

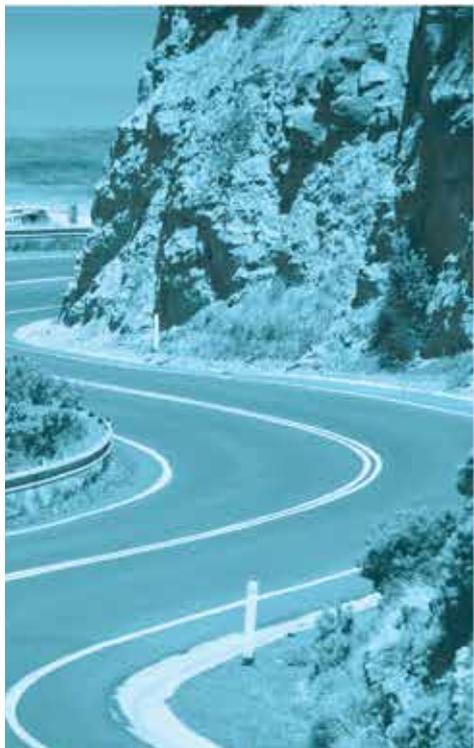


# Benthic Community Monitoring - Statistical Analysis

Chain Valley Colliery

---

Prepared for Delta Coal  
April 2020





# Servicing projects throughout Australia and internationally

## SYDNEY

Ground Floor, 20 Chandos Street  
St Leonards NSW 2065  
T 02 9493 9500

## NEWCASTLE

Level 3, 175 Scott Street  
Newcastle NSW 2300  
T 02 4907 4800

## BRISBANE

Level 1, 87 Wickham Terrace  
Spring Hill QLD 4000  
T 07 3648 1200

## ADELAIDE

Level 1, 70 Pirie Street  
Adelaide SA 5000  
T 08 8232 2253

## MELBOURNE

Ground Floor, 188 Normanby Road  
Southbank VIC 3006  
T 03 9993 1905

## PERTH

Suite 9.02, Level 9, 109 St Georges Terrace  
Perth WA 6000  
T 02 9339 3184

## CANBERRA

Level 8, 121 Marcus Street  
Canberra ACT 2600

# Benthic Community Monitoring - Statistical Analysis

Chain Valley Colliery

---

**Report Number**

H190850 1

---

**Client**

Delta Coal

---

**Date**

24 April 2020

---

**Version**

v2 Final

---

**Prepared by****Paul Goldsworthy**

Associate - Marine Risk

24 April 2020

---

**Approved by****Nathan Garvey**

Divisional Leader – Ecology, Heritage and Spatial Solutions

24 April 2020

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

© Reproduction of this report for educational or other non-commercial purposes is authorised without prior written permission from EMM provided the source is fully acknowledged. Reproduction of this report for resale or other commercial purposes is prohibited without EMM's prior written permission.

# Table of Contents

1	Introduction	1
2	Methods	3
3	Analysis results	5
3.1	Benthic data 2012-2020	5
3.2	Benthic data 2016-2020	8
3.3	Analysis of Similarity	10
3.4	Cluster analysis	10
3.5	Multi-dimensional Scaling	11
3.6	SIMPER	12
3.7	Temporal comparison of site groups	12
3.8	Environmental data	14
4	Discussion	17
5	Recommendations	18
6	References	19

## Appendices

### Appendix A CVC Benthic Monitoring Sites

## Tables

Table 1.1	Benthic monitoring data statistical methods (BCMP 2019)	2
Table 3.1	Operational Taxonomic Units (OTUs) derived for CVC benthos, 2016-2020	5
Table 3.2	CVC site environmental data for each monitoring site	14
Table 3.3	CVC subsidence monitoring data – change in bed levels	15

## Figures

Figure 3.1	Total number of (a) operational taxonomic units (OTUs) and (b) individuals identified in benthic samples from each CVC monitoring site for the period 2012-2020	6
Figure 3.2	(a) Shannon Weiner diversity, (b) Margalef's richness and (c) Pielou's evenness for benthic samples from each CVC monitoring site for the period 2012-2020	7
Figure 3.3	Total number of (a) operational taxonomic units (OTUs) and (b) individuals identified in benthic samples from each CVC monitoring site for the period 2016-2020	8

Figure 3.4	(a) Shannon Weiner diversity, (b) Margalef’s richness and (c) Pielou’s evenness for benthic samples from each CVC monitoring site for the period 2016-2020	9
Figure 3.5	ANOSIM test results for benthic data across site types, September 2016 to March 2020. Vertical line indicates global R value of 0.037	10
Figure 3.6	Dendrogram derived from cluster analysis of CVC benthic community monitoring data across all sites between September 2016 and March 2020	11
Figure 3.7	Patterns in community structure depicted as nMDS plot based on square-root transformed abundance data of all taxa (OTUs) for each site, September 2016-March 2020	11
Figure 3.8	Temporal comparison of benthic abundances by site group for the most abundant OTUs	13
Figure 3.9	Principle components analysis (PCA) plot for normalised environmental data – water depth (m), percentage sand and percentage mud for all sites	15
Figure 3.10	CVC measured changes in bed levels	16

# 1 Introduction

Chain Valley Colliery (CVC) is an underground coal mine located beneath the southern end of Lake Macquarie, NSW, approximately 60 km south of Newcastle (Appendix A). CVC produces thermal coal for the domestic and export markets.

As part of CVC's environmental performance, and to satisfy Condition 7(h), Schedule 4 of Development Consent SSD-5465 (Modification 2), a Benthic Communities Management Plan (BCMP) has been developed (CVC 2019). The stated purpose of this BCMP is to:

- outline details of the benthic communities monitoring data collected;
- outline existing and predicted subsidence levels;
- outline the methodology to be used to identify depth changes at monitoring locations;
- identify benthic community monitoring locations;
- identify reporting requirements;
- detail benthic community management measures;
- identify the requirements for incident or exceedances reporting and reviews of the document; and
- identify persons responsible for implementation of requirements.

Since 2012, CVC has monitored the soft sediment benthic community in shallow lake environments above their coal workings. The overall aim of the monitoring is to assess potential impacts of underground coal operations (primarily subsidence) on aquatic ecology, with benthic community composition as the specific indicator of impact.

CVC undertakes six-monthly sampling of lake sediments for analysis of benthic community composition and environmental variables (eg grain size). Samples are collected in Spring (March) and Autumn (September) at (potential) impact, reference and control sites (Appendix A).

The BCMP defines the three site types:

- Impact sites – currently or historically impacted upon by subsidence.
- Reference sites – not currently impacted by subsidence but fall within the proposed future mining footprint. Following undermining, Reference sites are redesignated as Impact sites.
- Control sites - will not be impacted upon by subsidence, ie those areas lying outside the footprint of current and future coal workings.

Full details of the benthic sampling and analysis regime are provided in Section 4 of the BCMP (CVC 2019). At each site, five replicate sediment samples are collected by diver using 200 x 200 x 100 mm sieve boxes with 1 mm mesh. Samples are sieved to remove particles less than 1 mm and captured material is preserved in formaldehyde for laboratory sorting and enumeration of infauna. Sediment grain size analysis is undertaken on one 250 mL sample of sediment from each site.

The BCMP prescribes statistical analysis methods for univariate and multivariate analysis of the benthic monitoring data – biological and environmental (Table 1.1).

**Table 1.1 Benthic monitoring data statistical methods (BCMP 2019)**

<b>Variable Type</b>	<b>Analysis</b>	<b>Description</b>
Environmental: Water Quality	ANZECC/ARMCANZ Guidelines	Trigger values for slightly – moderately disturbed ecosystems: Estuaries
Biotic and Environmental	Univariate	Descriptive graphical statistics. Analysis of Variance (2-way nested) Analysis of Similarity (2-way nested)
Biotic and Environmental	Multivariate	A square-root transformed, Bray-Curtis similarity matrices, Cluster analysis and dendrograms
	Multidimensional Scaling Ordination	Sites represented as points in space, relative distances indicate similarity.
	BIOENV	Correlation between biotic and environmental data using PRIMER.

