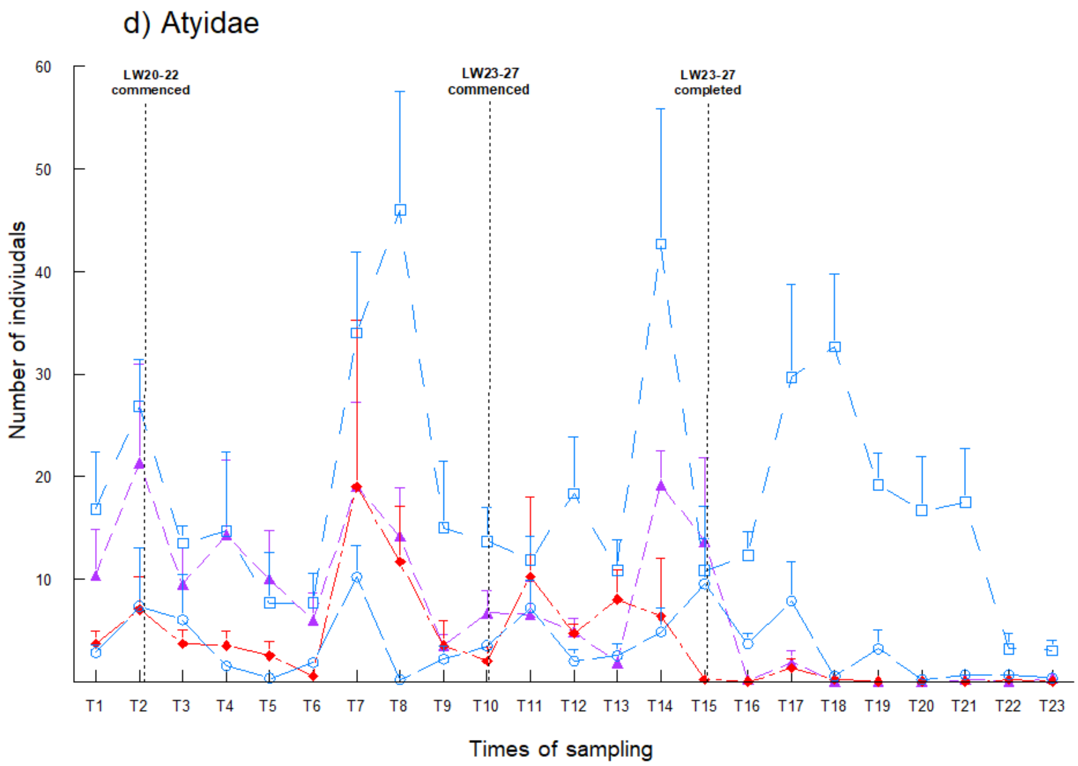


Figure 18 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2009 (T1) and spring 2020 (T23) (*n* = 6).

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.28 (C2 in spring 2011) and 0.97 (OC in spring 2014) (Figure 19a). OE50 Taxa Scores for samples collected in autumn ranged from 0.09 (Location C4 in autumn 2016, autumn 2018 and autumn 2019) to 0.88 (Location OC in autumn 2017) (Figure 19b). All of the OE50 Taxa scores were below 1.00 (Figure 19a&b), indicating that the number of taxa observed was less on all occasions than would be expected relative to the AUSRIVAS reference watercourses.

Only one location achieved a Band A score (equivalent to AUSRIVAS reference condition) in autumn (i.e. OC in autumn 2017) and two locations in spring (WR in spring 2014 and OC in spring 2014 and spring 2017) (Figure 19a&b). Locations that achieved a Band A score were sampled on control streams (i.e. Woronora River and O'Hares Creek).

Since the previous survey (autumn 2020), the condition of aquatic macroinvertebrate fauna at the Woronora River location increased by one AUSRIVAS Band level, from Band C (severely impaired) to Band B (significantly impaired) (Figure 19b).

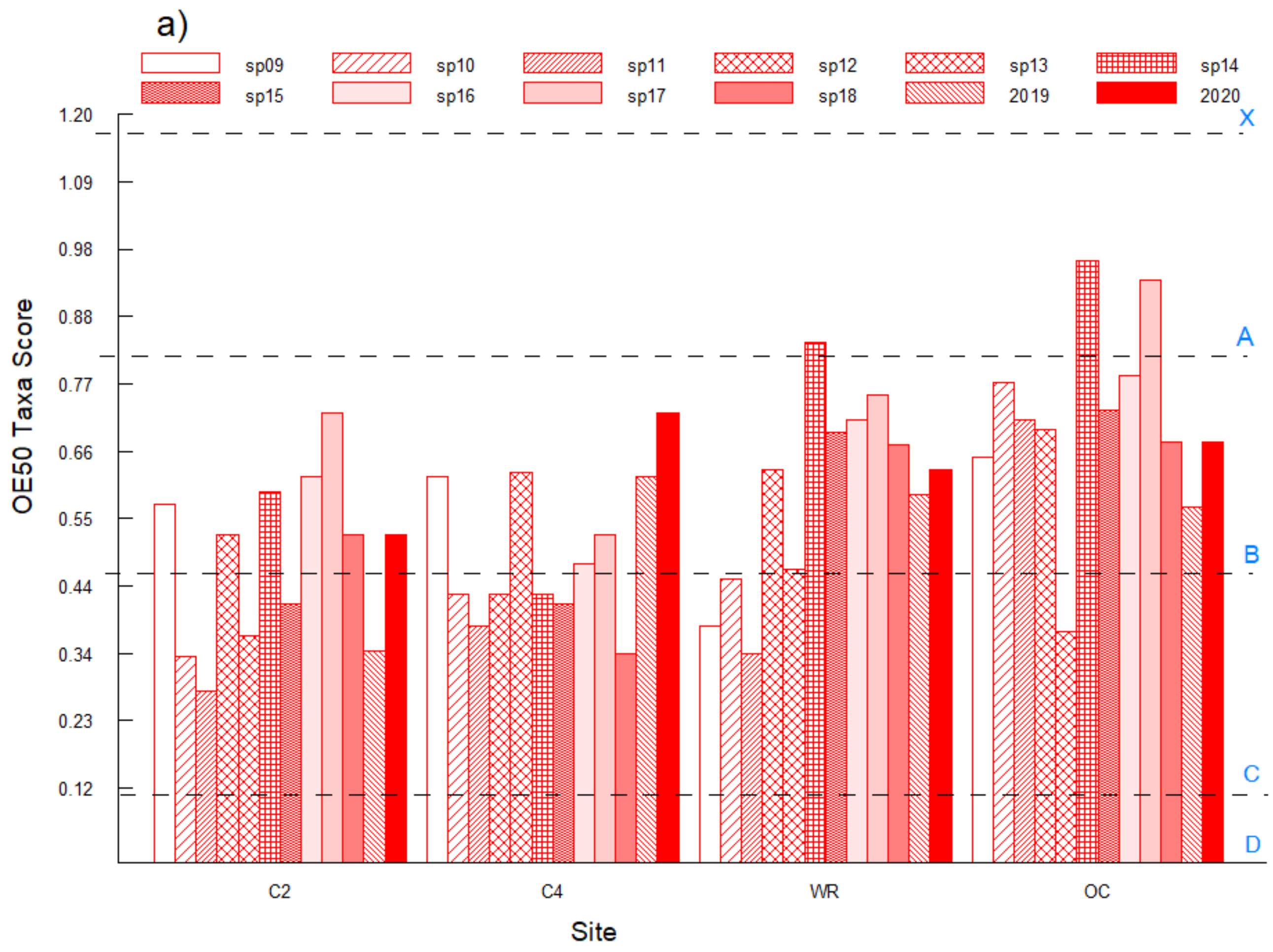


Figure 18a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2009 and 2020 (*n* = 2).

