

AQUATIC ECOLOGY MONITORING: METROPOLITAN COAL LONGWALLS 20-22

SPRING 2018 SURVEY



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1.0 INTRODUCTION

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

The Project comprises the continuation, upgrade and extension of underground coal mining operations and surface facilities at Metropolitan Coal. Longwalls 20-22 define the first secondary extraction mining sub-domain within the Approved Project underground mining area (Figure 1). Mining of Longwall 20 commenced in May 2010 and was completed in August 2011. Mining of Longwall 21 commenced in September 2011 and was completed in January 2013. Mining of Longwall 22A commenced in January 2013 and was completed in August 2013. Mining of Longwall 22B commenced in August 2013 and was completed in April 2014.

An aquatic ecology monitoring programme has been developed as a component of the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan (2014)*¹ to:

- Monitor subsidence-induced impacts on aquatic ecology (referred to as stream monitoring); and
- 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 (i.e. “Beyond BACI”) and focuses on representative sampling of selected locations (i.e. stream monitoring) and pools (i.e. pool monitoring) within streams in the Longwalls 20-22 mining area and in suitable control streams (i.e. not subject to mine subsidence).

¹ The *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan* is superseded by the *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan*. The monitoring program remains consistent with the program implemented during the mining of Longwalls 20-22 and Longwalls 23-27.

This report presents results of the stream monitoring and pool monitoring surveys carried out in spring 2018. This report also presents 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 – Temporal Analyses).

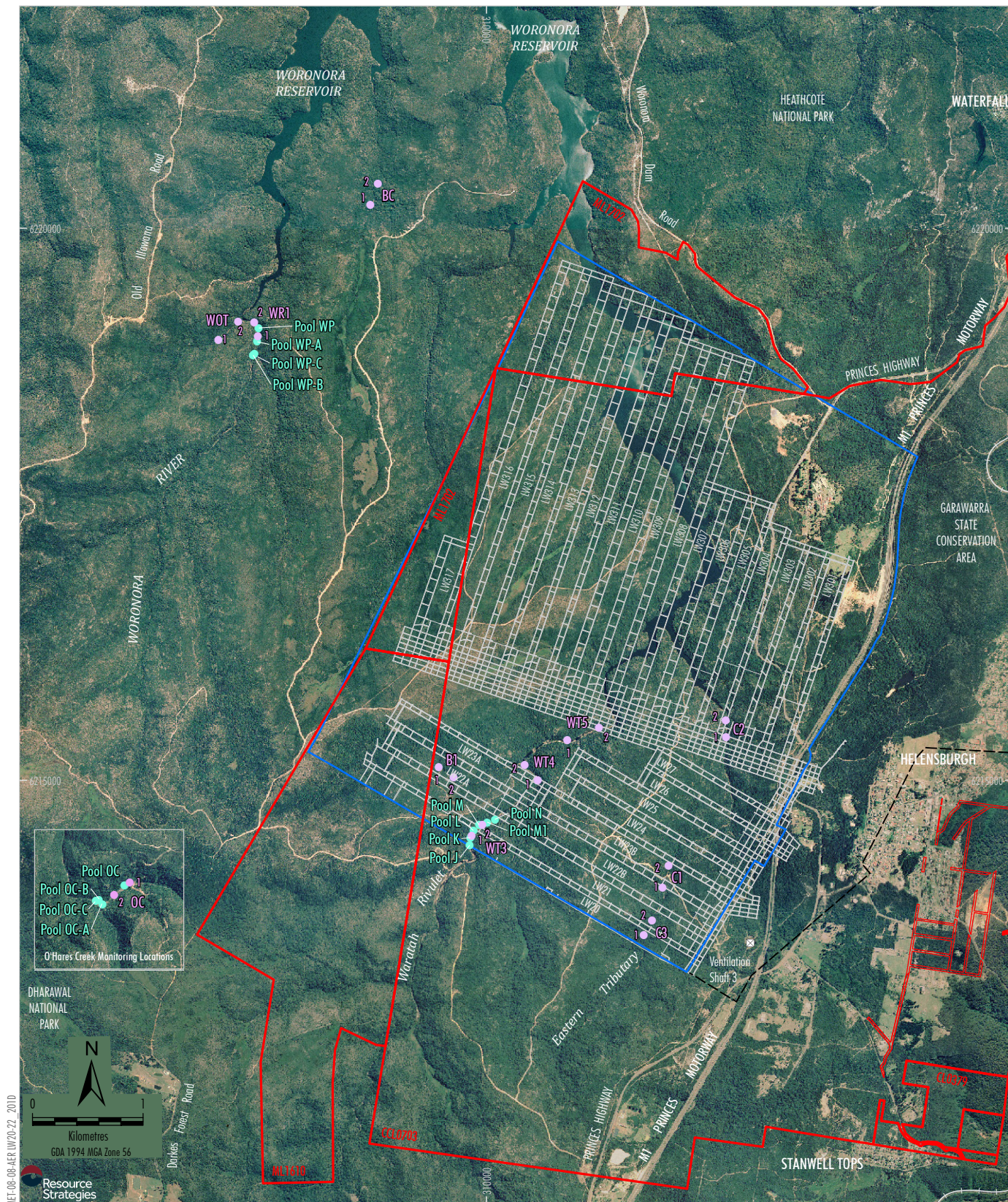


Figure 1

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 20-22 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).

Tributary B is a relatively small stream (approximately 2.75 km long) that flows through a broad valley into Waratah Rivulet. The upper reach of Tributary B traverses the completed Longwalls 14-17 and Longwalls 18-19a underground mining areas (Figure 1).

Bee Creek, the Woronora Tributary and Woronora River occur within the WSA but lie outside the area potentially affected by past and current mining activities at Metropolitan Coal. As such, these systems 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 reference 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 programmes have been designed to monitor:

- (i) subsidence-induced impacts on aquatic ecology; and
- (ii) the response of aquatic ecosystems to the implementation of stream restoration works.

These programmes are described in Section 2.2.1 and Section 2.2.2, respectively.

2.2.1 Stream Monitoring

In accordance with the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan* (Metropolitan Coal, 2014)², the aquatic ecology along Waratah Rivulet, Tributary C/Eastern Tributary and Tributary B as well as in appropriate control systems (i.e. Bee Creek, Woronora Tributary, 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 1a):

- Locations WT3 on Waratah Rivulet, C1 and C3³ on Tributary C/Eastern Tributary and B1 on Tributary B overlying Longwalls 20-22.

² The *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan* is superseded by the *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan*. The stream monitoring program and monitoring methods remain the same as those implemented during the mining of Longwalls 20-22 and Longwalls 23-27.

³ Locations C1, C2 and C3 are referred to as ET1, ET3 and ET2 in the *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan* (and previously in the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan*).

- Locations WT4 and WT5 on Waratah Rivulet and C2³ on Tributary C/Eastern Tributary, downstream of Longwalls 20-22.
- Control locations: WR1 on Woronora River; OC on O'Hares Creek; BC on Bee Creek; and WOT on Woronora Tributary.

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

Locations WT4 and WT5 on the Waratah Rivulet and Location C2 on Tributary C/Eastern Tributary located downstream of Longwalls 20-27, 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.

2.2.2 Pool Monitoring

In accordance with Condition 1, Schedule 6 of the Project Approval, Metropolitan Coal is required to achieve the rehabilitation objective: *Restore surface flow and pool holding capacity as soon as reasonably practicable* for:

- Waratah Rivulet, between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir; and
- Eastern Tributary, between the main-gate of Longwall 26 and the full supply level of the Woronora Reservoir.

A number of pools are monitored to allow the response of aquatic ecosystems to the implementation of future stream remediation works to be assessed, namely:

- Larger pools (defined as pools >40 m in length), J, M1 and N on Waratah Rivulet overlying Longwalls 20-22 (Figure 1).

- Smaller pools (defined as pools <40 m in length) K, L and M on Waratah Rivulet overlying Longwalls 20-22 (Figure 1).
- One larger control/reference pool on Woronora River (pool WP) and one larger control/reference pool on O'Hares Creek (pool OC).
- Three smaller control/reference pools on Woronora River (pools WP-A, WP-B and WP-C) and three smaller control/reference pools on O'Hares Creek (pools OC-A, OC-B and OC-C).

Monitoring of the pools is conducted bi-annually in spring (September 15 to December 15) and autumn (March 15 to June 15).

The design for this component also incorporates a “Beyond BACI” type experimental design, with sampling conducted at two random sites within the larger pools and at one site within the smaller pools. Two large and three small reference pools (not impacted by mining) of similar size and character were also sampled at the same spatial and temporal scales on Woronora River and O'Hares Creek (Appendix 1b).

The sampling of larger pools N on Waratah Rivulet, WP on Woronora River and OC on O'Hares Creek commenced in spring 2008. The sampling of larger pools J and M1 on Waratah Rivulet, and smaller pools K, L and M on Waratah Rivulet, WP-A to WP-C on Woronora River and OC-A to OC-C on O'Hares Creek commenced in spring 2009.

2.3 Sampling Techniques

2.3.1 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. One method, the quantitative sampling technique, was used to sample assemblages of macroinvertebrates in pools sampled as part of the Pool Monitoring Programme.

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.

2.3.2 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 (Sections 3.1.1, 3.2.1.1 and 3.2.2.1).

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 m² quadrats, using a stratified sampling technique. This information provided a quantitative measure of aquatic macrophytes within each site at each location and pool (Sections 3.1.3, 3.2.1.3 and 3.2.2.3). The spatial distribution of floating attached and submerged macrophytes (i.e. *Chara/Nitella* spp., *Myriophyllum pendiculatum* and *Triglochin procerum*) was also mapped in each pool sampling site (i.e. the pool monitoring program) to provide a visual comparison of their distribution through time.

2.3.3 Water Quality

For the Stream and Pool Monitoring Programmes, 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 ($\mu\text{S}/\text{cm}$), dissolved oxygen (% Saturation and mg/L), pH, temperature ($^{\circ}\text{C}$), turbidity (NTU) and oxygen reduction potential (mV).

For the Stream Monitoring Programme, 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 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 or pools subject to mining of Longwalls 20-22 (i.e. potential ‘impact’ sites) in comparison to independent sites that are not subject to mine subsidence (i.e. control streams and pools).

These analyses were performed separately for the large streams (Eastern Tributary [Locations C1, C2 and C3], Waratah Rivulet [Locations WT3, WT4 and WT5], Woronora River [Location WR] and O’Hares Creek [Location OC]), small streams (Tributary B [Location B1], Woronora Tributary [Location WOT] and Bee Creek [Location BC]), large pools (Waratah Rivulet [Pool J, Pool M1 and Pool N], Woronora River [Pool WP] and O’Hares Creek [Pool OC]) and small pools (Waratah Rivulet [Pool K, Pool L and Pool M], Woronora River [WP-A, WP-B, WP-C] and O’Hares Creek [OC-A, OC-B, and OC-C]).

For the Longwalls 20-22 aquatic ecology monitoring programme, two to four replicate times (spring 2008 or spring 2009⁴ to autumn 2010) have been sampled within the ‘Before’ commencement of Longwall 20 period and 17 replicate times (spring 2010 to spring 2018) have been sampled within the ‘After’ period.

Mining of the Longwalls 20-22 mining area commenced in May 2010 and was completed in April 2014.

⁴ The sampling of Location C3 on the Eastern Tributary, larger pools J and M1 on Waratah Rivulet, and smaller pools K, L and M on Waratah Rivulet, WP-A to WP-C on Woronora River and OC-A to OC-C on O’Hares Creek commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

3.0 RESULTS

3.1 Stream Monitoring

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 and C3), Waratah Rivulet (Locations WT3, WT4 and WT5), Tributary B (Location B1) and at two control locations (Woronora River, O'Hares Creek) (Figure 1), undertaken between spring 2008 or spring 2009⁵ and spring 2018, is presented below.

Tributary C/Eastern Tributary

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

⁵ The sampling of Location C3 on the Eastern Tributary commenced in spring 2009.

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. Since then, pool water level at Site C1-1 appeared to be below pre-mining levels in autumn 2016, spring 2017 and autumn 2018. At Site C1-2, which has a predominantly sandy substratum, pool water level appeared lower than pre-mining levels at the time of the autumn 2016 survey but not subsequently.

The main findings from the current survey (spring 2018) are summarised below:

- Pool water level at Site C1-1 was similar to pre-mining levels and there was surface flow out of the pool (Plate 1). At Site C1-2, the water level appeared similar to baseline levels (Plate 2);
- A thick iron precipitate/micro-organism complex continues to be observed at both sites (Plate 2);
- The fern, *Gleichenia dicarpa*, appeared desiccated in areas immediately adjacent to the stream, particularly Site C1-1 (Plate 1). Reduced pool water levels at Site C1-1 on several occasions are likely to have contributed to observed declines in riparian health;
- *Empodisma minus*, *Baumea juncea* and *Viminaria juncea* were relatively abundant at the time of this survey (Appendix 2a);
- Submerged aquatic macrophytes have consistently not been recorded at this location (Appendices 2a&b).



Plate 1: Tributary C – Location C1 (C1-1) (sp-18)

Looking upstream



Plate 2: Tributary C – Location C1 (C1-2) (sp-18)

Looking downstream

Location C2

Location C2 is situated downstream of the Longwalls 20-22 and the Longwalls 23-27 underground mining areas (Figure 1). 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 2016⁶, since sampling commenced in spring 2008. Iron staining was observed to cover the stream substratum from the top of Site C2-1 to the bottom of Site C2-2 in spring 2016, autumn 2017, spring 2017⁷ and autumn 2018. In spring 2017, pool water level at Site C2-1 appeared to be ~ 0.5 m below pre-mining levels but similar to pre-mining levels by the autumn 2018 survey.

⁶ In spring 2016, Location C2 was sampled on 24 October 2016.

⁷ Pools were impacted by the 'Eastern Tributary Incident' (exceedance of the Eastern Tributary performance measure) in spring 2016.

The main findings from the current survey (spring 2018) 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 (Plate 3);
- *Baumea juncea*, *Lepidosperma filiforme* and *Lomandra fluviatilis* were relatively abundant at the time of this survey and in good health (Appendix 2a). Similar to Location C1, submerged aquatic macrophytes have consistently not been present (Appendices 2a&b).



Plate 3: Tributary C – Location C2 (C2-1) (sp-18)

Looking upstream



Plate 4: Tributary C – Location C2 (C2-2) (spt-18)

Looking upstream

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 was predominantly bedrock and sand with large boulders in several places. Submerged aquatic macrophytes have consistently not been present (Appendices 2a&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 noted in spring 2015, particularly at Site C3-2. From spring 2015 to autumn 2017 pool water levels appeared to be below pre-mining levels. At the time of the spring 2017 and autumn 2018 surveys, pool water levels appeared similar to pre-mining levels at the upstream site (i.e. Site C3-1) but there was no water at Site C3-2.

The main findings from the spring 2018 survey are summarised below:

- Pool water level at both sites was similar to pre-mining levels and flow was apparent along both study reaches (Plates 5&6);
- Riparian vegetation immediately adjacent to the stream channel, particularly at Site C3-2, appeared desiccated (Plates 5&6);
- *Empodisma minus*, *Viminaria operculata* and *Gahnia clarkei* were the most abundant components of the riparian emergent macrophyte vegetation (Appendix 2a).

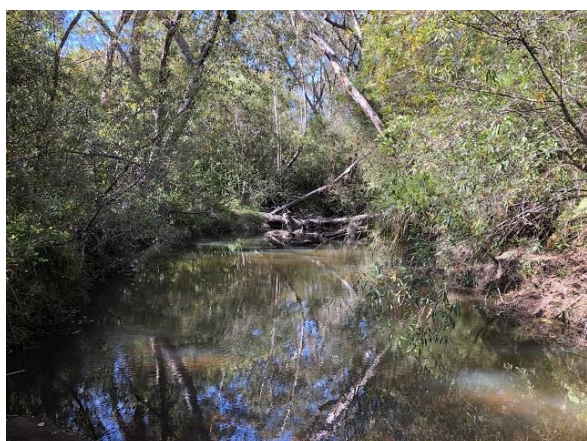


Plate 5: Tributary C – Location C3 (C3-1) (sp-18)

Looking upstream



Plate 6: Tributary C – Location C3 (C3-2) (sp-18)

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 km² and the sub-catchment areas vary from 1.6 km² to 6.7 km² (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 7&8). Cummins et al. (2007) reported that the dominant riparian vegetation included *Banksia integrifolia*, *Bauera rubioides*, *Centrolepis strigose*, *Hakea sericea* and *Leptospermum polygalifolium*.

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

The main findings from the current survey (spring 2018) are summarised below:

- Riparian vegetation present in this reach of the Waratah Rivulet appeared healthy and relatively undisturbed;
- The emergent species, *Gleichenia dicarpa* and *Lepidosperma filiforme* have consistently been amongst the most common components of assemblages of aquatic macrophytes (Appendix 2);

- Iron staining continues to be present along the study reach (Plates 7&8). An iron precipitate/micro-organism complex covered up to approximately 95 % of the stream substratum;
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 7&8).



**Plate 7: Waratah Rivulet – Location WT3 (WT3-1)
(sp-18)**
Looking downstream



**Plate 8: Waratah Rivulet – Location WT3 (WT3-2)
(sp-18)**
Looking downstream

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 2a&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.

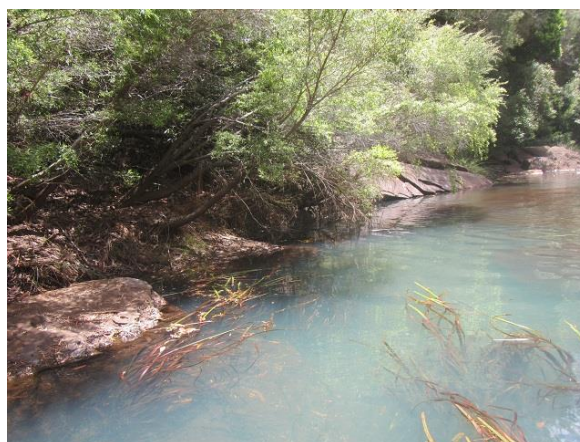
The main findings from the current survey (spring 2018) are summarised below:

- Pool water levels along the study reach were up to approximately 0.75 m below levels observed during the autumn 2017 survey but there was flow along the study reach (Plates 9&10). Reductions in pool water levels were also noted prior to spring 2018, in autumn 2018, spring 2017, autumn 2016 and spring 2015;
- To date, there has been no evidence of mining related fracturing of the stream substratum;

- Cover of the substratum by iron precipitate was limited on this occasion;
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 9&10);
- 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 2);
- The weed species, *Isolepis prolifera*, was present at both sites;
- *Triglochin procerum* and patches of *Chara/Nitella* spp. were relatively common.



**Plate 9: Waratah Rivulet – Location WT4 (WT4-1)
(sp-18)**
Looking upstream



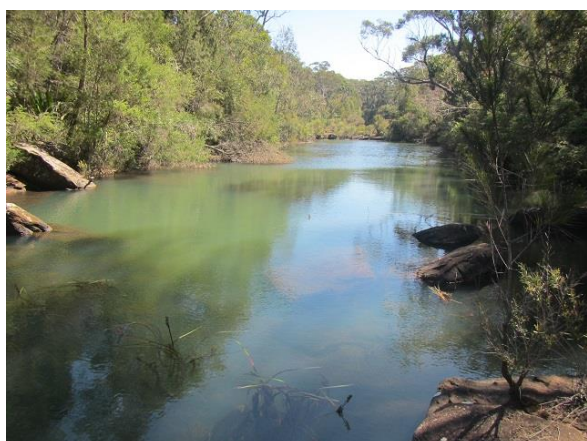
**Plate 10: Waratah Rivulet – Location WT4 (WT4-2)
(sp-18)**
Looking downstream

Location WT5

At Location WT5, a gauging station operated by WaterNSW is situated between the two sampling sites (WT5-1 and WT5-2). The in-stream habitat was predominantly bedrock and sand. Pools have consistently been up to approximately 110 m long, 30 m wide and 2.0 m deep at their deepest point (Plates 11&12). Previously, the dominant riparian vegetation was reported to include *Acacia binervia*, *Acacia floribunda*, *Acacia longifolia*, *Acacia parramattensis*, *Epacris calvertiana*, *Gleichenia dicarpa*, *Leptospermum polygalifolium* and *Tristaniopsis laurina* (Bio-Analysis Pty Ltd, 2008). The submerged aquatic macrophyte, *Triglochin procerum*, has been relatively abundant at this location.

The main findings from the current survey (spring 2018) are summarised below:

- To date, there has been no evidence of mining related fracturing of the stream substratum at this location;
- Pool water levels along the study reach were similar to the autumn 2018 and spring 2017 surveys but up to approximately 0.4 m below levels observed by the autumn 2017 survey (Plates 11&12). Flow was apparent along the study reach;
- Approximately 80 % of the submerged stream substratum was covered by an iron precipitate/microorganism complex;
- Pool water had a milky-green tinge, as observed on prior sampling occasions (Plates 11&12);
- The riparian strip was relatively healthy despite some evidence of desiccation of the fern, *Gleichenia dicarpa*;
- The emergent species, *Gleichenia dicarpa* and *Lepidosperma filiforme* were amongst the most common components of the assemblage of aquatic macrophytes (Appendix 2);
- *Triglochin procerum* and *Chara/Nitella* spp. were observed at Site WT5-1.



**Plate 11: Waratah Rivulet – Location WT5 (WT5-1)
(sp-18)**
Looking upstream



**Plate 12: Waratah Rivulet – Location WT5 (WT5-2)
(sp-18)**
Looking downstream

Tributary B

Tributary B is a relatively small stream (approximately 2.75 km long) that flows through a broad valley into Waratah Rivulet. In the past, a series of shallow (i.e. up to approximately 1.20 m deep in places) pools up to approximately 12 m wide, separated by areas of exposed rock (where the stream appeared to run subsurface) were sampled at Location B1.

A large pool situated within the survey reach in Tributary B at Location B1 was found to have almost completely drained of water in spring 2012. Since then, pools along the study reach have been mostly dry and there has been no surface-flow (including spring 2017) (Plates 13&14).

AUSRIVAS sampling has not been carried out at Location B1 (Sites B1-1 and B-2) from spring 2012 on (with the exception of Site B1-2 in autumn 2012) due to insufficient habitat available for sampling. However, there was sufficient aquatic habitat at Sites B1-1 and B1-2 to enable the collection of quantitative samples of aquatic macroinvertebrates in spring 2012, autumn 2013 and autumn 2014.

Quantitative samples have not been collected at either site since autumn 2014 due to insufficient habitat available for sampling.

The dominant riparian vegetation was previously reported to include *Acacia binervia*, *Acacia floribunda*, *Acacia longifolia*, *Acacia parramattensis*, *Banksia ericifolia*, *Baumea rubioides*, *Baumea rubiginosa*, *Eucalyptus* sp. and *Juncus prismatocarpus* (Bio-Analysis Pty Ltd, 2008). Submerged aquatic macrophytes have not been recorded at sampling sites in this tributary since first sampled in spring 2008 (Appendix 2).

At the time of this survey, the emergent species, *Lepidosperma filiforme*, was relatively abundant (Appendix 2). Several species of plant, including *Gahnia clarkei* have started to encroach upon/colonise the stream channel at both sites (Plates 13&14).



Plate 13: Tributary B (B1-1) (sp-18)

Looking upstream



Plate 14: Tributary B (B1-2) (sp-18)

Looking downstream

Control Locations

Bee Creek

The headwaters of Bee Creek originate in a large upland swamp and the stream runs through a relatively open valley into the Woronora Reservoir. Bee Creek is situated to the north-west of the Longwalls 20-22 mining area (Figure 1). In general, the study reach has been characterised by small to moderate sized (up to approximately 5 m wide), shallow (up to approximately 0.6 m deep) pools and runs interspersed in places by relatively steep (up to approximately 10 m high) cascades. In many places, boulders and dead trees occupy the stream channel. The substratum was predominantly bedrock with occasional small deposits of sand in many of the pools.

As previously reported, the riparian vegetation was dominated by *Juncus prismatocarpus*, *Acacia floribunda*, *Acacia longifolia*, *Baumea rubiginosa*, *Leptospermum polygalifolium* and *Viminaria juncea* (Bio-Analysis Pty Ltd, 2008).

Reduced pool water levels and surface flow were noted at Location BC by the autumn and spring 2016 and autumn and spring 2017 surveys. At the time of the autumn 2018 survey, a large proportion (~ 95 %) of the study reach was dry.

At the time of the spring 2018 survey, water was present along the study reach (Plates 15&16). *Gahnia clarkei* was amongst the most common components of the emergent macrophyte assemblage (Appendix 2), which showed signs of desiccation (Plates 15&16). No exotic plants or animals were observed (Appendices 2, 3 and 4).



Plate 15: Bee Creek (BC1) (sp-18)

Looking upstream



Plate 16: Bee Creek (BC2) (sp-18)

Looking downstream

Woronora Tributary

This tributary of the Woronora River is a small stream which runs through a steep valley situated to the north-west of the Longwalls 20-22 mining area. The sampling location consisted of steep, cascading pools (up to approximately 12 m wide and 0.4 m deep) down the reach and dry areas where the stream naturally ran subsurface (Plates 17&18). Steep cascades (up to approximately 10 m) along the study reach are likely to form natural barriers to fish migration. The substratum was predominantly bedrock and boulders with some deposits of sand in larger pools.

In some places dense vegetation, dominated by *Eucalyptus* sp., *Acacia floribunda*, *Acacia longifolia*, *Acacia parramattensis* and *Callistemon citrinus* had overgrown the stream bed (Bio-Analysis Pty Ltd, 2008). Submerged aquatic macrophytes have not been recorded at sampling sites in this tributary (Appendix 2) since the commencement of sampling, probably due to the tributary being steep and narrow with a mostly bedrock substratum.

Similar to the autumn 2018 survey, there was no flow along the study reach at Site WOT1 at the time of the spring 2018 survey and a large proportion (~ 50 %) of the study reach at Site WOT2 was dry (Plates 17&18). *Empodisma minus* and *Viminaria juncea* were amongst the most common emergent macrophytes at this location but showed signs of desiccation at Site WOT2 (Plates 17&18, Appendix 2). No exotic plants or animals were observed at the sites (Appendices 2, 3 and 4). Where present, water visibility was clear and free of sediment.



Plate 17: Woronora Tributary (WOT1) (sp-18)

Looking upstream



Plate 18: Woronora Tributary (WOT2) (sp-18)

Looking downstream

Woronora River

Sites were chosen on the Woronora River approximately 7 km from its headwaters (Appendix 1). 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* (Plates 19&20) (Appendix 2).

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 this survey, emergent macrophytes included *Lepidosperma filiforme* and *Gleichenia dicarpa* (Appendix 2). No exotic plants or animals were observed (Appendices 2, 3 and 4).

With the exception of the gauging station located approximately 300 m downstream, there was no evidence of de-vegetation or bank degradation associated with human activities. Slumping of the left-bank (looking downstream) has been apparent since the autumn 2017 survey.

Pool water levels were noted to have declined by this survey and the previous two surveys (i.e. autumn 2018 and spring 2017). Flow along the study reach was not apparent at the time of this or the autumn 2018 survey (Plates 19&20). Visibility of the water was considered fair.



Plate 19: Woronora River (WR1) (sp-18)

Looking upstream



Plate 20: Woronora River (WR2) (sp-18)

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 1.2 m (Plates 21&22). 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 *Gahnia clarkei* (Appendix 2a). *Triglochin procerum* and *Chara/Nitella* spp. were common at Site OC1, the most upstream site (Appendix 2a). The exotic macrophyte, *Isolepis prolifera*, was observed at Site OC1 on this and many earlier occasions (Appendix 2a). Stream water visibility was excellent but much of the stream substratum (~95 %) of both sites was covered by diatomaceous/filamentous algal complex.



Plate 21: O'Hares Creek (OC1) (sp-18)

Looking upstream



Plate 22: O'Hares Creek (OC2) (sp-18)

Looking upstream

3.1.2 Aquatic Macroinvertebrates

AUSRIVAS Assessment

A total of 38 taxon were collected from the 20 sites sampled using the AUSRIVAS sampling protocol (Appendix 3). Sampling sites B1-1 and B1-2 were not sampled on this occasion due to insufficient aquatic habitat (Section 3.1.1). 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 WT3 (10 individuals), WT4 (3 individuals) and WT5 (22 individuals) on the Waratah Rivulet using the AUSRIVAS technique.

For the sites sampled, the OE50 scores ranged between 0.10 (C1-1 and C1-2) and 0.86 (WOT1) (Table 1). Two sites were grouped in Band A (WOT1 and WR1-2), ten were grouped in Band B (C2-2, C3-1, C3-2, WT3-1, WT3-2, WT4-2, BC2, WOT2, OC1 and OC2), six were grouped in Band C (C2-1, WT4-1, WT5-1, WT5-2, BC1 and WR1-1) and two were grouped in Band D (C1-1 and C1-2) (Table 1).

Thus, with the exception of Sites C2-2, WOT2 and WR1-1, fewer families of macroinvertebrates than expected were collected from sites sampled (including reference sites) in autumn 2018, compared to reference sites selected by the AUSRIVAS model (Table 1). Similar numbers of families of macroinvertebrates were collected at WOT1 and WR1-2 in spring 2018 compared to reference sites selected by the AUSRIVAS model (Table 1).

Taxon with > 0.86 probability of occurrence but not collected included the water mite family, Acarina, at all sites except WOT1, WOT2, WR1, OC1 and OC2, and the mayfly family, Leptophlebiidae, at sites C1-1, C1-2 and WT5-1. Also expected but not collected was the caddis fly family, Leptoceridae, at C1-1, C1-2, C2-1, C2-2, C3-2, WT4-1, WT4-2, WT5-1, WT5-2, BC1 and OC2 and the Gyrinidae, at C1-1, C1-2, C2-2, C3-2, WT4-1, WT5-2, BC1 and WOT2.

Table 1. AUSRIVAS outputs for sites sampled in Tributary C/Eastern Tributary (C), Waratah Rivulet (WT), Tributary B (B), Bee Creek (BC), Woronora Tributary (WOT), Woronora River (WR) and O'Hares Creek (OC) (spring 2018) ($n = 1$).

System	Location	Site	Site Code	OE50	Band
Tributary C	1	1	C1-1	0.10	D
	1	2	C1-2	0.10	D
	2	1	C2-1	0.48	C
	2	2	C2-2	0.57	B
	3	1	C3-1	0.76	B
	3	2	C3-2	0.57	B
Waratah Rivulet	3	1	WT3-1	0.61	B
	3	2	WT3-2	0.73	B
	4	1	WT4-1	0.48	C
	4	2	WT4-2	0.55	B
	5	1	WT5-1	0.35	C
	5	2	WT5-2	0.44	C
Tributary B	1	1	B1-1	#	#
	1	2	B1-2	#	#
Bee Creek	1	1	BC1	0.46	C
	1	2	BC2	0.67	B
Woronora Tributary	1	1	WOT1	0.86	A
	1	2	WOT2	0.67	B
Woronora River	1	1	WR1-1	0.50	C
	1	2	WR1-2	0.84	A
O'Hares Creek	1	1	OC1	0.78	B
	1	2	OC2	0.57	B

Sample not collected due to insufficient aquatic habitat.

Quantitative Assessment

A total of 1,473 individuals from 47 macroinvertebrate taxon were collected from sites using the quantitative sampling technique (Appendix 4). The most abundant macroinvertebrate taxon was the Leptophlebiidae (285 individuals) followed by the Chironomidae (256 individuals), Atyidae (159 individuals) and the Dytiscidae (143 individuals) (Appendix 4). The native freshwater crayfish (*Euastacus* sp.) was not collected by either the AUSRIVAS or quantitative sampling techniques during the survey period (Appendix 4). *Gambusia* were collected at Location WT3 (6 individuals), Location WT4 (1 individuals) and Location WT5 (40 individuals) on this sampling occasion using the quantitative technique.

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 and abundance of macroinvertebrates was greatest at the control locations sampled at O'Hares Creek and the Woronora River on this sampling occasion, compared to all other locations sampled (Figures 2&3). Samples of aquatic macroinvertebrates could not be collected at the sites sampled along Tributary B (Location B1, Sites B1-1 and B1-2) due to insufficient aquatic habitat (Figures 2&3).

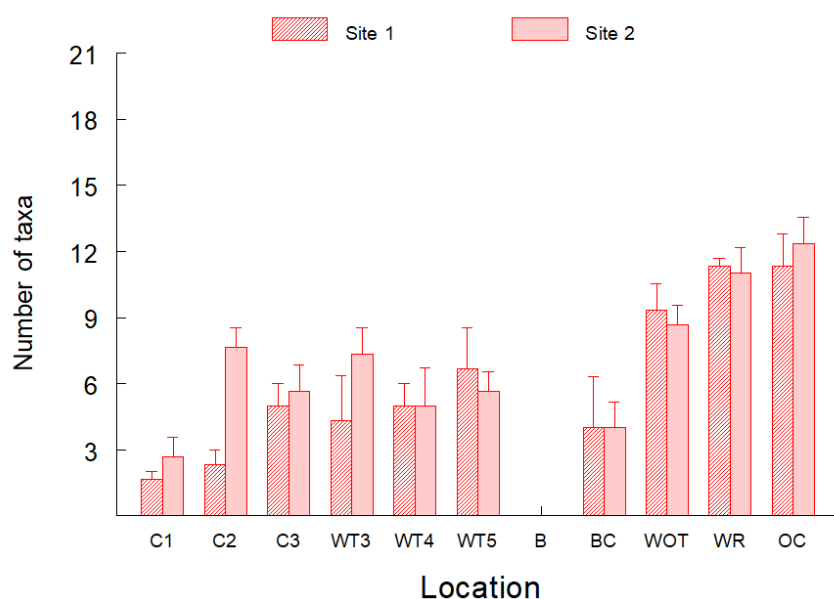


Figure 2. Mean (+SE) diversity of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], B – Tributary B, BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O’Hares Creek). NB: Sites B1-1 and B1-2 were not sampled due to insufficient aquatic habitat.

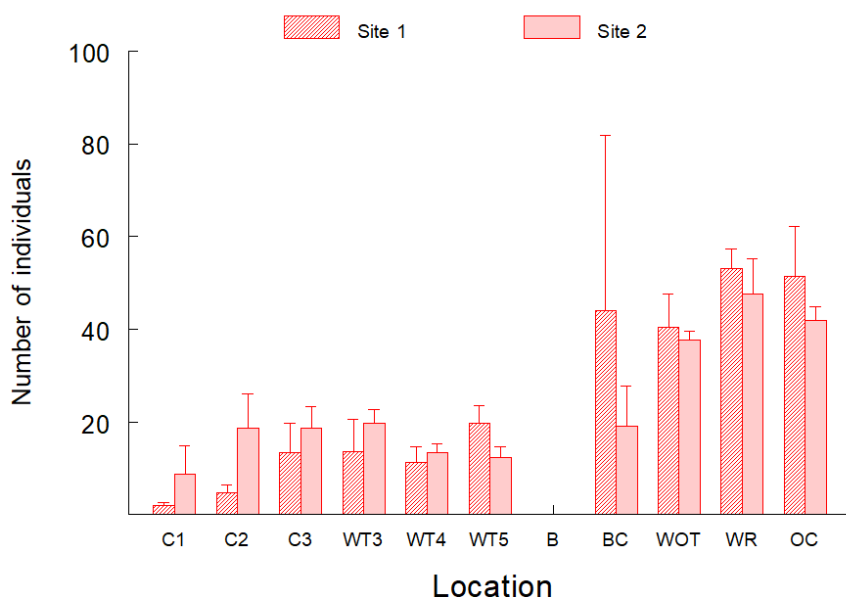


Figure 3. Mean (+SE) abundance of macroinvertebrates at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], B – Tributary B, BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O’Hares Creek). NB: Sites B1-1 and B1-2 were not sampled due to insufficient aquatic habitat.

3.1.3 Aquatic Macrophytes

A total of 24 aquatic macrophyte species were found in quantitative samples at sites on Tributary C/Eastern Tributary (C1: 7 species, C2: 9 species, C3: 7 species), Waratah Rivulet (WT3: 10 species, WT4: 10 species, WT5: 7 species), Tributary B (5 species), Bee Creek (8 species), Woronora Tributary (7 species), Woronora River (9 species) and O'Hares Creek (12 species) (Appendix 2b).

In general, mean percentage cover of macrophytes was greatest at Location WT3 situated on the Waratah Rivulet followed by the O'Hares Creek sampling location (Figure 4). Cover of macrophytes has been smallest at the Tributary B location (B) for some time (Figure 4). The mean diversity of macrophytes recorded in the 0.25 m² quadrats at any one location was generally low (i.e. < 4 species) (Figure 5).

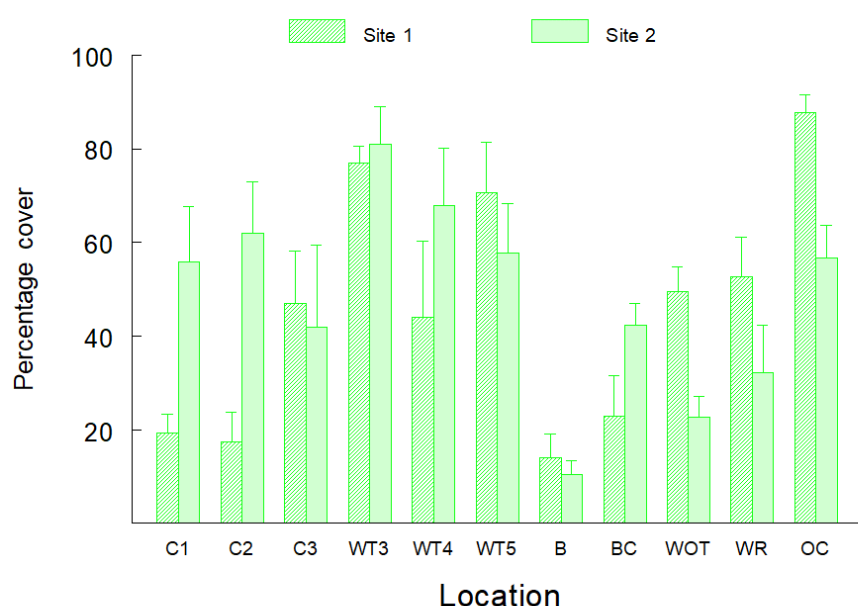


Figure 4. Mean (+SE) percentage cover of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], B – Tributary B, BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O'Hares Creek).

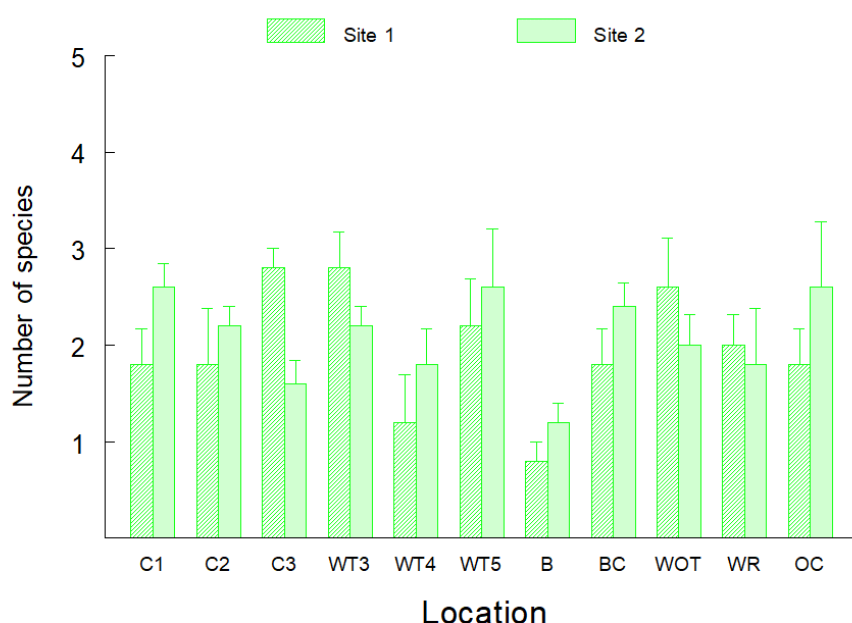


Figure 5. Mean (+SE) diversity of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], WT – Waratah Rivulet [WT3 - Location 3 etc], B – Tributary B, BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O’Hares Creek).

3.1.4 Water Quality

Physico-chemical water quality, alkalinity, total phosphorous and total nitrogen measurements are summarised in Table 2 with values highlighted in bold type indicating where mean values were outside the ANZECC/ARMCANZ (2000) guidelines.

In general, mean water temperature within the seven creeks ranged from 14.6 to 24.6 ° C (Table 2), which is typical for the time of year the samples were collected. Mean pH (range = 5.0 – 8.1) was once again below the lower Default Trigger Values (DTV) (i.e. pH 6.5-8.0; ANZECC/ARMCANZ, 2000) for upland rivers at several sites including, Site BC-1, BC-2, WOT-1 and WOT-2 (Table 2). Relatively low pH values are common in areas with a sandstone substratum. Mean pH was above the upper DTV at Site WT3-2 (Table 2).

Mean conductivity (range = 93 – 232 $\mu\text{S}/\text{cm}$) was within the guideline values at all of the sites sampled (Table 2). Mean dissolved oxygen levels (range = 12.3 – 121.1 %) were below the lower DTV at all of the sites sampled except C1-2, WT3-1, WT5-1, OC-1 and OC-2 (within DTV range) and WT3-2 and WT5-2 (above the upper DTV) (Table 2).

Mean turbidity (range = 4.8 – 79.3 NTU) was above the upper DTV recommended by ANZECC/ARMCANZ (2000) at Site C1-1, C2-1, C2-2, WT3-1, WT5-1, WT5-2, WOT-1, WOT-2, WR1-1 and WR1-2 while mean oxidation-reduction potential at the sites sampled ranged from 449 to 667 mV (Table 2). Mean alkalinity ranged from 0 to 45 mg/L CaCO_3 (Table 2). For nutrients, mean concentrations of total phosphorous were above the upper DTV at WT5-1 while total nitrogen (range = <0.05 to 0.40 mg/L) was above the upper DTV at Site BC-1 and WOT-2 (Table 2). The raw water quality data are provided in Appendix 5.

Table 2. Mean ($\pm$ SE) measurements of water quality variables recorded at each site (spring 2018). 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 ($n = 3$)	19.1 (0.0)	24.6 (0.0)	19.1 (0.0)	16.9 (0.0)	16.3 (0.0)	17.1 (0.0)
pH ($n = 3$)	6.9 (0.0)	7.0 (0.0)	6.7 (0.0)	7.0 (0.0)	6.5 (0.0)	7.2 (0.0)
Conductivity ($\mu\text{S}/\text{cm}$) ($n = 3$)	146.0 (0.0)	151.0 (0.0)	212.0 (0.0)	232.0 (0.0)	165.0 (0.0)	156.0 (0.0)
Dissolved Oxygen (% Saturation) ($n = 3$)	76.8 (0.7)	96.4 (1.1)	59.6 (0.2)	48.6 (0.7)	64.4 (0.0)	80.4 (0.1)
Turbidity (NTU) ($n = 3$)	37.6 (0.5)	19.8 (0.3)	57.6 (0.4)	62.8 (0.2)	11.2 (0.0)	21.7 (0.0)
ORP (mV) ($n = 3$)	493.3 (0.7)	504.0 (0.6)	655.0 (10.0)	605.7 (1.8)	449.0 (1.2)	510.7 (0.3)
Alkalinity (mg/L CaCO_3) ($n = 2$)	18	18	17	25	19	20
Total phosphorous (mg/L) ($n = 2$)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)
Total nitrogen (mg/L) ($n = 2$)	0.13 (0.04)	0.08 (0.03)	<0.05 (0.0)	<0.05 (0.0)	0.10 (0.0)	0.09 (0.0)
Watercourse	Waratah Rivulet					
Location/Site	WT3-1	WT3-2	WT4-1	WT4-2	WT5-1	WT5-2
Temperature °C ($n = 3$)	22.6 (0.0)	23.4 (0.1)	19.3 (0.0)	19.1 (0.0)	19.6 (0.0)	23.4 (0.1)
pH ($n = 3$)	7.8 (0.0)	8.1 (0.0)	6.9 (0.0)	7.2 (0.0)	8.0 (0.0)	8.0 (0.0)
Conductivity ($\mu\text{S}/\text{cm}$) ($n = 3$)	162.0 (0.0)	163.7 (0.3)	215.0 (0.0)	216.0 (0.0)	181.7 (0.3)	185.7 (0.3)
Dissolved Oxygen (% Saturation) ($n = 3$)	106.5 (0.1)	114.6 (0.7)	83.2 (0.1)	84.3 (0.1)	99.4 (0.0)	121.1 (1.1)
Turbidity (NTU) ($n = 3$)	30.2 (0.2)	22.2 (0.9)	9.8 (0.0)	6.6 (0.5)	79.3 (0.7)	79.2 (0.4)
ORP (mV) ($n = 3$)	472.0 (0.0)	495.7 (0.3)	594.0 (0.0)	599.3 (0.3)	582.7 (0.3)	587.0 (0.0)
Alkalinity (mg/L CaCO_3) ($n = 2$)	24	30	45	30	27	35
Total phosphorous (mg/L) ($n = 2$)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	0.06 (0.0)	<0.02 (0.0)
Total nitrogen (mg/L) ($n = 2$)	0.15 (0.0)	0.11 (0.0)	0.07 (0.0)	0.23 (0.0)	0.14 (0.0)	0.08 (0.0)

NB¹: ANZECC (2000) guideline values for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 $\mu\text{S}/\text{cm}$); 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.

NB²: # = Insufficient aquatic habitat.

NB³: *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. Cont'd.

