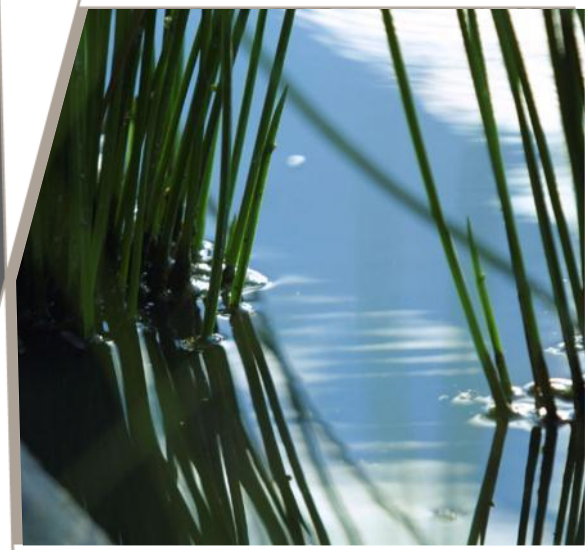
Dendrobium Area 3B

Aquatic Ecology Monitoring 2010 to 2015

59916047



Prepared for
South32 – Illawarra Coal

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Executive Summary

Background

South32 is extracting coal from Dendrobium Area 3B (DA3B) in the Southern Coalfield of NSW using longwall mining techniques. DA3B currently comprises Longwalls 9 to 18 which are situated west of Wongawilli Creek (**Figure ES1**). The sequence of extraction is as follows:

> Extraction of Longwall 9 commenced on 9 February 2013 and was completed on 2 June 2014;

> Extraction of Longwall 10 commenced on 21 January 2014 and was completed on 20 January 2015; and

> Extraction of Longwall 11 commenced on 18 February 2015 and was completed on 26 January 2016.

Extraction of Longwall 12 commenced 22 February 2016. Cardno Ecology Lab was commissioned by South32 to design and implement a monitoring program designed to detect potential impact to indicators of the condition of aquatic ecology due to mining-related subsidence. The monitoring program is based on a Before, After, Control, Impact (BACI) design that provides a measure of natural spatial and temporal variability in key aquatic ecology indicators at potential impact and control sites before, during and after coal extraction. This enables changes in the mining area to be distinguished from changes due to natural variability. The potential for physical effects of mining were considered by other specialists, who predicted that subsidence and minor fracturing of rock will occur locally in some first and second order streams. These effects could include flow diversions and reductions in pool water levels. Physical effects of mining in Wongawilli Creek which resulted in flow diversions were unlikely to occur.

Methods

The monitoring program focuses on four key indicators:

> Habitat condition, assessed using the Riparian, Channel and Environmental (RCE) Inventory method and by establishing a photographic record through time of aquatic habitat at each monitoring site;

> Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS);

> Aquatic macroinvertebrates sampled quantitatively using artificial collectors;

> Sampling of fish using bait traps and backpack electrofishing; and

> Limited in situ water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

Monitoring is undertaken at potential Impact sites on Wongawilli Creek, WC21 (a tributary of Wongawilli Creek) and Donalds Castle Creek, and at comparable Control sites established on Wongawilli, Sandy, Donalds Castle and Kentish creeks. Univariate and multivariate statistical analyses of data obtained from the AUSRIVAS sampling and artificial collectors were used to examine changes to aquatic ecology that may have occurred and to assess whether such changes are associated with mining. Surveys were undertaken in 2010, 2011, 2013 and 2015. This report presents data from all of these years.

Mining impacts and Assessment

As per predictions there were no impacts detected in Wongawilli Creek during the reporting period. Impacts were identified in first and second order streams within DA3B.

Some fracturing of bedrock and reductions in pool water levels and flow associated with the extraction of Longwalls 9 and 10 were observed in WC21 from December 2013. This represents a direct loss of aquatic habitat and probably also aquatic biota. During field visits for this study the only water present was at one site (X2) on WC21 which consisted of a few small, shallow, disconnected pools. By March 2016, approximately 1 km west (**Figure ES1**) had been affected by flow diversions and reductions in pool water levels. In Donalds Castle Creek similar, but less extensive physical mining impacts and loss of aquatic habitat were observed (Site X1, **Figure ES1**) in September 2013 and in 2015. This extended over 10 m of the creek

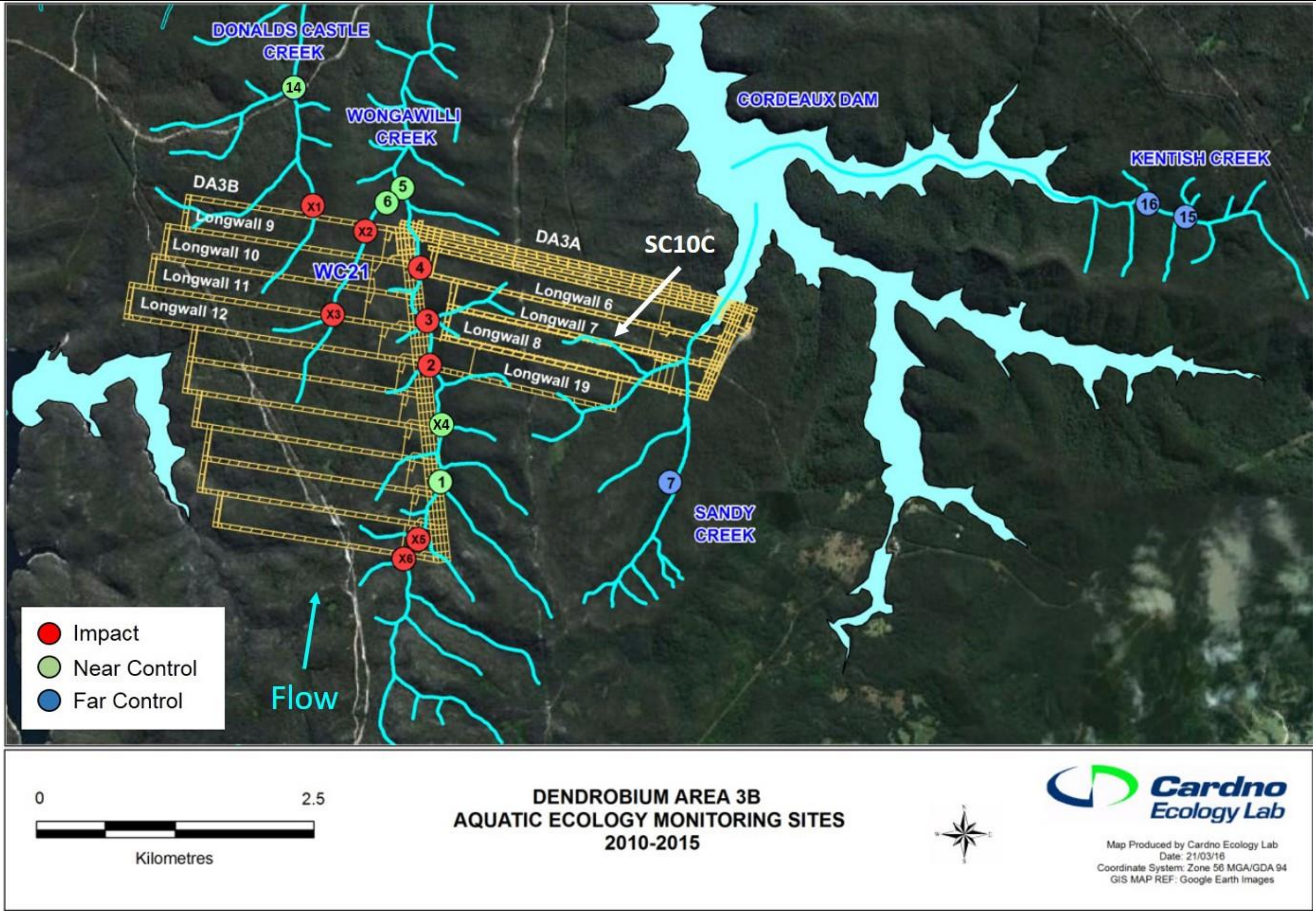

Figure ES1: Map of Dendrobium Area 3B showing aquatic ecology monitoring sites

In addition to direct habitat loss, there was some evidence of changes in the abundance of chironomins (a pollution tolerant sub-family of non-biting midge) and leptophlebiids (a pollution sensitive family of mayfly) in the artificial collectors deployed at Sites X1 and X2. These included an apparent increase in the number of chironomins at X2 and reduction in the numbers of leptophlebiids at X1 during 2015. No ecological impacts were identified at any of the sites monitored within Wongawilli Creek.

This is similar to SC10C (a tributary of Sandy Creek) with impacts to flow, pool water levels and water quality due to mining related subsidence in DA3A. Potential changes were evident during individual surveys only and were usually only apparent relative to one of the Controls. Subsequent changes in these indicators (i.e. apparent reductions and increases in numbers of chironomins and leptophlebiids, respectively) further suggested that impacts, if any, were short term. Also, no changes to water quality associated with these physical mining impacts have been observed in these creeks. Further monitoring will help determine whether the apparent reduction in the number of leptophlebiids at X2 observed between June and November of 2015 persists.

Similar changes occurring at Impact sites on Wongawilli Creek, and those occurring in WC21 during 2013, are less likely to be due to mining in the absence of observed changes in water quality and anything more than minor fracturing that did not result in flow diversions and pool water level reductions in Wongawilli Creek. Thus, these changes are likely due to natural variation, rather than mining. Overall, patterns in data from the collectors are complex and hence difficult to interpret due to large variability in these data, particularly assemblage data.

There was no evidence in AUSRIVAS and fish data of any changes due to mining. While OE50 Taxa Scores (a biotic index of habitat and water quality), Band Scores (derived from OE50 Taxa Scores) and SIGNAL2 Indices (a biotic index of water pollution) derived from the AUSRIVAS samples suggest that some sections of the watercourses may experience environmental stress, this is more likely due to ephemeral flows and to naturally low pH of the water, unrelated to mining. Fish data were similar before and after commencement of extraction. Moreover, no observations of dead of stressed fish were made at any of the sites during the study.

Conclusion and Recommendations

The observed loss of aquatic habitat and inferred loss of biota in WC21, and Donalds Castle Creek associated with the physical effects of mining following extraction of Longwalls 9 and 10 are relatively severe at the the local level (within each individual watercourses). In the context of the Sydney Catchment Area, the loss of 1 km (WC21) and 10 m (Donalds Castle Creek) of creek habitat is small compared with the large amount of creek habitat in the local area. Ongoing monitoring will help determine if changes observed during the last survey of 2015 persist.

It is recommended that biennial monitoring of aquatic ecology in DA3B should continue, with the next round of sampling undertaken in 2017, in line with the requirements of the Subsidence Management Plan (SMP) for DA3B. Monitoring of the general condition of creeks will continue to be undertaken by South32 as required by the SMP. The Indentification of any changes in flow characterisitics and aquatic habitat that may be related to mining should lead to consideration of additional monitoring of aquatic ecology.

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1 Introduction

1.1 Background and Aims

South32 – Illawarra Coal (South32), formerly BHP Billiton Illawarra Coal (BHPBIC) is extracting coal using longwall mining techniques from the Dendrobium Coal Mine, situated near Cordeaux approximately 15-20 km west of Wollongong. Consent for the mine, granted in November 2001, allows extraction from three Longwall domains, known as Areas DA1, DA2 and DA3. DA3, situated to the west of Lake Cordeaux, is currently being mined. A modification to the mine layout of DA3 approved in December 2008 allowed the mine to be expanded and Area 3 to be sub-divided into three smaller domains, DA3A, DA3B and DA3C. DA3A currently comprises Longwalls 6, 7, 8 and 19 which are situated between Wongawilli and Sandy Creeks. Longwalls 6, 7 and 8 were completed from 2010 to 2012. Mining of DA3B Longwalls 9 to 18 commenced following completion of Longwall 8 in the following sequence:

> Longwall 9 commenced 9 February 2013; completed on 2 June 2014;

> Longwall 10 commenced 21 January 2014; completed 20 January 2014; and

> Longwall 11 commenced on 18 February 2015; completed 26 January 2016

Extraction of Longwall 12 commenced 22 February 2016. Extraction of DA3A Longwall 19 will follow mining in DA3B.

Cardno NSW/ACT Pty. Ltd., trading as Cardno Ecology Lab (formerly The Ecology Lab Pty. Ltd.) was commissioned by BHPBIC to assess the potential impacts on aquatic ecology due to mining and to undertake monitoring of aquatic habitats and biota in all domains of DA3. The monitoring program was designed in accordance with the recommendations made by the NSW Department of Planning's (now Department of Planning and Environment) 'Strategic Review of impacts of Underground Coal Mining on Natural Features in the Southern Coalfield' (NSW DoP 2008). The monitoring program is based on a Before, After, Control, Impact (BACI) sampling design with a minimum of two years of baseline data being collected before mining commences at appropriate temporal and spatial scales. This will provide a measure of the natural variability in aquatic ecology indicators. Sampling at the same sites during and after extraction and consideration of physical changes from subsidence will enable changes in these indicators that may be caused by extraction to be distinguished from natural variability.

In this report, comparisons are made between data collected before and after the extraction of each DA3B longwall to determine if changes in aquatic ecology have occurred as a result of extraction.

1.2 Effects of Longwall Mining

Longwall mining is the most common form of coal mining in the Illawarra Region. Longwall mining contrasts with open-cut mining, with the former being undertaken by extracting coal accessed via tunnels. The coal seams are progressively accessed and extracted by longwalls. Despite being deep beneath the ground surface, longwall mining can affect the surface, principally by the effects of subsidence.

The potential impacts of subsidence were modelled and assessed as part of the approvals process. In DA3B, the longwall layouts and their extent were designed to avoid causing more than minor subsidence impacts to Wongawilli Creek, the main watercourse in that domain. Under the approved proposal for DA3B, subsidence was predicted to occur in some of the tributaries (first and second order streams). These potential impacts are discussed further in **Section 2.2** of this report.

1.3 Notes on Terminology

Previous reports for DA3 have referred to data collected Pre-extraction, During-extraction and Post-extraction. These periods reflected the timing of data collection with respect to the scheduling of extraction of the DA3A and DA3B domains. Following a review of the approach to the statistical analyses and interpretation it was considered appropriate to simplify the analytical design (**Section 3.6.4**), Accordingly, sampling undertaken Pre-extraction is hereafter referred to as Before (commencement of extraction) and that undertaken During-extraction and Post-extraction referred to as After (commencement of extraction) in the DA3B domain. Years (Before) refer to Surveys before (2010 and 2011) and Years (After) refer to Surveys (2013 and 2015) after commencement of extraction, with Surveys (previously "Sampling Event") undertaken within each Year. The rationale behind the data analyses and interpretation is discussed in detail in **Section 3.6.4**.

2 Previous Studies

2.1 Previous Studies Relevant to DA3B: Initial Studies

Since 2007, several reports have been prepared as part of the impact assessment and ongoing aquatic ecology monitoring undertaken in DA3. Five reports relevant to DA3B include those associated with the initial assessment of impacts in DA3 and those associated with ongoing monitoring in DA3B. These are summarised as follows.

Dendrobium Area 3 – Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota (The Ecology Lab 2007)

The assessment of mine subsidence impacts on aquatic ecology included the following:

> A review of existing information relating to aquatic ecology, including threatened species within the proposed mine area and the broader Cordeaux River catchment;

> Results of field-based investigations of aquatic habitats and biota occurring in significant waterways located within and adjacent to DA3;

> Assessment of the potential impacts of the proposed DA3A mine workings on aquatic habitats, water quality and aquatic biota, including threatened species;

> Design of a monitoring program to detect and determine the extent and nature of impacts on aquatic habitat and biota arising from the mine workings; and

> Recommendations on management measures that could be implemented if impacts were detected.

While this initial assessment was based upon potential impacts associated with subsidence predictions for DA3A, much of the information presented in this report is relevant to DA3B.

The main findings were:

> There is 'significant' aquatic habitat (characterised by permanently flowing creek) in reaches of Wongawilli and Sandy Creeks in DA3 and 'moderate' aquatic habitat (intermittent creek with permanent pools) in these and other named creeks and their tributaries. Other tributaries contained 'minimal' (intermittent creek and with sporadic refuge / intermittent pools) or 'unlikely' habitat (flow present immediately after rain events only);

> Four threatened species (Sydney hawk dragonfly (*Austrocordulia leonardi*), Adams emerald dragonfly (*Archaeophya adamsii*), Macquarie perch (*Macquaria australasica*) and Australian grayling (*Prototroctes maraena*), could potentially occur in DA3. This study has identified Macquarie perch in the study area (within Lake Cordeaux and Wongawilli Creek, downstream of the mining area);

> The DA3A subsidence predictions for the main channel of Wongawilli Creek indicated that the longwalls did not pose a significant threat to threatened species that may occur in Area 3A;

> MSEC (2007) predicted that minor fracturing may occur in Wongawilli and Sandy creeks due to extraction of DA3A longwalls, but is unlikely to result in significant diversion of surface flows. Fracturing in first and second order streams could result in drainage of pools, rapid drops in surface water flow and have localised, significant impacts to aquatic ecology in these pools;

> Significant changes in water quality are unlikely to occur in Wongawilli, Sandy or Donalds Castle creeks, but may occur in some associated tributaries (Ecoengineers 2007). The latter changes could have minor, localised and short term impacts on aquatic biota; and,

> Aquatic ecology should be monitored in reaches of creek with 'significant' and 'moderate' aquatic habitat and include habitat assessment, limited *in situ* water quality measurement, quantitative and AUSRIVAS sampling of macroinvertebrates, threatened species sampling and surveys of aquatic macrophytes (if present);

This report was incorporated into the Subsidence Management Plan for DA3A, Longwalls 6 to 10 (BHPBIC 2007) which was approved by the NSW Department of Planning in November 2008.

Baseline Aquatic Ecology Monitoring Spring 2008 – Spring 2010 (Cardno Ecology Lab 2011a)

This report included the results of the first year of before extraction monitoring for DA3B in autumn and spring 2010 following the incorporation of the DA3B potential impact sites (Sites X1 to X6) (**Figure 3.1**) into the ongoing DA3 monitoring program. The Control sites established for DA3A were maintained for DA3B.

The main findings were:

> The aquatic habitat at all sites is largely undisturbed;

> The macroinvertebrate fauna was comparable at the impact and control sites; and

> The similarities in macroinvertebrate indicators among locations should facilitate the detection of any indirect effects on aquatic ecology resulting from longwall extraction.

Dendrobium Area 3 – Aquatic Ecology Monitoring 2008 to 2011 (Cardno Ecology Lab 2012a)

This report included the second year of before extraction data collected at sites relevant to DA3B. Data collected from these Impact and Control locations were found to be largely comparable. Significant, small scale temporal variation in the data were not expected to prevent or hinder the detection of potential changes to aquatic ecology taking place during or post-extraction.

It was recommended that monitoring continue in DA3 in line with the SMP requirements, so that any changes to aquatic ecology during and Post-extraction period related to mining could be detected. Following the collection of two years of before extraction data for DA3B longwalls, it was also recommended that further monitoring be postponed until the commencement of extraction of DA3B Longwall 9.

Cardno Ecology Lab (2012b)

An Aquatic Flora and Fauna Assessment (AFFA) was prepared to support the SMP Application for DA3B. The AFFA included:

> A review and synthesis of existing information on the aquatic flora and fauna of the SMP Area and broader Cordeaux River catchment;

> Description of the diversity and relative abundance of native and introduced aquatic flora and fauna within these watercourses based on data collected during the baseline surveys and recent aquatic flora and fish surveys;

> Assessment of the potential impacts on aquatic flora and fauna (including threatened species) arising directly and indirectly from the proposed mining; and

> Recommendations on impact mitigation measures and monitoring.