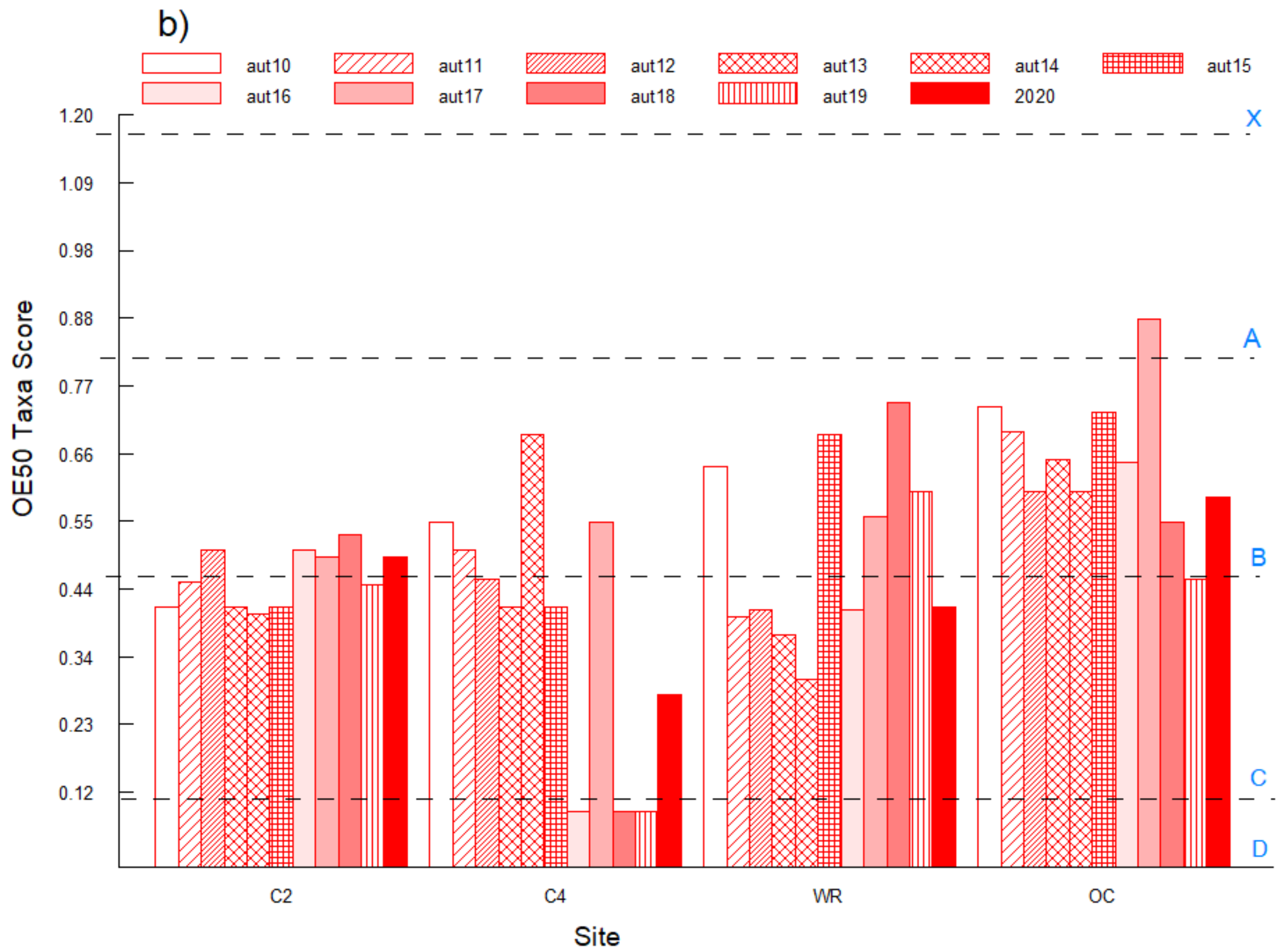


Figure 19b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2010 and 2020 (*n* = 2).

4.2.2 Aquatic Macrophytes

Location C2 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

There has been no evidence of a significant impact to aquatic macrophytes at Location C2 during or after mining of the Longwalls 23-27 mining area (Figures 20a&21a&b).

Current Survey (Spring 2020)

Analyses of temporal changes in the structure of assemblages of aquatic macrophytes (Table 14, Figure 20a) and univariate estimates of total cover and species diversity (Table 15, Figures 21a&b) at Location C2 found no significant changes in relation to control locations that would indicate an impact from mining.

SIMPER analyses indicate that *Baumea juncea* has increased its contribution to assemblages at Location C2 (Before: 13 %; After: 42 %). Contributions made by the fern, *Gleichenia dicarpa*, decreased at Location C2 (Before: 33 %; After: 12 %) but increased at the controls (Before: 14 %; After: 56 %) (SIMPER).

Location C4 v Controls

Prior Surveys (Spring 2009 – Autumn 2020)

Multivariate analyses have detected evidence of a mining-related change in assemblages of macrophytes at Location C4 since autumn 2018 (T18). Occasional mining-related reductions in pool water level along the study reach (Section 3.1.1), between spring 2015 (T13) and spring 2019 (T21), are likely to have contributed to this result.

Analyses have consistently found no significant change in mean total cover or species diversity at Location C4 that would indicate a significant impact from mining.

Current Survey (Spring 2020)

Multivariate analyses detected evidence of a mining related change to the assemblage of aquatic macrophytes at Location C4 in spring 2020 (T23) (Table 14). *Post-hoc* tests indicated that this result was due to temporal differences in dispersion between periods at Location C4 in relation to the control group (P = 0.001) as well as changes in the composition of assemblages (C4: t = 1.83, P = 0.004; Control: t = 1.60, P = 0.002) (Figure 20c).

This result is reflected in the patterns seen in the PCoA, which shows that the centroids representing assemblages at Location C4 and the Control group in the 'before' period tend to group separately from centroids representing the assemblage within the 'after' period (Figure 20c).

SIMPER indicated that *Lepidosperma filiforme* (37.3 %), *Gleichenia dicarpa* (23.3%), *Lomandra fluviatilis* (20.3 %) contributed most to the structure of the macrophyte assemblage at Location C4 within the 'before' period whilst *Lepidosperma filiforme* (28.7 %), *Viminaria juncea* (27.0 %) and *Gleichenia dicarpa* (19.0 %) contributed most within the 'after' period.

Analyses have consistently found no significant change in mean cover of diversity of aquatic macrophytes at Location C4 that would indicate a mining-related impact (Table 15). Overall, species diversity of macrophytes at Location C4 appears to have differed little over time (Figure 21a). Graphically, there appears to have been a considerable decrease in cover at Location C4 after the spring 2017 (T17) survey (Figure 21b).

Table 14. PERMANOVA on Bray Curtis dissimilarities of macrophyte assemblage data (non-transformed) to compare locations sampled on Tributary C/Eastern Tributary (C2 and C4) with the control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown.

C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	18225	1.44	0.118	3.22
Impact = Im	1	116470	1.70	0.143	8.81
Time (Pe) = Ti(Pe)	**21**	**4464**	**1.32**	**0.016**	**4.44**
Location (Im) = Lo(Im)	1	67029	1.27	0.178	5.61
Pe x Im	1	19977	1.65	0.060	5.39
Site (Lo(Im)) = Si(Lo(Im))	**3**	**51523**	**18.06**	**0.000**	**14.30**
Pe x Lo(Im)	1	10574	1.22	0.185	3.20
Ti(Pe) x Im	21	3569	1.06	0.322	2.64
Pe x Si(Lo(Im))	**3**	**7611**	**2.67**	**0.000**	**6.32**
Ti(Pe) x Lo(Im)	**21**	**3375**	**1.18**	**0.043**	**5.02**
Ti(Pe) x Si(Lo(Im))	63	2853	0.82	1.000	0.00
Residual	552	3497			41.06
C4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**30716**	**2.64**	**0.01**	**6.27**
Impact = Im	1	70718	1.13	0.38	3.94
Time (Pe) = Ti(Pe)	21	3931	1.14	0.17	3.08
Location (Im) = Lo(Im)	1	62528	1.48	0.08	7.22
Pe x Im	**1**	**18932**	**1.83**	**0.03**	**6.12**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**40644**	**14.96**	**0.00**	**13.68**
Pe x Lo(Im)	1	8994	1.22	0.17	3.25
Ti(Pe) x Im	21	3273	0.95	0.66	0.00
Pe x Si(Lo(Im))	**3**	**6108**	**2.25**	**0.00**	**5.79**
Ti(Pe) x Lo(Im)	**21**	**3462**	**1.27**	**0.01**	**6.35**
Ti(Pe) x Si(Lo(Im))	63	2717	0.75	1.00	0.00
Residual	552	3630			44.30

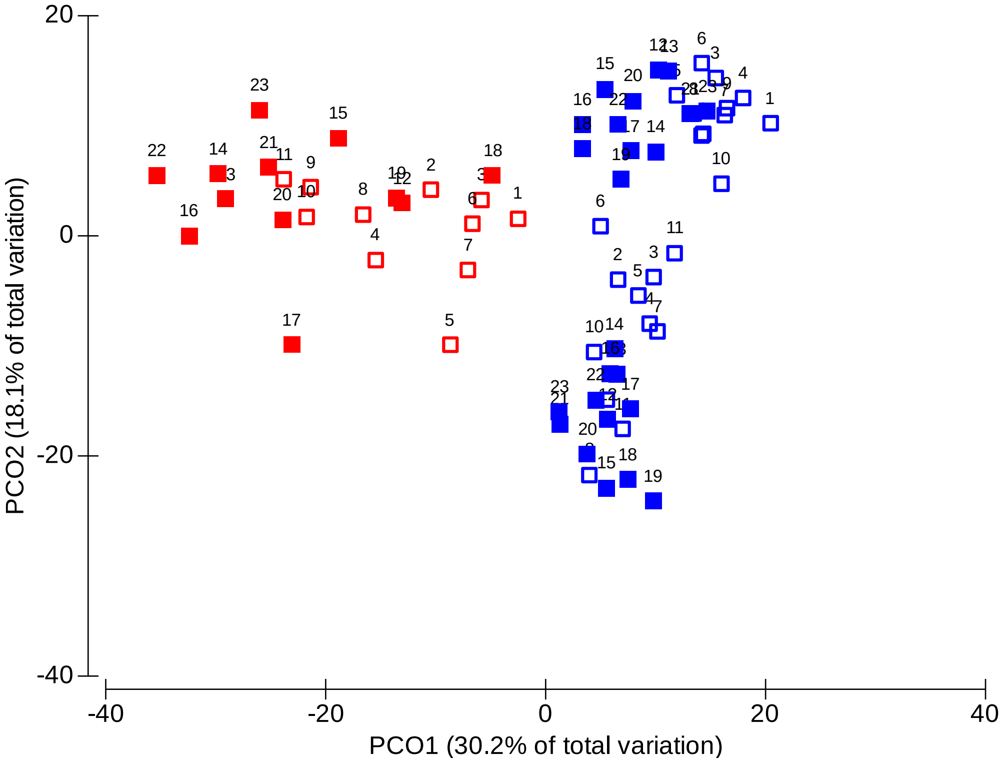
Bold numbers indicate significant results at $P < 0.05$.