Watercourse	Tributary B		Bee Creek		Woronora Tributary	
Location/Site	B1-1	B1-2	BC-1	BC-2	WOT-1	WOT-2
Temperature °C (n = 3)	#	#	15.0 (0.0)	15.4 (0.0)	17.2 (0.0)	14.6 (0.0)
pH (n = 3)	#	#	5.0 (0.0)	5.6 (0.0)	5.9 (0.0)	6.0 (0.0)
Conductivity (µS/cm) (n = 3)	#	#	230.0 (0.0)	204.0 (0.0)	93.0 (0.0)	104.0 (0.0)
Dissolved Oxygen (% Saturation) (n = 3)	#	#	12.3 (1.4)	40.2 (0.0)	68.0 (0.2)	45.6 (0.2)
Turbidity (NTU) (n = 3)	#	#	4.8 (0.3)	9.0 (0.2)	69.9 (0.8)	67.4 (0.0)
ORP (mV) (n = 3)	#	#	531.3 (0.3)	534.0 (1.7)	625.0 (0.6)	601.3 (0.9)
Alkalinity (mg/L CaCO ₃) (n = 2)	#	#	5	5	0	0
Total phosphorous (mg/L) (n = 2)	#	#	0.02* (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)
Total nitrogen (mg/L) (n = 2)	#	#	0.40 (0.04)	0.10 (0.01)	0.24 (0.01)	0.34 (0.07)
Watercourse	Woronora River		O'Hares Creek			
Location/Site	WR1-1	WR1-2	OC-1	OC-2		
Temperature °C (n = 3)	17.1 (0.0)	18.4 (0.0)	22.4 (0.0)	24.6 (0.0)		
pH (n = 3)	6.9 (0.0)	6.7 (0.0)	6.7 (0.0)	7.0 (0.0)		
Conductivity (µS/cm) (n = 3)	125.7 (1.3)	119.0 (0.0)	108.0 (0.0)	114.0 (0.0)		
Dissolved Oxygen (% Saturation) (n = 3)	55.5 (0.1)	63.6 (0.3)	97.2 (0.2)	102.3 (0.1)		
Turbidity (NTU) (n = 3)	68.0 (0.0)	70.7 (0.1)	21.8 (0.1)	22.9 (0.1)		
ORP (mV) (n = 3)	662.0 (0.0)	667.0 (0.0)	597.7 (0.3)	575.0 (0.0)		
Alkalinity (mg/L CaCO ₃) (n = 2)	5	5	5	5		
Total phosphorous (mg/L) (n = 2)	0.02* (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)		
Total nitrogen (mg/L) (n = 2)	0.19 (0.03)	0.15 (0.00)	0.17 (0.01)	0.23 (0.04)		

NB¹: 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.

NB²: # = Insufficient aquatic habitat.

NB³: *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).

3.2 Pool Monitoring

3.2.1 Large Pools

3.2.1.1 Pool Characteristics

Waratah Rivulet Pools

Three large pools (defined as pools > 40 m in length) were sampled on the Waratah Rivulet: Pools J, M1 and N.

Pool J

Pool J is situated approximately 400 m downstream of Flat Rock Crossing. In general, the pool was approximately 54 m long, from 11 to 17 m wide and 0.3 m to 1.5 m (Plates 23&24). The pool bed was sandstone covered with deposits of sand and sediment.

The stream substratum has commonly been covered by a thick mat of an iron precipitate/microorganism complex since autumn 2010 and has had a milky-green tinge. Apparent fracturing of the sandstone substratum of the pool was first noted to have occurred by the spring 2013 survey.

At the time of the spring 2018 survey, water depth varied from approximately 0.3 m to 1.5 m. For the first time since sampling commenced, methane bubbles were apparent near the downstream end of the pool (Figure 10). Up to ~95 % of the stream substratum was covered by a relatively thin iron complex and pool water had a milky-green tinge, similar to previous surveys (Plates 23&24). Riparian vegetation was healthy and mostly dominated by *Gleichenia dicarpa* and *Lepidosperma filiforme* (Appendix 6). One small patch of *Triglochin procerum* was present and *Chara/Nitella* spp. was abundant (Figure 10, Appendix 6).

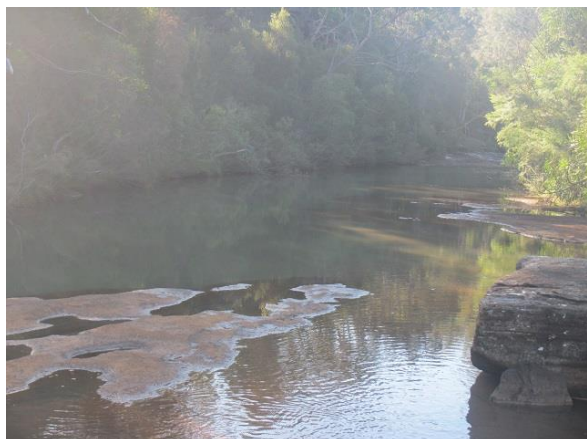


Plate 23: Pool J (PJ) (aut-18)⁸,
Upstream end looking downstream



Plate 24: Pool J (PJ) (aut-18)
Downstream end looking upstream

Pool M1

Pool M1 is located approximately 560 m downstream from Flat Rock Crossing. In general, the pool is approximately 38 m in length, 8 m to 27 m wide and up to 1.05 m deep (Plates 25&26). Blocks of sandstone (~ 1 - 6 m in size) detached from the upstream substratum and washed downstream have settled along the north western side of the pool near large boulders (as noted by earlier surveys). Pool M1 ends at a boulder field that also consisted of blocks and vegetation.

An iron precipitate/microorganism complex has been observed to cover up to ~95 % of the stream substratum since sampling commenced in spring 2009 and has had a milky-green tinge. Evidence of cracking of bedrock in the stream channel of Pool M1 and along the stream bank was first noted in spring 2012.

At the time of the spring 2018 survey, observations were consistent with prior surveys - iron staining and pool water had a milky-green tinge (Plates 25&26). Water depth varied from approximately 0.1 m to 0.95 m. *Juncus planifolia* was the most common component of the macrophyte assemblage at both sites (Appendix 6). Patches of *Chara/Nitella* spp. were observed in Pool M1 in spring 2018. Surface flow was evident.

⁸ Photos of the Waratah Rivulet pools were not taken in spring 2018



Plate 25: Pool M1 (PM1) (aut-18)

Upstream looking downstream



Plate 26: Pool M1 (PM1) (aut-18)

Downstream looking upstream

Pool N

Pool N, the most downstream pool, is approximately 900 m downstream of Flat Rock Crossing. In general, the substratum of Pool N is mostly sandstone covered by deposits of sand and sediment. Water level within Pool N has been observed to fluctuate since a considerable decline (by ~ 1.8 m) was observed in spring 2012.

On the following two sampling occasions (autumn and spring 2013), water level in Pool N was similar to that reported by surveys carried out prior to spring 2012 (i.e. up to approximately 2 m deep). In autumn 2014, the pool water level had dropped by approximately 0.8 m since the previous sampling occasion (spring 2013). Pool water level has been similar to pre-mining levels since spring 2014 (Plates 27&28).

An iron precipitate/microorganism complex has been observed to cover up to ~95 % of the stream substratum since autumn 2011, and the pool has been observed to have a milky-green tinge. Cracking of the rock-bar situated at the downstream end of Pool N was observed, consistent with earlier reporting.

Between spring 2013 and spring 2015, a large proportion ($\geq 60\%$) of the riparian macrophyte assemblage was in poor condition. Desiccation of some species of emergent macrophytes, particularly *Gleichenia dicarpa*, and apparent erosion of the stream banks since autumn 2015 were most likely due the considerable fluctuations in water-level (Plates 27&28).

Since spring 2015, *Gleichenia dicarpa* has once again been an abundant component of the riparian vegetation assemblage. *Triglochin procerum* has continued to be relatively abundant despite many plants observed to have been left exposed by declines in water-level in spring 2012 and autumn 2014.

At the time of the spring 2018 survey, observations were consistent with the previous survey: an iron complex covered a large proportion of the pool substratum and pool water had a milky-green tinge (Plates 27&28). Erosion and bank retreat however, appears to have continued on either side of the pool since autumn 2015.

Lepidosperma filiforme, *Gahnia clarkei* and *Chorizandra cymbaria* were relatively common components of the emergent macrophyte assemblage (Appendix 6). *Gleichenia dicarpa* was also present (Appendix 6) but still appears desiccated in several areas adjacent to the stream bank. *Triglochin procerum* and *Chara/Nitella* spp. were relatively common (Appendix 6). Several trees on the west bank near the upstream end of the pool appear desiccated (Plate 27).



Plate 27: Pool N (PN) (aut-18)

Downstream end looking across-stream



Plate 28: Pool N (PN) (aut-18)

Upstream end looking downstream

Control Pools

Control pools were chosen within the Woronora River and O'Hares Creek. The Woronora pool was approximately 1.35 m deep at its deepest, 55 m long and up to 15 m wide (Plates 29&30). The pool bed was predominantly sand interspersed with large boulders. Patches of the submerged macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum*, were common. Dense vegetation surrounded the pool, comprised mostly of the emergent species *Gleichenia dicarpa* and *Lepidosperma filiforme* (Appendix 6). At the time of sampling, there were no obvious signs of disturbance. Surface flow was not apparent at the time of the autumn or spring 2018 surveys and visibility of the water was only considered fair.



Plate 29: Woronora pool (WP) (sp-18)

Upstream end looking downstream



Plate 30: Woronora pool (WP) (sp-18)

Downstream end looking upstream

The control pool on O'Hares Creek (i.e. OP) was approximately 0.7 m deep at its deepest, 110 m long and up to 22 m wide (Plates 31&32). The pool bed was predominantly sandstone interspersed with deposits of sand and boulders. Patches of the submerged macrophyte, *Triglochin procerum*, were common and there were small patches of *Chara/Nitella* spp. dispersed throughout the pool. Dense vegetation surrounded the pool, comprised mostly of the emergent species, *Gleichenia dicarpa*, *Empodisma minus* and *Sticherus flabellatus* (Appendix 6). The introduced aquatic weed, *Isolepis prolifera*, was once again recorded, growing adjacent to the left bank (looking downstream) at the downstream end of the pool. Stream water visibility was good but much of the stream substratum (~95 %) was covered by a diatomaceous/filamentous algal complex.



Plate 31: O'Hares pool (OP) (sp-18)

Downstream end looking upstream



Plate 32: O'Hares pool (OP) (sp-18)

Upstream end looking across-stream

3.2.1.2 Aquatic Macroinvertebrates

A total of 948 individuals from 38 macroinvertebrate taxon were collected from the five pools sampled using the quantitative sampling technique (Appendix 7). The most abundant macroinvertebrate taxon was the Leptophlebiidae (262 individuals) and Atyidae (150 individuals), followed by the Chironomidae (81 individuals) and Dytiscidae (73 individuals) (Appendix 7).

Gambusia were collected from Pool J (5 individuals), Pool M1 (1 individuals) and Pool N (6 individuals) 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) or the native freshwater crayfish (*Euastacus* sp.) were collected (Appendix 7).

In general, mean abundance and diversity of macroinvertebrates was greatest in the Woronora River Pool in comparison to the other pools sampled (Figures 6&7). Diversity and abundance of macroinvertebrates were smallest in Pool J (Figure 6&7).

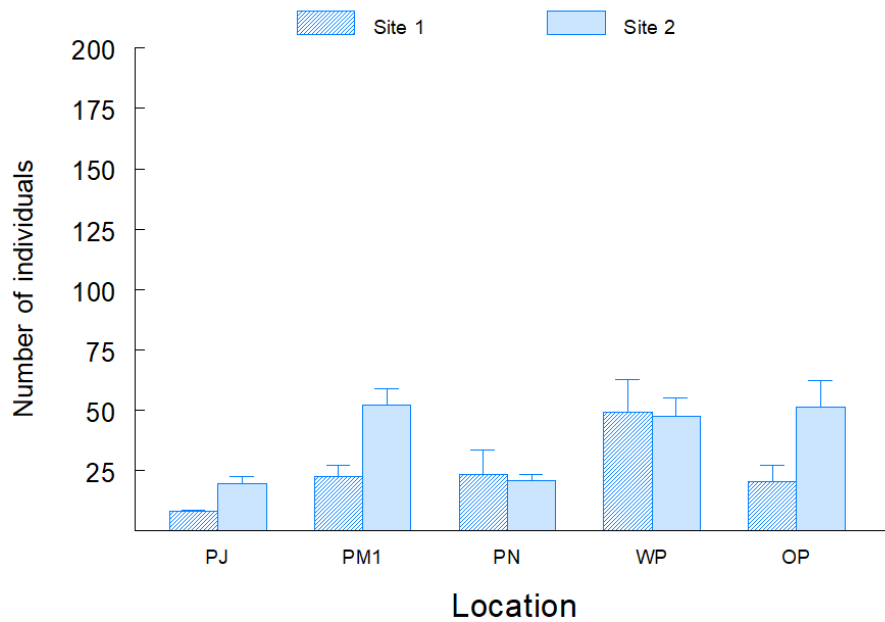


Figure 6. Mean (+SE) abundance of macroinvertebrates at each pool (PJ – Pool J, PM1 – Pool M1, PN – Pool N, WP – Woronora Pool, OP - O’Hares Pool) ($n = 3$).

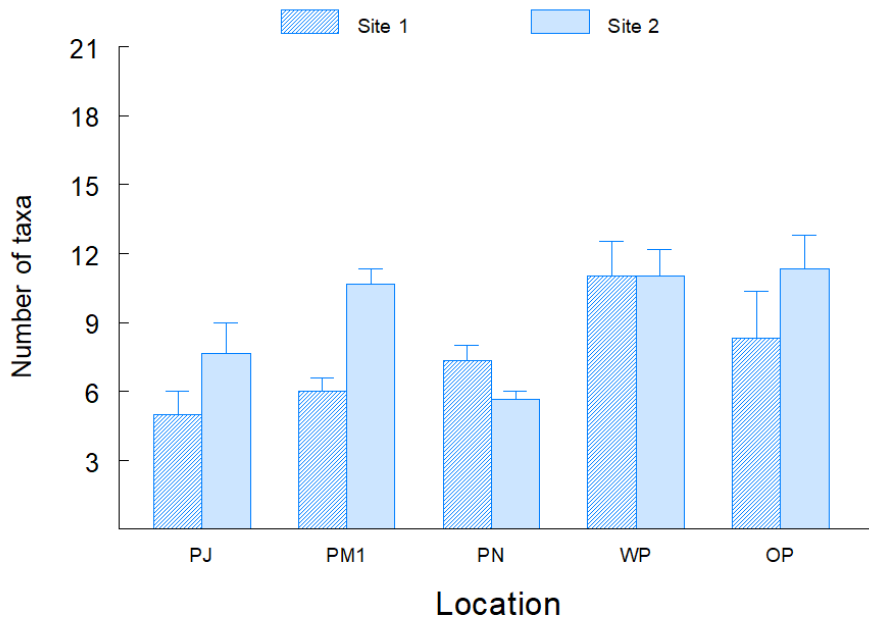


Figure 7. Mean (+SE) diversity of macroinvertebrates at each pool (PJ – Pool J, PM1 – Pool M1, PN – Pool N, WP – Woronora Pool, OP - O’Hares Pool) ($n = 3$).

3.2.1.3 Aquatic Macrophytes

A total of 20 aquatic macrophyte species were found in quantitative samples at the pools sampled: Pool J (9 species), Pool M1 (9 species), Pool N (9 species), Woronora pool (10 species) and O'Hares pool (8 species) (Appendix 6). Similar to the findings of the previous survey, mean percentage cover of aquatic macrophytes was greatest at the O'Hares pool followed by Pool J (Figure 8). The mean diversity of macrophytes recorded in the 0.25 m² quadrats at any one location was generally low (i.e. < 4 species) (Figure 9).

Three species of submerged macrophyte were mapped within the large pools sampled in spring 2018: *Triglochin procerum*, *Chara/Nitella* spp. and *Myriophyllum pedunculatum* (Figures 10-14). The largest area of macrophytes has consistently occurred at the reference pool on the Woronora River, where just over approximately 25 % of the pool bed was covered, mostly by *Triglochin procerum* (Figures 10-14).

Patches of *Triglochin procerum* were also recorded in Pool J (one small patch only), Pool N and O'Hares pool (Figures 10-14). *Myriophyllum pedunculatum* was only observed in the Woronora pool (Figure 13). Patches of *Chara/Nitella* spp. were recorded in Pool J, Pool M1 and Pool N on the Waratah Rivulet and the O'Hares pool on this sampling occasion (Figures 10-14).

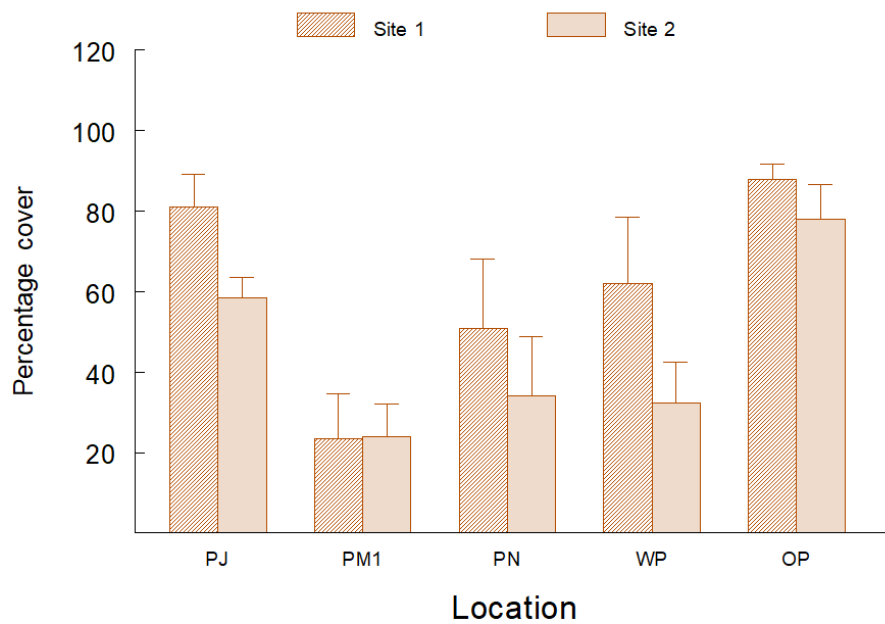


Figure 8. Mean (+SE) percentage cover of macrophytes at each pool (PJ – Pool J, PM1 – Pool M1, PN – Pool N, WP – Woronora Pool, OP - O’Hares Pool) ($n = 5$).

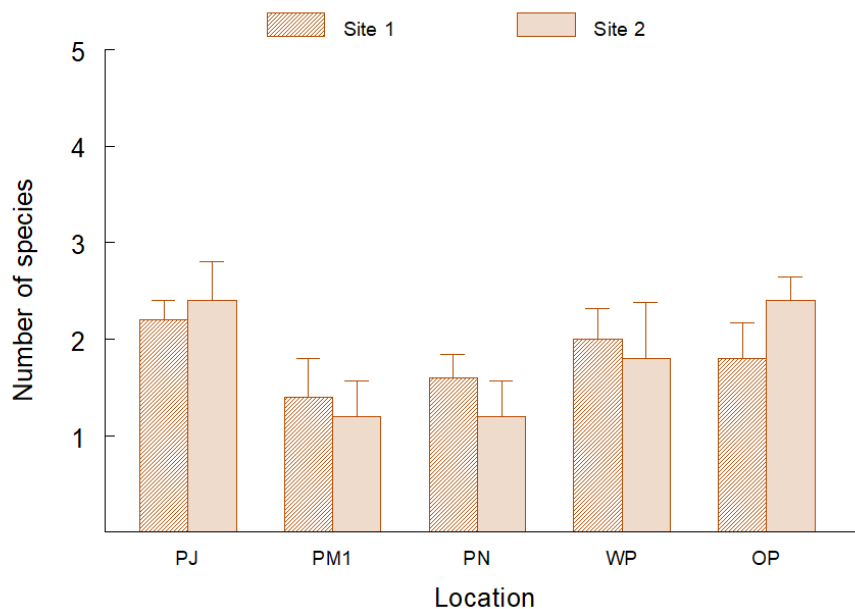
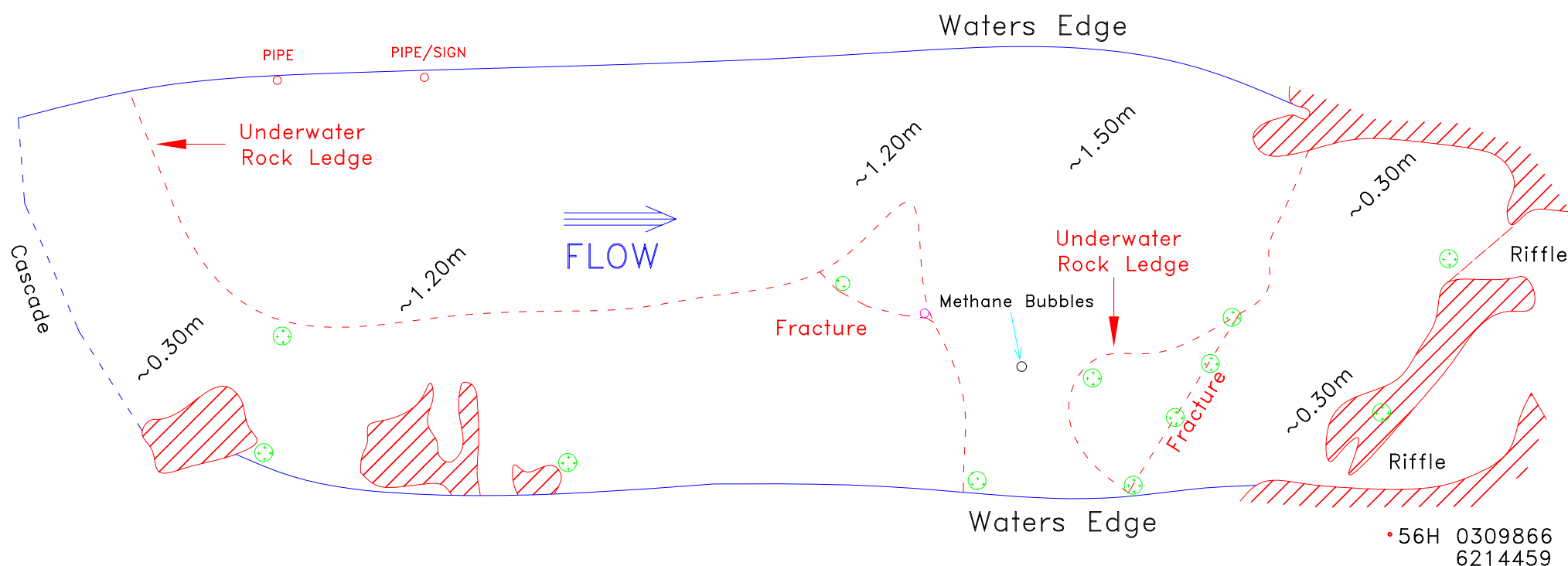
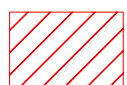


Figure 9. Mean (+SE) diversity of macrophytes at each pool (PJ – Pool J, PM1 – Pool M1, PN – Pool N, WP – Woronora Pool, OP - O’Hares Pool) ($n = 5$).

FIGURE 10



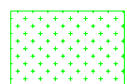
LEGEND



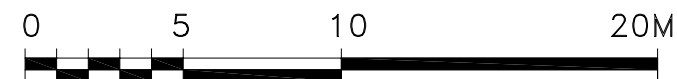
Exposed Rock



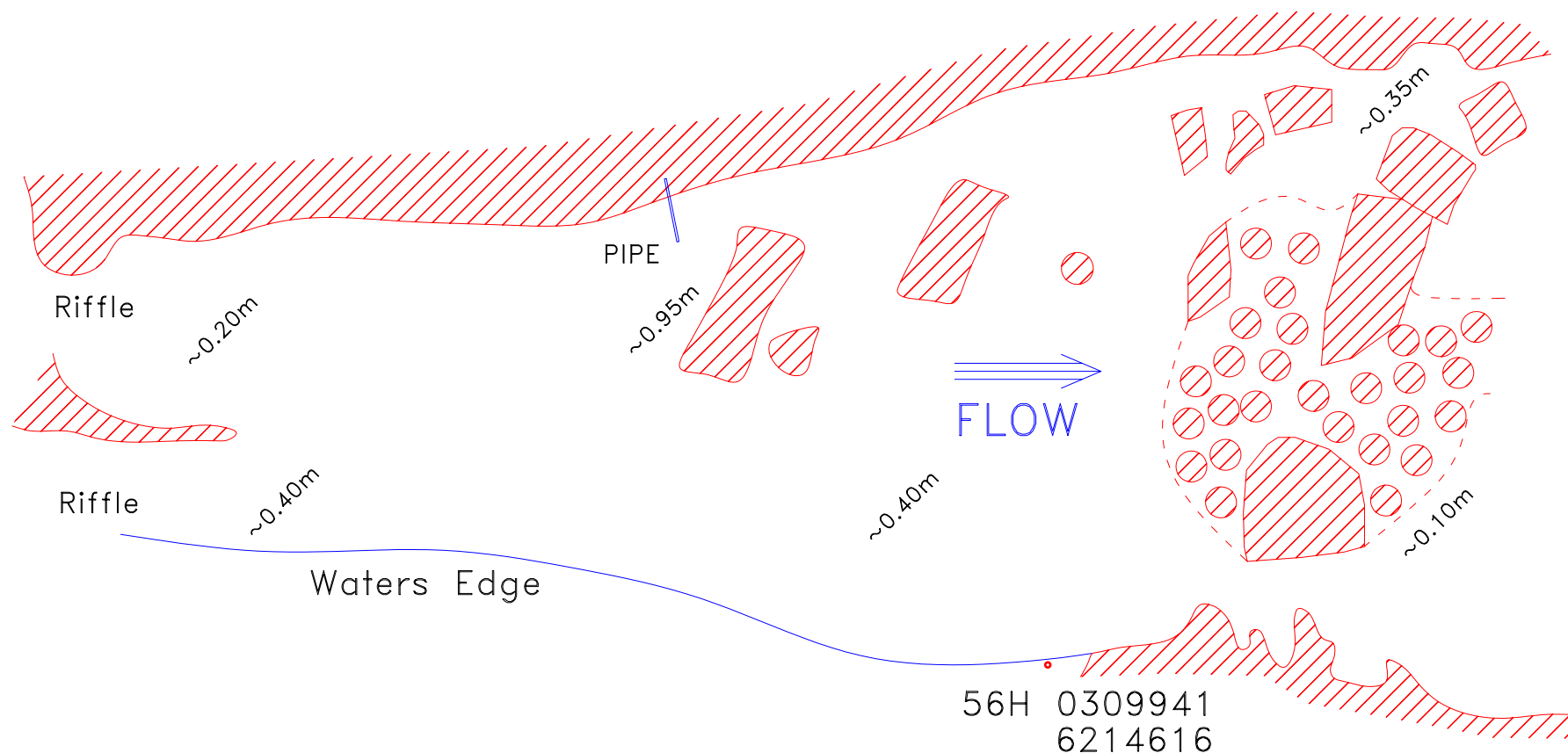
Triglochin procerum



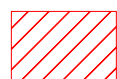
Chara/Nitella spp.



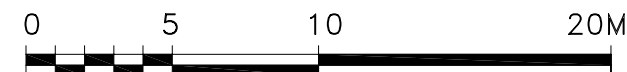
SCALE



LEGEND



Exposed Rock



SCALE

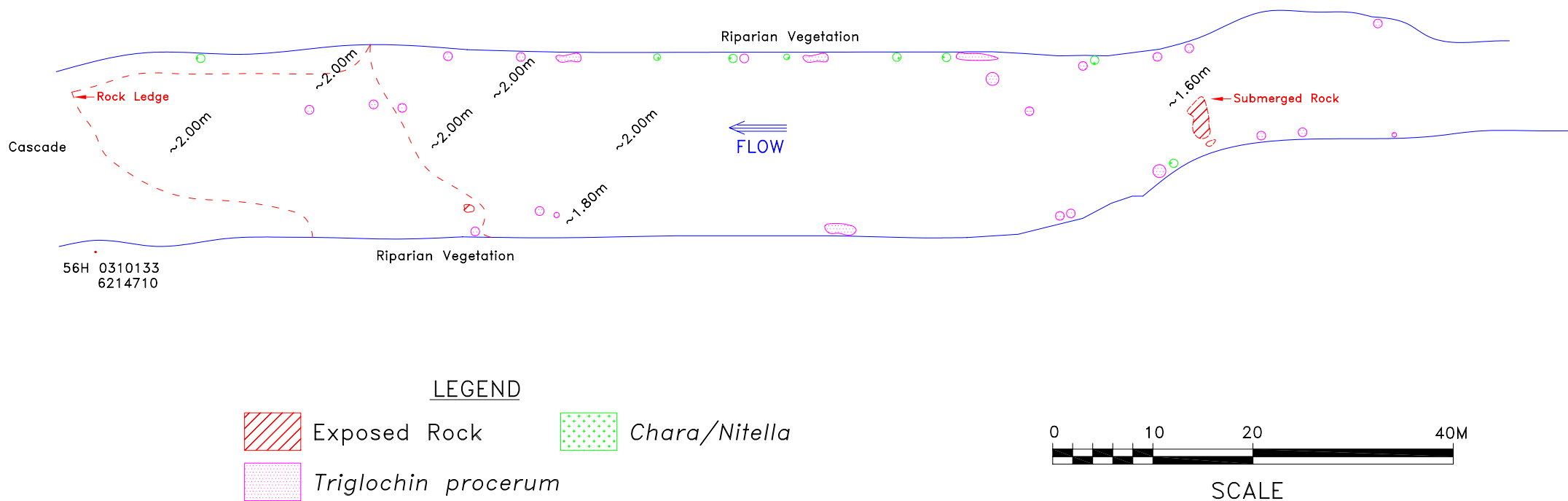
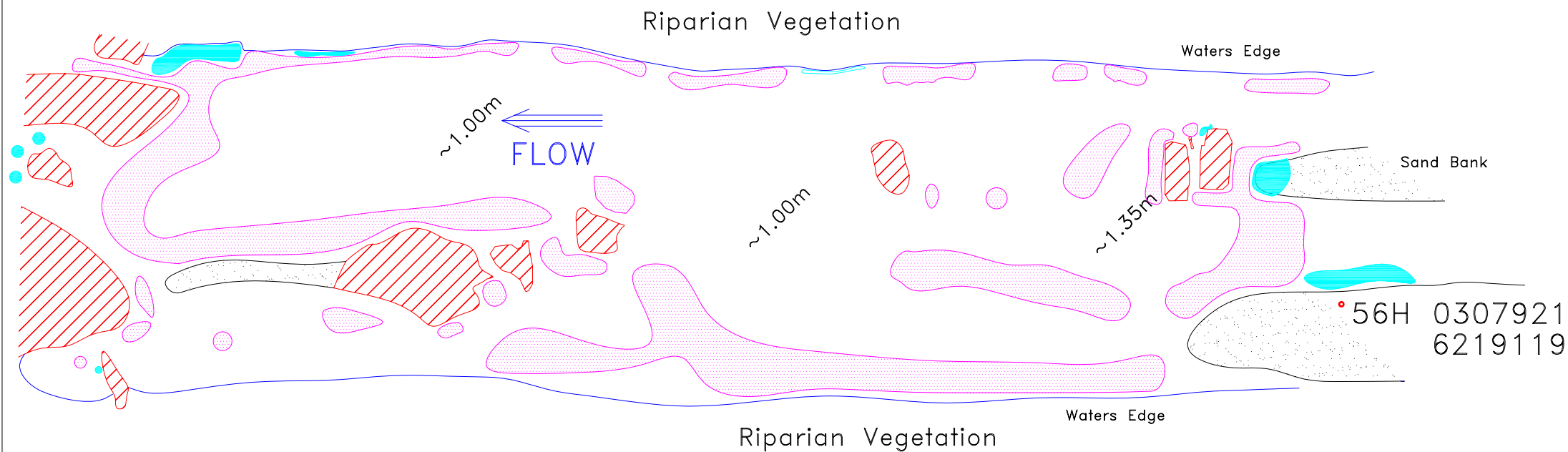
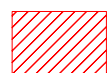


FIGURE 13



LEGEND



Exposed Rock



Triglochin procerum



Myriophyllum pedunculatum



SCALE

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Mobile: 0414477066

WORONORA POOL WP
SPRING SURVEY 2018

DATE:

19/11/2018

No OF SHEETS:

1

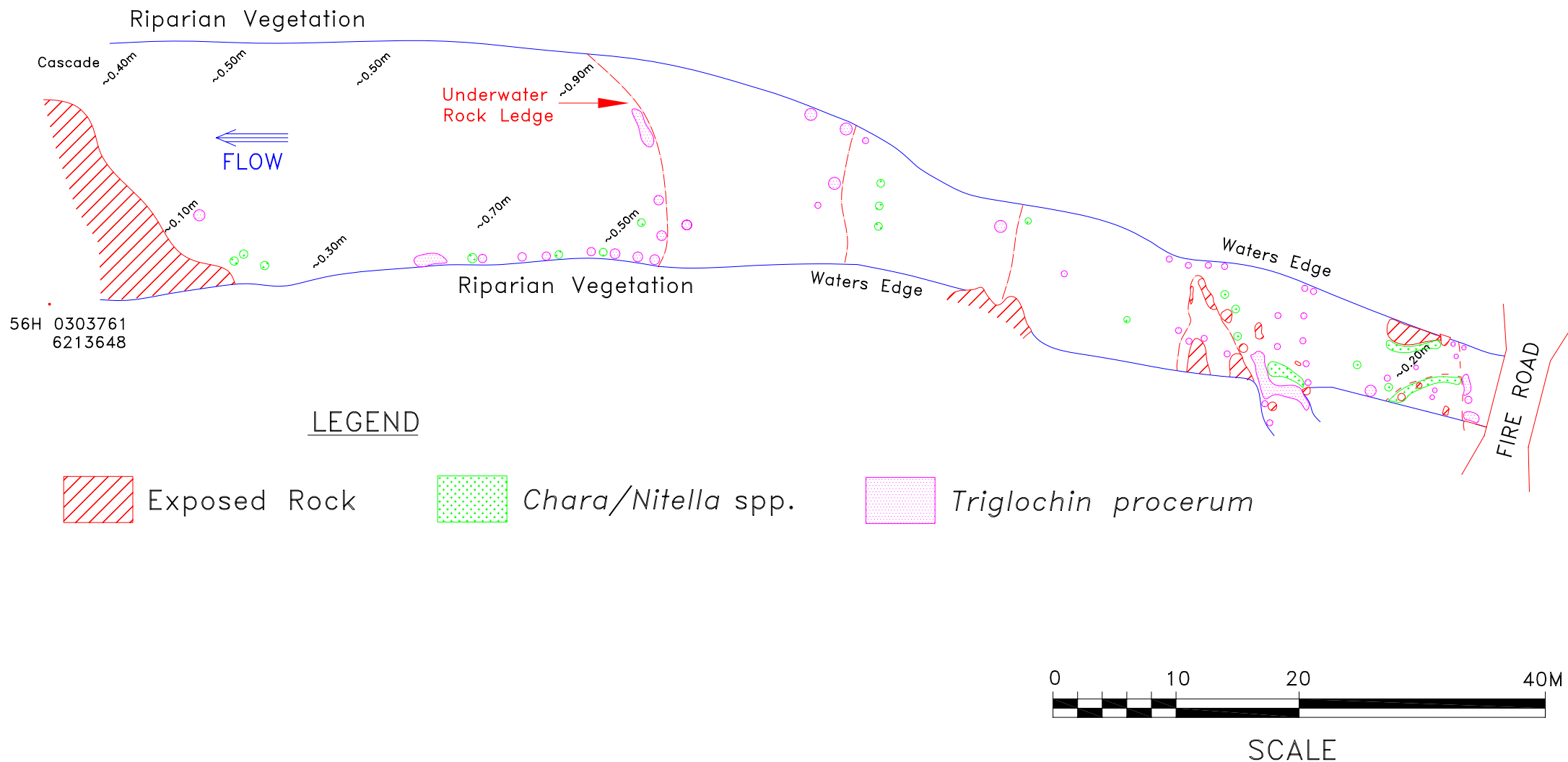
SCALE:

BAR SCALE

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1

FIGURE 14



3.2.1.4 Water Quality

Physico-chemical water quality measurements are summarised in Table 3, with values highlighted in bold type indicating where mean values were outside the ANZECC (2000) guideline values. In general, the mean water temperature within the five pools ranged from 17.5 to 23.4 °C (Table 3). Similar to the findings of the previous survey, pH (range = 6.5 – 8.1) was above the upper guideline value recommended by ANZECC (2000) for upland rivers (i.e. systems at > 150 m altitude) in Pool J (Table 3). Conductivity ranged between 108 and 165 µS/cm and turbidity from 2.5 to 71 NTU (Table 3). Mean dissolved oxygen (DO) (range = 62.1 – 115.1 % Saturation) was above the upper ANZECC (2000) value at Pool J and below the lower limit at Pools N1, WP1 and WP2 (Table 3). Oxidation-reduction potential ranged between 408 to 670 mV (Table 3). The raw water quality data are provided in Appendix 8.

Table 3. Mean (± SE) measurements of water quality variables recorded at each site (spring 2018).

	Pool J		Pool M1	
Site	J1	J2	M11	M12
Temperature °C (n = 3)	23.2 (0.3)	23.4 (0.1)	21.2 (0.1)	19.8 (0.0)
pH (n = 3)	8.1 (0.0)	8.1 (0.0)	7.6 (0.0)	7.5 (0.0)
Conductivity (µS/cm) (n = 3)	164.7 (1.3)	163.7 (0.3)	162.0 (0.0)	162.0 (0.0)
Dissolved Oxygen (% Saturation) (n = 3)	115.1 (1.8)	114.6 (0.7)	102.6 (0.3)	99.9 (0.0)
Turbidity (NTU) (n = 3)	19.0 (0.1)	22.2 (0.9)	24.6 (0.4)	2.5 (0.0)
ORP (mV) (n = 3)	486.3 (1.2)	495.7 (0.3)	420.7 (1.5)	408.3 (0.3)
	Pool N		Woronora Pool	
Site	N1	N2	WP1	WP2
Temperature °C (n = 3)	20.0 (0.0)	20.3 (0.0)	17.5 (0.2)	18.4 (0.0)
pH (n = 3)	7.5 (0.0)	7.5 (0.0)	6.8 (0.0)	6.7 (0.0)
Conductivity (µS/cm) (n = 3)	161.7 (0.3)	160.3 (0.3)	121.0 (0.0)	119.0 (0.0)
Dissolved Oxygen (% Saturation) (n = 3)	86.9 (0.5)	91.7 (0.1)	62.1 (0.1)	63.6 (0.3)
Turbidity (NTU) (n = 3)	2.5 (0.0)	21.7 (0.0)	68.9 (0.2)	70.7 (0.1)
ORP (mV) (n = 3)	473.7 (0.3)	463.3 (0.7)	669.7 (0.3)	667.0 (0.0)
	O'Hares Pool			
Site	OP1	OP2		
Temperature °C (n = 3)	22.4 (0.0)	22.0 (0.0)		
pH (n = 3)	6.7 (0.0)	6.5 (0.0)		
Conductivity (µS/cm) (n = 3)	108.0 (0.0)	109.0 (0.0)		
Dissolved Oxygen (% Saturation) (n = 3)	97.2 (0.2)	93.6 (0.6)		
Turbidity (NTU) (n = 3)	21.8 (0.1)	24.4 (0.5)		
ORP (mV) (n = 3)	597.7 (0.3)	615.3 (2.7)		

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). There are no ANZECC (2000) guideline values for Temperature or ORP.

3.2.2 Small Pools

3.2.2.1 Pool Characteristics

Waratah Rivulet Pools

Three small pools (defined as pools < 40 m in length) are sampled along the Waratah Rivulet: Pools K, L and M.

Pool K is approximately 480 m downstream of Flat Rock Crossing. Dimensions of the pool were approximately 10 m long by 10 m wide (Plate 33). At the time of the spring 2018 survey, water depth was from approximately 0.3 m up to 1.1 m deep. An iron complex has been observed covering a large proportion of the stream substratum since sampling commenced in spring 2009, including during the current survey. Pool water has commonly had a milky-green tinge. Blocks of sandstone detached from the upstream substratum and washed downstream were noted to have settled at the edge of the pool in autumn 2014. At the time of this survey, *Eurychorda complanata* and *Empodisma minus* were amongst the most common emergent macrophyte species (Appendix 9). *Chara/Nitella* sp. was present on this sampling occasion (Appendix 9).

Pool L is downstream of Rock bar K. In general, pool length has been approximately 22 m, width approximately 10 m to 13 m wide (Plate 34) and water depth up to approximately 0.4 m deep. The pool bed is sandstone covered with sediment and an iron complex. Pool water has commonly had a milky-green tinge. Boulders to about 1 m size were located on the eastern bank and at the downstream end of the pool. *Gleichenia dicarpa* and *Lepidosperma filiforme* were amongst the most common emergent macrophyte species (Appendix 9). *Chara/Nitella* spp. was present at the time of sampling (Appendix 9). Gas bubbles were not observed at the upstream end of the pool on this occasion. Gas release has been noted in Pool L on several occasions since spring 2012.



Plate 33: Pool K (K) (aut-18)

Looking downstream



Plate 34: Pool L (L) (aut-18)

Downstream end looking upstream

Pool M is downstream of Rock Bar L. In general, the pool has been approximately 11 m long, 11 m wide and up to approximately 1.2 m deep (Plate 35). The substratum of the pool was predominantly sandstone covered with sediment and sand deposits. At the time of the autumn 2018 survey, *Gleichenia dicarpa* and *Juncus planifolia* were the most common riparian species (Appendix 9). Patches of *Chara/Nitella* spp. were present on this sampling occasion (Appendix 9). An iron complex has been observed to cover up to ~90 % of the stream substratum since sampling commenced in spring 2009. Pool water has commonly had a milky-green tinge (Plate 35).



Plate 35: Pool M (M) (aut-18)

Downstream end looking upstream



Plate 36: Woronora pool A (WP-A) (sp-18)

Upstream end looking across-stream

Small Control Pools

Three small control pools are sampled on each of the Woronora River (i.e. WP-A, WP-B and WP-C) and O'Hares Creek (i.e. OP-A, OP-B and OP-C).

Pool WP-A is the most downstream of the small pools sampled on the Woronora River, situated approximately 165 m upstream from the gauging station. At the time of this survey, pool dimensions were approximately 10.5 m long and up to 6 m wide (Plate 36). Pool depth was up to approximately 0.2 m deep. Boulders to about 1 m in size were located at the upstream and downstream ends of the pool (Plate 36). The substratum of the pool was predominantly sandstone covered with sediment and sand deposits.

Dense vegetation surrounded the pool. Of the emergent species present, *Gleichenia dicarpa* and *Lepidosperma filiforme* were the most common riparian emergent macrophyte species (Appendix 9). The submerged macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum*, were common (Appendix 9). At the time of sampling, there were no obvious signs of disturbance. Visibility of the water was good.

Pool WP-B is the most upstream pool sampled, situated approximately 325 m upstream from the gauging station. Dimensions of the pool were approximately 28 m long and up to 7 m wide (Plate 37). Pool depth was up to approximately 1.3 m deep. Boulders to about 2 m in size were located at the upstream and downstream ends of the pool. The substratum of the pool was predominantly sandstone covered with sediment and sand deposits. Dense vegetation surrounded the pool.

Of the emergent species present, *Sticherus flabellatus*, *Eurychorda complanata* and *Lepidosperma filiforme* were amongst the most abundant (Appendix 9). Large patches of the submerged macrophyte, *Triglochin procerum*, were recorded. *Chara/Nitella* and *Myriophyllum pedunculatum* were also present. At the time of sampling, there were no obvious signs of human disturbance (Plate 37). Visibility of the water was good.

Pool WP-C is situated between Pools WP-B and WP-A. Dimensions of the pool were approximately 9 m long and up to 3.5 m wide (Plate 38). Pool depth was up to approximately 0.3 m deep. Boulders were located at the upstream end of the pool. The substratum of the pool was predominantly sandstone, boulders and some deposits of sand. Dense vegetation surrounded the pool. Of the macrophyte species present, *Lomandra fluviatilis* and *Lepidosperma filiforme* were the most abundant (Appendix 9). At the time of this survey, one small patch of *Triglochin procerum* was present (Appendix 9). There were no obvious signs of disturbance and visibility of the water was good.



Plate 37: Woronora pool B (WP-B) (sp-18)

Downstream end looking upstream



Plate 38: Woronora pool C (WP-C) (sp-18)

Downstream end looking upstream

Small control pools on O'Hares Creek are all situated downstream of the crossing at Fire Road 10C. Dimensions of pool OP-A were approximately 40 m long and up to 12 m wide. Pool depth was up to 0.5 m deep. Boulders were located at the upstream and downstream ends of the pool. The substratum of the pool was predominantly sandstone. Of the emergent species present, *Empodisma minus* and *Lomandra fluviatilis* were among the most abundant (Appendix 9). At the time of the survey, *Triglochin procerum* was not present but small patches of *Chara/Nitella* spp. were observed growing amongst boulders situated near the top of the pool. There were no obvious signs of disturbance. Visibility of the water was excellent (Plate 39).

Dimensions of pool OP-B were approximately 20 m long and up to 10 m wide (Plate 40). Pool depth was up to 0.9 m deep. The substratum of the pool was predominantly sandstone with some boulders, mostly located at the upstream end of the pool. Of the emergent species present, *Empodisma minus* and *Gleichenia dicarpa* were the most abundant (Appendix 9). *Chara/Nitella* spp. was also present (Appendix 9). Visibility of the water was excellent.

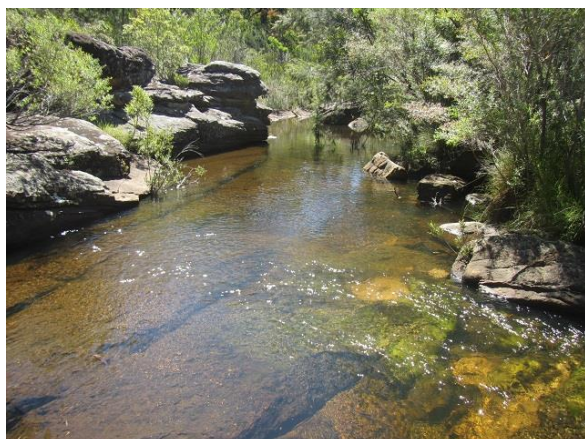


Plate 39: O'Hares pool A (OP-A) (sp-18)

Upstream end looking downstream



Plate 40: O'Hares pool B (OP-B) (sp-18)

Downstream end looking upstream

Dimensions of pool OP-C were approximately 37 m long and up to 12.5 m wide (Plate 41). Pool depth was up to 0.8 m deep. The substratum of the pool was predominantly sandstone with some boulders at the upstream and downstream ends of the pool. Of the emergent species present, *Gleichenia dicarpa*, *Empodisma minus* and *Eurychorda complanata* were amongst the most abundant (Appendix 9). Visibility of the water was excellent.



