Delta Coal
Mannering & CVC Collieries

Lake Macquarie Benthos Survey
Results No. 22

By Dr Emma Laxton

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Summary

J.H. & E.S. Laxton – Environmental Consultants P/L was engaged by Mr. Lachlan McWha of Chain Valley Colliery to assess the potential effects of bord and pillar extraction mining beneath Lake Macquarie on benthic fauna.

The benthic survey was conducted on 7th and 12th September 2022 by Dr Emma Laxton of J.H. & E.S. Laxton – Environmental Consultants P/L. The survey involved the collection of benthos at 22 stations. The stations consisted of seven Control, eight Reference and seven Impact stations.

A total of 1981 benthic marine organisms greater than 1 mm in size were captured in the study area of Lake Macquarie during the survey. These organisms represented twelve species. The fauna included four species of polychaete worm; six species of bivalve; one species of brittle star; and one crab species. The greatest numbers of organisms were collected at station R10 (302 organisms), and the least numbers of organisms at station R7 (35 total).

The bivalve *Soletellina alba* was the most encountered organism and was collected in relatively large numbers throughout the study area. Polychaete worms were also common in the benthos.

Very few mussels were found alive during the survey. Mussel mortality may be due to the inflow of freshwater into the lake. Dissolved oxygen concentrations may not be a factor. Mine subsidence is also unlikely to be a cause of mussel deaths. The station with the greatest number of living mussels was R7 where samples were collected at around -5.85m AHD.

Species diversity at each station ranged from 3 to 8 species and was comparable with previous years. In September 2022, Control stations had a range of 5 to 7 species represented; Reference stations had a range of 4 to 7 species; and the Impact stations had a range of 3 to 8 species.

Seven species differentiated sampling stations during the September 2022 sampling period. These included the polychaete *Sthenelais petitiboneae* that characterized stations R9, R7 and C5, and the bivalve *Dosinia sculpta* that differentiated station R10.

There was variation between the sediments collected at each station within the study area. For most stations, the sediment collected off Summerland Point, Chain Valley Bay and Bardens Bay was largely composed of fine grey silt with small to large shell fragments. However, sediment collected at stations C7 and R10 also contained a large amount of coarse grey sand. The sediment sample collected at R7 was comprised of 98% shell

In September 2022, water quality profiles measured at each station recorded the effects of water depth on dissolved oxygen, salinity, conductivity and water temperature in Lake Macquarie. The concentration of dissolved oxygen, water temperature and pH decreased with depth. Conductivity was relatively uniform throughout the water column. Salinity increased slightly from surface to bottom.

Testing of the bottom water at each station found dissolved oxygen ranged from 93.8% to 109.2%. Mean dissolved oxygen of bottom waters was 101.1% saturation. Water temperature ranged from 17.09^{o}C to 17.87^{o}C, with a mean water temperature of 17.42^{o}C. Conductivity ranged from 49.99 mS/cm to 51.84 mS/cm. Mean conductivity of bottom water was 51.04 mS/cm. Salinity ranged from 32.72 ppt to 34.07 ppt, with a mean salinity of 33.49 ppt. Turbidity ranged from 2.3 NTU to 39.3 NTU. Mean turbidity was 12.1 NTU. pH ranged from 8.09 to 9.16, mean pH was 8.31.

Rainfall in the months preceding the survey were 11mm, 402.8mm, and 37.8mm for June, July and August respectively (Cooranbong Lake Macquarie AWS No. 61412). By 12th September a further 69 mm had fallen in the catchment.

These results appear to support the notion that increasing the water depth by up to 0.78m (SSD-5465 subsidence limit in Lake Macquarie) has, to date, had little to no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin.

1. Introduction

Lake Macquarie is the largest saline lake in New South Wales. It lies on the central coast between Sydney and Newcastle within the local government areas of Central Coast Council and Lake Macquarie Council. Lake Macquarie has a catchment of 700 square kilometers and a water surface area of 125 square kilometers (Bell & Edwards, 1980). The lake has a permanent entrance to coastal waters at Swansea.

The catchment of Lake Macquarie is largely rural with large areas of bushland and grazing land. The shoreline of Lake Macquarie is heavily urbanized, especially the eastern, western and northern shorelines. The region has a relatively long history of coal mining and power generation, with mining occurring since the late 1800s and the first power station at Lake Macquarie commencing operations in 1958.

Chain Valley Colliery is situated on the southern shores of Lake Macquarie near Mannering Park, NSW. The mine has been operating since 1963. Mining is continuing within the Chain Valley Coal Lease Area using the miniwall method. Prior to mining, there were three economically viable seams in the lease area, namely the Wallarah seam (not mined since 1997); the Great Northern seam, and the Fassifern seam. In 2018 Chain Valley Colliery went into voluntary receivership and was taken over by Great Southern Energy Pty Ltd (trading as Delta Coal) to provide coal for Vales Point Power Station.

Delta Coal is currently mining the Fassifern Seam beneath Lake Macquarie. As part of the protection of the lake foreshore, the mining leases require a protection zone. This zone, known as the High Water Mark (HWM) Subsidence Barrier, was calculated using a 35^{o} angle of draw from the depth of mining. The zone is approximately 130 meters wide. J.H. & E.S. Laxton – Environmental Consultants P/L was engaged by Mr. Lachlan McWha, Environmental Compliance Coordinator for Chain Valley Colliery, to assess the potential effects of pillar extraction mining on benthic fauna in Lake Macquarie.

The monitoring programme consists of 22 stations, seven Control, eight Reference and seven Impact stations. Control stations are in areas of lakebed sufficiently remote from previous or proposed mining. Reference stations are located in areas of lakebed above subsidence areas of previous mining. Impact stations are in areas of lakebed where subsidence is expected from future mining. Two depth zones within the mud basin were sampled, -4.5m AHD and -5.5 to -6.0m AHD.

This report presents the results of the just completed 22nd sampling of stations situated off Summerland Point, in Chain Valley Bay, Bardens Bay and Sugar Bay. These results will be compared with those obtained from the previous twenty-one surveys (February 2012 to March 2022). The September 2022 benthic survey was conducted between the 7th and 12th September. Water quality variables were measured on 12th September 2022.

2. Location of Sampling Stations

Figure 2.1 shows the location of sampling stations, depth contours of the lake, and the locations of existing and proposed underground mine workings. **Table 2.1** provides the exact location of each sampling station by latitude and longitude and by eastings and northings using WGS84 datum. The table also shows the depth of water at each station. **Figure 2.2** shows the extent of mining from March 2021 to March 2022, it is noted that all workings undertaken by Delta Coal from September 2021 have been classified as First Workings only.

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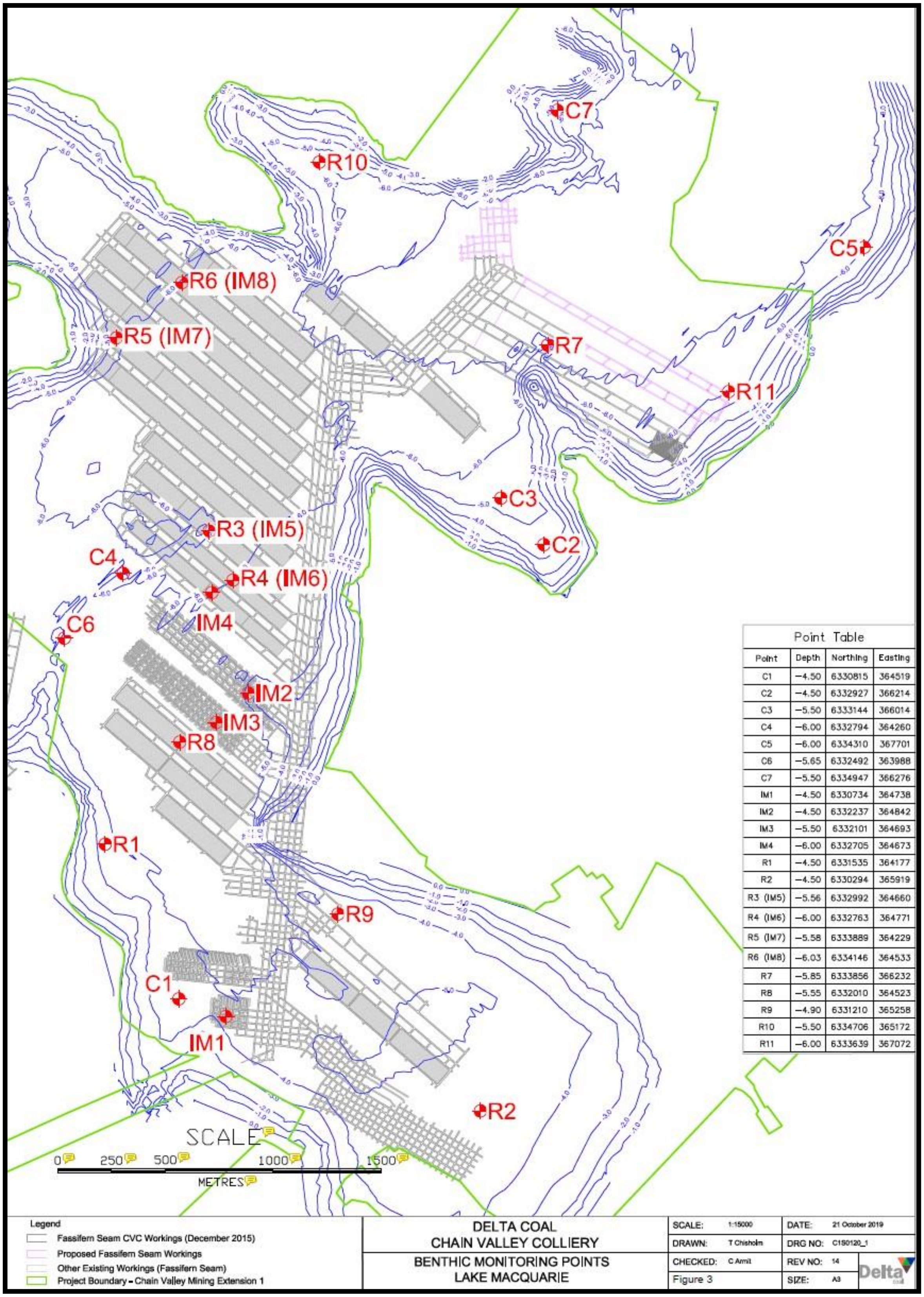


Point	Depth	Northing	Easting
C1	−4.50	6330815	364519
C2	−4.50	6332927	366214
C3	−5.50	6333144	366014
C4	−6.00	6332794	364260
C5	−6.00	6334310	367701
C6	−5.65	6332492	363988
C7	−5.50	6334947	366276
IM1	−4.50	6330734	364738
IM2	−4.50	6332237	364842
IM3	−5.50	6332101	364693
IM4	−6.00	6332705	364673
R1	−4.50	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

Figure 2.1 Location of benthic sampling stations

Table 2.1 Co-ordinates and water depth at each benthic sampling station

Station	Sample depth (m) AHD	Latitude	Longitude	MG-56 Easting	MG56 Northing
C1	-4.50	S33º 09' 10.69"	E151º 32' 50.11"	364519	6330815
C2	-4.50	S33º 08' 02.89"	E151º 33' 56.65"	366214	6332927
C3	-5.50	S33º 07' 55.78"	E151º 33' 49.05"	366014	6333144
C4	-6.00	S33º 08' 06.35"	E151º 32' 41.17"	364260	6332794
C5	-6.00			367701	6334310
C6	-5.50			363988	6332492
C7	-5.50			366276	6334947
IM1	-4.50	S33º 09' 13.44"	E151º 32' 58.51"	364738	6330734
IM2	-4.50	S33º 08' 24.67"	E151º 33' 03.34"	364842	6332237
IM3	-5.50	S33º 08' 29.02"	E151º 32' 57.52"	364693	6332101
IM4	-6.00	S33º 08' 09.42"	E151º 32' 57.04"	364873	6332705
R1	-4.50	S33º 08' 47.18"	E151º 32' 37.31"	364177	6331535
R2	-4.50	S33º 09' 28.23"	E151º 33' 43.87"	365919	6330294
R3 (IM5)	-5.50	S33º 08' 00.10"	E151º 32' 56.72"	364660	6332992
R4 (IM6)	-6.00	S33º 08' 07.58"	E151º 33' 00.88"	364771	6332763
R5(IM7)	-5.50	S33º 07' 30.78"	E151º 32' 40.55"	364229	6333889
R6 (IM8)	-6.00	S33º 07' 22.56"	E151º 32' 52.42"	364533	6334146
R7	-6.00			366232	6333856
R8	-5.50			364523	6332010
R9	-4.50			365258	6331210
R10	-5.50			365172	6334706
R11	-6.00			367072	6333639

