AQUATIC ECOLOGY MONITORING: METROPOLITAN COAL LONGWALLS 20-27

AUTUMN 2020 SURVEYS

Prepared for

METROPOLITAN COAL

24 March 2021

BIO-ANALYSIS Pty Ltd

Marine, Estuarine & Freshwater Ecology

2/1 Botham Close Charmhaven, NSW 2263

(Mobile) 0414 477066, (Email) info@bioanalysis.com.au

Document Information

Prepared for	Metropolitan Coal
Prepared by	Dr Sharon Cummins
Project Name	Metropolitan Coal: Longwalls 20-22 & Longwalls 23-27 Aquatic Ecology Monitoring (Autumn 2020 Surveys)
File Name:	Autumn 2020 LW20-27 Aquatic Ecology Report Final.01.2403-2021
Citation	BIOANALYSIS (2021). Autumn 2020 Longwalls 20-27 Aquatic Ecology Monitoring Report. Report for Metropolitan Coal. Authors: Cummins, S. P., BIOANALYSIS Pty Ltd, Charmhaven.

Contact Information

Dr Sharon Cummins

Telephone: 043 811 2962
Email: cumminssharon@bigpond.com

Document Control

Version	**Date Issued**
Draft Version	17/02/2021
Draft Final Version	21/03/2021
Final Version	24/03/2021

Acknowledgements

Danny Roberts and Jan Roberts provided management support. Nicholas Roberts, Ella Roberts, Ethan Roberts and Jennifer Cummins are thanked for assistance in the field and laboratory.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

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).

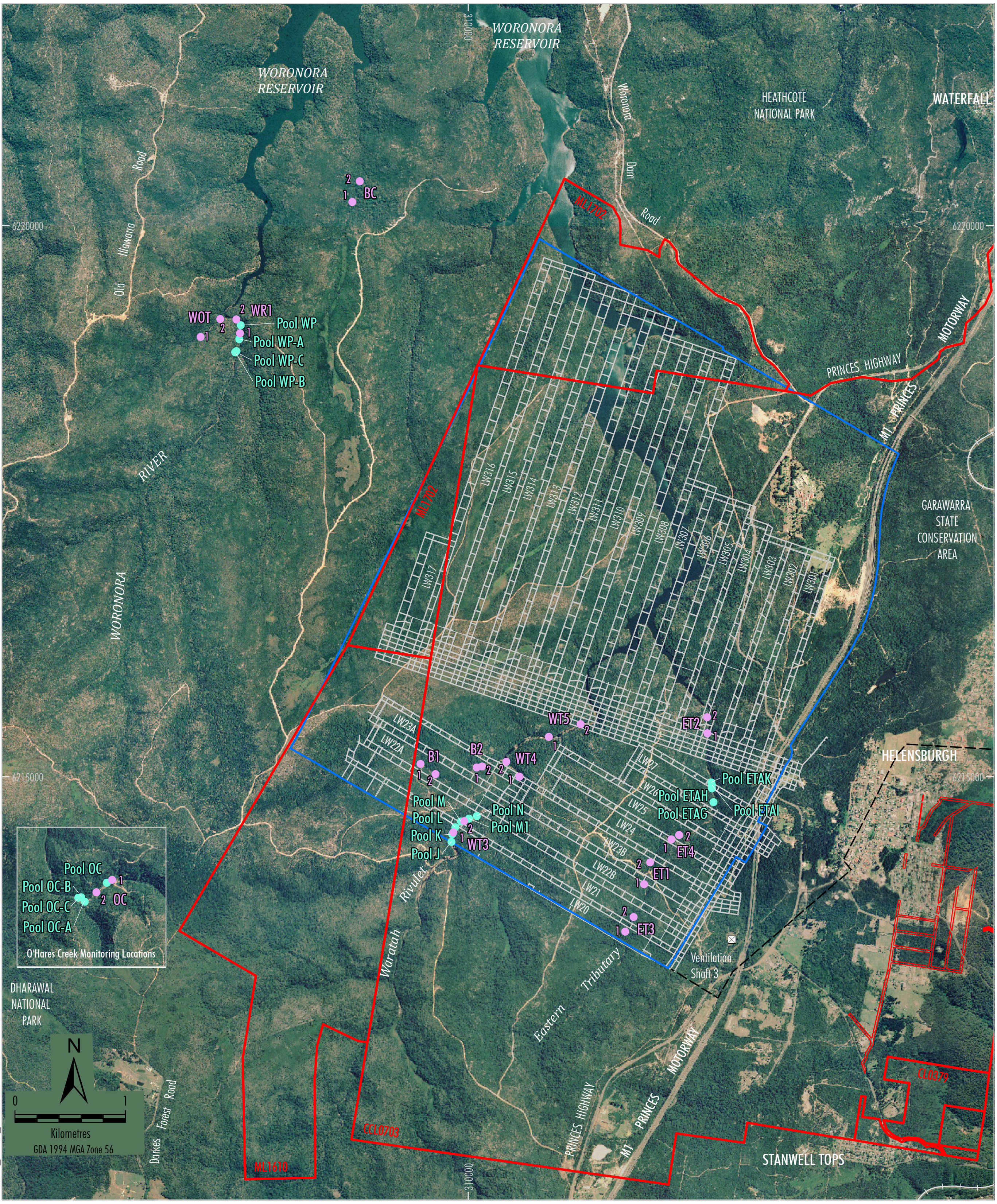
The design of the monitoring programmes uses the current best practice approach for monitoring impacts on aquatic habitats "Beyond BACI" and focused on representative sampling of selected locations within streams in the Longwalls 20-22 and Longwalls 23-27 mining area's and in suitable control streams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

The primary objective of monitoring was to determine whether the extent and nature of observed impacts, primarily subsidence-induced fracturing of bedrock, diversion and loss of aquatic habitat, if any, are consistent with the predictions made in the Extraction Plan's and 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.

This report presents the results of the autumn 2020 stream monitoring surveys (Section 3) and a temporal analysis of the assemblages of aquatic macrophytes and macroinvertebrates in order to examine patterns in diversity and abundance among sampling events (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)

Peabody

METROPOLITAN COAL

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.

---

[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 habitat and biota over time as mining progresses.

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.

[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-	Before-	
Autumn 2009	Before-	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-	LW303 commenced November 2018/completed June 2019
Autumn 2019	After-	After-	
Spring 2019	After-	After-	LW304 commenced July 2019/completed January 2020
Autumn 2020	After-	After-	LW305 commenced April 2020

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 (°C), 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 and the Longwalls 23-27 mining areas (i.e. potential 'impact' sites) in comparison to independent locations that are not subject to mine subsidence (i.e. control streams).

3.0 RESULTS

3.1 Aquatic Habitat & General Observations

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 autumn 2020, is presented below.

<u>Tributary C/Eastern Tributary</u>

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 autumn 2020.

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 (autumn 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;
- An iron precipitate/micro-organism complex covered a large proportion of the substratum at both sites (Plates 1&2);
- Recent (subsequent to the spring 2019 survey) bank scour, fallen trees and trapped debris reflected heavy rainfall within the catchment in late January/February 2020. Areas of desiccated, riparian vegetation (mostly *Gleichenia dicarpa* and *Empodisma minus*) showed some signs of regeneration (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) (aut-20)
Looking upstream

Plate 2: Tributary C – Location C1 (C1-2) (aut-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 (autumn 2020) are summarised below:

- Heavy iron staining/iron flocculent was observed at Site C2-1 and Site C2-2 and pool water had a pale-green milky 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).

[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) (aut-20)

Looking upstream

Plate 4: Tributary C – Location C2 (C2-2) (aut-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 autumn 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);
- Recent (subsequent to the spring 2019 survey) fallen trees and trapped were apparent in the riparian zone. Riparian health at Site C3-2 appears to have continued to improve since obvious signs of desiccation in spring 2018; and
- *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) (aut-20)
Looking upstream

Plate 6: Tributary C – Location C3 (C3-2) (aut-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.

Since spring 2015, large proportions of the study reach at Site C4-1 have commonly been dry but flow has consistently been present along the study reach at Site C4-2.

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

- Pool water level appeared similar to baseline levels at both sites and surface flow was apparent (Plates 7&8);
- An iron complex covered up to approximately 95% of the submerged substratum at both sites (Plates 7&8);
- *Lepidosperma filiformis*, *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) (aut-20)
Looking downstream

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

Waratah Rivulet

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 (autumn 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);
- Iron staining continues to be present along the study reach (Plates 9&10). An iron precipitate/micro-organism complex covered up to approximately 95 % of the stream substratum; 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) (aut-20)
Looking upstream

Plate 10: Waratah Rivulet – Location WT3 (WT3-2) (aut-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. 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.

Pool water at Location WT4 has been commonly observed to have a milky-green tinge.

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

- Pool water levels along the study reach had increased since the spring 2019 survey to become similar to 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;
- An iron precipitate covered up to approximately 80% of the stream substratum;
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 11&12);
- The riparian strip was relatively healthy;
- The emergent species, *Lomandra fluviatilis* and *Lepidosperma filiforme* were amongst the most common components of the assemblage of aquatic macrophytes (Appendix 3a&b);
- The weed species, *Isolepis prolifera*, was not observed on this sampling occasion; and
- *Triglochin procerum* was relatively common but *Chara/Nitella* spp. was not observed, most likely due to recent high flows along the study reach (Plates 11&12).

Plate 11: Waratah Rivulet – Location WT4 (WT4-1) (aut-20)
Looking upstream

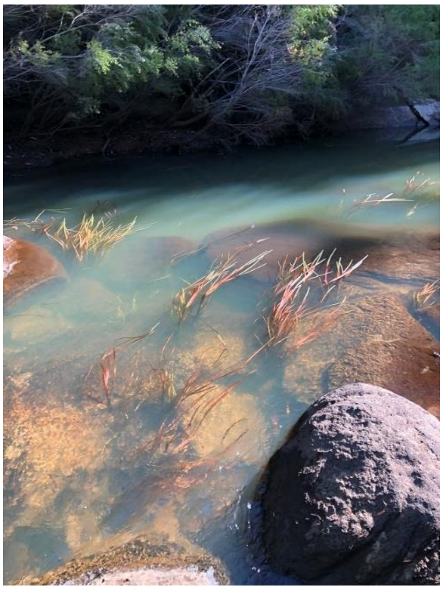


Plate 12: Waratah Rivulet – Location WT4 (WT4-2) (aut-20)
Looking upstream

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 (autumn 2020) are summarised below:

- To date, there has been no evidence of mining related fracturing of the stream substratum at this location;
- 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. The emergent species, *Gleichenia dicarpa* and *Lepidosperma filiforme* were amongst the most common components of the assemblage of aquatic macrophytes (Appendix 3a&b);
- *Triglochin procerum* was only observed in the deeper pools at the upstream site (Site WT5).

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

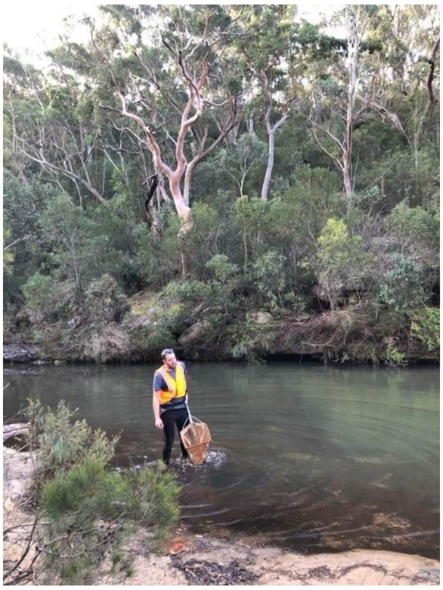


Plate 14: Waratah Rivulet – Location WT5 (WT5-2) (aut-20)
Looking across stream

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 autumn 2020 survey, emergent macrophytes included *Lepidosperma filiforme* 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 had increased compared to levels noted by the spring and autumn 2018 and spring 2017 surveys and flow was apparent along the study reach (Plates 15&16). Visibility of the water was considered excellent.

Plate 15: Woronora River (WR1) (aut-20)

Looking upstream

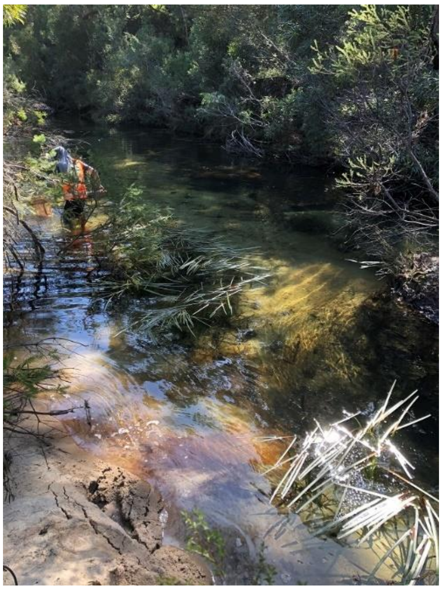


Plate 16: Woronora River (WR2) (aut-20)

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.

At the time of this survey, dominant riparian vegetation 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 (Appendix 3a). There was evidence of recent high flows (fallen trees and trapped debris) since spring 2019.

The exotic macrophyte, *Isolepis prolifera*, was observed at Site OC1 on this and many earlier occasions (Appendix 3a). Stream water visibility was excellent.

Plate 17: O'Hares Creek (OC1) (aut-20)
Looking upstream

Plate 18: O'Hares Creek (OC2) (aut-20)
Looking upstream

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 11.1 to 16.1 ° C (Table 1), which is typical for the time of year the samples were collected. Mean pH (range = 4.8 – 8.4) 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 WT3-2 in autumn 2020 (Table 2).

Mean conductivity (range = 125 – 3,018 µS/cm) exceeded the upper DTV at sites C1-2 and WT3-1 (Table 2). Mean dissolved oxygen levels (range = 61.1 – 103.7 %) were below the lower DTV at sites C1-1, C2-1, C2-2, C3-1, C4-1, C4-2, WT4-1, WT4-2, WT5-1, WT5-2, WR1-1 and WR1-2 (Table 2).

Mean turbidity (range = 1.4 – 18.2 NTU) levels were within the recommended DTV’s while mean oxidation-reduction potential ranged from 536 to 613 mV (Table 2). Mean alkalinity ranged from 0 to 37 mg/L $CaCO_3$ (Table 2). For nutrients, mean concentrations of total phosphorous (0.003 to 0.007 mg/L) and total nitrogen (range = 0.069 to 0.185 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 (autumn 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)	12.8 (0.0)	14.6 (0.0)	15.9 (0.0)	14.9 (0.0)	13.1 (0.0)	13.1 (0.0)
pH (*n* =3)	7.1 (0.0)	7.7 (0.0)	7.0 (0.0)	7.2 (0.0)	7.3 (0.0)	7.5 (0.0)
Conductivity (µS/cm) (*n* = 3)	176.7 (0.3)	**2,799** (9.0)	192.0 (0.0)	187.0 (0.0)	188.0 (0.0)	186.3 (0.3)
Dissolved Oxygen (% Saturation) (*n* = 3)	**77.0** (0.0)	101.5 (0.1)	**61.1** (0.3)	**87.2** (0.0)	**86.0** (0.1)	96.4 (0.1)
Turbidity (NTU) (*n* = 3)	8.7 (0.1)	16.4 (0.4)	10.3 (0.2)	14.9 (0.0)	10.2 (0.1)	10.0 (0.1)
ORP (mV) (*n* = 3)	607.0 (0.0)	584.7 (0.3)	552.0 (0.0)	560.0 (10.0)	596.0 (0.0)	586.0 (0.0)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	24	25	30	30	35	36
Total phosphorous (mg/L) (*n* = 2)	0.004 (0.004)	0.005 (0.001)	0.007 (0.000)	0.006 (0.001)	0.005 (0.001)	0.005 (0.000)
Total nitrogen (mg/L) (*n* = 2)	0.107 (0.013)	0.106 (0.024)	0.136 (0.055)	0.110 (0.010)	0.071 (0.006)	0.088 (0.012)
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)	13.4 (0.0)	13.8 (0.0)	13.7 (0.0)	13.0 (0.0)	16.1 (0.0)	16.1 (0.0)
pH (*n* =3)	7.1 (0.0)	7.2 (0.0)	7.8 (0.0)	**8.4** (0.0)	6.9 (0.0)	6.9 (0.0)
Conductivity (µS/cm) (*n* =3)	171.0 (0.0)	178.0 (0.0)	**3,018** (4.4)	180.0 (0.0)	131.0 (0.0)	149.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	**85.5** (0.0)	**84.4** (0.0)	98.3 (0.0)	103.7 (0.0)	**82.5** (0.2)	**77.6** (0.1)
Turbidity (NTU) (*n* =3)	18.2 (0.2)	8.7 (0.3)	11.6 (0.1)	12.6 (2.8)	4.0 (0.1)	5.0 (0.0)
ORP (mV) (*n* = 3)	542.0 (0.0)	549.0 (0.0)	572.7 (0.3)	556.0 (0.0)	613.0 (0.0)	575.7 (0.3)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	25	24	35	37	25.5	20
Total phosphorous (mg/L) (*n* = 2)	0.006 (0.001)	0.007 (0.001)	0.004 (0.000)	0.004 (0.001)	0.005 (0.000)	0.004 (0.000)
Total nitrogen (mg/L) (*n* = 2)	0.069 (0.010)	0.085 (0.011)	0.106 (0.015)	0.109 (0.021)	0.111 (0.040)	0.085 (0.001)

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]: # = Insufficient aquatic habitat.
NB[3]: *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)	15.3 (0.0)	15.5 (0.0)	13.2 (0.0)	13.4 (0.0)	11.2 (0.0)	11.1 (0.0)
pH (*n* =3)	7.0 (0.0)	7.2 (0.0)	**4.8** (0.0)	**4.9** (0.0)	7.7 (0.0)	7.9 (0.0)
Conductivity (µS/cm) (*n* = 3)	140.0 (0.0)	139.0 (0.0)	134.0 (0.0)	134.0 (0.0)	125.0 (0.0)	125.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	**76.1** (0.3)	**77.7** (0.1)	**69.8** (0.2)	**65.8** (0.3)	98.9 (0.0)	103.2 (0.0)
Turbidity (NTU) (*n* = 3)	2.1 (0.0)	3.4 (0.1)	1.4 (0.0)	2.4 (0.1)	2.1 (0.0)	1.8 (0.0)
ORP (mV) (*n* = 3)	602.0 (0.0)	593.3 (0.3)	570.7 (0.3)	536.0 (2.3)	544.0 (0.0)	536.0 (0.0)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	23.5	24.5	0	0	5	5
Total phosphorous (mg/L) (*n* = 2)	0.004 (0.001)	0.006 (0.002)	0.003 (0.000)	0.004 (0.001)	0.004 (0.001)	0.004 (0.000)
Total nitrogen (mg/L) (*n* = 2)	0.093 (0.001)	0.105 (0.035)	0.108 (0.012)	0.185 (0.035)	0.130 (0.000)	0.110 (0.000)

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]: # = Insufficient aquatic habitat.
NB[3]: *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 33 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 0.18 (C4-1) and 0.74 (C1-2, WT3-1, WT4-1 and OC1) (Table 3). Eleven sites were grouped in Band B (C1-1, C1-2, C2-2, C3-1, C3-2, WT3-1, WT3-2, WT4-1, WT4-2, WR1-1 and OC1) and seven were grouped in Band C (C2-1, C4-1, C4-2, WT5-1, WT5-2, WR1-2 and OC2) (Table 3). Thus, fewer families of macroinvertebrates than expected were collected from sites sampled (including reference sites) in autumn 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 C3-2, WT4-1 and OC1. Also expected but not collected was the caddis fly family, Leptoceridae, at C2-1, C2-2, C3-1, C4-1, C4-2, WT4-1, WT4-2, WT5-1 and WT5-2.

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

System	Location	Site	Site Code	OE50	Band
Tributary C	1	1	C1-1	0.55	B
	1	2	C1-2	0.74	B
	2	1	C2-1	0.28	C
	2	2	C2-2	0.71	B
	3	1	C3-1	0.65	B
	3	2	C3-2	0.64	B
	4	1	C4-1	0.18	C
	4	2	C4-2	0.37	C
Waratah Rivulet	3	1	WT3-1	0.74	B
	3	2	WT3-2	0.53	B
	4	1	WT4-1	0.74	B
	4	2	WT4-2	0.53	B
	5	1	WT5-1	0.46	C
	5	2	WT5-2	0.35	C
Woronora River	1	1	WR1-1	0.55	B
	1	2	WR1-2	0.28	C
O'Hares Creek	1	1	OC1	0.74	B
	1	2	OC2	0.44	C

Quantitative Assessment

A total of 2,195 individuals from 42 macroinvertebrate taxon were collected from sites using the quantitative sampling technique (Appendix 5). The most abundant macroinvertebrate taxon was the Leptophlebiidae (1,359 individuals) followed by the Chironomidae (146 individuals), Caenidae (98 individuals), Dytiscidae (89 individuals) and the Baetidae (86 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 WT5 (6 individuals) and Site OC1 (one 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 the Waratah Rivulet (Figure 2). The total abundance of macroinvertebrates was greatest at Location 3 sampled on the Waratah Rivulet, followed by Location 4, also situated on the Waratah Rivulet (Figure 3).

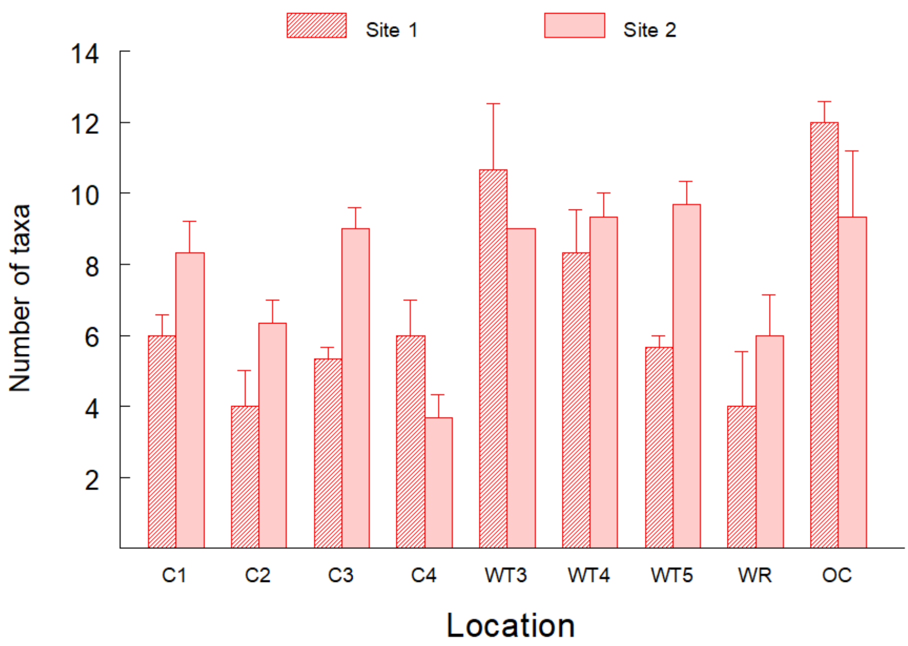


Figure 2. Mean (+SE) diversity of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

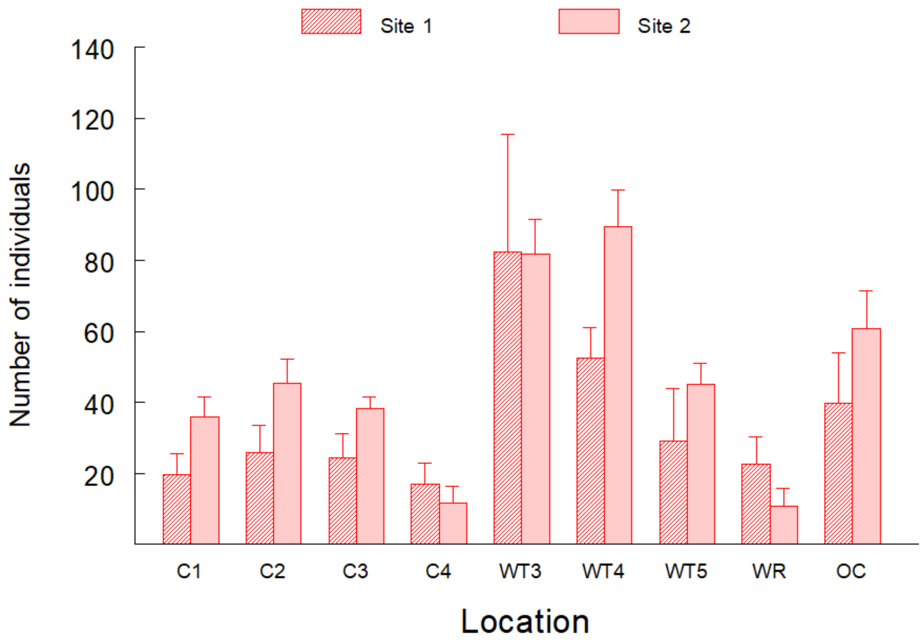


Figure 3. Mean (+SE) abundance of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

3.1.4 Aquatic Macrophytes

A total of 19 aquatic macrophyte species were found in quantitative samples at sites on Tributary C/Eastern Tributary (C1: 8 species, C2: 6 species, C3: 7 species, C4: 7 species), Waratah Rivulet (WT3: 10 species, WT4: 6 species, WT5: 7 species), Woronora River (9 species) and O'Hares Creek (13 species) (Appendix 3b).

In general, mean percentage cover of macrophytes was greatest at Location C3 and WT4 situated on the Waratah Rivulet followed by WR situated on the Woronora River (Figure 4). 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 5).

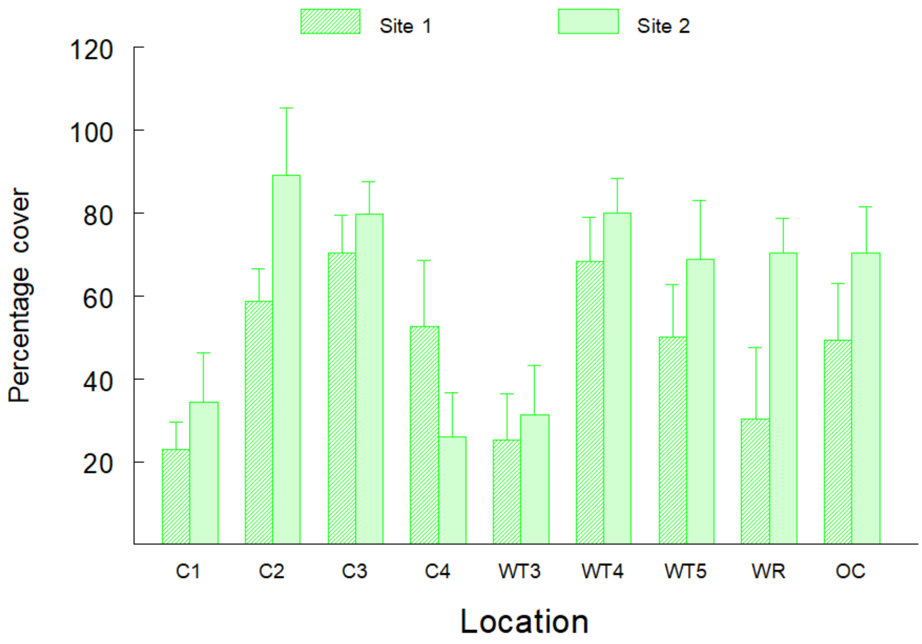


Figure 4. Mean (+SE) percentage cover of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

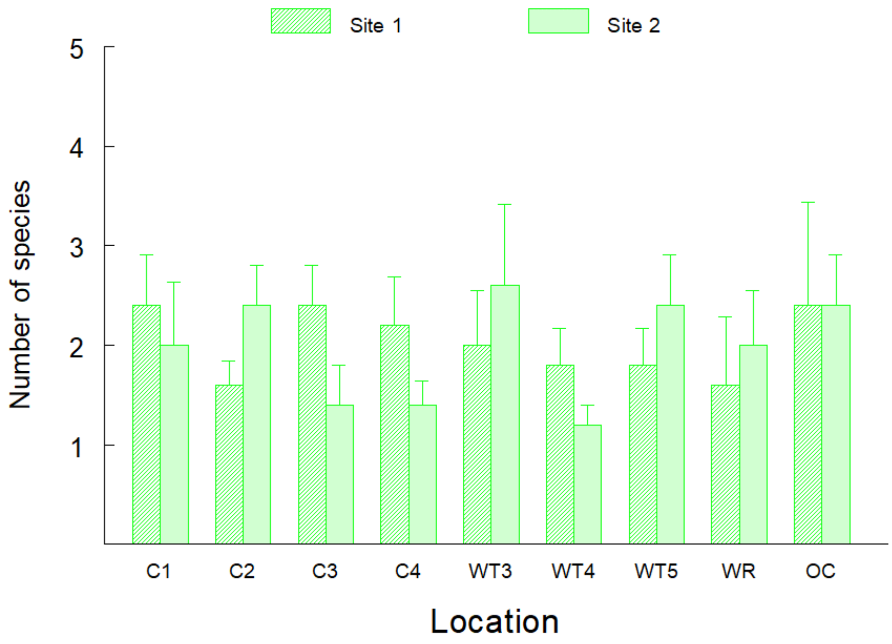


Figure 5. Mean (+SE) diversity of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], WR – Woronora River, OC – O'Hares Creek).

