Marsden Point Refinery: A Resource Consent Application to Renew 20 Resource Consents from the Northland Regional Council

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Prepared for: ChanceryGreen on behalf of The New Zealand Refining Company Limited, trading as 'Refining NZ'

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Assessment of Effects on Marine Ecological Values

Reconsenting of discharges and structures in the CMA
Prepared for Refining New Zealand

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Executive Summary

Refining NZ is New Zealand's only oil refinery and is the leading supplier of refined petroleum products to the New Zealand market. The refinery is located at Marsden Point, Whangarei, Northland, and is operated by Refining NZ (RNZ). RNZ has resource consent for the discharge of stormwater, wastewater and uncontaminated seawater into the coastal marine area (CMA), and resource consent for situating a number of structures (jetties and dolphins) in the CMA. These consents are due to expire in 2022. Consequently, RNZ is seeking new resource consents that are necessary for the Refinery to continue operating beyond 2022.

To support their resource consent application, RNZ has engaged Drs Sharon De Luca and Phillip Ross to undertake an assessment of the effects their operations on marine ecological values of the CMA in the vicinity of the Refinery (Whangarei Harbour and Bream Bay). This assessment includes:

1. A review and assessment of the marine ecological values of the CMA in the vicinity of the refinery;
2. An assessment of the effects of the discharge of treated stormwater and wastewater into Whangarei Harbour;
3. An assessment of the effects of the discharge of uncontaminated seawater into Whangarei Harbour;
4. An assessment of the effects of the occupation of seafloor by jetty structures associated with the refinery.

The marine ecological values[1] at, and adjacent to, the RNZ Jetty (where discharges occur) were found to be high. Low concentrations of contaminants were recorded in harbour sediments and water quality was high in the receiving environment. Invertebrate species diversity was high in both soft sediment and hard shore substrates and included species known to be sensitive to environmental stressors such as contaminants, sediment and organic enrichment.

The concentration of contaminants in seawater within the proposed reasonable mixing zone, at various adjacent sites and at significant sites within the harbour were significantly lower than water quality guideline values (a) under past rainfall events, (b) 100-year average recurrence interval (ARI) events, and (c) diffuser only discharges during both La Niña and El Niño conditions.

Process chemicals in discharges from the stormwater basin (SWB) have been assessed by Stewart (2020). Chemicals that are used as part of daily processes, during plant shutdowns and those that have previously been accidentally discharged were assessed by Stewart (2020) with respect to existing ecotoxicology data, their persistence in the receiving environment, bioaccumulation properties, and predicted no-effect concentration. Overall, the magnitude of effect of the routine or accidental discharge of process

[1] Seabirds and marine mammals do not form part of this assessment.

chemicals on marine ecological values is assessed as negligible to low due to the rapid and high dilution afforded by the exchange of water beneath the RNZ jetty and low duration of exposure (Stewart, 2020).

A summary of groundwater quality on the RNZ site is contained in the Groundwater Quality Assessment Report (Tonkin & Taylor, 2020). Contaminants in groundwater in wells on the perimeter of the RNZ site that could migrate to the CMA include copper, iron, manganese, zinc, nitrate, and arsenic. However, a survey of dissolved metals and nitrate in groundwater within temporary wells on the foreshore adjacent to Mair Bank revealed contaminants were almost all below ANZECC 80%[2] protection level, with lead and nickel below laboratory detection limits. Arsenic and zinc were detected above the 80% guideline concentration. However, Tonkin & Taylor Ltd (2020) concluded that those two metals are naturally occurring and not related to the RNZ site[3].

Shellfish were collected from beneath the RNZ jetty and reference sites[4], and contaminant body burden assessments were performed. Testing revealed:

- Metal concentrations in oysters living beneath the RNZ jetty were low compared to reference sites adjacent to Northport and were lower than body burdens recorded in pipi and mussel from Mair Bank.
- Chromium and nickel were elevated in mussels and pipi collected from Mair Bank, but not in oysters living beneath the RNZ jetty. Chromium and nickel are not elevated in RNZ discharges nor in groundwater but are present in sediments throughout Whangarei Harbour and Bream Bay. Therefore, it is unlikely that the source of chromium and nickel is RNZ.
- Total phenol concentrations recorded in oysters from the RNZ jetty were lower than in oysters living adjacent to Northport, but higher than in oysters from Little Munroe Bay (reference site). Phenols are ubiquitous in the environment, potentially derived from a range of sources, including RNZ. However, regular monitoring of groundwater and the quality of discharged water suggests RNZ is not a significant source.
- Total polycyclic aromatic hydrocarbons (tPAHs) body burdens were comparable across much of the lower harbour (Northport Rocks, Little Munroe Bay, Urquharts Bay and Manganese Point) and were not elevated at RNZ. Similar to phenols, PAHs are ubiquitous in the environment, potentially coming from a range of sources, including RNZ. As with phenols, regular monitoring of groundwater and the quality of discharged water suggests RNZ is not a significant source.

Laboratory ecotoxicology tests were conducted to determine how much dilution was required for SWB discharges to become non-toxic. No adverse effects were recorded on microalgae growth or bivalve survival and reburial at low levels of dilution (2-9 times dilution). However, in one of four tests

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[2] The pNRP states at C.6.8.2(3) that 80% ANZECC (2000) water quality guidelines are appropriate for assessment of contaminants in groundwater.

[3] Table 5.3 and following paragraphs (Tonkin & Taylor Ltd, 2020).

[4] NRC staff assisted with determining the most suitable reference sites.

carried out in August 2019, on blue mussel larvae, a dilution of 256 times was required for there to be no adverse effect. Modelling indicates that 256 times, or greater, levels of dilution are the norm (based on actual La Niña and El Niño data from 2010-2011 and 2015-2016 respectively), except on rare occasions (less than 1% of the time, and predominately for 1-3 hours duration), at C3 (south eastern corner of mixing zone), P6 to the west of Marsden Bank, and on Mair Bank. Given the low duration of exposure (1-3 hours) and the very low proportion of time that less than 256 times dilution occurs, we consider that it is highly unlikely that discharges from the diffuser would have a more than negligible effect on marine organisms.

Given the rarity of these low dilution events, the very short duration of exposure and the small area of harbour over which they occur, it is unlikely that such events signify an ecologically significant threat to larval shellfish at the population level nor will adversely impact the marine ecological values of the lower harbour. This view is supported by the fact that there was no indication of reduced ecological values C3 nor at Marsden and Mair Banks.

Based on this suite of analyses it is concluded that impact of the discharge of treated stormwater and wastewater, process chemicals and groundwater are negligible to low magnitude of effect, which results in a very low to low level of effect (de minimis to less than minor).

The discharge of uncontaminated seawater occurs at three locations:

- From a service pump to maintain pressure in the fire main (a continuous discharge);
- From cooling diesel pumps if firefighting system activated, and
- From an overpressure value on the jetty.

Discharge of uncontaminated seawater was assessed as having a negligible magnitude of effect on marine ecological values (de minimis).

Occupation of the seabed by jetty piers, piles and dolphins is assessed as negligible due to the small area involved (de minimis).

Together, the cumulative effects of discharges from the RNZ site and the occupation of the seabed are considered to be negligible (de minimis) based on the high energy receiving environment, large dilution factor and the small area of seabed occupied compared to the harbour or the mouth of the harbour.

Summary of ecological values, magnitude of effect, and level of effect in EIANZ impact assessment guideline terminology and RMA planning terminology.

	ECOLOGICAL VALUE	MAGNITUDE OF ECOLOGICAL EFFECT	LEVEL OF ECOLOGICAL EFFECT	RMA PLANNING TERMINOLOGY	AVOIDANCE OR MITIGATION REQUIRED
Discharge of treated stormwater and wastewater	High	- Low	Low	Less than Minor	No
Discharge of ground water	High	Negligible	Very Low	De Minimis	No

Discharge of process chemicals	High	Low	Low	Less than Minor	No
Discharge of clean seawater	High	Negligible	Very Low	De minimis	No
Occupation of the seabed for structures associated with the jetty and dolphins	High	Negligible	Very Low	De minimis	No
Cumulative effects	High	Negligible	Very Low	De minimis	No

There is no evidence of significant adverse effects resulting from RNZ operations on marine ecological values within the proposed reasonable mixing zone or the wider receiving environment. With the overall level of effects on marine ecological values being low to very low (de minimis to less than minor), avoidance or mitigation is not required. However, RNZ is encouraged to continue improving practices and treatment of stormwater and wastewater in order to keep seeking to reduce the load of contaminants discharged to the marine environment.

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Appendix 3: Benthic Invertebrate Tolerance/Sensitivity Information

1.0 Introduction

The Marsden Point Oil Refinery, operated by Refining NZ (RNZ), is located at Marsden Point, the south head of Whangarei Harbour in Northland, New Zealand. The refinery presently receives and processes over 40 million barrels of crude oil per year, supplying around 85% of New Zealand's jet fuel, 67% of its diesel, 58% of all petrol and all the fuel oil used by ships. The crude oil processed by the refinery is sourced by RNZ's customers from a number of different locations and suppliers and is delivered to Marsden Point via ship. Once processed, approximately 52% of all refined product leaves the Refinery via the Auckland Pipeline and around 40% is transported to other domestic centres by coastal tankers[5].