Table 15. PERMANOVA analysis on Euclidean Distances of non-transformed total diversity and abundance of macrophytes collected from three locations within Tributary C and at two control locations.

C2		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	0.81	0.30	8155	0.95
Impact = Im	1	5.72	3.01	153	0.19
Time (Pe) = Ti(Pe)	21	**8.06**	**3.77**	1064	0.98
Location (Im) = Lo(Im)	1	0.25	0.48	5201	0.64
Pe x Im	1	0.42	0.60	0	0.11
Site (Lo(Im)) = Si(Lo(Im))	3	0.84	0.71	**8191**	**11.07**
Pe x Lo(Im)	1	1.89	0.56	8642	1.73
Ti(Pe) x Im	21	2.37	1.11	1306	1.21
Pe x Si(Lo(Im))	3	3.34	2.81	**4356**	**5.89**
Ti(Pe) x Lo(Im)	21	**2.14**	**1.80**	1082	1.46
Ti(Pe) x Si(Lo(Im))	63	1.19	0.85	**740**	**1.50**
Residual	552	1.40		493	
Total	689				
C4		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	4.24	0.73	9050	1.06
Impact = Im	1	0.47	2.69	237	0.35
Time (Pe) = Ti(Pe)	21	3.51	1.74	1391	1.28
Location (Im) = Lo(Im)	1	0.00	0.23	2915	0.54
Pe x Im	1	0.23	0.37	31	0.12
Site (Lo(Im)) = Si(Lo(Im))	3	**4.06**	**2.97**	**5516**	**8.48**
Pe x Lo(Im)	1	5.12	1.16	**8170**	**5.82**
Ti(Pe) x Im	21	0.92	0.46	894	0.82
Pe x Si(Lo(Im))	3	3.58	2.62	427	0.66
Ti(Pe) x Lo(Im)	21	2.02	1.48	1088	1.67
Ti(Pe) x Si(Lo(Im))	63	1.37	1.08	650	1.25
Residual	552	1.27		522	
Total	689				

Bold numbers indicate significant results at $P < 0.05$.

A. C2 v Controls



B. C4 v Controls

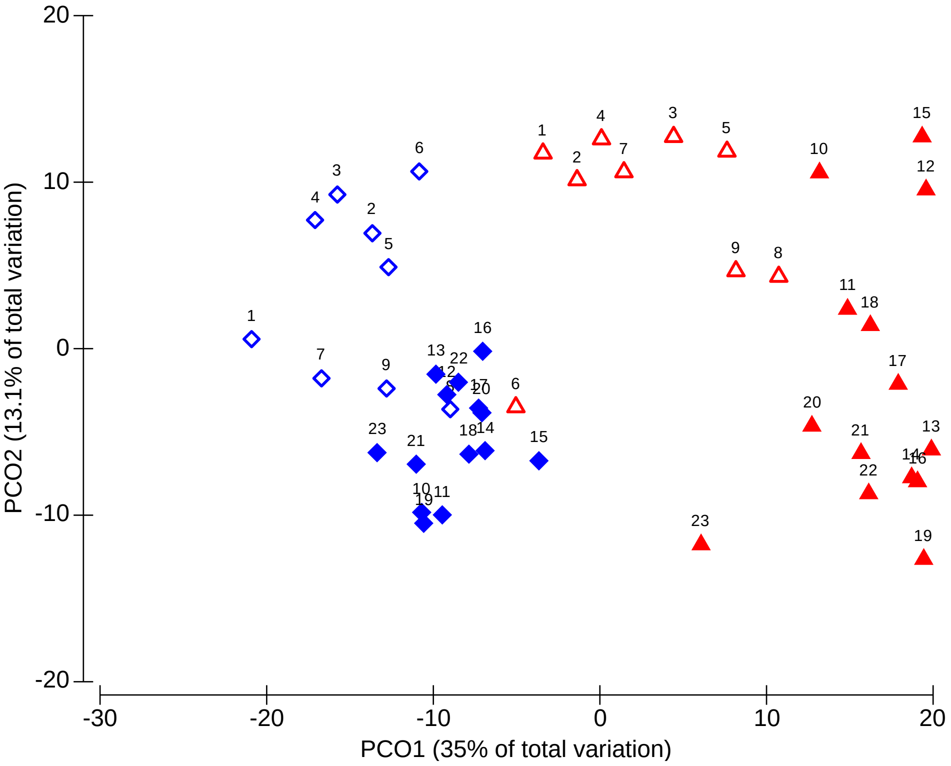


Figure 19. PCoA of centroids for assemblages of macrophytes sampled at locations a) C2 (red squares) and b) C4 (red diamonds) and the Control group (blue diamonds) between spring 2009 (T1) and spring 2020 (T23). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

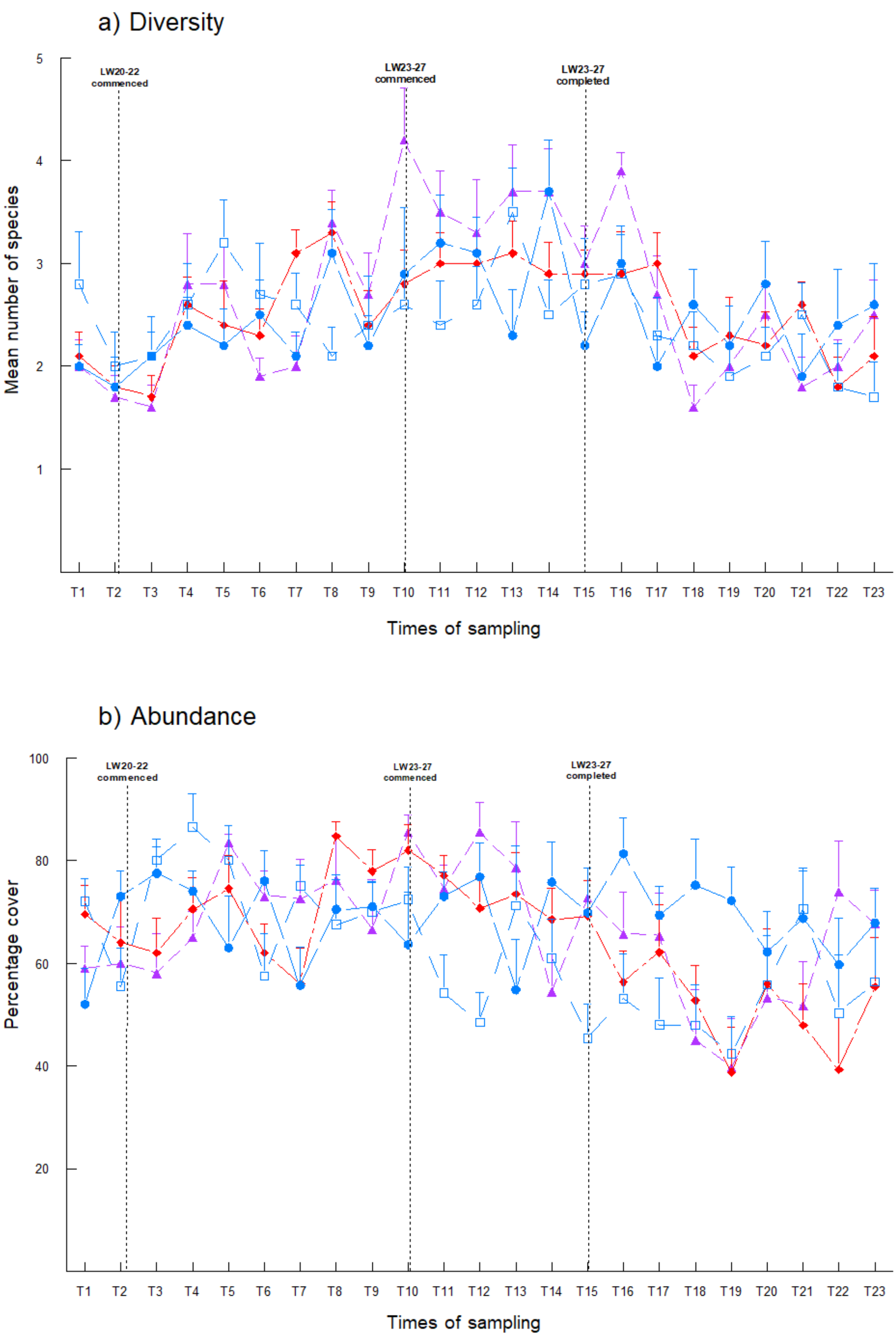


Figure 20. **Mean (+SE) a) Number of species/quadrat (*n* = 10) and b) Percentage cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2009 (T1) and spring 2020 (T23).**

5.0 SUMMARY & CONCLUSIONS

The primary objective of monitoring was to determine whether the extent and nature of any impacts, primarily associated with subsidence-induced fracturing of bedrock and diversion and loss of aquatic habitat, are consistent with the predictions made in the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan* (Longwalls 20-22 BMP) (Metropolitan Coal, 2015a) and the *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan* (Longwalls 23-27 BMP) (Metropolitan Coal, 2015b) [9].