4.0 TEMPORAL ANALYSES

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

4.1 Longwalls 20-22 Mining Area

The objective of the following comparisons of aquatic macroinvertebrates and macrophytes was to determine whether any changes may have occurred at sampling locations in Tributary C/Eastern Tributary (Section 4.1.1) and the Waratah Rivulet (Section 4.1.2) following the commencement of mining of the Longwalls 20-22 mining area, in relation to Control locations. Two to four replicate times (spring 2008 or spring 2009[7] to autumn 2010) have been sampled within the 'Before' commencement of Longwall 20 period and 20 replicate times (spring 2010 to autumn 2020) have been sampled within the 'After' 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).

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.

[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 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

<u>Quantitative Assessment</u>

Location C1 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

Multivariate and univariate analyses of the Before- vs After-commencement of mining monitoring data indicated that to date, any effect of longwall mining on assemblages of aquatic macroinvertebrates at Location C1 was within the range of natural variability in these assemblages as measured by the control locations.

Current Survey (Autumn 2020)

Multivariate analyses did not detect a significant Before- vs After- difference in the structure of assemblages of aquatic macroinvertebrates at Location C1 in relation to the control locations (Table 4, Figure 6a). Similar to the findings of the previous survey, 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 right of the diagram, compared to those from O’Hares Creek, which occur more in the upper left (Figure 6a). There does appear to be greater dispersion among centroids representing the assemblage at Location C1 than for each of the control locations (Figure 6a).

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 increased its contribution to assemblages at Location C1 (Before: 5.6 %; After: 55.0 %) and O'Hares Creek (Before: 8.8 %, After: 36.6 %) between Periods but changed little at the Woronora River Location (Before: 16.1 %, After: 24.0 %).

Atyid shrimps made a larger contribution to the structure of assemblages at Location C1 within the Before- (59.6 %) than After-period (4.9 %) but changed little at the Woronora River (Before: 72.8 %; After: 63.4 %) and O'Hares Creek (Before: 4.9 %; After: 4.7 %) locations.

Univariate analyses have found no evidence of significant change in mean diversity or abundance of macroinvertebrates or mean numbers of Leptophlebiidae and Atyidae at Location C1 that may have resulted from mining of Longwalls 20-22 (Table 5, Figure 7a-d).

In general, macroinvertebrate diversity at Location C1 was similar to the control locations in autumn 2020 (T24) (Figure 7a). Greater numbers of individuals were collected at Location C1 in autumn 2020 (T23) than in spring 2019 (T23) (Figure 7b). Small numbers (three individuals) of Atyidae were collected at Location C1 for the first time since autumn 2018 (T20) (Figure 7d). In contrast to the control locations, numbers of Leptophlebiidae increased at Location C1 between the spring 2019 and autumn 2020 surveys (Figure 7c).

Location C2 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

Multivariate analyses of the aquatic macroinvertebrate data have consistently found no significant difference between the structure of assemblages at Location C2 and the control locations that would indicate an impact from mining of Longwalls 20-22 (Figure 6b). Macroinvertebrate taxa that contributed most to the structure of assemblages at Location C2 and the Control locations were mayflies (Leptophlebiidae) and freshwater shrimp (Atyidae).

Univariate analyses have consistently found no significant difference to total diversity or abundance of macroinvertebrates or numbers of Leptophlebiidae at Location C2 compared to the controls (Figures 7a-c).

Analyses detected a significant difference in mean numbers of Atyidae at Location C2 within the after-mining period in spring 2015 (T15) and autumn 2017 (T18), but not subsequently (Figure 7d).

Current Survey (Autumn 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 6b). Similar to the findings for Location C1, the 'Location' factor contributed most (19 %) to the components of variation (Table 4, Figure 6b).

Although not significant, the PCoA indicates greater variability in the structure of the assemblage at Location C2 over time than at the control locations (Figure 6b). Notably, the centroid for the spring 2019 and autumn 2020 surveys plot separately from all other times of sampling (Figure 6b). This pattern coincides with the finding that Leptophlebiidae was the only species ranked by SIMPER to contribute to the structure of the assemblage at Location C2 in spring 2019 (93%) and autumn 2020 (92.4%). Also notable is that within the Before-mining period, SIMPER ranked Atyidae as contributing most to the assemblage at Location C2 (71%), followed by the Leptophlebiidae (12%).

To date, univariate analyses have found no evidence of significant change in mean diversity, abundance or numbers of individuals of Leptophlebiidae at Location C2 that may have resulted from mining of Longwalls 20-22 (Table 5, Figure 7a-c). Graphically, it can be seen that spikes in the total abundance of aquatic macroinvertebrates and numbers of Leptophlebiidae have been common at Location C2 and the control locations throughout the study period (Figures 7b&c). Similar numbers of individuals, taxa and Leptophlebiidae were collected at Location C2 and the control locations in autumn 2020 (Figures 7b&c).

Analyses detected a significant difference in mean numbers of Atyidae at Location C2 within the after-mining period in spring 2015 (T15) and autumn 2017 (T18), but not on this sampling occasion (Table 5, Figure 7d). Atyidae have rarely been collected at Location C2 by surveys done since spring 2017 (T19) (Figure 7d).

Location C3 v Controls

Prior Surveys (Spring 2009 – Spring 2019)

Multivariate analyses have consistently detected significant small-scale interactions between time (nested in periods) and location (nested within type of creek) for Location C3, but not between Period (Before- vs After-) and Impact (Location C3 vs Control locations) (Figure 6c). A significant interaction between Time and Location indicates that differences in the structure of assemblages of macroinvertebrates between Location C3 and the control locations depended on the time of sampling (Figure 6c).

Univariate analyses have consistently found no significant interactions related to the commencement of mining of the Longwalls 20-22 mining area (Figures 7a-d).

Current Survey (Autumn 2020)

Multivariate analyses did not detect a significant change in the structure of the assemblages of aquatic macroinvertebrates at Location C3 in relation to the control locations (Table 4, Figure 6c). Leptophlebiidae contributed most to the structure of the assemblage at Location C3 in spring 2019 (84.2 %), followed by the Megapodagrionidae (3.1 %) and Dytiscidae (2.9 %) (SIMPER).

Univariate analyses did not detect a significant difference in mean total diversity and abundance or mean numbers of Leptophlebiidae and Atyidae at Location C3 in autumn 2020, in relation to the control locations (Table 5, Figures 7a-d). Graphically, diversity changed little at C3 and the control locations between the spring 2019 (T21) and autumn 2020 (T22) surveys (Figure 7a). Similar to the control locations, mean abundance and numbers of Leptophlebiidae decreased at Location C3 between the spring 2019 (T21) and autumn 2020 (T22) surveys (Figure 7b&c). Very few Atyidae have been collected at Location C3 since spring 2016 (T17) (Figure 7d).

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**	**35694**	**2.56**	**0.01**	**8.64**
Impact = Im	1	17478	0.26	1.00	0.00
Time (Pe) = Ti(Pe)	**22**	**7563**	**1.85**	**0.00**	**8.43**
Location (Im) = Lo(Im)	**1**	**77930**	**8.84**	**0.00**	**17.16**
Pe x Im	1	12327	1.20	0.28	4.14
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5052**	**1.70**	**0.02**	**4.13**
Pe x Lo(Im)	**1**	**7993**	**1.69**	**0.02**	**6.06**
Ti(Pe) x Im	**22**	**5651**	**1.38**	**0.00**	**7.99**
Pe x Si(Lo(Im))	3	2386	0.80	0.78	0.00
Ti(Pe) x Lo(Im)	**22**	**4097**	**1.38**	**0.00**	**7.86**
Ti(Pe) x Si(Lo(Im))	**66**	**2969**	**1.65**	**0.00**	**11.33**
Residual	288	1795			24.27
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	24955	1.73	0.06	6.73
Impact = Im	1	19767	0.29	1.00	0.00
Time (Pe) = Ti(Pe)	22	**8835**	**2.16**	**0.00**	**10.82**
Location (Im) = Lo(Im)	1	**77936**	**8.67**	**0.00**	**18.76**
Pe x Im	1	7278	0.90	0.64	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**5199**	**1.99**	**0.00**	**5.05**
Pe x Lo(Im)	1	**7985**	**1.67**	**0.02**	**6.48**
Ti(Pe) x Im	22	4689	1.14	0.16	5.41
Pe x Si(Lo(Im))	3	2259	0.86	0.69	0.00
Ti(Pe) x Lo(Im)	22	**4097**	**1.57**	**0.00**	**9.87**
Ti(Pe) x Si(Lo(Im))	66	**2618**	**1.55**	**0.00**	**11.09**
Residual	288	1683			25.79
C3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	10838	1.36	0.19	5.44
Impact = Im	1	15278	0.37	0.99	0.00
Time (Pe) = Ti(Pe)	20	**7366**	**2.03**	**0.00**	**10.23**
Location (Im) = Lo(Im)	1	**46017**	**6.71**	**0.00**	**20.69**
Pe x Im	1	4038	0.96	0.54	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	3656	1.26	0.18	3.93
Pe x Lo(Im)	1	3273	1.18	0.24	4.35
Ti(Pe) x Im	20	4683	1.29	0.05	7.67
Pe x Si(Lo(Im))	3	1623	0.56	0.96	0.00
Ti(Pe) x Lo(Im)	20	**3634**	**1.25**	**0.02**	**7.38**
Ti(Pe) x Si(Lo(Im))	60	**2905**	**1.98**	**0.00**	**14.67**
Residual	264	1467			25.65

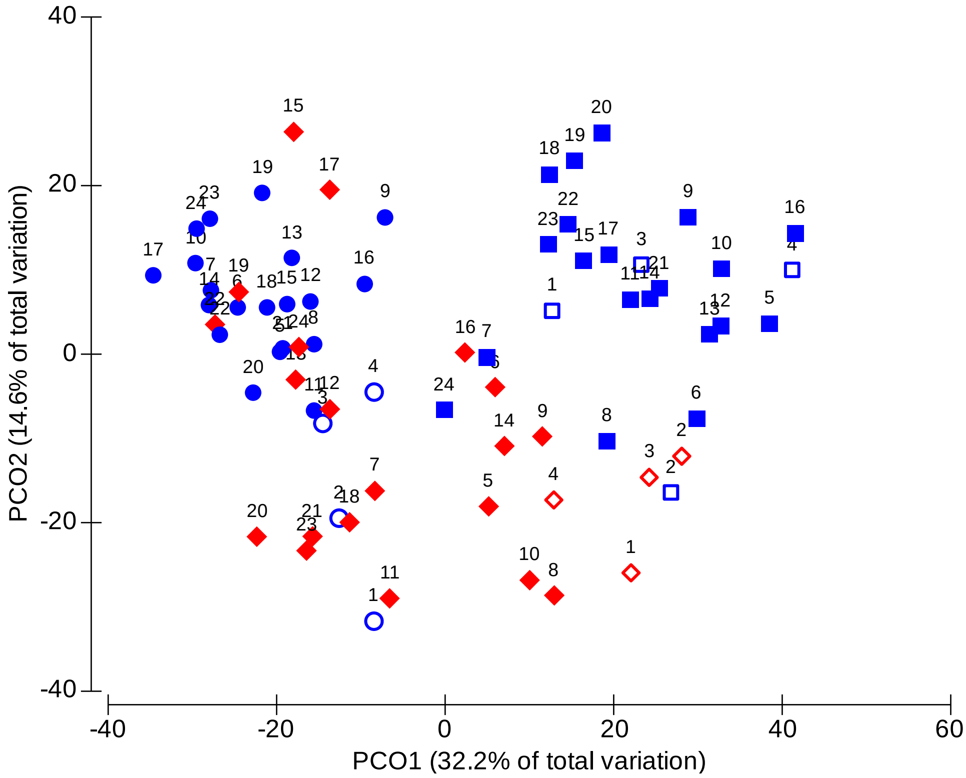
Bold numbers indicate significant results at $P < 0.05$.

Table 5. PERMANOVA analysis on diversity, abundance, and number of Leptophlebiidae and Atyidae of the macroinvertebrate data 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	31.52	1.16	9755	1.66	4690	2.19	67	0.79
Impact = Im	1	317.42	0.60	13365	1.89	2	0.12	1028	0.16
Time (Pe) = Ti(Pe)	22	**45.89**	**2.09**	6163	3.30	**1748**	**9.69**	363	1.03
Location (Im) = Lo(Im)	1	**548.83**	**15.81**	5850	2.64	154	2.30	**8434**	**13.07**
Pe x Im	1	30.17	3.21	224	0.68	326	0.27	540	2.45
Site (Lo(Im))	3	13.44	1.24	952	0.60	86	0.19	309	1.52
Pe x Lo(Im)	1	0.25	0.46	852	1.14	**480**	**3.84**	163	1.02
Ti(Pe) x Im	22	15.97	0.73	2201	1.18	**1423**	**7.89**	200	0.57
Pe x Si(Lo(Im))	3	2.04	0.19	281	0.18	64	0.14	8	0.04
Ti(Pe) x Lo(Im)	22	**21.96**	**2.03**	1866	1.17	180	0.39	352	1.73
Ti(Pe) x Si(Lo(Im))	66	10.84	1.28	**1589**	**2.57**	**459**	**2.52**	**204**	**1.65**
Residual	288	8.49		619		182		124	
C2		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	128.48	3.06	6915	2.59	2393	2.25	58	0.59
Impact = Im	1	463.48	0.86	16196	2.61	113	0.86	130	0.06
Time (Pe) = Ti(Pe)	22	**48.91**	**2.23**	2539	1.36	**665**	**3.69**	536	1.52
Location (Im) = Lo(Im)	1	**548.83**	**15.58**	5850	2.37	154	1.27	**8434**	**13.33**
Pe x Im	1	0.05	1.31	935	1.45	2	0.27	513	2.84
Site (Lo(Im))	3	13.86	1.53	1030	1.03	76	0.44	294	1.73
Pe x Lo(Im)	1	0.25	0.36	852	0.86	**480**	**3.16**	163	0.88
Ti(Pe) x Im	22	16.50	0.75	1081	0.58	186	1.03	142	0.40
Pe x Si(Lo(Im))	3	4.18	0.46	277	0.28	26	0.15	29	0.17
Ti(Pe) x Lo(Im)	22	**21.96**	**2.42**	**1866**	**1.86**	180	1.04	**352**	**2.06**
Ti(Pe) x Si(Lo(Im))	66	9.08	1.12	**1002**	**1.98**	**173**	**2.15**	**170**	**1.57**
Residual	288	8.13		505		80		108	
C3		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	0.13	0.36	741	0.73	1504	1.50	**655**	**7.28**
Impact = Im	1	149.46	0.41	7694	1.67	417	0.85	1067	0.23
Time (Pe) = Ti(Pe)	20	**60.86**	**2.59**	3620	1.79	**976**	**5.09**	141	0.38
Location (Im) = Lo(Im)	1	**400.30**	**6.86**	4226	1.84	171	1.60	**6046**	**8.72**
Pe x Im	1	32.58	2.53	86	1.19	36	0.33	184	1.96
Site (Lo(Im))	3	**36.52**	**3.28**	990	0.75	187	0.43	335	2.16
Pe x Lo(Im)	1	4.75	0.54	175	0.63	151	2.64	0	0.34
Ti(Pe) x Im	20	17.40	0.74	1592	0.79	**547**	**2.85**	285	0.76
Pe x Si(Lo(Im))	3	5.80	0.52	369	0.28	31	0.07	79	0.51
Ti(Pe) x Lo(Im)	20	**23.46**	**2.11**	2017	1.53	192	0.44	**376**	**2.42**
Ti(Pe) x Si(Lo(Im))	60	11.14	1.34	**1317**	**2.22**	**437**	**3.05**	**155**	**1.75**
Residual	264	8.29		592		143		89	

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

A



B

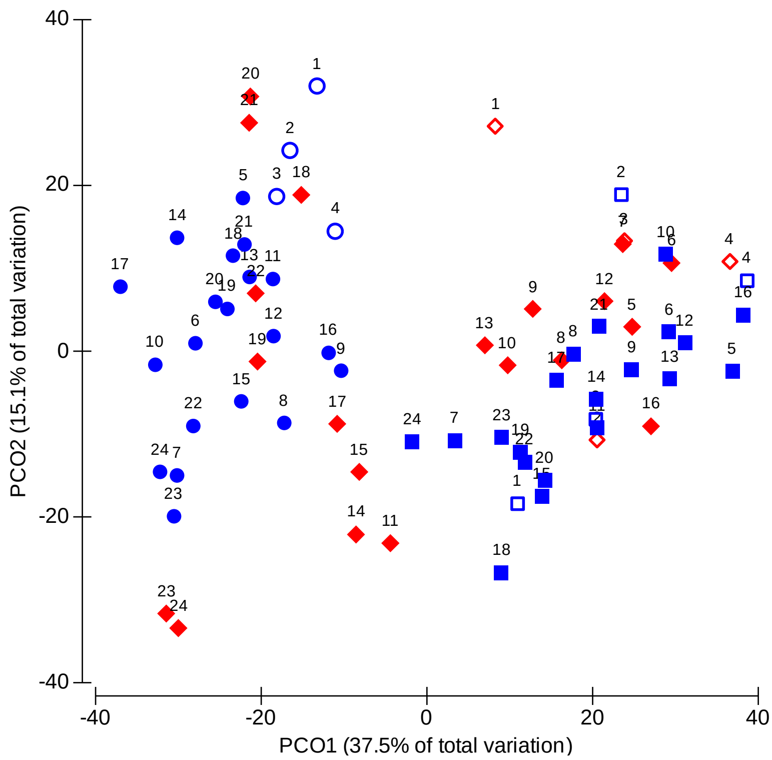


Figure 6. PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at locations a) C1 and b) C2 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2008 (T1) and spring 2019 (T23). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 20-22.

C

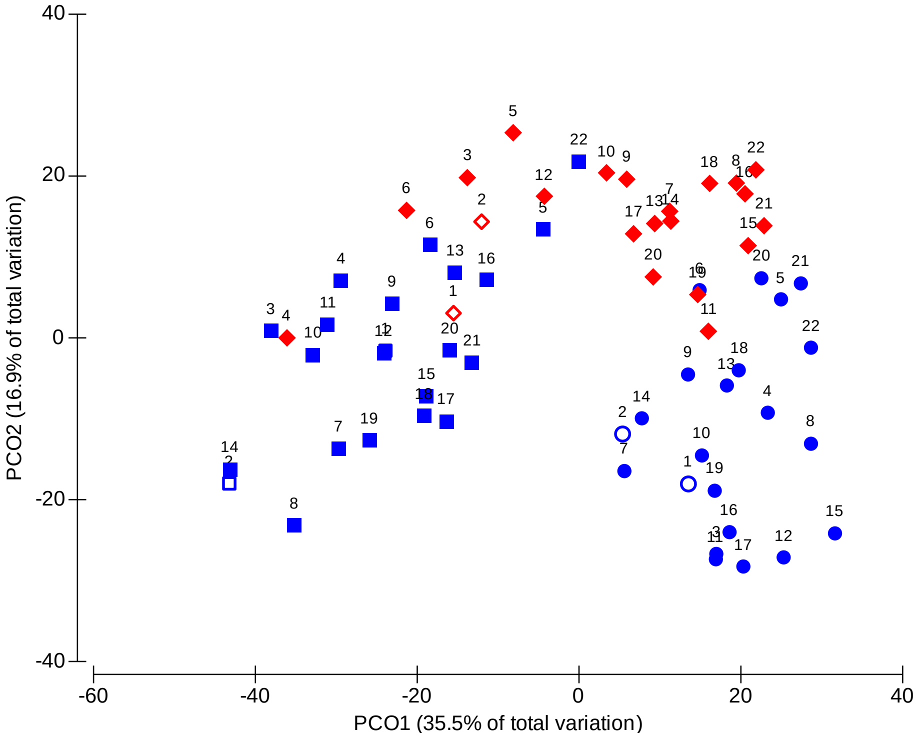
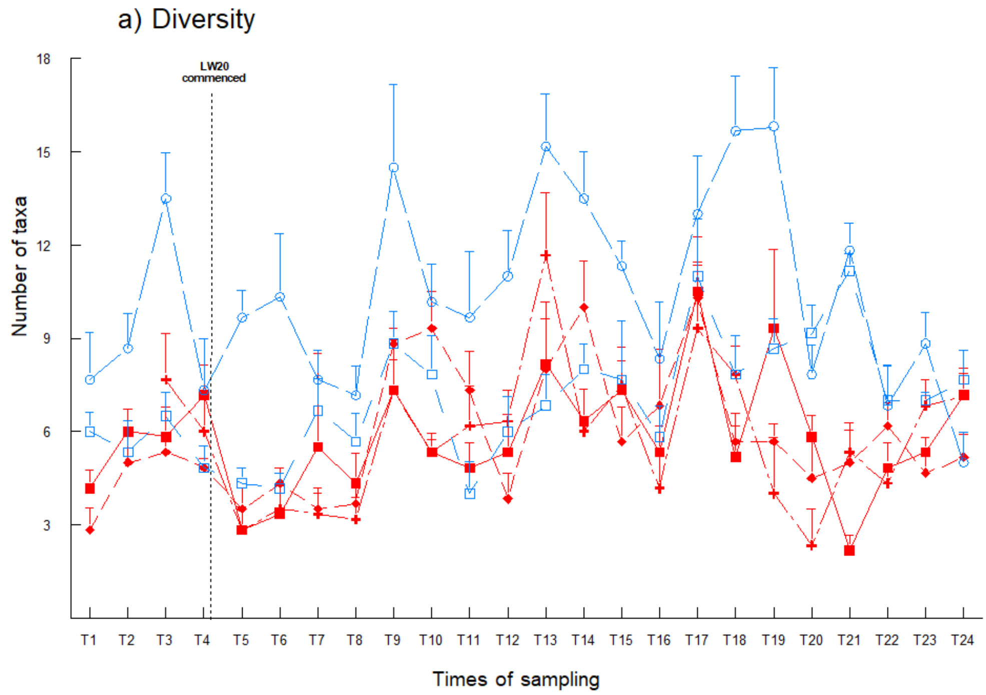


Figure 6 (Cont'd). c) Location C3 and two control locations (Woronora River and O'Hares Creek) for each time of sampling (n = 6). Red triangles: Tributary C; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: Before-commencement of mining; Filled symbols: after-mining. Numbers indicate sampling time. NB Sampling of location C3 commenced in spring 2009.



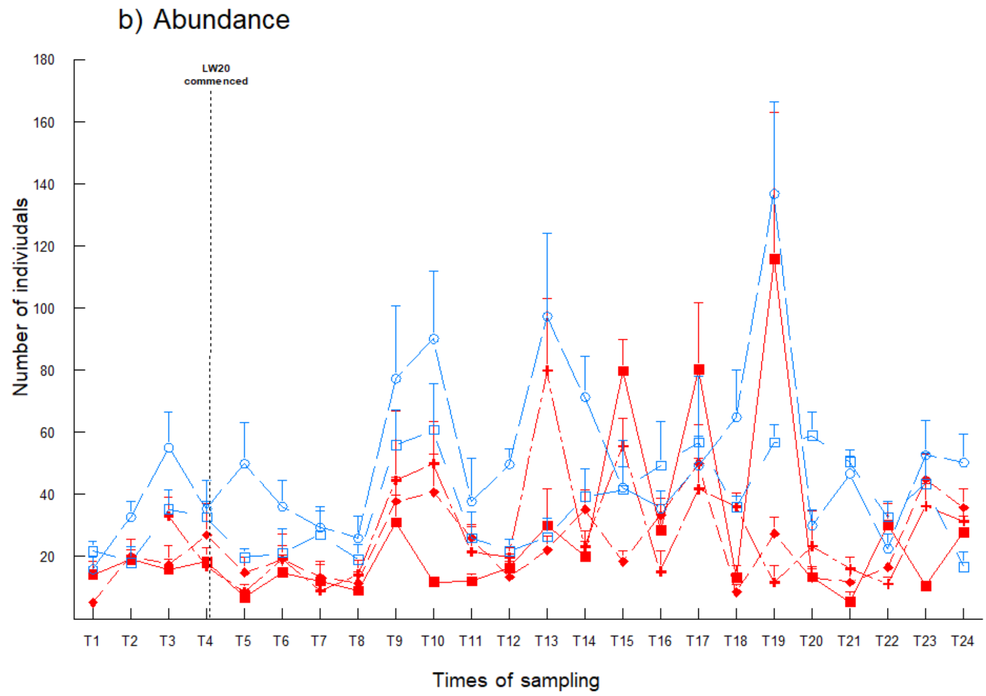
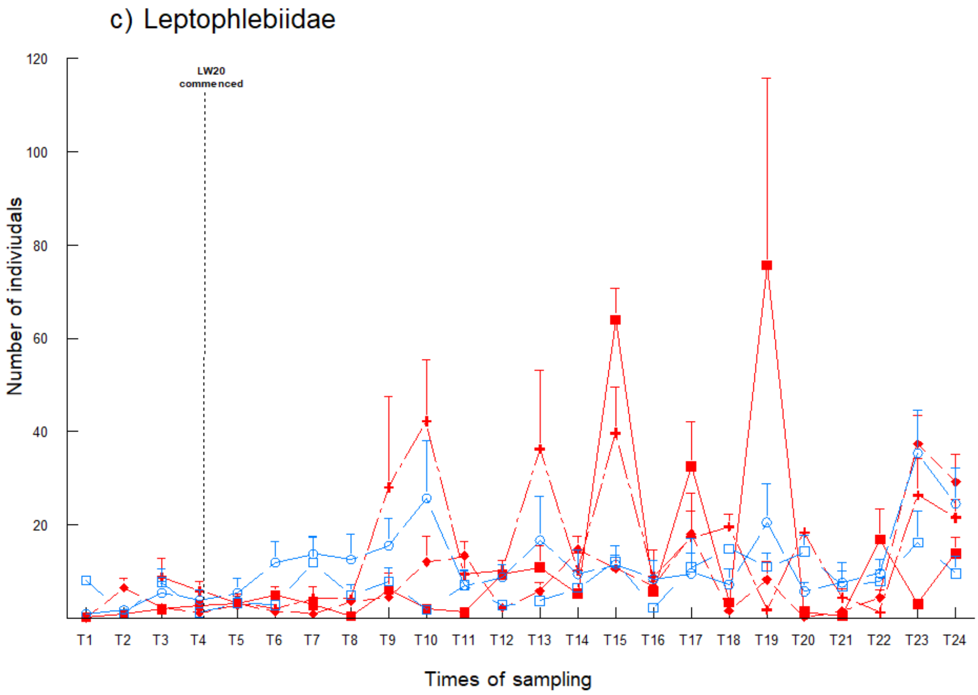


Figure 7. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).



