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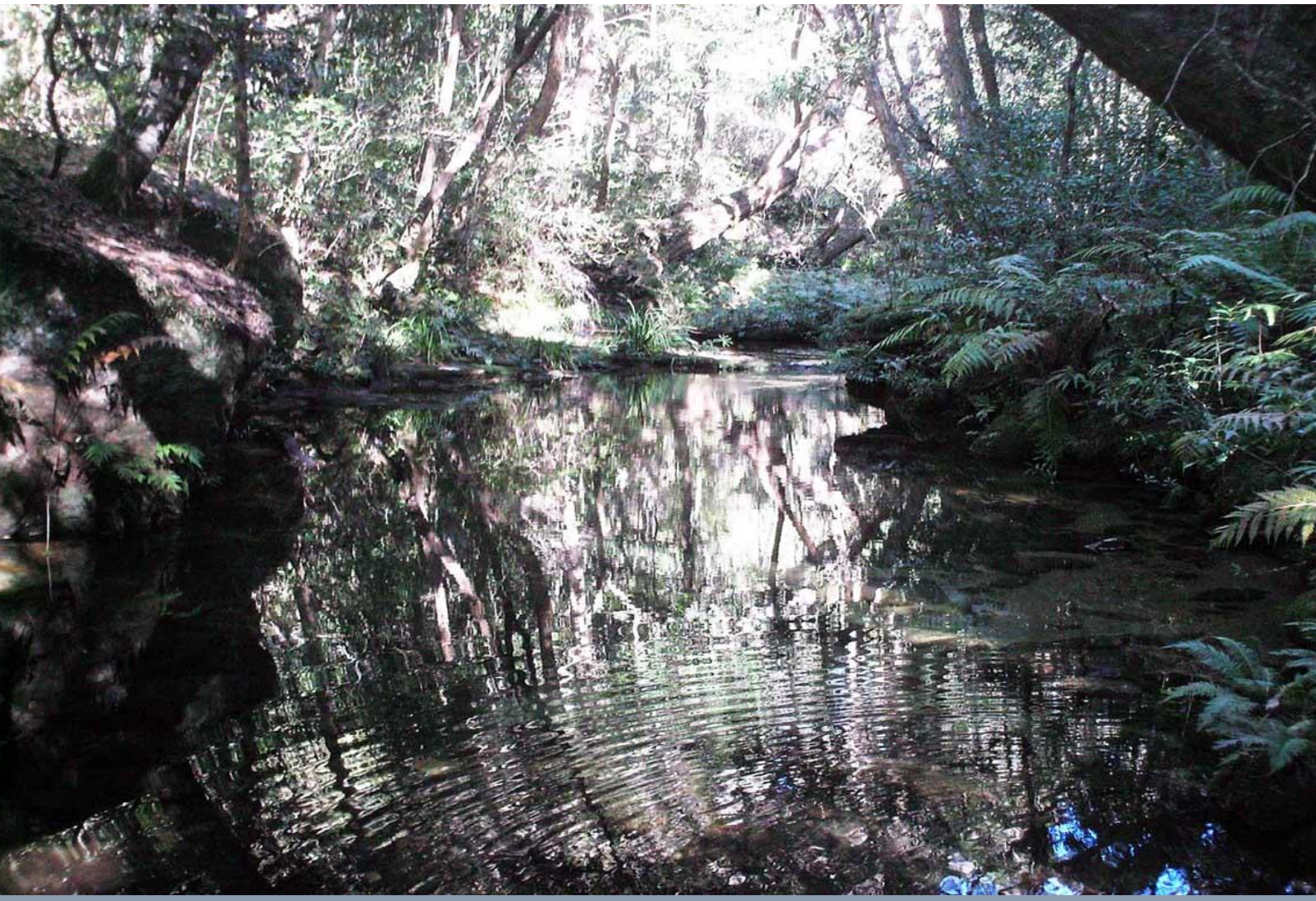

Dendrobium Area 3

Aquatic Ecology Monitoring 2008-2011

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Cover Image: Wongawilli Creek, within Dendrobium Area 3A Study Area, 17 July 2007.

Photographer Doug Hazell, Cardno Ecology Lab

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Executive Summary

BHP Billiton - Illawarra Coal (BHPBIC) are extracting coal from Dendrobium Areas 3A and B (referred to hereafter as DA3A and DA3B, respectively) in the Southern Coalfield of NSW using longwall mining techniques. Cardno Ecology Lab was commissioned by BHPBIC to implement a monitoring program designed to detect potential impacts on aquatic ecology that may arise due to mining-related subsidence. The monitoring program is based on a Before, After, Control, Impact (BACI) design with sampling undertaken at potential impact and control locations prior to the commencement of extraction, this design provides a measure of natural spatial and temporal variability in key aquatic ecology indicators. Additional sampling undertaken at the same set of locations during and after extraction will enable changes in the key indicators associated with mining-related impacts to be distinguished from those due to natural variability.

The monitoring program focuses on the following key indicators:

- Habitat condition, assessed using the Riparian, Channel and Environmental (RCE) Inventory method and by making a photographic record of the aquatic habitat present at each of the aquatic ecology monitoring sites;
- Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS) ;
- Aquatic macroinvertebrates sampled using standardised artificial macroinvertebrate collectors; and
- Fish diversity.

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 and Sandy Creek, the two major permanent watercourses that flow through DA3A and DA3B. Comparable control sites have been established on Wongawilli, Sandy, Donalds Castle and Kentish Creeks. Univariate and multivariate statistical analyses undertaken on data obtained from the AUSRIVAS sampling and artificial collector data are used to examine changes to aquatic ecology that may have occurred and assess whether such changes are associated with mining. Aquatic ecology monitoring for Dendrobium Area 3 commenced in spring 2008. To date, two years of baseline and one year of during-extraction data have been collected for DA3A and two years of baseline data have been collected for DA3B. The baseline monitoring indicates that the aquatic habitat in DA3A and DA3B is relatively undisturbed.

The data collected prior to and following the commencement of extraction in DA3A provides little evidence to suggest mining-related impacts have had any negative consequences on aquatic ecology. There was evidence at some potential impact sites of changes to aquatic ecology indicators that could be related to mining, however, these impacts appeared transient and were observed in only some indicators. There is also no evidence of any impact to aquatic ecology at Site 13 on SC10C, despite recent observations of mining-related fracturing and pool water loss further upstream. This finding suggests that impacts to aquatic ecology, if any, due to the mining related impacts observed in the watercourse are localised.

The two years of pre-extraction data collected from DA3B is expected to provide a sufficient baseline to enable the detection of changes to aquatic ecology associated with mining-related impacts. Data collected from the DA3B potential impact and control locations are comparable. Significant, small scale temporal variation in the data is not expected to prevent the detection of potential changes to aquatic ecology taking place during or post-extraction.

It is recommended that monitoring continue in DA3A, in line with the SMP requirements, using the methods and sites described in this report. This will enable the detection of any changes to aquatic ecology during and post-extraction related to mining. As two years of pre-extraction data for DA3B is now available, it is recommended that monitoring associated with DA3B resume once extraction commences, or autumn 2014, whichever is earlier.

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1 Introduction

BHP Billiton – Illawarra Coal (BHPBIC) is extracting coal from the Dendrobium Coal Mine, situated near Cordeaux approximately 15-20 km west of Wollongong, using longwall mining techniques. Consent for the mine, granted in November 2001, allows extraction from three longwall domains, known as Areas 1, 2 and 3. Mining of Area 3, situated to the west of Lake Cordeaux, is currently underway. A Subsidence Management Plan (SMP) application for Dendrobium Area 3A (DA3A) was submitted in November 2007 (Cardno Forbes Rigby 2007). A modification to the mine layout of Area 3 approved in December 2008 allowed the mine to be expanded and sub-divided into three smaller domains, Areas 3A, 3B and 3C. The revised SMP for DA3A, incorporating monitoring and management plans for potential impacts from DA3A, was finalised in December 2009 (BHPBIC 2009). A SMP for Area 3B (DA3B) is currently being prepared for submission to the relevant NSW Government Departments. The SMP for Area 3C will be submitted once further exploration has been completed and the longwall layouts are finalised.

DA3A currently comprises Longwalls 6, 7, 8 and 19 situated between Wongawilli and Sandy Creeks. Extraction of Longwall 6 commenced in February 2010 and was completed in March 2011. Extraction of Longwall 7 commenced in May 2011 and was completed in January 2012. DA3B currently comprises Longwalls 9 to 18, situated to the west of Wongawilli Creek.

Cardno Ecology Lab (formally The Ecology Lab) was commissioned by BHPBIC to prepare an assessment of the potential impacts on aquatic ecology due to mining and to undertake monitoring of aquatic habitats and biota in Dendrobium Area 3. The aquatic ecology monitoring program was designed in accordance with the recommendations made by the NSW Department of Planning's (now Department of Planning and Infrastructure) '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 at appropriate frequency and scale to provide a measure of the natural variability in appropriate aquatic ecology indicators before mining commences. Additional sampling undertaken at the same set of locations during and after extraction will enable changes in these indicators associated with mine subsidence-related impacts to be distinguished from those due to natural variability.

In this report, the two years of pre-extraction and first year of during-extraction data for DA3A and the second year of pre-extraction data for DA3B, are presented. Comparisons are also made between pre and during-extraction data collected from DA3A to determine if changes in aquatic ecology have occurred since extraction began and whether these are associated with potential mining- related impacts. Also, the suitability of the two years of pre-extraction data collected from DA3B as a baseline sufficient to enable detection of potential impacts to aquatic ecology is assessed.

2 Previous Studies

Four reports have been prepared as part of the impact assessment and ongoing aquatic ecology monitoring undertaken in Dendrobium Area 3:

1. Dendrobium Area 3A: Assessment of Mine Subsidence Impacts on Aquatic Habitats and Biota (The Ecology Lab 2007);
2. Aquatic Ecology Monitoring for Dendrobium Area 3A – Baseline Technical Report (Cardno Ecology Lab 2009);
3. Dendrobium Area 3 – Baseline Aquatic Ecology Monitoring Spring 2008 – Spring 2010 (Cardno Ecology Lab 2011); and,
4. Dendrobium Area 3B Subsidence Management Plan Aquatic Flora and Fauna Assessment (Cardno Ecology Lab 2012).

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 Dendrobium Area 3A;
- Assessment of the potential impacts of the proposed mine workings on aquatic habitats, water quality and aquatic biota, including threatened species;
- A comprehensive monitoring program designed 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.

The main findings were:

- There is 'significant' aquatic habitat in reaches of Wongawilli and Sandy Creeks in Dendrobium Area 3 and 'moderate' aquatic habitat in these and other named creeks and their tributaries. Other tributaries contained 'minimal' or 'unlikely' habitat;
- 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 Dendrobium Area 3. Only Macquarie perch have been recorded in the study area (within Lake Cordeaux); and,
- The proposed longwall mining does not pose a significant threat to threatened species, provided that the subsidence predictions for the main channel of Wongawilli Creek in relation to future longwall layouts for Areas 3B and 3C are similar to those made for Area 3A;
- Minor fracturing may occur in Wongawilli and Sandy creeks, but is unlikely to result in significant diversion of surface flows (MSEC 2007). Fracturing in ephemeral drainage lines could result in drainage of pools, rapid drops in surface water flow and have localised, significant impacts to aquatic ecology;
- Significant changes in water quality are unlikely to occur in Wongawilli, Sandy or Donald's Castle creeks, but may occur in some associated tributaries (Ecoengineers 2007). The latter changes could have minor, localised and transient impacts on aquatic biota;

- Aquatic ecology monitoring should be undertaken in reaches of creek with 'significant' and 'moderate' aquatic habitat and include habitat assessment, limited *in situ* water quality sampling, quantitative macroinvertebrate sampling, AUSRIVAS sampling, threatened species sampling and monitoring of aquatic macrophytes (if present); and,
- This report was incorporated into the Subsidence Management Plan for Dendrobium Area 3, Longwalls 6 to 10 (BHPBIC 2007) which was approved by the NSW Department of Planning in November 2008.

Cardno Ecology Lab (2009)

This report described the results of the initial year of pre-extraction monitoring undertaken at potential impact sites relevant to DA3A and at ecologically comparable control sites. Sites were selected on the basis of the longwall layout provided by BHPBIC and the aquatic habitat in the SMP area. Monitoring was undertaken in spring 2008 and autumn 2009. The report included:

- Descriptions of the study design and methodologies used to assess aquatic habitats, and sample aquatic macroinvertebrates and fish during the baseline field investigations;
- Results of the first year of the monitoring plan recommended in The Ecology Lab (2007); and,
- Recommendations for ongoing monitoring.

Cardno Ecology Lab (2011)

This report included the results of the second year of pre-extraction monitoring for DA3A undertaken in 2010. The suitability of the pre-extraction data collected from DA3A as a baseline sufficient to enable detection of potential mining induced impacts on aquatic ecology was also assessed. The main findings were:

- The aquatic habitat at the potential impact and control sites is largely undisturbed;
- The macroinvertebrate fauna was comparable at the potential impact and control locations;
- The similarities in macroinvertebrate indicators among locations should facilitate the detection of any indirect effects on aquatic ecology resulting from longwall extraction; and,
- Extraction of Longwall 6 commenced prior to this study, hence the data collected from Site 4 in 2010 forms part of the during-extraction monitoring for this Longwall. There was no evidence of any change to aquatic ecology at Site 4 during this period that could be linked with the extraction of Longwall 6.

During the 2011 surveys, the sampling design was expanded to incorporate additional monitoring sites (Sites X1-X6) as part of the first year of baseline monitoring for DA3B. No additional control sites were necessary as the control sites selected for DA3A were also suitable for DA3B.

In response to the modified longwall layout in DA3A, the following refinements to the sampling design were recommended:

- As Longwall 10 will no longer be extracted, monitoring should cease at Site 10 and Site 8 should become an additional control site; and,
- As Longwall 19 will not be extracted until after DA3B, further monitoring at sites 2 and 11 should be postponed until closer to the extraction period.

Cardno Ecology Lab (2012a)

The Aquatic Flora and Fauna Assessment (AFFA) was prepared to support the SMP Application for Dendrobium Area 3B that is currently being prepared for submission to the relevant NSW Government Departments. 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 for inclusion within the SMP.

The assessment of potential impacts on aquatic ecology arising from the extraction of Longwalls 9-18 was based on the maximum predicted subsidence parameters and their predicted impacts on the physio-chemical characteristics of the watercourses traversing DA3B. The predictions with respect to aquatic ecology were:

- Changes in ponding, flooding and scouring of river banks due to subsidence would have only minor, localised effects on aquatic habitats or biota in the watercourse;
- The effects on aquatic ecology associated with fracturing of the river bed and diversion of surface flows would be minor, localised and transient;
- Changes in water quality as a result of the formation of ferruginous springs or weathering of underlying substrata are also unlikely to have any effect on aquatic habitat or biota; and,
- It is unlikely that the proposed mining would have any significant impact on any threatened aquatic species that may be present in the SMP Area.

This report included the following recommendations:

- Aquatic ecology monitoring be undertaken during and after mining. Monitoring would help determine the nature and extent of any subsidence-induced impacts on aquatic ecology and responses of aquatic ecosystems to any remediation or management works implemented; and,
- Additional aquatic ecology studies be undertaken in response to specific impacts on water quality and availability of aquatic habitats within the watercourses.

3 Study 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 (pre-extraction surveys) data collected during several sampling events prior to mining to provide a measure of the natural temporal variation of each monitoring component before mining commences;
- Data collected from potential impact sites (where mining-induced impacts on aquatic ecology, if any, would most likely occur) and from ecologically comparable control sites that will not be affected by mining. Data from control sites provides a measure of the natural background variability in each monitoring component in nearby catchments and the greater Cordeaux catchment disassociated from any mine subsidence impacts;
- Statistical comparison of data collected from potential impact sites and control sites during and post-extraction with pre-extraction data, to determine whether any changes that have occurred at potential impact sites are outside the range of natural variation.

3.2 Study Sites

The GPS coordinates of each site are presented in **Appendix 1** and their location in relation to the longwall layout for DA3A and DA3B are presented in **Figure 1**. **Appendix 1** also shows the watercourse each site is located on and the designation of each site (i.e. whether it is a potential impact or control site and is relevant to DA3A or DA3B). Potential impact sites are split between the DA3A and DA3B areas and control sites are split across 'Near' and 'Far' catchments. There are two Near Control catchments: Wongawilli Creek and Sandy Creek. The Far Control consists of the sites on Donalds Castle Creek and Kentish Creek, which are situated in catchments some distance away from DA3.

Potential Impact sites can therefore be compared with controls sites on the same creek / catchment and with control sites located some distance away in different catchments. The separation of control sites in this way will allow the variation occurring at the catchment level and wider local area to be taken into account when undertaking the analyses and when making conclusions about the likely cause of changes in aquatic habitat and biota.

It should be noted that Site 14 on Donalds Castle Creek is included in the Far Control location and therefore does not form part of the Near Control for Site X1, despite being situated on the same creek. This was done because Site X1 is considered to be more ecologically comparable on the basis of observations of vegetation cover, creek morphology and water depth to the control sites on Wongawilli Creek, than Site 14.

3.3 Sampling Dates

The dates of sampling events undertaken during the aquatic ecology monitoring program are presented in **Appendix 2**. There have been 12 sampling events since monitoring began in September 2008. The data collected during these sampling events provide two years of pre-extraction and one year of during-extraction data for DA3A, and two years of pre-extraction data for DA3B. However, because extraction of Longwall 6 began in February 2010 (**Section 2**), only one year of pre-extraction and two years of during-extraction data are available for Site 4.

AUSRIVAS sampling was undertaken twice each autumn and spring, with Sampling Events during each season being six-eight weeks apart. AUSRIVAS data collected during spring

and autumn are treated separately and each autumn / spring season represents a Survey (i.e. the two Sampling Events undertaken in spring 2008 constitute the first spring AUSRIVAS pre-extraction Survey for DA3A).

Macroinvertebrate collectors were deployed during the first AUSRIVAS Sampling Event of the season and retrieved during the second. One set of data from macroinvertebrate collectors is consequently available from each season and two consecutive seasons (autumn and spring) represent a Survey.

Thus, data is available from three autumn AUSRIVAS Surveys, three spring AUSRIVAS Surveys and three macroinvertebrate collector Surveys in DA3A (Pre-extraction 1, Pre-extraction 2 and During-extraction 1). For DA3B, data is available from two surveys (Pre-extraction 1 and Pre-extraction 2).

3.4 Field Methods

The following methods have been used in the aquatic ecology program since it commenced in October 2008.

3.4.1 Aquatic Habitat Assessment

The condition of the aquatic habitat at each site was assessed using a modified version of 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 3**). 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 developed by Peterson (1992), was 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. Subsequent to the initial survey in October 2008, any changes in the initial observations have been recorded.

During each event, a comprehensive photo record was also assembled for each site to gain an understanding of environmental variation within the watercourses. This involved taking standardised photos, using a 2 m tall x 1 m wide T-bar, 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 determine whether changes in water levels, geomorphology or aquatic habitats have occurred over the monitoring program.

3.4.2 Water Quality

Water quality was measured *in situ* with a YeoKal 611 water quality probe and meter that was calibrated prior to sampling. This was done 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). Six replicate readings were taken for turbidity as this measure tends to be more variable.

3.4.3 Aquatic Macroinvertebrates

Two methods were used to sample aquatic macroinvertebrates: the AUSRIVAS protocol for NSW streams (Turak *et al.* 2004) and deployment of artificial macroinvertebrate collectors.

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

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

3.4.3.2 Artificial Collectors

During the first Sampling Event, eight replicate artificial collector units were deployed at each site. These collectors consisted of 24 cm long x 3 cm diameter bundles of 18 wooden chopsticks held together with plastic cable ties. The collectors provide a standardised habitat for colonisation by macroinvertebrates and enable the collection of quantitative data. The collectors were attached to vegetation with nylon twine and submerged at least 1 metre apart at the edge of pools in 30-60 cm of water. The collectors were retrieved during the second Sampling Event approximately six to eight weeks later. Each bundle of chopsticks was put into a separate, labelled, plastic bag and then preserved in 70% ethanol for subsequent analysis in the laboratory.

3.4.4 Fish

Fish and large crustaceans inadvertently captured at each site during the AUSRIVAS macroinvertebrate sampling were immediately transferred to a fish box for identification and released as quickly as practicably possible. Additional observations of fish occurrences were made with the aid of polarised sunglasses during each site visit.

3.5 Laboratory Methods

3.5.1 AUSRIVAS Samples

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).

3.5.2 Macroinvertebrate Collectors

The aquatic macroinvertebrates that had colonised each bundle of chopsticks were rinsed through a 0.5 mm mesh sieve and examined in the laboratory using a binocular microscope. The samples were sorted and macroinvertebrates identified to family (most invertebrate taxa), sub-family (chironomids) or class (flatworms and leeches) level and counted.

3.6 Statistical Methods

3.6.1 Descriptive Statistics

3.6.1.1 Water Quality

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

Water quality data collected during the aquatic ecology monitoring programme are intended to aid in the interpretation of macroinvertebrate data. More detailed water quality monitoring is undertaken by the Illawarra Coal Environmental Field Team 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. 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 - This is 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 values range from 0 to 1 and 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 follows:

  Band X = Richer invertebrate assemblage than reference condition;

  Band A = Equivalent to reference condition;

  Band B = Sites below reference condition (i.e. significantly impaired);

  Band C = Sites well below reference condition (i.e. severely impaired); and,

  Band D = Impoverished.

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 or taxa found, 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.

For macroinvertebrate data collected using artificial collectors, only the SIGNAL2 Index was calculated.

3.6.2 Multivariate Analyses

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. Separate analyses were undertaken individually for each potential impact site, because each may experience impacts at different times due to the staging of mining activities. If potential impact sites were treated as a group, it would be difficult to differentiate changes occurring at individual sites.

A matrix of differences in the types and relative abundance of the taxa between all possible pairs of 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). Differences in the levels of significant factors and interaction terms were examined by *post hoc* permutational t-tests.

The analytical design for the data collected from DA3A was:

- **Extraction Period**: A fixed factor with two levels: Pre-extraction vs. During-extraction;
- **Treatment**: A fixed factor with three levels: Potential Impact Site, Near Control (Wongawilli Creek / Sandy Creek Control - depending on Potential Impact site in question) and Far Control;
- **Survey**: A random factor with three levels: Pre-extraction 1, Pre-extraction 2 and During-extraction 1 (for Site 4: Pre-extraction 1, During-extraction 1 and During-extraction 2). Nested in Extraction Period; and,
- **Sampling Event**: A random factor with two levels nested in Survey and Extraction Period.

The analytical design for the data collected from DA3B was:

- **Treatment**: Fixed, three levels: Potential Impact, Near Control (Wongawilli Creek Control) and Far Control;
- **Survey**: Random, two levels: Pre-extraction 1 and Pre-extraction 2; and,
- **Sampling Event**: Random, two levels. Nested in Survey.

In these analyses, statistically significant ($P \leq 0.05$) interaction terms are of interest, because they may be indicative of an impact associated with mining. Note that no other significant sources of variation will be discussed as these are unrelated to potential impacts of mining. 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).

3.6.3 Univariate Analyses

Permanova+ was also used to examine spatial differences and temporal changes in the number of taxa, OE50 Taxa Scores and SIGNAL2 Scores derived from AUSRIVAS samples and the number of taxa and SIGNAL2 Scores calculated from macroinvertebrate collector samples. Separate analyses were undertaken individually for each potential impact site. In this case, the analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest. The PERMANOVA approach does not require that the data come from a normal distribution and is robust to heterogeneity of variances, unlike "traditional" ANOVA.

3.7 QA/QC Procedures

Data generated in the field was checked for accuracy and completeness before leaving each site. On return to the laboratory, field data sheets were photocopied, entered into spreadsheet format and checked using standard QC procedures. Spreadsheet files were locked prior to analysis to prevent accidental over-writes or corruption.

In the laboratory, the remains of each macroinvertebrate sample were retained and checked by another staff member to ensure that no animals were missed. A staff member with appropriate training and experience checked the identifications and counting of samples. These activities were recorded on the Laboratory Management Sheet. Data were entered into an electronic spreadsheet and data for each sample was printed out and checked by a second staff member.

4 Results

The weather during most sampling events was generally overcast, with short periods of light rain. During the October 2011 event, rainfall resulted in restricted access to the Sydney Catchment area, so sampling was undertaken over several weeks rather than days.

4.1 Aquatic Habitat Assessment

The RCE scores for the DA3A and DA3B potential impact sites varied from 46 to 50, and from 50 to 51, respectively, out of a possible 52 (**Table 1**). 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 48 to 51 for the Near Control (Wongwawilli Catchment) sites, 49 to 50 for the Far Control Sites, and 46 at both of the Near Control (Sandy Catchment) sites. RCE scores have not changed at any of the sites over the course of the monitoring program.

The photographic record undertaken at each site over the 2011 monitoring period is presented in **Plates 1-89**. There appeared to have been some alterations to bankside vegetation cover and some additional accumulations of loose sediment along sections of Wongawilli and Sandy Creeks. These observations suggest some scouring of aquatic habitat and vegetation occurred during high rainfall events. There was evidence of recent high flows (damaged bankside vegetation, log jams) during the last survey of 2011 at each site visited. Visual observations undertaken during sampling indicated that potential mining-related impacts, such as fracturing, drops in water level or iron floc formation, had not occurred at any of the sites visited.

4.2 Water Quality

The mean water quality data for each site measured during each of the 2008-2011 sampling events are presented in **Table 2**. The main observations were:

- Temperature ranged from 8.6 to 21.3 C and was comparable among DA3A and DA3B potential impact sites and controls. Fluctuations in temperature through time were consistent across all potential impact sites and controls and reflected seasonal differences;
- Conductivity ranged from 5 to 240 µS/cm and appeared comparable among DA3A and DA3B potential impact sites and controls. However on occasion, conductivity was below the lower Default Trigger Value (DTV) at potential impact and control sites on Sandy Creek. There were no obvious trends in conductivity through time;
- pH ranged from 4.5 to 7.3 and was comparable among potential impact sites in DA3A and DA3B and the Near Control sites. It was often below the lower DTV at these sites. The pH at Far Control sites 15 and 16, but not Site 14, was often higher than that at the potential impact and Near Control sites in both pre and during-extraction surveys. This observation is not related to mining.
- Oxidation Reduction Potential (ORP) ranged from 100 to 723 mV and was comparable among DA3A and DA3B potential impact sites and controls. There appeared to be a slight trend for lower ORP during extraction at DA3A potential impact Site 3 during extraction, compared with that pre-extraction, which was not obvious at the controls. However, on its own, this weak trend provides little evidence to suggest an impact has occurred.
- Dissolved oxygen ranged from 32.4 to 127.0% saturation. Dissolved oxygen was relatively variable and was often outside DTV. There were no obvious trends in dissolved oxygen data that would suggest an impact.
- Turbidity ranged from 0.0 to 60.2 NTU and was comparable among DA3A and DA3B potential impact sites and controls. It was often below the lower DTV in both pre and

during-extraction surveys and there were no obvious trends in the data. Turbidity at DA3A potential impact sites 3 and 4 on Wongawilli Creek was relatively high and above the upper DTV in the during-extraction spring 2011 Sampling Event. Elevated turbidity readings were also observed at some control sites during the spring 2011 Sampling Event. These observations were most likely due to recent rainfall events rather than any potential mining related impact.