As part of their operations, RNZ has resource consent for the discharge of stormwater, wastewater and uncontaminated seawater into the coastal marine area (CMA), and resource consent for situating a number of structures (jetties and dolphins) in the CMA. RNZ's current resource consents are due to expire in 2022. Consequently, RNZ is seeking new resource consents that are necessary for the Refinery to continue operating beyond 2022.

To support their resource consent application, RNZ has engaged Boffa Miskell Ltd to undertake an assessment of the effects their operations on marine ecological values of the CMA in the vicinity of the Refinery (Whangarei Harbour and Bream Bay). This assessment specifically considers the following components of RNZs resource consent application:

- The discharge of treated stormwater and wastewater;
- The discharge of uncontaminated seawater;
- Structures placed by RNZ in the CMA (RNZ Jetty and dolphins).

Each of these components and the CMA (in the vicinity of the Refinery) are described in detail in the following sections of this report. Figures 1-4 and Photograph 1 show the layout of structures on the RNZ site and their locations within in the CMA.

[5] The remaining 8% of RNZ products are exported (3%) and loaded onto local trucks (3%).

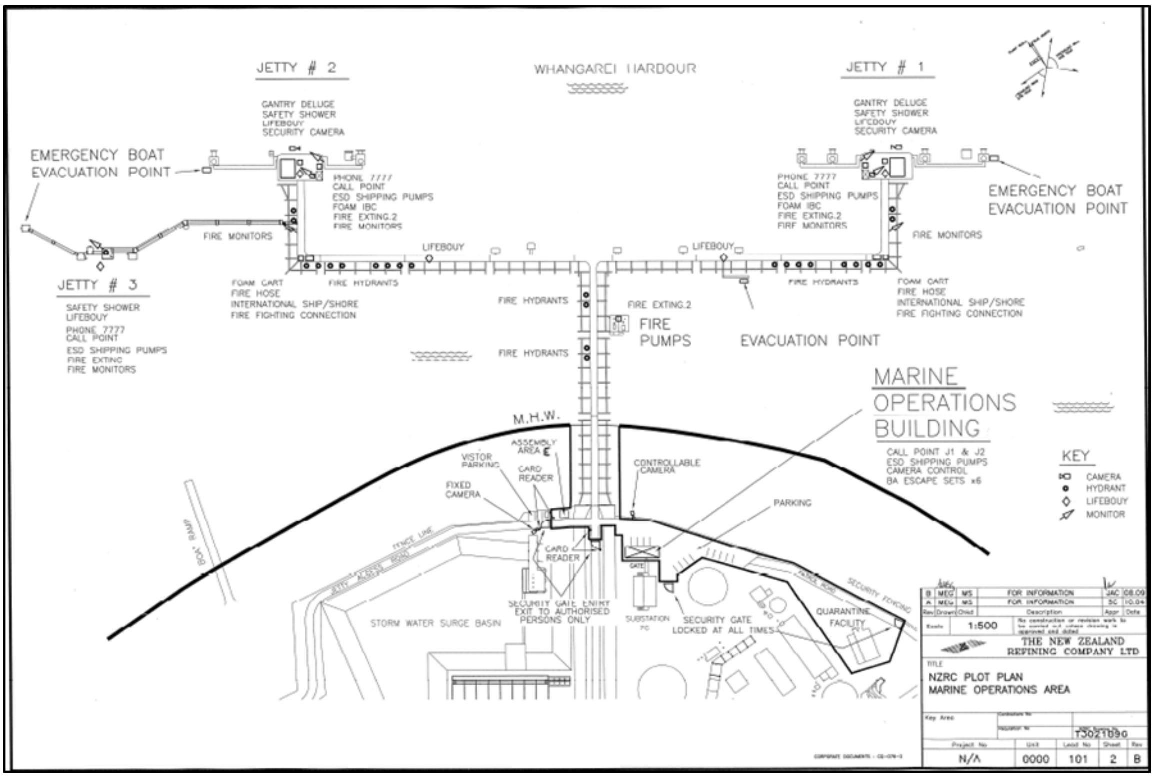

Figure 1: Refining New Zealand's jetty layout (source Refining NZ Port and Terminal Handbook 2017)

Photograph 1: View of RNZ site and jetties, with Marsden Bank on the left and Northport on the right of the photograph.

Figure 2: RNZ site showing location of the retention basin and the stormwater basin

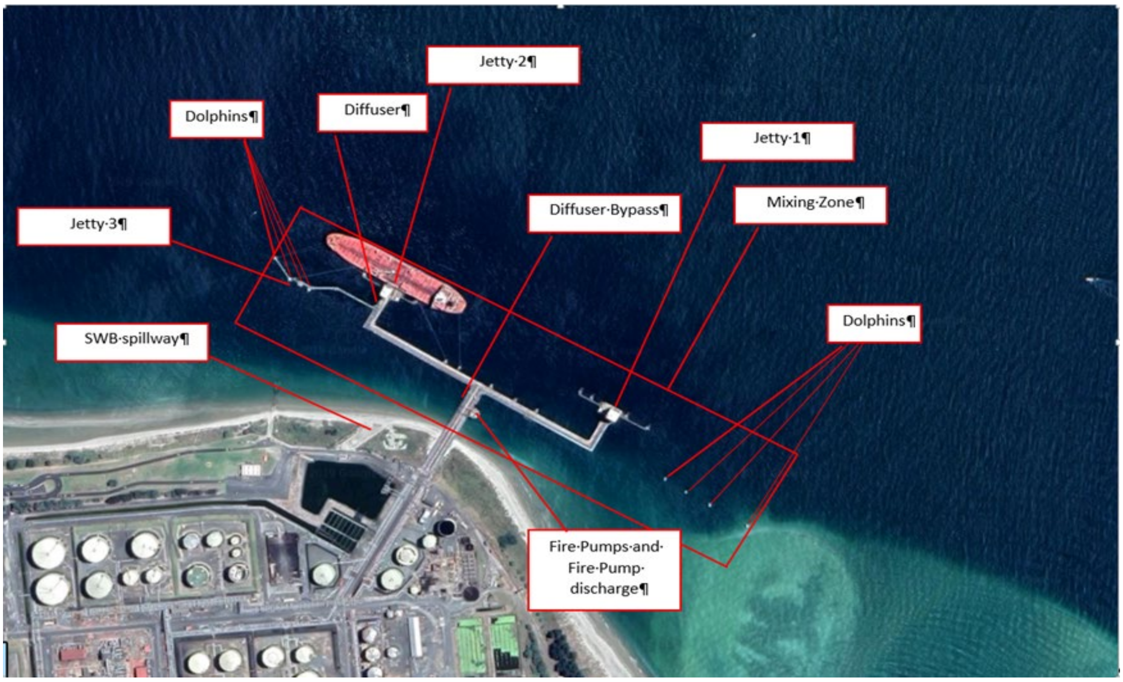

Figure 3: Jetty layout

1.1 Project Area and CMA

RNZ is located at the tip of Marsden Point, which is at the juncture of the mouth of Whangarei Harbour and the northern end of Bream Bay (Figure 4). The RNZ jetty is located at the mouth of the harbour and is within the Marine 5 Management Area (Port Facilities) identified in the operative Northland Regional Coastal Plan (map C13); and is zoned Marsden Point Port Zone in the proposed Regional Plan for Northland. For the purposes of this assessment, the immediate project area is defined as the coastal marine area at and around the RNZ (Figure 4).

To the north-west of RNZ is Northport, Whangarei's deep-water cargo port. Activities associated with operation of Northport include large vessel movements, stormwater discharge, maintenance dredging and the handling of cargo such as pine logs, wood chips, phosphate rock, cement clinker, coal and packaged cargo.

Whangarei Harbour is a drowned river valley system, with a catchment of almost 30,000 ha. The area of the harbour is approximately 10,000 ha, with 5,400 ha of intertidal habitat exposed at low tide. The inlet between Marsden Point and Home Point connects Whangarei Harbour to the wider Bream Bay (Morrison, 2003).

At the mouth of Whangarei Harbour, wind speeds are typically low and wave heights are low to moderate (Beamsley, 2019. Moderate tidal currents are associated with the entrance channel, with peak tidal velocities reaching 2.0-2.5 knots over the length of the channel (Beamsley, 2016). Mair bank, Marsden bank and Calliope bank fringe the harbour mouth entrance channel (Figure 4).

The Whangarei Harbour and Bream Bay have been extensively studied and reported on, most recently in a number of assessments and statements of evidence relating to RNZ's Crude Shipping Project (capital and maintenance dredging) consent application in 2018 (summarised in Table 6 (Coffey, 2017). The marine ecological values of Whangarei Harbour and Bream Bay have been described in detail (Coffey, 2018). This report does not reproduce the level of detail contained in those recent assessments, but instead provides high-level summaries where relevant.

