Delta Coal

Mannering & CVC Collieries

Lake Macquarie Benthos Survey

Results No. 23

By Dr Emma Laxton

March 2023

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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 11th and 15th March 2023 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 1287 benthic marine organisms greater than 1 mm in size were captured in the study area of Lake Macquarie during the survey. These organisms represented thirteen species. The fauna included six species of polychaete worm; five species of bivalve; one species of gastropod; and one crab species. The greatest numbers of organisms were collected at station R10 (193 organisms), and the least numbers of organisms at station C4 (18 total).

The bivalve *Soletellina alba* was the most commonly encountered organism. A total of 808 *Soletellina* were recorded during the survey, representing 63 percent of the organisms collected. Polychaete worms were also common in the benthos. A total of 284 were recorded, representing 22 percent of the organisms collected. Other species recorded, in small numbers only, included the bivalves *Paphia undulata*, *Corbula truncata* and *Dosinia sculpta*; the gastropod *Nassarius jonassii*; and juvenile crabs.

Very few mussels were found alive during the survey. *Trichomya hirsuta* was found alive at IM1 only. No living mussels were collected from the beds located at R7, IM2 or IM5.

Species diversity at each station ranged from 4 to 9 species and was comparable with previous years. In March 2023, Control stations had a range of 5 to 6 species; Reference stations had a range of 4 to 6 species; and the Impact stations had a range of 4 to 9 species.

In March 2023, the polychaete worm *Sthenelais petitiboneae* was recorded at all stations in the study area. However, the species occurred in greater numbers at stations C2, R11 and IM1. The polychaete worm designated as mud (P2) was also found in relatively large numbers throughout the survey area, particularly stations C7, R11 and IM5. Cirratulid worms characterized the fauna at stations C7, R1, R10 and IM5.

The bivalve *Soletellina alba* was found at all stations, and characterized the fauna at stations

C2, C3, R10, IM7 and IM8. *Corbula truncata* occurred in greater numbers at C1, C6, R2 and IM7. *Trichomya hirsuta* characterized station IM1.

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 R1 also contained a large amount of coarse grey sand. Stations IM2 and IM3 had a high portion of shell in the sediment, 47% and 41% respectively.

In March 2023, water temperature, conductivity, salinity and pH were uniform throughout the water column. The concentration of dissolved oxygen declined with water depth at many stations. Testing of the bottom water at each station found dissolved oxygen ranged from 69.60% to 100.8%. Mean dissolved oxygen of bottom waters was 88.35% saturation. Water temperature ranged from 26.18^{o}C to 28.01^{o}C, with a mean water temperature of 26.90^{o}C. Conductivity ranged from 56.97 mS/cm to 57.86 mS/cm. Mean conductivity of bottom water was 57.48 mS/cm. Salinity ranged from 34.85 ppt to 35.57 ppt, with a mean salinity of 35.28 ppt. Turbidity ranged from 14.20 NTU to 43.60 NTU. Mean turbidity was 27.46 NTU. pH ranged from 7.57 and 7.84, mean pH was 7.73.

Rainfall in the months preceding the survey of March 2023 were 124.6mm and 90.8mm for January and February 2023 respectively (Cooranbong Lake Macquarie AWS No. 061412). By 15th March a further 28.2 mm had fallen in the catchment.

These finding are comparable to previous water quality testing of bottom waters. For instance, in March 2021 and March 2022, average dissolved oxygen concentrations of bottom waters were 84.4% saturation and 68% saturation respectively. Average water temperature of bottom waters was 24.6^{o}C in March 2021 and 25.41^{o}C in March 2022. Average conductivity of bottom waters was 51.9 mS/cm in March 2021 and 50.05 mS/cm in March 2022. Salinity of bottom waters had a mean of 34.1 ppt in March 2021 and an average of 32.9 ppt in March 2022. pH of bottom waters in March 2021 and March 2022 averaged 7.99 and 7.83 respectively.

Note water temperature is increasing in Lake Macquarie.

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. To protect the lake foreshore, a protection zone has been established as part of the extraction plan. This zone, known as the High Water Mark (HWM) Subsidence Barrier, was calculated using a 35° 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 impact of previous miniwall mining on benthic fauna in Lake Macquarie. The mine in currently undertaking first workings.

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/ experienced from previous workings or proposed future workings. 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 23rd 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-two surveys (February 2012 to September 2022). The March 2023 benthic survey was conducted between the 11th and 15th March. Water quality variables were measured on 11th and 15th March 2023.

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 prepared by Mr Lachlan McWha and the Delta Coal team in January 2023. **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.

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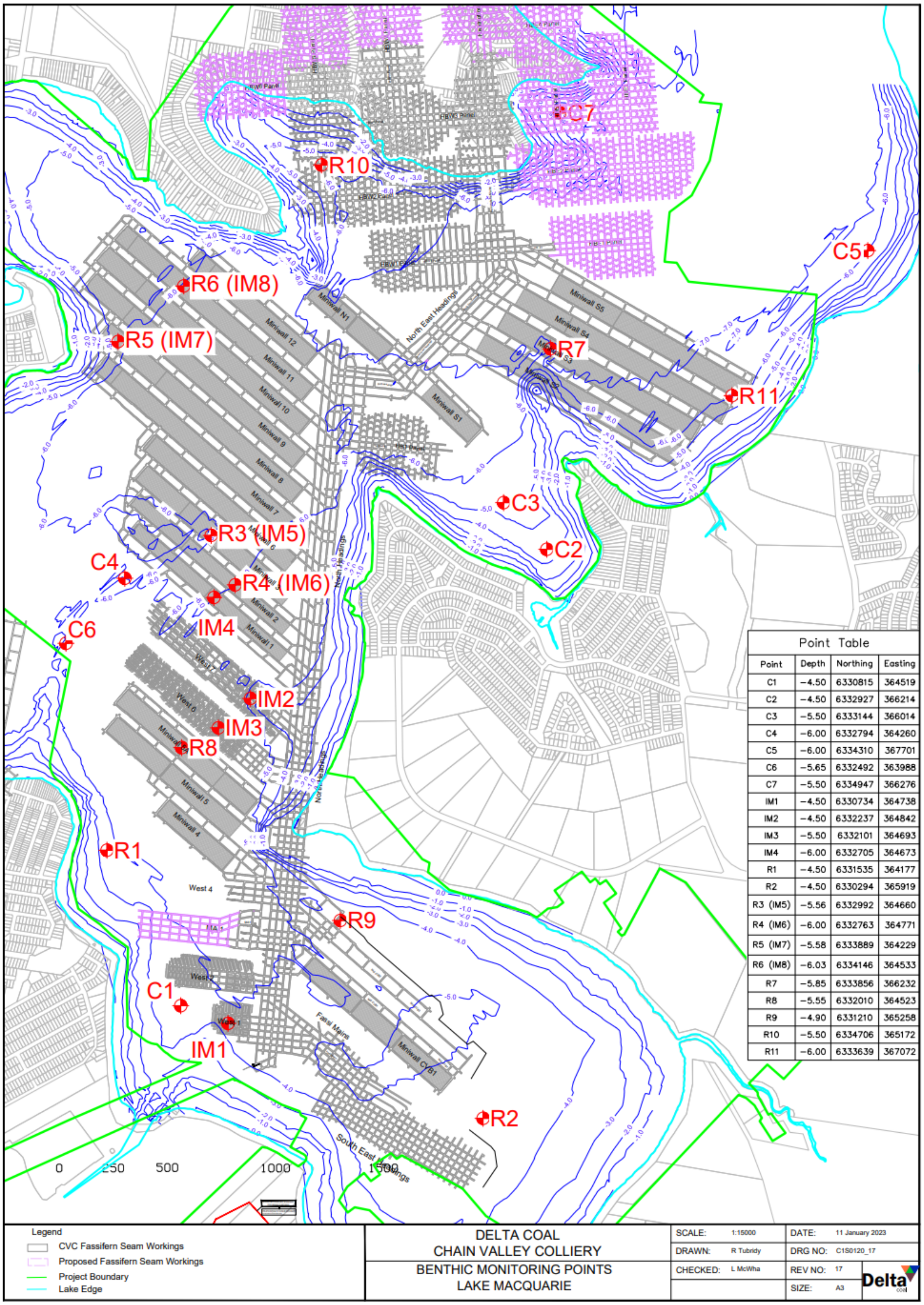


Figure 2.1 Location of benthic sampling stations

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

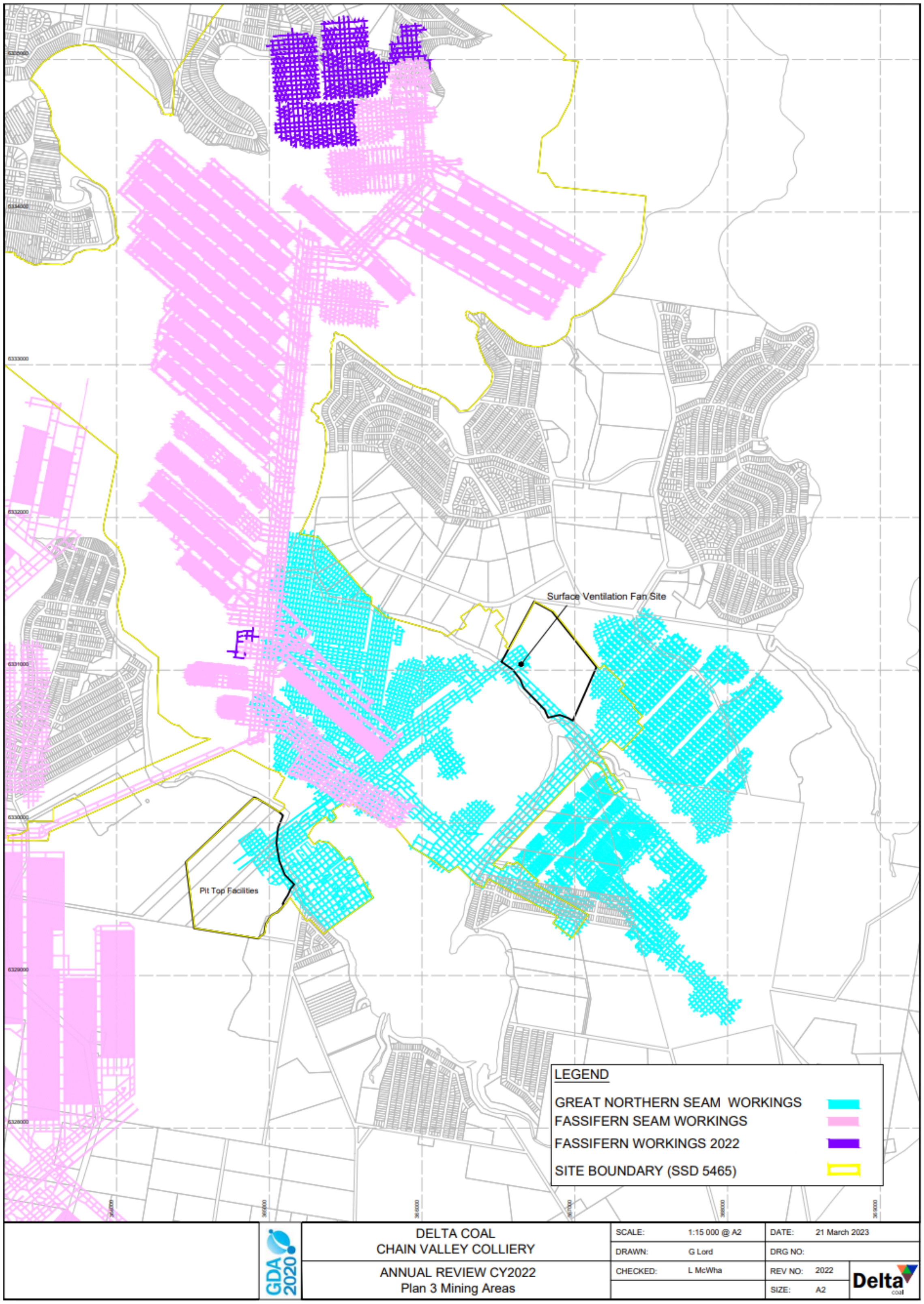


Figure 2.2 Extent of Fassifern Seam Workings – Annual Review CY2022

3. Sampling Procedure

Twenty-two stations were sampled in March 2023. 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.