Plate 41: O'Hares pool C (OP-C) (sp-18)

Upstream end looking downstream

3.2.2.2 Aquatic Macroinvertebrates

A total of 700 individuals from 38 macroinvertebrate taxon were collected from the nine small pools sampled using the quantitative sampling technique (Appendix 10). The most abundant macroinvertebrate taxon was the Atyidae (163 individuals) followed by the Leptophlebiidae (133 individuals) and the Chironomidae (87 individuals) (Appendix 10). *Gambusia* (13 individuals) were collected in the small pools sampled along the Waratah Rivulet 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), or the native freshwater crayfish (*Euastacus* sp.) were collected (Appendix 10). In general, mean abundance and diversity of macroinvertebrates was greatest in the Woronora River pools and smallest in pools sampled along Waratah Rivulet (Figure 15&16).

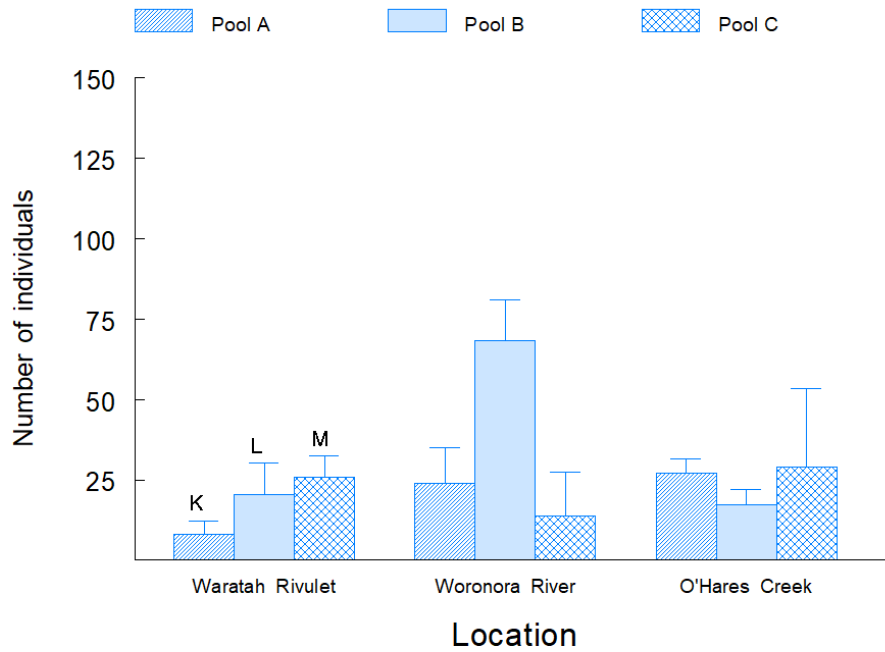


Figure 15. Mean (+SE) abundance of macroinvertebrates at small pools ($n = 3$).

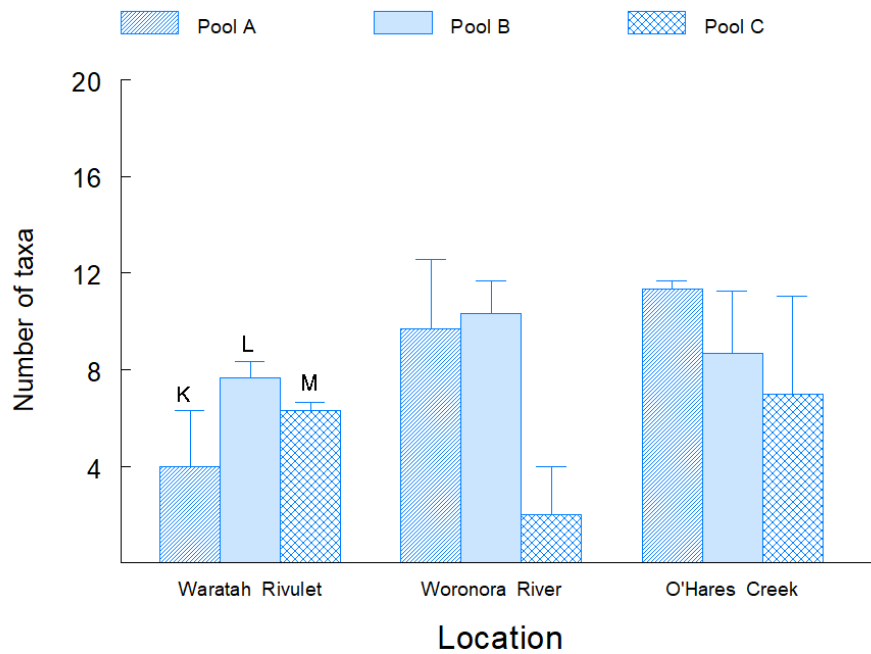


Figure 16. Mean (+SE) diversity of macroinvertebrates at small pools ($n = 3$).

3.2.2.3 Aquatic Macrophytes

A total of 18 aquatic macrophyte species were found in quantitative samples at the small pools sampled on Waratah Rivulet (13 species), Woronora River (10 species) and O'Hares Creek (10 species) (Appendix 9). Overall, mean percentage cover of aquatic macrophytes was greatest at pools sampled along O'Hares Creek (Figure 17). The mean diversity of macrophytes recorded in the 0.25 m² quadrats at any one location was generally low (i.e. < 4 species) (Figure 18).

Three species of submerged macrophyte were mapped within the small pools sampled in spring 2018: *Triglochin procerum*, *Myriophyllum pedunculatum* and *Chara/Nitella* spp. (Figures 19-27). *Triglochin procerum* was recorded in all three of the pools sampled on the Woronora River on this sampling occasion (Figures 19-27). *Chara/Nitella* spp. was present in Pool K, Pool L and Pool M on the Waratah Rivulet, Pool B on the Woronora River and in Pools A, B and C on O'Hares Creek (Figures 19-27). The largest area of macrophytes occurred at Woronora pool B, where approximately 15 % of the pool bed was covered by patches of *Triglochin procerum*, *Myriophyllum pedunculatum* and *Chara/Nitella* spp. (Figure 23).

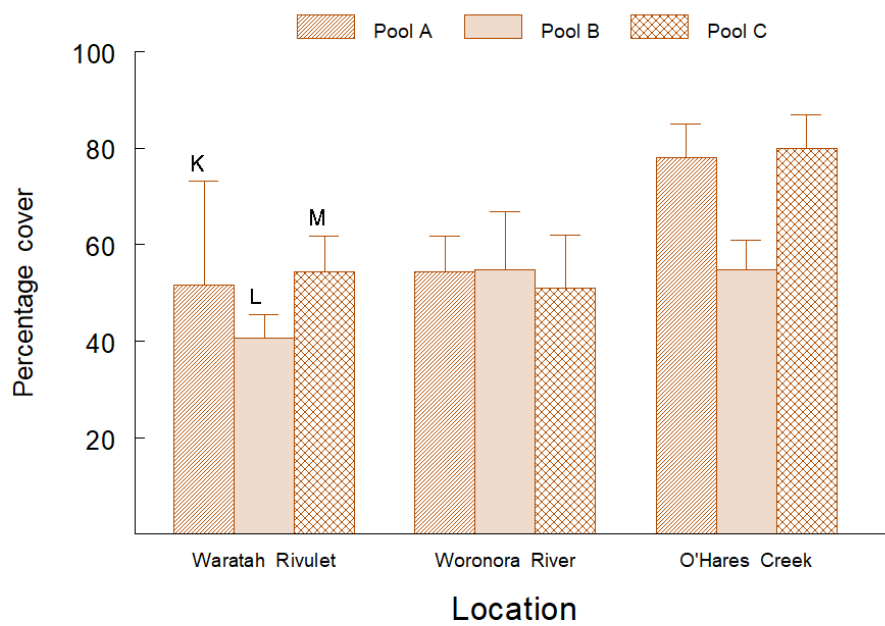


Figure 17. Mean (+SE) percentage cover of macrophytes at small pools ($n = 5$).

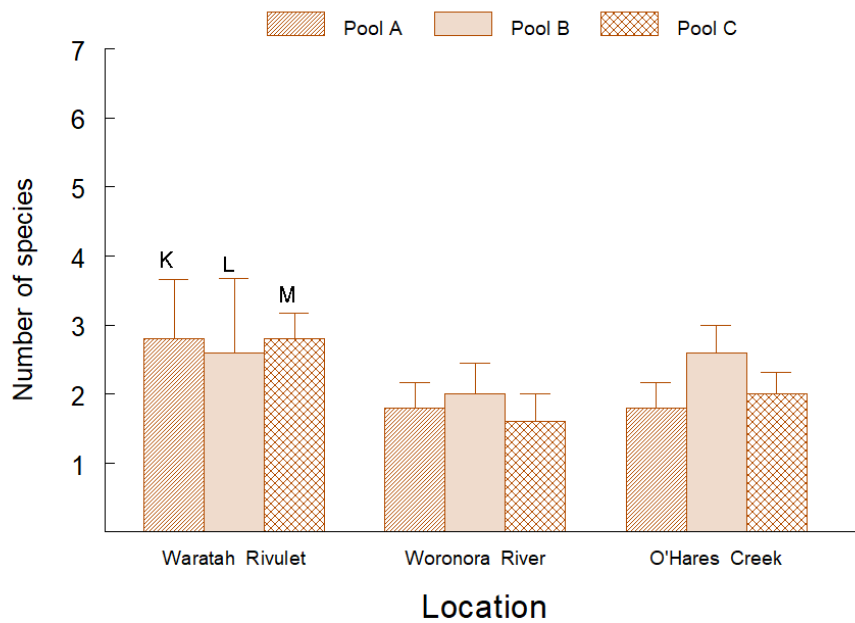
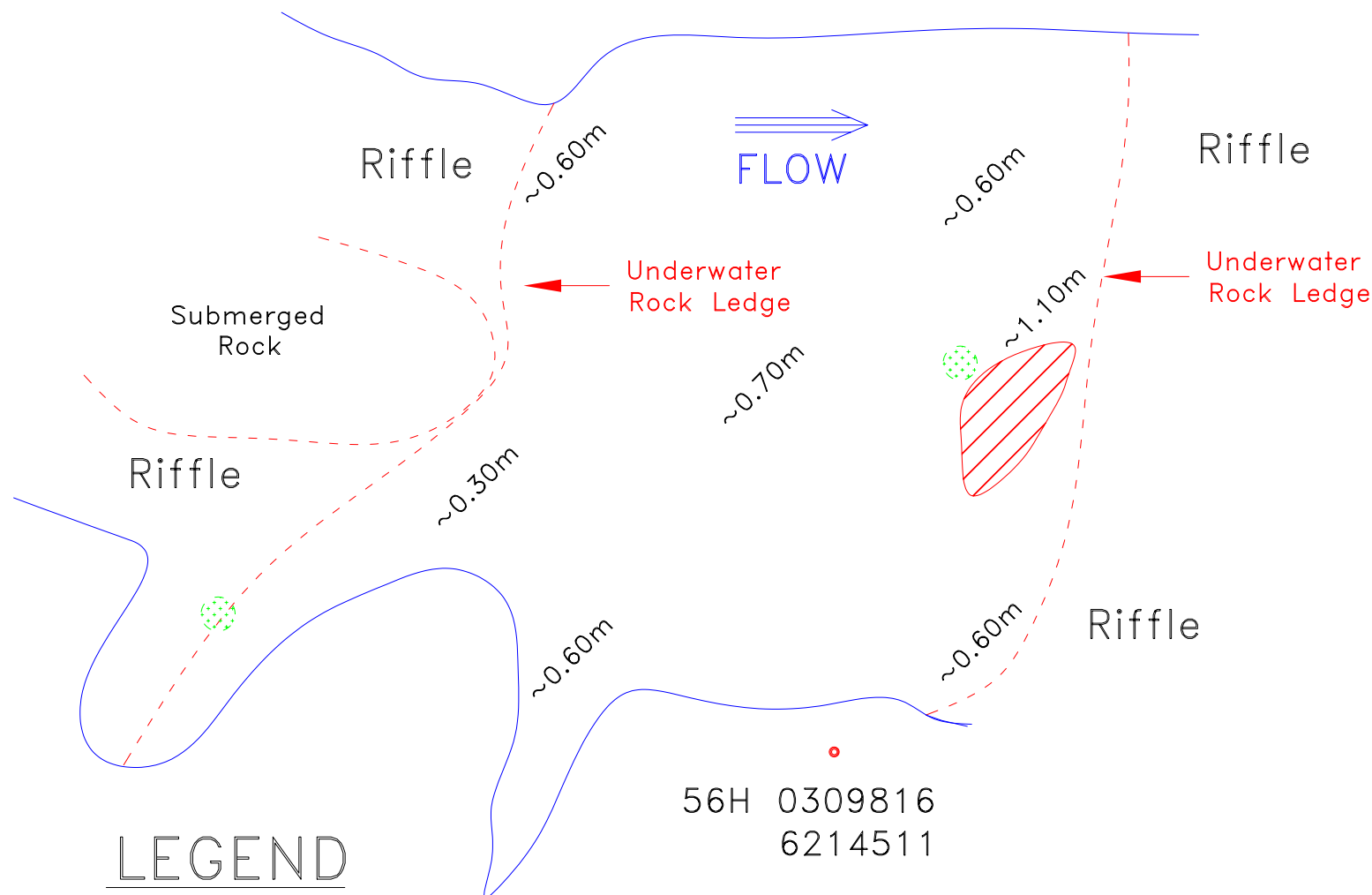


Figure 18. Mean (+SE) diversity of macrophytes at small pools ($n = 5$).

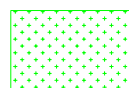
FIGURE 19



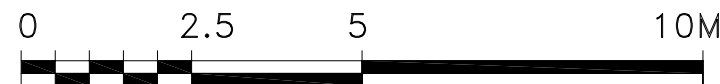
LEGEND



Exposed Rock

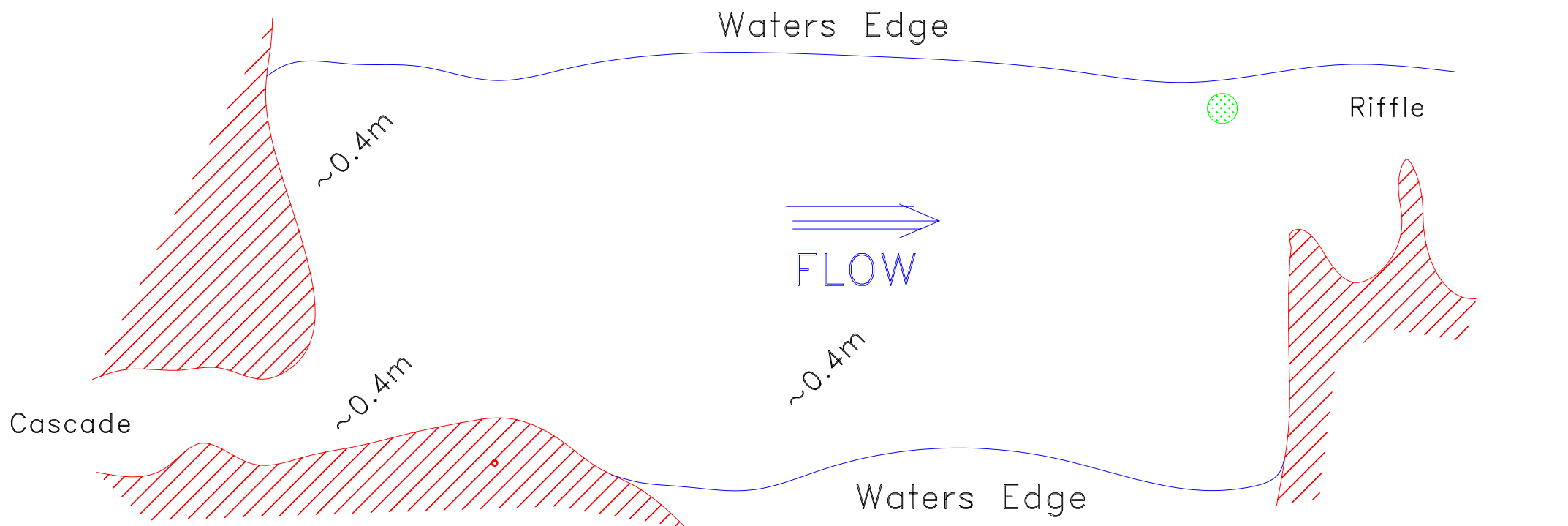


Chara/Nitella



SCALE

FIGURE 20

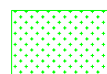


56H 0309887
6214539

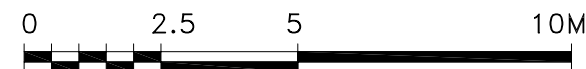
LEGEND



Exposed Rock

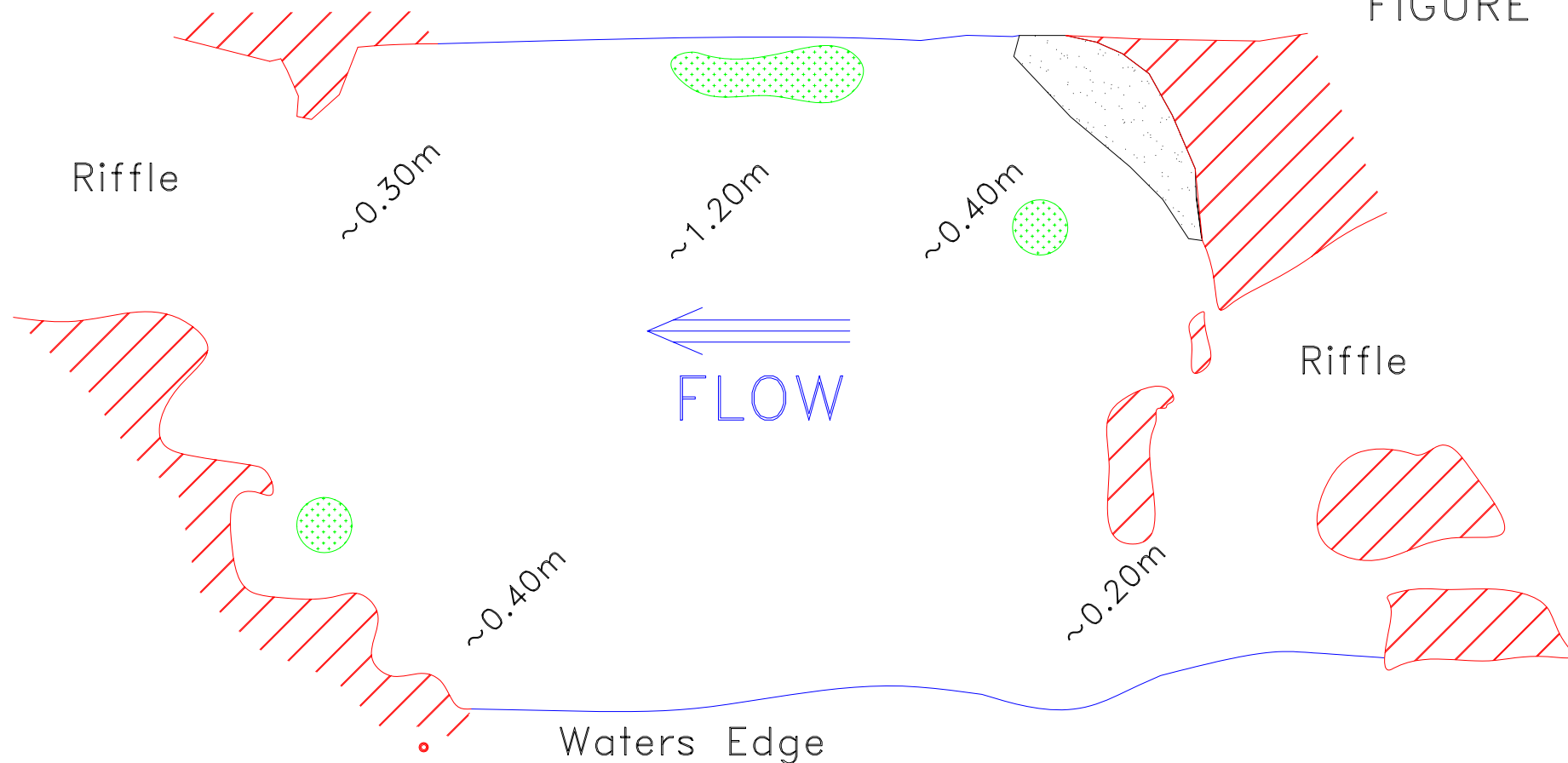


Chara/Nitella spp.



SCALE

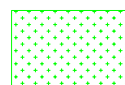
FIGURE 21



LEGEND



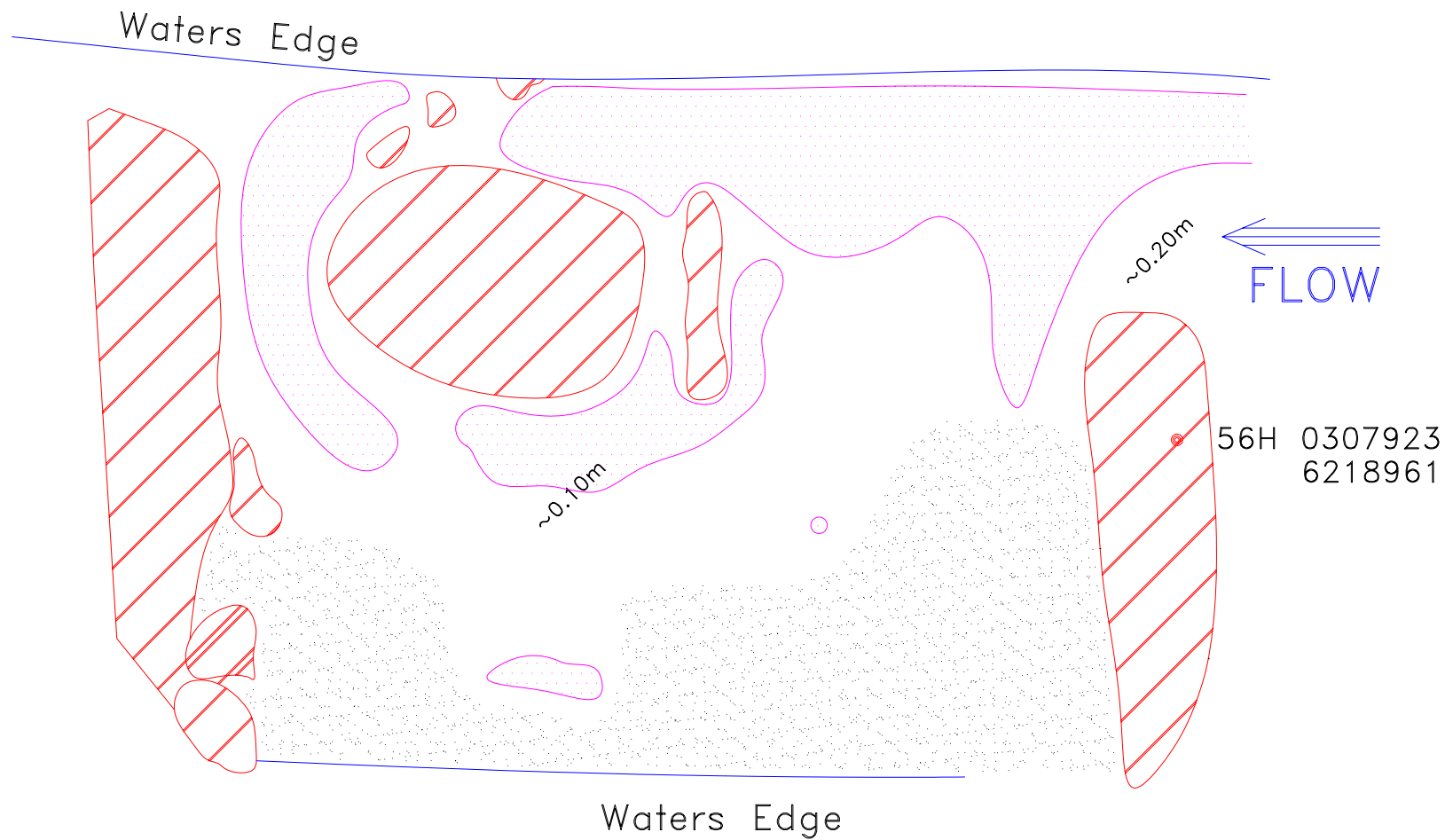
Exposed Rock



Chara/Nitella



SCALE



LEGEND



Exposed rock

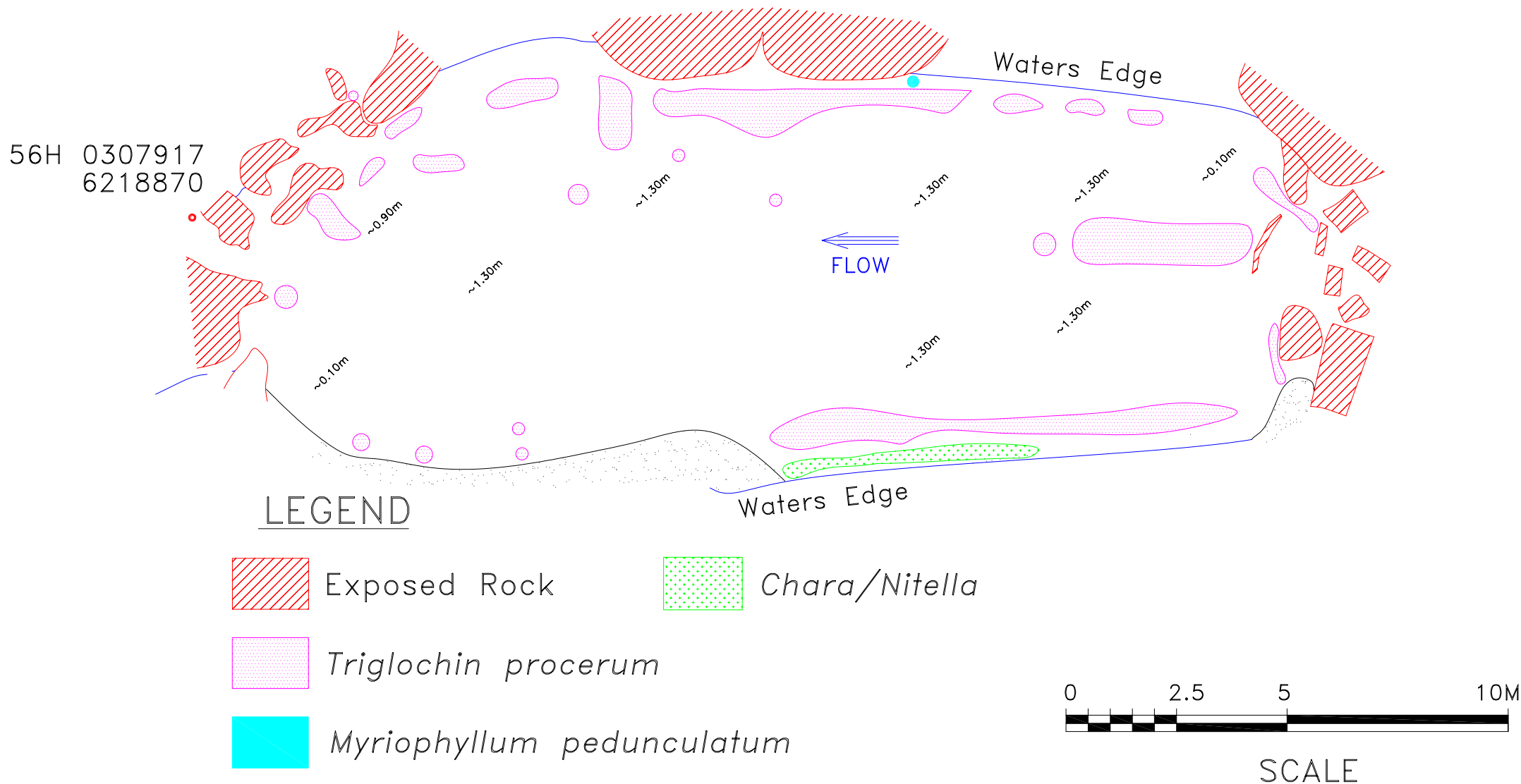


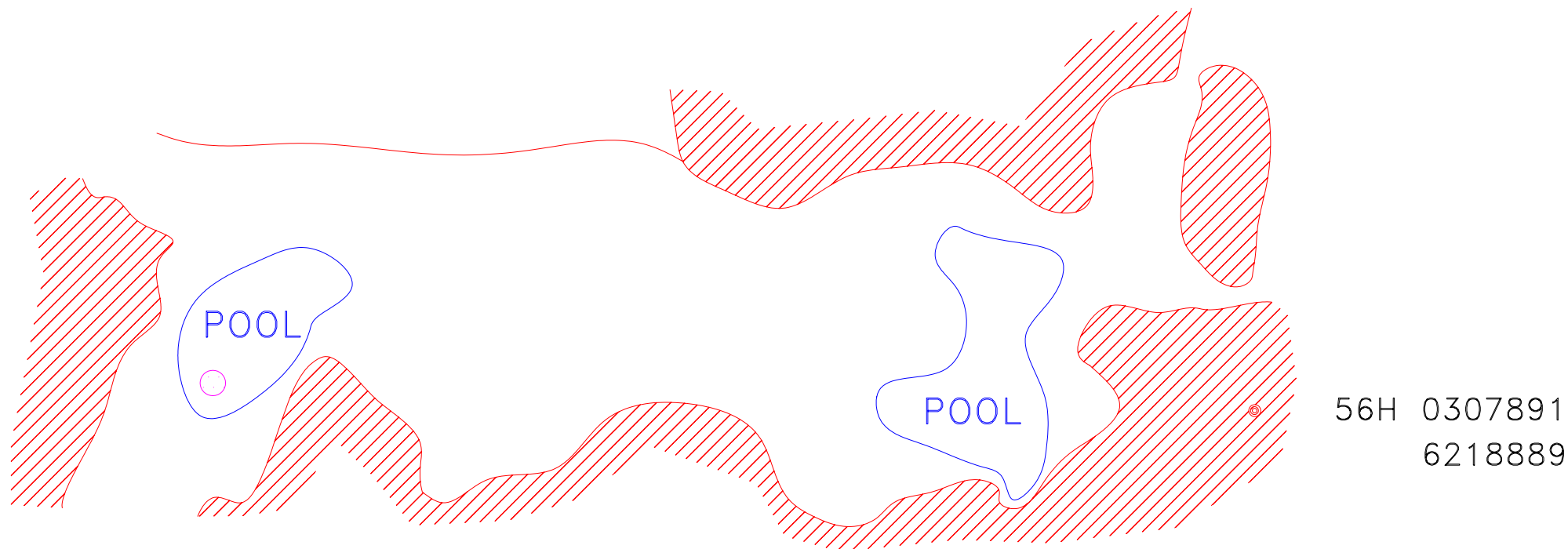
Sand

*Triglochin procerum*

SCALE

FIGURE 23





LEGEND



Exposed rock

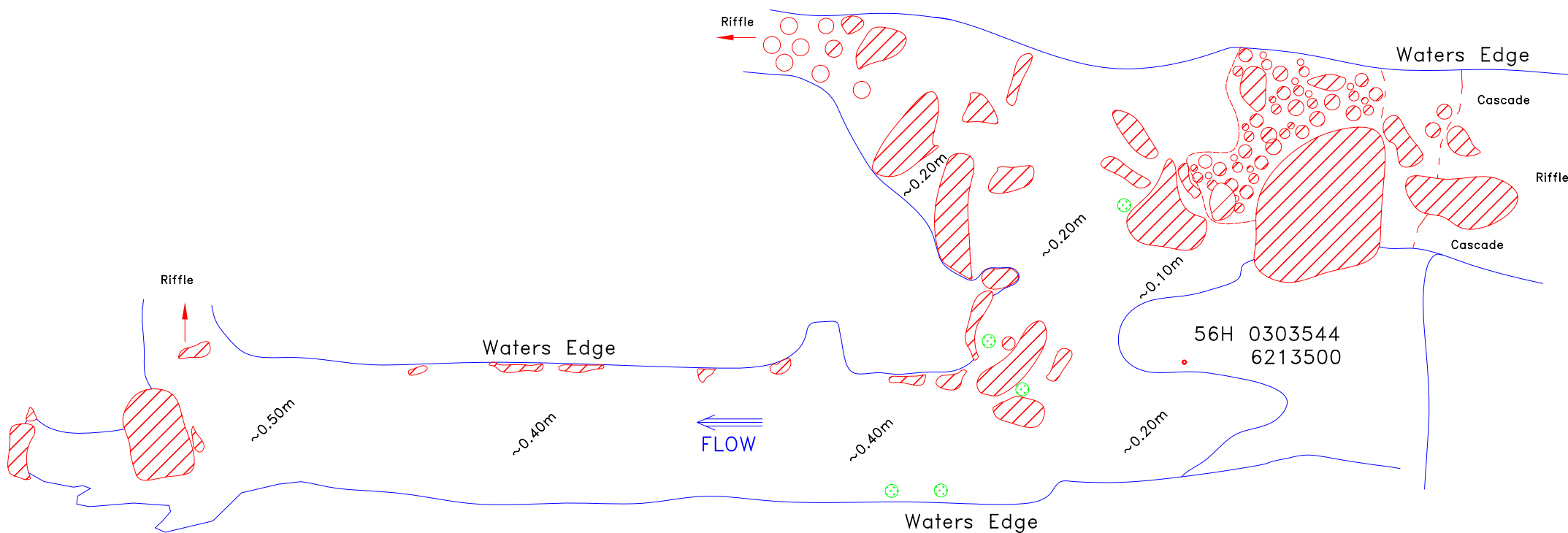


Triglochin procerum

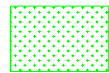


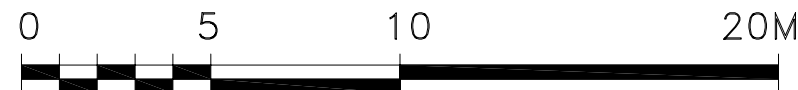
SCALE

FIGURE 25



LEGEND

 Exposed Rock  Chara/Nitella



SCALE

BIO-ANALYSIS Pty Ltd
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2/1 Botham Close Charmhaven, NSW 2263
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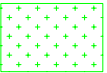
O'HARES POOL A
SPRING SURVEY 2018

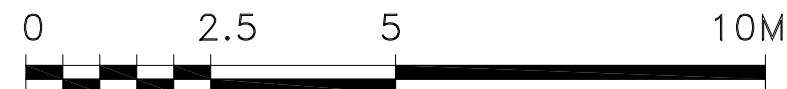
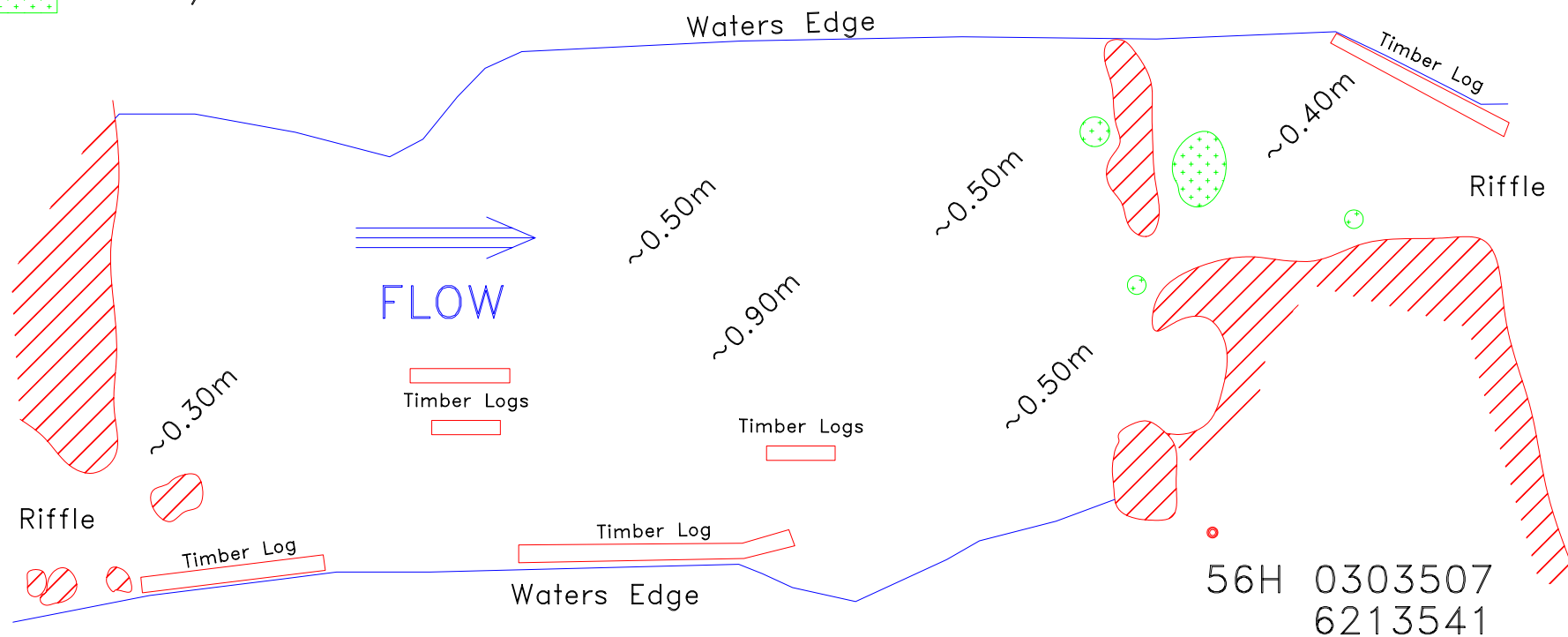
DATE:
03/12/2018
No OF SHEETS:
1

SCALE:
BAR SCALE
SHEET No:
1

LEGEND

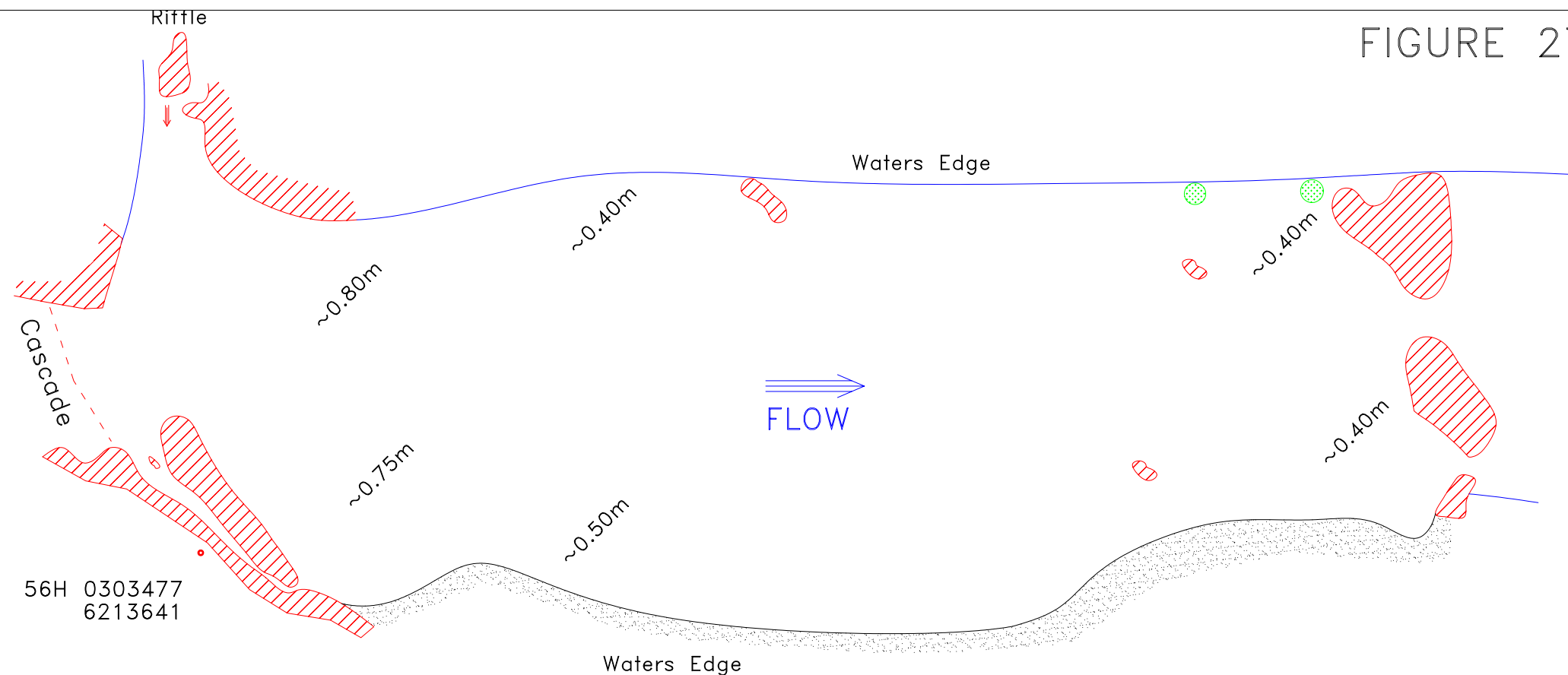
 Exposed Rock

 Chara/Nitella



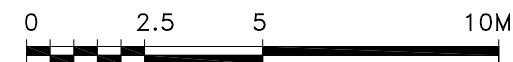
SCALE

FIGURE 27



LEGEND

-  Exposed Rock
-  *Chara/Nitella*



SCALE

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 Mobile: 0414477066

O'HARES POOL C
 SPRING SURVEY 2018

DATE:
 03/12/2018
 No OF SHEETS:
 1

SCALE:
 BAR SCALE
 SHEET No:
 1

3.2.2.4 Water Quality

Physico-chemical water quality measurements are summarised in Table 4, with values highlighted in bold type indicating where mean values were outside the ANZECC (2000) guideline values. In general, the mean water temperature within the nine small pools ranged from 16.8 to 24.9 °C whilst the level of pH ranged from 6.6 to 7.8 (Table 4).

Conductivity ranged from 112 to 171 µS/cm while turbidity was from 19 to 70 NTU (Table 4). Mean dissolved oxygen (DO) (range = 49.3 – 114.9 % Saturation) was below the lower ANZECC (2000) guideline value in Pool L on the Waratah Rivulet and in the Woronora pools and above the upper ANZECC (2000) guideline value at Pool K (Table 4). Oxidation-reduction potential ranged between 338 and 654 mV (Table 4). The raw water quality data are provided in Appendix 11.

Table 4. Mean ($\pm$ SE) measurements of water quality variables recorded at each site (spring 2018).

Pool	K	L	M
Temperature °C ($n = 3$)	22.7 (0.0)	18.5 (0.1)	21.4 (0.0)
pH ($n = 3$)	7.8 (0.0)	6.9 (0.0)	7.5 (0.0)
Conductivity (µS/cm) ($n = 3$)	162.0 (0.0)	171.3 (0.3)	161.0 (0.0)
Dissolved Oxygen (% Saturation) ($n = 3$)	114.9 (0.1)	49.3 (5.5)	103.1 (0.1)
Turbidity (NTU) ($n = 3$)	28.0 (0.0)	23.0 (0.1)	27.9 (0.4)
ORP (mV) ($n = 3$)	492.0 (0.0)	338.0 (9.5)	396.3 (0.3)
Pool	WP-A	WP-B	WP-C
Temperature °C ($n = 3$)	16.8 (0.0)	18.1 (0.2)	17.3 (0.0)
pH ($n = 3$)	7.0 (0.0)	6.6 (0.0)	6.6 (0.0)
Conductivity (µS/cm) ($n = 3$)	128.0 (0.0)	114.3 (0.9)	122.0 (0.0)
Dissolved Oxygen (% Saturation) ($n = 3$)	72.9 (0.5)	62.1 (0.4)	69.9 (0.2)
Turbidity (NTU) ($n = 3$)	69.3 (0.1)	70.3 (1.3)	66.4 (0.1)
ORP (mV) ($n = 3$)	654.0 (0.0)	635.0 (0.0)	643.7 (0.7)
Pool	OCA	OCB	OCC
Temperature °C ($n = 3$)	24.9 (0.0)	24.2 (0.0)	23.1 (0.0)
pH ($n = 3$)	7.2 (0.1)	7.6 (0.0)	7.6 (0.1)
Conductivity (µS/cm) ($n = 3$)	113.0 (0.0)	113.3 (1.7)	112.0 (0.0)
Dissolved Oxygen (% Saturation) ($n = 3$)	102.0 (0.5)	102.1 (0.2)	107.9 (1.1)
Turbidity (NTU) ($n = 3$)	19.0 (0.1)	23.4 (0.1)	24.1 (0.0)
ORP (mV) ($n = 3$)	551.3 (3.7)	523.3 (0.3)	504.3 (0.7)

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). There are no ANZECC (2000) guideline values for Temperature or ORP.

4.0 TEMPORAL ANALYSES

A temporal comparison of the aquatic macroinvertebrate and macrophyte data was carried out for the Stream Monitoring (Section 4.1) and Pool Monitoring (Section 4.2) components of the Longwalls 20-22 Aquatic Ecology Monitoring Programme. The quantitative data from the surveys done between spring 2008 or spring 2009 and spring 2018 were analysed using both multivariate and univariate techniques. AUSRIVAS data collected from the stream monitoring locations are also presented.

4.1 Stream Monitoring

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), the Waratah Rivulet (Section 4.1.2) and Tributary B (Section 4.1.3) following the commencement of mining of the Longwalls 20-22 mining area, in relation to Control locations.

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). Mining of the Longwalls 20-22 mining area 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.

4.1.1.1 Aquatic Macroinvertebrates

Quantitative Assessment

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

Multivariate analyses of the monitoring data Before- vs After-commencement of mining indicated that 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 (Figure 28a).

Univariate analyses have found no significant difference for mean total diversity or total abundance of macroinvertebrates or mean numbers of Leptophlebiidae and Atyidae at Location C1 compared to the control locations that would indicate an impact from mining (Figures 29a-d). Atyidae have commonly been most abundant at the Woronora River location, compared to all other locations sampled (Figure 29d).

Current Survey (Spring 2018)

Multivariate analyses did not detect a significant before-to-after difference in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations (Table 5, Figure 28a). With the exception of the factor 'Impact', each of the main factors appeared to have significant effects ($P < 0.05$), particularly 'Location', which contributed 18 % to the components of variation (Table 5).