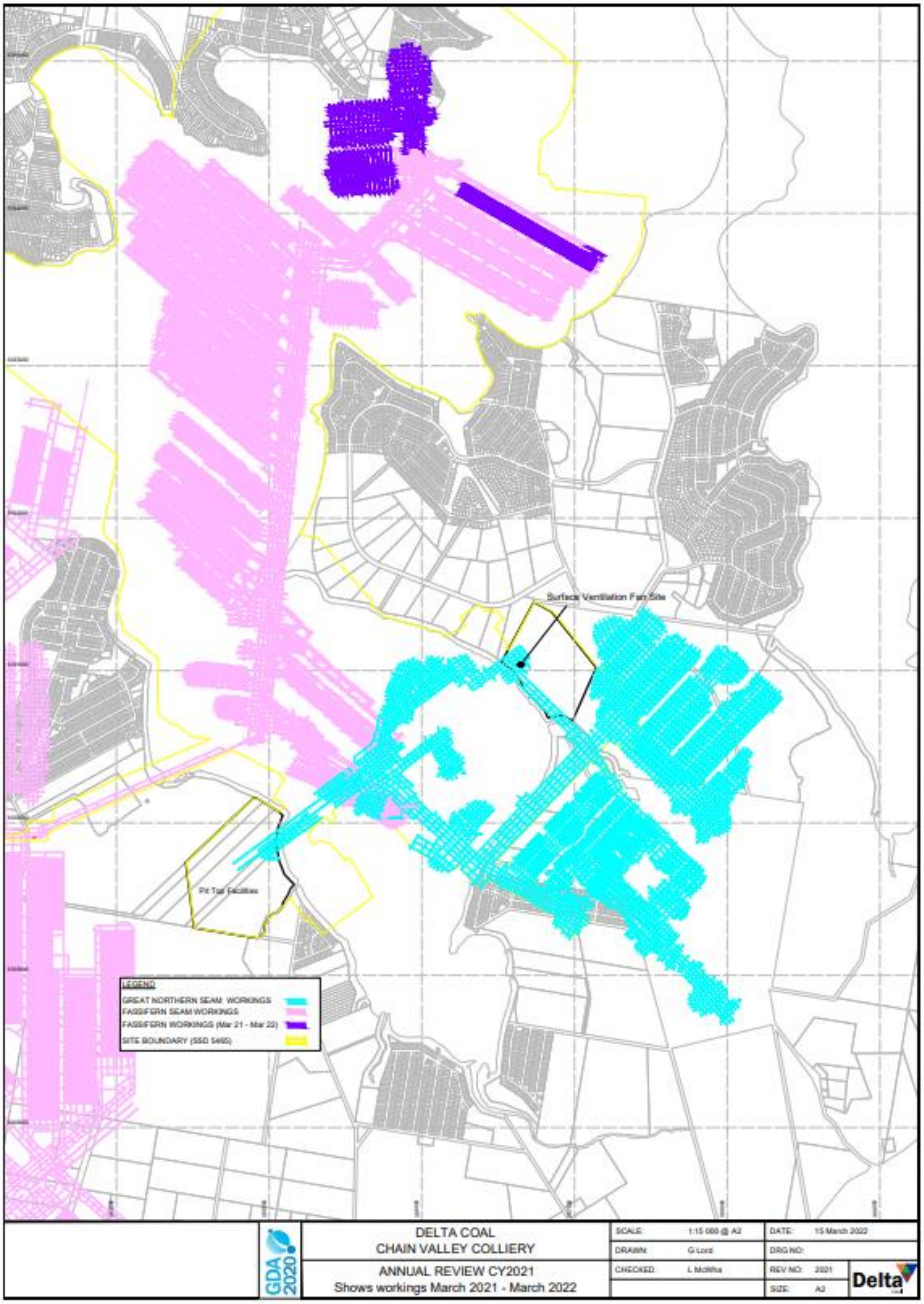


Figure 2.2 Extent of Fassifern Seam Workings from March 2021 – March 2022 (purple)

3. Sampling Procedure

Twenty-two stations were sampled in September 2022. At each station the following procedure was carried out:

- A GPS unit was used to locate the sampling station.
- A line with five sieve boxes (five replicates of 200 x 200 x 100 mm collection boxes with 1 mm mesh) and two core samplers (100 x 200 mm cylinders with 1 mm mesh) was cast overboard and secured as the boat drifted into position.
- The sieve boxes were filled using the forward momentum of the work boat.
- The samplers were then hauled to the surface, and the contents of each sampler placed in a clean, labeled zip-lock plastic bag.
- A 250mL jar was filled using the sediment collected from the core samplers.
- Processing of samples occurred in the laboratory.
- A water quality profile from surface to bottom was measured using a calibrated Yeo-Kal 618RU Water Quality Analyser. Water temperature, conductivity, salinity, pH, dissolved oxygen, turbidity and depth were measured. Each line of data was stored in the memory of the machine.

In the laboratory the marine benthic samples were treated in the following way:

- Each sample was tipped into a 1 mm mesh sieve and washed free of mud.
- The washed material from each sample was then placed into a tray and sorted for animals.
- Organisms and parts of organisms were removed, counted, identified and the results entered into a spread sheet. This process was repeated until the debris of the entire sample had been examined.
- Sorted organisms were preserved in formaldehyde solution.
- All shell remaining in the sample was kept for later examination.

The 250mL samples of whole sediment were treated in the following way:

- Each sample was tipped into a 1L measuring cylinder and the volume made up to 800mL with freshwater.
- The cylinders were stoppered and shaken vigorously to suspend the sediment in the

freshwater.

- The cylinders were then placed on the laboratory bench to allow the fractions of the sediment to settle.
- Fractions were decanted into separate measuring cylinders and allowed to settle.
- Once settled the volumes of each fraction (silt, sand, gravel and shell) were calculated and recorded. Results were displayed relative to the final volume of sediment collected.

4. Factors affecting the depth of water in Lake Macquarie

The bathymetric chart (**Figure 4.1**) of Lake Macquarie shows water depths relative to AHD throughout the year 1997. The actual depth of water above the lakebed varied greatly, between 0 and 1.3m above AHD.

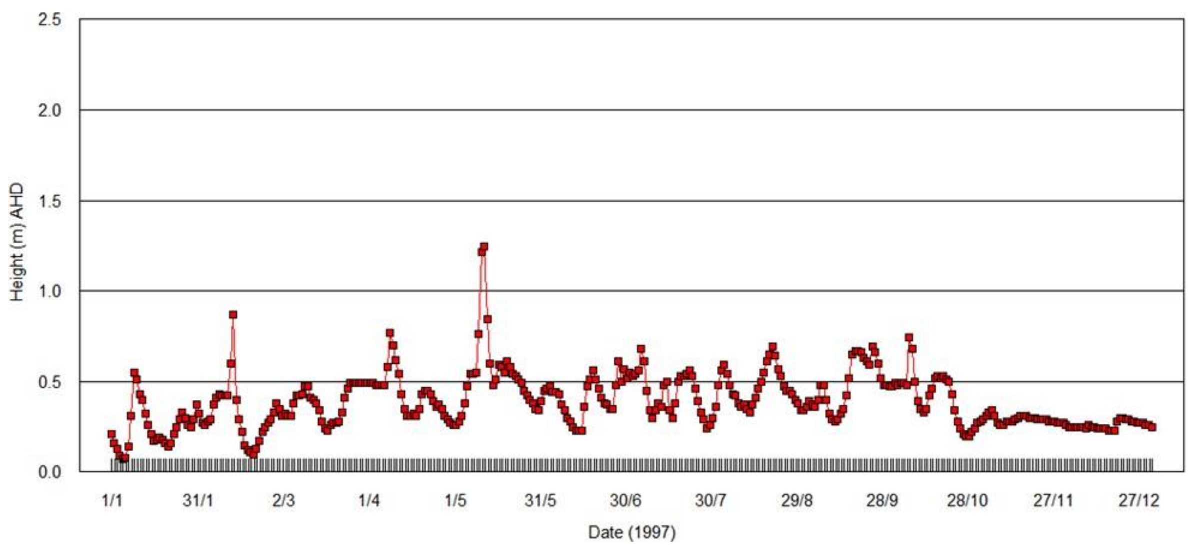


Figure 4.1 Water level changes in a coastal lagoon with an entrance open to coastal waters.

Water depths in coastal saline lakes with an open entrance to coastal waters vary due to combinations of the following factors:

- The body of Lake Macquarie is subject to tidal influence. The height of the tidal prism at Swansea Head may reach almost 2m (during spring tides) but by the time the body of the lake is reached, the tidal prism has been reduced to around 0.05m.

- The height of coastal waters and coastal lakes are influenced by changes in atmospheric pressure. The Tasman Sea acts as a huge barometer. When the atmospheric pressure is high the sea surface is depressed. This causes water to drain from Lake Macquarie causing the depth of water in the body of the lake to decrease. When the atmospheric pressure over the Tasman Sea is low, the surface of the sea bulges upwards. This raising of sea level causes water to flow into Lake Macquarie, increasing the water depth.

- Low pressure systems in the Tasman Sea almost always generate strong winds and coastal rainfall. The strong winds cause large swells to form that impact the coast. Wave setup at the entrance to Lake Macquarie causes the water level in the lake to rise as large volumes of seawater enter the system.

- Rainfall during a period of low atmospheric pressure causes runoff into catchment rivers and streams to increase. When this extra water reaches the body of Lake Macquarie, the water level rises in proportion to the runoff volume. This water is prevented from exiting the lake by wave setup at the entrance and the state of the tide. Under these circumstances, the level of the lake can rise to heights of a meter or more above AHD (**Figure 4.1**).

5. Benthos of the study area – February 2012 to September 2022

Table 5.1 shows the organisms found in the sediment samples collected off Summerland Point and in Chain Valley Bay between February 2012 and September 2022. **Plates 5.1** to **5.6** provide information about the benthic organisms present in the basin mud of Lake Macquarie, NSW.

Table 5.1 Organisms found in Benthos of Lake Macquarie (2012-2022)

Designated name	**Family or Species**	**Comments**
Anemone	Coelenterata	Found associated with mussel shells.
Planaria (Flat worm)	Platyhelminthes	2 specimens found in 2017.
Polychaete	*Sthenelais pettiboneae*	Most common polychaete present.
Polychaete	Cirratulidae	Present in small numbers.
Polychaete (mud tube)	Not yet identified	Present in small numbers.
Polychaete	*Chaetopterus*	Present in small numbers.
Polychaete	*Pectinaria sp*	First found in March 2019
Gastropod	*Nassarius jonasii*	Present in small numbers.
Gastropod	*Lepsiella* (*Bedeva*) *hanleyi*	Present in small numbers.
Gastropod	Bullimorph slug	One specimen found in August 2014.
Bivalve	*Corbula truncata*	Common as live animals and dead shells.
Bivalve	*Soletellina alba*	Common
Bivalve	*Paphia undulata*	Uncommon as live animals. Common as dead shells.
Bivalve	*Cyamiomactra mactroides*	Uncommon. (Brown or pink bivalve)
Bivalve	*Anadara trapezia*	Uncommon.
Bivalve	*Dosinia sculpta*	Many juveniles found in sandy sediment in September 2019.
Bivalve	*Trichomya hirsuta*	Common as dead shells. Found in large clumps at C2, C6, R3, R7, IM2 and IM3.
Bivalve	*Saccostrea glomerata*	Oysters were first observed on mussels and other bivalves at C4 and C6 in 2021.
Ophuroid	Brittle star	Uncommon. Found amongst mussel clumps and on mud.
Echinoid	Sea urchin	Uncommon. Found at C5 and C7 in 2021.
Sponge	White calcareous sponge	Specimen found associated with mussels.
	Pink sponge	Small species found on mud surface.
	Red sponge	Several specimens found in 2019.
Crabs	Small	Uncommon.
Prawn	Small	One specimen taken in March 2013 at R3 and one specimen in September 2013 at C4.

Fish	Small (35mm)	One specimen taken at C3 (September 2012), at R1 (September 2013) and at IM4 in March 2017. 1 specimen in C6 in 2019.

Plate 5.1 Annelid species found in the benthos of Lake Macquarie (February 2012 – September 2022).

Phylum: Annelida
Class: Polychaeta
Subclass: Errantia
Order: Phyllodocida
Family: Sigalionidae
Species: *Sthenelais pettiboneae*

Remarks: Found in marine environments.

Phylum: Annelida
Class: Polychaeta
Subclass: Canalipalpata
Order: Terebellida
Family: Cirratulidae

Remarks: Cirratulids vary in size from 1-20 cm long. They are mostly burrowers in soft sediments but some live in rock crevices. The head is conical or wedge-shaped and has no antennae. The body is generally cylindrical, tapering at both ends. Cirratulids are characterised by many simple elongate filaments along the body. The genera are poorly defined.

Phylum: Annelida
Class: Polychaeta
Subclass: Canalipalpata
Order: Terebellida
Family: Chaetopteridae
Genus: *Chaetopterus*

Remarks: *Chaetopterus* or the parchment worm or parchment tube worm is a genus of marine polychaete worm that live in a tube constructed in sediments or attaches to a rocky or coral reef substrate. The common name arises from the parchment-like appearance of the tubes that house these worms.

Phylum: Annelida
Class: Polychaeta
Subclass: Canalipalpata
Order: Terebellida
Family: Pectinariidae

Remarks: Pectinariidae live vertically, head-down in sandy sediments, with the narrow tip of the conical tube at about the sediment surface. They feed on buried organic matter within the sediments. *Pectinaria anitpoda* is one of the most common and widespread member of this family. Found in inshore waters and off the continental shelf to a depth of about 90 m.

Plate 5.2 Gastropod species found in the benthos of Lake Macquarie (February 2012 – March 2022).

Phylum: Mollusca
Class: Gastropoda
Superfamily: Buccinoidea
Family: Nassariidae
Species: *Nassarius jonasii*

Remarks: Endemic to Australia; Noosa Heads, Qld, to SA. Inhabit sand and mud flats in estuaries and lagoons, intertidal down to 100 m. Most *Nassarius* species are very active scavengers. They often burrow into marine substrates and then wait with only their siphon protruding, until they smell nearby food.

Phylum: Mollusca Class:
Gastropoda
Order: Neogastropoda
Family: Muricidae
Species: *Lepsiella* (*Bedeva*) *hanleyi*

Remarks: Common name mussel drill. Shell up to 32 mm, with angulated whorls, a high spire and moderately long anterior canal and with both spiral threads and axial ribs. Endemic to Australia. Found in temperate and southern parts of tropical Australia. Lives mainly on sheltered shores, including estuaries and often in association with mangroves. Feeds by drilling holes in bivalves. Lays lens-shaped capsules and development is direct.