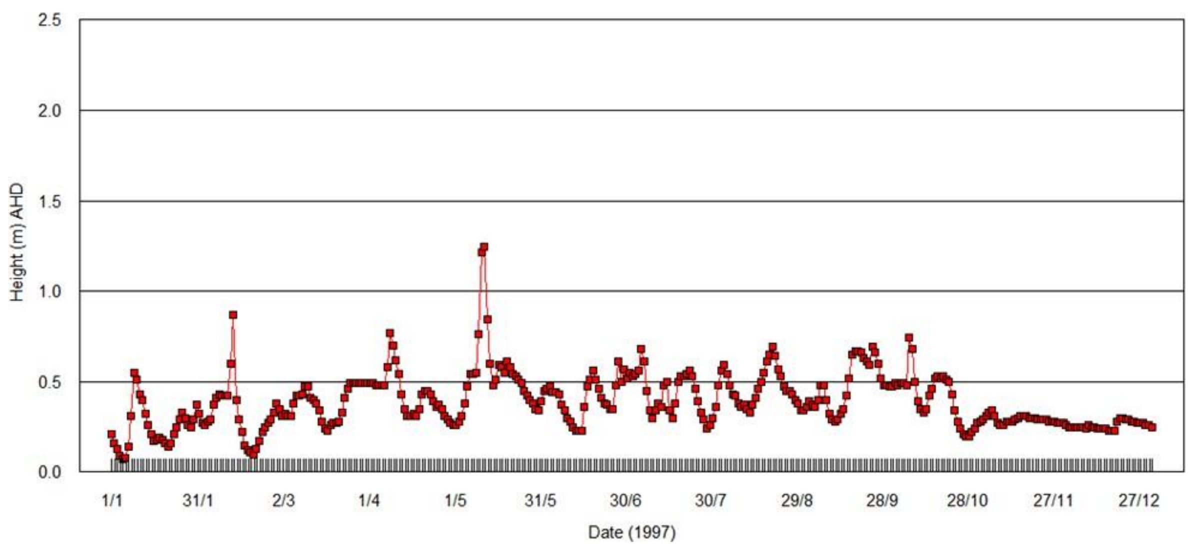


Figure 4.1 Water level changes in a coastal lagoon with an entrance open to coastal waters.

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 March 2023

Table 5.1 shows the organisms found in the sediment samples collected off Summerland Point and in Chain Valley Bay between February 2012 and March 2023.

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 (2012-2023)

Designated name	Family or Species	Comments
Anemone	Coelenterata	Found associated with mussel shells.
Planaria (Flat worm)	Platyhelminthes	Two specimens found in 2017.
Polychaete thin	*Sthenelais pettiboneae*	Most common polychaete present.
Polychaete	Cirratulidae	Present in small numbers.
Polychaete (mud tube)	Not yet identified	Present in small numbers.
Polychaete	*Chaetopterus sp*	Common.
Polychaete	*Diopatra sp*	Common.
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 as live animals.
Bivalve	*Mactra sp*	First collected in December 2022 off Pulbah Island.
Bivalve	*Anadara trapezia*	Uncommon.
Bivalve	*Dosinia sculpta*	Found in sandy sediments.
Bivalve	*Trichomya hirsuta*	Common as dead shells. Found in large clumps.
Bivalve	*Saccostrea glomerata*	Occasionally found on mussel shells.
Ophuroid	Brittle star	Found amongst mussel clumps and on mud.
Echinoid	Sea urchins	Encountered in sandy sediments.
Echinoid	*Echinocardium cordatum*	Encountered in sandy sediments.
Sponge	White calcareous sponge	Specimen found associated with mussels.
Sponge	Pink sponge	Small species found on mud surface.
Sponge	Red sponge	Several specimens found in 2019.
Crabs	Small	Captured occasionally.
Prawn	Small	Captured occasionally.

Plate 5.1 Annelid species found in the benthos of Lake Macquarie (February 2012 – March 2023).

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

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 lives in a tube it constructs 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.

Phylum: Annelida
Class: Polychaeta
Subclass: Errantia
Order: Eunicida
Family: Onuphidae
Genus: *Diopatra*

Remarks: Members of this genus live in thick, parchment-like tubes that project from the sediment on the seabed. The tubes comprise of fragments of shell, algae, fibers and other small objects collected by the worm and stuck in place by mucus.

Plate 5.2 Gastropod species found in the benthos of Lake Macquarie (Feb 2012 – March 2023)

Phylum: Mollusca
Class: Gastropoda
Superfamily: Buccinoidea
Family: Nassariidae
Genus: *Nassarius*
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
Genus: *Lepsiella* (*Bedeva*)
Species: *Lepsiella 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 – March 2023).

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*

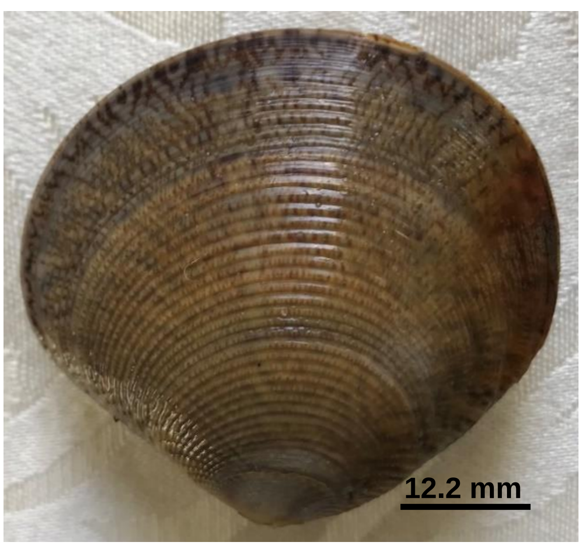
Remarks: Saltwater clam, marine bivalve mollusc. Inhabits inshore shallow sandy seabeds.

Phyllum: Mollusca
Class: Bivalvia
Order: Veneroida
Family: Veneridae
Species: *Dosinia sculpta*

Remarks: *Dosinia* is a genus of saltwater clam or marine bivalve molluscs in the sub-family 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: Veneroida
Family: Mactridae
Species: *Mactra*

Remarks: Large genus of medium-sized marine bivalve mollusc or clam, commonly known as trough shells or duck clams. The word "trough" refers to the large ligamental pit at the hinge line, which contains a large internal ligament. Most bivalves in other families have an external ligament.

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*

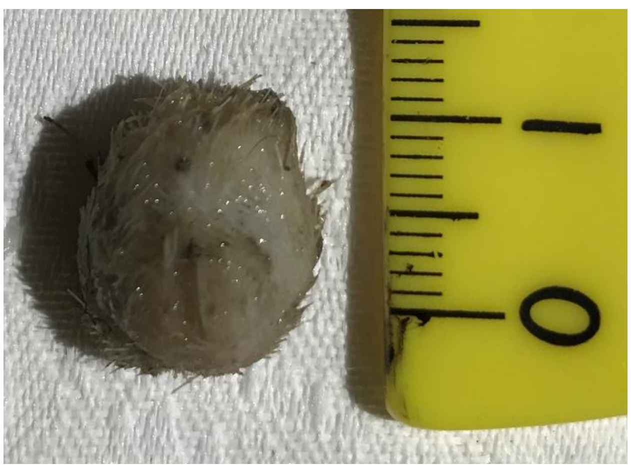
Remarks: Sydney rock oysters are endemic to Australia and New Zealand. In Australia it is found in bays, inlets and sheltered estuaries from Wingan Inlet in eastern Victoria, along the east coast of NSW and up to Hervey Bay QLD, around northern Australia and down the west coast to Shark Bay in WA. Sydney 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 in 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.

Plate 5.5 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.

Phylum: Echinodermata
Class: Echinoidea
Order: Cidaroida

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 March 2023 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 6.1 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.

Similar masses of shell were found in the samples of the September 2013 to March 2023 surveys. The following organisms were identified amongst the shell:

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

Plates 6.3 and **6.4** 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 6.3 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 6.4 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 – March 2023

Table 7.1 shows the organisms found at each station sampled off Summerland Point and in Chain Valley Bay and Bardens Bay in March 2023.

A total of 1287 benthic marine organisms greater than 1 mm in size were captured in the study area of Lake Macquarie during the March 2023 survey of 22 stations (**Table 7.1**). Thirteen species of benthic marine organisms were found. The fauna included six species of polychaete worm (**Plate 5.1**); five species of bivalve (**Plate 5.3**); one species of gastropod (**Plate 5.4**); and one crab species.

In March 2023, the greatest numbers of organisms were collected at stations R10 (193 organisms), C2 (175 organisms) and C3 (107 organisms). The stations with the least numbers of organisms were C4 (18 total), IM6 (19 total), IM2 (21 total), IM4 (22 organisms) and IM5 (23 organisms) (**Table 7.1**).

The bivalve *Soletellina alba* was the most commonly encountered organism. A total of 808 *Soletellina* were recorded during the survey, representing 63 percent of the organisms collected. The number of *S. alba* at each station ranged from 1 to 177. The bivalve was present at every station (**Fig 7.2**). Polychaete worms were also common in the benthos (**Table 7.1**). A total of 284 were recorded, representing 22 percent of the organisms collected. Other species recorded, in small numbers only, included the bivalves *Paphia undulata*, *Corbula truncata* and *Dosinia sculpta*; the gastropod *Nassarius jonassii*; and juvenile crabs.

Very few mussels were found alive during the survey. *Trichomya hirsuta* was found alive at IM1 only. No living mussels were collected from the beds located at R7, IM2 or IM5 (**Table 7.1**).

Table 7.1 Organisms found at sampling stations on 11th and 15th March 2023.

Control Station C1 Depth -4.50m AHD 56 364519 6330815 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C1.1	2	1	1	0	0	0	0	0	3	9	0	0	0	0	0	0
C1.2	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
C1.3	2	0	0	0	0	0	1	0	3	2	0	0	0	0	0	0
C1.4	1	0	3	0	0	0	0	0	1	8	0	0	0	0	0	0
C1.5	1	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
Total	**6**	**1**	**4**	**0**	**0**	**0**	**1**	**0**	**7**	**35**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.2	0.2	0.8	0.0	0.0	0.0	0.2	0.0	1.4	7.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	30	5	20	0	0	0	5	0	35	175	0	0	0	0	0	0
No. species	**6**											**Total Organisms at Station**				**54**

Control Station C2 Depth -4.50m AHD 56 366214 6332927 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C2.1	1	0	2	0	0	0	1	0	0	17	0	0	0	0	0	0
C2.2	5	0	2	0	0	0	0	0	0	16	0	0	0	0	0	0
C2.3	3	0	2	0	0	0	0	0	0	44	0	5	0	0	0	0
C2.4	1	0	1	0	0	0	0	0	1	35	0	0	0	0	0	0
C2.5	5	0	0	0	0	0	0	0	1	33	0	0	0	0	0	0
Total	**15**	**0**	**7**	**0**	**0**	**0**	**1**	**0**	**2**	**145**	**0**	**5**	**0**	**0**	**0**	**0**
Mean/station	3.0	0.0	1.4	0.0	0.0	0.0	0.2	0.0	0.4	29.0	0.0	1.0	0.0	0.0	0.0	0.0
no./m2	75	0	35	0	0	0	5	0	10	725	0	25	0	0	0	0
No. species	**6**											**Total Organisms at Station**				**175**

Control Station C3 Depth -5.50m AHD 56 366014 6333144 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C3.1	2	0	1	1	0	0	0	0	0	12	0	0	0	0	0	0
C3.2	2	0	1	0	0	0	0	0	2	26	0	0	0	0	0	0
C3.3	3	0	2	0	0	0	0	0	1	13	0	0	0	0	0	0
C3.4	3	0	1	0	0	0	0	0	1	33	0	0	0	0	0	0
C3.5	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Total	**11**	**0**	**5**	**1**	**0**	**0**	**0**	**0**	**4**	**86**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	2.2	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.8	17.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	55	0	25	5	0	0	0	0	20	430	0	0	0	0	0	0
No. species	**5**											**Total Organisms at Station**				**107**

Control Station C4 Depth -5.50m AHD 56 364260 6332794 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C4.1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
C4.2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
C4.3	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0
C4.4	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0
C4.5	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0
Total	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**4**	**7**	**3**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.4	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.8	1.4	0.6	0.0	0.0	0.0	0.0	0.0
no./m2	10	5	5	0	0	0	0	0	20	35	15	0	0	0	0	0
No. species	**6**												**Total Organisms at Station**			**18**

Control Station C5 Depth -5.50m AHD 56 367701 6334510 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C5.1	1	0	2	0	0	1	1	0	0	2	0	0	0	0	0	0
C5.2	2	0	2	1	0	0	0	0	0	6	0	0	0	0	0	0
C5.3	3	0	2	0	0	0	0	0	0	4	0	0	0	0	0	0
C5.4	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0
C5.5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**9**	**0**	**8**	**1**	**0**	**1**	**1**	**0**	**0**	**15**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.8	0.0	1.6	0.2	0.0	0.2	0.2	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	45	0	40	5	0	5	5	0	0	75	0	0	0	0	0	0
No. species	**6**												**Total Organisms at Station**			**35**