These results are reflected in the patterns seen in the PCoA, which shows that there is a tendency for samples from the Woronora River location to occur in the upper left of the diagram, compared to those from O'Hares Creek, which occur more in the upper right (Figure 26c). There appears to be greater dispersion among centroids representing the assemblage at Location C1 than for each of the control locations (Figure 28a).

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. Leptophlebiidae increased its contribution to assemblages at Location C1 (Before: 5.1 %; After: 51.2%) and O'Hares Creek (Before: 9 %, After: 30.4 %) between Periods but changed little at the Woronora River Location (Before: 16.1 %, After: 20.5%). Atyid shrimps made a larger contribution to the structure of assemblages at Location C1 within the before- (59.6 %) than after-period (15.1 %) but changed little at the Woronora River (Before: 72.8 %; After: 67.0 %) and O'Hares Creek (Before: 4.9 %; After: 5.9 %) 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 6, Figure 29c). There have been considerable spikes in abundance of Leptophlebiidae at Location C1 within the after-period but very few individuals have been collected at Location C1 since spring 2017 (T19) (Figure 27c).

In general, macroinvertebrate diversity and abundance have commonly been greatest at the O'Hares Creek location (Figures 29a&b). Very few individuals of Atyidae have been collected at Location C1 since spring 2016 (Figure 29d).

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

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 28b). 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 29a-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 in autumn 2016 (T16), spring 2016 (T17) or spring 2017 (T19) (Figure 29d).

Current Survey (Spring 2018)

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 5, Figure 28b). Similar to the findings for Location C1, the 'Location' factor contributed most (20 %) to the components of variation (Table 5, Figure 28b).

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 6, Figure 29a-c). Graphically, it can be seen that spikes in the total abundance of aquatic macroinvertebrates and numbers of Leptophlebiidae at Location C2 and at the control locations have been common throughout the study period (Figures 29b&c).

Analyses examining patterns of change in Atyidae did not detect a significant difference at Location C2 in relation to the control locations on this occasion (Figure 29d). Atyidae have not been collected at Location C2 since spring 2017 (T19) (Figure 29d). There also appeared to have been a decline at the O'Hares Creek location in autumn 2018 (T20) and at the Woronora River location in spring 2018 (T21) (Figure 29d).

Location C3 v Controls

Prior Surveys (Spring 2009 – Autumn 2018)

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 28c). 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 28c).

Univariate analyses used to examine temporal patterns in mean diversity and abundance of macroinvertebrates and mean numbers of Leptophlebiidae and Atyidae between Location C3 and the control locations have consistently found no significant interactions related to the commencement of mining of the Longwalls 20-22 mining area (Figures 29a-d).

Current Survey (Spring 2018)

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 5, Figure 28c). Leptophlebiidae contributed most to the structure of the assemblage at Location C3 in spring 2018 (31 %), followed by the Dytiscidae (28 %). Chironomidae (16 %) and Notonectidae (15 %) (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 spring 2018, in relation to the control locations (Table 6, Figures 29a-d). Graphically, diversity had increased at C3 and at the control locations since the previous survey (Figure 29a). There appeared to have been little change in mean abundance and numbers of Leptophlebiidae at Location C3 and the controls since autumn 2018 (Figure 29b&c). Very few Atyidae have been collected at Location C3 since spring 2016 (T17) (Figure 29d).

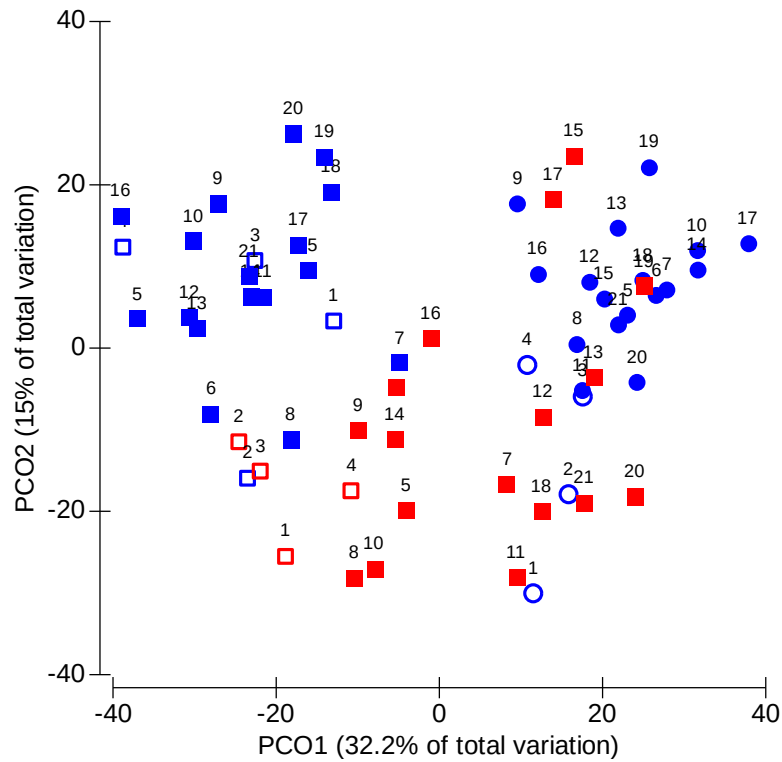
Table 5. PERMANOVA on macroinvertebrate assemblage data to compare locations C1, C2 and C3 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek) Before- versus After-mining of Longwall 20. Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

C1					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	29447	2.19	0.02	7.75
Impact = Im	1	18697	0.27	1.00	0.00
Time (Pe) = Ti(Pe)	19	7280	1.69	0.00	7.93
Location (Im) = Lo(Im)	1	78679	8.72	0.00	17.77
Pe x Im	1	11726	1.17	0.31	3.95
Site (Lo(Im)) = Si(Lo(Im))	3	5046	1.71	0.01	4.29
Pe x Lo(Im)	1	8168	1.67	0.02	6.24
Ti(Pe) x Im	19	5499	1.27	0.03	7.08
Pe x Si(Lo(Im))	3	2346	0.80	0.79	0.00
Ti(Pe) x Lo(Im)	19	4317	1.47	0.00	8.82
Ti(Pe) x Si(Lo(Im))	57	2944	1.60	0.00	
Residual	252	1839			
C2					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	17554	1.41	0.16	5.12
Impact = Im	1	21865	0.31	1.00	0.00
Time (Pe) = Ti(Pe)	19	7392	1.71	0.00	9.09
Location (Im) = Lo(Im)	1	78686	8.73	0.00	19.95
Pe x Im	1	5818	0.79	0.77	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	4985	1.94	0.00	5.18
Pe x Lo(Im)	1	8157	1.66	0.02	6.87
Ti(Pe) x Im	19	4674	1.08	0.31	4.37
Pe x Si(Lo(Im))	3	2135	0.83	0.72	0.00
Ti(Pe) x Lo(Im)	19	4318	1.68	0.00	11.21
Ti(Pe) x Si(Lo(Im))	57	2564	1.48	0.00	10.91
Residual	252	1733			27.30
C3					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	8888	1.26	0.25	4.58
Impact = Im	1	16494	0.39	0.99	0.00
Time (Pe) = Ti(Pe)	17	6834	1.79	0.00	9.32
Location (Im) = Lo(Im)	1	47024	6.56	0.00	21.27
Pe x Im	1	3696	0.95	0.56	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	3785	1.33	0.14	4.50
Pe x Lo(Im)	1	3246	1.15	0.27	4.09
Ti(Pe) x Im	17	4670	1.23	0.10	7.03
Pe x Si(Lo(Im))	3	1494	0.53	0.97	0.00
Ti(Pe) x Lo(Im)	17	3811	1.34	0.00	8.63
Ti(Pe) x Si(Lo(Im))	51	2839	1.89	0.00	14.33
Residual	228	1499			26.25

Table 6. 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. Bold numbers indicate significant results at $P < 0.05$.

C1		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	41.86	1.22	11477	1.69	4173	1.86	8	0.64
Impact = Im	1	340.69	0.62	13621	1.83	46	0.13	1050	0.16
Time (Pe) = Ti(Pe)	19	50.40	2.33	6959	3.50	2005	12.63	364	0.97
Location (Im) = Lo(Im)	1	567.70	15.99	6181	2.57	75	1.89	8657	11.54
Pe x Im	1	39.83	3.40	307	0.68	540	0.39	562	2.07
Site (Lo(Im)) = Si(Lo(Im))	3	14.60	1.22	1087	0.63	122	0.27	394	1.86
Pe x Lo(Im)	1	1.51	0.58	1024	1.28	324	3.55	229	1.17
Ti(Pe) x Im	19	16.59	0.77	2347	1.18	1490	9.39	223	0.60
Pe x Si(Lo(Im))	3	1.67	0.14	162	0.09	61	0.13	3	0.02
Ti(Pe) x Lo(Im)	19	21.65	1.80	1990	1.15	159	0.35	374	1.77
Ti(Pe) x Si(Lo(Im))	57	12.00	1.34	1737	2.57	456	2.38	211	1.54
Residual	252	8.96		676		192		138	
C2		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	157.89	3.29	6940	2.41	1204	2.81	0	0.50
Impact = Im	1	469.15	0.84	18669	2.88	245	1.97	102	0.05
Time (Pe) = Ti(Pe)	19	53.03	2.45	2688	1.35	161	1.01	520	1.39
Location (Im) = Lo(Im)	1	567.70	15.58	6181	2.33	75	0.81	8657	11.79
Pe x Im	1	0.05	1.11	1709	1.83	44	0.45	450	2.15
Site (Lo(Im)) = Si(Lo(Im))	3	15.42	1.57	1116	1.07	82	0.68	375	2.16
Pe x Lo(Im)	1	1.51	0.44	1024	0.96	324	2.79	229	1.00
Ti(Pe) x Im	19	18.03	0.83	1002	0.50	130	0.82	155	0.41
Pe x Si(Lo(Im))	3	4.18	0.42	158	0.15	0	0.00	26	0.15
Ti(Pe) x Lo(Im)	19	21.65	2.20	1990	1.90	159	1.32	374	2.16
Ti(Pe) x Si(Lo(Im))	57	9.83	1.15	1048	1.92	120	1.59	173	1.44
Residual	252	8.51		546		75		120	
C3		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	0.02	0.33	1065	0.78	1223	1.43	486	7.49
Impact = Im	1	169.43	0.44	8235	1.66	527	0.99	1126	0.23
Time (Pe) = Ti(Pe)	17	68.58	2.94	3897	1.79	884	5.20	117	0.29
Location (Im) = Lo(Im)	1	416.56	6.72	4477	1.78	106	1.38	6244	7.99
Pe x Im	1	42.91	3.38	167	1.15	75	0.36	213	1.91
Site (Lo(Im)) = Si(Lo(Im))	3	40.39	3.47	1132	0.80	218	0.51	396	2.53
Pe x Lo(Im)	1	2.56	0.52	242	0.68	91	2.95	2	0.34
Ti(Pe) x Im	17	17.05	0.73	1796	0.82	599	3.53	323	0.80
Pe x Si(Lo(Im))	3	4.01	0.34	272	0.19	6	0.01	58	0.37
Ti(Pe) x Lo(Im)	17	23.33	2.00	2183	1.53	170	0.40	405	2.59
Ti(Pe) x Si(Lo(Im))	51	11.65	1.32	1423	2.18	428	2.93	156	1.58
Residual	228	8.82		652		146		99	

A



B

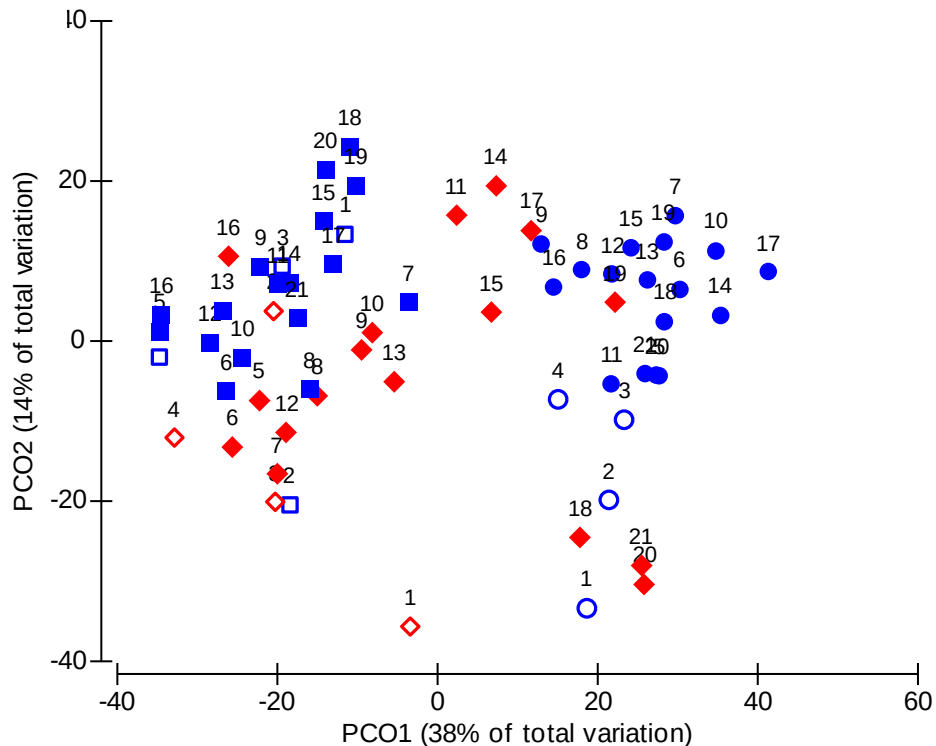


Figure 28. PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at locations a) C1 and b) C2 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2008 (T1) and spring 2018 (T21). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 20-22.

C

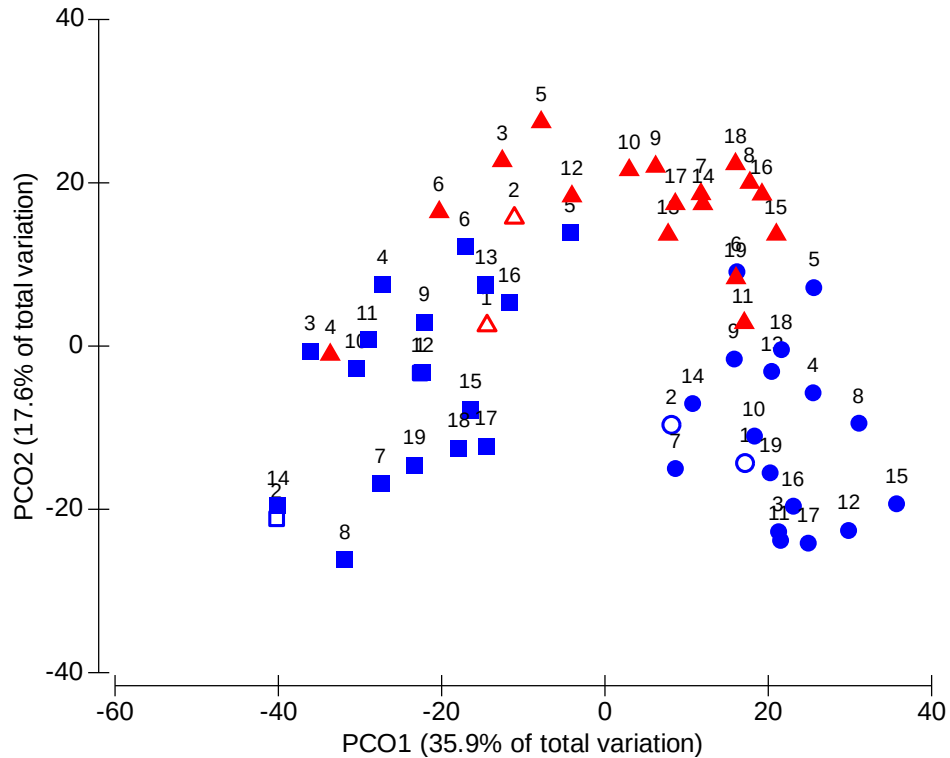


Figure 28 (Cont'd). c) Location C3 and two control locations (Woronora River and O'Hares Creek) for each time of sampling (n = 6). Red triangles: Tributary C; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. NB Sampling of location C3 commenced in spring 2009.

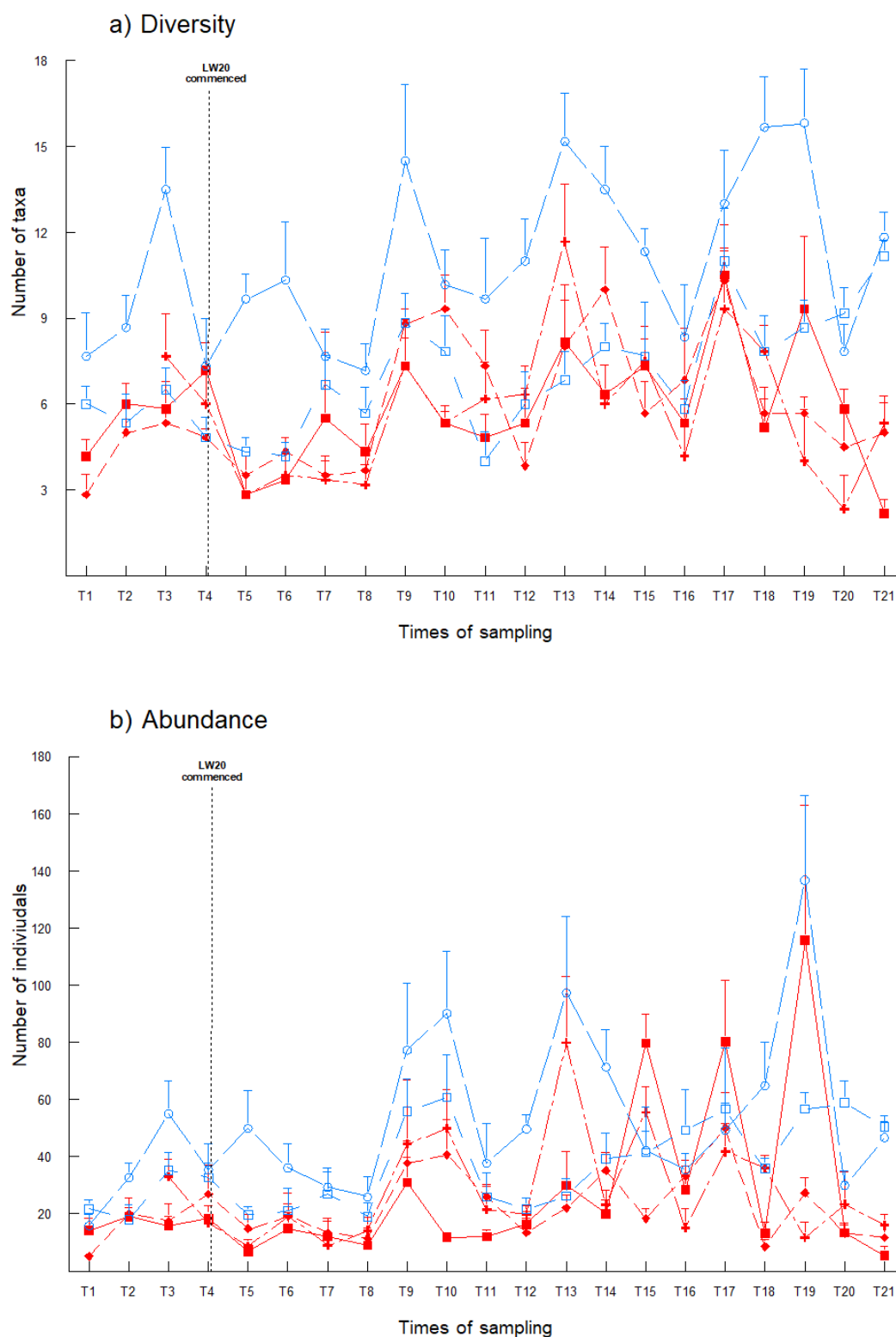


Figure 29. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) ($n = 6$). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).

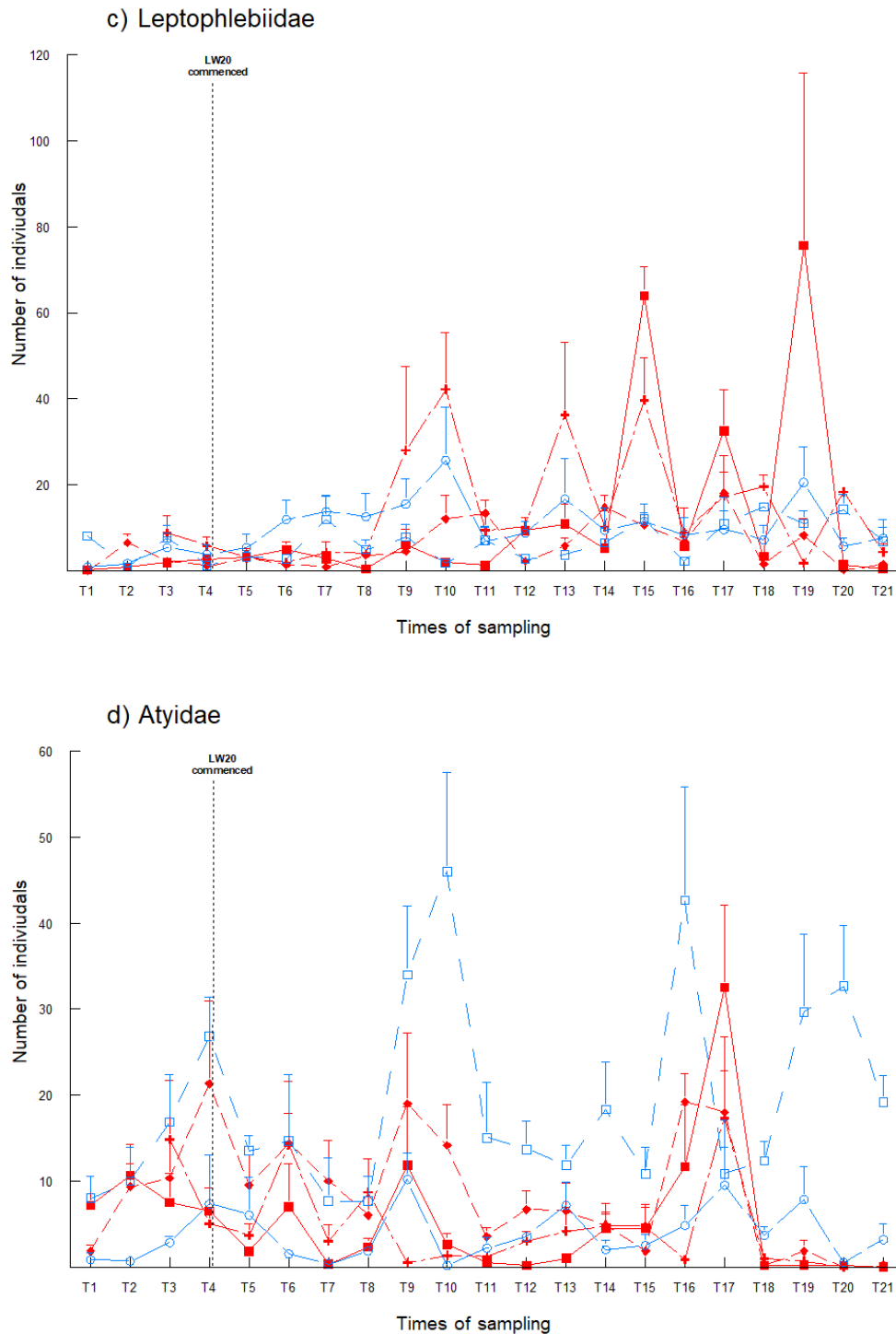


Figure 29 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the control locations (Woronora River: empty squares; O'Hares Creek: circles) ($n = 6$). Time 1 = spring 2008, T2 = autumn 2009 etc. NB Sampling of C3 commenced in spring 2009 (T3).

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.10 (Site C1 in spring 2018) and 1.015 (Site C3 in spring 2014) (Figure 30a). OE50 Taxa Scores for samples collected in autumn ranged from 0.30 (Site C3 in autumn 2014) to 0.88 (Site OC in autumn 2017) (Figure 30b). With the exception of one sample (i.e. Site C3 in spring 2014), all of the OE50 Taxa scores were below 1.00 (Figure 30a&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 30a). Four Band A scores were obtained in spring (Sites C3, WR and OC in spring 2014 and Site OC in spring 2017) (Figure 30a&b). Notably, three of the eleven locations sampled achieved a Band A score in spring 2014.

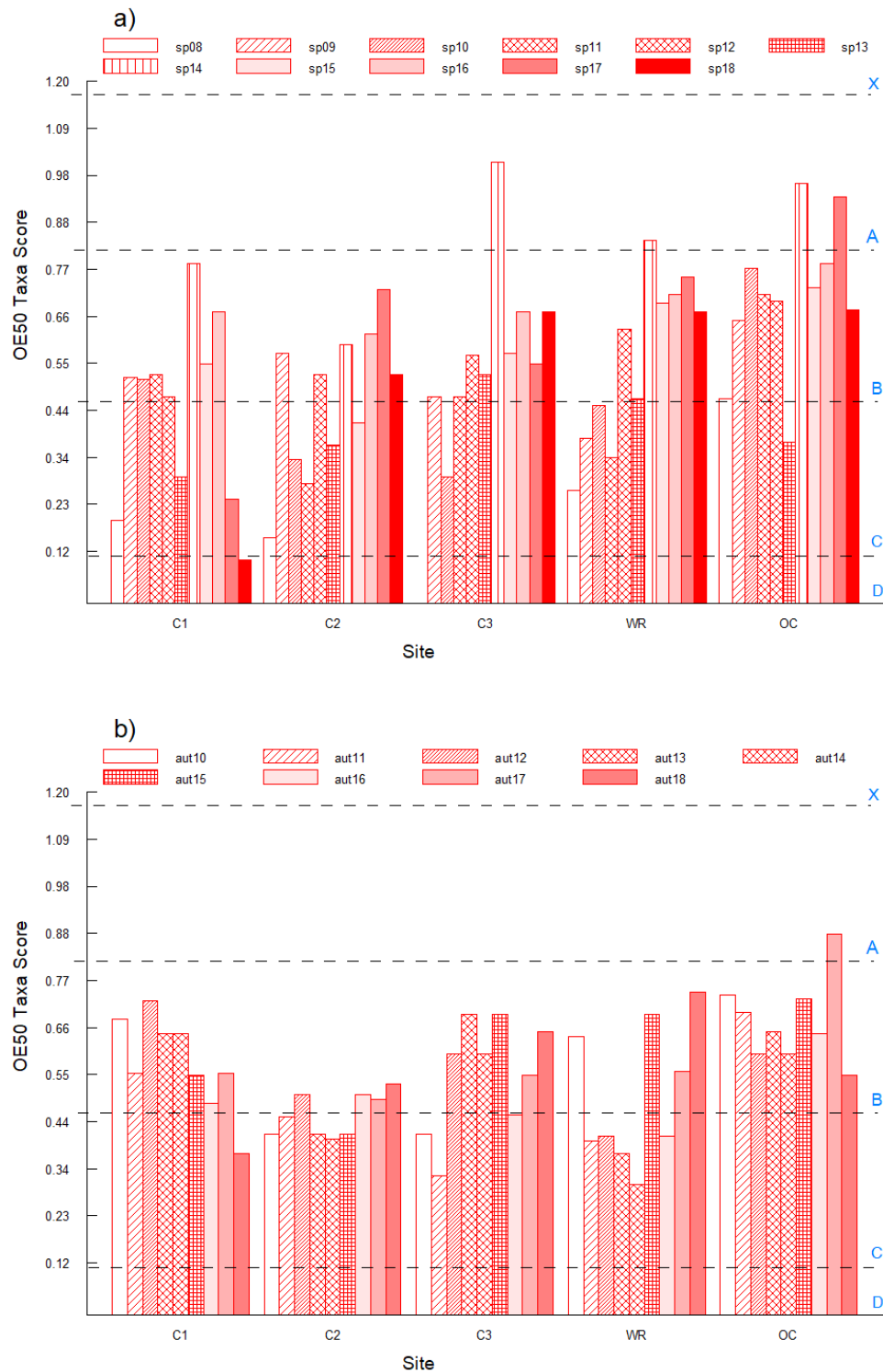


Figure 30. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in a) spring and b) autumn between 2008 and 2018 ($n = 2$).

4.1.1.2 Aquatic Macrophytes

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

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

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

Current Survey (Spring 2018)

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) result, not mining related activities (Table 7, Figure 31a).

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 31a). 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 8, Figures 32a&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 32b). Whilst cover also appears to have decreased at the Woronora River location within that period, it is likely that mining related drops in pool water levels at Location C1 have contributed to the observed decline in aquatic plants in the riparian zone.

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

Similar to the findings for Location C1, analyses detected a significant before-to-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 31b). 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 32a&b).

Current Survey (Spring 2018)

Analyses of temporal changes in the structure of assemblages of aquatic macrophytes (Table 7, Figure 31b) and univariate estimates of total cover and species diversity (Table 8, Figures 32a&b) at Location C2 found no significant changes in relation to control locations that would indicate an impact from mining. In spring 2018, *Lepidosperma filiforme* (61 %), and *Baumea juncea* (32 %) contributed most to the structure of the assemblage at Location C2 (SIMPER).

Graphically, it can be seen that there has been a gradual decline in mean percentage cover of macrophytes at Location C2, particularly after the spring 2017 (T19) survey, when pool levels appeared to be well below pre-mining levels (Figures 32a&b). Whilst cover also appears to have decreased at the Woronora River location, it is likely that mining related drops in pool water levels at Location C2 have contributed to the observed decline in aquatic plants in the riparian zone.

Location C3 v Controls

Prior Surveys (Spring 2009 – Autumn 2018)

Analyses of before- (spring 2009 – autumn 2010) vs after- (spring 2010 – autumn 2017) mining changes in the structure of assemblages of aquatic macrophytes (Figure 31c) and univariate estimates of total cover and species diversity (Figures 32a&b) have consistently found no significant changes at Location C3 in relation to control locations that would indicate an impact from mining.

Current Survey (Spring 2018)

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 7, Figure 31c). In spring 2018, *Empodisma minus* (47 %) contributed most to the structure of the assemblage at Location C3, followed by *Gleichenia dicarpa* (39 %) (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 8, Figure 31a). Total cover of macrophytes differed significantly between the scales of Time nested in Period and Locations nested within type of Creek (i.e. $Ti(Pe) \times Lo(Im)$), indicating that differences in the structure of assemblages of macrophytes among locations depended on the time of sampling not mining related activities (Table 8, Figure 31b).

Graphically, it can be seen that there has been a gradual decline in cover of macrophytes in the riparian zone at Location C3 since autumn 2017 (T18) (Figures 32a&b).

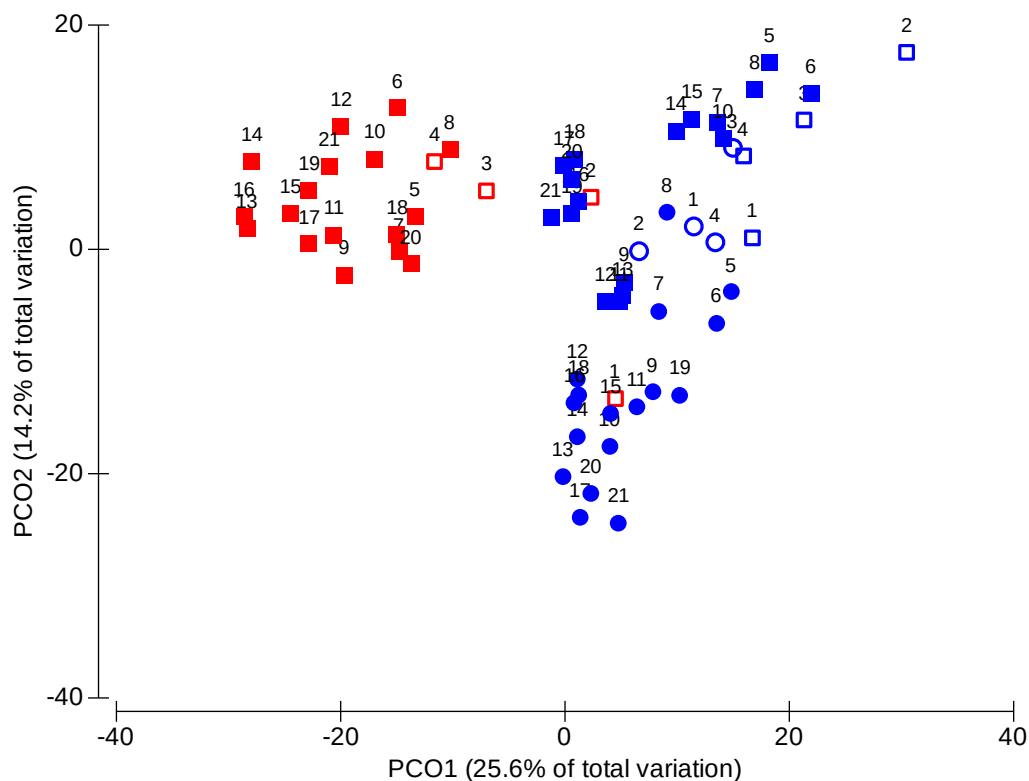
Table 7. PERMANOVA on macrophyte assemblage data to compare locations C1, C2 and C3 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

C1					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	23362	1.31	0.21	4.05
Impact = Im	1	50140	1.67	0.10	7.41
Time (Pe) = Ti(Pe)	19	6313	1.56	0.00	6.07
Location (Im) = Lo(Im)	1	27109	1.50	0.05	5.78
Pe x Im	1	14038	0.91	0.62	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	15828	5.85	0.00	9.39
Pe x Lo(Im)	1	14598	1.46	0.06	6.05
Ti(Pe) x Im	19	5308	1.31	0.03	6.40
Pe x Si(Lo(Im))	3	7800	2.88	0.00	8.27
Ti(Pe) x Lo(Im)	19	4053	1.50	0.00	7.66
Ti(Pe) x Si(Lo(Im))	57	2706	0.78	1.00	0.00
Residual	504	3480			
C2					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	20133	1.24	0.25	3.62
Impact = Im	1	43292	1.37	0.20	5.98
Time (Pe) = Ti(Pe)	19	5219	1.35	0.01	4.93
Location (Im) = Lo(Im)	1	29850	1.63	0.03	6.86
Pe x Im	1	14901	1.01	0.50	0.96
Site (Lo(Im)) = Si(Lo(Im))	3	16183	5.65	0.00	9.96
Pe x Lo(Im)	1	14110	1.58	0.03	6.81
Ti(Pe) x Im	19	4504	1.16	0.12	4.76
Pe x Si(Lo(Im))	3	6862	2.40	0.00	7.72
Ti(Pe) x Lo(Im)	19	3877	1.35	0.00	7.00
Ti(Pe) x Si(Lo(Im))	57	2862	0.81	1.00	0.00
Residual	504	3554			41.40
C3					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	14196	1.46	0.15	5.80
Impact = Im	1	24394	1.38	0.20	6.80
Time (Pe) = Ti(Pe)	17	4823	1.19	0.15	4.06
Location (Im) = Lo(Im)	1	16339	1.65	0.03	7.74
Pe x Im	1	6954	0.93	0.59	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	7704	2.52	0.00	8.52
Pe x Lo(Im)	1	7667	1.27	0.15	5.98
Ti(Pe) x Im	17	4195	1.04	0.40	2.57
Pe x Si(Lo(Im))	3	4398	1.44	0.09	6.47
Ti(Pe) x Lo(Im)	17	4038	1.32	0.01	7.40
Ti(Pe) x Si(Lo(Im))	51	3058	0.86	0.99	0.00
Residual	456	3562			44.64

Table 8. PERMANOVA on estimates of diversity and cover of aquatic macrophytes. Bold numbers indicate significant results at $P < 0.05$.

C1		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	29.99	4.97	8	0.23
Impact = Im	1	0.31	0.59	8	0.36
Time (Pe) = Ti(Pe)	19	5.03	2.27	2905	2.19
Location (Im) = Lo(Im)	1	0.04	0.42	1458	0.63
Pe x Im	1	0.45	0.47	165	0.29
Site (Lo(Im)) = Si(Lo(Im))	3	1.18	0.85	1801	3.45
Pe x Lo(Im)	1	1.44	1.08	2838	0.99
Ti(Pe) x Im	19	4.24	1.91	2276	1.72
Pe x Si(Lo(Im))	3	0.40	0.29	2076	3.97
Ti(Pe) x Lo(Im)	19	2.22	1.60	1326	2.54
Ti(Pe) x Si(Lo(Im))	57	1.39	1.07	523	0.89
Residual	504	1.30		584	
C2		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	45.25	6.40	2056	1.17
Impact = Im	1	2.93	1.82	1	0.86
Time (Pe) = Ti(Pe)	19	6.68	3.21	1436	0.90
Location (Im) = Lo(Im)	1	0.32	0.56	662	0.39
Pe x Im	1	1.28	1.06	235	0.64
Site (Lo(Im)) = Si(Lo(Im))	3	0.73	0.58	1690	2.69
Pe x Lo(Im)	1	0.72	0.70	1667	0.78
Ti(Pe) x Im	19	2.44	1.17	1182	0.74
Pe x Si(Lo(Im))	3	0.75	0.60	1338	2.13
Ti(Pe) x Lo(Im)	19	2.08	1.66	1590	2.53
Ti(Pe) x Si(Lo(Im))	57	1.26	0.94	628	1.35
Residual	504	1.34		466	
C3		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	8.80	1.93	28	0.70
Impact = Im	1	0.07	0.64	22	2.01
Time (Pe) = Ti(Pe)	17	3.00	1.47	1750	0.99
Location (Im) = Lo(Im)	1	1.88	0.86	442	0.34
Pe x Im	1	0.01	0.51	785	2.03
Site (Lo(Im)) = Si(Lo(Im))	3	1.82	1.28	946	1.98
Pe x Lo(Im)	1	2.62	1.80	812	0.41
Ti(Pe) x Im	17	1.41	0.69	448	0.25
Pe x Si(Lo(Im))	3	0.21	0.15	1353	2.83
Ti(Pe) x Lo(Im)	17	2.04	1.43	1766	3.70
Ti(Pe) x Si(Lo(Im))	51	1.42	1.03	477	0.97
Residual	456	1.38		494	

A



B

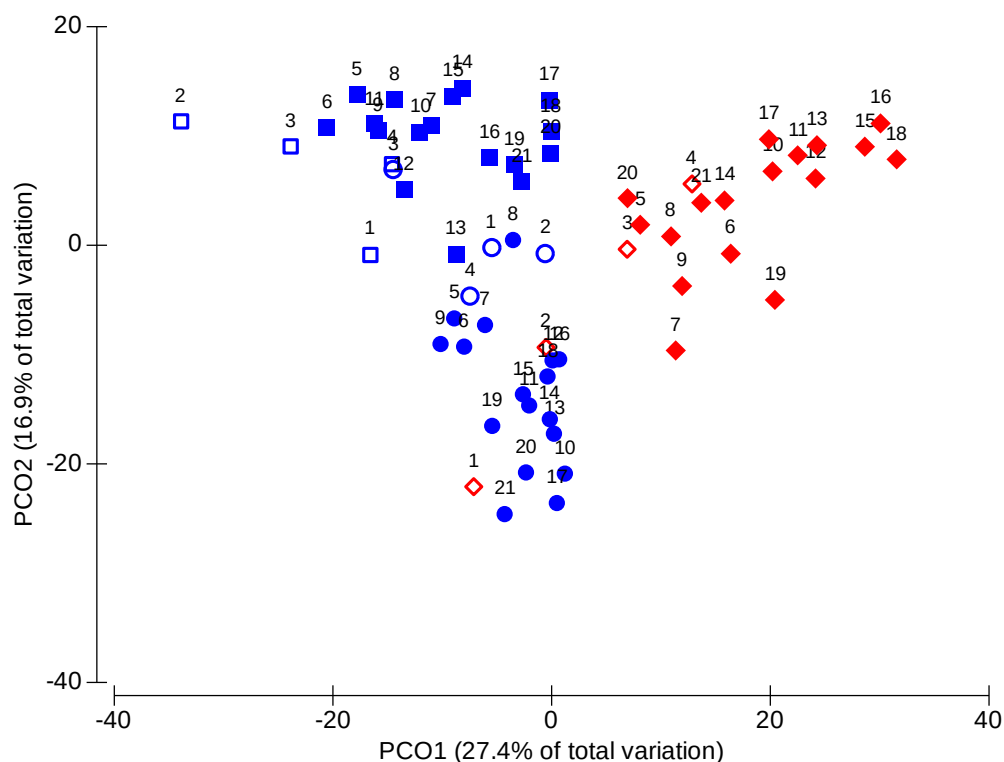


Figure 31. PCoA of centroids for macrophyte data for a) Location C1 and b) Location C2 and two control locations (Woronora River and O'Hares Creek) for each time of sampling ($n=10$). Red symbols: Potential 'impact' locations; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. NB Sampling of locations C1 and C2 commenced in spring 2008 (T1).

C

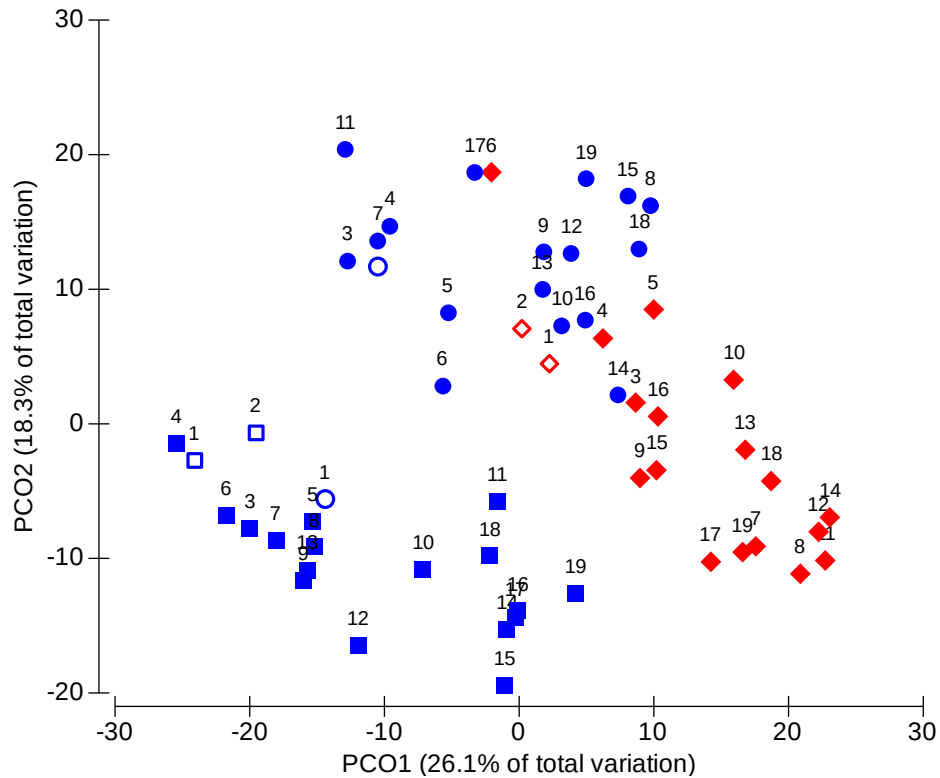


Figure 31 (Cont'd). PCoA of centroids for macrophyte data for c) Location C3. Red triangles: Potential 'impact' location; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. NB sampling of location C3 commenced in spring 2009.

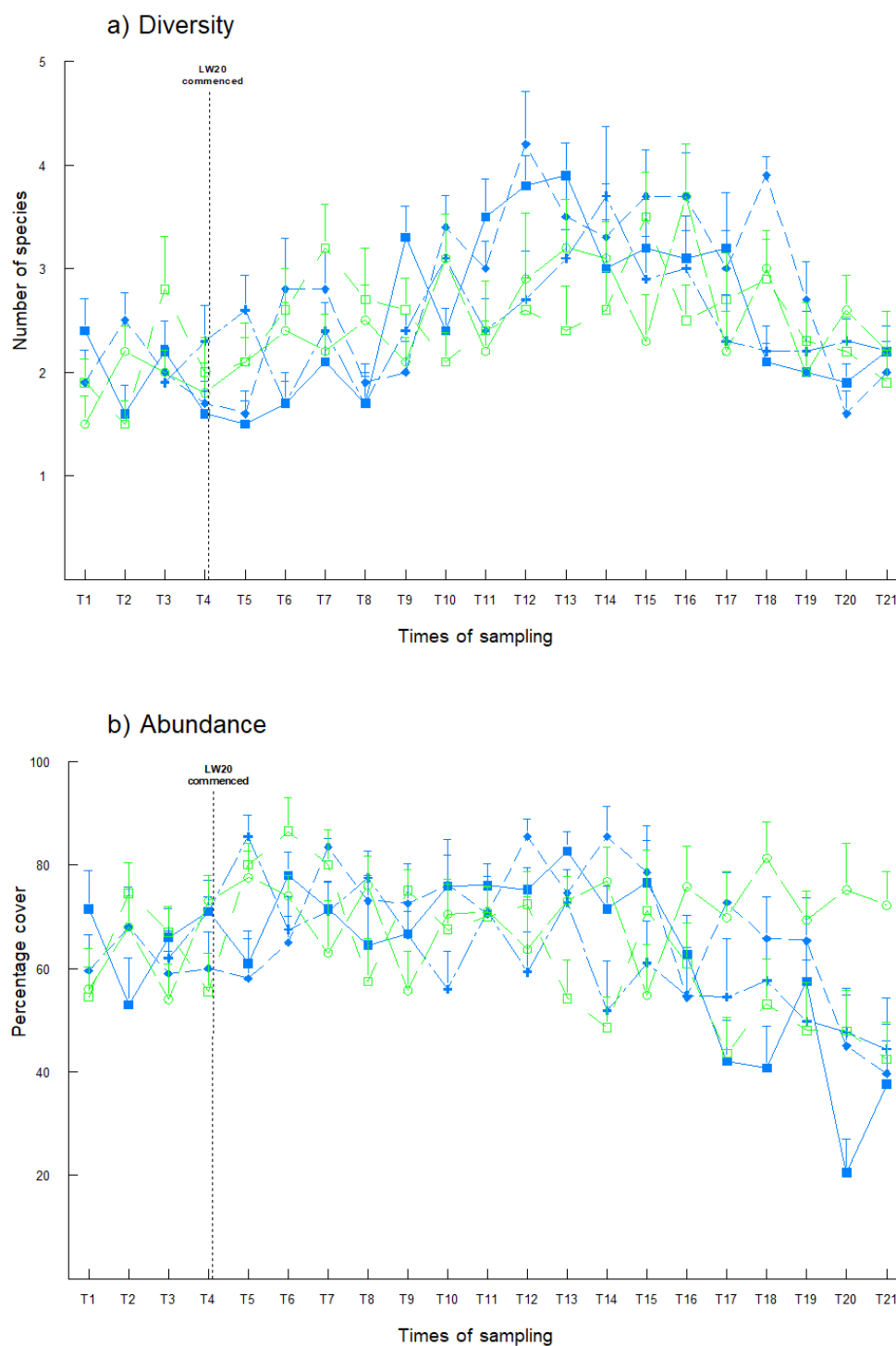


Figure 32. Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C1: solid squares; C2: diamonds; C3: plus symbols) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) ($n = 10$). NB Sampling of location C3 commenced in spring 2009.