Plate 5.3 Bivalve species found in the benthos of Lake Macquarie (February 2012 – September 2022).

Phylum: Mollusca

Class: Bivalvia

Order: Myoida

Family: Corbulidae

Species: *Corbula truncata*

Remarks: Marine bivalve mollusc.

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Psammobiidae

Species: *Soletellina alba*

Remarks: Posterior and anterior margins almost parallel. Shell thin and normally bluish, rarely white. Lives intertidally and subtidally in sand and mud, especially in sheltered environments. Occurs all around Australia; not recorded elsewhere.

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Veneridae

Species: *Paphia undulata*

Remarks: Saltwater clam, marine bivalve mollusc. Inhabits inshore shallow sandy seabeds.

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Veneridae

Species: *Dosinia sculpta*

Remarks: *Dosinia* is a genus of saltwater clams, marine bivalve molluscs in the family Veneridae, (subfamily Dosiniinae). The shell of *Dosinia* species is disc-like in shape, usually white, and therefore is reminiscent of the shells of Lucinid bivalves.

Typically found in the intertidal zone at the water's edge at a mean distance from sea level of -15 meters (-50 feet).

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Cyamiidae

Species: *Cyamiomactra mactroides*

Phylum: Mollusca

Class: Bivalvia

Order: Arcoida

Family: Arcidae

Species: *Anadara trapezia*

Remarks: Sydney cockle, or ark cockle is an estuarine filter-feeding bivalve. Its calcareous, heavily-ribbed, shell can grow to approximately 7 to 8 cm across. Its current range is along the east coast of Australia, from Queensland to Victoria. It has been used as an indicator species to study levels of the metals selenium, copper and cadmium.

Phylum: Mollusca

Class: Bivalvia

Order: Mytiloida

Family: Mytilidae

Species: *Trichomya hirsuta*

Remarks: The hairy mussel is a major part of the megafauna of Lake Macquarie. It is tolerant of low oxygen levels in the water and its temperature tolerance range has been researched in connection with using the waters of the lake for cooling power stations.

Hairy mussels have been used as bioindicators to monitor concentrations of heavy metals (namely Pb, Cd, Cu, Zn, Co, Ni, and Ag) in marine environments.

Phylum: Mollusca

Class: Bivalvia

Order: Ostreoida

Family: Pectinidae

Species: *Saccostrea glomerata*

Remarks: Sydney rock oysters are endemic to Australia and New Zealand. In Australia it is found in bays, inlets and sheltered estuaries from Wingan Inlet in eastern Victoria, along the east coast of NSW and up to Hervey Bay QLD, around northern Australia and down the west coast to Shark Bay in WA. Sydney rock oysters are capable of tolerating a wide range of salinities. They are usually found in the intertidal zone to 3 metres below the low water mark.

Plate 5.4 Brittle stars found amongst the mussel beds of Lake Macquarie, NSW.

Phylum: Echinodermata

Class: Ophiuroidea

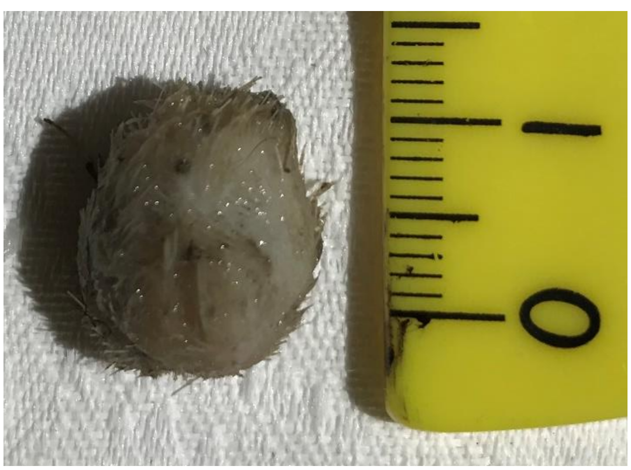
Order: Ophiurida

Family: Ophionereididae

Species: *Ophionereis schayeri*

Remarks: Largest and most common brittle star found in Sydney waters. Brittle stars have five long, slender arms which radiate out from a central disc. The mouth is located in the centre of the underside of the disc. There is no anus. Offshore, brittle stars form dense aggregations. In intertidal zones, they are typically found as single individuals in crevices, under stones and amongst seaweed. They feed by raising their arms above the substrate; extending tube-feet; and removing particles from the water. They pass food along the arms to the mouth. They also scavenge on decaying matter. They inhabit the hairy mussel beds of Lake Macquarie.

Plate 5.5 Sand dollar sea urchins found in Lake Macquarie, NSW



Phylum: Echinodermata

Class: Echinoidea

Order: Clypeasteroida

Family: Spatangidae

Species: *Echinocardium cordatum*

Remarks: Sand dollars are small in size. They possess a rigid skeleton called a test. The test consists of calcium carbonate plates arranged in a fivefold symmetric pattern.

Plate 5.6 Crab species found in Lake Macquarie, NSW

Phylum: Arthropoda
Class: Malacostraca
Order: Decapoda

6. Molluscs found as dead shells

Benthic organism samples collected between February 2012 and September 2022 included a large component of shell. **Plates 6.1** and **6.2** show the mass of shell obtained from the sixty 200x200x100mm samples of sediment taken in February 2012. **Plate 6.3** and **Plate 6.4** show the mass of shell collected in September 2012 and **Plates 6.5** and **6.6** show the mass of shells collected in March 2013.

Plate 6.1 Large shell removed from samples during sorting process - February 2012 survey.

Plate 6.2 Small shells removed from samples during sorting process - February 2012 survey.

Plate 6.3 Large shells removed from samples - September 2012 survey.

Plate 6.4 Small shells removed from samples during sorting in September 2012.

Plate 6.5. Large shells removed from samples during sorting in March 2013.

Plate 6.6. Small shells removed from samples during sorting in March 2013.

Similar masses of shell were found in the samples of the September 2013 to September 2022 surveys. The following organisms were identified amongst the shell:

1. *Paphia undulata*
2. *Anomia sp.*
3. *Dosinia sculpta*
4. *Trichomya hirsuta*
5. *Katelysia rhytiphora*
6. *Pecten sp.*
7. *Chlamys sp.*
8. *Saccostrea glomerata*
9. *Corbula truncata*
10. *Batillaria (Velacumantis) australis*
11. *Conuber sp.*
12. *Anadara trapezia*

Plates 6.7 and **6.8** provide information about the mollusc and gastropod species found as dead shells in the basin mud of Lake Macquarie, New South Wales during the periods of monitoring.

Plate 6.7 Mollusc species found as dead shells in the benthos of Lake Macquarie, NSW.

Phylum: Mollusca

Class: Bivalvia

Order: Ostreoida

Family: Anomiidae

Genus: *Anomia*

Remarks: Genus of saltwater clam, marine bivalve mollusc. Known as "jingle shells". Common in both tropical and temperate oceans and live primarily attached to rock or other shells via a calcified byssus that extends through the lower valve. *Anomia* shells tend to take on the surface shape of what they are attached to; thus if an *Anomia* is attached to a scallop shell, the shell of the *Anomia* will also show ribbing.

Phylum: Mollusca

Class: Bivalvia

Order: Veneroida

Family: Veneridae

Genus: *Katelysia*

Species: *Katelysia rhytiphora*

Remarks: Commonly known as mud cockles, this group of commercially important bivalves often represents a major faunal component of shallow estuarine and marine embayments. *K. rhytiphora* is broadly distributed around Australia's temperate coastline from Augusta, Western Australia to Port Jackson, NSW.

Phylum: Mollusca
Class: Bivalvia
Order: Ostreoida
Family: Pectinidae
Genus: *Pecten*

Remarks: Genus of large saltwater clams or scallops. Marine bivalve mollusc.

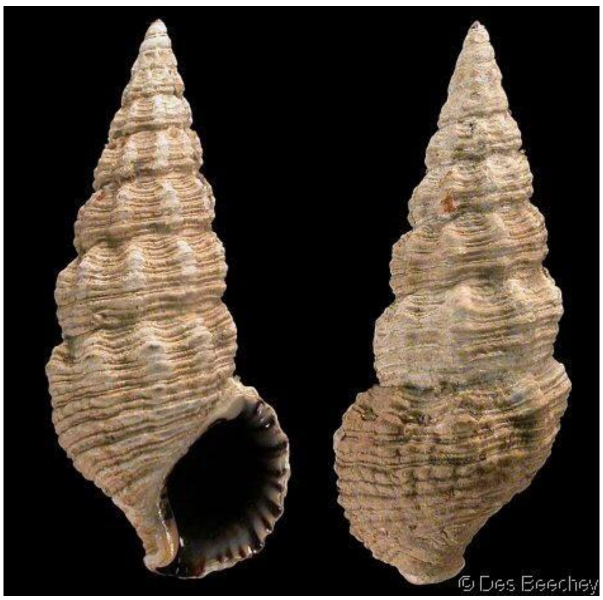
Phylum: Mollusca
Class: Bivalvia
Order: Ostreoida
Family: Pectinidae
Genus: *Chlamys*

Remarks: Genus of saltwater clams or scallops. Marine bivalve mollusc.

Plate 6.8 Gastropod species found as dead shells in the benthos of Lake Macquarie, NSW.

Phylum: Mollusca
Class: Gastropoda
Family: Naticidae
Genus: *Conuber*
Species: *Conuber sordidum*

Remarks: Species of predatory sea snail. A marine gastropod mollusc known commonly as the moon snail. Lives on intertidal muddy sand flats near mangroves or sea weed.



Phylum: Mollusca
Class: Gastropoda
Family: Batillariidae
Species: Batillaria australis

Remarks: The Australian Mud Whelk is a marine gastropod found on mud flats in estuaries, river mouths and mangrove swamps. The snail has a high resistance to predation and environmental tolerance, which may partially explain its success as an invasive species. This species is one of the hosts for the flatworm parasite *Austrobilharzia*. Larvae of the flatworm are discharged from the snail into the surrounding water. They normally burrow into the legs of wading birds and complete their life cycle, but may burrow though the skin of humans, causing "bathers itch”.

7. Benthic organisms in the study area - September 2022

Table 7.1 shows the organisms found at each station sampled off Summerland Point and in Chain Valley Bay and Bardens Bay in September 2022.

Table 7.1 Organisms found at sampling stations on 7th and 12th September 2022.

Control Station C1 Depth -4.50m AHD 56 364519 6330815 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C1.1	0	0	0	0	0	0	2	0	0	0	0	0	0	0
C1.2	1	0	0	0	0	1	13	0	0	0	0	0	0	0
C1.3	0	1	0	0	0	3	18	0	0	0	0	0	0	0
C1.4	0	0	0	0	0	1	17	0	0	0	0	0	0	0
C1.5	0	0	0	0	0	1	19	1	0	0	0	0	0	0
Mean/station	0.2	0.2	0.0	0.0	0.0	1.2	13.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	5	5	0	0	0	30	345	5	0	0	0	0	0	0
No. species	**5**										**Total Organisms at Station**			**78**

Control Station C2 Depth -4.50m AHD 56 366214 6332927 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C2.1	1	1	0	0	0	9	37	0	0	0	0	0	0	0
C2.2	3	1	0	0	0	2	30	1	0	0	0	0	0	0
C2.3	0	2	0	0	0	3	16	0	0	0	0	0	0	0
C2.4	1	1	0	0	0	11	20	0	0	0	0	0	0	0
C2.5	0	1	0	0	0	0	23	0	0	0	0	0	0	0
Mean/station	1.0	1.2	0.0	0.0	0.0	5.0	25.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	25	30	0	0	0	125	630	5	0	0	0	0	0	0
No. species	**5**										**Total Organisms at Station**			**163**

Control Station C3 Depth -5.50m AHD 56 366014 6333144 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C3.1	0	2	1	0	0	0	9	0	0	0	0	0	0	0
C3.2	0	0	0	0	0	0	4	0	0	0	0	0	0	0
C3.3	4	2	0	0	0	1	21	0	1	0	0	0	0	0
C3.4	1	1	0	0	0	0	15	1	0	0	0	0	0	0
C3.5	0	0	1	0	0	0	11	0	0	0	0	0	0	0
Mean/station	1.0	1.0	0.4	0.0	0.0	0.2	12.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
no./m2	25	25	10	0	0	5	300	5	5	0	0	0	0	0
No. species	**7**										**Total Organisms at Station**			**75**

Control Station C4 Depth -5.50m AHD 56 364260 6332794 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C4.1	0	1	1	0	0	0	11	0	0	0	0	0	0	0
C4.2	2	0	0	0	1	0	15	1	0	0	0	0	0	0
C4.3	0	0	0	0	0	1	14	0	0	0	0	0	0	0
C4.4	0	0	0	0	0	1	7	0	0	0	0	0	0	0
C4.5	1	1	0	0	0	0	16	0	0	0	0	0	0	0
Mean/station	0.6	0.4	0.2	0.0	0.2	0.4	12.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	15	10	5	0	5	10	315	5	0	0	0	0	0	0
No. species	**7**										**Total Organisms at Station**			**73**

Control Station C5 Depth -5.50m AHD 56 367701 6334510 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C5.1	2	2	1	0	0	0	7	0	0	0	0	0	0	0
C5.2	0	1	0	0	0	0	5	0	0	0	0	0	0	0
C5.3	0	2	0	0	0	0	13	0	0	0	0	0	1	0
C5.4	0	1	0	0	0	0	19	0	0	0	0	0	1	1
C5.5	1	3	1	0	0	0	8	0	0	0	0	0	0	0
Mean/station	0.6	1.8	0.4	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.4	0.2
no./m2	15	45	10	0	0	0	260	0	0	0	0	0	10	5
No. species	**6**										**Total Organisms at Station**			**69**