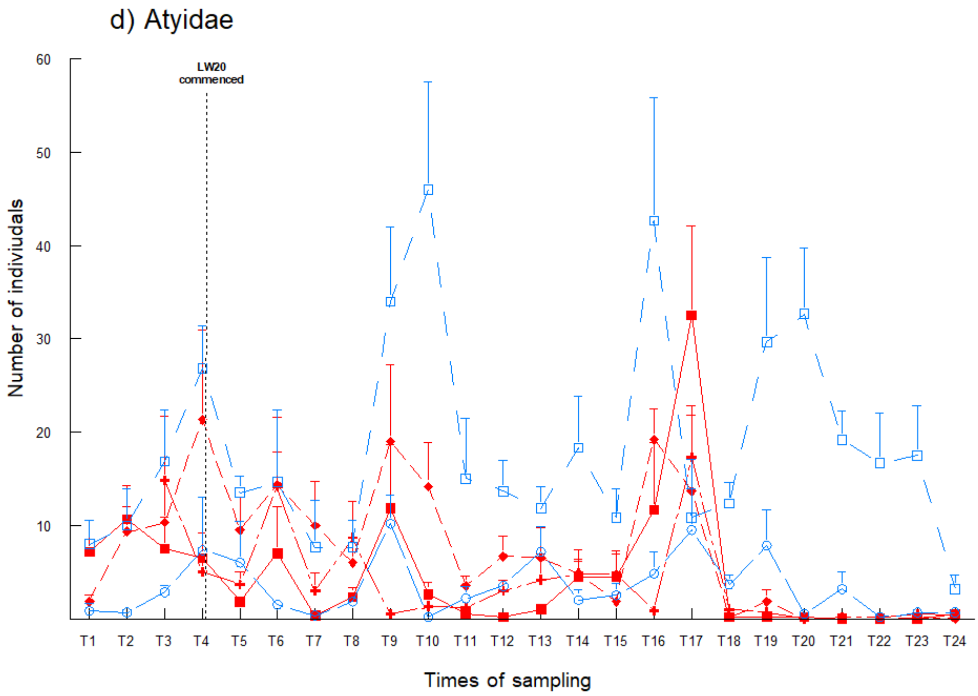


Figure 7 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).

<u>AUSRIVAS Analyses</u>

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 8a). 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 8b). With the exception of one sample (i.e. Location C3 in spring 2014), all of the OE50 Taxa scores were below 1.00 (Figure 8a&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 8a). Four Band A scores have been obtained in spring (Locations C3, WR and OC in spring 2014 and Location OC in spring 2017) (Figure 8a&b).

The results from this sampling occasion (autumn 2020) indicated that the condition of aquatic macroinvertebrate fauna at Location C2 had increased by one AUSRIVAS Band level, from Band C (severely impaired) to Band B (significantly impaired), since the spring 2019 survey (Figure 8a&b). The opposite pattern was observed at the Woronora River location, decreasing from Band B to Band C between surveys (Figure 8a&b). OE50 Taxa Score's recorded at Location C1, C3 and OC changed little between spring 2019 and autumn 2020 (Figure 8a&b).

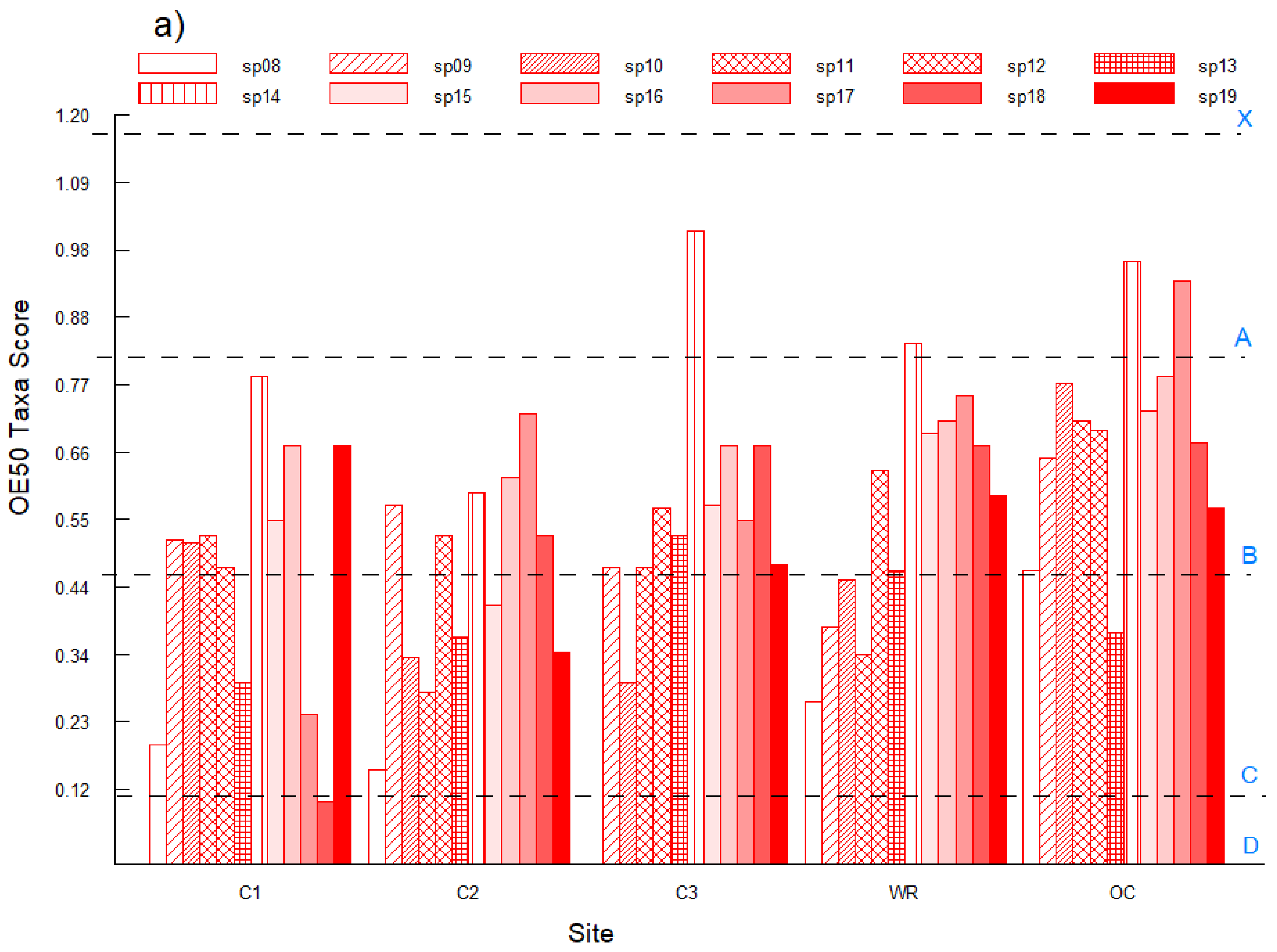


Figure 8a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2008 and 2020 (*n* = 2).

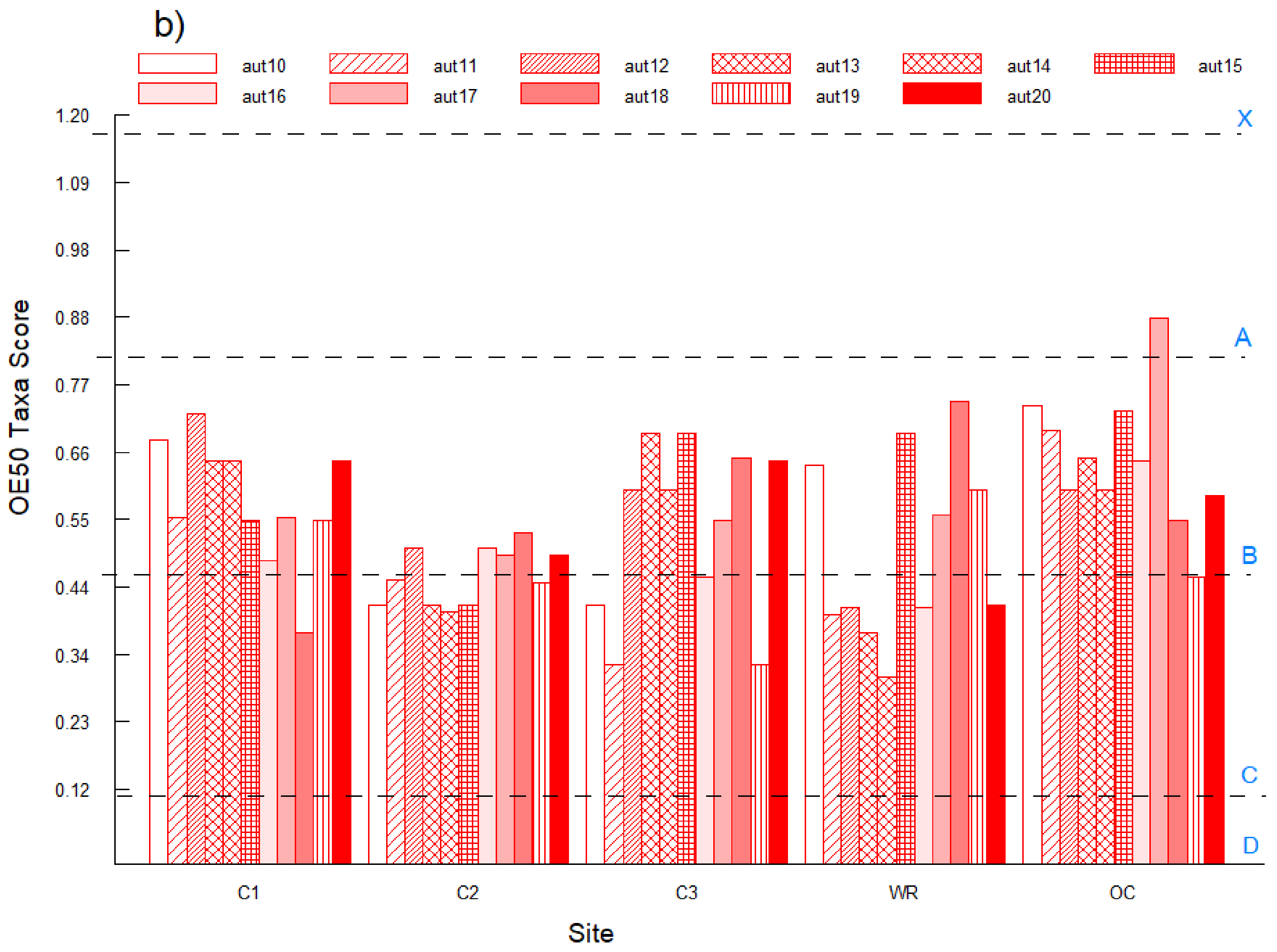


Figure 9b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2008 and 2020 (*n* = 2).

4.1.1.2 Aquatic Macrophytes

Location C1 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

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 (Autumn 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 among locations depended on the time of sampling, evidenced by the significant Ti(Pe) x Lo(Im) interaction and Ti(Pe) x Impact results, not mining related activities (Table 6, Figure 9a).

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 9a). 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 (Table 7, Figures 10a&b).

Graphically it appears that there has been a gradual decrease in mean percentage cover at Location C1 since the spring 2015 (T15) survey (Figure 10b). It is likely that mining related drops in pool water level at Location C1 have contributed to the observed decline in aquatic plants in the riparian zone.

Location C2 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

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 locations (Figure 9b). 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 10a&b).

Current Survey (Autumn 2020)

Analyses of temporal changes in the structure of assemblages of aquatic macrophytes (Table 6, Figure 9b) and univariate estimates of total cover and species diversity (Table 7, Figures 10a&b) at Location C2 found no significant changes in relation to control locations that would indicate an impact from mining. In autumn 2020, *Baumea juncea* contributed most (85 %) to the structure of the assemblage at Location C2, followed by *Gleichenia dicarpa* (5 %) and *Lepidosperma filiforme* (5 %) (SIMPER).

Graphically, it can be seen that since the spring 2019 survey (T23), mean diversity and percentage cover of macrophytes increased at Location C2 (Figures 10a&b).

Location C3 v Controls

Prior Surveys (Spring 2009 – Spring 2019)

Analyses of Before- (spring 2009 – autumn 2010) vs After- (spring 2010 – spring 2019) mining changes in the structure of assemblages of aquatic macrophytes (Figure 9c) and univariate estimates of total cover and species diversity (Figures 10a&b) have consistently found no significant changes at Location C3 in relation to control locations that would indicate an impact from mining.

Current Survey (Autumn 2020)

Consistent with the findings of the previous surveys, multivariate analyses found a significant interaction between Time nested in Period and Location nested within type of creek (impact or control), indicating that differences in the structure of assemblages of macrophytes between Location C3 and the control locations depended on the time of sampling not mining related activities (Table 6, Figure 9c). In autumn 2020, *Gleichenia dicarpa* contributed most to the structure of the assemblage (46 %) at Location C3, followed by *Lomandra fluviatilis* (30 %) and *Empodisma minus* (20 %) (SIMPER).

Similar to the findings of the previous report, univariate analyses of total diversity found no significant difference at any of the scales examined (Table 9, Figure 10a). 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 the structure of assemblages of macrophytes among locations depended on the time of sampling not mining related activities (Table 7, Figure 10b).

Graphically, it can be seen that diversity and cover of macrophytes in the riparian zone at Location C3 was similar among the autumn 2020, spring 2019 and autumn 2019 surveys (Figures 10a&b). Since the spring 2019 survey, mean cover appears to have increased at Location C3 but decreased at each of the control locations (Figure 10b).

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	24014	1.26	0.24	3.73
Impact = Im	1	50001	1.61	0.11	7.06
Time (Pe) = Ti(Pe)	22	**6481**	**1.66**	**0.00**	**6.46**
Location (Im) = Lo(Im)	1	**28075**	**1.54**	**0.03**	**5.92**
Pe x Im	1	14873	0.89	0.64	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**16175**	**5.79**	**0.00**	**9.32**
Pe x Lo(Im)	1	**15729**	**1.57**	**0.03**	**6.62**
Ti(Pe) x Im	22	**5386**	**1.38**	**0.01**	**6.92**
Pe x Si(Lo(Im))	3	**7868**	**2.82**	**0.00**	**8.12**
Ti(Pe) x Lo(Im)	22	**3912**	**1.40**	**0.00**	**6.97**
Ti(Pe) x Si(Lo(Im))	66	2792	0.80	1.00	0.00
Residual	576	3492			38.89
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	21586	1.23	0.26	3.56
Impact = Im	1	46027	1.43	0.17	6.30
Time (Pe) = Ti(Pe)	22	**5210**	**1.39**	**0.00**	**5.11**
Location (Im) = Lo(Im)	1	**30534**	**1.68**	**0.02**	**6.96**
Pe x Im	1	16842	1.04	0.46	2.14
Site (Lo(Im)) = Si(Lo(Im))	3	**16183**	**5.38**	**0.00**	**9.68**
Pe x Lo(Im)	1	**15370**	**1.78**	**0.01**	**7.58**
Ti(Pe) x Im	22	4359	1.16	0.10	4.68
Pe x Si(Lo(Im))	3	**6562**	**2.18**	**0.00**	**7.11**
Ti(Pe) x Lo(Im)	22	**3743**	**1.24**	**0.01**	**5.90**
Ti(Pe) x Si(Lo(Im))	66	3009	0.85	1.00	0.00
Residual	576	3548			41.01
C3					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	14479	1.47	0.14	5.82
Impact = Im	1	24430	1.36	0.20	6.56
Time (Pe) = Ti(Pe)	20	4461	1.15	0.18	3.53
Location (Im) = Lo(Im)	1	**16749**	**1.67**	**0.02**	**7.84**
Pe x Im	1	6613	0.87	0.66	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	**7997**	**2.58**	**0.00**	**8.68**
Pe x Lo(Im)	1	8010	1.32	0.12	6.41
Ti(Pe) x Im	20	4092	1.06	0.34	3.09
Pe x Si(Lo(Im))	3	4570	1.48	0.07	6.73
Ti(Pe) x Lo(Im)	20	**3865**	**1.25**	**0.02**	**6.56**
Ti(Pe) x Si(Lo(Im))	60	3096	0.86	0.99	0.00
Residual	528	3586			44.78

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	**24.15**	**3.90**	766	0.33
Impact = Im	1	0.06	0.56	308	0.39
Time (Pe) = Ti(Pe)	22	**5.10**	**2.36**	**3509**	**2.96**
Location (Im) = Lo(Im)	1	0.02	0.37	1200	0.61
Pe x Im	1	0.13	0.41	1119	0.45
Site (Lo(Im)) = Si(Lo(Im))	3	1.36	1.05	**1830**	**2.84**
Pe x Lo(Im)	1	1.65	1.15	2495	0.94
Ti(Pe) x Im	22	3.92	1.81	**2633**	**2.22**
Pe x Si(Lo(Im))	3	0.40	0.31	**2165**	**3.35**
Ti(Pe) x Lo(Im)	22	2.16	1.67	**1186**	**1.84**
Ti(Pe) x Si(Lo(Im))	66	1.29	0.98	646	1.08
Residual	576	1.32		595	
C2		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	**36.69**	**4.96**	1315	0.91
Impact = Im	1	2.00	1.62	2	0.77
Time (Pe) = Ti(Pe)	22	**6.85**	**3.33**	1428	1.02
Location (Im) = Lo(Im)	1	0.20	0.53	571	0.45
Pe x Im	1	0.68	0.84	174	0.56
Site (Lo(Im)) = Si(Lo(Im))	3	0.79	0.61	1761	2.10
Pe x Lo(Im)	1	0.96	0.90	1538	0.80
Ti(Pe) x Im	22	2.30	1.12	1241	0.89
Pe x Si(Lo(Im))	3	0.44	0.34	1563	1.86
Ti(Pe) x Lo(Im)	22	2.06	1.58	1396	1.66
Ti(Pe) x Si(Lo(Im))	66	1.30	0.97	**840**	**1.73**
Residual	576	1.34		485	
C3		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	6.28	1.33	17	0.69
Impact = Im	1	0.17	0.73	4	1.54
Time (Pe) = Ti(Pe)	20	3.30	1.64	1506	0.99
Location (Im) = Lo(Im)	1	1.68	0.80	382	0.42
Pe x Im	1	0.00	0.47	467	1.48
Site (Lo(Im)) = Si(Lo(Im))	3	1.75	1.31	883	1.39
Pe x Lo(Im)	1	2.95	1.89	734	0.49
Ti(Pe) x Im	20	1.32	0.66	614	0.40
Pe x Si(Lo(Im))	3	0.26	0.19	1244	1.96
Ti(Pe) x Lo(Im)	20	2.02	1.50	**1526**	**2.40**
Ti(Pe) x Si(Lo(Im))	60	1.34	0.96	635	1.23
Residual	528	1.39		516	

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

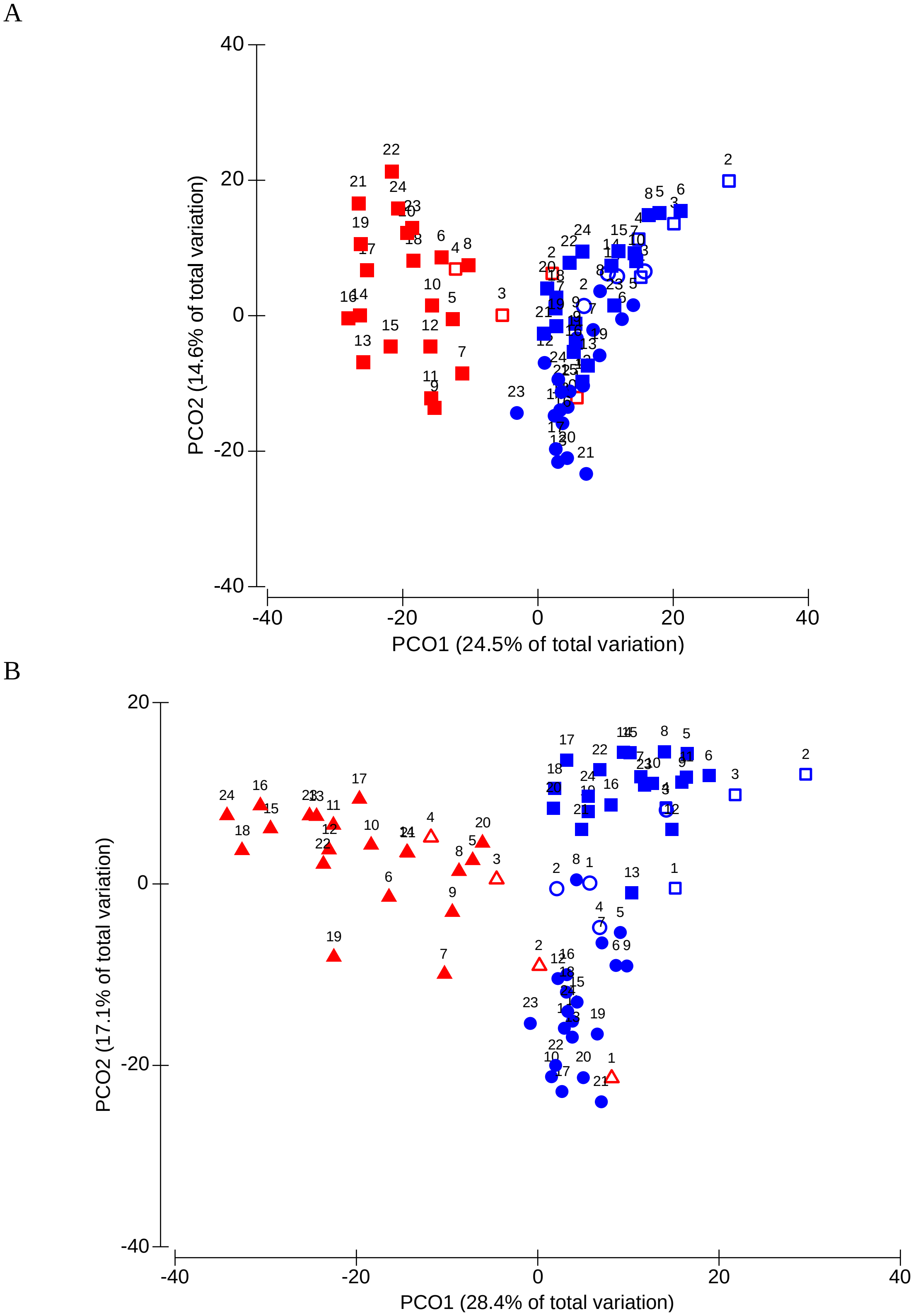


Figure 10. PCoA of centroids for macrophyte data for a) Location C1 and b) Location C2 and two control locations (Woronora River and O'Hares Creek) for each time of sampling (*n*= 10). Red symbols: Potential 'impact' locations; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: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

C

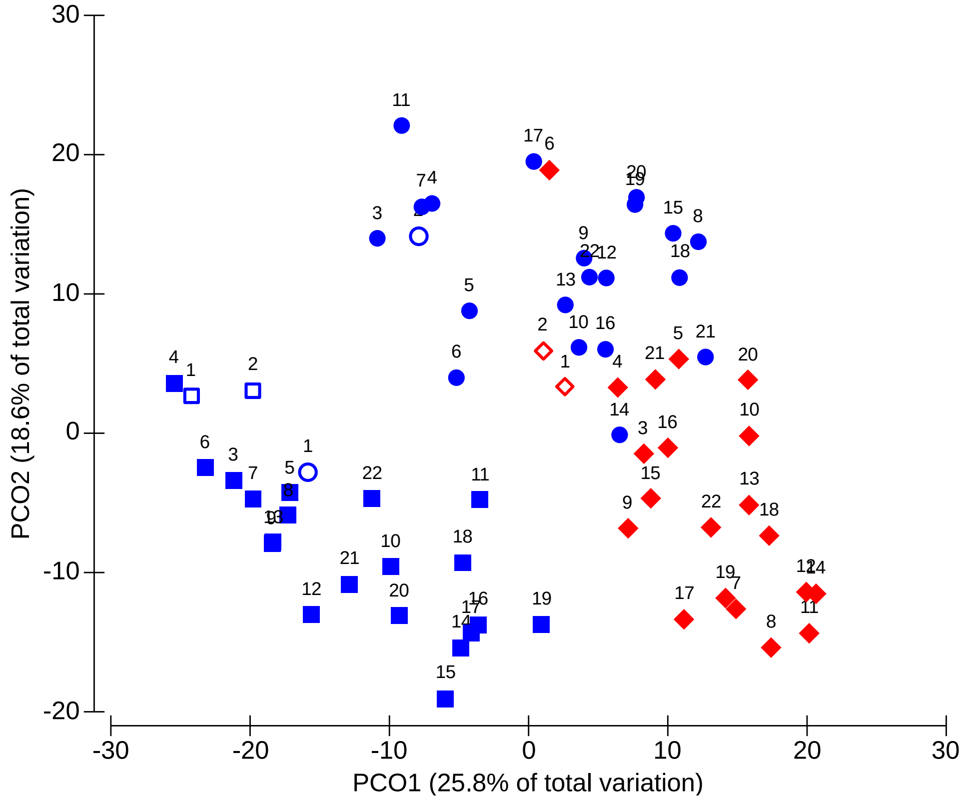


Figure 9 (Cont'd). PCoA of centroids for macrophyte data for c) Location C3. Red triangles: Potential 'impact' location; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: Before-mining; Filled symbols: After-mining. Numbers indicate sampling time. NB sampling of location C3 commenced in spring 2009.

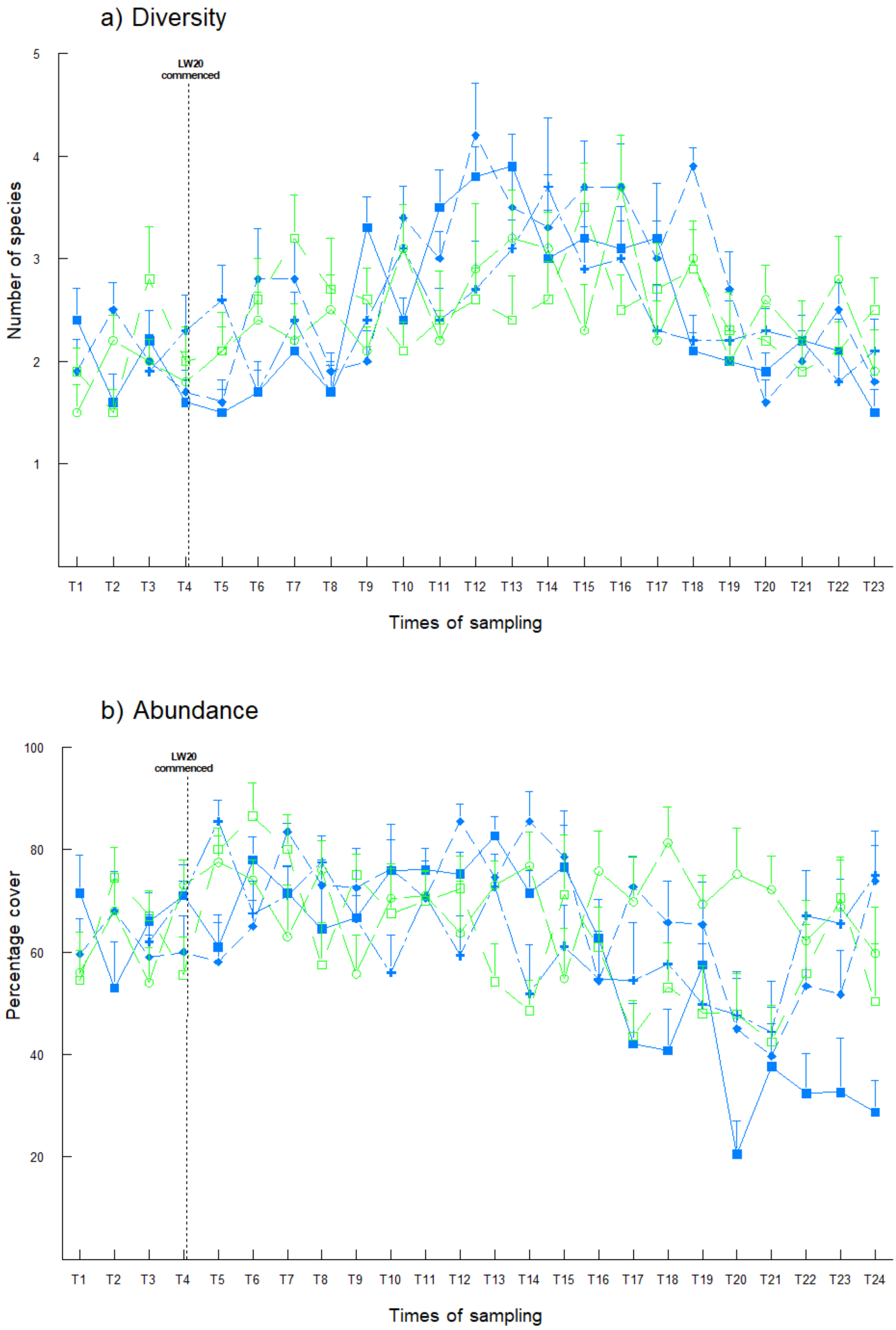


Figure 11. Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 10). NB Sampling of location C3 commenced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

4.1.2 Waratah Rivulet

PERMANOVA was used to test the null hypothesis of no significant change in aquatic macroinvertebrate and macrophyte indicators at Waratah Rivulet locations (Locations WT3, WT4 and WT5) Before- (spring 2008 to autumn 2010) vs After- (spring 2010 to autumn 2020) mining of the Longwalls 20-22 area in relation to control locations (Woronora River and O'Hares Creek). Mining of Longwalls 20-22 commenced in May 2010 and was completed in April 2014.