The Spring 2020 post-mining aquatic ecology monitoring programme for the Longwalls 20-27 sub-domain, as outlined in this report, was conducted in accordance with the currently approved Longwalls 305-307 Biodiversity Management Plan, which includes post-mining monitoring and management of aquatic flora and fauna for Longwalls 20-22, 23-27, 301-303 and 304 (subject to the respective previously approved Extraction Plans). Limited *in-situ* water quality information was also collected, to assist with interpretation of trends in the above indicators.

Mining of the Longwalls 20-22 area commenced in May 2010 and was completed in April 2014. Subsequently, mining of the Longwalls 23-27 area commenced in May 2014 and was completed in March 2017. Longwalls 301-303 area commenced in April 2017 and was completed in June 2019. Longwall 304 commenced in July 2019 and was completed in January 2020. Longwall 305 commenced in April 2020 and was completed in November 2020. Longwall 306 commenced in June 2021.

The results of this survey (spring 2020) were compared with those obtained from previous surveys carried out at potential impact locations within Tributary C/Eastern Tributary and the Waratah Rivulet at control locations situated within the Woronora River and O'Hares Creek. Monitoring for the Longwalls 20-22 and Longwalls 23-27 areas commenced in spring 2008 and spring 2009, respectively. A summary of the main findings to date are presented in Sections 5.1 and 5.2, respectively.

9

A reconciliation against the Trigger Action Response Plan in the Metropolitan Coal Longwalls 305-307 BMP (Appendix 1) has been completed in Section 5.3.

5.1 Longwalls 20-22 Mining Area

The following comparisons consider the ongoing effects of extraction of Longwalls 20-22 on aquatic indicators at selected sampling locations within Tributary C/Eastern Tributary (Locations C1, C2 and C3) and the Waratah Rivulet (Locations WT3, WT4 and WT5), and any changes that may have occurred following the commencement of extraction of Longwalls 23-27 (May 2014), Longwalls 301-303 (June 2017), Longwall 304 (July 2019) and Longwall 305 (April 2020).

Two to four replicate times (spring 2008 or spring 2009[10] to autumn 2010) have been sampled at the Tributary C/Eastern Tributary, Waratah Rivulet and Control (Woronora River and O'Hares Creek) locations within the 'Before' mining of Longwalls 20-22 period and 21 replicate times (spring 2010 to spring 2020) have been sampled within the 'After' period.

5.1.1 Tributary C/Eastern Tributary Locations (C1, C2 & C3)

At Location C1, visual evidence of mining related impacts, including iron staining, fracturing of the streambed (predominantly bedrock) and falls in pool water levels below pre-mining levels, were first noted at Location C1 in autumn 2014. Since then, pool water level in the upstream reaches appeared to be below pre-mining levels in autumn 2016, spring 2017, autumn 2018, autumn 2019 and spring 2019, but not subsequently.

The AUSRIVAS condition of the aquatic macroinvertebrate fauna at Location C1 has ranged between 0.10 (Band D – extremely impaired) in spring 2018 to 0.78 (Band B – significantly impaired) in spring 2014.

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10 The sampling of Location C3 (ET3) on the Eastern Tributary commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

Quantitative analyses have consistently found no changes to aquatic macroinvertebrate or macrophyte indicators at Location C1 that would indicate a significant mining-related impact during or after mining of the Longwalls 20-22 area. Mining-related drops in pool water levels at C1 since spring 2017 have most likely contributed to observed desiccation of plants within the riparian strip, but patterns of change have not differed significantly in relation to the control locations.

At Location C2, iron staining and falls in pool water levels below pre-mining levels were first noted by the spring 2016 and spring 2017 surveys, respectively. The AUSRIVAS condition of the fauna at Location C2 has ranged from an OE50 score of 0.15 (Band C, in spring 2008) to 0.72 (Band B, in spring 2017).

Analyses of the aquatic macroinvertebrate data have consistently found no significant changes in the structure of assemblages, diversity, abundance or mean numbers of Leptophlebiidae at Location C2 that would indicate an impact during or after mining of the Longwalls 20-22 area. There has been evidence of significant mining-related changes to mean numbers of Atyidae at Location C2 post-extraction of the Longwalls 20-22 area, in spring 2015, but not subsequently. There have been no measurable changes to macrophyte indicators at Location C2 that would indicate an impact from mining.

At Location C3 in autumn 2013, dieback of riparian vegetation was noted at one of the sites sampled (i.e. Site C3-2), thought to be associated with tilting of the stream bank by mine subsidence. Occasional falls in pool water levels below pre-mining levels have been recorded at Site C3-2 between spring 2015 and autumn 2019, but not subsequently. The AUSRIVAS condition of the aquatic macroinvertebrate fauna at Location C3 has ranged between 0.29 (Band C) in spring 2010 to 1.02 (Band A) in spring 2014. To date, quantitative analyses have not detected significant changes in aquatic macroinvertebrate or aquatic macrophyte indicators sampled at Location C3 that would indicate an impact from mining.

5.1.2 Waratah Rivulet Locations (WT3, WT4 & WT5)

An iron precipitate/micro-organism complex has commonly been observed at Locations WT3, WT4 and WT5 since sampling commenced in spring 2008. Cracking of bedrock in the stream channel due to subsidence was first noted at Location WT3 in spring 2013. Mining-related cracking does not appear to have occurred at Locations WT4 or WT5.

The AUSRIVAS scores obtained at the rivulet locations from spring 2008 to spring 2020 ranged between:

- Location WT3: 0.27 (Band C) in autumn 2019 to 0.84 (Band A) in spring 2016;
- Location WT4: 0.33 (Band C) in autumn 2011 to 0.88 (Band A) in autumn 2012;
- Location WT5: 0.18 (Band C) in spring 2012 to 0.91 (Band A) in autumn 2015.

To date, analyses comparing temporal changes in components of assemblages of macroinvertebrates and macrophytes at Locations WT3, WT4 and WT5 on the Waratah Rivulet with control locations have not detected significant changes that would indicate an impact during or after mining of the Longwalls 20-22 underground area.

Univariate analyses however, have detected a significant change in mean diversity of macroinvertebrates at Location WT3, in spring 2016, autumn 2018 and subsequent surveys (including spring 2020). Differences appear to be related to small differences in the direction of change in mean diversity at WT3 (Before: 9.5; After: 8.0) compared to the control group (Before: 8.0; After: 9.0) between periods. There were no conspicuous differences in mean diversity at Locations WT4 or WT5 in relation to the control locations.

There have been no significant mining-related changes to the mean abundance of macroinvertebrates or mean numbers of the two main components of assemblages, Leptophlebiidae (a mayfly family) and Atyidae (freshwater shrimps), at locations WT3, WT4 or WT5.

There have been no detectable changes to aquatic macrophytes at the Waratah Rivulet locations in relation to the control locations that could be associated with mining.

5.2 Longwalls 23-27 Mining Area

The following comparisons consider the ongoing effects of mining of the Longwalls 23-27 mining area on aquatic indicators at sampling locations within Tributary C/Eastern Tributary (Locations C2 and C4) and any changes that may have occurred following the commencement of extraction of Longwalls 301-303 (June 2017 to July 2019), Longwall 304 (July 2019 to January 2020) and Longwall 305 (April 2020 to November 2020).

Location C4 overlies the Longwalls 23-27 underground mining area while Location C2 is downstream of the Longwalls 23-27 underground mining area. Nine replicate times (spring 2009 to spring 2013) were sampled within the ‘Before’ commencement of mining of Longwall 23 ‘Period’ and fourteen replicate times (autumn 2014 to spring 2020) within the ‘After’ commencement of mining of Longwall 23 ‘Period’.

