The Deepening, Lengthening and Widening of Berths 203 to 205 at Pier 2 Container Terminal, Port of Durban, KwaZulu-Natal Province

Environmental Monitoring Report

Spring 2021

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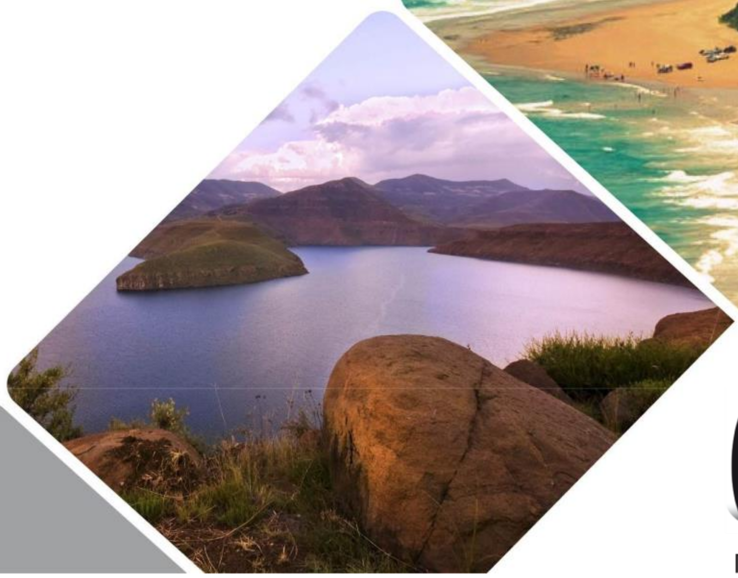
December 2021



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Environmental Monitoring Report, December 2021

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Report Details

1	**Project name**	The Deepening, Lengthening and Widening of Berths 203 to 205 at Pier 2 Container Terminal, Port of Durban, KwaZulu-Natal Province
2	**Report title**	Environmental Monitoring Report, Spring 2021
3	**Authority reference**	No: 14/12/16/3/3/2/275
4	**Report status**	Draft 1
5	**Client**	Transnet National Ports Authority
6	**Scope**	Conduct quarterly monitoring during the two-year construction period of the Sandbank Extension. Thereafter, the monitoring should take once every six months during the construction of the Berth 203 to 205 Expansion
7	**Standard:**	Environmental Authorisation (NEAS: DEA/EIA/0000988/2012. DEA Ref: 14/12/16/3/3/32/275) and Central Sandbank Mitigation Plan (CSMP), October 2017
8	**Objective**	Conduct environmental monitoring, to track the health of the Durban bay over the construction period of the Berth 203 to 205 expansion project
9	**Methodology**	As per the CSMP Rev 06 Report, October 2017
10	**Date of fieldwork**	6, 13, 20, 21, 26 October 2021
11	**Dates of bird fieldwork**	Sampling done on the first spring tide of every month. This report includes bird results from December 2019 – November 2021, with the exception of April – July 2020.
12	**Report publish date**	30 November 2021
13	**Key notes**	Construction had not yet commenced at the time of this sample run
14	**Activity schedule**	**<u>Quarterly Monitoring Events:</u>** • October 2018 (Spring I) – Sampling undertaken 9 - 18 October 2018 • January 2019 (Summer I) – Did not occur, project put on hold. • April 2019 (Autumn I) – Did not occur, project put on hold. • August 2019 (Winter I) – Sampling undertaken 15 - 30 August 2019 • October 2019 (Spring II) – Sampling undertaken 13 - 29 October 2019 • January 2020 (Summer II) – Sampling undertaken 03 - 24 January 2020 • June 2020 (Autumn II) – Sampling undertaken 05 – 23 June 2020. Note that autumn sampling performed in June due to National Lockdown. • July 2020 (Winter II) – Sampling undertaken 05 – 22 July, bird sampling undertaken throughout August. • October 2020 (Spring III) – Sampling undertaken 01 – 28 October • January 2021 (Summer III) – Sampling undertaken 13 – 29 January • April 2021 (Autumn III) – Sampling undertaken 12 – 28 April • July 2021 (Winter III) – Sampling undertaken 1 – 24 July • October 2021 (Spring IV) – Sampling undertaken 6 – 26 October

15	**Authors**	• Kolawole Akinoshun (PhD Candidate Marine Biology (Genetics), UKZN). • Charl Kruger (BSc Hons Environmental Management), GIBB Environmental (Environmental Scientist) • Robyn Phillips (PrSciNat, MSc Zoology) GIBB Environmental (Avifaunal Specialist) • Dr Lisa Skein (PhD Zoology), GIBB Environmental (Marine Scientist) **Reviewers:** • Mark Muir (B.Soc.Sci Environmental Management), GIBB Environmental (Project Manager) • Dr Lisa Skein (PhD Zoology), GIBB Environmental (Marine Scientist) • Walter Fyvie (PrSciNat, MSc Environmental Biotechnology), GIBB Environmental (Senior Associate)
16	**Contact person**	Charl Kruger Tel: +27 31 267 8572 Fax: +27 31 266 3310 Email: ckruger@gibb.co.za

Revision Status

Rev No.	**Issue Date**	**Revision Description**
0	30/11/2021	Draft 1 for client review

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Abbreviations

CSMP	Central Sandbank Mitigation Plan
CTD	Conductivity, temperature, and depth
EA	Environmental Authorisation

ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
EMC	Environmental Monitoring Committee
EMPR	Environmental Management Programme
ERL	Effects Range Limits
ERM	Effects Range Medium
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry & Fisheries
MACE	Marine biodiversity, Aquaculture, Conservation education & Ecophysiology
NOAA	National Oceanic Atmospheric Administration
NTU	Nephelometric Turbidity Units
PPM	Parts Per Million
TOC	Total Organic Carbon
UKZN	University of KwaZulu-Natal
YSI	Yellow Springs Instrument

Executive Summary

GIBB (Pty) Ltd was appointed by Transnet Group Capital, now Transnet National Ports Authority, to conduct environmental monitoring in the Port of Durban as per the requirements of the Central Sandbank Mitigation Plan (Clark et al., 2017). The rationale for the expansion of the Berths is to improve the safety of the Berths and increase the efficiency of the Port (see EIA report for full project description; DEA ref 14/12/16/3/3/2/275). The objective of the monitoring programme is to monitor biotic and abiotic habitats and species count changes measured against the approved baseline which was established per condition 27 of the EA (DEA ref 14/12/16/3/3/2/275) and is contained in Central Sandbank Mitigation Plan (CSMP) (Clark et al., 2017). Monitoring takes place at the sandbank areas and associated infrastructure and is conducted before, during and after the construction and expansion of Berths 203 – 205. As specified in this plan (CSMP), monitoring will be undertaken quarterly during each season (i.e. summer, autumn, winter and spring) for the duration of the sandbank extension period, after which monitoring will be undertaken biannually for the remaining construction period. The quarterly assessment exercise includes monitoring of water and sediment characteristics, benthic microalgae, benthic macrofaunal communities, biomonitoring of mussels, as well as fish and monthly bird surveys on and adjacent to all sandbank habitats in the Port of Durban. This report provides a summary of information gathered during the spring 2021 survey, which commenced on 6 October 2021 and was the 11th sampling event of this programme. Note that construction had not yet commenced at the time of this survey, so all results obtained thus far may be interpreted as building on the baseline data reported in Clark et al. (2017).

The survey was carried out by GIBB Environmental in collaboration with the University of KwaZulu-Natal (UKZN), Marine biodiversity, Aquaculture, Conservation education & Ecophysiology (MACE) Laboratory at the UKZN, Westville Campus. Field samples were collected over the period of 6 – 26 October 2021 by GIBB personnel and students from the UKZN MACE Lab. The following components are assessed as part of this monitoring programme: water quality, sediment characteristics, benthic macrofaunal communities, benthic microalgae, mussel biomonitoring, fish- and bird communities.

Water Quality

Water quality parameters including temperature, salinity, dissolved oxygen, pH, and turbidity were measured using a YSI (Model: EXO 1 – 18H112179) CTD water quality meter. Measurements were taken at 20 sampling stations distributed along the navigation channels around the intertidal and shallow subtidal sandbank areas in the Port. While no specific limits or thresholds have been set for water quality parameters, the majority of these parameters were similar to the results reported in the baseline study. In spring 2021, water temperatures increased slightly, as expected from seasonal changes. Salinity levels of surface waters were very low and were likely influenced by heavy seasonal rains around the time of sampling. Salinity levels of deeper water (> 1 m depth) were typical of marine conditions. Turbidity levels were similar to those recorded throughout the year and greater than those described in the baseline study. Dissolved oxygen concentrations and pH levels were similar than those reported in the previous survey.

Sediment Characteristics

Sediment samples were collected from 64 stations (39 intertidal and 25 subtidal) on sandbanks in the Port. Intertidal and subtidal sites are further divided into impact and control sites, with impact sites being those that will most likely be affected by the planned developments in the Port. Intertidal and subtidal sites on/around the northern bank are control sites, while those on/around the central bank and little lagoon are impact sites. The impact sites are thus also those that are generally more exposed to shipping activity and therefore more susceptible to anthropogenically-induced changes to natural conditions. Several sediment parameters were assessed, including grain size distribution, Total Organic Carbon (TOC) concentration and trace metal concentrations. According to the ranges defined in the baseline study, sediment grain size must be comprised of mostly sandy sediment and very little proportions of mud. Proportions of sand and mud were within allowable ranges. The concentration of TOC in intertidal and subtidal sediment were, as in several previous seasons, below the minimum allowable threshold, indicative of a nutrient-deficient system. All trace metals, apart from iron in subtidal sediments, were below maximum allowable concentrations.

Benthic Macrofauna

Intertidal and subtidal benthic macrofaunal samples were collected from the same stations as sediment samples and results of abundance and species richness are contrasted against season-specific limits defined in the CSMP. All measures, apart from intertidal species richness, were lower than the minimum baseline thresholds for spring. As an important indicator of overall ecosystem health, these trends represent a noteworthy cause for concern.

Benthic Microalgae (Microphytobenthos)

Microalgae are photosynthetically active micro-organisms that contribute significantly to primary production in sediment and pelagic habitats with important trophic linkages with variety of organisms including macrofauna, fish and birds (Pinckney & Zingmark, 1993). In addition to the functional importance of microalgae in estuarine and marine systems, it is also a useful parameter that can be used to assess ecological health and eutrophication levels of these systems (Stevenson & Pan, 1999). The concentration of chlorophyll-a (chl-a) is used as a proxy for the abundance of microalgae. In this survey (spring 2021), median intertidal and subtidal chl-a concentrations decreased from winter and were within the allowable ranges specified in the baseline study. As in previous surveys, intertidal chl-a levels were greater than those of subtidal environments, owing to greater light availability in the former habitat.

Biomonitoring Using Mussels (*Perna perna*)

Samples of brown mussels (*Perna perna*) were collected from 15 out of 16 designated channel buoys (one buoy did not contain mussels) adjacent to the sandbanks and were analyzed at a SANAS accredited laboratory for trace metal concentrations. Apart from mercury, all trace metals were below the maximum threshold values of the baseline study. This is the seventh consecutive season that mercury concentrations have violated these limits and remains a serious health risk that needs to be addressed by Port management authorities.

Fish

The nearshore fish community in the Port of Durban was sampled using a beach seine net at 14 stations along the margins of the main sandbank areas. Fish communities were, as in previous seasons, dominated by the Bald Glassy (*Ambassis dussumieri*) that also contributed the most to overall biomass. The overall abundance, biomass and species richness of fish communities were below the minimum thresholds for spring, as also recorded in previous seasons this year.

Birds

Monthly bird counts are conducted in accordance with methodology used in long-term avian monitoring programmes in the Port. This is also the methodology that informed the CSMP. These surveys are taking place in five main habitats across the Port (central bank/Little lagoon, northern sand banks, mangrove habitat, island view sand bank, open water). Waders and wading birds dominated the various functional groups, and piscivores and invertebrate feeders dominated feeding groups. Abundance, but not species richness, was above the threshold minimum set in the baseline study. The fact that species richness continues to violate the minimum thresholds indicates that the diversity of avian communities across the Port is demonstrating a consistent decline. While these results cannot be attributed to the construction phase of this project, it is likely that they are attributable to anthropogenic impacts such as plastic pollution that can directly impact the health of marine birds.

Conclusion

The information presented in this report is part of an ongoing quarterly monitoring programme against which the impacts associated with the proposed development at Pier 2 can be assessed. These assessments will inform the Environmental Control Officer (ECO) and Environmental Monitoring Committee (EMC) who will oversee that the sampled parameters for the Port of Durban are maintained during the construction and operational phases of this development. As construction had not yet commenced, the data gathered thus far can be viewed as additions to an ongoing dataset and will ultimately enable more accurate detection of any potential impacts associated with the planned developments when they occur.

However, factors that require increased attention and potential mitigation measures from Port management authorities are (1) the consistently high concentrations of mercury in *Perna perna* mussels, (2) decreasing macrofaunal abundance and diversity, (3) decreasing fish abundance and diversity, and (4) decreasing avifaunal diversity.

There are several factors that may be affecting these ecosystem components. As stated in previous reports, these potential factors include the Umbilo river oil spill of October 2020, storm water runoff and associated pollutants entering the Port and the persistent and ever-increasing plastic pollution in this habitat. The latter was once again prevalent following seasonal rains in spring. These factors cannot be viewed as separate from this monitoring programme as they ultimately affect the integrity of the environment in which surveys are taking place. The impacts of both oil and plastic pollution on marine life are widely acknowledged. The bird roosting habitats in the Port presently consists mainly of plastic debris and inevitably affects the health of these animals. Marine birds often mistake plastic for food and can feed it to their chicks. It is also becoming increasingly difficult for fieldworkers to conduct counts on sandbanks as plastic debris are obscuring birds. Plastic that has broken down to smaller sizes (microplastics) are also fed on by fish, which can ultimately result in death as it is indigestible. While the effects of microplastics on benthic macrofauna are still being investigated, current research suggests that these communities are also most likely negatively affected.

1 Background

The Port of Durban is located on the east coast of South Africa and occupies the natural area of the Durban Bay, an estuarine embayment fed by the uMbilo, uMhlatuzana and aManzimnyama rivers (Whitfield, 1998). It is one of the few natural harbours on the South African coast and is under the jurisdiction of the Transnet National Ports Authority. Since the development of the Durban Container Terminal in 1977, the Port of Durban has experienced consistently high growth of import and export cargo volumes from around the world. Of the eight commercial Ports in South Africa, the Durban Port is currently South Africa's main general cargo and container Port, handling over 80 million tons of cargo per year (Clark et al., 2016).

Transnet National Ports Authority intends to deepen, widen and lengthen Berths 203 to 205 in the Port of Durban and was granted Environmental Authorisation for the work on 21 January 2015 (EIA and EA reference number 14/12/16/3/3/2/275). The objective is to maximize the efficiency of the Port as well as improve the safety of the Berths. Condition No. 27 of the EA required that baseline monitoring be undertaken for 24 months prior to construction. The EA was appealed and on 9 September 2015 the Minister of Environmental Affairs upheld the EA against the appeal (Appeal Decision Ref LSA 141396) wherein under section 4.2.4 the following was added: *"Amend the EA in line with the eThekwini Municipality's concerns in respect of 4.3.14 below. To this end, the aforementioned EA is amended to include the following condition: the eThekwini Municipality is to be involved in the baseline monitoring of the sandbank and must ensure that the outcomes of the baseline monitoring inform the central sandbank mitigation plan. The monitoring of compliance against the baseline monitoring must solely be the responsibility of the ECO and be independent of the applicant. Construction activities on the central sandbank may only commence upon the successful implementation of the central sandbank mitigation plan".*

Transnet undertook the 24 months of environmental monitoring within the Durban Bay, and as part of the Environmental Management Programme (EMPR) produced a plan specifically dealing with marine works on and around the Centre Sand Bank (the Central Sandbank Mitigation Plan – CSMP; Clark et al., (2017)).

In line with Clause 4.2.4 of the Appeal Decision, the "implementation" of the CSMP was clarified with then DEA (now the Department of Forestry, Fisheries and the Environment; DFFE) to mean:

1) the completion and publication of the plan
2) the submission to the Authorities and approval of the plan; and
3) the issuing of the plan to the contractors prior to commencement of construction activities.

The Department was in agreement with this interpretation, and hence construction could commence.

Through an open tender process GIBB was appointed as the ECO on the project and in light of EA condition 27 and Appeal Decision condition 4.2.4, initiated this monitoring programme for all the sandbank areas in the Port during the proposed construction of the Berths. The intention is to thereby assess the impacts of any disturbances associated with this development such as loss of supratidal, intertidal and subtidal habitats within the Port. Monitoring activities include quarterly surveys of water quality, sediment characteristics, benthic microalgae, benthic macrofauna, mussel biomonitoring, fish and a monthly bird survey on and adjacent to all sandbank habitats during the sandbank works, and thereafter bi-annually for the remainder of the construction period.

The development of the Port of Durban, together with the growth and urbanisation of the surrounding city of Durban has resulted in significant changes in the natural functioning of this estuary. However, Durban Bay is still considered an estuary with high national conservation importance, with an overall importance score of 92% (Turpie & Clark, 2007). It is ranked as the 10th most important estuary in South Africa (Turpie & Clark, 2007). In order to secure the benefits provided by this system in terms of ecosystem goods and services, it has been recommended that at least partial protection be assigned to the estuary. This has become an objective of the Bay of Natal Estuarine Management Plan (ERM/MER, 2012) to protect and enhance estuarine habitats, which are characteristic of the original Bay; and to explore opportunities for rehabilitating/improving and expanding existing soft habitat. It is important to conserve and manage the remaining mangroves, mudflats and sandbanks of Durban Harbour in order to retain the valuable ecological functions that they offer to the entire system.