Control Station C6 Depth -5.50m AHD 56 363988 6332492 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C6.1	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0
C6.2	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0
C6.3	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0
C6.4	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
C6.5	0	0	0	0	0	0	0	0	3	1	1	0	0	0	0	0
Total	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**14**	**1**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.8	0.2	0.0	0.0	0.0	0.0	0.0
no./m2	5	0	0	0	0	0	0	0	50	70	5	0	0	0	0	0
No. species	**4**												**Total Organisms at Station**			**26**

Control Station C7 Depth -5.50m AHD 56 364736 6334947 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
C7.1	2	1	7	0	0	0	0	0	0	0	0	0	0	0	0	1
C7.2	0	1	1	0	0	0	0	0	0	3	0	0	0	0	0	2
C7.3	3	0	5	0	0	0	0	0	0	5	0	0	0	0	0	2
C7.4	2	0	6	0	0	0	0	0	0	0	0	0	0	0	0	2
C7.5	1	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0
Total	**8**	**2**	**23**	**3**	**0**	**0**	**0**	**0**	**0**	**8**	**0**	**0**	**0**	**0**	**0**	**7**
Mean/station	1.6	0.4	4.6	0.6	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	1.4
no./m2	40	10	115	15	0	0	0	0	0	40	0	0	0	0	0	35
No. species	**6**												**Total Organisms at Station**			**51**

Station R1 Depth -4.50m AHD 56 364177 6331535 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R1.1	3	0	3	0	0	0	0	0	0	2	1	0	0	0	0	0
R1.2	3	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
R1.3	2	0	1	0	0	0	0	0	1	17	0	0	0	0	0	0
R1.4	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
R1.5	1	0	1	0	0	0	0	0	3	18	0	0	0	0	0	0
Total	**11**	**0**	**5**	**2**	**0**	**0**	**0**	**0**	**4**	**42**	**1**	**0**	**0**	**0**	**0**	**0**
Mean/station	2.2	0.0	1.0	0.4	0.0	0.0	0.0	0.0	0.8	8.4	0.2	0.0	0.0	0.0	0.0	0.0
no./m2	55	0	25	10	0	0	0	0	20	210	5	0	0	0	0	0
No. species	**6**												**Total Organisms at Station**			**65**

Station R2 Depth -4.50m AHD 56 365919 6330294 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R2.1	2	0	0	0	0	0	1	0	1	8	0	0	0	0	0	0
R2.2	1	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0
R2.3	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
R2.4	0	0	0	0	0	0	0	0	4	6	0	0	0	0	0	0
R2.5	4	0	0	0	0	0	0	0	0	5	0		0	0	0	0
Total	**9**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**7**	**24**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.8	0.0	0.0	0.0	0.0	0.0	0.4	0.0	1.4	4.8	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	45	0	0	0	0	0	10	0	35	120	0	0	0	0	0	0
No. species	**4**												**Total Organisms at Station**			**42**

Station R7 Depth -6.00m AHD 56 366232 6333856 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R7.1	2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
R7.2	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
R7.3	1	0	2	0	0	0	0	0	0	1	3	0	0	0	0	0
R7.4	0	0	2	0	0	0	0	0	0	10	0	1	0	0	0	0
R7.5	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Total	**4**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**23**	**3**	**1**	**0**	**0**	**0**	**0**
Mean/station	0.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.6	0.2	0.0	0.0	0.0	0.0
no./m2	20	0	20	0	0	0	0	0	0	115	15	5	0	0	0	0
No. species	**5**												**Total Organisms at Station**			**35**

Station R8 Depth -6.00m AHD 56 364323 63322010 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R8.1	0	0	1	0	0	0	0	0	0	7	1	0	0	0	0	0
R8.2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
R8.3	1	0	0	0	0	0	0	0	1	8	0	0	0	0	0	0
R8.4	2	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
R8.5	0	0	0	0	0	0	0	0	0	12	0	3	0	0	0	0
Total	**3**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**39**	**1**	**3**	**0**	**0**	**0**	**0**
Mean/station	0.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	7.8	0.2	0.6	0.0	0.0	0.0	0.0
no./m2	15	0	5	0	0	0	0	0	5	195	5	15	0	0	0	0
No. species	**6**												**Total Organisms at Station**			**48**

Station R9 Depth -6.00m AHD 56 366232 6331210 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R9.1	3	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
R9.2	1	0	0	0	0	0	1	0	2	6	0	0	0	0	0	0
R9.3	3	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0
R9.4	3	0	0	0	0	0	0	0	3	6	1	0	0	0	0	0
R9.5	3	0	2	0	0	0	0	0	0	5	1	0	0	0	0	0
Total	**13**	**0**	**6**	**0**	**0**	**0**	**2**	**0**	**6**	**19**	**2**	**0**	**0**	**0**	**0**	**0**
Mean/station	2.6	0.0	1.2	0.0	0.0	0.0	0.4	0.0	1.2	3.8	0.4	0.0	0.0	0.0	0.0	0.0
no./m2	65	0	30	0	0	0	10	0	30	95	10	0	0	0	0	0
No. species	**6**												**Total Organisms at Station**			**48**

Station R10 Depth -6.00m AHD 56 365172 6334708 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R10.1	1	0	1	0	0	0	0	0	1	50	0	0	0	0	0	0
R10.2	2	0	2	1	0	0	0	0	1	20	0	0	0	0	0	0
R10.3	2	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0
R10.4	0	0	2	0	0	0	0	0	0	49	0	0	0	0	0	0
R10.5	1	0	0	0	0	0	0	0	2	41	0	0	0	0	0	0
Total	**6**	**0**	**5**	**1**	**0**	**0**	**0**	**0**	**4**	**177**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.2	0.0	1.0	0.2	0.0	0.0	0.0	0.0	0.8	35.4	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	30	0	25	5	0	0	0	0	20	885	0	0	0	0	0	0
No. species	**5**												**Total Organisms at Station**			**193**

Station R11 Depth -6.00m AHD 56 367072 6333638 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R11.1	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
R11.2	1	0	3	0	0	0	0	0	0	9	0	0	0	0	0	0
R11.3	3	0	1	0	0	0	0	0	0	11	0	0	0	0	0	0
R11.4	5	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0
R11.5	5	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0
Total	**16**	**0**	**10**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**1**	**0**	**0**	**0**	**0**	**0**
Mean/station	3.2	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.2	0.0	0.0	0.0	0.0	0.0
no./m2	80	0	50	0	0	0	0	0	0	110	5	0	0	0	0	0
No. species	**4**												**Total Organisms at Station**			**49**

Station IM1 Depth -4.50m AHD 56 364738 6330734 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
IM1.1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
IM1.2	2	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0
IM1.3	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
IM1.4	4	0	1	0	0	0	0	0	0	2	0	0	0	0	2	0
IM1.5	0	0	0	0		0	0	0	1	0	0	0	0	0	0	0
Total	**14**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**2**	**3**	**0**	**1**	**0**	**0**	**7**	**0**
Mean/station	2.8	0.0	0.2	0.2	0.0	0.0	0.2	0.0	0.4	0.6	0.0	0.2	0.0	0.0	1.4	0.0
no./m2	70	0	5	5	0	0	5	0	10	15	0	5	0	0	35	0
No. species	**8**												**Total Organisms at Station**			**30**

Station IM2 Depth -4.50m AHD 56 364842 6332237 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
IM2.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
IM2.2	2	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0
IM2.3	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1
IM2.4	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
IM2.5	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Total	**10**	**1**	**2**	**1**	**1**	**0**	**0**	**0**	**3**	**1**	**0**	**1**	**0**	**0**	**0**	**1**
Mean/station	2.0	0.2	0.4	0.2	0.2	0.0	0.0	0.0	0.6	0.2	0.0	0.2	0.0	0.0	0.0	0.2
no./m2	50	5	10	5	5	0	0	0	15	5	0	5	0	0	0	5
No. species	**9**											**Total Organisms at Station**				**21**

Station IM3 Depth -5.50m AHD 56 364693 6332101 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
IM3.1	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
IM3.2	0	0	0	0	0	0	0	0	1	8	0	0	0	0	0	0
IM3.3	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
IM3.4	2	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
IM3.5	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0
Total	**4**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**3**	**22**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.6	4.4	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	20	0	5	0	0	0	0	0	15	110	0	0	0	0	0	0
No. species	**4**											**Total Organisms at Station**				**30**

Station IM4 Depth -6.00m AHD 56 364673 6332705 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
IM4.1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IM4.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IM4.3	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
IM4.4	2	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
IM4.5	3	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0
Total	**9**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	45	0	5	0	0	0	0	0	0	60	0	0	0	0	0	0
No. species	**3**											**Total Organisms at Station**				**22**

Station R3 (now IM5) Depth -5.50m AHD 56 364660 6332992 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R3.1	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0
R3.2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
R3.3	1	1	2	0	0	0	0	0	1	1	0	0	0	0	0	0
R3.4	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
R3.5	1	0	2	1	0	0	1	0	1	0	0	0	0	0	0	0
Total	**6**	**1**	**9**	**2**	**0**	**0**	**1**	**0**	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	1.2	0.2	1.8	0.4	0.0	0.0	0.2	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	30	5	45	10	0	0	5	0	15	5	0	0	0	0	0	0
No. species	**7**												**Total Organisms at Station**			**23**

Station R4 (now IM6) Depth -6.00m AHD 56 364771 6332763 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R4.1	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0
R4.2	0	0	2	0	0	0	0	0	2	1	0	0	0	0	0	0
R4.3	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
R4.4	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
R4.5	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Total	**4**	**0**	**5**	**0**	**0**	**0**	**0**	**0**	**5**	**5**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	20	0	25	0	0	0	0	0	25	25	0	0	0	0	0	0
No. species	**4**												**Total Organisms at Station**			**19**

Station R5 (now IM7) Depth -6.00m AHD 56 364229 6333889 Sampled 11 - 15 March 2023

Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R5.1	0	0	1	0	0	0	0	0	1	7	0	0	0	0	0	0
R5.2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
R5.3	1	0	0	0	0	0	0	0	1	15	0	0	0	0	0	0
R5.4	0		0	0	0	0	0	0	0	11	0	0	0	0	0	0
R5.5	0	0	0	0	0	0	0	0	4	14	0	0	0	0	0	0
Total	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**6**	**50**	**0**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.2	10.0	0.0	0.0	0.0	0.0	0.0	0.0
no./m2	5	0	5	0	0	0	0	0	30	250	0	0	0	0	0	0
No. species	**4**												**Total Organisms at Station**			**58**

Station R6 (now IM8)			Depth -6.00m AHD				56 364533	6334146		Sampled 11 - 15 March 2023						
Replicates	Polychaete *Sthenelais*	Polychaete thin	Polychaete mud	Polychaete Cirratulidae	Polychaete *Chaetopterus*	Polychaete Pectinariidae	Gastropod *Nassarius*	Gastropod *Bedeva*	Bivalve *Corbula*	Bivalve *Soletellina*	Bivalve *Paphia*	Bivalve *Dosinia*	Bivalve *Anadara*	Bivalve *Cyamiomactra*	Bivalve *Trichomya*	Crab
R6.1	0	0	1	0	0	0	0	0	1	20	0	0	0	0	0	0
R6.2	0	0	0	0	0	0	0	0	3	10	1	0	0	0	0	0
R6.3	0	0	0	0	0	0	0	0	1	10	0	0	0	0	0	0
R6.4	0	0	0	0	0	0	0	0	0	15	1	0	0	0	0	0
R6.5	1	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0
Total	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**5**	**58**	**2**	**0**	**0**	**0**	**0**	**0**
Mean/station	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	1.0	11.6	0.4	0.0	0.0	0.0	0.0	0.0
no./m2	5	0	10	0	0	0	0	0	25	290	10	0	0	0	0	0
No. species	**5**													**Total Organisms at Station**		**68**

Total Organisms collected **1287**
Total number of species recorded **13**

At the time of survey, species diversity at each station ranged from 4 to 9 species and was comparable to previous years (**Table 7.2**). In March 2023, Control stations had a range of 5 to 6 species; Reference stations had a range of 4 to 6 species; and the Impact stations had a range of 4 to 9 species.