EMM has undertaken statistical analysis of the supplied benthic monitoring data in accordance with the BCMP.

## 2 Methods

Statistical analysis was undertaken on the full benthic dataset (September 2012 – March 2020) provided by Laxton Environmental, who undertake the field sampling programs on behalf of Delta Coal. The supplied benthic data were checked and reordered within multiple MS Excel worksheets to facilitate statistical analysis in accordance with the BCMP (CVC 2019).

Descriptive statistics (ie means, standard deviations, standard errors, minimums, maximums and counts) were calculated within MS Excel. Summary statistics were subsequently used for visualisation of trends by site and by treatment (impact versus control versus reference sites). For the purposes of analysis, the control and reference groups have been kept separate.

Raw data were imported into PRIMER v6 for univariate and multivariate analysis. PRIMER (Plymouth Routines in Multivariate Ecological Research) consists of a “wide range of univariate, graphical and multivariate routines for analysing arrays of species-by-samples data from community ecology” (Clarke & Gorley 2006) and is the software of choice for benthic ecology.

Univariate diversity indices were calculated from the raw benthic count data. Total number of species (S), total number of individuals (N), species richness (Margalef, d), evenness (Pielou, J') and diversity (Shannon-Wiener,  $\log e$ , H') were calculated within PRIMER v6 (DIVERSE) and graphically presented to identify any site-by-site trends in benthic community structure.

Due to the high frequency of zeros in the benthic count data, the data were square root transformed to downplay taxa with comparatively high counts and to increase the statistical visibility of the rarer taxonomic groups. Bray-Curtis similarity (resemblance) matrices were subsequently developed from the transformed data and statistical analysis of these multivariate data was undertaken using PRIMER v6 routines.

Simple agglomerative hierarchical clustering was undertaken, producing dendrograms to visually identify distinct data groups based on different levels of similarity in benthic community structure. Dendrograms (also known as tree diagrams) display groups of samples in successively smaller numbers of clusters as the threshold of similarity at which two groups merge decreases. Groups (clusters) of sites (or other factors) can be identified for further data exploration with respect to the potential drivers of the groupings.

Non-metric multidimensional scaling (nMDS) was undertaken using PRIMER v6. nMDS is a powerful multivariate tool used to analyse benthic community data whereby points (eg sites) are plotted in 2-dimensional space such that the relative distance between points is relative to the same rank order as relative dissimilarities of each sample, ie points close together represent samples that are very similar in community composition and points further apart are more different. Distance between points cannot be used as an absolute measure of similarity or dissimilarity, rather relative distance between points indicates relative similarity/dissimilarity.

The PRIMER v6 routine for analysis of similarities (ANOSIM) provides an approximate analogue of standard univariate analysis of variance (ANOVA). Using the resemblance matrix calculated from benthic count data, ANOSIM was used to test the null hypothesis that there are no differences between treatments (ie CVC's Impact, Reference and Control sites) allowing for potential differences between individual sites. A two-way crossed design – sites within treatments – was used. ANOSIM produces p and R values, where p indicates the level of significance for differences between benthic communities, in this case grouped into the three different site types, and R values indicate the strength of any differences. As R values approach 1 the strength of the difference between groups increases. R values close to zero indicate no difference between the groups. This is an important consideration given the inherently variable nature of benthic community data where small-scale variability (between replicates) can often be as great (or greater) than the larger scale differences between sites.

Subsequent interpretation of which individual benthic taxa are driving any of the observed differences between treatments and/or sites was undertaken using similarity percentage analysis (SIMPER) within PRIMER v6. SIMPER outputs indicate the percentage that each taxa contributes to the observed pairwise differences and informs the investigation of why the abundance (or absence) of certain species occur at individual sites.

Environmental data – water depth and sediment grain size – collected at each of CVC’s benthic monitoring sites were investigated as potential influencing factors in benthic community composition. The environmental data were normalised (subtract mean and divide by standard deviation) to allow comparison between factors with different units of measure, ie metres water depth and percent silt, percent sand. Principle components analysis (PCA) was used to visualise site-by-site groupings based on water depth and sediment grain size (PRIMER v6).

The variation in environmental data was subsequently used to help identify potential factors, eg water depth, that are driving the development of the benthic assemblages. This approach is critical in defining the potential reasons for variation in benthic community structure within the context of natural variability, driven by environmental factors, and potential impacts from project-related activities.

Ongoing development of CVC’s underground coal extraction has led to the redesignation of several of the early Reference sites as Impact sites. Sites R3, R4, R5 and R6 have become IM5, IM6, IM7 and IM8, respectively. Changing the ‘treatment’ designation of sites is necessary to account for the ongoing expansion of the coal workings but it does complicate the statistical analysis process since the potential for impacts from subsidence at these sites changes over time. To help discern greater relationship information, EMM focused statistical analysis of the different site types (ie impact, reference and control) on the monitoring period after redesignation of the earlier reference sites to impact sites (ie from September 2016 onwards).

## 3 Analysis results

In the laboratory, biological samples were sorted into different taxonomic groups. Molluscs and one polychaete worm were sorted to genus level while all other fauna were grouped into operational taxonomic units (OTUs). The broader OTU groupings comprised higher taxa (eg terebellids, ophiuroids), general organism groups (sponges, crabs, barnacles, fish) or were split according to specific descriptive types (eg mud polychaetes, thin polychaetes and thick polychaetes).

The infauna were categorised into 21 OTUs (Table 3.1) and these have been used to differentiate sites during statistical analysis.

**Table 3.1 Operational Taxonomic Units (OTUs) derived for CVC benthos, 2016-2020**

Polychaetes – thin (P)	<i>Soletellina</i> (B)	prawns (C)
Polychaetes – thick (P)	<i>Paphia</i> (B)	crabs (C)
Polychaetes – mud (P)	<i>Anadara</i> (B)	barnacles (C)
terebellids (P)	<i>Cyamiomactra</i> (B)	ophiuroids (E)
<i>Pectinaria</i> (P)	<i>Trichomya</i> (B)	sponges
<i>Nassarius</i> (G)	<i>Dosinia</i> (B)	fish
<i>Bedevela</i> (G)	<i>Corbula</i> (B)	planaria (F)

Notes: (P) = polychaete worm  
 (G) = gastropod mollusc  
 (B) = bivalve mollusc  
 (C) = crustacean  
 (E) = brittle starfish (Echinoderm)  
 (F) = flatworm (Platyhelminth)

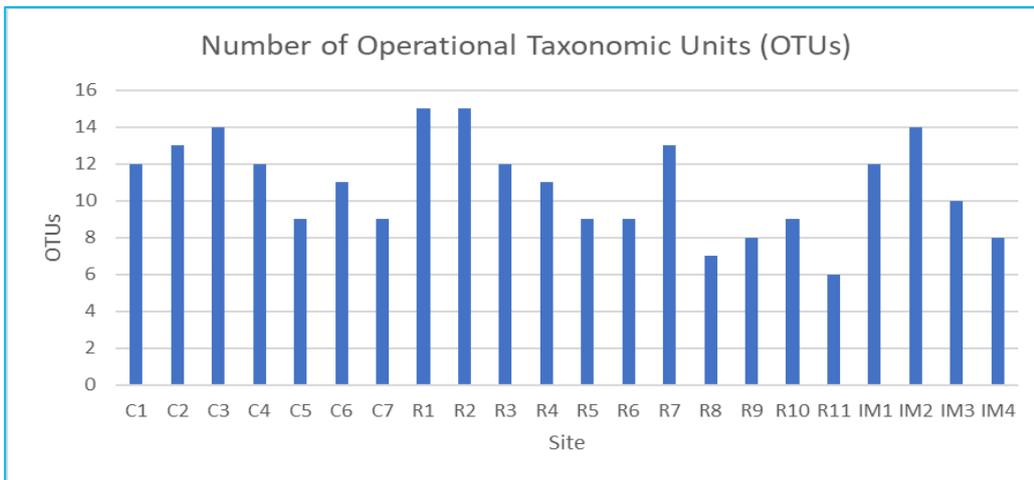
### 3.1 Benthic data 2012-2020

From 14 sampling events between September 2012 and March 2020, a total of 16,825 benthic individuals from the 21 different taxonomic groups were counted in sediment samples from across the study area. The three most abundant taxa are the bivalve *Corbula* (5,345 individuals), polychaetes-thin (4,665 individuals) and the bivalve mollusc *Soletellina* (4,097 individuals); together these taxa account for 84% of the total number of benthic individuals collected in sediment samples throughout the monitoring period. The most speciose faunal group is bivalve molluscs (7 species).