The intertidal sandbank habitats in the Port are important to its ecological functioning (Newman et al., 2008; Weerts, 2010). They have significant ecological importance as they contribute to the various ecosystem goods and services provided by the Port. Intertidal sandbanks in the Port become exposed at low tide and play an important role in the recycling of terrestrial and marine derived nutrients and organic matter (Deborde et al., 2008). The sandbank habitats are important from a conservation perspective as they harbour a diverse community of invertebrate fauna. They are also important feeding areas for fish and birds and thus help maintain biodiversity in the Port (Allan et al., 1999). The Bay of Natal Estuary Management Plan (MER/ERM, 2012) has accordingly identified the sandbank habitat for conservation.

A number of studies have been completed in recent years focusing on the estuarine biota of the Port of Durban (Allan et al., 1999; Pillay, 2002; Blackler et al., 2004; Forbes & Demetriades, 2006; Angel & Clark, 2008; Newman et al., 2008; Weerts, 2010; MER/ERM, 2012; Clark et al., 2016). Key sandbank habitats in the Port include the Centre Bank, Little Lagoon, Northern Banks and the Mangroves. This document details sampling procedures and information gathered from the spring 2021 environmental monitoring survey.

2 Project Location and Baseline Environment

2.1 Port of Durban

The Port of Durban is considered an estuarine embayment with three perennial rivers that feed into it. The harbour has approximately 57 storm water outfalls, which feed the bay with surface runoff. The total size of the Durban Harbour catchment is approximately 242 km^2. The surface area of the Durban harbour bay is approximately 8 km^2, with a shoreline perimeter of approximately 27 km (Day & Morgan, 1956; Guastella, 1994*;* Hay et al., 1995).

2.2 Geology

The Durban Harbour is considered a bay, which serves as a major receiver of run-off water from canals and surrounding rivers. The Port of Durban is underlain by Cretaceous, aged siltstone rocks of the St Lucia Formation, Zululand Group, that have weathered to varying degrees. Residual soils have been derived from the *in situ* weathering of the bedrock. Younger unconsolidated alluvial and estuarine sediments referred to as the Harbour Beds unconformably overlie the Cretaceous-aged strata in the Port of Durban (Hindmarch et al., 2008; Cawthra et al., 2012).

2.3 Site Location

The study site (**Figure 1**) is located within the Port of Durban (29°52'17.87"S; 31° 1'9.08"E). The Port occupies the natural expanse of the full Durban Bay, spanning an area of 1850ha (18.5km^2) (Transnet National Ports Authority, 2017). The city centre is located approximately 5km north of the Port of Durban, with the residential and industrial area of the Bluff located 10 km south. The Port is one of the few in the world with such a close proximity to the central city.

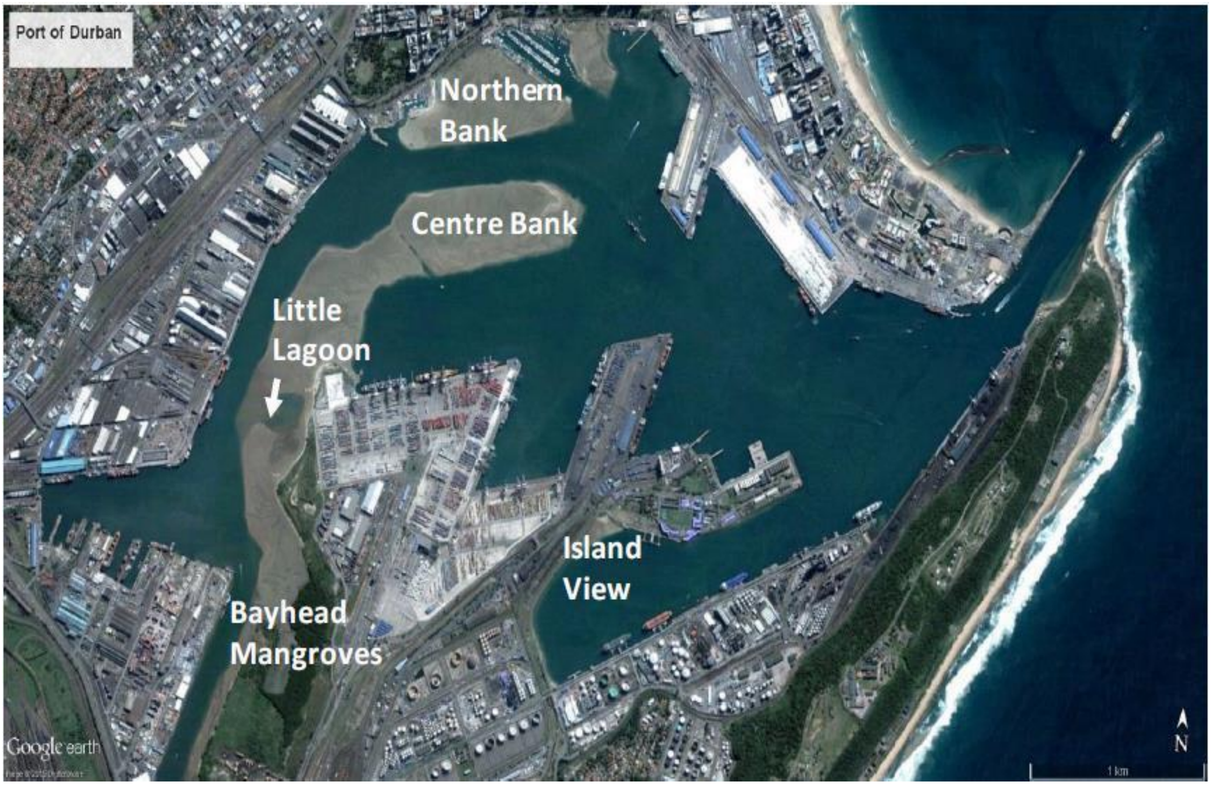

Figure 1: Ariel view of intertidal sandbank habitats (Northern Bank, Centre Bank, Little Lagoon, Island View, Bayhead Mangroves) in the Port of Durban (Google Earth, 2015).

2.4 Aspects of environmental monitoring

The environmental monitoring presented in this report include monitoring of physico-chemical variables and assemblages of fauna and flora in the Port of Durban.

Physico-chemical variables include:

i. Salinity
ii. Temperature
iii. Dissolved Oxygen
iv. pH
v. Turbidity
vi. Sediment grain size distribution
vii. Sediment organic carbon content
viii. Trace metal concentrations in sediment and mussels (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg)

Fauna and flora assemblages include:

i. Benthic microalgae (microphytobenthos)
ii. Benthic macrofauna
iii. Fish
iv. Birds

Detailed methodologies for each of these components are presented in the subsections below. A quarterly (once every 3 months) sampling schedule is being followed for water and sediment quality, benthic microalgae, benthic macrofauna and fish surveys, while a monthly schedule is being followed for bird surveys. Dates of the quarterly surveys were selected to correspond with the middle of each season and are centred around one of the spring tide episodes in each period.

Surveys have been completed in the following months:

- October 2018 (Spring I). Completed.
- January 2019 (Summer I) – This sample run did not occur as Transnet put the project on hold
- May 2019 (Autumn I) – This sample run did not occur as Transnet put the project on hold
- August 2019 (Winter I) – Completed.
- October 2019 (Spring II) – Completed.
- January 2020 (Summer II) – Completed.
- June 2020 (Autumn II) – Completed.
- July 2020 (Winter II) – Completed.
- October 2020 (Spring III) – Completed.
- January 2021 (Summer III) – Completed.
- April 2021 (Autumn III) – Completed.
- July 2021 (Winter III) – Completed.
- October 2021 (Spring IV) - Completed. Presented in this report.

3 Water Quality

3.1 Introduction

Estuaries are dynamic water bodies, influenced both by the marine environment and freshwater from catchments. The conditions within estuaries vary both seasonally and diurnally (a result of tide, temperature and sunlight). Estuaries are extremely productive ecosystems due to the combination of high nutrient river water with a shallow, sheltered habitat. Parameters typically measured include salinity, temperature, light intensity, dissolved oxygen, nutrients and chlorophyll-a. These parameters help monitor natural phenomena such as stratification and tidal flushing, as well as impacts caused by human activities and from the catchment. Estuaries are important for their role as nurseries for juvenile marine fish and invertebrates that inhabit these protected and nutrient-rich areas during their developmental stages (Beck et al. 2001). However, water quality in the Durban Bay has become severely degraded because of poor catchment management upstream including erosion, pollution, water abstraction, and harbour development (Durban Port). This presents concern for the biota within the systems.

Estuaries are fragile and sensitive ecosystems that are easily affected by changes in land and developments. Monitoring of water quality is important for the identification of pollution events and for identifying areas of chronic contamination. An example is the introduction of organic waste that can result in deoxygenation, eutrophication and/or the formation of algal blooms with potential adverse impacts on biodiversity (Varadharajan et al., 2013). In addition, Port development activities such as dredging can increase turbidity and total suspended solids in water, reducing light penetration and hinder photosynthetic activities in the water column. This invariably affects the ecosystem functioning of higher organisms that directly depend on primary producers (Brzeski & Newkirk, 1997). Basic water quality of the Port is assessed as part of ongoing monitoring for this project. Water quality parameters that are considered include temperature, salinity, dissolved oxygen content, pH and turbidity.

3.1.1 Temperature

Water temperature is closely associated with many of the chemical and biological processes occurring in estuaries (Snow & Taljaard, 2007). Concentrations and saturation levels of dissolved oxygen in the water is directly influenced by temperature. As water temperature increases, the solubility of oxygen decreases. Therefore, cold water generally holds more oxygen than warmer waters (Madeira et al., 2013). Temperature also influences other biological processes such as photosynthesis, animal reproductive cycles, -migrations, -metabolic rates and susceptibility to parasites and disease (Caffrey, 2003; Pillay & Perissinotto, 2008). Water temperature in estuaries can vary with depth, anthropogenic activities, season, atmospheric conditions and tidal phases. Thermal stratification (i.e. water layers with strong temperature differences) can occur when the mixing of water layers is inadequate. If such conditions persist, it could result in hypoxic / anoxic conditions in bottom waters with potential negative impacts on benthic biota (Chadwick et al., 1996).

3.1.2 Salinity

Salinity is a measure of the amount of dissolved salts in water. In estuarine environments, there are significant fluctuations in salinity levels because of the input of freshwater from river inflow or anthropogenic discharge via storm water canals, which can have a direct influence on the type and distribution of plants and animals in an estuary. Salinity levels also fluctuate with season (Kamer & Fong, 2000; Pillay & Perissinotto, 2008). During the rainy season, greater amounts of freshwater enter estuaries thereby lowering salinity levels. In contrast, a dry season could result in increased salinities due to less freshwater coming into the system, and possibly less variation in salinity levels. Just like temperature, salinity stratification could also be a problem in an estuarine environment causing hypoxia and anoxia in benthic habitats.

3.1.3 Dissolved Oxygen

Dissolved oxygen concentration refers to the amount of oxygen present in water and is vital for the survival of most aquatic life. Dissolved oxygen plays an important role in the various chemical and biological processes occurring in estuaries (Reddi et al., 1993). Season, temperature, salinity and plant photosynthetic activity all influence dissolved oxygen levels in an estuary (Attrill et al., 1999). Sufficient levels of dissolved oxygen are crucial for the survival of estuarine fauna and thus have an important influence on their distribution and abundance (Pillay & Perissinotto, 2008). The toxicity of trace metal contaminants such as lead, copper, and zinc can increase with a decrease in dissolved oxygen concentrations. Therefore, the monitoring of dissolved oxygen in estuarine environments is important, as it is a good indicator of estuary health.

3.1.4 pH

pH is a measure of alkalinity or acidity of a solution or substance. It is recorded on a scale of 0 to 14; where 0 – 6 is regarded as acidic and 8 – 14 is alkaline. A pH of 7 is commonly referred to as neutral. In estuaries, it is an important water quality parameter, as slight changes in pH can significantly alter the chemistry of the water and influence biogeochemical processes (Doering, 1996). Changes in pH can influence solubility of some metals such as copper and iron, as well as the toxicity of many harmful compounds such as ammonia (Das & Sahu, 2005). The optimal range of pH values for estuarine fauna is approximately between 6.5 and 8.6 (Clark et al., 2016). pH levels lower than 5 or greater than 9 may be fatal for estuarine fauna and this is often an indication of the introduction of industrial or agricultural pollutants to the estuarine system.

3.1.5 Turbidity

Turbidity is an important measure of water quality especially in estuaries where there is usually mixing and inflow of freshwater from connecting rivers and inland canals (Hellweger et al., 2004). Turbidity is a measure of light penetration in the water column and can be defined as the transparency of water in relation to the amount of light scattered by particulates and dissolved substances, recorded in Nephelometric Turbidity Units (NTU). Monitoring turbidity in aquatic environments is important as changes in turbidity may affect availability of light for plant photosynthetic activities, food availability in the system and other ecological processes such as oxygen production (Moore et al., 1997). Elevated turbidity levels can also influence ecological interactions (e.g. predator-prey interaction) through affecting visibility.

3.2 Methodology

Water quality parameters including temperature, salinity, dissolved oxygen, pH, and turbidity were measured using a YSI (EXO 1 – 18H112179) CTD water quality meter. Measurements were taken at spring tide (high and low) and neap tide (high and low) at all 20 stations distributed in the navigation channels surrounding the main intertidal and shallow subtidal sandbank areas (**Figure 2**).

The YSI water quality meter was held at the surface for approximately one minute to flush the sensors and was then lowered and retrieved at approximately 1 m/s at each station. Data from all sites were subsequently downloaded and processed according to the manufactures' recommendations. Water quality data from each station were further analysed by deriving appropriate summary statistics to investigate spatial physical-chemical variability in the Port.

Figure 2: Water quality monitoring sites (white pins) in the Port of Durban.

3.3 Results

3.3.1 Temperature

Overall, water temperatures were relatively uniform across the water quality stations in the Port and mean temperatures were greater than those recorded in winter. Mean surface water temperatures ranged from 18.82 – 21.73 °C and deeper water between 20.5 - 21.7 °C (**Table 1**), demonstrating no decrease in temperature with depth which suggests that the water column is well-mixed. Overall, temperature readings are similar to those reported in the baseline study (Clark et al., 2017).

3.3.2 Salinity

Surface water salinity values were far below the range typical of marine waters, ranging from 6.3 – 32.3 PSU, although that of deeper waters were between 33.6 – 36.6 PSU more typical of marine systems. The low salinity values of surface waters were likely driven by heavy seasonal rains around the time of sampling.

3.3.3 Dissolved Oxygen

Dissolved oxygen concentrations in estuaries typically range between 6 – 8 mg/L. Concern is warranted when levels below 2 - 5 mg/L persist over long periods, which can result in physiological stress for most estuarine biota. In spring, mean dissolved oxygen conditions of surface waters were in the range of 6.7 – 8.9 mg/L and 6.1 – 7.18 mg/L in deeper waters (**Table 1**). These concentrations have remained mostly constant throughout the monitoring events completed thus far.

3.3.4 pH

As with other water quality parameters, pH levels varied minimally across all tidal phases throughout the 20 water quality stations in the Port, with means ranging between 6.8 – 8.6 for surface waters and from 7.9 – 8.3 for deeper waters (**Table 1**). pH values recorded at all monitoring stations in the Port appears to remain constant with depth.

3.3.5 Turbidity

Turbidity levels in spring 2021 ranged from 4.3 – 9.55 NTU (Nephelometric Turbidity Units) in surface waters and from 4.5 – 10 NTU in deeper water layers (**Table 1**). These values are slightly greater than those reported in the baseline study (i.e. 1 – 7 NTU; Clark et al., 2017).

Table 1: Water quality results of surface (< 1 m depth) and bottom layers recorded during the spring 2021 sampling event. All results given as mean ± standard deviation.