1.2 The proposed activities

1.2.1 Discharge of treated stormwater and wastewater

Section 1.1 of Stewart (2020) summarises the surface water and groundwater infrastructure at the RNZ site as follows:

> *There are two types of drainage system employed by the Refinery: The Continuously Oil Contaminated System ('the COC') and the Accidentally Oil Contaminated System ('the AOC'). The COC and AOC systems are described in detail in the AEE. A summary is provided here.*
>
> *The COC intercepts process water, stormwater and tank drainage water that is likely to be contaminated from several processing and treatment activities at the site. The COC system consists of five sewer networks and oil interceptors, oil sumps and pumps. The oil that is collected in the interceptors is directed back to the slops processing unit for recycling. The separated water is then pumped to the water treatment unit (the biotreater unit) for further treatment. Separated water from the interceptors (for rainfall*

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Data Sources: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and

Projection: PCS: NZGD 2000 New Zealand Transverse Mercator

LEGEND

Marine Management Areas

MM1 (Protection)

Significant Ecological Areas - Proposed Regional Plan (Decisions Version)

BM19109 RECONSENTING WASTEWATER DISCHARGES FROM MARSDEN OIL REFINERY

Location Map

Date: 9 September 2019 | Revision: B

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Figure 4

events of up to 6 mm/hr) is also pumped back to the biotreater for further treatment. Where rainfall intensity exceeds 6 mm/hr the treated water from the interceptors is discharged into the AOC system.

The AOC system typically collects water that is unlikely to be contaminated by process activities or chemicals, but may, as a consequence of contact, be potentially contaminated. The AOC is effectively the stormwater system for the site. The reticulated stormwater network drains to the open channel drains within the site that all flow to the stormwater retention ponds and eventually discharge to the stormwater storage basin (SWB). Stormwater from the SWB is pumped through a pipe along the No. 2 (western) Oil Jetty to an outfall. The stormwater discharge is tested for a range of water quality parameters in accordance with the consent conditions.

A hydraulic containment system has operated at the site since 1983 to manage hydrocarbon contamination of groundwater. The current extraction system comprises recovery wells and operates continuously. Recovered product is pumped to the COC and slops system for separation and treatment.

Surface water quality impacts were assessed on the discharge of water and sediment – and associated contaminants contained within – from the Refinery Stormwater Basin (SWB) to the marine receiving environment of the Lower Whangarei Harbour. For the contaminants assessed in the surface water discharge it was necessary to separate the assessment of effects into those that are considered "traditional" (for example, petroleum hydrocarbons, metals, ammoniacal-nitrogen) and those that are considered "non-traditional", which encompasses many chemicals contained within formulations (hereafter called process chemicals) used in the refinery process. "Traditional" contaminants are those that are routinely measured in the SWB and receiving environment. These are covered in Section 2. The majority of process chemicals have not been measured in the SWB or receiving environment.

Ships tank washings and de-ballast water are also treated on site using a biotreater plant, which forms part of a Water Effluent Treatment Unit.

The effluent from the Water Effluent Treatment Unit is then discharged into a Retention Basin for further treatment, and then onto the Stormwater Storage Basin (SWB). Of note is that the SWB is designed to absorb fluctuations in the flows from the Site (principally from the stormwater discharges, as the discharges from the biotreater and groundwater wells tend to be relatively stable / constant). Water levels in the SWB are typically kept low to provide surge capacity (and thus be able to accommodate events such as heavy rainfall). From the SWB the treated stormwater and wastewater is discharged into the Whangarei Harbour ('the Harbour") via a submarine diffuser that is attached to the RNZ Jetty, in the vicinity of Jetty 2 (Figure 1).

The SWB has a design capacity of 30,000 m^3. It has four pumps, two being two Dry Weather Flow Pumps with a combined capacity of 20,000m^3/day, and two being Stormflow Pumps with a combined capacity of 44,000m^3/day. The maximum design discharge rate from the SWB is limited to 48,000m^3/day with a corresponding hourly discharge rate of 2,000m^3/hr. This discharge rate reflects the design capacity of the diffuser. To accommodate heavy to extreme rainfall events, a diffuser bypass increases its' discharge capacity to 65,000m^3/day. The diffuser bypass has been used 23 times in the past eight years. In the event of even greater flow requirements (due to extreme rainfall) there is a spillway from the stormwater basin which discharges directly onto the foreshore (used once in the past eight years).

1.2.2 Discharge of uncontaminated seawater

RNZ can discharge uncontaminated seawater from its firefighting systems into the CMA via three processes (Figure 1 and Tonkin & Taylor 2020).

- A service pump located on the jetty and is used to maintain pressure in the fire main within the Site. It discharges seawater to the Harbour at a rate of approximately 100 m^3/hr. This discharge is from the jetty, close to where the seawater is abstracted (Figure 1);
- When the firefighting system is activated, a small volume of water is diverted from the fire main and used to cool the diesel pumps that are used to abstract the firefighting seawater from the Harbour. This cooling water is also discharged (at an approximate rate of 50 m^3/hr) to the Harbour, near the point of take (that is, below the jetty); and
- Seawater may also be discharged from overpressure valves that are situated on the jetty. These valves are only used if there is a need to prevent the fire main from being over pressurised. The discharge is directly to the Harbour and can be at a rate of up to 11,000 m^3/hr.

1.2.3 Structures in the CMA

As part of its operations, RNZ has a number of consented structures in the CMA (detailed in Figure 3). These include:

- Jetties 1 and 2 (built in the 1960's);
- Jetty 3 (built in 2009);
- a number of mooring and breasting dolphins (isolated structures assist with berthing of vessels.).

These structures play an essential functional role in enabling access by vessels loaded with crude to visit and unload cargo to the refinery, and the loading of coastal tankers to transport refined product throughout New Zealand.

The jetty piers occupy approximately 33 m^2 of seafloor and the breasting and mooring dolphins occupy approximately 110 m^2 of seafloor.

1.3 Purpose of assessment

The purpose of this assessment is to determine effects of RNZ discharges and structures on marine ecological values of the CMA. Specifically, we want to understand the impact of RNZs water discharges on:

- Water quality;
- Sediment quality;
- Marine ecology in the vicinity of RNZ;
- Shellfish contaminant body burdens.

We also want to understand what impact the jetty and dolphin structures may be having on the ecology of the area.

To determine these impacts we reviewed existing literature, carried out a gap analysis to determine additional knowledge requirements, and then conducted a series of new studies to address those knowledge gaps.

With this knowledge we are able assess the impacts of the proposed activities on the marine ecological values of the CMA.

1.4 Structure of Report

This report consists of:

- Section 2: A review of existing literature and knowledge;
- Section 3: A gap analysis and details of new studies conducted to address knowledge gaps;
- Section 4: An assessment of effects;
- Section 5: Conclusions.

2.0 Review of existing data

We have reviewed and summarised the relevant data from reports prepared in support of RNZ's successful application for resource consents for its crude shipping project.

We have also obtained monitoring data from both RNZ and Northland Regional Council (NRC), and considered NRC's descriptions of significant marine areas.

2.1 Identified Significant Marine Ecological Areas

The operative Northland Regional Coastal Plan (2004) identifies marine sites of special scientific or conservation value adjacent to the Project Area; Motukaroro Island Whangarei Marine Reserve, Outer harbour sandbanks and Busby Head Marine 1 Management Area (Figure 5). Motukaroro Island marine reserve[6] has a high diversity of species, including subtropical species. Calliope Bank[7] is identified as providing intertidal habitat for internationally significant habitat for migratory and endemic avifauna (Coffey, 2017). Snake, Mair, Calliope, McDonald banks are identified as intertidal areas that provide internationally significant habitat for international migratory and New Zealand endemic wading and wetland birds, including threatened species. Mair Bank is also identified based on historic values relating to shellfish abundance (pipi)[8]. Busby Head is identified on the basis of incorporating a rocky shore that is internationally significant habitat for New Zealand endemic wading and coastal birds, including threatened species[9]. Busby Head[10] is identified for the rocky shore that provides habitat for a range of *Threatened* and *At Risk* wading and coastal birds.

The proposed Northland Regional Plan (decisions version, 4 May 2019) (pNRP) identifies a large proportion of Whangarei Harbour as a Significant Ecological Area (SEA) (Figure 4) based on a collection of ten areas that were assessed against Appendix 5 of the Northland Regional Council Proposed Policy Statement. The main channels and upper harbour areas are excluded from the SEA layer. Mair and Marsden Banks are also mapped as a SEA in the pNRP, based on the historic (now largely absent) pipi population (Figure 4). The pNRP has separate layers for Significant Bird Areas and Significant Marine Mammal and Seabird Areas. The Regional Policy Statement (2016) also identifies Marsden and Mair Bank as having high natural character.

2.2 Water Quality

Water quality in Whangarei Harbour is of a high standard at the harbour mouth and lower quality in upper harbour (Tweddle, Eyre, Griffiths, & McRae, 2011). Bream Bay water quality is also generally of a high standard but influenced by riverine inputs (including sediment and associated contaminants), particularly from Ruakaka River, during rainfall events. Contaminant

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[6] Assessed as nationally significant.