Table 7.2 Number of species found at each Station from February 2012 to March 2023

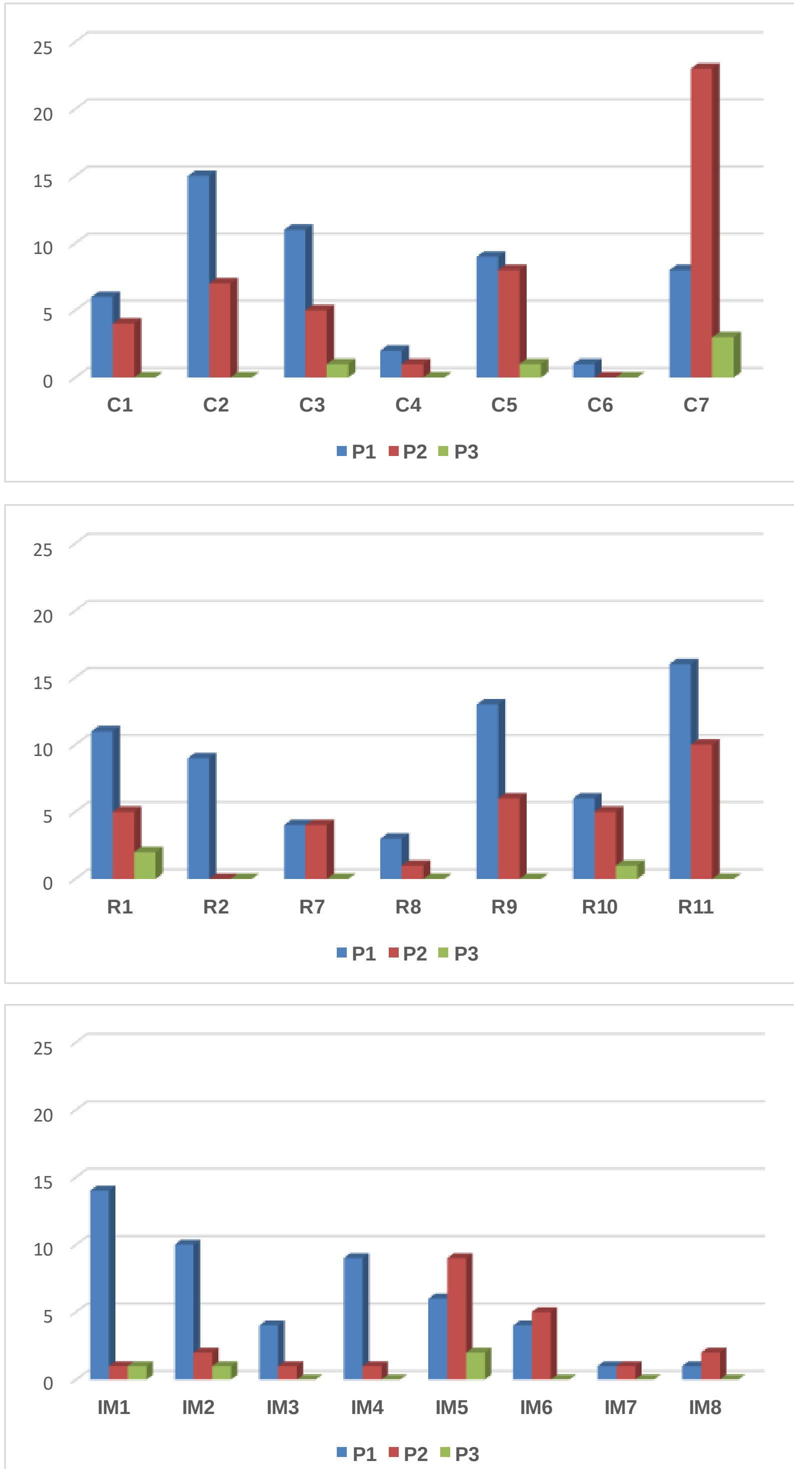
Station	C1	C2	C3	C4	C5	C6	C7	R1	R2	R7	R8
Feb 2012	10	5	5	7				8	8		
Sept 2012	3	6	4	4				6	3		
March 2013	4	5	7	7				6	5		
Sept 2013	6	6	3	7				5	6		
March 2014	4	3	5	5				6	4		
Sept 2014	3	4	4	8				6	5		
March 2015	3	3	5	3				5	3		
Sept 2015	5	4	4	3				5	3		
March 2016	6	4	5	5	5			6	5	8	
Sept 2016	7	3	6	5	4	8		8	4	7	5
March 2017	2	4	5	3	5	5		4	5	4	3
Sept 2017	4	4	4	4	4	5		4	3	4	5
March 2018	4	4	8	4	4	3	5	7	8	4	3
Sept 2018	3	4	4	6	5	5	5	4	4	6	4
March 2019	6	3	4	4	6	5	3	4	5	4	4
Sept 2019	5	6	5	5	4	5	6	4	3	5	4
March 2020	5	6	6	4	7	3	6	6	6	8	3
August 2020	6	5	4	4	3	5	5	4	5	8	4
March 2021	5	6	3	4	5	2	2	5	4	5	4
Sept 2021	4	4	7	6	7	7	6	5	4	7	3
March 2022	5	6	4	7	6	7	4	6	4	8	3
Sept 2022	5	5	7	7	6	5	6	6	5	4	6
March 2023	6	6	5	6	6	4	6	6	4	5	6

Station	R9	R10	R11	IM1	IM2	IM3	IM4	IM5	IM6	IM7	IM8
Feb 2012				7	4	4	5	5	5		
Sept 2012				4	4	3	5	4	5		
March 2013				7	5	5	5	6	5		
Sept 2013				4	3	4	5	5	4		
March 2014				5	9	4	5	5	3	4	3
Sept 2014				5	6	3	6	6	6	3	3
March 2015				5	4	4	5	6	5	3	3
Sept 2015				5	5	4	4	4	6	5	4
March 2016				6	6	3	4	6	4	4	4
Sept 2016	8			6	4	6	3	5	6	6	7
March 2017	5			3	4	3	4	4	5	4	4
Sept 2017	4			5	5	5	5	6	5	4	4
March 2018	4	4	4	5	7	3	4	5	4	6	3
Sept 2018	5	4	4	4	8	4	4	5	5	5	4
March 2019	4	6	6	5	5	2	4	7	3	5	4
Sept 2019	4	4	3	6	5	7	5	7	4	4	4
March 2020	4	4	4	7	7	4	4	7	4	4	4
August 2020	5	5	4	5	6	4	6	7	4	7	5
March 2021	6	5	8	7	7	5	7	7	4	5	5
Sept 2021	4	6	7	3	7	4	4	8	3	4	4
March 2022	5	6	6	5	6	5	6	9	7	4	4
Sept 2022	7	6	5	6	8	6	3	7	6	5	4
March 2023	6	5	4	8	9	4	7	4	4	4	5

In March 2023, the polychaete worm *Sthenelais petitiboneae* was recorded at all stations in the study area. However, the species occurred in greater numbers at stations C2, R11 and IM1. The polychaete worm designated as mud (P2) was also found in relatively large numbers throughout the survey area, particularly stations C7, R11 and IM5. Cirratulid worms characterized the fauna at stations C7, R1, R10 and IM5 (**Figure 7.1**).

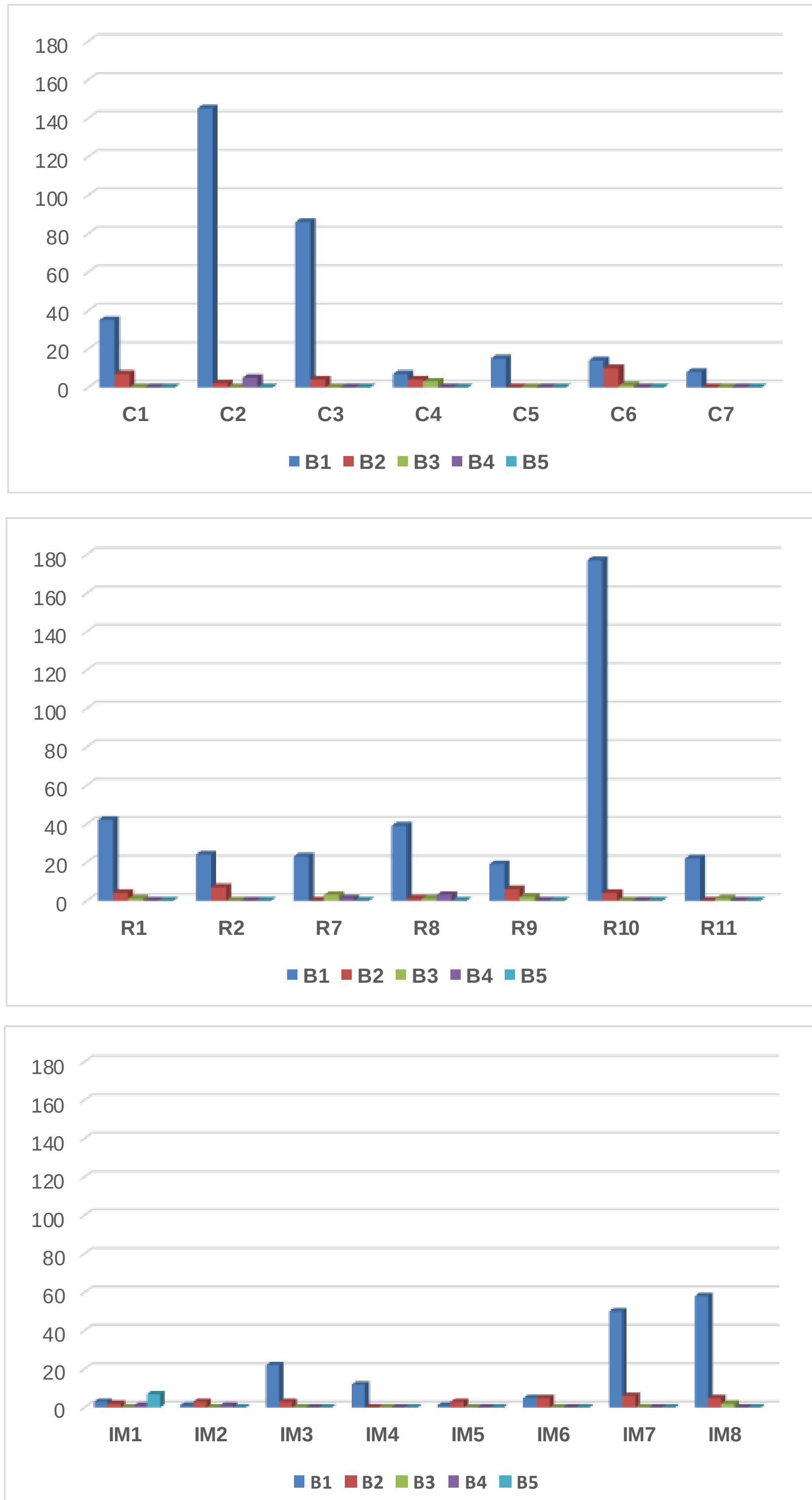
The bivalve *Soletellina alba* was found at all stations, and characterized the fauna at stations C2, C3, R10, IM7 and IM8. *Corbula truncata* occurred in greater numbers at C1, C6, R2 and IM7. *Trichomya hirsuta* characterized station IM1 (**Figure 7.2**).

Figure 7.1 Number of polychaetes found at each Control, reference and Impact Station, March 2023



Key: P1 *Sthenelais pettiboneae* P2 Polychaete mud P3 Cirratulidae

Figure 7.2 Number of bivalves found at each control, reference and impact Station, March 2023



Key: B1 *Soletellina* B2 *Corbula* B3 *Paphia* B4 *Dosinia* B5 *Trichomya*

8. Sediment Analysis

In March 2023, 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 contained a large amount of coarse grey sand (**Table 8.2**). The sediment samples collected at IM2, IM3, C1 and C2 comprised a high portion of shell (**Table 8.2**).

Table 8.1 Description of sediment collected from sampling stations in March 2023.