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.

4.1.2.1 Aquatic Macroinvertebrates

<u>Quantitative Assessment</u>

Prior Surveys (Spring 2008 – Spring 2019)

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 (Autumn 2020)

Consistent with previous surveys, there was a significant interaction of the factors Location nested within Impact and Time nested within Period (i.e. Ti(Pe) x Lo(Im)) (Table 8, Figures 11a-c).

Most notably, the Principle Component Ordination (PCoA) of centroids for macroinvertebrate data suggests that the assemblage sampled at the Woronora River location regularly differed from the assemblage at the Waratah Rivulet locations and O'Hares Creek (Figures 11a-c: blue square symbols tend to group separately to blue circle and red 'other' symbols).

SIMPER analyses indicate that throughout the survey period, temporal differences at the Waratah Rivulet locations in relation to the control locations have been mostly due to differences in abundances of the macroinvertebrate taxa, particularly Atyidae and Leptophlebiidae, rather than the presence or absence of species.

Most notably, 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: 5.9 %; WT4: 8.7 %; WT5: 14.5 %) periods. In contrast, Atyidae differed little in its contribution to assemblages at the control locations (Before- WR: 72.5 %, OH: 4.9 %; After - WR: 63.6 %, OH: 4.8 %).

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: 42.6 %; WT4: 47.6 %; WT5: 35.4 %; WR: 24.0; OH: 37.1 %) period.

Similar to the findings of the spring 2016 (T15), autumn 2018 (T20), spring 2018 (T21), autumn 2019 (T22) and spring 2019 (T23) 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 12a). When PERMDISP was used to formally compare the apparent variability (dispersion), a non-significant result was obtained ($P = 0.319$). 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: 9.5; After: 8.0) between periods (Figure 12a).

Mean diversity did not differ significantly between periods at Location WT4 and Location WT5 in relation to the controls (Table 9, Figure 12a). Graphically, it can be seen that diversity changed little at the rivulet and control locations between the spring 2019 (T23) and autumn 2020 (T24) surveys (Figure 12a).

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 12b-d). Mean abundance of macroinvertebrates and Leptophlebiidae increased at each of the rivulet locations between spring 2019 (T23) and autumn 2020 (T24) (Figure 12b). Atyidae have consistently been most abundant at the Woronora River location, whilst similar numbers have been collected at the rivulet locations and at O'Hares Creek (Figure 12d).

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	15857	1.31	0.21	4.27
Impact = Im	**1**	**22772**	**0.33**	**1.00**	**0.00**
Time (Pe) = Ti(Pe)	**22**	**7626**	**1.88**	**0.00**	**9.64**
Location (Im) = Lo(Im)	**1**	**77404**	**8.37**	**0.00**	**19.14**
Pe x Im	1	6763	0.86	0.69	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5520**	**2.06**	**0.00**	**5.43**
Pe x Lo(Im)	**1**	**7608**	**1.53**	**0.03**	**6.08**
Ti(Pe) x Im	22	4961	1.23	0.05	6.89
Pe x Si(Lo(Im))	3	2690	1.00	0.45	0.38
Ti(Pe) x Lo(Im)	**22**	**4047**	**1.51**	**0.00**	**9.72**
Ti(Pe) x Si(Lo(Im))	**66**	**2683**	**1.48**	**0.00**	**10.99**
Residual	288	1812			
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)	**22**	**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	22	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)	**22**	**3826**	**1.47**	**0.00**	**9.38**
Ti(Pe) x Si(Lo(Im))	**66**	**2598**	**1.63**	**0.00**	**12.03**
Residual	288	1589			26.14
WT5					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	19299	1.57	0.10	5.71
Impact = Im	1	21627	0.31	1.00	0.00
Time (Pe) = Ti(Pe)	**22**	**7300**	**1.80**	**0.00**	**9.16**
Location (Im) = Lo(Im)	**1**	**77404**	**7.99**	**0.00**	**19.01**
Pe x Im	1	6686	0.89	0.64	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5970**	**2.27**	**0.00**	**5.87**
Pe x Lo(Im)	1	**7608**	**1.51**	**0.04**	**5.96**
Ti(Pe) x Im	22	4511	1.11	0.17	4.89
Pe x Si(Lo(Im))	3	2750	1.04	0.40	1.55
Ti(Pe) x Lo(Im)	**22**	**4047**	**1.54**	**0.00**	**9.86**
Ti(Pe) x Si(Lo(Im))	**66**	**2634**	**1.45**	**0.00**	**10.61**
Residual	288	1816			27.38

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	0.51	0.32	2069	0.77	644.8	0.62	75	1.15
Impact = Im	1	5.00	0.05	936	0.33	588.9	1.15	1814	0.25
Time (Pe) = Ti(Pe)	22	**73.19**	**3.22**	**4330**	**2.31**	**843.3**	**4.68**	207	0.59
Location (Im) = Lo(Im)	1	**576.33**	**16.20**	6070	2.44	154.1	1.48	**8434**	**13.29**
Pe x Im	1	**98.71**	**5.98**	4291	1.91	626.4	0.81	563	2.72
Site (Lo(Im)) = Si(Lo(Im))	3	13.44	1.37	1042	1.01	80.2	0.35	295	1.90
Pe x Lo(Im)	1	0.08	0.29	797	0.58	479.6	0.86	163	0.88
Ti(Pe) x Im	22	20.22	0.89	2424	1.30	**512.2**	**2.84**	172	0.49
Pe x Si(Lo(Im))	3	11.66	1.19	1301	1.26	**648.8**	**2.80**	11	0.07
Ti(Pe) x Lo(Im)	22	**22.74**	**2.31**	**1871**	**1.81**	180.4	0.78	**352**	**2.27**
Ti(Pe) x Si(Lo(Im))	66	9.84	1.06	**1035**	**1.61**	**231.4**	**1.58**	**155**	**1.88**
Residual	288	9.29		643		146.9		82	
WT4		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	102.98	2.30	10508	2.20	1306	0.87	178	0.80
Impact = Im	1	88.70	0.19	2115	0.47	2197	2.36	1884	0.26
Time (Pe) = Ti(Pe)	22	**54.58**	**2.40**	**4842**	**2.59**	**1230**	**6.82**	497	1.41
Location (Im) = Lo(Im)	1	**576.33**	**15.22**	6070	2.53	154	1.55	**8434**	**12.28**
Pe x Im	1	0.86	0.96	72	0.60	204	0.29	3	0.75
Site (Lo(Im)) = Si(Lo(Im))	3	15.81	1.55	959	0.87	61	0.28	355	1.44
Pe x Lo(Im)	1	0.08	0.43	797	0.64	480	2.28	163	0.96
Ti(Pe) x Im	22	24.51	1.08	2436	1.30	**853**	**4.73**	308	0.87
Pe x Si(Lo(Im))	3	1.37	0.13	1096	0.99	126	0.57	78	0.32
Ti(Pe) x Lo(Im)	22	**22.74**	**2.23**	**1871**	**1.69**	180	0.82	352	1.42
Ti(Pe) x Si(Lo(Im))	66	10.20	1.16	**1105**	**1.73**	**221**	**1.53**	**247**	**2.03**
Residual	288	8.76		639		145		122	
WT5		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	84.17	2.08	11549	2.97	2472	2.93	40	0.61
Impact = Im	1	156.79	0.30	9353	1.42	230	0.89	748	0.13
Time (Pe) = Ti(Pe)	22	**51.19**	**2.25**	3727	1.99	427	2.37	478	1.36
Location (Im) = Lo(Im)	1	**576.33**	**15.95**	6070	2.48	154	1.22	**8434**	**12.37**
Pe x Im	1	0.00	1.13	12	0.71	0	0.23	459	2.08
Site (Lo(Im)) = Si(Lo(Im))	3	14.01	1.39	993	0.96	88	0.51	343	2.19
Pe x Lo(Im)	1	0.08	0.41	797	0.84	480	3.18	163	0.86
Ti(Pe) x Im	22	20.01	0.88	1847	0.99	305	1.69	227	0.65
Pe x Si(Lo(Im))	3	1.85	0.18	294	0.29	25	0.15	20	0.12
Ti(Pe) x Lo(Im)	22	**22.74**	**2.26**	**1871**	**1.82**	180	1.04	**352**	**2.25**
Ti(Pe) x Si(Lo(Im))	66	10.05	1.06	**1031**	**1.66**	**174**	**1.85**	**156**	**1.66**
Residual	288	9.44		622		94		94	

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

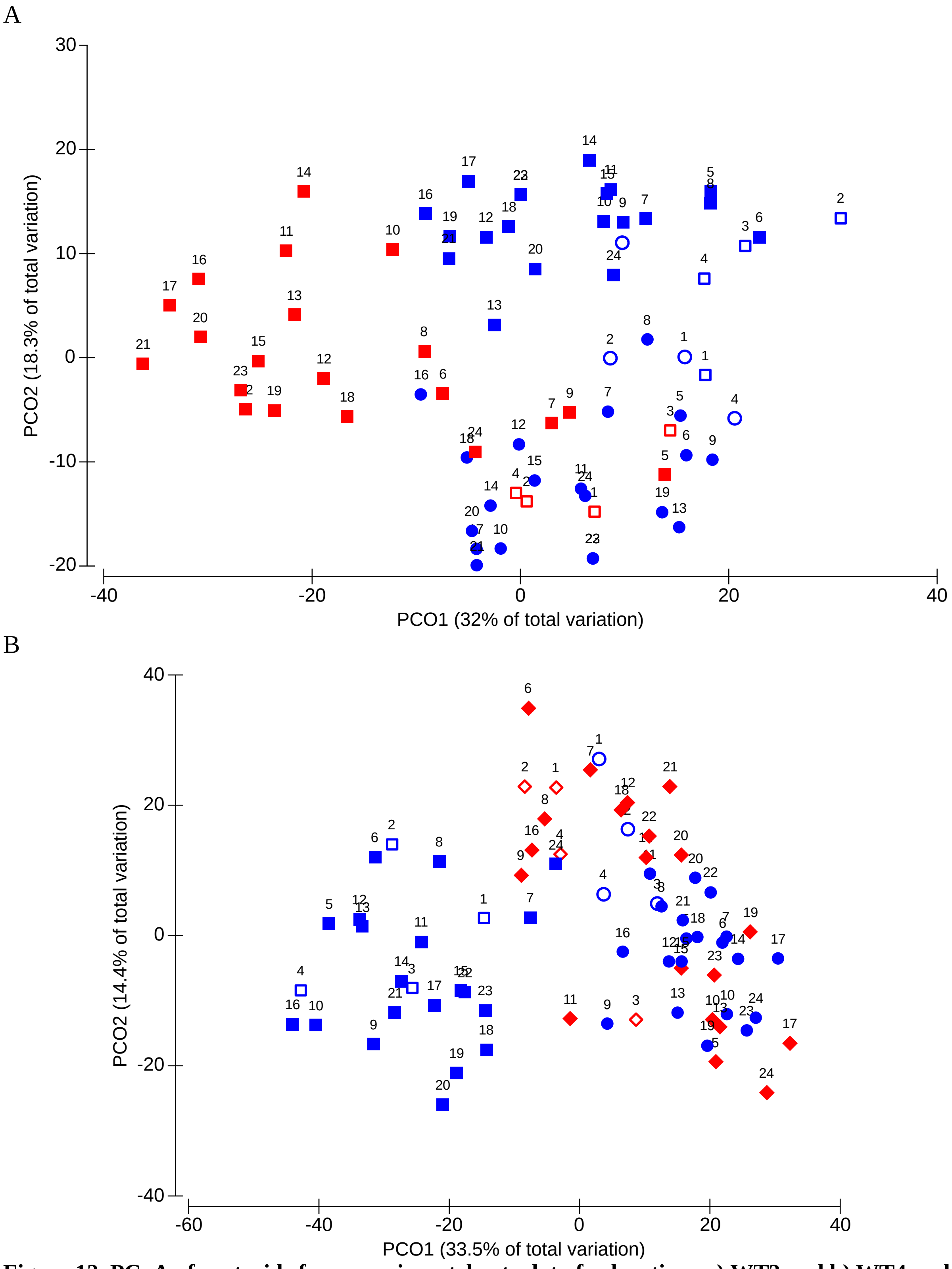


Figure 12. PCoA of centroids for macroinvertebrate data for locations a) WT3 and b) WT4 and two control locations (Woronora River and O'Hares Creek) for each time of sampling (*n* = 6). Red symbols: Waratah Rivulet; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.

C

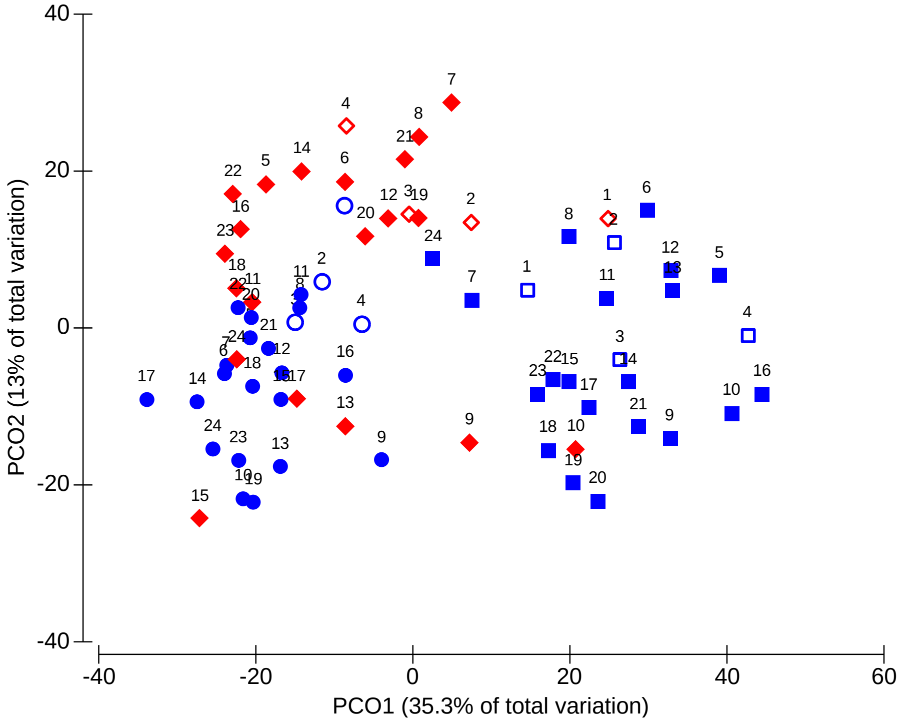


Figure 11 (Cont'd). PCoA of centroids for macroinvertebrate data for c) Location WT5 (Red triangles) and two control locations (Woronora River and O'Hares Creek) for each time of sampling (n = 6); Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.

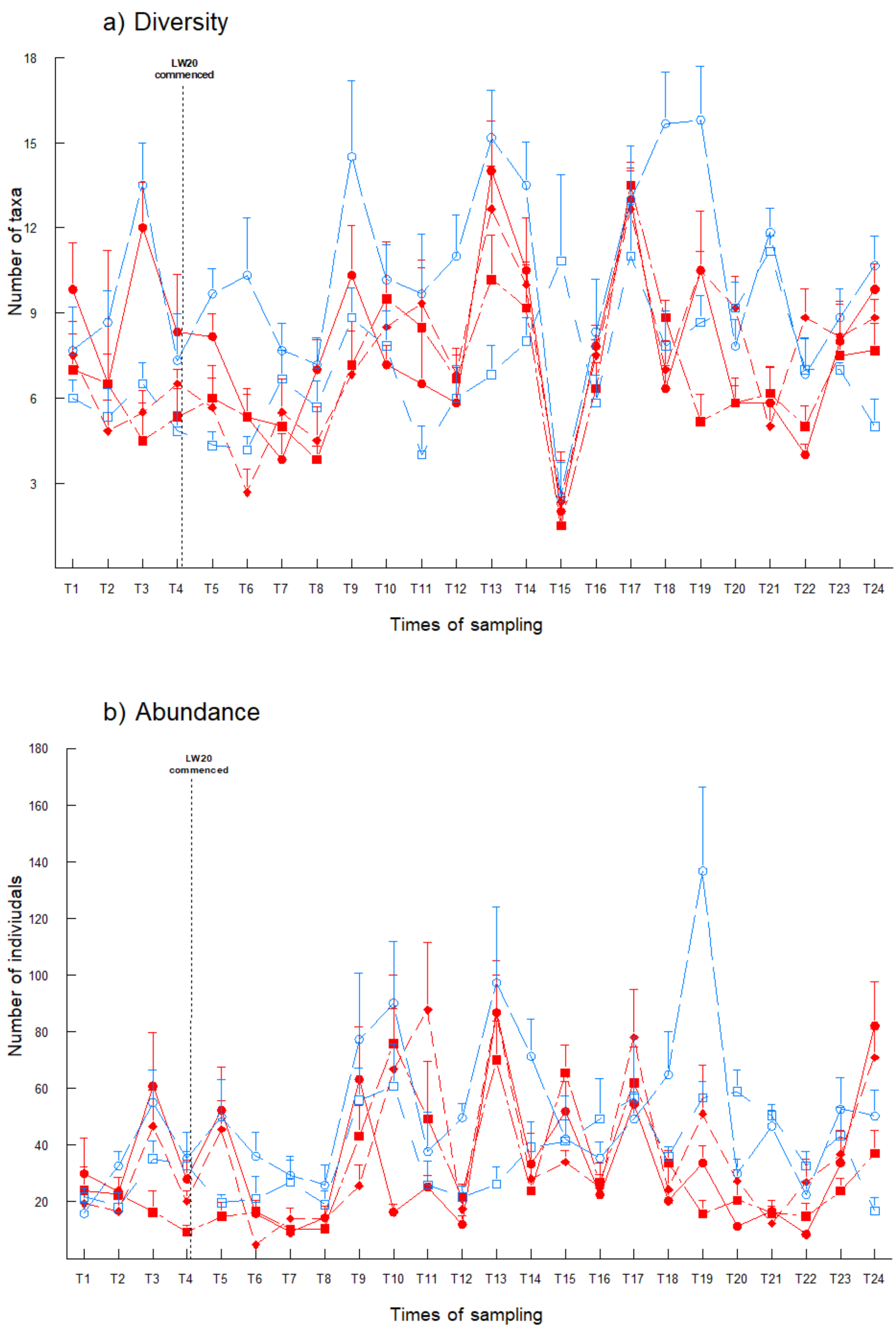
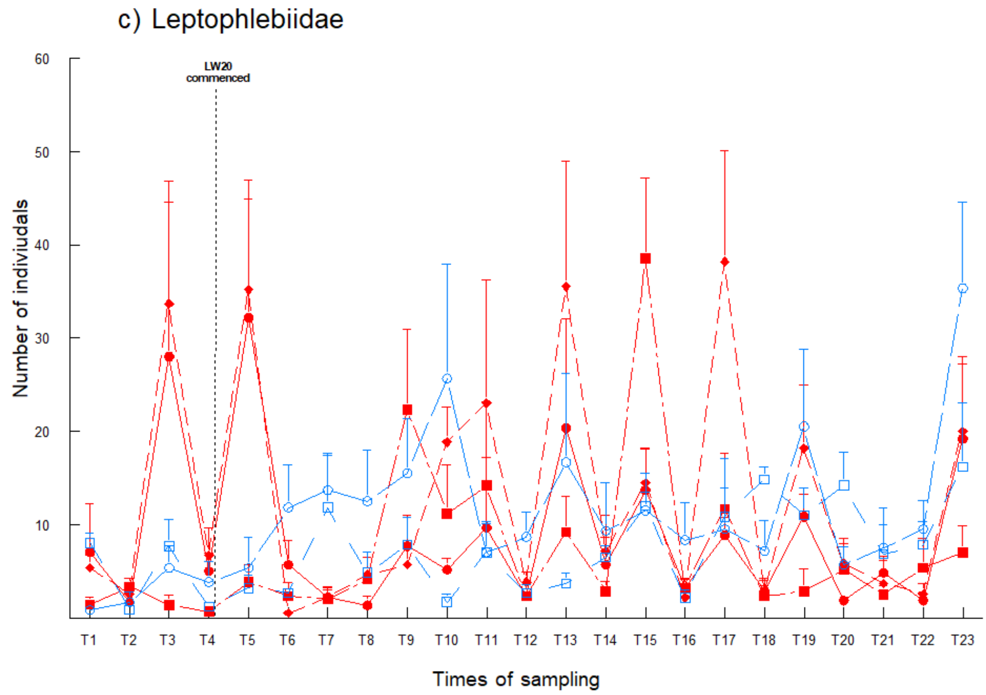


Figure 13. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc.



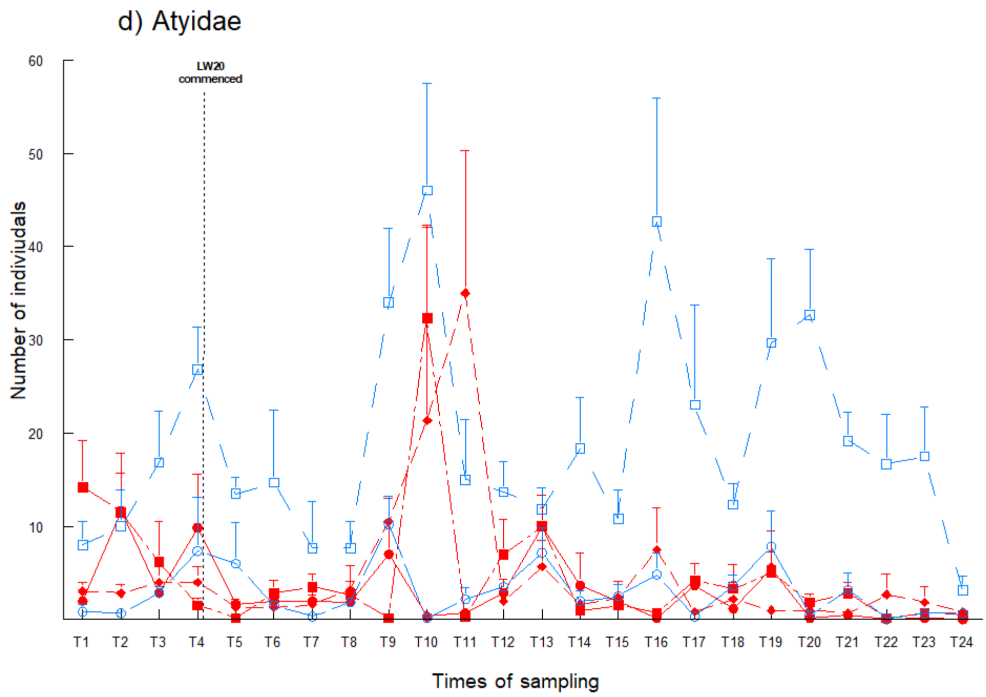


Figure 12 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 6). Time 1 = spring 2008, T2 = autumn 2009 etc.

<u>AUSRIVAS Analyses</u>

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 13a). 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 13a&b), indicating that the number of taxa observed was less than would be expected relative to the AUSRIVAS reference watercourses.

Five 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 13a). 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 13b).

On this sampling occasion (autumn 2020), the OE50 Taxa scores ranged from 0.41 at Location WT5 and 0.64 at Locations WT3 and WT4 (Figure 13b). Location WT3 and OC increased by one AUSRIVAS band level between the spring 2019 and autumn 2020 surveys, from Band C to Band B (Figure 13b).

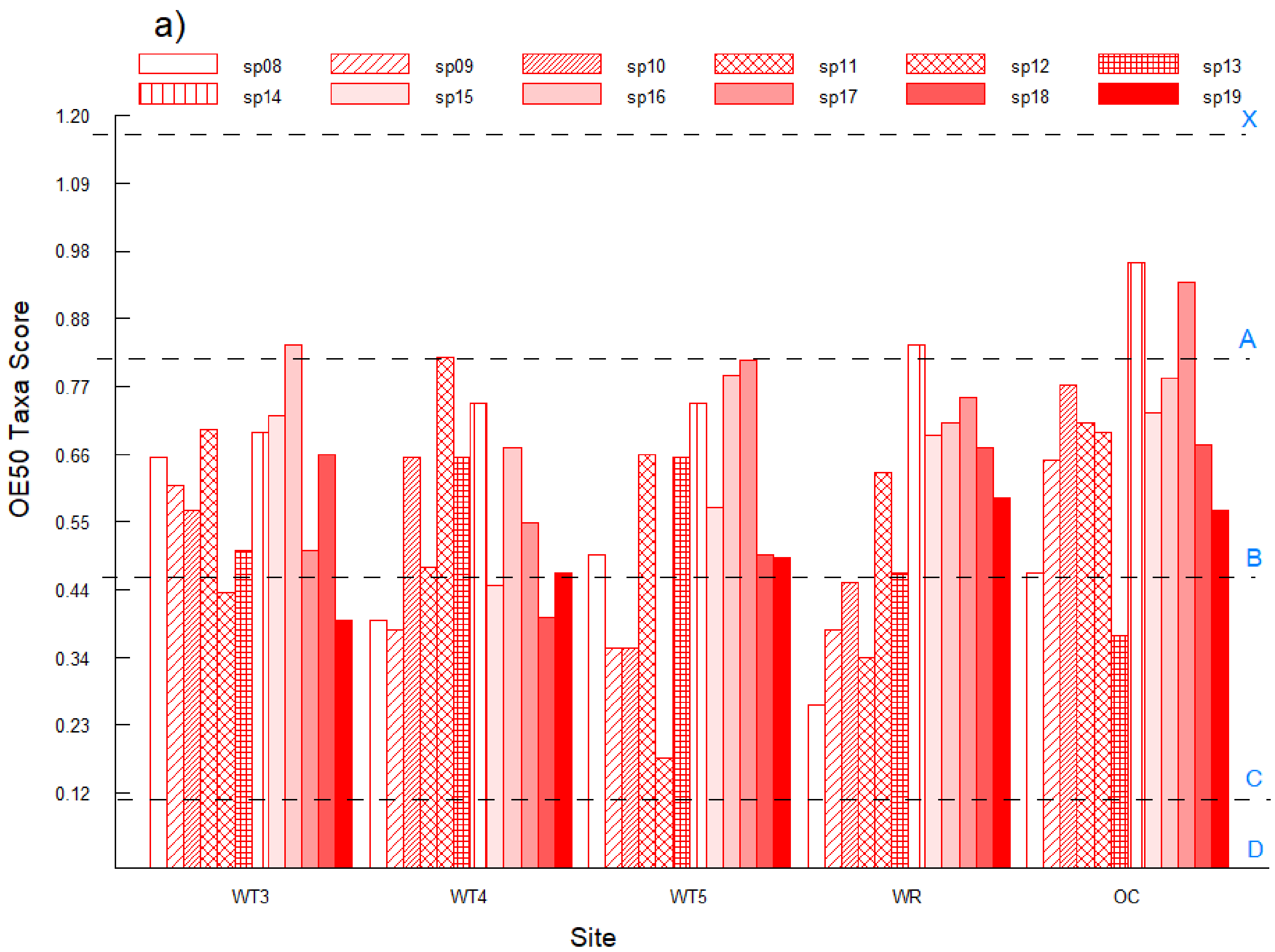


Figure 14a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2008 and 2019 (*n* = 2).