Identified mining impacts include visual evidence of iron staining, cracking of the stream substratum and occasional falls in pool water levels at Location C4 since autumn 2014, coinciding with completion of Longwall 22B and commencement of Longwall 23. At Location C2, iron staining and falls in pool water levels below pre-mining levels were first noted by the spring 2016 and spring 2017 surveys, respectively. Pool water levels at Location C2 have appeared similar to pre-mining levels subsequent to the spring 2017 survey.

Statistical analyses have detected evidence of mining related changes to the structure of assemblages of aquatic macroinvertebrates at Location C2 since spring 2019. Significantly fewer Atyidae were collected at C2 by surveys done between autumn 2016 and autumn 2018, in autumn 2020 and spring 2020. There has been no evidence of a significant impact to aquatic macrophytes at Location C2.

At Location C4, the AUSRIVAS condition of macroinvertebrate fauna ranged from an OE50 score of 0.09 (Band D) in autumn 2016, 2018 and 2019 to 0.63 (Band B) in autumn 2014. Mining-related changes to the structure of assemblages of aquatic macroinvertebrates have been detected at C4 since the spring 2019 survey.

There has also been evidence of mining related changes to mean diversity of macroinvertebrates (between autumn 2018 and spring 2020). Significantly fewer Atyidae were collected at Location C4 in autumn 2016, spring 2018, spring 2019 and autumn 2020 but not spring 2020.

The structure of the aquatic macrophyte assemblage at Location C4 has differed significantly from assemblages within the before-period since autumn 2018. Observed changes at Location C4 are most likely attributable to subsidence caused by mining and consequential loss of aquatic habitat and stream connectivity.

5.3 Metropolitan Coal Longwalls 305-307 Biodiversity Management Plan Trigger Action Response Plan

A reconciliation against the Trigger Action Response Plan in the Metropolitan Coal Longwalls 305-307 BMP (Appendix 1) has been completed in Table 16.

Table 16. Assessment of Environmental Performance – Underground Mining Area and Surrounds against the Longwalls 305-307 Trigger Action Response Plan.

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded		Comments	Subsidence Impact Performance Indicator Exceeded?	Action/Response
Monitoring of Aquatic Biota, Stream Monitoring								
Negligible impact on Threatened Species, Populations, or Ecological Communities[4]	*The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*	Two sampling sites (approximately 100 m in length) at the following locations: • Location WT3 on Waratah Rivulet and Locations ET1, ET3 and ET4 on the Eastern Tributary overlying Longwalls (LW) 20-27. • Location WT4 on Waratah Rivulet adjacent to LW 20-27. • Location WT5 on the Waratah Rivulet and Location ET2 on the Eastern Tributary, downstream of LW 20-27. • Control Locations: WR1 on Woronora River; and OC on O'Hares Creek.	• Aquatic macroinvertebrates • Aquatic macrophytes	Level 1	Data analysis indicates no significant changes in relation to control places pre-mining[1] compared to post-extraction[2] occur in the aquatic macroinvertebrate and/or macrophyte indicators at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Locations WT4, WT5, ET1 and ET3.	No	Continue monitoring. Six monthly reporting.
				Level 2	Data analysis indicates significant (not long-term[3]), changes in relation to control places pre-mining[1] compared to post-extraction[2] occur in the aquatic macroinvertebrate and/or macrophyte indicators at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Location ET2: significant change in assemblage of macroinvertebrates detected in spring 2019 and subsequent surveys. Location ET4: significant change to assemblage of macroinvertebrates detected since spring 2019; decreased numbers of Atyidae in autumn 2016, spring 2018, spring 2019 and autumn 2020, but not spring 2020.	No	Consider recent stream features mapping results and pool water level monitoring data. Consider status/progress of stream remediation activities. Six monthly reporting.
				Level 3	Data analysis indicates significant long-term[3] changes in relation to control places pre-mining[1] compared to post-extraction[2] occur in the aquatic macroinvertebrate and/or macrophyte indicators at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Location WT3: altered diversity of macroinvertebrate taxa in spring 2016, autumn 2018 and subsequent surveys, including spring 2020. Location ET2: altered numbers of Atyidae in spring 2015, between autumn 2016 and autumn 2018, in autumn 2020 and in spring 2020; Location ET4: altered patterns of diversity of macroinvertebrate taxa since autumn 2018; altered macrophyte assemblage since autumn 2018.	Yes	Assessment against the performance measure triggered in spring 2020. Consider the need for management measures (i.e. stream remediation).

1 Pre-mining data is as follows: sites WT3 and ET1 (spring 2008 to autumn 2010); site ET3 (spring 2009 to autumn 2010); site ET4 (spring 2009 to spring 2013); site ET2 (will be assessed for two periods: spring 2008 to autumn 2010 [i.e. pre-mining of Longwalls 20-22] and spring 2009 to spring 2013 [i.e. pre-mining of Longwalls 23-27]).

2 Post-extraction data is represented as follows: sites WT3 and ET1 (from spring 2010 on); site ET3 (from spring 2010 on); site ET4 (from autumn 2014 on) site ET2 (will be assessed for two periods: spring 2010 on [Longwalls 20-22] and autumn 2014 on [Longwalls 23-27]).

3 Long-term changes to the macroinvertebrate and macrophyte assemblages are considered to be significant changes that are persistent (over time) and resulting from mining.

4 Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

6.0 REFERENCES

Anderson, M. J. (2001). A new method for non-parametric multivariate analysis of variance. *Austral Ecology*. 26: 32-46.

Anderson, M. J., Gorley, R. N., Clarke, K.R. (2008). PERMANOVA + for PRIMER: Guide to Software and Statistical Methods. PRIMER-E. Plymouth, UK.

ANZECC/ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Waters.* Australian and New Zealand Environment and Conservation Council Agriculture and Resource Management Council of Australia and New Zealand.

Clarke K. R. & Warwick R. M. (1994). Change in marine communities: An approach to statistical analysis and interpretation. Natural Environment Council, United Kingdom. pp. 144.

Gilbert and Associates (2006). *Metropolitan Colliery – Longwall Panels 14 to 17 Review of Hydrological Issues for Subsidence Management Plan*. Report prepared for Helensburgh Coal Pty Ltd.

Metropolitan Coal (2015a) *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan.*

Metropolitan Coal (2015b) *Metropolitan Coal Longwalls 22-27 Biodiversity Management Plan.*

Metropolitan Coal (2018) *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan.*

NSW Fisheries (2002). *Threatened Species in NSW, Adams Emerald Dragonfly, Archaeophya adamsi*. Fishnote, Department of NSW Fisheries.

NSW Fisheries (2007) *Threatened Species in NSW, Sydney Hawk Dragonfly Austrocordulia leonardi*. NSW Department of Primary Industries, Primefact 184.

Ransom, G., Coysh, J., Nichols, S. (2004). AUSRIVAS User Manual. Website: http://ausrivas.canberra.edu.au/Bioassessment/Macroinvertebrates/Manuals and Datasheets/User Manual. Date Retrieved: 27 November 2006.

Turak, E., Waddell, N., Johnstone, G. (2004). *New South Wales Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual*. Department of Environment and Conservation, Sydney, Australia.

Underwood, A. J. (1992). Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161: 145-178.

Underwood, A. J. (1993). The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Australian Journal of Ecology* 18: 99-116.

Underwood, A. J. (1994). On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological Applications* 4: 3-15.

Table 19
Trigger Action Response Plan – Monitoring of Aquatic Biota, Stream Monitoring

Performance Measure	Performance Indicator	Monitoring Sites	Parameters	Frequency/ Sample Size	Analysis Methodology	Error Types	Baseline	Significance Levels/ Triggers		Action/Response
Negligible impact on Threatened Species, Populations, or Ecological Communities	*The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence.*	Two sampling sites (approximately 100 m in length) at the following locations: • Location WT3 on Waratah Rivulet and Locations ET1, ET3 and ET4 on the Eastern Tributary overlying Longwalls (LW) 20-27. • Location WT4 on Waratah Rivulet adjacent to LW20-27. • Location WT5 on the Waratah Rivulet and Location ET2 on the Eastern Tributary, downstream of LW20-27. • Control Locations: WR1 on Woronora River; and OC on O'Hares Creek.	• Aquatic macroinvertebrates. • Aquatic macrophytes.	Biannually, in autumn and spring.	• Analysis of macroinvertebrate and macrophyte multivariate[1] and univariate[2] data using PERMANOVA to test the null hypothesis of no significant change in relation to control places, bi-annually following completion of survey.	Statistical significance levels. Significant = $P < 0.05$	• LW20-22 stream sites, as detailed in the LW20-22 aquatic ecology monitoring reports for the spring 2008 to autumn 2010 surveys[3]. • LW23-27 stream sites, as detailed in the LW23-27 aquatic ecology monitoring reports for the spring 2009 to spring 2013 surveys[4].	Level 1	Data analysis indicates no significant changes in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Continue monitoring. Six monthly reporting.
								Level 2	Data analysis indicates significant (not long-term[8]), changes in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Consider recent stream features mapping results and pool water level monitoring data. Consider status/progress of stream remediation activities. Six monthly reporting.
								Level 3	Data analysis indicates significant long-term changes[8] in relation to control places pre-mining[6] compared to post-extraction[7] occur in the aquatic macroinvertebrate and/or macrophyte assemblages at Locations WT3, WT4 or WT5 on the Waratah Rivulet or Locations ET1, ET2, ET3 or ET4 on the Eastern Tributary during the mining of LW305-307.	Initiate assessment against the performance measure[9]. Consider the need for management measures, in accordance with Sections 8 and 9.