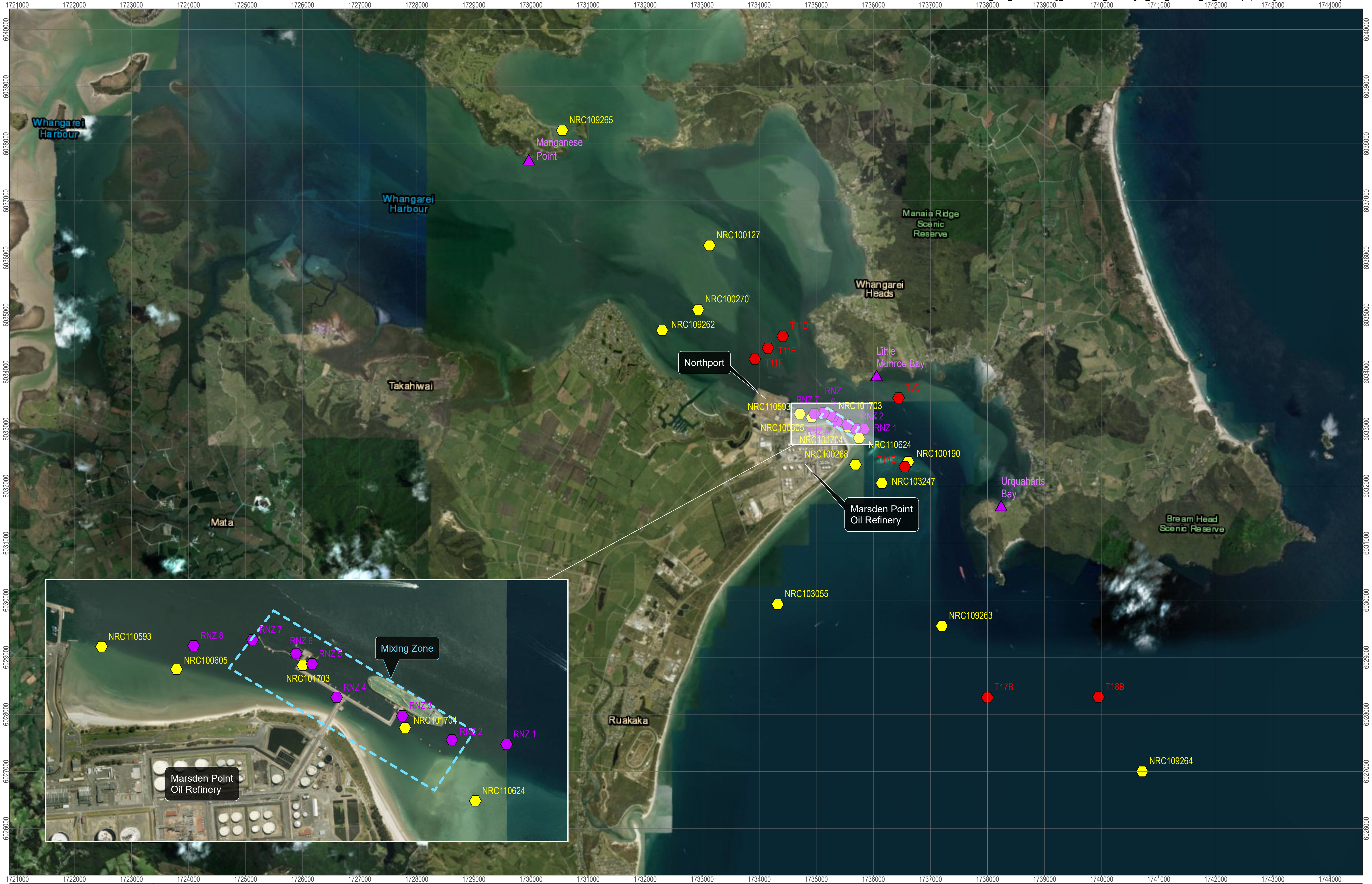
[7] Assessed as regionally significant.

[8] Assessed as regionally significant (based on historic shellfish values).

[9] Appendix 6, operative Northland Regional Coastal Plan.

[10] Assessed as regionally significant.

File Ref: BM19109_SDe_Reconsenting_Wastewater_Discharges_from_Marsden_Oil_Refinery.aprx, Fig 5 Sediment Survey Sites



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Projection: New Zealand Transverse Mercator 2000

LEGEND

Sampling Site
- NRC (15)
- RNZ 2019 (8)
- RNZ 2019 Ref Site (3)
- RNZ 2015 (7)

BM19109 RECONSENTING WASTEWATER DISCHARGES FROM MARSDEN OIL REFINERY

NRC and RNZ Sediment Survey Sites

Date: 19 August 2019 | Revision: G

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Figure 5

concentrations and turbidity are low at the harbour mouth (e.g. at Marsden Point and Mair Bank; Figure 5) and elevated in the upper harbour (Table 3, (Coffey, 2017)).

A review of existing water quality data in the receiving environment (four inner harbour sites, two sites at the edges of the mixing zone, and three outer harbour sites) by Stewart (2020)[11] indicated that:

(1) Water is consistently well oxygenated,

(2) pH is well within the required range,

(3) Temperature was consistent across sites,

(4) Ammoniacal nitrogen was low (and below threshold concentration),

(5) Metals and metalloids were largely below detection limits (except for two sites in 2015 when arsenic was just above the 95% ANZECC marine trigger value),

(6) Phenols and sulphide were below detection limits at all sites,

(7) TPH was generally very low and below detection limits at all sites, and

(8) TSS was not excessively high at of the sites surveyed.

With respect to trends in the receiving environment water quality parameters, only temperature showed a statistically significant trend, with all sites showing an increase in temperature between 2014 and 2019 (Stewart, 2020).

Water quality discharge limits for RNZ have been set at a level to protect the ecological values of the Harbour. A review of the Refinery's discharges into the CMA found (1) that the stormwater discharge quality is predominantly within consent parameters, and (2) that the coastal water quality at sites close to the RNZ jetty is similar to water quality at more distant reference sites.

Analyses of groundwater from perimeter wells revealed that several contaminants were present above guideline concentrations at the eastern coastal edge of the RNZ site (Tonkin & Taylor Ltd, 2020):

- Copper > 80% ANZECC water quality guideline (site P8A and P8C)
- Iron > Drinking water standard and > ANZECC low reliability value (site P8C)
- Manganese > ANZECC low reliability value (site P8B and P8C)
- Zinc > 80% ANZECC water quality guideline (site P8A)
- Nitrate > 80% ANZECC water quality guideline (site P9)
- Arsenic > Drinking water standard and > 80% ANZECC water quality guideline (site P8C)
- Cobalt > 95% ANZECC water quality guideline (site P8B and P8C)

NIWA carried out ecotoxicology testing of a sample collected from Refining NZ's stormwater basin in July 2017[12] (NIWA, 2017) to calculate the degree of dilution required for the stormwater

[11] NRC monitoring data.

[12] 28.5mm of rain had fallen in the seven days prior to sample collection, with 13.5mm falling on 20 July (Marsden Point Oil Refinery rain gauge).

(also referred to as produced water) to have no toxic effect on a suite of standard laboratory test organisms. Standard laboratory tests included:

- Growth of microalgae (*Dunaliella tertiolecta*);
- Survival and reburial of wedge shell (*Macomona liliana*);
- Embryo development of blue mussel (*Mytilus galloprovincialis*).

Of the results, the most sensitive test (microalgae) indicated that an 8.8 times dilution of treated effluent[13] was required in order for there to be no toxic effects (NIWA, 2017). The effluent had low toxicity for algae growth, wedge shell survival/morbidity, or blue mussel embryo development.

Details on the test parameters are included in Appendix 1.

2.3 Sediment Quality

NRC have collected surface sediment samples from a number of sites throughout Whangarei Harbour over the past 10-15 years and analysed them for a range of contaminants as part of their State of the Environment reporting and compliance monitoring of RNZ's consents (Figure 4). While sampling is conducted annually, there hasn't been consistency in which sites have been sampled or the contaminants for which sediments were analysed, which makes trend analysis difficult (Mortimer, 2010).

Sample collection has primarily been via a grab sampler, with triplicate samples extracted from the sediment grab and then combined to form a single composite sample. Contaminants that have been analysed have included total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), phenol and metals[14]. In addition, grain size, dry matter and organic matter have also been analysed at some sites/years.

We have plotted sediment contaminant concentrations at, adjacent to, and distant from, the RNZ jetty from 2002 onwards (Appendix 2). Where contaminant concentrations are reported as below laboratory detection limits, we have used the detection limit as the sample concentration for the purposes of our analyses.

As part of the estuary monitoring programme, in 2012 NRC surveyed surface sediment quality at intertidal and subtidal sites throughout Whangarei Harbour (Griffiths, 2012). At each site, approximately 200 g of the top 2 cm of sediment was collected and analysed for grain size, nitrogen, phosphorus, cadmium, chromium, copper, lead, nickel and zinc.

Sediment samples were collected from 26 soft sediment sampling locations in 2016, as part of the Crude Shipping Project, and analysed by the University of Waikato using a Malvern Lasersizer to determine the proportions of sediment grain sizes present (V. C. Kerr, 2016). We have extracted data from sites that provide relevant background to the current resource consent application (Figure 5).

We have applied conservative Sediment Quality Guideline values as per Table 4 of (Stewart, 2020).

Analysis of data collected from 2002-2016 indicate for sites near the RNZ jetty and sites upstream and downstream from the jetty that:

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[13] Stormwater and wastewater

[14] Arsenic, cadmium, chromium, copper, lead, mercury and zinc.

(1) Metals are present in low concentrations, significantly below Sediment Quality Guidelines (see graphs in Appendix 2, and Table 4 (Stewart, 2020));

(2) Total petroleum hydrocarbon concentrations were spatially varied among sites and temporally variable within sites. The maximum concentrations detected approached the DGV[15] of 280 mg/kg, with no pattern of accumulation near the RNZ jetty detected i.e. TPH was not higher at and near the RNZ jetty compared to sites distant from the jetty (see graphs in Appendix 2).