Station	Description
C1	Dark grey silt with some small sized shell fragments.
C2	Dark grey silt with some small sized shell fragments.
C3	Dark grey silt with some shell fragments.
C4	Dark grey silt with some small to large shell fragments.
C5	Dark grey silt with some coarse grey sand and shell fragments.
C6	Dark grey silt with some small to large shell fragments. Mud plastic in nature.
C7	Coarse grey sand and dark grey silt.
R1	Dark grey silt with fine grey sand. No shell fragments or gravel.
R2	Dark grey silt with some shell fragments. No sand or gravel.
R6	Dark grey silt. Mud plastic in nature.
R7	Dark grey silt with some small to medium shell fragments.
R8	Dark grey silt with some large shell fragments.
R9	Dark grey silt with some shell.
R10	Dark grey silt with some small shell fragments.
R11	Dark grey silt with some small shell fragments.
IM1	Dark grey silt with medium to large shell fragments and some coarse 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 some 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	83	0	0	17
C2	83	0	0	17
C3	95	0	0	5
C4	95	0	0	5
C5	97	1	0	2
C6	99	0	0	1
C7	42	58	0	0
R1	89	11	0	0
R2	99	0	0	1
R6	100	0	0	0
R7	99	0	0	1
R8	99	0	0	1
R9	95	0	0	5
R10	99	0	0	1
R11	99	0	0	1
IM1	91	1	0	8
IM2	52	1	0	47
IM3	59	1	0	41
IM4	98	0	0	2
R3 (IM5)	98	0	0	2
R4 (IM6)	90	0	0	10
R5 (IM7)	100	0	0	0

March 2023

9. Physical characteristics of water in Lake Macquarie – March 2023

At each station, a water quality profile was taken using a calibrated Yeo-Kal 618RU Analyser. The physical characteristics were measured on 11th and 15th March 2023. 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:

Water temperature was very high and uniform throughout the water column and throughout the study area. For instance:

- C6, water temperature ranged from 27.77ºC at the surface to 28.01ºC at -6.5m AHD.
- R3 (now IM5), water temperature ranged from 27.00ºC at the surface to 27.04ºC at -6.5m AHD.
- R4 (now IM6), water temperature ranged from 27.47ºC at the surface to 27.26ºC at -6.5m AHD.
- R9, water temperature ranged from 28.07ºC at the surface to 27.27ºC at -4.5m AHD.

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

- C1, conductivity ranged from 57.52 mS/cm at the surface to 57.64 mS /cm at -5.0m AHD.
- C2, conductivity ranged from 56.10 mS /cm at the surface to 56.40 mS at -5.5m AHD.
- IM1, conductivity ranged from 57.53 mS /cm at the surface to 57.61 mS /cm at -5.0m AHD.
- IM2, conductivity ranged from 57.57 mS /cm at the surface to 57.55 mS /cm at -6.1m AHD.
- R1, conductivity ranged from 57.55 mS /cm at the surface to 57.59 mS /cm at -4.5m AHD.

Salinity was relatively uniform throughout the water column and the study area. For instance:

- C3, salinity ranged from 33.98 ppt at the surface to 35.11 ppt at -6.5m AHD.
- IM3, salinity ranged from 35.32 ppt at the surface to 35.31 ppt at -6.5m AHD.
- R2, salinity ranged from 35.38 ppt at the surface to 35.40 ppt at -5.0m AHD.
- R7, salinity ranged from 33.94 ppt at the surface to 35.45 ppt at -8.0m AHD.

pH was relatively uniform throughout the water column and the study area. For instance:

- C4, pH ranged from 7.78 at the surface to 7.80 at -6.0m AHD.
- C5, pH ranged from 7.75 at the surface to 7.63 at -6.5m AHD
- IM4, pH ranged from 7.79 at the surface to 7.80 at -7.5m AHD.
- R8, pH ranged from 7.81 at the surface to 7.81 at -7.0m AHD.

Dissolved oxygen decreased with depth or was uniform throughout the water column and the study area. For instance:

- C7, dissolved oxygen decreased from 94.9% saturation at the surface to 89.4% saturation at -- -6.0m AHD.

- R5 (now IM7), dissolved oxygen decreased from 91.9% saturation at the surface to 69.6% saturation at -7.5m AHD.
- R6 (now IM8), dissolved oxygen decreased from 94.2% saturation at the surface to 75.8% saturation at -6.5m AHD
- R10, dissolved oxygen decreased from 94.6% saturation at the surface to 80.0 % saturation at -6.5m AHD (**Appendix 1**).

The physical characteristics of the bottom waters of Lake Macquarie in March 2023 were as follows:

- Water Temperature ranged from 26.18^{o}C to 28.01^{o}C. Mean water temperature was 26.90^{o}C.
- Conductivity ranged from 56.97 mS/cm to 57.86 mS/cm. Mean conductivity was 57.48 mS/cm.
- Salinity ranged from 34.85 ppt to 35.57 ppt. Mean salinity was 35.28 ppt.
- Turbidity ranged from 14.20 NTU to 43.60 NTU. Mean turbidity was 27.46 NTU.
- pH ranged from 7.57 and 7.84. Mean pH was 7.73.
- Dissolved oxygen (% saturation) ranged from 69.60% to 100.8%. Mean dissolved oxygen was 88.35% saturation.
- Dissolved oxygen (mg/L) ranged from 4.51 mg/L to 6.45 mg/L. Mean dissolved oxygen was 5.68 mg/L (**Table 9.1**).

Rainfall in the months preceding the survey were 124.6mm and 90.8mm for January and February 2023 respectively (Cooranbong Lake Macquarie AWS No. 061412). By 15th March a further 28.2 mm had fallen in the catchment.

Table 9.2 provides the averages for bottom water quality variables from 2013 to 2022. Average conductivity, salinity, dissolved oxygen and turbidity were comparable to current levels. Average water temperatures of bottom waters in the study area, however, have increased since March 2017.

Table 9.1 Physical characteristics of the bottom water – March 2023

Station	Temperature °C	Conductivity mS/cm	Salinity ppt	DO % sat	DO mg/L	pH	Turbidity NTU	Depth m
Control Stations								
C1	26.72	57.65	35.41	93.3	6.00	7.83	34.2	5.00
C2	26.33	56.97	34.85	85.6	5.58	7.64	33.0	5.50
C3	26.46	57.27	35.12	77.3	5.05	7.62	29.0	6.50
C4	27.54	57.54	35.36	97.6	6.20	7.80	23.7	6.00
C5	26.32	57.16	35.04	74.7	4.85	7.63	22.3	6.50
C6	28.01	57.69	35.44	89.6	5.65	7.79	19.7	6.50
C7	26.18	56.98	34.91	90.2	5.88	7.70	21.1	6.00
Mean	**26.79**	**57.32**	**35.16**	**86.90**	**5.60**	**7.72**	**26.14**	**6.00**
Min	**26.18**	**56.97**	**34.85**	**74.7**	**4.85**	**7.62**	**19.7**	**5**
Max	**28.01**	**57.69**	**35.44**	**97.6**	**6.2**	**7.83**	**34.2**	**6.5**
Reference Stations								
R1	27.34	57.61	35.37	83.5	5.36	7.75	22.6	4.50
R2	26.45	57.62	35.40	90.2	5.78	7.81	32.8	5.00
R7	26.55	57.71	35.45	69.6	4.58	7.58	43.6	8.00
R8	27.35	57.51	35.31	94.6	6.03	7.81	20.1	7.00
R9	27.25	57.63	35.40	99.7	6.36	7.83	17.0	4.50
R10	26.45	57.45	35.25	80.8	5.21	7.64	40.8	6.50
R11	26.36	57.30	35.14	90.9	5.90	7.68	20.9	7.50
Mean	**26.82**	**57.55**	**35.33**	**87.04**	**5.60**	**7.73**	**28.26**	**6.14**
Min	**26.36**	**57.3**	**35.14**	**69.6**	**4.58**	**7.58**	**17**	**4.50**
Max	**27.35**	**57.71**	**35.45**	**99.7**	**6.36**	**7.83**	**43.6**	**8.00**
Impact Stations								
IM1	26.69	57.62	35.38	93.8	6.04	7.84	33.5	5.00
IM2	27.35	57.56	35.34	100.8	6.45	7.80	29.1	4.50
IM3	27.31	57.50	35.31	94.4	6.01	7.80	14.2	6.50
IM4	27.4	57.46	35.26	98.5	6.29	7.80	26.3	7.50
R3 (IM5)	27.05	57.34	35.19	97.8	6.26	7.82	27.6	6.50
R4 (IM6)	27.29	57.40	35.20	95.0	6.06	7.79	24.1	6.50
R5 (IM7)	26.64	57.86	35.57	70.4	4.51	7.57	33.4	7.50
R6 (IM8)	26.79	57.64	35.40	75.5	4.88	7.59	35.1	6.50
Mean	**27.07**	**57.55**	**35.33**	**90.78**	**5.81**	**7.75**	**27.91**	**6.31**
Min	**26.64**	**57.34**	**35.19**	**70.4**	**4.51**	**7.57**	**14.2**	**4.50**
Max	**27.4**	**57.86**	**35.57**	**100.8**	**6.45**	**7.84**	**35.1**	**7.50**
Bottom Water Quality - all stations								
Mean	**26.90**	**57.48**	**35.28**	**88.35**	**5.68**	**7.73**	**27.46**	**6.16**
Min	**26.18**	**56.97**	**34.85**	**69.60**	**4.51**	**7.57**	**14.20**	**4.50**
Max	**28.01**	**57.86**	**35.57**	**100.8**	**6.45**	**7.84**	**43.60**	**8.00**

Table 9.2 Average water quality of bottom waters - 2013 to 2022.

	Temperature ºC	Conductivity mS/cm	Salinity ppt	Dissolved Oxygen % sat	Dissolved Oxygen Mg/L	pH	Turbidity MTU
Sep-13	17.34	53.23	35.11	95.43	7.41	8.69	11.83
Mar-14		49.60	32.40	92.3		8.10	7.8
Mar-16	27.54	51.00	33.40	99.2	6.50	8.20	4.0
Mar-17	23.90	57.10	38.00	109.5	7.42	8.30	7.5
Mar-18	25.73	58.47	39.04	87.7	5.73	8.96	46.5
Mar-19	26.20	58.39	38.97	83.3	5.39	9.74	1.6
Mar-20	24.86	50.52	33.33	63.6	4.36	8.69	6.88
Mar-21	24.93	51.88	34.11	88.9	6.05	7.98	5.02
Mar-22	24.36	53.77	35.55	90.0	6.12	8.58	11.39

10. Conclusions

The results from the March 2023 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 March 2023, 22 benthic stations were sampled in the study area. A total of 1287 organisms greater than 1mm in size were found, comprising 13 species. This compares with the results from March 2018, March 2019, March 2020, March 2021 and March 2022 where 1160, 832, 1032, 797 and 1196 organisms respectively were recorded representing approximately twelve species. As in previous years, polychaete worms and bivalve molluscs were the most frequently encountered animals. Although it should be noted that the bivalve *Soletellina alba* comprised 63 percent of the fauna collected. Stations were distinguished by the relative abundance of the dominant species. Water depth does not appear to be determining species composition.

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 March 2023, dissolved oxygen levels of Lake Macquarie ranged from 4.50 mg/L to 6.49 mg/L or 69.6% to 101.1% saturation. Surface waters generally 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 within the subsidence limit of 0.78m defined in Development Consent SSD-5465 (MOD 4) 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

Laxton, J.H. and Emma Laxton (2007). Aquatic Biology of Chain Valley Bay Lake Macquarie, NSW. Report to Peabody/Lake Coal Chain Valley Colliery.