1 Multivariate Analysis: comparisons of two (or more) samples based on the degree to which these samples share particular species, at comparable levels of abundance.

2 Univariate Analysis: comparison of individual variables (e.g. total number of taxa, total abundance, abundances of individual taxa).

3 Cummins, S. P., Roberts, D. E. (2009a; 2009b; 2010a; 2010b). Aquatic Ecology Monitoring: Metropolitan Coal Longwalls 20-22 Spring 2008 to Autumn 2010 Survey Reports. Prepared for Metropolitan Coal Pty Ltd. BIO-ANALYSIS: Marine, Estuarine & Freshwater Ecology.

4 Cummins, S. P., Roberts, D. E. (2010a; 2010b; 2011; 2012a; 2012b; 2012c; 2013a; 2013b, 2014). Aquatic Ecology Monitoring: Metropolitan Coal Longwalls 23-27 Spring 2009 to Spring 2013 Survey Reports. Prepared for Metropolitan Coal Pty Ltd. BIO-ANALYSIS: Marine, Estuarine & Freshwater Ecology.

6 Pre-mining data is as follows: sites WT3 and ET1 (spring 2008 to autumn 2010); site ET3 (spring 2009 to autumn 2010); site ET4 (spring 2009 to spring 2013); site ET2 (will be assessed for two periods: spring 2008 to autumn 2010 [i.e. pre-mining of Longwalls 20-22] and spring 2009 to spring 2013 [i.e. pre-mining of Longwalls 23-27]).

7 Post-extraction data is represented as follows: sites WT3 and ET1 (from spring 2010 on); site ET3 (from spring 2010 on); site ET4 (from autumn 2014 on); site ET2 (will be assessed for two periods: spring 2010 on [Longwalls 20-22] and autumn 2014 on [Longwalls 23-27]).

8 Long-term changes to the macroinvertebrate and macrophyte assemblages are considered to be significant changes that are persistent (over time) and resulting from mining.

9 Threatened species, populations and ecological communities include those listed under the BC Act, EPBC Act or Fisheries Management Act at the time of Project Approval (i.e. the lists current as at 22 June 2009).

Appendix 2. Spring 2020 Longwalls 20-27 Aquatic Ecology Monitoring - GPS positions (UTMs).

System	Location	Site	Easting	Northing
Tributary C/Eastern Tributary	1	1	03116120	6214116
	1	2	0311634	6214158
	2	1	0312173	6215401
	2	2	0312167	6215577
	3	1	0311433	6213610
	3	2	0311462	6213718
	4	1	0311804	6214448
	4	2	0312034	6214503
Waratah Rivulet	3	1	0309863	6214303
	3	2	0309850	6214455
	4	1	0310426	6215080
	4	2	0310322	6215160
	5	1	0310525	6215340
	5	2	0310687	6215363
Woronora River	1	1	0307941	6219050
	1	2	0307929	6219104
O'Hares Creek	1	1	0303740	6213657
	1	2	0303684	6213621

Sampling Dates: 12/11/2020, 23/11/2020 & 2/12/2020

APPENDIX 3a. SPRING 2020 LONGWALLS 20-27 AQUATIC ECOLOGY MONITORING - MACROPHYTE CLASS DATA

	Tributary C / Eastern Tributary								**Waratah Rivulet**						**Woronora River**		**O'Hares Creek**	
Species	**C11**	**C12**	**C21**	**C22**	**C31**	**C32**	**C41**	**C42**	**WT31**	**WT32**	**WT41**	**WT42**	**WT51**	**WT52**	**WR11**	**WR12**	**OC1**	**OC2**
Andropogon virginicus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Baumea juncea	3	2	3	3	0	0	3	1	0	1	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	1	1	0	1	0	0	1	0	0	1	0	0	1	2	1	0
Baumea teretifolia	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	3	1
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3
Chara/Nitella spp.	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0
Chorizandra cymbaria	1	2	0	0	0	0	0	1	0	0	0	1	0	2	2	0	1	2
Dicksonia antarctica	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	1	0	1	2	1	1	0	0	0	0	0	0	0	0
Drosera spatulata	1	2	2	1	1	1	0	1	1	2	0	0	1	2	1	1	1	1
Empodisma minus	3	2	3	2	2	3	1	3	0	2	0	0	0	0	2	0	3	3
Eurychorda complanata	0	0	0	0	0	0	0	0	2	2	0	0	1	3	0	0	1	3
Gahnia clarkei	1	1	0	0	3	2	1	1	0	2	0	0	0	0	1	2	2	1
Gleichenia dicarpa	0	2	0	0	3	2	2	2	3	3	1	0	3	3	2	2	3	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Juncus planifolius	0	0	0	0	0	0	0	0	0	1	0	0	1	3	0	0	1	1
Juncus prismatocarpus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Lepidosperma filiforme	3	3	3	3	3	3	3	0	2	3	1	3	1	2	3	2	2	2
Lomandra fluviatilis	0	0	2	2	1	1	1	3	0	1	3	2	1	0	0	3	0	3
Lomandra longfolia	2	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	0	1
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0
Schoenus brevifolius	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	1	0	0	0	0	2	0	0	0	2	1	0	0	0	2	2	2	1
Triglochin procerum	0	0	0	0	0	0	0	0	1	0	1	3	3	0	3	3	1	0
Viminaria juncea	3	3	2	3	2	0	3	3	3	2	0	0	2	1	0	0	2	1
Xyris operculata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

* Denotes introduced species

Site Codes: C11 = Tributary C, Location 1, Site 1, etc.

APPENDIX 3b. SPRING 2020 LONGWALLS 20-27 AQUATIC ECOLOGY MONITORING - MACROPHYTE PERCENTAGE COVER DATA

	Tributary C / Eastern Tributary																			
Species	**C11-1**	**C11-2**	**C11-3**	**C11-4**	**C11-5**	**C12-1**	**C12-2**	**C12-3**	**C12-4**	**C12-5**	**C21-1**	**C21-2**	**C21-3**	**C21-4**	**C21-5**	**C22-1**	**C22-2**	**C22-3**	**C22-4**	**C22-5**
Baumea juncea	0	10	0	10	4	35	0	50	0	0	25	0	0	0	20	95	70	85	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	2	0	15
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Drosera spatulata	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	35	0	0	0	4	0	0	15	20	0	10	0	0	0	0	15
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	95	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	4	50	15
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus prismatocarpus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	45	0	15	0	0	0	5	0	10	0	0	40	60	50	20	0	0	0	0	20
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	15	0	0	15	0	0	4	2	75	0	5	2	0	0	0	0	0	0	10	0

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

APPENDIX 3b.

	Tributary C / Eastern Tributary																			
Species	**C31-1**	**C31-2**	**C31-3**	**C31-4**	**C31-5**	**C32-1**	**C32-2**	**C32-3**	**C32-4**	**C32-5**	**C41-1**	**C41-2**	**C41-3**	**C41-4**	**C41-5**	**C42-1**	**C42-2**	**C42-3**	**C42-4**	**C42-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	20	0	50	0	60	0	0	0
Baumea rubiginosa	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Drosera binata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	40	50	80	0	0	0	0	0	0	0	0	0	0	65	40
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	60	0	0	0	0	0	0	0	0	60	0	35	0	0	0	65	0	0	0	0
Gleichenia dicarpa	20	50	30	0	4	0	15	0	0	0	0	0	0	50	2	2	0	45	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus prismatocarpus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	25	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra fluviatilis	0	0	0	85	85	0	0	0	0	0	0	0	0	0	0	0	2	45	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	2	0	0	0	0	0	0	0	0	0	0	20	2	0	0	2	20

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

APPENDIX 3b.

	Waratah Rivulet																			
Species	**WT31-1**	**WT31-2**	**WT31-3**	**WT31-4**	**WT31-5**	**WT32-1**	**WT32-2**	**WT32-3**	**WT32-4**	**WT32-5**	**WT41-1**	**WT41-2**	**WT41-3**	**WT41-4**	**WT41-5**	**WT42-1**	**WT42-2**	**WT42-3**	**WT42-4**	**WT42-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Baumea teretifolia	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eurychorda complanata	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	50	5	30	10	45	10	35	2	0	0	0	0	25	0	0	0	0	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus prismatocarpus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	50	0	0	0	0	0	0	45	0	0	0	0	30	0	0	50	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	60	90	100	30	0	0	80	0	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0
Viminaria juncea	10	0	0	5	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

APPENDIX 3b.