2.2 Potential Effects of Longwall Mining on DA3B

The potential impacts of the mine-induced subsidence on physical attributes and aquatic ecology of the major watercourses flowing through the DA3B SMP Area and the level of impact predicted included in Cardno Ecology Lab (2012b) are summarised in **Table 2.1**.

Table 2-1 Predicted physical impacts and consequences for the aquatic ecology of the watercourses flowing through the DA3B SMP Area

Watercourse	Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology
Wongawilli Creek	Ponding, flooding and scouring of stream banks	No significant change in ponding, flooding or scouring of stream banks. There could be some highly localised changes in levels of ponding or flooding where the maximum changes in grade coincide with existing pools, steps or cascades, but these are not expected to result in adverse impacts.	No measurable effects on the availability and connectivity of most aquatic habitats. Potential, localised changes in the availability of aquatic habitat in some pools.
	Fracturing of bedrock and diversion of surface flows	No significant fracturing of bedrock or surface water flow diversions. Minor, isolated fractures of the stream bed may occur within 400 metres from the proposed Longwalls. No diversion of surface flows	Minor fracturing of the creek bed and subsequent diversion of flows would not have significant geochemical effects. Formation of ferruginous springs is unlikely, but could occur at the margins or upslope of swamps (Ecoengineers 2011). No significant changes in the quantity or quality of permanent aquatic habitat.
Donalds Castle Creek and Drainage Lines	Ponding, flooding and scouring of stream banks	No reversals of grade along Donalds Castle Creek and no changes in the levels of ponding, flooding or scouring of banks due to tilt. Reversals in grade may occur along Drainage Line DC1, adjacent to the tailgate of Longwall 9, and along Drainage Line WC21, adjacent to the tailgates of Longwalls 10 and 11. These could result in small increases in the levels of ponding, flooding and scouring of stream banks in highly localised areas along the drainage lines. The impacts resulting from such changes are expected to be small relative to those that occur naturally during floods.	There is unlikely to be any significant change in the availability or connectivity of aquatic habitats within Donalds Castle Creek. Localised changes in habitat availability and connectivity may occur along the drainage lines, but will be difficult to detect because of the large variability in natural flows within these ephemeral systems.
	Fracturing of bedrock and diversion of surface flows	Fracturing of the uppermost bedrock is likely to occur. In ephemeral creeks with alluvial deposits, fractures are likely to be in-filled by deposits during flow events. In areas with exposed bedrock, some diversion of surface flows into underlying strata and drainage of pools may occur, particularly during low flows. The diverted water is likely to re-emerge downstream, so net loss of water from the catchment is unlikely.	It is unlikely, that this would result in a significant impact on the overall quantity or quality of water flowing from the catchment. There is also unlikely to be any significant long-term changes in the quantity, quality or connectivity of aquatic habitats. Any losses of habitat and connectivity that do occur would be minor, localised and transient.
	Water quality	Ferruginous springs could form in the slopes of the southwest-draining catchments.	There is unlikely to be an impact on water quality, due to the relatively short length and high gradients of the creeks. These creeks do not contain aquatic habitat.

Watercourse	Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology
Lake Avon	Fracturing of bedrock and diversion of surface flows	Minor isolated cracking may occur in the lake bed. These are likely to be filled by water and alluvial deposits within the lake, so loss of water is unlikely.	There is unlikely to be any measurable effects on the availability of aquatic habitat within the lake.
	Water quality	There is unlikely to be any impact on water quality, because of infilling of cracks and the large volume of water within the Lake.	Inputs from any ferruginous springs that form on the drainage lines would be diluted and dispersed at the Lake Avon shoreline. There is consequently unlikely to be any measurable effects on the quality of aquatic habitat within the lake.

2.3 Recent Studies in DA3A and DA3B

Dendrobium Areas 3A and B. Aquatic Ecology Monitoring 2008 to 2013 (Cardno Ecology Lab 2014)

In this report, the first two years (2010 and 2011) of before extraction and the first year (2013) of during extraction data for DA3B were presented. Comparisons were made between data collected from DA3B before and after the commencement of extraction to determine if changes in aquatic ecology had occurred since extraction began and whether any such changes were associated with potential mining-related impacts. The main findings were:

> There was evidence at Site 4 on Wongawilli Creek of a short term change to aquatic ecology. As no physical impacts from mining were observed at the site, it is uncertain if these changes were related to mining; and

> Whilst there was minor physical disturbance at Site X1 (Donalds Castle Creek) (**Figure 3.1**), no changes were detected in macroinvertebrates using AUSRIVAS or the macroinvertebrate collectors caused by extraction of Longwall 9.

It was recommended that aquatic ecology monitoring in DA3 continue, in line with the SMP requirements for these areas.

Dendrobium Area 3A – Aquatic Ecology Monitoring 2008 to 2014 (Cardno Ecology Lab 2015)

This report was concerned primarily with the final year of after extraction monitoring for DA3A Longwalls 6 to 8, undertaken in 2014. It also included a description of visual observations of mining impacts and effects on aquatic habitat in WC21 (a tributary of Wongawilli Creek and within DA3B) in 2014 that were attributed to extraction of Longwalls 9 and 10.

Fracturing of rock and flow diversions in WC21 were first observed by South32 in December 2013 and associated with extraction of Longwall 9. Further impacts attributed to Longwall 10 were observed in November 2014. Small fractures were identified on Donalds Castle Creek (also undermined by Longwalls 9 and 10) within the upstream extent of the Impact site) during extraction of Longwall 9. Iron staining at Site X2 on WC21 was also observed.

Fracturing attributed to the extraction of Longwall 9 in Wongawilli Creek in December 2013 was assessed as minor, located at the edge of a pool not submerged during normal flow and does not appear to have resulted in any flow diversions. An extension of this fracture was observed during extraction of Longwall 10; this was not considered to be due to extraction of Longwall 10 owing to the apparent age of the fracture.

DA3B aquatic ecology impact sites were not visited by Cardno in 2014 as the biennial DA3B monitoring was not scheduled for this sampling period. However, there was no evidence in macroinvertebrate and fish data of any impacts to the aquatic ecology at the DA3A monitoring sites further downstream on WC21 and Donalds Castle Creek. Both these sites are downstream of the mining impacts observed in these creeks by the ICEFT. Thus, if any impacts to aquatic ecology did occur further upstream in these drainage lines (e.g., loss of aquatic habitat due to flow diversions) they appear to have been localised to the affected areas. Such impacts would be limited to a small spatial scale within the catchment area.

3 Methods

3.1 Study Design

The monitoring program is based on the Before, After, Control, Impact (BACI) sampling design recommended by the NSW Department of Planning (NSW DoP, 2008) and includes the following components:

> Baseline (Before commencement of extraction) Surveys to provide a measure of the natural temporal variation of each monitoring component before mining commences;

> Surveys at potential Impact sites and at ecologically comparable Control sites that will not be affected by mining. Data from Control sites provides a concurrent measure of the natural background variability in each monitoring component in nearby catchments and the greater Cordeaux catchment disassociated from any mine subsidence impacts; and

> Statistical comparison of Before and After data from Impact and Control sites to determine whether any changes that have occurred at potential impact sites are outside the range of natural variation and hence may be attributable to the effects of mining.

3.2 Study Sites

The GPS coordinates of DA3B monitoring sites are presented in **Table 3.1** and their locations in relation to the DA3 longwall layout are shown in **Figure 3.1**. There were six impact sites: 2 to 4, X1 and X3 to X6 on Wongawilli Creek to the east of DA3B and Impact Site X2 is located on Donalds Castle Creek within DA3B. All these sites could experience impacts as a result of the DA3B Longwalls. The magnitude and timing of potential impacts experienced by the sites would depend upon their proximity to each longwall and timing of extraction.

Table 3-1 Location, geographic coordinates and designation of each of the DA3B aquatic ecology monitoring sites (Datum: WGS 84, Zone 56H)

Site	Watercourse	Easting	Northing	Designation
2	Wongawilli Creek	290977	6192444	Potential Impact
3	Wongawilli Creek	290939	6192926	Potential Impact
4	Wongawilli Creek	290844	6193506	Potential Impact
X1	Donalds Castle Creek	289643	6194191	Potential Impact
X2	Wongawilli Creek 21	290247	6193847	Potential Impact
X3	Wongawilli Creek 21	289911	6193002	Potential Impact
X4*	Wongawilli Creek	291083	6191801	Potential Impact
X5**	Wongawilli Creek	290950	6190581	Potential Impact
X6**	Wongawilli Creek	290775	6190356	Potential Impact
1	Wongawilli Creek	290977	6192444	Near Control
5	Wongawilli Creek	290625	6194378	
6	Wongawilli Creek 21	290531	6194246	
14***	Donalds Castle Creek	289400	6195445	
7*	Sandy Creek	293661	6191227	Far Control
15	Kentish Creek	299290	6194270	
16	Kentish Creek	298869	6194403	

***Currently provides additional Near Control data until nearer the extraction date of adjacent Longwalls. **Monitoring postponed until nearer the extraction date of adjacent Longwalls. ** Previously grouped within the Far Control (**Section 3.6**)

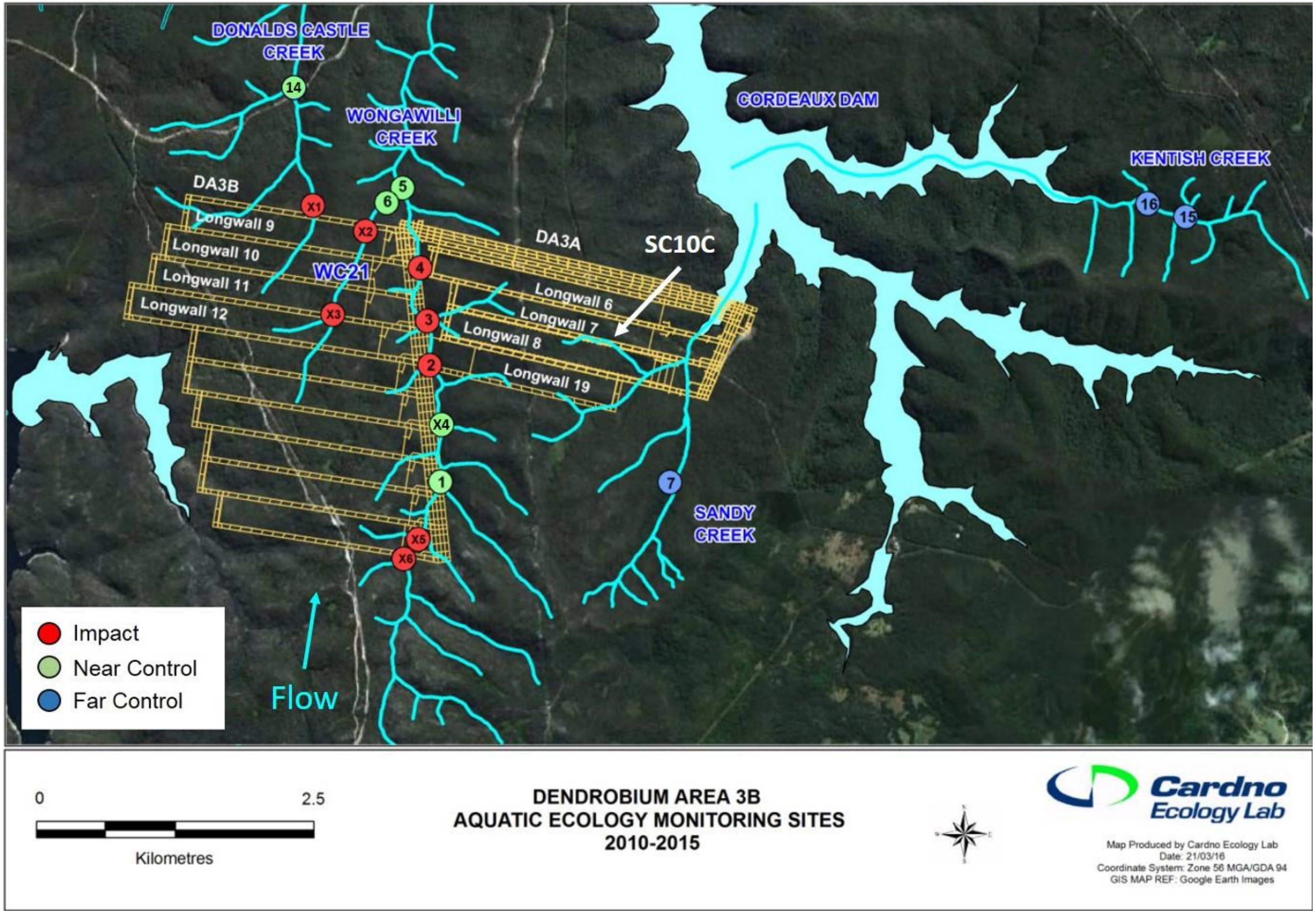

Figure 3-1 Map of Dendrobium Area 3B aquatic ecology monitoring sites

Table 3.1 also indicates the watercourse on which each site is located and the designation of each site (i.e. Impact or Control). Control sites are categorised as ‘Near Control’: the catchments of Wongawilli Creek and Donalds Castle Creek and ‘Far Control’: sites in the other catchments of Sandy Creek and Kentish Creek, which are not within the Wongawilli and Donalds Castle Catchments. Previously, the Control site on Donalds Castle Creek (Site 14) was assigned as a Far Control. It has now been reclassified as a Near Control due to its close proximity to the Impact sites and its location within the Donalds Castle Creek Catchment.

The partitioning of Control sites as Near and Far allows the variation occurring at the catchment level and wider local area to be considered when assessing the likely causes of any measured changes in aquatic habitat and biota. Control sites that are located downstream of Impact sites are in areas of creek not expected to experience any mining impacts, although they may be affected by indirect impacts and they are not statistically independent of the impact site.

3.3 Sampling Dates

Macroinvertebrate surveys undertaken in relation to DA3B and the timing of longwall extraction are summarised in **Table 3.2**. AUSRIVAS Surveys were undertaken twice in autumn and spring of each year, with the two Surveys each season six to eight weeks apart (four Surveys per Year). Macroinvertebrate collectors were deployed during collection of the first AUSRIVAS Survey in each Season and retrieved during the second (two collector ‘Retrievals’ per Year).

Table 3-2 Timing of AUSRIVAS and Macroinvertebrate Collector sampling undertaken to date for Dendrobium Area 3B. Dark grey shading indicates timing of extraction of each Longwall.

Phase:			Before				After				
Year:			**2010**		**2011**		**2013**		**2014**	**2015**	
Season (AUSRIVAS Only):			**Autumn**	**Spring**	**Autumn**	**Spring**	**Autumn**	**Spring**		**Autumn**	**Spring**
Survey (AUSRIVS):			**Mar May**	**Sep Nov**	**Apr Jun**	**Sep Oct**	**Apr Jun**	**Sep Nov**		**May Jun**	**Oct Nov**
Retrieval (Macroinvertebrate Collector Retrieval):			**May**	**Nov**	**Jun**	**Oct**	**Jun**	**Nov**		**Jun**	**Nov**
Longwall	**Start**	**Finish**									
LW 9	9/2/13	2/6/14									
LW 10	20/1/14	20/1/15									
LW 11	18/2/15	2/1/16									
LW 12-18	22/2/16	Not yet finished									

Note: Site 2 not sampled in 2011

3.4 Field Methods

3.4.1 Aquatic Habitat Assessment

The condition of the aquatic habitat at each site was assessed using the Riparian, Channel and Environmental (RCE) Inventory method (Chessman *et al.* 1997). This assessment involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site (**Appendix B**). The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) a heavily channelled stream without any riparian vegetation. This methodology was developed by Peterson (1992), but modified for Australian conditions by Chessman *et al*. (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4.

During each Survey, a comprehensive photo record was also assembled for each site to gain an understanding of environmental variation within the watercourses. This involved taking photos with a standardised 2 m tall x 1 m wide T-bar within the frame, from the top of the site looking downstream, the middle of the site looking upstream, the middle of the site looking downstream, and the bottom of the site looking upstream. These photographs were examined to infer changes in water levels, geomorphology or aquatic habitats through time.

3.4.2 Water Quality

Water quality was measured *in situ* with a YSI 6920 water quality probe and meter that were calibrated prior to sampling. Water quality was measured before aquatic fauna were sampled to avoid disturbance to the waterway. The following variables were recorded:

> Temperature (°C);

> Conductivity (µs/cm);

> pH;

> Dissolved oxygen (mg/L and % saturation);

> Oxidation Reduction Potential (ORP) (mV); and,

> Turbidity (ntu).

Two replicate readings of each variable were taken in accordance with Australian Guidelines (ANZECC/ARMCANZ 2000). Water quality was not measured in November 2015 due to a probe malfunction.

3.4.3 Aquatic Macroinvertebrates

Two methods were used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak *et al*. 2004), which is semi-quantitative and artificial macroinvertebrate collectors which is quantitative.

3.4.3.1 AUSRIVAS Sampling

Aquatic macroinvertebrates associated with edge habitats were sampled using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al*. 2004). Riffle habitat was not sampled, because this habitat was not represented in all the stretches of creek surveyed. Samples were collected with dip nets (250 µm mesh) over a period of 3-5 mins from a 10 m length of habitat within a 100 m reach of the creek at each site. The dip net was used to agitate and scoop up material from vegetated river edge habitats. Where the habitat was discontinuous, patches of habitats with a total length of 10 m were sampled over the 100 m reach. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked live using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals either until no new specimens had been found or total of 60 minutes (i.e. the initial 40 minutes plus up to another 20 minutes). Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous and / or slow. The animals collected at each site were placed into a labelled jar containing 70% alcohol / water.

Environmental variables, including alkalinity, modal river width and depth, percentage boulder or cobble cover, latitude and longitude were recorded in the field. These are required for running the spring AUSRIVAS predictive model for edge habitat. Distance from source, altitude, and land-slope were determined from appropriate topographic maps. Mean annual rainfall was determined in the laboratory from the regional precipitation maps presented in the AUSRIVAS Sampling and Processing Manual (Turak *et al*. 2004).

3.4.3.2 Artificial Collectors

During collection of the first AUSRIVAS sample each season, eight replicate artificial collector units were deployed at each site. Each replicate consisted of 18 wooden chopsticks (24 cm long) held together with two small plastic cable ties one fixed at each end. To facilitate collection and deployment, the collectors were deployed in two sets of four replicates. Each set was tied together with nylon twine, attached to bankside vegetation and submerged at least 1 metre apart at the edge of pools in water depths of 30 to 60 cm. The collectors were retrieved approximately six to eight weeks later during collection of the second AUSRIVAS sample that season.

Each replicate was put into a separate, labelled, plastic bag and preserved in 70% ethanol for subsequent macroinvertebrate identification and enumeration in the laboratory. The collectors provide a standardised habitat for colonisation by macroinvertebrates and enable the collection of quantitative data

Over the course of the monitoring program some macroinvertebrate collectors were lost due to them being dislodged and washed downstream during flood events. The number of replicate units that were retrieved during each Survey is identified in **Appendix G**.

3.4.4 Fish

Fish and mobile invertebrates were sampled using a back-pack electrofisher (Model Smith-Root LR24) and collapsible bait traps (40 cm x 20 cm x 20 cm with 2-3 mm mesh, tapering to a 3 cm entrance). At each site, the back-pack electrofisher was operated around the edge of pools, around snags and aquatic vegetation, overhanging banks and rocky crevices. Electrofishing was conducted in sets of four, two minute shots. Fish were collected in a small scoop net and identified. Eight bait traps were deployed at each site for 30-60 minutes and all caught fish were identified. Following identification, all native species were released unharmed. No invasive fish species were caught.

3.5 Laboratory Methods

AUSRIVAS samples were sorted under a binocular microscope (at 40 X magnification) and identified to family level with the exception of Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily). Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al.* 2004).