Station	Temperature (°C)		Salinity (PSU)		Dissolved Oxygen (mg/L)		pH		Turbidity (NTU)	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
WQ01	21.2 (±0.9)	21.7 (±1)	22.13 (±14.9)	33.6 (±2.5)	6.7 (±2.6)	6.4 (±1.7)	7.9 (±0.4)	8.3 (±0.4)	6.7 (±12.6)	10 (±18)
WQ02	20.78 (±1.7)	21.27 (±0.5)	19.23 (±16.72)	34 (±1.7)	7.13 (±1.4)	6.1 (0.3)	8 (±0.6)	7.9 (±0.4)	6.34 (±14.6)	4.5 (±7.5)
WQ03	20.6 (±0.7)	21.18 (±0.4)	16.6 (±17.1)	35.4 (±1.7)	7.4 (±1.2)	6.46 (±0.6)	7.4 (±0.3)	7.9 (±0.4)	7.88 (±9.3)	5.76 (±8.5)
WQ04	20.8 (±1.1)	21.26 (±0.6)	14.3 (±16.73)	34.9 (±1.7)	7.8 (±1.5)	6.43 (±0.4)	7.7 (±0.3)	8.03 (±0.3)	5.45 (±8.1)	5.71 (±4.6)
WQ05	21.73 (±1.2)	21.1 (±0.8)	20.2 (±17.1)	35.4 (±2.4)	7.4 (±1.1)	6.6 (±0.7)	7.73 (±0.4)	7.9 (±0.4)	4.24 (±10.7)	6.55 (±13.1)
WQ06	20.9 (±1.2)	21.25 (±0.9)	13.32 (±16.1)	34.9 (±2.1)	7.4 (±1.1)	6.35 (±0.8)	7.7 (±0.4)	8 (±0.3)	7.74 (±7.7)	9 (±17.1)
WQ07	20.7 (±1)	21.28 (±1)	17.5 (±16.8)	34.3 (±3.4)	7.4 (±1.2)	6.7 (±0.6)	7.7 (±0.2)	7.9 (±0.3)	6.93 (±9.8)	7.39 (±8.3)
WQ08	18.82 (±1.9)	21.3 (±0.9)	6.5 (±13.4)	35 (±3.1)	8.2 (±1)	6.47 (±0.5)	8.39 (±0.4)	8.1 (±0.3)	2.67 (±3.1)	5.44 (±10.3)
WQ09	19.5 (±1.9)	21.2 (±0.9)	9.3 (±14.9)	35.1 (±3.9)	8.32 (±1.2)	6.6 (±0.5)	8.2 (±0.2)	8.03 (±0.2)	4.31 (±6.2)	8.17 (±14.3)
WQ10	20.7 (±0.7)	21.5 (±0.9)	15.1 (±16.8)	34.7 (±3.6)	7.7 (±1.1)	6.93 (±0.5)	8.1 (±0.2)	8.1 (±0.3)	9.55 (±14)	4.5 (±3.6)
WQ11	20.79 (±0.8)	20.9 (±0.3)	19.2 (±17.2)	35.7 (±1.7)	7.5 (±1.2)	6.58 (±0.4)	7.9 (±0.2)	8.03 (±0.2)	8.21 (±9.4)	5.4 (±3.3)
WQ12	20.62 (±0.4)	20.5 (±0.6)	24.3 (±16.9)	36.6 (±1.5)	7.4 (±1)	7.17 (±0.5)	7.9 (±0.1)	8.1 (±0.2)	8.3 (±4.3)	6.39 (±4.5)
WQ13	20.7 (±0.8)	20.84 (±0.33)	14.2 (±17.2)	35.9 (±3.1)	8.2 (±1.2)	6.86 (±0.4)	7.9 (±0.2)	8.05 (±0.3)	5.7 (±4.1)	6.6 (±9.9)
WQ14	20.94 (±0.4)	20.7 (±0.5)	13.8 (±17.3)	36.1 (±1.1)	8.43 (±1.2)	7.18 (±0.4)	6.8 (±1.3)	8.04 (±0.2)	4.6 (±2.6)	7.76 (±13.7)
WQ15	20.46 (±0.5)	20.9 (±0.4)	32.3 (±10)	35.8 (±1)	7.74 (±0.9)	6.9 (±0.7)	7.93 (±0.1)	8.03 (±0.2)	2.59 (±0.8)	5.91 (±6.7)
WQ16	20.76 (±0.4)	20.9 (±0.3)	23.1 (±17)	35.6 (±1.6)	7.51 (±1.3)	6.7 (±0.4)	8 (±0.2)	8.06 (±0.3)	5.97 (±4.2)	6.13 (±8.6)
WQ17	20.38 (±2.5)	21.6 (±1.2)	11.1 (±16.2)	35.63 (±1.8)	8.37 (±1.3)	6.6 (±0.6)	8.2 (±0.4)	8.04 (±0.2)	5.23 (±8.9)	5.95 (±3.9)
WQ18	20.52 (±1.2)	21.4 (±0.9)	21.7 (±17.6)	35.1 (±2.7)	7.45 (±1.4)	6.6 (±0.7)	7.6 (±1.6)	8 (±0.2)	4.9 (±6.5)	5.39 (±8.4)
WQ19	18.94 (±2.2)	21.4 (±0.8)	7.2 (±13.5)	35.2 (±1.8)	8.9 (±1.2)	6.6 (±0.6)	8.6 (0.5)	8.04 (±0.3)	4.2 (±3.5)	5.32 (±5.7)
WQ20	21.17 (±1.2)	21.2 (±0.8)	16.5 (±17.2)	35.1 (±2.7)	7.6 (±0.9)	6.68 (±0.5)	7.9 (±0.1)	8.04 (±0.1)	5.98 (±10.7)	5.52 (±4.9)

3.4 Conclusion

Physico-chemical conditions of water in the Port were mostly uniform across all the water stations surveyed and have demonstrated typical seasonal fluctuations throughout the monitoring conducted thus far. In the previous sampling season (summer 2021), salinity levels were lower than the typical ranges reported for marine systems, but these ranges increased to more acceptable levels in autumn 2021. Concentrations of dissolved oxygen, turbidity and pH have remained fairly constant from the previous survey and are in line with the baseline conditions reported in Clark et al. (2017). As Berth construction had not begun, these data can be viewed as a compliment to baseline data used to characterize pre-construction water quality conditions.

4 Sediments

4.1 Introduction

Sediments play an important role in terms of habitat provisioning for aquatic organisms. These organisms, in turn, play a role in the establishment of an ecosystem. Several sediment characteristics are frequently incorporated into long-term monitoring programmes, including grain size composition, concentrations of nutrients such as carbon (measured as Total Organic Carbon) and trace metals. Contaminants present in water can settle in the sediment where they can accumulate over time. As such, sediments can be regarded as a pollutant sink (David, 2006). When these sediments are disturbed (e.g. through dredging), contaminants can become suspended in the water column and become available for uptake by marine biota. In addition, sediment characteristics can also be used to explain the community dynamics of macrofaunal invertebrates (Anthony & Héquette, 2007; Watson et al., 2013).

The distribution of different grain sizes are driven mostly by water movement. Finer sediment tends to accumulate in areas with minimal hydrodynamic disturbance, whereas coarser sediment occurs in areas with greater disturbance. Sediments are classified according to grain size (**Table 2**) and studying the composition of grain sizes can reveal areas that are likely to have elevated contaminant levels. This is because pollutants bind more easily to fine or muddy sediments with larger surface areas (Ellingsen, 2002; Austen & Widdicombe, 2006; Anderson, 2008).

Table 2: Sediment grain size characterization.

Descriptive term		**Grain size**
Gravel		> 2000 µm
Sand	Very coarse	1000 – 2000 µm
	Coarse	500 – 1000 µm
	Medium	250 – 500 µm
	Fine	125 – 250 µm
	Very fine	63 – 125 µm
Mud/silt		< 63 µm

Sediment contamination can stem from various activities including wastewater treatment and disposal, runoff, mining, industrial activity, etc. The pollutants introduced from such activities can pose risks to the health and functioning of aquatic ecosystems (Sponseller et al., 2013; Effendi et al., 2016).

Another sediment parameter that serves as a useful metric of overall sediment quality is the concentration of Total Organic Carbon (TOC). While organic matter represents an important food source for organisms such as benthic macrofauna (Lopez et al., 1989; Snelgrove &

Butman 1994), an excess of such nutrients may result in negative impacts on these communities. The degradation process of these nutrients in the sediments requires oxygen and can produce toxic by-products (e.g. ammonia, sulphide) (Gray et al., 2002). Areas that have elevated levels of TOC are also likely to contain other contaminants. The proportions of TOC in sediments can be classified into three broad system types: oligotrophic, mesotrophic and eutrophic (Forbes & Demetriades, 2003) (**Table 3**). Habitats with high TOC levels are at risk to become oxygen depleted (i.e. eutrophic).

Table 3: Total Organic Carbon (TOC) classification levels in sediments (adapted from Forbes & Demetriades, 2003).

% Total Organic Carbon	Class	System Type
<0.5%	Very Low	**Oligotrophic**
0.5 – 1 %	Low	very low levels of nutrients
1 – 2 %	Moderate	**Mesotrophic** intermediate level of productivity
2 – 4 %	Medium	**Eutrophic**
>4%	High	rich in nutrients and minerals, can have excessive algal growth and thus diminished oxygen content to the detriment of other organisms

The final sediment characteristic that is considered as part of this monitoring programme is the concentration of trace metals. Trace metals (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg) occur naturally in marine environments and play fundamental physiological roles. They tend to accumulate in fine sediments where they are largely passive (non-threatening) but can become harmful when sediments are disturbed (e.g. through dredging) and subsequently suspended in the water column (Summers et al., 1996; Ellingsen, 2002; Austen & Widdicombe, 2006; Anderson, 2008; CSIR, 2016). Metals may be assimilated by organisms such as filter-feeders and can lead to bioaccumulation in higher order marine organisms which may further result in human health consequences if such organisms are consumed.

In this monitoring programme, sediment trace metal concentrations are contrasted against the South African regulations and the Effects Range Low (ERL) and Effects Range Median (ERM) concentrations specified by the National Oceanographic and Atmospheric Administration (NOAA) (**Table 4**). The ERL values (lower 10^{th} percentile) and ERM (median) are derived from the literature and refers to the 10^{th} percentile and median concentrations of a particular trace metals at which biological effects of trace metal contamination have been observed.

Table 4: South African and NOAA sediment quality guidelines for trace element concentrations. Concentrations are parts per million (ppm) dry weight (mg/kg), ERL = Effects Range Low, ERM = Effects Range Median (DEA, n.d).

	South African guidelines		NOAA Guidelines	
Metal	**Special Care Range (ppm)**	**Prohibited (ppm)**	**ERL (ppm)**	**ERM (ppm)**
Arsenic (As)	30 – 50	>150	8.2	70
Cadmium (Cd)	1.5 – 10	>10.0	1.2	9.6
Chromium (Cr)	50 – 500	>500	81	370
Copper (Cu)	50 – 500	>500	34	270
Mercury (Hg)	0.5 – 5.0	>5.0	0.15	0.71
Lead (Pb)	100 – 500	>500	46.7	218
Nickel (Ni)	50 – 500	>500	20.9	51.6
Zinc (Zn)	150 – 750	>750	150	410

4.1.1 Sediment Threshold Limits set in the Central Sand Bank Mitigation Plan, 2017

Threshold (warning) levels have been established for grain size (% sand and % mud), Total Organic Carbon concentration (%TOC) and trace metals in sediment samples from the Central Sand Bank Mitigation Plan (Clark et al., 2017) (**Table 5**). If these limits are violated, negative impacts on biota such as invertebrates, fish and birds in the Port can occur.

Table 5: Baseline threshold (warning) levels for sediment parameters (%sand, mud %, Total Organic Carbon (TOC) %, and trace metal concentrations) in intertidal and subtidal sediment samples from control and impact monitoring stations across the Port of Durban (adapted from Clark et al., 2017). Values for grain sizes (sand, mud) must fall between 10 – 90th percentiles whereas values for trace metals must fall below the 90th percentile.

Parameter	Intertidal limits		Subtidal limits	
	10th percentile	90th percentile	10th percentile	90th percentile
Sand (%)	99.6	100	97.4	99.9
Mud (%)	0.0	0.4	0.1	2.6
TOC (%)	1.0	2.0	1.4	6.0
As (ppm)	1.734	4.58	1.734	7.73
Cd (ppm)	n/a	0.58	n/a	1.38
Co (ppm)	n/a	3.93	n/a	7.09
Cr (ppm)	n/a	29.93	n/a	54.59
Cu (ppm)	n/a	16.13	n/a	58.88
Fe (%)	n/a	1.14	n/a	2.19
Mn (ppm)	n/a	214.44	n/a	202.83
Ni (ppm)	n/a	7.38	n/a	15.63
Pb (ppm)	n/a	10.94	n/a	46.70
Zn (ppm)	n/a	25.67	n/a	127.26
Hg (ppm)	n/a	0.10	n/a	0.18

4.2 Methodology

4.2.1 Sampling locations

Sediment samples were taken at 39 intertidal (**Figure 3**) and 25 subtidal (**Figure 4**) sites distributed across the Port.

Figure 3: Intertidal sediment sample sites in the Port of Durban. This includes 21 intertidal stations on the existing central sandbank (yellow pins – Int 10-31), 10 intertidal northern bank stations (yellow pins, Int 40-49), and additional 12 intertidal impact-monitoring stations on the central (black pins, Int 2 - 9). Sites immediately adjacent to the newly established sand bank (red pins, Int 53 - 63) will be sampled once development has commenced. Impact monitoring stations: Int2 – Int31, control monitoring stations: Int40 – Int49. Samples are collected at these sites for sediment characteristics, microalgae and benthic macrofauna. The area highlighted in red is where dredging is to take place.

Figure 4: Subtidal sites within the Port of Durban where sediment samples are taken. These sites represent three habitats: the central bank (Sub13 – Sub26), the little lagoon (Sub27 – Sub33), and the northern bank (Sub40 – Sub48). Impact monitoring stations: Sub13-Sub33, control stations: Sub40-Sub48. Samples are collected at these sites for sediment characteristics, microalgae and benthic macrofauna. The area highlighted in red is where dredging is to take place.

4.2.2 Sampling protocol

Intertidal sediment samples were taken at low tide when these sandbanks were exposed. Intertidal sediment samples were collected using a hand corer with a diameter of 18 cm. Once inserted into the sediment, the sides around the tube were dug out to insert the separator. The top surface of sediment was then separated from the remaining layers of sediment with these remaining layers then discarded. The top layers where subsequently transferred to sample containers and stored in a cooler box with ice.

Subtidal sediment samples were collected using a stainless steel van Veen grab. This grab was attached to 50 m long rope that was fixed onto a vessel so the grab could be manually lowered onto the seafloor for benthic sediment collection. The grab was locked in place with a safety pin prior to deployment, after which it was hoisted over the side of the vessel and lowered until it reached the seafloor where sediment samples were collected. Field scientists standing on the vessel lowered the grab at a constant speed to the seafloor bottom. Once the grab made contact with the seafloor the safety pin triggered (indicated by slack in the lowering wire), the tension on the rope was slowly increased, causing the lever arms to close the grab and take a sample. On retrieval of the van Veen grab, water trapped above sediment in the grab was drained through a bleeder hole, taking care to lose as little fine-grained material as possible. The samples were collected with a Teflon scoop and placed in sterile cups, sealed and labelled with cross-referencing to sampling sites.

Following collection, all intertidal and subtidal sediment samples were placed in individual containers and kept on ice in the field until delivery to the Talbot and Talbot laboratory (SANAS accredited). Once in the laboratory they were stored frozen (-4ºC) until further processing and analysis. From these samples, the grain size distribution, Total Organic Carbon (TOC) content and trace metal concentrations were established.

4.3 Results

The CSMP study stipulates that the median values of the various sediment characteristics (grain size, TOC concentration, trace metal concentration) of impact and control sites must be contrasted against the baseline levels established in the CSMP. The key results of all intertidal and subtidal sediment characteristics in relation to these levels are summarised below (**Table 6, Table 7**). As in the previous season, the majority of intertidal sediment characteristics were within allowable limits, apart from grain size proportions and TOC concentrations (**Table 6**), both of which were below their minimum threshold values.

Table 6: Key results of intertidal sediment characteristics (grain size, TOC, trace metal concentrations) in relation to the 90th percentile threshold limits of the CSMP. Values for grain sizes (sand, mud) must fall between 10 – 90th percentiles whereas values for trace metals must fall below the 90th percentile. Values printed in red are outside of allowable ranges. Sites are grouped as overall (all sites), impact sites (Int3 – Int 31) and control sites (Int40 – Int49).

Characteristic	10th percentile	90th percentile	Median (all sites)	Median (impact sites)	Median (control sites)
Sand (%)	99.6%	100%	**99.39**	**99.11**	**99.56**
Mud (%)	0%	0.4%	0.29	0.31	0.26
Total Organic Carbon (%)	1%	2%	**0.59**	**0.595**	**0.48**
As (ppm)	1.7834	4.58	2.73	2.88	2.15
Cd (ppm)	n/a	0.58	0.18	0.19	0.1
Co (ppm)	n/a	3.93	1.36	1.46	0.9
Cr (ppm)	n/a	29.93	11.36	12.01	8.78
Cu (ppm)	n/a	16.13	5.4	5.7	4.83
Fe (%)	n/a	1.14	2.4	2.79	1.68
Mn (ppm)	n/a	214.44	66.81	88.05	37.43
Ni (ppm)	n/a	7.38	3.18	3.25	2.34
Pb (ppm)	n/a	10.94	8.12	8.36	7.26
Zn (ppm)	n/a	25.67	15.36	16.76	11.91
Hg (ppm)	n/a	0.1	0.08	0.08	0.08

In subtidal sediments all parameters apart from TOC and iron concentrations were within allowable limits (**Table 7**). TOC concentrations were lower that then the threshold minimum stipulated in the baseline study while those of iron exceeded the maximum allowable concentrations.

Table 7: Key results of subtidal sediment characteristics (grain size, TOC, trace metal concentrations) in relation to the 90th percentile threshold limits of the CSMP. Values for grain sizes (sand, mud) must fall between 10 – 90th percentiles whereas values for trace metals must fall below the 90th percentile. Values printed in red are outside of allowable ranges. Sites are grouped as overall (all sites), impact sites (Sub13 – Sub33) and control sites (Sub40 – Sub48).

Characteristic	10th percentile (CSMP)	90th percentile (CSMP)	Median (all sites)	Median (impact sites)	Median (control sites)
Sand (%)	97.4%	99.9%	99.2	98.99	99.59
Mud (%)	0.1%	2.6%	0.41	0.41	0.45
Total Organic Carbon (%)	1.4%	6%	**0.69**	**0.7**	**0.66**
As (ppm)	n/a	7.73	3.47	3.45	3.53
Cd (ppm)	n/a	1.38	0.18	0.18	0.17
Co (ppm)	n/a	7.09	1.36	1.46	1.16
Cr (ppm)	n/a	54.59	10.9	11.38	9.79
Cu (ppm)	n/a	58.88	7	7.72	5.82
Fe (%)	n/a	2.19	**2.8**	**3.29**	**2.38**
Mn (ppm)	n/a	202.83	84.1	86.3	80.64
Ni (ppm)	n/a	15.63	2.87	3.1	2.47
Pb (ppm)	n/a	46.7	9.56	10.61	8.2
Zn (ppm)	n/a	127.26	17.54	19.52	14.42
Hg (ppm)	n/a	0.18	0.06	0.07	0.04

4.4 Conclusion

Sediment monitoring is being undertaken at 64 sites in the intertidal (39 sites) and subtidal (25 sites) zones of the sandbanks within the Port of Durban. The majority of sediment characteristics align with what those described in the baseline study and are within acceptable levels.