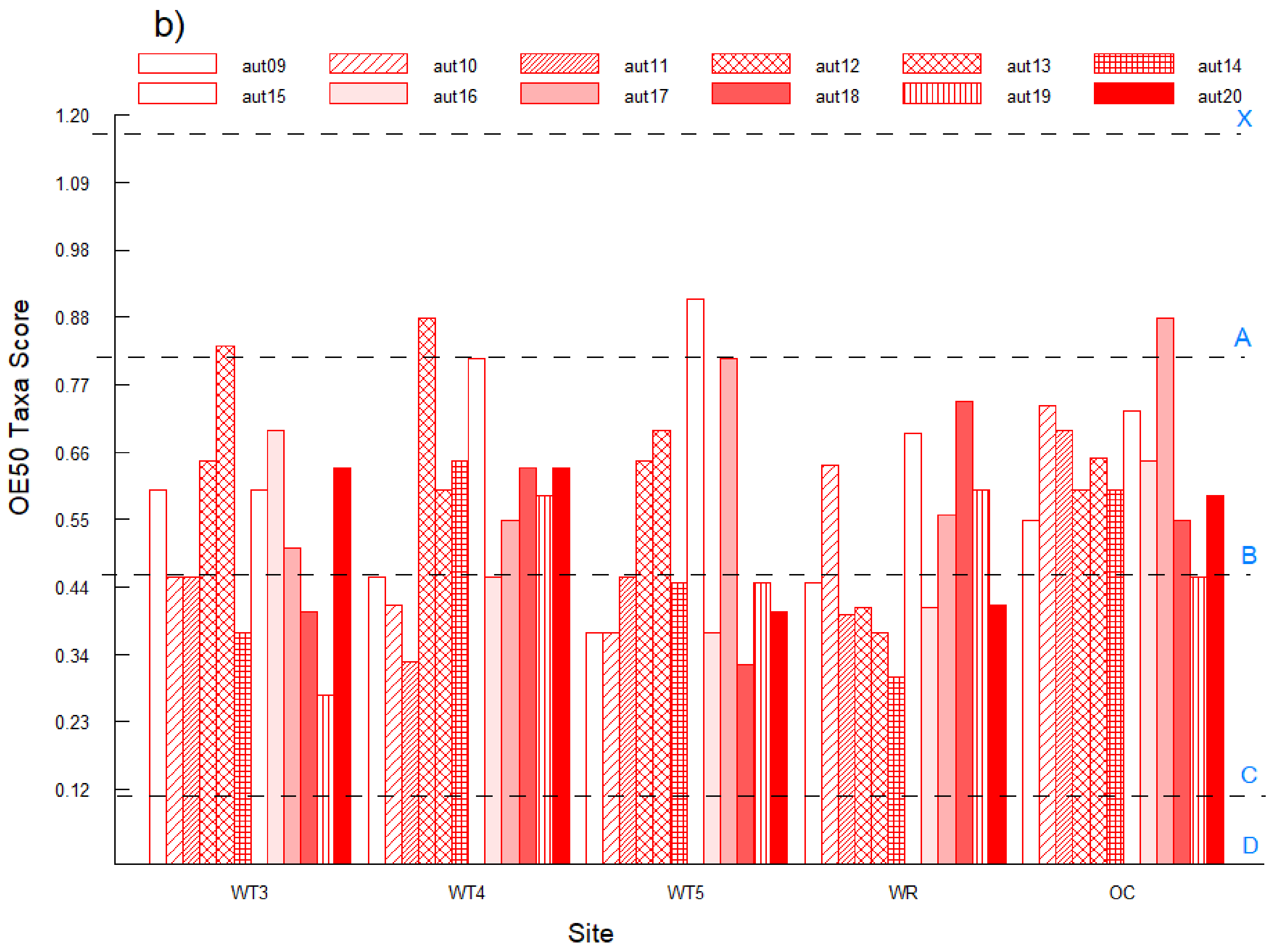


Figure 15b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2008 and 2020 (*n* = 2).

4.1.2.2 Aquatic Macrophytes

Waratah Rivulet v Controls

Prior Surveys (Spring 2009 – Spring 2019)

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 (Autumn 2020)

Consistent with the findings of the previous report, analyses comparing patterns of change in assemblages of aquatic macrophytes at each of the potential impact locations with the control locations found significant interactions between the factors Location nested within Impact and Time nested within Period (i.e. Ti(Pe) x Lo(Im)), indicating that there was significant variation among locations, which depended on the time of sampling and *vice versa* (Table 10, Figures 14a-b).

The PCoA indicates that assemblages of aquatic macrophytes sampled at the Waratah Rivulet locations have consistently differed considerably from assemblages at the Woronora River location (Figures 14a-c). SIMPER has consistently indicated that differences were largely 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 15a&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 15a). Cover decreased at all locations except WT4 between the spring 2019 (T23) and autumn 2020 surveys (Figure 15b).

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	35948	1.74	0.07	6.95
Impact = Im	1	40397	1.33	0.22	5.57
Time (Pe) = Ti(Pe)	**22**	**6644**	**1.61**	**0.00**	**6.88**
Location (Im) = Lo(Im)	**1**	**29903**	**1.99**	**0.00**	**7.87**
Pe x Im	1	13377	0.87	0.66	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**12397**	**4.10**	**0.00**	**8.41**
Pe x Lo(Im)	**1**	**16386**	**1.99**	**0.00**	**8.53**
Ti(Pe) x Im	22	3678	0.89	0.79	0.00
Pe x Si(Lo(Im))	**3**	**5624**	**1.86**	**0.00**	**6.27**
Ti(Pe) x Lo(Im)	**22**	**4133**	**1.37**	**0.00**	**7.49**
Ti(Pe) x Si(Lo(Im))	66	3020	0.86	1.00	0.00
Residual	576	3511			42.03
WT4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	28552	1.60	0.090	6.33
Impact = Im	1	30470	1.06	0.429	2.61
Time (Pe) = Ti(Pe)	22	4389	1.05	0.348	2.18
Location (Im) = Lo(Im)	1	29710	1.51	0.049	6.93
Pe x Im	1	10474	0.78	0.789	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**17424**	**5.90**	**0.000**	**11.21**
Pe x Lo(Im)	**1**	**16012**	**1.91**	**0.003**	**8.86**
Ti(Pe) x Im	22	2834	0.68	0.999	0.00
Pe x Si(Lo(Im))	**3**	**5758**	**1.95**	**0.002**	**6.98**
Ti(Pe) x Lo(Im)	**22**	**4170**	**1.41**	**0.000**	**8.39**
Ti(Pe) x Si(Lo(Im))	66	2953	0.79	1.000	0.00
Residual	576	3738			46.51
WT5					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	47514	1.93	0.050	8.61
Impact = Im	1	17775	0.67	0.891	0.00
Time (Pe) = Ti(Pe)	22	5242	1.28	0.067	4.78
Location (Im) = Lo(Im)	1	29304	1.52	0.049	6.63
Pe x Im	1	8039	0.49	0.988	0.00
Site (Lo(Im)) = Si(Lo(Im))	**3**	**17184**	**5.68**	**0.000**	**10.61**
Pe x Lo(Im)	**1**	**21487**	**2.22**	**0.003**	**10.34**
Ti(Pe) x Im	22	3391	0.83	0.878	0.00
Pe x Si(Lo(Im))	**3**	**6970**	**2.30**	**0.001**	**7.92**
Ti(Pe) x Lo(Im)	**22**	**4091**	**1.35**	**0.002**	**7.52**
Ti(Pe) x Si(Lo(Im))	66	3025	0.84	0.998	0.00
Residual	576	3586.3			43.59

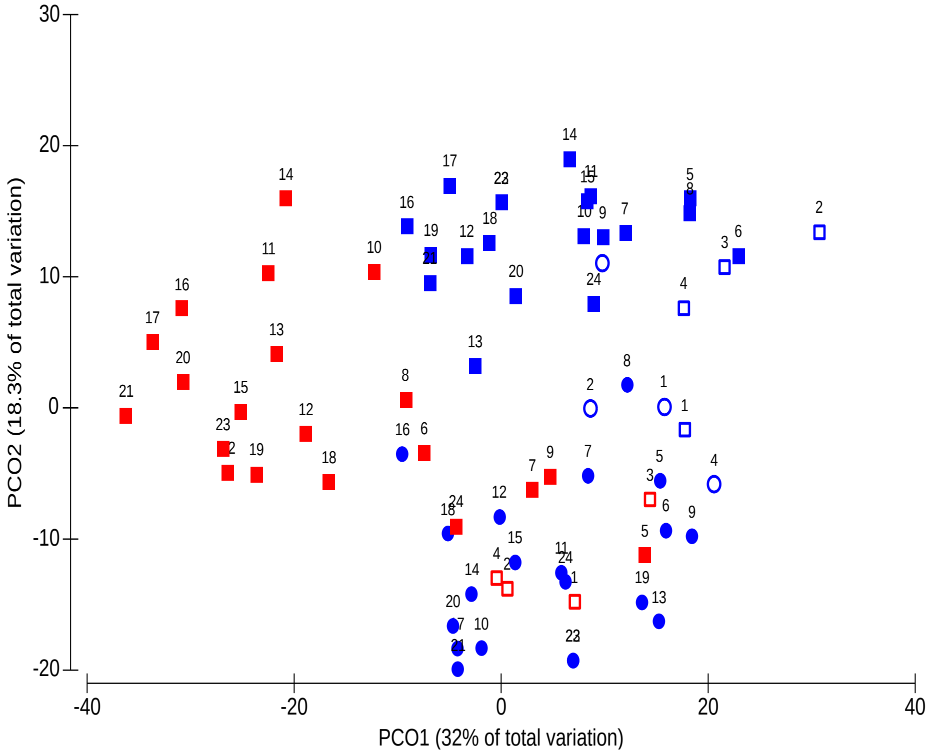
Bold numbers indicate significant results at $P < 0.05$.

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

WT3		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	17.80	3.97	2808	1.59
Impact = Im	1	**3.04**	**4.36**	8428	4.36
Time (Pe) = Ti(Pe)	22	3.39	1.67	959	0.70
Location (Im) = Lo(Im)	1	0.03	0.39	655	0.38
Pe x Im	1	1.45	1.27	1387	0.85
Site (Lo(Im)) = Si(Lo(Im))	3	1.20	0.96	**1728**	**3.26**
Pe x Lo(Im)	1	1.60	1.14	1673	0.74
Ti(Pe) x Im	22	1.14	0.56	1592	1.16
Pe x Si(Lo(Im))	3	0.47	0.38	**1603**	**3.03**
Ti(Pe) x Lo(Im)	22	2.03	1.63	**1374**	**2.59**
Ti(Pe) x Si(Lo(Im))	66	1.25	0.94	529	1.03
Residual	576	1.33		512	
WT4		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	0.70	0.99	421	0.67
Impact = Im	1	**27.50**	**27.60**	15	1.14
Time (Pe) = Ti(Pe)	22	1.80	0.87	1184	0.85
Location (Im) = Lo(Im)	1	0.18	0.45	572	0.35
Pe x Im	1	4.25	3.35	0	0.63
Site (Lo(Im)) = Si(Lo(Im))	3	0.78	0.71	**2073**	**3.28**
Pe x Lo(Im)	1	1.00	0.85	1539	0.98
Ti(Pe) x Im	22	0.89	0.43	668	0.48
Pe x Si(Lo(Im))	3	0.40	0.36	832	1.32
Ti(Pe) x Lo(Im)	22	**2.07**	**1.88**	**1395**	**2.21**
Ti(Pe) x Si(Lo(Im))	66	1.10	0.89	632	1.16
Residual	576	1.24		546	
WT5		**Richness**		**Abundance**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	**21.23**	**4.93**	6356	1.10
Impact = Im	1	**8.34**	**4.55**	**5769**	**7.56**
Time (Pe) = Ti(Pe)	22	2.13	1.00	946	0.73
Location (Im) = Lo(Im)	1	1.08	0.81	206	0.24
Pe x Im	1	0.28	0.63	2634	0.58
Site (Lo(Im)) = Si(Lo(Im))	3	0.91	0.65	**2291**	**3.51**
Pe x Lo(Im)	1	2.60	0.52	6007	1.85
Ti(Pe) x Im	22	1.22	0.57	730	0.56
Pe x Si(Lo(Im))	3	**5.56**	**4.02**	**2288**	**3.51**
Ti(Pe) x Lo(Im)	22	2.13	1.54	**1304**	**2.00**
Ti(Pe) x Si(Lo(Im))	66	1.38	1.06	652	1.21
Residual	576	1.30		541	

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

A



B

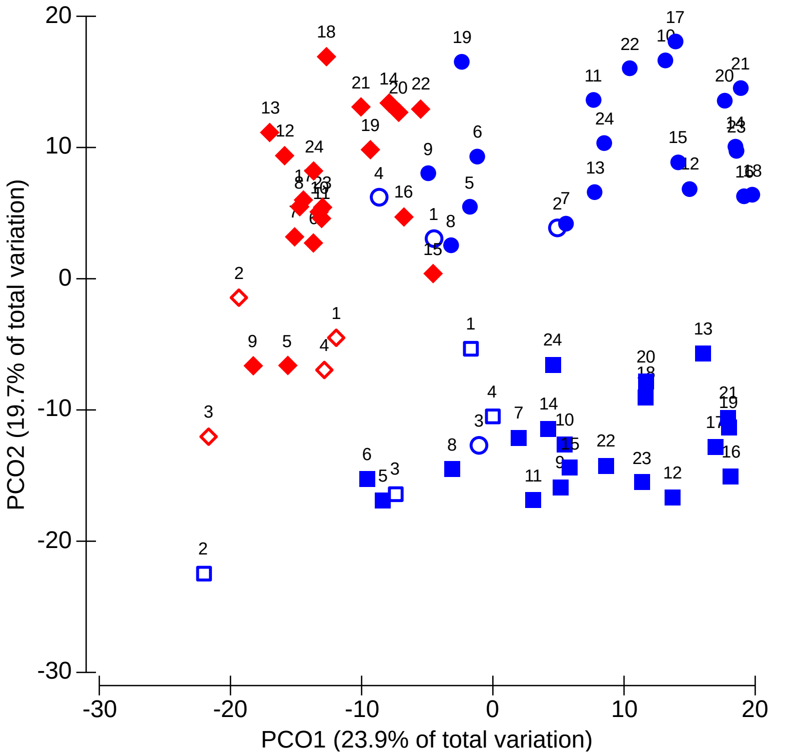


Figure 16. PCoA of centroids for macrophyte data for a) Location WT3 and b) Location WT4 and two control locations for each time of sampling. Red symbols: Potential 'impact' locations; Woronora River: Blue squares; O'Hares Creek: Blue circles. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.

C

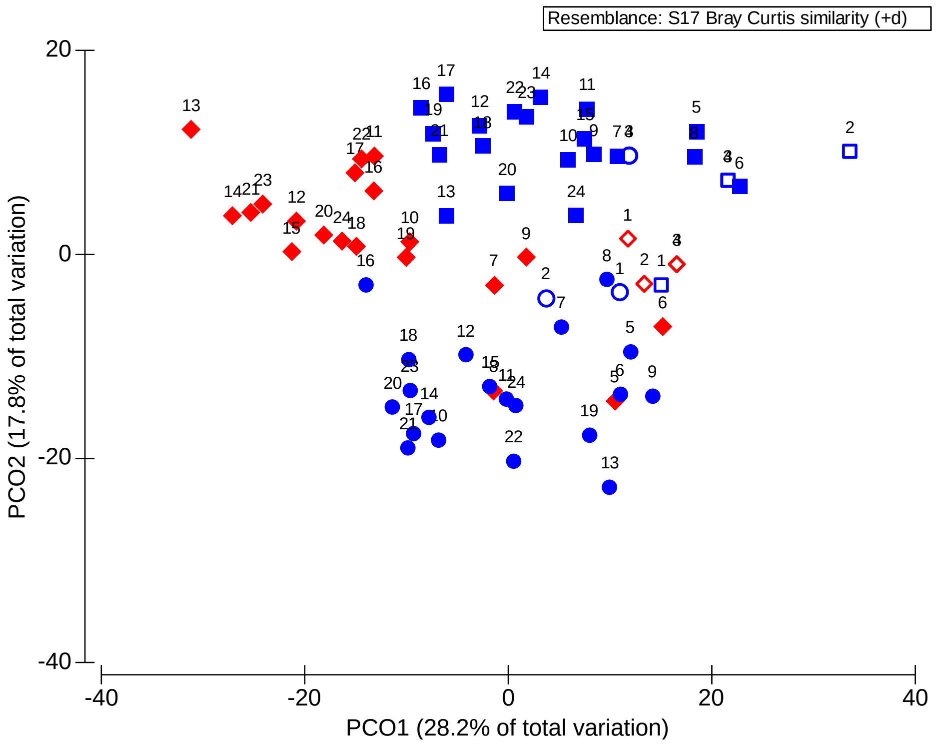


Figure 14 (Cont'd). PCoA of centroids for macrophyte data for c) Location WT5. Red triangles: Potential 'impact' location; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.

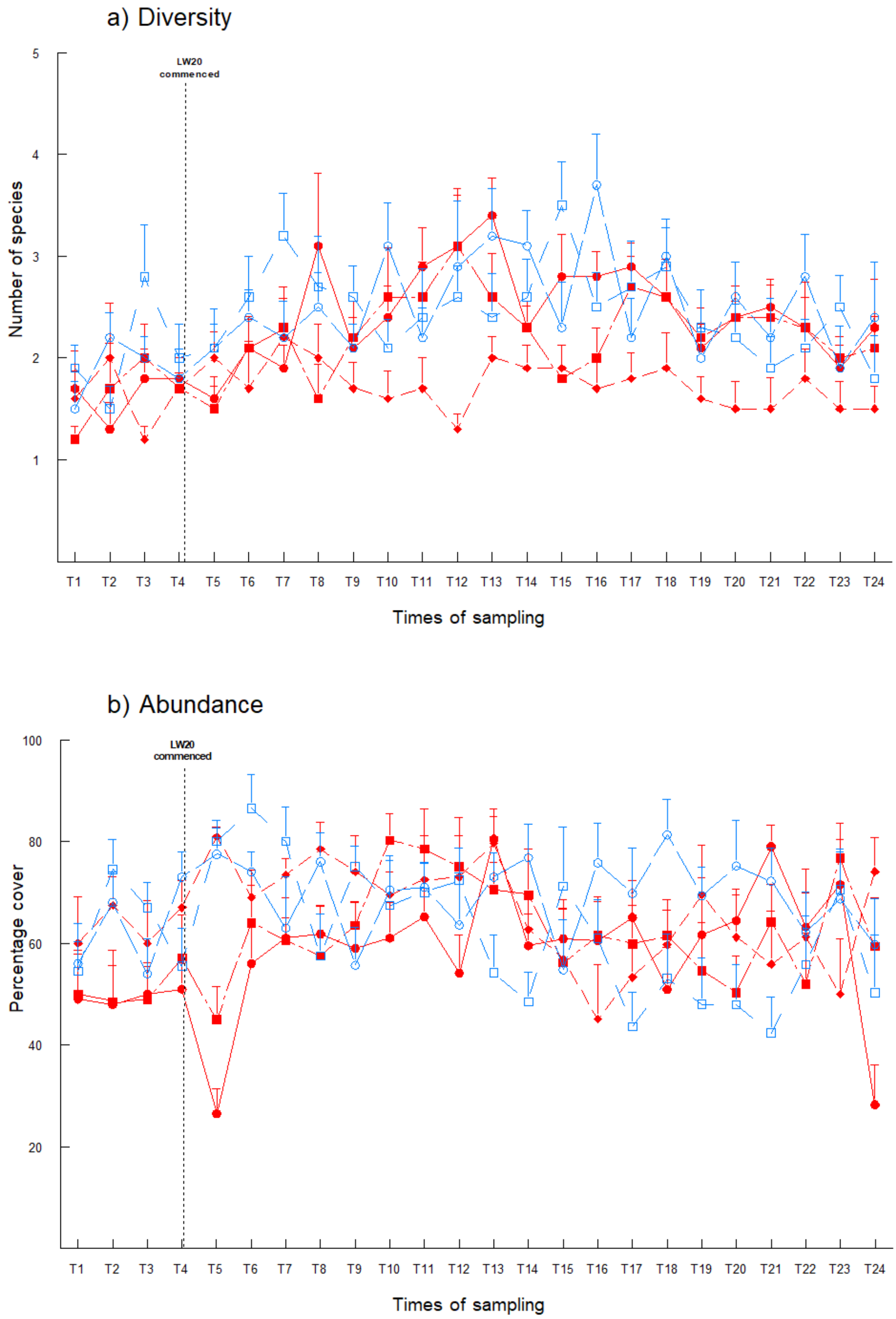


Figure 17. Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Waratah Rivulet (WT3: circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) (*n* = 10). Time 1 = spring 2008, T2 = autumn 2009, etc.

4.2 Longwalls 23-27 Mining Area

A temporal comparison of the aquatic macroinvertebrate and macrophyte data was carried out for the Stream Monitoring component of the Longwalls 23-27 Aquatic Ecology Monitoring Programme. The quantitative data from the surveys done between spring 2008[8], and autumn 2020 were analysed using both multivariate and univariate techniques. AUSRIVAS data collected from the stream monitoring locations are also presented.

The objective of the following comparisons of aquatic macroinvertebrates and macrophytes was to determine whether any changes may have occurred at sampling locations in Tributary C/Eastern Tributary (Locations C1, C2 and C4) Before- vs After-commencement of mining of the Longwalls 23-27 area in relation to Control locations (Woronora River and O'Hares Creek). Mining of the Longwalls 23-27 mining area commenced in May 2014 and was completed in March 2017. Nine to eleven replicate times (spring 2008 or spring 2009[9] to spring 2013) were sampled within the 'Before' commencement of Longwall 23 period and thirteen replicate times (autumn 2014 to autumn 2020) have been sampled within the 'After' period.

8 Up until autumn 2018, temporal analyses for the Longwalls 23-27 monitoring report examined data for Locations C1 and C2 from spring 2009, to coincide with the commencement of sampling of Location C4 (BIOANALYSIS, 2018). For the spring 2018 survey, data collected at Locations C1 and C2 in spring 2008 and autumn 2009 were also examined to assist in interpretation of results and to increase the power of analyses. Similar results were obtained. Consequently, future analyses include the spring 2008 and autumn 2009 data.

9 The sampling of Location C4 (ET4) on the Eastern Tributary commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

4.2.1 Aquatic Macroinvertebrates

<u>Quantitative Assessment</u>

Location C1 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

Multivariate analyses have detected a significant before-to-after change in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations in spring 2016 (T17), autumn 2019 (T22) and spring 2019 (T23). SIMPER analyses indicated that mayflies (Leptophlebiidae) and freshwater shrimp (Atyidae) have consistently contributed most to the structure of assemblages of macroinvertebrates at Location C1 and the control locations.

Univariate analyses detected a significant increase in mean numbers of Leptophlebiidae at Location C1 in relation to the control locations before- vs after-commencement of mining of the Longwalls 23-27 area between autumn 2015 (T14) and spring 2019 (T23), when considerable spikes in abundance of Leptophlebiidae occurred in spring 2013 (T11), spring 2015 (T15), spring 2016 (T17) and spring 2017 (T19) (Figure 17c). Analyses have consistently found no significant difference to mean total diversity, total abundance or numbers of Atyidae at Location C1 that would indicate a significant impact from mining.

Current Survey (Autumn 2020)

Similar to the findings of the spring 2016 (T17), autumn 2019 (T22) and spring 2019 (T23) surveys, multivariate analyses detected a significant before- vs after- difference in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations (Table 12, Figure 16a).

Visual examination of the PCoA found that there was greater dispersion among centroids representing the assemblage at Location C1 within the ‘after’ period than for each of the control locations, which could have contributed to the relatively low *P*-value (Figure 16a).

The structure of the assemblage at C1 also appears to have changed significantly between periods (Pair-wise test: t = 2.12, P = 0.000) but not at the Controls (t = 1.26, P = 0.07), largely due to the decline in contribution that Atyidae made to the structure of the assemblage at C1 within the Before (72.5 %) compared to After (3.3 %) period according to the SIMPER analysis.

Of the other key variables examined, univariate analyses have consistently found no significant difference in mean total diversity and abundance of macroinvertebrates or mean numbers of Atyidae at Location C1 compared to the control locations (Table 15, Figures 17a,b&d). In general, macroinvertebrate diversity at Location C1 was similar to the control locations in autumn 2020 (T24) (Figure 17a). Greater numbers of individuals were collected at Location C1 in autumn 2020 (T23) than in spring 2019 (T23) (Figure 17b). Small numbers (three individuals) of Atyidae were collected at Location C1 for the first time since autumn 2018 (T20) (Figure 17d).

Similar to the findings of the previous survey (i.e. spring 2019), univariate analyses did not detect a significant Period x Impact interaction for mean abundance of Leptophlebiidae (Table 13, Figure 17c). In contrast to the control locations, numbers of Leptophlebiidae increased at Location C1 between the spring 2019 and autumn 2020 surveys (Figure 17c).

Location C2 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

To date, multivariate analysis of the aquatic macroinvertebrate data have detected a significant interaction of the factors Period x Impact in autumn 2019 (T22) and spring 2019 (T23), which indicates an impact from mining at Location C2.

Univariate analyses detected a significant before- vs after-mining change in mean numbers of Atyidae at Location C2 in relation to the control locations between autumn 2016 (T16) and autumn 2019 (T22), but not at the time of the spring 2019 (T23) survey.

A significant Period x Impact change in mean abundance was detected at Location C2 in relation to the controls in spring 2018 (T21) and subsequent surveys (i.e. autumn and spring 2019). Analyses have consistently found no significant change in total diversity or numbers of Leptophlebiidae at Location C2 in relation to the controls (Figures 17a-c).

Current Survey (Autumn 2020)

Similar to the findings from the 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 16b). The PCoA indicated greater variability in the structure of assemblages at Location C2 than at the control locations within the After-Period (Figure 16b). When PERMDISP was used to formally compare the apparent variability (dispersion), pair-wise tests did in fact find that temporal variation (i.e. among surveys) at Location C2 differed significantly between Periods at Location C2 (t = 4.21, P = 0.001), but also at the Control treatment (t = 2.70, P = 0.018).

Pair-wise tests detected a significant change in the composition of assemblages between Periods at Location C2 (t = 1.92, P = 0.002) but not at the Controls (t = 1.26, P = 0.073). SIMPER indicates that changes in the contribution that Atyidae have made to the assemblage at Location C2 (Before: 67.1 %; After: 12.9 %) have contributed greatly to this result. Atyidae have consistently been ranked highest for the Control treatment (Before: 40.8 %; After: 30.4 %). Leptophlebiidae has increased its contribution to the assemblage at Location C2 (Before: 18.5 %; After: 53.8%) and to a lesser extent, the Controls (Before: 27.6 %; After: 37.3 %).

Leptophlebiidae was the only species ranked by SIMPER to contribute to the structure of the assemblage at Location C2 in spring 2019 (93%) and autumn 2020 (92.4%).

Univariate analyses detected a significant change in mean numbers of Atyidae at Location C2 in relation to the control locations between autumn 2016 (T16) and autumn 2019 (T22) and in autumn 2020 (T24) (Table 13, Figure 17d). Atyidae have rarely been collected at Location C2 by surveys done since spring 2017 (T19) (Figure 17d).