3.6 Statistical Methods

3.6.1 Descriptive Statistics

3.6.1.1 Water Quality

Mean water quality measurements were compared with the Australia, New Zealand Environment Conservation Council default trigger values (DTVs) for protection of aquatic ecosystems for physical and chemical stressors for slightly disturbed upland rivers in southeast Australia (ANZECC/ARMCANZ 2000).

Water quality data collected during the aquatic ecology monitoring programme were intended to aid in the interpretation of macroinvertebrate data. More detailed water quality monitoring, analysis and assessment is undertaken by the Illawarra Coal Environmental Field Team (ICEFT) and other consultants.

3.6.1.2 AUSRIVAS and Macroinvertebrate Collector Samples

The AUSRIVAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at undisturbed, reference sites (Coysh *et al.* 2000). The health of the stream is assessed by comparing the observed freshwater macroinvertebrate assemblages (i.e. those collected in the field) with macroinvertebrate assemblages expected to occur in reference waterways with similar environmental characteristics. The data from this study were analysed using the NSW models for pool edge habitat sampled in spring and autumn. The AUSRIVAS predictive model generates the following indices:

- OE50Taxa Score – The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence. OE50 taxa scores provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.
- Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as described in **Table 3.3**.
- The combined (autumn and spring) AUSRIVAS model was not utilised, as this may have masked changes occurring in individual seasons only.

Table 3-3 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in autumn and spring

Band	Description	Autumn OE50 Score	Spring OE50 Score
X	Richer invertebrate assemblage than reference condition	> 1.17	>1.16
A	Equivalent to reference condition	0.82 to 1.17	0.84 to 1.16
B	Sites below reference condition (i.e. significantly impaired)	0.47 to 0.81	0.52 to 0.83
C	Sites well below reference condition (i.e. severely impaired)	0.12 to 0.46	0.20 to 0.51
D	Impoverished (i.e. extremely impaired)	≤0.11	≤0.19

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants. The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 Index. The SIGNAL2 Index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site. SIGNAL2 values are as follows:

> SIGNAL > 6 = Healthy habitat;

> SIGNAL 5 – 6 = Mild pollution;

> SIGNAL 4 – 5 = Moderate pollution; and,

> SIGNAL < 4 = Severe pollution.

AUSRIVAS data collected during spring and autumn are treated separately in the analyses. For macroinvertebrate data collected using artificial collectors, only the SIGNAL2 Index was calculated.

3.6.2 Multivariate Analyses

A matrix of differences in the types and relative abundance of the taxa between all possible pairs of macroinvertebrate collector samples was compiled by calculating their respective Bray-Curtis dissimilarity coefficients, after transforming data, where appropriate. Transformations reduce the influence of highly abundant animals and thereby ensure that dissimilarities reflect groups of animals with large and moderate abundances (Warwick 1993).

Permutational analysis of variance (PERMANOVA+ in Primer v6) was used to examine spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblages sampled using artificial collectors. Differences in the levels of factors and interaction terms were examined by *Post-hoc* permutational t-tests. Only statistical differences with a significance level of $P \leq 0.05$ are considered. Significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (equivalent to variance) among groups or a combination of both. Each of these outcomes could be indicative of an impact.

Multivariate patterns in the data were examined using the Principal Coordinates Ordination (PCO) routine in Permanova+. This is a generalised form of Principal Components Analysis (PCA) in which samples are projected onto linear axes based on their dissimilarities in a way that best describes the patterns among them using as few dimensions as possible (Clarke and Gorley 2006). The amount of variation “explained” by each principal axis is indicated and the dissimilarity between data points can be determined from their distances apart on the axes (Anderson *et al*. 2008).

The Similarity Percentages (SIMPER) routine can be used to determine which taxa were responsible for discriminating between pairs of Treatments that differ significantly (Clarke 1993). It was determined that this routine was not necessary for this study (**Section 4.3.2.2**).

3.6.3 Univariate Analyses

Permanova+ was used to examine spatial and temporal variabilityin the number of taxa, OE50 Taxa Scores and SIGNAL2 Indices calculated from AUSRIVAS samples and the number of taxa and abundances of individual taxa (Leptophlebiidae and Chironominae) calculated from macroinvertebrate collector samples. Leptophlebiids and chironomins were the most abundant taxa with 72% of the individuals sampled from the collectors belonging to these taxons. The occurrence and abundance of these taxa may also provide an indication of water quality, with chironomins and tending to be more pollution tolerant, and leptophlebiids less so. An increase in the number of chironomids (comprising the sub-families Chironominae, Tanypodinea and Orthocladinae), and a decrease in the number of leptophlebiids, had been found at one of the impact sites for DA3A (Cardno Ecology Lab 2015), hence this was a focus for the DA3B analyses. Analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest. Only statistical differences with a significance level of $P \leq 0.05$ are considered.

The PERMANOVA approach does not require the data conform to a normal distribution unlike "traditional" ANOVA. As is the case with multivariate analyses, 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. A potential impact could be expected to affect both the magnitude and dispersion of an indicator (e.g. number of taxa). When a statistically significant difference between groups is detected that could be indicative of a mining impact, the proportion of the statistical difference attributable to the difference in variance between pairs of groups is explored using the PERMDISP procedure. This procedure tests for a statistical difference between variances. If there is no statistical difference between variances, the statistical difference detected between groups is most likely due to differences between group means. When a statistical difference between variances is detected, the difference between groups could be due to both the difference in variance and the mean between groups.

3.6.4 Analytical Framework

3.6.4.1 Statistical Design

The analytical design for AUSRIVAS data was:

> **Phase**: A fixed factor with two levels: Before and After;

> **Treatment**: A fixed factor with three levels: Impact (Sites 2, 3, 4, X1, X2 and X3), Near Control (Sites 1, 5, 6, 14 and X4) and Far Control (Sites 7, 15 and 16);

> **Season**: A fixed factor with two levels: Autumn and Spring;

> **Year**: A random factor with four levels nested in Phase; 2010 and 2011 nested in Before and 2013 and 2015 nested in After; and

> **Survey**: A random factor with two levels nested in Phase, Season and Year: May and November in 2010, June and October in 2011, June and November in 2013 and June and November in 2015

One AUSRIVAS sample was collected from each Site during each Survey (**Section 3.3**).

In the previous report (Cardno Ecology Lab 2014), analysis of AUSRIVAS indicators was undertaken separately for each Impact Treatment (i.e. Site). This was done in anticipation of the timing of Longwall extraction and, thus, the timing of potential impacts that may be experienced by each site (**Section 3.2**). Separate analyses were also undertaken for autumn and spring, due to putative differences between AUSRIVAS macroinvertebrate communities between these seasons. However, this resulted in a large number of tests and a potential increase in the Type 1 error rate (false positive). Following a review of the analytical design, one main test, including data from each Site and from both Seasons, was undertaken for each AUSRIVAS indicator. This reduced the number of tests, the Type 1 error rate, and the amount of interpretation that was required. It also removed the potential temporal confounding effect associated with utilising Surveys as replicates. This required that potential impacts be assessed at the Treatment level only (i.e. large scale potential changes in indicators).

Lower order interaction terms were pooled with the residual sequentially to enable higher order interaction terms of interest (**Section 3.6.4.2**) to be tested over the residual, thereby providing more sensitive tests. Only terms with $P \geq 0.25$ were pooled. The results of the pooled models have presented.

The analytical design for macroinvertebrate collector data (assemblage, number of taxa and chrironomin and leptophlebiid abundance) was:

> **Phase**: A fixed factor with three levels: Before and After

> **Treatment**: A fixed factor with eight levels: Impact: Site 2, Site 3, Site 4, Site X1, Site X2, Site X3, Near Control (consisting of Sites 1, 5, 6 and 14) and Far Control (consisting of Sites 7, 15 and 16);

> **Year**: A random factor with four levels nested in Phase; 2010 and 2011 nested in Before and 2013 and 2015 nested in After; and

> **Retrieval**: A random factor with two levels nested in Year: May and November in 2010, June and October in 2011, June and November in 2013 and June and November in 2015.

Eight collector samples were collected from each Site during each Retrieval (**Section 3.3**).

Despite several Sites been included in each Control Treatment, a factor representing the variation associated with Site not included in this design as only one Site was included in each Impact Treatment.

It is noted that the statistical designs described here are unbalanced, due to unequal observations across the levels of factor Treatment following the grouping of several Sites within the Controls, and due to the unequal observations across levels of all factors due to absent data following the loss of some collectors in flood events (**Section 3.4.3.2**). While PERMANOVA is robust to heterogeneity of variances for balanced designs, it can be more liberal (when the smaller group has greater variance) or conservative (when the larger group has greater variance) in the presence of heterogeneous variances in unbalanced designs (Anderson and Walsh 2013). Recommendations on ways in which the analytical design can be revised to help reduce this potential effect in the future are provided in **Section 6**.

Due to the nature of the sampling (i.e. monitoring at the same sites through time, all located on the same watercourse) data may not be statistically independent. Generally, the consequence of potential non-independence is an increase in the Type 1 error (false positive) rate. This would be expected to result in more liberal tests, and, thus, could be considered precautionary in the context of detecting an impact. However, it could also conceivably result in an increase in the Type 2 error (false negative) rate, if any disturbance occurring at the impact sites affected Control Sites farther downstream (though this is considered unlikely based on the distance between sites and earlier observations of the extent of changes to aquatic ecology that have been experienced in DA3A (Cardno Ecology Lab 2015). The potential effects of any non-independence need to be taken into consideration when interpreting the results of the statistical analyses.

3.6.4.2 Interpretation and Data Presentation

The aim of the statistical analyses is to identify differences in the selected indicators of aquatic ecology at the Impact Treatments that are in a different direction, or of a different magnitude, to those at the Controls. Statistically significant differences provide evidence that an impact may have occurred. Evidence is assessed by examining data from Before with those collected After.

The statistically significant interaction of Phase and Treatment could potentially provide evidence of a substantial, long-term change in the biotic community due to mining. Thus, this interaction was the main focus of these analyses. The statistically significant interaction of Treatment and Year (Phase), and Treatment and Survey (Year (Phase)) could also provide evidence of, albeit shorter term, changes due to mining. Such comparisons indicate how differences among Treatments vary among Years and Surveys, with particular patterns of change potentially indicative of an effect due to mining of individual Longwalls. For AUSRIVAS data, such two-way interactions could potentially provide evidence of a change that was apparent in autumn and spring. Three-way interactions involving those described above and Season may provide evidence of a change that was dependant on Season (i.e. was apparent in autumn or spring data only).

Other statistically significant interactions and main effects cannot provide evidence for or against an impact occurring. Thus, for brevity, they not considered in detail.

Statistical analysis of fish data was not undertaken. Due to the inherently large natural variability present in these data, and many samples with no fish, statistical tests were not considered appropriate. Rather, examination of raw fish data was undertaken in an attempt to identify obvious changes in the number of individuals and species caught at each site through time, which could be indicative of a potential effect due to mining.

4 Results

4.1 Aquatic Habitat Assessment

The RCE scores for the DA3B Potential Impact Sites varied from 46 to 50 out of a possible 52 (**Appendix C**). These scores are indicative of natural, undisturbed habitat with negligible disturbance to the watercourses and adjoining riparian vegetation. The scores for the control sites were also high, ranging from 47 to 51 for the Near Control Sites, 49 to 50 for the Far Control Sites, and being 46 for the two Near Control sites. There was a reduction in the score for the riffle / pool sequence at Site X2. This was associated with fracturing and flow diversions due to physical mining impacts identified upstream in WC21 during extraction of Longwalls 9 and 10 (**Section 2**). RCE scores have not changed over the course of the monitoring program.

The photographic record undertaken at each site over the 2015 monitoring period is presented in **Appendix K**. Water levels at most sites appeared relatively unchanged throughout 2015. However, the mining related fracturing and flow diversions first observed in WC21 by South32 in December 2013 have affected pool water levels and flow at X2 (and further upstream) since the last aquatic ecology monitoring event in 2013 (**Plate 1**). In 2015, there was a complete loss of flow at X2 and water was restricted to a few small, disconnected pools. There had been little change since the 2014 visual observations (**Section 2**) (Cardno Ecology Lab 2015), except that the pool immediately upstream of the site was now completely dry. This may have been related to local rainfall patterns, rather than further physical mining impacts. The little water that was present at X2 in 2015 was almost certainly derived from recent rainfall. Flow reappeared a few 10s of metres downstream of the site and there did not appear to be any sign of flow reductions further downstream on WC21 at Site 6. However, iron staining was present at the upstream extent of Site 6 during each visit in 2015. By March 2016 the length of WC21 that had been affected by fracturing and pool water loss was 1050 m (South32 Pers. Comm. 18/03/16).

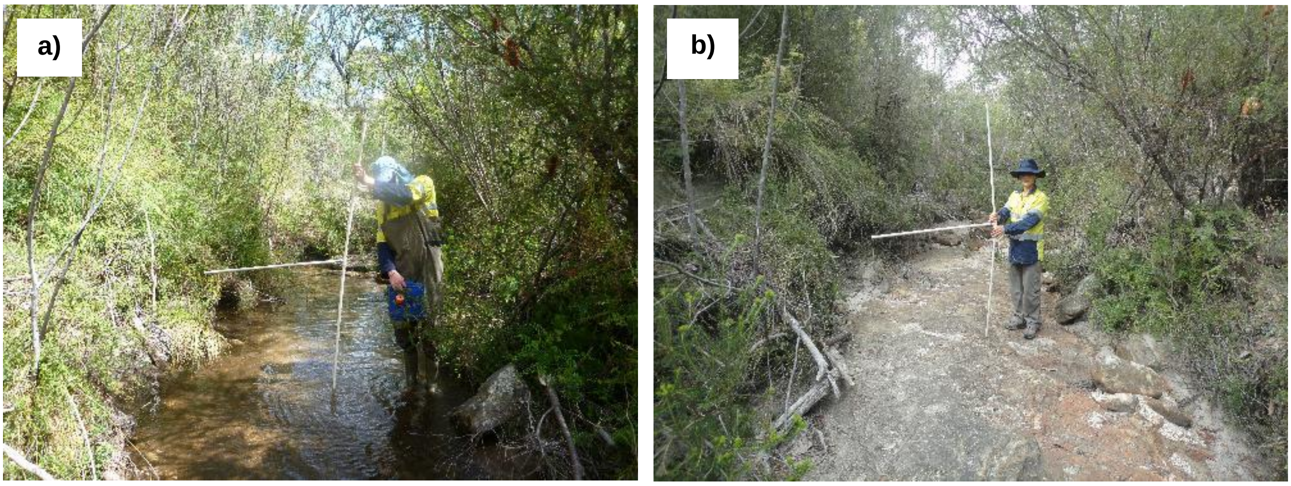

Plate 1: Site X2 on WC21 in a) November 2013 and b) November 2015

The fracturing of bedrock and diversion of flow at Site X1 was first observed in September 2013 and was restricted to the upstream extent of the site where the watercourse emerges from an upland swamp. There appeared to be some evidence of a drop in the water level of a pool just downstream of the fracturing (**Plate 2b**). Pool water levels immediately downstream of these features appeared unaffected. These changes were relatively minor and not apparent during aquatic ecology monitoring in 2012 (**Plate 2a**). There did not appear to be any change during observations in 2015.

Plate 2: Site X1 on Donalds Castle Creek in a) 2012 b) November 2013. Note absence of flow in November 2013

4.2 Water Quality

The mean values of water quality variables for each site measured during May, June and October 2015 are presented in **Appendix D**. The main observations were:

> Temperature ranged from 8.2 to 17.2 C. Fluctuations in temperature among sampling events were consistent across all Potential Impact Sites and Controls and reflected seasonal differences;

> Conductivity ranged from 54 to 108 µS/cm and was within the DTV threshold at all sites during each visit.

> pH ranged from 4.2 to 6.6 and was often below the lower DTV at most sites sampled;

> Oxidation Reduction Potential (ORP) ranged from 48 to 329 mV and tended to be lower at Sites 6 than at the other sites sampled;

> Dissolved oxygen ranged from 53.0 to 98.5 % saturation and was generally within, or very slightly below, DTVs; and

> Turbidity ranged from 0.0 to 6.3 NTU and was often below the lower DTV at each site.

Measures of water quality were comparable with those measured from 2010 to 2013 (Cardno Ecology Lab 2011a, 2012a and 2014).

4.3 Aquatic Macroinvertebrates

4.3.1 AUSRIVAS Samples

The number of taxa, OE50 Taxa Scores and SIGNAL2 Indices for each of the AUSRIVAS samples collected from DA3B monitoring sites during 2010 to 2015 are presented in **Appendix D**. The values of indicators were largely comparable among Impact Sites, and Sites in the Near Control and Far Control. The number of Taxa ranged from 9 to 25 at the Impact Sites, 9 to 29 at the Near Control and 7 to 25 at the Far Control. The OE50 Taxa Score ranged from 0.41 to 1.25, 0.35 to 1.30 and 0.46 to 1.11 at the Impact Sites, Near Control and Far Control, respectively. These values correspond to Band C (macroinvertebrate assemblage severally impaired relative to reference condition) to Band X (macroinvertabrate assemblage more diverse than reference condition). SIGNAL2 Indices ranged from 3.6 to 5.6, 3.8 to 5.8 and 3.9 to 6.1 at the Impact Sites, Near Control and Far Control, respectively. These are indicative of severe to mild water pollution.

A summary of the PERMANOVA analyses done on AUSRIVAS data collected from DA3A is presented in **Table 4.1** and the full analyses are presented in **Appendix E**.

None of the PERMANOVA analyses undertaken yielded results that were potentially indicative of an impact. Statistically significant sources of variation included the main effect of Year (Phase) for OE50 Taxa Score and SIGNAL2 Index and the main effect of Survey (Season x Year (Phase)) for OE50 Taxa Score. None of these provided evidence of an impact.

Table 4-1 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected in autumn and spring in DA3A during 2010 to 2015. *=P≤0.05, **P≤0.01, ***P≤0.001, ns=not statistically significant, RED = Redundant due to statistically significant interaction term. Pooled = pooled with the residual at P>0.025. Bold type indicates terms of interest (Section 3.6.4).

Source of Variation	Number of Taxa	OE50 Taxa Score	SIGNAL2 Index
Phase	ns	ns	ns
Treatment	ns	ns	***
Season	ns	ns	Ns
Year (Phase)	ns	*	**
Phase x Treatment	ns	ns	ns
Phase x Season	ns	ns	ns
Treatment x Season	ns	ns	ns
Treatment x Year (Phase)	Pooled	ns	ns
Season x Year (Phase)	ns	ns	ns
Phase x Treatment x Season	ns	ns	ns
Survey(Season x Year (Phase))	*	**	ns
Treatment x Season x Year (Phase)	ns	ns	ns
Treatment x Survey(Season x Year	Pooled	Pooled	ns

4.3.2 Macroinvertebrate Collectors

A total of 63 macroinvertebrate taxa were sampled using collectors (**Appendix F**). The mean (± SE) number of taxa, chironominae and leptophlebiid per Site during each Survey calculated from macroinvertebrate collector data are presented in **Appendix G**. PERMANOVA analyses were undertaken using abundance data for each of these taxa.

PERMANOVA indicated a statistically significant interactive effect of Treatment and Survey for assemblage and for chironominae and leptophlebiid abundance, indicating that the variation among Treatments depended on the Survey considered and / or vice versa (**Table 4-2**). Such differences may provide evidence of an impact occurring and are examined in detail in **Sections 4.3.2.2** to **4.3.2.4**. Note, for brevity, for examination of differences between pairs of Treatments, only the results of *post-hoc* tests involving Impact and Control Treatments have been presented and interpreted. The results of tests between pairs of Impact Treatments have not been presented as these cannot provide evidence of an impact. Other statistically significant sources of variation included the main effects of Treatment and of Year (Phase) for Number of Taxa data. Neither of these provided evidence of an impact and variation in Number of Taxa data is not discussed further.