	Waratah Rivulet										Woronora River 1									
Species	**WT51-1**	**WT51-2**	**WT51-3**	**WT51-4**	**WT51-5**	**WT52-1**	**WT52-2**	**WT52-3**	**WT52-4**	**WT52-5**	**WR11-1**	**WR11-2**	**WR11-3**	**WR11-4**	**WR11-5**	**WR12-1**	**WR12-2**	**WR12-3**	**WR12-4**	**WR12-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	10	0	2	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
Eurychorda complanata	30	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	40	0	2	0	50	0	0	0	60	0	0	45	0	0	0	0	0	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	4	15	0	0	0	0	0	0	0	0	0	0	0	0
Juncus prismatocarpus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	4	0	5	0	0	0	0	5	0	5	15	0	0	0	0	0	20
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	45	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
Triglochin procerum	4	0	50	0	90	0	0	0	0	0	0	100	0	0	100	0	85	15	0	0
Viminaria juncea	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

APPENDIX 3b.

	O'Hares Creek									
Species	**OC1-1**	**OC1-2**	**OC1-3**	**OC1-4**	**OC1-5**	**OC2-1**	**OC2-2**	**OC2-3**	**OC2-4**	**OC2-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	2	0	18	65	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	15	6	0
Chorizandra cymbaria	20	0	0	0	0	10	0	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	0	0	10	0
Empodisma minus	0	4	0	0	90	30	15	0	0	0
Eurychorda complanata	0	0	0	0	0	0	30	0	70	0
Gahnia clarkei	0	0	0	0	0	0	8	0	0	0
Gleichenia dicarpa	15	60	65	10	0	0	0	0	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	6	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0
Juncus prismatocarpus	0	0	0	0	0	0	0	2	0	0
Lepidosperma filiforme	0	0	0	0	0	0	10	0	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	80
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	2	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	30	0	0	5	0	0	0	0	0	0

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

APPENDIX 4. SPRING 2020 LONGWALLS 20-27 AQUATIC ECOLOGY MONITORING - AUSRIVAS DATA

	Tributary C / Eastern Tributary								**Waratah Rivulet**						**Woronora River 1**		**O'Hares Creek**	
Taxa	**C11**	**C12**	**C21**	**C22**	**C31**	**C32**	**C41**	**C42**	**WT31**	**WT32**	**WT41**	**WT42**	**WT51**	**WT52**	**WR11**	**WR12**	**OC1**	**OC2**
Acariformes	0	4	0	9	1	4	0	0	1	0	0	0	0	0	0	3	2	0
Aeshnidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0	19	1	0	0
Baetidae	0	0	1	0	0	2	0	0	2	2	0	0	0	7	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	7	5	3	0	5	12	0	0	11	7
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ceinidae	0	0	0	0	0	0	0	0	0	1	0	3	3	0	0	0	22	0
Ceratopogonidae	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Chironomidae (L.) - Chironominae	0	4	0	0	2	0	2	7	4	2	0	2	1	5	1	5	0	9
Chironomidae (L.) - Tanypodinae	0	0	0	2	0	1	1	1	4	1	1	0	0	5	1	0	0	1
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Corixidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	5	17	7	5	2	3	3	1	7	2	9	15	6	9	2	0	1	4
Elmidae	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	1
Gelastocoridae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	4	2	0	0	2	0	0	0	0	0	0	0	0	0	0	1	2	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	3
Gyrinidae	0	1	1	0	0	0	1	0	1	1	5	1	0	2	1	0	0	0
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hydraenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	1	0	4	0	0	0	0	0	5	1	0	0	1	0	0	2	11
Leptoceridae	6	3	5	12	0	9	11	1	2	3	1	2	0	0	4	2	22	1
Leptophlebiidae	6	14	40	53	50	10	4	3	70	44	26	23	30	39	24	8	94	46
Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Libellulidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Notonectidae	7	8	0	18	0	7	1	0	14	2	0	4	1	0	0	3	10	2
Scirtidae	3	3	0	0	1	0	13	0	0	0	0	1	0	0	0	3	13	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Telephlebiidae	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Tipulidae	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Unidentified Damselfly	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**6**	**14**	**5**	**13**	**6**	**10**	**9**	**6**	**11**	**11**	**9**	**9**	**8**	**10**	**7**	**13**	**17**	**11**

APPENDIX 5. SPRING 2020 LONGWALLS 20-27 AQUATIC ECOLOGY MONITORING - QUANTITATIVE MACROINVERTEBRATE DATA

	Tributary C / Eastern Tributary																							
Taxa	C11-1	C11-2	C11-3	C12-1	C12-2	C12-3	C21-1	C21-2	C21-3	C22-1	C22-2	C22-3	C31-1	C31-2	C31-3	C32-1	C32-2	C32-3	C41-1	C41-2	C41-3	C42-1	C42-2	C42-3
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	1	2	0	1	0	4	2	0	0	4	4	0	3	1	0	2	3	1	0	1	0	1	0	0
Atyidae	0	0	0	0	0	0	2	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	1	7	3	6	2	0	0	6	2	0	0	3	0	5	1	0	14	4	4	1	0	1
Belastomatidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	1	1	0	0
Chironomidae	0	1	0	7	1	2	1	0	1	0	2	0	2	0	0	0	1	0	0	1	0	1	7	2
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	1	3	0	0	0	0	0	0
Dytiscidae	2	0	1	5	5	3	9	5	2	2	6	3	1	4	2	1	1	1	3	1	1	0	6	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	4	2	0	0	0	1	0	0
Gyrinidae	0	0	0	0	0	1	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydainidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hydrophilidae	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	1	0	1	0	0	0	6	0	0	6	1	9	0	0	0	4	0	6	0	3	0	0	0	0
Leptophlebiidae	31	17	0	8	14	22	46	14	18	18	57	18	15	66	48	23	52	12	3	0	8	22	6	27
Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Libellulidae	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	3	0	0	0	0	0	0	0
Notonectidae	5	3	2	1	9	3	0	0	1	5	6	7	0	0	1	5	1	4	3	1	3	0	1	0
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oniscidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycentropodidae	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psphenidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	4	1	0	0	0	0	2	0	0	0	2	0	0	0	2	1	1	3	1	0	2	0	1	0
Simulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Staphylinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Unknown Diptera pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Unknown Juvenile Anisoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Juvenile Zygoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**46**	**34**	**6**	**34**	**34**	**46**	**76**	**19**	**23**	**43**	**83**	**40**	**26**	**78**	**54**	**52**	**70**	**35**	**26**	**14**	**20**	**27**	**21**	**30**
Number of Taxa	**8**	**11**	**5**	**10**	**7**	**10**	**12**	**2**	**5**	**8**	**11**	**7**	**7**	**6**	**5**	**14**	**11**	**11**	**7**	**9**	**6**	**6**	**5**	**3**

Not included in the sum of the 'Total Number of Taxa' for the survey period

Appendix 5 (Cont'd)

Taxa	Waratah Rivulet																	
	WT31-1	WT31-2	WT31-3	WT32-1	WT32-2	WT32-3	WT41-1	WT41-2	WT41-3	WT42 -1	WT42 -2	WT42 -3	WT51-1	WT51-2	WT51-3	WT52-1	WT52-2	WT52-3
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Acariformes	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Baetidae	3	5	12	1	3	1	0	0	0	0	0	0	0	0	0	1	0	3
Belastomatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	27	10	10	3	1	3	0	0	6	2	0	0	7	1	2	13	9
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	1	3	3	0	1	0	0	0	1
Ceratopogonidae	0	0	14	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
Chironomidae	24	2	13	7	11	1	2	1	0	2	2	1	3	1	1	1	1	0
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	2	0	1	1	0	1	0	0	0
Corixidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Dytiscidae	1	5	5	7	0	1	4	1	8	1	0	5	12	1	4	10	3	7
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	1	0	0	0	1	2	1	0	0	0	1	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	1	1	2	0	2	1	0	0	0	0	0	0	0	0	0	1	0
Hydainidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	1	1	0	2	0	0	2	0	0	0	2	1	0	0	0	2
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	1	1	4	0	0	0	0	1	0	0	5	1	3	0	0	0
Leptophlebiidae	12	78	31	33	44	18	31	68	8	83	5	39	39	44	68	68	41	20
Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0
Notonectidae	0	2	1	3	0	2	0	0	0	0	2	9	1	0	2	0	0	2
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
Oniscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psphenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0
Simulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staphylinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Unknown Diptera pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Juvenile Anisoptera	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Juvenile Zygoptera	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Total Macroinvertebrates	**40**	**123**	**90**	**66**	**66**	**34**	**42**	**71**	**19**	**98**	**16**	**67**	**67**	**57**	**83**	**84**	**60**	**45**
Number of Taxa	**4**	**9**	**11**	**10**	**5**	**14**	**6**	**4**	**4**	**9**	**6**	**11**	**10**	**8**	**10**	**7**	**6**	**8**