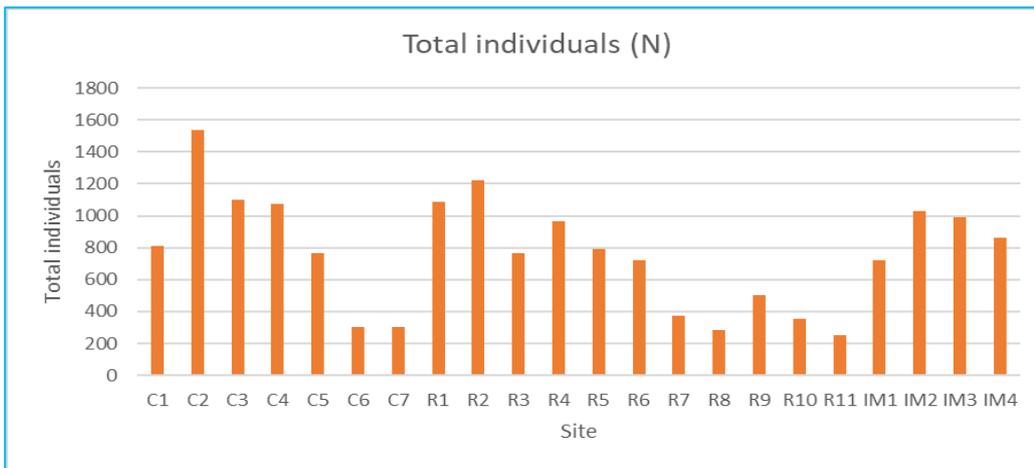
The number of OTUs and individuals identified for each site over time is shown in Figure 3.1. In these figures the site numbering reflects the original reference site designations rather than changes that were made due to subsequent undermining.

Between 6 and 15 OTUs (mean 10.8) were reported per site. The lowest number of OTUs was at R11 (6) and R8 (7) and the highest number of OTUs was at R1 and R2 (15) and C3 and IM2 (14). There is no clear spatial pattern associated with the number of OTUs per site.

The total number of individuals per site varied between 253 (R11) and 1,535 (C2). Abundances were lowest (<350 individuals) at C6 (306), C7 (303), R8 (285) and R11 (253). Abundances were highest (>1,200) at C2 (1,535) and R2 (1,221). There is no clear spatial pattern associated with the abundance of benthic species per site.



(a)



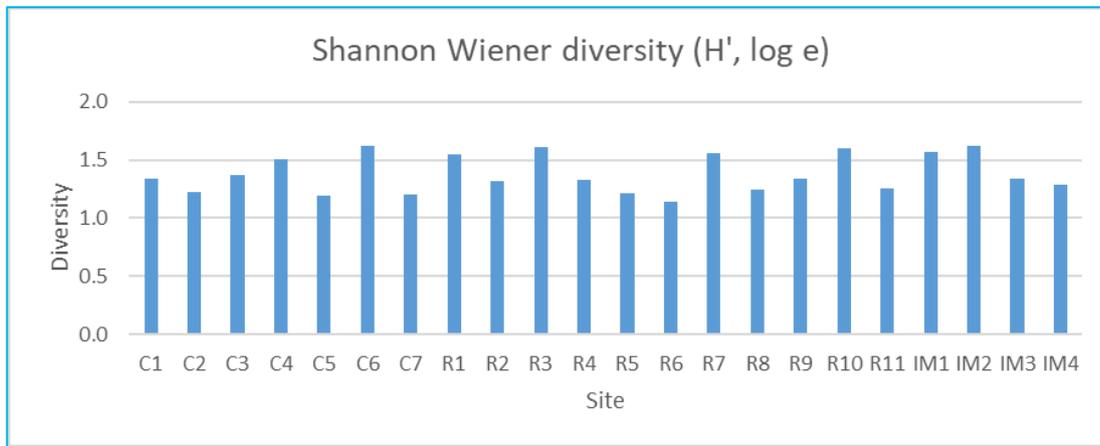
(b)

C = Control sites      R = Reference sites      IM = Impact sites

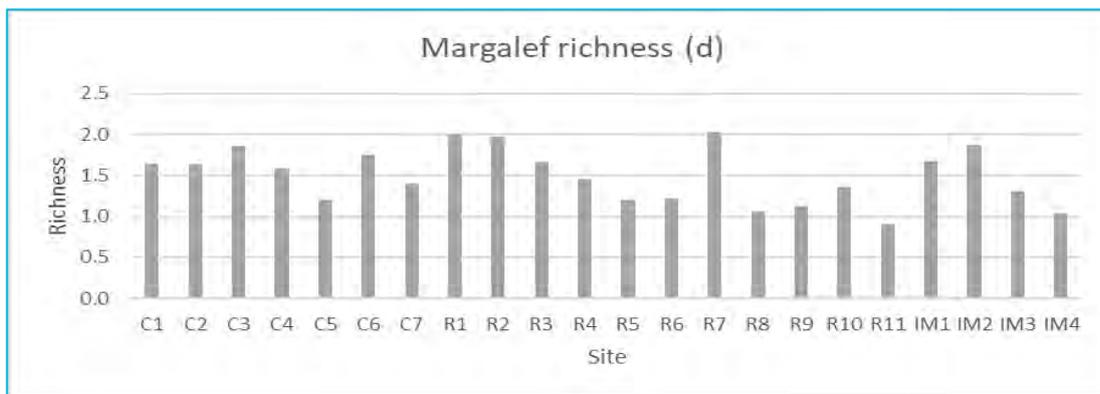
**Figure 3.1** Total number of (a) operational taxonomic units (OTUs) and (b) individuals identified in benthic samples from each CVC monitoring site for the period 2012-2020

Shannon Wiener diversity ( $H'$ , log e), Margalef richness (d) and Pielou's evenness ( $J'$ ) values for each site over time are shown in Figure 3.2.

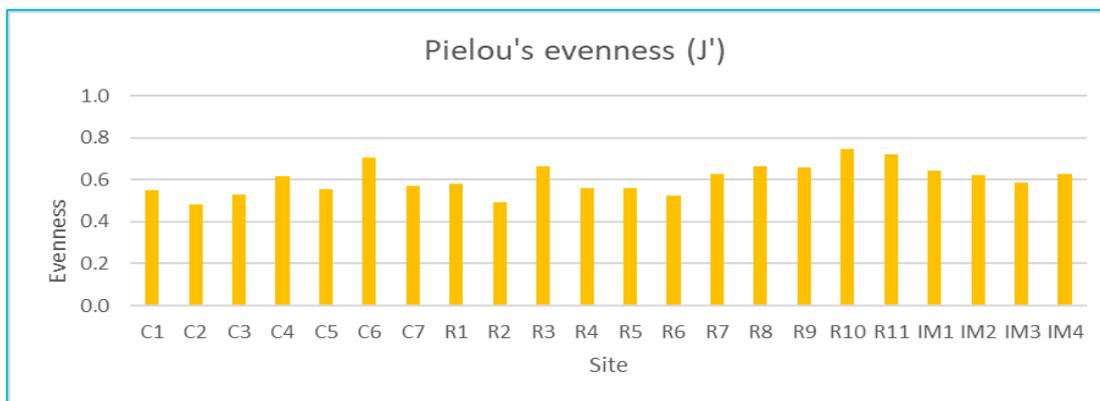
Each of these biodiversity indices are broadly similar across all sampling sites. Margalef richness most closely follows the distribution of OTUs per site, with marginally lower richness (<1.1) apparent at R8, R11 and IM4. The diversity and evenness vary across the sites within a narrow range of 1.16–1.69 and 0.49–0.75, respectively.