Control Station C6 Depth -5.50m AHD 56 363988 6332492 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C6.1	2	0	0	0	0	3	2	0	0	0	0	0	0	0
C6.2	2	0	0	0	0	2	11	0	0	0	0	0	0	0
C6.3	3	0	0	0	0	3	5	0	0	0	0	0	0	0
C6.4	1	0	1	0	0	2	8	0	0	0	0	0	0	0
C6.5	0	1	1	0	0	2	9	0	0	0	0	0	0	0
Mean/station	1.6	0.2	0.4	0.0	0.0	2.4	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	40	5	10	0	0	60	175	0	0	0	0	0	0	0
No. species	**5**										**Total Organisms at Station**			**58**

Control Station C7 Depth -5.50m AHD 56 364736 6334947 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C7.1	0	1	0	0	0	0	26	0	0	0	0	0	0	0
C7.2	2	3	0	0	0	1	22	0	0	0	0	0	0	0
C7.3	0	2	2	0	0	0	16	0	0	0	0	0	0	0
C7.4	0	2	1	1	0	0	9	0	0	0	0	0	0	0
C7.5	0	1	1	0	0	0	13	0	0	0	0	0	0	0
Mean/station	0.4	1.8	0.8	0.2	0.0	0.2	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	45	20	5	0	5	430	0	0	0	0	0	0	0
No. species	**6**										**Total Organisms at Station**			**103**

Station R1 Depth -4.50m AHD 56 364177 6331535 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R1.1	1	2	0	0	0	0	16	0	0	0	0	0	0	0
R1.2	1	1	1	0	0	4	21	0	0	0	0	0	0	0
R1.3	0	2	0	0	0	4	18	0	0	0	0	0	0	0
R1.4	0	2	1	0	1	1	20	0	0	0	0	0	0	0
R1.5	0	2	0	0	0	1	22	0	0	0	0	0	0	0
Mean/station	0.4	1.8	0.4	0.0	0.2	2.0	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	45	10	0	5	50	485	0	0	0	0	0	0	0
No. species	**6**										**Total Organisms at Station**			**121**

Station R2 Depth -4.50m AHD 56 365919 6330294 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R2.1	0	1	0	0	0	3	8	0	0	0	0	0	0	0
R2.2	0	0	0	0	0	0	4	0	0	0	0	0	0	0
R2.3	1	0	1	0	0	1	10	0	0	0	0	0	0	0
R2.4	1	1	0	0	0	1	5	0	0	0	0	0	0	0
R2.5	1	0	0	0	0	1	9	0	0	0	0	0	0	0
Mean/station	0.6	0.4	0.2	0.0	0.0	1.2	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	15	10	5	0	0	30	180	0	0	0	0	0	0	0

No. species **5** **Total Organisms at Station** **48**

Station R3 (now IM5) Depth -5.50m AHD 56 364660 6332992 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R3.1	0	2	0	0	3	0	4	0	0	0	0	0	0	0
R3.2	1	4	0	0	0	1	6	0	0	0	0	0	0	0
R3.3	1	4	0	0	1	0	12	0	0	0	0	0	0	0
R3.4	5	5	0	0	0	1	12	0	0	0	0	0	0	0
R3.5	1	5	1	0	0	0	1	0	0	0	2	0	0	0
Mean/station	1.6	4.0	0.2	0.0	0.8	0.4	7.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
no./m2	40	100	5	0	20	10	175	0	0	0	10	0	0	0

No. species **7** **Total Organisms at Station** **72**

Station R4 (now IM6) Depth -6.00m AHD 56 364771 6332763 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R4.1	0	0	0	0	0	1	2	1	0	0	0	0	0	0
R4.2	0	2	1	0	0	0	8	0	0	0	0	0	0	0
R4.3	0	0	0	0	0	0	10	0	0	0	0	0	0	0
R4.4	0	0	0	0	0	0	5	0	0	0	0	0	0	0
R4.5	1	0	0	0	0	3	8	0	0	0	0	0	0	0
Mean/station	0.2	0.4	0.2	0.0	0.0	0.8	6.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	5	10	5	0	0	20	165	5	0	0	0	0	0	0

No. species **6** **Total Organisms at Station** **42**

Station R5 (now IM7) Depth -6.00m AHD 56 364229 6333889 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R5.1	0	0	0	0	0	0	15	0	0	0	0	0	0	0
R5.2	0	0	1	0	0	0	12	0	0	0	0	0	0	0
R5.3	2	1	1	0	0	2	3	0	0	0	0	0	0	0
R5.4	0	1	0	0	0	1	15	0	0	0	0	0	0	0
R5.5	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Mean/station	0.4	0.4	0.4	0.0	0.0	0.6	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	10	10	0	0	15	245	0	0	0	0	0	0	0

No. species **5** **Total Organisms at Station** **58**

Station R6 (now IM8) Depth -6.00m AHD 56 364533 6334146 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R6.1	2	0	0	0	0	0	12	0	0	0	0	0	0	0
R6.2	0	1	0	0	0	1	21	0	0	0	0	0	0	0
R6.3	0	1	0	0	0	2	18	0	0	0	0	0	0	0
R6.4	0	1	0	0	0	1	18	0	0	0	0	0	0	0
R6.5	0	0	0	0	0	3	25	0	0	0	0	0	0	0
Mean/station	0.4	0.6	0.0	0.0	0.0	1.4	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	15	0	0	0	35	470	0	0	0	0	0	0	0

No. species **4** **Total Organisms at Station** **106**

Station R7 Depth -6.00m AHD 56 366232 6333856 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R7.1	0	0	0	1	0	0	0	0	0	0	12	0	0	0
R7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R7.3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
R7.4	0	0	1	0	0	0	0	0	0	0	18	1	0	0
R7.5	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Mean/station	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.2	0.0	0.0
no./m2	0	0	10	5	0	0	0	0	0	0	155	5	0	0

No. species **4** **Total Organisms at Station** **35**

Station R8 Depth -6.00m AHD 56 364323 63322010 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R8.1	2	1	0	0	0	1	11	0	0	0	0	0	0	0
R8.2	0	0	1	0	1	0	7	0	0	0	0	0	0	0
R8.3	0	0	0	0	0	0	13	0	0	0	0	0	0	0
R8.4	0	1	0	0	0	0	6	0	0	0	0	0	0	0
R8.5	0	0	0	0	0	0	11	0	0	0	0	0	0	0
Mean/station	0.4	0.4	0.2	0.0	0.2	0.2	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	10	5	0	5	5	240	0	0	0	0	0	0	0

No. species **6** **Total Organisms at Station** **55**

Station R9 Depth -6.00m AHD 56 366232 6331210 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R9.1	2	0	7	0	0	0	0	0	0	0	0	0	0	0
R9.2	0	1	0	0	1	1	22	0	0	0	0	0	0	0
R9.3	0	3	0	0	0	2	16	0	0	0	0	0	0	0
R9.4	0	0	0	0	0	2	7	1	0	0	0	0	0	0
R9.5	0	0	0	0	0	1	5	0	0	0	0	0	0	0
Mean/station	0.4	0.8	1.4	0.0	0.2	1.2	10.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	20	35	0	5	30	250	5	0	0	0	0	0	0

No. species **7** **Total Organisms at Station** **71**

Station R10 Depth -6.00m AHD 56 365172 6334708 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R10.1	0	1	0	0	0	2	51	0	9	0	0	0	0	0
R10.2	3	4	0	2	0	3	36	0	2	0	0	0	0	0
R10.3	1	2	0	0	0	0	80	0	10	0	0	0	0	0
R10.4	0	2	0	0	0	4	49	0	4	0	0	0	0	0
R10.5	2	3	0	0	0	2	26	0	4	0	0	0	0	0
Mean/station	1.2	2.4	0.0	0.4	0.0	2.2	48.4	0.0	5.8	0.0	0.0	0.0	0.0	0.0
no./m2	30	60	0	10	0	55	1210	0	145	0	0	0	0	0

No. species 6 **Total Organisms at Station** 302

Station R11 Depth -6.00m AHD 56 367072 6333638 Sampled 12th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
R11.1	0	1	0	0	0	0	7	0	0	0	0	0	0	0
R11.2	1	0	0	0	0	0	14	1	0	0	0	0	0	0
R11.3	0	3	0	0	0	0	13	0	0	0	0	0	0	0
R11.4	0	2	1	0	0	0	7	1	0	0	0	0	0	0
R11.5	0	2	0	0	0	0	12	0	0	0	0	0	0	0
Mean/station	0.2	1.6	0.2	0.0	0.0	0.0	10.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	5	40	5	0	0	0	265	10	0	0	0	0	0	0

No. species 5 **Total Organisms at Station** 65

Station IM1 Depth -4.50m AHD 56 364738 6330734 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
IM1.1	3	2	0	0	0	1	16	0	0	0	0	0	0	0
IM1.2	0	1	0	0	0	2	3	0	0	0	0	0	0	0
IM1.3	0	0	2	0	0	0	20	0	0	0	0	0	0	0
IM1.4	5	0	2	0	0	1	10	0	0	0	0	0	0	0
IM1.5	2	0	1	0	0	1	17	0	0	0	2	0	0	0
Mean/station	2.0	0.6	1.0	0.0	0.0	1.0	13.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0
no./m2	50	15	25	0	0	25	330	0	0	0	10	0	0	0

No. species 6 **Total Organisms at Station** 91

Station IM2 Depth -4.50m AHD 56 364842 6332237 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
IM2.1	0	3	0	0	0	0	6	0	0	0	4	0	0	0
IM2.2	2	1	0	0	2	1	2	1	0	0	0	0	0	0
IM2.3	0	0	3	0	0	2	6	0	0	0	0	0	0	0
IM2.4	0	3	2	0	0	0	9	0	0	0	0	0	0	0
IM2.5	3	3	3	0	0	2	3	0	0	0	0	0	0	0
Mean/station	1.0	2.0	1.6	0.0	0.4	1.0	5.2	0.2	0.0	0.0	0.8	0.0	0.0	0.0
no./m2	25	50	40	0	10	25	130	5	0	0	20	0	0	0

No. species 8 **Total Organisms at Station** 61

Station IM3 Depth -5.50m AHD 56 364693 6332101 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
IM3.1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
IM3.2	0	0	0	0	2	0	10	1	0	0	0	0	0	0
IM3.3	2	0	0	0	0	1	11	0	0	0	0	0	0	0
IM3.4	0	0	0	0	0	0	14	0	0	0	0	0	0	0
IM3.5	0	1	0	0	0	2	13	0	0	0	0	0	0	0
Mean/station	0.4	0.2	0.0	0.0	0.4	0.6	9.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	5	0	0	10	15	245	5	0	0	0	0	0	0
No. species	**6**											**Total Organisms at Station**		**58**

Station IM4 Depth -6.00m AHD 56 364673 6332705 Sampled 7th September 2022

Replicates	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete Cirratulidae	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
IM4.1	1	0	0	0	0	0	8	0	0	0	0	0	0	0
IM4.2	0	1	0	0	0	0	9	0	0	0	0	0	0	0
IM4.3	0	3	0	0	0	0	2	0	0	0	0	0	0	0
IM4.4	1	3	0	0	0	0	9	0	0	0	0	0	0	0
IM4.5	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Mean/station	0.4	1.6	0.0	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	10	40	0	0	0	0	145	0	0	0	0	0	0	0
No. species	**3**											**Total Organisms at Station**		**39**

Total organisms collected 1981
Total number of species recorded 12

A total of 1981 benthic marine organisms greater than 1 mm in size were captured in the study area of Lake Macquarie during the September 2022 survey of 22 stations (**Table 7.1**). Twelve species of benthic marine organisms were found. The fauna included four species of polychaete worm (**Plate 5.1**); six species of bivalve (**Plate 5.3**); one species of brittle star (**Plate 5.4**); and one crab species.

In September 2022, the greatest numbers of organisms were collected at stations R10 (302 organisms), C2 (163 organisms), R1 (121 organisms), R6 now IM8 (106 organisms), and C7 (103 organisms). The stations with the least numbers of organisms were R7 (35 total), IM4 (39 organisms), R4 now IM6 (42 total), R2 (48 total) and R8 (55 total) (**Table 7.1**).

The bivalve *Soletellina alba* was the most commonly encountered organism and was collected in relatively large numbers throughout the study area. The number of *S. alba* in each replicate sample ranged from 0 to 80 and the species was present at 21 out of the 22 stations. The majority of *S. alba* were juveniles. Polychaete worms were also common in the benthos (**Table 7.1**). Other species recorded included the bivalves *Corbula truncata*, *Dosinia sculpta* and *Paphia undulata*; the gastropod *Nassarius jonassii*; and the brittle star *Ophionereis schayeri*.

Very few mussels were found alive during the survey. *Trichomya hirsuta* was found alive in small numbers at stations R7, R3 now IM5, IM1 and IM2 only (**Table 7.1**). The mussel mortality may be due to the inflow of freshwater into the lake as opposed to low dissolved oxygen concentrations. Mine subsidence is unlikely to be a factor. The station with the greatest number of living mussels was R7 where samples were collected at around -5.85m AHD.

At the time of survey, species diversity at each station ranged from 3 to 8 species and was comparable with previous years (**Table 7.2**). In September 2022, Control stations had a range of 5 to 7 species; Reference stations had a range of 4 to 7 species; and the Impact stations had a range of 3 to 8 species.