4.3 Aquatic Macroinvertebrates

4.3.1 Dendrobium Area 3A

4.3.1.1 AUSRIVAS Samples

Number of Taxa

The mean number of taxa collected ranged from 12.5 to 23.7 in autumn, and from 12.0 to 25.0 in spring (**Table 3**; **Figures 2 - 6**). The number of taxa found at potential impact sites and controls appeared comparable. The spring data showed a decrease in the number of taxa at potential impact Site 9 through time. Declines were also evident at the near and Far Control, but were less marked (**Figure 4**).

Only one of the PERMANOVA tests showed a significant interactive effect. In this case, the variation in numbers of taxa among treatments (Site 4, Near and Far controls) was not consistent across Sampling Events in spring (**Appendix 4**). Post-hoc tests showed that the number of taxa at Site 4 was significantly greater than that at the Far Control in the spring 2010 Sampling Event during-extraction, and significantly greater than that at the Near Control in the spring 2011 Sampling Event during-extraction.

OE50 Taxa Score

The mean OE50 Taxa Scores ranged from 0.61 to 1.15 during autumn, and from 0.59 to 1.04 during spring (**Table 3**; **Figures 7-11**). The OE50 Taxa Scores for potential impact sites and controls appeared comparable. The slight trend for lower OE50 Taxa Scores at some potential impact sites during-extraction was also apparent at the controls, and therefore probably not related to mining.

Four of the PERMANOVA tests based on OE50 Taxa Scores showed a significant interactive effect:

- The Variation among Treatments (Site 4, Near and Far Controls) was not consistent across Extraction Periods in spring (**Appendix 5**). Post-hoc comparisons of the three pairs of treatments in each Extraction Period indicate the interaction was due to a difference in OE50 taxa scores in the two control catchments during-extraction. There was consequently no evidence to suggest that the changes in OE50 taxa score that occurred at Site 4 differed from that due to natural variation;
- The variation among Treatments (Site 3, Near and Far Controls) in autumn was not consistent at the scale of Surveys. Post-hoc tests showed that the score for Site 3 was significantly greater than that for the Far Control, but not the Near Control in the autumn during-extraction survey;
- The variation among Treatments (Site 9, Near and Far Controls) was not consistent in spring. However, differences between Site 9 and the Controls could not be resolved by Post-hoc tests; and,
- The variation among Treatments (Site 13, Near and Far Controls) was not consistent in spring. In the second spring Pre-extraction survey, the score for Site 13 was significantly lower than that at the Far Control, but not the Near Control.

Such differences are unlikely to be related to mining.

BAND Scores ranged from A to B at the potential impact sites and controls during both the autumn and spring surveys. There was little evidence to suggest changes in BAND Scores at potential impact sites from before to during-extraction were of different magnitude or direction to that observed at near and far controls. In autumn, there was a trend for lower BAND Scores at the controls during-extraction which was not evident at the potential impact sites. However, a change of only one BAND Score (in either direction), by itself, does not provide sufficient evidence to suggest an impact has occurred. BAND Scores provide a much coarser indication of potential changes to the macroinvertebrate assemblage than the OE50 Taxa Scores from which they are derived.

SIGNAL2 Scores

The mean SIGNAL2 Scores ranged from 4.0 to 5.1 in autumn and from 4.1 to 4.9 in spring (**Table 3**; **Figures 12-16**). None of the potential impact sites on Wongawilli and Sandy Creeks appeared to have consistently higher or smaller SIGNAL2 Scores. The SIGNAL2 Score at the potential impact sites was also comparable to the controls. There were no obvious trends in SIGNAL2 Scores.

None of the PERMANOVA tests showed a significant interactive effect (**Appendix 6**).

4.3.1.2 Macroinvertebrate Collectors

Number of Taxa

The mean number of taxa per site ranged from 7.0 to 18.7 (**Table 4**; **Figures 17-21**) and was largely comparable among potential impact sites and controls. There were no obvious trends in the data.

None of the PERMANOVA tests showed a significant interactive effect (**Appendix 7**).

SIGNAL2 Scores

The mean SIGNAL2 Score ranged from 4.3 to 5.2. (**Table 4**; **Figures 17-21**). SIGNAL2 Scores at potential impact sites were generally comparable with those at the controls and among pre and during-extraction surveys. There are no trends in SIGNAL2 Scores.

PERMANOVA indicated two significant interactions, with differences in SIGNAL2 scores among Treatments - Site 4, Near and Far Controls depending on Sampling Event and differences in scores among Treatments - Site13, Near and Far Controls depending on the Survey considered (**Appendix 8**). Post-hoc tests showed that:

- During autumn 2009 and 2010 (pre-extraction), and autumn 2011 (during-extraction), the SIGNAL2 Score at Site 4 was significantly lower than that at the Far Control, but not at the Near Control. In autumn 2010 (pre-extraction), the SIGNAL2 Score at the Near Control was significantly greater than that at the Far Control; and
- The interaction involving Treatments; Site 13, Near and Far Controls was due to a difference in SIGNAL2 Scores in the two control catchments during-extraction.

It should be noted that during autumn 2010, data was not available from Sites 15 and 16 in Kentish Creek (due to a flood event washing away the artificial collectors). During this event, the Far Control consisted of data from Site 14 only.

Assemblages

PERMANOVA indicated a significant interaction between Treatment and Sampling Event, for each of the analyses undertaken (**Appendix 9**). This indicates that small-scale temporal changes in assemblages were not consistent among Treatments. Post-hoc tests involving potential impact sites in the Wongawilli Creek catchment showed that:

- The assemblages at Site 3 were significantly different to those at the Far Control more often than the Near Control in both the pre-extraction (3 vs 1 event) and during-extraction (2 vs 1 event) periods. The assemblages at Site 3 also differed from those in the Near Control, but only once in each Extraction Period;

- The assemblage at Site 4 was significantly different to those at both the Near and Far Controls during all six Sampling Events; and
- The assemblages at the Near Controls on Wongawilli Creek were significantly different from those at the Far Controls during five of the six Sampling Events.

Post-hoc tests involving potential impact sites in the Sandy Creek catchment showed that:

- The assemblages at Site 9 were significantly different to those at the Near Control more often than the Far Control in both the pre-extraction (3 vs 1 event) and during-extraction periods (2 vs 1 event). The assemblages at Site 9 also differed from those in the Far Control, but only once in each Extraction Period;
- The assemblages at Site 12 were significantly different to those at both the Far and Near Controls in 5 of the 6 sampling events;
- The assemblages at Site 13 were significantly different to those at the Near Control more often than the Far Control (5 vs 4 sampling events) and were different to the Near Control more often in the during extraction period than pre-extraction period; and
- The assemblages at the Potential Impact sites and Near Controls in the Sandy Creek catchment differed from those in the Far Controls on two of the four pre-extraction sampling events and the two during-extraction sampling events.

These results suggest the small-scale temporal changes in assemblages at the potential impact sites in the Wongawilli Creek and Sandy Creek catchments are not related to mining.

The Principle Component Ordinations provided no evidence to suggest there were differences in assemblages sampled during pre and post-extraction surveys (**Figures 22-26**). The generally diffuse grouping indicates that the composition and relative abundance of the assemblages that developed on the macroinvertebrate collectors deployed at the potential impact and control locations, before and after extraction commenced, were similar. There appeared to be some evidence of differences between assemblages sampled at Site 4 and those sampled at the Far Control irrespective of time (**Figure 23**), this observation is consistent with the results of the PERMANOVA analysis.

4.3.1.3 Summary

AUSRIVAS

The AUSRIVAS indices were generally comparable among potential impact sites and controls. Where trends in the data were apparent, these were observed at both potential impact sites and controls and are therefore unlikely to be related to mining.

The significant difference between the mean number of taxa at Site 4, the Near and Far Controls in the during-extraction Sampling Events, could indicate a transient impact has occurred. The significant difference detected between the OE50 Taxa Scores at Sites 3 and 13 and the Far Controls in during and pre-extraction Surveys, respectively, most likely represents natural, inter-catchment variation unrelated to mining.

Macroinvertebrate Collectors

The mean numbers of taxa and SIGNAL2 Scores appeared largely comparable among potential impact sites and controls. The trends in SIGNAL2 Scores observed at potential impact sites on Sandy Creek were also evident at controls and therefore not indicative of an impact.

The significant interaction between Treatment and Sampling Event detected in each of the analyses based on assemblage data appeared due to natural, short-term temporal variations unrelated to mining.

4.3.2 Dendrobium Area 3B

4.3.2.1 AUSRIVAS Samples

Number of Taxa

The mean number of taxa per site ranged from 15.5 to 21.5 in autumn and from 9.5 to 21.5 in spring (**Table 3**; **Figure 27**). Data were largely comparable among potential impact sites and controls in autumn and spring. There appeared to be a decline in numbers of taxa averaged across the controls in autumn, but no change at the potential impact sites. The data collected in spring was more variable than that in autumn.

PERMANOVA did not indicate any significant interactive effects (**Appendix 10**).

OE50 Taxa Score

The mean OE50 Taxa Score ranged from 0.61 to 1.11 in autumn (±0.04) and from 0.58 to 1.05 in spring (**Table 3**; **Figure 28**). Data were comparable among potential impact sites and controls during autumn and spring. The OE50 Taxa Scores at both potential impact sites and controls were noticeably lower in the second autumn pre-extraction survey. A similar, but much weaker difference was apparent in spring.

PERMANOVA did not indicate any significant interactive effects (**Appendix 10**).

BAND Scores ranged from A to B at the potential impact sites and controls during both the autumn and spring surveys. The BAND Score at potential impact sites during the second autumn pre-extraction survey was either the same or lower than that in the first survey, the same trend was apparent for the controls. BAND scores at potential impact sites and controls were comparable between the two pre-extraction Surveys.

SIGNAL2 Score

The mean SIGNAL2 Score ranged from 3.9 to 5.0 in autumn and from 4.1 to 5.1 in spring (**Table 3**; **Figure 29**). Data were comparable among potential impact sites, and among potential impact sites and controls, in autumn and spring. There were no obvious trends in autumn or spring data.

PERMANOVA did not indicate any significant interactive effects (**Appendix 10**).

4.3.2.2 Macroinvertebrate Collectors

Number of Taxa

The mean number of taxa found on the macroinvertebrate collectors ranged from 9.0 to 21.0 per site (**Table 4**; **Figure 30**). Most potential impact sites were comparable with the controls. The number of taxa at Sites X1 and X3 was slightly lower than that at other potential impact sites and controls. The data for these two sites was also more variable between surveys.

PERMANOVA did not indicate any significant sources of variation (**Appendix 10**).

SIGNAL2 Score

The mean SIGNAL2 Score calculated from samples collected using macroinvertebrate collectors ranged from 4.3 to 5.2 (**Table 4**; **Figure 30**). Data was comparable among potential impact sites and among potential impact sites and controls. There were no obvious trends in the data.

PERMANOVA did not indicate any significant sources of variation (**Appendix 10**).

Assemblage

PERMANOVA indicated a significant Treatment by Sampling Event interaction (**Appendix 10**). The assemblage at the potential impact sites was significantly different to that at the Near Control during the first pre-extraction Sampling Event (autumn 2010). There were significant differences among treatments in each of the other Sampling Events in both pre-

extraction surveys. PERMANOVA did not indicate a significant Treatment by Survey interaction.

The Principle Component Ordination provided little evidence to suggest the grouping of assemblages on the basis of treatments, Survey or Sampling Event, instead it shows one relatively diffuse group of sites with no obvious outliers (**Figure 31**).

4.3.2.3 Summary

AUSRIVAS

AUSRIVAS data was generally comparable among potential impact sites and controls. Trends in OE50 Taxa Score data were apparent at both potential impact sites and controls and therefore unrelated to mining. PERMANOVA did not indicate any significant differences.

No significant interaction between Treatment and any of the temporal scales considered was detected. This indicates that temporal changes in AUSRIVAS data at potential impact sites and controls are similar. This should facilitate the detection of mining impacts on aquatic ecology.

Macroinvertebrate Collectors

The variability in number of taxa among potential impact sites should not hinder the detection of potential impacts as similar changes were observed at the controls.

The significant interaction between Treatment and Sampling Event, and significant differences among treatments in both pre-extraction surveys indicates short-term temporal variation in background macroinvertebrate collector data from DA3B. This is similar to what has been observed in macroinvertebrate collector data from DA3A. However, no significant Treatment by Survey interaction was detected, this suggests that temporal variation is not present at the scale of Survey and therefore should not hinder the detection of potential impacts.

4.4 Fish

The species of fish observed during each Sampling Event in each section of the watercourses are presented in **Table 5**. Galaxids (*Galaxias* sp.) were the most common species observed during the monitoring program. Freshwater crayfish (*Euastacus* sp.) were also often observed. Australian smelt (*Retropinna semoni*) were observed on occasion along with one short finned eel (*Anguilla australis*) at Site X4 during November 2010. The limited data collected over the course of the monitoring program does not provide any evidence to suggest that fish abundance or diversity has changed.

5 Discussion

There is no evidence in the Riparian, Channel and Environmental Inventory (RCE) assessment, the photographic record, measurements of water quality or fish data, to suggest that the changes to aquatic ecology that have occurred are outside what would be expected due to natural variation. Data collected using these methods following the commencement of extraction are comparable to data collected pre-extraction. The assessments of these indicators that have been undertaken to date indicate that the aquatic ecology of DA3A and DA3B is relatively undisturbed.

The relatively low OE50 Taxa Scores, Band Scores and SIGNAL2 Scores derived from the AUSRIVAS samples and data collected using macroinvertebrate collectors suggest that some sections of the watercourses may have experienced environmental stress. However, this may not necessarily be the case. Low scores that may be indicative of environmental stress could be related to the ephemeral nature of some creeks and ephemeral habitats favouring taxa regarded as pollution tolerant. Many taxa with low SIGNAL grades are air breathers and most of these utilise surface water habitat. These taxa would be able to successfully colonise ephemeral creeks. The relatively low natural pH levels in each watercourse may also influence macroinvertebrate diversity.

Statistically significant interactions were detected in the data collected from DA3A, however, very few of these interactions appear related to mining.

The conclusions from the DA3A analyses are:

- AUSRIVAS data provided little evidence of changes in aquatic ecology that could be attributed to mining. The significant interaction terms found were due to either significant differences in temporal trajectories between potential impact sites and the Far Control, or significant differences in trajectories between the controls. Alone, such differences do not indicate any impact on aquatic ecology. The only result that could be indicative of an impact was the significant difference in temporal variation in the number of taxa at Site 4 and at the Near Control in the during-extraction spring 2011 Sampling Event. This represents only a transient impact, if any, to aquatic ecology. Monitoring of this site will continue and the additional data collected will be analysed to confirm if this effect is related to mining.
- The data from the collectors also provide little evidence of changes in aquatic ecology that could be attributed to mining. For SIGNAL2 scores, the significant Treatment by Sampling Event interaction was due to significant differences between potential impact Site 4 and the Far Control, and significant differences between the controls in the analysis that included Site 13. As is the case with AUSRIVAS data, by themselves, these significant differences do not indicate an impact has occurred. The significant Treatment by Sampling Event interactions detected in analyses based on assemblages also appears to represent small scale temporal variation, rather than any potential impact.
- There is no evidence of any impacts to aquatic ecology at Site 13 on SC10C. This is despite observations of upstream mining-related impacts, including creek bed fracturing, gas releases and pool drainage and associated loss of aquatic habitat that has been attributed to the extraction of Longwall 7 (ICEFT 2012; Cardno Ecology Lab 2012). This suggests that impacts to the aquatic ecology of SC10C are limited to the area affected by mining, and that the mining-related impacts that have been observed have not had any measurable impacts on the aquatic indicators monitored further downstream. In the absence of any impact at Site 13, the apparent impact at Site 9 on Sandy Creek, which is downstream of the confluence with SC10C, is unlikely to be related to the fracturing and pool drainage observed in SC10C. These findings are consistent with the conclusions of the aquatic ecology assessment of SC10 undertaken on behalf of BHPBIC, following the observation of mining impacts in SC10C (Cardno Ecology Lab 2012).

The PERMANOVA tests undertaken on macroinvertebrate data collected from DA3B indicate that the Potential Impact and Control locations are comparable. The similarities in indicators among treatments should facilitate the detection of any changes to aquatic ecology associated with mining- related impacts in DA3B. The significant small scale temporal variation detected (i.e. between Sampling Events) is to be expected and should not hinder the detection of potential future changes in the indicators monitored.

6 Conclusions and Recommendations

The data collected prior to and following the commencement of extraction in DA3A provides little evidence to suggest mining-related impacts on the key aquatic ecology indicators. There was evidence at potential impact Site 4 on Wongawilli Creek, and potential impact Site 9 on Sandy Creek, of impacts to aquatic ecology. However, these impacts appeared transient and were observed in only some indicators. Monitoring of these sites will continue and further analysis will determine any relationship with mining.

It is recommend that aquatic ecology monitoring in DA3A continue, in line with the SMP requirements, and using the methods and study sites described in this report.

As two years of baseline monitoring for DA3B is now available, it is recommended that further monitoring at DA3B potential impacts sites be postponed until extraction commences. If, however, extraction in DA3B has not commenced by the beginning of autumn 2014, baseline aquatic ecology monitoring should resume. This would help ensure that baseline monitoring captures natural variation occurring close to the commencement of extraction, and enable confident conclusions to be made about potential changes to aquatic ecology occurring during and post-extraction.

7 References

ANZECC and ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4, Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand, October 2000.

BHP Billiton – Illawarra Coal (IC) (2009). Dendrobium Colliery Area 3A – Longwalls 6 to 10. Part B – Subsidence Management Plan for Areas 1, 2, and 3A. Final Report, December 2009.

Cardno Ecology Lab (2009). Aquatic Ecology Monitoring for Dendrobium Area 3A. Baseline Technical Report. Report EL0607058B. Prepared for BHPBIC.

Cardno Ecology Lab (2011). Dendrobium Area 3 – Baseline Aquatic Ecology Monitoring Spring 2008 – Spring 2010. Report EL0607058C. Prepared for BHPBIC.

Cardno Ecology Lab (2012a). Dendrobium Area 3B, Subsidence Management Plan. Aquatic Flora and Fauna Assessment. Report EL1112029A.

Cardno Ecology Lab (2012). SC10C Aquatic Ecology Investigation. Report Prepared for BHPBIC. February 2012.

Cardno Forbes Rigby (2007). Dendrobium Colliery Area 3A – Longwalls 6 to 10 Subsidence Management Plan Application Part A – Written Report. Final Report, November 2007.

Chessman, B.C Growns, J.E and Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. Marine and Freshwater Research, 48, pp. 159-172.

Clarke K. R. (1993). Non-parametric multivariate analyses of changes in assemblage structure. *Australian Journal of Ecology,* **18**: pp. 117-143.

Clarke K.R. and Gorley R.N. (2006). *Primer V6: User Manual/Tutorial.* Primer-E, Plymouth.

Illawarra Coal Environmental Field Team (ICEFT) (2012). Dendrobium Area 3A Longwall 7. End of Panel Report. Landscape Monitoring.

NSW Department of Planning (2008). Impacts of underground coal mining on natural features in the Southern Coalfield: strategic review. http://www.planning.nsw.gov.au/planningsystem/pdf/report_southern_coalfields_final_jul08.pdf Accessed 10 August 2009.

Peterson, R.C. (1992). The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology, 27, pp. 295-306.

The Ecology Lab (2007). Dendrobium Area 3: Assessment of mine subsidence impacts on aquatic habitat and biota. Report 58/0607A prepared for BHPBIC.

Turak, E., Waddell, N. and Johnstone, G. (2004). New South Wales (NSW) Australian River Assessment System (AUSRIVAS). Sampling and Processing Manual. Environmental Protection Authority. pp. 45.

8 Tables

Table 1: Habitat assessment based the Riparian, Channel and Environmental Inventory (RCE) scores for each site monitored by Cardno Ecology Lab as part of the ongoing aquatic ecology monitoring for Dendrobium Area 3.

Table 2: Mean (n=2, (turbidity=6)) water quality data sampled at aquatic ecology monitoring sites by Cardno Ecology Lab Dendrobium Area 3. SE = Standard Error. Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in southeast Australia.

Table 3: Mean number of taxa, OE50 Taxa Scores and SIGNAL2 Scores from AUSRIVAS samples collected from potential impact locations and control locations in Dendrobium Area 3A and B during surveys undertaken in autumn and spring prior to, and during, extraction of DA3A. Potential Impact locations: n=2, Wongawilli Creek control: n=6, Sandy Creek control: n=4, Donalds Castle / Kentish creeks control: n=6. SE=Standard Error.

Table 4: Mean number of taxa and SIGNAL2 Scores from macroinvertebrate assemblages sampled using artificial collectors at Potential Impact and Control locations in Dendrobium Area 3. Potential Impact locations: n=16; Wongawilli Creek control: n=48; Sandy Creek control: n=32; Donalds Castle / Kentish creeks control (DA3A): n=48, except pre-extraction 2 = 32; Donalds Castle / Kentish creeks control (DA3B): pre-extraction 1 n=24, pre-extraction 2 n=48. SE=Standard Error.

Table 5: Species of fish observed by Cardno Ecology Lab at Potential Impact and Control locations in Dendrobium Area 3.

Table 1: Habitat assessment based on Riparian, Channel and Environmental Inventory (RCE) scores for each of the aquatic ecology monitoring sites for Dendrobium Area 3 recorded throughout the course of the monitoring program.

Designation		DA3A Potential Impact Sites					DA3B Potential Impact Sites						Near Control Sites (Wongawilli Catchment)			Near Control Sites (Sandy Catchment)		Far Control Sites		
Site		3	4	9	12	13	X1	X2	X3	X4	X5	X6	1	5	6	7	8	14	15	16
1	Land use pattern beyond the immediate riparian zone	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
2	Width of riparian strip of woody vegetation	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
3	Completeness of riparian strip of woody vegetation	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
4	Vegetation of riparian zone within 10m of channel	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	Stream bank structure	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
6	Bank undercutting	3	3	3	3	4	4	4	4	4	4	4	3	3	4	3	3	3	3	3
7	Channel form	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	Riffle/pool sequence	3	3	4	4	4	4	4	3	4	4	4	4	3	4	3	4	4	4	3
9	Retention devices in stream	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
10	Channel sediment accumulations	3	3	4	3	4	4	4	4	4	4	4	3	4	4	2	2	4	4	4
11	Stream bottom	2	2	3	4	4	4	4	4	4	4	4	4	4	4	3	3	3	4	4
12	Stream detritus	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
13	Aquatic vegetation	4	4	3	3	3	3	3	4	4	4	3	3	3	4	4	3	4	4	4
Total score		46	46	48	48	50	50	50	50	51	51	50	48	47	51	46	46	49	50	49

Table 2: Mean water quality data for each of the Dendrobium Area 3 aquatic ecology monitoring sites measured in April, June, September and October 2011. (SE = Standard Error, n = 2, except for turbidity where n =6). Default Trigger Values (DTV) taken from ANZECC/ARMCANZ (2000) guidelines for slightly disturbed upland rivers in southeast Australia. n/a = data not available due to probe malfunction.