Importantly, mercury concentrations in intertidal and subtidal sediments have remained low for three consecutive seasons despite stark spikes earlier in the year. The concentration of iron in subtidal sediments exceeded the maximum allowable threshold at impact and control sites, and the TOC content in intertidal and subtidal sediments continues to be below minimum allowable thresholds as in several previous seasons. This suggests an overall deficiency of nutrients of Port sediments. This could be having effects on organisms such as benthic macrofauna that require sufficient nutrient levels to enable basic physiological functioning.

5 Benthic Macrofauna

5.1 Introduction

The term benthic macrofauna is used to describe the community of small (> 0.5 mm), mainly invertebrate organisms that live upon or within aquatic sandy and muddy substrata (Hauer & Resh, 2017). They play a significant role in the reworking of sediments and assist with enhancing sediment porosity (Goodnight, 1973). This process helps the exchange of oxygen and nutrients in substrates. Macrofaunal organisms are also an important food source for many marine and estuarine predators (Hauer & Resh, 2017) and are fed on by numerous fish, birds and invertebrates (França et al., 2011). Macrofaunal communities within estuaries often have important ecological linkages with neighbouring habitats as certain species from other areas depend on the health of these habitats for their survival (e.g. trophic subsidy) (Weinstein et al., 2005; França et al., 2011). Therefore, degradation or loss of these habitats and communities can have significant effects on ecologically connected environments.

It is important to monitor biological components of the ecosystem in addition to physico-chemical and eco-toxicological variables, as they provide a direct measure of the state of the ecosystem in space and time (O'Brien et al., 2016). Surveys of benthic macrofaunal communities are often done as part of environmental monitoring programmes and these organisms have come to represent a sort of 'bio-indicator' for the health of an aquatic environment. This is because these organisms are sensitive to changes in the surrounding environment (Pinto et al., 2009) and, because they are relatively non-mobile (Gray et al., 2002), they can provide an indication of localised impacts. If a pollution source is known (e.g. discharges, oil spills, dredging activities, other pollutants), it is possible to examine macrofaunal communities along a distance gradient from the pollution source in order to establish the extent of impact. In addition, because these organisms are short-lived, environmental changes will be reflected rapidly in their community compositions (Warwick, 1993).

Various factors can affect the composition of macrofaunal communities. This includes pollutants and environmental variables such as sediment grain size (Riera et al., 2013), brine discharges (Riera et al., 2012), dredging and trace metal concentrations (Ryu et al., 2011; Fonseco et al., 2020) and other pollutants (e.g. sewage (Riera et al., 2013)). Properties of macrofaunal communities that are often examined include abundance, species richness and diversity. Those that are close to a pollution source generally have lower diversity and the densities of different species may be determined by species-specific tolerances to specific pollutants (Pearson & Rosenberg, 1978).

Organic matter is one of the most important pollutants affecting marine life and it can lead to significant changes in community composition and abundance, particularly in semi-enclosed or closed bays such as the Port of Durban where water circulation is limited. High organic loading often results in eutrophication that can alter macrofaunal community dynamics such as growth rates. Resulting anoxic conditions can further drive complete exclusion of certain species based on specific respiratory requirements (Saunders et al., 2007).

The aim for monitoring benthic macrofaunal communities in the Port of Durban is to assess and monitor potential changes in intertidal and subtidal sandbank macrofaunal communities in response to the planned development activities in the Port. The use of dredging equipment to create an extension of the existing sandbanks will create additional shallow intertidal and subtidal sandbank habitats that will be expected to mimic the lost or existing ones, as has been demonstrated in mudflats (Ray, 2000) and saltmarsh (Streever, 2000) systems.

5.1.1 Benthic macrofauna threshold limits set in the Central Sandbank Mitigation Plan, 2017

Threshold (warning) levels have been established for the benthic macrofauna from the Central Sand Bank Mitigation Plan, 2017 (**Table 8**). If levels fall below these limits, recovery of invertebrate populations may be delayed and negative impacts on biota such as fish and birds in the port can be expected.

Table 8: Threshold (warning) levels of benthic macrofauna abundance (mean abundance/m^2) and species richness (number of species) for intertidal and subtidal communities (adapted from Clark et al., 2017).

	Spring	Summer	Autumn	Winter
Intertidal invertebrates				
Abundance (individuals/m^2)	162.4	209.6	277.6	204.3
Species richness (no. species)	4.0	5.2	6.4	5.6
Subtidal invertebrates				
Abundance (individuals/m^2)	232.0	256.0	232.0	176.0
Species richness (no. species)	7.2	8.0	7.2	6.4

5.2 Methodology

5.2.1 Sampling protocol

Benthic macrofauna samples were collected from the same 64 monitoring stations as for sediments and benthic microalgae along adjacent sandbanks (intertidal and subtidal samples) in the Port (**Figure 3**). Methods used in the baseline report (Clark et al., 2017) were also applied here. Intertidal samples were collected at spring low tide by inserting an 18 cm diameter corer into the sediment to a depth of 30 cm and transferring the contents to a 0.5 mm mesh cone sieve. At each intertidal sampling site, three core samples were taken and kept separate. Contents of the cores were transferred to mesh cones (0.5 mm^2 mesh size) that were agitated until all possible sediment have been removed. The remaining contents were transferred to honey jars and preserved in 90% ethanol. At each subtidal site, three samples were collected using a Van Veen Grab with a bite of 0.085 m^2. These samples were processed and preserved in the same way as intertidal samples. Subtidal stations had depths of 3 – 8m and were adjacent to sandbanks.

5.2.2 Measures of Diversity

Various measures can be used to assess spatial and/or temporal variation macrofaunal communities. For the purposes of this report, key results are given per habitat (intertidal habitats: central bank, northern bank; subtidal habitats: central bank, northern bank, little lagoon) as well as an overall estimates of intertidal and subtidal communities. The following measures were determined:

- taxonomic composition of each habitat (intertidal habitats: central bank, northern bank; subtidal habitats: central bank, northern bank, little lagoon),
- abundance,
- species richness,
- Shannon-Wiener diversity indices,
- statistical comparisons of overall community compositions and identification of key species

5.2.3 Statistical Analysis

For intertidal habitats, t-tests were used to determine whether there are statistically significant differences in mean abundance, species richness, and Shannon-Wiener diversity indices of communities inhabiting different areas within the Port. A t-test is a statistical test used to compare the means of two groups (e.g. the mean abundance of intertidal macrofauna in the central bank vs the northern bank). For subtidal habitats, similar comparisons were made but in this case a one-way ANOVA was used as this is the appropriate test to use when comparing more than two groups. In this case comparisons were made among communities of the central bank, little lagoon, and northern bank. Both t-tests and ANOVAs produces p-values, whereby a p-value smaller than 0.05 indicates that there is a statistically significant difference among the means of the groups compared. A p-value larger than 0.05 indicates that the groups compared do not differ significantly. These analyses were conducted in R (R Core Team, 2020).

Multivariate statistics can be used to determine whether there are significant differences in the compositions of communities across space/time. To do this, a PERMANOVA test was used. This test operates based on abundance and the presence/absence data of a species in a given habitat. Comparisons were made between intertidal macrofaunal communities inhabiting the central vs northern bank, and among subtidal communities inhabiting the central bank, little lagoon, and the northern bank. After assessing potential differences in communities inhabiting different areas in the Port, a SIMPER analysis was performed to determine which species distinguished the various communities. The results from this test also provides an indication of species most likely to drive differences (if they exist) among communities. These analyses were carried out through the PRIMER (v6) software.

5.3 Results

5.3.1 Key results

The CMSP baseline study stipulates minimum limits for parameters such as macrofauna abundance and species richness. These parameters are not to fall below their respective minimums during the construction phase of this project. In intertidal habitats (impact and control sites), species richness was equal to or slightly greater than the baseline limit for spring. Median abundance in both tidal zones was, as in previous seasons, below the minimum baseline limit. In addition, subtidal species richness was once again below the minimum baseline limits in impact and control sites (**Table 9**).

Table 9: Median macrofauna abundance and species richness in intertidal and subtidal impact and control stations as determined in the spring 2021 survey. Values printed in red violate the minimum 80%tile thresholds of the CSMP.

	80% limit	Median (overall)	Median (impact)	Median (control)
Intertidal				
Abundance	162.4	**91.7**	**117.9**	**78.6**
Species richness	4.0	5	5	4
Subtidal				
Abundance	176	**40**	**42**	**20**
Species richness	6.4	**5**	**5**	**4**

5.3.2 Intertidal communities

Abundance, species richness, and diversity

This spring, a total of 38 intertidal species were recorded, the majority of which were from the central bank (n = 37) with fewer on the northern bank (n = 19). There were no significant differences in abundance ($T_{16.66} = -0.789$, $p > 0.05$), species richness ($T_{21.27} = 0.941$, $p > 0.05$) and Shannon-Weiner diversity indices ($T_{23.3} = 0.224$, $p > 0.05$) between macrofaunal communities on the central and northern banks (**Table 10**, **Figure 5**).

Table 10: Mean (± standard error) species richness, abundance (per m^2) and Shannon-Wiener H' diversity indices of intertidal macrofaunal communities inhabiting the central and northern banks in spring 2021.

	Central Bank	**Northern Bank**	**Overall**
Abundance/m^2	124.68 (±14.27)	103.49 (±22.73)	119.24 (±12.05)
Species richness	5 (±0.4)	4.4 (±1.58)	4.85 (±2.01)
Shannon-Wiener H'	1.34 (±0.1)	1.3 (±0.12)	1.33 (±0.1)

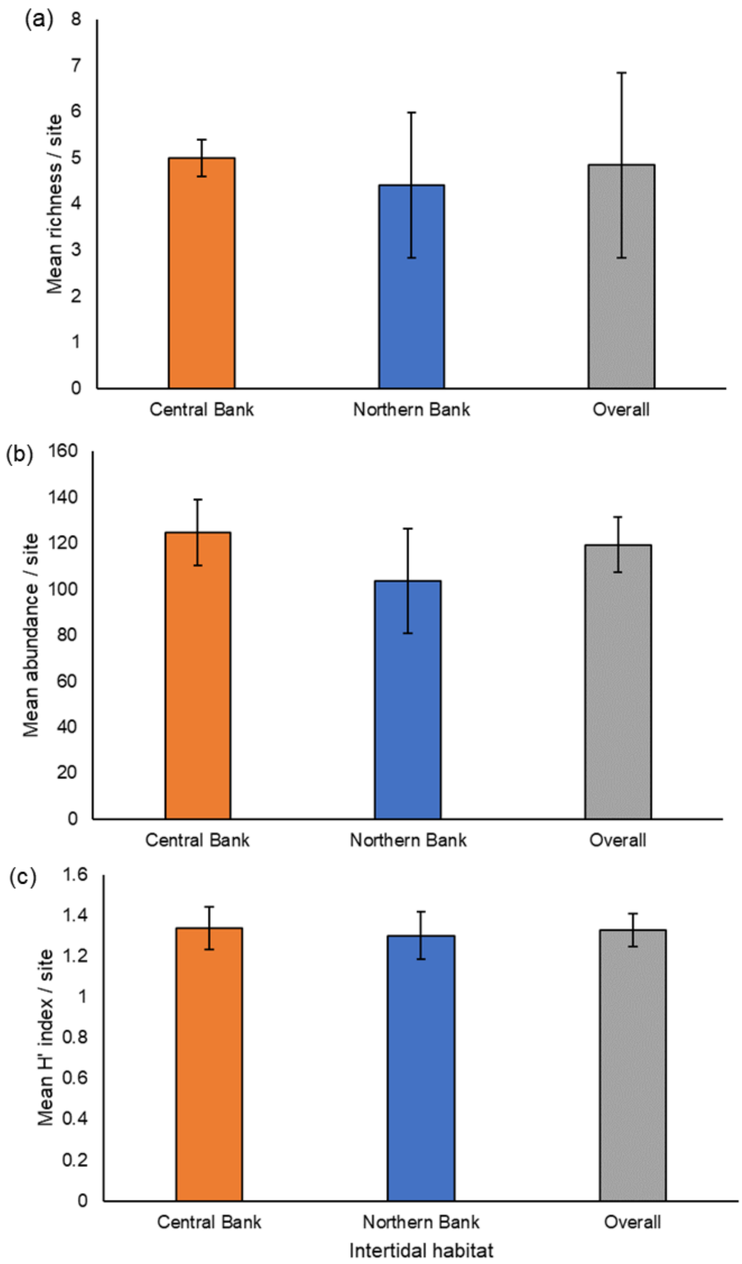

Figure 5: Mean (± standard error) (a) species richness, (b) abundance and (c) diversity of intertidal macrofaunal communities of the central and northern sandbanks.

Taxonomic composition

Similar classes were dominant in the two intertidal habitats, although gastropods (snails) were substantially more dominant on the northern bank than the central bank (**Figure 6**), while polychaetes (bristle worms) and bivalves dominated the northern bank.

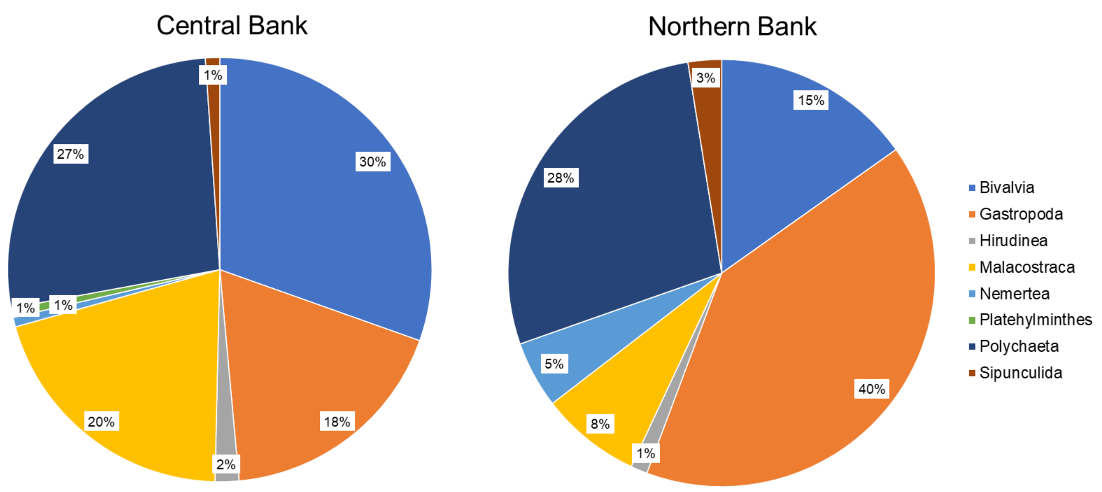

Figure 6: Percentage abundance of various macrofaunal classes in communities on the central bank and northern bank.

Comparisons among communities

Intertidal macrofaunal community composition did not differ significantly between central and northern banks (PERMANOVA, Pseudo-F = 0.764, p = 0.66). This was further confirmed through results from the SIMPER analysis demonstrating that similar species dominated both habitats (

Table 11).

Table 11: Species that contributed up to 60% to overall similarity within intertidal habitats sampled (central bank, northern bank).

Species	Contribution (%)	Cumulative contribution (%)
Central Bank (average similarity = 17.26%)		
Dosinia hepatica	23.37	23.37
Aquilaspio sexoculata	19.17	42.55
Spiroplax spiralis	14.54	57.09
Natica gualteriana	12.46	69.55
Northern Bank (average similarity = 24%)		
Dosinia hepatica	41.99	41.99
Aquilaspio sexoculata	21.38	63.37

5.3.3 Subtidal communities

Abundance, species richness, and diversity

A total of 30 species were detected from subtidal habitats, the northern bank having the most species (n = 21) followed by the little lagoon (n = 19) and then the central bank (n = 17). This is in contrast to previous seasons where the greatest number of species were recorded from the central bank. However, as in previous seasons, there were no significant differences in abundance ($F_2 = 1.687$, $p > 0.05$), species richness ($F_2 = 3.656$, $p > 0.05$) or Shannon Weiner diversity indices ($F_2 = 3.21$, $p > 0.05$) among the three subtidal habitats (**Table 12**, **Figure 7**).

Table 12: Mean (± standard error) abundance/m^2, species richness, and diversity (H' index) of subtidal macrofaunal communities inhabiting the central bank, little lagoon, northern bank and overall.

	Central Bank	**Little Lagoon**	**Northern Bank**	**Overall**
Abundance/m^2	54.8 (±8.85)	19.7 (±6.97)	29.71 (±7.45)	40 (±5.12)
Species richness	4.2 (±0.61)	4.75 (±1.06)	5 (±0.82)	4.6 (±0.46)
Shannon-Wiener H'	1.01 (±0.54)	1.28 (±0.7)	1.38 (±0.38)	1.2 (±0.56)

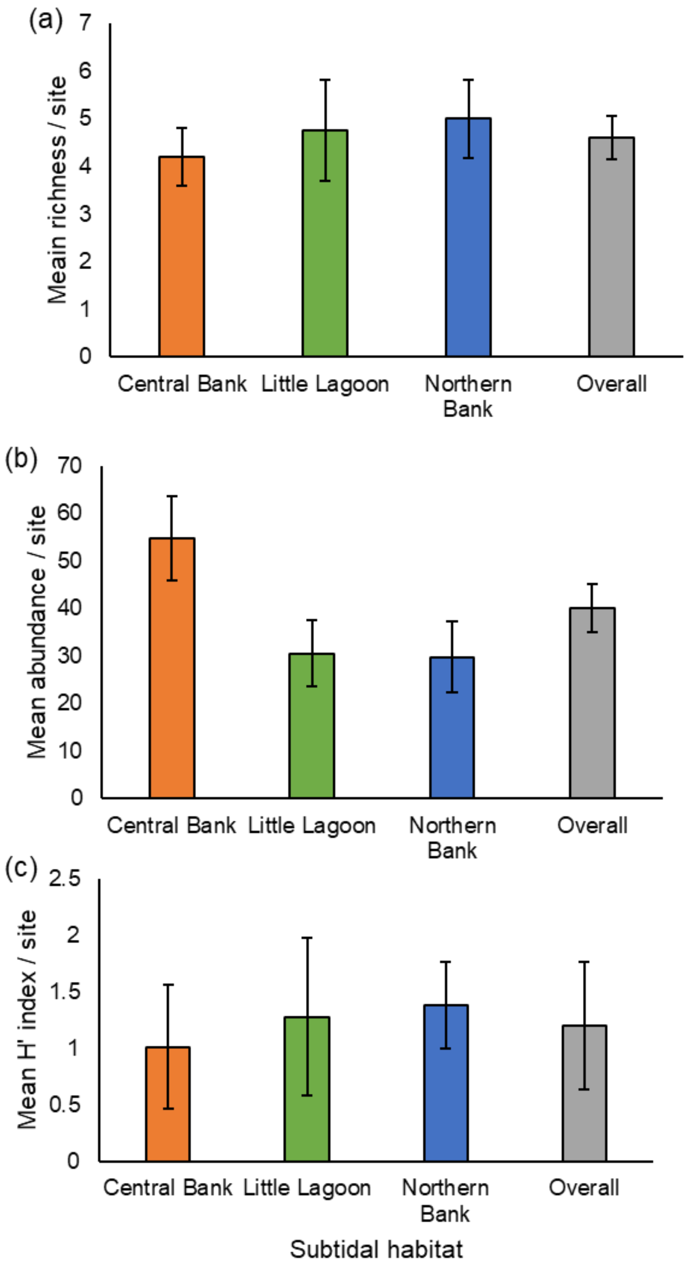

Figure 7: Mean (± standard error) (a) abundance, (b) species richness and (c) diversity of subtidal macrofaunal communities of the central bank, northern bank and little lagoon.