In addition, RNZ surveyed surficial sediment quality within and adjacent to proposed capital dredging areas (West and Don, 2016). Sites surveyed between Home Point and Northport all had low levels of contaminants, with PAHs all below the laboratory detection limit. Stewart (2020) analysed arsenic, chromium, lead and zinc data from NRC sediment monitoring at sites under and adjacent to the RNZ jetty between 2002 and 2016. The data revealed statistically significant decreases in the concentrations of arsenic, chromium and lead within the inner harbour (site NRC 100127), as well as statistically significant decreases in arsenic at the mixing zone boundary (site NRC 100605) and lead in the outer harbour (site NRC 100268).

As part of the estuary monitoring programme carried out in 2012, intertidal sediment grain size at Marsden Bay and subtidal sediment at Snake Bank was found to be dominated by fine and medium sand (Griffiths, 2012).

NRC have surveyed sediment grain size at some sites in past years. The 2014 sediment grain size data indicated that sites close to the RNZ jetty and sites located adjacent and a small distance up harbour and down harbour were dominated by sand grain sizes, with silt and clay forming a very small proportion (c.1-4%).

A survey of sediment grain size (V. C. Kerr, 2016) revealed clean fine sands outside the harbour entrance, with coarse sand and shell substrates prevalent within the inner harbour. In locations away from the main channels, sediment was generally finer and had higher silt content.

2.4 Marine Ecology

Subtidal and intertidal benthic habitats within Whangarei Harbour and Bream Bay are generally dominated by soft sediment (predominantly sand grain sizes), whilst rocky shore habitats occur between Bream Head and Home Point, and between Darch Point and Home Point, plus at Motukaroro Islands and High Island (Figure 4). Shellbanks are present at the mouth of the Harbour, including Marsden, Mair, Calliope, Snake Bank and MacDonald Bank (Figure 4).

NRC surveyed a range of benthic soft sediment intertidal and subtidal sites throughout the Whangarei Harbour in 2012 (Griffiths, 2012). At each site, three replicate core samples (150mm diameter by 150mm deep) were collected, sieved through a 0.5mm mesh, preserved in ethanol and stained with rose Bengal. Organisms were extracted and analysed by Coastal Marine Ecology Consultants.

In 2016, Kerr surveyed 26 soft sediment sampling locations, six subtidal rocky reef sponge garden sites, one Sabellid fan worm site and five *Ecklonia radiata* canopy sites within Whangarei Harbour and Bream Bay for the purposes of providing information for the resource consent application for the Crude Shipping Project (V. C. Kerr, 2016). We have extracted data from sites that provide relevant background information for the current resource consent application (Figure 5). At each soft sediment site, five replicate core samples were collected

[15] Default Guideline Value (ANZ, 2018), which supersedes Interim Sediment Quality Guideline Low (ANZECC, 2000)

using a 138mm diameter coring tool to a depth of 150mm. Samples were sieved through a 0.5mm mesh, preserved in 70% ethanol and 2% glycol and sent to Cawthron Institute for extraction, identification and enumeration of organisms. At each subtidal rocky reef site, photographs of quadrats were collected (360mm x 260mm) and later analysed for percentage cover of encrusting organisms and identification of mobile species.

The results of these studies are described in sections 2.4.1 through 2.4.4 below.

2.4.1 Subtidal soft sediment

The subtidal benthic soft sediment habitat beneath and adjacent to the RNZ jetty comprises low relief, coarse sandy sediment which supports a diverse invertebrate epifauna and infauna community (Kerr, pers comm).

Of the subtidal areas surveyed by NRC in 2012 as part of their estuary monitoring programme, Snake Bank is the closest site to the RNZ jetty. The benthic invertebrate assemblage at Snake Bank was dominated by the polychaetes *Euchone* sp., and *Boccarcia syrtis*, crustaceans *Tanaidacea* sp., ostracods and amphipods. Species richness in Group B (comprising Snake Bank and Manganese Point) revealed 20 taxa, 136 individuals and a Shannon Weiner diversity index of 2.2 (indicating high diversity) (Griffiths, 2012).

An extensive survey of subtidal benthic soft sediment ecology was carried out in 2016 to inform the assessment of effects for Refining New Zealand's capital dredging proposal (V. C. Kerr, 2016). At 26 sites within Whangarei Harbour (inner harbour) and Bream Bay (outer harbour), five replicate core samples (138mm diameter, 150mm deep) were collected, sieved through a 0.5mm mesh and analysed for benthic invertebrate community composition and abundance. Inner harbour sites supported a higher diversity and abundance of benthic invertebrates than outer harbour sites.

At inner harbour sites, the total number of individual organisms recorded ranged from 102 and 1,498 per core, whereas species richness (the number of species recorded at a site) ranged from 10 to 91. Dominant taxa groups included polychaete worms, amphipods, gastropods, bivalves, nematodes, oligochaete worms, polyplacophora, cnidaria, echinoderms, and cephalocordata. Less abundant taxonomic groups included nemertea, copepods, isopods, decapods, ostracods, cumacea, platyhelminthes, bryozoan, hemichordata, chaetognatha, ascidians, and rhodophyta (V. C. Kerr, 2016).

At outer harbour sites, the total number of individuals ranged from 31 to 154, and species richness ranged from 13 to 36. Dominant taxonomic groups were similar to those in the inner harbour (V. C. Kerr, 2016).

Subtidal sandflats in the wider Bream Bay area are inhabited by a range of benthic invertebrates including gastropods (olive snail (*Amalda depressa*), sea snail (*Sigapatella* sp.), morning star shell (*Tawera spissa*)), bivalves (*Bassina yatei, Dosinia subrosea*), echinoderms (sand dollar (*Fellaster zealandica*), cushion star (*Patiriella regularis*)), crustaceans (*Pagurus* sp., *Ovalipes catharus* and *Petrolisthes* sp., mysid shrimps) and polychaete worms (Golder, 2010).

2.4.2 Intertidal soft sediments

NRC's estuary monitoring programme revealed intertidal sites closest to Marsden Point (Marsden Bay 2-3)[16] were dominated by the polychaete worms *Prionospio aucklandica*, *Aonides* sp., *Scoloplos cylindrifer*, *Heteromastus filiformis* and *Capitella* sp., bivalves *Austrovenus stutchburyi* (cockle), *Nucula hartvigiana* (nut shell), *Macomona liliana* (wedge shell) and *Paphies australis* (pipi), anemone *Anthopleura aureoradiata*, and shrimp *Colurostylis lemurum*. Shannon Weiner diversity index of 1.9 (Marsden Bay 2 and 3) and 2.0 (Marsden Bay 1) indicated moderate to high diversity, with 12 (Marsden Bay 2 and 3) and 16 (Marsden Bay 1) species detected and number of individuals recorded as 151 (Marsden Bay 2 and 3) and 128 (Marsden Bay 1) (Griffiths, 2012).

The benthic invertebrate community composition on open sandy beaches in Bream Bay are characterised by sea-slater (*Scyphax ornatus*), common sandhopper (*Talorchestia quoyana*), Sphaeromidae and Eurydicidae isopods, paddle crab (*Ovalipes catharus*), ghost shrimp (*Callianiassa filholi*), mantis shrimp (S*quilla* sp.) and tuatua (*Paphies subtriangulata*) (V. C. Kerr, 2005). Between the RNZ jetty and Northport, there are patches of finer grained sediment that support cockles (*Austrovenus stutchburyi*), mud whelk (*Cominella glandiformis*) and sand dollar[17] (Photograph 2 to Photograph 5).

Pipi (*Paphies australis*) historically dominated Mair and Marsden bank (Photograph 5), but over the past c. 10 years pipi populations have collapsed (approximately 1% of the abundance in 2005) (J. R. Williams, Roberts, & Chetham, 2017). Sparse green-lipped mussel (*Perna canaliculus*) and more abundant *Ruditapes* spp are also present on the banks (Kerr, pers. comm. and (J. R. Williams et al., 2017).

A 2014 pipi survey (Pawley, 2014) indicated low abundances and patchy distribution of pipi in the intertidal, and the disappearance of the large subtidal pipi bed. In 2014, pipi biomass was recorded at approximately 1% of the biomass present in 2005. Size-frequency data indicated that much of the 2005 pipi biomass is made up of a single cohort which may have reached the end of natural lifespan between 2010 and 2014. Williams & Hume ,(2014) reported that recruitment of pipi into the adult population has failed since 2010). In the 2016/2017 survey, pipi were only recorded along a small narrow band on the southern intertidal flank of Mair Bank (J. R. Williams et al., 2017). Pipi were found in low density and considered insufficient abundance for cultural or recreational harvesting. A 2019 survey (V. Kerr, 2019) indicated that pipi remain absent from the vast majority of Mair and Marsden banks, leading to the conclusion that pipi populations have collapsed over the past decade. Pipi were only recorded in two small areas in the 2019 survey, one on Mair Bank and the other on Marsden Bank. Together, these areas cover 300-400 m^2 (forming together 0.04%[18] of the proposed Mair Bank Significant Ecological Area as delineated in the proposed Northland Regional Plan).