Table 4-2 Summary of results of PERMANOVA analyses undertaken using macroinvertebrate collector data collected in DA3A during 2010 to 2015. *=P≤0.05, **P≤0.01, ***P≤0.001, ns=not statistically significant, RED=Redundant due to statistically significant interaction term. Bold type indicates terms of interest (Section 3.6.4).

Source of Variation	Assemblage	Number of Taxa	Chironominae Abundance	Leptophlebiid Abundance
Phase	ns	ns	ns	ns
Treatment	RED	*	RED	RED
Year (Phase)	ns	*	ns	ns
Phase x Treatment	**ns**	**ns**	**ns**	**ns**
Retrieval (Year (Phase))	RED	ns	RED	RED
Treatment x Year (Phase)	**ns**	**ns**	**ns**	**ns**
Treatment x Retrieval (Year (Phase)	*******	**ns**	*******	*******

4.3.2.2 Assemblages

Post-hoc tests indicated a statistically significant difference for 78 of the 94 pairs of Treatments examined (**Table 4-3**). There was no evidence of changes in assemblages at any Impact Site that may be indicative of an impact. Statistical differences between Impact and Control Treatments in the Before Phase (44 differences) were common, and, in general, more apparent than in the After Phase (34 differences). A similar pattern was seen for most individual Impact Sites, with differences more apparent in the Before, rather than the After, Phase. These observations may have hindered the identification of changes that could be indicative of an impact.

Table 4-3 Summary of *post-hoc* permutational t-tests undertaken for macroinvertebrate collector assemblage data for pairs of Treatments for each Time. *=P≤0.05, **P≤0.01, ***P≤0.001, ns = not statistically significant. Note, for brevity, only the results of tests involving an Impact and a Control Treatment have been presented. Site 2 was not sampled in 2011.

Phase:	Before				After				
Year:	**2010**		**2011**		**2013**		**2015**		
Survey:	**May**	**Nov**	**Jun**	**Oct**	**Jun**	**Nov**	**Jun**	**Nov**	
Impact Treatment									**Control Treatment**
Site 2	**	**	*Not sampled*		*	ns	*	*	Near Control
Site 3	**	***	ns	***	***	ns	ns	ns	Near Control
Site 4	***	***	**	***	**	*	**	**	Near Control
Site X1	***	***	***	***	***	ns	*	**	Near Control
Site X2	***	**	*	***	*	ns	**	***	Near Control
Site X3	***	***	*	*	ns	*	*	ns	Near Control
Site 2	*	*	*Not sampled*		**	ns	**	ns	Far Control
Site 3	***	*	***	***	**	ns	***	***	Far Control
Site 4	***	*	***	***	**	ns	***	***	Far Control
Site X1	***	***	***	***	***	ns	***	**	Far Control
Site X2	***	ns	***	***	*	**	*	***	Far Control
Site X3	***	***	***	***	**	***	ns	***	Far Control

Similarly, statistical differences between pairs of Times were very common (28 of the 32 of the post-hoc tests were statistically significant), which hinders the detection of patterns of change that could be indicative of an impact (**Table 4-4**). Nevertheless, there was no evidence of any change that was indicative of an impact.

Table 4-4 Summary of post-hoc permutational t-tests undertaken for macroinvertebrate collector assemblage data for pairs of Times (T1 vs. T2) within Year and Phase for each Treatment. *=P≤0.05, **P≤0.01, ***P≤0.001, ns = not statistically significant. Site 2 was not sampled in 2011.

Phase	Before		After	
Year:	**2010**	**2011**	**2013**	**2015**
Survey	**May vs Nov**	**Jun vs Oct**	**Jun vs Nov**	**Jun vs Nov**
Treatment				
Site 2	***	*Not sampled*	ns	***
Site 3	***	*	***	ns
Site 4	**	**	**	***
Site X1	***	***	***	*
Site X2	***	*	**	**
Site X3	ns	*	***	***
Near Control	***	***	*	***
Far Control	**	***	*	***

There was little evidence of grouping of Treatments and / or Times in the PCO for macroinvertebrate assemblages with the points tending to form a diffuse cloud (**Figure 4.1**). There was some slight evidence to suggest assemblages sampled in November 2013 were less variable than those sampled at other times, with assemblages from this survey tending to group closer together than those form other surveys. However, this was marginal.

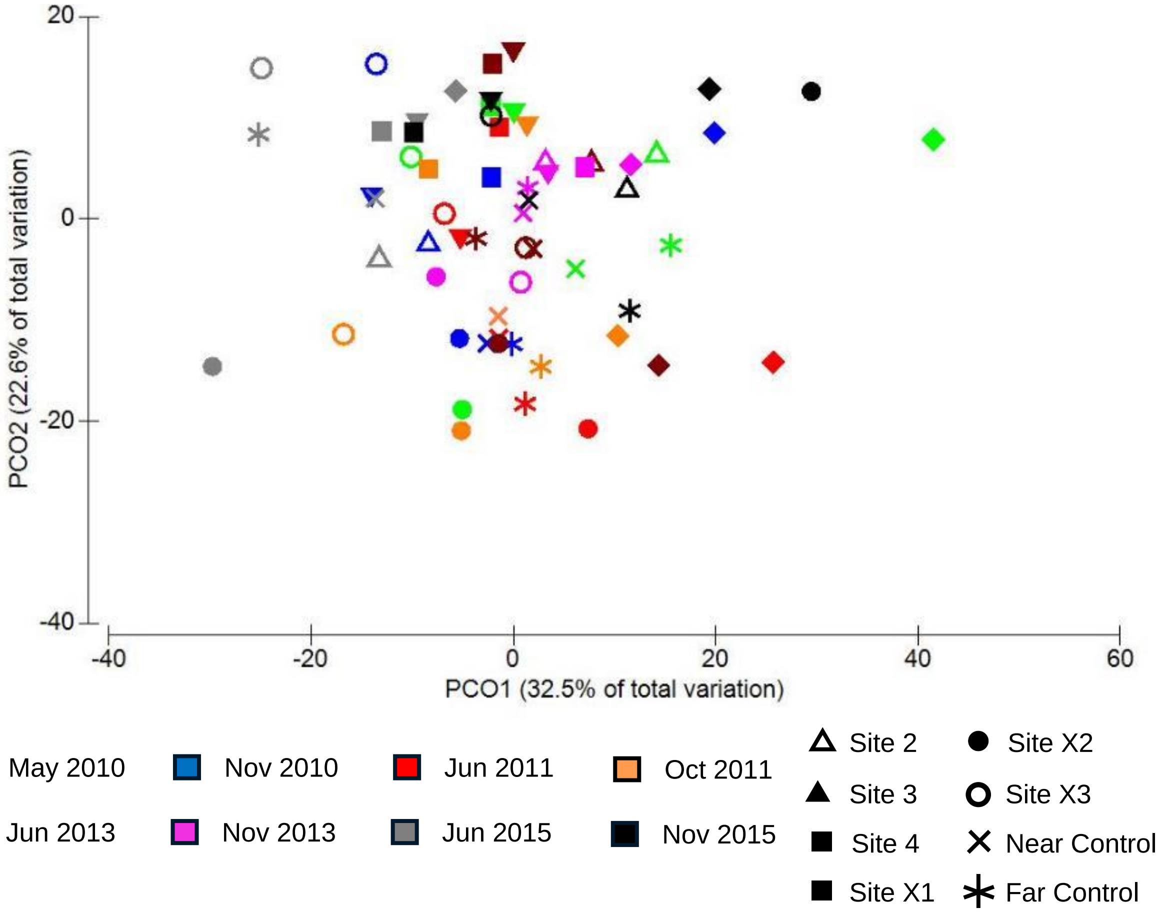

Figure 4-1 Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at DA3B Impact (Sites 2 to 4 and X1 to X3) and Control (Near Control and Far Control) Treatments and Times (May and Nov 2010; June and Oct 2011; Jun and Nov 2013; June and Nov 2015)

4.3.2.3 Chironominae Abundance

The mean number of chironomins collected at each Site ranged from 1.3 (SE = 0.6) to 71.3 (SE = 8.5). While PERMDISP $P < 0.05$ (indicating statistical differences may be due to differences between means and variances), examination of the *post-hoc* tests involving pairs of Impact and Control Treatments (**Table 4-5**) and **Figure 4-2a** indicates that:

> More chironomins were found at Site 2 than at the Near Control in November 2015 and the Far Control in June 2015;

> Fewer were found at Site 3 than at the Near Control in November 2010 and the Far Control in May 2010 and November 2015. More were found at Site 3 than at the Near Control in June 2015;

> Fewer were found at Site 4 than at the Near Control in June and October 2011 and November 2015 and at the Far Control in May 2010. More were found at Site 4 than at the Far Control in June 2015

> Fewer were found at X1 than at the Near Control, except in October 2011 and June 2015, and the Far Control, except in October 2011 and November of 2013 and 2015;

> More were found at X2 than at the Near Control in June 2011 and November 2015 and fewer were found here than at the Far Control in May 2010 and October 2011;

Table 4-5 Summary of the results of the post hoc tests for chironomin abundance between pairs of Treatments for each Time. Arrows indicate the difference (as indicated by Figure 4-1a) in the magnitude of the response variable at the Impact Site relative to the Near and Far Controls (i.e. up arrows indicate more individuals at the Impact Site than the Control). Only differences with P≤0.05 are displayed, the full results of the *post-hoc* tests are provided in Appendix H. Note that relative differences are indicative only, as PERMDISP P < 0.05 indicated that statistically significant differences between groups may be due to differences in mean and / or variance (Section 3.6.4).

Phase:		Before				After			
Year:	**2010**		**2011**		**2013**		**2015**		
Survey:	**May**	**Nov**	**Jun**	**Oct**	**Jun**	**Nov**	**Jun**	**Nov**	
Impact Treatment									**Control Treatment**
Site 2	ns	ns	*Not sampled*		ns	ns	ns	↑	Near Control
Site 3	ns	↓	ns	ns	ns	ns	ns	ns	Near Control
Site 4	ns	ns	↓	↓	ns	ns	ns	↓	Near Control
Site X1	↑	↑	↑	ns	↑	↑	ns	↑	Near Control
Site X2	ns	ns	↑	ns	ns	ns	ns	↑	Near Control
Site X3	↑	↓	ns	↓	ns	ns	ns	ns	Near Control
Site 2	ns	ns	ns	ns	ns	ns	↑	ns	Far Control
Site 3	↓	ns	ns	ns	ns	ns	↑	↓	Far Control
Site 4	↓	ns	↓	↓	ns	ns	↑	↓	Far Control
Site X1	↑	↑	↑	ns	↑	ns	↑	ns	Far Control
Site X2	↓	ns	ns	↓	ns	ns	ns	ns	Far Control
Site X3	↑	ns	↓	↓	ns	ns	ns	↓	Far Control

- More were found at X3 than at both Controls in May 2010 and fewer were found here than at the Near Control in November 2010 and October 2011 and the Far Control in 2011 and November 2015; and
- The pattern of change at Sites 2 to 4 and X2 (i.e. an apparent increase in the number of chironomins after the commencement of extraction) may be indicative of an, albeit short term, impact at these sites (**Section 5.4**). The patterns of change at the other Impact sites were not indicative of a mining impact, with either fewer individuals detected here than at the Controls, or, more individuals detected here than at the Controls, but before extraction only.

Examination of post-hoc tests between pairs of Surveys (**Table 4.6**) and **Figure 4-2b** suggests:

- Fewer chironomins were found at Site 3 in November 2010 than May 2010;
- More were found at Site 4 in October 2011 than in June 2011 and in November 2013 than in June 2013;
- Fewer were found at X1 and X2 in October 2011 than June 2011 and in November 2013 than in June 2013;
- More were found at each site, except Site 4 where fewer were found, in November 2015 than in June 2015 (it should be noted that **Figure 4-2b** suggest that the difference at Site 4 was likely due to a change in variance, rather than mean); and
- More were found at the Controls in November 2015 than in June 2015.

None of these patterns of change are indicative of a mining impact (**Section 5.4**)

There was some evidence of a trend for more chironomins at X1, with the more individuals found here than at the other Treatments during the majority of Surveys (**Figure 4.2b**). Also, fewer individuals appear to have been found in June 2013 than in other Surveys (**Figure 4.2a**).

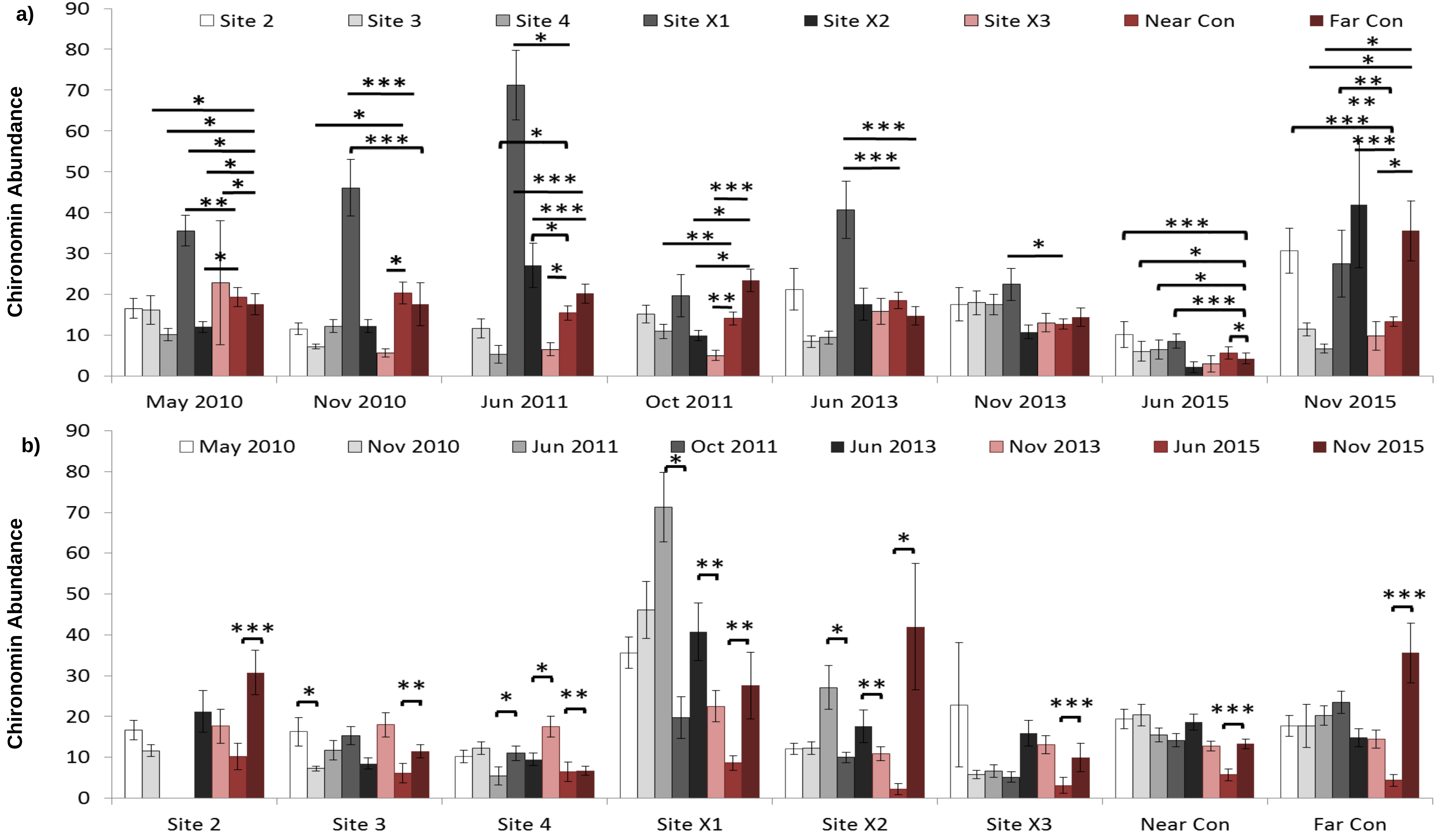

Figure 4-2 Number of chironomins found on macroinvertebrate collectors deployed at Impact and Control Treatments in Dendrobium Area 3B for a) pairs of Treatments and b) pairs of Surveys between 2010 and 2015. Bars indicate statistically significant differences, *=P≤0.05, **P≤0.01, ***P≤0.001. Note, these may be due to differences between means and / or variances (PERMDISP P<0.05).

Table 4-6 Summary of the results of the post hoc tests for chironomin abundance between pairs of Times for each Treatment. Arrows indicate the change (as indicated by Figure 4-1b) in the magnitude of the response variable at the Impact Site between the two times (i.e. up arrows indicate an increase in the number of individuals). Only differences with P≤0.05 are displayed, the full results of the post hoc tests are provided in Appendix H. It should be noted that relative differences are indicative only, as PERMDISP P < 0.05 indicated that statistically significant differences between groups may be due to differences in mean and variance (Section 3.6.4).

Phase:	Before		After	
Year:	2010	2011	2013	2015
Survey:	May vs Nov	Jun vs Oct	Jun vs Nov	Jun vs Nov
Treatment				
Site 2	ns	ns	ns	↑
Site 3	↓	ns	ns	↑
Site 4	ns	↑	↑	↓
Site X1	ns	↓	↓	↑
Site X2	ns	↓	↓	↑
Site X3	ns	ns	ns	↑
Near Control	ns	ns	ns	↑
Far Control	ns	ns	ns	↑

4.3.2.4 Leptophlebiid Abundance

The mean number of leptophlebiids collected at each Site ranged from 1.3 (SE = 0.6) to 71.3 (SE = 8.5). While PERMDISP P < 0.05 (indicating statistical differences may be due to differences between means and variances), examination of the *post-hoc* tests involving pairs of Impact and Control Treatments (**Table 4-7**) and (**Figure 4-3a)** suggests:

> Fewer leptophlebiids were found at Site 2 than at the Near Control in May 2010 and at the Near and Far Controls in June 2013. More were found here than at the Near Control in June 2015;

> Fewer were found at Site 3 than at the Near Control in June 2013 and the Far Control in October 2011 and June of 2011, 2013 and 2015;

> Fewer were found at Site 4 than at the Near Control in November 2010 and June 2011 and the Far Control in June of 2011, 2013 and 2015;

> Fewer were found at X1 than the Near Control during each before extraction Survey and after extraction in November 2015. Fewer were also found here than at the Far Control during each Survey;

> Fewer were found at X2 than at the Near Control in June 2013 and November 2015 and the Far Control in June of 2011 and 2015 and November 2015. More were found at X2 than at either Control in May 2010 and the Near Control in June 2015; and

> More were found at X3 than at both Controls in May 2010 and fewer were found here than at the Far Control in June 2011 and November 2013.

The pattern of change at Sites 2, 3 and X2 (i.e. an apparent reduction in the number of leptophlebiids after the commencement of extraction) may be indicative of an, albeit short term, impact at these sites (**Section 5.4**). The patterns of change at the other Impact sites were not indicative of a mining impact, with either fewer individuals detected here than at the Controls before extraction.

Table 4-7 Summary of the results of the post hoc tests for leptophlebiid abundance between pairs of Treatments for each Time. Arrows indicate the direction of difference (as indicated by Figure 4-2a) in the magnitude of the response variable at the Impact Site relative to the Control (i.e. up arrows indicate a greater number of individuals at the Impact Site compared with the Control). Only differences with P≤0.05 are displayed, the full results of the post hoc tests are provided in Appendix H. It should be noted that relative differences are indicative only, as PERMDISP P < 0.05 indicated that statistically significant differences between groups may be due to differences in mean and variance (Section 3.6.4).