Taxonomic composition

All subtidal habitats were dominated by polychaetes (bristle worms), followed by malacostracans (crustaceans) at the central bank and little lagoon and by gastropods (snails) at the northern bank (**Figure 8**).

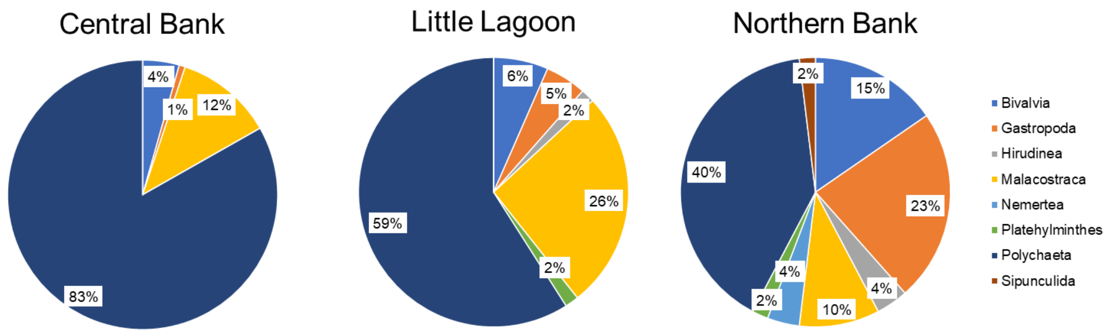

Figure 8: Percentage abundance of subtidal macrofauna classes in communities of the central bank, little lagoon and northern bank.

Comparisons among communities

As in intertidal habitats, there were no significant differences in overall community composition among subtidal habitats (PERMANOVA, Pseudo-F = 1.53, $p > 0.05$). Subsequent SIMPER analysis confirmed the similarity among these habitats as the same species contributed to overall similarity within each subtidal habitats, namely the polychaetes *Aquilaspio sexoculata* and *Orbinia* species (**Table 13**).

Table 13: Species that contributed up to 60% to overall similarity within subtidal habitats sampled (central bank, little lagoon, northern bank).

Species	Contribution (%)	Cumulative contribution (%)
Central Bank (average similarity = 43.87)		
Aquilaspio sexoculata	76.47	76.47
Little Lagoon (average similarity = 17.43)		
Aquilaspio sexoculata	54.49	54.49
Orbinia spp.	16.14	70.64
Northern Bank (average similarity = 18.42)		
Aquilaspio sexoculata	51.75	51.75
Orbinia spp.	17.95	69.71

5.4 Conclusion

As highlighted in previous seasonal report, there are concerning trends regarding macrofaunal biodiversity that are starting to intensify and are not showing signs of improvement. All measures, apart from intertidal species richness, were once again below minimum thresholds set in the baseline study. As stated in previous reports, these trends are not related to the construction phase of this project as it had not yet commenced. However these results still reflect on the overall ecological health of the Port. The key driver of these trends is most likely pollution, for example from oil spills and the persistent and increasing nature of plastic litter in this Port. During laboratory analyses many samples were noted to be strong-smelling and consisted of oily layers covering invertebrates in the respective sample. These concerns have not been addressed and until they are, it is unlikely that the current community dynamics of macrofaunal organisms will improve.

Figure 9: (a) Holes made by common sandprawn *Callichirus kraussi* through a plastic bag, January 2021, (b) litter covering a macrofauna sampling site, October 2021.

6 Benthic Microalgae (Microphytobenthos)

6.1 Introduction

Algae is a term used for a diverse group of microorganisms living in the ocean. Microalgae are photosynthetically active microorganisms. Benthic algae, also known as microphytobenthos, refers to microscopic, unicellular photoautotrophs that usually occur in the upper few centimeters of shelf sediments. Below this level, insufficient sunlight hampers their growth. Where the bottom is sandy or muddy the benthic algae cannot attach themselves as they have no roots. Benthic algae deliver major contributions to food webs and biogeochemistry in aquatic ecosystems, energy and cover for many other organisms (Christiansen et al., 2012). In this way, the productivity of the benthic algae in shallow waters directly or indirectly affects the efficiency of the entire marine ecosystem. Benthic microalgae are ubiquitous in aquatic areas where sunlight reaches the sediment surface. Although they are part of the microbial community already discussed, they deserve special attention because they are a very important component of benthic communities in shallow water systems (N-Uptake, 1999). Besides the fact that they contribute significantly to the primary productivity in sediments and pelagic habitats, they also have important trophic linkages with a variety of organisms, including macrofauna, birds and fish (Davis et al., 2015).

Like other single-celled “plant-like” organisms, they use energy gained from sunlight to transform carbon into organic matter via photosynthesis. They generally live in the top few millimeters to centimeters of aquatic sediment but may go deeper in sandy sediments when light availability is very high. In order to grow, benthic microalgae require nitrogen, phosphorus, and other micronutrients in addition to carbon dioxide. Much of the carbon they take up during photosynthesis is released as extracellular polymeric substances (EPS or “slime”) into the sediment (Wolfstein & Stal, 2002). EPS plays an important role in sticking sediment particles together, which may increase sediment stabilization and, thereby, reducing resuspension. In addition, EPS is rapidly metabolized by the bacterial community.

Benthic microorganisms (microalgae and bacteria) are instrumental in controlling the exchange of nutrients, such as nitrogen and phosphorus, across the sediment-water interface (Paerl & Pinckney, 1996). Benthic microalgae in particular, may help to buffer the water column from eutrophication by storing nutrients that would otherwise be used by phytoplankton and bacteria in the water column. Nutrients used by benthic microalgae are derived not only from the water column but also from the sediments themselves as bacteria break down organic matter (Tengberg et al., 2003). Because of their location near the sediment surface, benthic microorganisms play a role in capping the sediments and reducing the release of nutrients to the overlying water column. Nutrients taken up by benthic microalgae and bacteria can be passed up the food chain, especially to meiofauna.

Microalgal communities in the Port of Durban occur on the sandbanks and bottom sediments as microphytobenthos and in the water column as phytoplankton. Microphytobenthos, however, is often suspended in the water column and can be as important as phytoplankton, particularly in turbid estuaries such as in the Port of Durban. Microphytobenthos play a vital and functional role in estuarine systems. As such, monitoring these communities is an important tool in the overall ecological health assessment of the Port ecosystem.

6.1.1 Benthic Microalgae Threshold Limits set in the Central Sandbank Mitigation Plan, 2017

Threshold (warning) levels have been established for benthic microalgae in the Central Sand Bank Mitigation Plan (CSMP) (Clark et al., 2017) (**Table 14**). According to the CSMP, the biomass of benthic microalgae, measured as the concentration of chlorophyll-a (ug/m^2) should not drop below the 20th percentile value of the median from baseline data, and should not rise above the 80th percentile of these data (**Table 14**). Comparisons are to be made separately for impact and control sites in intertidal and subtidal habitats. Intertidal impact sites are those located on the central bank (Int2 – Int31) and control sites are those on the northern bank (Int40 – Int49). Similarly, subtidal impact sites are those around the central bank and little lagoon (Sub13 – Sub33), while control sites are those around the northern bank (Sub40 – Sub48).

Table 14: Threshold (warning) levels of chlorophyll-a (µg/m^2) from intertidal and subtidal sediment samples across the four seasons in a year (adapted from Clark et al., 2017). Median levels measured at impact and control sites should not be lower than the 20th percentile values and not above the 80th percentile values.

	Spring	**Summer**	**Autumn**	**Winter**
Intertidal				
20%	6.3	7.7	1.4	0.6
Median	22.6	17.7	12.3	2.5
80%	47.7	66.4	43.7	21.6
Subtidal				
20%	1.5	6.6	1.6	1.1
Median	3.7	11.5	6.5	3.0
80%	8.2	21.2	26.8	8.3

6.2 Methodology

6.2.1 Sampling protocol

Benthic microalgae samples were collected from each of the 64 sediment monitoring sites and analyzed in accordance with methods prescribed by Pinckney and Zingmark (1993). Samples were collected by inserting a 20 mm vial directly into the sandbank sediment for intertidal samples, or into the top layer of sediment collected by an Ekman grab sampler for subtidal samples. From both habitats, a sample core of 40 mm in length was extracted and immediately sealed off with a plastic lid. Samples were immediately placed on ice in a dark container and transported to the laboratory for chlorophyll-a analysis.

6.2.2 Laboratory protocol

In the laboratory, the biomass of microalgae in the sediment samples was estimated as total chlorophyll (Chl-a) according to the methods of Whitney & Darley (1979), Dandonneau & Neveux (2002) and Seuront & Leterme (2006). Chlorophyll was extracted from the sediment samples through addition of 8 – 10 mL of 90% acetone. This mixture was then centrifuged for approximately 5 minutes at 8000rpm. For each sample, 1mL of the supernatant containing the chlorophyll was pipetted into microfuge tubes and analyzed using a Trilogy Turner Fluorometer™, which yielded results of chlorophyll-a concentrations in μgL^{-1} at each site. 1 - 2 drops of 1 M HCl was used to eliminate interference from degraded pigments that are common in sediment samples (Cahoon & Cooke, 1992).

6.3 Results

The median chl-a concentrations of control and impact sites in intertidal and subtidal habitats were within the allowable ranges in intertidal and subtidal habitats (**Table 15**). In intertidal habitats, chl-a concentrations were greatest at site 10, 12 and 29 on the Central Bank and at site 41 and 44 on the northern bank. These were the only sites where chl-a concentrations were greater than the 80^{th} percentile values of the baseline study (**Figure 10**). As in previous surveys, the Little Lagoon had higher chl-a concentrations in comparison to the Northern and Central Banks overall, the greatest concentration recorded at site 29 (10.3 $\mu g/m^2$) and closely followed by site 34 (10.23 $\mu g/m^2$) (**Figure 11**).

Table 15: Median chlorophyll-a concentrations ($\mu g/m^2$) at intertidal and subtidal impact and control sites as measured in spring 2021. Values are not to drop below the 20% limit and not above the 80% limit.

	20% limit	80% limit	Median (overall)	Median (impact)	Median (control)
Intertidal					
Chl-a ($\mu g/m^2$)	6.3	47.7	26.6	26.6	29.03
Subtidal					
Chl-a ($\mu g/m^2$)	1.5	8.2	6.27	5.92	6.42

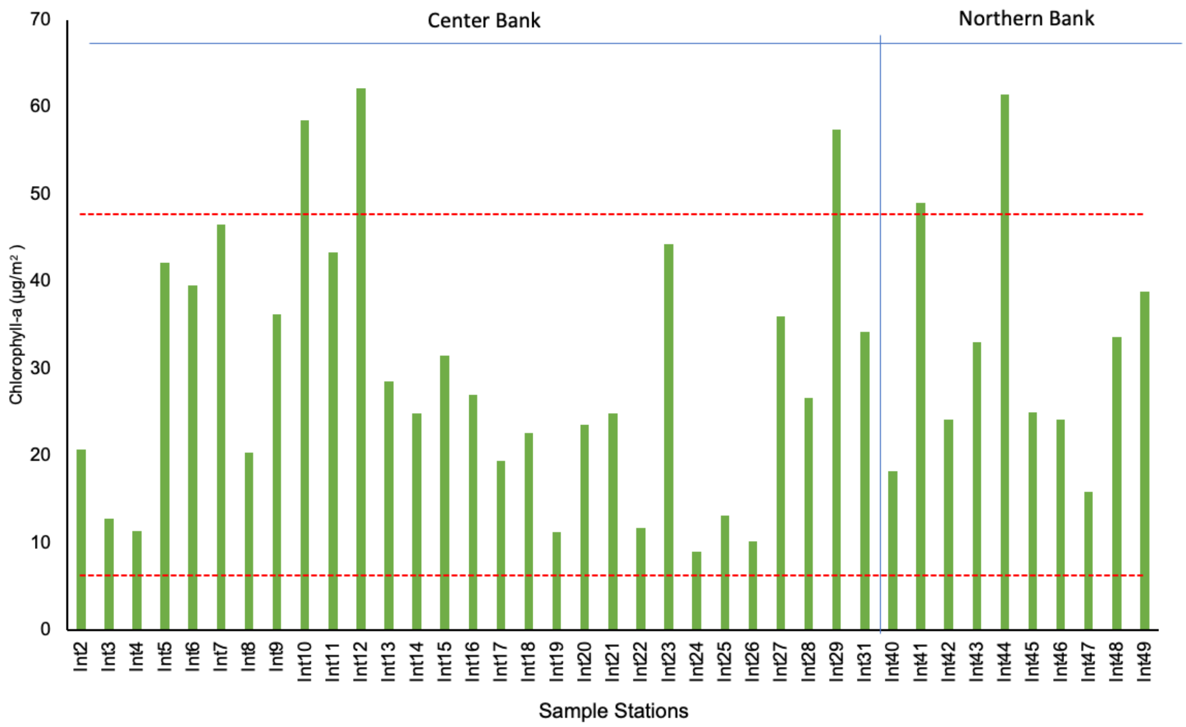

Figure 10: Chlorophyll-a concentrations (µg/m^2) in 39 intertidal monitoring stations in the Port of Durban, spring 2021. Impact sites = Int2 – Int31 (central bank), control sites = Int40 – Int49 (northern bank). Red dotted lines: 20%tile (6.3 µg/m^2) and 80%tile (47.7 µg/m^2) intertidal spring threshold limits stipulated in the CSMP.

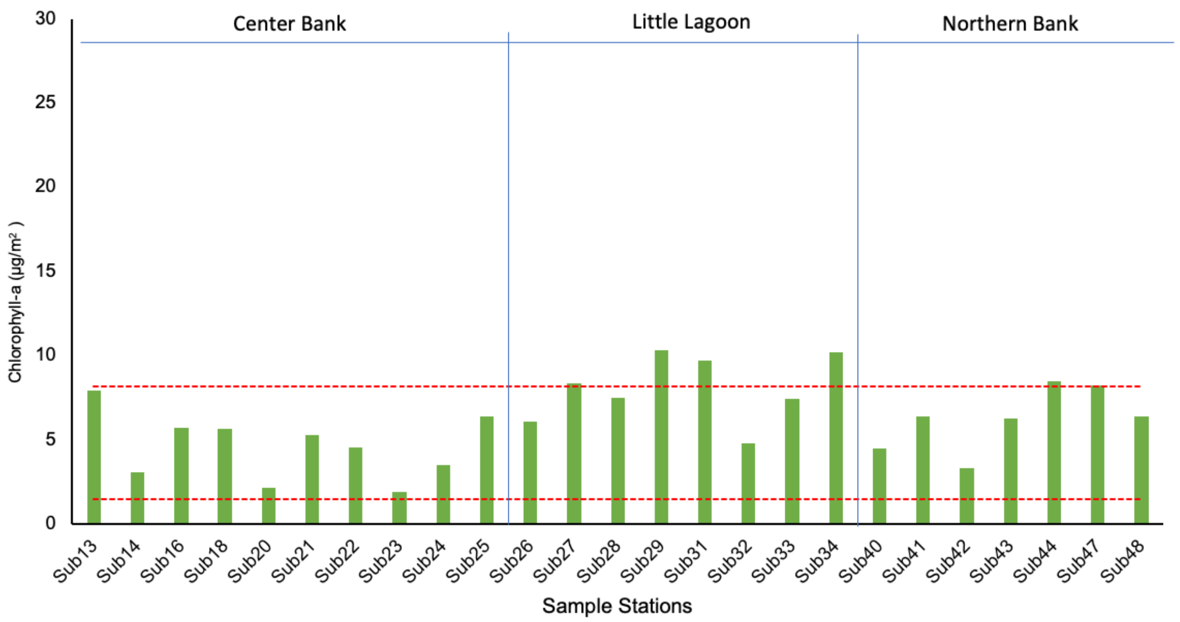

Figure 11: Chlorophyll-a concentrations (µg/m^2) in 25 subtidal monitoring stations in the Port of Durban, spring 2021. Impact sites = Sub13 – Sub34, control sites = Sub40 – Sub48. Red dotted lines: 20%tile (1.5 µg/m^2) and 80%tile (8.2 µg/m^2) subtidal spring threshold limits stipulated in the CSMP.