4.1.2 Waratah Rivulet

PERMANOVA was used to test the null hypothesis of no significant change in aquatic macroinvertebrate or macrophyte indicators at Waratah Rivulet locations (Locations WT3, WT4 and WT5) Before (spring 2008 to autumn 2010)- vs After (spring 2010 to spring 2018)- mining in relation to Control locations (Woronora River and O'Hares Creek). Mining of the Longwalls 20-22 mining area 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

Quantitative Assessment

Prior Surveys (Spring 2008 – Autumn 2018)

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- to After-commencement of mining of the Longwalls 20-22 underground mining area.

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

Current Survey (Spring 2018)

Consistent with previous surveys (Cummins and Roberts, 2017), there was a significant interaction of the factors Location nested within Impact and Time nested within Period (i.e. $Ti(Pe) \times Lo(Im)$) (Table 9, Figures 33a-c). Most notably, the Principle Component Ordination (PCoA) of centroids for macroinvertebrate data suggests that the assemblage sampled at the Woronora River location consistently differed from the assemblage at the Waratah Rivulet locations and O'Hares Creek (Figures 33a-c: blue square symbols tend to group to the left of the PCoA while blue circle and red 'other' symbols tend to group to the right).

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, Atyidae contributed more to the structure of assemblages at the Waratah Rivulet locations within the before- (WT3: 25.9 %; WT4: 33 %; WT5: 52.8 %) compared to after-mining (WT3: 8.1 %; WT4: 10.5 %; WT5: 18.5 %) period. The contribution that Atyidae made to the assemblage at the control locations differed little between periods (Before: 43.2 %; After: 37.2 %).

Similar to the findings of the spring 2016 (T15) and autumn 2018 (T20) surveys, univariate analyses detected a significant change in mean diversity at Location WT3 within the after-period, in relation to the control locations (Table 10, Figure 34a). When PERMDISP was used to formally compare the apparent variability (dispersion), a non-significant result was obtained ($P = 0.197$). Similarly, pair-wise tests were unable to determine differences among means ($P > 0.05$). Differences appear to be related to diversity at Location WT3 decreasing between periods (Before: 9.5; After: 8.1) whilst there has been an increase at the control locations (Before: 7.8; After: 9.3) (Figure 34a).

Mean diversity did not differ significantly between periods at Location WT4 and Location WT5 in relation to the controls (Table 10, Figure 34a). Fewer taxa were collected at the rivulet compared to the control locations in spring 2018 (T21) (Figure 34a).

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 10, Figures 34b-d). Graphically it can be seen that fewer individuals of macroinvertebrates have been collected at the rivulet compared to the control locations on the last 4 occasions (Figure 34b). Fewer Leptophlebiidae were collected at the rivulet compared to the control locations in spring 2018 (T21) (Figure 34c). 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 34d).

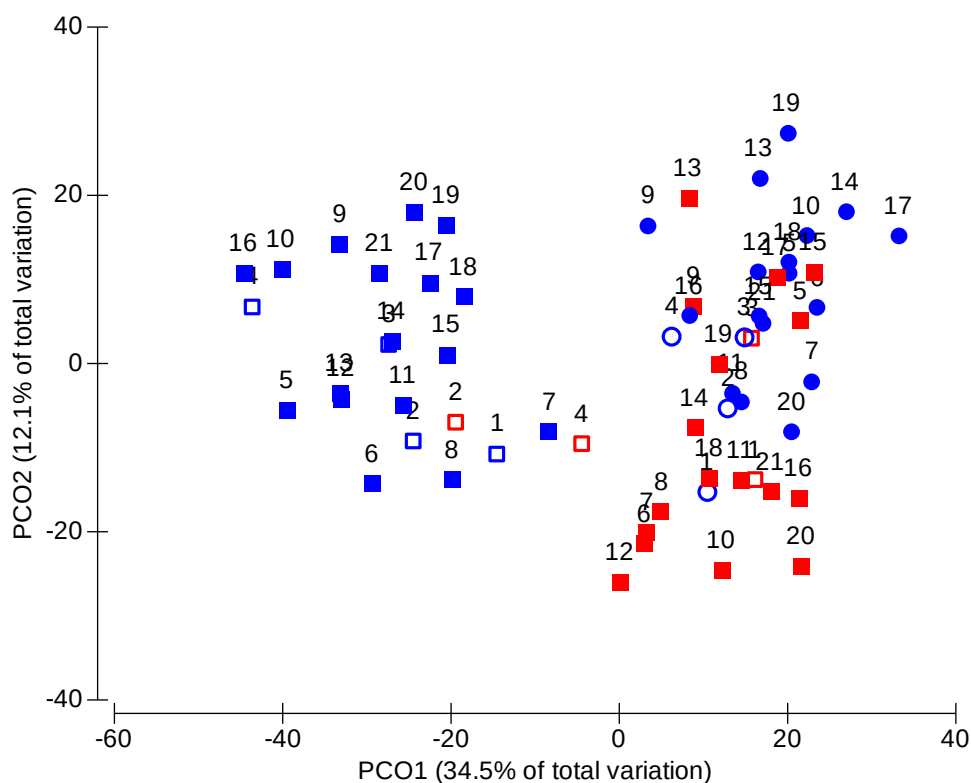
Table 9. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate assemblage data (non-transformed) to compare locations WT3, WT4 and WT5 sampled on Waratah Rivulet with control locations (Woronora River and O'Hares Creek) Before- vs After-commencement of mining. Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

WT3					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	12667	1.15	0.34	3.00
Impact = Im	1	22545	0.32	1.00	0.00
Time (Pe) = Ti(Pe)	19	6978	1.64	0.00	8.58
Location (Im) = Lo(Im)	1	78153	8.31	0.00	19.90
Pe x Im	1	7060	0.88	0.66	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	5454	2.08	0.00	5.62
Pe x Lo(Im)	1	7798	1.54	0.03	6.40
Ti(Pe) x Im	19	5105	1.20	0.08	6.76
Pe x Si(Lo(Im))	3	2488	0.95	0.56	0.00
Ti(Pe) x Lo(Im)	19	4262	1.63	0.00	10.89
Ti(Pe) x Si(Lo(Im))	57	2620	1.42	0.00	10.54
Residual	252	1851			28.32
WT4					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	11895	1.13	0.35	0.83
Impact = Im	1	25484	0.38	0.99	0.24
Time (Pe) = Ti(Pe)	19	7131	1.78	0.00	3.84
Location (Im) = Lo(Im)	1	72622	8.31	0.00	1.86
Pe x Im	1	6603	0.92	0.61	0.58
Site (Lo(Im)) = Si(Lo(Im))	3	5045	1.96	0.00	11.53
Pe x Lo(Im)	1	6899	1.44	0.06	2.98
Ti(Pe) x Im	19	4647	1.16	0.15	3.84
Pe x Si(Lo(Im))	3	2567	1.00	0.47	11.53
Ti(Pe) x Lo(Im)	19	3999	1.56	0.00	11.53
Ti(Pe) x Si(Lo(Im))	57	2571	1.57	0.00	51.23
Residual	252	1643			0.83
WT5					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	16841	1.53	0.12	5.69
Impact = Im	1	20390	0.32	1.00	0.00
Time (Pe) = Ti(Pe)	19	6710	1.68	0.00	8.81
Location (Im) = Lo(Im)	1	72622	8.14	0.00	19.81
Pe x Im	1	6022	0.89	0.64	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	5209	2.22	0.00	5.85
Pe x Lo(Im)	1	6899	1.47	0.05	5.94
Ti(Pe) x Im	19	4408	1.10	0.23	4.84
Pe x Si(Lo(Im))	3	2285	0.97	0.51	0.00
Ti(Pe) x Lo(Im)	19	3999	1.71	0.00	11.24
Ti(Pe) x Si(Lo(Im))	57	2345	1.38	0.00	9.88
Residual	252	1705			27.95

Table 10. 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. Bold numbers indicate significant results at $P < 0.05$.

WT3		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	0.50	0.30	2105	0.77	154.7	0.47	17	0.92
Impact = Im	1	2.93	0.04	1742	0.45	386.9	1.33	1907	0.26
Time (Pe) = Ti(Pe)	19	75.91	3.38	4344	2.18	341.2	2.15	198	0.53
Location (Im) = Lo(Im)	1	596.83	16.29	6410	2.38	74.8	1.00	8657	11.74
Pe x Im	1	105.79	5.97	5799	2.66	836.1	1.51	628	2.41
Site (Lo(Im)) = Si(Lo(Im))	3	14.83	1.39	1153	1.06	105.0	0.56	376	2.42
Pe x Lo(Im)	1	1.11	0.32	967	0.65	323.9	0.70	229	1.01
Ti(Pe) x Im	19	20.38	0.91	1960	0.98	336.6	2.12	188	0.50
Pe x Si(Lo(Im))	3	13.74	1.29	1177	1.08	573.1	3.05	7	0.04
Ti(Pe) x Lo(Im)	19	22.47	2.11	1996	1.83	158.8	0.84	374	2.41
Ti(Pe) x Si(Lo(Im))	57	10.64	1.10	1091	1.61	188.1	1.41	155	1.72
Residual	252	9.69		677		133.6		90	
WT4		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	111.63	1.93	11765	2.06	0.78	0.62	378	1.00
Impact = Im	1	90.67	0.17	2437	0.48	2.70	0.13	1811	0.25
Time (Pe) = Ti(Pe)	19	66.06	3.05	5479	2.71	4.79	0.00	538	1.36
Location (Im) = Lo(Im)	1	622.43	14.87	7015	2.62	1.03	0.42	8604	10.18
Pe x Im	1	0.38	0.96	159	0.61	0.38	0.86	3	0.66
Site (Lo(Im)) = Si(Lo(Im))	3	20.94	1.91	1106	0.93	0.47	0.72	477	1.75
Pe x Lo(Im)	1	2.93	0.57	1231	0.77	2.16	0.11	234	1.04
Ti(Pe) x Im	19	20.01	0.92	2329	1.15	4.30	0.00	366	0.93
Pe x Si(Lo(Im))	3	2.56	0.23	1128	0.95	0.43	0.74	93	0.34
Ti(Pe) x Lo(Im)	19	21.65	1.98	2025	1.70	1.02	0.45	395	1.45
Ti(Pe) x Si(Lo(Im))	57	10.95	1.17	1191	1.66	1.08	0.38	272	1.94
Residual	252	9.35		717		0.78	0.62	140	
WT5		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	102.38	2.07	14414	3.07	2105	2.99	0.0	0.53
Impact = Im	1	145.35	0.26	8525	1.16	108	0.70	722.0	0.13
Time (Pe) = Ti(Pe)	19	57.03	2.63	4129	2.04	414	2.50	513.3	1.30
Location (Im) = Lo(Im)	1	622.43	16.28	7015	2.61	86	0.75	8604.0	10.39
Pe x Im	1	0.03	0.92	1	0.61	14	0.28	443.4	1.66
Site (Lo(Im)) = Si(Lo(Im))	3	17.27	1.56	1104	0.96	107	0.90	448.8	2.75
Pe x Lo(Im)	1	2.93	0.60	1231	1.08	346	2.71	234.0	0.97
Ti(Pe) x Im	19	20.62	0.95	2087	1.03	304	1.84	269.6	0.68
Pe x Si(Lo(Im))	3	1.80	0.16	177	0.15	6	0.05	12.5	0.08
Ti(Pe) x Lo(Im)	19	21.65	1.95	2025	1.77	165	1.39	394.8	2.42
Ti(Pe) x Si(Lo(Im))	57	11.08	1.08	1146	1.63	119	1.23	163.0	1.51
Residual	252	10.29		705		97		107.8	

A



B

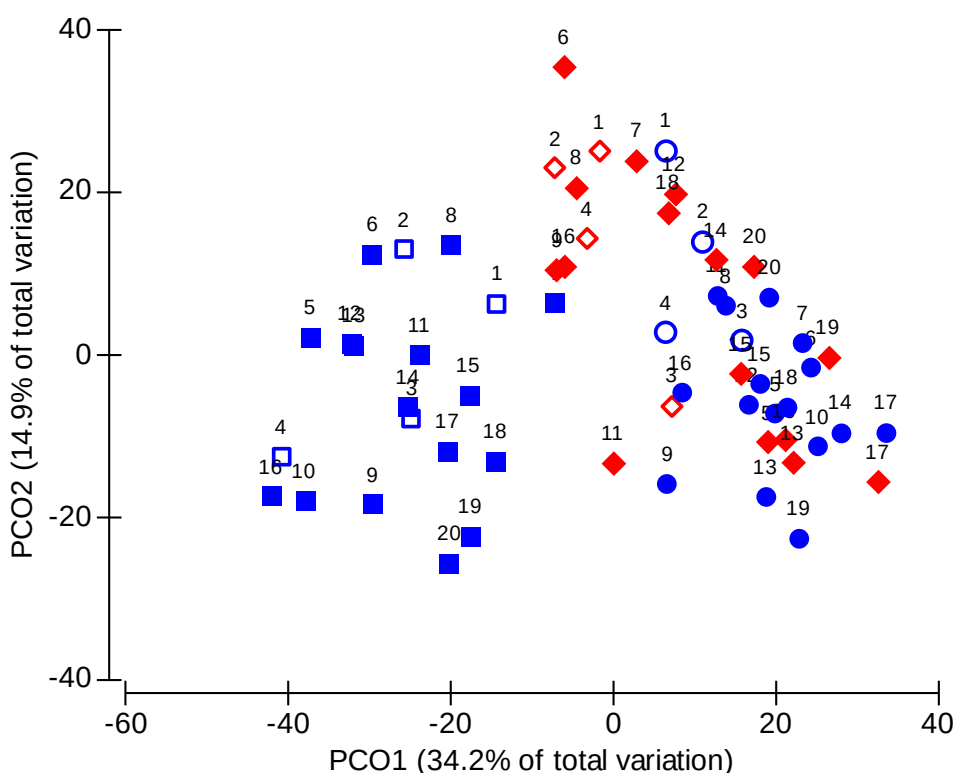


Figure 33. PCoA of centroids for macroinvertebrate data for locations a) WT3 and b) WT4 and two control locations (Woronora River and O'Hares Creek) for each time of sampling ($n = 6$). Red symbols: Waratah Rivulet; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.

C

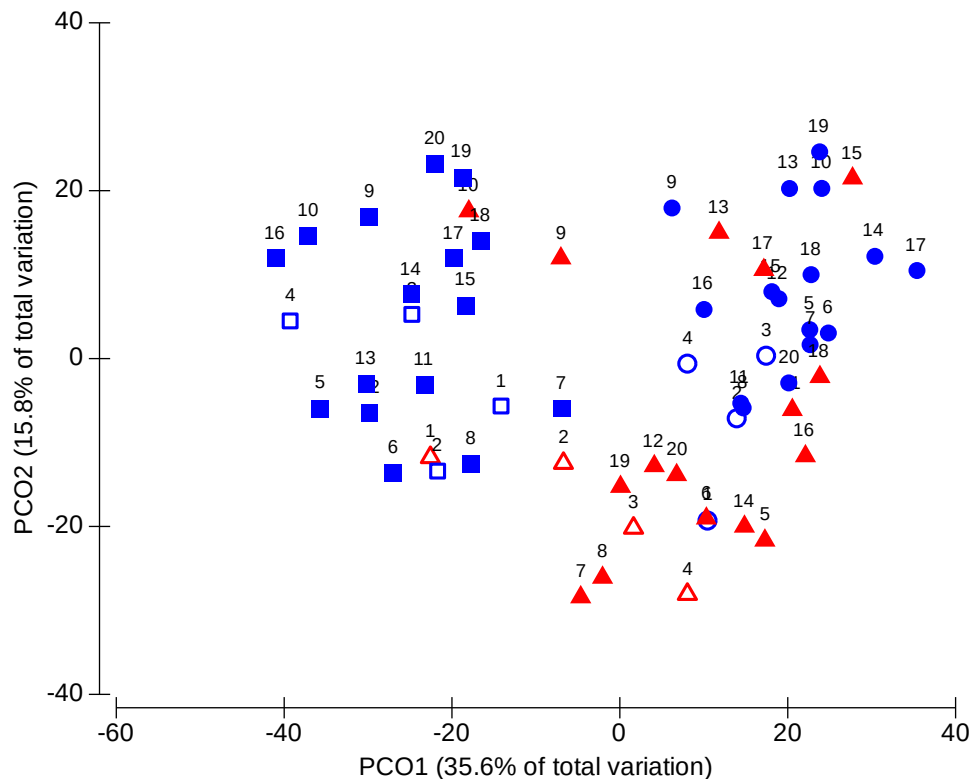


Figure 33 (Cont'd). PCoA of centroids for macroinvertebrate data for c) Location WT5 (Red triangles) and two control locations (Woronora River and O'Hares Creek) for each time of sampling (n = 6); Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' commencement of mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009 etc.

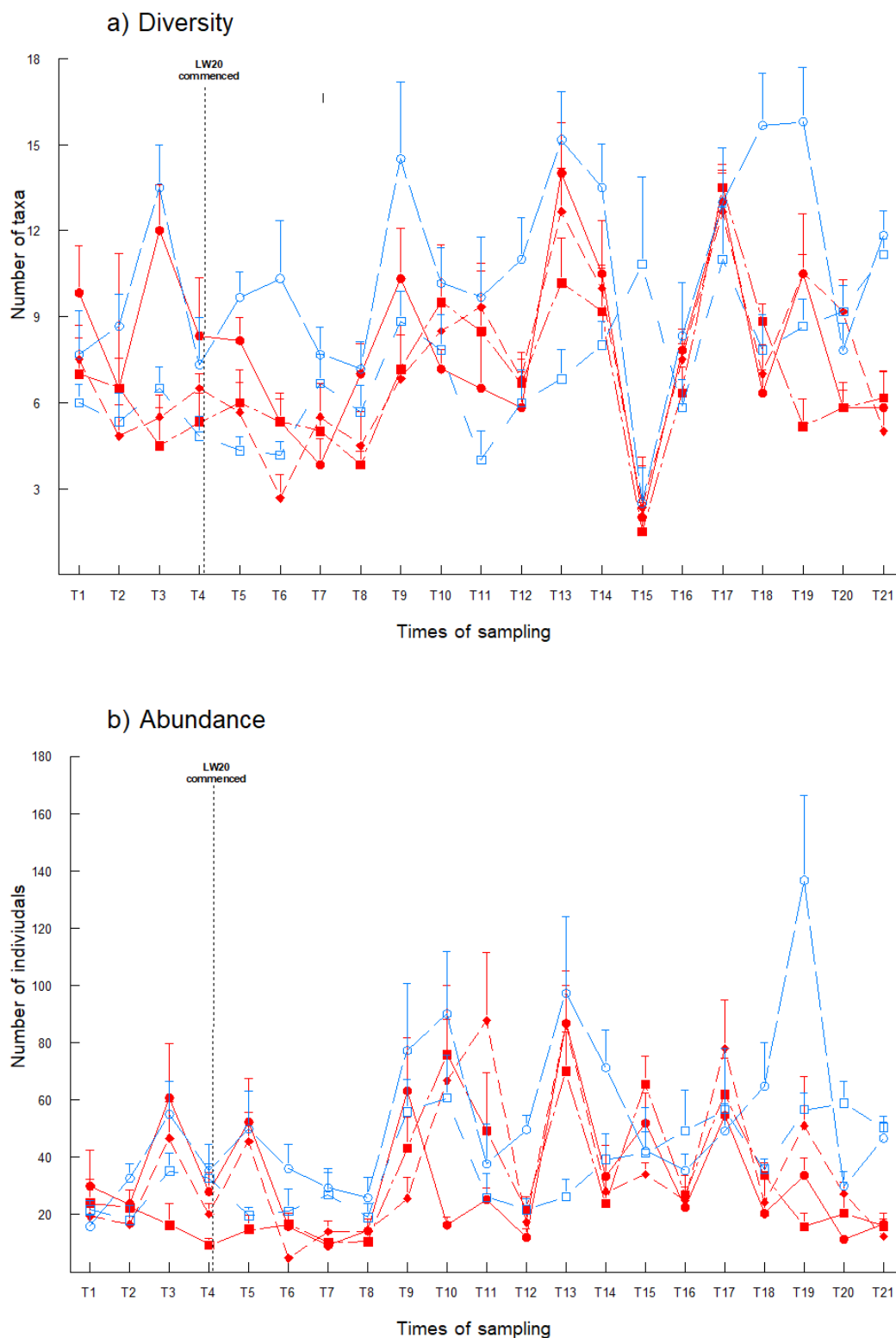


Figure 34. Mean macroinvertebrate (+SE) a) diversity and b) abundance at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) ($n = 6$). Time 1 = spring 2008, T2 = autumn 2009 etc.

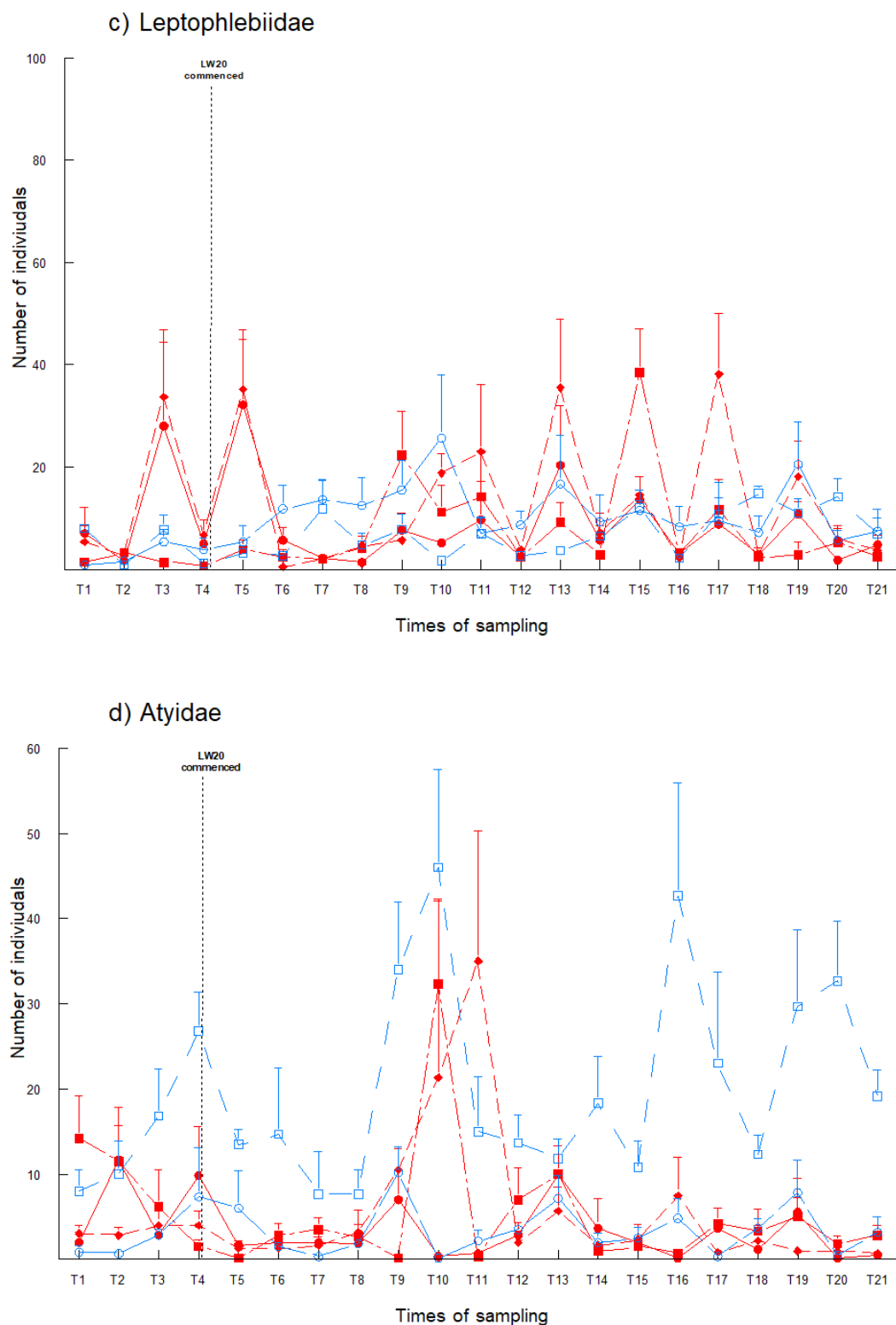


Figure 34 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Waratah Rivulet (WT3: solid circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) ($n = 6$). Time 1 = spring 2008, T2 = autumn 2009 etc.

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.18 (Site WT5 in spring 2012) and 0.965 (Site OC in spring 2014) (Figure 35a). OE50 Taxa Scores for samples collected in autumn ranged from 0.30 (Site WR in autumn 2014) to 0.91 (Site WT5 in autumn 2015) (Figure 35b). All of the OE50 Taxa scores were below 1.00 (Figure 35a&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 35a). Four locations achieved a Band A score in autumn (WT3 in autumn 2013, WT4 in 2012, WT5 in 2015 and OC in autumn 2017) (Figure 35b). Notably, the O'Hares Creek location only scored lower than a Band B on one occasion, in spring 2013 (Figures 35a&b).

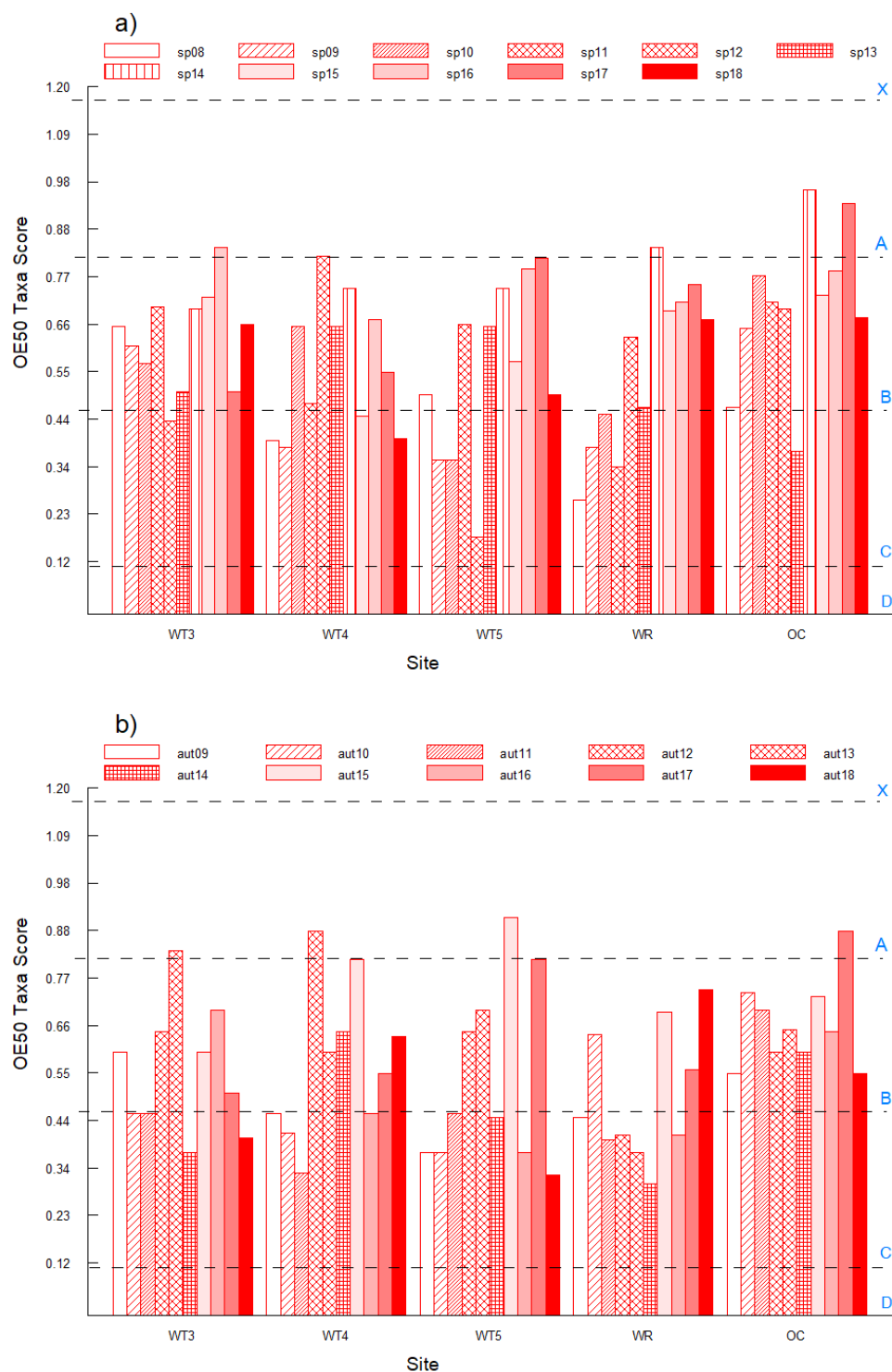


Figure 35. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in a) spring and b) autumn between 2008 and 2019 ($n = 2$).

4.1.2.2 Aquatic Macrophytes

Waratah Rivulet v Controls

Prior Surveys (Spring 2009 – Autumn 2018)

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

Current Survey (Spring 2018)

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. $Ti(Pe) \times Lo(Im)$), indicating that there was significant variation among Locations, which depended on the time of sampling and *vice versa* (Table 11, Figures 36a-b).

The Principal Coordinate Analyses (PCoA) indicates that assemblages of aquatic macrophytes sampled at the Waratah Rivulet locations differed considerably from assemblages at the Woronora River location (Figures 36a-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 12, Figures 37a&b).

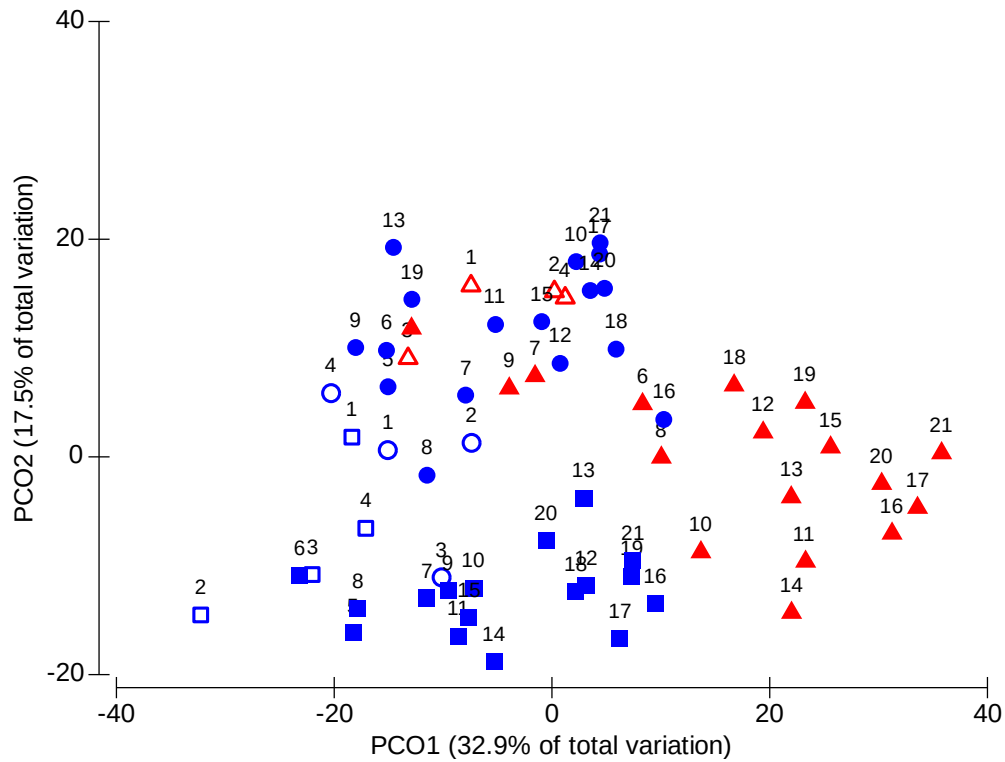
Table 11. PERMANOVA on macrophyte assemblage data to compare locations on Waratah Rivulet (WT3, WT4 and WT5) with control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown.

WT3					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	35334	1.86	0.05	7.29
Impact = Im	1	39145	1.34	0.22	5.63
Time (Pe) = Ti(Pe)	19	6541	1.50	0.01	6.39
Location (Im) = Lo(Im)	1	28908	1.97	0.01	7.79
Pe x Im	1	12657	0.92	0.60	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	11828	4.01	0.00	8.29
Pe x Lo(Im)	1	14853	1.78	0.01	7.78
Ti(Pe) x Im	19	3682	0.84	0.86	0.00
Pe x Si(Lo(Im))	3	5615	1.90	0.01	6.43
Ti(Pe) x Lo(Im)	19	4372	1.48	0.00	8.45
Ti(Pe) x Si(Lo(Im))	57	2949	0.84	1.00	0.00
Residual	504	3510			41.96
WT4					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	26998	1.62	0.10	6.36
Impact = Im	1	29377	1.06	0.43	2.58
Time (Pe) = Ti(Pe)	19	4540	1.04	0.40	1.92
Location (Im) = Lo(Im)	1	28908	1.50	0.06	6.93
Pe x Im	1	9967	0.81	0.74	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	16827	5.69	0.00	11.17
Pe x Lo(Im)	1	14853	1.77	0.01	8.36
Ti(Pe) x Im	19	2871	0.66	1.00	0.00
Pe x Si(Lo(Im))	3	5676	1.92	0.00	7.00
Ti(Pe) x Lo(Im)	19	4372	1.48	0.00	9.09
Ti(Pe) x Si(Lo(Im))	57	2956	0.79	1.00	0.00
Residual	504	3724			46.60
WT5					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	44435	1.93	0.05	8.52
Impact = Im	1	17514	0.68	0.88	0.00
Time (Pe) = Ti(Pe)	19	5321	1.24	0.12	4.56
Location (Im) = Lo(Im)	1	28784	1.52	0.06	6.70
Pe x Im	1	7032	0.48	0.99	0.00
Site (Lo(Im)) = Si(Lo(Im))	3	16663	5.46	0.00	10.59
Pe x Lo(Im)	1	19902	2.07	0.00	9.89
Ti(Pe) x Im	19	3503	0.82	0.86	0.00
Pe x Si(Lo(Im))	3	6819	2.24	0.00	7.88
Ti(Pe) x Lo(Im)	19	4281	1.40	0.00	8.11
Ti(Pe) x Si(Lo(Im))	57	3050	0.85	1.00	0.00
Residual	504	3585			43.75

Table 12. PERMANOVA on diversity and cover of aquatic macrophytes. Bold numbers indicate significant results at $P < 0.05$.

WT3		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	20.93	5.31	4023	2.61
Impact = Im	1	2.66	3.18	8370	4.44
Time (Pe) = Ti(Pe)	19	3.58	1.71	479	0.30
Location (Im) = Lo(Im)	1	0.29	0.48	663	0.32
Pe x Im	1	1.62	1.90	1275	0.88
Site (Lo(Im)) = Si(Lo(Im))	3	1.30	0.96	1801	4.31
Pe x Lo(Im)	1	0.76	0.88	1669	0.62
Ti(Pe) x Im	19	1.20	0.58	1580	0.99
Pe x Si(Lo(Im))	3	0.29	0.22	1796	4.29
Ti(Pe) x Lo(Im)	19	2.09	1.55	1589	3.80
Ti(Pe) x Si(Lo(Im))	57	1.35	1.04	418	0.86
Residual	504	1.30		487	
WT4		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	1.36	1.36	748	0.80
Impact = Im	1	27.79	23.04	14	1.37
Time (Pe) = Ti(Pe)	19	1.79	0.85	1257	0.79
Location (Im) = Lo(Im)	1	0.29	0.52	663	0.32
Pe x Im	1	4.56	3.77	0	0.73
Site (Lo(Im)) = Si(Lo(Im))	3	0.65	0.57	2096	4.21
Pe x Lo(Im)	1	0.76	0.74	1669	0.84
Ti(Pe) x Im	19	1.01	0.48	509	0.32
Pe x Si(Lo(Im))	3	0.47	0.41	1000	2.01
Ti(Pe) x Lo(Im)	19	2.09	1.82	1589	3.19
Ti(Pe) x Si(Lo(Im))	57	1.15	0.94	498	0.99
Residual	504	1.22		500	
WT5		Richness		Abundance	
Source	df	MS	PseudoF	MS	PseudoF
Period = Pe	1	23.77	5.94	6804	1.19
Impact = Im	1	8.73	4.07	6121	8.19
Time (Pe) = Ti(Pe)	19	2.20	1.01	801	0.54
Location (Im) = Lo(Im)	1	1.30	0.94	143	0.17
Pe x Im	1	0.17	0.66	2229	0.53
Site (Lo(Im)) = Si(Lo(Im))	3	0.77	0.53	2541	4.87
Pe x Lo(Im)	1	2.17	0.49	6173	1.78
Ti(Pe) x Im	19	1.38	0.63	785	0.53
Pe x Si(Lo(Im))	3	5.17	3.54	2285	4.37
Ti(Pe) x Lo(Im)	19	2.17	1.49	1484	2.84
Ti(Pe) x Si(Lo(Im))	57	1.46	1.13	522	1.02
Residual	504	1.29		511	

A



B

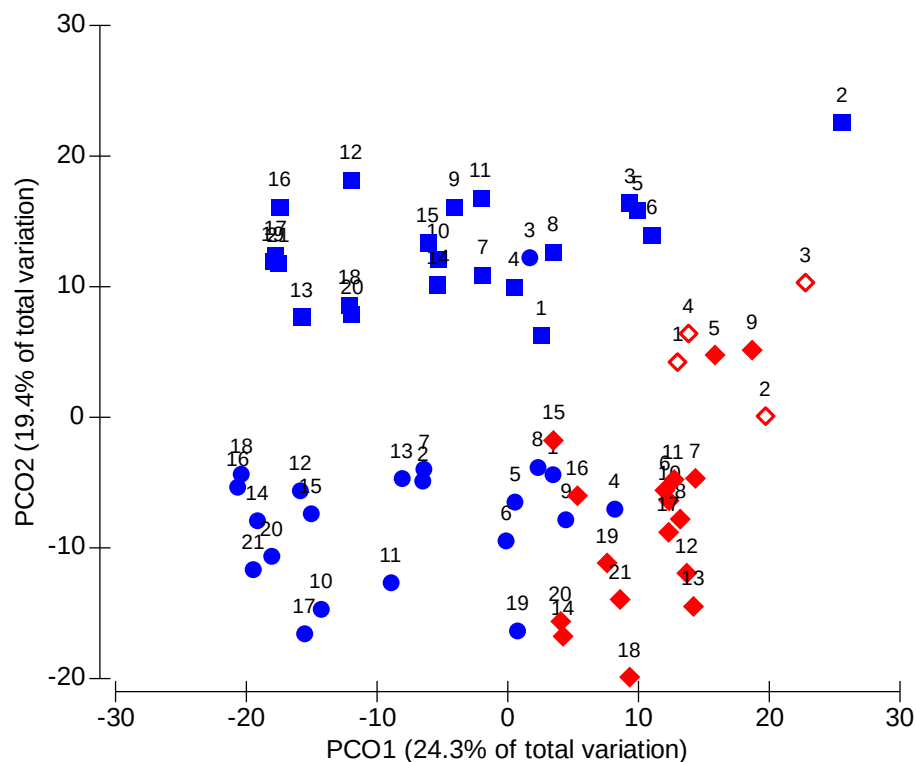


Figure 36. PCoA of centroids for macrophyte data for a) Location WT3 and b) Location WT4 and two control locations for each time of sampling. Red symbols: Potential 'impact' locations; Woronora River: Blue squares; O'Hares Creek: Blue circles. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.

C

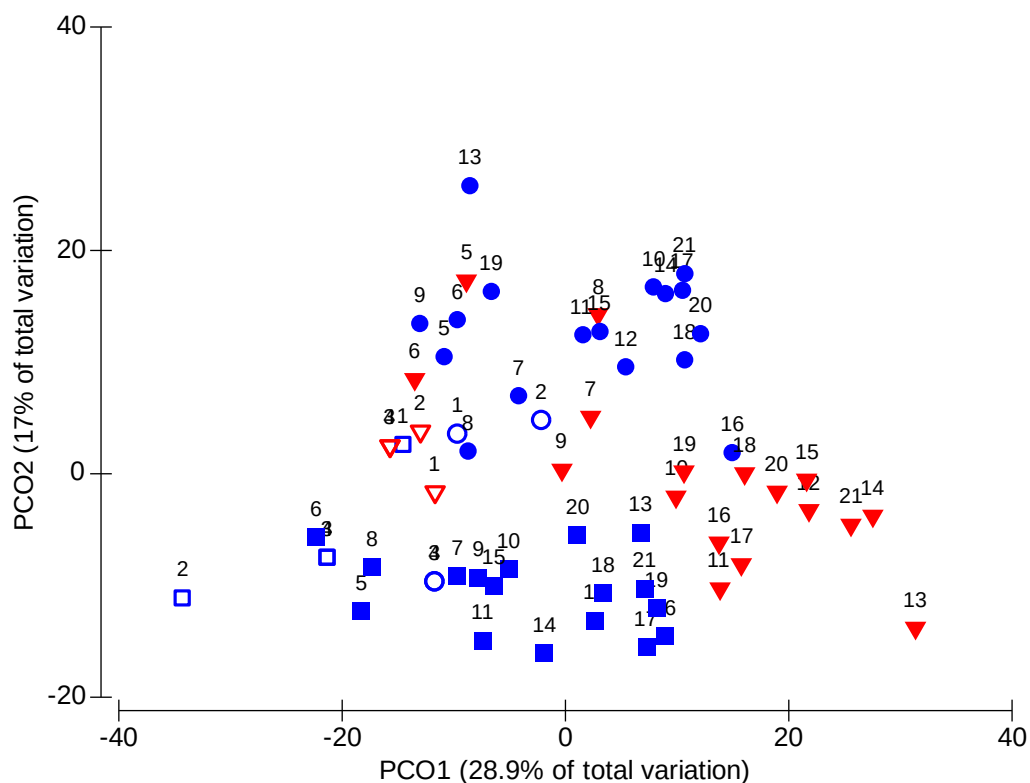


Figure 36 (Cont'd). PCoA of centroids for macrophyte data for c) Location WT5. Red triangles: Potential 'impact' location; Blue squares: Woronora River; Blue circles: O'Hares Creek. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc.

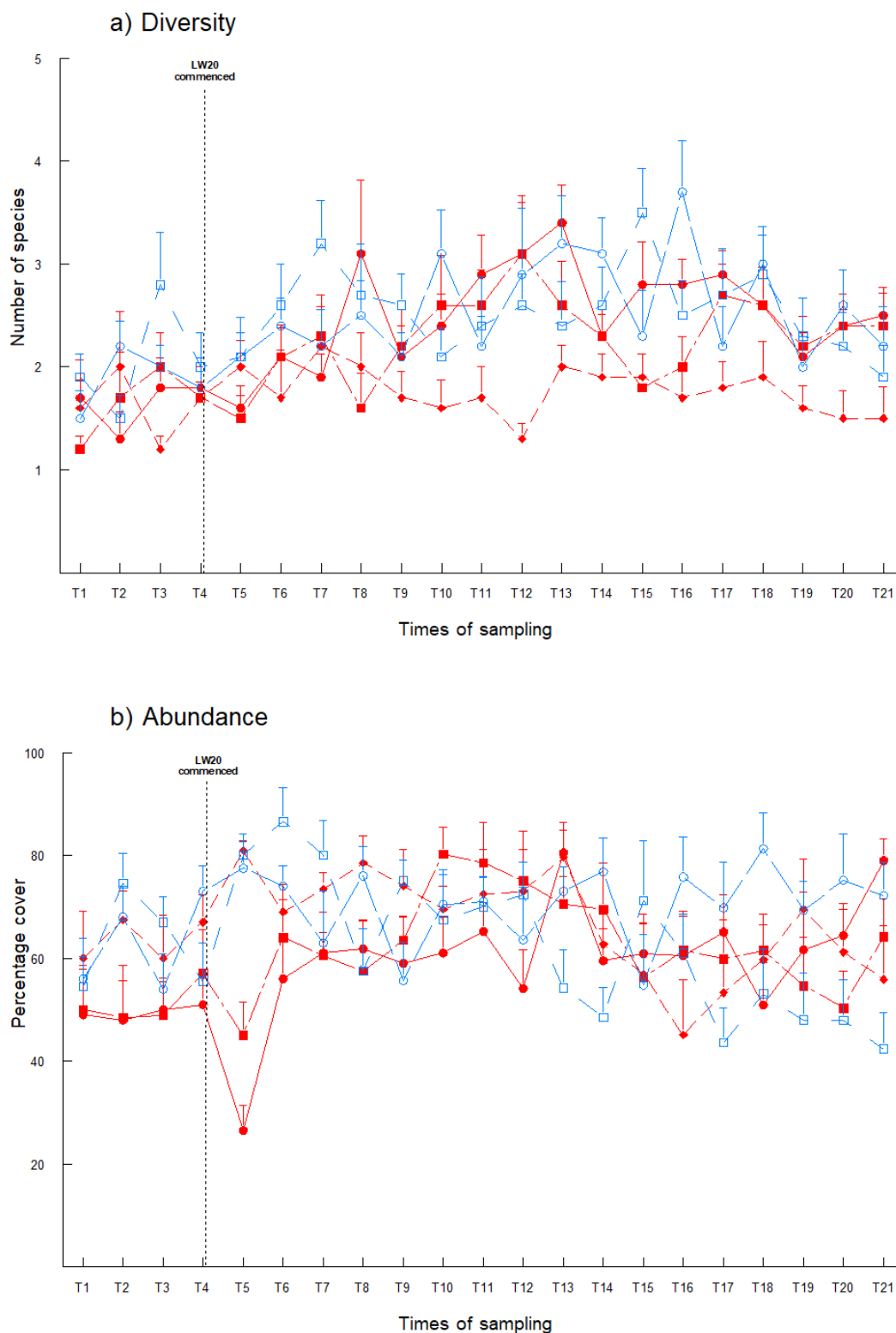


Figure 37. Mean (+SE) a) diversity and b) cover of aquatic macrophytes at locations on Waratah Rivulet (WT3: circle; WT4: diamond; WT5: solid square) and the reference locations (Woronora River: empty square; O'Hares Creek: empty circle) ($n = 10$). Time 1 = spring 2008, T2 = autumn 2009, etc.