Phase:	Before				After				
Year:	**2010**		**2011**		**2013**		**2015**		
Survey:	**May**	**Nov**	**Jun**	**Oct**	**Jun**	**Nov**	**Jun**	**Nov**	
Impact Treatment									**Control Treatment**
Site 2	↓	ns	*Not sampled*		↓	ns	↑	ns	Near Control
Site 3	ns	ns	ns	ns	↓	ns	ns	ns	Near Control
Site 4	ns	↓	↓	ns	ns	ns	ns	ns	Near Control
Site X1	↓	↓	↓	↓	ns	ns	ns	↓	Near Control
Site X2	↑	ns	ns	ns	↓	ns	↑	↓	Near Control
Site X3	↑	ns	ns	ns	ns	ns	ns	ns	Near Control
Site 2	ns	ns	*Not sampled*		↓	ns	ns	ns	Far Control
Site 3	ns	ns	↓	↓	↓	ns	↓	ns	Far Control
Site 4	ns	ns	↓	ns	↓	ns	↓	ns	Far Control
Site X1	↓	↓	↓	↓	↓	↓	↓	↓	Far Control
Site X2	↑	ns	↓	ns	ns	ns	↓	↓	Far Control
Site X3	↑	ns	↓	ns	ns	↓	ns	ns	Far Control

Examination of the results *post-hoc* tests between pairs of Surveys (**Table 4.8**) and **Figure 4-2b** suggests:

> More leptophlebiids were found at Sites 2 and 3 in November 2010 than in May 2010 and in November 2013 than in June 2013;

> More were found at Site 4 in October 2011 than in June 2011, in November 2013 than in June 2013 and in November 2015 than in June 2015;

> More were found at X1 in November 2010 than in May 2010;

> Fewer were found at X2 in November 2013 than in June 2013 an in November 2015 than in June 2015;

> More were found at X3 in November 2013 than in June 2013;

> More were found at X3 in November 2010 than in May 2010 and in November 2015 than in June 2015; and

> More were found at both Controls in November 2010 than in May 2010 and more were found at the Near Control in November 2015 than in June 2015.

The apparent decrease in the number of individuals at X2 during 2013 and 2015 could be indicative of an impact due to mining (**Section 5.4**). Changes at the other Impact sites are not indicative of an impact, with apparent increases in the number of individuals here relative to the Controls, or, patterns of change here that are similar to those observed at the Controls.

There was also some evidence of a trend for fewer individuals at X1, and to a lesser degree Sites 3 and 4 (**Figure 4-2b**).

As for chironomins, the large variability Before extraction and at the Controls makes it very difficult to infer any impact to leptophlebiids.

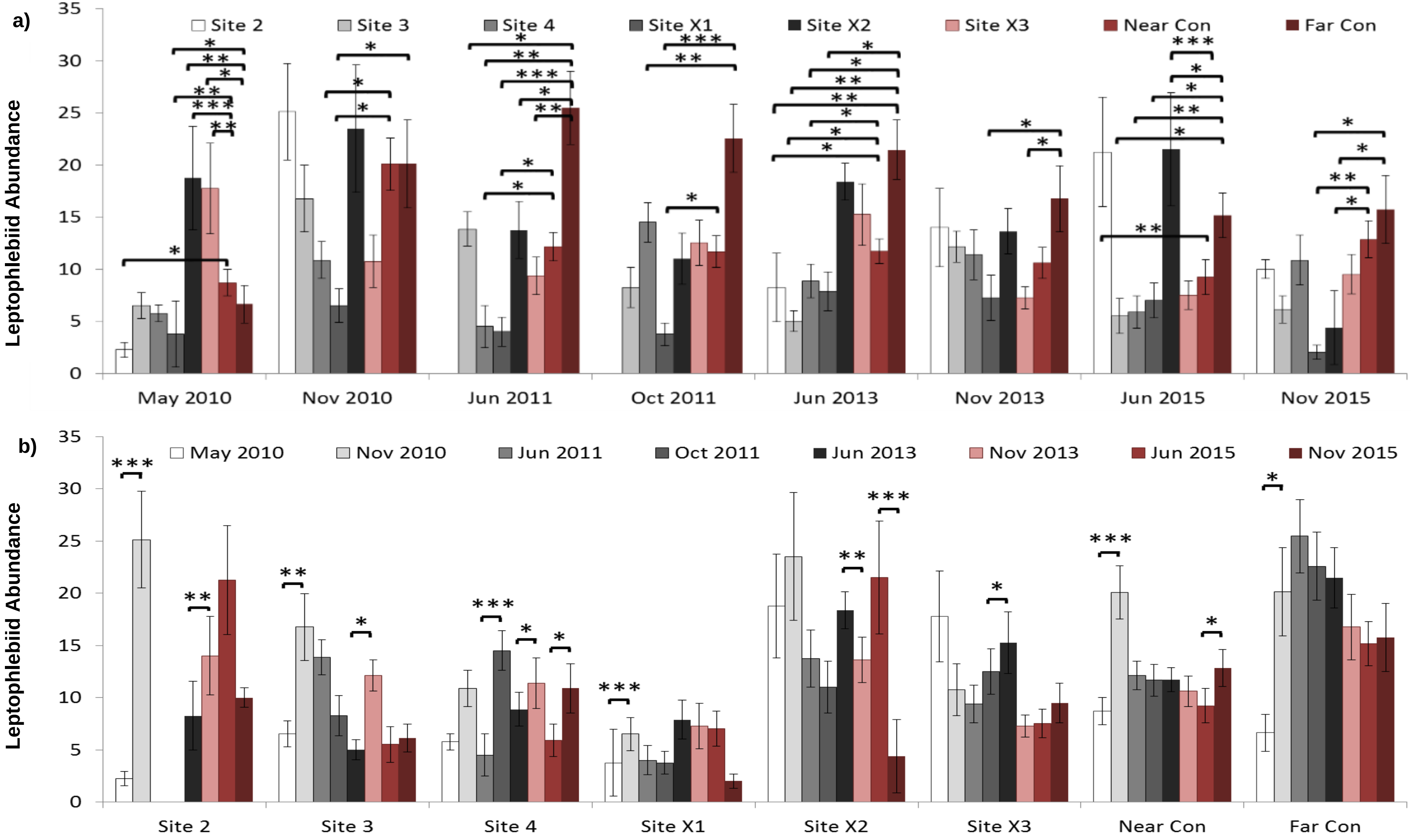

Figure 4-3 Number of leptophlebiids found on macroinvertebrate collectors deployed at Impact and Control Treatments in Dendrobium Area 3B for a) pairs of Treatments and b) pairs of Surveys between 2010 and 2015. Bars indicate statistically significant differences, *=P≤0.05, **P≤0.01, ***P≤0.001. Note, these may be due to differences between means and / or variances (PERMDISP P<0.05).

Table 4-8 Summary of the results of the post hoc tests for leptophlebiid abundance between pairs of Times for each Treatment. Arrows indicate the change (as indicated by Figure 4-2b) in the magnitude of the response variable at the Impact Site between the two times (i.e. up arrows indicate an increase in the number of individuals). Only differences with P≤0.05 are displayed, the full results of the post hoc tests are provided in Appendix H. It should be noted that relative differences are indicative only, as PERMDISP P < 0.05 indicated that statistically significant differences between groups may be due to differences in mean and variance (Section 3.6.4).

Phase:	Before		After	
Year:	2010	2011	2013	2015
Survey:	May vs Nov	Jun vs Oct	Jun vs Nov	Jun vs Nov
S02	↑	*Not sampled*	↑	ns
S03	↑	ns	↑	ns
S04	ns	↑	↑	↑
X1	↑	ns	ns	ns
X2	ns	ns	↓	↓
X3	ns	ns	↑	ns
Near Control	↑	ns	ns	↑
Far Control	↑	ns	ns	ns

4.4 Fish

The numbers of fish caught whilst backpack electrofishing and in bait traps in 2015 are provided in **Appendices I** and **J**, respectively. No fished classes as threatened (e.g. Macquarie perch) were captured or observed. These do occur farther downstream in Wongawilli Creek (downstream of DA3). Similarly, no introduced species (e.g. eastern gambusia) were caught or observed. Four species were caught by electrofishing, these were Galaxid (*Galaxais* sp.), Australian smelt (*Retropinna semoni*), shortfinned eel (*Anguilla australis*) and Coxs gudgeon (*Gobiomorphus coxii*). Galaxids were the most widespread and abundant species, occurring at the majority of sites. Australian smelt were found at Sites 5 and 16, shortfinned eel at Sites 3 and 5 and Coxs gudgeon at Site 3 only. Galaxids and Australian smelt were also caught in bait traps. Galaxids were caught at most sites on one more occasion in 2015, though in relatively low abundance compared with backpack electrofishing. Australian smelt were caught at Sites 16 and X4 in May 2015. Freshwater crayfish (*Euasticus* sp.) were observed at the majority of sites, as was the case in previous years.

All these species, except Coxs gudgeon, have been caught previously in DA3 (Cardno Ecology Lab 2009, 2011a, 2013a and 2014). The galaxids were small, up to approximately 5 cm in length, and were difficult to identify to species in the field without magnification. One larger (approximately 13 cm long) specimen caught in Sandy Creek in 2013 appeared very likely to be climbing galaxias (*Galaxias brevipinnis*). While the large variability and number of zero counts in fish data made statistical analyses inappropriate, there was no evidence of any changes in data collected in 2015 that could be indicative of a mining impact. There was also no sign of any ill health in fish and no dead fish and fish kills were observed during sampling.

5 Discussion

As predicted in relation to the physical effects of mining, no physical impacts associated with mining have been identified along the major watercourse in DA3B, Wongawilli Creek, and there have been minor (i.e. small scale) impacts identified in Donalds Castle Creek and a tributary of Wongawilli Creek. The evidence for ecological change potentially due to extraction is discussed below.

5.1 Aquatic Habitat

There was no evidence of changes in RCE scores (except from X2 on WC21, which experienced a reduction in the condition of its riffle / pool sequence), to suggest that the changes to aquatic ecology that have occurred are outside what would be expected due to natural variation. Except for X2, data collected using this method were comparable from Before to After commencement of extraction. With the exception of changes to habitat observed at Sites X1 and X2, the habitat assessment undertaken to date indicate that the aquatic ecology of DA3B has been undisturbed by extraction.

The complete drainage of all but a few small pools at X2 following fracturing and flow diversions first observed in 2013 has led to a direct loss of aquatic habitat and likely also biota. Other impacts to aquatic habitat include the loss of longitudinal connectivity. Despite this, impacts to pool water levels and flow appear to be restricted to the upstream section of this creek (approximately 1 km in length) and water and flow re-appears a short distance downstream of here. This suggests that impacts to aquatic ecology, while severe for WC21, are relatively minor considering the abundance of similar habitat in the catchment area.

At this stage the loss of pool water levels and flow at Site X1 is restricted to the upstream extent of the site (approximately 10 m long) where the creek emerges from a swamp. Thus, associated impacts to aquatic habitat here are also minor and not as severe as that experienced at X2.

The impact to aquatic ecology due to desiccation of aquatic macrophytes would likely be negligible, as no in-stream aquatic vegetation has been identified at X1 and X2.

5.2 Water Quality

There was no evidence in the limited water quality sampling of any changes that could be associated with mining, including that from Sites X1 and X2 where the physical mining impacts have been reported (**Sections 4.1** and **5.1**).

Assessment of surface water quality and creek flow and catchment yield was undertaken by Hydrosimulations (2016) as part of the End of Panel Reporting for Longwall 11. A reduction in dissolved oxygen below the water quality Trigger Action Response Plan (TARP) trigger was observed at Donalds Castle Creek Site DCS2 (400 m downstream of X1) and at Wongawilli Creek tributary WC15 Site WC15S1 (which enters Wongawailli Creek within Site 2) during or soon after extraction of Longwall 11. However, these were observed in January to February 2016, subsequent to the aquatic ecology sampling in 2015. A loss of sub-catchment yield in the headwater of Donalds Castle Creek and in the sub-catchment of WC21 was also observed during extraction of Longwall 11. Reductions in yields were not observed further downstream.

5.3 AUSRIVAS Data

None of the four sources of significant statistical variation detected in AUSRIVAS data by PERMANOVA were indicative of an impact.

Although the RCE scores indicate the watercourses and adjoining riparian zone are largely undisturbed (**Sections 4.1**. and **5.1**), the OE50 Taxa Scores, Band Scores and SIGNAL2 Indices derived from the AUSRIVAS samples suggest that some sections of the watercourses may experience environmental stress. Low scores indicative of environmental stress could, however, be related to the ephemeral nature of some creeks and the possibility of ephemeral habitats favouring taxa regarded as pollution tolerant. Many taxa with low SIGNAL grades are air breathers that generally utilise surface water habitat and would be able to colonise ephemeral creeks. The relatively low natural pH levels and low nutrient status in the watercourses may also influence macroinvertebrate diversity.

5.4 Macroinvertebrate Collectors

The data from the collectors provide very limited evidence of changes in aquatic ecology at Sites 2 to 4 on Wongawilli Creek and X2 on WC21 that could be indicative of a mining impact. Particularly given the large natural variability observed at the Control sites. Possible impacts include the potential increase in the number of chironomins at Sites 2 to 4 relative to one or both Controls during 2015 (after the completion of Longwalls 9 and 10 and the commencement of extraction of Longwall 11). However, if impacts occurred, they appear to be minor and short term (at least based on the data collected up until the end of 2015). In each case, changes are apparent relative to one Control in one Survey only, moreover, at Sites 3 and 4, numbers appeared to subsequently decrease relative to one or both Controls from June to November 2015. Furthermore, while more chironomins appear to have been found at X2 than at the Near Control in November 2015, this also appears to have been the case before extraction in June 2011, suggesting that relatively large numbers may occur at X2, irrespective of mining.

Apparent increases in the number of chironomins evident at most Impact sites from June to November 2015 were also observed at the Controls, thus, these were likely related to natural variation, rather than any potential mining impact. The apparent increase in the number of chironomins at Site 4 from June to November of 2013 is also unlikely to have been due to mining, despite evidence of a similar change at the Controls. An increase also appears to have occurred here between June and October of 2011, before extraction commenced, suggesting this pattern may be due to natural variation. In any case, fewer individuals were found at Site 4 in 2015 than in 2014, suggesting that if an impact occurred, it was likely short term.

Changes in leptophlebiid abundance also provide limited evidence of minor and short term impacts. The relatively few numbers of leptophlebiids at sites on Wongawilli Creek (Sites 2 and 3), Donalds Castle Creek (X1) and WC21 (X2) following commencement of extraction were evident in one Survey only, and, except for Site 2, apparent relative to one Control only. The apparent reduction in the number of individuals at X2 between June and November of 2015 was not observed at either Control and may provide some evidence of a change due to mining. If this were the case, the response appears to have been delayed as a relatively large number of individuals were found here in June 2015, sometime after the observed physical mining impacts. There is less evidence to suggest a mining impact explains the potential reduction here between June and November of 2013, as similar (although not statistically significant) changes occurred at the Controls (**Figure 4-3b**) and physical mining impacts were not observed here until December 2013 (**Section 4.1**).

All these changes, aside from the potential reduction in the number of leptophlebiids at X2 in 2013, occurred in 2015. It is unclear if changes occurring in 2015 were due to extraction of Longwall 9, which commenced in February 2013, Longwall 10, which commenced in January 2014, and / or Longwall 11, which commenced in February 2015. They may be due to a cumulative effect associated with extraction of all these longwalls, although it appears unlikely that extraction of Longwall 11 contributed substantially to any change. While some rock fracturing attributed to extraction of Longwall 11 has been observed in WC21 approximately 600 to 700 m upstream of X2, this was observed in 2016 and no impacts were observed in WC21 prior to, and during, the 2015 aquatic ecology sampling (South32 2016). Thus, at this stage, there is no evidence that extraction of Longwall 11 has had any effect on aquatic ecology in addition to that attributed to extraction of Longwalls 9 and 10. Nevertheless, it is possible that impacts associated with this Longwalls that were observed in 2016 may have exacerbated impacts due to previous longwalls. These impacts, and any others that did occur following commencement of extraction of Longwall 11, could delay any natural remediation (e.g. filling in of fractures with sand and other material) that may occur in WC21.

Any increase in chironomin, and reduction in leptophlebiid, numbers in WC21 and Donalds Castle Creek could be associated with the physical mining impacts, flow diversions and loss of aquatic habitat observed here. Chironomins and leptophlebiids are tolerant and sensitive to water pollution, respectively, and could be expected to respond to changes in water quality associated with changes to flow and habitat in these creeks. While impacts to creek connectivity also associated with pool water loss may also have affected some macroinvertebrates, both these taxa have an airborne adult stage which would enable them to colonise isolated pools. Similar changes to numbers of chironomids (comprising the sub-families Chironominae, Tanypodinea and Orthocladinae) and leptophlebiids were detected in SC10C (a tributary of Sandy Creek) following a reduction in aquatic habitat and changes in water quality here associated with extraction of DA3A Longwalls and identified physical mining impacts (Cardno Ecology Lab 2015).

Previously, fewer leptophlebiids have been associated with elevated ECs due to mine water discharge in the Georges River (Cardno Ecology Lab 2010a and references therein). This study, and the findings of an Australian Coal Industry Research Program (ACARP) funded study into the effects of saline water discharge on aquatic biota in the Southern and Hunter Coalfields of NSW (Cardno Ecology Lab 2010b), also suggested that elevated EC can influence the abundance of aquatic macroinvertebrates. Neither WC21 nor Donalds Castle Creek nor SC10C are subject to mine water discharge and any mining associated changes to water quality that may have occurred here are due to physical mining impacts following subsidence, rather than mine water discharges.

Potential changes in the abundance of these taxa occurring at sites on Wongawilli Creek are less likely to be associated with mining in the absence of any observed impacts to water quality before or during sampling of aquatic ecology in 2015 and any more than minor observed physical impacts. While some fracturing attributed to the extraction of Longwall 9 was observed in Wongawilli Creek in December 2013, this was minor, located at the edge of a pool not submerged during normal flow and does not appear to have resulted in any flow diversions (BHPBIC 2014). An extension of this fracture was observed during extraction of Longwall 10, although this was not considered due to extraction of this longwall owing to the apparent age of the fracture. Thus, and in the absence of any consistent patterns of change at Wongawilli Creek Impact sites, the changes that were observed in Wongawilli Creek are more likely due to natural variation, rather than potential mining impacts.

Patterns of change evident in macroinvertebrate assemblages sampled using macroinvertebrate collectors are much harder to interpret due to the relatively large variability in assemblages and the difficulty in identifying changes that could be indicative of an impact. This is particularly the case when differences between Treatments are more evident before, rather than after, commencement of extraction. Univariate measures, such as the abundance of chironomins and leptophlebiids, may be better indicators of potential impacts to aquatic ecology due to mining related subsidence. These univariate measures are also easier to interpret than changes in assemblages.

Under the aquatic ecology TARP for DA3B, a reduction in aquatic habitat for 1 year constitutes a Level 1 Trigger, a reduction for 2 years following the active subsidence period (i.e. when a Longwall is within 400 m of a feature, such as a creek) is a Level 2 Trigger and a reduction for more than 2 years or a complete loss of habitat following the active subsidence period is a Level 3 Trigger. For Site X1, the active subsidence period ended on 24 October 2013 when Longwall 9 was more than 400 m away from this site. Longwall 10 did not come within 400 m of X1. For X2, the active subsidence periods ended when Longwalls 9 and 10 (which finish within 400m of this site) were completed; 2 June 2014 and 20 January 2015, respectively. Thus, at this stage, the reduction in aquatic habitat observed at Site X1 on Donalds Castle Creek constitutes a Level 2 Trigger, and that at X2 on WC21 constitutes a Level 1 Trigger (less than 2 years has passed since extraction of Longwalls 9 and 10 were completed).