6.4 Conclusion

Chlorophyll-a and light availability are major determinants of benthic primary production (MacIntyre et al. 1996). Microphytobenthos may also contribute significantly to production in the water column when sediment is re-suspended by currents, upwelling or other forms of disturbance. These algae and cyanobacteria are an important food source for deposit-feeding and suspension-feeding macrofauna. An abundance of microphytobenthos can result in a greater diversity of species higher up the food chain and plays a significant role in system productivity and trophic dynamics.

The chlorophyll-a levels recorded in spring 2021 were lower than those recorded in autumn. The median chl-a levels at impact and control sites were within the allowable ranges specified in the baseline study (Clark et al. 2017).

7 Biomonitoring using Mussels (*Perna perna*)

7.1 Introduction

Trace or heavy metals are persistent pollutants in aquatic ecosystems. They are all naturally occurring chemical elements, some of which (e.g. copper and zinc) are required by organisms in considerable quantities (Phillips, 1980). Aquatic organisms will normally accumulate essential trace metals that occur naturally in water. However, these metals can be toxic at greater concentrations (Rainbow, 1995). Anthropogenic activities and other naturally occurring geochemical processes may significantly increase the rates of mobilization of trace metals from the earth's crusts, which can lead to increases in their bioavailability in coastal waters through runoffs and wastewater discharge (Phillips, 1995).

Even though monitoring of heavy metal concentrations in sediments is more preferable when resolving analytical and temporal variability problems due to their accumulation in aquatic sediments, this method does not provide accurate information regarding their bioavailability to organisms inhabiting these environments. Measuring metal concentrations in the tissues of aquatic organisms appears to be the most suitable method for assessing eco-toxicity as the metals are frequently accumulated in high (easily measurable) concentrations and reflect a time-integrated measure of bioavailable metal levels (Rainbow, 1995).

Long-term pollution impacts on marine environments is increasingly being monitored through the assessment of contaminants that build up in marine biota. Filter feeding organisms such as mussels have been used successfully as bio-indicator organisms in environmental monitoring programs throughout the world (Kljaković-Gašpić et al., 2006, 2010). They are suitable indicators because they are abundant, widely distributed, sessile, tolerant of salinity changes, stress-resistant and can accumulate a wide range of contaminants (Phillips & Rainbow, 1993; Desideri et al., 2009; Kljaković-Gašpić et al., 2010). In addition, mussels can accumulate trace metals, hydrocarbons and pesticides in their flesh (Rainbow et al., 2006). As such, assessments of contaminant levels in mussel flesh can be used to detect pollution levels that may go unnoticed between pollution events or that may occur at chronically low levels that can be difficult to measure in the water column. Monitoring contaminant levels in mussels can therefore provide a reliable indication of water quality and spatial/temporal changes in bioavailable contaminant levels in the water column. For this purpose, the trace metal concentrations in mussels (*Perna perna*) throughout the Port of Durban are assessed.

7.1.1 Trace metal concentration guidelines for molluscs

Several guidelines are available regarding the acceptable concentrations of trace metals in animals such as molluscs (e.g. mussels) (**Table 16**). In addition, the CSMP (Clark et al. 2017) also provides local maximum thresholds specifically for *Perna perna* that should be assessed as part of this monitoring programme (**Table 17**). If levels exceed limits specified below, risks to health of people consuming shellfish and fish from the Port are likely to be elevated and negative impacts on biota such as invertebrates, fish and birds in the Port are likely.

Table 16: Established Guidelines for trace metals in molluscs in different countries including South Africa (maximum acceptable levels)

Country	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Cd (ppm)	Hg (ppm)
South Africa[1].	-	0.5	-	3.0	3.0	0.5
Canada[2]	70	2.5	150.0	1.0	2.0	-
Australia & NZ[3]	-	2.0	-	-	2.0	0.5
European Union[4]	-	1.5	-	-	1.0	0.5
Japan[5]	-	10.0	-	-	2.0	0.2
Switzerland[2]	-	1.0	-	-	0.6	0.5
Russia[6]	-	10.0	-	-	2.0	-
South Korea[2]	-	0.3	-	-	-	-
United States[7, 8]	-	1.7	-	-	4.0	-
China[9]	-	-	-	-	2.0	-
Brazil[10]	-	-	-	-	-	0-.5
Israel[10]	-	-	-	-	-	1.0

1. Regulation R.500 (2004) published under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act 54 of 1972)
2. Fish Products Standard Method Manual, Fisheries & Oceans, Canada (1995)
3. Food Standard Australia and New Zealand (website)
4. Commission Regulation (EC) No. 221/2002
5. Specifications and Standards for Foods. Food Additives, etc. Under the Food Sanitation Law JETRO (Dec 1999)
6. Food Journal of Thailand. National Food Institute (2002)
7. FDA Guidance Documents
8. Compliance Policy Guide 540.600
9. Food and Agricultural Import Regulations and Standards.
10. Fish Products Inspection Manual, Fisheries and Oceans, Canada, Chapter 10, Amend. No. 5 BR-1, 1995.

In addition to the national guidelines, local guidelines for trace metal concentrations in *P. perna* have also been established as part of the baseline study (**Table 17**).

Table 17: Threshold (warning) levels of trace metal concentrations for *Perna perna* from control and impact monitoring stations (adapted from Clark et al., 2017). Note that the concentration for mercury (Hg) is given as parts per billion and not parts per million as for other metals.

Trace metal	90^{th} Percentile
As (ppm)	3.61
Cd (ppm)	1.08
Co (ppm)	0.95
Cr (ppm)	8.44
Cu (ppm)	23.18
Fe (ppm)	800.11
Mn (ppm)	134.75
Ni (ppm)	5.60
Pb (ppm)	8.95
Zn (ppm)	223.88
Hg (ppb)	293.06

7.2 Methodology

As per the CSMP, mussels (*Perna perna*) must be collected from 16 channel buoys adjacent to the sandbanks in the Port (**Figure 12**). Sites 11, 12, 14, 16, 18 – 21 have been designated as impact sites, and sites 8 –10, 13, 15, 17, 22 and 23 are control sites. Mussels collected were placed on ice in plastic containers and transported to a SANAS accredited analytical laboratory for trace metal (Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg) analyses. Trace metal concentrations are contrasted against the 90th percentile maximum threshold levels prescribed in the CSMP (Clark et al., 2017) and against the maximum legal limits prescribed for each contaminant in shellfish for human consumption in South Africa, as stipulated by the Regulation R.500 (2004) published under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act 54 of 1972). Where threshold values have not been specified in national legislation, those adopted by other countries were employed.

Figure 12: Locations of channel buoys for brown mussel (*Perna perna*) biomonitoring in the Port of Durban. Impact sites: 11, 12, 14, 16, 18 – 21; Control sites: 8 – 10, 13, 15, 17, 22 and 23.

7.3 Results

The majority of trace metal concentrations in mussels collected from 16 channel buoys were within the established national guidelines and consumable threshold levels for South Africa and other countries of the world (**Table 18**). However, as in the previous monitoring events this year, the median concentrations of mercury at impact and control sites continued to exceed the CSMP and the national maximum threshold (**Table 19**).

Table 18: Median concentrations of trace metals in *Perna perna* collected throughout the Port of Durban in spring 2021. Medians are given for all sites, impact (site 11, 12, 14, 16, 18-21) and control (site 8, 9, 10, 15, 17, 22, 23). Values printed in red exceed the 90th percentile threshold of the CSMP. National Guideline levels are given for reference to other work. Note that the concentrations for mercury are given as part per million and not parts per billion as in guidelines

Metal (mg/kg)	90th percentile	National guideline level	Median (all sites)	Median (impact sites)	Median (control sites)
Aluminium	--	--	13.98	13.93	14.98
Arsenic	3.61	3	1.17	1.21	1.16
Cadmium	1.08	3	0.02	0.02	0.02
Chromium	8.44	--	1.00	1.15	0.94
Cobalt	0.95	--	0.16	0.17	0.16
Copper	23.18	70	2.62	2.49	2.62
Iron	800.11	--	38.64	54.41	29.28
Lead	8.95	0.5	0.52	0.51	0.53
Manganese	134.75	--	6.88	6.88	7.60
Mercury	0.293	0.5	**0.93**	**0.92**	**0.97**
Nickel	5.6	--	0.62	0.64	0.60
Zinc	223.88	150	16.63	15.82	18.96

Table 19: Raw laboratory data of trace metal concentrations in brown mussels (*Perna perna*) collected during the spring 2021 survey from 16 channel buoys (control and impact sites) adjacent to the sandbanks in the Port of Durban. Concentrations that exceed the baseline guideline values are printed in red.

Trace Metal (mg/kg)	Control Sites								Impact Sites							
	Site 8	Site 9	Site 10	Site 13	Site 15	Site 17	Site 22	Site 23	Site 11	Site 12	Site 14	Site 16	Site 18	Site 19	Site 20	Site 21
Aluminium	10.71	16.25	13.09	51.32	2.64	13.72	18.69	51.35	13.62	39.89	49.82	5.99	24.48	9.47	9.75	14.24
Arsenic	0.79	0.85	1.14	1.18	1.50	1.38	0.84	1.28	1.74	1.26	1.16	0.64	2.00	0.90	0.40	1.43
Cadmium	0.05	0.04	0.03	0.02	0.01	0.01	0.03	0.02	0.04	0.02	0.02	0.01	0.02	0.02	0.01	0.03
Copper	2.24	2.08	2.62	2.96	2.28	2.63	3.05	4.91	2.24	2.77	2.63	2.33	3.94	2.36	1.92	3.07
Cobalt	0.08	0.22	0.15	0.17	0.04	0.12	0.50	0.22	0.09	0.18	0.15	0.07	0.21	0.22	0.34	0.04
Chromium	0.93	0.88	0.95	1.21	0.75	1.18	0.88	0.99	1.30	1.34	1.20	0.55	1.35	1.10	0.95	1.01
Manganese	8.79	4.14	6.47	8.66	5.67	11.44	6.55	9.05	5.67	7.10	12.92	2.31	6.65	7.42	5.05	15.23
Nickel	0.67	0.88	0.55	0.59	0.60	0.57	0.68	0.55	0.72	0.64	0.72	0.50	0.64	0.90	0.54	0.53
Lead	<8	1.77	0.53	<8	0.23	0.53	0.66	0.52	0.79	<8	0.86	0.17	0.33	1.65	0.51	0.39
Zinc	21.25	47.95	41.34	10.55	16.67	35.47	12.32	14.29	15.04	18.62	21.98	5.87	12.30	16.59	8.11	18.15
Mercury	**0.63**	**1.25**	**0.86**	**1.16**	**1.07**	**0.80**	**0.66**	**1.21**	**1.25**	**0.62**	**1.07**	**0.84**	**1.00**	**0.84**	**0.43**	**0.99**
Iron	26.63	25.79	28.32	78.02	17.28	30.25	83.51	58.21	125.6	71.22	66.35	34.81	42.46	29.06	30.35	66.99

In summer 2021, mercury concentrations were alarmingly high (**Figure 13**) and at levels that represented serious health risks for human and marine life. In subsequent sampling events (autumn - spring 2021), these concentrations were lower but still not below allowable national or local baseline thresholds and therefore remains a matter of concern and requires increased management attention.

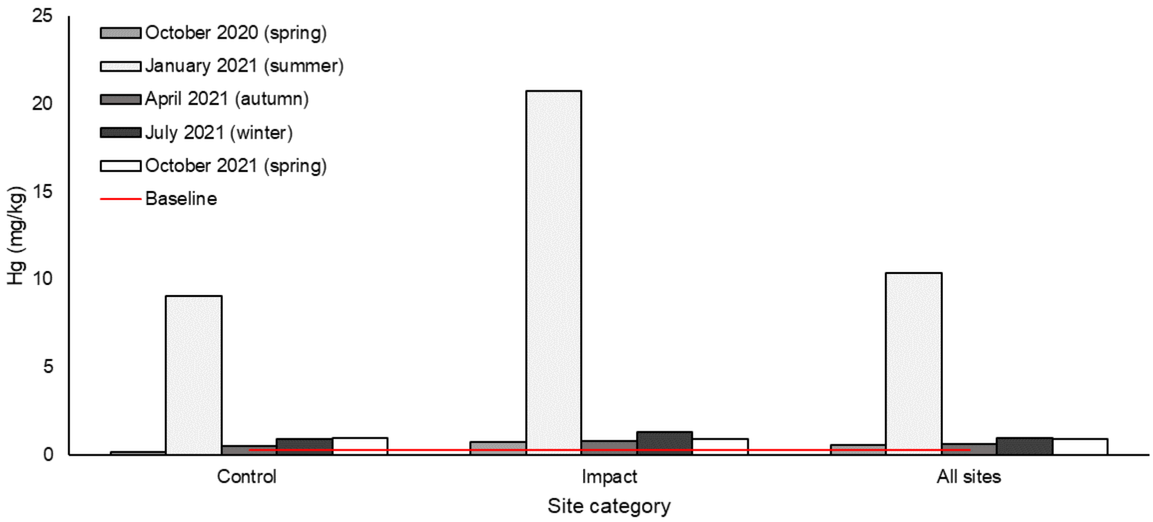

Figure 13: Median mercury concentrations (mg/kg) quantified from October 2020 (spring) to October 2021 (spring). Red line = baseline threshold value (0.29306 mg/kg).

7.4 Conclusion

Biomonitoring of mussels is an important tool for the assessment of pollution levels and indices of when action is required to maintain good water quality. All metals, apart from mercury, were below maximum baseline concentrations. These levels were similar to those recorded in winter and remain above the allowable threshold values. It therefore continues to represent a cause for concern. These concentrations remain at levels that pose health risks to animals and humans.

Bioaccumulation of trace metals in mussels take place over long periods, so the specific driver behind these elevated mercury concentrations will be difficult to pinpoint. Mercury can enter the marine environment through various sources, including agricultural run-off, waste from manufacturing electrical equipment, mine tailings and the burning of fossil fuels (DWAF 1995). The crude oil spill that occurred in the Umbilo river in October 2020 and/or the increased effluent and storm water runoff into the Port associated with the rainy season may be potential drivers. Nonetheless, this remains an important problem that needs to be urgently addressed by Port management authorities.

8 Fish

8.1 Introduction

Fish communities in the Port of Durban have been described as very diverse in past research conducted in the 1950s, where around 186 fish species were recorded (Day & Morgan, 1956). During this time, the most common species included *Terapon jarbua*, *Mugil cephalus*, *Liza dumerili*, *Ambassis dussumieri* and *Leiognathus equulus*. Many of these species are recognised as being dependent on estuaries, and the Bay was revealed as an important nursery areas for these and other economically important marine fish species. To this end, the shallow sandbanks and the little lagoon area specifically have been described as especially valuable nursery habitats (Cyrus & Forbes, 1996; Forbes & Demetriades, 2003).

More recent fish surveys in the Port by Angel and Clark (2008) and Newman et al. (2008) recorded far fewer species, at 29 and 34 species respectively. Most of the species either are listed as “Least Concern” on the IUCN Red List (2013) or have not been assessed. In these studies, the most abundant species have always been the Bald Glassy (*Ambassis dussumieri*), a small species that often dominates abundance but not biomass.

8.1.1 Threshold limits set in the Central Sand Bank Mitigation Plan, 2017

The CSMP study stipulated various thresholds applicable to fish monitoring. According to this study, the median values of fish abundance, biomass and species richness are not to drop below the 80th percentile of the season-specific baseline median value (**Table 20**). If levels drop below limits specified, recovery of these faunal components in the Port may be delayed.

Table 20: Threshold (warning) levels to be adopted for fish abundance (no. ind./haul), biomass (g/haul) and species richness (no. species/haul) for the impact monitoring stations (adapted from Clark et al., 2017).

	Spring	Summer	Autumn	Winter
Abundance				
Median	15.2	31.6	408.7	255.3
80%	19.0	39.5	510.9	319.2
Biomass				
Median	175.2	252	711.15	2126.1
80%	219	315	888.9	2657.6
Species richness				
Median	4	4.4	5.2	4.8
80%	5.0	5.5	6.5	6.0

8.2 Methodology

8.2.1 Sampling protocol

The nearshore fish community in the Port of Durban was sampled using a beach seine net of 30 m length, 2 m depth and a stretched mesh size of 12 mm. Seine netting was conducted at 14 stations along the margins of the main sandbank areas in the Port (**Figure 14**). These sites are characterised as either impact or control sites in relation to the planned developments (**Table 21**).The net was deployed from a small fishing boat 30 – 50 m from the shore during daylight hours. All fish caught in the net at each station were identified, counted, weighed, measured and, where possible, returned to the estuary alive. All species caught were classified using an adaption of Whitfield's (1994) estuarine fish classification system. Four broad categories were used: marine, estuarine dependent, estuarine resident and freshwater species.

Table 21: Classification of impact and control sites for fish surveys in the Port of Durban.

Habitat	Site	Treatment
Central bank	6	Impact
Central bank	7	Impact
Central bank	8	Impact
Central bank	9	Impact
Central bank	10	Impact
Little lagoon	11	Impact
Little lagoon	12	Impact
Little lagoon	13	Control
Little lagoon	14	Control
Northern bank	19	Control
Northern bank	20	Control
Northern bank	21	Control
Northern bank	22	Control
Northern bank	23	Control

Figure 14: Location of fish sampling stations in the Port of Durban. Yellow pins = control sites, green pins = impact sites, black pins = additional sampling sites that will be included after the construction of the berths to monitor sandbank recovery.

8.2.2 Statistical Analyses

Multivariate analyses were conducted using PRIMER (v.6) where fish abundance data were subjected to a fourth root transformation to reduce the weight of abundant species and to achieve a balance of contribution between the rare and most common species. All analyses were performed using Bray-Curtis similarities of the fourth root abundance data. A PERMANOVA (Permutational Analysis of Variance) was used to determine if there are significant differences in the composition of fish communities found around impact and control sites. This test produces a p-value which, when smaller than 0.05 indicates a significant difference between the fish communities that inhabit the different sandbanks.Thereafter a SIMPER (Similarity Percentage) test was used to elucidate which species contributed the most to overall community similarity at impact and control sites.