Univariate analyses did not detect a significant Period x Impact change in mean abundance at Location C2 in relation to the Controls on this sampling occasion (Table 13, Figure 17b). Similar numbers of individuals were collected at Location C2 and the control locations in autumn 2020 (Figure 17b).

Similar to previous surveys, univariate analyses found no significant difference in mean numbers of species or Leptophlebiidae at Location C2 in relation to the Control (Table 13, Figure 17a&c). Similar numbers of taxa and Leptophlebiidae were collected at Location C2 and the Control treatments in autumn 2020 (Figures 17a&c).

Location C4 v Controls

Prior Surveys (Spring 2009 – Spring 2019)

For the first time since sampling commenced at Location C4 (spring 2009), PERMANOVA detected a significant Period x Impact interaction in the structure of assemblages in spring 2019. A significant 'Before' to 'After' change in mean diversity has been detected at Location C4 in relation to the Control treatment since autumn 2018 (T18). Patterns of change in abundance of Atyidae at Location C4 differed significantly compared to those at the Control treatment in autumn 2016 (T14), spring 2018 (T21) and spring 2019 (T23).

Analyses have consistently found no significant difference to the total abundance of macroinvertebrates or numbers of Leptophlebiidae at Location C4 that would indicate an impact from mining of Longwalls 23-27.

Current Survey (Autumn 2020)

Similar to the findings of the spring 2019 survey (T23), 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 16c).

The PCoA and PERMDISP indicated that the structure of the assemblage of macroinvertebrates has become significantly more variable at Location C4 ‘after’ the commencement of mining ($t = 3.97$, $P = 0.001$), but not at the Control locations (PERMDISP: $t = 1.27$, $P = 0.231$) (Figure 16c). The structure of the assemblage at C4 has also changed significantly between periods (Pair-wise test: $t = 1.71$, $P = 0.004$) but not the Controls ($t = 1.17$, $P = 0.16$).

SIMPER indicates that changes in the contribution that Atyidae have made to the assemblage at Location C4 (Before: 39.6 %; After: 7.0 %) have contributed greatly to this result. Atyidae have consistently been ranked highest for the Control treatment (Before: 42.4 %; After: 42.0 %). Leptophlebiidae contributed most (42.2 %) to the structure of the assemblage at Location C4 within the ‘after’ period, followed by the family, Chironomidae (31.6 %), and the Dytiscidae (8.5 %) (SIMPER).

Considerable spikes in mean abundance of macroinvertebrates and numbers of Leptophlebiidae were observed at C4 between spring 2015 (T15) and autumn 2018 (T20), coinciding with declines in pool water level at the most upstream site (i.e. Site C41) (Figures 17b&c). Observed patterns of change however, did not differ significantly in relation to the control locations (Table 13, Figure 17b&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 17b&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 (autumn 2020) (Table 13, Figure 17a). *Post-hoc* tests indicated that this result was due to a combination of differences in dispersion ($P = 0.002$) and the group means (Location C4: $t = 0.66$, $P = 0.86$ ns; Control: $t = 2.33$, $P = 0.02$).

Mean numbers of Atyidae collected at Location C4 in autumn 2020 (T22), spring 2019 (T21), spring 2018 (T19), autumn 2016 (T16) differed significantly from the control treatment (Table 13, Figure 17d). Atyidae were not collected at Location C4 in autumn 2017, spring 2018, autumn 2019 or spring 2019 (Figure 17d).

Table 12. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate assemblage data (non-transformed) to compare locations C1, C2 and C4 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek) Before- vs After-commencement of mining. Percentages of Components of Variation (% CV) are shown.

C1					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**45056**	**3.89**	**0.001**	**8.07**
Impact = Im	1	40276	0.30	0.999	0.00
Time (Pe) = Ti(Pe)	**22**	**7137**	**1.70**	**0.000**	**7.88**
Location (Im) = Lo(Im)	**1**	**140490**	**12.24**	**0.000**	**17.68**
Pe x Im	**1**	**17211**	**1.96**	**0.019**	**6.10**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**7503**	**2.60**	**0.000**	**4.68**
Pe x Lo(Im)	1	5521	1.01	0.450	0.48
Ti(Pe) x Im	**22**	**5429**	**1.29**	**0.020**	**7.20**
Pe x Si(Lo(Im))	3	4152	1.44	0.052	3.46
Ti(Pe) x Lo(Im)	**22**	**4209**	**1.46**	**0.000**	**8.64**
Ti(Pe) x Si(Lo(Im))	**66**	**2888**	**1.61**	**0.000**	**11.12**
Residual	288	1795			
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**40664**	**3.29**	**0.002**	**7.98**
Impact = Im	1	25564	0.21	1.000	0.00
Time (Pe) = Ti(Pe)	**22**	**8121**	**1.93**	**0.000**	**9.75**
Location (Im) = Lo(Im)	**1**	**140490**	**12.86**	**0.000**	**18.93**
Pe x Im	**1**	**18387**	**2.33**	**0.005**	**7.25**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**6912**	**2.75**	**0.000**	**4.89**
Pe x Lo(Im)	1	5530	0.91	0.624	0.00
Ti(Pe) x Im	22	4184	0.99	0.508	0.00
Pe x Si(Lo(Im))	**3**	**4610**	**1.84**	**0.005**	**4.78**
Ti(Pe) x Lo(Im)	**22**	**4208**	**1.68**	**0.000**	**10.49**
Ti(Pe) x Si(Lo(Im))	**66**	**2511**	**1.49**	**0.000**	**10.35**
Residual	288	1684			25.58
C4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	**29498**	**3.09**	**0.002**	**7.19**
Impact = Im	1	47893	0.41	0.978	0.00
Time (Pe) = Ti(Pe)	20	**6725**	**1.85**	**0.000**	**8.70**
Location (Im) = Lo(Im)	1	**122380**	**12.15**	**0.000**	**18.80**
Pe x Im	1	**11995**	**1.91**	**0.021**	**5.87**
Site (Lo(Im)) = Si(Lo(Im))	3	**6641**	**2.70**	**0.000**	**5.08**
Pe x Lo(Im)	1	4001	0.81	0.791	0.00
Ti(Pe) x Im	20	4160	1.14	0.150	5.05
Pe x Si(Lo(Im))	3	**4295**	**1.75**	**0.008**	**4.76**
Ti(Pe) x Lo(Im)	20	**3635**	**1.48**	**0.000**	**8.80**
Ti(Pe) x Si(Lo(Im))	60	**2458**	**1.47**	**0.000**	**10.13**
Residual	263	1675			25.63

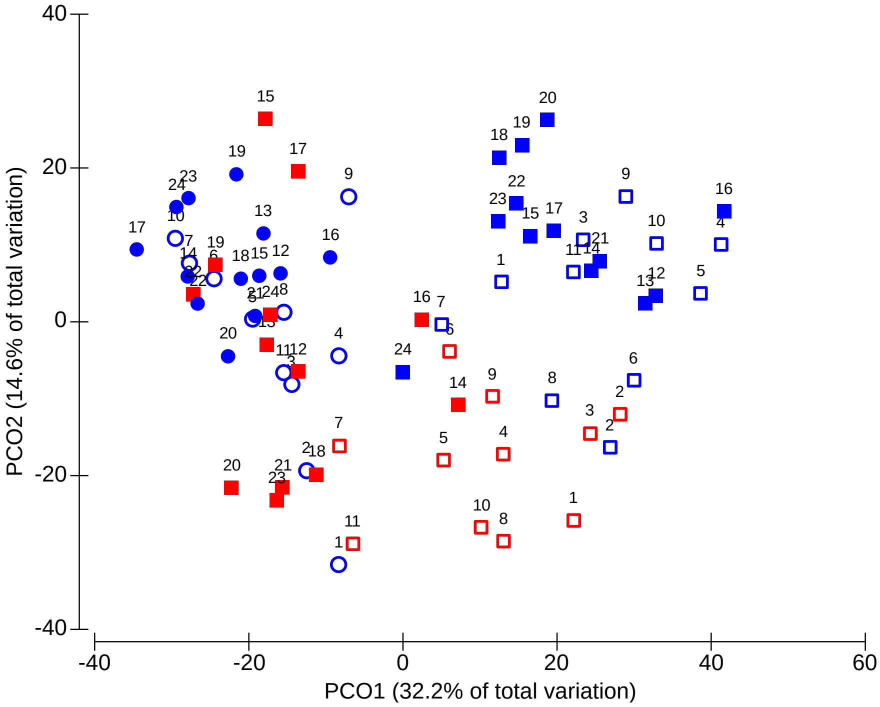
Bold numbers indicate significant results at $P < 0.05$.

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 three locations within Tributary C with two control locations Before- vs After-commencement of mining.

C1		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	**249**	**7.55**	**26039**	**4.94**	**9526**	**6.37**	37	0.99
Impact = Im	1	810	0.81	29480	1.72	168	0.14	3929	0.24
Time (Pe) = Ti(Pe)	22	36	1.64	5423	2.86	**1528**	**7.56**	365	1.02
Location (Im) = Lo(Im)	1	**1013**	**18.91**	**16142**	**5.76**	**1302**	**3.96**	**17873**	**21.04**
Pe x Im	1	12	2.02	2038	1.67	3452	2.85	113	1.85
Site (Lo(Im)) = Si(Lo(Im))	3	**32**	**2.98**	1174	0.77	237	0.54	501	2.50
Pe x Lo(Im)	1	0	0.43	237	0.52	0	0.54	34	0.53
Ti(Pe) x Im	22	17	0.77	2119	1.12	**1281**	**6.34**	220	0.61
Pe x Si(Lo(Im))	3	3	0.28	1511	0.99	597	1.37	82	0.41
Ti(Pe) x Lo(Im)	22	**22**	**2.02**	1893	1.23	202	0.47	**358**	**1.79**
Ti(Pe) x Si(Lo(Im))	66	11	1.27	**1534**	**2.48**	**435**	**2.39**	**200**	**1.62**
Residual	288	9		619		182		124	
C2		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	**208**	**5.08**	6172	2.87	2564	4.21	908	2.38
Impact = Im	1	796	0.80	37749	2.30	274	0.32	1059	0.08
Time (Pe) = Ti(Pe)	22	45	2.07	2574	1.36	**657**	**3.25**	497	1.39
Location (Im) = Lo(Im)	1	**1013**	**17.95**	**16142**	**5.40**	**1302**	**4.12**	**17873**	**21.82**
Pe x Im	1	23	2.93	1419	2.56	139	1.89	**1198**	**10.77**
Site (Lo(Im)) = Si(Lo(Im))	3	**35**	**4.23**	1272	1.33	152	0.97	**469**	**2.79**
Pe x Lo(Im)	1	0	0.19	237	0.37	0	0.27	34	0.46
Ti(Pe) x Im	22	15	0.71	1059	0.56	180	0.89	111	0.31
Pe x Si(Lo(Im))	3	**22**	**2.70**	1306	1.37	371	2.36	78	0.46
Ti(Pe) x Lo(Im)	22	**22**	**2.65**	**1893**	**1.98**	202	1.29	**358**	**2.13**
Ti(Pe) x Si(Lo(Im))	66	8	1.01	**956**	**1.89**	**157**	**1.96**	**168**	**1.55**
Residual	288	8		505		80		108	
C4		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	47.28	2.19	11339	2.47	2090	2.34	405	2.11
Impact = Im	1	978.11	0.99	31682	1.89	183	0.17	4323	0.27
Time (Pe) = Ti(Pe)	20	31.53	1.37	5367	2.63	**933**	**4.67**	370	0.98
Location (Im) = Lo(Im)	1	**989.21**	**17.71**	**16387**	**5.54**	**1599**	**4.44**	**17374**	**17.03**
Pe x Im	1	**95.36**	**6.66**	802	1.94	336	0.78	**150**	**4.64**
Site (Lo(Im)) = Si(Lo(Im))	3	**33.46**	**3.62**	1136	0.94	224	0.80	**655**	**3.86**
Pe x Lo(Im)	1	0.54	0.28	38	0.38	46	0.47	1	0.34
Ti(Pe) x Im	20	17.21	0.75	1425	0.70	**637**	**3.19**	113	0.30
Pe x Si(Lo(Im))	3	12.18	1.32	1224	1.01	501	1.79	125	0.73
Ti(Pe) x Lo(Im)	20	**22.93**	**2.48**	2038	1.69	199	0.71	**376**	**2.22**
Ti(Pe) x Si(Lo(Im))	60	9.25	1.16	**1210**	**1.52**	280	1.10	**170**	**1.41**
Residual	263	7.97		795		254		120	

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

A. C1 v Controls



B. C2 v Controls

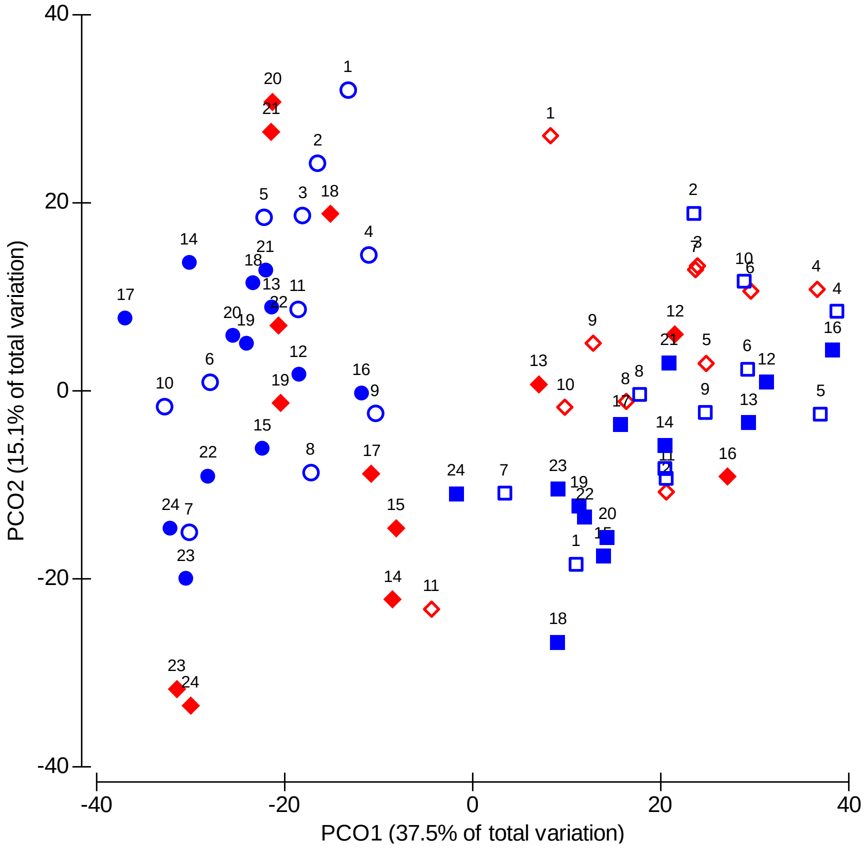


Figure 18. Principle Coordinates ordination (PCoA) of centroids for assemblages of aquatic macroinvertebrates sampled at locations a) C1 (red squares), b) C2 (red diamonds) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles)) from spring 2008 (T1) to autumn 2020 (T24). Empty symbols: 'Before'; Filled symbols: 'After' commencement of mining Longwalls 23-27.

C. C4 v Controls

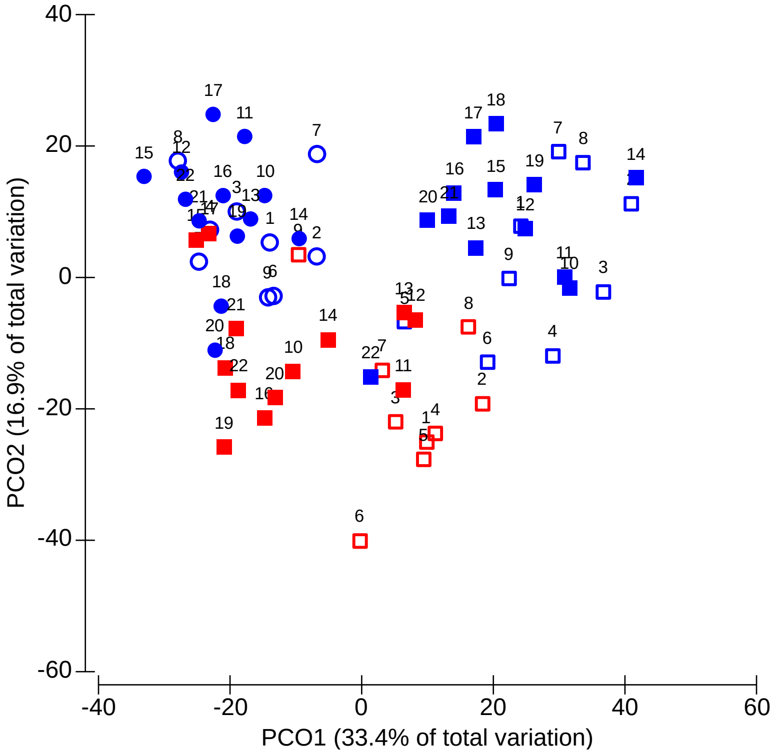


Figure 16 (Cont'd). PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at location c) C4 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2009 (T1) and autumn 2020 (T22). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

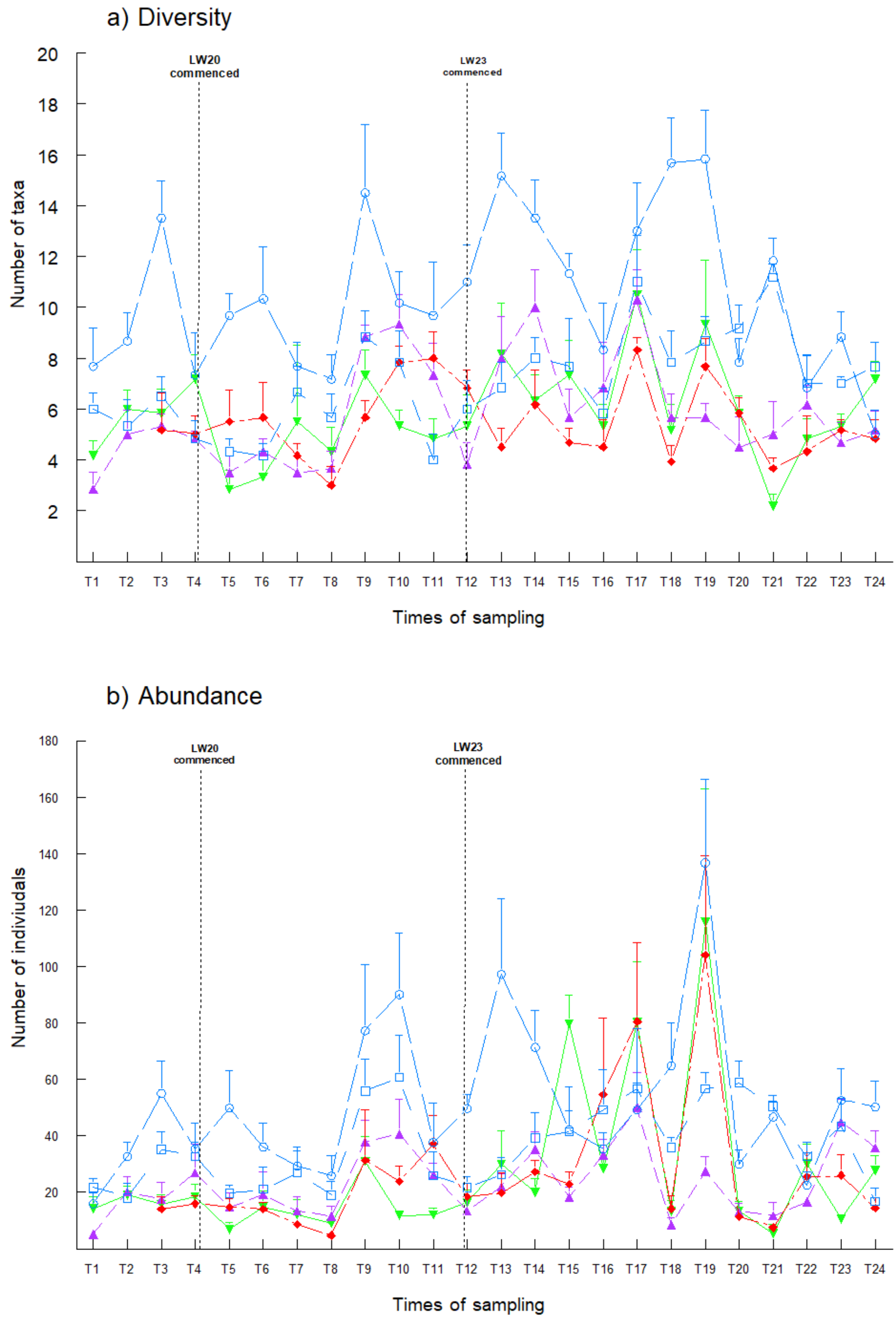
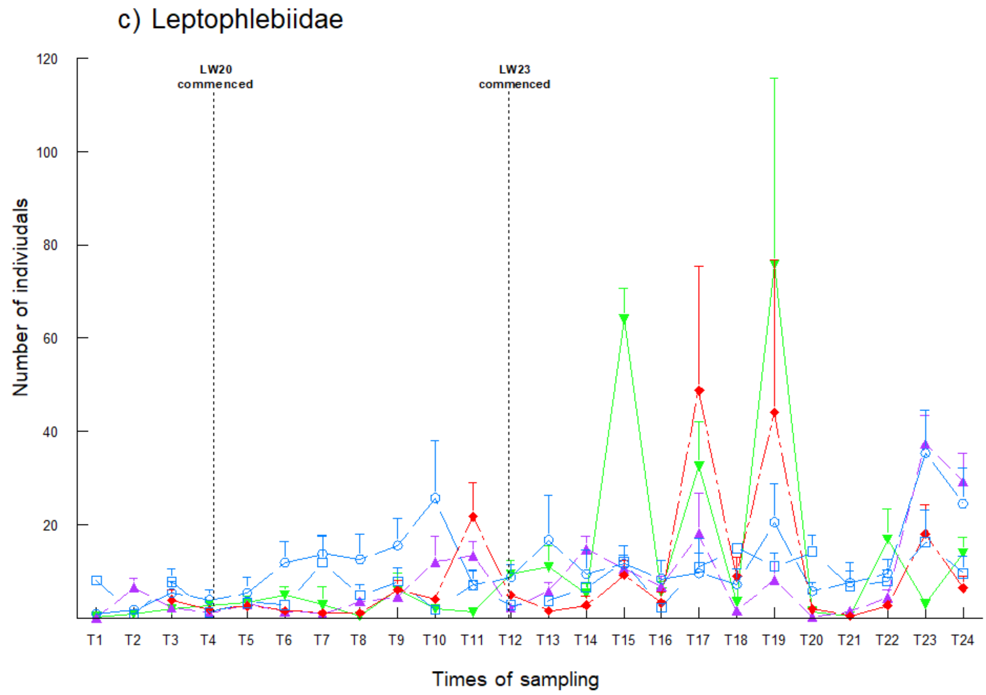


Figure 19. Mean number (+SE) of a) Taxa and b) Individuals of aquatic macroinvertebrates at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles), between spring 2008 (T1) and autumn 2020 (T24) (*n* = 6).



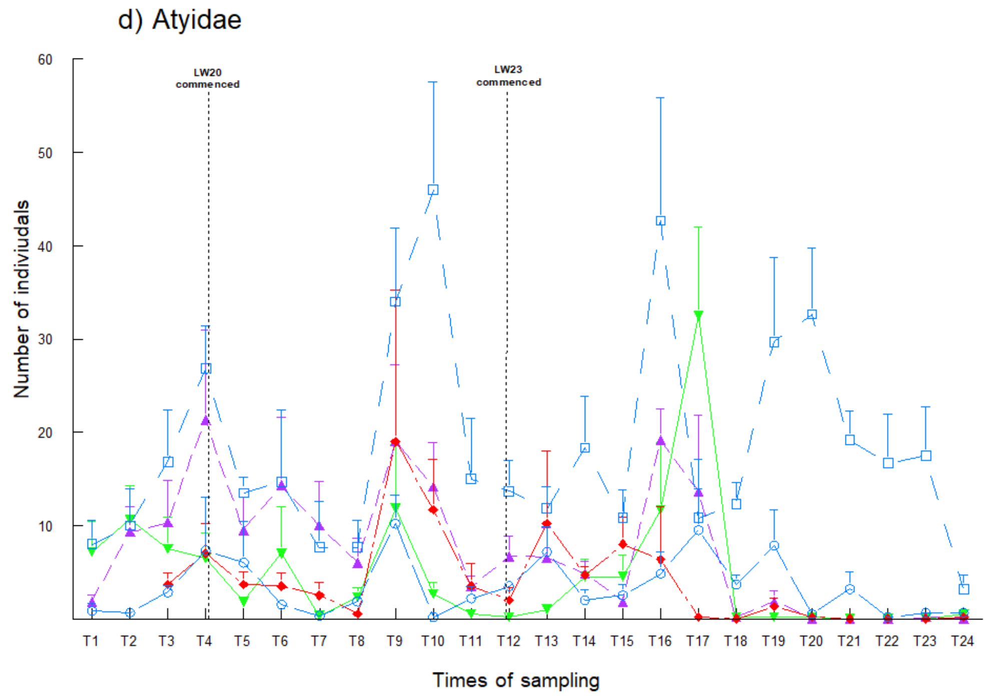


Figure 17 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2008 (T1) and autumn 2020 (T24) (*n* = 6).

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.10 (C1 in spring 2018) and 0.97 (OC in spring 2014) (Figure 18a). 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 18b). All of the OE50 Taxa scores were below 1.00 (Figure 18a&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 18a&b). Locations that achieved a Band A score were sampled on control streams (i.e. Woronora River and O'Hares Creek).

Notably, since the previous autumn survey (autumn 2019), Location C2 and C4 increased by one AUSRIVAS Band level (Figure 18b). Location C2 increased from Band C (severely impaired) to Band B (significantly impaired) (Figure 18b). Location C4 increased from Band D (extremely impaired) to Band C (Figure 18b).

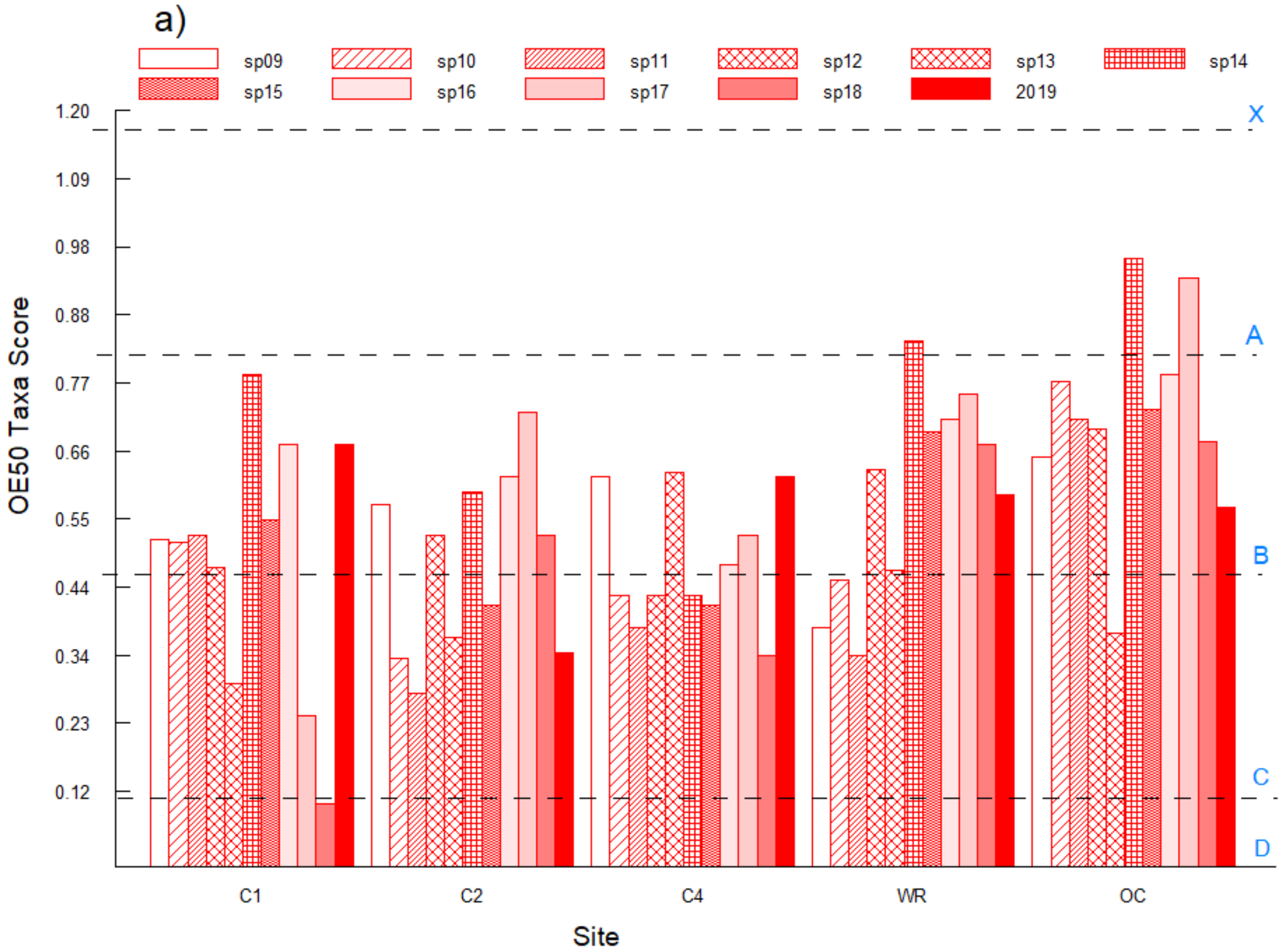


Figure 20a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2009 and 2019 (*n* = 2).