Table 7.2 Number of species found at each Station from February 2012 to September 2022

Station	C1	C2	C3	C4	C5	C6	C7	R1	R2	R3	R4
Feb 2012	10	5	5	7				8	8	5	5
Sept 2012	3	6	4	4				6	3	4	5
March 2013	4	5	7	7				6	5	6	5
Sept 2013	6	6	3	7				5	6	5	4
March 2014	4	3	5	5				6	4	5	3
Sept 2014	3	4	4	8				6	5	6	6
March 2015	3	3	5	3				5	3	6	5
Sept 2015	5	4	4	3				5	3	4	6
March 2016	6	4	5	5	5			6	5	6	4
Sept 2016	7	3	6	5	4	8		8	4	5	6
March 2017	2	4	5	3	5	5		4	5	4	5
Sept 2017	4	4	4	4	4	5		4	3	6	5
March 2018	4	4	8	4	4	3	5	7	8	5	4
Sept 2018	3	4	4	6	5	5	5	4	4	5	5
March 2019	6	3	4	4	6	5	3	4	5	7	3
Sept 2019	5	6	5	5	4	5	6	4	3	7	4
March 2020	5	6	6	4	7	3	6	6	6	7	4
August 2020	6	5	4	4	3	5	5	4	5	7	4
March 2021	5	6	3	4	5	2	2	5	4	7	4
Sept 2021	4	4	7	6	7	7	6	5	4	8	3
March 2022	5	6	4	7	6	7	4	6	4	9	7
Sept 2022	5	5	7	7	6	5	6	6	5	7	6

Station	R5	R6	R7	R8	R9	R10	R11	IM1	IM2	IM3	IM4
Feb 2012								7	4	4	5
Sept 2012								4	4	3	5
March 2013								7	5	5	5
Sept 2013								4	3	4	5
March 2014	4	3						5	9	4	5
Sept 2014	3	3						5	6	3	6
March 2015	3	3						5	4	4	5
Sept 2015	5	4						5	5	4	4
March 2016	4	4	8					6	6	3	4
Sept 2016	6	7	7	5	8			6	4	6	3
March 2017	4	4	4	3	5			3	4	3	4
Sept 2017	4	4	4	5	4			5	5	5	5
March 2018	6	3	4	3	4	4	4	5	7	3	4
Sept 2018	5	4	6	4	5	4	4	4	8	4	4
March 2019	5	4	4	4	4	6	6	5	5	2	4
Sept 2019	4	4	5	4	4	4	3	6	5	7	5
March 2020	4	4	8	3	4	4	4	7	7	4	4
August 2020	7	5	8	4	5	5	4	5	6	4	6
March 2021	5	5	5	4	6	5	8	7	7	5	7
Sept 2021	4	4	7	3	4	6	7	3	7	4	4
March 2022	4	4	8	3	5	6	6	5	6	5	6
Sept 2022	5	4	4	6	7	6	5	6	8	6	3

Table 7.3 shows the mean number of marine benthic organisms for each station and species sampled in September 2022. The table includes depths relative to AHD for each station. At the time of sampling, water depth does not appear to be influencing the marine fauna present in the benthos of Lake Macquarie.

Figure 7.1 shows a biplot representing the relationship between marine benthic organisms and stations for the September 2022 survey. Information on biplots is provided in **Appendix 2**.

Table 7.3 **Mean number of marine benthic organisms at Control (C), Reference (R) and Impact Stations (IM)**

	Depth (m)	Polychaete thin	Polychaete mud	Polychaete *Sthenelais*	Polychaete *Chaetopterus*	Gastropod *Nassarius*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Cyamiom*ɛ	Bivalve *Trichomya*	Bivalve *Saccostrea*	Ophuroid	Crab
C1	-4.5	0.2	0.2	0.0	0.0	0.0	1.2	13.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
C2	-4.5	1.0	1.2	0.0	0.0	0.0	5.0	25.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
C3	-5.5	1.0	1.0	0.4	0.0	0.0	0.2	12.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0
C4	-6.0	0.6	0.4	0.2	0.0	0.2	0.4	12.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
C5	-6.0	0.6	1.8	0.4	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.4	0.2
C6	-5.5	1.6	0.2	0.4	0.0	0.0	2.4	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C7	-5.5	0.4	1.8	0.8	0.2	0.0	0.2	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R1	-4.5	0.4	1.8	0.4	0.0	0.2	2.0	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R2	-4.5	0.6	0.4	0.2	0.0	0.0	1.2	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R3 (IM5)	-5.5	1.6	4.0	0.2	0.0	0.8	0.4	7.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
R4 (IM6)	-6.0	0.2	0.4	0.2	0.0	0.0	0.8	6.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
R5 (IM7)	-5.5	0.4	0.4	0.4	0.0	0.0	0.6	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R6	-6.0	0.4	0.6	0.0	0.0	0.0	1.4	18.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R7	-6.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.2	0.0	0.0
R8	-5.5	0.4	0.4	0.2	0.0	0.2	0.2	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R9	-4.5	0.4	0.8	1.4	0.0	0.2	1.2	10.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
R10	-5.5	1.2	2.4	0.0	0.4	0.0	2.2	48.4	0.0	5.8	0.0	0.0	0.0	0.0	0.0
R11	-6.0	0.2	1.6	0.2	0.0	0.0	0.0	10.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0
IM1	-4.5	2.0	0.6	1.0	0.0	0.0	1.0	13.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0
IM2	-4.5	1.0	2.0	1.6	0.0	0.4	1.0	5.2	0.2	0.0	0.0	0.8	0.0	0.0	0.0
IM3	-5.5	0.4	0.2	0.0	0.0	0.4	0.6	9.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
IM4	-6.0	0.4	1.6	0.0	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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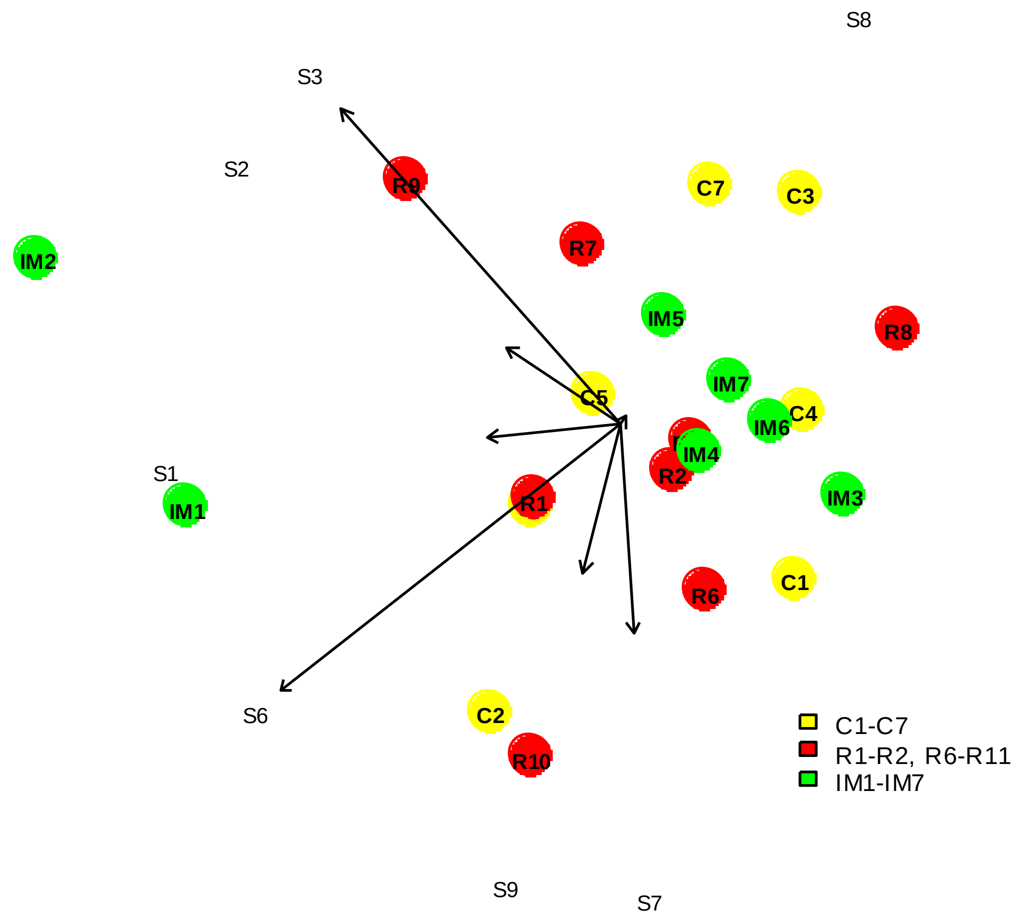

Figure 7.1 Relationship between benthic organisms and sampling stations – Lake Macquarie benthos survey September 2022 (PC biplot goodness-of-fit: 59.0)

Station		**Organism**
C1 – Control Station C1	R8 – Reference Station R8	S1 Polychaete thin
C2 – Control Station C2	R9 – Reference Station R9	S2 Polychaete mud
C3 – Control Station C3	R10 – Reference Station R10	S3 *Sthenelais pettiboneae*
C4 – Control Station C4	R11 – Reference Station R11	S6 *Corbula truncata*
C5 – Control Station C5	IM1 – Impact Station IM1	S7 *Soletellina alba*
C6 – Control Station C6	IM2 – Impact Station IM2	S8 *Paphia undulata*
C7 – Control Station C7	IM3 – Impact Station IM3	S9 *Dosinia sculpta*
R1 – Reference Station R1	IM4 – Impact Station IM4	
R2 – Reference Station R2	IM5 – Impact Station IM5	
R6 – Reference Station R6	IM6 – Impact Station IM6	
R7 – Reference Station R7	IM7 – Impact Station IM7	

Seven species differentiated sampling stations during the September 2022 sampling period (**Figure 7.1**):

- Polychaete designated thin (S1) characterized the Impact stations IM1 and IM2.
- Polychaete designated S2 characterised stations IM2, R9, R7, and C5.
- Polychaete *Sthenelais petitiboneae* (S3) characterised the Reference Stations R9 and R7, and the Control Station C5.
- Bivalve *Corbula truncata* (S6) defined Stations C2, R1 and C6.
- Bivalve *Soletellina alba* (S7) characterised Control Stations C1 and C2; the Reference Stations R1, R6, R10 and R2; and the Impact Stations IM3 and IM4.
- The bivalve *Dosinia sculpta* (S9) differentiated station R10.
- The bivalve *Trichomya hirsuta* (not included in biplot) differentiated the Reference Station R7.

8. Sediment Analysis

In September 2022, the sediment in the mud basin of Lake Macquarie off Summerland Point, Chain Valley Bay and Bardens Bay was largely composed of fine grey silt that was mildly plastic in nature (able to be molded into a coherent shape). Small to large shell fragments were present in the sediment at most stations (**Table 8.1**).

Sediment collected at stations C7 and R10 contained a large amount of coarse grey sand and silt (**Table 8.2**). The sediment sample collected at R7 was 98% shell (**Table 8.2**).

Table 8.1 Description of sediment collected from sampling stations in September 2022.

Station	Description
C1	Dark grey silt with some shell fragments.
C2	Dark grey silt with some shell fragments.
C3	Dark grey silt with some shell fragments.
C4	Dark grey silt with some shell fragments.
C5	Dark grey silt with some coarse grey sand, gravel and shell fragments.
C6	Dark grey silt with large shell fragments.
C7	Dark grey silt and coarse grey sand with some shell fragments.
R1	Dark grey silt with coarse grey sand. No shell fragments.
R2	Dark grey silt with some shell fragments.
R6	Dark grey silt with some shell fragments.
R7	Large shell fragments with some silt.
R8	Dark grey silt with some shell.
R9	Dark grey silt with some shell.
R10	Dark grey silt and sand. No shell fragments.
R11	Dark grey silt.
IM1	Dark grey silt with large shell fragments and some sand
IM2	Dark grey silt with large shell fragments.
IM3	Dark grey silt with large shell fragments.
IM4	Dark grey silt with some large shell fragments.
R3 (IM5)	Dark grey silt with large shell fragments.
R4 (IM6)	Dark grey silt with some shell fragments.
R5 (IM7)	Dark grey silt with some sand and shell fragments.

Table 8.2 Percentage of silt, sand, gravel and shell for control, reference and impact stations

	% Silt	% Sand	% Gravel	%Shell
C1	98	0	0	2
C2	99	0	0	1
C3	98	0	0	2
C4	98	0	0	2
C5	96	2	1	1
C6	83	0	0	17
C7	56	43	0	1
R1	96	4	0	0
R2	98	0	0	2
R3 (IM5)	82	0	0	18
R4 (IM6)	99	0	0	1
R5 (IM7)	98	1	0	1
R6	99	0	0	1
R7	2	0	0	98
R8	99	0	0	1
R9	99	0	0	1
R10	61	39	0	0
R11	100	0	0	0
IM1	80	1	0	19
IM2	80	0	0	20
IM3	90	0	0	10
IM4	99	0	0	1

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9. Physical characteristics of water in Lake Macquarie – September 2022

At each station, a water quality profile was taken using a calibrated Yeo-Kal 618RU Analyser. The physical characteristics were measured on 12th September 2022. Units of measurement were temperature - degrees Celsius; conductivity - mS/cm; salinity - parts per thousand; pH; dissolved oxygen - % saturation and mg/L; and turbidity - NTU.

The water quality profile for each station is presented in **Appendix 1**. At the time of sampling, the water profile had the following characteristics:

Conductivity was relatively uniform throughout the water column and the study area. For instance, at:

- R1, conductivity ranged from 50.02 mS/cm at the surface to 51.23 mS /cm at -4.5m AHD.
- R2, conductivity ranged from 50.04 mS /cm at the surface to 49.99 mS at -4.6m AHD.
- R10, conductivity ranged from 50.13 mS /cm at the surface to 50.12 mS /cm at -5.0m AHD.
- R11, conductivity ranged from 50.18 mS /cm at the surface to 51.84 mS /cm at -6.1m AHD.