(a)



(b)



(c)

C = Control sites      R = Reference sites      IM = Impact sites

**Figure 3.2** (a) Shannon Weiner diversity, (b) Margalef's richness and (c) Pielou's evenness for benthic samples from each CVC monitoring site for the period 2012-2020

As indicated in Methods (Section 2), to help discern greater relationship information, EMM has focused statistical analysis of the different site types (ie impact, reference and control) on the monitoring period after redesignation of Sites R3, R4, R5 and R6 as IM5, IM6, IM7 and IM8, respectively. The analysis focus was shifted to the monitoring period from September 2016 onwards.

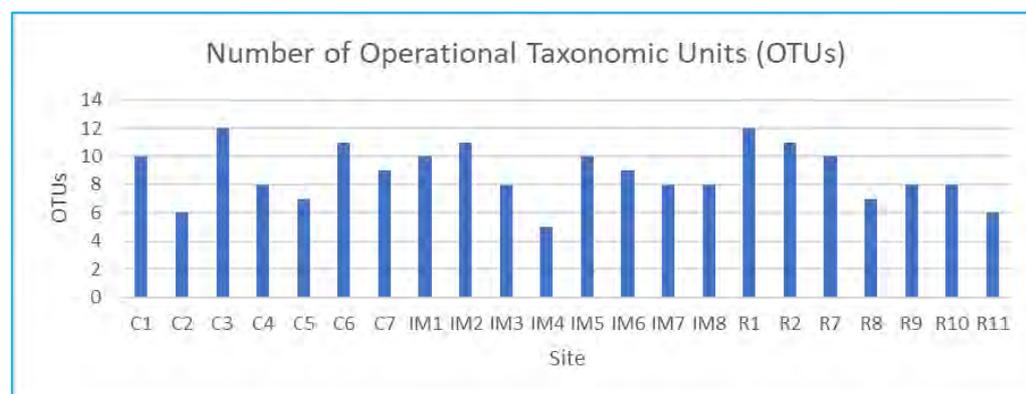
### 3.2 Benthic data 2016-2020

From eight sampling events between September 2016 and March 2020, a total of 8,620 benthic individuals from 20 different taxonomic groups were counted in sediment samples from across the study area.

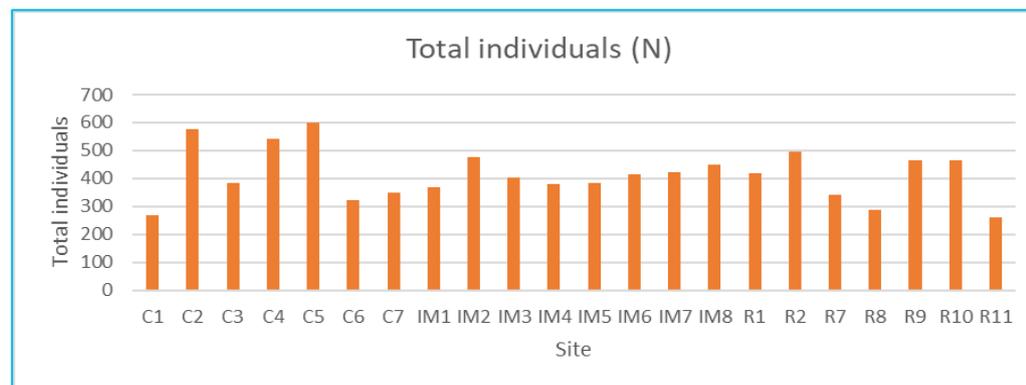
The number of OTUs and individuals identified for each site over time is shown in Figure 3.3. In these figures the site numbering reflects the redesignation of reference sites (R3-R6) as impact sites (IM5-IM8) due to ongoing expansion of the underground coal workings.

Between 5 and 12 OTUs (mean 9.0) were reported per site. The lowest number of OTUs were at IM4 (5), C2 and R11 (6) and the highest number of OTUs were at C3 and R1 (12). There is no clear spatial pattern associated with the number of OTUs per site.

The total number of individuals per site varied between 260 (R11) and 601 (C5). Abundances were lowest (<300 individuals) at C1 (268), R8 (288) and R11 (260). Abundances were highest (>500 individuals) at C2 (577), C4 (542) and C5 (601). There is no clear spatial pattern associated with the abundance of benthic species per site.



(a)



(b)

C = Control sites

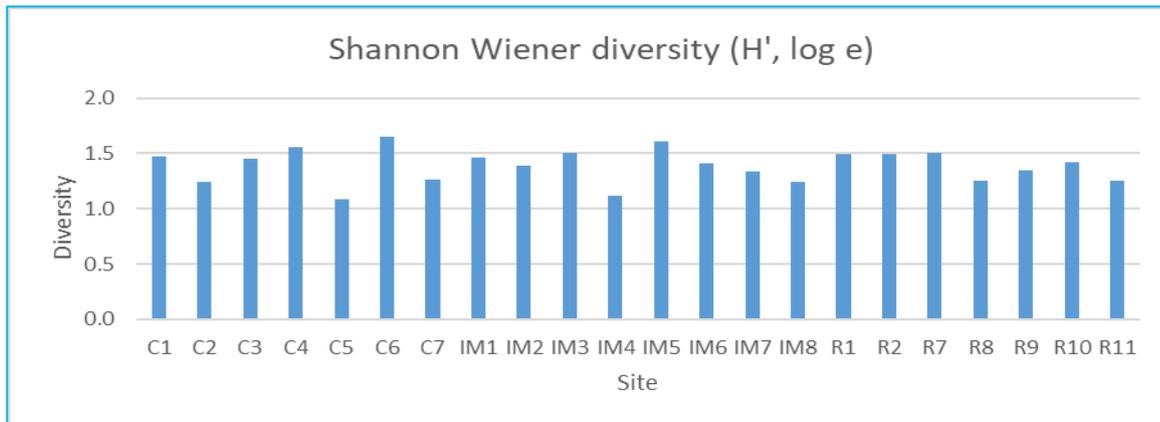
IM = Impact sites

R = Reference sites

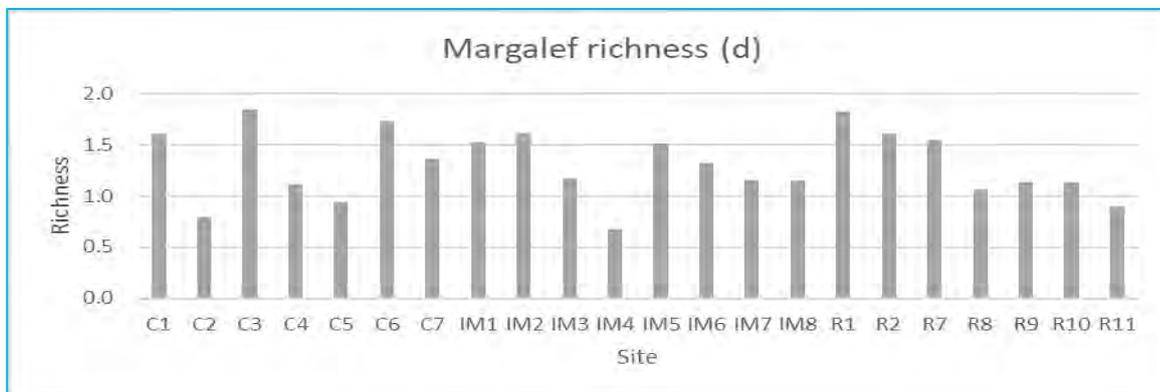
**Figure 3.3 Total number of (a) operational taxonomic units (OTUs) and (b) individuals identified in benthic samples from each CVC monitoring site for the period 2016-2020**

Shannon Wiener diversity, Margalef richness and Pielou's evenness values for each site over time (2016-2020) are shown in Figure 3.4.