8.3 Results

8.3.1 Key results

As in the previous season, few fish were caught in spring and the baseline thresholds of most parameters (abundance, biomass and species richness) were violated when considering all sites. (**Table 22**).

Table 22: Median values of fish community dynamics at impact and control sites identified during the spring 2021 survey. Values given alongside 80th percentile thresholds stipulated in CSMP baseline study. Values printed in red violate CSMP threshold guidelines.

Parameter	80% limit (CSMP)	Median Overall	Median Impact	Median Control
Abundance	19	**11**	**3**	57
Biomass	175.2	**43.5**	342	417
Species richness	4	**1.5**	**1**	**1.5**

8.3.2 Catch Composition

The catch composition comprised of 933 fish (~ 714 g), representing 10 species. Abundance was, as in previous seasons, dominated by Bald Glassy (*Ambassis dussumieri*) that contributed 94.5 % to the overall abundance but only 21.5 % to overall biomass. Surprisingly, no Bald Glassy individuals were caught at any of the impact sites. Small Scale Pursemouth (*Gerres longirostis*) was the second most dominant species in terms of abundance and biomass (**Table 23, Table 24, Figure 15, Figure 16**).

Table 23: Abundance of fish species caught overall (all sites) and at control and impact sites in spring 2021.

Common name	Species	All sites	Control	Impact
Bald Glassy	*Ambassis dussumieri*	882	882	0
Cuttlefish spp.	*Cuttlefish spp.*	3	0	3
Small Scale Pursemouth	*Gerres longirostris*	24	5	19
Groovy Mullet	*Liza dumerili*	9	9	0
Bartailed Flathead	*Platycephalus indicus*	6	3	3
Spotted Grunter	*Pomadasys commersonnii*	2	0	2
Piggy Grunter	*Pomadasys olivaceum*	2	0	2
Large Tooth Flounder	*Pseudorhombus arsius*	1	0	1
Natal Stumpnose	*Rhadbosargus sarba*	2	2	0
Shadow Goby	*Yongeichthys nebulosus*	2	1	1

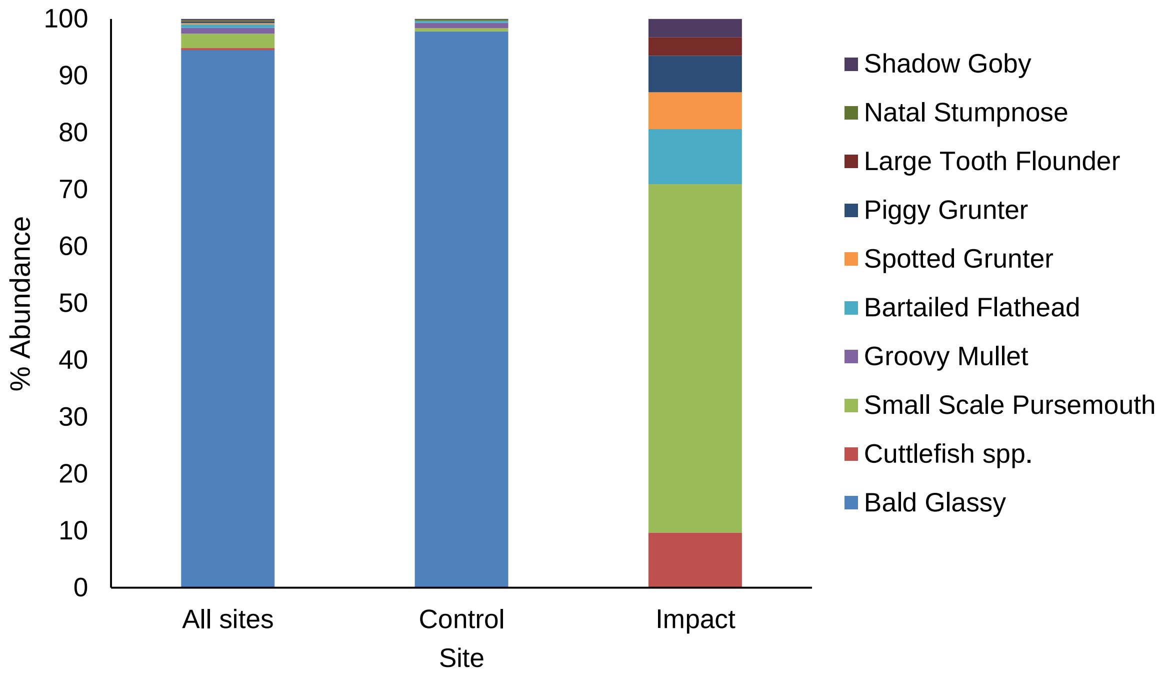

Figure 15: Relative abundance (%) of fish species caught overall (all sites) and at impact and control sites.

Species that dominated by mass include Bald Glassy and Small Scale Pursemouth (**Table 24, Figure 16**).

Table 24: Mass (g) of fish species caught overall (all sites) and at control and impact sites in spring 2021.

Common name	Species	All sites	Control	Impact
Bald Glassy	*Ambassis dussumieri*	154	154	0
Cuttlefish spp.	*Cuttlefish spp.*	50	0	50
Small Scale Pursemouth	*Gerres longirostris*	235	85	150
Groovy Mullet	*Liza dumerili*	95	95	0
Bartailed Flathead	*Platycephalus indicus*	46	27	19
Spotted Grunter	*Pomadasys commersonnii*	31	0	31
Piggy Grunter	*Pomadasys olivaceum*	35	0	35
Large Tooth Flounder	*Pseudorhombus arsius*	8	0	8
Natal Stumpnose	*Rhadbosargus sarba*	50	50	0
Shadow Goby	*Yongeichthys nebulosus*	10	6	4

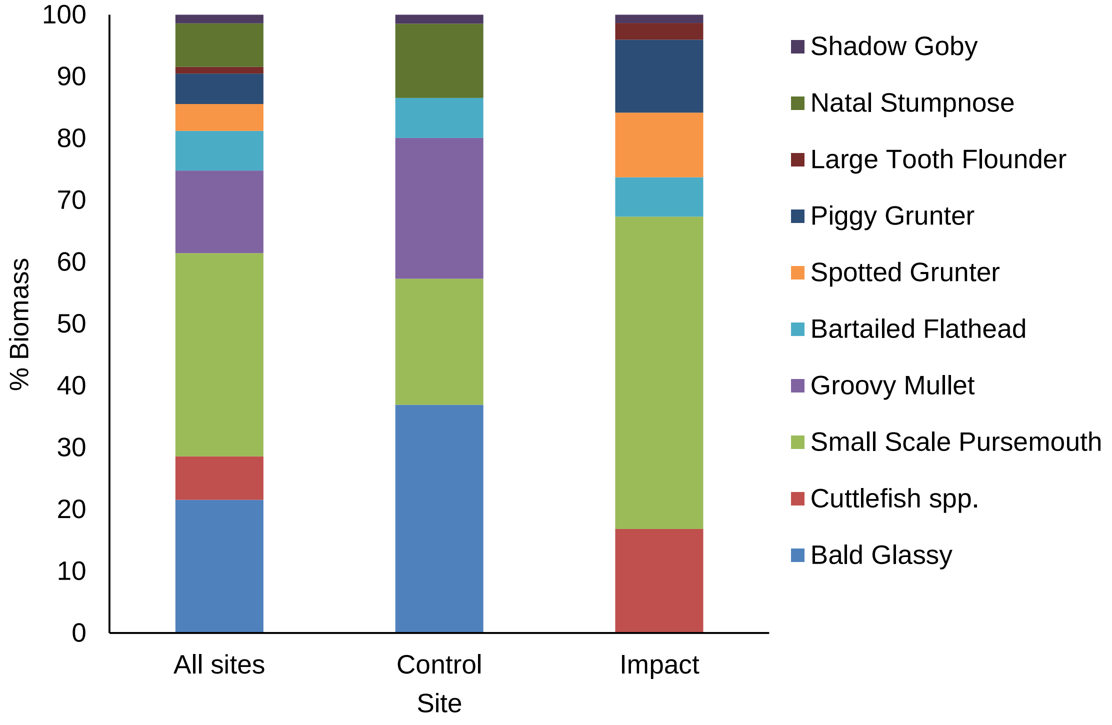

Figure 16: Relative mass (%) of fish species caught overall (all sites) and at impact and control sites.

8.3.3 Multivariate analyses and spatial patterns of diversity

Fish community composition differed significantly between impact and control sites (Pseudo-F = 7.69, df = 1, $p < 0.05$) and a subsequent SIMPER test revealed that the communities at impact sites were characterised by cuttlefish species and Bartailed Flathead while those at control sites were characterised by Bald Glassy. Species richness and Shannon-Weiner H' indices for all sites surveyed are summarised below (**Table 25**).

Table 25: Species richness and Shannon-Weiner H' indices of fish communities surveyed at 14 monitoring stations within the Port of Durban in spring 2021. No fish were caught at sites 8 and 20.

Site number	Habitat	Richness	Diversity (H')
Impact Sites			
6	Central Bank	2	0.21
7	Central Bank	3	1.1
8	Central Bank	0	0
9	Central Bank	3	1.04
10	Central Bank	2	0.56
11	Little Lagoon	1	0
12	Little Lagoon	1	0
Control Sites			
13	Little Lagoon	1	0
14	Little Lagoon	1	0
19	Northern Bank	1	0
20	Northern Bank	0	0
21	Northern Bank	2	0.23
22	Northern Bank	4	0.93
23	Northern Bank	4	0.07

8.3.4 Estuarine Association in Fish Communities

Estuarine associations of marine and estuarine fish species have been well described by Whitfield (1994), especially species that live and breed in estuaries (referred to as estuarine resident species). Estuarine dependent species, on the other hand, are marine fishes that breed at sea but whose juveniles show varying degrees of dependency of estuaries. In spring 2021, catches were dominated by the estuarine resident species (mainly Bald Glassy).

8.4 Conclusion

As in previous seasons, Bald Glassy dominated catches overall, although no individuals of this species were caught at impact sites. Median fish abundance, biomass and species richness across all sites violated the CSMP guideline values. This follows from the similarly low levels recorded in the previous season. While in winter cooler temperatures were thought to have influenced the poor performance of these parameters, it was not the case in spring when temperatures were characteristic of this season. These persistent violations of baseline thresholds indicates that the observed results are not sporadic but that the abundance, biomass and species richness of the fish communities in the Port of Durban have indeed been reduced.

9 Birds

9.1 Introduction

The natural habitats within Durban Bay have long been transformed and replaced by infrastructure associated with harbour developments. The original tidal flats, mangrove forests, and other littoral vegetation have vastly been reduced and replaced by open water areas and concrete berths. According to Allan et al. (1999), bird abundance and diversity dropped to 30% of that recorded in 1965 and avifaunal health of the Port was rated as poor in the 2011 National Biodiversity Assessment, due to substantial habitat loss and poor prey abundance and diversity (Driver et al., 2012).

Prior to construction, the aim of the avifaunal monitoring programme was to assess spatial and seasonal variability in avifaunal community structure. The monitoring must be continued during the construction phases to assess the impacts and effectiveness of the mitigation measures implemented during construction. This also forms part of the avifaunal monitoring programme recommended in the Bay of Natal Estuarine Management Plan (ERM/MER, 2012 and 2015), which proposes monthly surveys of birds on the intertidal, shallow subtidal, and mangrove habitats of the Bay.

9.2 Methodology

9.2.1 Sampling protocol

The monitoring programme has been designed to align with the long-term monitoring already being conducted by the Durban Natural Science Museum (Allan et al., 1999; McInnes et al., 2005; Allan, 2012). The methodology followed that defined in the CSMP (Clark et al., 2017).

Five natural and semi-natural habitats have been identified in 20 sampling areas in Durban Bay (**Figure 17**), which will be monitored during the construction phase:

- Centre Bank and Little Lagoon (Bayhead North, MW West, MW East, CT West, CT East, FW North, FW South and Centre Bank Roost)
- Northern Sand Banks (Yacht Basin, Fish Wharf East and Fish Wharf West)
- Muddy/mangrove habitat (Sporting Bodies, Pelican Island, Bayhead West, Bayhead Central)
- Island View Sandbank
- Open Water (Harbour East, West, North and Harbour Mouth)

Figure 17: Aerial view of Durban Bay (Port of Durban) with 20 bird survey areas.

In the series of monitoring sections, individual birds of each species are counted and recorded by circumnavigating the inner periphery of the Port on a motorised vessel once per month at spring-low tide between 08h30 and 12h30. Bird counts are conducted by at least two observers with the aid of binoculars. To avoid double counting, observers count birds to the right of the vessel and flying overhead from the front only.

9.2.2 Statistical analyses

Data collected during September, October and November 2021 (spring) are included in this report. Data have been collated and used to characterise overall taxonomic composition, community structure, abundance, species richness and diversity, and compared to the baseline / preconstruction situation. Diversity indices were used as a measure of species richness and evenness to define community structure and diversity. The Shannon-Wiener diversity index (H') and the Pielou's evenness index (J') were calculated for each habitat type.

9.3 Results

9.3.1 Key results

Bird abundance, but not species richness, was above the minimum thresholds set for this period (**Table 26**). Abundance figures were dominated by Swift Tern (*Thalasseus bergii*) roosting on exposed sand bank during low tide.

As stated in previous reports, the fact that species richness continues to be lower than the minimum thresholds set in the CSMP remains a matter of concern. As the construction phase of this project has not yet commenced these declines are not related to project-specific impacts but rather most likely due to other anthropogenic drivers or natural fluctuations. The degree of plastic pollution in the Port remains a persistent threat to the health of bird communities as much of this litter accumulates on the sand banks that birds depend on. It affects feeding opportunities for birds both in the water (for piscivorous species) and on the sandbanks (for invertebrate feeders). As in previous monitoring events, field workers had difficulty with bird counts and identification as they are primarily located on the sand banks that are consistently inundated with litter (**Figure 18**).

Table 26: Comparison with threshold levels of bird numbers and species richness recorded for Central Bank and Little Lagoon in the Durban harbour over the sampling period for all bird species. Values in red violate threshold limits.

	June	July	August
CSMP threshold			
Total # species	23	23	24
Total # individuals	386	591	808
Jun '21 – Aug '21			
Total # species	**16**	**19**	**17**
Total # individuals	1171	1394	1240

Figure 18: Accumulating plastic pollution on the Central Bank where monthly bird counts are conducted (January 2021).

9.3.2 Avian community composition

A total of 4 771 individual birds, representing 38 species were recorded during the three-month spring sampling period (September - November 2021). The largest proportion was counted at the Centre Bank and Little Lagoon (3 805 birds), which is in line with the overall findings of the baseline study. As in the baseline surveys, waders and wading birds comprised the largest proportion, consisting of 12 (32%) and six species (16%), respectively (**Figure 19**). This was followed by cormorants, darters, pelicans and terns, comprising four species (10%) each.

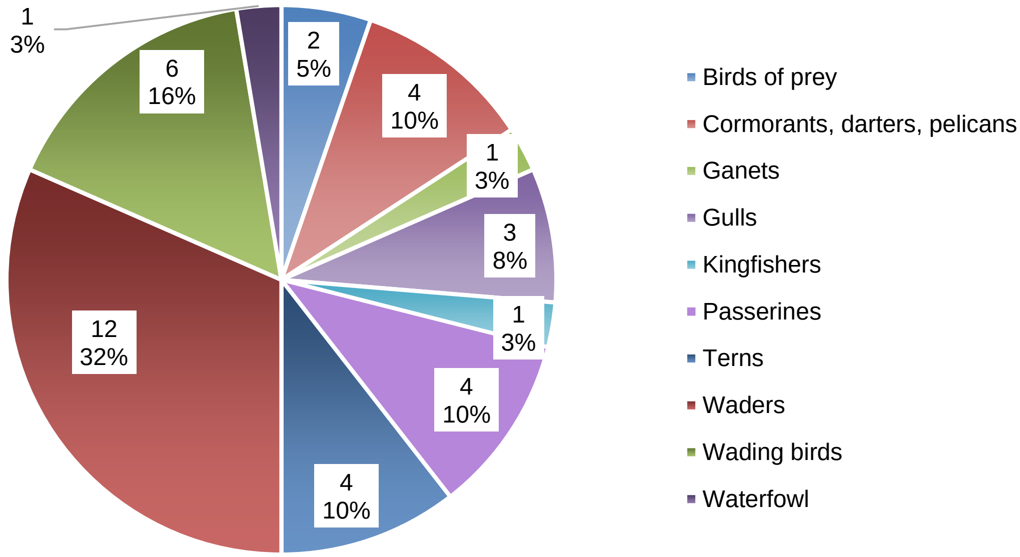

Figure 19: Taxonomic composition (number and percentage of species) of bird communities recorded during monthly counts from September - October 2021.

In terms of feeding guilds, piscivores (fish eaters) and invertebrate feeders made up the largest proportion of bird species recorded over the three-month sampling period, each contributing 17 (45%) and 15 (39%) species, respectively (**Figure 20**). This is also comparable to the baseline scenario where piscivores and invertebrate feeders comprised the largest proportion of birds observed over the sampling period.