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[16] Marsden 2 and 3 formed part of a grouping of sites with similar assemblages referred to as Group C. Group C also included McLeod Bay 2, Takahiwai 2, Tamaerau, Waikaraka and Onerahai. Marsden Bay 1 had an assemblage that was not similar to other sites.

[17] A shallow subtidal species that often washes up on intertidal flats.

[18] Significant Ecological Marine Area Assessment Sheet, Whangarei Harbour Marine Values, Mair Bank.

Photograph 2: Comb star (Austropecten polyacanthus), mud whelk (Cominella glandiformis), cockle (Austrovenus stutchburyi) in intertidal sandy habitat between RNZ jetty and Northport.

Photograph 3: Sand dollar (Fellaster zealandica) in shallow subtidal habitat adjacent to RNZ jetty

Photograph 4: Intertidal rocky shore species inhabiting a concrete structure adjacent to RNZ jetty (Pacific oyster, Chaemosipho columna, oyster borer (Haustrum scobina), snake skin chiton (Sypharochiton pelliserpentis).

Photograph 5: View from south looking across Mair and Marsden Banks

Two surveys of pipi histology were carried out at various sites within the Whangarei Harbour and Bream Bay in 2019 and 2020 (Howell, 2019 and Howell, 2020). No significant pathogens were detected in pipi from Mair Bank, Marsden Bank and One Tree Point in 2019 (Howell, 2019). In the 2020 survey, the researcher concluded that it was unlikely that protozoa, parasites, bacteria, nutrients and heavy metals, and general water quality were having adverse effects on shellfish health. At all five sites surveyed, mucus and haemocyte responses, plus the presence of symbiotic bacteria (*Endoziocomonas*) were present, although more prevalent at One Tree Point, Mair and Marsden Bank (the estuarine sites) compared to open water sites along Bream Bay. Howell (2019 and 2020) was unable to identify and single cause of these effects, although a post-spawning immunity response was put forward as a possible cause. Pipi at all sites were noted to have small bodies within their shells (Howell, 2020), which also could be a natural post-spawning response.

2.4.3 Intertidal Rocky Shore

Hard shore assemblages are similar to those recorded within the Hauraki Gulf. Intertidal habitats are dominated by barnacles (*Chaemosipho columna*), Pacific oysters (*Crassostrea gigas*), tubeworms (*Pomatoceros* spp.), Coralline algae and Neptune's necklace (*Hormosira banksii*). Common sessile and mobile organisms include chitons, gastropods, and crabs (Coffey, 2017).

2.4.4 Subtidal Rocky Shore

The shallow subtidal zone is dominated by brown algae including *Carpophyllum* and *Cystophora* species, which give way to *Ecklonia radiata* in deeper water (Coffey, 2017).

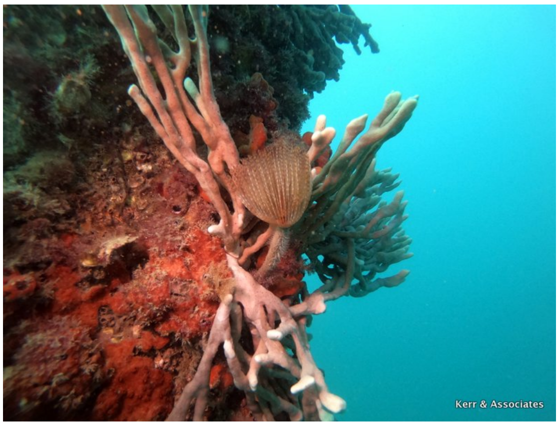
In 2016, Subtidal rocky shore communities were surveyed at Darch Point, Motukaroro Island, Castle Rock, Home Point, and Bream Head (V. C. Kerr, 2016). The subtidal assemblages were diverse, with dominant taxa including coralline paint, filamentous and foliose algae, a variety of sponges, cnidaria, gastropods, bivalves, cup corals, tubeworms, anemones, hydroids, polychaete worms, and bryozoans. Diverse sponge garden habitats are present within the Motukaroro Island marine reserve (V. C. Kerr, 2016).

A survey of subtidal encrusting communities of the Refinery wharf undertaken in December 2018 and repeated in February 2019. Communities on three piles at Jetty 1 were assessed using quadrat photo images to a depth of 12m (V. Kerr, 2019). Five replicate photo quadrats were analysed for community composition and percentage cover. Encrusting communities had 100% cover and were found to be healthy. A variety of upright and encrusting sponges, hydroids, tubeworms, and bivalves (oysters) dominated the assemblages, with ascidians, algae and bryozoans less common.

The photographs below were opportunistically collected in May 2019, whilst the dive team were carrying out the subtidal benthic soft sediment survey below the RNZ jetty. The photographs support the findings of the survey before and after the maintenance dredging programme that occurred in January 2019 i.e. a diverse assemblage of encrusting communities on the jetty piles (V. Kerr, 2019).

Photograph 6: Diverse encrusting assemblages on the RNZ jetty piles.

Photograph 7: Diverse encrusting assemblages on the RNZ jetty piles.



Photograph 8: Diverse encrusting assemblages (including invasive Mediterranean fanworm, Sabella spallanzanii, which has since been removed) on the RNZ jetty piles.

Photograph 9: Leatherjacket (Meuschenia scaber) alongside the encrusting assemblages on the RNZ jetty piles.

Subtidal encrusting communities at Motukaroro Island, located to the north-east of the Refinery wharf, were also surveyed in 2019 (V. Kerr, 2019). Species diversity was higher at Motukaroro Island than on the jetty piles, which is expected on account of the greater habitat diversity provided by a natural rocky reef relative to concrete piles. Both reef sites and jetty piles were dominated by diverse mixes of encrusting and upright sponges. Sponge and ascidians (being filter feeders) are commonly used as indicators of stress in marine environments as they are sensitive to perturbations (Alcolada, 2007) (Carballo, 2006) (Carballo & Naranjo, 2002) (Carballo, Naranjo, & Garcia-Gomez, 1996).

Data from those two studies (Kerr, 2016 and Kerr 2019) can be combined to tell us about how rocky subtidal community at the RNZ jetty compares to elsewhere within Whangarei Harbour and Bream Bay. In 2016, Kerr surveyed Darch Point, Motukaroro Island, Castle Rock, Home Point, and Bream Head, whereas in 2019 Kerr surveyed Motukaroro Island and the RNZ jetty.

Similar taxonomic groups present across all sites. Dominant species were upright and encrusting sponges, hydroids, tubeworms, and bivalves (oysters). Ascidians, algae and bryozoans were less common. Importantly, the same types of species were present across RNZ and reference sites.

Both soft sediment and hard shore habitats at and adjacent to the RNZ jetty and at sites distant to the jetty comprise a mix of species that are sensitive to environmental perturbations (e.g. elevated contaminants, suspended and deposited sediment, changes to sediment grain size etc.) and some taxa which are considered tolerant.

2.4.5 Fish

A high diversity of fish have been detected within the Project Area and in adjacent areas (summarised in Section 2.6.3, (Coffey, 2017). The most commonly detected species adjacent to the Project Area include snapper (*Pagrus auratus*), spotty (*Notolabrus celidotus*), kahawhai (*Arripis trutta*), sweep (*Scorpis lineolatus*), parore (*Girella tricuspidata*), jack mackerel (*Trachurus novaezelandiae*), and goatfish (*Upeneichthys lineatus*) (Kerr and Moretti, 2012). Triplefin species are also abundant (V. C. Kerr, 2016).

2.5 Shellfish Contaminant Body Burden

Shellfish (pipi and cockles) have been sporadically collected and analysed for contaminant body burden by NRC at established survey sites between 2003 and 2012, with some caged mussels deployed at the RNZ mixing zone boundary and western dolphin in 2005/2006. Each survey included one or more of the following species; mussels (*Perna canaliculus*), pipi (*Paphies australis*), cockle (*Austrovenus stutchburyi*) or tuatua (*Paphies subtriangulata*). At each site surveyed, 15 adult shellfish were collected and combined to form a single composite sample. Contaminants analysed included all or a subset of the following; PAHs, phenol and metals (Mortimer, 2010). Shellfish body burden surveys ceased in 2012 due to a lack of available shellfish and issues with third party interference with caged sentinel shellfish.

Data from NRC established survey sites indicates low levels of contaminants in shellfish tissue at all four sites surveyed, apart from Parua Bay where elevated chromium was detected in pipi (4 mg/kg) (Table 1). Data from caged sentinel mussels also indicates low concentrations of contaminants (Table 2).