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 Mar 23

C1	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	10:30:53	27.52	57.54	19.7	7.81	35.33	95.3	6.06	0.5
	11/03/2023	10:31:16	27.44	57.52	20.0	7.81	35.32	96.8	6.17	1.0
	11/03/2023	10:31:19	27.43	57.53	20.1	7.81	35.32	96.8	6.17	1.5
	11/03/2023	10:31:40	27.40	57.56	20.0	7.81	35.34	97.6	6.23	2.0
	11/03/2023	10:32:14	27.34	57.57	19.8	7.81	35.36	98.4	6.28	2.5
	11/03/2023	10:32:32	27.14	57.61	19.9	7.82	35.38	99.4	6.36	3.0
	11/03/2023	10:32:56	26.92	57.62	20.7	7.82	35.39	98.9	6.35	3.5
	11/03/2023	10:33:14	26.76	57.66	22.9	7.82	35.42	97.7	6.30	4.0
	11/03/2023	10:33:30	26.72	57.64	28.8	7.82	35.40	97.5	6.29	4.5
	11/03/2023	10:35:13	26.72	57.64	43.4	7.83	35.40	92.6	5.97	5.0
		Average	**27.14**	**57.59**	**23.53**	**7.82**	**35.37**	**97.10**	**6.22**	**2.75**
		Min	**26.72**	**57.52**	**19.70**	**7.81**	**35.32**	**92.60**	**5.97**	**0.50**
		Max	**27.52**	**57.66**	**43.40**	**7.83**	**35.42**	**99.40**	**6.36**	**5.00**

C2	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	11:57:36	26.20	56.10	17.6	7.67	34.25	94.2	6.16	0.5
	15/03/2023	11:57:39	26.19	56.10	17.6	7.67	34.25	94.0	6.15	1.0
	15/03/2023	11:57:59	25.94	56.23	17.5	7.71	34.35	98.4	6.47	1.5
	15/03/2023	11:58:19	25.89	56.23	17.2	7.72	34.35	100.7	6.62	2.0
	15/03/2023	11:58:44	25.82	56.22	16.9	7.72	34.34	102.3	6.74	2.5
	15/03/2023	11:59:01	25.77	56.22	16.8	7.72	34.34	103.0	6.79	3.0
	15/03/2023	11:59:45	25.76	56.27	18.6	7.71	34.37	100.8	6.64	3.5
	15/03/2023	12:00:05	25.82	56.30	22.2	7.70	34.40	101.1	6.66	4.0
	15/03/2023	12:00:31	26.09	56.76	32.8	7.64	34.75	87.9	5.75	4.5
	15/03/2023	12:00:34	26.08	56.76	33.4	7.64	34.75	87.7	5.74	5.0
	15/03/2023	12:02:00	25.96	56.40	31.5	7.68	34.47	91.0	5.97	5.5
		Average	**25.96**	**56.33**	**22.01**	**7.69**	**34.42**	**96.46**	**6.34**	**3.00**
		Min	**25.76**	**56.10**	**16.80**	**7.64**	**34.25**	**87.70**	**5.74**	**0.50**
		Max	**26.20**	**56.76**	**33.40**	**7.72**	**34.75**	**103.00**	**6.79**	**5.50**

C3	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	11:35:03	25.57	55.75	16.6	7.74	33.98	96.9	6.42	0.5
	15/03/2023	11:35:37	25.58	56.03	16.6	7.74	34.19	96.7	6.40	1.0
	15/03/2023	11:35:58	25.72	56.16	16.8	7.74	34.29	97.3	6.42	1.5
	15/03/2023	11:36:28	25.78	56.26	17.1	7.73	34.37	98.2	6.47	2.0
	15/03/2023	11:36:56	26.11	56.55	17.7	7.72	34.59	97.3	6.36	2.5
	15/03/2023	11:37:33	26.17	56.66	18.5	7.72	34.67	99.2	6.48	3.0
	15/03/2023	11:38:09	26.26	56.78	18.1	7.72	34.76	100.0	6.52	3.5
	15/03/2023	11:38:12	26.26	56.78	18.1	7.72	34.76	100.0	6.52	4.0
	15/03/2023	11:38:36	26.34	56.90	18.3	7.71	34.85	100.1	6.51	4.5
	15/03/2023	11:39:04	26.45	57.05	18.5	7.70	34.96	99.3	6.45	5.0
	15/03/2023	11:39:24	26.53	57.21	18.6	7.69	35.08	98.6	6.39	5.5
	15/03/2023	11:39:43	26.51	57.22	21.5	7.66	35.09	94.3	6.11	6.0
	15/03/2023	11:41:25	26.48	57.25	29.3	7.62	35.11	78.9	5.12	6.5
		Average	**26.14**	**56.66**	**18.90**	**7.71**	**34.67**	**96.68**	**6.32**	**3.50**
		Min	**25.57**	**55.75**	**16.60**	**7.62**	**33.98**	**78.90**	**5.12**	**0.50**
		Max	**26.53**	**57.25**	**29.30**	**7.74**	**35.11**	**100.10**	**6.52**	**6.50**

C4	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	7:04:09	27.96	57.69	22.0	7.78	35.44	93.3	5.89	0.5
	11/03/2023	7:04:17	27.98	57.70	21.1	7.78	35.45	94.5	5.97	1.0
	11/03/2023	7:04:40	27.92	57.66	22.0	7.78	35.42	93.3	5.90	1.5
	11/03/2023	7:05:11	27.89	57.66	21.7	7.78	35.42	97.4	6.16	2.0
	11/03/2023	7:05:52	27.83	57.58	23.8	7.79	35.36	95.0	6.02	2.5
	11/03/2023	7:06:14	27.69	57.61	21.5	7.79	35.38	97.6	6.20	3.0
	11/03/2023	7:06:39	27.68	57.60	22.3	7.79	35.38	98.1	6.23	3.5
	11/03/2023	7:07:02	27.57	57.57	21.6	7.80	35.36	99.5	6.33	4.0
	11/03/2023	7:07:27	27.57	57.58	22.2	7.80	35.36	100.0	6.36	4.5
	11/03/2023	7:07:48	27.56	57.58	23.5	7.80	35.36	100.3	6.38	5.0
	11/03/2023	7:08:06	27.54	57.58	25.8	7.80	35.36	100.5	6.40	5.5
	11/03/2023	7:09:23	27.54	57.56	26.2	7.80	35.34	96.7	6.15	6.0
		Average	**27.73**	**57.61**	**22.81**	**7.79**	**35.39**	**97.18**	**6.17**	**3.25**
		Min	**27.54**	**57.56**	**21.10**	**7.78**	**35.34**	**93.30**	**5.89**	**0.50**
		Max	**27.98**	**57.70**	**26.20**	**7.80**	**35.45**	**100.50**	**6.40**	**6.00**

C5	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	10:11:13	25.58	55.86	18.6	7.75	34.07	95.7	6.34	0.5
	15/03/2023	10:11:31	25.58	55.85	18.5	7.76	34.06	96.3	6.38	1.0
	15/03/2023	10:11:45	25.69	56.02	18.8	7.75	34.19	97.0	6.41	1.5
	15/03/2023	10:12:04	25.78	56.18	19.1	7.75	34.31	98.0	6.46	2.0
	15/03/2023	10:12:21	25.81	56.26	19.1	7.75	34.37	98.7	6.50	2.5
	15/03/2023	10:12:37	25.90	56.38	19.2	7.74	34.46	99.1	6.51	3.0
	15/03/2023	10:12:53	25.96	56.50	19.3	7.74	34.55	99.5	6.53	3.5
	15/03/2023	10:13:30	26.28	56.93	19.8	7.71	34.87	97.5	6.35	4.0
	15/03/2023	10:14:02	26.36	57.05	20.1	7.70	34.97	94.7	6.16	4.5
	15/03/2023	10:14:30	26.37	57.09	20.2	7.69	34.99	93.6	6.09	5.0
	15/03/2023	10:14:50	26.34	57.13	21.8	7.65	35.02	86.8	5.64	5.5
	15/03/2023	10:15:03	26.32	57.16	31.3	7.60	35.05	77.1	5.01	6.0
	15/03/2023	10:16:39	26.34	57.14	22.2	7.63	35.03	75.0	4.87	6.5
		Average	**26.02**	**56.58**	**20.62**	**7.71**	**34.61**	**93.00**	**6.10**	**3.50**
		Min	**25.58**	**55.85**	**18.50**	**7.60**	**34.06**	**75.00**	**4.87**	**0.50**
		Max	**26.37**	**57.16**	**31.30**	**7.76**	**35.05**	**99.50**	**6.53**	**6.50**

C6	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	6:36:52	27.77	57.67	20.1	7.78	35.43	91.7	5.81	0.5
	11/03/2023	6:36:55	27.77	57.66	20.0	7.78	35.42	91.7	5.81	0.5
	11/03/2023	6:37:14	27.78	57.65	20.4	7.78	35.42	91.3	5.78	1.0
	11/03/2023	6:37:42	27.75	57.65	47.2	7.78	35.42	93.8	5.95	1.5
	11/03/2023	6:38:11	27.75	57.65	19.8	7.78	35.41	95.5	6.06	2.0
	11/03/2023	6:38:33	27.71	57.64	19.3	7.79	35.41	97.2	6.17	2.5
	11/03/2023	6:38:52	27.69	57.63	19.6	7.79	35.40	98.5	6.25	3.0
	11/03/2023	6:39:10	27.68	57.63	19.6	7.79	35.40	99.5	6.31	3.5
	11/03/2023	6:39:27	27.59	57.62	18.7	7.80	35.39	101.6	6.46	4.0
	11/03/2023	6:39:48	27.57	57.62	21.2	7.80	35.39	104.0	6.61	4.5
	11/03/2023	6:40:04	27.56	57.61	19.5	7.80	35.39	104.4	6.64	5.0
	11/03/2023	6:40:35	27.51	57.60	22.3	7.80	35.38	103.5	6.59	5.5
	11/03/2023	6:41:17	27.52	57.60	30.7	7.80	35.37	99.9	6.36	6.0
	11/03/2023	7:03:31	28.01	57.69	19.7	7.79	35.44	89.6	5.65	6.5
		Average	**27.69**	**57.64**	**22.72**	**7.79**	**35.41**	**97.30**	**6.18**	**3.29**
		Min	**27.51**	**57.60**	**18.70**	**7.78**	**35.37**	**89.60**	**5.65**	**0.50**
		Max	**28.01**	**57.69**	**47.20**	**7.80**	**35.44**	**104.40**	**6.64**	**6.50**

C7	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	9:46:33	24.92	55.62	17.7	7.77	33.89	94.9	6.36	0.5
	15/03/2023	9:46:55	24.97	55.74	18.5	7.77	33.98	95.2	6.37	1.0
	15/03/2023	9:47:14	25.00	55.75	18.5	7.77	33.99	95.6	6.40	1.5
	15/03/2023	9:47:33	25.05	55.82	18.8	7.77	34.04	96.4	6.44	2.0
	15/03/2023	9:47:51	25.06	55.86	18.8	7.77	34.07	97.3	6.50	2.5
	15/03/2023	9:48:09	25.17	55.96	18.9	7.76	34.14	97.9	6.52	3.0
	15/03/2023	9:48:38	25.36	56.28	19.4	7.75	34.38	97.0	6.44	3.5
	15/03/2023	9:48:57	25.40	56.35	19.4	7.75	34.43	97.3	6.45	4.0
	15/03/2023	9:49:13	25.88	56.87	20.5	7.73	34.83	96.7	6.34	4.5
	15/03/2023	9:49:35	26.11	56.96	20.2	7.72	34.89	97.6	6.38	5.0
	15/03/2023	9:49:48	26.18	57.01	21.6	7.70	34.93	95.8	6.25	5.5
	15/03/2023	9:51:32	26.17	56.99	20.8	7.70	34.91	89.4	5.83	6.0
		Average	**25.44**	**56.27**	**19.43**	**7.75**	**34.37**	**95.93**	**6.36**	**3.25**
		Min	**24.92**	**55.62**	**17.70**	**7.70**	**33.89**	**89.40**	**5.83**	**0.50**
		Max	**26.18**	**57.01**	**21.60**	**7.77**	**34.93**	**97.90**	**6.52**	**6.00**

IM1	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	10:56:26	27.88	57.53	19.8	7.82	35.33	96.4	6.10	0.5
	11/03/2023	10:56:47	27.63	57.54	20.2	7.83	35.33	97.5	6.20	1.0
	11/03/2023	10:57:50	27.48	57.55	19.1	7.83	35.34	98.6	6.28	1.5
	11/03/2023	10:58:06	27.38	57.57	18.9	7.83	35.35	99.3	6.34	2.0
	11/03/2023	10:58:21	27.19	57.60	18.8	7.84	35.38	100.8	6.45	2.5
	11/03/2023	10:58:34	26.90	57.69	19.0	7.85	35.44	101.9	6.55	3.0
	11/03/2023	10:58:47	26.71	57.64	20.8	7.85	35.41	101.6	6.55	3.5
	11/03/2023	10:58:58	26.69	57.63	22.9	7.85	35.40	100.9	6.51	4.0
	11/03/2023	10:59:13	26.69	57.63	28.3	7.84	35.40	99.7	6.43	4.5
	11/03/2023	11:00:37	26.71	57.61	24.4	7.84	35.39	93.1	6.01	5.0
		Average	**27.13**	**57.60**	**21.22**	**7.84**	**35.38**	**98.98**	**6.34**	**2.75**
		Min	**26.69**	**57.53**	**18.80**	**7.82**	**35.33**	**93.10**	**6.01**	**0.50**
		Max	**27.88**	**57.69**	**28.30**	**7.85**	**35.44**	**101.90**	**6.55**	**5.00**