Salinity increased slightly with water depth, and the concentration of salinity at similar depths were consistent across the study area:

- C1, salinity ranged from 32.72 ppt at the surface to 33.12 ppt at -4.6m AHD.
- C6, salinity ranged from 32.65 ppt at the surface to 33.64 ppt at -6.0m AHD.
- R6 now IM8, salinity ranged from 32.83 ppt at the surface to 34.02 ppt at -6.0m AHD.
- R3 now IM5, salinity ranged from 32.75 ppt at the surface to 34.01 ppt at -5.6m AHD.
- C5, salinity ranged from 32.96 ppt at the surface to 34.00 ppt at -6.0m AHD.

pH decreased slightly with water depth:

- IM1, pH ranged from 8.39 at the surface to 8.24 at -4.6m AHD.
- C4, pH ranged from 9.13 at the surface to 8.72 at -6.0m AHD
- R5 now IM7, pH ranged from 8.71 at the surface to 8.29 at -5.6m AHD.
- C3, pH ranged from 8.46 at the surface to 8.38 at -5.6m AHD.

Water temperature decreased with depth:

- R9, water temperature ranged from 18.05^{o}C at the surface to 17.75^{o}C at -4.9m AHD.
- R7, water temperature ranged from 17.99^{o}C at the surface to 17.34^{o}C at -5.6m AHD.
- C7, water temperature ranged from 18.53^{o}C at the surface to 17.69^{o}C at -4.0m AHD.
- IM4, water temperature ranged from 17.92^{o}C at the surface to 17.16^{o}C at -6.0m AHD.

Dissolved oxygen generally decreased slightly with depth however concentrations were over 93% saturation throughout the water column:

- C2, dissolved oxygen decreased from 105.4% saturation at the surface to 103.5% saturation at -4.7m AHD.

- R4, dissolved oxygen decreased from 107.4% saturation at the surface to 96.3% saturation at -6.1m AHD.
- R2, dissolved oxygen increased from 107.1% saturation at the surface to 108.5% saturation at -4.6m AHD
- C6, dissolved oxygen decreased from 97.5% saturation at the surface to 95.1 % saturation at -4.7m AHD (**Appendix 1**).

The physical characteristics of the bottom waters of Lake Macquarie in September 2022 were as follows:

- Water Temperature ranged from 17.09°C to 17.87°C. Mean water temperature was 17.42°C.
- Conductivity ranged from 49.99 mS/cm to 51.84 mS/cm. Mean conductivity was 51.04 mS/cm.
- Salinity ranged from 32.72 ppt to 34.07 ppt. Mean salinity was 33.49 ppt.
- Turbidity ranged from 2.3 NTU to 39.3 NTU. Mean turbidity was 12.05 NTU.
- pH ranged from 8.09 and 9.16. Mean pH was 8.31.
- Dissolved oxygen (% saturation) ranged from 93.8% to 109.2%. Mean dissolved oxygen was 101.1% saturation.
- Dissolved oxygen (mg/L) ranged from 7.34 mg/L to 8.54 mg/L. Mean dissolved oxygen was 7.92 mg/L (**Table 9.1**).

Rainfall in the months preceding the survey were 11mm, 402.8mm, and 37.8mm for June, July and August respectively (Cooranbong Lake Macquarie AWS No. 61412). By 12th September a further 69 mm had fallen in the catchment.

Table 9.1 Physical characteristics of the bottom water – September 2022

Station	Temperature	Conductivity	Salinity	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Depth
	^oC	mS/cm	ppt	% sat	mg/L		NTU	m
C1	17.85	50.54	33.12	100.3	7.81	8.29	28.6	-4.60
C2	17.29	50.08	32.78	103.5	8.17	8.42	12.7	-4.70
C3	17.47	50.70	33.24	106.3	8.33	8.38	4.9	-5.60
C4	17.40	51.17	33.58	99.8	7.82	8.72	5.0	-6.00
C5	17.10	51.74	34.00	101.0	7.95	8.09	12.7	-6.00
C6	17.36	51.25	33.64	95.1	7.46	9.16	6.0	-6.00
C7	17.69	50.24	32.90	109.2	8.54	8.09	2.3	-4.00
R1	17.51	51.23	33.63	93.8	7.34	8.16	24.1	-4.60
R2	17.87	49.99	32.72	108.5	8.47	8.36	9.0	-4.60
R3 (IM5)	17.09	51.75	34.01	98.2	7.72	8.31	8.2	-5.50
R4 (IM6)	17.14	51.75	34.01	96.3	7.57	8.17	12.8	-6.10
R5 (IM7)	17.38	51.10	33.53	101.3	7.95	8.29	39.3	-4.50
R6	17.24	51.76	34.02	94.5	7.41	8.22	19.9	-4.60
R7	17.34	51.04	33.49	105.5	8.28	8.14	3.8	-5.60
R8	17.23	51.69	33.97	96.9	7.60	8.15	10.2	-6.10
R9	17.75	50.69	33.23	99.7	7.77	8.25	6.8	-5.60
R10	17.84	50.12	32.81	105.4	8.23	8.41	17.3	-6.00
R11	17.14	51.84	34.07	95.7	7.52	8.09	14.3	-5.90
IM1	17.76	50.69	33.23	99.4	7.76	8.24	10.2	-5.60
IM2	17.42	50.99	33.45	105.2	8.25	8.31	5.7	-4.90
IM3	17.31	50.81	33.32	108.4	8.52	8.31	2.9	-5.00
IM4	17.16	51.67	33.96	99.2	7.79	8.21	8.3	-6.10
Mean	**17.42**	**51.04**	**33.49**	**101.1**	**7.92**	**8.31**	**12.05**	
Min	**17.09**	**49.99**	**32.72**	**93.8**	**7.34**	**8.09**	**2.3**	
Max	**17.87**	**51.84**	**34.07**	**109.2**	**8.54**	**9.16**	**39.3**	

10. Conclusions

The results from the September 2022 benthic communities monitoring results show compliance to the Schedule 4 Environmental Conditions - underground mining of SSD5465 - Modification 4 in the Performance Measures table with respect to the Subsidence Impact Performance Measure for Benthic communities which display nil to minor environmental consequences due to underground mining.

The below summary of findings outlines the historical basis for this compliance statement and the compliance is detailed in the table below.

Conditions from SSD-5465 – Mod 4	Compliance Status and Comments
Schedule 4 Environmental Conditions – underground mining Performance Measures – Natural Environment Biodiversity – Benthic Communities Subsidence Impact Performance Measure – Minor environmental consequences, including minor changes composition and/or distribution.	Compliant – See section 16 - Conclusions
Measurements undertaken by generally accepted methods. Measures Methods fully described.	Compliant – See section 4 and 5 Compliant – See section 4 and 5

In September 2022, 22 benthic stations were sampled in the study area. A total of 1981 organisms greater than 1mm in size were found, comprising 12 species. This compares with the results from September 2018, September 2019, September 2020 and September 2021 where 1576, 815, 1367, 1032 and 2096 organisms respectively were recorded representing approximately twelve species. As in previous years, polychaete worms and bivalve molluscs were the most frequently encountered animals. Stations were distinguished by the relative abundance of the dominant species. Water depth was not in any way important in determining the species composition at a station.

Physical variables such as salinity, conductivity and turbidity of the bottom water had little influence on the species composition of the benthos. Dissolved oxygen concentration, however, can have a major effect on abundance. Major extinction events have occurred in the mud basin of Lake Macquarie. The evidence for this lies in the presence of large numbers of intact but dead bivalve shells entombed in the mud. The cause of extinction events appears to be prolonged dissolved oxygen depletion of bottom water. Prolonged dissolved oxygen depletion of the bottom water was measured during the water quality study conducted by Laxton and Laxton (1983 to 1997) and low dissolved oxygen levels were measured during the March 2020 benthic survey. In September 2022, dissolved oxygen levels of Lake Macquarie ranged from 7.34 mg/L to 8.54 mg/L or 93.8% to 109.2%.saturation. Surface waters had higher concentrations of dissolved oxygen than the bottom waters.

Bottom sediment in the study area was composed of fine black mud with varying proportions of black sand and shell fragments.

These results appear to support the notion that increasing the water depth by up to 0.78m (SSD-5465 subsidence limit in Lake Macquarie) has, to date, had little to no discernible effect on the composition and abundance of organisms making up the benthos of the mud basin.

11. References

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12. Acknowledgements

We wish to acknowledge the help of Mr Lachlan McWha in facilitating the study.

Appendix 1 – Water quality profiles for control, impact and reference stations Sept 22

C1	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:15:48	0.5	17.74	50.00	32.72	8.39	107.1	8.38	7.0
	12/09/2022	8:16:13	1.0	17.75	50.01	32.73	8.40	107.4	8.40	6.1
	12/09/2022	8:16:31	1.5	17.72	50.02	32.74	8.40	107.5	8.42	6.5
	12/09/2022	8:16:45	2.0	17.71	50.03	32.74	8.40	107.4	8.41	6.5
	12/09/2022	8:17:11	2.5	17.69	50.02	32.74	8.39	108.3	8.48	6.1
	12/09/2022	8:17:28	3.0	17.68	50.03	32.74	8.39	108.3	8.49	6.5
	12/09/2022	8:17:45	3.5	17.66	50.03	32.74	8.38	108.5	8.50	5.8
	12/09/2022	8:18:00	4.0	17.65	50.03	32.74	8.38	108.6	8.51	6.7
	12/09/2022	8:19:15	4.5	17.83	50.36	32.99	8.31	100.5	7.84	16.7
	12/09/2022	8:19:27	4.6	17.85	50.54	33.12	8.29	100.3	7.81	28.6

C2	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	9:16:59	0.4	17.69	50.10	32.79	8.59	105.4	8.25	4.2
	12/09/2022	9:17:27	0.5	17.67	50.06	32.77	8.59	105.6	8.27	4.0
	12/09/2022	9:17:52	1.0	17.64	50.10	32.80	8.58	106.2	8.33	3.5
	12/09/2022	9:18:08	1.5	17.66	50.13	32.82	8.58	106.5	8.34	2.9
	12/09/2022	9:18:11	2.0	17.66	50.13	32.82	8.58	106.5	8.34	3.0
	12/09/2022	9:18:27	2.5	17.63	50.13	32.82	8.57	106.7	8.36	3.0
	12/09/2022	9:18:49	3.0	17.59	50.14	32.83	8.56	106.9	8.38	3.1
	12/09/2022	9:19:10	3.5	17.53	50.12	32.81	8.54	106.7	8.38	3.2
	12/09/2022	9:19:31	4.0	17.45	50.11	32.80	8.50	106.5	8.38	5.2
	12/09/2022	9:20:09	4.5	17.24	50.05	32.76	8.44	104.6	8.27	16.1
	12/09/2022	9:21:33	4.7	17.29	50.08	32.78	8.42	103.5	8.17	12.7

C3	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:58:36	0.5	17.67	50.14	32.82	8.46	107.9	8.45	3.2
	12/09/2022	8:59:04	1.0	17.66	50.15	32.83	8.46	107.9	8.45	3.3
	12/09/2022	8:59:24	1.5	17.68	50.16	32.84	8.46	107.8	8.44	3.0
	12/09/2022	8:59:27	2.0	17.68	50.16	32.84	8.46	107.8	8.44	3.0
	12/09/2022	8:59:44	2.5	17.66	50.16	32.84	8.45	108.1	8.46	3.6
	12/09/2022	9:00:06	3.0	17.65	50.16	32.84	8.45	108.0	8.46	3.2
	12/09/2022	9:00:22	3.5	17.63	50.16	32.84	8.44	107.9	8.46	3.1
	12/09/2022	9:00:42	4.0	17.61	50.16	32.84	8.44	107.6	8.44	2.9
	12/09/2022	9:00:58	4.5	17.60	50.15	32.84	8.43	107.6	8.44	3.1
	12/09/2022	9:01:14	5.0	17.59	50.14	32.82	8.43	107.5	8.43	4.0
	12/09/2022	9:01:31	5.5	17.59	50.11	32.81	8.42	107.4	8.43	3.0
	12/09/2022	9:02:34	5.6	17.47	50.70	33.24	8.38	106.3	8.33	4.9

C4	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	6:52:14	0.5	18.24	49.89	32.64	9.13	101.5	7.87	4.1
	12/09/2022	6:52:37	1.0	18.15	49.98	32.71	9.12	103.2	8.01	4.0
	12/09/2022	6:53:00	1.5	18.09	50.01	32.73	9.09	104.5	8.12	3.7
	12/09/2022	6:53:17	2.0	18.02	50.03	32.75	9.07	105.2	8.19	3.9
	12/09/2022	6:53:34	2.5	17.98	50.06	32.77	9.04	105.3	8.20	3.6
	12/09/2022	6:53:48	3.0	17.97	50.06	32.77	9.02	105.5	8.22	3.5
	12/09/2022	6:54:03	3.5	17.96	50.06	32.77	9.00	105.7	8.23	3.5
	12/09/2022	6:54:22	4.0	17.95	50.06	32.76	8.98	105.8	8.25	3.6
	12/09/2022	6:54:37	4.5	17.95	50.05	32.76	8.96	106.1	8.27	3.4
	12/09/2022	6:54:50	4.6	17.94	50.00	32.72	8.94	106.3	8.29	3.4
	12/09/2022	6:55:06	5.0	17.43	51.10	33.53	8.82	107.6	8.43	4.9
	12/09/2022	6:55:09	5.5	17.42	51.14	33.56	8.81	107.4	8.41	5.1
	12/09/2022	6:56:03	6.0	17.4	51.17	33.58	8.72	99.8	7.82	5.0