RNZ collected pipi from Mair Bank on 14 June 2018 and had the flesh analysed for body burden of fire-fighting foam contaminants. No fire-fighting contaminants were detected in pipi flesh,

Table 1: Shellfish contaminant body burden analyses undertaken in Whangarei Harbour/Bream Bay by NRC 2003-2012

	Lower Whangarei Harbour at Mair Bank Outer Marker Pile Site ID: 100190					**Bream Bay at Mair Bank seaward side Site ID: 103247**		**Parua Bay intertidal flat between Manganese Point and Motukiore Island Site ID: 109265**		**Whangarei Harbour @ Manganese Point Site ID: 101077**	
Date	**11/12/12**	**23/11/09**	**10/12/08**	**10/12/08**	**25/09/08**	**11/12/12**	**17/04/07**	**11/12/12**	**10/12/08**	**17/06/03**	**17/06/03**
Species	**Pipi**	**Pipi**	**Pipi**	**Shellfish[19]**	**Shellfish**	**Pipi**	**Shellfish**	**Pipi**	**Cockle**	**Cockle**	**Pipi**
Arsenic (mg/kg)	2.7	2.8	3.4	3.8	3.33	2.8	2.3	3	5.6	4.6	3.4
Chromium (mg/kg)	1	< 0.1	1.6	0.088	2.28	0.98	0.02	4	1.4	0.2	0.03
Copper (mg/kg)	1.9	1.1	2.5	1.4	2.97	1.6	0.7	2.7	2.5	0.8	0.55
Mercury (mg/kg)	0.073	< 0.01	0.005	0.003	0.008	0.003	-	0.02	-	-	-
Lead (mg/kg)	0.003	0.013	0.027	0.026	0.021	0.05	0.008	0.15	0.017	0.02	0.01
Zinc (mg/kg)	12	9.6	-	14	9.98	13	8.3	11	10.1	6.8	-

[19] Species not stated in report (Mortimer, 2010)

Table 2: Average sentinel mussel contaminant body burden analyses 2005/2006

	RNZ Outer Mixing Zone	RNZ jetty western dolphin
PAHs (mg/kg)	0.033	0.028
Phenol (mg/kg)	0.17	<0.2
Arsenic (mg/kg)	2.52	2.43
Chromium (mg/kg)	0.05	0.08
Copper (mg/kg)	0.72	0.72
Lead (mg/kg)	0.04	0.05
Zinc (mg/kg)	13	13.5

3.0 New Investigations (to Fill Knowledge Gaps)

Following review of the existing data, we carried out a gap analysis to inform what new or additional surveys were required to support the current assessment of effects on marine ecological values. We determined more information needed to make a robust assessment. Gaps identified in the ecological data were soft sediment benthic ecological beneath and adjacent to the jetty, sediment quality beneath the jetty and at reference sites, additional ecotoxicology data relating to water from the stormwater basin, and body burden of contaminants in shellfish at the jetty and at sites distant from the jetty (including Mair Bank). Consequently, we carried out the following additional analyses and surveys:

- Water quality
  - A summary of water quality in Whangarei Harbour and in the stormwater discharges (Stewart, 2020)
  - A summary of groundwater quality on the RNZ site (Tonkin & Taylor, 2020)
  - Ecotoxicology tests of RNZ Stormwater/Produced Water
  - Discharge Distribution and Dilution Modelling (MetOcean, 2020)
- Benthic sediment quality/grain size and benthic invertebrate surveys were carried out beneath and adjacent to the existing RNZ jetty (Fig. 2a [see inset]) to complement the existing information and provide a full understanding of the marine ecological values in the project area receiving environment. Sediment was also collected from three reference sites distant to RNZ (but not adjacent to significant sources of contaminants); Manganese Point, Little Munroe Bay, Urquharts Bay. In addition, two sites routinely surveyed by NRC (Sites NRC100605 and NRC100268) (Figure 5) were also surveyed for sediment quality;
- A survey of benthic invertebrate assemblages and sediment grain size on Marsden and Mair Bank was also undertaken on 31 August and 1 September 2019; and

- Oysters were collected from around the RNZ jetty and at reference sites and mussels and pipi from Mair Bank were collected for contaminant body burden analyses.

3.1 Water Quality

A summary of water quality in Whangarei Harbour and in the stormwater discharges from RNZ is contained in the Water Quality Assessment Report (Stewart, 2020). The range of contaminants that could be discharged from the site is extensive and includes PAHs, phenols, metals/metalloids, ammoniacal nitrogen, TPH, suspended sediment, faecal coliforms, sulphide, PFOS[20], PFHxS[21], PFOA[22], BTEX[23], and a range of process chemicals (see section 4 of (Stewart, 2020).

A summary of groundwater quality on the RNZ site is contained in the Groundwater Quality Assessment Report. Contaminants in RNZ perimeter well groundwater that were above the 80% ANZECC guideline that could enter the CMA include copper, iron, manganese, zinc, nitrate, and arsenic (Tonkin & Taylor Ltd, 2020). However, a survey of dissolved metals and nitrate in groundwater within temporary wells on the foreshore adjacent to Mair Bank revealed contaminants were almost all below ANZECC 80% protection level, with lead and nickel below also laboratory detection limits. Arsenic and zinc were detected above the 80% guideline but Tonkin & Taylor Ltd (2020) concluded that those metals were naturally occurring and not related to the RNZ site[24].

3.1.1 Ecotoxicology tests of RNZ Stormwater/Produced Water

Water samples were collected from the RNZ SWB and the marine receiving environment on 20 and 21 May 2019[25] (dry weather) and repeated on 21 August 2019[26] (wet weather) and sent on ice to Cawthron Institute for laboratory ecotoxicology testing. Replicate stormwater and replicate receiving environment samples were pooled separately, creating a single composite stormwater/wastewater and single composite receiving environment sample for analysis. Dilution series tests were set up using standard laboratory ecotoxicology methodology. Analyses included growth inhabitation in the green microalgae *Dunaliella tertiolecta*, survival and reburial[27] in the bivalve *Paphies australis* (pipi), survival of the amphipod *Paracorophium excavatum* and embryo larval development/survival in the bivalve *Mytilus galloprovincialis* (blue mussel).

Details on the test parameters are included in Appendix 1.

The ecotoxicology tests carried out by Cawthron (see Appendix 1) using produced water and receiving environment water collected on 20 and 21 May 2019 indicated that at a very low dilution rate of 1.1-1.23, produced water had no toxicological effects on the test organisms.

[20] Perfluorooctane sulfonate acid

[21] Perflurohexane sulfonate

[22] Perfluorooctanoic acid

[23] Benzene and o-&p-xylene

[24] Table 5.3 and following paragraphs (Tonkin & Taylor Ltd, 2020).

[25] 1.5mm of rain had fallen in the seven days prior to the sampling (Marsden Point Oil Refinery Rain Gauge).

[26] 32mm of rain fell in the previous seven days, with 22mm occurring on the 20th August (Marsden Point Oil Refinery Rain Gauge).

[27] The pipi reburial test carried out in May 2019 was inconclusive because none of the test organisms in the control and produced water replicates reburied after 60 minutes. The other ecotoxicology tests were within test parameters and those results can be relied upon.

Receiving environment water caused no significant adverse effects on the test organisms (Microalga - *Dunaliella tertiolecta*, *Paphies australis* (pipi), amphipod *Paracorophium excavatum Mytilus galloprovincialis* (blue mussel)).

Results from the same suite of ecotoxicology tests carried out by Cawthron (Appendix 1) on stormwater/wastewater and receiving environment water collected on 21 August 2019 during a rainfall event indicated that a very low dilution rate of less than 1.3 and less than 1.5 had no toxic effects on pipi survival and reburial and amphipod survival respectively. Algal growth was stimulated by stormwater/wastewater, whereas blue mussel embryo/larvae survival was negatively impacted and required a dilution of stormwater/wastewater greater than 256 times for there to be no adverse effect. It is noted that the blue mussel embryo/larvae survival test is carried out over 48 hours exposure and is the most sensitive ecotoxicology test given the early life stage of the organism. Receiving environment water caused no significant adverse effects on the test organisms. The quality of the water collected from the SWB on 20/21 May and 21 August 2019 was within the test parameters required[28].

3.1.2 Discharge Distribution and Dilution Modelling

A summary of the dilution modelling carried out by (Beamsley, 2019) is provided in the water quality assessment report (Stewart, 2020) in section 5.4. The outputs included conservative (95% percentile) concentrations of contaminants at the proposed mixing zone boundary and at nine priority sites around the mouth of the harbour.

Stewart (2020) identified that modelling indicated the lowest dilution occurs at site C3 (at the mixing zone boundary) with a 175 times dilution (duration 1-3 hours) at 24 hours following an extreme rainfall event.

Time-series dilution modelling of the discharge via the diffuser during El Niño and La Niña conditions during 2010-2011 indicates that dilution can be below 256 times at a few sites in some instances (MetOcean, 2020). The effect of lower dilution of RNZ discharges, however, depends on the quality of the discharge, duration of exposure and sensitivity of organisms present and life stages of those organisms. The sites selected for time-series dilution analyses were based on areas where the output plots from the hydrodynamic modelling indicated the highest concentration of RNZ discharges (and therefore lowest dilution), in addition to the four corners of the existing reasonable mixing zone (Figure 6).

During La Niña conditions (2010-2011) and El Niño conditions (2015-2016), the 5th percentile dilution was below 256 times at the mixing zone boundary in south east (C3), Mair Bank (P4) and west of Marsden Bank (P6) (Figure 6) less than 1% of the time. Dilution was not below 256 times at all other sites.

The lower dilution at site C3 (SE end of the mixing zone boundary) was an infrequent 1-3 hour event during the year modelled. Given that duration of potential exposure, and the very low likelihood of 2 hours exposure to less than 256 dilution combining with the presence of sensitive life stages of the most sensitive organisms, it is very unlikely that adverse effects would be occurring on organisms at this site on Marsden Bank.