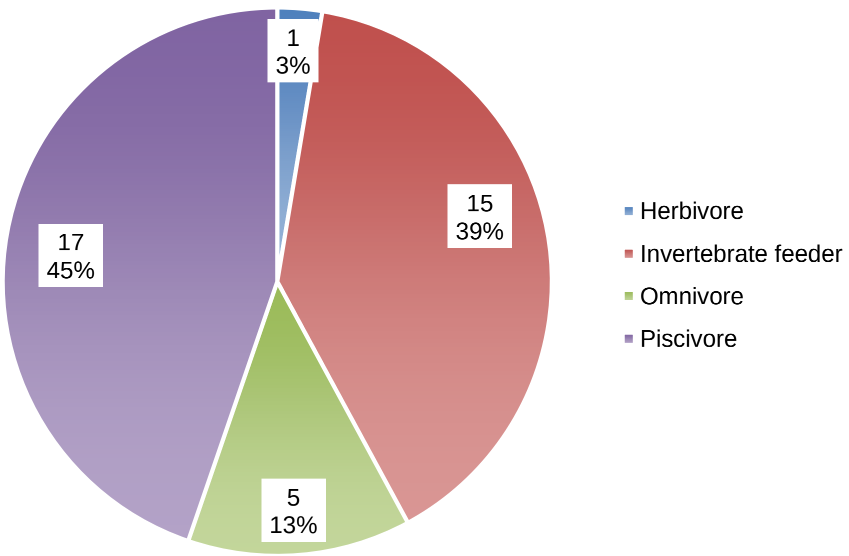

Figure 20: Composition of feeding guilds (number and percentage of species) recorded during monthly counts from September - November 2021.

The avifauna typically found in Durban harbour can be divided into eight different taxonomic orders (**Table 27**). The group with the greatest species richness in this three-month period were the Charadriiformes (waders, gulls and terns) comprising 19 of the 38 species recorded (50%). Within this group are the migratory waders and terns, which make up the highest number of migratory species (11 and two species respectively) recorded in this sampling period. Migratory species made up 39.5% of the total species recorded, which is typical during a spring period when some migratory species are returning.

Table 27: Taxonomic composition of common water-associated birds in the Port of Durban over the three-month sampling period (September - November 2021)

Bird Group	Order	No. of SA Resident Species	No. of Migrant Species
Birds of prey	Falconiformes	1	1
Cormorants, darters, pelicans	Pelecaniformes	4	
Gannets	Suliformes	1	
Gulls	Charadriiformes	3	
Kingfishers	Coraciiformes	2	
Passerines (swallows, martins, wagtails)	Passeriformes	3	1
Terns	Charadriiformes	2	2
Waders	Charadriiformes	1	11
Wading birds (herons, egrets, ibises)	Ciconiiformes	5	
Waterfowl (ducks, geese)	Anseriformes	1	
	Total	**23**	**15**

9.3.3 Avian abundance, species richness and diversity

Of the five habitats identified within the Durban harbour, the Central Bank and Little Lagoon had the greatest number of birds (3 805) compared to Open Water (489), the Northern Bank (165), and Mangroves (312) in this three-month sampling period (**Figure 21**). The Central Bank and Little Lagoon had the greatest number of birds on a monthly basis, followed by the Mangroves then Open Water (**Figure 22**). As in the previous season, no birds were recorded at Island View in the three-month period. Similar spatial patterns were observed during previous seasons and the baseline study, where the greatest numbers of birds were recorded from the Central Bank intertidal flats, and Island view had significantly lower bird abundance than all other sites. This is not surprising given that the Central Bank provides important feeding and roosting habitat for seabirds when exposed. It is also relatively isolated from harbour activities in comparison to other intertidal flats in the Port, so it may present the most undisturbed and attractive site for feeding and roosting birds. However, as emphasized in previous report, there is a continued concern that the degree of plastic pollution accumulating in this habitat may negatively affect avian communities.

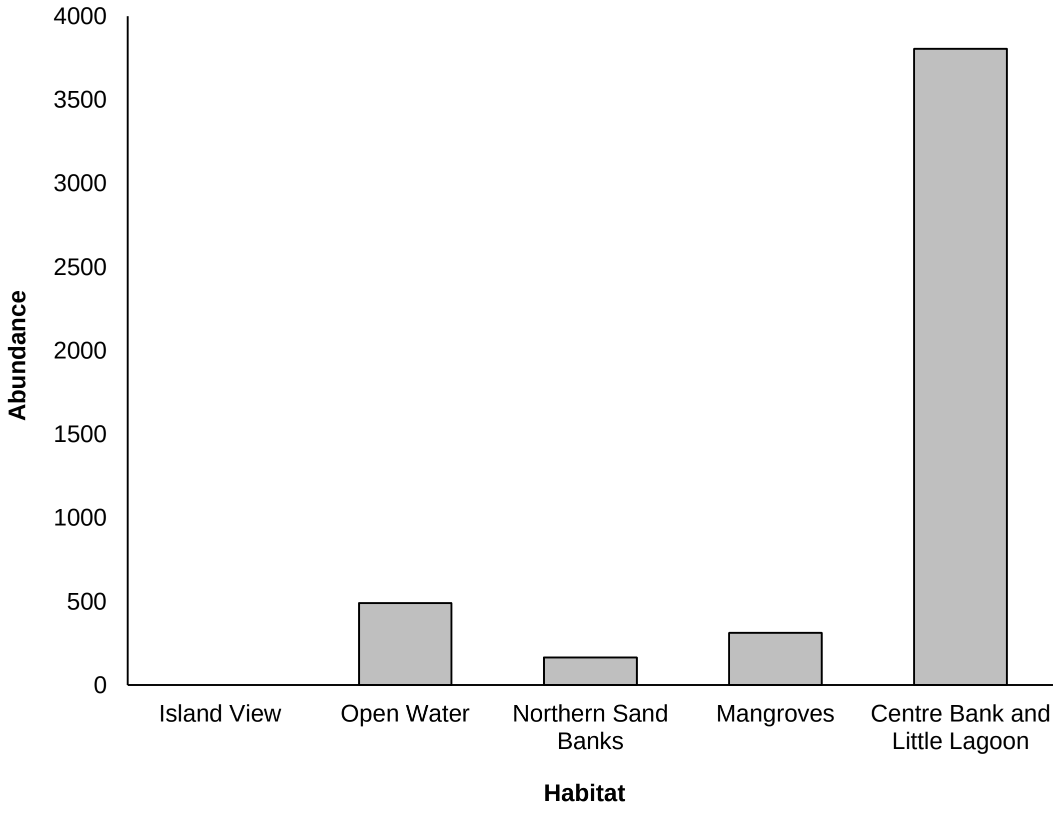

Figure 21: Total bird abundance per habitat recorded during monthly counts from September – November 2021.

The increase in number of birds recorded on the centre bank from winter 2021 (1 727 birds) to spring (3 805 birds) signifies the arrival of migrant waders to the area. This also accounts for the overall increase in bird numbers from winter (2 502 birds) to spring (4 771 birds). (**Figure 22**).

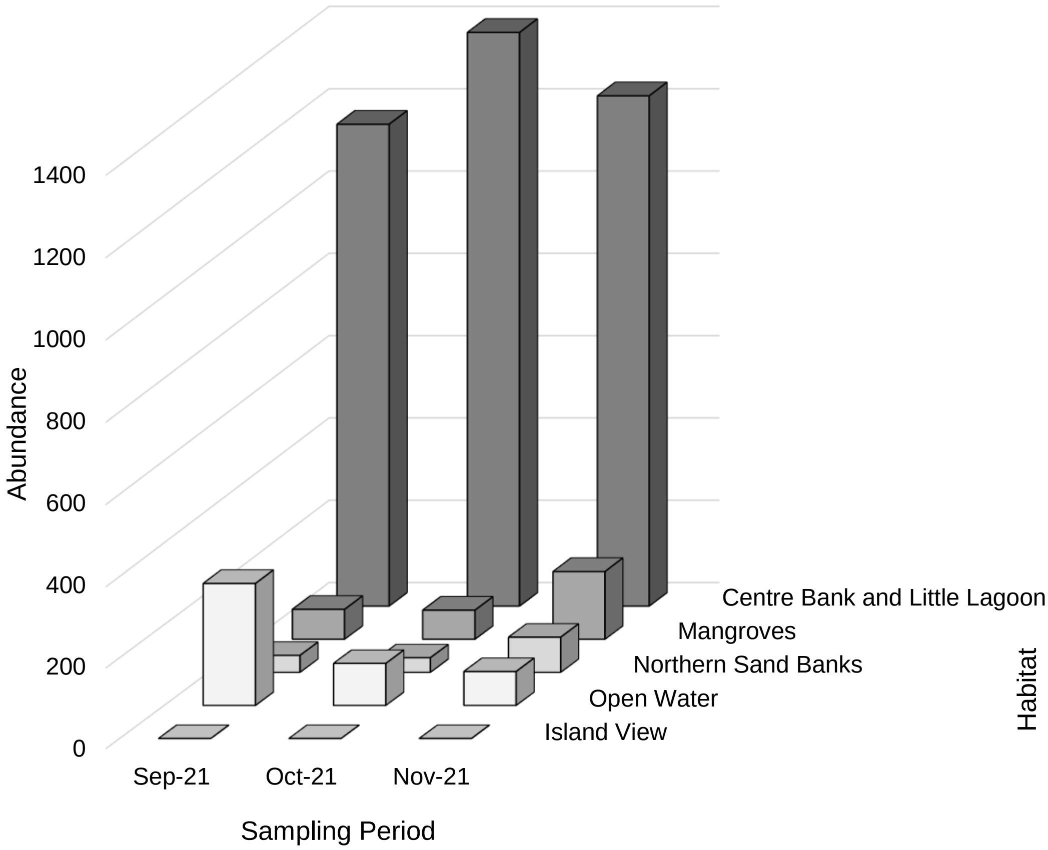

Figure 22: Monthly bird abundance per habitat recorded from September – November 2021.

While species richness (S) is purely a count of the number species present, diversity provides more information about the overall community composition. Species diversity incorporates relative species abundance and therefore provides information about rarity and commonness of species in a community (Stirling and Wilsey, 2001). Species diversity for bird communities in the Port of Durban is represented here by the Shannon Wiener Index (H'), which calculates diversity based on both abundance and evenness of the species present. Evenness in this case is represented by Pielou's evenness index (J') and is constrained between zero and one. A higher number (i.e. closer to one) signifies a more even community, while a smaller number (i.e. closer to zero) suggests that the community is dominated by a few species (Stirling and Wilsey, 2001).

The greatest species richness was found at the Mangroves and Centre Bank (S = 23 each), followed by Open Water habitat (S = 22). Diversity was greatest at the Mangroves (H' = 2.52=41), followed by Open Water (H' = 1.695) and Centre Bank and Little Lagoon (H' = 0.97)

(**Table 28**). The comparatively high diversity at the Mangroves may be explained by the fact that this is a protected area that offers a wide variety of habitats. In addition, the high diversity observed in the Open Water was likely driven by the fact that this habitat is used by piscivorous species for feeding and is a transition zone for birds moving between the other habitats. Certain species such as Egyptian Goose, Grey Heron, Little Egret and Blacksmith Lapwing also use the docks for resting, while White-breasted Cormorant are often found resting on the buoys in the harbour channels.

As recorded during baseline surveys, Island View and the Northern Bank had considerably lower species richness in comparison to other habitats, most likely due to the elevated levels of human activity in these areas (**Table 28**). The Mangroves displayed high evenness of species (J' = 0.81), which highlights the importance if the mangrove habitat in the harbour for supporting a diversity of birds. The Centre Bank had relatively low evenness in comparison (J' = 0.31) (**Table 28**). The intertidal flats of this habitat is visited by relatively few flocking species that have high numbers of individuals, using the area for roosting and feeding when the sand bank is exposed.

Table 28: Avifaunal species richness, diversity and evenness per habitat in the Durban harbour over the spring sampling period. No birds were recorded at Island View.

Habitat	**Species richness (S)**	**Diversity (H')**	**Evenness (J')**
Centre Bank and Little Lagoon	23	0.970	0.31
Mangroves	23	2.541	0.81
Open Water	22	1.695	0.55
Northern Sand Banks	16	1.493	0.54
Island View	0	0	0

9.4 Conclusion

The number of birds recorded during the 2021 spring sampling period was substantially higher than the number recorded during the winter and autumn 2021 sampling periods. This is expected and can be attributed to the arrival of migrants to the region. The largest proportion of birds was counted at the Centre Bank and Little Lagoon, while the Mangroves had the greatest diversity. Similar trends were observed during the baseline surveys. The high abundance at the Centre Bank is likely driven by the fact that this area represents important feeding and roosting (including shelter from the wind) habitat for seabirds when exposed.

Possibilities for potential refuge sites during the construction phase include the sandbanks at the Bayhead 'Natural Heritage' site, Fish Wharf opposite the Central Sandbank, and the smaller Yacht Basin, however to get full protection of these areas and to limit human disturbance will be difficult.

The sandbanks are not used for breeding by birds due to the transient nature of the intertidal flats (i.e. they become submerged at high tide every day), and many of the species utilising the sandbanks are non-breeding migrants. No nests or breeding birds are therefore at risk by the development at this time.

As found during the baseline surveys, waders, and wading birds (mostly utilising the centre bank intertidal flats) were the most abundant species recorded during the three-month period. Within this group are the migratory waders and terns, which make up the highest number of migratory species recorded in the sampling period. The Swift Tern (*Thalasseus bergii*) made up 68.9% (3 288 birds) of the total individuals recorded (4 771 birds). Migratory species made up 39.5% of the total species recorded highlighting the importance of managing the timing of disturbance to the centre bank during construction, with migratory season beginning in October and ending (based on previous studies) in April.

Piscivorous species (fish eaters) and invertebrate feeders made up the largest proportion of birds recorded in the three-month sampling period. The vast amount of litter in the harbour can impact on feeding opportunities for birds both in the water (for piscivorous species) and on the sandbanks (for invertebrate feeders). It is recommended that as an additional mitigation strategy for the approaching construction phase, the harbour is cleaned of litter on a regular basis, especially after heavy rainfall.

The species counts for Centre Bank and Little Lagoon over the sampling period, September to November 2021, were lower than the threshold values stipulated in the in the Central Sandbank Mitigation Plan, however the number of individuals recorded in each month were higher. This was driven by large numbers of Swift Tern (*Thalasseus bergii*) roosting on the exposed sand bank at low tide. As the construction phase for this project has not continued over the period November 2018 to November 2021, the difference in values observed is attributable to natural fluctuations or for other anthropogenically-driven reasons.

10 General Conclusion

Environmental aspects of this monitoring programme that failed to comply with limits set in the CSMP baseline study included the following:

- Total Organic Carbon (below minimum threshold) and subtidal iron concentrations (above maximum thresholds) iron concentration,
- mercury concentrations in *Perna perna* mussels (above maximum threshold)
- macrofaunal abundance and species richness (below minimum thresholds),
- abundance, biomass and species richness of fish communities (below minimum thresholds),
- bird species richness (below minimum thresholds).

The majority of these violations have persisted over several consecutive monitoring seasons and suggest that the overall ecological health of this system is poor. Ongoing chemical and plastic pollution are likely drivers of these observations and are concerning not only in terms of Port biodiversity but also for human health.

10.1 Water quality

Physico-chemical water quality parameters have been within ranges typical for marine environments. Typical seasonal increases in water temperatures were observed. Salinity levels of surface waters were lower than expected for marine environments but were likely influenced by seasonal rains. Turbidity, dissolved oxygen and pH levels were largely similar than those recorded during the previous survey.

10.2 Sediment characteristics

Medium to fine sand dominated intertidal and subtidal sediments and the total proportions of sand in the intertidal zone were within allowable baseline levels. Intertidal and subtidal TOC content were, as in previous seasons, below minimum allowable levels and is indicative of a nutrient-deficient system. The concentrations of all trace metals apart from iron in subtidal sediments were within acceptable levels.

10.3 Benthic macrofauna

A total of 38 intertidal and 30 subtidal macrofaunal species were identified in spring 2021. Intertidal species richness was the only measure that did not violate the minimum baseline threshold. Intertidal and subtidal abundance, and subtidal species richness were once again lower than the minimum limits specified for this season in the baseline study. The most likely drivers of these negative patterns include oil/other contaminants and plastic debris that have well-accepted negative effects on biodiversity.

10.4 Benthic microalgae

Microalgae, measured in this case as the concentration of chlorophyll-a, is important in its role as primary producers and the concentration thereof play crucial roles in the flow of energy throughout the aquatic food web. As in previous seasons, intertidal habitats had greater concentrations of chl-a than subtidal habitats. The overall concentrations of chl-a concentrations decreased from winter and were within allowable ranges specified for spring.

10.5 Biomonitoring using mussels (*Perna perna*)

Assessment of trace metal concentrations in aquatic animals such as mussels are often used as an indication of the trace metal bioavailability in a habitat. In this regard, brown mussels (*Perna perna*) that grow on channel buoys across the Port of Durban are sampled. Mussels collected from 16 channel buoys had trace metal concentrations below the baseline thresholds for all metals apart from mercury. While mercury concentrations decreased from the exceptionally high levels recorded in summer, these concentrations remain above the allowable thresholds and can therefore continue to cause health problems for marine life and humans.

10.6 Fish

The abundance, biomass and species richness were below baseline thresholds set for spring, and no fish were caught at two sites. Bald Glassy dominated catches, as in previous seasons. The consistently low abundance, species richness and biomass of fish communities in the Port indicates that they have become smaller and less diverse than was recorded at the time of the baseline study.

10.7 Birds

Spring bird monitoring took place from September to November 2021. Avian species richness was below the threshold minimum values in all three months, but abundance was above this threshold. Abundance was dominated by large numbers of Swift Tern recorded foraging during low tide. The fact that species richness continues to be low remains concerning and suggests that there has been a persistent decline in the overall diversity of avian communities across this area. There are various potential factors that may explain these declines, including the severe degree of plastic pollution and contaminants in the Port of Durban. For example, marine birds often mistake plastic for food and feed it to their chicks that cannot digest plastic. The Central Bank, a key roosting habitat for birds, has progressively become covered in plastic debris and this becomes more pronounced during spring rainfall season, coinciding with the arrival of migrant species. As stated before, this problem needs to be urgently addressed by Port management authorities.

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ORIGINAL	NAME W. Fyvie	NAME W. Fyvie, M. Muir, Dr L. Skein	NAME Dr Lisa Skein, Charl Kruger, Kolawole Akinoshun, Robyn Phillips
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