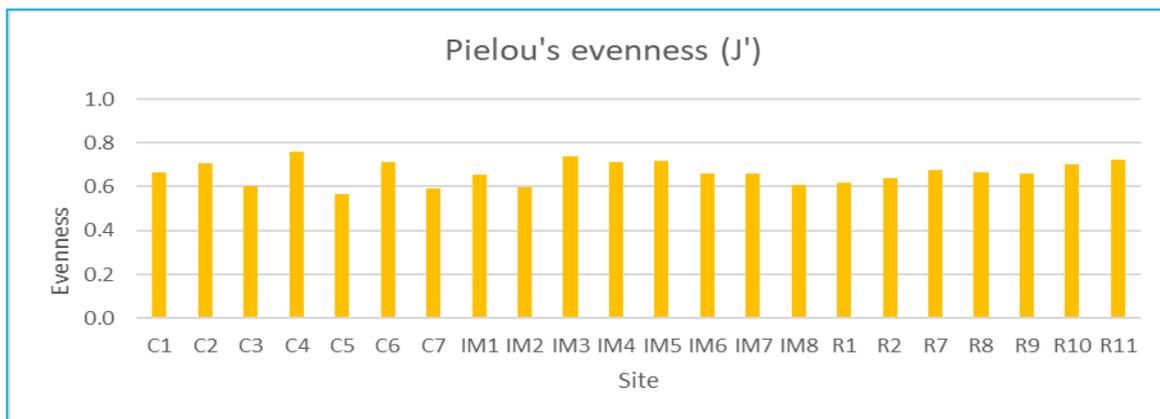
Each of these biodiversity indices are broadly similar across all sampling sites. Margalef richness most closely follows the distribution of OTUs per site, with marginally lower richness (<1.0) apparent at C2, C5, IM4 and R11. The diversity and evenness vary across the sites within a narrow range of 1.1-1.7 and 0.57-0.76, respectively.



(a)



(b)



(c)

C = Control sites

R = Reference sites

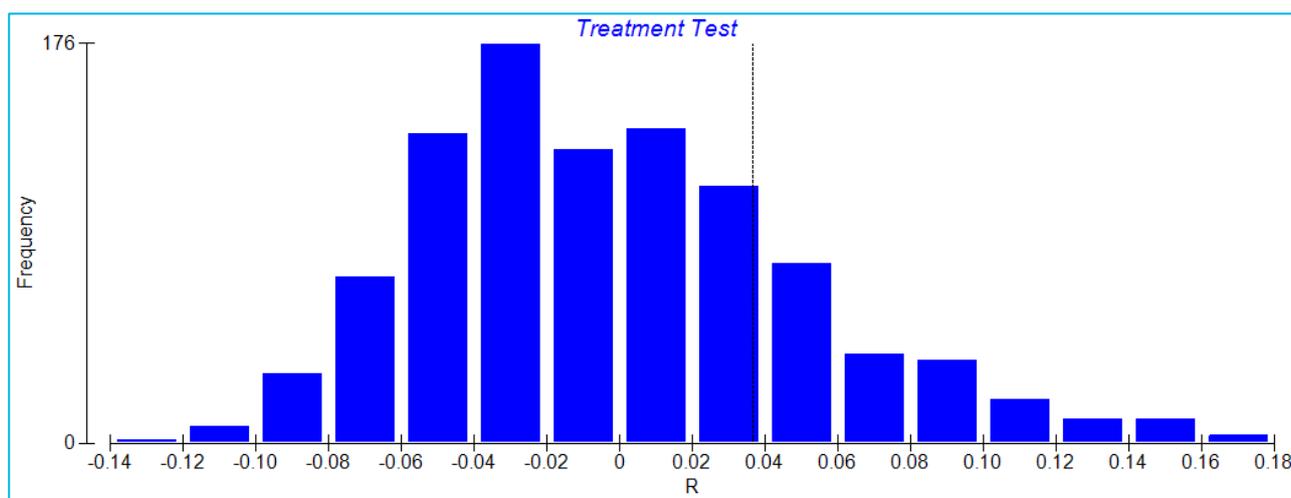
IM = Impact sites

**Figure 3.4** (a) Shannon Wiener diversity, (b) Margalef's richness and (c) Pielou's evenness for benthic samples from each CVC monitoring site for the period 2016-2020

### 3.3 Analysis of Similarity

In accordance with the statistical analysis suite identified in the BCMP (Table 2.1), benthic data were explored using analysis of similarity (ANOSIM), cluster analysis and non-metric multidimensional scaling (nMDS).

For ANOSIM, a two-way nested design was used to test for similarities between the three different site types (impact, reference and control). Testing for differences in benthic communities between the three site types during the period September 2016 to March 2020 derived a global R value of 0.037 at a significance level (p) of 21.3% (well above the statistical significance level of 5%). The ANOSIM plot indicates that there are no significant differences between the three site types (Figure 3.5) since the global R value (black vertical line) falls within the wider distribution of R values (blue bars).

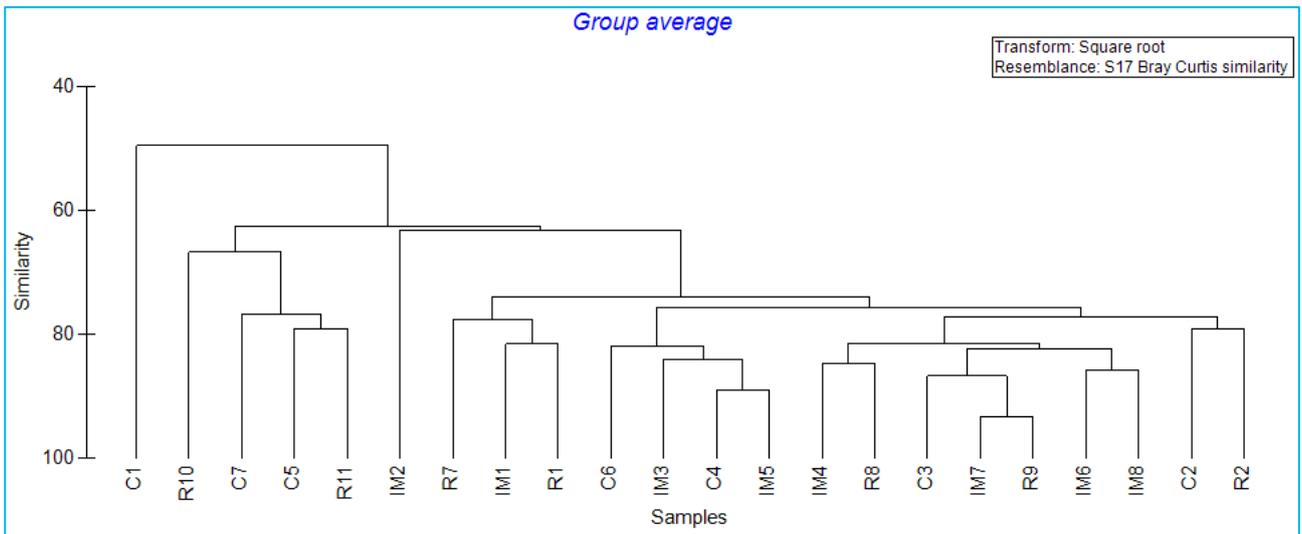


**Figure 3.5** ANOSIM test results for benthic data across site types, September 2016 to March 2020. Vertical line indicates global R value of 0.037

### 3.4 Cluster analysis

Cluster analysis was used to visualise pair-wise similarity between sites based on levels of Bray Curtis similarity for the monitoring period September 2016 to March 2020 (Figure 3.6). The dendrogram indicates that at 70% similarity level there are five clusters – C1, R10 and IM2 (which separate as individual 'clusters'), C5-C7-R11 and all remaining sites.