Site	Variable			Pre-extraction 1								Pre-extraction 2								During-extraction 1							
				Oct 08		Nov 08		Mar 09		Apr 09		Mar 10		May 10		Sep 10		Nov 10		Apr 11		Jun 11		Sep 11		Oct 11	
			DTVs	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
DA3A Potential Impact Sites																											
3	Temperature	°C		12.8	0.0	15.6	0.0	17.2	0.2	12.1	0.0	16.7	0.0	15.3	0.1	11.5	0.0	22.0	0.0	12.5	0.0	8.8	0.0	10.0	0.0	15.8	0.0
	Conductivity	µS/cm	30-350	62	3	n/a		77	5	60	0	83	0	61	13	10	10	n/a		64	1	51	0	172	12	141	2
	pH		6.5-8.0	5.6	0.0	4.5	0.0	4.8	0.0	5.3	0.0	5.2	0.0	5.3	0.1	5.2	0.0	5.1	0.0	5.9	0.1	5.2	0.0	6.7	0.1	5.4	0.0
	ORP	mV		447	1	640	2	558	2	251	1	544	2	723	1	463	4	496	1	204	7	265	0	358	1	164	10
	Dissolved Oxygen	% Sat	90-110	85.6	1.6	39.2	0.9	32.5	0.4	124.7	0.2	79.0	0.4	67.2	1.3	n/a		50.8	0.3	91.1	1.0	97.7	0.1	97.0	1.1	53.8	0.2
	Turbidity	ntu	2-25	9.8	0.6	4.0	0.2	n/a		0.0	0.0	2.6	0.1	13.6	0.2	2.5	0.3	5.8	0.3	7.9	0.2	0.5	0.1	0.0	0.0	57.9	1.2
4	Temperature	°C		13.0	0.0	15.8	0.0	17.5	0.1	11.9	0.0	17.1	0.0	15.0	0.0	11.9	0.0	22.0	0.0	12.4	0.0	8.7	0.0	9.9	0.0	15.8	0.0
	Conductivity	µS/cm	30-350	65	0	n/a		49	4	50	0	83	0	82	0	27	3	0	0	64	0	56	0	98	6	195	4
	pH		6.5-8.0	5.7	0.1	5.6	0.0	5.4	0.0	5.4	0.0	5.3	0.0	5.3	0.0	5.2	0.0	5.1	0.0	5.6	0.0	5.3	0.0	6.1	0.0	5.3	0.0
	ORP	mV		441	2	599	1	560	11	301	0	509	3	753	10	478	2	499	0	298	7	297	4	398	3	223	4
	Dissolved Oxygen	% Sat	90-110	76.0	0.5	33.5	0.0	40.6	0.3	n/a		78.1	0.3	66.7	0.5	n/a		67.5	0.1	78.4	0.7	94.1	0.3	90.2	0.5	50.6	0.1
	Turbidity	ntu	2-25	2.1	0.1	3.7	0.0	n/a		n/a		2.6	0.0	5.3	0.1	2.2	0.3	5.9	0.1	4.2	0.2	0.9	0.2	0.0	0.0	60.2	0.9
9	Temperature	°C		13.4	0.0	15.6	0.0	16.7	0.0	12.3	0.0	17.4	0.0	13.3	0.0	12.7	0.1	19.6	0.3	13.3	0.0	9.4	0.0	12.8	0.0	13.7	0.0
	Conductivity	µS/cm	30-350	69	0	n/a		59	5	45	5	89	2	240	0	96	0	48	4	63	3	71	0	81	4	73	0
	pH		6.5-8.0	6.0	0.1	5.7	0.0	5.8	0.0	5.6	0.0	5.5	0.0	5.7	0.0	5.4	0.0	5.0	0.0	5.8	0.0	5.4	0.0	5.4	0.0	5.4	0.0
	ORP	mV		339	4	459	8	476	3	392	7	451	3	333	1	203	10	525	3	409	4	428	1	173	6	449	1
	Dissolved Oxygen	% Sat	90-110	83.0	0.6	51.7	0.1	59.4	1.1	n/a		71.8	0.3	58.2	0.2	96.5	3.4	54.3	1.4	101.1	0.0	91.8	0.2	95.6	3.1	85.0	0.4
	Turbidity	ntu	2-25	4.0	0.3	3.6	0.2	n/a		n/a		2.4	0.1	11.3	0.2	0.6	0.1	6.1	0.1	3.0	0.1	1.7	0.2	8.9	0.4	7.2	0.3
12	Temperature	°C		14.5	0.0	16.5	0.0	18.5	0.1	13.8	0.0	20.3	0.0	12.0	0.0	12.0	0.0	n/a		14.0	0.1	8.6	0.0	11.8	0.0	13.3	0.0
	Conductivity	µS/cm	30-350	62	0	n/a		84	4	77	0	94	0	107	0	46	8	n/a		70	1	54	2	43	1	63	0
	pH		6.5-8.0	5.5	0.1	5.2	0.0	5.2	0.0	5.1	0.0	4.5	0.4	5.1	0.0	5.0	0.0	n/a		4.6	0.1	5.0	0.0	5.5	0.0	4.7	0.0
	ORP	mV		621	2	621	2	506	0	288	1	496	2	670	6	429	2	n/a		300	3	368	3	408	2	255	4
	Dissolved Oxygen	% Sat	90-110	97.1	2.3	70.1	0.4	75.6	2.8	n/a		93.1	0.3	80.1	0.3	85.1	0.8	n/a		99.4	1.0	99.3	0.7	100.9	0.8	63.2	0.4
	Turbidity	ntu	2-25	9.4	0.4	1.0	0.0	n/a		n/a		2.8	0.2	1.9	0.1	1.1	0.1	n/a		8.7	0.3	1.3	0.5	0.2	0.0	4.8	0.2
13	Temperature	°C		12.0	0.0	16.5	0.0	17.0	0.1	14.3	0.0	17.6	0.0	11.5	0.0	12.0	0.2	16.6	0.1	13.4	0.0	8.7	0.1	12.1	0.1	13.4	0.0
	Conductivity	µS/cm	30-350	49	0	n/a		36	18	76	0	104	0	121	0	n/a		139	30	71	0	59	3	21	11	5	0
	pH		6.5-8.0	5.6	0.0	5.4	0.0	5.1	0.0	5.1	0.0	5.0	0.0	5.4	0.0	6.5	0.4	5.7	0.4	4.7	0.0	4.9	0.0	5.5	0.0	5.0	0.0
	ORP	mV		553	2	553	2	510	1	228	1	462	5	597	3	371	10	156	60	280	6	312	2	438	6	455	1
	Dissolved Oxygen	% Sat	90-110	88.0	0.9	81.0	0.1	83.5	0.1	n/a		92.5	0.2	86.0	0.5	93.8	9.1	114.1	3.1	95.3	0.8	105.4	0.5	104.9	0.5	98.5	0.0
	Turbidity	ntu	2-25	7.2	0.7	0.4	0.1	n/a		n/a		0.6	0.0	3.6	0.1	1.5	0.2	14.5	1.8	9.8	0.3	7.8	0.5	0.0	0.0	2.6	0.2

Continued…

Table 2: Continued.

Site	Variable		DTVs	Pre-extraction 1								Pre-extraction 2							
				Mar 10		May 10		Sep 10		Nov 10		Apr 11		Jun 11		Sep 11		Oct 11	
				Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
DA3A Potential Impact Sites																			
X1	Temperature	°C		18.2	0.1	15.3	0.0	12.9	0.0	19.3	0.1	15.7	0.0	12.2	0.0	11.5	0.0	15.5	0.0
	Conductivity	µS/cm	30-350	106	0	118	0	95	0	102	1	100	0	92	0	148	5	25	0
	pH		6.5-8.0	4.2	0.0	4.4	0.0	4.2	0.0	4.4	0.0	4.2	0.0	4.0	0.0	5.0	0.0	4.5	0.0
	ORP	mV		555	2	709	4	545	2	508	17	505	3	560	5	557	1	487	13
	Dissolved Oxygen	% Sat	90-110	99.1	0.1	88.9	0.6	84.6	1.8	54.5	0.1	98.7	0.0	92.7	0.1	98.0	0.1	98.5	1.0
	Turbidity	ntu	2-25	1.4	0.4	14.7	0.3	1.5	0.0	3.6	0.0	2.7	0.1	0.3	0.1	0.0	0.0	46.7	0.5
X2	Temperature	°C		20.8	0.0	14.8	0.0	14.9	0.0	20.6	0.0	14.2	0.0	10.7	0.0	12.2	0.0	15.5	0.0
	Conductivity	µS/cm	30-350	121	0	143	0	132	6	112	0	87	3	64	6	118	0	50	5
	pH		6.5-8.0	4.7	0.0	5.0	0.0	4.7	0.0	4.7	0.0	4.7	0.0	4.6	0.0	5.5	0.0	5.1	0.0
	ORP	mV		503	1	600	0	552	2	538	1	420	0	474	4	436	0	418	8
	Dissolved Oxygen	% Sat	90-110	100.1	0.2	75.2	0.0	109.3	7.8	45.9	1.7	101.3	0.0	91.7	0.1	97.9	0.7	90.5	0.8
	Turbidity	ntu	2-25	3.8	0.1	8.6	0.4	3.1	0.2	5.8	0.1	4.0	0.3	0.6	0.2	0.4	0.1	12.8	1.4
X3	Temperature	°C		17.7	0.0	14.4	0.0	12.0	0.0	15.1	0.0	15.3	0.0	11.4	0.0	11.1	0.0	13.0	0.0
	Conductivity	µS/cm	30-350	112	0	128	0	100	8	106	0	82	0	76	3	139	6	16	0
	pH		6.5-8.0	4.7	0.0	5.0	0.0	4.5	0.0	4.8	0.0	4.7	0.0	4.8	0.0	5.4	0.0	4.9	0.0
	ORP	mV		493	1	567	5	514	5	515	1	447	1	509	1	471	3	471	5
	Dissolved Oxygen	% Sat	90-110	51.0	0.4	32.4	0.2	109.9	0.8	48.9	1.6	71.8	0.3	73.6	0.1	80.4	1.2	80.4	0.9
	Turbidity	ntu	2-25	4.5	0.0	3.0	0.3	1.7	0.5	6.2	0.0	1.8	0.1	2.7	0.2	4.9	0.2	0.5	0.1
X4	Temperature	°C		15.6	0.0	11.5	0.0	10.5	0.0	15.0	0.0	13.7	0.0	9.1	0.0	10.8	0.0	13.9	0.0
	Conductivity	µS/cm	30-350	81	0	86	2	76	5	29	5	58	3	57	5	115	2	70	0
	pH		6.5-8.0	5.2	0.0	5.6	0.0	5.3	0.0	5.1	0.0	5.4	0.0	5.3	0.0	5.1	0.0	5.6	0.0
	ORP	mV		478	1	640	62	469	1	496	2	417	11	434	1	318	1		n/a
	Dissolved Oxygen	% Sat	90-110	79.8	0.1	73.6	0.5	100.4	0.5	50.1	1.6	86.5	0.4	89.9	0.3	88.3	1.0	87.5	1.2
	Turbidity	ntu	2-25	0.7	0.1	5.0	0.1	6.7	0.1	6.6	0.4	0.9	0.4	0.9	0.2	5.5	0.1	0.6	0.0
X5	Temperature	°C		17.3	0.0	11.5	0.0	11.3	0.0	16.3	0.0	*no data*		9.4	0.0	11.3	0.0	14.7	0.0
	Conductivity	µS/cm	30-350	78	0	102	2	14	0	104	2	69	0	60	5	127	6	58	3
	pH		6.5-8.0	5.0	0.0	5.8	0.0	5.1	0.0	4.9	0.0	5.9	0.0	5.3	0.1	5.9	0.0	5.6	0.0
	ORP	mV		508	1	697	5	490	0	663	7	407	2	211	6	447	1	504	1
	Dissolved Oxygen	% Sat	90-110	95.7	0.1	76.3	0.4	92.8	2.8	66.1	0.5	96.3	0.2	98.8	0.2	104.0	1.2	95.4	0.1
	Turbidity	ntu	2-25	0.6	0.2	7.6	0.1	1.2	0.1	7.2	0.2	7.1	0.2	0.6	0.0	0.0	0.0	0.6	0.1
X6	Temperature	°C		19.8	0.0	13.7	0.1	14.8	0.0	19.2	0.0	*no data*		10.4	0.0	13.6	0.3	16.5	0.0
	Conductivity	µS/cm	30-350	82	0	115	1	43	2	98	2	68	0	49	0	107	25	68	0
	pH		6.5-8.0	4.9	0.0	6.0	0.0	5.1	0.0	5.1	0.0	6.2	0.0	5.3	0.0	6.0	0.1	5.7	0.0
	ORP	mV		482	1	728	8	487	0	459	1	243	4	180	1	382	0	437	2
	Dissolved Oxygen	% Sat	90-110	80.5	0.1	76.6	0.3	127.0	0.1	67.5	0.3	87.2	0.6	103.4	0.4	94.6	0.1	90.3	0.2
	Turbidity	ntu	2-25	0.4	0.1	13.9	0.3	0.3	0.1	4.7	0.2	9.6	0.4	0.6	0.0	0.0	0.0	0.8	0.1

Continued…

Table 2: Continued.

Site	Variable			Pre-extraction 1								Pre-extraction 2 (DA3A) / Pre-extraction 1 (DA3B)								During-extraction 1 (DA3A) / Pre-extraction 2 (DA3B)							
				Oct 08		Nov 08		Mar 09		Apr 09		Mar 10		May 10		Sep 10		Nov 10		Apr 11		Jun 11		Sep 11		Oct 11	
			DTVs	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Near Control Wongawilli Catchment Sites																											
S1	Temperature	°C		13.0	0.0	14.5	0.0	16.4	0.0	12.5	0.0	15.8	0.0	11.0	0.0	10.4	0.0	15.9	0.0	13.8	0.0	9.2	0.0	10.7	0.0	14.2	0.0
	Conductivity	µS/cm	30-350	61	3	n/a		73	0	59	0	81	0	97	5		n/a	118	28	58	3	52	3	115	3	99	0
	pH		6.5-8.0	5.5	0.0	5.6	0.0	5.2	0.0	5.1	0.0	5.0	0.0	5.5	0.0	5.3	0.0	4.9	0.0	5.8	0.0	5.5	0.1	5.1	0.0	5.9	0.0
	ORP	mV		473	5	636	1	607	5	180	1	502	2	584	11	452	3	595	6	417	2	437	7	295	2	n/a	
	Dissolved Oxygen	% Sat	90-110	94.2	0.5	63.7	0.9	76.0	1.2	n/a		91.9	0.3	75.7	1.8	93.2	2.8	68.2	0.3	99.6	0.3	98.5	0.8	100.3	0.3	100.8	1.8
	Turbidity	ntu	2-25	7.4	0.5	2.3	0.0	n/a		n/a		0.8	0.1	1.8	0.2	13.1	0.0	11.0	0.4	2.6	0.2	1.1	0.1	2.4	0.3	0.3	0.0
S5	Temperature	°C		13.4	0.0	15.6	0.0	16.7	0.0	12.3	0.0	17.4	0.0	13.3	0.0	12.7	0.1	19.6	0.3	13.6	0.0	8.7	0.0	11.3	0.1	17.0	0.0
	Conductivity	µS/cm	30-350	69	0	n/a		59	5	45	5	89	2	240	0	96	0	48	4	80	1	67	11	156	3	57	19
	pH		6.5-8.0	6.0	0.1	5.7	0.0	5.8	0.0	5.6	0.0	5.5	0.0	5.7	0.0	5.4	0.0	5.0	0.0	5.3	0.0	5.3	0.0	5.5	0.0	5.7	0.1
	ORP	mV		339	4	459	8	476	3	392	7	451	3	333	1	203	10	525	3	337	6	446	4	456	5	346	4
	Dissolved Oxygen	% Sat	90-110	83.0	0.6	51.7	0.1	59.4	1.1	n/a		71.8	0.3	58.2	0.2	96.5	3.4	54.3	1.4	84.8	1.5	96.6	1.8	94.1	0.5	79.1	2.6
	Turbidity	ntu	2-25	4.0	0.3	3.6	0.2		n/a	n/a		2.4	0.1	11.3	0.2	0.6	0.1	6.1	0.1	2.1	0.2	4.9	0.4	0.8	0.1	20.0	0.8
S6	Temperature	°C		13.8	0.3	15.8	0.0	18.6	0.0	11.6	0.1	21.3	0.0	14.8	0.1	16.0	0.0	13.2	0.0	15.3	0.0	9.5	0.0	12.8	0.0	17.1	0.2
	Conductivity	µS/cm	30-350	76	3		n/a	105	18	101	0	8	0	19	10	116	0	132	0	82	0	77	6	160	5	72	5
	pH		6.5-8.0	5.4	0.1	5.3	0.0	5.0	0.0	5.5	0.0	4.9	0.0	5.1	0.0	4.9	0.0	5.2	0.0	5.4	0.0	5.2	0.0	5.5	0.0	5.5	0.3
	ORP	mV		417	16	544	5	560	3	330	5	538	1	460	18	508	1	640	1	389	11	430	3	504	15	395	17
	Dissolved Oxygen	% Sat	90-110	93.7	0.6	73.6	0.4	62.8	0.4	n/a		67.8	0.0	n/a		101.1	0.8	83.1	0.1	108.7	1.4	96.7	0.2	100.6	0.2	96.2	0.6
	Turbidity	ntu	2-25	2.6	0.5	0.2	0.0	n/a		n/a		n/a		n/a		1.7	0.4	9.8	0.1	3.3	0.2	0.3	0.1	0.5	0.0	5.7	0.8
Near Control Sandy Catchment Sites																											
S7	Temperature	°C		12.3	0.0	15.3	0.0	19.2	0.0	12.4	0.0	18.9	0.0	13.6	0.0	12.2	0.0	16.2	0.0	13.5	0.0	9.9	0.0	12.0	0.0	12.8	0.0
	Conductivity	µS/cm	30-350	68	3	n/a		104	1	84	5	101	0	139	4	92	1	92	2	75	0	71	1	106	2	75	0
	pH		6.5-8.0	5.7	0.0	5.5	0.0	5.4	0.0	5.9	0.1	5.5	0.0	5.7	0.0	5.2	0.1	5.6	0.0	5.3	0.0	5.1	0.0	5.2	0.0	5.3	0.0
	ORP	mV		416	5	626	3	457	4	309	8	428	1	100	1	493	7	456	1	408	1	453	2	229	0	462	1
	Dissolved Oxygen	% Sat	90-110	68.1	0.5	38.2	0.1	32.8	0.1	n/a		67.8	0.8	58.1	0.1	52.7	0.1	44.4	1.5	92.1	0.4	89.6	0.4	101.1	0.0	84.2	0.1
	Turbidity	ntu	2-25	4.9	0.3	2.5	0.1	n/a		n/a		7.2	0.1	14.1	0.2	2.7	0.1	6.7	0.1	3.2	0.5	0.9	0.1	2.8	0.2	1.0	0.2
S8	Temperature	°C		13.0	0.1	15.2	0.0	16.6	0.3	12.6	0.0	17.8	0.0	11.9	0.0	10.3	0.0	16.0	0.0	12.9	0.0	9.2	0.0	12.1	0.2	13.2	0.0
	Conductivity	µS/cm	30-350	64	0	n/a		69	33	79	0	99	0	98	0	89	0	66	0	64	8	69	3	107	2	74	0
	pH		6.5-8.0	6.1	0.1	5.8	0.0	5.4	0.0	5.7	0.0	5.6	0.0	5.8	0.0	6.0	0.1	5.5	0.0	5.4	0.0	5.1	0.0	5.5	0.1	5.5	0.0
	ORP	mV		376	9	528	2	486	9	279	2	405	2	502	22	90	13	399	4	369	1	415	1	204	1	431	1
	Dissolved Oxygen	% Sat	90-110	86.1	1.0	62.6	0.5	69.0	2.0	n/a		59.9	0.1	80.6	0.1	105.6	2.8	62.0	3.7	92.6	0.1	87.6	0.1	96.9	5.9	86.8	0.1
	Turbidity	ntu	2-25	4.0	0.2	5.9	0.3	n/a		n/a		9.7	0.1	5.2	0.5	15.0	0.4	0.7	0.0	2.6	0.4	0.3	0.1	0.5	0.0	1.7	0.2

Continued…

Table 2: Continued.

Site	Variable			Pre-extraction 1								Pre-extraction 2								During-extraction 1							
				Oct 08		Nov 08		Mar 09		Apr 09		Mar 10		May 10		Sep 10		Nov 10		Apr 11		Jun 11		Sep 11		Oct 11	
			DTVs	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Far Control Sandy Catchment Sites																											
S14	Temperature	°C		13.7	0.0	17.1	0.0	21.3	0.0	14.8	0.1	19.4	0.0	14.8	0.0	12.5	0.0	16.8	0.0	14.5	0.0	9.7	0.1	11.8	0.1	15.6	0.0
	Conductivity	µS/cm	30-350	79	0	n/a		8	0	19	10	129	0	189	0	113	3	114	3	103	0	98	0	185	1	94	0
	pH		6.5-8.0	5.2	0.0	5.5	0.2	4.9	0.0	5.1	0.0	4.8	0.0	5.1	0.0	4.8	0.0	4.8	0.0	4.5	0.0	4.8	0.1	5.4	0.1	4.9	0.0
	ORP	mV		451	15	451	15	538	1	460	18	491	2	519	1	475	34	530	4	456	1	510	3	491	1	370	16
	Dissolved Oxygen	% Sat	90-110	91.2	1.1	62.0	0.0	67.8	0.0	n/a		80.2	0.3	73.6	0.8	122.3	1.1	43.5	0.1	102.7	0.1	90.8	0.4	95.5	0.7	92.8	0.1
	Turbidity	ntu	2-25	13.1	0.1	4.8	0.0		n/a	n/a		6.9	0.1	14.3	0.1	0.9	0.1	11.3	0.1	1.4	0.2	0.2	0.1	0.5	0.0	38.7	0.8
S15	Temperature	°C		11.8	0.0	14.4	0.0	14.9	0.0	12.4	0.0	15.9	0.1	11.6	0.0	10.9	0.0	14.3	0.0	12.5	0.0	9.4	0.0	10.2	0.0	12.9	0.0
	Conductivity	µS/cm	30-350	72	6	n/a		109	5	84	5	101	3	116	0	90	0	74	0	72	10	77	0	159	0	23	2
	pH		6.5-8.0	6.9	0.3	6.4	0.0	6.5	0.0	7.1	0.1	6.5	0.0	6.3	0.0	6.3	0.0	7.2	0.0	6.2	0.1	6.0	0.0	6.6	0.0	6.3	0.0
	ORP	mV		603	1	603	1	540	0	386	0	475	1	403	19	509	1	455	1	364	1	437	9	373	0	420	1
	Dissolved Oxygen	% Sat	90-110	89.8	2.4	70.1	0.5	71.1	0.5	n/a		99.1	0.8	85.2	1.3	58.4	3.9	73.0	1.0	96.1	0.0	95.2	1.4	88.5	0.5	96.2	0.3
	Turbidity	ntu	2-25	11.6	3.0	2.6	0.2	n/a		n/a		8.8	0.0	4.1	0.2	4.0	0.1	9.4	0.1	6.9	0.3	6.2	0.2	0.0	0.0	0.5	0.0
S16	Temperature	°C		12.4	0.0	14.7	0.0	15.1	0.0	12.3	0.0	16.1	0.0	12.3	0.0	11.3	0.0	14.7	0.0	12.4	0.0	9.6	0.0	10.5	0.1	13.9	0.0
	Conductivity	µS/cm	30-350	92	0	n/a		104	38	89	0	120	0	126	0	132	0	77	2	98	0	88	0	204	0	88	0
	pH		6.5-8.0	7.3	0.0	6.5	0.0	6.7	0.0	6.9	0.0	6.7	0.0	6.8	0.0	6.5	0.0	6.5	0.1	6.5	0.0	6.2	0.0	6.6	0.0	6.6	0.0
	ORP	mV		611	2	611	2	533	1	375	2	449	1	396	5	49	10	48	29	362	2	424	9	430	30	412	7
	Dissolved Oxygen	% Sat	90-110	87.2	0.4	62.0	0.9	66.1	0.2	n/a		100.7	0.3	78.3	0.0	106.7	1.3	97.8	3.7	102.4	0.1	93.4	0.6	96.0	0.9	94.9	0.1
	Turbidity	ntu	2-25	3.0	0.1	2.4	0.1	n/a		n/a		7.4	0.0	10.4	0.2	2.5	0.1	15.0	0.2	3.0	0.1	3.3	0.3	0.0	0.0	0.5	0.0

Table 3: Mean number of taxa, OE50 Taxa Scores and SIGNAL2 Scores for AUSRIVAS samples collected from potential impact sites (X. Y and Z) and control sites (a, b and c) in Dendrobium Area 3A and B in autumn and spring prior to and during extraction of longwalls X and Y. DA3A and DA3B Potential Impact Sites: n=2. For controls, data is averaged accross all sites, therefore Wongawilli Creek control: n=6, Sandy Creek control: n=4, Donalds Castle / Kentish creeks control: n=6. SE=Standard Error.

Site	Indicator	Autumn						Spring					
		Pre-extraction 1		Pre-extraction 2		During-extraction 1		Pre-extraction 1		Pre-extraction 2		During-extraction 1	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
DA3A Potential Impact Sites										**Spring**			
3	Number of taxa	20.5	1.5	18.0	2.0	17.0	3.0	20.0	0.0	22.0	1.0	18.5	4.5
	OE50 taxa	1.02	0.00	1.15	0.10	0.89	0.06	0.87	0.02	0.80	0.12	0.75	0.16
	SIGNAL2 Score	4.7	0.1	4.3	0.1	4.4	0.2	4.6	0.2	4.7	0.1	4.9	0.1
	BAND		A		A		A		A		B		B
4	Total number of taxa	19.5	2.5	15.5	2.5	20.0	3.0	21.0	2.0	22.0	3.0	18.0	4.0
	OE50 taxa	1.03	0.00	0.93	0.10	0.88	0.11	0.93	0.05	0.90	0.17	0.70	0.10
	SIGNAL2 Score	5.1	0.2	4.0	0.2	4.7	0.2	4.7	0.1	4.6	0.2	4.7	0.2
	BAND		A		A		A		A		A		B
9	Total number of taxa	19.0	2.0	19.0	5.0	19.0	0.0	25.0	1.0	19.0	2.0	12.0	2.0
	OE50 taxa	1.02	0.00	0.78	0.14	0.77	0.06	1.00	0.04	0.75	0.00	0.59	0.11
	SIGNAL2 Score	4.4	0.0	4.2	0.1	4.8	0.2	4.7	0.2	4.7	0.0	4.3	0.4
	BAND		A		B		B		A		B		B
12	Total number of taxa	17.5	0.5	13.5	1.5	19.0	0.0	17.5	0.5	18.0	1.0	17.5	2.5
	OE50 taxa	0.80	0.00	0.60	0.05	0.83	0.09	0.91	0.14	0.87	0.09	0.71	0.06
	SIGNAL2 Score	4.3	0.1	4.4	0.1	4.5	0.1	4.5	0.2	4.8	0.0	4.4	0.2
	BAND		B		B		A		A		A		B
13	Total number of taxa	17.5	0.5	12.5	1.5	18.5	0.5	18.0	0.0	17.0	3.0	14.5	0.5
	OE50 taxa	1.11	0.00	0.74	0.19	0.88	0.04	0.86	0.00	0.77	0.09	0.67	0.03
	SIGNAL2 Score	4.3	0.0	4.4	0.2	4.2	0.0	4.3	0.1	4.2	0.3	4.1	0.0
	BAND		A		B		A		A		B		B

Continued…

Table 3: Continued

Site	Indicator	Autumn				Spring			
		Pre-extraction 1		Pre-extraction 2		Pre-extraction 1		Pre-extraction 2	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
DA3B Potential Impact Sites									
X1	Total number of taxa	18.0	2.8	18.5	0.5	20.5	0.5	17.5	4.2
	OE50 taxa	0.87	0.05	0.62	0.00	0.75	0.13	0.77	0.19
	SIGNAL2 Score	4.2	0.4	4.2	0.3	4.3	0.0	4.3	0.5
	BAND		A		B		B		B
X2	Total number of taxa	18.0	2.8	18.0	2.8	17.5	2.3	15.0	0.9
	OE50 taxa	1.11	0.09	0.61	0.04	0.81	0.05	0.70	0.05
	SIGNAL2 Score	4.0	0.2	4.7	0.0	4.3	0.0	4.4	0.3
	BAND		A		B		B		B
X3	Total number of taxa	17.5	3.3	19.0	0.9	20.5	3.3	19.0	0.0
	OE50 taxa	0.73	0.07	0.66	0.16	0.76	0.04	0.78	0.01
	SIGNAL2 Score	3.9	0.1	4.4	0.2	4.2	0.1	4.7	0.2
	BAND		B		B		B		B
X4	Total number of taxa	17.5	0.5	16.0	0.9	9.5	0.5	16.5	1.4
	OE50 taxa	1.07	0.05	0.65	0.00	0.67	0.08	0.58	0.09
	SIGNAL2 Score	4.1	0.2	4.2	0.3	4.1	0.2	4.7	0.1
	BAND		A		B		B		B
X5	Total number of taxa	16.0	1.9	16.0	1.9	19.0	0.0	14.5	2.3
	OE50 taxa	0.97	0.13	0.70	0.04	0.90	0.18	0.76	0.31
	SIGNAL2 Score	4.6	0.3	5.0	0.1	5.1	0.1	4.8	0.5
	BAND		A		B		A		B
X6	Total number of taxa	16.5	2.3	15.5	2.3	21.5	3.3	15.5	0.5
	OE50 taxa	1.02	0.09	0.83	0.00	1.05	0.08	0.75	0.20
	SIGNAL2 Score	4.4	0.1	4.2	0.2	4.7	0.0	4.4	0.1
	BAND		A		A		A		B

Continued...

Table 3: Continued.