C5	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	10:34:24	0.5	18.34	50.33	32.96	8.22	109.0	8.42	5.4
	12/09/2022	10:34:58	1.0	17.91	50.40	33.01	8.19	110.3	8.59	2.1
	12/09/2022	10:35:39	1.5	17.8	50.33	32.96	8.15	109.9	8.58	2.7
	12/09/2022	10:36:12	2.0	17.77	50.33	32.97	8.15	109.6	8.56	2.4
	12/09/2022	10:36:25	2.1	17.77	50.36	32.99	8.14	109.6	8.56	2.7
	12/09/2022	10:36:53	2.5	17.67	50.50	33.09	8.14	109.2	8.54	1.7
	12/09/2022	10:37:27	3.0	17.62	50.54	33.12	8.14	109.3	8.55	1.5
	12/09/2022	10:37:49	3.5	17.48	50.58	33.15	8.13	109.5	8.59	2.2
	12/09/2022	10:38:39	4.0	17.17	51.32	33.70	8.07	107.5	8.45	2.6
	12/09/2022	10:39:10	4.5	17.12	51.46	33.80	8.07	106.8	8.40	2.1
	12/09/2022	10:39:34	5.0	17.06	51.67	33.95	8.06	106.3	8.37	7.2
	12/09/2022	10:40:35	5.5	17.09	51.73	34.00	8.06	102.2	8.03	9.4
	12/09/2022	10:42:00	6.0	17.1	51.74	34.00	8.09	101.0	7.95	12.7

C6	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	6:42:30	0.5	18.17	49.89	32.65	9.90	94.2	7.31	3.4
	12/09/2022	6:43:07	0.6	18.20	49.90	32.65	9.85	97.5	7.57	3.7
	12/09/2022	6:43:27	1.0	18.22	49.96	32.70	9.83	98.3	7.62	3.7
	12/09/2022	6:43:42	1.5	18.14	50.05	32.76	9.81	99.3	7.71	3.6
	12/09/2022	6:43:59	2.0	18.13	50.05	32.76	9.78	99.7	7.74	4.0
	12/09/2022	6:44:27	2.5	18.12	50.05	32.76	9.74	100.4	7.80	4.0
	12/09/2022	6:44:47	3.0	18.11	50.06	32.77	9.70	101.3	7.87	3.7
	12/09/2022	6:45:04	3.5	18.02	50.11	32.80	9.67	101.5	7.89	3.5
	12/09/2022	6:45:07	3.6	18.02	50.10	32.80	9.67	101.5	7.90	3.4
	12/09/2022	6:45:24	4.0	17.91	50.18	32.85	9.64	102.2	7.97	3.2
	12/09/2022	6:45:43	4.5	17.73	50.31	32.95	9.60	102.8	8.04	2.8
	12/09/2022	6:46:03	5.0	17.48	50.66	33.21	9.53	103.7	8.13	3.8
	12/09/2022	6:46:54	5.5	17.43	51.00	33.46	9.38	99.1	7.77	5.5
	12/09/2022	6:47:29	6.0	17.31	51.48	33.81	9.28	97.4	7.64	8.1
	12/09/2022	6:48:52	6.0	17.36	51.25	33.64	9.16	95.1	7.46	6.0

C7	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	11:02:00	0.5	18.53	50.22	32.88	8.17	109.7	8.44	2.2
	12/09/2022	11:02:31	1.0	18.09	50.17	32.85	8.14	111.1	8.63	2.4
	12/09/2022	11:02:58	1.5	17.90	50.22	32.88	8.10	111.1	8.66	2.3
	12/09/2022	11:03:19	2.0	17.81	50.22	32.88	8.09	110.8	8.65	2.6
	12/09/2022	11:03:48	2.5	17.77	50.20	32.87	8.08	109.9	8.59	2.9
	12/09/2022	11:04:06	3.0	17.74	50.21	32.88	8.08	109.6	8.57	2.7
	12/09/2022	11:04:28	3.5	17.71	50.22	32.88	8.08	109.2	8.54	2.9
	12/09/2022	11:05:17	4.0	17.69	50.24	32.90	8.09	109.2	8.54	2.3

IM1	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:22:33	0.5	17.83	50.00	32.72	8.39	106.9	8.35	5.5
	12/09/2022	8:22:57	0.5	17.83	50.01	32.73	8.39	107.3	8.38	5.5
	12/09/2022	8:23:15	1.0	17.82	50.01	32.73	8.39	107.7	8.41	5.6
	12/09/2022	8:23:45	1.5	17.82	50.03	32.75	8.39	108.3	8.46	5.5
	12/09/2022	8:24:13	2.0	17.81	50.04	32.75	8.38	108.8	8.50	5.2
	12/09/2022	8:24:16	2.5	17.81	50.04	32.75	8.38	108.8	8.50	5.3
	12/09/2022	8:24:33	3.0	17.80	50.05	32.76	8.38	108.9	8.51	5.0
	12/09/2022	8:24:53	3.0	17.80	50.05	32.76	8.37	108.6	8.49	4.7
	12/09/2022	8:25:12	3.5	17.79	50.04	32.76	8.36	108.8	8.50	4.6
	12/09/2022	8:26:58	4.0	17.69	50.87	33.36	8.23	98.6	7.69	17.9
	12/09/2022	8:27:39	4.5	17.64	51.00	33.46	8.21	97.2	7.59	42.6
	12/09/2022	8:29:01	4.6	17.76	50.69	33.23	8.24	99.4	7.76	10.2

IM2	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	7:37:05	0.5	17.94	50.02	32.74	8.52	108.3	8.44	3.4
	12/09/2022	7:37:23	0.5	17.93	50.02	32.74	8.52	108.5	8.46	3.4
	12/09/2022	7:37:49	1.0	17.94	50.02	32.74	8.51	109.1	8.50	3.4
	12/09/2022	7:38:12	1.5	17.93	50.03	32.74	8.50	109.2	8.51	3.5
	12/09/2022	7:38:31	2.0	17.91	50.03	32.74	8.49	109.1	8.51	3.5
	12/09/2022	7:38:53	2.5	17.90	50.02	32.74	8.48	109.4	8.54	3.5
	12/09/2022	7:39:10	2.5	17.90	50.03	32.75	8.48	109.5	8.54	3.7
	12/09/2022	7:39:24	3.0	17.71	50.37	33.00	8.45	110.3	8.62	2.8
	12/09/2022	7:40:06	3.5	17.63	50.44	33.05	8.41	109.3	8.55	2.7
	12/09/2022	7:40:22	4.0	17.32	50.60	33.17	8.38	110.1	8.66	2.0
	12/09/2022	7:40:44	4.5	17.36	50.91	33.39	8.35	109.5	8.60	3.2
	12/09/2022	7:42:02	4.6	17.42	50.99	33.45	8.31	105.2	8.25	4.5

IM3	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	7:46:59	0.5	18.02	50.04	32.75	8.49	108.2	8.42	4.0
	12/09/2022	7:47:17	1.0	18.02	50.04	32.75	8.48	108.3	8.43	4.3
	12/09/2022	7:47:32	1.5	18.02	50.04	32.75	8.48	108.5	8.44	3.7
	12/09/2022	7:47:51	2.0	18.01	50.05	32.76	8.47	108.6	8.45	3.7
	12/09/2022	7:48:13	2.5	18.01	50.04	32.75	8.46	108.6	8.46	3.7
	12/09/2022	7:48:33	3.0	17.97	50.12	32.81	8.44	109.0	8.49	3.9
	12/09/2022	7:48:49	3.5	17.68	50.37	32.99	8.42	109.9	8.60	2.7
	12/09/2022	7:49:11	4.0	17.54	50.56	33.14	8.38	110.1	8.63	2.8
	12/09/2022	7:50:01	4.5	17.53	50.70	33.23	8.33	107.3	8.41	3.1
	12/09/2022	7:50:15	5.0	17.32	50.78	33.30	8.33	107.8	8.48	2.7
	12/09/2022	7:51:09	5.5	17.31	50.81	33.32	8.31	108.4	8.52	2.9

IM4	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	7:25:09	0.5	17.92	50.01	32.73	8.55	107.6	8.39	6.5
	12/09/2022	7:25:30	0.5	17.93	50.02	32.74	8.55	108.0	8.42	5.8
	12/09/2022	7:25:50	1.0	17.93	50.01	32.73	8.55	108.5	8.46	5.8
	12/09/2022	7:26:11	1.5	17.92	50.01	32.73	8.54	109.1	8.51	5.7
	12/09/2022	7:26:14	2.0	17.92	50.02	32.73	8.54	109.1	8.51	5.6
	12/09/2022	7:26:34	2.5	17.93	50.02	32.74	8.53	108.9	8.49	5.3
	12/09/2022	7:26:37	2.5	17.93	50.02	32.74	8.53	108.8	8.49	5.3
	12/09/2022	7:26:54	3.0	17.93	50.01	32.73	8.53	108.8	8.48	5.2
	12/09/2022	7:27:18	3.5	17.93	50.02	32.74	8.51	108.8	8.48	5.1
	12/09/2022	7:27:44	4.0	17.93	50.04	32.75	8.50	108.9	8.49	4.8
	12/09/2022	7:28:00	4.5	17.89	50.16	32.84	8.49	109.1	8.51	4.4
	12/09/2022	7:28:20	5.0	17.73	50.22	32.89	8.46	109.5	8.56	4.0
	12/09/2022	7:29:59	5.5	17.21	51.52	33.84	8.28	104.2	8.18	6.2
	12/09/2022	7:30:39	6.0	17.13	51.76	34.02	8.21	99.6	7.83	11.3
	12/09/2022	7:32:04	6.1	17.16	51.67	33.96	8.21	99.2	7.79	8.3

R1	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:05:17	0.5	17.92	50.02	32.74	8.44	107.2	8.36	4.5
	12/09/2022	8:05:44	1.0	17.91	50.02	32.74	8.44	107.9	8.41	5.0
	12/09/2022	8:06:06	1.5	17.91	50.03	32.74	8.43	108.2	8.44	4.2
	12/09/2022	8:06:33	2.0	17.90	50.03	32.75	8.42	108.8	8.49	3.9
	12/09/2022	8:06:56	2.5	17.90	50.03	32.74	8.42	109.0	8.50	4.2
	12/09/2022	8:07:20	2.5	17.90	50.04	32.75	8.41	109.1	8.51	4.2
	12/09/2022	8:07:39	3.0	17.88	50.04	32.76	8.39	109.1	8.51	4.6
	12/09/2022	8:08:23	3.5	17.83	50.34	32.97	8.34	106.4	8.30	8.8
	12/09/2022	8:09:07	4.0	17.58	51.15	33.57	8.20	99.5	7.77	23.8
	12/09/2022	8:10:16	4.5	17.51	51.23	33.63	8.16	93.8	7.34	24.1

R2	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:34:35	0.5	17.94	50.04	32.75	8.42	107.1	8.35	5.6
	12/09/2022	8:35:07	1.0	17.93	50.03	32.75	8.42	107.5	8.38	6.6
	12/09/2022	8:35:22	1.5	17.91	50.04	32.75	8.42	107.7	8.4	5.7
	12/09/2022	8:35:52	2.0	17.91	50.04	32.76	8.42	107.8	8.41	6.0
	12/09/2022	8:36:16	2.5	17.90	50.04	32.76	8.41	107.8	8.41	5.6
	12/09/2022	8:36:44	2.5	17.89	50.05	32.76	8.40	107.9	8.42	6.9
	12/09/2022	8:37:03	3.0	17.88	50.05	32.76	8.39	108.0	8.43	13.4
	12/09/2022	8:37:21	3.5	17.88	50.04	32.75	8.39	107.9	8.42	7.7
	12/09/2022	8:37:39	4.0	17.87	49.99	32.72	8.38	107.9	8.42	8.4
	12/09/2022	8:38:41	4.5	17.87	49.99	32.72	8.36	108.5	8.47	8.6
	12/09/2022	8:38:44	4.6	17.87	49.99	32.72	8.36	108.5	8.47	9.0

R3 (IM5)	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	6:59:23	0.5	17.93	50.03	32.75	8.77	106.00	8.27	4.6
	12/09/2022	6:59:26	0.5	17.93	50.03	32.75	8.76	106.10	8.27	4.5
	12/09/2022	6:59:46	1.0	17.92	50.03	32.74	8.75	106.80	8.33	4.7
	12/09/2022	7:00:02	1.5	17.93	50.02	32.74	8.74	107.40	8.38	4.4
	12/09/2022	7:00:24	2.0	17.94	50.03	32.74	8.73	108.10	8.42	4.5
	12/09/2022	7:00:39	2.5	17.93	50.02	32.74	8.72	108.60	8.47	4.4
	12/09/2022	7:01:14	3.0	17.94	50.05	32.76	8.69	109.30	8.52	4.3
	12/09/2022	7:01:33	3.5	17.95	50.06	32.77	8.67	109.60	8.54	4.3
	12/09/2022	7:01:49	4.0	17.95	50.18	32.86	8.66	109.80	8.55	3.6
	12/09/2022	7:03:12	4.5	17.34	51.09	33.52	8.46	102.40	8.04	5.6
	12/09/2022	7:04:11	5.0	17.22	51.58	33.89	8.36	99.20	7.79	8.6
	12/09/2022	7:04:35	5.5	17.12	51.72	33.99	8.35	98.70	7.76	9.5
	12/09/2022	7:05:51	5.6	17.09	51.75	34.01	8.31	98.20	7.72	8.2