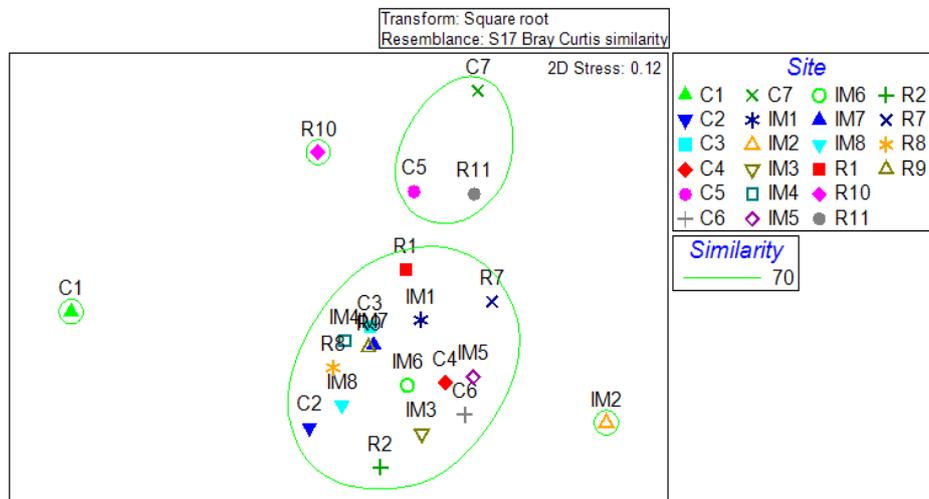
Importantly, the impact sites do not cluster together as a discrete group but rather are spread along the x-axis, interspersed amongst reference and control sites.



**Figure 3.6** Dendrogram derived from cluster analysis of CVC benthic community monitoring data across all sites between September 2016 and March 2020

### 3.5 Multi-dimensional Scaling

Non-metric multi-dimensional scaling (nMDS) is used to represent samples as points in 2-D space such that points that are close together represent samples that are very similar in community composition (Clarke & Gorley 2006). The similarity patterns indicated in the cluster analysis are further explored using an nMDS plot for abundance data at each site (Figure 3.7). The green circles indicate site groupings that correspond to the 70% similarity level.



**Figure 3.7** Patterns in community structure depicted as nMDS plot based on square-root transformed abundance data of all taxa (OTUs) for each site, September 2016-March 2020

The distribution (in nMDS space) of Impact, Reference and Control sites does not indicate site groupings that could be attributed to impacts from CVC operations since most sites have similar benthic communities (tightly grouped). Except for IM2, those sites that exhibit different benthic communities to the main group of sites are designated as reference (R10, R11) and control (C1, C5, C7) sites.

### 3.6 SIMPER

SIMPER analysis was undertaken on the square-root transformed biological data to identify which taxa are contributing to the separation between benthic communities evident at the C1, IM2, R10 and the C5-C7-R11 site groups identified during cluster analysis and confirmed by nMDS.

SIMPER results indicate that more than 80% of the differences between the site groupings are attributed to abundances of two polychaetes (mud and thin) and four bivalve molluscs, *Corbula*, *Dosinia*, *Soletellina* and *Trichomya*.

Specific differences between the groups are:

- C1:
  - much higher abundances of polychaete-thin compared to all other sites (accounts for 60–70% of differences).
- IM2:
  - higher abundances of *Trichomya* and lower abundances of polychaete-thin, polychaete-mud and *Soletellina* compared to most sites; and
  - higher abundances of *Trichomya* and polychaete-thick and lower abundances of *Dosinia* and *Corbula* compared to R10.
- R10:
  - higher abundances of *Dosinia*, polychaete-mud and polychaete-thin and lower abundances of *Corbula* and *Soletellina* compared to most other sites; and
  - higher abundances of *Dosinia* and lower abundances of polychaete-mud and polychaete-thin compared to C5-C7-R11.
- C5-C7-R11:
  - higher abundances of polychaete-mud, polychaete-thin and *Soletellina* and lower abundances of *Corbula* and *Trichomya* compared to most sites;
  - higher abundances of polychaete-mud and lower abundances of *Trichomya*, polychaete-thick and *Soletellina* compared to IM2; and
  - higher abundances of polychaete-mud and polychaete-thin and lower abundances of *Dosinia* compared to R10.

### 3.7 Temporal comparison of site groups

Comparison of temporal variation in abundances (mean + standard deviation) for each site group (C1, IM2, R10, C5-C7-R11 and 'all other') are provided for the four most abundant OTUs reported across the benthic monitoring area (Figure 3.8).

*Soletellina* has occurred in varying abundances at most sites over time. Abundances at IM2 are comparable with abundances elsewhere, except in March 2020 (2003) where a comparatively high mean abundance was apparent. The mean is associated with high variability between replicates indicated by the high standard deviation. *Soletellina* abundances were comparatively low across all site groups in September 2019 (1909).

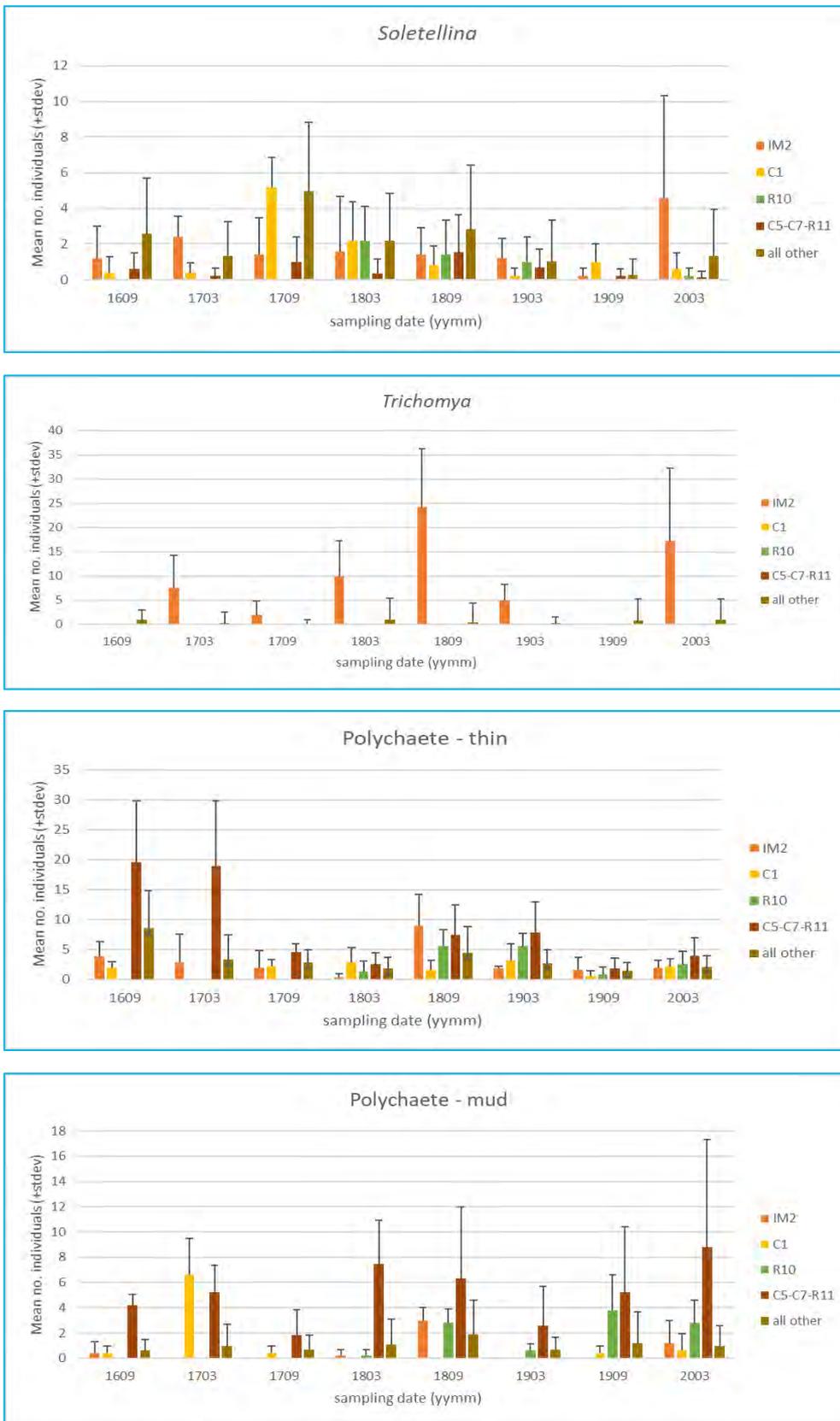


Figure 3.8 Temporal comparison of benthic abundances by site group for the most abundant OTUs

*Trichomya* is mostly found at IM2, which drives the separation of this site’s benthic community from the other sites. Abundances vary across time.