Site	Indicator	Autumn						Spring					
		Pre-extraction 1 (DA3A)		Pre-extraction 2 (DA3A) Pre-extraction 1 (DA3B)		During-extraction 1 (DA3A) Pre-extraction 2 (DA3B)		Pre-extraction 1 (DA3A)		Pre-extraction 2 (DA3A) Pre-extraction 1 (DA3B)		During-extraction 1 (DA3A) Pre-extraction 2 (DA3B)	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Control Sites													
Near Control Wongawilli Catchment Sites 1, 5 and 6	Total number of taxa	22.5	1.6	21.5	1.6	16.3	1.1	23.2	0.7	18.8	1.3	16.5	1.6
	OE50 taxa	0.94	0.03	1.10	0.05	0.71	0.05	0.96	0.05	0.86	0.04	0.70	0.08
	SIGNAL2 Score	4.5	0.1	4.5	0.1	4.7	0.1	4.6	0.1	4.6	0.2	4.7	0.2
	BAND	A		A		B		A		A		B	
Near Control Sandy Catchment Sites 7 and 8	Total number of taxa	15.8	2.0	16.8	3.0	18.3	1.4	20.8	1.3	15.8	1.4	16.0	0.4
	OE50 taxa	0.83	0.05	0.87	0.06	0.77	0.06	1.04	0.06	0.76	0.08	0.70	0.04
	SIGNAL2 Score	4.3	0.2	4.5	0.2	4.7	0.0	4.7	0.2	4.6	0.1	4.7	0.1
	BAND	A		A		B		A		B		B	
Far Control Sites 14, 15 and 16	Total number of taxa	23.7	2.3	21.2	2.6	20.5	2.0	20.2	1.5	20.2	1.1	18.3	1.0
	OE50 taxa	0.98	0.04	1.01	0.05	0.76	0.09	0.81	0.06	0.92	0.07	0.75	0.06
	SIGNAL2 Score	4.8	0.2	4.7	0.1	5.0	0.2	4.9	0.3	4.4	0.1	4.9	0.2
	BAND	A		A		B		B		A		B	

Table 4: Mean number of taxa and SIGNAL2 Scores for macroinvertebrate assemblages that developed on artificial collectors deployed at each Potential Impact site and Control sites in Dendrobium Area 3. (SIGNAL 2 Score: potential impact sites: n=16; Wongawilli Creek control: n=48; Sandy Creek control: n=32; Donalds Castle / Kentish creeks control (DA3A): n=48, except pre-extraction 2=32; Donalds Castle / Kentish creeks control (DA3B): pre-extraction 1 n=24, pre-extraction 2 n=48; Number of taxa: potential impact sites: n=2; Wongwaillli Creek Control: 6; Sandy Creek control: n=4; Donalds Castle / Kentish creeks control (DA3A): n=6, except pre-extraction 2=4; Donalds Castle / Kentish creeks control (DA3B): pre-extraction 1 n=4, pre-extraction 2 n=6. SE=Standard Error.

Site	Indicator	Pre-extraction 1		Pre-extraction 2		During-extraction 1	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
DA3A Potential Impact Sites							
3	Total Number of Taxa	16.5	1.5	8.5	1.5	13.5	2.5
	SIGNAL2 Score	4.9	0.1	5.2	0.1	4.8	0.2
4	Total Number of Taxa	8.5	2.5	13.0	1.0	13.0	2.0
	SIGNAL2 Score	4.6	0.2	4.8	0.1	4.3	0.3
9	Total Number of Taxa	15.5	2.5	13.5	1.5	14.0	2.0
	SIGNAL2 Score	4.5	0.1	4.7	0.1	4.6	0.1
12	Total Number of Taxa	14.5	1.5	7.0	2.0	10.0	0.0
	SIGNAL2 Score	4.7	0.1	4.9	0.1	4.7	0.1
13	Total Number of Taxa	11.0	2.0	8.5	0.5	11.5	1.5
	SIGNAL2 Score	4.6	0.0	5.0	0.1	4.7	0.1

Site	Indicator	Pre-extraction 1		Pre-extraction 2	
				Mean	**SE**
DA3B Potential Impact Sites					
X1	Total Number of Taxa			10.0	1.0	11.0	0.0
	SIGNAL2 Score			4.3	0.2	4.4	0.1
X2	Total Number of Taxa			15.0	1.0	19.0	0.0
	SIGNAL2 Score			5.0	0.1	5.2	0.1
X3	Total Number of Taxa			9.0	1.0	13.0	2.0
	SIGNAL2 Score			4.8	0.1	4.6	0.1
X4	Total Number of Taxa			18.0	1.0	21.0	1.0
	SIGNAL2 Score			4.3	0.1	4.5	0.1
X5	Total Number of Taxa			16.5	0.5	14.5	0.5
	SIGNAL2 Score			4.8	0.1	4.6	0.1
X6	Total Number of Taxa			13.5	1.5	14.0	1.0
	SIGNAL2 Score			5.0	0.1	4.6	0.1

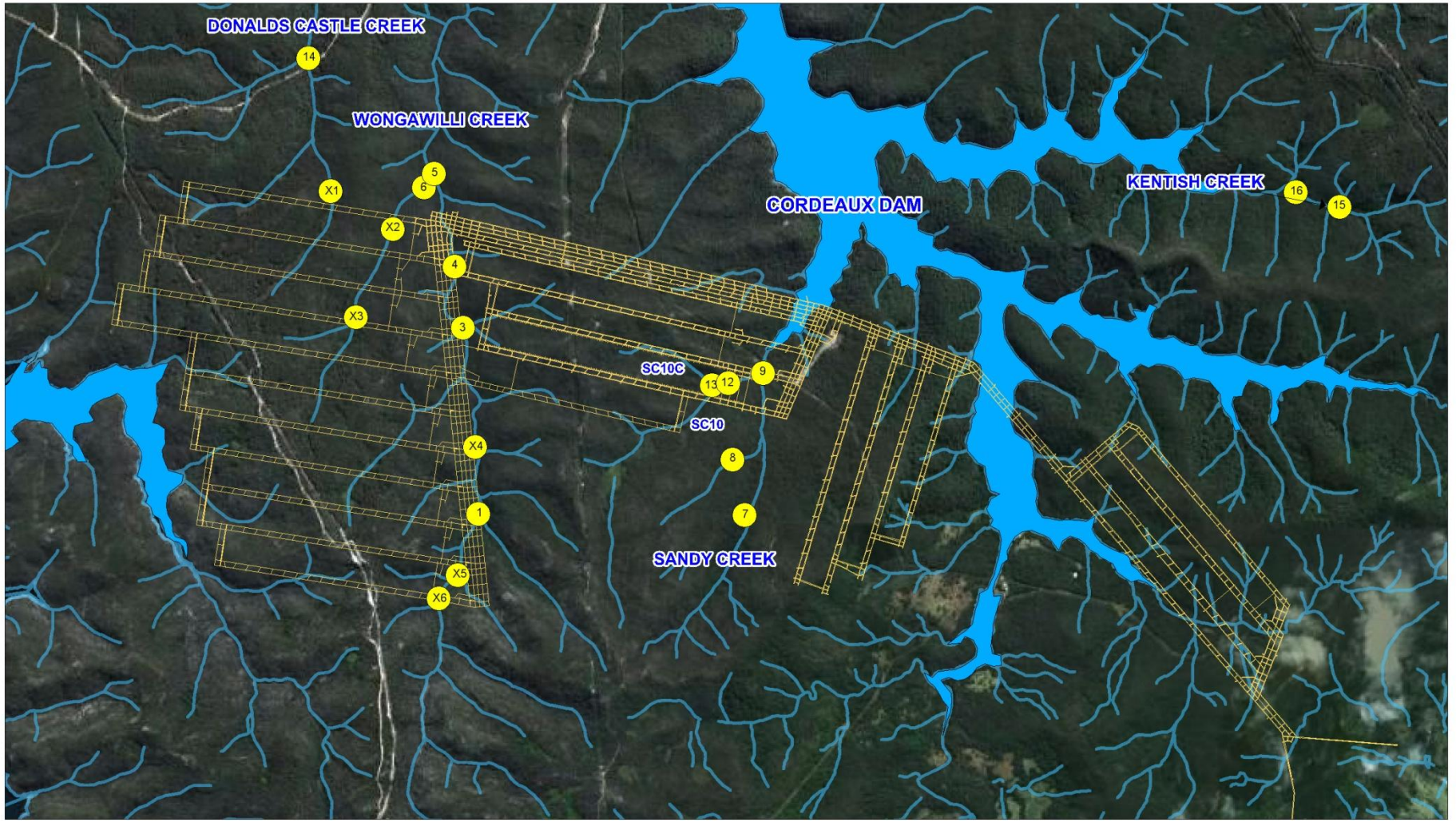
Site	Indicator	Pre-extraction 1 (DA3A)		Pre-extraction 2 (DA3A) Pre-extraction 1 (DA3B)		During-extraction 1 (DA3A) Pre-extraction 2 (DA3B)	
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**
Control Sites							
Near Control Wongawilli Catchment Sites 1, 5 and 6	Total Number of Taxa	16.3	1.2	15.0	0.9	16.0	1.5
	SIGNAL2 Score	4.8	0.1	4.8	0.1	4.7	0.1
Near Control Sandy Catchment Sites 7 and 8	Total Number of Taxa	13.3	1.8	12.5	0.3	14.8	1.3
	SIGNAL2 Score	4.8	0.1	4.8	0.1	4.6	0.1
Far Control 14, 15 and 16	Total Number of Taxa	14.7	2.2	16.8	3.4	18.7	1.1
	SIGNAL2 Score	4.8	0.1	4.5	0.1	4.8	0.1

Table 5: Species of fish observed by Cardno Ecology Lab at Potential Impact and Control sites in Dendrobium Area 3.

Sampling Event	Wongawilli Potential Impact Sites (DA3A)	Sandy Potential Impact Sites (DA3A)	Potential Impact Sites (DA3B)	Near Control Sites (Wongawilli Catchment)	Near Control Sites (Sandy Cachment)	Far Control Sites
Galaxid (*Galaxias* sp.)						
30/09/08 - 03/10/08	x	x	n/a	x		x
17/11/08 -20/11/08			n/a	x	x	x
17/03/09 - 20/03/09	x		n/a	x		
27/04/09 - 30/04/09	x		n/a	x		
16/03/10 - 25/03/10	x		x	x		
04/05/10 - 07/05/10	x		x	x		x
20/09/10 - 27/09/10	x		x	x		x
08/11/10 - 11/11/10	x		x	x	x	x
11/04/11 - 14/04/11			x	x		
07/06/11 - 10/06/11	x					x
06/09/11 - 09/09/11			x		x	
10/10/11 - 31/11/11	x		x	x		
Australian Smelt (*Retropinna semoni*)						
30/09/08 - 03/10/08						x
17/11/08 -20/11/08						
17/03/09 - 20/03/09						x
27/04/09 - 30/04/09				x		x
16/03/10 - 25/03/10						
04/05/10 - 07/05/10				x		
20/09/10 - 27/09/10			x			x
08/11/10 - 11/11/10						x
11/04/11 - 14/04/11						
07/06/11 - 10/06/11						
06/09/11 - 09/09/11						
10/10/11 - 31/11/11						
Short Finned Eel (*Anguilla australis)*						
30/09/08 - 03/10/08						
17/11/08 -20/11/08						
17/03/09 - 20/03/09						
27/04/09 - 30/04/09						
16/03/10 - 25/03/10						
04/05/10 - 07/05/10						
20/09/10 - 27/09/10						
08/11/10 - 11/11/10			x			
11/04/11 - 14/04/11						
07/06/11 - 10/06/11						
06/09/11 - 09/09/11						
10/10/11 - 31/11/11						
Freshwater Crayfish (*Euastacus* sp.)						
30/09/08 - 03/10/08	x	x				
17/11/08 -20/11/08		x		x	x	x
17/03/09 - 20/03/09		x			x	
27/04/09 - 30/04/09		x		x		x
16/03/10 - 25/03/10		x	x		x	x
04/05/10 - 07/05/10				x		x
20/09/10 - 27/09/10	x	x				
08/11/10 - 11/11/10	x	x		x		x
11/04/11 - 14/04/11	x					x
07/06/11 - 10/06/11			x	x		
06/09/11 - 09/09/11	x	x			x	x
10/10/11 - 31/11/11	x	x	x	x		

9 Figures

Figure 31. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact, Near Control and Far Control sites prior to, the commencement of extraction in DA3B.



0 2.5

Kilometres

Figure 1: Map of sites monitored by Cardno Ecology Lab as part of the aquatic ecology monitoring program for Dendrobium Areas 3A and B.

Cardno Ecology Lab

Map Produced by Cardno Ecology Lab
Date: 11 April 2012
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: Google Earth Images

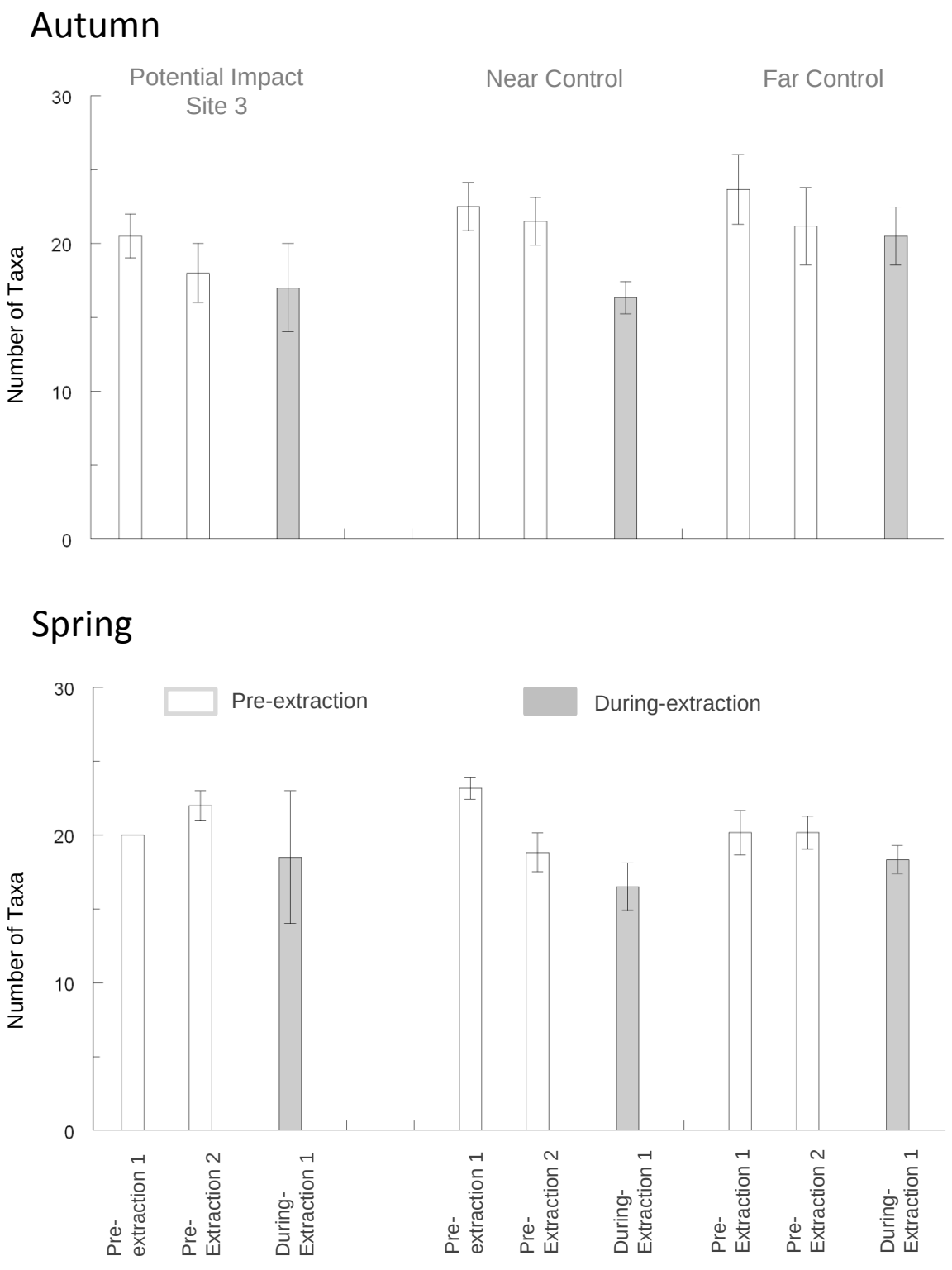


Figure 2. Mean (SE) number of taxa found in AUSRIVAS samples collected at Potential Impact Site 3 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

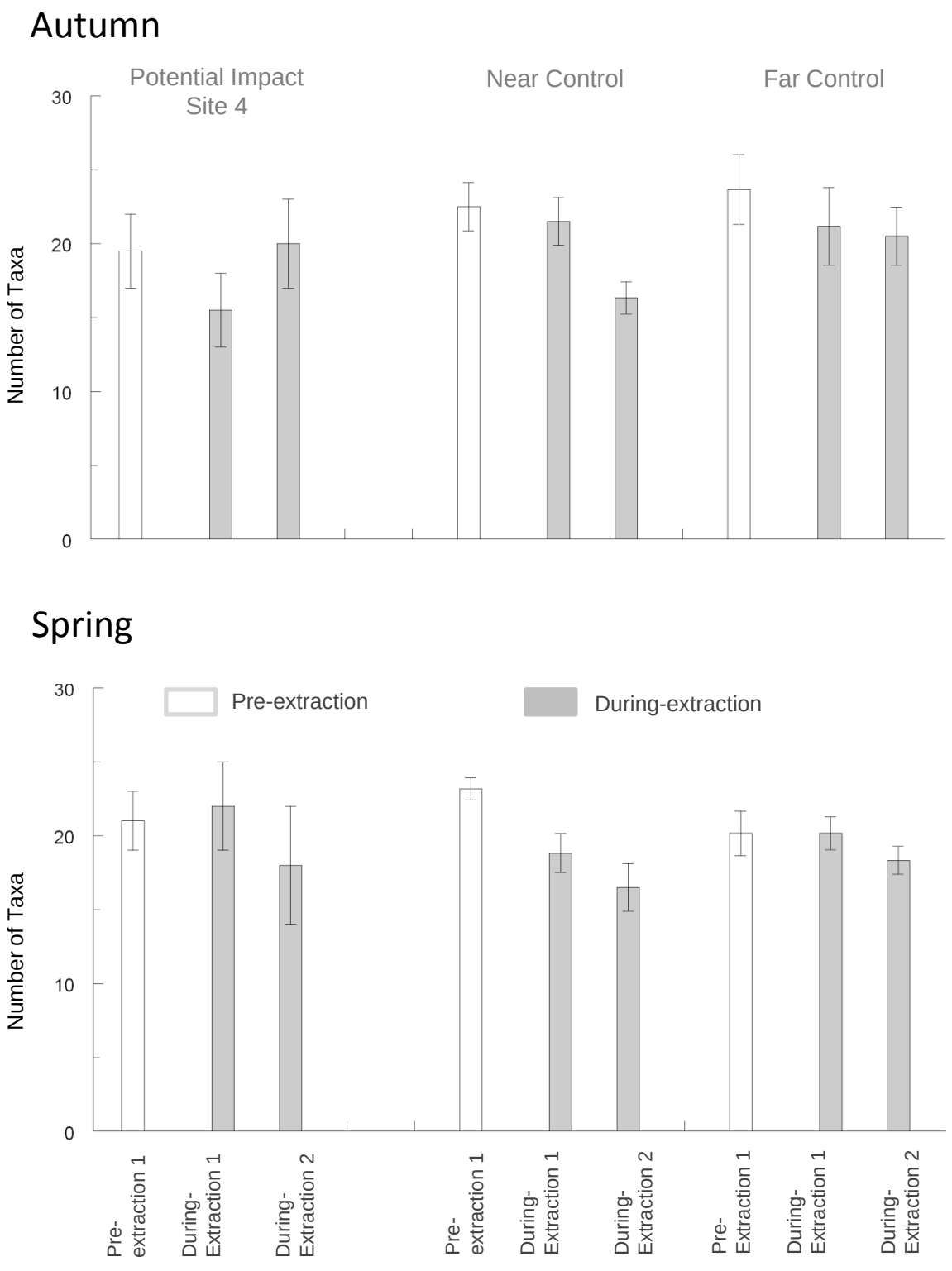


Figure 3. Mean (SE) number of taxa found in AUSRIVAS samples collected at Potential Impact Site 4 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

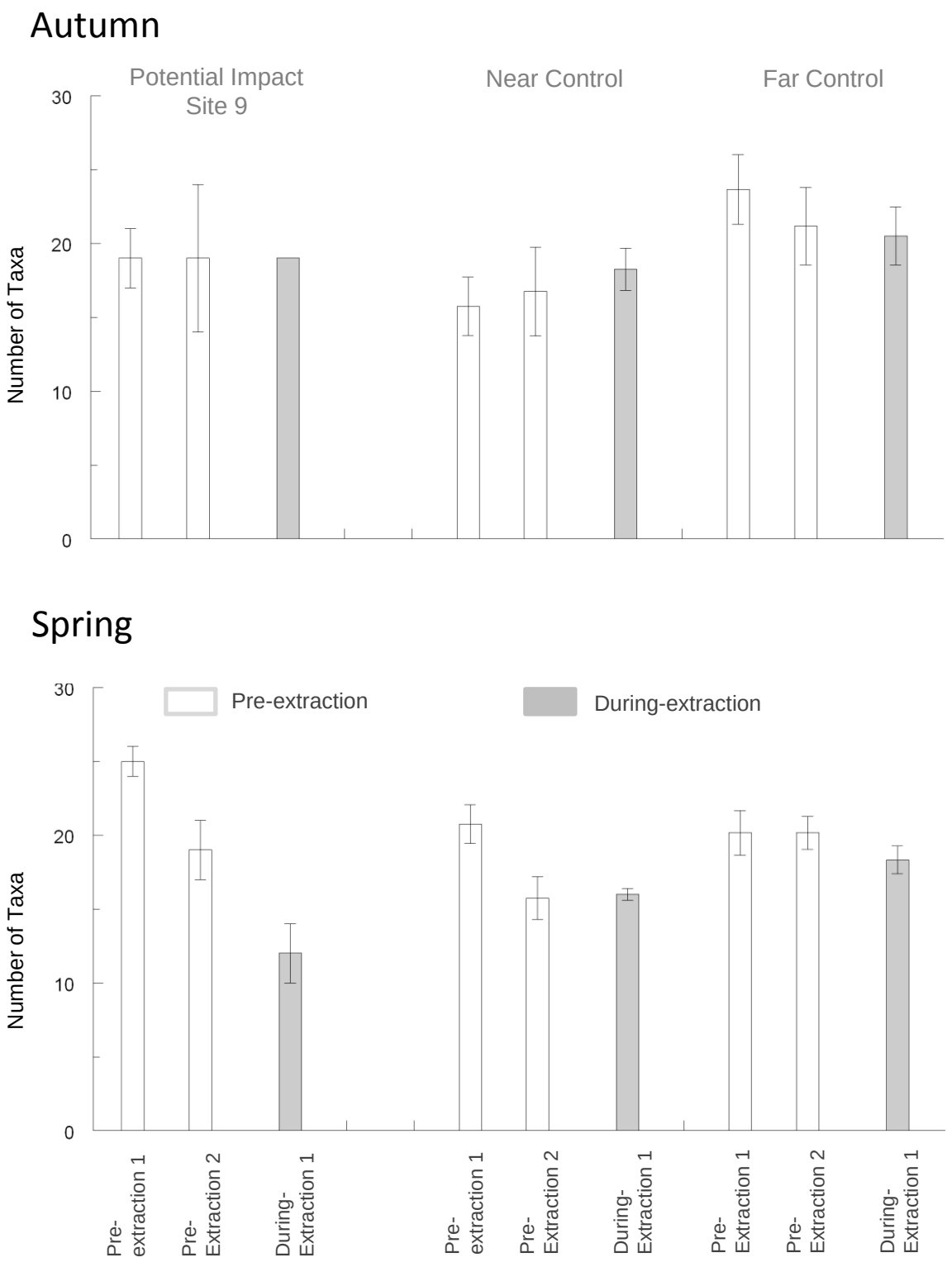


Figure 4. Mean (SE) number of taxa found in AUSRIVAS samples collected at Potential Impact Site 9 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

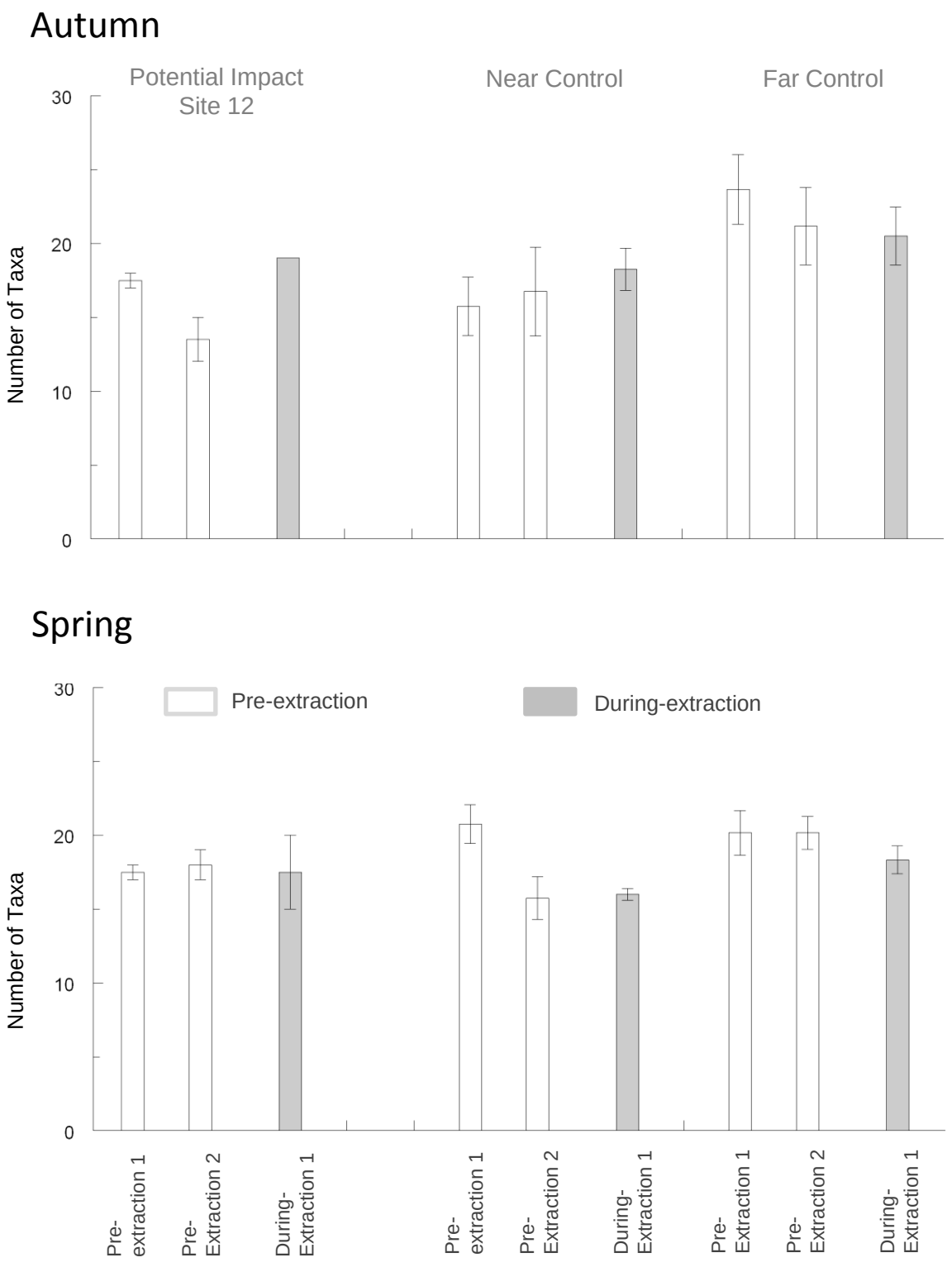


Figure 5. Mean (SE) number of taxa found in AUSRIVAS samples collected at Potential Impact Site 12 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