R4 (IM6)	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	7:09:56	0.5	17.91	50.01	32.73	8.58	107.4	8.38	3.4
	12/09/2022	7:09:59	0.5	17.91	50.01	32.73	8.59	107.5	8.38	3.3
	12/09/2022	7:10:22	1.0	17.92	50.01	32.73	8.59	108.4	8.46	3.5
	12/09/2022	7:10:44	1.5	17.91	50.01	32.73	8.58	109.3	8.52	3.5
	12/09/2022	7:11:00	2.0	17.92	50.01	32.73	8.58	109.5	8.54	3.4
	12/09/2022	7:11:18	2.0	17.93	50.01	32.73	8.57	109.6	8.55	3.4
	12/09/2022	7:11:35	2.5	17.92	50.01	32.73	8.56	110.0	8.58	3.5
	12/09/2022	7:11:58	3.0	17.91	50.02	32.74	8.55	110.2	8.59	3.5
	12/09/2022	7:12:19	3.1	17.91	50.06	32.77	8.53	110.3	8.60	3.4
	12/09/2022	7:12:48	3.5	17.87	50.14	32.82	8.51	110.6	8.63	3.1
	12/09/2022	7:13:13	4.0	17.30	50.74	33.26	8.44	112.1	8.82	1.9
	12/09/2022	7:14:15	4.5	17.32	51.12	33.55	8.36	107.8	8.46	3.3
	12/09/2022	7:14:48	5.0	17.33	51.17	33.59	8.34	106.8	8.38	3.7
	12/09/2022	7:15:48	5.5	17.23	51.45	33.79	8.30	102.0	8.01	3.8
	12/09/2022	7:17:03	6.0	17.16	51.68	33.96	8.21	98.2	7.71	8.5
	12/09/2022	7:19:11	6.1	17.14	51.75	34.01	8.17	96.3	7.57	12.8

R5 (IM7)	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	12:18:36	0.5	19.33	50.14	32.82	8.71	107.2	8.13	6.5
	12/09/2022	12:19:06	1.0	19.31	50.09	32.79	8.68	107.3	8.15	3.6
	12/09/2022	12:19:38	1.5	18.91	50.05	32.76	8.62	108.4	8.29	3.3
	12/09/2022	12:19:59	2.0	18.76	50.03	32.75	8.59	108.3	8.31	3.2
	12/09/2022	12:20:23	2.5	18.26	50.14	32.83	8.53	109.3	8.47	3.0
	12/09/2022	12:20:38	3.0	18.19	50.09	32.79	8.50	109.0	8.45	3.1
	12/09/2022	12:20:56	3.5	18.14	50.02	32.74	8.48	108.5	8.43	2.7
	12/09/2022	12:20:59	4.0	18.14	50.02	32.74	8.48	108.5	8.42	2.7
	12/09/2022	12:21:16	4.5	18.04	50.08	32.78	8.45	108.3	8.42	4.0
	12/09/2022	12:21:55	5.0	17.84	50.22	32.88	8.39	106.7	8.32	8.9
	12/09/2022	12:23:12	5.5	17.42	51.22	33.62	8.28	101.4	7.94	7.0
	12/09/2022	12:24:18	5.6	17.38	51.10	33.53	8.29	101.3	7.95	39.3

R6 (IM8)	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	11:53:24	0.5	19.14	50.14	32.83	8.68	106.3	8.09	2.9
	12/09/2022	11:53:56	1.0	18.89	50.06	32.77	8.62	107.3	8.21	3.1
	12/09/2022	11:54:29	1.5	18.30	50.14	32.83	8.57	108.5	8.39	3.0
	12/09/2022	11:54:52	1.5	18.19	50.17	32.85	8.54	108.2	8.39	2.8
	12/09/2022	11:55:13	2.0	18.16	50.18	32.85	8.52	107.8	8.36	3.3
	12/09/2022	11:55:33	2.5	17.98	50.15	32.83	8.50	108.0	8.41	3.1
	12/09/2022	11:55:53	3.0	17.93	50.18	32.85	8.47	107.6	8.38	3.2
	12/09/2022	11:56:07	3.5	17.87	50.18	32.85	8.45	107.2	8.36	3.3
	12/09/2022	11:56:24	4.0	17.79	50.30	32.94	8.43	107.0	8.35	4.4
	12/09/2022	11:57:31	4.5	17.67	50.51	33.10	8.35	101.5	7.94	7.4
	12/09/2022	11:59:17	5.5	17.42	51.45	33.79	8.26	95.2	7.45	10.1
	12/09/2022	11:59:53	6.0	17.24	51.76	34.02	8.22	94.5	7.41	19.9

R7	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	9:37:52	0.4	17.99	50.16	32.84	8.33	107.0	8.33	2.9
	12/09/2022	9:38:16	0.5	17.91	50.15	32.83	8.31	107.4	8.37	2.8
	12/09/2022	9:38:37	1.0	17.83	50.15	32.83	8.29	107.7	8.41	2.9
	12/09/2022	9:38:59	1.5	17.79	50.16	32.84	8.27	108.0	8.44	2.9
	12/09/2022	9:39:23	2.0	17.74	50.19	32.86	8.25	108.2	8.46	2.7
	12/09/2022	9:39:44	2.5	17.67	50.19	32.86	8.24	108.3	8.48	2.6
	12/09/2022	9:40:04	3.0	17.66	50.26	32.92	8.23	108.2	8.47	2.6
	12/09/2022	9:40:25	3.5	17.53	50.43	33.04	8.22	108.8	8.53	2.3
	12/09/2022	9:40:42	4.0	17.45	50.43	33.04	8.20	109.2	8.57	1.7
	12/09/2022	9:40:55	4.5	17.37	50.51	33.10	8.18	109.3	8.59	1.7
	12/09/2022	9:41:14	5.0	17.28	50.78	33.30	8.17	109.0	8.58	1.6
	12/09/2022	9:42:07	5.5	17.34	51.04	33.49	8.13	105.6	8.29	3.8
	12/09/2022	9:42:10	5.9	17.34	51.04	33.49	8.14	105.5	8.28	3.8

R8	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	7:54:58	0.4	17.96	50.03	32.75	8.44	107.4	8.37	4.1
	12/09/2022	7:55:31	0.5	17.95	50.03	32.75	8.44	108.3	8.44	4.1
	12/09/2022	7:55:55	1.0	17.96	50.04	32.75	8.44	108.2	8.43	4.0
	12/09/2022	7:56:09	1.5	17.96	50.04	32.75	8.44	108.1	8.43	4.0
	12/09/2022	7:56:30	2.0	17.94	50.04	32.76	8.43	108.3	8.44	4.1
	12/09/2022	7:56:47	2.5	17.94	50.04	32.76	8.42	108.6	8.47	4.3
	12/09/2022	7:57:04	3.0	17.94	50.05	32.76	8.41	108.6	8.46	3.9
	12/09/2022	7:57:26	3.5	17.77	50.35	32.98	8.39	109.1	8.52	3.6
	12/09/2022	7:57:42	4.0	17.73	50.43	33.04	8.37	109.0	8.51	4.0
	12/09/2022	7:58:01	4.5	17.51	50.70	33.24	8.34	109.2	8.56	3.3
	12/09/2022	7:58:20	5.0	17.42	50.94	33.42	8.29	108.6	8.52	4.5
	12/09/2022	8:00:20	5.5	17.28	51.59	33.89	8.17	97.7	7.66	9.0
	12/09/2022	8:00:42	5.6	17.23	51.69	33.97	8.15	96.9	7.60	41.2

R9	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	8:43:23	0.4	18.05	50.06	32.76	8.42	106.5	8.28	4.1
	12/09/2022	8:43:26	0.5	18.05	50.05	32.76	8.42	106.5	8.28	4.1
	12/09/2022	8:43:49	1.0	17.98	50.06	32.76	8.41	107.5	8.37	4.0
	12/09/2022	8:44:06	1.5	17.95	50.06	32.77	8.40	107.9	8.41	3.8
	12/09/2022	8:44:25	2.0	17.94	50.07	32.77	8.40	108.2	8.43	4.5
	12/09/2022	8:44:53	2.5	17.93	50.07	32.77	8.39	108.5	8.46	4.2
	12/09/2022	8:45:09	3.0	17.92	50.07	32.77	8.39	108.9	8.49	4.1
	12/09/2022	8:45:23	3.5	17.88	50.09	32.79	8.38	108.8	8.49	4.7
	12/09/2022	8:45:49	4.0	17.85	50.10	32.79	8.35	107.8	8.42	8.1
	12/09/2022	8:46:40	4.5	17.82	50.29	32.94	8.30	103.3	8.06	8.8
	12/09/2022	8:47:51	4.9	17.76	50.67	33.22	8.25	99.6	7.77	7.0
	12/09/2022	8:47:56	4.9	17.75	50.69	33.23	8.25	99.7	7.77	6.8

R10	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	11:29:17	0.5	18.28	50.13	32.82	8.56	107.8	8.34	3.0
	12/09/2022	11:29:42	1.0	18.3	50.14	32.82	8.55	107.8	8.34	3.0
	12/09/2022	11:30:02	1.5	18.22	50.12	32.81	8.54	108.1	8.38	2.9
	12/09/2022	11:30:23	2.0	18.21	50.13	32.82	8.53	108.0	8.37	2.7
	12/09/2022	11:30:39	2.5	18.02	50.14	32.82	8.51	108.6	8.45	2.9
	12/09/2022	11:30:55	3.0	17.97	50.15	32.83	8.48	108.3	8.43	3.2
	12/09/2022	11:31:15	3.5	17.94	50.17	32.85	8.48	107.7	8.39	3.1
	12/09/2022	11:31:44	4.0	17.86	50.18	32.85	8.45	107.6	8.39	4.8
	12/09/2022	11:32:12	4.5	17.84	50.14	32.82	8.43	106.7	8.33	14.9
	12/09/2022	11:33:24	5.0	17.84	50.12	32.81	8.41	105.4	8.23	17.3

R11	Date	Time	Depth (m)	Temp (C)	Cond (ms/cm)	Sal (ppt)	pH	D.O. (%sat)	D.O. (mg/L)	Turb (ntu)
	12/09/2022	10:06:56	0.5	17.93	50.18	32.86	8.25	109.1	8.5	2.6
	12/09/2022	10:07:24	1.0	17.69	50.22	32.89	8.22	109.8	8.6	2.5
	12/09/2022	10:07:53	1.5	17.58	50.23	32.89	8.20	109.6	8.6	2.7
	12/09/2022	10:08:17	2.0	17.46	50.26	32.91	8.18	109.6	8.6	3.9
	12/09/2022	10:08:40	2.5	17.39	50.25	32.91	8.17	109.0	8.6	3.2
	12/09/2022	10:09:05	3.0	17.33	50.28	32.93	8.17	108.5	8.6	3.4
	12/09/2022	10:09:08	3.5	17.33	50.28	32.93	8.17	108.4	8.5	3.4
	12/09/2022	10:09:25	4.0	17.33	50.44	33.04	8.16	108.0	8.5	3.5
	12/09/2022	10:09:47	4.5	17.4	50.49	33.08	8.19	107.7	8.5	1.4
	12/09/2022	10:10:10	5.0	17.36	50.55	33.13	8.18	108.6	8.5	1.6
	12/09/2022	10:11:37	5.5	17.39	50.68	33.22	8.16	97.4	7.7	13.1
	12/09/2022	10:12:45	6.0	17.21	51.69	33.97	8.08	95.8	7.5	11.9
	12/09/2022	10:13:14	6.1	17.14	51.84	34.07	8.09	95.7	7.5	14.3

Appendix 2 – Principal Component Biplots

Statistics

Principal component (PC) biplots or multivariate scatterplots produced by the R-statistical program were used to explore the relationship between benthos study sites, animal species found in the sediment, and water quality variables at the lake bed. Points in the matrix were obtained by standardizing the data by subtracting the variable (column) mean from the species (cell) mean and dividing the subsequent value by the variable or column mean (Gabriel, 1971; Gabriel and Odoroff, 1990).

Biplots

A biplot is a particular kind of scatterplot used for displaying multivariate data which results from mapping a matrix of field observations, **X**, into a 2-dimensional graphical display. The name derives from the fact that this is a *joint* display of the rows and columns of **X**. Sample units (rows) are shown by points and variables (columns) by arrows. Biplots have several appealing properties. Firstly, they are capable of presenting graphically large amounts of information on composition, structure and relationships with surpassing ease and efficiency. It enables a truly global look at the data.

Interpretation of Biplots

Sample Points

- The proximity of any pair of sample points is directly proportional to their resemblance with respect to all the variables studied, the closer the points the greater the resemblance;
- Points close to the origin tend to be representative of the sample as a whole, that is, they tend to be average samples,
- Points far from the origin are atypical in that they possess usually large or small values of one or more variables.

Variable Arrows

- The origin of the configuration of arrows marks the mean value of each variable, an important reference point.
- Arrows can be extended through the origin (by eye) in either direction to any desired extent.
- With increasing distance from the origin along an arrow in the direction of an arrow, the value of the variable increases steadily above its mean; similarly, with increasing distance from the origin along an arrow extended by eye in the opposite direction, the value of a variable falls increasingly below its mean.
- Arrow length is directly proportional to the correlation coefficient, r, between the two variables. The smaller the angle the stronger the correlation. Variables x and y with arrows subtending an angle of:

1. 0^o are perfectly correlated $r_{xy} = 1$
2. 90^o are strictly uncorrelated $r_{xy} = 0$
3. $0^o \leq$ Angle $< 90^o$ $0 \leq r_{xy} < 1$
4. $90^o \geq$ Angle $\leq 180^o$ $0 < r_{xy} < -1$

From 3 it follows that variables whose arrows subtend angles less than 90^o are positively correlated, and from 4, that variables whose arrows subtend angles greater than 90^o are negatively correlated; in particular, where the angle is 180^o, $r_{xy} = -1$.

In general, long arrows can be regarded as more useful in interpretation than short arrows. They have greater influence in differentiating sites.