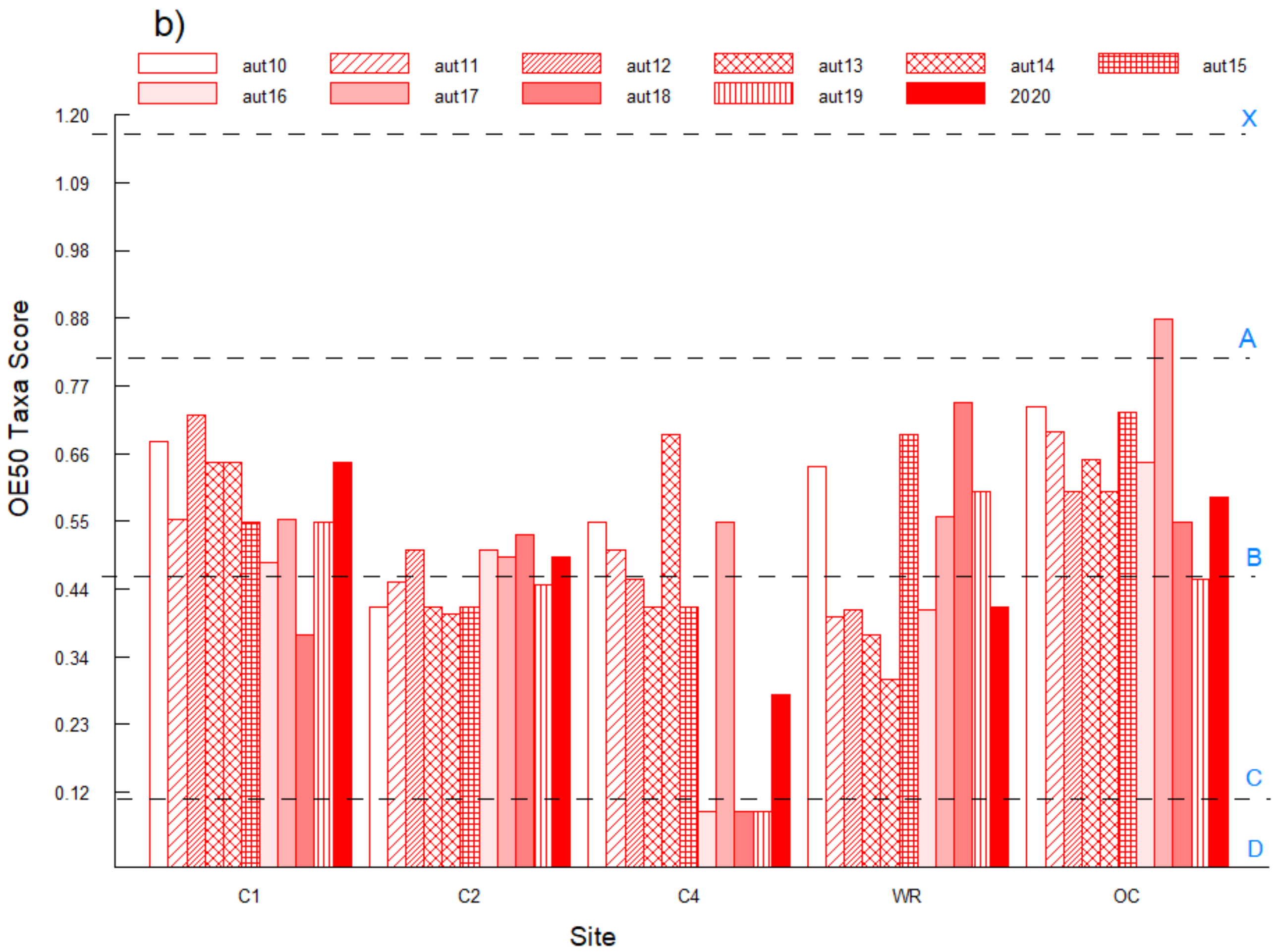


Figure 18b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2010 and 2020 (*n* = 2).

4.2.2 Aquatic Macrophytes

Location C1 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

Multivariate analyses have detected a significant change in the structure of the assemblage of aquatic macrophytes at Location C1 since spring 2017. Total cover and diversity of macrophytes however, have not differed significantly between periods in relation to the control locations.

The presence of the floating-attached species, *Triglochin procerum,* at the control locations but not at Location C1 has contributed greatly to observed differences in the structure of macrophyte assemblages between the treatment groups. In addition, *Baumea juncea* has been common at Location C1 but not at either of the control locations. The submerged species, *Myriophyllum pedunculatum,* has only been recorded at the Woronora River location.

Current Survey (Autumn 2020)

Similar to the findings of surveys done since spring 2017 (T19), multivariate analyses detected a significant 'before' to 'after' change in assemblages of aquatic macrophytes at Location C1 in relation to the control locations (Table 14, Figure 19a). *Post hoc* tests indicated that differences were partly due to the composition of assemblages at Location C1 changing significantly less between periods than at the control locations (Figure 19a).

SIMPER analyses indicate that the fern, *Gleichenia dicarpa*, contributed most to the structure of assemblages at Location C1 within the Before (38.2 %) period but its contribution has declined within the After period (17.0 %). *Triglochin procerum* (29 %), *Lepidosperma filiforme* (25.0 %) and *Gleichenia dicarpa* (15.8 %) contributed most to the control assemblage within the 'before' period, whereas *Gleichenia dicarpa* (58.7 %), *Lepidosperma filiforme* (15.9 %) and *Chorizandra cymbaria* (5.3 %) were ranked highest within the 'after' period.

Univariate analysis of mean diversity and cover of macrophytes did not detect any changes at Location C1 that might be related to mining of the Longwalls 23-27 area (Table 15, Figures 20a&b).

Graphically, it can be seen that total diversity of macrophytes at Location C1 has changed little over time (Figure 20a). It appears that there has been a gradual decrease in mean percentage cover at Location C1 since the spring 2015 (T15) survey (Figure 20b). 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. Since then, pool water level at Site C1-1 has commonly appeared to be below pre-mining levels.

Location C2 v Controls

Prior Surveys (Spring 2008 – Spring 2019)

A significant before-to-after change in assemblages was detected at Location C2 in spring 2014 (T13) and between autumn 2016 (T16) and spring 2019 (T23). A significant increase in species diversity was detected at Location C2 by the autumn 2017 (T18) and spring 2017 (T19) surveys, whilst a significant increase in total cover of macrophytes was detected in spring 2014 (T13).

Changes in the assemblage at Location C2 prior to the spring 2017 survey did not appear to be related to mining activities given the absence of apparent physical changes to the riparian strip that might be associated with mining activities (e.g. gas release, altered pool-water levels or surface flow). Iron staining and falls in pool water levels below pre-mining levels were, however, noted at Location C2 by the spring 2016 and spring 2017 surveys, respectively.

Current Survey (Autumn 2020)

A significant before-to-after change in the structure of the assemblage of aquatic macrophytes was detected at Location C2 in relation to the control locations in autumn 2020 (Table 14, Figure 19b). Similar to the findings for Location C1, pairwise tests indicated that differences were mostly due to the composition of assemblages at Location C2 changing significantly less between periods than at the control locations (i.e. Before v After at Location C2: t = 1.39, P = 0.051; Before v After at the Controls: t = 1.57, P = 0.012) (Figure 19a).

This result is reflected in the patterns seen in the PCoA, which shows that the centroids representing assemblages at the Woronora River and O'Hares Creek locations within the 'before' period tend to group separately from the centroids within the 'after' period (Figure 19a).

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). In autumn 2020, *Baumea juncea* contributed most (85 %) to the structure of the assemblage at Location C2, followed by *Gleichenia dicarpa* (5 %) and *Lepidosperma filiforme* (5 %) (SIMPER).

Analyses found no statistically significant interaction in the effects of Period and Impact on variability in mean diversity or percentage cover of aquatic macrophytes (Table 15, Figure 20a&b). Graphically, it can be seen that mean diversity and percentage cover of macrophytes increased at Location C2 between the spring 2019 survey (T23) and autumn 2020 (T24) surveys (Figure 20a&b).

Location C4 v Controls

Prior Surveys (Spring 2009 – Spring 2019)

Multivariate analyses have detected a significant before-to-after change in assemblages at Location C4 in relation to the Control since autumn 2018 (T18). Analyses of temporal changes in total cover and species diversity at Location C4 have consistently found no significant changes in relation to control locations that would indicate an impact from mining.

Current Survey (Autumn 2020)

Analyses detected a significant before-to-after change in the structure of assemblages of aquatic macrophytes at Location C4 in autumn 2020 (T22), in relation to the Controls (Table 14). *Post-hoc* tests indicated that this result was due to temporal differences in dispersion (P = 0.001) between periods at Location C4 in relation to the control locations as well as changes in the composition of assemblages (C4: t = 2.00, P = 0.001; Control: t = 1.65, P = 0.005) (Figure 19c).

This result is reflected in the patterns seen in the PCoA, which shows that the centroids representing assemblages at Location C4 in the 'before' period tend to group separately from centroids representing the assemblage within the 'after' period (Figure 19c).

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* (31.1 %), *Viminaria juncea* (27.2 %) and *Gleichenia dicarpa* (18.5 %) contributed most within the 'after' period.

Analyses of species diversity and total cover of aquatic macrophytes did not detect a significant interaction between the factors of interest (Pe and Im) (Table 15). Overall, species diversity of macrophytes at Location C4 appears to have differed little over time (Figure 20a). Graphically, there appeared to have been a considerable decrease in cover at Location C4 after the spring 2017 (T19) survey (Figure 20b). Large reductions in pool water levels have been noted along the study reach since spring 2015, particularly at the upstream site (Site C4-1). Between the spring 2019 (T22) and autumn 2020 (T23) surveys, mean cover decreased at Location C4 and the control locations (Figure 20b).

Table 14. PERMANOVA on Bray Curtis dissimilarities of macrophyte assemblage data (non-transformed) to compare locations sampled on Tributary C/Eastern Tributary (C1, C2 and C4) 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**	**39109**	**2.405**	**0.010**	**5.76**
Impact = Im	1	105880	1.841	0.093	8.13
Time (Pe) = Ti(Pe)	**22**	**5634**	**1.387**	**0.010**	**4.96**
Location (Im) = Lo(Im)	1	55145	1.067	0.356	2.52
Pe x Im	**1**	**36364**	**2.393**	**0.010**	**7.87**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**50071**	**19.176**	**0.000**	**12.90**
Pe x Lo(Im)	1	12314	0.955	0.550	0.00
Ti(Pe) x Im	22	4581	1.127	0.200	4.03
Pe x Si(Lo(Im))	**3**	**11566**	**4.430**	**0.000**	**7.93**
Ti(Pe) x Lo(Im)	**22**	**4064**	**1.556**	**0.000**	**7.79**
Ti(Pe) x Si(Lo(Im))	66	2611	0.752	1.000	0.00
Residual	576	3474			38.11
		C2			
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**29080**	**1.88**	**0.03**	**4.75**
Impact = Im	1	101110	1.57	0.16	7.49
Time (Pe) = Ti(Pe)	**22**	**4869**	**1.26**	**0.04**	**4.18**
Location (Im) = Lo(Im)	1	63011	1.35	0.13	5.78
Pe x Im	**1**	**31550**	**2.16**	**0.02**	**7.47**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**44926**	**15.64**	**0.00**	**12.81**
Pe x Lo(Im)	1	12669	1.16	0.23	2.85
Ti(Pe) x Im	22	3691	0.95	0.64	0.00
Pe x Si(Lo(Im))	**3**	**9588**	**3.34**	**0.00**	**7.24**
Ti(Pe) x Lo(Im)	**22**	**3866**	**1.35**	**0.00**	**6.80**
Ti(Pe) x Si(Lo(Im))	66	2872	0.81	1.00	0.00
Residual	576	3548			40.63
		C4			
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	1	**31738**	**2.82**	**0.004**	**6.60**
Impact = Im	1	69425	1.13	0.377	4.05
Time (Pe) = Ti(Pe)	20	3621	1.08	0.263	2.40
Location (Im) = Lo(Im)	1	61035	1.46	0.091	7.18
Pe x Im	1	**20172**	**1.96**	**0.023**	**6.66**
Site (Lo(Im)) = Si(Lo(Im))	3	**40357**	**14.71**	**0.000**	**13.90**
Pe x Lo(Im)	1	8816	1.27	0.143	3.56
Ti(Pe) x Im	20	3193	0.96	0.630	0.00
Pe x Si(Lo(Im))	3	**5754**	**2.10**	**0.001**	**5.56**
Ti(Pe) x Lo(Im)	20	**3338**	**1.22**	**0.026**	**5.70**
Ti(Pe) x Si(Lo(Im))	60	2743	0.76	1.000	0.00
Residual	528	3608			44.39

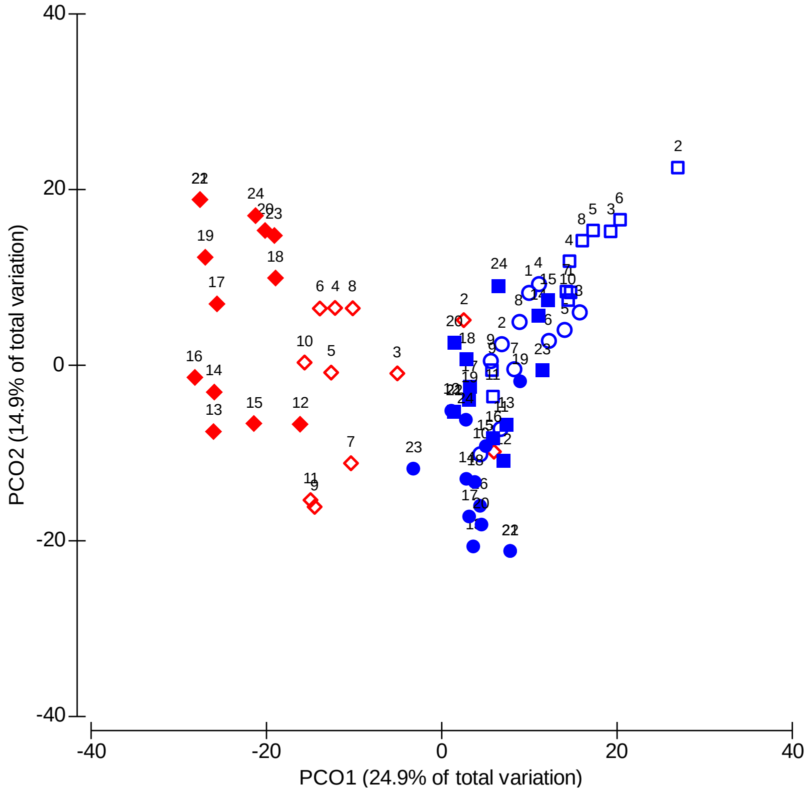
Bold numbers indicate significant results at $P < 0.05$.

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.

C1		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	27.49	3.85	15643	1.40
Impact = Im	1	0.65	0.64	1939	0.26
Time (Pe) = Ti(Pe)	22	**5.02**	**2.46**	**2769**	**2.81**
Location (Im) = Lo(Im)	1	0.41	0.45	8749	1.01
Pe x Im	1	1.90	0.61	4559	0.48
Site (Lo(Im)) = Si(Lo(Im))	3	1.78	1.36	**8328**	**12.21**
Pe x Lo(Im)	1	2.66	1.19	**9086**	**3.32**
Ti(Pe) x Im	22	3.79	1.86	**2397**	**2.43**
Pe x Si(Lo(Im))	3	1.29	0.98	1956	2.87
Ti(Pe) x Lo(Im)	22	2.04	1.56	986	1.45
Ti(Pe) x Si(Lo(Im))	66	1.31	0.99	682	1.17
Residual	576	1.32		582	
Total	719				
C2		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	30.74	3.25	2752	0.37
Impact = Im	1	5.96	3.73	56	0.24
Time (Pe) = Ti(Pe)	22	**7.12**	**3.62**	1363	1.29
Location (Im) = Lo(Im)	1	0.02	0.38	3480	0.53
Pe x Im	1	4.90	1.36	705	0.17
Site (Lo(Im)) = Si(Lo(Im))	3	1.36	1.08	**7034**	**9.07**
Pe x Lo(Im)	1	2.95	1.25	9028	2.42
Ti(Pe) x Im	22	2.11	1.07	1217	1.15
Pe x Si(Lo(Im))	3	1.41	1.12	**2990**	**3.86**
Ti(Pe) x Lo(Im)	22	1.97	1.57	1055	1.36
Ti(Pe) x Si(Lo(Im))	66	1.25	0.94	**775**	**1.60**
Residual	576	1.34		485	
Total	719				
C4		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	5.95	1.10	8314	0.99
Impact = Im	1	0.55	2.53	166	0.34
Time (Pe) = Ti(Pe)	20	3.40	1.70	1449	1.27
Location (Im) = Lo(Im)	1	0.05	0.25	2931	0.54
Pe x Im	1	0.29	0.48	10	0.13
Site (Lo(Im)) = Si(Lo(Im))	3	3.55	2.60	**5398**	**9.00**
Pe x Lo(Im)	1	3.85	1.06	**8101**	**6.24**
Ti(Pe) x Im	20	0.96	0.48	930	0.82
Pe x Si(Lo(Im))	3	2.91	2.14	254	0.42
Ti(Pe) x Lo(Im)	20	2.00	1.47	**1141**	**1.90**
Ti(Pe) x Si(Lo(Im))	60	1.36	1.07	599	1.17
Residual	528	1.27		512	
Total	659				

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

A. C1 v Controls



B. C2 v Controls

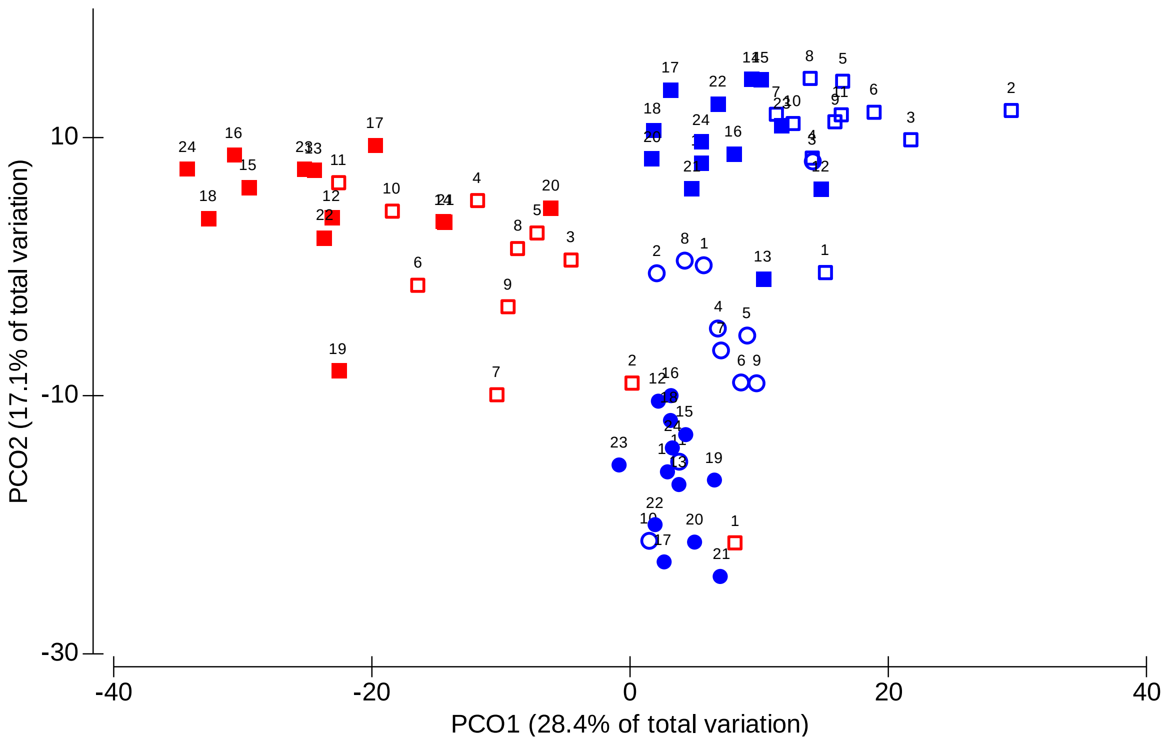


Figure 21. PCoA of centroids for assemblages of macrophytes sampled at locations a) C1 and b) C2 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2008 (T1) and autumn 2020 (T24). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

C. C4 v Controls

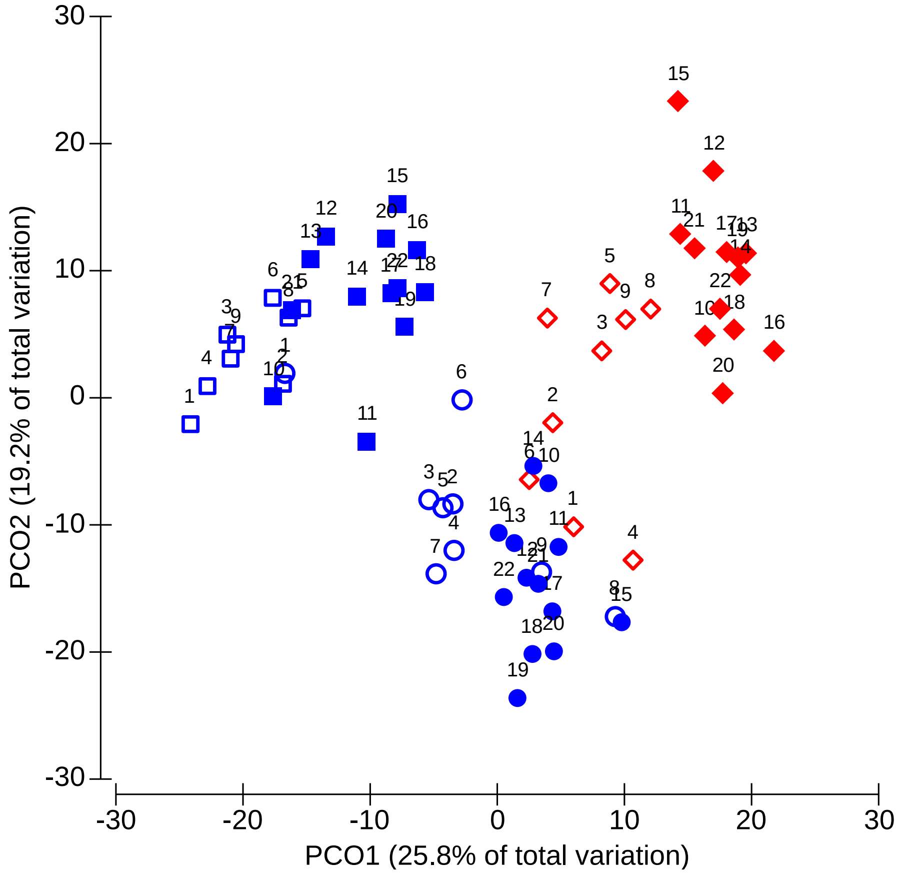


Figure 19 (Cont'd). PCoA of centroids for assemblages of macrophytes sampled at location c) C4 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2009 (T1) and autumn 2020 (T22). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

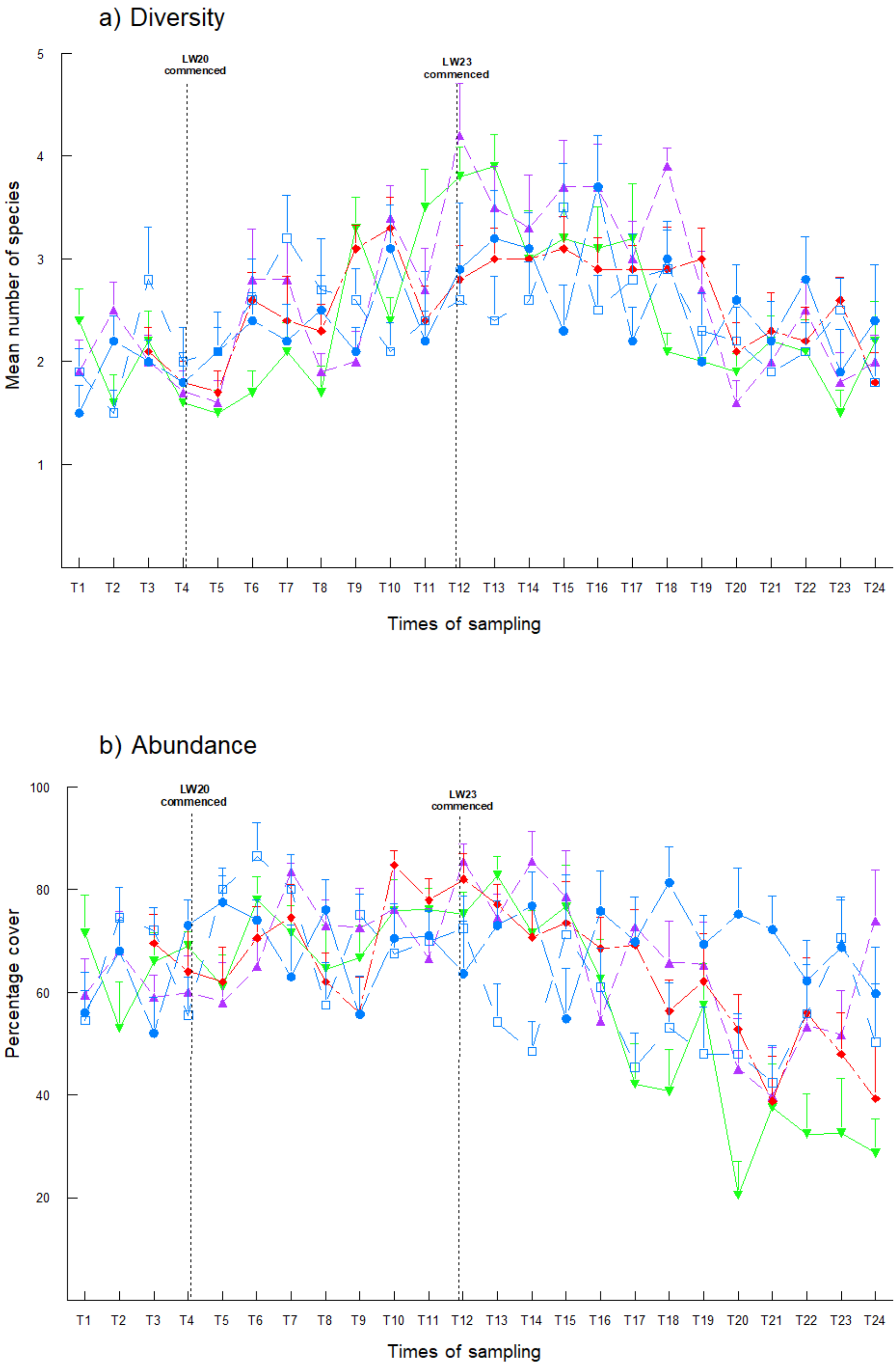


Figure 22. Mean (+SE) a) Number of species/quadrat (*n* = 10) and b) Percentage cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2008 (T1) and autumn 2020 (T24).