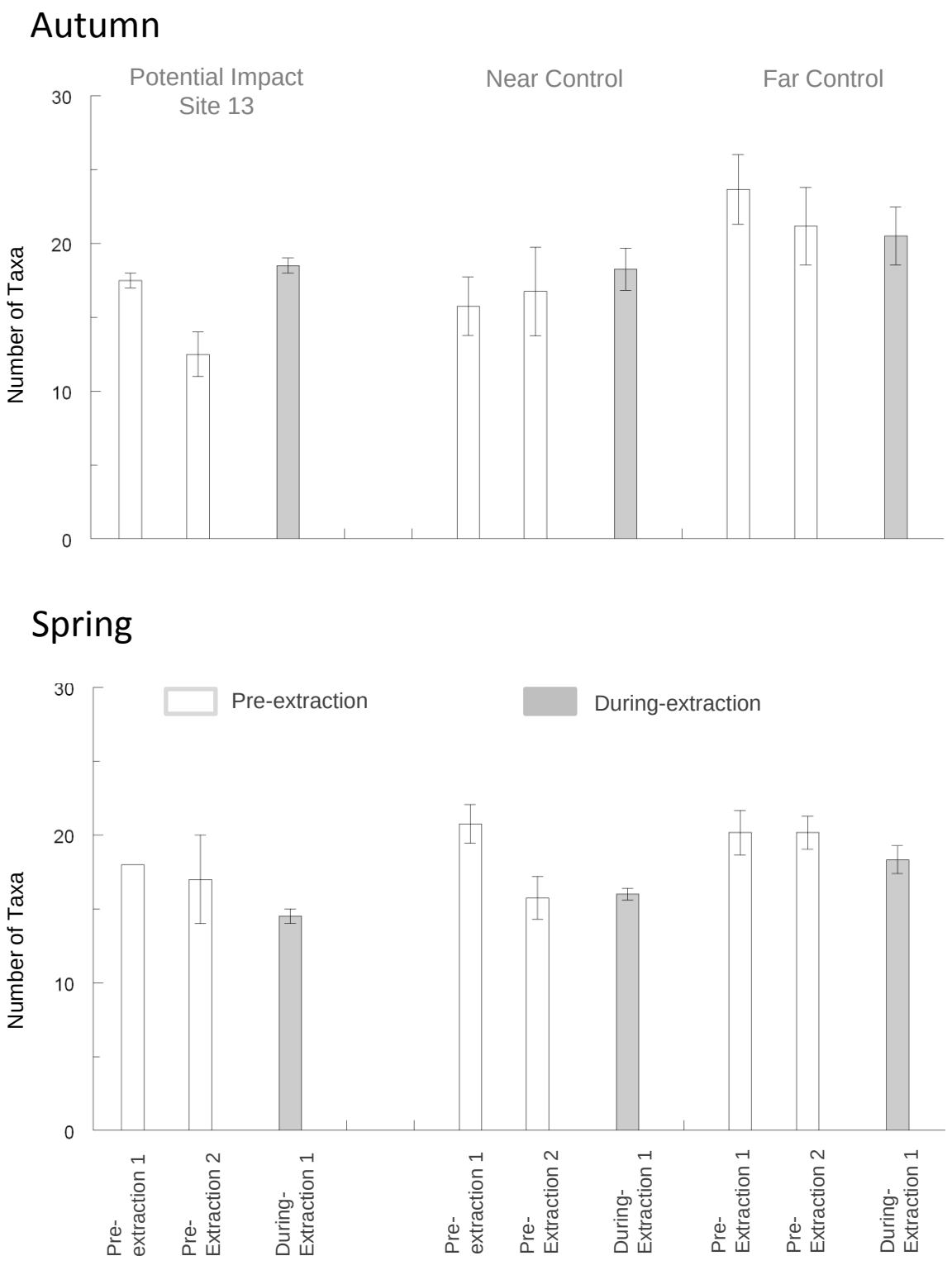


Figure 6. Mean (SE) number of taxa found in AUSRIVAS samples collected at Potential Impact Site 13 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

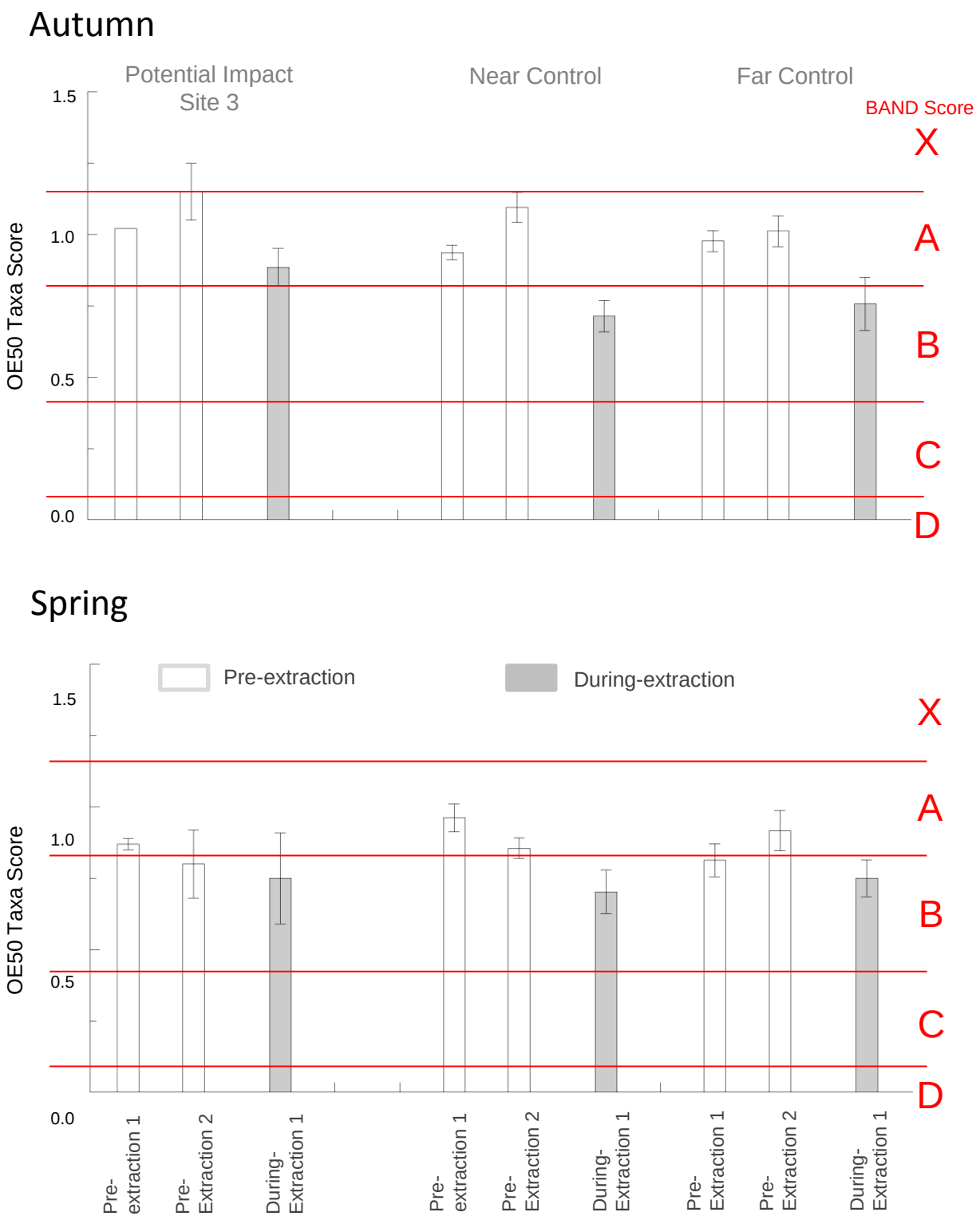


Figure 7. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at Potential Impact Site 3 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

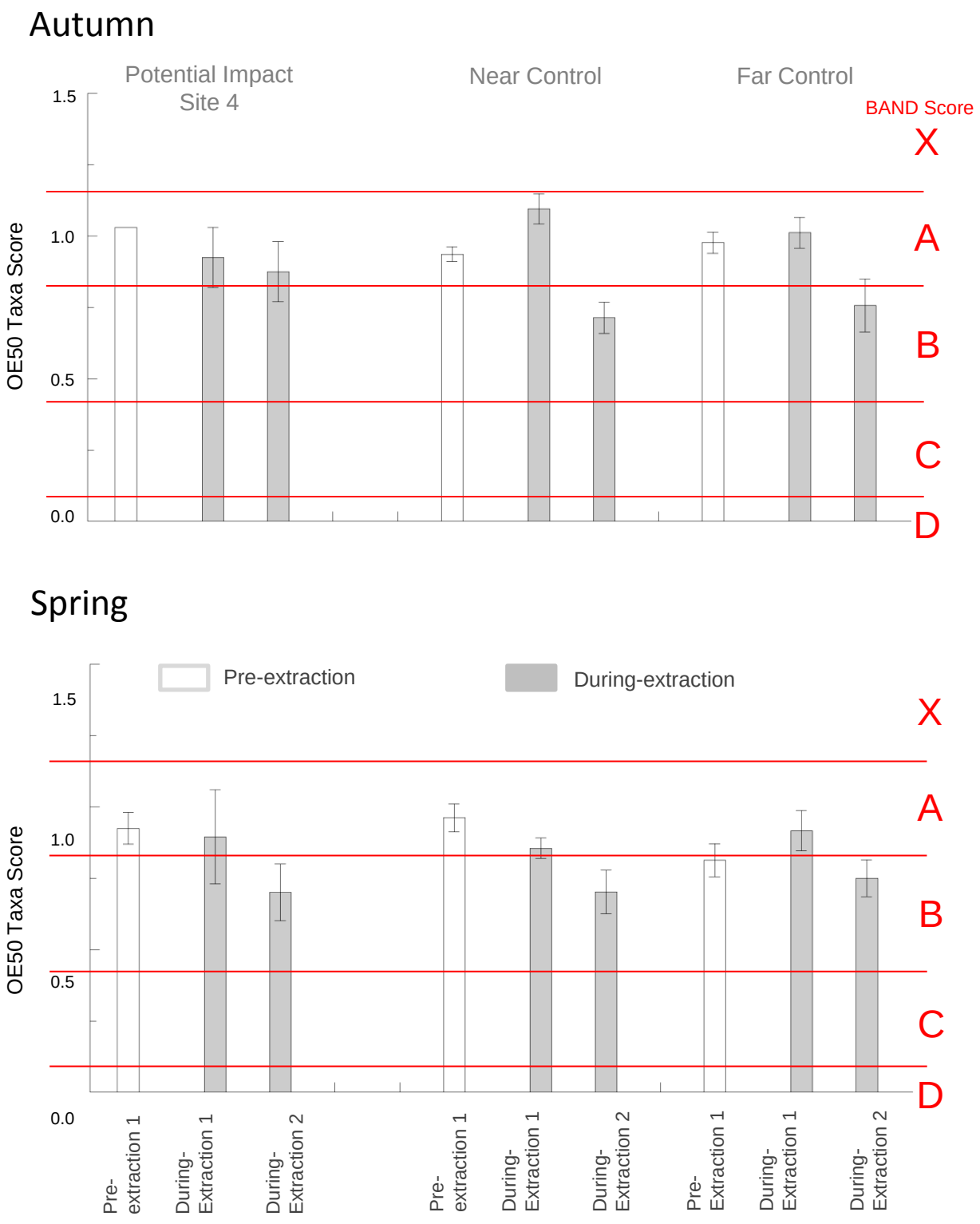


Figure 8. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at Potential Impact Site 4 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

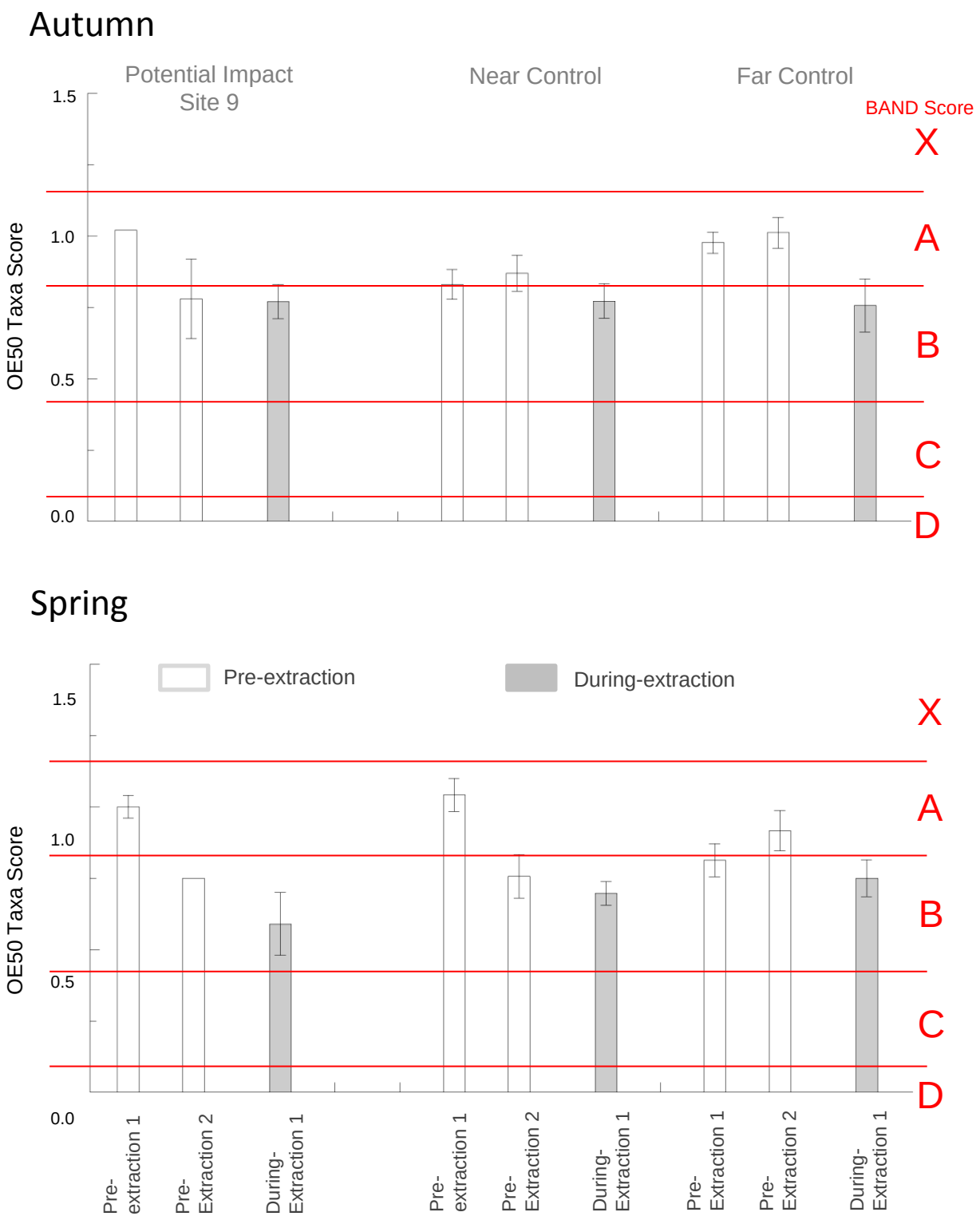


Figure 9. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at Potential Impact Site 9 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

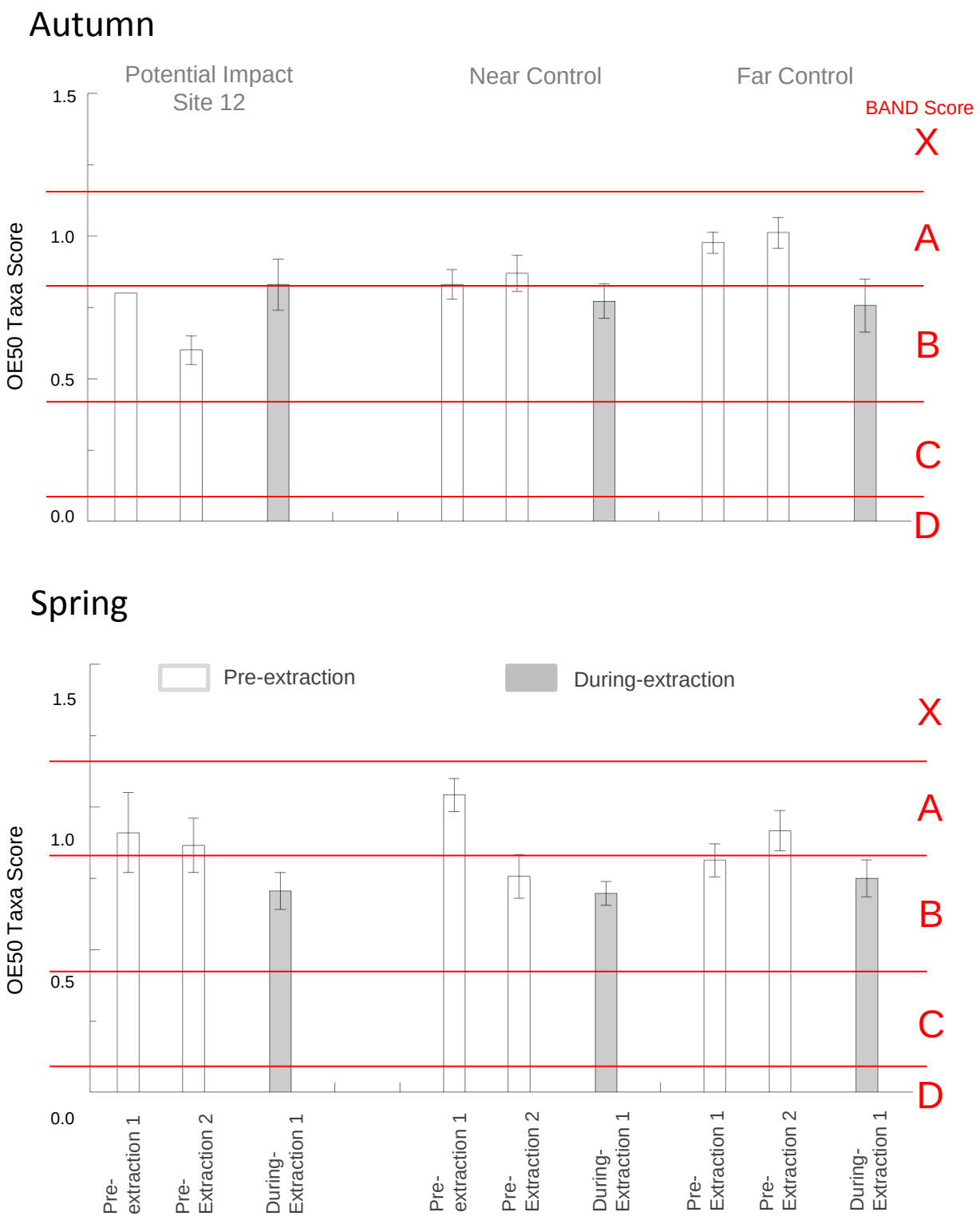


Figure 10. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at Potential Impact Site 12 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

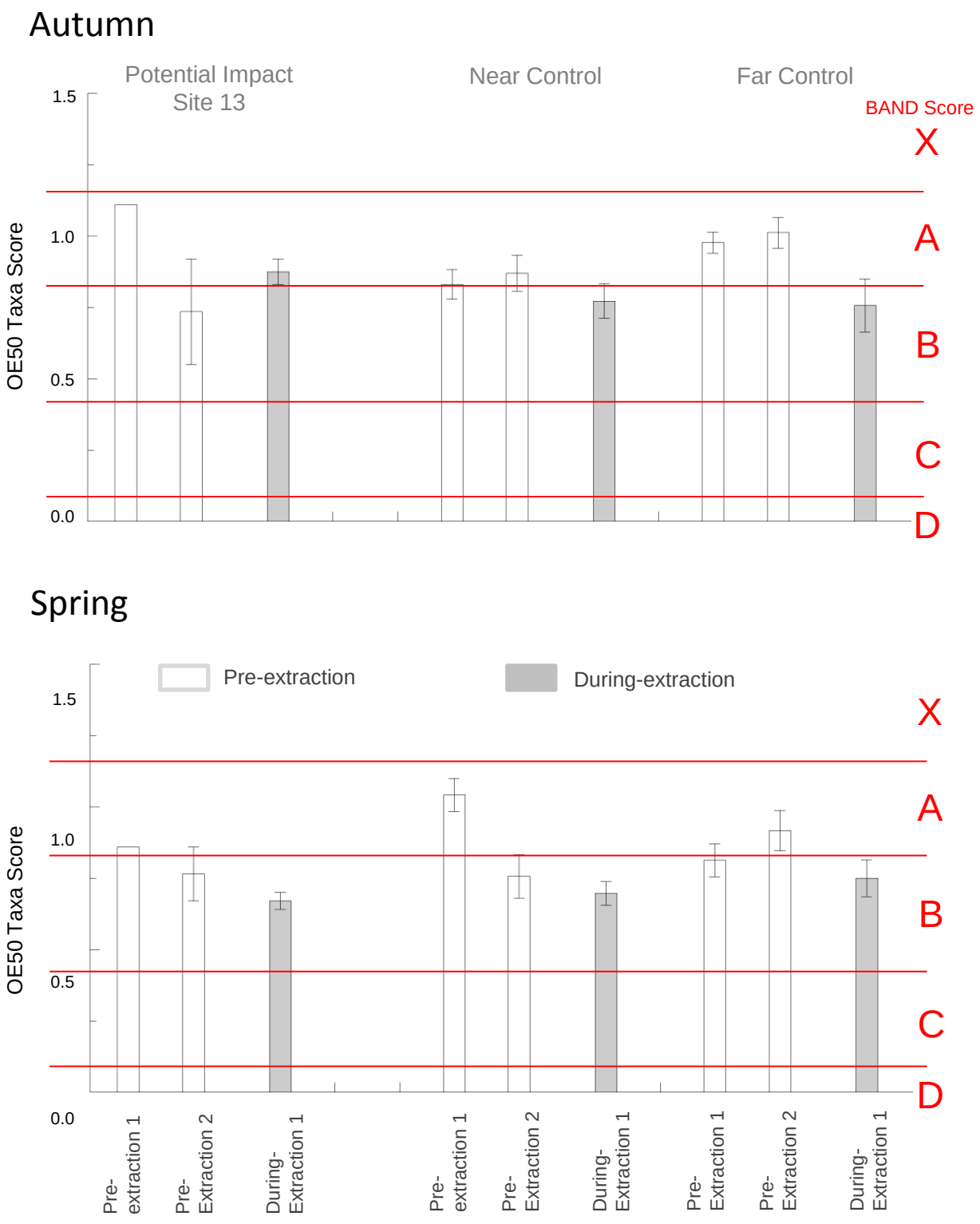


Figure 11. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at Potential Impact Site 13 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

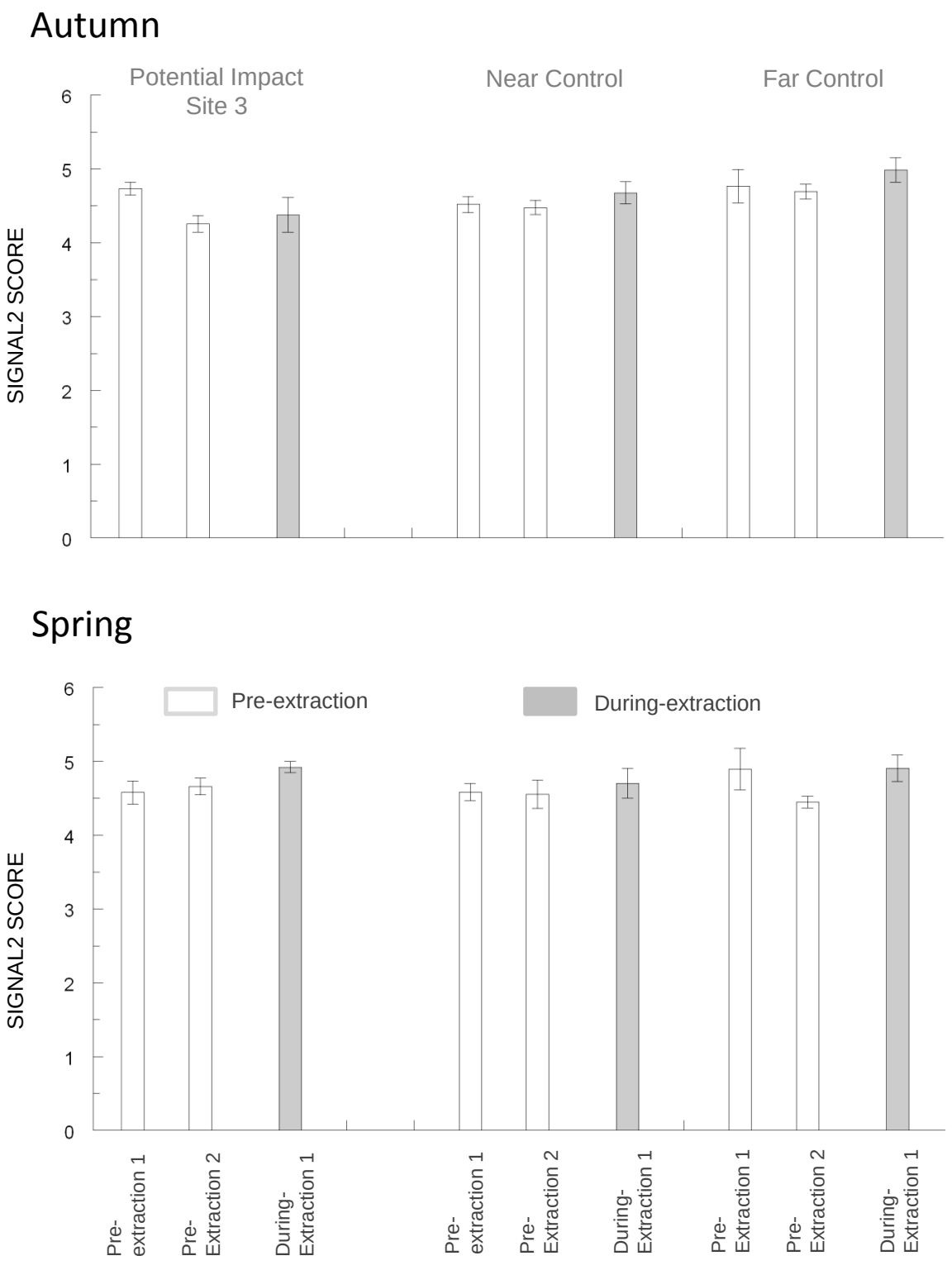


Figure 12. Mean (SE) SIGNAL2 Scores for AUSRIVAS samples collected at Potential Impact Site 3 on Wongawilli Creek, Near Controls (Wongawilli Creek Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-Extraction and During Extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