5.5 Fish

The loss of aquatic habitat and impacts to creek connectivity in WC21, and to a lesser degree Donalds Castle Creek, could have impacted fish. However, impacts to fish populations in DA3B due to the physical mining impacts in these creeks are likely minimal due to the relatively small amount of potential fish habitat that has been lost. There is no other evidence of any impacts to fish occurring in DA3B due to extraction of Longwalls 9, 10 and 11. Importantly, no threatened species have been put at risk by extraction in DA3B and it is most unlikely that any introduced species would be favoured by the extraction in this area.

6 Conclusion and Recommendations

The fracturing of bedrock and reductions of pool water levels and flow in WC21 following the extraction of DA3B Longwalls 9 and 10 represents a local loss of aquatic habitat and probably also biota. The potential changes in the abundance of chironomins and leptophlebiids may be associated with these physical effects. Similarly, relatively minor reductions in abundance of leptophlebiids in Donalds Castle Creek could be mining related impacts associated with extraction of Longwall 9. However, changes in these indicators were apparent in individual Retrievals only, may be short term and are very limited spatially (and very small in the context of the catchment area). Any changes in numbers of these taxa may be related to the fracturing of bedrock and loss of pool water levels in these creeks. No impacts to water quality have been observed in data collected by Cardno. The changes in dissolved oxygen observed by Hydrosimulations (2016) in Donalds Castle Creek and Wongawilli Creek tributary WC15 occurred after the latest sampling of aquatic ecology in 2015.

It is recommended that biennial monitoring of aquatic ecology in DA3B should continue, with the next round of sampling undertaken in 2017, in line with the requirements of the SMP for DA3B (BHPBIC 2012). As no monitoring is scheduled for 2016, South32 should continue to monitor changes in aquatic habitat (i.e. loss of flow, reduction in pool water levels and any evidence of impacts to aquatic biota, particularly freshwater crayfish which can die following loss of water) occurring in DA3B during this time. Further observed changes in aquatic ecology due to mine subsidence may trigger additional aquatic ecology surveys.

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Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

A

RIVER, CHANNEL AND ENVIRONMENTAL (RCE) CATAGORIES

Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone	
Undisturbed native vegetation	4
Mixed native vegetation and pasture/exotics	3
Mainly pasture, crops or pine plantation	2
Urban	1
2. Width of riparian strip of woody vegetation	
More than 30 m	4
Between 5 and 30 m	3
Less than 5 m	2
No woody vegetation	1
3. Completeness of riparian strip of woody vegetation	
Riparian strip without breaks in vegetation	4
Breaks at intervals of more than 50 m	3
Breaks at intervals of 10 - 50 m	2
Breaks at intervals of less than 10 m	1
4. Vegetation of riparian zone within 10 m of channel	
Native tree and shrub species	4
Mixed native and exotic trees and shrubs	3
Exotic trees and shrubs	2
Exotic grasses / weeds only	1
5. Stream bank structure	
Banks fully stabilised by trees, shrubs etc.	4
Banks firm but held mainly by grass and herbs	3
Banks loose, partly held by sparse grass etc.	2
Banks unstable, mainly loose sand or soil	1
6. Bank undercutting	
None, or restricted by tree roots	4
Only on curves and at constrictions	3
Frequent along all parts of stream	2
Severe, bank collapses common	1
7. Channel form	
Deep: width / depth ratio < 7:1	4
Medium: width / depth ratio 8:1 to 15:1	3
Shallow: width / depth ratio > 15:1	2
Artificial: concrete or excavated channel	1

Descriptor and category	Score
8. Riffle / pool sequence	
Frequent alternation of riffles and pools	4
Long pools with infrequent short riffles	3
Natural channel without riffle / pool sequence	2
Artificial channel; no riffle / pool sequence	1
9. Retention devices in stream	
Many large boulders and/or debris dams	4
Rocks / logs present; limited damming effect	3
Rocks / logs present, but unstable, no damming	2
Stream with few or no rocks / logs	1
10. Channel sediment accumulations	
Little or no accumulation of loose sediments	4
Some gravel bars but little sand or silt	3
Bars of sand and silt common	2
Braiding by loose sediment	1
11. Stream bottom	
Mainly clean stones with obvious interstices	4
Mainly stones with some cover of algae / silt	3
Bottom heavily silted but stable	2
Bottom mainly loose and mobile sediment	1
12. Stream detritus	
Mainly un-silted wood, bark, leaves	4
Some wood, leaves etc. with much fine detritus	3
Mainly fine detritus mixed with sediment	2
Little or no organic detritus	1
13. Aquatic vegetation	
Little or no macrophyte or algal growth	4
Substantial algal growth; few macrophytes	3
Substantial macrophyte growth; little algae	2
Substantial macrophyte and algal growth	1

APPENDIX

B

RCE SCORES FOR EACH OF THE DA3B AQAUTIC ECOLOGY MONITORING SITES

RCE Category	Potential Impact Sites							Near Control Sites						Far Control Sites		
	2	3	4*	X1	X2	X3		1	5	6	14	X4		7**	15	16
Land use pattern beyond the immediate riparian zone	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Width of riparian strip of woody vegetation	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Completeness of riparian strip of woody vegetation	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Vegetation of riparian zone within 10 m of channel	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Stream bank structure	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Bank undercutting	3	3	3	4	4	4		3	3	4	3	4		3	3	3
Channel form	3	3	3	3	3	3		3	3	3	3	3		3	3	3
Riffle/pool sequence	3	3	3	2	2	3		4	3	4	4	3		3	4	3
Retention devices in stream	4	4	4	4	4	4		4	3	4	4	4		4	4	4
Channel sediment accumulations	3	3	3	4	4	4		3	4	4	4	4		2	4	4
Stream bottom	2	2	2	4	4	4		4	4	4	3	4		3	4	4
Stream detritus	4	4	4	4	4	4		4	4	4	4	4		4	4	4
Aquatic vegetation	4	4	4	3	3	4		3	3	4	4	4		4	4	4
Total	46	46	46	48	48	50		48	47	51	49	51		46	50	49

APPENDIX

C

MEAN WATER QUALITY DATA FOR EACH DA3B AQUATIC ECOLOGY MONITORING SITES MEASURED IN MAY, JUNE, OCTOBER AND DECEMBER 2015

Variable	DTV	May		June		October		November	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Site 1									
Temperature (°C)		10.6	0.0	8.9	0.0	12.8	0.0		
Conductivity (µS/cm)	30-350	62	0	63	0	72	1		
pH	6.5-8.0	5.5	0.1	5.6	0.0	5.3	0.0		
ORP (mV)		226	0	241	1	242	3		
DO (% Sat)	90-110	94.2	0.0	95.0	0.0	93.7	0.3		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	3.6	0.5		
Site 2									
Temperature (°C)		10.3	0.0	8.8	0.0	11.6	0.0		
Conductivity (µS/cm)	30-350	67.0	0.0	66	0	72	1		
pH	6.5-8.0	6.4	0.0	5.8	0.0	5.7	0.1		
ORP (mV)		169	2	172	0	329	104		
DO (% Sat)	90-110	86.8	0.2	89.2	0.1	87.6	0.0		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	1.2	0.0		
Site 3									
Temperature (°C)		10.2	0.0	9.0	0.0	12.4	0.0		
Conductivity (µS/cm)	30-350	76	0	77	0	81	0		
pH	6.5-8.0	5.8	0.0	6.3	0.0	5.3	0.0		
ORP (mV)		182	0	153	0	197	2		
DO (% Sat)	90-110	90.6	0.0	91.3	0.0	89.1	0.1		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	0.0	0.0		
Site 4									
Temperature (°C)		10.0	0.0	8.4	0.0	12.4	0.0		
Conductivity (µS/cm)	30-350	68	0	68	0	80	0		
pH	6.5-8.0	5.0	0.0	6.1	0.0	5.4	0.0		
ORP (mV)		226	0	196	1	186	0		
DO (% Sat)	90-110	87.0	0.0	89.5	0.0	89.4	0.0		
Turbidity (NTU)	2-25	0.3	0.0	0.0	0.0	1.7	0.0		
Site 5									
Temperature (°C)		11.8	0.0	8.2	0.0	12.4	0.0		
Conductivity (µS/cm)	30-350	68	1	67	0	74	0		
pH	6.5-8.0	6.4	0.0	5.8	0.0	5.7	0.0		
ORP (mV)		165	2	173	1	161	1		
DO (% Sat)	90-110	87.7	0.0	89.7	0.1	90.1	0.0		
Turbidity (NTU)	2-25	0.1	0.0	0.0	0.0	3.1	0.1		
Site 6									
Temperature (°C)		14.2	0.0	12.1	0.0	17.2	0.0		
Conductivity (µS/cm)	30-350	80	0	86	1	92	0		
pH	6.5-8.0	6.4	0.1	6.6	0.0	6.1	0.0		
ORP (mV)		67	1	48	1	70	1		
DO (% Sat)	90-110	96.0	0.0	96.7	0.0	94.9	0.4		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	3.6	0.1		
Site 7									
Temperature (°C)		10.8	0.0	9.3	0.0	12.2	0.0		
Conductivity (µS/cm)	30-350	84	0	81	0	85	0		
pH	6.5-8.0	5.8	0.0	5.4	0.0	5.0	0.0		
ORP (mV)		199	0	218	0	222	1		
DO (% Sat)	90-110	88.8	0.1	87.6	0.0	86.7	0.0		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	0.0	0.0	*Not sampled*	

Variable	DTV	May		June		October		November	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Site 14									
Temperature (°C)		11.9	0.0	9.4	0.0	13.9	0.0		
Conductivity (µS/cm)	30-350	79	0	80	1	93	0		
pH	6.5-8.0	5.4	0.0	6.3	0.0	5.3	0.0		
ORP (mV)		199	0	180	4	201	1		
DO (% Sat)	90-110	94.6	0.1	92.5	0.0	96.4	0.0		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	1.6	0.0		
Site 15									
Temperature (°C)		10.5	0.0	9.5	0.0	11.7	0.0		
Conductivity (µS/cm)	30-350	93	0	84	0	90	1		
pH	6.5-8.0	5.4	0.0	6.0	0.0	5.4	0.0		
ORP (mV)		166	1	147	0	200	1		
DO (% Sat)	90-110	90.6	0.0	92.8	0.0	93.5	0.3		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	6.3	0.0		
Site 16									
Temperature (°C)		10.9	0.0	9.7	0.0	11.6	0.0		
Conductivity (µS/cm)	30-350	108	0	97	0	88	0		
pH	6.5-8.0	6.0	0.0	6.3	0.0	5.5	0.0		
ORP (mV)		118	0	134	0	200	2		
DO (% Sat)	90-110	94.0	0.0	93.7	0.0	92.1	0.0		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	1.0	0.0		
Site X1									
Temperature (°C)		14.7	0.0	12.7	0.0	13.9	0.0		
Conductivity (µS/cm)	30-350	70	0	72	0	85	1		
pH	6.5-8.0	5.2	0.0	6.2	0.0	4.5	0.0		
ORP (mV)		252	1	230	4	265	2		
DO (% Sat)	90-110	71.5	0.2	91.1	0.1	70.8	0.0		
Turbidity (NTU)	2-25	1.4	0.3	0.8	0.0	0.0	0.0		
Site X2									
Temperature (°C)		15.0	0.0	8.7	0.0	14.7	0.0		
Conductivity (µS/cm)	30-350	85	0	54	1	80	0		
pH	6.5-8.0	4.2	0.0	6.3	0.4	5.7	0.0		
ORP (mV)		300	3	234	16	265	2		
DO (% Sat)	90-110	53.0	0.2	85.8	0.7	98.5	0.0		
Turbidity (NTU)	2-25	0.0	0.0	3.5	0.1	0.2	0.0		
Site X3									
Temperature (°C)		12.5	0.1	10.3	0.0	11.1	0.0		
Conductivity (µS/cm)	30-350	61	0	64	0	61	0		
pH	6.5-8.0	5.5	0.0	5.2	0.0	4.6	0.0		
ORP (mV)		213.0	0.0	265	0	276	0		
DO (% Sat)	90-110	88	0	82.4	0.0	80.7	0.1		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	0.0	0		
Site X4									
Temperature (°C)		10.3	0.0	8.7	0.0	11.9	0.0		
Conductivity (µS/cm)	30-350	65	0	66	0	73	1		
pH	6.5-8.0	6.2	0.0	6.0	0.0	5.5	0.0		
ORP (mV)		196	0	203	0	205	1		
DO (% Sat)	90-110	90.5	0.0	91.5	0.0	89.3	0.0		
Turbidity (NTU)	2-25	0.0	0.0	0.0	0.0	2.4	0.0	*Not sampled*	

SE = Standard Error, n = 2. Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in southeast Australia. Grey shading indicates measure outside of DTVs. November 2015 not sampled due to probe malfunction

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

D

NO. OF TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FOR AUSRIVAS SAMPLES COLLECTED AT DA3B SITES IN 2010, 2011, 2013 AND 2015

Site / Indicator	2010				2011				2013				2015			
	Mar	May	Sep	Nov	Apr	Jun	Sep	Oct	Apr	Jun	Sep	Nov	May	Jun	Sep	Nov
Site 1																
No. of Taxa	18	16	19	16	16	12	11	19	18	13	12	15	12	9	14	19
OE50 Taxa Score	1.15	0.92	0.83	0.72	0.63	0.65	0.35	0.9	0.97	0.8	0.41	0.67	0.58	0.62	0.66	0.65
SIGNAL2 Index	4.1	4.7	4.6	5.4	4.2	5.2	5.5	4.2	5.0	4.4	5.5	4.9	5.4	5.8	4.8	4.9
Site 2																
No. of Taxa	19	15	15	16	20	19	18	18	24	14	15	20	24	14	15	20
OE50 Taxa Score	1.06	0.77	0.71	0.81	1.16	0.97	0.52	0.89	0.77	0.82	0.7	0.82	0.77	0.82	0.7	0.82
SIGNAL2 Index	3.9	4.1	4.8	4.2	4.4	4.4	4.5	4.5	4.7	5.3	5.4	5.4	4.7	5.3	5.4	5.4
Site 3																
No. of Taxa	20	16	21	23	14	20	14	23	17	14	15	20	16	17	17	18
OE50 Taxa Score	1.25	1.05	0.92	0.68	0.82	0.95	0.59	0.91	0.7	0.77	0.7	0.86	0.69	0.85	0.66	0.7
SIGNAL2 Index	4.4	4.1	4.6	4.8	4.1	4.6	4.8	5.0	4.4	4.3	4.4	4.7	5.2	4.9	4.7	4.8
Site 4																
No. of Taxa	18	13	19	25	23	17	14	22	21	18	16	18	14	14	16	24
OE50 Taxa Score	1.03	0.82	0.73	1.06	0.98	0.77	0.6	0.8	1.09	0.87	0.64	0.81	0.67	0.97	0.77	0.87
SIGNAL2 Index	4.2	3.8	4.4	4.8	4.5	4.9	4.9	4.5	4.8	4.4	4.9	4.8	4.5	4.4	5.6	5.1
Site 5																
No. of Taxa	24	22	21	24	20	16	22	14	23	16	24	21	23	17	18	25
OE50 Taxa Score	1.3	1.08	0.82	0.94	0.6	0.93	0.78	0.71	1.15	0.98	0.92	0.82	0.8	0.92	0.71	0.81
SIGNAL2 Index	4.4	4.5	4.1	4.5	4.8	4.5	5.0	4.2	4.8	4.4	4.6	4.8	5.3	5.1	5.2	5.3
Site 6																
No. of Taxa	22	27	17	16	18	16	18	15	20	13	16	19	9	12	13	25
OE50 Taxa Score	1.11	1.01	0.96	0.86	0.83	0.64	0.77	0.7	1.01	0.83	0.73	0.92	0.64	0.64	0.64	1.01
SIGNAL2 Index	4.6	4.7	4.4	4.3	4.9	4.5	4.7	4.7	4.4	4.2	5.0	3.9	5.1	5.4	5.2	4.9
Site 7																
No. of Taxa	11	25	14	15	19	20	16	13	12	13	15	13	12	7	16	23
OE50 Taxa Score	0.69	0.88	0.64	0.71	0.72	0.93	0.7	0.5	0.64	0.83	0.73	0.67	0.65	0.46	0.67	0.97
SIGNAL2 Index	4.4	5.1	4.3	4.6	4.7	4.6	4.5	4.3	3.9	4.6	4.8	4.3	4.2	5.4	4.8	4.8
Site 14																
No. of Taxa	25	29	24	19	20	15	19	19	20	20	11	20	13	19	20	18
OE50 Taxa Score	1.16	1.11	0.92	0.64	0.69	0.54	0.55	0.73	0.79	0.89	0.59	0.91	0.65	0.65	0.7	0.73
SIGNAL2 Index	4.5	4.8	4.2	4.5	4.7	4.7	4.4	4.4	4.4	4.8	4.8	4.7	5.0	5.0	4.8	4.5
Site 15																
No. of Taxa	22	15	19	17	16	16	15	17	13	21	14	13	17	15	17	22
OE50 Taxa Score	1.11	0.92	1.05	0.79	0.46	0.92	0.67	0.67	0.65	0.83	0.59	0.73	0.74	0.74	0.57	0.86
SIGNAL2 Index	5.0	4.4	4.6	4.3	5.7	5.1	4.7	5.2	4.9	5.4	4.9	5.6	5.2	5.7	6.1	5.4

Site 16																
No. of Taxa	24	12	23	19	20	22	18	22	21	15	16	18	18	20	16	22
OE50 Taxa Score	0.94	0.83	1.05	1.05	0.92	1.01	0.92	0.96	1.01	0.83	0.77	0.96	0.83	0.74	0.49	0.84
SIGNAL2 Index	4.5	4.9	4.8	4.3	4.7	5.1	5.2	5.5	4.8	4.6	5.8	5.5	5.9	5.1	5.9	5.3
Site X1																
No. of Taxa	15	21	21	20	19	18	13	22	25	20	19	19	9	15	15	16
OE50 Taxa Score	0.92	0.82	0.61	0.88	0.62	0.62	0.57	0.97	1.03	0.82	0.79	1.05	0.41	0.82	0.79	0.79
SIGNAL2 Index	3.7	4.7	4.2	4.3	3.9	4.6	4.8	3.8	4.4	4.5	4.3	4.3	3.6	3.8	4.6	4.0
Site X2																
No. of Taxa	15	21	15	20	21	15	14	16	18	18	12	12				
OE50 Taxa Score	1.01	1.2	0.86	0.76	0.65	0.57	0.64	0.75	0.92	0.83	0.57	0.67				
SIGNAL2 Index	3.8	4.1	4.3	4.3	4.7	4.7	4.7	4.1	4.6	5.3	4.5	4.5				*No water*
Site X3																
No. of Taxa	14	21	17	24	20	18	19	19	15	19	17	17	15	17	12	20
OE50 Taxa Score	0.65	0.81	0.72	0.8	0.49	0.83	0.79	0.77	0.73	0.65	0.8	0.67	0.65	0.65	0.5	0.67
SIGNAL2 Index	3.8	3.9	4.0	4.3	4.6	4.3	4.9	4.5	4.9	4.9	4.7	4.7	4.3	5.5	4.8	4.8
Site X4																
No. of Taxa	18	17	10	9	17	15	18	15	11	11	11	11	12	10	11	11
OE50 Taxa Score	1.12	1.02	0.75	0.58	0.65	0.65	0.67	0.48	0.82	0.72	0.69	0.49	0.77	0.72	0.49	0.61
SIGNAL2 Index	3.9	4.4	4.4	3.9	4.6	3.9	4.8	4.7	4.0	4.1	4.9	4.9	3.8	4.9	5.7	4.9