4.1.3 Tributary B vs Controls

4.1.3.1 Aquatic Macroinvertebrates

A considerable drop (approximately 1 m) in water level was noted in a large pool at the Tributary B location (B1) in spring 2012 (T9). By autumn 2013, the pool had almost completely emptied and there was no surface flow along the study reach (Section 3.1.1 – Stream Characteristics), due to subsidence associated with mining of the Longwalls 20-22 underground mining area. Sampling of aquatic macroinvertebrates was not carried out at Location B1 in spring 2013 or from spring 2014 to spring 2018 because pools along the study reach have been dry.

Past analyses examining patterns of change in the assemblage of aquatic macroinvertebrates and key components at the Tributary B location in relation to control locations found evidence of impacts related to mining activities within the Longwalls 20-22 underground mining area.

4.1.3.2 Aquatic Macrophytes

Results indicate that assemblages of macrophytes at the Tributary B location (Location B1) have experienced a degree of environmental stress since spring 2012 as a result of mining activities within the Longwalls 20-22 underground mining area.

4.1.3.3 Summary

As described in the Longwalls 301-303 Biodiversity Management Plan (Metropolitan Coal, 2018), the aquatic ecology subsidence impact performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded at Location B1 for aquatic macroinvertebrates since the spring 2016 survey and assessments have been made against the performance measure. Given the distance from Longwalls 301-303, Tributary B is not expected to experience any measurable subsidence or valley related movements resulting from the extraction of Longwalls 301-303 (Metropolitan Coal, 2016).

4.2 Monitoring of Large Pools

For this report, analyses were used to compare temporal and spatial patterns of aquatic macroinvertebrates and macrophytes at each of the large pools sampled on the Waratah Rivulet (Pools J, M1 and N), separately. PERMANOVA was used to test the hypothesis that each of the Waratah Rivulet pools would show greater change Before (Pool N: spring 2008 to autumn 2010; Pools J and M1: spring 2009 to autumn 2010) vs After (spring 2010 to spring 2018) mining than found in the Control pools. Analyses took into consideration: two Periods (Before- and After-mining), several Times within each period, two types of creek (i.e. potential ‘impact’ vs control), various Pools within each type of creek and two Sites within each Pool.

4.2.1 Aquatic Macroinvertebrates

Prior Surveys (Spring 08/09 – Autumn 2018)

To date, assemblages of aquatic macroinvertebrates in the Waratah Rivulet pools have not been found to differ significantly between Periods (i.e. from Before- to After-mining) or pools (i.e. Impact vs Control pools). Visual examination of the PCoAs indicate that temporal (i.e. among sampling times) variation of assemblages in the Waratah Rivulet pools, particularly Pools J and N, was larger than that measured for assemblages collected from Control pools (Figures 38a-c).

Univariate analyses detected a significant increase in mean diversity of macroinvertebrates in Pools J (from autumn 2015 to autumn 2017) and M1 (from autumn 2015 to autumn 2018) within the before- compared to after-mining period in relation to the control pools (Figure 39a).

Univariate analyses used to examine changes in key indicators in Pool N have consistently found no significant differences before- vs after-commencement of mining of the Longwalls 20-22 area in relation to the Control pools (Figures 39a-d). Additional analyses to examine temporal patterns of change in macroinvertebrate indicators in Pool N before- compared to after- an observed decline in pool water level (up to 1.8 m) in spring 2012 (T9) also found no evidence of a significant impact (Figures 39a-d).

Current Survey (Spring 2018)**Pool J**

Assemblages of aquatic macroinvertebrates in Pool J were not found to differ significantly between Periods (i.e. from Before- to After-mining) or streams (i.e. Impact vs Control streams) (Table 13, Figure 38a). Multivariate analyses have consistently found a significant Time nested in Period x Impact interaction (i.e. $Ti(Pe) \times Im$), which indicates that assemblages in Pool J have varied differently from those in the control pools over time but not between the Before- and After-mining periods (Table 13, Figure 38a).

Visual examination of the PCoA found no apparent differences in temporal changes in the assemblage at Pool J in relation to the control locations (Figure 38a). The SIMPER analysis indicates that Atyidae made a larger contribution to the assemblage within Pool J within the before- (28 %) versus after- (7 %) period. In contrast, Leptophlebiidae has increased its contribution to the assemblage within Pool J (Before: 23 %; After: 40 %).

Univariate analyses did not detect a significant $Pe \times Im$ interaction for mean diversity of macroinvertebrates on this sampling occasion (T21) (Table, 14, Figure 39a). Fewer taxa have been collected in Pool J than at the control pools since spring 2016 (T17) however, diversity within Pool J has been similar to that measured during the before-period (Figure 39a).

Analyses have consistently found no interaction between the scales of Period and Impact for mean abundance of macroinvertebrates or mean numbers of Leptophlebiidae and Atyidae (Figures 39b-d). On this occasion, Atyidae were not collected in Pool J (Figure 39d).

Pool M1

Similar to the findings for Pool J, assemblages of aquatic macroinvertebrates in Pool M1 did not differ significantly between Periods (i.e. from Before- to After-mining) or streams (i.e. Impact vs Control streams) on this or previous sampling occasions (Table 13, Figure 38b).

SIMPER found that Leptophlebiidae (53 %), Dytiscidae (22 %) and Chironomidae (13 %), contributed most to the structure of the assemblage in spring 2018.

Univariate analyses detected a significant $Pe \times Im$ interaction for mean diversity of macroinvertebrates (Table 14, Figure 35a). *Post-hoc* tests indicate that this result was partly due to the numbers of taxa collected on each occasion within the after-period varying significantly more than within the before-period at Pool M1 ($t = 2.37$, $P = 0.03$) but not at the control pools ($t = 0.68$, $P = 0.55$) (Figure 35a). In addition, diversity increased significantly between periods at Pool M1 ($t = 2.27$, $P = 0.03$) but there was no measurable change at the control pools ($t = 0.87$, $P = 0.66$).

Patterns of change in mean abundance of macroinvertebrates and in mean numbers of Atyidae and Leptophlebiidae did not differ significantly between the scales of interest (Table 16, Figures 39b-d). Most notably, there have been considerable spikes in mean abundance of macroinvertebrates in Pool M1 since spring 2015 (T13), most likely related to increased numbers of Leptophlebiidae (Figures 39b&d). Very low numbers of Atyidae have been collected in Pool M1 since the commencement of sampling in spring 2009 (Figure 39d).

Pool N

Consistent with the findings of previous surveys, analyses examining changes in assemblages of aquatic macroinvertebrates in Pool N found no evidence of impacts that could be related to mining activities within the Longwalls 20-22 underground mining area (Table 13, Figure 38c).

SIMPER indicated that Atyidae contributed most to the structure of assemblages at Pool N (32 %) and the control locations (47 %) within the before-mining period, followed by the Leptophlebiidae (Pool N: 25 %; Controls: 17 %). Within the after-mining period, Leptophlebiidae contributed most to assemblages at Pool N (Leptophlebiidae: 61 %; Atyidae: 7 %), whilst Atyidae continued to contribute most to assemblages at the control locations (42 %).

Univariate analyses examining changes in estimates of mean diversity and abundance of macroinvertebrates and mean numbers of Leptophlebiidae and Atyidae have consistently found no significant changes in Pool N that would indicate a long-term impact from mining of the Longwalls 20-22 area (Table 14, Figures 39a-d). Graphically, it can be seen that mean diversity has changed little between periods (Figure 39a). Mean abundance of macroinvertebrates appears to have been more variable at Pool N and the O'Hares pool since spring 2012 (T9), largely due to changes in abundance of Leptophlebiidae (Figure 39b&d). Leptophlebiidae in Pool N have been considerably more variable than in the control pools since spring 2012 (T9), with spikes in abundance commonly recorded in spring (Figure 39d).

With the exception of spring 2012 (T9), mean numbers of Atyidae collected at Pool N have been relatively low (Figure 39c).

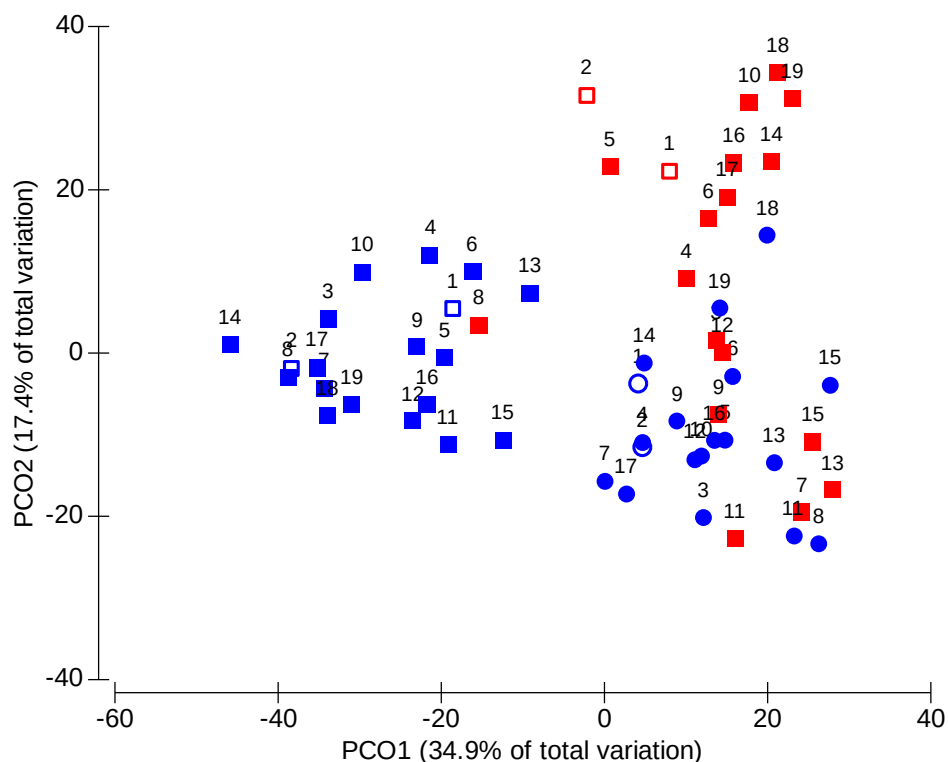
Table 13. PERMANOVA on macroinvertebrate assemblage data to compare pools sampled on the Waratah Rivulet (Pools N, J and M1) with control pools (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

Pool J					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	9081	1.20	0.31	4.24
Impact = Im	1	25107	0.75	0.77	0.00
Time (Pe) = Ti(Pe)	17	7746	2.16	0.00	11.32
Pool (Im) = Po(Im)	1	33636	6.28	0.00	18.67
Pe x Im	1	4108	1.02	0.49	1.58
Site (Po(Im)) = Si(Po(Im))	3	2150	0.89	0.61	0.00
Pe x Po(Im)	1	2843	0.77	0.85	0.00
Ti(Pe) x Im	17	4713	1.31	0.03	8.31
Pe x Si(Po(Im))	3	3267	1.35	0.12	6.21
Ti(Pe) x Po(Im)	17	3592	1.48	0.00	9.79
Ti(Pe) x Si(Po(Im))	51	2428	1.46	0.00	11.23
Residual	228	1662			28.64
Pool M1					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	8326	1.05	0.45	2.11
Impact = Im	1	39684	1.06	0.44	4.27
Time (Pe) = Ti(Pe)	17	8455	2.25	0.00	11.55
Pool (Im) = Po(Im)	1	35450	6.40	0.00	18.31
Pe x Im	1	2773	0.75	0.80	0.00
Site (Po(Im)) = Si(Po(Im))	3	2117	1.00	0.46	0.00
Pe x Po(Im)	1	3063	0.74	0.90	0.00
Ti(Pe) x Im	17	5692	1.52	0.00	10.49
Pe x Si(Po(Im))	3	3239	1.53	0.04	6.88
Ti(Pe) x Po(Im)	17	3754	1.77	0.00	11.12
Ti(Pe) x Si(Po(Im))	51	2120	1.13	0.02	6.10
Residual	228	1874			29.17
Pool N					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	16996	1.66	0.07	6.22
Impact = Im	1	36918	0.66	0.86	0.00
Time (Pe) = Ti(Pe)	19	8111	2.27	0.00	11.77
Pool (Im) = Po(Im)	1	55584	9.84	0.00	18.08
Pe x Im	1	3507	0.74	0.82	0.00
Site (Po(Im)) = Si(Po(Im))	3	2314	0.98	0.49	0.00
Pe x Po(Im)	1	4257	1.09	0.34	2.61
Ti(Pe) x Im	19	5333	1.49	0.00	10.36
Pe x Si(Po(Im))	3	2507	1.06	0.37	1.88
Ti(Pe) x Po(Im)	19	3574	1.51	0.00	9.91
Ti(Pe) x Si(Po(Im))	57	2367	1.44	0.00	10.83
Residual	252	1646			28.34

Table 14. PERMANOVA on four univariate estimates (non-transformed diversity, abundance, and abundances of Leptophlebiidae and Atyidae) of the macroinvertebrate data. Bold numbers indicate significant results at $P < 0.05$.

Pool J		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	141.96	2.14	4245	1.16	659.1	1.51	290	0.92
Impact = Im	1	180.88	0.40	12509	4.17	84.9	0.24	4112	0.56
Time (Pe) = Ti(Pe)	17	66.44	2.94	3880	2.42	511.7	4.43	264	1.11
Pool (Im) = Po(Im)	1	479.02	19.66	1839	1.71	554.4	5.16	7441	22.26
Pe x Im	1	40.88	1.69	1995	1.32	177.0	1.00	212	0.77
Site (Po(Im)) = Si(Lo(Im))	3	2.46	0.17	45	0.05	29.7	0.15	103	0.58
Pe x Po(Im)	1	10.33	0.81	1183	1.30	2.4	0.92	310	1.05
Ti(Pe) x Im	17	27.29	1.21	1546	0.96	291.5	2.52	274	1.15
Pe x Si(Po(Im))	3	7.73	0.54	64	0.07	98.2	0.50	229	1.27
Ti(Pe) x Po(Im)	17	22.63	1.59	1605	1.62	115.5	0.59	239	1.33
Ti(Pe) x Si(Po(Im))	51	14.22	1.39	989	1.30	194.8	1.86	180	1.29
Residual	228	10.20		762		104.5		140	
Pool M1		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	200.06	2.65	6163	1.09	636.37	1.01	250	1.12
Impact = Im	1	274.58	0.60	10969	3.62	3.74	0.11	6741	0.92
Time (Pe) = Ti(Pe)	17	73.77	3.26	5953	3.71	744.89	6.45	127	0.53
Pool (Im) = Po(Im)	1	479.02	19.28	1839	1.77	554.35	4.79	7441	22.95
Pe x Im	1	74.36	4.29	3366	1.77	165.36	0.54	249	1.12
Site (Po(Im)) = Si(Lo(Im))	3	2.83	0.24	9	0.01	34.12	0.21	90	0.82
Pe x Po(Im)	1	10.33	0.88	1183	1.35	2.35	0.47	310	1.04
Ti(Pe) x Im	17	12.30	0.54	1631	1.02	516.52	4.47	127	0.53
Pe x Si(Po(Im))	3	2.72	0.23	31	0.03	237.42	1.46	165	1.51
Ti(Pe) x Po(Im)	17	22.63	1.90	1605	1.57	115.49	0.71	239	2.18
Ti(Pe) x Si(Po(Im))	51	11.93	1.16	1022	0.98	162.92	0.96	110	0.90
Residual	228	10.28		1043		170.37		121	
Pool N		Diversity		Abundance		Leptophlebiidae		Atyidae	
Source	df	MS	Ps-F	MS	Ps-F	MS	Ps-F	MS	Ps-F
Period = Pe	1	131.60	1.86	10771	1.61	2594	3.12	0	0.42
Impact = Im	1	340.37	0.61	15108	2.87	169	0.21	5382	0.55
Time (Pe) = Ti(Pe)	19	82.45	3.50	5727	3.72	773	7.02	516	2.19
Pool (Im) = Po(Im)	1	581.62	21.56	3619	2.80	576	6.58	9858	27.83
Pe x Im	1	0.00	1.57	806	0.57	490	0.72	103	0.78
Site (Po(Im)) = Si(Lo(Im))	3	4.15	0.26	309	0.20	18	0.07	126	0.61
Pe x Po(Im)	1	1.00	0.55	1918	1.64	95	2.14	48	0.56
Ti(Pe) x Im	19	13.99	0.59	2171	1.41	745	6.77	385	1.63
Pe x Si(Po(Im))	3	7.12	0.45	578	0.37	59	0.22	214	1.04
Ti(Pe) x Po(Im)	19	23.58	1.48	1538	0.99	110	0.41	236	1.15
Ti(Pe) x Si(Po(Im))	57	15.97	1.90	1559	2.30	267	3.04	205	1.74
Residual	252	8.41		678		88		118	

A



B

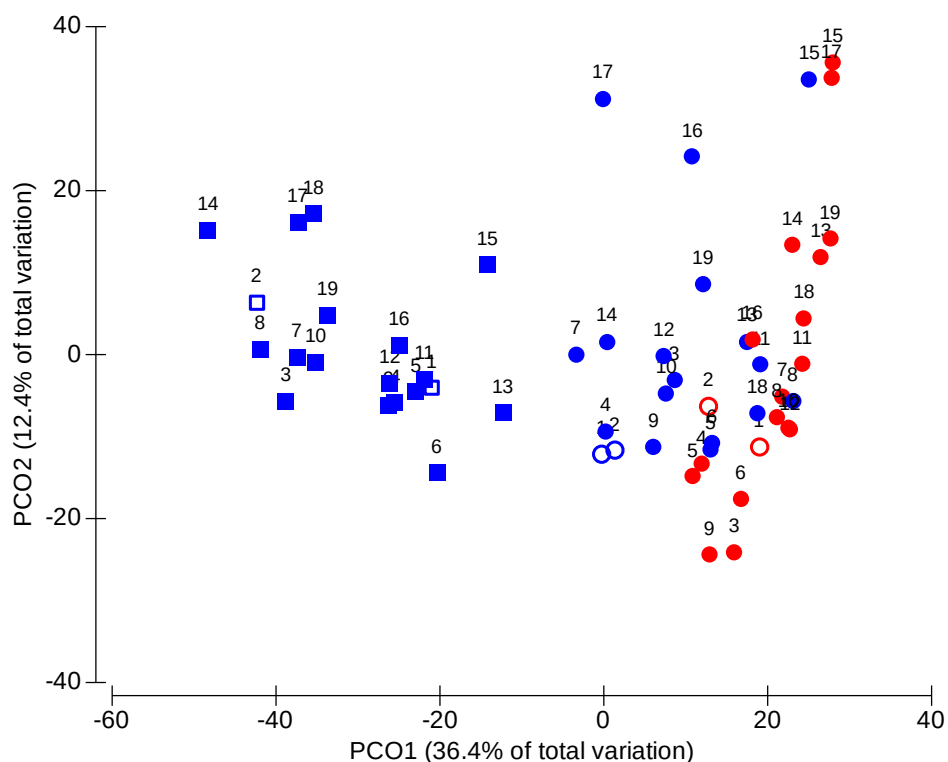


Figure 38. PCoA of centroids for each pool per time on macroinvertebrate data for a) Pool J and b) Pool M1 and two control pools. Red symbols: Potential 'impact' pools; Blue squares: Woronora River Pool; Blue circles: O'Hares Creek Pool. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. NB Sampling of Pools J and M1 commenced in spring 2009.

C

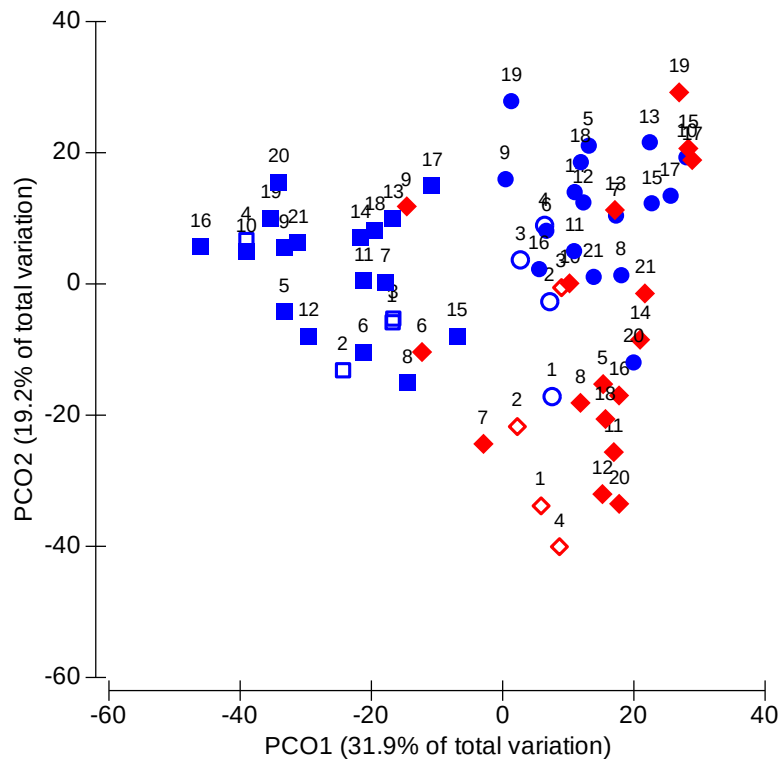


Figure 38 (Cont'd). PCoA of centroids for c) Pool N (red squares) compared to the Woronora River (Blue squares) and O'Hares Creek (blue circles) Pools. Empty symbols: 'Before' mining; Filled symbols: 'After' mining. Numbers indicate sampling time. NB Sampling of Pool N commenced in spring 2008.

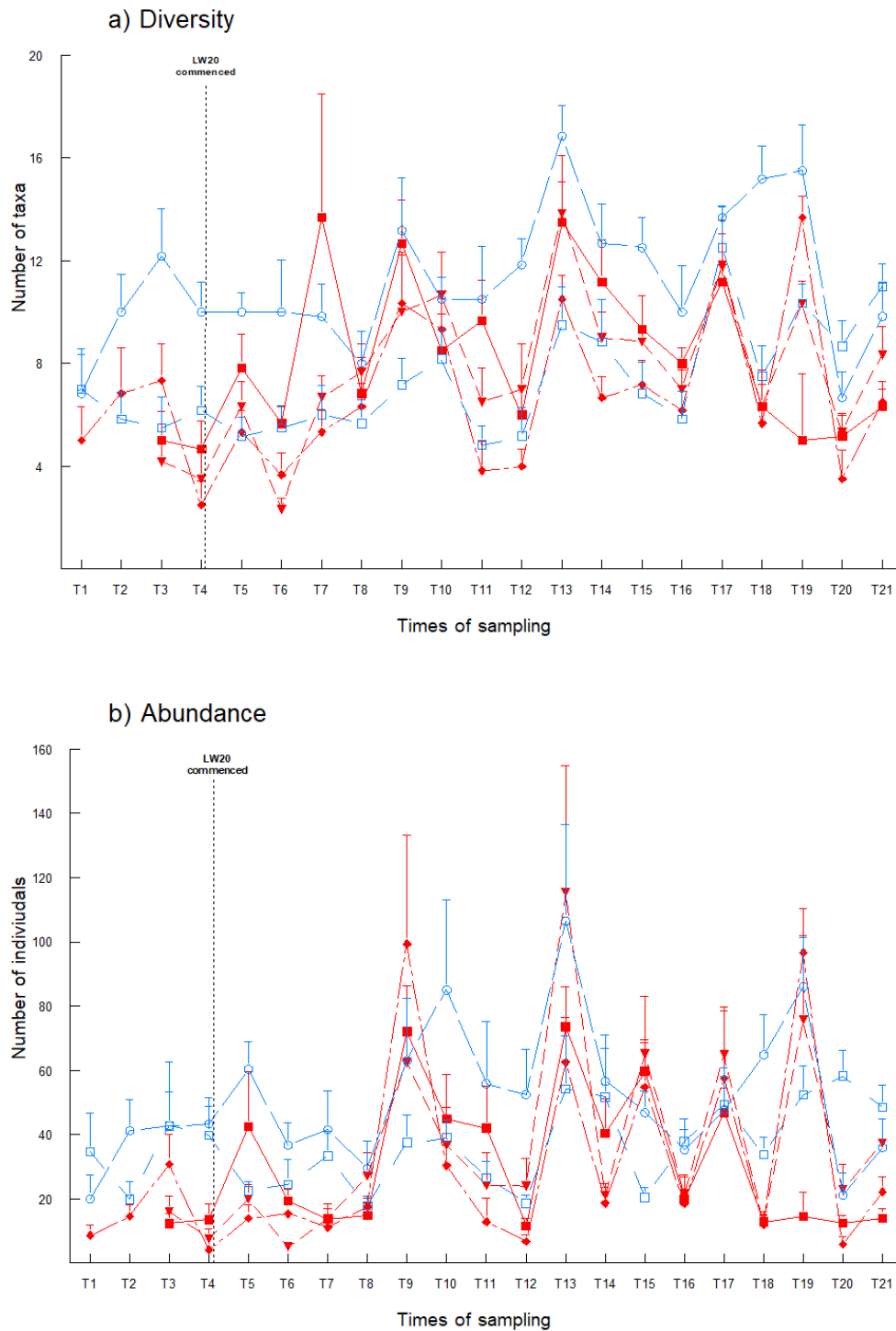


Figure 39. Mean (+SE) of a) diversity and b) abundance of macroinvertebrates in pools sampled on Waratah Rivulet and at control pools ($n = 6$). Pool J = filled squares; Pool M1 = triangles; Pool N = diamonds; Woronora pool = empty squares; O'Hares pool = empty circles. Time 1 = spring 2008, T2 = autumn 2009, etc. NB Sampling of Pools J and M1 commenced at T3 (spring 2009).

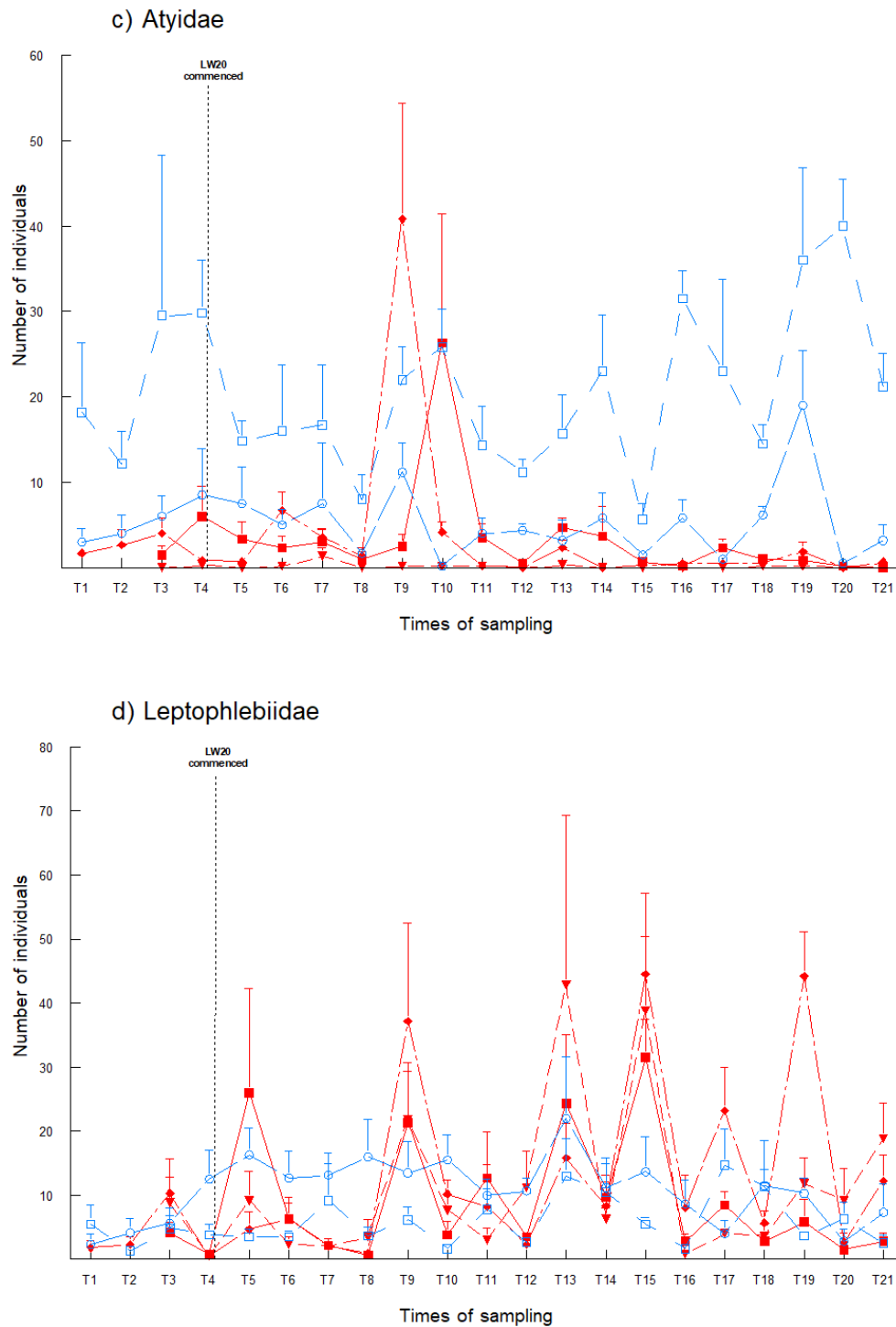


Figure 39. (Cont'd) Mean number (+SE) of c) Atyidae and d) Leptophlebiidae in pools sampled on Waratah Rivulet and at control pools ($n = 6$). Pool J = squares; Pool M1 = triangles; Pool N = diamonds; Woronora pool = empty squares; O'Hares pool = empty circles. Time 1 = spring 2008, T2 = autumn 2009, etc. NB Sampling of Pools J and M1 commenced at T3 (spring 2009).

4.2.2 Aquatic Macrophytes

Prior Surveys (Spring 2008/2009 – Autumn 2018)

To date, analyses comparing temporal and spatial patterns of change in assemblages of aquatic macrophytes at large pools sampled along the Waratah Rivulet (Pools J, M1 and N) with control pools have not detected significant differences from before-to-after mining.

Since autumn 2016, analyses have indicated that:

- Total cover of aquatic macrophytes at Pool M1 has decreased significantly within the after-mining period in relation to the control pools;
- Diversity of macrophytes within the riparian strip adjacent to Pool N has decreased significantly in relation to the control pools.

Current Survey (Spring 2018)

Assemblages in the Waratah Rivulet pools were found to differ significantly at the Period x Pool nested in Impact interaction (i.e. $Pe \times Po(Im)$), indicating that there were differences between Periods but differences varied depending on the Pool being examined, not whether or not the pool was within a Control or Impact stream (Table 15, Figure 40a-c).

In general, the multivariate ordinations (PCoA) show that the structure of assemblages at Pools J and M1 have consistently differed from those found in control pools, mostly due to the absence of the floating-attached species, *Triglochin procerum* (Figure 40a&b). *Triglochin procerum* has consistently been present in the Control pools. *Triglochin procerum* has also been relatively abundant in Pool N although plants were left exposed when the water level in the pool dropped considerably in spring 2012 (T9) and then again in autumn 2014 (T12). Also notable was that the centroids representing assemblages at the Woronora River pool tend to group separately from assemblages at the rivulet pools and at O'Hares Creek (Figures 40a-c: blue square symbols tend to group to the left of the PCoA while blue circle and red 'other' symbols tend to group to the right). SIMPER indicates that the submerged species, *Myriophyllum pedunculatum*, which has only been recorded at the Woronora River location, contributes to this pattern.

Univariate analyses did not find a significant Period x Impact interaction for estimates of mean diversity or mean total cover of macrophytes when comparing changes between Pool J and the Control pools (Table 16, Figures 41a-b). In general, patterns of change in diversity and percentage cover of macrophytes at Pool J has been within the range displayed at the control pools (Figures 41a-b).

Consistent with the findings from surveys done since autumn 2016, analyses detected a significant before- vs after-mining change in mean total cover of aquatic macrophytes at Pool M1 in relation to the control pools (Table 16, Figure 41b). *Pair-wise* tests indicated that this result was mostly due to cover decreasing at M1 within the after-period but not at the control pools (Figure 41b).

A significant change in diversity of macrophytes has also been detected at Pool N since autumn 2016, in relation to the control pools (Table 16, Figure 41a). *Post-hoc* tests indicate that the mean diversity of macrophytes at Pool N has become significantly more variable (PERMDISP: $P = 0.001$) within the after-period in relation to the control pools (Figure 41a). In general, mean abundance of macrophytes at Pool N declined considerably after the autumn 2012 survey (T8), coinciding with the considerable reduction in pool water level (up to ~ 1.8 m) noted by the spring 2012 (T9) survey (Figures 41b).

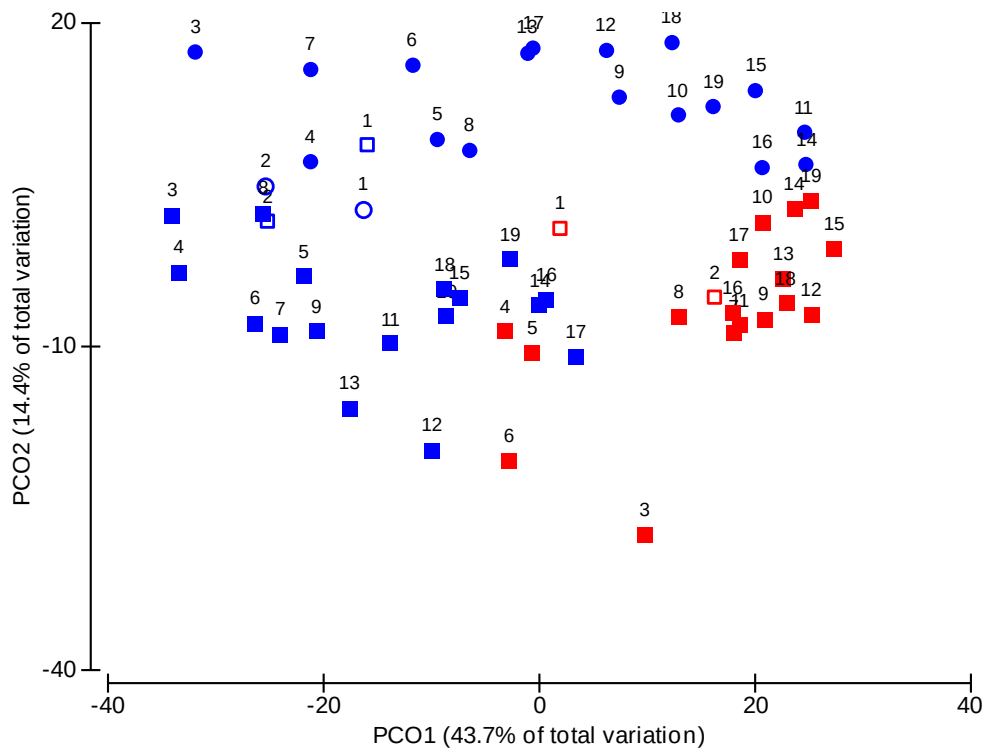
Table 15. PERMANOVA macrophyte assemblage data to compare pools sampled along the Waratah Rivulet (J, M1 and N) with control Pools (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

Pool J					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	11578	0.98	0.53	0.00
Impact = Im	1	39800	2.50	0.03	13.25
Time (Pe) = Ti(Pe)	17	6529	1.68	0.01	7.97
Pool (Im) = Po(Im)	1	13496	3.15	0.00	10.13
Pe x Im	1	7356	0.84	0.69	0.00
Site (Po(Im)) = Si(Po(Im))	3	1444	0.44	0.99	0.00
Pe x Po(Im)	1	9295	2.13	0.01	10.94
Ti(Pe) x Im	17	4005	1.03	0.42	2.44
Pe x Si(Po(Im))	3	2025	0.61	0.91	0.00
Ti(Pe) x Po(Im)	17	3881	1.18	0.10	6.10
Ti(Pe) x Si(Po(Im))	51	3299	1.04	0.25	4.19
Residual	456	3162			44.98
Pool M1					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	10334	0.91	0.60	0.00
Impact = Im	1	36531	2.13	0.04	11.50
Time (Pe) = Ti(Pe)	17	6242	1.59	0.00	7.13
Pool (Im) = Po(Im)	1	12869	2.55	0.00	8.98
Pe x Im	1	11475	1.00	0.51	0.00
Site (Po(Im)) = Si(Po(Im))	3	2402	0.73	0.84	0.00
Pe x Po(Im)	1	9381	2.04	0.00	10.30
Ti(Pe) x Im	17	6095	1.55	0.00	9.75
Pe x Si(Po(Im))	3	2292	0.69	0.88	0.00
Ti(Pe) x Po(Im)	17	3934	1.19	0.07	6.04
Ti(Pe) x Si(Po(Im))	51	3312	0.91	0.95	0.00
Residual	456	3654			46.30
Pool N					
Source	df	MS	Pseudo-F	P	% CV
Period = Pe	1	13805	0.89	0.63	0.00
Impact = Im	1	8717	0.43	1.00	0.00
Time (Pe) = Ti(Pe)	19	8387	1.85	0.00	10.12
Pool (Im) = Po(Im)	1	24396	3.83	0.00	10.60
Pe x Im	1	9013	0.73	0.83	0.00
Site (Po(Im)) = Si(Po(Im))	3	2727	0.80	0.77	0.00
Pe x Po(Im)	1	12126	2.20	0.00	9.62
Ti(Pe) x Im	19	6492	1.43	0.01	10.21
Pe x Si(Po(Im))	3	2536	0.74	0.84	0.00
Ti(Pe) x Po(Im)	19	4526	1.33	0.01	8.87
Ti(Pe) x Si(Po(Im))	57	3413	0.94	0.83	0.00
Residual	504	3616			50.58

Table 16. PERMANOVA on three univariate estimates (non-transformed diversity and total cover) of the macrophyte data. Bold numbers indicate significant results at $P < 0.05$.

Pool J		Diversity		Abundance	
Source	df	MS	Ps-F	MS	Ps-F
Period = Pe	1	26.06	6.59	4290	4.84
Impact = Im	1	1.02	1.02	1049	0.43
Time (Pe) = Ti(Pe)	17	3.20	2.99	863	0.62
Pool (Im) = Po(Im)	1	1.29	1.97	4893	3.05
Pe x Im	1	0.30	0.81	98	1.44
Site (Po(Im)) = Si(Lo(Im))	3	0.28	0.21	432	0.67
Pe x Po(Im)	1	0.92	1.88	310	0.69
Ti(Pe) x Im	17	0.76	0.71	720	0.52
Pe x Si(Po(Im))	3	0.15	0.11	8	0.01
Ti(Pe) x Po(Im)	17	1.07	0.78	1388	2.13
Ti(Pe) x Si(Po(Im))	51	1.37	1.40	650	1.43
Residual	456	0.98		455	
Pool M1		Diversity		Abundance	
Source	df	MS	Ps-F	MS	Ps-F
Period = Pe	1	10.08	3.07	881	1.25
Impact = Im	1	10.40	7.20	19249	4.00
Time (Pe) = Ti(Pe)	17	3.04	2.50	1470	0.99
Pool (Im) = Po(Im)	1	0.48	0.92	4069	2.36
Pe x Im	1	0.96	1.23	6267	5.06
Site (Po(Im)) = Si(Lo(Im))	3	0.59	0.50	480	0.85
Pe x Po(Im)	1	0.64	1.12	417	0.64
Ti(Pe) x Im	17	1.13	0.93	1114	0.75
Pe x Si(Po(Im))	3	0.40	0.34	44	0.08
Ti(Pe) x Po(Im)	17	1.21	1.03	1482	2.64
Ti(Pe) x Si(Po(Im))	51	1.18	1.07	562	1.14
Residual	456	1.10		492	
Pool N		Diversity		Abundance	
Source	df	MS	Ps-F	MS	Ps-F
Period = Pe	1	0.04	0.40	510	0.64
Impact = Im	1	8.35	3.15	14098	0.88
Time (Pe) = Ti(Pe)	19	2.21	1.93	2897	1.87
Pool (Im) = Po(Im)	1	0.57	0.86	14490	3.71
Pe x Im	1	16.42	5.55	10147	3.17
Site (Po(Im)) = Si(Lo(Im))	3	0.70	0.69	2486	5.06
Pe x Po(Im)	1	0.73	0.60	318	0.47
Ti(Pe) x Im	19	2.44	2.13	3368	2.18
Pe x Si(Po(Im))	3	1.76	1.75	184	0.37
Ti(Pe) x Po(Im)	19	1.15	1.14	1549	3.15
Ti(Pe) x Si(Po(Im))	57	1.01	1.00	491	0.96
Residual	504	1.01		509	

A



B

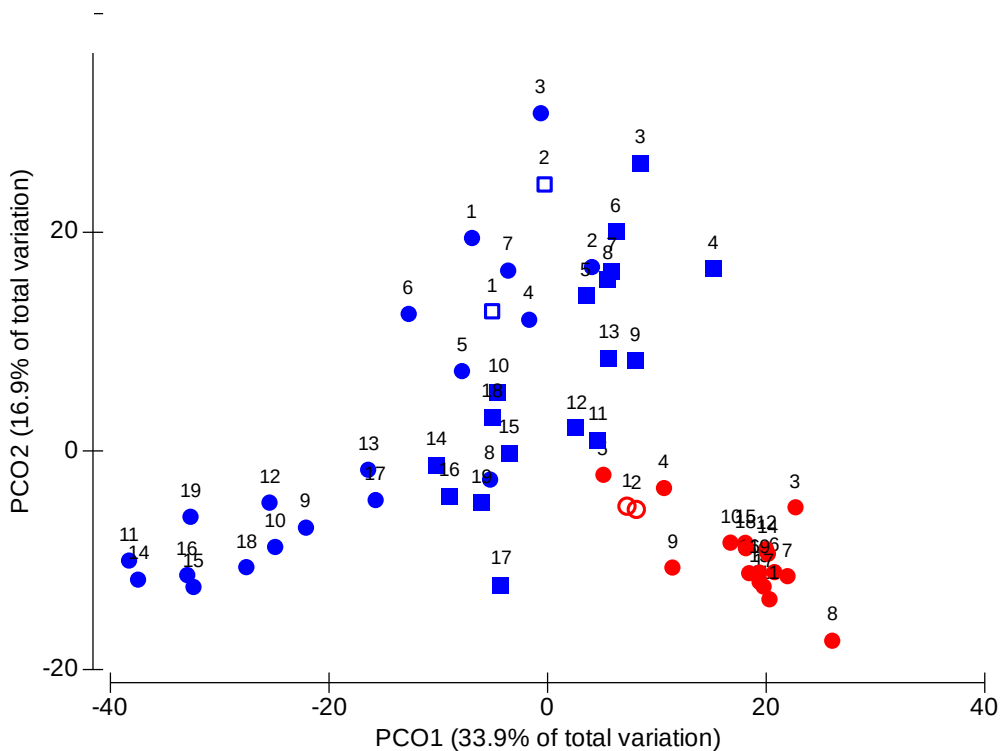


Figure 40. PCoA of centroids for each Pool for each time using Bray-Curtis dissimilarities based on macrophyte data (non-transformed) for a) Pool J: red squares, b) Pool M1: red circles and two control pools: Woronora River (blue squares) and O'Hares Creek (blue circles). Empty symbols: Before-commencement of mining; Filled symbols: After-mining. Numbers represent time of sampling. Time 1 = spring 2008, T2 = autumn 2009, etc. Sampling commenced in spring 2008, with the exception of Pools J and M1, which commenced at T3 (spring 2009).

C

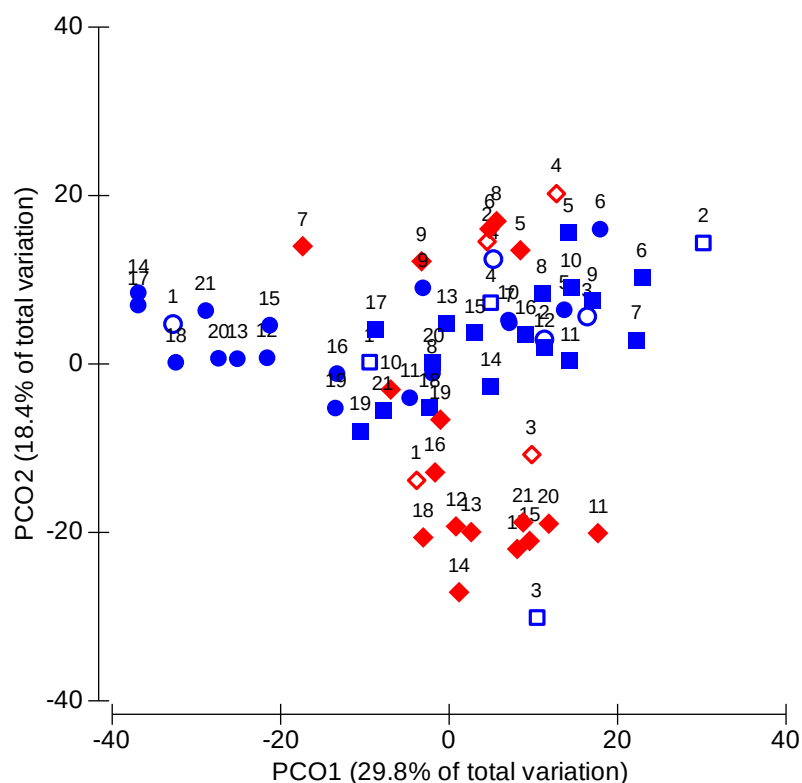


Figure 40 (Cont'd). PCoA of centroids for c) Pool N (red diamonds) compared to the Woronora River (Blue squares) and O'Hares Creek (blue circles) Pools. Empty symbols: Before-commencement of mining; Filled symbols: After- mining. Numbers indicate sampling time. Time 1 = spring 2008, T2 = autumn 2009, etc. NB Sampling of Pools N, WR and OC commenced in spring 2008.