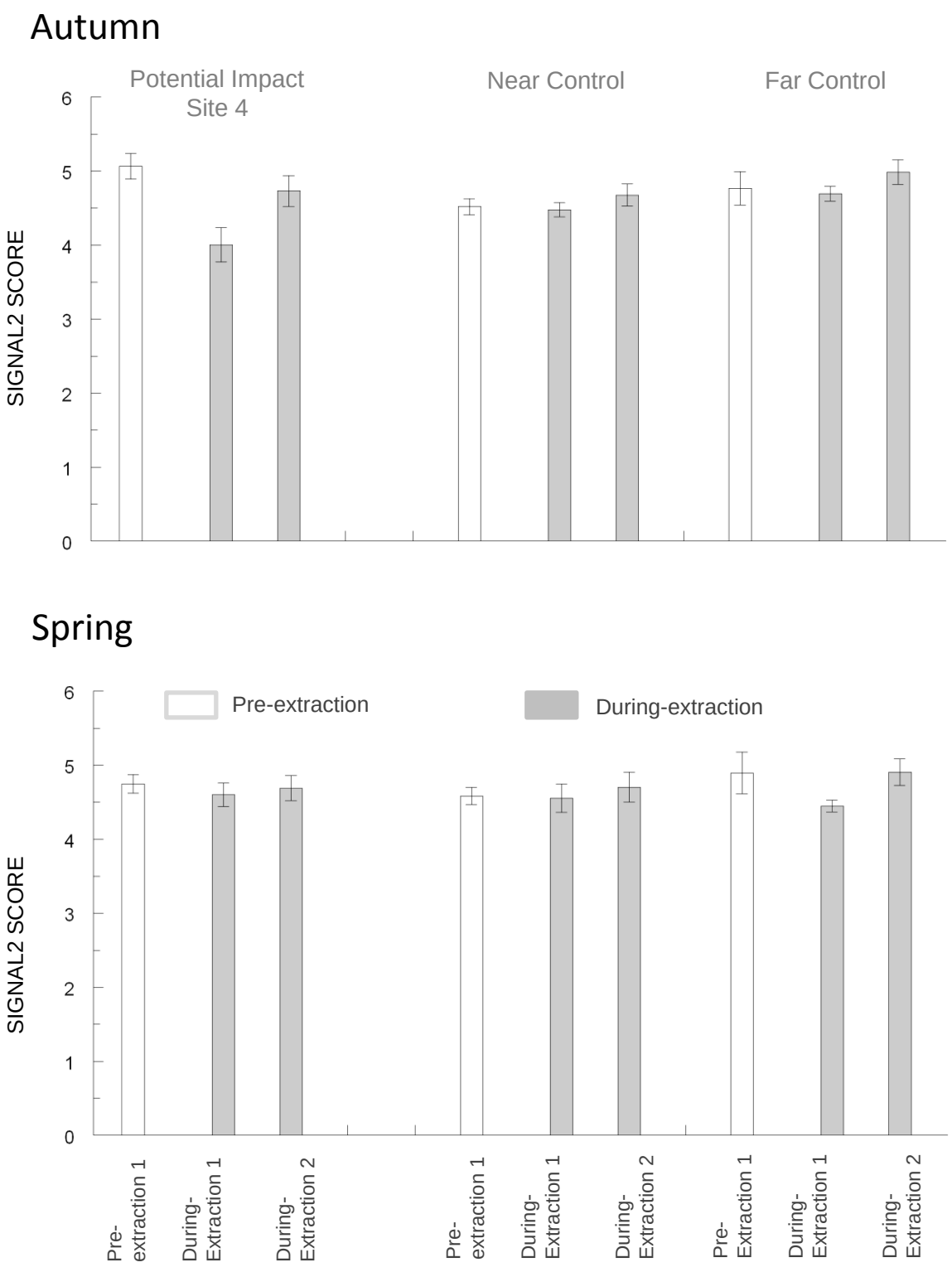


Figure 13. Mean (SE) SIGNAL2 Scores for AUSRIVAS samples collected at Potential Impact Site 4 on Wongawilli Creek, Near Controls (Wongawilli Creek Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-Extraction and During Extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

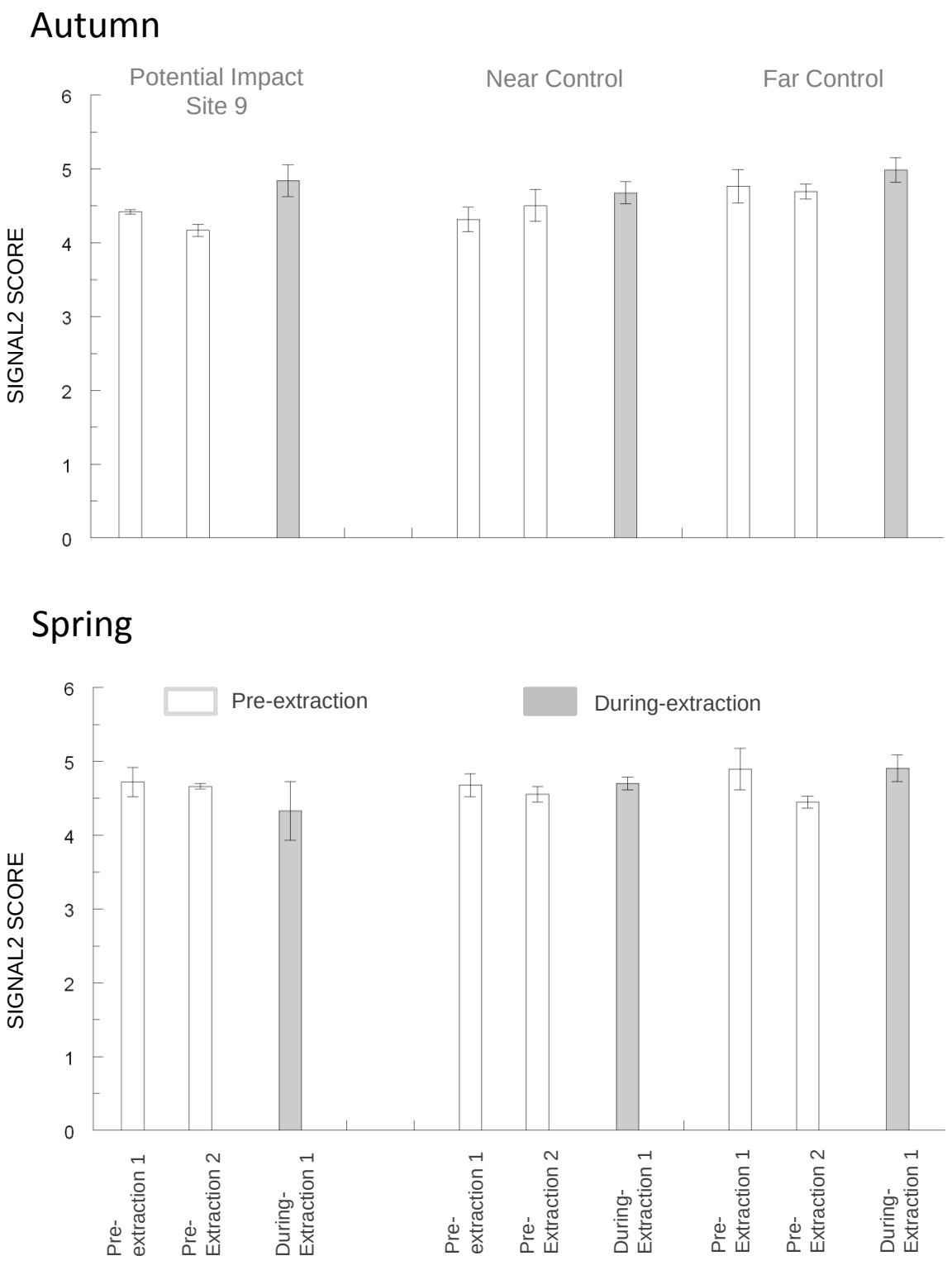


Figure 14. Mean (SE) SIGNAL2 Score for AUSRIVAS samples collected at Potential Impact Site 9 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

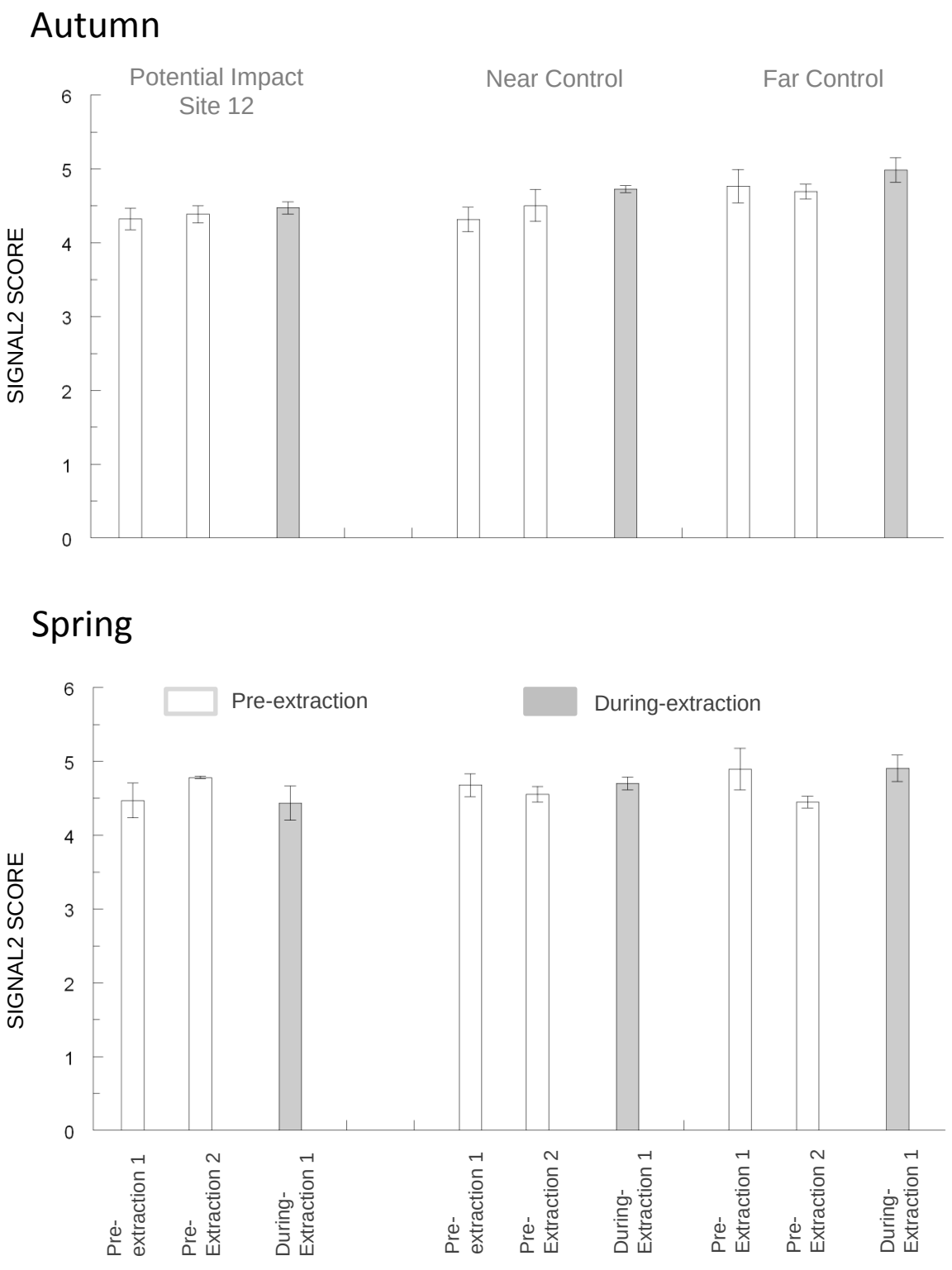


Figure 15. Mean (SE) SIGNAL2 Score for AUSRIVAS samples collected at Potential Impact Site 12 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

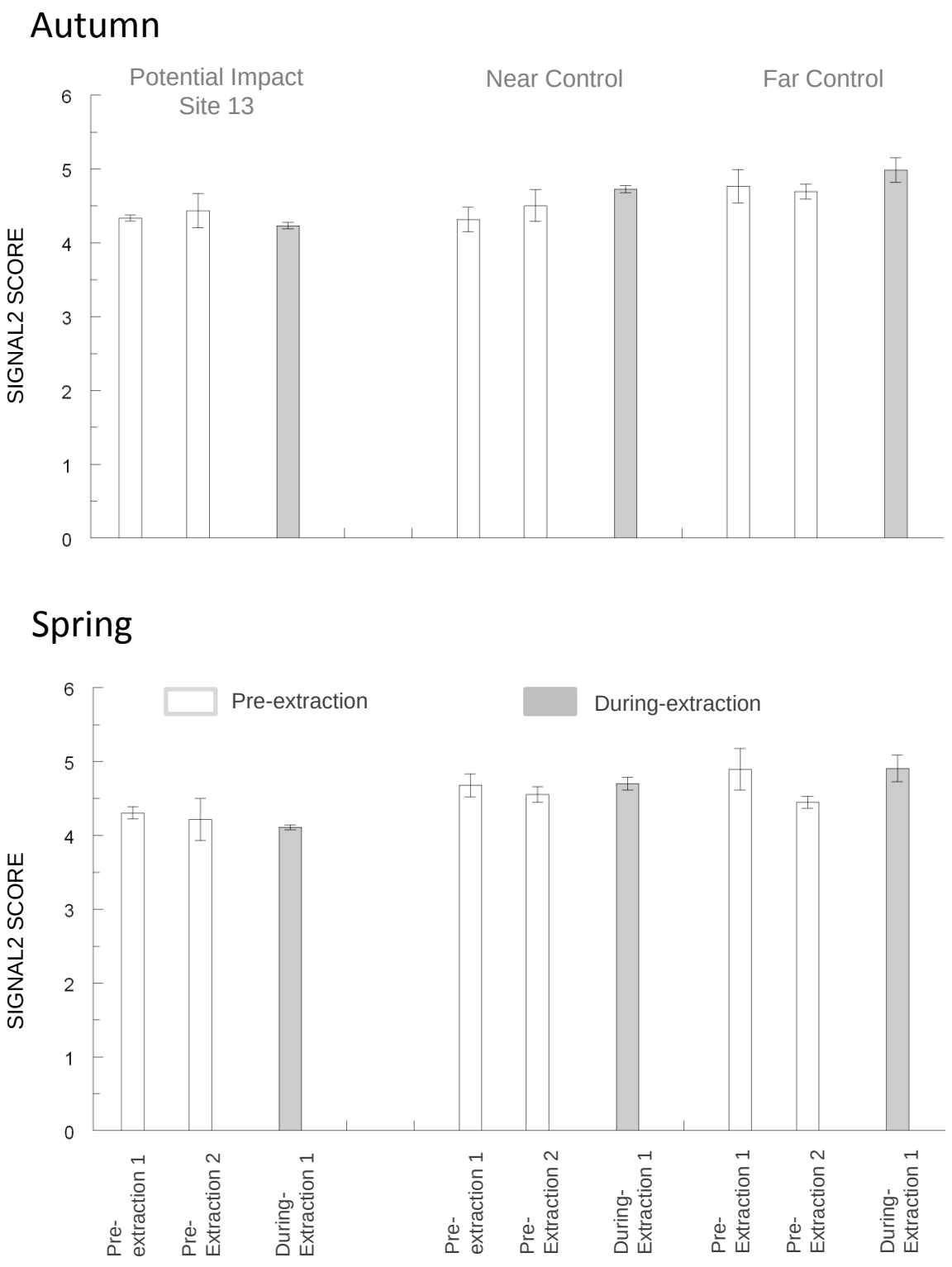


Figure 16. Mean (SE) SIGNAL2 Score for AUSRIVAS samples collected at Potential Impact Site 13 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre-extraction and During-extraction surveys. (Potential Impact: n=2, Near Control and Far Control: n=6).

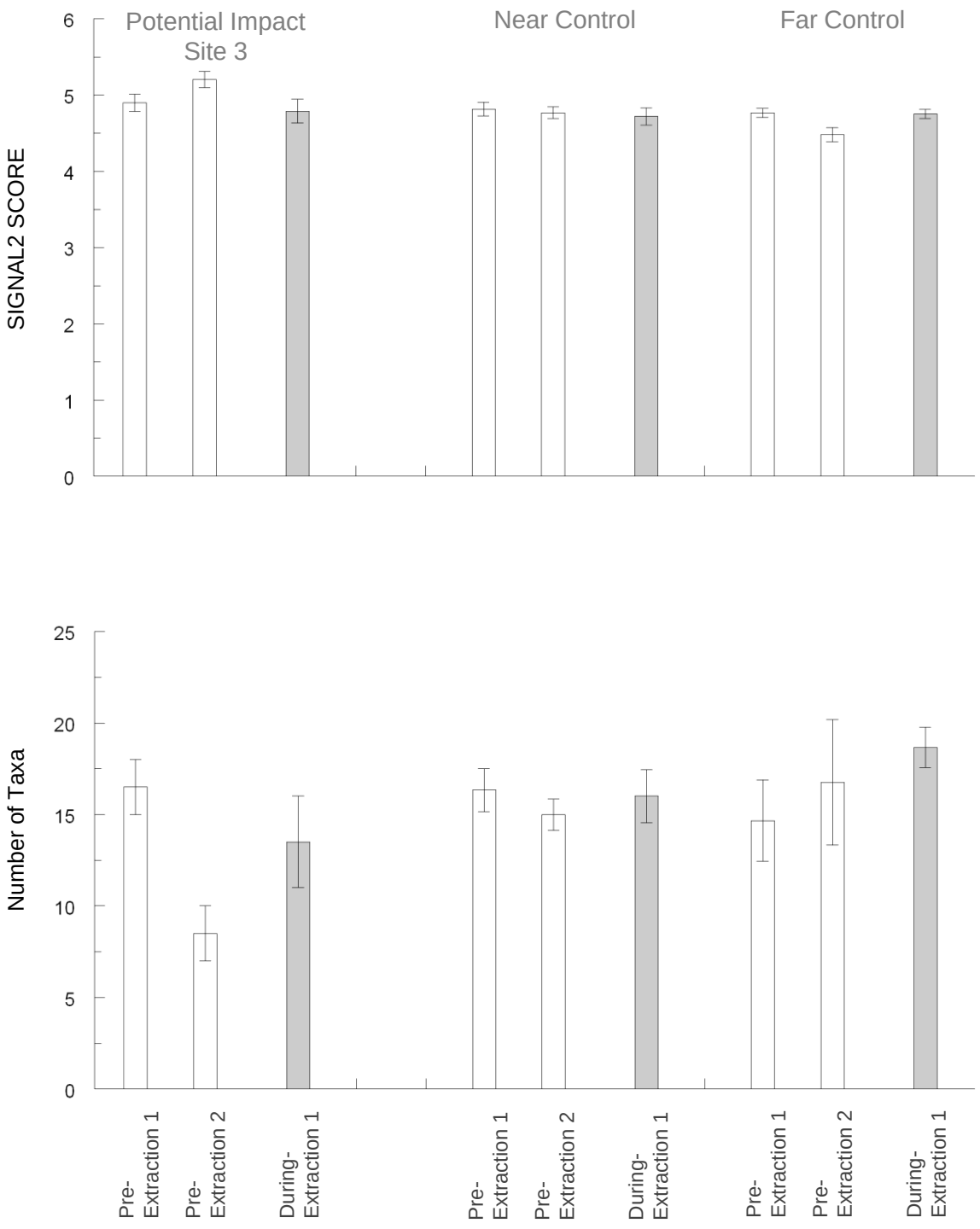


Figure 17. Mean (SE) SIGNAL2 Scores and numbers of taxa for artificial collector samples from Potential Impact Site 3 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre- Extraction and During Extraction surveys. (Potential Impact: SIGNAL2 Score n=16, number of taxa n=2; Near Control and Far Control: SIGNAL2 Score n=48, except Far Control autumn 2010 / spring 2010: n=32, number of taxa n=6, except autumn 2010 / spring 2010 n=4).

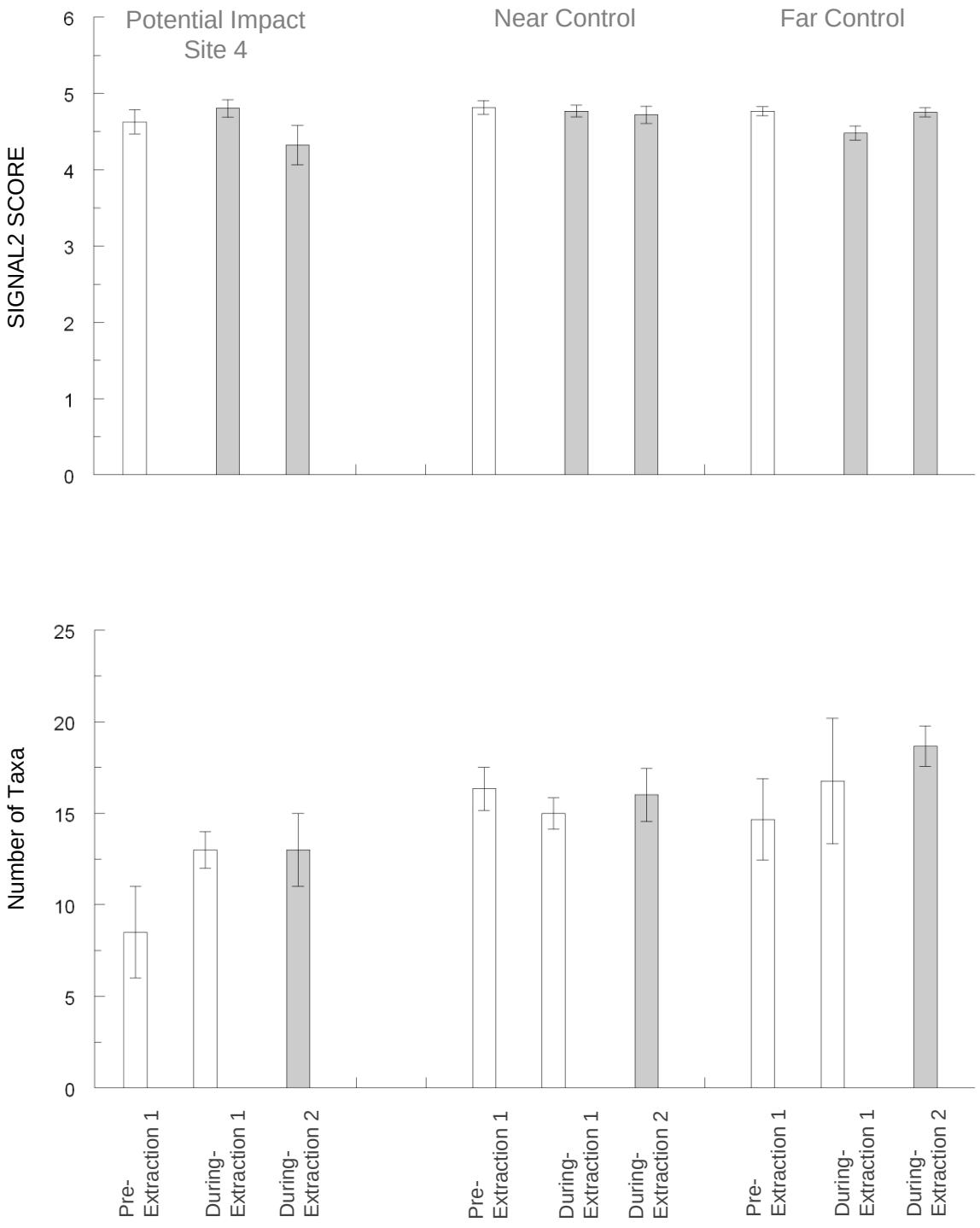


Figure 18. Mean (SE) SIGNAL2 Scores and numbers of taxa for artificial collector samples from Potential Impact Site 4 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre- Extraction and During Extraction surveys. (Potential Impact: SIGNAL2 Score n=16, number of taxa n=2; Near Control and Far Control: SIGNAL2 Score n=48, except Far Control autumn 2010 / spring 2010: n=32, number of taxa n=6, except Far Control autumn 2010 / spring 2010 n=4).