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX E

PERMANOVAS COMPARING NO. OF TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES CALCULATED FROM AUSRIVAS SAMPLES FROM DA3B SITES DURING 2010 TO 2015

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Shaping the Future

A) AUSRIVAS No. of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	148.46	148.46	6.138	0.1312
Treatment	2	20.81	10.41	0.748	0.477
Season	1	1.57	1.57	0.025	0.905
Year (Phase)	2	49.69	24.85	0.852	0.459
Phase x Treatment	2	17.26	8.63	0.621	0.542
Phase x Season	1	46.47	46.47	0.736	0.490
Treatment x Season	2	4.31	2.15	0.093	0.912
Season x Year (Phase)	2	126.25	63.12	2.235	0.161
Phase x Treatment x Season	2	53.56	26.78	1.162	0.398
Survey(Season x Year (Phase))	**8**	**233.79**	**29.22**	**2.102**	**0.040**
Treatment x Season x Year (Phase)	4	92.20	23.05	1.658	0.168
Residual (pooled with Treatment x Year (Phase) and Treatment x Survey(Season x Year (Phase))	188	2614.20	13.91		
Total	215	3416.60			

B) AUSRIVAS OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.190	0.190	0.409	0.596
Treatment	2	0.004	0.002	0.048	0.944
Season	1	0.278	0.278	2.649	0.252
Year (Phase)	**2**	**0.931**	**0.466**	**8.486**	**0.011**
Phase x Treatment	2	0.026	0.013	0.349	0.716
Phase x Season	1	0.019	0.019	0.181	0.713
Treatment x Season	2	0.081	0.040	1.217	0.390
Treatment x Year (Phase)	4	0.151	0.038	1.897	0.113
Season x Year (Phase)	2	0.210	0.105	1.911	0.202
Phase x Treatment x Season	2	0.008	0.004	0.127	0.891
Survey(Season x Year (Phase))	**8**	**0.458**	**0.057**	**2.879**	**0.005**
Treatment x Season x Year (Phase)	4	0.133	0.033	1.673	0.163
Residual (pooled with Treatment x Survey(Season x Year (Phase))	184	3.661	0.020		
Total	215	6.483			

C) AUSRIVAS SIGNAL2 Index

Phase	1	4.75	4.75	2.133	0.276
Treatment	**2**	**4.93**	**2.46**	**16.128**	**<0.001**
Season	1	0.59	0.59	15.169	0.062
Year (Phase)	**2**	**4.72**	**2.36**	**8.814**	**0.008**
Phase x Treatment	2	0.01	0.01	0.040	0.960
Phase x Season	1	0.27	0.27	7.016	0.125
Treatment x Season	2	0.16	0.08	0.309	0.745
Season x Year (Phase)	2	0.08	0.04	0.149	0.869
Phase x Treatment x Season	2	0.60	0.30	1.187	0.392
Survey(Season x Year (Phase))	8	2.14	0.27	1.754	0.091
Treatment x Season x Year (Phase)	4	1.02	0.25	1.665	0.148
Residual (pooled with Treatment x Year (Phase) and Treatment x Survey(Season x Year (Phase))	188	28.73	0.15		
Total	215	48.63			

APPENDIX F

TOTAL NUMBER OF MACROINVERTEBRATES IDENTIFIED FROM MACROINVERTEBRATE COLLECTORS DEPLOYED IN DA3B 2010 TO 2015

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Taxa	AUSRIVAS		Macroinvertebrate
	Presence	Presence	Total Number of Individuals
Hydridae			9
Dugesiidae			68
Temnocephalidae			35
Nematoda			13
Corbiculidae/ Sphaeriidae			2
Oligochaeta			816
Cladocera			11
Copepoda			44
Ostracoda			4
Ceinidae			2
Oniscidae			1
Araneae			12
Hydracarina			142
Entomobryidae			4
Baetidae			1
Oniscigastridae			1
Leptophlebiidae			10573
Megapodagrionidae			101
Synlestidae			1
Gomphidae			1
Aeshnidae			2
Telephlebiidae (=Aeshnidae)			45
Austrocorduliidae			42
Cordulephyidae (=Corduliidae)			1
Hemicorduliidae (=Corduliidae)			5
Synthemistidae (=Corduliidae)			1
Gripopterygiidae			179
Mesoveliidae			1
Veliidae			5
Gelastocoridae			1
Corixidae			1
Corydalidae			28
Dytiscidae			287
Gyrinidae			240
Hydrochidae			3
Hydrophilidae			95
Hydraenidae (= Limnebiidae)			22
Staphylinidae			1
Scirtidae (= Helodidae,			61
Elmidae			44
Psephenidae			3
Dixidae			4
Culicidae			1
Chironomidae/Aphroteniinae			25
Chironomidae/Chironominae			13789
Chironomidae/Orthocladiinae			2504
Chironomidae/Tanypodinae			3563
Ceratopogonidae			428
Simuliidae			1
Tipulidae			7
Athericidae			12
Stratiomyidae			3
Empididae			36

Taxa	AUSRIVAS		Macroinvertebrate
	Presence	Presence	Total Number of Individuals
Hydrobiosidae			14
Hydroptilidae			51
Polycentropodidae			10
Ecnomidae			274
Conoesucidae			2
Helicopsychidae			12
Odontoceridae			2
Calamoceratidae			1
Leptoceridae			390
Pyralidae			6
Total Taxa			63

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

G

MEAN NUMBER OF TAXA AND ABUNDANCE OF CHRINOMINAE AND LEPTOPHLEBIIDAE (AND STANDARD ERROR (SE)) CALCLUATED FROM MACROINVERTEBRATE COLLECTORS DEPLOYED IN DA3B 2010 TO 2015

Site	Replicates Retrieved	No. of Taxa		Chrironominae		Leptophlebiidae	
		Mean	SE	Mean	SE	Mean	SE
May 2010							
Site 1	7	5.9	0.6	17.4	2.3	6.0	2.5
Site 2	8	5.6	0.5	18.6	3.2	2.5	0.7
Site 3	8	4.9	0.4	13.3	2.1	4.9	1.1
Site 4	8	5.4	0.3	10.9	1.4	6.0	0.8
Site 5	8	8.4	0.5	19.3	2.6	12.6	1.5
Site 6	8	7.1	0.9	8.8	3.8	2.9	1.1
Site 7	8	5.5	0.6	17.4	2.7	5.5	1.7
Site 14	8	6.1	0.6	20.1	5.4	13.9	4.0
Site 15	0						*None retrieved*
Site 16	0						*None retrieved*
Site X1	8	3.5	0.7	38.4	3.6	0.5	0.2
Site X2	8	7.1	0.7	19.0	6.4	18.6	5.0
Site X3	8	4.9	0.5	8.4	1.3	25.0	6.4
Site X4	8	8.3	0.8	35.9	6.7	6.1	2.9
November 2010							
Site 1	8	7.1	1.0	15.6	5.6	31.3	4.7
Site 2	8	5.6	0.5	12.3	1.6	30.0	3.2
Site 3	8	5.0	0.5	7.3	0.6	19.4	3.3
Site 4	8	4.8	0.3	11.6	1.7	11.0	1.8
Site 5	8	6.4	0.7	35.3	8.1	13.1	2.7
Site 6	8	6.4	0.6	9.6	2.0	16.4	3.3
Site 7	8	6.0	0.6	6.4	1.8	35.3	5.4
Site 14	8	7.1	0.4	19.1	4.3	10.4	3.9
Site 15	8	5.8	1.0	21.5	5.6	17.3	8.4
Site 16	8	7.5	0.9	11.3	3.6	9.6	4.5
Site X1	8	4.8	1.0	39.6	7.7	9.3	2.2
Site X2	8	6.3	0.4	14.3	2.6	16.3	3.5
Site X3	8	4.3	1.0	6.6	1.3	12.4	2.2
Site X4	8	7.1	1.0	13.9	1.9	37.3	5.3
June 2011							
Site 1	8	7.1	1.7	15.1	5.1	13.9	5.1
Site 2							*Not sampled*
Site 3	7	6.7	0.9	10.7	2.8	11.7	2.6
Site 4	8	3.8	0.5	4.3	1.5	3.9	1.8
Site 5	8	7.1	0.6	16.0	2.8	7.8	1.6
Site 6	8	6.9	0.7	5.6	3.1	10.5	1.5
Site 7	8	7.8	1.0	12.3	2.0	15.0	2.7
Site 14	8	7.4	0.5	16.6	2.2	10.1	1.8
Site 15	8	8.5	0.6	13.4	1.6	38.8	7.4
Site 16	8	9.3	0.9	32.0	3.8	24.3	5.3
Site X1	8	5.8	0.4	71.3	8.5	4.9	1.6
Site X2	8	9.4	0.9	31.4	5.3	12.4	3.0
Site X3	8	5.4	0.5	7.5	1.5	8.6	1.9
Site X4	8	8.8	0.7	24.8	3.5	14.3	1.3
October 2011							
Site 1	8	8.1	0.9	8.8	1.5	18.8	2.5
Site 2							*Not sampled*
Site 3	8	5.3	0.8	15.3	2.2	9.6	2.3
Site 4	8	5.0	0.7	10.1	2.0	13.9	2.2
Site 5	8	6.4	0.3	18.6	3.5	10.3	1.3
Site 6	8	5.1	0.4	7.1	1.8	6.6	1.0
Site 7	8	7.3	0.4	8.3	1.4	25.8	5.0
Site 14	8	7.4	0.3	22.9	4.9	6.5	4.1
Site 15	8	6.3	0.6	22.0	2.2	13.3	6.4
Site 16	8	9.8	0.7	37.3	3.9	25.5	4.1
Site X1	8	5.8	0.5	19.8	5.1	6.9	3.3
Site X2	8	7.5	0.4	10.4	1.3	10.9	2.5
Site X3	8	6.8	0.8	4.8	1.1	13.6	2.2
Site X4	8	7.8	0.6	11.6	1.8	23.4	3.5

Site	Replicates Retrieved	No. of Taxa		Chrironominae		Leptophlebiidae	
		Mean	SE	Mean	SE	Mean	SE
May 2013							
Site 1	8	5.9	0.9	25.6	4.9	11.0	2.4
Site 2	8	5.1	0.5	21.4	5.0	7.3	2.4
Site 3	8	4.4	0.2	8.9	1.3	4.6	1.1
Site 4	8	4.3	0.3	11.9	2.1	7.8	1.1
Site 5	8	5.9	0.7	15.3	1.7	9.5	2.1
Site 6	8	4.6	0.5	8.4	1.3	8.3	1.0
Site 7	8	3.9	0.3	4.9	1.0	10.9	2.2
Site 14	8	6.1	0.4	26.8	5.1	12.6	2.7
Site 15	8	5.3	0.5	14.0	1.6	13.8	3.2
Site 16	8	9.4	1.1	21.4	2.5	31.0	5.5
Site X1	8	5.8	0.4	41.8	6.5	9.4	1.9
Site X2	8	5.1	0.5	19.3	3.6	17.1	2.2
Site X3	8	4.3	0.2	17.9	2.5	16.1	3.2
Site X4	8	4.9	0.4	18.6	3.7	16.6	3.7
November 2013							
Site 1	4	4.0	0.7	17.0	5.3	24.8	7.1
Site 2	8	3.8	0.5	20.3	3.9	17.9	3.8
Site 3	8	5.1	0.7	18.6	3.2	14.5	2.3
Site 4	8	4.4	0.5	18.8	2.3	11.3	2.5
Site 5	8	5.3	0.5	14.4	3.6	8.0	2.3
Site 6	8	5.8	0.6	9.0	1.3	9.3	2.1
Site 7	4	3.3	0.5	10.8	2.9	8.3	3.3
Site 14	8	6.9	0.5	13.4	2.2	5.1	1.1
Site 15	8	5.0	0.6	14.3	3.2	18.6	3.9
Site 16	0				*None retrieved*		
Site X1	8	5.3	0.6	23.1	3.9	9.4	3.1
Site X2	8	5.5	0.6	11.0	1.8	11.1	1.4
Site X3	8	5.8	0.5	11.3	2.2	7.4	1.1
Site X4	7	4.7	0.8	14.4	2.9	11.4	2.3
June 2015							
Site 1	8	4.3	0.4	10.6	4.5	14.0	4.0
Site 2	8	5.1	0.4	8.6	2.1	18.4	5.6
Site 3	8	4.8	0.5	4.1	1.4	6.4	1.7
Site 4	8	5.0	0.4	4.9	1.0	4.3	1.1
Site 5	8	4.0	0.3	1.3	0.4	4.4	0.7
Site 6	8	3.8	0.4	24.9	10.5	5.5	2.1
Site 7	8	4.4	0.5	10.3	7.0	17.1	5.1
Site 14	8	4.9	0.3	3.9	0.9	5.5	2.2
Site 15	8	3.4	0.7	1.3	0.6	10.9	2.7
Site 16	8	4.5	0.6	1.6	0.6	13.3	3.3
Site X1	8	3.8	0.2	6.4	0.9	8.9	2.4
Site X2	4	3.8	0.8	1.3	0.9	19.5	7.1
Site X3	8	3.6	0.3	1.3	0.3	10.6	2.9
Site X4	8	4.8	0.5	2.3	0.6	12.0	3.1
November 2015							
Site 1	8	3.5	0.5	11.5	3.1	10.8	2.8
Site 2	8	4.8	0.7	32.4	4.5	8.9	1.4
Site 3	8	4.4	0.5	14.9	3.4	7.6	1.3
Site 4	8	5.9	0.6	7.4	0.8	10.9	2.4
Site 5	8	7.3	0.3	9.5	1.2	11.0	3.1
Site 6	8	5.3	0.5	5.4	1.3	3.8	1.1
Site 7	8	5.4	0.5	25.1	6.9	29.8	6.9
Site 14	8	6.0	0.7	18.6	2.0	8.3	2.4
Site 15	8	4.8	0.6	60.5	17.7	4.5	1.7
Site 16	8	7.4	0.6	37.8	12.8	7.9	2.5
Site X1	7	4.4	0.6	30.9	7.0	5.6	3.5
Site X2	8	4.1	0.5	42.8	15.2	0.9	0.2
Site X3	8	5.1	0.5	25.9	15.1	8.6	2.1
Site X4	8	4.0	0.4	15.9	0.7	22.4	3.4

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

H

PERMANOVAS COMPARING NO. OF TAXA AND ABUNDANCE OF CHRINOMINAE AND LEPTOPHLEBIIDAE FOUND ON MACROINVERTEBRATE COLLECTORS DEPLOYED IN DA3B DURING 2010 TO 2015

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A) Assemblage

Source of Variation	df	SS	MS	F	P
Phase	1	13187	13187	1.656	0.190
Treatment	7	80420	11489	4.419	RED
Year (Phase)	2	16273	8137	0.770	0.637
Phase x Treatment	7	20100	2871	1.104	0.351
Retrieval (Year (Phase))	4	43380	10845	13.172	RED
Treatment x Year (Phase)	13	34338	2641	1.106	0.311
Treatment x Retrieval (Year (Phase)	**27**	**64733**	**2398**	**2.912**	**<0.001**
Residual	763	628180	823		
Total	824	939170			

i) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Treatments

Comparisons among Treatments	t	P	Comparisons among Treatments	t	P
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	**1.613**	**0.009**	**Ncon, S02**	**1.844**	**0.004**
Ncon, S03	**1.674**	**0.010**	**Ncon, S03**	**2.625**	**<0.001**
Ncon, S04	**2.114**	**<0.001**	**Ncon, S04**	**2.036**	**0.001**
Ncon, Fcon	**1.931**	**0.001**	**Ncon, Fcon**	**1.772**	**0.005**
Ncon, X1	**3.461**	**<0.001**	**Ncon, X1**	**3.811**	**0.000**
Ncon, X2	**2.197**	**0.001**	**Ncon, X2**	**1.845**	**0.002**
Ncon, X3	**2.390**	**<0.001**	**Ncon, X3**	**3.717**	**<0.001**
S02, Fcon	**1.494**	**0.037**	**S02, Fcon**	**1.679**	**0.021**
S03, Fcon	**2.856**	**<0.001**	**S03, Fcon**	**1.721**	**0.013**
S04, Fcon	**3.122**	**<0.001**	**S04, Fcon**	**1.610**	**0.026**
Fcon, X1	**3.666**	**<0.001**	**Fcon, X1**	**2.622**	**<0.001**
Fcon, X2	**3.301**	**0.001**	Fcon, X2	1.199	0.182
Fcon, X3	**3.085**	**0.001**	**Fcon, X3**	**2.327**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S03	1.188	0.170	**Ncon, S03**	**2.164**	**<0.001**
Ncon, S04	**2.172**	**0.002**	**Ncon, S04**	**2.169**	**<0.001**
Ncon, Fcon	**2.275**	**<0.001**	**Ncon, Fcon**	**2.064**	**<0.001**
Ncon, X1	**2.506**	**<0.001**	**Ncon, X1**	**2.246**	**<0.001**
Ncon, X2	**1.639**	**0.022**	**Ncon, X2**	**2.054**	**<0.001**
Ncon, X3	**1.782**	**0.011**	**Ncon, X3**	**1.595**	**0.014**
S03, Fcon	**2.227**	**<0.001**	**S03, Fcon**	**2.502**	**<0.001**
S04, Fcon	**2.907**	**<0.001**	**S04, Fcon**	**2.327**	**<0.001**
Fcon, X1	**3.381**	**<0.001**	**Fcon, X1**	**2.720**	**<0.001**
Fcon, X2	**2.386**	**<0.001**	**Fcon, X2**	**2.376**	**<0.001**
Fcon, X3	**3.077**	**<0.001**	**Fcon, X3**	**2.245**	**<0.001**

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2013' of factor 'Year'			Within level '2013' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S03	**1.519**	**0.044**	Ncon, S02	1.369	0.090
Ncon, S04	**2.337**	**<0.001**	Ncon, S03	0.950	0.509
Ncon, Fcon	**1.925**	**0.004**	**Ncon, S04**	**1.550**	**0.026**
Ncon, X1	**1.966**	**0.001**	Ncon, Fcon	1.342	0.087
Ncon, X2	**2.107**	**0.001**	Ncon, X1	1.298	0.117
Ncon, X3	**1.545**	**0.034**	Ncon, X2	1.269	0.134
S02, Fcon	1.087	0.325	**Ncon, X3**	**1.554**	**0.024**
S03, Fcon	**2.041**	**0.002**	S02, Fcon	0.672	0.864
S04, Fcon	**2.265**	**0.001**	S03, Fcon	0.979	0.472
Fcon, X1	**2.034**	**0.003**	S04, Fcon	0.701	0.901
Fcon, X2	**2.771**	**<0.001**	Fcon, X1	1.245	0.136
Fcon, X3	**1.515**	**0.050**	**Fcon, X2**	**1.584**	**0.006**
	1.814	**0.007**	**Fcon, X3**	**1.932**	**0.001**
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2015' of factor 'Year'			Within level '2015' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	**1.517**	**0.040**	**Ncon, S02**	**1.734**	**0.008**
Ncon, S03	1.250	0.164	Ncon, S03	1.269	0.129
Ncon, S04	**1.936**	**0.004**	**Ncon, S04**	**1.814**	**0.003**
Ncon, Fcon	**2.783**	**<0.001**	Ncon, Fcon	2.438	**<0.001**
Ncon, X1	**1.725**	**0.014**	**Ncon, X1**	**1.814**	**0.007**
Ncon, X2	**1.942**	**0.003**	Ncon, X2	2.701	**<0.001**
Ncon, X3	**1.691**	**0.012**	Ncon, X3	1.298	0.114
S02, Fcon	**1.880**	**0.003**	S02, Fcon	1.494	0.060
S03, Fcon	**2.358**	**<0.001**	**S03, Fcon**	**2.578**	**0.001**
S04, Fcon	**2.803**	**<0.001**	**S04, Fcon**	**3.077**	**<0.001**
Fcon, X1	**2.457**	**<0.001**	**Fcon, X1**	**2.005**	**0.005**
Fcon, X2	**1.628**	**0.026**	**Fcon, X2**	**2.627**	**<0.001**
Fcon, X3	1.214	0.190	**Fcon, X3**	**2.582**	**<0.001**

ii) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Retrievals

Comparisons among treatments	t	P	Comparisons among	t	P
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
T1, T2	**2.861**	**<0.00**	T1, T2	1.217	0.178
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
T1, T2	**1.942**	**<0.00**	**T1, T2**	**1.753**	**0.013**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S02' of factor 'Treaments'			Within level 'Ncon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**2.736**	**<0.00**	**T1, T2**	**1.449**	**0.046**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'Ncon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**2.626**	**<0.00**	**T1, T2**	**3.314**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'S02' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**1.729**	**0.025**	T1, T2	1.372	0.133
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments'			Within level 'S02' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**1.899**	**0.003**	**T1, T2**	**2.697**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments'			Within level 'S03' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**1.626**	**0.004**	**T1, T2**	**2.099**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treaments			Within level 'S03' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**1.930**	**0.003**	T1, T2	1.532	0.072
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treaments			Within level 'S04' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**1.791**	**0.001**	**T1, T2**	**1.589**	**0.003**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'S04' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**2.128**	**<0.00**	**T1, T2**	**2.950**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'Fcon' of factor 'Treament		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**2.991**	**<0.00**	T1, T2	1.095	0.296
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treaments'			Within level 'Fcon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**1.981**	**0.001**	**T1, T2**	**4.850**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treaments'			Within level 'X1' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**1.490**	**0.041**	**T1, T2**	**2.400**	**<0.001**

ii) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Retrievals Continued

Comparisons among treatments	t	*P*	Comparisons among treatments	t	*P*
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2015' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**1.795**	**0.025**	**T1, T2**	**1.948**	**0.001**
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2013' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**1.969**	**0.003**	**T1, T2**	**2.245**	**0.001**
Within level 'After' of factor 'Phase'					
Within level 'X2' of factor					
Within level '2015' of factor 'Year'					
T1, T2	**3.093**	**0.003**			

B) Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	202.5	202.500	4.255	0.166
Treatment	**7**	**288.9**	**41.270**	**4.159**	**0.024**
Year (Phase)	**2**	**97.3**	**48.652**	**9.280**	**0.029**
Phase x Treatment	7	136.5	19.494	1.965	0.157
Retrieval (Year (Phase))	4	21.2	5.293	1.524	0.196
Treatment x Year (Phase)	13	131.0	10.073	1.973	0.094
Treatment x Retrieval (Year (Phase)	27	138.1	5.116	1.474	0.055
Residual	763	2649.3	3.472		
Total	824	4060.1			

C) Chironominae abundance

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	83	83	0.258	0.657
Treatment	7	29194	4171	6.379	RED
Year (Phase)	2	653	327	0.062	0.945
Phase x Treatment	7	7283	1041	1.591	0.239
Retrieval (Year (Phase))	4	21526	5381	32.25	RED
Treatment x Year (Phase)	13	8647	665	0.628	0.798
Treatment x Retrieval (Year (Phase)	**27**	**28745**	**1065**	**6.380**	**<0.001**
Residual	763	127320	167		
Total	824	233540			

i) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Treatments

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'Before' of factor			Within level 'Before' of factor		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	1.023	0.319	Ncon, S02	1.144	0.242
Ncon, S03	1.522	0.140	**Ncon, S03**	**2.013**	**0.048**
Ncon, S04	1.879	0.070	Ncon, S04	0.886	0.385
Ncon, Fcon	0.166	0.871	Ncon, Fcon	1.282	0.214
Ncon, X1	**3.047**	**0.005**	**Ncon, X1**	**3.976**	**0.001**
Ncon, X2	1.600	0.110	Ncon, X2	1.027	0.299
Ncon, X3	**2.533**	**0.013**	**Ncon, X3**	**2.261**	**0.031**
S02, Fcon	1.304	0.207	S02, Fcon	0.333	0.747
S03, Fcon	**2.177**	**0.048**	S03, Fcon	1.379	0.185
S04, Fcon	**3.025**	**0.011**	S04, Fcon	0.028	0.986
Fcon, X1	**3.533**	**0.002**	**Fcon, X1**	**4.966**	**<0.001**
Fcon, X2	**2.605**	**0.021**	Fcon, X2	0.193	0.851
Fcon, X3	**4.332**	**0.001**	Fcon, X3	1.674	0.095
Within level 'Before' of factor			Within level 'Before' of factor		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S03	0.776	0.443	Ncon, S03	0.094	0.939
Ncon, S04	**2.645**	**0.012**	Ncon, S04	1.065	0.298
Ncon, Fcon	1.844	0.069	**Ncon, Fcon**	**3.093**	**0.002**
Ncon, X1	**11.401**	**<0.001**	Ncon, X1	0.381	0.710
Ncon, X2	**2.452**	**0.019**	Ncon, X2	1.253	0.218
Ncon, X3	1.890	0.067	**Ncon, X3**	**2.754**	**0.009**
S03, Fcon	2.017	0.058	S03, Fcon	1.686	0.101
S04, Fcon	**4.048**	**<0.001**	**S04, Fcon**	**2.505**	**0.017**
Fcon, X1	**9.421**	**<0.001**	Fcon, X1	1.439	0.168
Fcon, X2	1.236	0.225	**Fcon, X2**	**2.649**	**0.013**
Fcon, X3	**3.274**	**0.003**	**Fcon, X3**	**3.674**	**0.001**
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2013' of factor 'Year'			Within level '2013' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	0.454	0.664	Ncon, S02	1.851	0.072
Ncon, S03	1.636	0.110	Ncon, S03	1.153	0.258
Ncon, S04	1.824	0.074	Ncon, S04	1.606	0.122
Ncon, Fcon	1.497	0.140	Ncon, Fcon	0.554	0.589
Ncon, X1	**4.438**	**<0.001**	**Ncon, X1**	**2.454**	**0.019**
Ncon, X2	0.160	0.888	Ncon, X2	1.463	0.144
Ncon, X3	0.082	0.950	Ncon, X3	0.306	0.779
S02, Fcon	1.547	0.136	S02, Fcon	1.163	0.268
S03, Fcon	0.949	0.361	S03, Fcon	0.609	0.575
S04, Fcon	1.226	0.237	S04, Fcon	1.050	0.313
Fcon, X1	**5.780**	**<0.001**	Fcon, X1	1.669	0.118
Fcon, X2	1.382	0.177	Fcon, X2	1.973	0.071
Fcon, X3	1.169	0.263	Fcon, X3	0.759	0.471

i) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Treatments continued

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2015' of factor 'Year'			Within level '2015' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	1.644	0.110	**Ncon, S02**	**7.212**	**<0.001**
Ncon, S03	0.411	0.686	Ncon, S03	1.352	0.200
Ncon, S04	0.052	0.959	**Ncon, S04**	**3.101**	**0.004**
Ncon, Fcon	**2.046**	**0.046**	**Ncon, Fcon**	**4.149**	**<0.001**
Ncon, X1	1.256	0.211	**Ncon, X1**	**3.487**	**0.002**
Ncon, X2	0.987	0.330	**Ncon, X2**	**5.018**	**<0.001**
Ncon, X3	1.620	0.110	Ncon, X3	0.927	0.366
S02, Fcon	**4.110**	**<0.001**	S02, Fcon	0.554	0.588
S03, Fcon	**2.620**	**0.013**	**S03, Fcon**	**2.303**	**0.024**
S04, Fcon	**2.407**	**0.019**	**S04, Fcon**	**2.575**	**0.016**
Fcon, X1	**4.860**	**<0.001**	Fcon, X1	0.917	0.396
Fcon, X2	0.269	0.787	Fcon, X2	0.931	0.364
Fcon, X3	0.900	0.378	**Fcon, X3**	**2.241**	**0.026**

ii) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Retrievals

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
T1, T2	1.234	0.232	T1, T2	1.195	0.258
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
T1, T2	0.488	0.627	T1, T2	1.758	0.102
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S02' of factor 'Treaments'			Within level 'Ncon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	1.584	0.137	T1, T2	1.850	0.072
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'Ncon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**2.925**	**0.011**	**T1, T2**	**7.493**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'S02' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	0.747	0.459	T1, T2	0.038	0.969
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments'			Within level 'S02' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	0.775	0.448	T1, T2	6.253	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments'			Within level 'S03' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**2.380**	**0.034**	T1, T2	1.861	0.088
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treaments			Within level 'S03' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	1.691	0.103	**T1, T2**	**2.762**	**0.013**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treaments			Within level 'S04' of factor 'Treaments		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	0.799	0.436	**T1, T2**	**3.276**	**0.005**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'S04' of factor 'Treaments		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	0.168	0.888	**T1, T2**	**3.222**	**0.005**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'Fcon' of factor 'Treament		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**7.282**	**<0.00**	T1, T2	0.420	0.678
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treaments'			Within level 'Fcon' of factor 'Treament		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	0.317	0.756	**T1, T2**	**5.244**	**<0.001**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treaments'			Within level 'X1' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**3.059**	**0.009**	**T1, T2**	**2.504**	**0.027**

ii) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Retrievals Continued

Comparisons among treatments	t	P	Comparisons among treatments	t	P
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2015' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**3.081**	**0.005**	T1, T2	1.591	0.151
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2013' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**2.589**	**0.022**	**T1, T2**	**3.197**	**<0.001**
Within level 'After' of factor 'Phase'					
Within level 'X2' of factor					
Within level '2015' of factor 'Year'					
T1, T2	**2.213**	**0.045**			

D) Leptophlebiidae abundance

Source of Variation	df	SS	MS	F	P
Phase	1	522	522	5.526	0.124
Treatment	7	10219	1460	5.213	RED
Year (Phase)	2	189	94	0.132	0.922
Phase x Treatment	7	451	64	0.230	0.960
Retrieval(Year (Phase))	4	2924	731	7.260	RED
Treatment x Year (Phase)	13	3695	284	0.822	0.603
Treatment x Retrieval(Year (Phase)	**27**	**9376**	**347**	**3.449**	**<0.001**
Residual	763	76819	101		
Total	824	110830			

i) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Treatments

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	**2.105**	**0.038**	Ncon, S02	1.123	0.255
Ncon, S03	0.798	0.454	Ncon, S03	0.828	0.426
Ncon, S04	0.490	0.654	**Ncon, S04**	**2.090**	**0.042**
Ncon, Fcon	1.032	0.310	Ncon, Fcon	0.006	1.000
Ncon, X1	**2.686**	**0.009**	**Ncon, X1**	**2.766**	**0.008**
Ncon, X2	**4.518**	**<0.001**	Ncon, X2	0.806	0.425
Ncon, X3	**2.760**	**0.008**	Ncon, X3	1.879	0.066
S02, Fcon	1.558	0.144	S02, Fcon	0.863	0.392
S03, Fcon	0.379	0.709	S03, Fcon	0.642	0.538
S04, Fcon	0.737	0.476	S04, Fcon	1.616	0.123
Fcon, X1	**2.588**	**0.023**	**Fcon, X1**	**2.138**	**0.041**
Fcon, X2	**3.110**	**0.007**	Fcon, X2	0.625	0.543
Fcon, X3	**2.624**	**0.019**	Fcon, X3	1.453	0.154
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S03	1.026	0.334	Ncon, S03	1.260	0.221
Ncon, S04	**2.586**	**0.013**	Ncon, S04	0.930	0.368
Ncon, Fcon	**5.386**	**<0.001**	**Ncon, Fcon**	**3.644**	**0.001**
Ncon, X1	**2.653**	**0.013**	**Ncon, X1**	**2.530**	**0.013**
Ncon, X2	0.865	0.387	Ncon, X2	0.134	0.897
Ncon, X3	0.397	0.709	Ncon, X3	0.419	0.701
S03, Fcon	**2.036**	**0.047**	**S03, Fcon**	**2.829**	**0.009**
S04, Fcon	**3.531**	**0.002**	S04, Fcon	1.452	0.150
Fcon, X1	**3.551**	**0.001**	**Fcon, X1**	**3.654**	**0.001**
Fcon, X2	**2.181**	**0.034**	Fcon, X2	1.928	0.061
Fcon, X3	**2.723**	**0.010**	Fcon, X3	1.753	0.093
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2013' of factor 'Year'			Within level '2013' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	**2.450**	**0.013**	Ncon, S02	1.723	0.086
Ncon, S03	**2.224**	**0.030**	Ncon, S03	0.165	0.878
Ncon, S04	1.606	0.116	Ncon, S04	0.491	0.658
Ncon, Fcon	**2.913**	**0.005**	Ncon, Fcon	1.584	0.125
Ncon, X1	1.153	0.259	Ncon, X1	1.149	0.258
Ncon, X2	**2.534**	**0.015**	Ncon, X2	0.167	0.871
Ncon, X3	0.643	0.542	Ncon, X3	1.262	0.214
S02, Fcon	**3.094**	**0.005**	S02, Fcon	0.239	0.812
S03, Fcon	**2.963**	**0.008**	S03, Fcon	1.083	0.300
S04, Fcon	**2.586**	**0.014**	S04, Fcon	0.798	0.431
Fcon, X1	**2.300**	**0.024**	**Fcon, X1**	**2.093**	**0.048**
Fcon, X2	0.034	0.987	Fcon, X2	1.118	0.298
Fcon, X3	1.134	0.270	**Fcon, X3**	**2.294**	**0.033**

i) Pairwise tests of Treatments x Retrievals (Year (Phase)) for Pairs of Treatments Continued

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'After' of factor 'Phase'			Within level 'After' of factor		
Within level '2015' of factor 'Year'			Within level '2015' of factor 'Year'		
Within level 'T1' of factor 'Retrieval'			Within level 'T2' of factor 'Retrieval'		
Ncon, S02	**3.013**	**0.008**	Ncon, S02	0.728	0.482
Ncon, S03	0.789	0.471	Ncon, S03	1.706	0.097
Ncon, S04	0.940	0.378	Ncon, S04	0.506	0.632
Ncon, Fcon	**3.113**	**0.003**	Ncon, Fcon	0.697	0.489
Ncon, X1	0.409	0.717	**Ncon, X1**	**2.815**	**0.010**
Ncon, X2	**4.508**	**0.001**	**Ncon, X2**	**3.256**	**0.003**
Ncon, X3	0.225	0.842	Ncon, X3	1.139	0.269
S02, Fcon	0.826	0.428	S02, Fcon	0.883	0.406
S03, Fcon	**2.605**	**0.011**	S03, Fcon	1.501	0.138
S04, Fcon	**2.762**	**0.008**	S04, Fcon	0.740	0.482
Fcon, X1	**2.304**	**0.031**	**Fcon, X1**	**2.169**	**0.029**
Fcon, X2	**2.086**	**0.044**	**Fcon, X2**	**2.474**	**0.020**
Fcon, X3	1.848	0.068	Fcon, X3	1.145	0.263

ii) Pairwise tests of Treatments x Retrieval (Year (Phase)) for Pairs of Retrievals

Comparisons among treatments	t	*P*	Comparisons among treatments	t	*P*
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2010' of factor 'Year'		
T1, T2	**5.113**	**<0.001**	T1, T2	1.191	0.251
Within level 'Before' of factor 'Phase'			Within level 'Before' of factor 'Phase'		
Within level 'Ncon' of factor 'Treament			Within level 'X3' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2011' of factor 'Year'		
T1, T2	1.172	0.248	T1, T2	1.565	0.130
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S02' of factor 'Treaments'			Within level 'Ncon' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**8.854**	**<0.001**	T1, T2	0.471	0.647
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'Ncon' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**3.795**	**0.003**	**T1, T2**	**2.381**	**0.023**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S03' of factor 'Treaments'			Within level 'S02' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	1.738	0.109	**T1, T2**	**3.233**	**0.007**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments'			Within level 'S02' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	1.808	0.097	T1, T2	1.616	0.124
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'S04' of factor 'Treaments			Within level 'S03' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	**4.493**	**0.001**	**T1, T2**	**2.851**	**0.011**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treament			Within level 'S03' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**2.371**	**0.023**	T1, T2	0.723	0.479
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'Fcon' of factor 'Treament			Within level 'S04' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	0.637	0.534	**T1, T2**	**2.158**	**0.049**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'S04' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**4.451**	**0.001**	**T1, T2**	**2.452**	**0.030**
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor 'Treaments'			Within level 'Fcon' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	0.285	0.790	T1, T2	0.780	0.448
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treatments'			Within level 'Fcon' of factor 'Treaments'		
Within level '2010' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	1.181	0.254	T1, T2	0.085	0.940
Within level 'Before' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor 'Treatments'			Within level 'X1' of factor 'Treaments'		
Within level '2011' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	0.099	0.925	T1, T2	0.538	0.586

ii) Pairwise tests of Treatments x Retrievals (Year (Phase)) for Pairs of Retrievals

Comparisons among treatments	t	*P*	Comparisons among	t	*P*
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X1' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2015' of factor 'Year'			Within level '2013' of factor 'Year'		
T1, T2	2.114	0.056	**T1, T2**	**2.209**	**0.041**
Within level 'After' of factor 'Phase'			Within level 'After' of factor 'Phase'		
Within level 'X2' of factor			Within level 'X3' of factor 'Treaments'		
Within level '2013' of factor 'Year'			Within level '2015' of factor 'Year'		
T1, T2	**3.295**	**0.006**	T1, T2	0.209	0.833
Within level 'After' of factor 'Phase'					
Within level 'X2' of factor					
Within level '2015' of factor 'Year'					
T1, T2	**10.36**	**<0.00**			

Note: for 2010: T1 = May 2010, T2 = November 2010, for 2011: T1 = June 211, T2 = October 2011, for 2013: T1 = June 2013, T2 = November 2013, for 2015: T1 = June 2015, T2 = November 2015

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

I

NUMBERS OF FISH CAUGHT BY BACKPACK ELECTROFISHING IN DA3B IN 2015

Cardno
Shaping the Future

Species	Galaxid (*Galaxias* sp.)				Australian smelt (*Retropinna semoni*)				Shortfinned eel (*Anguilla australis*)				Coxs gudgeon (*Gobiomorphus coxii*)			
Date (2015)	May	Jun	Oct	Nov	May	Jun	Oct	Nov	May	Jun	Oct	Nov	May	Jun	Oct	Nov
Site 1	1		1													
Site 2	1		1	1												
Site 3	1			2					1				1			
Site 4	1															
Site 5	2				15							1				
Site 6	1															
Site 7		1														
Site 14		14	5	1												
Site 15	1	1														
Site 16	1	1			4	15		*								
Site X1																
Site X2																
Site X3	6		1	1												
Site X4	1															

*Several observed
Data are summed across all 4 replicates per site (2 for site X1). Only a few small pools (where water was present) in X2 were electrofished for a small amount of time.

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

J

NUMBERS OF FISH CAUGHT IN BAIT TRAPS DEPLOYED IN DA3B IN 2015

Species	**Galaxid (*Galaxias* sp.)**				**Australian smelt (*Retropinna semoni*)**			
Date	May 2015	Jun 2015	Oct 2015	Nov 2015	May 2015	Jun 2015	Oct 2015	Nov 2015
Site 1	1			1				
Site 2		2						
Site 3	3							
Site 4								
Site 5								
Site 6	1							
Site 7				2				
Site 14		2	2					
Site 15								
Site 16			2		8			
Site X1								
Site X2								*Not sampled*
Site X3	3							
Site X4	1				1			

Data are summed across all 8 replicates per site, except X2, where the water that present was not deep enough for bait traps to be deployed.

Aquatic Ecology Monitoring 2010 to 2015

APPENDIX

K

PHOTOGRAPHIC RECORD 2015