Thin polychaete abundances are broadly similar for each group at each monitoring event, although the distinguishing differences are most likely due to high abundances in the C5-C7-R11 group apparent in September 2016 (1609) and March 2017 (1709).

Mud polychaete abundances are variable between site groups and over time. The notable differences are higher abundances (and variability) apparent in the C5-C7-R11 group.

The important aspect to note from these plots is that the only impact site (IM2) that differs in benthic community structure from all other sites is not changing consistently over time (either increasing or decreasing abundances) and therefore is not indicative of an impact from the CVC operations.

### 3.8 Environmental data

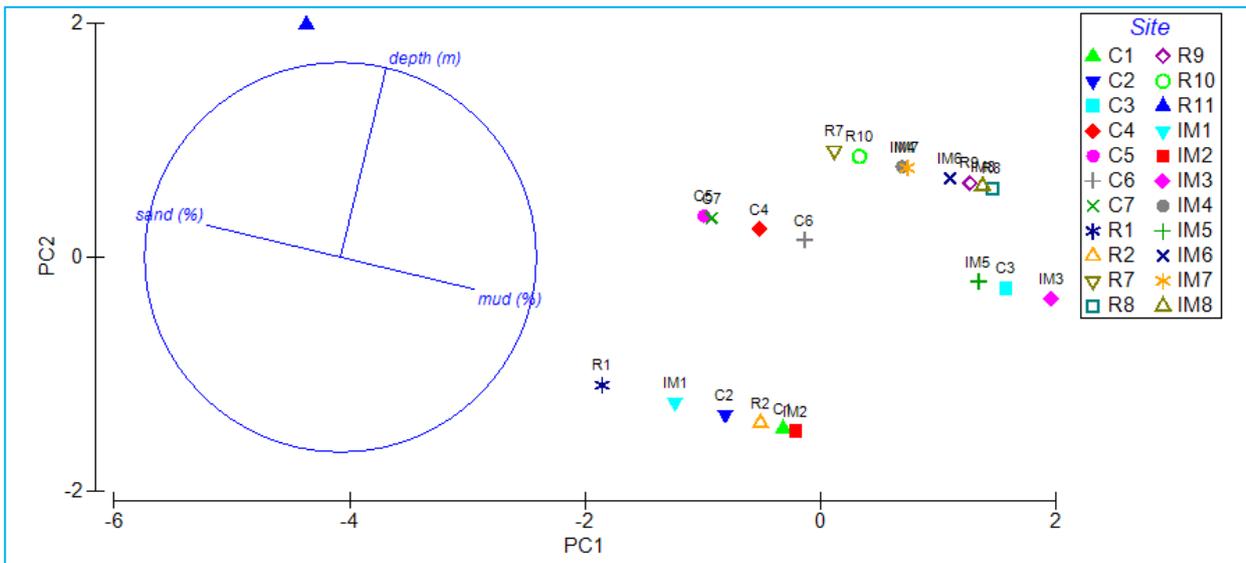
Water depths and sediment grain size were reported for each site (Table 3.2). These environmental variables were analysed alongside the biological data to discern potential environmental drivers of the observed variation in benthic community structure.

**Table 3.2 CVC site environmental data for each monitoring site**

Site	Water depth (m)	Sand (%)	Mud (%)	Site	Water depth (m)	Sand (%)	Mud (%)
C1	4.5	15.4	84.6	IM1	4.5	19.7	80.3
C2	4.5	17.7	82.3	IM2	4.5	14.9	85.1
C3	5.5	8.3	91.7	IM3	5.5	6.5	93.5
C4	5.5	18.1	81.9	IM4	6.0	13.3	86.7
C5	5.5	20.3	79.7	IM5	5.5	9.4	90.6
C6	5.5	16.3	83.7	IM6	6.0	11.4	88.6
C7	5.5	20.0	80.0	IM7	6.0	13.1	86.9
R1	4.5	22.6	77.4	IM8	6.0	10.1	89.9
R2	4.5	16.3	83.7				
R7	6.0	16.0	84.0				
R8	6.0	9.7	90.3				
R9	6.0	10.6	89.4				
R10	6.0	15.0	85.0				
R11	6.0	37.0	63.0				

Principle components analysis (PCA) was undertaken on the normalised environmental data (Figure 3.9). The results indicate five main site groups:

- Group 1: shallow water (4.5m) – sites R1, R2, IM1, IM2, C1, C2.
- Group 2: mid depth (5m), medium sand – C4, C5, C6 and C7.
- Group 3: mid depth (5m), high mud – IM3, IM5 and C3.
- Group 4: deep (6.0m) – R7, R8, R9, R10, IM4, IM6, IM7 and IM8.
- Group 5: deep (6.0m), very sandy – R11.



**Figure 3.9** Principle components analysis (PCA) plot for normalised environmental data – water depth (m), percentage sand and percentage mud for all sites

The site groupings based on environmental variables (ie PCA) are different to the site groupings evident in benthic community structure (nMDS) which suggests that factors other than, or in addition to, water depth and sediment grain size are driving the benthic structure.

As part of subsidence monitoring, CVC monitors changes in lake bed levels above the underground workings (impact sites) and at reference and control sites. Changes in bed levels measured since August 2017 are provided in Table 3.3.

**Table 3.3** CVC subsidence monitoring data – change in bed levels

Site	Date	Bed level change (m)	Site	Date	Bed level change (m)	Site	Date	Bed level change (m)
C1		nil	IM1		nil	R1		nil
C2	Apr-20	-0.154	IM2		nil	R2		nil
C3	Apr-20	-0.101	IM3		nil	R7	Apr-20	-0.124
C4	Jan-19	-0.079	IM4	Jan-19	-0.145	R8	Aug-17	-0.320
C5		nil	IM5	Jan-19	-0.462	R9	Apr-20	-0.169
C6		nil	IM6	Jan-19	-0.361	R10		nil
C7		nil	IM7	Jul-19	-0.394	R11	Apr-20	-0.176
			IM8	Jul-19	-0.424			

The measured changes in bed levels are shown graphically in Figure 3.10.



**Figure 3.10** CVC measured changes in bed levels

The largest bed level changes are apparent at benthic monitoring sites IM5-IM8 with water levels increasing by approximately 0.4 m. However, these changes are not reflected in detectable change in benthic community structure since the statistical analysis of benthos (eg cluster analysis and nMDS) did not identify these sites as being part of a separate group distinct from the majority of the monitoring sites.

## 4 Discussion

Benthic communities are inherently variable across different spatial and temporal scales, typically in response to differences in environmental conditions. When assessing potential impacts from project activities it is important not to attribute site-by-site differences to project impacts without due consideration of the environmental and biological context.

The soft sediment benthic communities within the CVC monitoring area are dominated by polychaete worms and bivalve molluscs. Fauna abundances and diversity indices (richness, evenness and diversity) differ between each site (as expected) although were found to be within a relatively narrow range across the monitoring area. Statistical analysis of the benthic data indicates that the level of variability within the treatment groups (impact, reference and control) is similar to or greater than the variability between treatment groups. There are no significant differences between the treatments.

From an ecological perspective, the benthic assemblages across the monitoring area fall into several groups that do not appear to be a response to CVC operations but are most likely grouping due to subtle environmental variations driven by currently unknown environmental factors.

As an example, sites C5, C7 and R11 were identified as having similar benthic assemblages. These sites are all located at the northerly extent of the project area which is expected to have higher water circulation from central Lake Macquarie compared to areas further south. Water circulation influences a range of important environmental variables including water temperatures, flow of nutrients, food for benthic filter feeders, pH and dissolved oxygen). Small-scale variability of these (and other) physico-chemical parameters influence the development of benthic assemblages and may be causing some of the observed differences in benthic community structure across CVC's monitoring area.