	Woronora River 1						O'Hares Creek					
Taxa	**WR11-1**	**WR11-2**	**WR11-3**	**WR12-1**	**WR12-2**	**WR12-3**	**OC1-1**	**OC1-2**	**OC1-3**	**OC2-1**	**OC2-2**	**OC2-3**
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	0	13	0	0	1	1	0	1	0	0
Atyidae	0	2	2	3	7	4	2	0	0	0	0	0
Baetidae	1	0	0	0	0	0	0	0	6	0	0	1
Belastomatidae	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	6	3	15	6	1	11
Calamoceratidae	0	0	0	0	0	0	0	1	0	1	0	0
Ceinidae	0	0	0	0	0	0	3	20	0	0	0	0
Ceratopogonidae	0	1	0	0	0	0	0	0	0	0	0	0
Chironomidae	0	4	2	1	0	0	1	2	2	42	15	4
Coenagrionidae	0	0	0	0	0	0	0	1	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	1	0	0	1	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	1	0	0	0	0
Dytiscidae	0	1	1	0	0	0	1	3	5	5	5	1
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	1	0	1	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	1
Gomphidae	0	0	0	0	0	0	0	0	0	1	0	5
Gripopterygidae	3	0	0	0	0	8	1	0	0	0	0	0
Gyrinidae	0	1	0	0	0	0	0	0	0	0	0	0
Hydainidae	0	0	0	0	0	1	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	1	0	0	0	2	1	1	2	1
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0
Isostictidae	0	0	0	0	0	0	0	1	0	0	0	0
Leptoceridae	5	1	0	6	3	13	4	7	8	0	0	1
Leptophlebiidae	50	9	6	2	7	1	54	43	38	46	21	49
Lestidae	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	1	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	1	1	1	4	6	5	0	0	1
Odontoceridae	0	0	0	0	0	0	1	0	0	0	0	2
Oniscidae	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0
Psphenidae	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	1	0	0	0	0	0	0	0	0
Scirtidae	2	1	2	2	1	1	0	4	0	0	0	0
Simulidae	0	0	0	0	0	0	0	0	0	0	0	0
Staphylinidae	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	1	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	1	0	0	0	0	0
Tipulidae	1	0	0	0	0	1	0	0	0	0	0	0
Unknown Diptera pupae	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Juvenile Anisoptera	0	0	0	0	0	0	0	0	0	0	0	0
Unknown Juvenile Zygoptera	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**62**	**20**	**13**	**30**	**19**	**30**	**79**	**99**	**80**	**104**	**45**	**77**
Number of Taxa	**6**	**8**	**5**	**9**	**5**	**8**	**12**	**18**	**8**	**9**	**6**	**11**

APPENDIX 6. SPRING 2020 LONGWALLS 20-27 AQUATIC ECOLOGY MONITORING - WATER QUALITY DATA

	Tributary C/Eastern Tributary																	
	C11-1	**C11-2**	**C11-3**	**C12-1**	**C12-2**	**C12-3**	**C21-1**	**C21-2**	**C21-3**	**C22-1**	**C22-2**	**C22-3**	**C31-1**	**C31-2**	**C31-3**	**C32-1**	**C32-2**	**C32-3**
Temperature (°C)	18.77	18.78	18.78	19.85	19.86	19.87	17.14	17.12	17.12	17.21	17.21	17.22	18.22	18.2	18.22	18.56	18.56	18.56
pH	7.74	7.75	7.75	8.08	80.08	8.09	7.86	7.86	7.85	7.86	7.86	7.86	7.71	7.73	7.74	7.84	7.84	7.84
Conductivity (µS/cm)	155	155	155	153	155	154	198	198	198	181	181	181	166	166	166	164	164	164
Dissolved Oxygen (%Sat)	65.2	65.1	65	89.9	89.9	89.8	22	21.9	21.8	53.2	53	52.7	77.9	77.9	77.9	84.2	84.2	84.2
Turbidity (NTU)	5.7	5.8	5.5	7.5	7.2	7.2	28.6	28.6	28.6	29.8	33.1	32.2	8.3	8	8.1	16.8	16.8	16.8
REDOX (mv)	612	613	613	576	576	575	609	609	609	599	599	599	623	623	623	616	616	616
Alkalinity (mg/L)	18	N/R	N/R	23	N/R	N/R	25	N/R	N/R	30	N/R	N/R	21	N/R	N/R	20	N/R	N/R
Total phosphorous (mg/L)	0.024	0.006	N/R	0.006	0.005	N/R	0.012	0.010	N/R	0.010	0.010	N/R	0.006	0.019	N/R	0.008	0.007	N/R
Total Nitrogen (mg/L)	0.210	0.130	N/R	0.100	0.080	N/R	0.120	0.100	N/R	0.150	0.140	N/R	0.060	0.150	N/R	0.130	0.100	N/R

	Tributary C/Eastern Tributary						**Waratah Rivulet**											
	C41-1	**C41-2**	**C41-3**	**C42-1**	**C42-2**	**C42-3**	**WT31-1**	**WT31-2**	**WT31-3**	**WT32-1**	**WT32-2**	**WT32-3**	**WT41-1**	**WT41-2**	**WT41-3**	**WT42-1**	**WT42-2**	**WT42-3**
Temperature (°C)	18.51	18.51	18.51	18.66	18.66	18.66	23.0	23.0	23.0	23.05	23.05	23.05	19.75	19.76	19.76	19.49	19.54	19.53
pH	7.73	7.73	7.73	7.82	7.82	7.82	7.7	7.7	7.7	7.99	7.99	7.99	7.9	7.9	7.9	7.85	7.85	7.85
Conductivity (µS/cm)	156	156	156	159	159	159	183	183	183	184	184	184	155	155	155	157	156	156
Dissolved Oxygen (%Sat)	77.5	77.4	77.4	81.8	81.8	81.7	102.4	102.4	102.5	104.0	104.0	104.0	94.4	94.4	94.3	87.2	87.1	87.1
Turbidity (NTU)	18.7	18.7	18.5	15	15	14.7	10.4	10.2	10.2	9.9	9.6	9.7	5.4	5.2	5.8	4.2	4.3	4.3
REDOX (mv)	606	606	606	606	606	606	584	584	584	569	569	569	619.0	619.0	619.0	614.0	614.0	614.0
Alkalinity (mg/L)	20	N/R	N/R	23	N/R	N/R	35	N/R	N/R	30	N/R	N/R	25	N/R	N/R	N/R	N/R	N/R
Total phosphorous (mg/L)	0.006	0.007	N/R	0.006	0.007	N/R	0.006	0.004	N/R	0.007	0.007	N/R	0.006	0.006	N/R	0.006	0.006	N/R
Total Nitrogen (mg/L)	0.100	0.320	N/R	0.070	0.200	N/R	0.090	0.090	N/R	0.140	0.130	N/R	0.130	0.200	N/R	0.150	0.200	N/R

	Waratah Rivulet						**Woronora River 1**						**O'Hares Creek**					
	WT51-1	**WT51-2**	**WT51-3**	**WT52-1**	**WT52-2**	**WT52-3**	**WR11-1**	**WR11-2**	**WR11-3**	**WR12-1**	**WR12-2**	**WR12-3**	**OC1-1**	**OC1-2**	**OC1-3**	**OC2-1**	**OC2-2**	**OC2-3**
Temperature (°C)	19.45	19.42	19.42	20.94	20.97	20.97	16.9	17.0	16.9	16.81	16.82	16.82	22.19	22.19	22.18	22.3	22.3	22.3
pH	7.99	8	8	8.11	8.12	8.12	6.27	6.28	6.29	6.28	6.29	6.29	7.07	7.07	7.07	7.63	7.63	7.63
Conductivity (µS/cm)	158	158	158	157	158	158	137	137	137	138	138	138	125	125	125	128	128	128
Dissolved Oxygen (%Sat)	92.7	93.4	93.4	97.9	98	98	91.8	91.7	91.6	89.1	89.1	88.9	84.8	84.7	84.7	99.3	99.3	99.3
Turbidity (NTU)	3.8	3.8	3.8	8	8	8	2.5	2.7	2.7	15.4	15.4	15.5	3.3	3.4	3.3	3.1	3.0	3.0
REDOX (mv)	612	612	612	603	602	601	668	668	668	669	669	669	585	585	585	559	559	559
Alkalinity (mg/L)	21	N/R	N/R	19	N/R	N/R	5	N/R	N/R	5	N/R	N/R	11.5	N/R	N/R	11.5	N/R	N/R
Total phosphorous (mg/L)	0.005	0.005	N/R	0.005	0.007	N/R	0.004	0.004	N/R	0.004	0.003	N/R	0.009	0.011	N/R	0.007	0.007	N/R
Total Nitrogen (mg/L)	0.090	0.140	N/R	0.110	0.17	N/R	0.230	0.150	N/R	0.110	0.100	N/R	0.180	0.190	N/R	0.210	0.170	N/R

N/R = Not Recorded