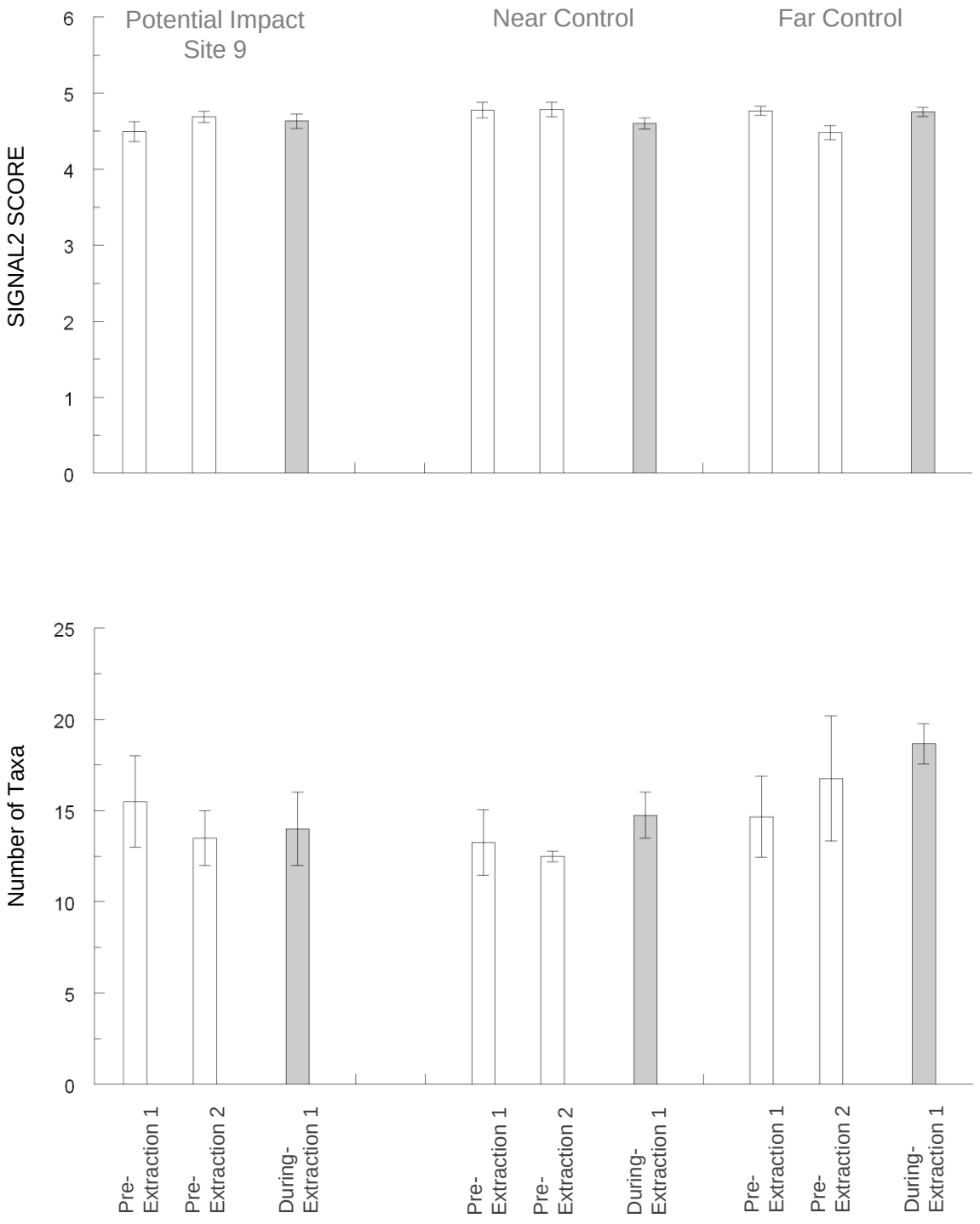


Figure 19. Mean (SE) SIGNAL2 Scores and numbers of taxa for artificial collector samples from Potential Impact Site 9 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre- Extraction and During Extraction surveys. (Potential Impact: SIGNAL2 Score n=16, number of taxa n=2; Near Control and Far Control: SIGNAL2 Score n=48, except autumn 2010 / spring 2010: n=32, no. of taxa n=6, except autumn 2010 / spring 2010: n=4).

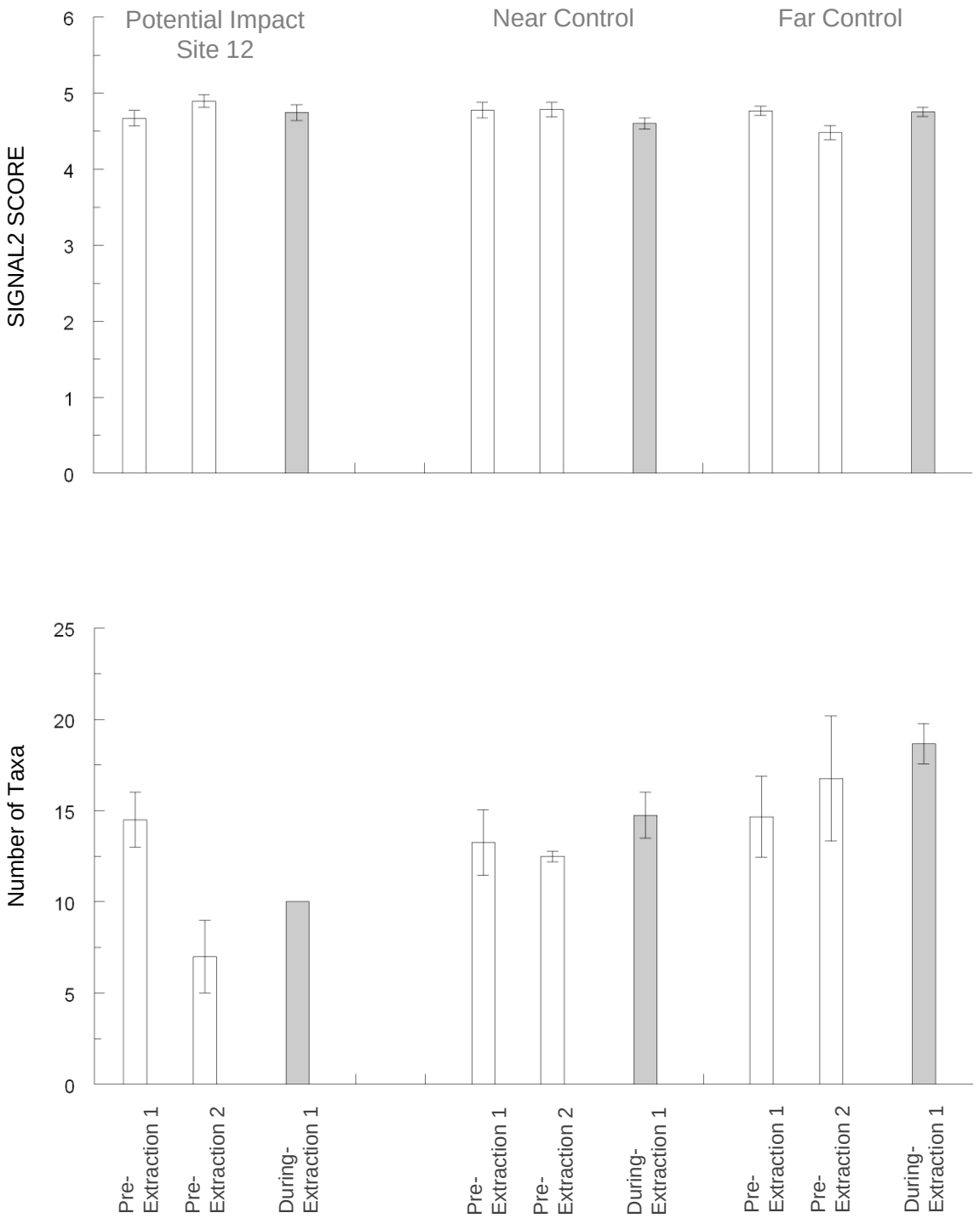


Figure 20. Mean (SE) SIGNAL2 Scores and numbers of taxa for artificial collector samples from Potential Impact Site 12 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre- Extraction and During Extraction surveys. (Potential Impact: SIGNAL2 Score n=16, number of taxa n=6; Near Control and Far Control: SIGNAL2 Score n=48, except autumn 2010 / spring 2010: n=32, no. of taxa n=6, except autumn 2010 / spring 2010: n=4).

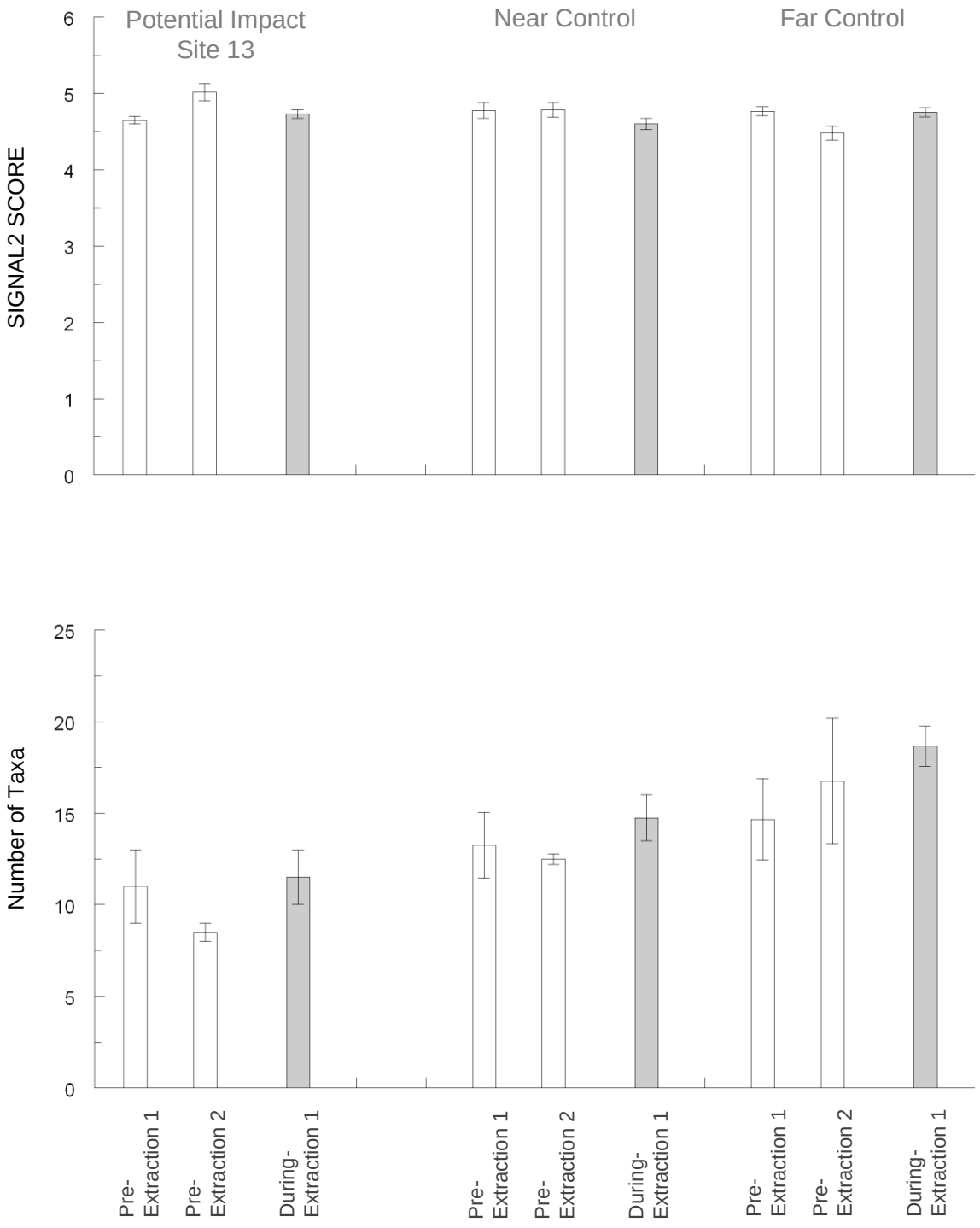


Figure 21. Mean (SE) SIGNAL2 Scores and numbers of taxa for artificial collector samples from Potential Impact Site 13 on Sandy Creek, Near Control (Sandy Creek Sites 7 and 8) and Far Control (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in the Pre- Extraction and During Extraction surveys. (Potential Impact: SIGNAL2 Score n=16, number of taxa n=6; Near Control and Far Control: SIGNAL2 Score n=48, except autumn 2010 / spring 2010: n=32, no. of taxa n=6, except autumn 2010 / spring 2010: n=4).

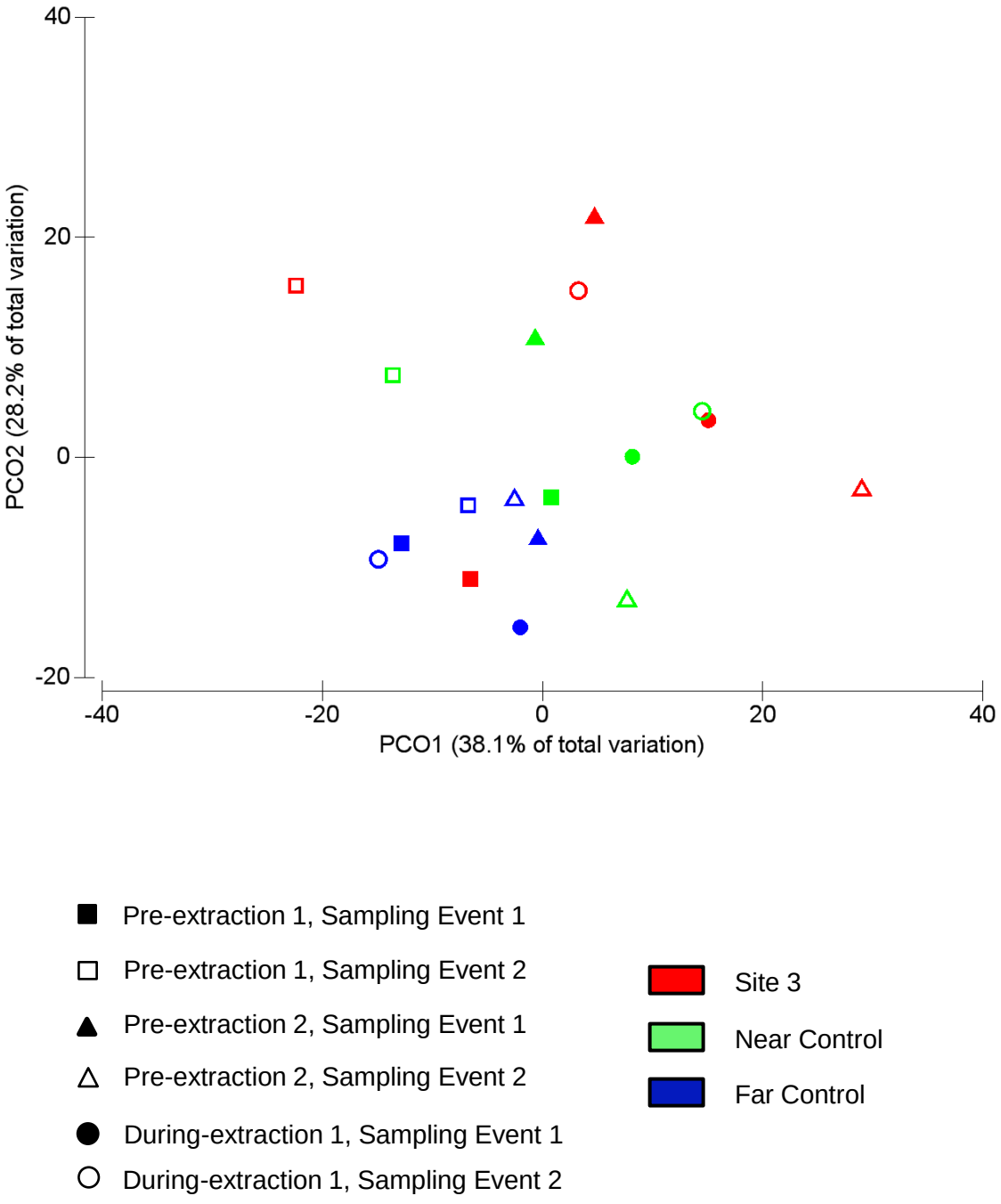


Figure 22. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact Site 3 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in pre-extraction and during-extraction Surveys and Sampling Events.

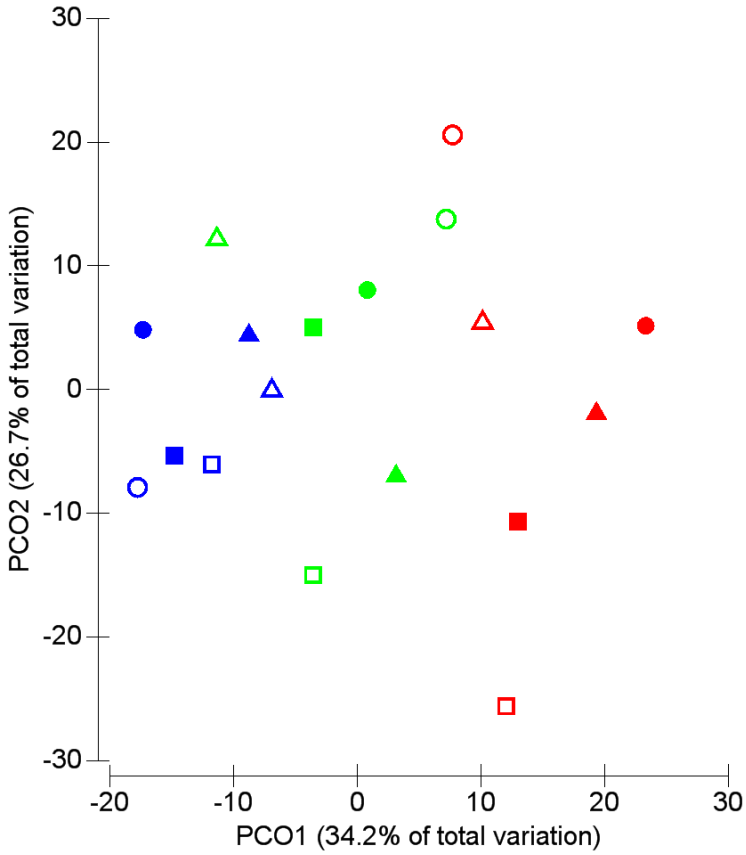


Figure 23. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact Site 4 on Wongawilli Creek, Near Control (Wongawilli Creek Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in pre-extraction and during-extraction Surveys and Sampling Events.

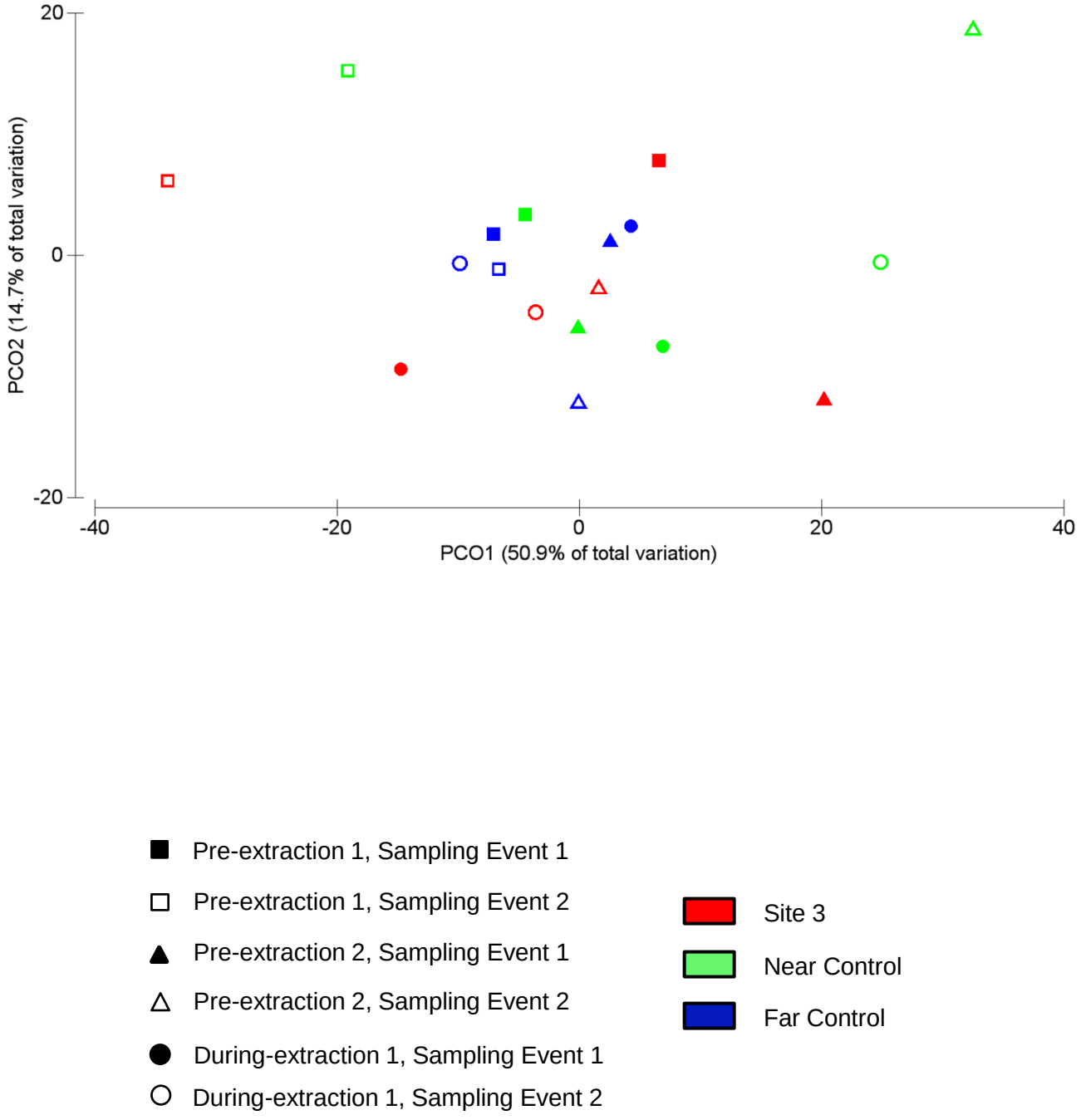


Figure 24. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact Site 9 on Sandy Creek, Near Control (Sandy Creek Sites 7and 8) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in pre-extraction and during-extraction Surveys and Sampling Events.

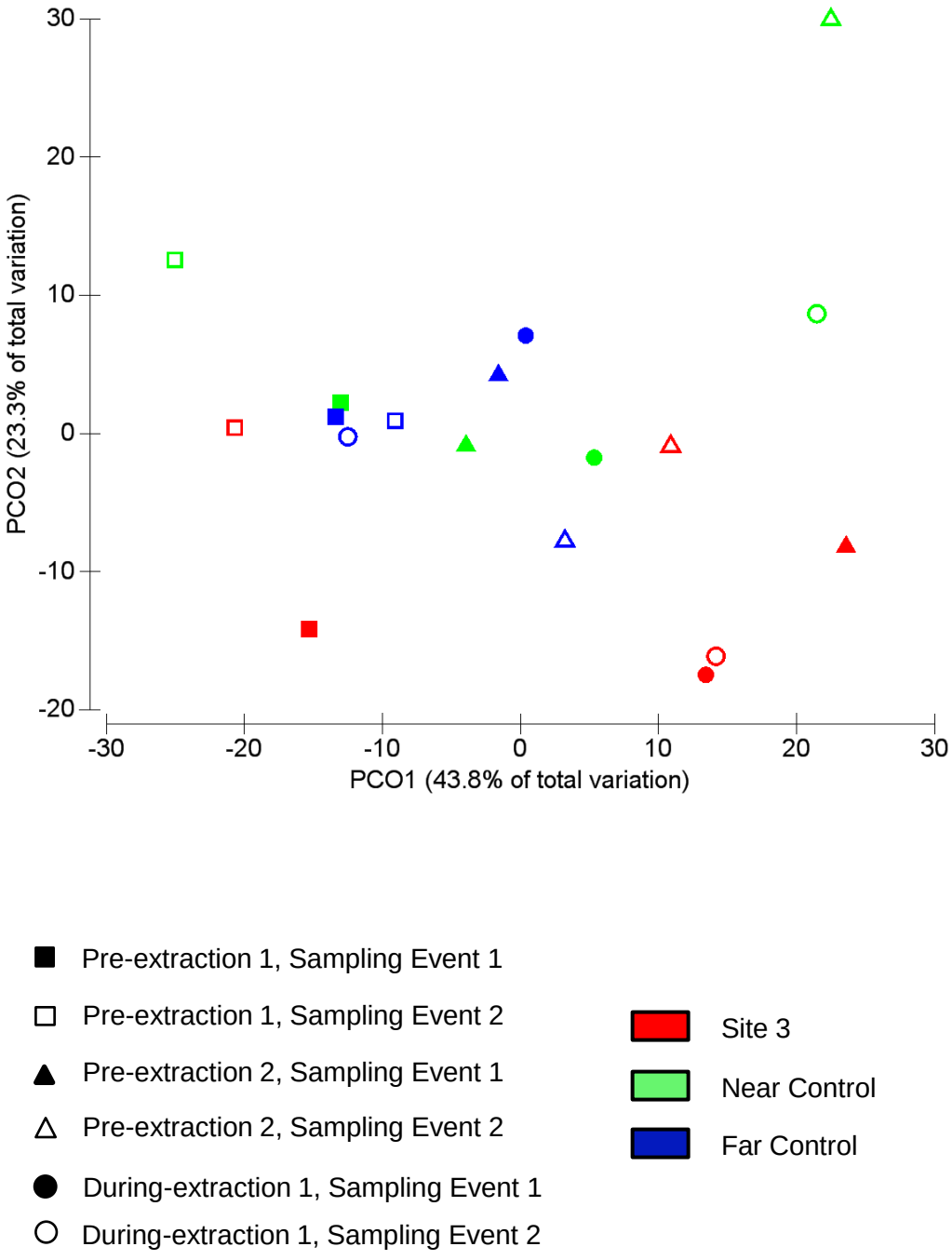


Figure 25. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact Site 12 on Sandy Creek, Near Control (Sandy Creek Sites 7and 8) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in pre-extraction and during-extraction Surveys and Sampling Events.

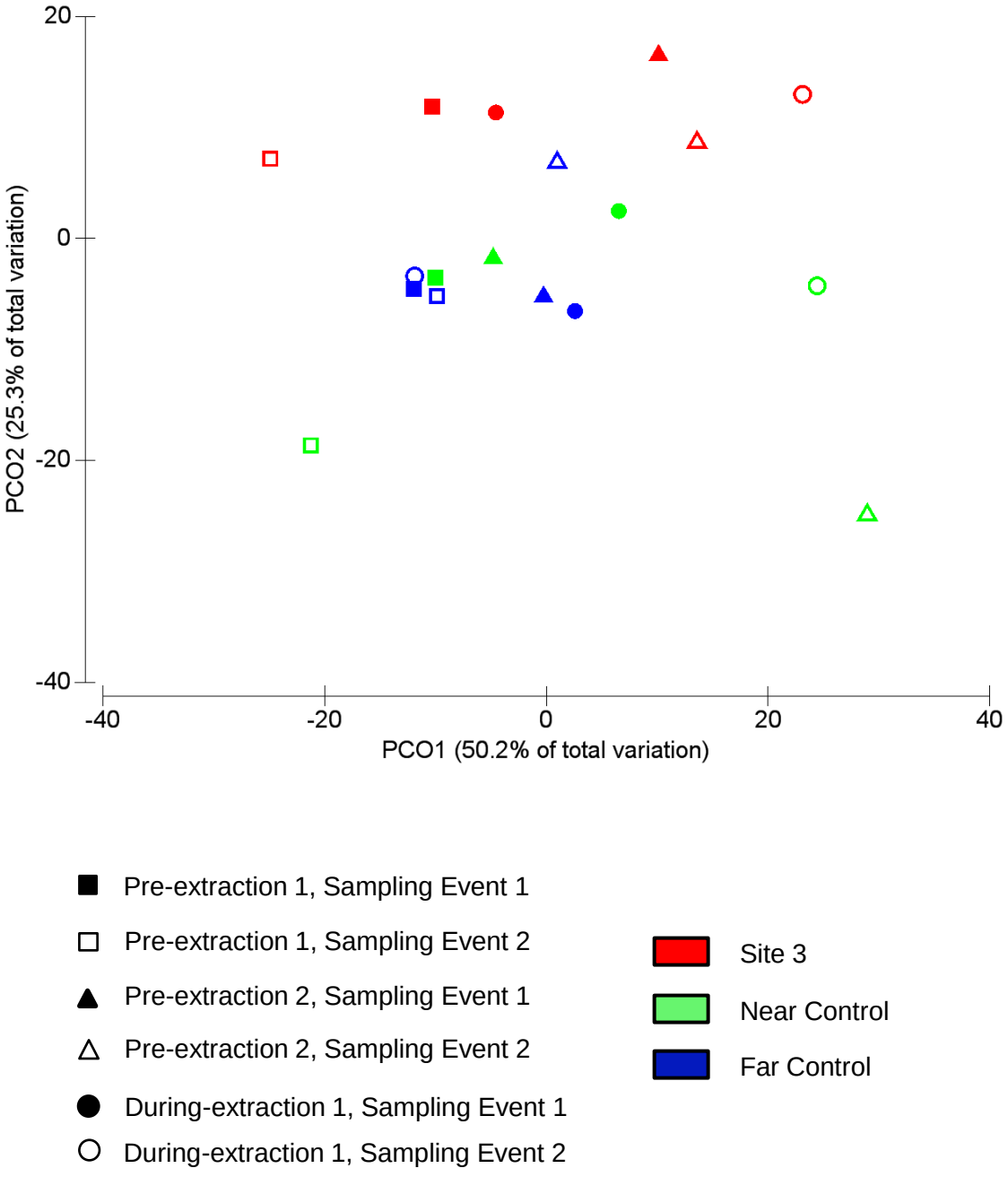


Figure 26. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact Site 13 on Sandy Creek, Near Control (Sandy Creek Sites 7and 8) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) in pre-extraction and during-extraction Surveys and Sampling Events.