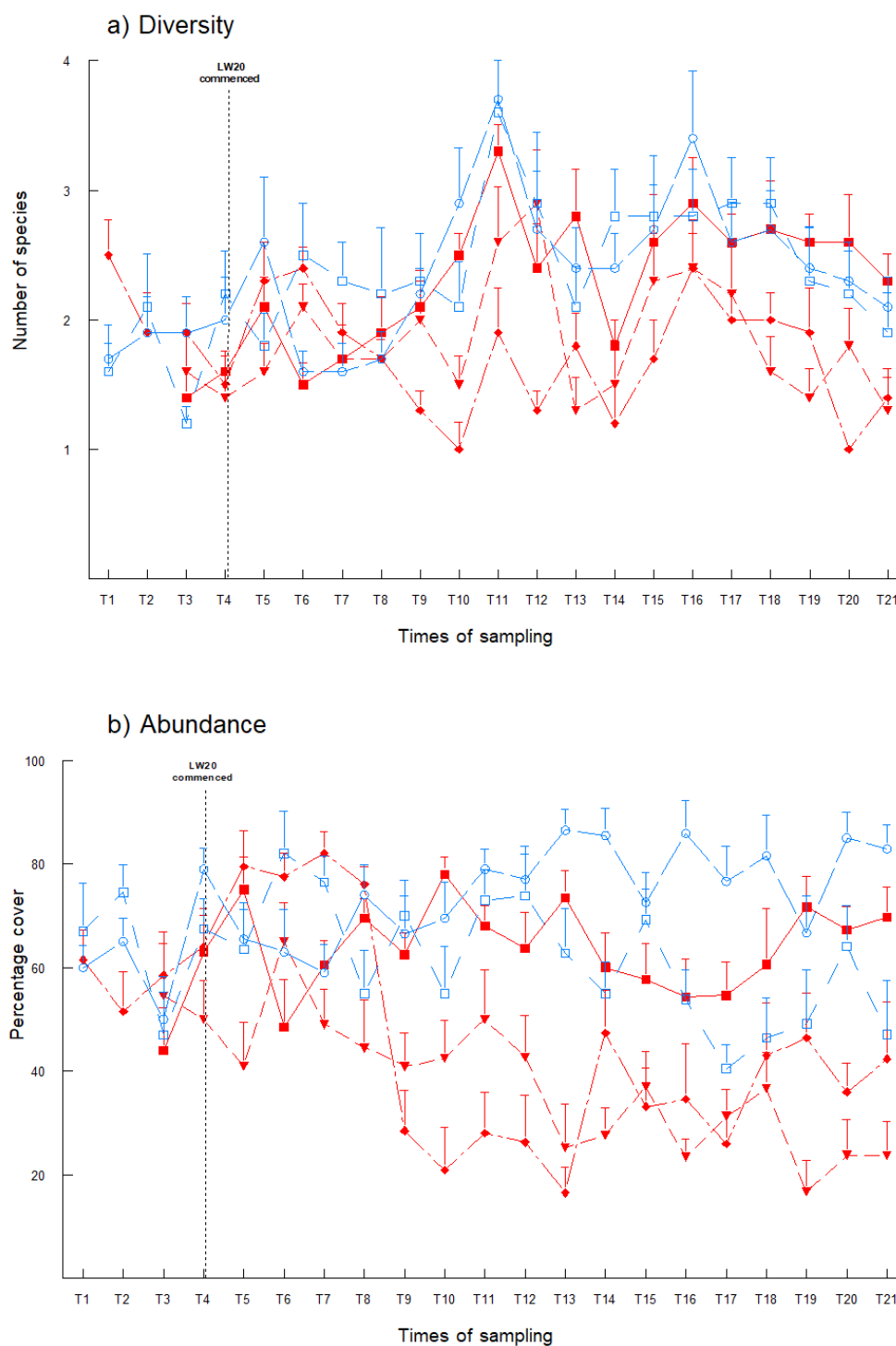


Figure 41. Mean (+SE) a) diversity and b) cover of macrophytes in pools sampled on Waratah Rivulet and at control pools ($n = 6$). Pool J = squares; Pool M1 = triangles; Pool N = diamonds; Woronora pool = empty squares; O'Hares pool = empty circles. Time 1 = spring 2008, T2 = autumn 2009, etc. NB Sampling of Pools J and M1 commenced at T3 (spring 2009)

4.3 Monitoring of Small Pools

PERMANOVA was used to test the hypothesis that mining of Longwalls 20-22 would change the structure of assemblages and/or populations of aquatic macroinvertebrates and aquatic macrophytes in small pools on the Waratah Rivulet in relation to Control pools, over time. The analysis took into consideration: two 'Periods' (Before- and After-mining), several Times within each Period (2-14), two types of creeks (i.e. potentially 'Impacted' vs Control) and three small Pools within each creek. Sampling commenced in spring 2009.

4.3.1 Aquatic Macroinvertebrates

Prior Surveys (Spring 2009 – Autumn 2018)

To date, multivariate analyses comparing temporal and spatial patterns of change in assemblages of aquatic macroinvertebrates in small pools (K, L and M) sampled on the Waratah Rivulet with the control pools have not detected significant differences in the structure of assemblages of macroinvertebrates.

Univariate analyses for Pools K, L and M (combined) have detected a significant Period x Impact interaction for mean diversity since autumn 2015. This result was largely due to an increase in diversity in the small Waratah Rivulet pools within the after-mining period, in relation to the control pools.

Current Survey (Spring 2018)

There were no detectable impacts to assemblages of aquatic macroinvertebrates within the Waratah Rivulet pools in relation to the control pools that could be associated with mining (Table 17, Figure 42). The 'Creek' factor contributed most (17 %) to the components of variation.

SIMPER indicate that the true fly family, Chironomidae, has increased its contribution to the structure of assemblages in small pools sampled along Waratah Rivulet, from before- (6 %) to after- (20 %) mining. Atyidae (Before: 61 %; After: 43 %) and Leptophlebiidae (Before: 13 %; After: 30 %) have consistently contributed the most to the structure of assemblages at the control pools.

Similar to the findings of the last six surveys, univariate analyses detected a significant change in mean diversity of macroinvertebrates from before- to after-mining in relation to the control pools (Table 18, Figure 43a). *Post-hoc* tests indicate that differences were not related to variability (PERMDISP: $P = 0.337$) and *Pair wise* comparisons were unable to differentiate among the means. Overall, diversity has increased in the rivulet pools within the ‘After’ period (Before: 4.3; After: 7.7), but changed little within the control pools (Before: 8.7; After: 7.4) (Figure 43a). Graphically it can be seen that diversity in the rivulet pools changed in a similar manner to the control pools between autumn 2018 (T18) and spring 2018 (T19) (Figure 43a).

Analyses found no evidence of change to total abundance of macroinvertebrates or mean numbers of Chironomidae that would indicate an impact from mining-related activities (Table 18, Figures 43b&c). Graphically, it can be seen that there have been considerable spikes in abundance of Chironomidae in the Waratah Rivulet pools since autumn 2014 (T10) (Figure 43c).

Table 17. PERMANOVA on macroinvertebrate assemblage data comparing small pools along the Waratah River with small control pools in Woronora River and O’Hares Creek. Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

Source	df	MS	Pseudo- <i>F</i>	<i>P</i>	% CV
Period = Pe	1	11426	0.91	0.58	0.00
Impact = Im	1	51746	1.08	0.44	4.64
Time(Pe) = Ti(Pe)	17	9655	1.41	0.04	7.29
Creek(Im) = Cr(Im)	1	48399	5.21	0.00	17.03
Pe x Im	1	13353	1.22	0.32	6.20
Pool(Cr(Im))	6	2982	1.08	0.32	2.12
Pe x Cr(Im)	1	10448	1.47	0.04	7.70
Ti(Pe) x Im	17	6086	0.89	0.72	0.00
Pe x Po(Cr(Im))	6	2159	0.78	0.90	0.00
Ti(Pe) x Cr(Im)	17	6834	2.47	0.00	14.29
Ti(Pe) x Po(Cr(Im))	102	2769	1.47	0.00	11.55
Residual	342	1883			29.18
Total	512				

Table 18. PERMANOVA on univariate estimates of mean diversity and abundance of macroinvertebrate data comparing small pools on the Waratah Rivulet with small control pools in Woronora River and O'Hares Creek. Bold numbers indicate significant results at $P < 0.05$.

Source	df	Richness		Abundance		Chironomidae	
		MS	Pseudo- <i>F</i>	MS	Pseudo- <i>F</i>	MS	Pseudo- <i>F</i>
Period = Pe	1	44.36	0.63	1513	0.19	459.24	1.51
Impact = Im	1	183.20	0.96	16335	1.59	234.23	0.90
Time(Pe) = Ti(Pe)	17	85.08	5.72	8642	4.52	311.29	11.80
Creek(Im) = Cr(Im)	1	180.81	7.08	8876	3.20	15.79	1.20
Pe x Im	1	231.86	7.39	11106	1.09	302.70	1.16
Pool(Cr(Im))	6	12.04	1.24	1153	1.25	80.66	0.71
Pe x Cr(Im)	1	8.70	0.64	9321	3.76	10.15	1.17
Ti(Pe) x Im	17	24.68	1.66	2586	1.35	273.87	10.38
Pe x Po(Cr(Im))	6	13.69	1.41	810	0.88	78.86	0.70
Ti(Pe) x Cr(Im)	17	14.87	1.53	1911	2.07	26.38	0.23
Ti(Pe) x Po(Cr(Im))	102	9.71	1.14	922	1.14	112.94	1.57
Residual	342	8.51		808		72.14	
Total	512						

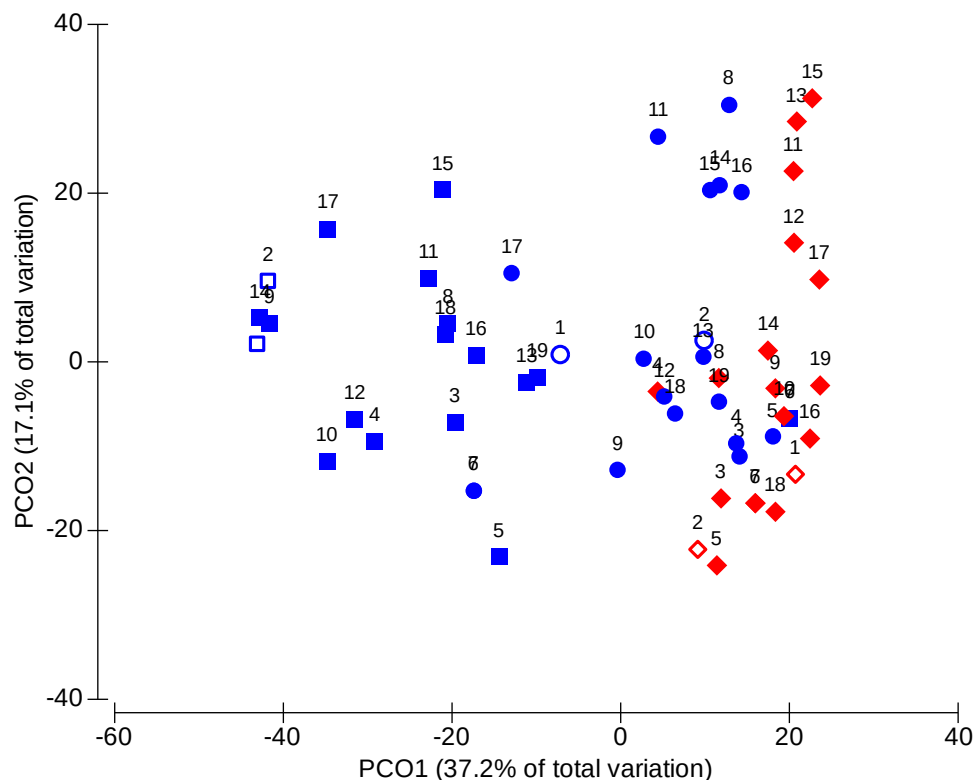


Figure 42. Principal Coordinates Analysis (PCoA) of centroids for each creek and time using Bray-Curtis dissimilarities based on macroinvertebrate data for small pools in Waratah Rivulet (red symbols) and two control creeks: Woronora River (blue squares) and O'Hares Creek (blue circles). Empty symbols: 'Before-commencement of mining'; Filled symbols: 'After-commencement of mining'. Numbers indicate time of sampling. Time 1 = spring 2009, T2 = autumn 2010, etc. Sampling commenced in spring 2009.

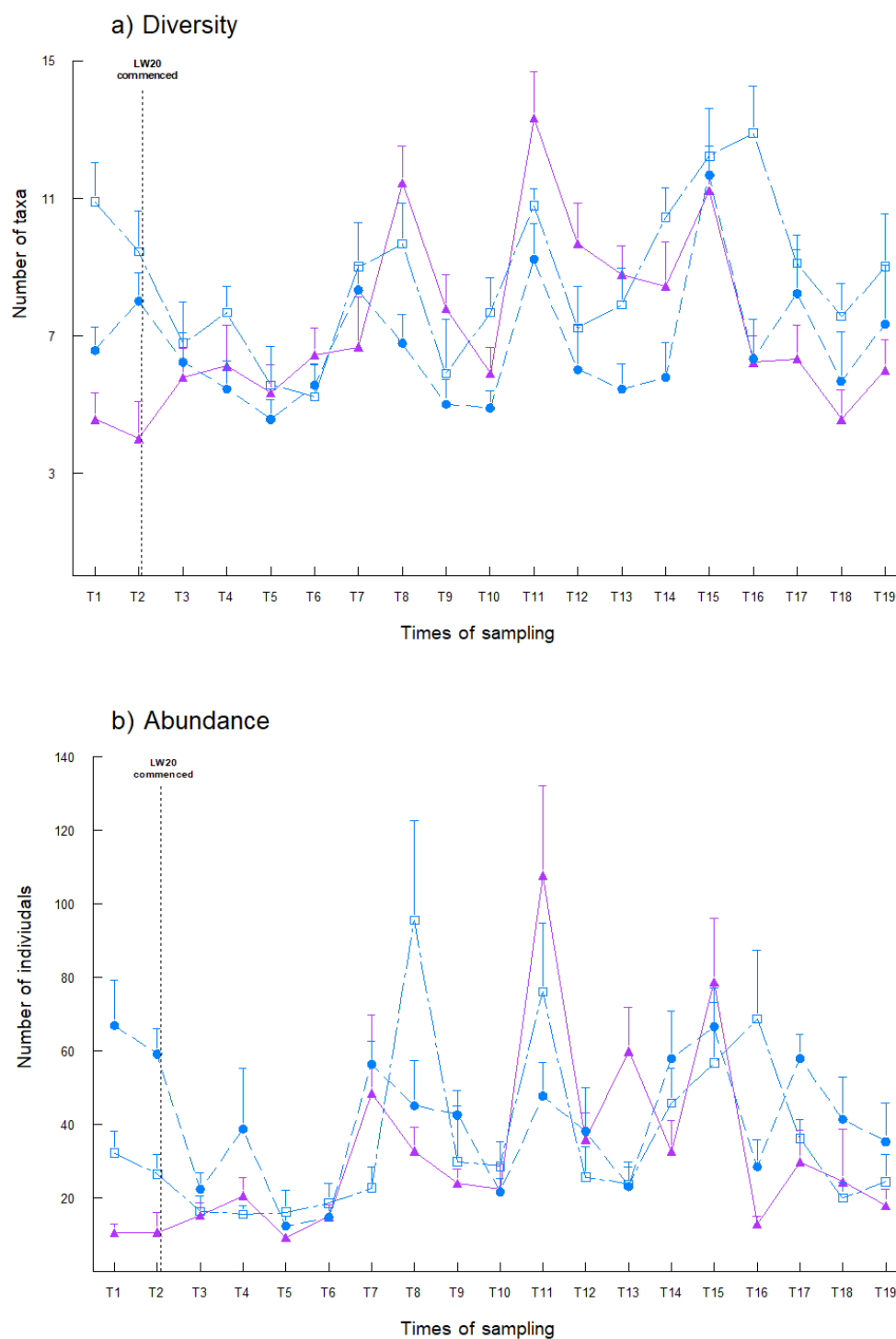


Figure 43. Mean (+SE) of a) diversity and b) abundance of macroinvertebrates in small pools sampled on Waratah Rivulet (triangles) and control pools (Woronora pools: circles; O'Hares Creek pools: squares) ($n = 9$). Time 1 = spring 2009, T2 = autumn 2010, etc. Sampling commenced in spring 2009.

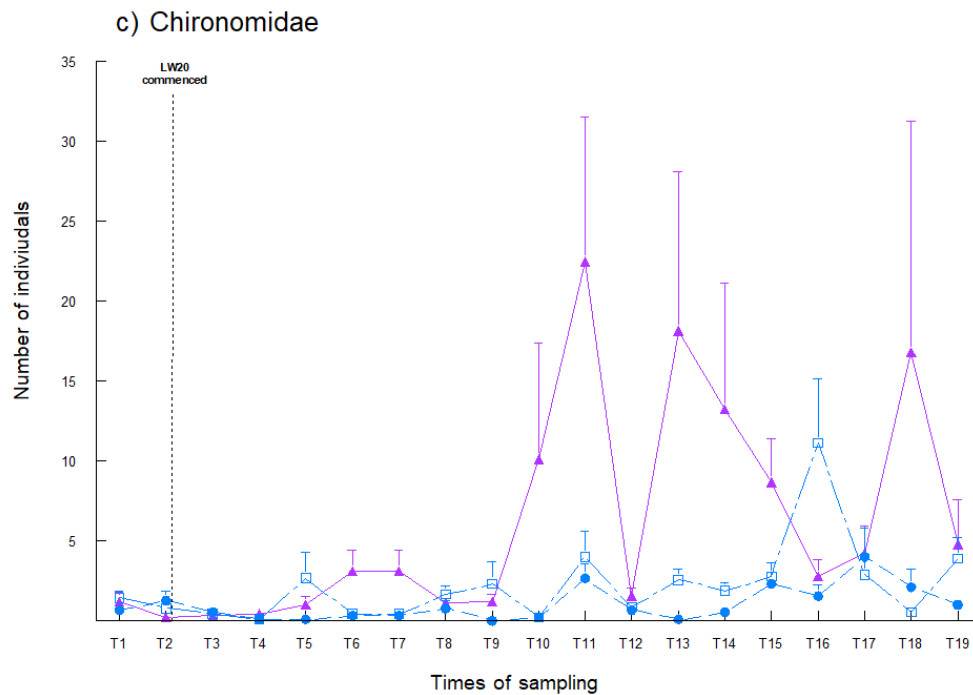


Figure 43 (Cont'd). Mean number (+SE) of c) Chironomidae in small pools sampled on Waratah Rivulet (triangles) and control pools (Woronora pools: circles; O'Hares Creek pools: squares) ($n = 9$). Time 1 = spring 2009, T2 = autumn 2010, etc. Sampling commenced in spring 2009.

4.3.2 Macrophytes

Prior Surveys (Spring 2009 – Autumn 2018)

To date, any effect of subsidence on aquatic macrophytes in small pools on the Waratah Rivulet appears to be within the range of natural variability as measured by the control locations.

Current Survey (Spring 2018)

Multivariate analyses found no evidence to suggest that there were spatial and/or temporal patterns of distributions of aquatic macrophytes in small pools sampled along the Waratah Rivulet related to the commencement of mining of Longwalls 20-22 (Table 19, Figure 44).

Multivariate ordinations (PCoA) have consistently indicated that macrophyte assemblages at the small pools are quite distinctive among streams (Figure 44). SIMPER indicates that *Gleichenia dicarpa* has commonly been the most abundant species recorded at small pools on Waratah Rivulet, whereas *Triglochin procerum*, which has not been recorded in the Waratah Rivulet's small pools, has commonly been abundant in pools sampled on the Woronora River and occasionally present in the O'Hares Creek pools.

Univariate analyses of estimates of mean diversity and abundance found no interaction at the scale of interest (i.e. Pe x Im) (Table 20, Figure 45a&b). Mean cover appears to have declined in areas adjacent to the rivulet pools since the autumn 2018 survey (Figure 44b).

Table 19. PERMANOVA on macrophyte assemblage data comparing small pools along the Waratah Rivulet with small control pools in Woronora River and O'Hares Creek. Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at $P < 0.05$.

Source	df	MS	Pseudo- <i>F</i>	<i>P</i>	% CV
Period = Pe	1	18419	1.95	0.04	6.17
Impact = Im	1	26074	0.66	0.85	0.00
Time(Pe) = Ti(Pe)	17	5785	1.81	0.00	5.79
Creek(Im) = Cr(Im)	1	40417	3.24	0.00	11.95
Pe x Im	1	10349	1.43	0.18	5.41
Pool(Cr(Im))	6	10110	3.83	0.00	10.37
Pe x Cr(Im)	1	5306	1.14	0.27	3.03
Ti(Pe) x Im	16	4183	1.32	0.04	5.09
Pe x Po(Cr(Im))	6	3830	1.45	0.02	5.86
Ti(Pe) x Cr(Im)	17	3156	1.20	0.05	4.21
Ti(Pe) x Po(Cr(Im))	100	2626	0.76	1.00	0.00
Residual	687	3448			42.13
Total	854				

Table 20. PERMANOVA on univariate estimates of mean diversity and abundance of macrophyte data to compare small pools on the Waratah Rivulet with small control pools in Woronora River and O'Hares Creek. Bold numbers indicate significant results at $P < 0.05$.

		Richness		Abundance	
Source	df	MS	Pseudo-F	MS	Pseudo-F
Period = Pe	1	46.93	8.41	2211	0.85
Impact = Im	1	0.05	0.16	5135	3.13
Time(Pe) = Ti(Pe)	17	3.70	2.96	1580	1.95
Creek(Im) = Cr(Im)	1	5.83	1.57	1283	0.40
Pe x Im	1	2.68	0.96	747	0.60
Pool(Cr(Im))	6	3.29	2.65	3533	7.55
Pe x Cr(Im)	1	2.06	2.12	1969	2.31
Ti(Pe) x Im	16	2.04	1.64	620	0.77
Pe x Po(Cr(Im))	6	0.33	0.27	257	0.55
Ti(Pe) x Cr(Im)	17	1.23	0.99	797	1.70
Ti(Pe) x Po(Cr(Im))	100	1.24	1.06	468	1.04
Residual	687	1.17		452	
Total	854				

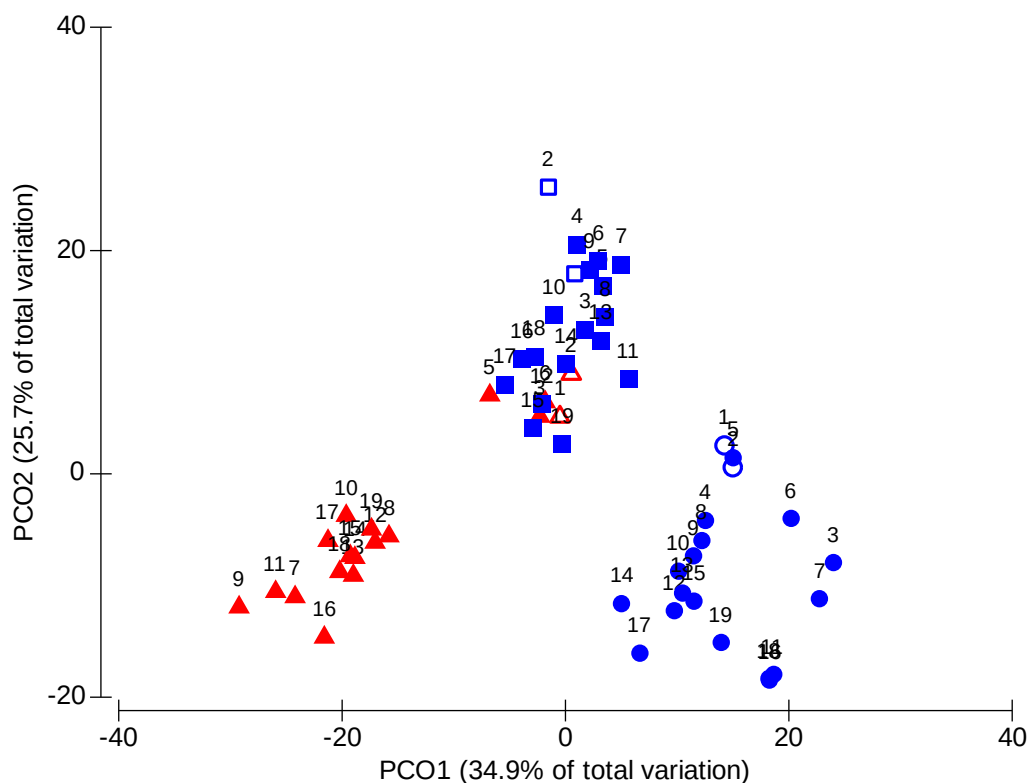


Figure 44. Principal Coordinates Analyses (PCoA) of centroids for each creek and time using Bray-Curtis dissimilarities based on macrophyte data (non-transformed) collected from small pools in Waratah Rivulet (red symbols) and two control pools: Woronora River (blue squares) and O'Hares Creek (blue circles). Empty symbols: 'Before-commencement of mining'; Filled symbols: 'After-commencement of mining'. Sampling commenced in spring 2009.

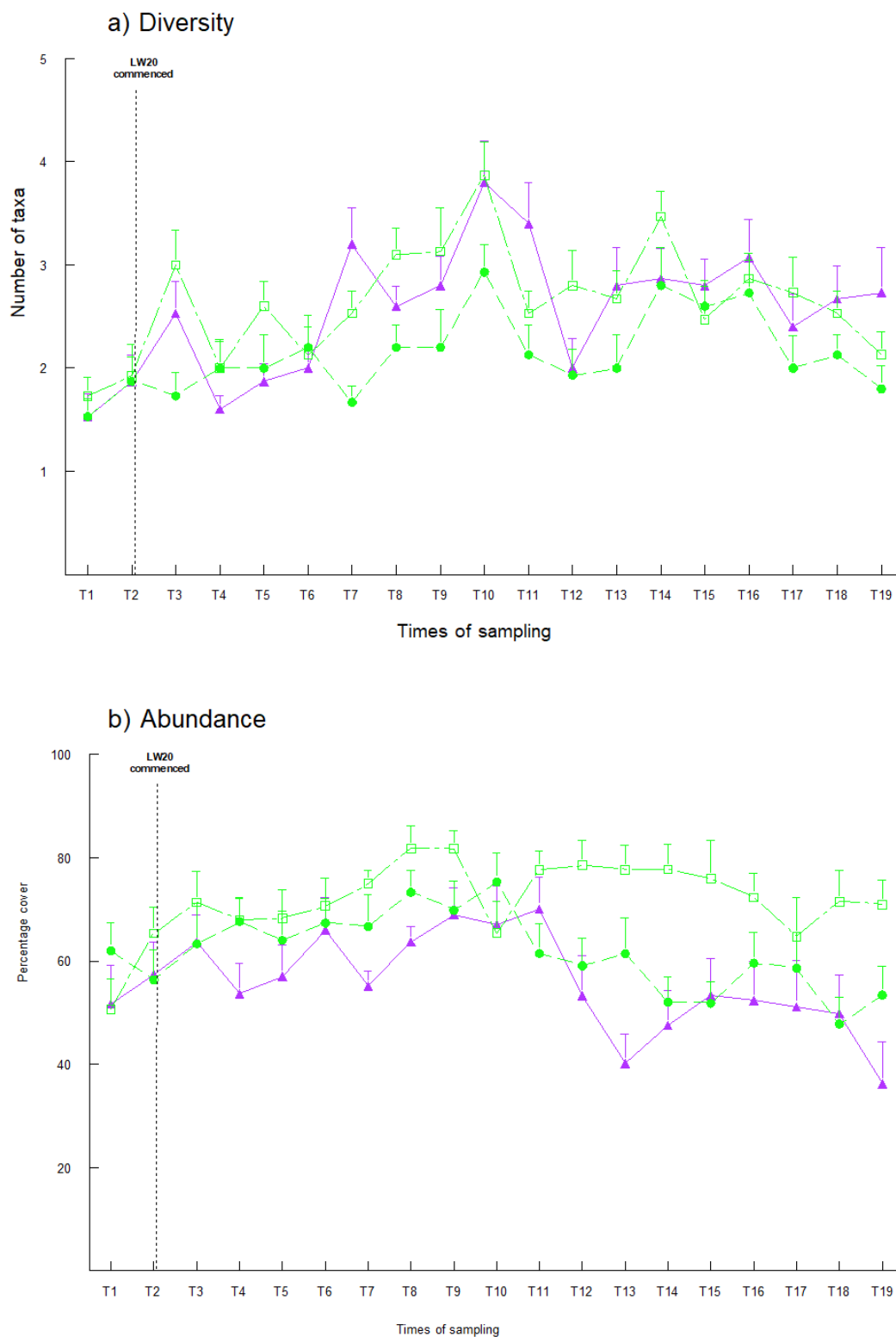


Figure 45. Mean (+SE) of a) diversity and b) cover of macrophytes in pools sampled on Waratah Rivulet (triangles) and control pools (Woronora pools: circles; O'Hares Creek pools: squares) ($n = 15$). Time 1 = spring 2009, T2 = autumn 2010, etc.

5.0 SUMMARY & CONCLUSIONS

The objective of this monitoring program is to assess whether any changes in aquatic macroinvertebrate and/or aquatic macrophyte indicators may have occurred at the potential impact locations or pools sampled in Tributary C/Eastern Tributary, the Waratah Rivulet and Tributary B before-versus after-commencement of mining of Longwalls 20-22. Mining of the Longwalls 20-22 mining area commenced in May 2010 and was completed in April 2014.

To date, up to four monitoring surveys have been carried out prior to commencement of mining of Longwalls 20-22 and up to seventeen surveys within the ‘After-mining’ monitoring phase. The sampling outlined in this assessment was undertaken at control and potential impact places (i.e. stream locations and pools).

A summary of the main findings to date are presented below.

5.1 Stream Monitoring

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

Multivariate and univariate analyses of the monitoring data were used to test whether there was evidence of significant change in aquatic macroinvertebrate and macrophyte indicators at Tributary C/Eastern Tributary locations before- versus after-commencement of mining of Longwalls 20-22, in relation to Control locations.

Evidence of mining related impacts were first noted at Location C1 in autumn 2014. Impacts included iron staining, fracturing of the streambed (predominantly bedrock) and occasional falls in pool water levels below pre-mining levels. Nevertheless, analyses have consistently found no significant changes to aquatic macroinvertebrate or macrophyte indicators that would indicate an impact from mining. A significant Before-to-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.

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. To date, analyses have detected a significant decrease in mean numbers of the freshwater shrimp family, Atyidae, within the after-mining period in spring 2015 and autumn 2017. There have been no measurable changes to macrophyte indicators that would indicate an impact from mining.

In autumn 2013, dieback of riparian vegetation was noted at one of the sites sampled at Location C3 (i.e. Site C3-2), thought to be associated with tilting of the stream bank by mine subsidence. In spring 2015, spring 2017 and autumn 2018 a considerable decline in pool water levels was noted. The study-reach at the downstream site (i.e. Site C3-2) was mostly dry in spring 2017 and autumn 2018. Pool water levels however, were similar to pre-mining levels at the time of the spring 2018 survey. To date, analyses have not found 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.

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 within the after-period in spring 2016, autumn 2018 and spring 2018. Differences appear to be related to diversity decreasing at Location WT3 within the after-mining period whilst 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.

5.1.3 Tributary B (B1)

In spring 2012, a considerable drop in water level was noted in a large pool at Location B1. Since autumn 2013 pools along the study reach have been mostly dry and there has been no surface-flow. Sampling of aquatic macroinvertebrates has not been undertaken at Location B1 since spring 2014, due to insufficient habitat available for sampling.

Past analyses examining patterns of change in the assemblage of aquatic macroinvertebrates and key components at Location B1 on Tributary B in relation to control locations found evidence of impacts related to mining activities within the Longwalls 20-22 underground mining area. Analyses indicate that the assemblage of macrophytes at Location B1 have experienced a degree of environmental stress since spring 2012 as a result of mining activities within the Longwalls 20-22 underground mining area.

As described in the Longwalls 301-303 Biodiversity Management Plan (Metropolitan Coal, 2018), the aquatic ecology subsidence impact performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded at Location B1 for aquatic macroinvertebrates since the spring 2016 survey and assessments have been made against the performance measure. Given the distance from Longwalls 301-303, Tributary B is not expected to experience any measurable subsidence or valley related movements resulting from the extraction of Longwalls 301-303 (Metropolitan Coal, 2016).

5.2 Pool Monitoring

5.2.1 Large Pools (Pools J, M1 & N)

An iron precipitate/micro-organism complex has commonly been observed at the rivulet pools since sampling commenced in spring 2009. Cracking of bedrock in the stream channel of Pools J and M1 was first noted in spring 2013 and spring 2012, respectively. Gas release was noted in Pool J at the time of the spring 2018 survey. Considerable reductions in pool water level were observed in Pool N in spring 2012 (~ 1.8 m) and autumn 2014 (~ 0.8 m), most likely related to mine subsidence.

Analyses have found no evidence to suggest that the composition of assemblages of aquatic macroinvertebrates or macrophytes at the Waratah Rivulet pools (J, M1 and N) have changed significantly before- vs after-mining of the Longwalls 20-22 mining area in relation to the Control pools.

Univariate analyses however, have determined that patterns of change in mean diversity of macroinvertebrates have differed significantly in Pools J (from autumn 2015 to autumn 2017) and M1 (from autumn 2015 to spring 2018) in relation to the control pools. Notably, differences in diversity are likely to be related to mining impacts and have now persisted at Pool M1 for more than 3 consecutive years. As a result, the performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in pools are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded at Pool M1. Accordingly, an assessment against the performance measure, *Negligible impact on Threatened Species, Populations, or Ecological Communities*, is required (see Table 21).

Patterns of change in mean abundance of macroinvertebrates and in mean numbers of Atyidae and Leptophlebiidae in the rivulet pools, including Pool N, did not differ significantly in relation to the control pools.

Analyses of macrophyte indices indicate that mean cover of macrophytes has decreased significantly at Pool M1 within the after-period (since autumn 2016) but not at the control pools. Diversity of macrophytes at Pool N has become significantly more variable within the after-period (since autumn 2016) in relation to the control pools.

5.2.2 Small Pools (Pools K, L & M)

An iron precipitate/micro-organism complex has commonly been observed at the small rivulet pools since sampling commenced in spring 2009. Gas release has been noted in Pool L on several occasions since spring 2012, but not at the time of the spring 2018 survey. Analyses examining temporal and spatial patterns of change in aquatic macroinvertebrates and macrophytes in small pools sampled along the Waratah Rivulet indicate that any effect of subsidence on assemblages has been within the range of natural variability, as measured by the Control pools.

Univariate analyses however, have detected a significant change in mean diversity of macroinvertebrates in the rivulet pools within the after-period since autumn 2015, in relation to the control pools. Overall, there appears to have been an increase in diversity in the rivulet pools within the after-period, but little change within the control pools. Notably, differences in diversity in the small rivulet pools are likely to be related to mining impacts and have now persisted for more than 3 consecutive years. As a result, the performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in pools are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded at Pools K, L and M. Accordingly, an assessment against the performance measure, *Negligible impact on Threatened Species, Populations, or Ecological Communities*, is required (cf Section 5.2.3).

5.2.3 Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan Trigger Action Response Plan

A reconciliation against the Trigger Action Response Plan in the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan has been completed (Table 21).

Table 21. Assessment of Environmental Performance – Underground Mining Area and Surrounds

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded		Comments	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
Monitoring of Aquatic Biota, Stream Monitoring								
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, Locations ET1 ⁹ and ET3 on the Eastern Tributary overlying Longwalls 20-22. - Locations WT4 and WT5 on the Waratah Rivulet, downstream of Longwalls 20-22. - Location ET2 on the Eastern Tributary, downstream of Longwalls 20-22 and within the Longwalls 301-303 35° angle of draw and/or predicted 20 mm subsidence contour. - 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 compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages in Waratah Rivulet or the Eastern Tributary at Locations WT3, ET1 or ET3, located within the LW20-22 mining area during the mining of LW301-303; - occur in aquatic macroinvertebrate and macrophyte assemblages in Waratah Rivulet or the Eastern Tributary at Locations WT4 and WT5 located downstream of the LW20-22 mining area during the mining of LW301-303; or - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET2 during the mining of LW301-303.	Locations WT4, WT5, ET1 and ET3. Locations WT3 and ET2 (all parameters excluding those noted in Level 2 below).	No	No-
				Level 2	Data analysis indicates significant (not long-term), changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages in Waratah Rivulet or the Eastern Tributary at Locations WT3, ET1 or ET3, located within the LW20-22 mining area during the mining of LW301-303; - occur in aquatic macroinvertebrate and macrophyte assemblages in Waratah Rivulet or the Eastern Tributary at Locations WT4 and WT5 located downstream of the LW20-22 mining area during the mining of LW301-303; or - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET2 within the LW301-303 mining area after the completion of Longwall 306.	Location WT3 (change in diversity in spring 2016, autumn 2018 and spring 2018). Location ET2 (change in Atyidae in spring 2015 and autumn 2017 but not subsequently; altered macrophyte assemblage in spring 2014 but not subsequently).	No	No
		Larger pools J, M1 and N on Waratah Rivulet overlying Longwalls 20-22. Smaller pools K, L and M on Waratah Rivulet overlying Longwalls 20-22. One larger control pool on Woronora River (Pool WP) and one larger control pool on O’Hares Creek (Pool OC).	Aquatic macroinvertebrates Aquatic macrophytes	Level 1	Data analysis indicates no significant changes or significant (not long term) changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages at pools J, K, L, M1, M or N.	Larger pools: - Pools J (change in diversity of macroinvertebrates from autumn 2015 to autumn 2017) and N on Waratah Rivulet.	No	No
				Level 3	Data analysis indicates significant long-term changes in relation to control places pre-mining compared to post-extraction:	Larger pools: - Pool M1 (change in diversity of	Yes	Assessment to be conducted

⁹ NB: Site ET1-1 overlies Longwall 22B; Site ET1-2 overlies LW23B (Figure 1)

		Three smaller control pools on Woronora River (Pools WP-A, WP-B and WP-C) and three smaller control pools on O'Hares Creek (Pools OC-A, OC-B and OC-C).			- occur in the aquatic macroinvertebrate and macrophyte assemblages in pools J, K, L, M1, M or N after one year of the completion of stream remediation on Waratah Rivulet.	macroinvertebrates from autumn 2015 to spring 2018; decrease in cover of macrophytes since autumn 2016) on Waratah Rivulet. Smaller pools: - Pools K, L and M (change in diversity of macroinvertebrates since autumn 2015) on Waratah Rivulet.		
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6.0 ACKNOWLEDGEMENTS

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Appendix 1a. GPS positions (UTMs) for stream monitoring sample locations on the Tributary C/Eastern Tributary, Waratah Rivulet, Tributary B, Bee Creek, Woronora Tributary, Woronora River and O'Hares Creek (spring 2018).

System	Location	Site	Easting	Northing
Tributary C	1	1	03116117	6214117
	1	2	0311642	6214197
	2	1	0312168	6215399
	2	2	0312151	6215554
	3	1	0311434	6213617
	3	2	0311464	6213712
Waratah Rivulet	3	1	0309863	6214299
	3	2	0309850	6214435
	4	1	0310426	6215080
	4	2	0310322	6215160
	5	1	0310524	6215345
	5	2	0310662	6215367
Tributary B	1	1	0309554	6215153
	1	2	0309645	6215045
Bee Creek	1	1	0308949	6220220
	1	2	0308973	6220295
Woronora Tributary	1	1	0307672	6219106
	1	2	0307755	6219148
Woronora River	1	1	0307952	6219051
	1	2	0307934	6219105
O'Hares Creek	1	1	0303812	6213711
	1	2	0303643	6213573

**Appendix 1b. GPS positions (UTMs) for pools sampled on the Waratah Rivulet,
TributaryC/Eastern Tributary, Woronora River and O'Hares Creek (spring 2018).**

System	Site Code	Easting	Northing
Waratah Rivulet			
Pool N	PN-1&2	0310138	6214706
Pool J	PJ-1&2	0309854	6214435
Pool M1	PM1-1&2	0309967	6214614
Pool K	PK-1	0309828	6214516
Pool L	PL-1	0309888	6214536
Pool M	PM-1	0309941	6214602
Large Reference Pools			
Woronora River Pool	WP-1&2	0307930	6219115
O'Hares Creek Pool	OC-1&2	0303745	6213657
Small Reference Pools			
Woronora River Pool	WP-A	0307916	6218965
	WP-B	0307915	6218872
	WP-C	0307893	6218882
O'Hares Creek Pool	OC-A	0303543	6213506
	OC-B	0303517	6213525
	OC-C	0303481	6213541

Appendix 2a. Spring 2018 Estimated Cover of Aquatic Macrophyte Species at Stream Sites

Species	Tributary C / Eastern Tributary						Waratah Rivulet						Tributary B		Bee Creek		Woronora Tributary		Woronora River		O'Hares Creek	
	C11	C12	C21	C22	C31	C32	WT31	WT32	WT41	WT42	WT51	WT52	B11	B12	BC1	BC2	WOT1	WOT2	WR11	WR12	OC1	OC2
<i>Baumea juncea</i>	1	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	0	0	0	2	1	0	2	0	0	2	0	2	0	0	0	1	1	1	0	1	0	0
<i>Baumea teretifolia</i>	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	2
<i>Centrolepis fascicularis</i>	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	2
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	1	3	3	3	0	1	0	0	0	0	0	0	0	0	2	1
<i>Chorizandra cymbaria</i>	1	1	0	2	2	1	1	0	0	3	0	3	0	0	1	0	0	1	0	1	0	1
<i>Dicksonia antarctica</i>	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Drosera binata</i>	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	1	0
<i>Drosera spatulata</i>	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	2
<i>Empodisma minus</i>	3	2	2	2	3	2	0	2	1	0	0	0	0	1	2	1	3	3	2	1	2	1
<i>Eurychorda complanata</i>	0	0	0	0	0	0	2	0	0	0	1	3	0	0	3	1	0	0	0	0	0	1
<i>Gahnia clarkei</i>	1	1	0	0	2	3	0	1	0	0	0	0	3	0	2	3	2	2	3	0	1	1
<i>Gleichenia dicarpa</i>	0	2	1	3	3	1	3	3	1	0	3	3	0	0	1	1	3	2	3	3	3	0
<i>Glossosstigma</i> sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
<i>Isolepis inundata</i>	0	0	0	0	0	0	2	0	2	3	0	2	0	0	0	0	0	0	2	0	0	1
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	1	1
<i>Juncus planifolius</i>	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	0	0	0	1	0	0	2
<i>Juncus prismatocarpus</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	2	1	3	0	2	1	2	3	2	3	3	3	2	2	3	3	3	2	3	3	2	2
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0
<i>Lomandra fluvialis</i>	0	0	2	3	3	1	0	0	3	2	1	2	0	0	0	0	0	0	0	0	0	3
<i>Lomandra longifolia</i>	1	0	0	1	0	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	1
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0
<i>Schoenus brevifolius</i>	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Sticherus flabellatus</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	2	0	2	0
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	3	3	3	1	0	0	0	0	0	0	3	3	2	0
<i>Viminaria juncea</i>	3	2	3	1	2	3	2	3	1	0	3	3	3	3	3	1	3	3	0	0	2	0
<i>Xyris operculata</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)
Bio-Analysis Pty Ltd: Marine, Estuarine Freshwater Ecology

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	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
<i>Baumea juncea</i>	0	0	0	0	0	50	0	5	20	50	0	5	0	10	0	5	50	0	0	60
<i>Baumea rubiginosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	5	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	20	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empodisma minus</i>	15	10	5	15	0	0	10	75	0	0	0	0	0	10	0	0	0	0	0	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gahnia clarkei</i>	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0
<i>Gleichenia dicarpa</i>	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	5	0	35	15
<i>Glossosstigma</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	0	0	0	2	15	0	15	0	0	0	5	10	10	2	15	0	0	0	0	0
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0
<i>Lomandra longfolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
<i>Sticherus flabellatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	0	15	5	15	0	0	0	5	2	10	0	0	0	20	0	0	0	0	0	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

Bio-Analysis Pty Ltdy

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	Tributary C / Eastern Tributary										Waratah Rivulet									
Species	C31-1	C31-2	C31-3	C31-4	C31-5	C32-1	C32-2	C32-3	C32-4	C32-5	WT31-1	WT31-2	WT31-3	WT31-4	WT31-5	WT32-1	WT32-2	WT32-3	WT32-4	WT32-5
<i>Baumea juncea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	10	0	0	0	0	0	0	0	0	0	0	5	0	35	0	0	0	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	2	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0	0	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empodisma minus</i>	0	10	15	0	0	90	0	20	0	10	0	0	0	0	0	5	0	0	0	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
<i>Gahnia clarkei</i>	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	35	0
<i>Gleichenia dicarpa</i>	20	0	25	45	65	0	0	0	2	0	70	75	60	0	65	90	75	50	35	70
<i>Glossosstigma</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	0	4	0	15	8	0	75	0	0	0	10	0	0	0	10	0	0	0	0	5
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra longifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sticherus flabellatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	4	0	0	8	4	0	2	0	0	0	0	5	4	0	0	0	15	5	0	20

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

Bio-Analysis Pty Ltdy

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	Waratah Rivulet																			
Species	WT41-1	WT41-2	WT41-3	WT41-4	WT41-5	WT42-1	WT42-2	WT42-3	WT42-4	WT42-5	WT51-1	WT51-2	WT51-3	WT51-4	WT51-5	WT52-1	WT52-2	WT52-3	WT52-4	WT52-5
<i>Baumea juncea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	10	0	0	30	0	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	15	10	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empodisma minus</i>	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	45	0	4	0	0
<i>Gahnia clarkei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gleichenia dicarpa</i>	0	8	0	0	0	0	0	0	0	0	95	40	0	80	0	8	45	60	40	0
<i>Glossostigma</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	15	0	0	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	0	5	0	0	0	0	0	0	0	90	0	0	5	8	10	0	0	0	0	0
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	40	75	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra longifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
<i>Sticherus flabellatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triglochin procerum</i>	0	0	0	0	0	90	0	0	15	0	0	0	20	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	0	0	0	0	0	0	0	0	0	0	0	10	20	0	30	0	2	10	10	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