5.0 SUMMARY & CONCLUSIONS

The primary objective of monitoring was to determine whether the extent and nature of any mining-related impacts, primarily subsidence-induced fracturing of bedrock, diversion and loss of aquatic habitat are consistent with the predictions made in the:

i) Extraction Plan and the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan (2014)* (Metropolitan Coal, 2015a);
ii) Extraction Plan and the *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan (2015)* (Metropolitan Coal, 2015b).

A summary of the main findings to date are presented in Sections 5.1 & 5.2, respectively.

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

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

Multivariate and univariate analyses of the monitoring data were used to test whether or not there was evidence of significant change in aquatic macroinvertebrate and macrophyte indicators at Tributary C/Eastern Tributary locations C1, C2 and C3 related to mining within the Longwalls 20-22 underground area. Two to four replicate surveys (spring 2008 or spring 2009[10] to autumn 2010) have been sampled within the 'Before' commencement of Longwall 20 period and 20 replicate times (spring 2010 to autumn 2020) have been sampled within the 'After' period.

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.

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

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.

Quantitative analyses have consistently found no changes to aquatic macroinvertebrate indicators at Location C1 that would indicate a significant impact from mining of the Longwalls 20-22 area. 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), but not subsequently. This result did not appear to be related to mining activities. Mining-related drops in pool water levels at C1 since spring 2017 have most likely contributed to the 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 ranged from an OE50 score of 0.15 (Band C) in spring 2008 to 0.72 (Band B) in spring 2017.

To date, analyses have detected a significant decrease in mean numbers of the freshwater shrimp family, Atyidae, at Location C2 within the after-mining period in spring 2015 and autumn 2017, 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 since spring 2015, but not in spring 2019 or autumn 2020. 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.

The AUSRIVAS scores obtained at the rivulet locations from spring 2008 to autumn 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 from before- to after-mining of the Longwalls 20-22 underground mining 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 (spring 2018, autumn 2019, spring 2019 and autumn 2020). Differences appear to be related to a decrease in diversity at Location WT3 within the after-mining period, whereas there was an increase at the control locations.

There were no conspicuous differences in mean diversity at Locations WT4 or WT5 in relation to the control locations. Mean abundance of macroinvertebrates and mean numbers of Leptophlebiidae and Atyidae did not differ at locations WT3, WT4 or WT5 in relation to the control locations between the before- and after-mining periods.

There were 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

Locations C1 and C4 overly the Longwalls 23-27 underground mining area while Location C2 is downstream of the Longwalls 23-27 underground mining area. Nine to eleven replicate times (spring 2008 or spring 2009[11] to spring 2013) were sampled within the 'Before' commencement of Longwall 23 period and thirteen replicate times (autumn 2014 to autumn 2020) have been sampled within the 'After' period.

Visual evidence of mining related impacts, including iron staining, cracking of the stream substratum and occasional falls in pool water levels, have been noted at Locations C1 and C4 since autumn 2014. 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.

Since the commencement of mining of the Longwalls 23-27 area (i.e. autumn 2014), analyses have detected a significant change in the structure of the assemblage of aquatic macroinvertebrates sampled at Location C1 in relation to the control locations at the time of the spring 2016, autumn 2019, spring 2019 and autumn 2020 surveys. Mean numbers of the mayfly family, Leptophlebiidae, have been significantly more variable within the after-period at Location C1 than at the control locations between autumn 2015 and autumn 2019 and in autumn 2020. A significant change in the assemblage of macrophytes has been detected at Location C1 since spring 2017.

A significant change in assemblages of macroinvertebrates indicative of a mining impact was detected at Location C2 in autumn and spring 2019 and autumn 2020. A significant Before- vs After-change in total abundance of macroinvertebrates has been detected in spring 2018, autumn and spring 2019. Mean numbers of the freshwater shrimp family, Atyidae, collected between autumn 2016 and 2018 and in autumn 2020 were significantly fewer than in the Before-mining period.

---

[11] The sampling of Location C4 (ET4) on the Eastern Tributary commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

The structure of assemblages of macrophytes sampled at Location C2 in spring 2014 and from autumn 2016 to autumn 2020 differed significantly from assemblages sampled within the Before-mining period. Changes in components of the macrophyte assemblage prior to the spring 2017 survey however, do not appear to be related to mining activities. Significantly greater diversity of macrophytes was detected at C2 in autumn and spring 2017, but not subsequently. Cover of macrophytes at C2 differed significantly from the control locations but not subsequently.

At Location C4, the AUSRIVAS condition of the 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. Assemblages of aquatic macroinvertebrates sampled at the time of the spring 2019 and autumn 2020 surveys differed significantly from assemblages collected within the before-period, in relation to the control locations. Temporal patterns in diversity of macroinvertebrates at Location C4 have differed significantly between periods since autumn 2018, in relation to the control locations. Significantly fewer Atyidae were collected at Location C4 in autumn 2016, spring 2018, spring 2019 and autumn 2020 than within the before-period.

The structure of the aquatic macrophyte assemblage at Location C4 has differed significantly from assemblages within the before-period since autumn 2018.

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 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.	Locations ET1, ET3, WT4 and WT5. Locations ET2, ET4 and WT3 (all parameters excluding those listed in Level 2 below).	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 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.	Location ET2 [pre-mining of Longwalls 20-22][1] (change in Atyidae in spring 2015 and autumn 2017 but not subsequently). Location ET2 [pre-mining of Longwalls 23-27][1] (significant change in assemblage of macroinvertebrates in autumn and spring 2019 and autumn 2020; abundance of macroinvertebrates in spring 2018, autumn and spring 2019; altered numbers of Atyidae between autumn 2016 and autumn 2019 and in autumn 2020; apparent mining-related change in the assemblage of aquatic plants within the after-period since spring 2017; increased diversity of macrophytes at C2 in autumn and spring 2017 in relation to control locations) Location ET4 (significant change in assemblage of macroinvertebrates in spring 2019 and autumn 2020; altered patterns of diversity of macroinvertebrates since autumn 2018; decreased numbers of Atyidae in autumn 2016, spring 2018, spring 2019 and autumn 2020; altered macrophyte assemblage in autumn 2018, spring 2018, spring 2019 and autumn 2020). Location WT3 (change in macroinvertebrate diversity in spring 2016, autumn 2018, spring 2018, autumn 2019, spring 2019 and autumn 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 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.	Nil	-	-

[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. **Autumn 2020 Longwalls 20-27 Aquatic Ecology Monitoring - GPS positions (UTMs).**

System	Location	Site	Easting	Northing
Tributary C/Eastern Tributary	1	1	03116120	6214115
	1	2	0311634	6214158
	2	1	0312163	6215413
	2	2	0312167	6215577
	3	1	0311425	6213645
	3	2	0311462	6213716
	4	1	0311805	6214447
	4	2	0312032	6214497
Waratah Rivulet	3	1	0309863	6214303
	3	2	0309852	6214454
	4	1	0310426	6215080
	4	2	0310322	6215160
	5	1	0310525	6215340
	5	2	0310687	6215363
Woronora River	1	1	0307939	6219048
	1	2	0307929	6219104
O'Hares Creek	1	1	0303812	6213711
	1	2	0303636	6213577

APPENDIX 3a. AUTUMN 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	2	3	3	3	0	1	1	1	0	0	0	0	0	0	0	0	0	1
Baumea rubiginosa	0	1	0	0	1	0	0	0	2	0	0	0	0	1	1	0	1	2
Baumea teretifolia	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	2	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Chara/Nitella spp.	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
Chorizandra cymbaria	1	1	0	1	0	1	0	0	0	1	0	2	0	2	1	1	3	2
Dicksonia antarctica	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	0	2
Empodisma minus	3	2	3	3	3	0	2	3	2	2	1	0	1	1	1	1	2	2
Eurychorda complanata	0	0	0	0	0	0	0	0	2	0	0	0	2	3	1	2	0	2
Gahnia clarkei	1	2	0	0	3	3	1	1	0	2	0	0	0	0	1	1	2	0
Gleichenia dicarpa	0	1	1	3	3	3	1	2	3	3	2	0	3	3	2	2	3	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Isolepis inundata	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
Lepidosperma filiforme	2	3	2	2	2	2	3	2	2	2	3	3	3	3	3	3	0	2
Lomandra fluviatilis	0	0	2	2	1	2	2	1	0	0	3	2	2	0	0	0	0	3
Lomandra longfolia	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0
Schoenus brevifolius	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	1	1	0	0	0	0	1	1	0	2	0	1	1	2	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	1	2	3	3	0	3	3	1	0
Viminaria juncea	1	2	3	3	2	1	3	3	3	2	1	0	2	2	0	1	2	1
Xyris operculata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

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

APPENDIX 3a. AUTUMN 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	2	3	3	3	0	1	1	1	0	0	0	0	0	0	0	0	0	1
Baumea rubiginosa	0	1	0	0	1	0	0	0	2	0	0	0	0	1	1	0	1	2
Baumea teretifolia	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	2	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Chara/Nitella spp.	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
Chorizandra cymbaria	1	1	0	1	0	1	0	0	0	1	0	2	0	2	1	1	3	2
Dicksonia antarctica	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	1	0	1	1	0	1	1	0	0	0	1	0	0	0	0	2
Empodisma minus	3	2	3	3	3	0	2	3	2	2	1	0	1	1	1	1	2	2
Eurychorda complanata	0	0	0	0	0	0	0	0	2	0	0	0	2	3	1	2	0	2
Gahnia clarkei	1	2	0	0	3	3	1	1	0	2	0	0	0	0	1	1	2	0
Gleichenia dicarpa	0	1	1	3	3	3	1	2	3	3	2	0	3	3	2	2	3	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Isolepis inundata	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
Lepidosperma filiforme	2	3	2	2	2	2	3	2	2	2	3	3	3	3	3	3	0	2
Lomandra fluviatilis	0	0	2	2	1	2	2	1	0	0	3	2	2	0	0	0	0	3
Lomandra longfolia	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0
Schoenus brevifolius	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	1	1	0	0	0	0	1	1	0	2	0	1	1	2	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	1	2	3	3	0	3	3	1	0
Viminaria juncea	1	2	3	3	2	1	3	3	3	2	1	0	2	2	0	1	2	1
Xyris operculata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

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

APPENDIX 3b. AUTUMN 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	5	0	0	10	15	0	0	0	40	0	0	65	10	75	80	80	95	10
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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	15	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	10	5	0	10	15	0	10	0	0	0	0	15	0	0	30	20	0	0	0	0
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	75	0	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	10	20	10	0	15
Glossostigma sp.	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	0	15	0	0	0	5	20	0	55	70	0	0	0	0	0	0	0
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	15	0	0	0	0	0	0	0	0	0	0	8	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
Schoenus brevifolius	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	5	10	0	10	5	5	2	0	0	0	0	0	0	0	0	0	10	20	0	0

* Denotes introduced species

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	40	0	0	0	0	0	0	10	5	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	15	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	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	30	90	0	0	0	0	0	10	0	0	0	0	0	0	0
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	15	0	0	0	0	0	75	80	0	0	0	0	0	0	0	60	0	0	0
Gleichenia dicarpa	55	45	85	55	5	8	0	0	0	0	0	10	0	0	0	0	0	0	5	10
Glossostigma sp.	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	25	0	15	0	0	0	100	20	0	10	0	30	0	0	0	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	30	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
Schoenus brevifolius	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	0	2	4	0	5	0	0	0	0	0	5	0	55	0	8	10	5	0	0	10

* Denotes introduced species

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	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	15	30	0	0	0	2	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	5	0	0	0	0	0	0	0	0	0	0	10	0
Drosera binata	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
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	0	0	20	10	0	0	0	0	0	0	0	0	0	0	0
Eurychorda complanata	0	0	0	0	55	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	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	4	0	0	0	8	8	10	5	70	0	0	0	8	8	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
Lepidosperma filiforme	0	0	0	0	5	0	0	0	0	0	0	75	0	10	35	0	50	0	70	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	95	0	80	25	0	80	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
Schoenus brevifolius	0	0	0	0	0	0	0	10	5	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	90	0	100
Viminaria juncea	0	1	2	5	0	2	0	0	0	0	0	0	5	0	0	0	0	0	0	0

* Denotes introduced species

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**	**WR1-1**	**WR1-2**	**WR1-3**	**WR1-4**	**WR1-5**	**WR2-1**	**WR2-2**	**WR2-3**	**WR2-4**	**WR2-5**
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	20	0	0	0	0	0	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	15	0	2	0	0	0	0	0	0	0	0	0	0	0	15
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	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	0	10	0	0	0	0	5	0	0	0	0	0	0	0	0
Eurychorda complanata	45	0	0	0	0	0	80	20	0	60	15	0	0	0	0	0	0	0	0	20
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	90	20	15	15	50	0	70	0	2	3	30	0	0	0	0	0	12	0	5
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Lepidosperma filiforme	5	0	0	40	10	0	0	10	0	5	0	5	8	0	0	60	0	80	80	0
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	80	0	0	0	0	0	0	0
Schoenus brevifolius	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	5	0	0	0	70	0	0	0
Viminaria juncea	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

* Denotes introduced species

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	10	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	15	0	15	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	5	5	0	0
Chorizandra cymbaria	15	0	0	5	0	0	15	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	15	10	0	0
Empodisma minus	0	20	0	5	0	0	0	0	0	90
Eurychorda complanata	0	0	0	0	0	0	0	50	0	0
Gahnia clarkei	0	0	0	4	0	0	0	0	0	0
Gleichenia dicarpa	70	15	0	30	0	0	0	0	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	0	0	0	0	0	4
Lomandra fluviatilis	0	0	0	0	0	55	0	0	90	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	50	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	2	0	0	0	0	2	0

* Denotes introduced species

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

APPENDIX 4. AUTUMN 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	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
Aeshnidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Atyidae	6	0	1	0	3	0	0	0	0	0	0	0	1	0	19	5	0	0
Austrocordulia cf *refracta*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Baetidae	0	6	0	2	1	2	1	0	15	0	0	0	0	2	0	0	0	0
Caenidae	0	0	0	0	2	0	0	0	30	4	4	0	1	3	0	0	0	4
Ceinidae	0	0	0	0	0	0	0	0	2	0	2	0	1	0	0	0	9	3
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Chironomidae (L.) - Chironominae	1	4	0	1	0	0	0	4	2	1	2	5	1	2	0	0	0	2
Chironomidae (L.) - Tanypodinae	0	0	0	0	0	0	0	0	4	2	1	6	0	0	1	0	1	3
Corydalidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	0
Corixidae	0	0	2	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0
Culicidae	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Dytiscidae	4	4	3	9	3	1	0	3	17	4	2	1	5	6	1	0	1	3
Ecnomidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gerridae	0	2	0	0	0	0	0	0	0	0	5	0	0	0	1	0	1	0
Gripopterygidae	0	1	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	1	2	4	5	1	1	0	0	1	0
Gyrinidae	0	1	0	1	5	3	0	0	7	3	2	0	0	0	0	0	0	0
Hydraenidae	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	1	0	1	0	0	1	0	5	3	1	16	1	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptoceridae	4	3	0	0	0	1	0	0	2	1	0	0	0	0	1	2	2	2
Leptophlebiidae	9	23	29	45	72	40	15	10	46	46	52	65	18	36	11	5	11	14
Libellulidae	0	0	1	1	1	0	0	0	1	2	0	0	0	0	0	0	0	0
Megapodagrionidae	0	1	0	1	1	0	0	1	0	0	0	3	0	0	0	0	2	0
Notonectidae	1	0	0	1	4	2	2	0	0	0	2	0	0	0	0	0	2	0
Scirtidae	0	2	0	1	0	5	0	0	1	0	2	0	1	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tipulidae	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Taxa	**6**	**10**	**5**	**12**	**12**	**11**	**4**	**5**	**15**	**9**	**15**	**7**	**11**	**8**	**7**	**5**	**13**	**8**

Site Codes: C11 - Tributary C, Location 1, Site 1, etc

APPENDIX 5. AUTUMN 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	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	0
Atyidae	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
Austrocordulia cf *refracta*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	6	2	0	1	1	0	0	0	0	0	3	0	1	3	0	3	0	1	6
Brentidae	0	0	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	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	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Chironomidae	0	0	0	3	11	2	5	0	2	1	0	3	2	0	0	0	2	1	0	2	3	1	7	1
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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0
Dixidae	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	2	0	2	3	0	0	3	0	0	1	1	2	1	1	2	0	0	2	0	0	0	0	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3
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
Gelastocoridae	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	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	2	0	2	1	2	3	0	0	0	0	1	0	0	2	0	0	3	0	0	0	0	0	0	0
Haliplidae	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	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	6	2	4	1	3	0	0	0	1	0	0	0	1	0	0	2	3	1	0	1	0	0	0	0
Leptophlebiidae	17	2	11	13	12	28	12	14	35	24	45	45	26	6	23	28	14	32	17	7	1	3	0	10
Libellulidae	0	0	0	0	0	0	0	0	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	3	2	2	0	1	2	1	2	0	0	0	0	0	0	0
Notonectidae	0	1	1	0	1	0	0	1	0	0	0	0	2	0	0	0	0	2	1	0	0	0	0	1
Parastacidae (*Cherax* sp.)	0	0	0	0	0	0	0	0	0	1	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	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	0	0	0	0	0	0
Scirtidae	3	1	0	1	4	0	0	0	0	0	0	0	1	0	0	4	1	1	3	1	1	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	1	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	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0
Unknown Diptera pupae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**30**	**10**	**19**	**25**	**41**	**42**	**19**	**18**	**41**	**32**	**50**	**54**	**34**	**11**	**28**	**43**	**32**	**40**	**29**	**11**	**11**	**5**	**9**	**21**
Number of Taxa	**6**	**7**	**5**	**8**	**10**	**7**	**3**	**3**	**6**	**7**	**5**	**7**	**6**	**5**	**5**	**9**	**10**	**8**	**7**	**4**	**7**	**3**	**3**	**5**

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

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

APPENDIX 5.

	Waratah Rivulet																	
Taxa	**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	0	0	0	0
Acariformes	0	0	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	1	1	3	0	2	0	0	1	0
Austrocordulia cf *refracta*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Baetidae	18	3	5	0	1	3	0	1	0	1	0	1	0	0	0	6	3	2
Brentidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	17	2	9	1	7	11	0	2	0	2	0	3	3	0	0	0	4	1
Ceinidae	1	0	8	12	6	4	0	5	0	1	0	1	3	0	1	0	0	1
Ceratopogonidae	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	3	1	2	7	7	2	1	2	7	2	0	0	0	1	44	5	0	2
Coenagrionidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	1	1	1	0	4	0	0	0	1	0	0	0	0
Corixidae	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	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	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	11	0	2	0	2	4	2	1	2	3	3	2	0	1	7	4	3	2
Ecnomidae	1	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
Gelastocoridae	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	1	1	0	0	0	1	0	0	1	0	0
Gomphidae	0	0	1	2	2	0	0	2	2	2	1	5	0	0	0	1	1	1
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	2	0	3	1	2	3	0	1	2	0	2	0	1	0	0	1	0	0
Haliplidae	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	2	0	0	0	1	0	0	0	0	0	0	0	2	0	0	5	2	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Leptoceridae	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	2	0	0
Leptophlebiidae	33	10	97	64	65	32	29	40	48	93	68	60	10	4	1	19	17	40
Libellulidae	1	0	0	0	0	0	0	0	1	1	2	0	0	0	4	5	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2
Notonectidae	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Parastacidae (*Cherax* sp.)	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	1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sialidae	0	0	0	1	0	0	0	0	0	0	0	1	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
Synthemistidae	0	0	1	0	0	0	2	0	0	0	2	1	0	0	0	0	0	0
Telephlebiidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	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
Total Macroinvertebrates	**91**	**21**	**135**	**90**	**93**	**62**	**36**	**56**	**65**	**110**	**80**	**78**	**20**	**9**	**58**	**50**	**33**	**52**
Number of Taxa	**12**	**7**	**13**	**9**	**9**	**9**	**6**	**10**	**9**	**10**	**8**	**10**	**6**	**5**	**6**	**11**	**9**	**9**

Not included in the sum of the '

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

APPENDIX 5.

	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	1	1	0	0	0	0	0	0	0	0
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	3	0	9	6	1	0	1	1	2	0	0	0
Austrocordulia cf *refracta*	0	0	0	0	0	0	1	0	0	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	3	1	11
Brentidae	0	0	0	1	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	1	2	3	23	7
Ceinidae	0	0	0	0	0	0	4	7	12	0	2	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	1	1	0
Chironomidae	0	0	0	2	0	0	5	0	2	2	1	2
Coenagrionidae	0	0	0	0	0	0	1	0	1	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	1	4	1	0	0
Corixidae	0	0	0	0	1	0	2	0	0	1	1	0
Culicidae	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
Dugesiidae	0	0	0	0	0	0	0	0	0	0	1	0
Dytiscidae	0	0	0	0	1	0	2	1	4	0	10	2
Ecnomidae	0	0	0	0	0	0	1	0	0	1	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0
Gelastocoridae	0	0	0	0	0	0	0	1	0	0	0	0
Gerridae	0	0	0	0	0	0	1	1	0	0	0	0
Gomphidae	0	0	1	0	0	0	0	1	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	1	0	0	0	0	0	1
Haliplidae	0	0	0	0	2	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	1	0	0	0	0	0	0	0	0	2	0
Isostictidae	0	0	0	0	0	0	0	1	2	0	0	0
Leptoceridae	1	0	2	1	0	1	0	0	1	0	1	0
Leptophlebiidae	6	21	21	7	1	1	8	6	33	30	15	55
Libellulidae	0	0	1	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	2	0	0	2	0	2	0	0	0
Notonectidae	0	0	0	0	0	1	0	1	2	0	0	0
Parastacidae (*Cherax* sp.)	0	0	0	0	0	0	0	0	0	0	0	0
Psphenidae	0	0	0	0	0	0	0	0	1	0	0	0
Pyralidae	0	0	1	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	1	0	0	0	1	0	0	1	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0
Staphylinidae	0	0	0	0	1	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	2	1
Unknown Diptera pupae	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**10**	**22**	**36**	**21**	**7**	**4**	**28**	**23**	**68**	**42**	**61**	**79**
Number of Taxa	**3**	**2**	**7**	**8**	**6**	**4**	**11**	**12**	**13**	**8**	**13**	**7**

Not included in the sum of the '

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

APPENDIX 6. AUTUMN 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)	12.85	12.83	12.83	14.65	14.61	14.63	15.88	15.88	15.88	14.94	14.93	14.93	13.12	13.12	13.12	13.15	13.14	13.15
pH	7.07	7.08	7.08	7.65	7.65	7.65	7.00	7.00	7.00	7.23	7.23	7.23	7.28	7.28	7.28	7.48	7.48	7.48
Conductivity (µS/cm)	177	177	176	2804	2812	2782	192	192	192	187	187	187	188	188	188	187	186	186
Dissolved Oxygen (%Sat)	77.1	77	77	101.4	101.6	101.5	61.5	61.4	60.5	87.2	87.2	87.1	86.1	86	85.9	96.5	96.4	96.3
Turbidity (NTU)	8.8	8.6	8.7	16.7	16.8	15.7	10.7	10.2	10.0	14.9	14.9	14.9	10.1	10.1	10.3	9.9	10.1	10.1
REDOX (mv)	607	607	607	585	585	584	552	552	552	550	550	580	596	596	596	586	586	586
Alkalinity (mg/L)	24	N/R	N/R	25	N/R	N/R	30	N/R	N/R	30	N/R	N/R	35	N/R	N/R	36	N/R	N/R
Total phosphorous (mg/L)	0.004	0.004	N/R	0.006	0.004	N/R	0.007	0.007	N/R	0.005	0.007	N/R	0.006	0.005	N/R	0.004	0.005	N/R
Total Nitrogen (mg/L)	0.120	0.094	N/R	0.130	0.082	N/R	0.190	0.081	N/R	0.100	0.120	N/R	0.065	0.076	N/R	0.100	0.076	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)	13.37	13.36	13.36	13.83	13.83	13.82	13.7	13.7	13.7	12.98	12.98	12.97	16.09	16.09	16.09	16.07	16.09	16.05
pH	7.14	7.14	7.14	7.23	7.23	7.23	7.8	7.8	7.8	8.37	8.37	8.37	6.9	6.9	6.9	6.9	6.9	6.9
Conductivity (µS/cm)	171	171	171	178	178	178	3026	3016	3011	180	180	180	131	131	131	149	149	149
Dissolved Oxygen (%Sat)	85.5	85.6	85.5	84.4	84.4	84.4	98.3	98.3	98.4	103.7	103.7	103.6	82.9	82.3	82.2	77.7	77.6	77.4
Turbidity (NTU)	18.6	17.9	18.1	9.2	8.7	8.3	11.4	11.6	11.8	9.8	9.8	18.1	4.1	3.9	3.9	5.1	5.0	5.0
REDOX (mv)	542	542	542	549	549	549	572	573	573	556	556	556	613.0	613.0	613.0	576.0	576.0	575.0
Alkalinity (mg/L)	25	N/R	N/R	24	N/R	N/R	35	N/R	N/R	37	N/R	N/R	25.5	N/R	N/R	20	N/R	N/R
Total phosphorous (mg/L)	0.006	0.007	N/R	0.006	0.008	N/R	0.004	0.004	N/R	0.005	0.004	N/R	0.005	0.005	N/R	0.004	0.004	N/R
Total Nitrogen (mg/L)	0.079	0.059	N/R	0.074	0.096	N/R	0.091	0.120	N/R	0.130	0.088	N/R	0.071	0.150	N/R	0.086	0.084	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)	15.34	15.28	15.27	15.52	15.53	15.55	13.2	13.2	13.2	13.45	13.39	13.38	11.17	11.17	11.17	11.1	11.1	11.1
pH	7.03	7.01	7.01	7.16	7.16	7.16	4.83	4.82	4.81	4.86	4.84	4.86	7.66	7.66	7.66	7.92	7.92	7.92
Conductivity (µS/cm)	140	140	140	139	139	139	134	134	134	134	134	134	125	125	125	125	125	125
Dissolved Oxygen (%Sat)	76.7	75.9	75.8	77.9	77.7	77.4	70.1	69.6	69.6	66.5	65.5	65.5	98.9	98.9	98.9	103.2	103.2	103.2
Turbidity (NTU)	2	2.1	2.1	3.6	3.4	3.3	1.5	1.4	1.4	2.3	2.3	2.7	2.1	2.1	2	1.8	1.9	1.8
REDOX (mv)	602	602	602	594	593	593	570	571	571	540	536	532	544	544	544	536	536	536
Alkalinity (mg/L)	23.5	N/R	N/R	24.5	N/R	N/R	0	N/R	N/R	0	N/R	N/R	5	N/R	N/R	5	N/R	N/R
Total phosphorous (mg/L)	0.003	0.004	N/R	0.009	0.004	N/R	0.003	0.003	N/R	0.005	0.003	N/R	0.003	0.005	N/R	0.004	0.004	N/R
Total Nitrogen (mg/L)	0.093	0.092	N/R	0.140	0.070	N/R	0.096	0.120	N/R	0.220	0.150	N/R	0.130	0.130	N/R	0.110	0.110	N/R

N/R = Not Recorded

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