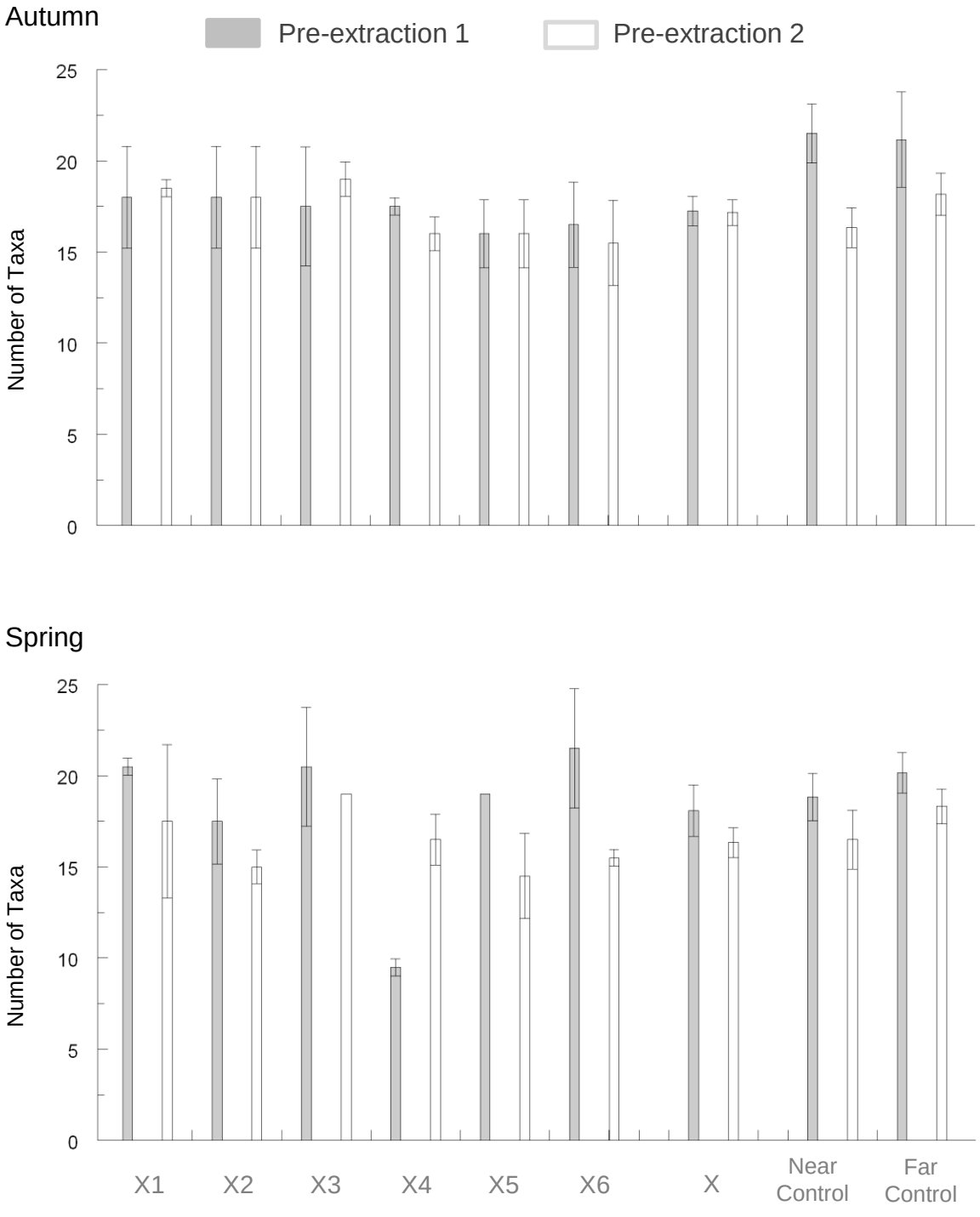


Figure 27. Mean (SE) number of taxa found in AUSRIVAS samples collected at DA3B Potential Impact sites X1-X6, all Potential Impact sites (X), Near Control (Wongawilli Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) during autumn and spring Pre-extraction surveys. (Potential Impact sites: n=2, Near Control: n=6, Far Control: n=6).

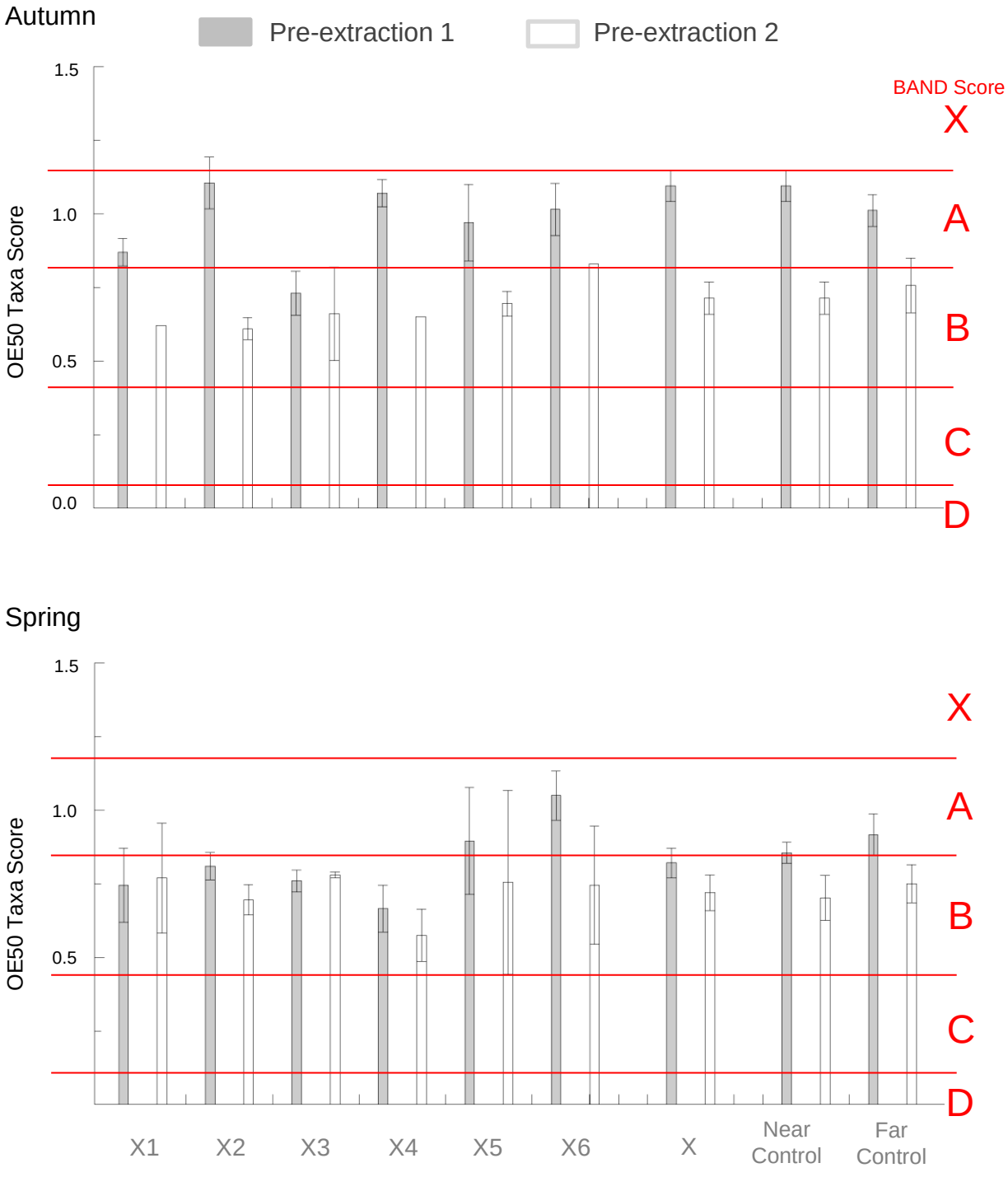


Figure 28. Mean (SE) OE50 Taxa Scores and BAND Scores for AUSRIVAS samples collected at DA3B Potential Impact sites X1-X6, all Potential Impact sites (X), Near Control (Wongawilli Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) during autumn and spring Pre-extraction surveys. (Potential Impact sites: n=2, Near Control: n=6, Far Control: n=6).

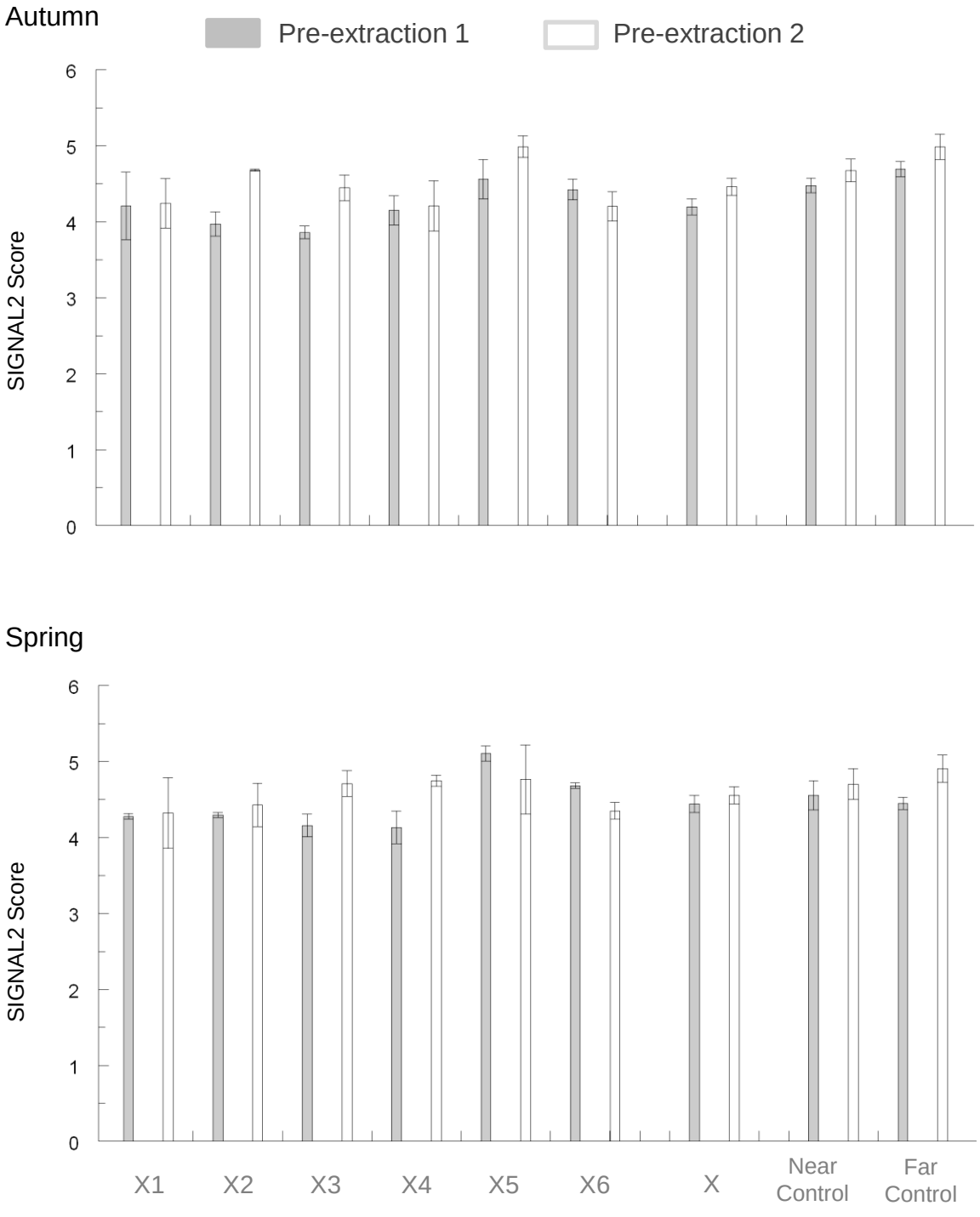


Figure 29. Mean (SE) SIGNAL2 Scores for AUSRIVAS samples collected at DA3B Potential Impact sites X1-X6, all Potential Impact sites (X), Near Control (Wongawilli Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) during autumn and spring Pre-extraction surveys. (Potential Impact sites: n=2, Near Control: n=6, Far Control: n=6).

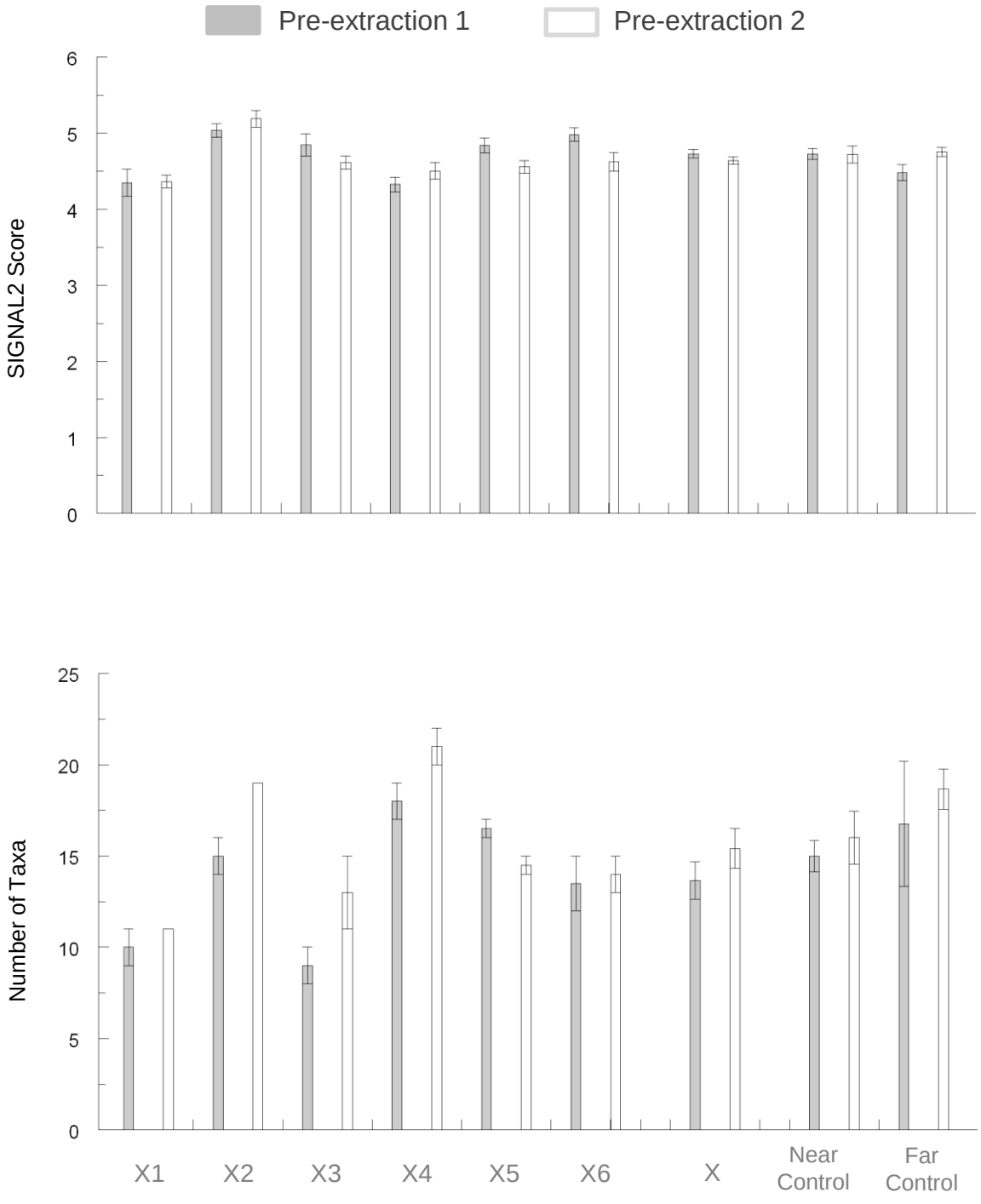


Figure 30. Mean (SE) SIGNAL2 Scores and number of taxa from macroinvertebrate assemblages sampled using macroinvertebrate collectors at DA3B Potential Impact sites X1-X6, all Potential Impact sites (X), Near Control (Wongawilli Sites 5 and 6) and Far Controls (Donalds Castle Creek Site 14 and Kentish Creek Sites 15 and 16) during autumn and spring Pre-extraction surveys. (Potential impact sites: SIGNAL2 Score n=16, number of taxa n=2, Near Control: SIGNAL2 Score n=48, number of taxa n=6, Far Control - pre-extraction 1: SIGNAL2 Score n=32, number of taxa n=4, Far Control - pre-extraction 2: SIGNAL2 Score n=48, number of taxa n=6.

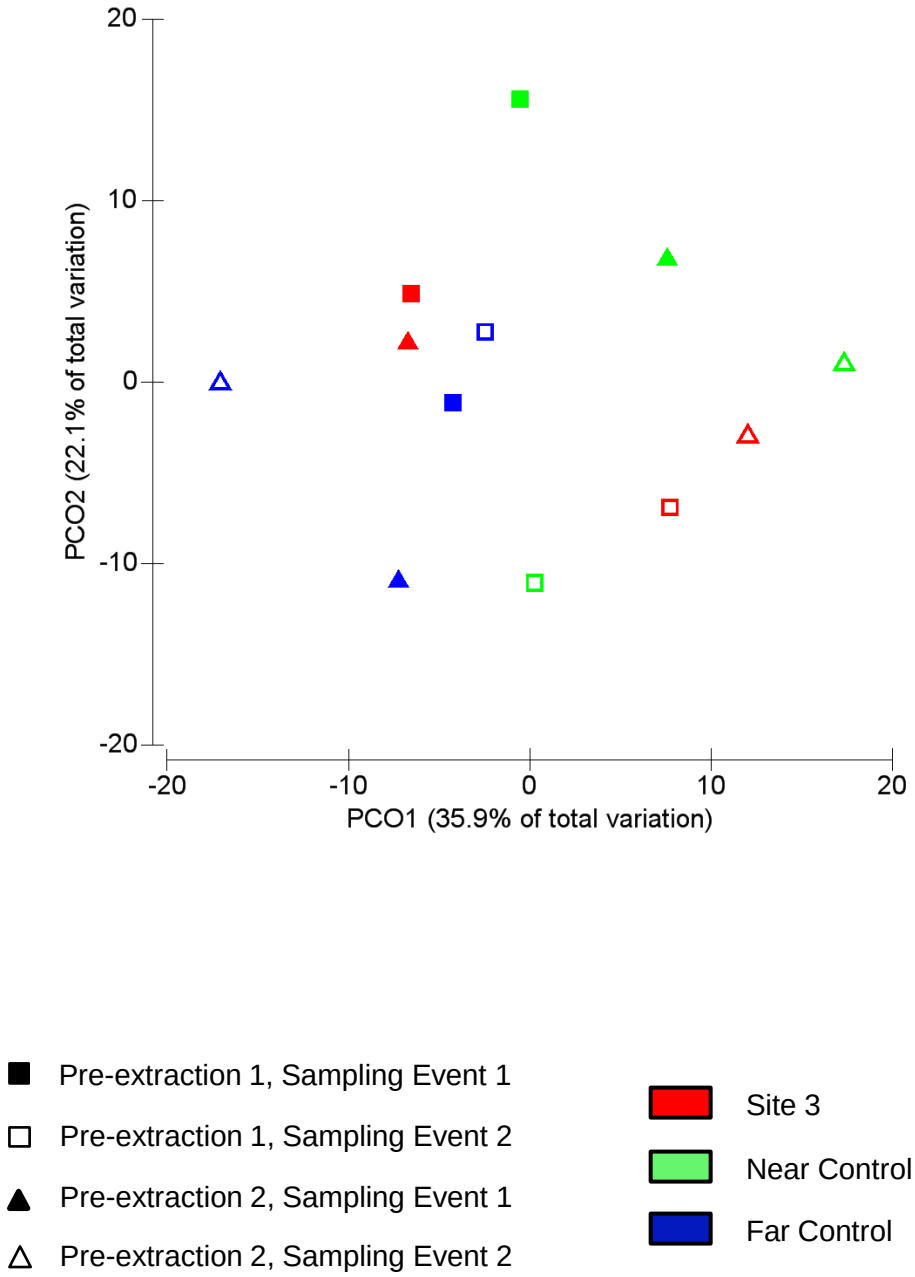


Figure 31. Principle Component Ordination (PCO) of macroinvertebrate assemblages sampled using artificial collectors at Potential Impact, Near Control and Far Control sites prior to the commencement of extraction in DA3B.

10 Plates

Plates 1-76: Photographic record of aquatic ecology monitoring sites visited by Cardno Ecology Lab in Dendrobium Area 3A and B during 2011.

11 Appendices

Appendix 1: Aquatic ecology sampling events undertaken by Cardno Ecology Lab in the aquatic ecology monitoring program for dendrobium Area 3 undertaken from 2008 to present by Cardno Ecology Lab.

Appendix 2: Aquatic ecology sampling events undertaken by Cardno Ecology Lab in the aquatic ecology monitoring program for dendrobium Area 3 undertaken from 2008 to present by Cardno Ecology Lab.

Appendix 3: PERMANOVA comparing number of taxa identified from AUSRIVAS samples collected from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 4: PERMANOVA comparing OE50 Taxa Scores calculated from AUSRIVAS samples collected from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 5: PERMANOVA comparing SIGNAL2 Scores calculated from AUSRIVAS samples collected from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 6: PERMANOVA comparing number of taxa identified from macroinvertebrate samples collected using artificial collectors from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 7: PERMANOVA comparing SIGNAL2 Scores calculated from macroinvertebrate samples collected using artificial collectors from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 8: PERMANOVA comparing macroinvertebrate assemblages sampled using artificial collectors from DA3A potential impact sites and control locations. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 9: PERMANOVA comparing number of taxa, OE50 Taxa Scores and SIGNAL2 Scores from AUSRIVAS data and macroinvertebrate collector data sampled from DA3B. RED = Redundant due to significant interaction term. Significant terms in bold ($p < 0.05$). Monte Carlo simulations used where unique permutations < 100.

Appendix 1: Location, geographic co-ordinates and designation (potential impact or control) of each of the Dendrobium Area 3 aquatic ecology monitoring sites.

Site	Water course	Easting	Northing	Designation
3	Wongawilli Creek	290939	6192926	DA3A Potential Impact Site
4	Wongawilli Creek	290844	6193506	DA3A Potential Impact Site
9	Sandy Creek	293812	6192547	DA3A Potential Impact Site
12	Sandy Creek 10	293489	6192462	DA3A Potential Impact Site
13	Sandy Creek C10C	293335	6192439	DA3A Potential Impact Site
X1	Donalds Castle Creek	289643	6194191	DA3B Potential Impact Site
X2	Wongawilli Creek 21	290247	6193847	DA3B Potential Impact Site
X3	Wongawilli Creek 21	289911	6193002	DA3B Potential Impact Site
X4	Wongawilli Creek	291083	6191801	DA3B Potential Impact Site
X5	Wongawilli Creek	290950	6190581	DA3B Potential Impact Site
X6	Wongawilli Creek	290775	6190356	DA3B Potential Impact Site
1	Wongawilli Creek	290977	6192444	Near control for sites 3 and 4
5	Wongawilli Creek	290625	6194378	
6	Wongawilli Creek 21	290531	6194246	
7	Sandy Creek	293661	6191227	Near control for sites 9, 12 and 13
8	Sandy Creek	293747	6191856	
14	Donalds Castle Creek	289400	6195445	Far control for all sites
15	Kentish Creek	299290	6194270	
16	Kentish Creek	298869	6194403	
2	Wongawilli Creek	290977	6192444	Monitoring postponed
10	SC7	293548	6191740	No further monitoring
11	SC10	293240	6192222	Monitoring postponed

Appendix 2: Aquatic ecology monitoring events undertaken for Dendrobium Area 3 from 2008 to present.

Season	Sampling Event†	Spring AUSRIVAS Survey (DA3A)	Artificial Collector Survey (DA3A)	Autumn AUSRIVAS Survey (DA3A)	Spring AUSRIVAS Survey (DA3A)	Artirfcial Collector Survey Period (DA3B)
Spring 2008	30/09/08 - 03/10/08	Pre-extraction 1	Pre-extraction 1			
	17/11/08 -20/11/08					
Autumn 2009	17/03/09 - 20/03/09					
	27/04/09 - 30/04/09					
Autumn 2010	16/03/10 - 25/03/10		Pre-extraction 2*	Pre-extraction 1		Pre-extraction 1
	04/05/10 - 07/05/10					
Spring 2010	20/09/10 - 27/09/10	Pre-extraction 2*			Pre-extraction 1	
	08/11/10 - 11/11/10					
Autumn 2011	11/04/11 - 14/04/11		During-extraction 1*	Pre-extraction 2		Pre-extraction 2
	07/06/11 - 10/06/11					
Spring 2011	06/09/11 - 09/09/11	During-extraction 1*			Pre-extraction 2	
	10/10/11 - 31/11/11					

*Data collected during 2010 and 2011 represent the first and second year of during-extraction sampling for Site 4, respectively.

Appendix 3: River Descriptors, Categories and Values Used in the Modified Riparian, Channel and Environmental Inventory (RCE) modified from Chessman *et al*. (1997).

Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone	
Undisturbed native vegetation	4
Mixed native vegetation and	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 andshrubs	3
Banks loose, partly held by sparse grass	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
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 unsilted 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