IM2	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	8:55:35	27.51	57.57	19.8	7.79	35.36	93.0	5.92	0.5
	11/03/2023	8:56:05	27.50	57.55	20.5	7.79	35.34	94.1	5.99	0.5
	11/03/2023	8:56:22	27.49	57.56	20.7	7.79	35.35	95.2	6.06	1.0
	11/03/2023	8:56:38	27.47	57.58	20.1	7.79	35.36	98.5	6.27	1.5
	11/03/2023	8:56:57	27.41	57.61	24.5	7.80	35.39	99.3	6.33	2.0
	11/03/2023	8:57:18	27.44	57.55	20.7	7.80	35.34	101.3	6.45	2.5
	11/03/2023	8:57:33	27.39	57.56	20.6	7.80	35.35	102.3	6.53	3.0
	11/03/2023	8:57:54	27.36	57.55	20.7	7.80	35.34	103.8	6.63	3.5
	11/03/2023	8:58:12	27.35	57.55	20.9	7.80	35.34	105.7	6.75	4.0
	11/03/2023	8:59:33	27.35	57.55	22.5	7.80	35.34	100.7	6.43	4.5
		Average	**27.43**	**57.56**	**21.10**	**7.80**	**35.35**	**99.39**	**6.34**	**2.30**
		Min	**27.35**	**57.55**	**19.80**	**7.79**	**35.34**	**93.00**	**5.92**	**0.50**
		Max	**27.51**	**57.61**	**24.50**	**7.80**	**35.39**	**105.70**	**6.75**	**4.50**

IM3	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	9:17:18	27.54	57.53	20.2	7.79	35.32	91.7	5.83	0.5
	11/03/2023	9:17:40	27.54	57.51	20.4	7.79	35.31	92.7	5.90	1.0
	11/03/2023	9:17:55	27.51	57.52	21.0	7.79	35.31	94.2	6.00	1.5
	11/03/2023	9:18:15	27.50	57.51	20.3	7.79	35.31	96.1	6.12	2.0
	11/03/2023	9:18:36	27.48	57.51	20.3	7.79	35.31	96.6	6.15	2.5
	11/03/2023	9:18:53	27.47	57.52	20.3	7.79	35.31	97.8	6.23	3.0
	11/03/2023	9:19:14	27.42	57.52	21.2	7.80	35.31	99.0	6.31	3.5
	11/03/2023	9:19:36	27.39	57.51	20.3	7.80	35.31	100.1	6.39	4.0
	11/03/2023	9:19:54	27.36	57.51	20.0	7.80	35.31	100.9	6.44	4.5
	11/03/2023	9:20:19	27.35	57.51	20.7	7.80	35.31	100.8	6.44	5.0
	11/03/2023	9:20:45	27.32	57.50	25.6	7.80	35.30	100.2	6.40	5.5
	11/03/2023	9:20:48	27.32	57.50	25.5	7.80	35.30	100.0	6.39	6.0
	11/03/2023	9:22:33	27.30	57.51	14.0	7.80	35.31	93.6	5.98	6.5
		Average	**27.42**	**57.51**	**20.75**	**7.80**	**35.31**	**97.21**	**6.20**	**3.50**
		Min	**27.30**	**57.50**	**14.00**	**7.79**	**35.30**	**91.70**	**5.83**	**0.50**
		Max	**27.54**	**57.53**	**25.60**	**7.80**	**35.32**	**100.90**	**6.44**	**6.50**

IM4	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	8:17:52	27.38	57.48	21.4	7.79	35.28	96.2	6.14	0.5
	11/03/2023	8:17:55	27.37	57.48	21.0	7.79	35.28	96.4	6.16	1.0
	11/03/2023	8:18:18	27.38	57.47	20.9	7.80	35.28	94.0	6.00	1.5
	11/03/2023	8:18:36	27.38	57.48	21.2	7.80	35.28	93.6	5.98	2.0
	11/03/2023	8:18:59	27.39	57.47	21.1	7.80	35.28	95.8	6.11	2.5
	11/03/2023	8:19:28	27.39	57.47	21.1	7.80	35.28	96.1	6.13	3.0
	11/03/2023	8:19:46	27.40	57.46	20.8	7.80	35.27	97.0	6.19	3.5
	11/03/2023	8:20:04	27.39	57.47	21.2	7.80	35.28	98.2	6.26	4.0
	11/03/2023	8:20:23	27.39	57.47	23.4	7.80	35.28	101.5	6.48	4.5
	11/03/2023	8:20:40	27.39	57.47	20.7	7.80	35.28	103.3	6.59	5.0
	11/03/2023	8:20:55	27.39	57.47	21.0	7.80	35.28	104.2	6.65	5.5
	11/03/2023	8:21:11	27.40	57.47	20.8	7.80	35.28	104.7	6.68	6.0
	11/03/2023	8:21:28	27.40	57.46	20.5	7.80	35.27	106.0	6.77	6.5
	11/03/2023	8:21:44	27.39	57.46	24.6	7.80	35.27	106.0	6.77	7.0
	11/03/2023	8:23:48	27.40	57.46	32.2	7.80	35.27	95.9	6.12	7.5
		Average	**27.39**	**57.47**	**22.13**	**7.80**	**35.28**	**99.26**	**6.34**	**4.00**
		Min	**27.37**	**57.46**	**20.50**	**7.79**	**35.27**	**93.60**	**5.98**	**0.50**
		Max	**27.40**	**57.48**	**32.20**	**7.80**	**35.28**	**106.00**	**6.77**	**7.50**

R3 (IM5)	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	7:27:53	27.00	57.37	21.6	7.83	35.20	91.0	5.85	0.5
	11/03/2023	7:28:23	27.02	57.36	21.6	7.82	35.19	93.4	6.00	1.0
	11/03/2023	7:28:44	27.04	57.36	22.0	7.82	35.20	97.5	6.26	1.5
	11/03/2023	7:29:00	27.04	57.36	23.6	7.82	35.19	98.2	6.30	2.0
	11/03/2023	7:29:17	27.05	57.41	23.3	7.82	35.23	97.6	6.27	2.5
	11/03/2023	7:29:20	27.06	57.40	23.8	7.82	35.23	97.7	6.27	3.0
	11/03/2023	7:29:36	27.05	57.35	21.9	7.82	35.19	99.0	6.36	3.5
	11/03/2023	7:29:53	27.04	57.36	21.7	7.82	35.19	100.3	6.44	4.0
	11/03/2023	7:30:07	27.04	57.35	21.7	7.83	35.19	100.6	6.46	4.5
	11/03/2023	7:30:30	27.05	57.35	24.8	7.82	35.19	100.9	6.48	5.0
	11/03/2023	7:30:56	27.04	57.36	21.7	7.82	35.20	101.1	6.49	5.5
	11/03/2023	7:31:16	27.04	57.35	23.1	7.82	35.19	101.2	6.50	6.0
	11/03/2023	7:32:19	27.04	57.36	30.0	7.82	35.19	97.0	6.23	6.5
		Average	**27.04**	**57.36**	**23.14**	**7.82**	**35.20**	**98.12**	**6.30**	**3.50**
		Min	**27.00**	**57.35**	**21.60**	**7.82**	**35.19**	**91.00**	**5.85**	**0.50**
		Max	**27.06**	**57.41**	**30.00**	**7.83**	**35.23**	**101.20**	**6.50**	**6.50**

R4 (IM6)	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	7:53:22	27.47	57.52	21.2	7.78	35.32	88.5	5.64	0.5
	11/03/2023	7:53:39	27.48	57.51	23.1	7.79	35.31	91.1	5.80	1.0
	11/03/2023	7:53:55	27.47	57.50	21.8	7.79	35.30	92.3	5.88	1.5
	11/03/2023	7:54:12	27.47	57.50	21.9	7.79	35.30	93.5	5.96	2.0
	11/03/2023	7:54:29	27.46	57.50	21.5	7.79	35.30	95.1	6.06	2.5
	11/03/2023	7:54:55	27.44	57.49	23.2	7.79	35.30	96.1	6.13	3.0
	11/03/2023	7:55:22	27.45	57.50	21.9	7.80	35.30	96.6	6.16	3.5
	11/03/2023	7:55:43	27.46	57.50	22.2	7.79	35.30	97.5	6.21	4.0
	11/03/2023	7:56:08	27.48	57.51	21.3	7.79	35.30	97.9	6.24	4.5
	11/03/2023	7:56:27	27.42	57.48	23.0	7.79	35.29	98.5	6.28	5.0
	11/03/2023	7:56:44	27.29	57.39	22.6	7.79	35.22	99.1	6.34	5.5
	11/03/2023	7:56:58	27.26	57.37	23.7	7.79	35.20	99.7	6.38	6.0
	11/03/2023	7:58:10	27.26	57.39	24.0	7.80	35.21	94.3	6.03	6.5
		Average	**27.42**	**57.47**	**22.42**	**7.79**	**35.28**	**95.40**	**6.09**	**3.50**
		Min	**27.26**	**57.37**	**21.20**	**7.78**	**35.20**	**88.50**	**5.64**	**0.50**
		Max	**27.48**	**57.52**	**24.00**	**7.80**	**35.32**	**99.70**	**6.38**	**6.50**

R5 (IM7)	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	8:30:20	27.41	57.12	19.7	7.65	35.01	91.9	5.87	0.5
	15/03/2023	8:30:57	27.41	57.12	19.6	7.65	35.01	91.9	5.87	1.0
	15/03/2023	8:31:18	27.37	57.15	19.3	7.65	35.04	93.0	5.94	1.5
	15/03/2023	8:31:39	27.26	57.10	18.7	7.65	35.00	95.3	6.10	2.0
	15/03/2023	8:32:02	27.03	57.11	19.0	7.67	35.01	97.5	6.27	2.5
	15/03/2023	8:32:19	26.63	57.08	17.9	7.69	34.98	99.4	6.43	3.0
	15/03/2023	8:32:35	26.86	57.40	18.1	7.67	35.23	99.0	6.37	3.5
	15/03/2023	8:32:57	26.99	57.45	18.0	7.66	35.26	98.8	6.35	4.0
	15/03/2023	8:33:21	27.04	57.51	18.9	7.64	35.31	95.4	6.12	4.5
	15/03/2023	8:33:49	27.04	57.88	21.5	7.60	35.58	85.7	5.49	5.0
	15/03/2023	8:33:52	27.04	57.86	21.5	7.60	35.57	85.4	5.48	5.5
	15/03/2023	8:34:27	26.71	57.85	20.0	7.59	35.57	79.1	5.10	6.0
	15/03/2023	8:35:00	26.64	57.86	26.7	7.57	35.57	74.1	4.78	6.5
	15/03/2023	8:35:26	26.64	57.85	28.3	7.57	35.57	73.3	4.73	7.0
	15/03/2023	8:36:50	26.64	57.86	32.4	7.57	35.57	69.6	4.49	7.5
		Average	**26.98**	**57.48**	**21.31**	**7.63**	**35.29**	**88.63**	**5.69**	**4.00**
		Min	**26.63**	**57.08**	**17.90**	**7.57**	**34.98**	**69.60**	**4.49**	**0.50**
		Max	**27.41**	**57.88**	**32.40**	**7.69**	**35.58**	**99.40**	**6.43**	**7.50**

R6 (IM8)	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	8:56:26	27.15	57.20	20.8	7.66	35.07	94.2	6.04	0.5
	15/03/2023	8:57:24	27.17	57.19	21.4	7.66	35.06	95.7	6.14	1.0
	15/03/2023	8:58:01	27.18	57.17	21.2	7.66	35.05	96.4	6.18	1.5
	15/03/2023	8:58:26	27.18	57.16	21.2	7.66	35.04	97.2	6.23	2.0
	15/03/2023	8:58:49	27.16	57.17	21.0	7.66	35.05	98.8	6.34	2.5
	15/03/2023	8:59:09	27.15	57.16	21.1	7.66	35.04	99.8	6.40	3.0
	15/03/2023	8:59:29	27.10	57.15	20.6	7.67	35.04	101.1	6.49	3.5
	15/03/2023	9:00:14	26.71	57.31	19.7	7.67	35.16	97.6	6.30	4.0
	15/03/2023	9:00:46	26.91	57.44	19.8	7.66	35.25	97.0	6.24	4.5
	15/03/2023	9:01:10	26.92	57.50	19.9	7.65	35.30	94.0	6.04	5.0
	15/03/2023	9:01:42	26.98	57.64	20.4	7.63	35.40	91.3	5.86	5.5
	15/03/2023	9:02:05	26.79	57.63	26.4	7.59	35.40	82.8	5.33	6.0
	15/03/2023	9:03:44	26.77	57.64	23.7	7.59	35.41	75.8	4.88	6.5
		Average	**27.01**	**57.34**	**21.32**	**7.65**	**35.17**	**93.98**	**6.04**	**3.50**
		Min	**26.71**	**57.15**	**19.70**	**7.59**	**35.04**	**75.80**	**4.88**	**0.50**
		Max	**27.18**	**57.64**	**26.40**	**7.67**	**35.41**	**101.10**	**6.49**	**6.50**