IM2 is the only Impact site that has a benthic assemblage that differs from the other monitoring sites. The statistical difference is attributed to higher abundances of *Trichomya* bivalve and lower abundances of polychaetes (thin and mud) and *Soletellina* bivalve compared to nearby sites. IM2 is in shallower water (4.5 m) compared to nearby sites, being located on a shallow shelf area that projects into the bay (see Appendix A). This environment may have thinner sediments that are less suitable for infaunal polychaetes and bivalves that bury in soft sediments. The shallower water may also support benthic primary producers although they were not reported in the benthic data. This subtle environmental difference compared to other sites nearby may be the cause of the different benthic assemblage at this location.

Importantly, the statistical analysis of CVC's benthic monitoring data, primarily undertaken for the period September 2016 to March 2020, has not identified any statistical differences between the benthic assemblages evident at sites designated as Impact, Reference and Control. The reported changes in bed levels associated with CVC underground working also do not correlate with detectable changes in the benthic communities above.

In conclusion, the results of statistical analysis of CVC's benthic monitoring data indicate that no exceedance of the BCMP (CVC 2019) subsidence impact performance measure of "minor environmental consequences, including minor changes to species composition and/or distribution" has occurred. Consequently, CVC is not required to implement any additional investigations of benthic communities within the project study area at this time and should continue the routine monitoring of benthic assemblages.

## 5 Recommendations

Currently, CVC conducts twice annual (seasonal) monitoring of benthic communities in southern Lake Macquarie. The overarching aim of the project is to monitor for detectable changes in benthic assemblages associated with potential subsidence of the lake bed due to undermining.

Subtidal benthic habitats which are not dominated by benthic primary producers (eg seagrass and/or macroalgae), like those monitored by CVC, do not typically exhibit strong seasonal variation since they do not photosynthesise (and are therefore largely unaffected by changing light levels). Additionally, benthic environments are often quite stable with respect to sediment conditions that do not change on a cyclical nature with the seasons.

For these reasons and given the current absence of statistically relevant differences between benthic assemblages at CVC's impact monitoring sites when compared to the reference and control sites, EMM recommends that the frequency of CVC's benthic monitoring could be reduced to once per year. The recommended timing of annual monitoring is March (Autumn) to more closely capture any variation in benthic assemblages that occur following any summer temperature extremes, and to allow ongoing statistical analysis of the historical and future March monitoring data.

Importantly, the frequency of monitoring should be reviewed if monitoring results indicate impacts to benthic assemblages that are potentially associated with CVC operations, or if the local environmental conditions change substantially.

## 6 References

CVC 2019, *Benthic Communities Management Plan – Environmental Management Plan*, Chain Valley Colliery (14 November 2019).

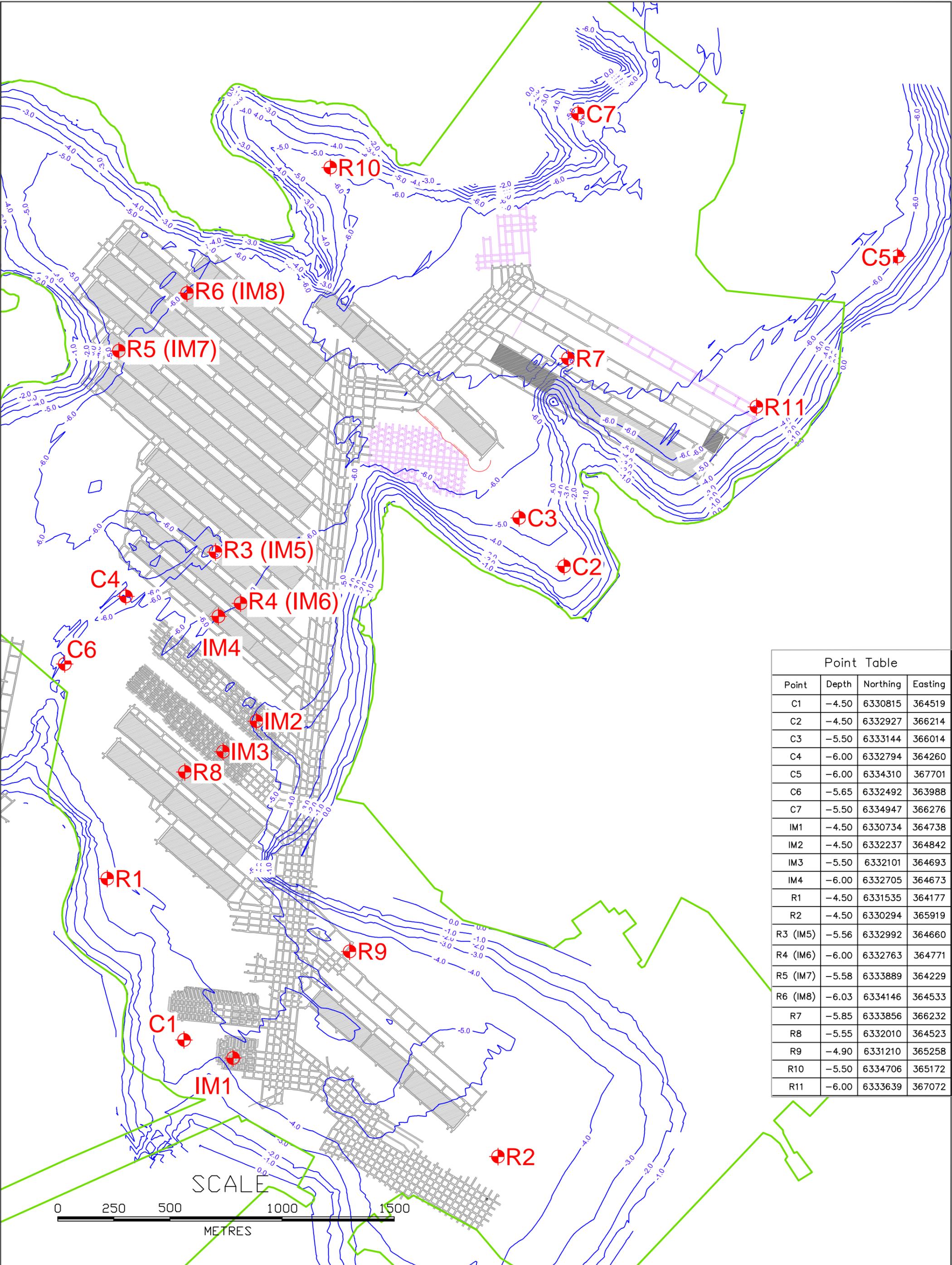
Clarke KR & Gorley RN 2006, *PRIMER v6: User Manual/Tutorial*. PRIMER-E, Plymouth 190pp.



# Appendix A

## CVC Benthic Monitoring Sites





Point Table

Point	Depth	Northing	Easting
C1	-4.50	6330815	364519
C2	-4.50	6332927	366214
C3	-5.50	6333144	366014
C4	-6.00	6332794	364260
C5	-6.00	6334310	367701
C6	-5.65	6332492	363988
C7	-5.50	6334947	366276
IM1	-4.50	6330734	364738
IM2	-4.50	6332237	364842
IM3	-5.50	6332101	364693
IM4	-6.00	6332705	364673
R1	-4.50	6331535	364177
R2	-4.50	6330294	365919
R3 (IM5)	-5.56	6332992	364660
R4 (IM6)	-6.00	6332763	364771
R5 (IM7)	-5.58	6333889	364229
R6 (IM8)	-6.03	6334146	364533
R7	-5.85	6333856	366232
R8	-5.55	6332010	364523
R9	-4.90	6331210	365258
R10	-5.50	6334706	365172
R11	-6.00	6333639	367072

Legend

- Fassifern Seam CVC Workings (December 2015)
- Proposed Fassifern Seam Workings
- Other Existing Workings (Fassifern Seam)
- Project Boundary - Chain Valley Mining Extension 1

**DELTA COAL**  
**CHAIN VALLEY COLLIERY**  
**BENTHIC MONITORING POINTS**  
**LAKE MACQUARIE**

SCALE:	1:15000	DATE:	24 April 2020
DRAWN:	T Chisholm	DRG NO:	C1S0120_1
CHECKED:	C Armit	REV NO:	15
		SIZE:	A3