Bio-Analysis Pty Ltdy

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	Tributary B										Bee Creek									
Species	B11-1	B11-2	B11-3	B11-4	B11-5	B12-1	B12-2	B12-3	B12-4	B12-5	BC1-1	BC1-2	BC1-3	BC1-4	BC1-5	BC2-1	BC2-2	BC2-3	BC2-4	BC2-5
<i>Baumea juncea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empodisma minus</i>	0	0	0	0	0	0	2	0	0	0	0	20	0	0	0	0	0	0	20	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0
<i>Gahnia clarkei</i>	0	0	25	0	0	0	0	0	0	0	0	0	0	45	0	3	2	0	0	0
<i>Gleichenia dicarpa</i>	0	0	0	0	0	0	0	0	0	0	15	0	0	4	0	0	0	15	0	0
<i>Glossosstigma</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	0	0	0	15	0	0	0	2	5	0	0	10	0	0	0	0	35	0	30	18
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra longifolia</i>	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sticherus flabellatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	25	0	20
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	25	0	0	0	5	18	0	0	0	0	0	0	2	4	5	0	0	0	10	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

Bio-Analysis Pty Ltdy

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	Woronora Tributary										Woronora River 1									
Species	WOT1-1	WOT1-2	WOT1-3	WOT1-4	WOT1-5	WOT2-1	WOT2-2	WOT2-3	WOT2-4	WOT2-5	WR11-1	WR11-2	WR11-3	WR11-4	WR11-5	WR12-1	WR12-2	WR12-3	WR12-4	WR12-5
<i>Baumea juncea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empodisma minus</i>	0	0	2	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	10	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gahnia clarkei</i>	2	0	0	0	30	0	0	0	0	0	0	0	45	0	25	0	0	0	0	0
<i>Gleichenia dicarpa</i>	50	25	50	40	0	8	0	0	0	0	0	50	10	8	20	0	0	40	0	60
<i>Glossostigma</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lepidosperma filiforme</i>	0	0	2	0	0	0	0	5	5	20	0	10	10	15	0	0	10	0	0	0
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lomandra longifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sticherus flabellatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	0	0	70	0	0	0	0	0	0	10	0	0
<i>Viminaria juncea</i>	10	25	5	0	5	15	15	0	15	10	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

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Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m² quadrats)

	O'Hares Creek									
Species	OC1-1	OC1-2	OC1-3	OC1-4	OC1-5	OC2-1	OC2-2	OC2-3	OC2-4	OC2-5
<i>Baumea juncea</i>	0	0	0	0	0	0	0	0	0	0
<i>Baumea rubiginosa</i>	0	0	0	0	0	0	0	0	0	0
<i>Baumea teretifolia</i>	0	2	0	15	45	0	0	0	15	0
<i>Centrolepis fascicularis</i>	0	0	0	0	0	0	20	5	4	0
<i>Chara/Nitella</i> spp.	0	0	0	0	0	0	0	0	0	0
<i>Chorizandra cymbaria</i>	0	0	0	0	0	0	0	0	0	0
<i>Drosera spatulata</i>	0	0	0	0	0	0	15	8	0	0
<i>Empodisma minus</i>	0	2	0	0	0	0	0	0	0	0
<i>Eurychorda complanata</i>	0	0	0	0	0	0	0	45	0	0
<i>Gahnia clarkei</i>	0	0	0	0	0	0	0	0	0	0
<i>Gleichenia dicarpa</i>	0	80	95	80	45	0	0	0	0	0
<i>Glossosstigma</i> sp.	0	0	0	0	0	0	15	0	0	0
<i>Isolepis inundata</i>	0	0	0	0	0	0	0	0	2	0
<i>Isolepis prolifera</i> *	0	0	0	0	0	0	0	0	10	0
<i>Juncus planifolius</i>	0	0	0	0	0	0	4	0	0	0
<i>Lepidosperma filiforme</i>	0	0	0	0	0	0	0	0	0	0
<i>Lepyrodia scariosa</i>	0	0	0	0	0	0	0	0	0	0
<i>Lomandra fluviatilis</i>	0	0	0	0	0	70	0	0	0	70
<i>Lomandra longifolia</i>	0	0	0	0	0	0	0	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	0	0	0	0
<i>Schoenus brevifolius</i>	0	0	0	0	0	0	0	0	0	0
<i>Sticherus flabellatus</i>	75	0	0	0	0	0	0	0	0	0
<i>Triglochin procerum</i>	0	0	0	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

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

Longwalls 20-22 Aquatic Monitoring (spring 2018)

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Appendix 3. Spring 2018 AUSRIVAS Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

Taxa	Tributary C / Eastern Tributary						Waratah Rivulet						Tributary B		Bee Creek		Woronora Tributary		Woronora River 1		O'Hares Creek	
	C11	C12	C21	C22	C31	C32	WT31	WT32	WT41	WT42	WT51	WT52	B11#	B12#	BC1	BC2	WOT1	WOT2	WR11	WR12	OC1	OC2
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Atyidae	0	0	0	0	5	0	0	0	1	0	0	2	0	0	0	0	0	0	22	41	2	1
Baetidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Caenidae	0	0	0	0	2	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
Ceinaeidae	0	0	0	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	12	0
Ceratopogonidae	0	0	0	0	0	1	0	3	0	2	0	0	0	0	0	0	0	1	0	0	1	0
Chironomidae (L.) - Chironominae	0	0	4	1	0	3	2	2	1	2	2	7	0	0	20	9	3	4	0	1	1	9
Chironomidae (L.) - Tanypodinae	0	0	1	1	1	0	1	1	1	1	0	2	0	0	3	5	3	0	0	0	2	0
Cordulephyidae	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0
Corixidae	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	1	0	0
Corydalidae	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	4	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Dugesidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	5	11	2	10	0	2	24	8	7	0	0	0	4	3	2	3	0	2	6	5
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
Gelastocoridae	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	14	0	0	1	3	1
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Gomphidae	0	0	0	0	0	1	0	1	4	1	0	0	0	0	0	0	2	0	0	1	1	0
Gyrinidae	0	0	2	0	3	0	3	0	0	2	2	0	0	0	0	3	5	0	6	2	0	0
Hydrophilidae	0	0	0	0	3	1	4	4	4	1	3	4	0	0	1	1	0	0	0	0	3	0
Isostictidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	1	0	2	2	0	0	0	0	0	0	0	2	10	19	6	25	2	0
Leptophlebiidae	0	0	2	2	6	7	8	3	2	12	0	1	0	0	3	18	19	10	16	4	20	6
Libellulidae	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Megapodagrionidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Notonectidae	0	1	0	3	4	3	1	0	0	0	0	0	0	0	0	0	17	5	2	3	5	3
Parastacidae (<i>Cherax</i> sp.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Pyalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Scirtidae	0	0	0	0	3	2	0	2	0	0	0	0	0	0	0	0	0	3	0	2	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Telephlebiidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	2	2	14	25	35	32	22	25	37	41	17	18	0	0	35	43	90	46	55	90	62	28

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

Taxa	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
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Austrocorduliidae (<i>Austrocordulia refracta</i>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	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
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0
Charoboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	2	0	0	0	1	11	5	0	1	0	1	2	0	0	1	2	2	2
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	2	0	8	1	0	4	5	0	4	1	0	0	7	13	3
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	3	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	0	0	1	3	4	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Gyrinidae	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	2	0
Leptophlebiidae	1	0	1	0	0	0	0	0	0	1	0	8	0	12	2	7	5	0
Libellulidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
cf Lumbriculiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	1	0	0	0	0	0	0	3	2	4	0	1	3	0	1	4
Physidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Temnocephalidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unkonwn larvae	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	1	0
Total Macroinvertebrates	3	1	2	2	3	21	7	1	6	14	9	33	3	25	12	18	27	11
Total Taxa	2	1	2	1	3	4	3	1	3	8	6	9	3	6	6	5	8	4

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

Taxa	Waratah Rivulet																	
	WT31-1	WT31-2	WT31-3	WT32-1	WT32-2	WT32-3	WT41-1	WT41-2	WT41-3	WT42 -1	WT42 -2	WT42 -3	WT51-1	WT51-2	WT51-3	WT52-1	WT52-2	WT52-3
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	3	0	0	0	0	0	0	1	0	0	2	1	7	0	1	4	0	5
Austrocorduliidae (<i>Austrocordulia refracta</i>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0
Brentidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	2	0	1	2	0	0	0	0	0	0	0	0	4	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Charoboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	5	1	9	8	1	11	2	0	0	2	2	0	2	0	3	2
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Corixidae	0	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	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	0	0	2	1	2	1	4	2	3	0	3	2	2	0	8	1	1	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	1	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	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	1	1	1	0	1	3	0	1	2	0	0	2	0	0	2	1	2	1
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	2	0	0	0	0	0	0	0	0	0	0	3	1	0	3	0
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	3	0	0	0	0	0	0	0	0	0	0	0	1	8	3	2	0	5
Leptophlebiidae	8	0	9	9	0	3	2	1	0	16	3	0	7	1	3	0	2	2
Libellulidae	0	0	0	2	0	2	0	1	0	0	0	0	0	0	0	0	0	1
cf Lumbriculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0
Physidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temnocephalidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unkonwn larvae	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	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	15	1	25	14	21	24	8	18	8	17	10	13	22	12	25	8	13	16
Total Taxa	4	1	8	5	8	9	4	7	4	2	5	8	8	3	9	4	7	6

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

Taxa	Tributary B						Bee Creek						WoronoraTributary					
	B1-1	B1-2	B1-3	B2-1	B2-2	B2-3	BC1-1	BC1-2	BC1-3	BC2-1	BC2-2	BC2-3	WOT1-1	WOT1-2	WOT1-3	WOT2-1	WOT2-2	WOT2-3
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3	2
Atyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocorduliidae (<i>Austrocordulia refracta</i>)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	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
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	1	0
Charoboridae	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	91	7	1	8	2	1	2	1	1	5	6
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0	1	6	8	1	0	0
Culicidae	0	0	0	0	0	0	0	9	0	2	1	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
Dugesidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	0	0	0	0	3	4	0	4	0	0	2	2	0	4	4
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	1	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	1	0	1	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	0	0	0	0	0	1	0	2	4	8	6	3	2
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	3	0	4	2	6	15	7	9
Leptophlebiidae	0	0	0	0	0	0	0	0	0	17	16	1	18	7	6	8	14	9
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf Lumbiculiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0	0	0	1	11	20	1	1	2
Physidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	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
Temnocephalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Tipulidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unkonwn larvae	0	0	0	0	0	0	0	3	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	0	0	0	0	0	0	0	119	13	21	33	3	32	34	55	40	39	34
Total Taxa	0	0	0	0	0	0	0	8	4	4	6	2	10	7	11	10	9	7

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

Taxa	Woronora River 1						O'Hares Creek					
	WR11-1	WR11-2	WR11-3	WR12-1	WR12-2	WR12-3	OC1-1	OC1-2	OC1-3	OC2-1	OC2-2	OC2-3
Acariformes	0	0	0	0	1	0	2	1	0	2	0	2
Atyidae	21	15	17	18	33	11	2	1	12	1	3	0
Austrocorduliidae (<i>Austrocordulia refracta</i>)	0	0	0	0	0	0	0	0	3	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	1	0	0	0	1
Ceinidae	0	0	0	0	0	0	0	31	1	0	0	0
Ceratopogonidae	1	0	0	1	0	0	0	1	0	0	0	1
Charoboridae	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	1	2	1	1	0	0	1	18	6	9	4	10
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	4	0	0
Corixidae	0	1	0	3	0	0	0	0	0	0	1	1
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	2	1	0	0	0
Dugesiidae	0	0	0	0	0	0	0	1	0	1	0	0
Dytiscidae	1	0	0	0	1	0	7	4	0	10	9	8
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	4	0	0	0	1	0	6	1	1	1	0	4
Gelastocoridae	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	1	1	2	0	0	2	1	1	7	2	2
Gomphidae	0	0	2	0	0	0	3	0	0	0	1	1
Gripopterygidae	1	1	0	1	0	2	0	0	0	0	0	0
Gyrinidae	1	2	0	2	0	1	0	0	0	0	0	0
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	3	3	0	0	3	1
Hydroptilidae	0	0	1	0	0	0	0	0	0	0	0	1
Leptoceridae	1	3	5	8	6	7	1	1	1	0	0	0
Leptophlebiidae	18	5	15	1	1	1	3	2	29	4	3	4
Libellulidae	0	0	0	0	0	0	0	0	0	0	3	0
cf Lumbriculiidae	0	0	0	0	0	0	0	0	0	0	1	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	2	0
Mesoveliidae	0	11	13	6	0	3	0	0	0	0	0	0
Notonectidae	3	1	1	8	10	3	0	0	0	8	4	4
Physidae	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0
Pyalidae	0	0	2	1	3	1	0	0	0	0	0	0
Scirtidae	0	0	0	1	1	2	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	1	0
Synlestidae	0	0	0	0	0	0	1	0	0	0	0	0
Synthemistidae	0	0	1	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0
Temnocephalidae	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0
Veliidae	2	3	1	0	0	1	0	0	0	0	0	2
Unkonwn larvae	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
Total Macroinvertebrates	54	45	60	53	57	33	31	68	55	47	37	42
Total Taxa	11	11	12	13	9	11	11	14	9	10	13	14

Appendix 5. Spring 2018 Measurements of Water Quality Variables Recorded at each Stream Site

	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)	19.2	19.07	19.06	24.62	24.66	24.6	19.13	19.12	19.08	17	16.85	16.85	16.27	16.26	16.25	17.01	17.09	17.11
pH	6.94	6.9	6.88	6.96	6.98	6.99	6.66	6.67	6.68	7.02	7.03	7.03	6.49	6.48	6.48	7.16	7.17	7.15
Conductivity (µS/cm)	146	146	146	151	151	151	212	212	212	232	232	232	165	165	165	156	156	156
Dissolved Oxygen (%Sat)	78.1	76.7	75.6	94.3	96.9	98	59.9	59.7	59.2	49.9	48.2	47.6	64.4	64.4	64.4	80.6	80.3	80.3
Turbidity (NTU)	38.6	37.4	36.8	19.3	19.7	20.3	58.3	57.5	57.1	63.2	62.8	62.4	11.2	11.2	11.2	21.7	21.7	21.8
REDOX (mv)	492	494	494	505	504	503	665	665	635	609	605	603	447	449	451	511	511	510
Alkalinity (mg/L)	18	N/R	N/R	18	N/R	N/R	17	N/R	N/R	25	N/R	N/R	19	N/R	N/R	20	N/R	N/R
Total phosphorous (mg/L)	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.09	0.17	N/R	0.11	0.05	N/R	<0.05	<0.05	N/R	<0.05	<0.05	N/R	0.14	0.06	N/R	0.08	0.1	N/R

N/R = Not recorded

	Waratah Rivulet																	
	WT31-1	WT31-2	WT31-3	WT32-1	WT32-2	WT32-3	WT41-1	WT41-2	WT41-3	WT42-1	WT42-2	WT42-3	WT51-1	WT51-2	WT51-3	WT52-1	WT52-2	WT52-3
Temperature (°C)	22.6	22.6	22.7	23.61	23.26	23.28	19.255	19.25	19.25	19.06	19.01	19.08	19.5	19.58	19.6	23.55	23.27	23.24
pH	7.8	7.8	7.8	8.09	8.08	8.07	6.9	7.0	7.0	7.18	7.19	7.18	8.05	8.05	8.04	8.01	8.04	8.05
Conductivity (µS/cm)	162	162	162	164	164	163	215	215	215	216	216	216	182	181	182	185	186	186
Dissolved Oxygen (%Sat)	106.3	106.5	106.6	115.8	114.7	113.4	83.3	83.1	83.1	84.2	84.4	84.3	99.4	99.5	99.4	118.9	121.7	122.7
Turbidity (NTU)	30.6	30	29.9	24.1	21.5	21.1	9.8	9.8	9.7	7.5	6.6	5.6	80.7	78.9	78.3	79.9	79.1	78.7
REDOX (mv)	472	472	472	495	496	496	594.0	594.0	594.0	600.0	599.0	599.0	582	583	583	587	587	587
Alkalinity (mg/L)	24	N/R	N/R	30	N/R	N/R	45	N/R	N/R	30	N/R	N/R	27	N/R	N/R	35	N/R	N/R
Total phosphorous (mg/L)	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	0.03	0.09	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.15	0.15	N/R	0.12	0.09	N/R	0.06	0.08	N/R	0.22	0.24	N/R	0.14	0.13	N/R	0.07	0.09	N/R

N/R = Not recorded

	Tributary B						Bee Creek						Woronora Tributary					
	B11-1	B11-2	B11-3	B12-1	B12-2	B12-3	BC1-1	BC1-2	BC1-3	BC2-1	BC2-2	BC2-3	WOT1-1	WOT1-2	WOT1-3	WOT2-1	WOT2-2	WOT2-3
Temperature (°C)	I/S	I/S	I/S	I/S	I/S	I/S	15.04	15.04	15.04	15.54	15.39	15.39	17.22	17.23	17.23	14.62	14.61	14.6
pH	I/S	I/S	I/S	I/S	I/S	I/S	4.98	4.97	4.97	5.63	5.61	5.6	5.86	5.85	5.85	5.97	5.96	5.95
Conductivity (µS/cm)	I/S	I/S	I/S	I/S	I/S	I/S	230	230	230	204	204	204	93	93	93	104	104	104
Dissolved Oxygen (%Sat)	I/S	I/S	I/S	I/S	I/S	I/S	9.5	13.6	13.7	40.3	40.2	40.2	68.3	68.1	67.5	45.9	45.5	45.3
Turbidity (NTU)	I/S	I/S	I/S	I/S	I/S	I/S	5.3	4.6	4.4	9.4	8.9	8.7	68.4	70.2	71.2	67.4	67.4	67.4
REDOX (mv)	I/S	I/S	I/S	I/S	I/S	I/S	531	531	532	531	534	537	624	625	626	600	601	603
Alkalinity (mg/L)	I/S	I/S	I/S	I/S	I/S	I/S	5	N/R	N/R	5	N/R	N/R	0	N/R	N/R	0	N/R	N/R
Total phosphorous (mg/L)	I/S	I/S	I/S	I/S	I/S	I/S	<0.02	30	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	I/S	I/S	I/S	I/S	I/S	I/S	0.36	0.44	N/R	0.09	0.11	N/R	0.25	0.23	N/R	0.4	0.27	N/R

I/S = Insufficient Aquatic Habitat

	Woronora River 1						O'Hares Creek					
	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)	17.1	17.1	17.1	18.41	18.43	18.47	22.38	22.36	22.36	24.6	24.6	24.6
pH	6.95	6.95	6.94	6.75	6.74	6.73	6.71	6.67	6.65	7.02	7	6.99
Conductivity (µS/cm)	123	127	127	119	119	119	108	108	108	114	114	114
Dissolved Oxygen (%Sat)	55.7	55.5	55.4	64.1	63.4	63.3	97.5	97.1	96.9	102.5	102.3	102.1
Turbidity (NTU)	68.0	68.0	68.0	70.8	70.6	70.8	22	21.8	21.7	23.0	23.0	22.8
REDOX (mv)	662	662	662	667	667	667	597	598	598	575	575	575
Alkalinity (mg/L)	5	N/R	N/R	5	N/R	N/R	5	N/R	N/R	5	N/R	N/R
Total phosphorous (mg/L)	24	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.22	0.16	N/R	0.15	0.14	N/R	0.18	0.16	N/R	0.19	0.26	N/R

N/R = Not recorded

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

Longwalls 20-22 Aquatic Ecology Monitoring (spring 2018)

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Appendix 6a. Spring 2018 Estimated Cover of Aquatic Macrophytes at Large Pool Sites

	Waratah Rivulet						Woronora River		O'Hares Creek	
Species	J1	J2	M11	M12	PN1	PN2	WP1	WP2	OC1	OC2
<i>Baumea rubiginosa</i>	0	0	0	0	3	3	2	1	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	0	3	2
<i>Centrolepis fascicularis</i>	0	1	1	2	0	1	1	1	0	0
<i>Chara/Nitella</i> spp.	3	1	1	0	2	1	0	0	2	3
<i>Chorizandra cymbaria</i>	0	0	0	3	2	2	2	1	0	0
<i>Dicksonia antarctica</i>	1	0	0	0	2	1	0	0	0	1
<i>Drosera binata</i>	2	2	1	0	0	0	0	0	1	1
<i>Drosera spatulata</i>	0	1	0	0	0	0	1	1	0	0
<i>Empodisma minus</i>	2	1	0	1	1	1	0	1	2	2
<i>Eurychorda complanata</i>	0	2	1	0	0	0	3	0	0	0
<i>Gahnia clarkei</i>	1	0	0	0	2	3	1	0	1	2
<i>Gleichenia dicarpa</i>	3	3	1	0	2	1	2	3	3	3
<i>Glossostigma</i> sp.	0	0	0	0	0	0	1	1	0	0
<i>Isolepis inundata</i>	0	3	1	1	0	0	0	0	0	0
<i>Isolepis prolifera</i> *	0	0	2	0	0	0	0	0	1	0
<i>Juncus planifolius</i>	0	1	2	2	1	1	0	0	0	0
<i>Lepidosperma filiforme</i>	3	2	2	0	2	3	0	3	2	2
<i>Lomandra fluviatilis</i>	0	0	2	1	1	0	0	0	0	0
<i>Lomandra longifolia</i>	0	0	1	0	2	2	1	0	0	0
<i>Myriophyllum pedunculatum</i>	0	0	0	0	0	0	3	1	0	0
<i>Sticherus flabellatus</i>	0	0	0	0	1	0	0	0	2	2
<i>Triglochin procerum</i>	0	1	0	0	3	3	3	3	2	2
<i>Viminaria juncea</i>	3	3	1	1	1	0	0	0	2	2
<i>Xyris operculata</i>	0	1	0	0	0	0	0	0	0	0

Appendix 6b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Large Pool Sites (0.25 m2 quadrats)

Pool J on Waratah Rivulet											Pool M1 on Waratah Rivulet										
Species	J1-1	J1-2	J1-3	J1-4	J1-5	J2-1	J2-2	J2-3	J2-4	J2-5	M11-1	M11-2	M11-3	M11-4	M11-5	M12-1	M12-2	M12-3	M12-4	M12-5	
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	2	0	0	10	0	0	0	0	0	0	0	10	
Chara/Nitella spp.	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	30	40	0	20	0	
Dicksonia antarctica	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	2	0	0	0	0	0	0	0	0	
Empodisma minus	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Eurychorda complanata	0	0	0	0	0	0	0	0	0	50	0	0	40	0	0	0	0	0	0	0	
Gahnia clarkei	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Gleichenia dicarpa	90	75	50	35	70	55	15	0	40	5	0	0	4	0	0	0	0	0	0	0	
Glossostigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Isolepis inundata	0	0	0	0	0	0	0	0	30	5	0	0	0	0	0	4	0	0	0	0	
Juncus planifolius	0	0	0	0	0	0	0	15	0	0	0	0	0	2	0	0	0	0	0	0	
Lepidosperma filiforme	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0	0	10	
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Viminaria juncea	0	15	5	0	20	20	40	0	15	0	0	0	0	0	0	10	0	0	0	0	
* Denotes introduced species																					
Pool N on Waratah Rivulet											Pool WP on Woronora River										
Species	PN1-1	PN1-2	PN1-3	PN1-4	PN1-5	PN2-1	PN2-2	PN2-3	PN2-4	PN2-5	WP1-1	WP1-2	WP1-3	WP1-4	WP1-5	WP2-1	WP2-2	WP2-3	WP2-4	WP2-5	
Baumea rubiginosa	25	0	0	0	0	0	0	0	35	70	0	0	0	15	0	3	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	6	0	0	0	0	
Chara/Nitella spp.	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Chorizandra cymbaria	0	0	80	0	0	0	0	0	0	15	0	0	0	5	0	0	0	0	0	0	
Dicksonia antarctica	0	0	0	0	4	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	
Empodisma minus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	10	5	0	0	70	0	0	0	0	0	
Gahnia clarkei	0	25	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	
Gleichenia dicarpa	0	0	0	30	0	0	0	0	0	10	75	0	5	0	0	0	0	40	0	60	
Glossostigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lepidosperma filiforme	0	0	0	0	0	0	40	5	0	0	0	0	0	0	0	0	10	0	0	0	
Lomandra fluviatilis	0	70	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	95	0	20	20	0	0	0	0	
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Triglochin procerum	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
* Denotes introduced species																					
Pool OC on 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 rubiginosa	0	0	0	0	0	0	0	0	0	0											
Baumea teretifolia	0	2	0	15	45	0	0	0	15	0											
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0											
Chara/Nitella spp.	0	0	0	0	0	0	0	0	0	35											
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0											
Dicksonia antarctica	0	0	0	0	0	0	0	0	0	0											
Drosera binata	0	0	0	0	0	0	0	0	0	0											
Empodisma minus	0	2	0	0	0	0	20	0	0	0											
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0											
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0											
Gleichenia dicarpa	0	80	95	80	45	55	35	20	20	0											
Glossostigma sp.	0	0	0	0	0	0	0	0	0	0											
Isolepis inundata	0	0	0	0	0	0	0	0	0	0											
Juncus planifolius	0	0	0	0	0	0	0	0	0	0											
Lepidosperma filiforme	0	0	0	0	0	5	0	5	0	0											
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0											
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0											
Sticherus flabellatus	75	0	0	0	0	0	0	70	0	0											
Triglochin procerum	0	0	0	0	0	0	0	0	0	55											
Viminaria juncea	0	0	0	0	0	0	0	0	55	0											
* Denotes introduced species																					

Site Codes: J1-1 = Pool J, Site 1, Replicate 1, etc.

Longwalls 20-22 Aquatic Monitoring (spring 2018)
Bio-Analysis Pty Ltd: Marine, Estuarine Freshwater Ecology

Appendix 7. Spring 2018 Quantitative Sampling of Large Pools - Macroinvertebrate Taxa and Abundance

Taxa	Pool J on Waratah Rivulet						Pool M1 on Waratah Rivulet						Pool N on Waratah Rivulet					
	PJ1-1	PJ1-2	PJ1-3	PJ2-1	PJ2-2	PJ2-3	PM11-1	PM11-2	PM11-3	PM12-1	PM12-2	PM12-3	PN1-1	PN1-2	PN1-3	PN2-1	PN2-2	PN2-3
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	0	0	0	1	0	2	0	0	1
Austrocorduliidae (<i>Austrocordulia</i> ref)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	2	0	1	0	1	2	3	0	0	4	1	1	2	2	4	1	3	0
Ceinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae (L.)	0	0	1	0	2	2	0	0	0	0	2	0	0	0	0	0	1	0
Chironomidae	0	1	3	1	9	8	6	2	3	6	2	2	1	1	1	0	0	1
Cordulephidae	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	1	1	0	0	1	2	0	0	2	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae (A. & L.)	0	0	0	1	2	1	8	2	4	6	7	7	2	4	1	2	1	1
Ecnomidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Elmidae (A. & L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	5	2	1	0	1	3	0	6	0	1	1	1	0	0	4	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae (A. & L.)	0	0	0	0	0	0	2	0	0	1	2	1	0	1	0	0	2	2
Hydrophilidae (A.)	0	1	0	0	1	0	0	0	1	2	0	0	0	3	0	0	0	0
Hydroptilidae	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	1	6	1	0	1	2	1	5
Leptophlebiidae	1	2	2	9	0	3	10	8	7	29	18	41	1	5	28	19	14	6
Libellulidae	0	1	1	2	0	2	1	2	0	1	2	1	0	1	0	0	0	0
Mesovellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nepidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Physidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrallidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae (A. & L.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Telephlebiidae	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	0	0	1	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dipteran pupae	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	8	8	9	14	21	24	31	21	16	52	40	64	8	19	43	25	22	16
Total Taxa	3	6	6	5	9	9	7	6	5	10	12	10	6	8	8	5	6	6

Site Codes: PJ1-1 = Pool J, Site 1, Replicate 1, etc.

Appendix 7. Spring 2018 Quantitative Sampling of Large Pools - Macroinvertebrate Taxa and Abundance

Taxa	Pool WP on Woronora River						Pool OC on O'Hares Creek					
	WP1-1	WP1-2	WP1-3	WP2-1	WP2-2	WP2-3	OC1-1	OC1-2	OC1-3	OC2-1	OC2-2	OC2-3
Aeshnidae	0	1	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	1	0	1	0	0	0	2	2	1	0
Atyidae	16	16	33	18	33	11	0	1	3	2	1	12
Austrocorduliidae (<i>Austrocordulia ref</i>	0	0	0	0	0	0	0	0	0	0	0	3
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	1	0	1	0
Ceinaidae	0	0	0	0	0	0	5	1	0	0	31	1
Ceratopogonidae (L.)	1	1	0	1	0	0	0	1	0	0	1	0
Chironomidae	0	1	5	1	0	0	0	1	1	1	18	6
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	3	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	2	1
Dugesidae	0	0	0	0	0	0	0	0	0	0	1	0
Dytiscidae (A. & L.)	1	0	2	0	1	0	1	2	6	7	4	0
Ecmonidae	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae (A. & L.)	0	1	1	0	1	0	0	4	4	6	1	1
Gerridae	0	0	0	2	0	0	5	0	0	2	1	1
Gomphidae	0	0	0	0	0	0	1	0	1	3	0	0
Gripopterygidae	0	0	1	1	0	2	0	0	0	0	0	0
Gyrinidae (A. & L.)	0	4	0	2	0	1	0	0	0	0	0	0
Hydrophilidae (A.)	0	0	0	0	0	0	0	0	0	3	3	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	4	1	16	8	6	7	0	0	1	1	1	1
Leptophlebiidae	3	0	9	1	1	1	0	1	9	3	2	29
Libellulidae	0	0	0	0	0	0	0	0	1	0	0	0
Mesovellidae	5	1	0	6	0	3	0	0	0	0	0	0
Nepidae	0	1	0	0	0	0	0	0	0	0	0	0
Notonectidae	9	2	3	8	10	3	2	3	4	0	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	1	0	0	0	0	0	0	0	0	0
Pyrallidae	0	2	1	1	3	1	0	0	0	0	0	0
Scirtidae (A. & L.)	0	0	0	1	1	2	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	1	0	0
Synthemistidae	0	0	2	0	0	0	0	0	0	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0
Veliidae	1	1	1	0	0	1	0	0	1	0	0	0
Dipteran pupae	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	40	32	76	53	57	33	14	14	34	31	68	55
Total Taxa	8	12	13	13	9	11	5	8	12	11	14	9

Site Codes: PJ1-1 = Pool J, Site 1, Replicate 1, etc.

Appendix 8. Spring 2018 Measurements of Water Quality Recorded at each Large Pool Site.

	Pool J on Waratah Rivulet					
Taxa	PJ1-1	PJ1-2	PJ1-3	PJ2-1	PJ2-2	PJ2-3
Temperature (°C)	23.8	22.8	23.1	23.61	23.26	23.28
pH	8.1	8.1	8.1	8.09	8.08	8.07
Conductivity (µS/cm)	162	166	166	164	164	163
Dissolved Oxygen (%Sat)	111.5	116.8	117.1	115.8	114.7	113.4
Turbidity (NTU)	18.7	19.1	19.1	24.1	21.5	21.1
REDOX (mv)	484	487	488	495	496	496

	Pool M1 on Waratah Rivulet					
Taxa	PM11-1	PM11-2	PM11-3	PM12-1	PM12-2	PM12-3
Temperature (°C)	21.3	21.15	21.15	19.82	19.76	19.76
pH	7.57	7.56	7.56	7.52	7.51	7.51
Conductivity (µS/cm)	162	162	162	162	162	162
Dissolved Oxygen (%Sat)	103	102.6	102.1	99.9	100	99.9
Turbidity (NTU)	24.3	25.4	24.1	2.5	2.5	2.5
REDOX (mv)	418	421	423	409	408	408

	Pool N on Waratah Rivulet					
Taxa	PN1-1	PN1-2	PN1-3	PN2-1	PN2-2	PN2-3
Temperature (°C)	19.87	19.97	20.04	20.34	20.31	20.33
pH	7.53	7.52	7.51	7.48	7.49	7.49
Conductivity (µS/cm)	162	162	161	160	161	160
Dissolved Oxygen (%Sat)	87.9	86.6	86.2	91.6	91.7	91.9
Turbidity (NTU)	2.5	2.5	2.5	21.7	21.7	21.7
REDOX (mv)	473	474	474	462	464	464

	Pool WP on Woronora River					
Taxa	WP1-1	WP1-2	WP1-3	WP2-1	WP2-2	WP2-3
Temperature (°C)	17.7	17.7	17.0	18.4	18.4	18.5
pH	6.76	6.76	6.75	6.75	6.74	6.73
Conductivity (µS/cm)	121	121	121	119	119	119
Dissolved Oxygen (%Sat)	62.2	62	62.1	64.1	63.4	63.3
Turbidity (NTU)	69.2	69.0	68.6	70.8	70.6	70.8
REDOX (mv)	670	670	669	667	667	667

	Pool OC on O'Hares Creek					
Taxa	OC1-1	OC1-2	OC1-3	OC2-1	OC2-2	OC2-3
Temperature (°C)	22.38	22.36	22.36	22.06	22.01	22.03
pH	6.71	6.67	6.65	6.57	6.49	6.44
Conductivity (µS/cm)	108	108	108	109	109	109
Dissolved Oxygen (%Sat)	97.5	97.1	96.9	94.7	93.3	92.7
Turbidity (NTU)	22	21.8	21.7	25.4	24.1	23.8
REDOX (mv)	597	598	598	610	618	618

Site Codes: J11 = Pool J, Site 1, Rep. 1, etc

Appendix 9a. Spring 2018 Estimated Cover of Aquatic Macrophytes at Small Pool Sites

	Waratah Rivulet			Woronora River			O'Hares Creek		
Species	K	L	M	WPA	WPB	WPC	OCA	OCB	OCC
<i>Baumea rubiginosa</i>	1	1	0	1	0	0	0	0	0
<i>Baumea teretifolia</i>	0	0	0	0	0	0	0	1	0
<i>Centrolepis fascicularis</i>	1	0	2	1	1	0	0	1	0
<i>Chara/Nitella</i> spp.	1	1	2	0	0	0	1	1	2
<i>Chorizandra cymbaria</i>	0	0	1	1	1	0	0	1	0
<i>Dicksonia</i>	0	0	0	0	0	0	1	0	0
<i>Drosera binata</i>	1	2	0	0	0	0	0	0	0
<i>Drosera spatulata</i>	1	0	0	1	1	0	1	0	0
<i>Empodisma minus</i>	2	2	1	0	1	1	3	3	2
<i>Eurychorda complanata</i>	2	1	1	1	3	0	1	0	2
<i>Gahnia clarkei</i>	0	0	2	1	0	0	1	1	2
<i>Gleichenia dicarpa</i>	1	3	3	3	1	1	2	3	3
<i>Glossostigma</i> sp.	0	0	0	1	0	0	1	0	0
<i>Isolepis inundata</i>	1	1	2	0	0	0	0	0	1
<i>Isolepis prolifera</i> *	1	0	2	0	0	0	0	0	0
<i>Juncus planifolius</i>	1	0	2	2	2	0	0	0	1
<i>Lepidosperma filiforme</i>	0	2	2	2	2	2	2	2	2
<i>Lomandra fluviatilis</i>	0	1	0	0	2	2	3	2	3
<i>Lomandra longifolia</i>	0	1	0	0	0	0	1	1	1
<i>Myriophyllum pedunculatum</i>	0	0	0	1	0	0	0	0	0
<i>Sticherus flabellatus</i>	0	0	0	1	2	1	1	1	0
<i>Triglochin procerum</i>	0	0	0	3	3	0	0	0	0
<i>Xyris operculata</i>	0	1	0	0	0	0	0	0	0
<i>Viminaria juncea</i>	2	2	2	0	0	0	0	0	2

* Denotes introduced species

Site Codes: K = Pool K, etc

Appendix 9b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Small Pool Sites

	Pool K on Waratah Rivulet					Pool L on Waratah Rivulet					Pool M on Waratah Rivulet				
Species	K-1	K-2	K-3	K-4	K-5	L-1	L-2	L-3	L-4	L-5	M-1	M-2	M-3	M-4	M-5
Baumea rubiginosa	0	0	0	0	0	2	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
Centrolepis fascicularis	0	0	0	0	2	0	0	0	0	0	0	0	0	0	10
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	5	4	0	10	0	0	0	0	0	0	0
Drosera spatulata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	2	2	4	8	0	0	0	0	0	0	10	0
Eurychorda complanata	0	0	2	0	18	0	0	10	0	0	30	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0
Gleichenia dicarpa	30	0	2	0	0	85	60	45	0	0	10	2	40	5	0
Isolepis inundata	4	0	0	0	4	0	0	0	0	0	0	0	0	0	10
Isolepis prolifera*	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Juncus planifolius	4	0	0	0	0	0	0	0	0	0	0	40	0	0	2
Lepidosperma filiforme	0	0	0	0	0	4	8	0	0	0	0	0	10	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	3	2	0	10	8	0	0	0	0	0	2	0

* Denotes introduced species

	Pool A on Woronora River					Pool B on Woronora River					Pool C on Woronora River				
Species	WPA-1	WPA-2	WPA-3	WPA-4	WPA-5	WPB-1	WPB-2	WPB-3	WPB-4	WPB-5	WPC-1	WPC-2	WPC-3	WPC-4	WPC-5
Baumea rubiginosa	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
Centrolepis fascicularis	0	0	2	0	0	0	0	55	0	0	0	0	0	0	0
Chorizandra cymbaria	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
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	0	0	0	4	0	10	0	0	0	0
Eurychorda complanata	40	0	0	0	0	0	25	0	4	60	0	0	0	0	0
Gahnia clarkei	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	60	0	60	15	0	10	0	0	0	5	0	10	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis prolifera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	15	0	0	0	15	0	0	0	0	0	0	0	40	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	60	0	0	40	10	80	60
Sticherus flabellatus	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	25	0	0	0	0	8	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

	Pool A on O'Hares Creek					Pool B on O'Hares Creek					Pool C on O'Hares Creek				
Species	OCA-1	OCA-2	OCA-3	OCA-4	OCA-5	OCB-1	OCB-2	OCB-3	OCB-4	OCB-5	OCC-1	OCC-2	OCC-3	OCC-4	OCC-5
Baumea rubiginosa	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	10	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Drosera binata	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
Empodisma minus	95	0	0	50	25	50	0	25	40	2	5	40	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Gleichenia dicarpa	0	0	0	15	30	25	20	0	0	10	95	0	0	70	35
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis prolifera*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	10	0	0	25	0	20	0	0	0	5	0
Lomandra fluviatilis	0	95	55	0	0	0	25	0	0	0	0	20	90	0	0
Sticherus flabellatus	0	0	15	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
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

Appendix 10. Spring 2018 Quantitative Sampling of Small Pools - Macroinvertebrate Taxa and Abundance

	Pool K on Waratah Rivulet			Pool L on Waratah Rivulet			Pool M on Waratah Rivulet			Pool A on Woronora River			Pool B on Woronora River			Pool B on Woronora River		
Taxa	PK1-1	PK1-2	PK1-3	PL1-1	PL1-2	PL1-3	PM1-1	PM1-2	PM1-3	WPA1-1	WPA1-2	WPA1-3	WPB1-1	WPB1-2	WPB1-3	WPC1-1	WPC1-2	WPC1-3
Acariformes	0	1	0	0	0	0	0	0	0	1	1	0	0	0	3	4	0	0
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	22	1	60	27	31	0	0	0
Austrocorduliidae (<i>Austrocordulia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Chironomidae	0	3	3	1	3	27	5	1	0	1	2	2	0	0	3	1	0	0
Cordulephyidae	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	1	0	0	0	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	3	0	1	2	4	3	5	17	0	1	1	0	0	0	9	0	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	1	0	8	1	10	0	0	0
Gerridae	0	0	0	0	0	1	0	1	0	1	1	0	5	0	3	0	0	0
Gomphidae	0	0	0	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Gyrinidae	0	0	0	0	1	3	0	2	1	0	0	0	2	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hydrophilidae	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	1	0	3	4	2	2	0	0
Leptophlebiidae	0	3	5	3	1	0	17	2	10	9	7	3	0	0	3	23	0	0
Libellulidae	0	1	0	0	1	1	4	0	2	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Mesovellidae	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0	2	1	5	3	12	2	0	0
Psephenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Pyrallidae	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Synthemistidae	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Unidentified Anisoptera adult fly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	0	14	10	10	11	40	32	12	33	13	46	13	88	45	72	41	0	0
Total Taxa	0	8	4	7	7	9	7	6	6	5	15	9	9	9	13	6	0	0

Site Codes: PK1-1 = Pool K, Replicate 1, etc.

Appendix 10. Spring 2018 Quantitative Sampling of Small Pools - Macroinvertebrate Taxa and Abundance

	Pool A on O'Hares Creek			Pool B on O'Hares Creek			Pool C on O'Hares Creek		
Taxa	OCA1-1	OCA1-2	OCA1-3	OCB1-1	OCB1-2	OCB1-3	OCC1-1	OCC1-2	OCC1-3
Acariformes	1	1	0	0	0	1	1	1	0
Aeshnidae	0	0	0	0	0	0	0	0	0
Atyidae	2	5	0	3	2	1	0	9	0
Austrocorduliidae (<i>Austrocordulia</i>	0	0	0	0	0	0	0	1	0
Baetidae	0	0	1	0	0	0	0	0	0
Caenidae	1	0	2	0	0	0	0	0	0
Calamoceratidae	0	1	0	1	0	1	0	0	0
Ceratopogonidae	0	0	0	0	0	1	0	2	0
Chironomidae	2	6	3	2	0	9	1	11	1
Cordulephyidae	0	0	1	0	0	0	0	2	0
Corixidae	0	0	0	0	0	0	0	0	0
Dixidae	0	0	1	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0
Dytiscidae	2	4	5	0	3	0	1	1	0
Ecnomidae	0	0	0	1	0	0	0	0	0
Elmidae	2	0	0	2	0	0	0	7	4
Gerridae	3	0	0	0	1	1	0	0	0
Gomphidae	1	2	0	3	0	0	0	8	0
Gripopterygidae	0	0	0	0	0	0	0	0	0
Gyrinidae	3	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	1	1	1	2	0	0	0	0
Hydroptilidae	4	3	3	3	0	0	0	1	0
Leptoceridae	1	4	0	2	0	1	0	1	0
Leptophlebiidae	1	8	1	2	0	4	1	30	0
Libellulidae	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0
Mesovellidae	0	0	0	0	0	0	0	0	0
Notonectidae	0	1	3	0	0	2	0	2	0
Psephenidae	0	0	0	0	0	0	0	0	0
Pyrilidae	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	1	0	0	0	0	0
Telephlebiidae	0	0	0	1	0	0	0	1	0
Tipulidae	0	0	0	0	0	0	0	0	0
Veliidae	0	0	1	1	0	0	0	0	0
Unidentified Anisoptera	0	0	0	0	0	0	0	1	0
adult fly	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	23	36	22	23	8	21	4	78	5
Total Taxa	12	11	11	13	4	9	4	15	2

Site Codes: PK1-1 = Pool K, Replicate 1, etc.

Longwalls 20-22 Aquatic Ecology Monitoring (spring 2018)
BIO-ANALYSIS Pty Ltd: Marine, Estuarine Freshwater Ecology

Appendix 11. Spring 2018 Measurements of Water Quality Recorded at each Small Pool.

	Pool K on Waratah Rivulet			Pool L on Waratah Rivulet		
Taxa	PK1-1	PK1-2	PK1-3	PL1-1	PL1-2	PL1-3
Temperature (°C)	22.66	22.79	22.67	18.32	18.61	18.68
pH	7.81	7.84	7.68	6.94	6.85	6.82
Conductivity (µs/cm)	162	162	162	172	171	171
Dissolved Oxygen (%Sat)	114.8	114.9	115.1	59.8	47.1	41.1
Turbidity (NTU)	28	28	28	23.3	22.9	22.9
REDOX (mv)	492	192	492	355	337	322

	Pool M on Waratah Rivulet			Pool A on Woronora River		
Taxa	PM1-1	PM1-2	PM1-3	WPA1-1	WPA1-2	WPA1-3
Temperature (°C)	21.35	21.38	21.42	16.79	16.79	16.82
pH	7.53	7.52	7.51	6.97	6.97	6.97
Conductivity (µs/cm)	161	161	161	128	128	128
Dissolved Oxygen (%Sat)	103	103.2	103.1	73.8	72.6	72.2
Turbidity (NTU)	27.2	28	28.4	69.4	69.4	69.2
REDOX (mv)	396	396	397	654	654	654

	Pool B on Woronora River			Pool C on Woronora River		
Taxa	WPB1-1	WPB1-2	WPB1-3	WPC1-1	WPC1-2	WPC1-3
Temperature (°C)	17.67	18.22	18.46	17.31	17.34	17.29
pH	6.66	6.63	6.62	6.58	6.57	6.57
Conductivity (µs/cm)	116	113	114	122	122	122
Dissolved Oxygen (%Sat)	61.4	62.9	62.1	70.4	69.8	69.6
Turbidity (NTU)	73	69	69	66.4	66.2	66.6
REDOX (mv)	635	635	635	643	643	645

	Pool A on O'Hares Creek			Pool B on O'Hares Creek		
Taxa	OCA1-1	OCA1-2	OCA1-3	OCB1-1	OCB1-2	OCB1-3
Temperature (°C)	24.85	24.86	24.86	24.17	24.17	24.16
pH	7.35	7.03	7.27	7.65	7.61	7.58
Conductivity (µs/cm)	113	113	113	115	110	115
Dissolved Oxygen (%Sat)	102.9	101.5	101.5	102.5	102.1	101.8
Turbidity (NTU)	19	19.2	18.7	23.3	23.5	23.5
REDOX (mv)	544	555	555	523	523	524

	Pool C on O'Hares Creek		
Taxa	OCC1-1	OCC1-2	OCC1-3
Temperature (°C)	23.11	23.11	23.09
pH	7.75	7.51	7.48
Conductivity (µs/cm)	112	112	112
Dissolved Oxygen (%Sat)	110.2	107.1	106.5
Turbidity (NTU)	24.1	24.1	24.1
REDOX (mv)	503	505	505