R1	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	10:05:20	27.55	57.55	20.9	7.81	35.34	93.1	5.92	0.5
	11/03/2023	10:05:49	27.54	57.57	21.1	7.80	35.35	93.9	5.98	1.0
	11/03/2023	10:06:12	27.56	57.56	20.5	7.81	35.35	94.9	6.04	1.5
	11/03/2023	10:06:32	27.44	57.59	21.2	7.79	35.37	92.8	5.92	2.0
	11/03/2023	10:06:59	27.46	57.58	20.4	7.80	35.36	94.2	6.00	2.5
	11/03/2023	10:07:28	27.36	57.58	19.9	7.77	35.36	90.1	5.75	3.0
	11/03/2023	10:07:51	27.35	57.60	21.4	7.75	35.37	86.3	5.51	3.5
	11/03/2023	10:08:17	27.32	57.62	43.9	7.74	35.39	81.5	5.20	4.0
	11/03/2023	10:09:33	27.35	57.59	21.4	7.76	35.37	83.3	5.32	4.5
		Average	**27.44**	**57.58**	**23.41**	**7.78**	**35.36**	**90.01**	**5.74**	**2.50**
		Min	**27.32**	**57.55**	**19.90**	**7.74**	**35.34**	**81.50**	**5.20**	**0.50**
		Max	**27.56**	**57.62**	**43.90**	**7.81**	**35.39**	**94.90**	**6.04**	**4.50**

R2	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	11:20:51	27.49	57.60	16.9	7.79	35.38	98.3	6.26	0.5
	11/03/2023	11:21:21	27.46	57.64	16.9	7.80	35.41	99.0	6.30	1.0
	11/03/2023	11:21:48	27.29	57.66	16.6	7.81	35.42	100.4	6.41	1.5
	11/03/2023	11:22:16	27.11	57.61	16.0	7.82	35.39	101.9	6.53	2.0
	11/03/2023	11:22:46	26.96	57.61	18.1	7.83	35.39	101.4	6.51	2.5
	11/03/2023	11:23:04	26.83	57.64	18.8	7.83	35.41	100.8	6.49	3.0
	11/03/2023	11:23:19	26.77	57.60	17.6	7.83	35.38	100.8	6.49	3.5
	11/03/2023	11:23:35	26.48	57.59	26.5	7.82	35.37	98.4	6.37	4.0
	11/03/2023	11:23:53	26.59	57.77	46.1	7.80	35.50	92.8	6.00	4.5
	11/03/2023	11:25:11	26.44	57.64	33.0	7.82	35.40	88.7	5.75	5.0
		Average	**26.94**	**57.64**	**22.65**	**7.82**	**35.41**	**98.25**	**6.31**	**2.75**
		Min	**26.44**	**57.59**	**16.00**	**7.79**	**35.37**	**88.70**	**5.75**	**0.50**
		Max	**27.49**	**57.77**	**46.10**	**7.83**	**35.50**	**101.90**	**6.53**	**5.00**

R7	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	11:08:34	25.68	55.69	18.1	7.75	33.94	97.8	6.47	0.5
	15/03/2023	11:08:59	25.66	55.69	17.2	7.76	33.94	98.9	6.54	1.0
	15/03/2023	11:09:23	25.48	55.64	17.1	7.77	33.90	100.3	6.66	1.5
	15/03/2023	11:09:50	25.44	55.65	16.9	7.77	33.91	101.4	6.74	2.0
	15/03/2023	11:10:17	25.98	56.47	17.7	7.74	34.53	99.8	6.55	2.5
	15/03/2023	11:10:42	26.22	56.70	18.4	7.73	34.70	99.1	6.47	3.0
	15/03/2023	11:11:03	26.27	56.76	18.6	7.71	34.74	97.9	6.39	3.5
	15/03/2023	11:11:28	26.37	56.96	19.6	7.69	34.89	94.3	6.13	4.0
	15/03/2023	11:11:57	26.50	57.26	21.5	7.66	35.12	88.8	5.76	4.5
	15/03/2023	11:12:19	26.52	57.30	22.7	7.66	35.15	89.0	5.76	5.0
	15/03/2023	11:12:38	26.52	57.30	23.0	7.65	35.15	88.5	5.74	5.5
	15/03/2023	11:13:05	26.52	57.39	22.2	7.64	35.22	86.8	5.62	6.0
	15/03/2023	11:13:36	26.52	57.40	21.1	7.64	35.23	86.5	5.60	6.5
	15/03/2023	11:14:01	26.58	57.65	23.7	7.60	35.42	79.4	5.13	7.0
	15/03/2023	11:14:31	26.56	57.71	30.7	7.59	35.46	74.4	4.81	7.5
	15/03/2023	11:16:06	26.56	57.70	34.6	7.58	35.45	69.6	4.50	8.0
		Average	**26.21**	**56.83**	**21.44**	**7.68**	**34.80**	**90.78**	**5.93**	**4.25**
		Min	**25.44**	**55.64**	**16.90**	**7.58**	**33.90**	**69.60**	**4.50**	**0.50**
		Max	**26.58**	**57.71**	**34.60**	**7.77**	**35.46**	**101.40**	**6.74**	**8.00**

R8	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	9:40:30	27.57	57.52	20.6	7.81	35.32	95.1	6.05	0.5
	11/03/2023	9:41:09	27.55	57.52	21.1	7.81	35.31	96.3	6.13	1.0
	11/03/2023	9:41:34	27.56	57.51	20.4	7.80	35.31	97.6	6.21	1.5
	11/03/2023	9:41:55	27.52	57.49	21.6	7.81	35.30	97.8	6.23	2.0
	11/03/2023	9:42:17	27.47	57.50	22.8	7.81	35.30	97.8	6.23	2.5
	11/03/2023	9:42:42	27.43	57.51	23.3	7.81	35.31	98.6	6.29	3.0
	11/03/2023	9:43:04	27.41	57.50	22.8	7.81	35.30	99.1	6.32	3.5
	11/03/2023	9:43:27	27.39	57.50	21.6	7.81	35.30	100.0	6.38	4.0
	11/03/2023	9:43:46	27.37	57.51	21.4	7.81	35.31	101.0	6.44	4.5
	11/03/2023	9:44:02	27.35	57.50	20.5	7.81	35.30	101.8	6.50	5.0
	11/03/2023	9:44:25	27.34	57.50	22.2	7.81	35.30	102.0	6.51	5.5
	11/03/2023	9:44:50	27.35	57.51	39.6	7.80	35.31	100.5	6.42	6.0
	11/03/2023	9:46:38	27.34	57.51	21.0	7.81	35.31	94.3	6.02	6.5
	11/03/2023	9:46:41	27.34	57.51	20.8	7.81	35.31	94.3	6.02	7.0
		Average	**27.43**	**57.51**	**22.84**	**7.81**	**35.31**	**98.30**	**6.27**	**3.75**
		Min	**27.34**	**57.49**	**20.40**	**7.80**	**35.30**	**94.30**	**6.02**	**0.50**
		Max	**27.57**	**57.52**	**39.60**	**7.81**	**35.32**	**102.00**	**6.51**	**7.00**

R9	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	11/03/2023	11:47:11	28.07	57.62	18.3	7.78	35.39	97.2	6.13	0.5
	11/03/2023	11:47:35	27.82	57.60	17.9	7.79	35.38	98.1	6.21	1.0
	11/03/2023	11:47:59	27.63	57.61	17.7	7.81	35.38	100.0	6.35	1.5
	11/03/2023	11:48:22	27.56	57.61	17.2	7.82	35.38	101.7	6.47	2.0
	11/03/2023	11:48:44	27.40	57.58	16.7	7.83	35.36	103.5	6.60	2.5
	11/03/2023	11:49:09	27.26	57.61	16.6	7.83	35.39	102.6	6.55	3.0
	11/03/2023	11:49:31	27.26	57.63	16.5	7.83	35.40	102.6	6.56	3.5
	11/03/2023	11:49:53	27.30	57.68	47.1	7.83	35.44	102.3	6.53	4.0
	11/03/2023	11:50:59	27.27	57.62	16.2	7.83	35.39	99.2	6.34	4.5
		Average	**27.51**	**57.62**	**20.47**	**7.82**	**35.39**	**100.80**	**6.42**	**2.50**
		Min	**27.26**	**57.58**	**16.20**	**7.78**	**35.36**	**97.20**	**6.13**	**0.50**
		Max	**28.07**	**57.68**	**47.10**	**7.83**	**35.44**	**103.50**	**6.60**	**4.50**

R10	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	9:23:29	24.87	55.62	17.4	7.77	33.89	94.6	6.35	0.5
	15/03/2023	9:23:53	24.87	55.64	17.9	7.77	33.91	95.5	6.41	1.0
	15/03/2023	9:25:01	25.05	55.80	18.2	7.77	34.03	95.8	6.40	1.5
	15/03/2023	9:25:24	25.22	55.88	18.2	7.77	34.08	96.6	6.44	2.0
	15/03/2023	9:25:39	25.39	56.08	18.4	7.76	34.24	97.6	6.48	2.5
	15/03/2023	9:25:52	25.58	56.24	18.5	7.74	34.36	97.6	6.45	3.0
	15/03/2023	9:26:12	25.71	56.54	19.0	7.73	34.58	96.9	6.39	3.5
	15/03/2023	9:26:32	26.12	56.86	19.8	7.71	34.82	96.0	6.27	4.0
	15/03/2023	9:26:51	26.43	57.20	20.0	7.70	35.08	98.0	6.36	4.5
	15/03/2023	9:27:08	26.59	57.29	20.2	7.69	35.14	98.1	6.35	5.0
	15/03/2023	9:27:31	26.55	57.39	20.6	7.68	35.21	95.9	6.21	5.5
	15/03/2023	9:28:04	26.44	57.44	38.8	7.64	35.26	84.9	5.50	6.0
	15/03/2023	9:29:21	26.45	57.44	43.0	7.64	35.26	80.0	5.19	6.5
		Average	**25.79**	**56.57**	**22.31**	**7.72**	**34.60**	**94.42**	**6.22**	**3.50**
		Min	**24.87**	**55.62**	**17.40**	**7.64**	**33.89**	**80.00**	**5.19**	**0.50**
		Max	**26.59**	**57.44**	**43.00**	**7.77**	**35.26**	**98.10**	**6.48**	**6.50**

R11	Date	Time	Temp (oC)	Cond ms/cm	Turb (ntu)	pH (pH)	Sal (ppt)	D.O. (%sat)	DO (mg/L)	Depth (m)
	15/03/2023	10:46:01	25.55	55.82	17.8	7.76	34.04	94.8	6.28	0.5
	15/03/2023	10:46:21	25.55	55.81	17.9	7.76	34.03	94.6	6.27	1.0
	15/03/2023	10:46:36	25.52	55.83	17.9	7.76	34.04	95.0	6.30	1.5
	15/03/2023	10:46:47	25.54	55.85	17.9	7.76	34.06	96.2	6.38	2.0
	15/03/2023	10:46:58	25.75	56.17	18.2	7.76	34.30	97.6	6.43	2.5
	15/03/2023	10:47:17	25.98	56.43	18.4	7.75	34.49	99.5	6.53	3.0
	15/03/2023	10:47:36	26.14	56.60	18.8	7.74	34.62	100.9	6.60	3.5
	15/03/2023	10:47:53	26.36	56.96	19.3	7.73	34.90	100.6	6.54	4.0
	15/03/2023	10:48:18	26.39	57.12	19.8	7.70	35.02	96.3	6.26	4.5
	15/03/2023	10:48:41	26.39	57.11	19.8	7.69	35.01	94.9	6.17	5.0
	15/03/2023	10:48:59	26.32	57.11	20.2	7.68	35.01	92.7	6.03	5.5
	15/03/2023	10:49:27	26.36	57.21	19.5	7.70	35.08	96.9	6.29	6.0
	15/03/2023	10:49:47	26.38	57.24	19.3	7.70	35.11	97.7	6.35	6.5
	15/03/2023	10:50:00	26.37	57.28	19.8	7.69	35.14	97.0	6.30	7.0
	15/03/2023	10:51:23	26.36	57.28	21.3	7.69	35.14	90.6	5.88	7.5
		Average	**26.06**	**56.65**	**19.06**	**7.72**	**34.67**	**96.35**	**6.31**	**4.00**
		Min	**25.52**	**55.81**	**17.80**	**7.68**	**34.03**	**90.60**	**5.88**	**0.50**
		Max	**26.39**	**57.28**	**21.30**	**7.76**	**35.14**	**100.90**	**6.60**	**7.50**