Site P6 is located in a wedge-shaped area between the shoreline and the intertidal edge of Marsden Bank, where it is likely that water (and contaminants) may get trapped in an intertidal pool at low tide. It is possible that there could be adverse effects on organisms within the very

[28] For pH, temperature, TOC, Ammoniacal nitrogen, BOD5, COD, phenols, sulphides, TPH and TSS.

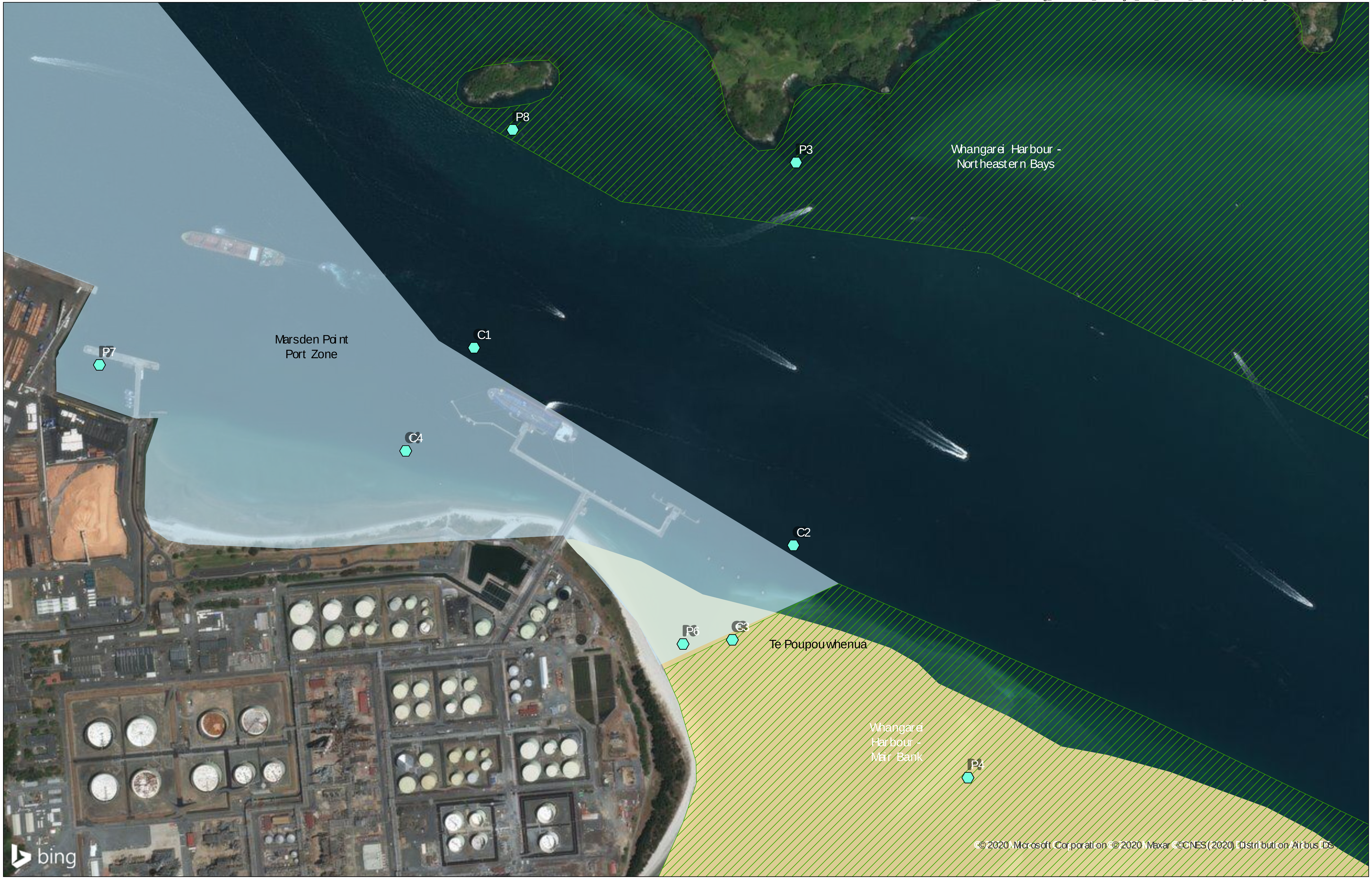
small pool area, but as per above, only if sensitive life stages of sensitive organisms are present and there is an extended period of exposure (far greater than a couple of hours) (Figure 6).

At site P4 (Mair Bank), modelling indicated that the dilution dropped below 256 very infrequently over a year, and only for 1-3 hours at a time. Given that duration of potential exposure (a couple of hours compared to 48 hours in the blue mussel larvae test), and the very low likelihood of 1-3 hours exposure to lower than 256 dilution combining with the presence of sensitive life stages of the most sensitive organisms it is very unlikely that adverse effects would be occurring on organisms on Mair Bank (Figure 6).

It is possible (but of very low likelihood) at those sites where modelling indicated periods of lower dilution of RNZ discharges and higher contaminant concentrations (e.g. due to large rainfall events) there could be adverse effects on the most sensitive life-history stage of the most sensitive organisms (if present). This conclusion is based on the result of a single ecotoxicology test on RNZ stormwater discharge on blue mussel larvae. It is considered that such effects are unlikely, as several factors would need to occur simultaneously i.e. sensitive species present (e.g. blue mussel), the sensitive species would have to have successfully spawned, larvae would have to remain present, dilution of RNZ discharges lower than 256 times would also have to occur for an extended period. Therefore, it is unlikely that an adverse effect on some sensitive individuals that are in a sensitive life history stage would result in more than negligible adverse effects on the population of that taxa nor on marine ecological functioning and values.

Pipi (also used in the ecotoxicology tests), which are present in low abundance at some sites surveyed, were unaffected in laboratory tests once the RNZ discharge had undergone low dilution (i.e. approximately 1-8 times across all three ecotoxicology surveys undertaken). From the field surveys undertaken for this proposal and existing information, there is no evidence of adverse effects on marine ecological values relating to the RNZ discharges.

File Ref: BM19109_SDe_Reconsenting_Wastewater_Discharges_from_Marsden_Oil_Refinery.aprx, Fig 28 Time Series Dilution Sites



Boffa Miskell

www.boffamiskell.co.nz

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Data Sources: MetOcean Solutions, CNES / Airbus - Pleiades dated 8 December 2018. Northland Regional Council District Plan (Decision Version)

Projection:

LEGEND

Sample Point

PNRP (Decisions Version)

Significant Ecological Areas

Areas of Significance to Tangata Whenua

Marsden Point Port Zone

BM19109 RECONSENTING WASTEWATER DISCHARGES FROM MARSDEN OIL REFINERY

Times Series Dilution Sites and PNRP Layers

Date: 23 April 2020 | Revision: C

Plan prepared by Boffa Miskell Limited

Project Manager: Sharon.DeLuca@boffamiskell.co.nz | Drawn: JWa | Checked: SDe

Figure 6

3.2 Sediment Quality

Sediment samples (top 2-3 cm) were collected (by scuba divers using a corer) at eight subtidal sites beneath and adjacent to the RNZ jetty in May 2019 and at a further five subtidal sites (three reference sites and two NRC monitoring sites) (using a box dredge) in July 2019 (Figure 5) and analysed for the following extensive range of contaminants:

- Heavy metals and aluminium
- Benzene, toluene, ethylbenzene and xylene (BTEX)
- Organonitro & Organophosphorus pesticides (OP)
- Polycyclic aromatic hydrocarbons (PAHs)
- Tributyl tins (TBT and derivatives)
- Total petroleum hydrocarbons (TPH)

Concentrations of all contaminants were well below Default Guideline Values (DGVs; (Australian and New Zealand Governments, 2018) and also below the Canadian Council of Ministers of the Environment (CCME) guidelines values (proposed to be used for metals in the pNRP)) (see graphs in Appendix 2 and Table 4 of Stewart (2020)). Only aluminium, arsenic, chromium, copper, lead, nickel and zinc were present at concentrations above laboratory detection limits[29]. All other contaminants[30] analysed including total petroleum hydrocarbons were either absent or present at concentrations at/below laboratory detection limits.

Aluminium[31], which does not have a DGV or GV and is not a metal commonly included in contaminant analyses, was detected within the reasonable mixing zone at a maximum concentration of 2,400 mg/kg (average concentration 2,030 mg/kg), and at sites RNZ2 and RNZ8 (outside of the reasonable mixing zone) the concentration was 3,300 mg/kg. Reference sites had aluminium concentration between approximately 4,000mg/kg and 6,700mg/kg. It is not uncommon to have high aluminium concentrations in marine sediment. For example, in 2008, Waikato Regional Council surveyed marine sediments in Aotea Harbour and Kawhia Harbour for an extensive range of contaminants including aluminium. Concentrations of aluminium ranged from 8,100 to 15,000 mg/kg in Aotea Harbour, and 13,000 to 26,000 mg/kg in Kawhia Harbour[32]. Both Aotea Harbour and Kawhia Harbour have predominantly rural catchments, with little urban/industrial landuse.

The 2019 survey revealed that concentrations of metals were similar within the reasonable mixing zone compared to the two sites on the boundary of the mixing zone and the two sites more remote to that boundary to the north-west and south-east. Reference sites had higher concentrations of metals compared to sites within the reasonable mixing zone Appendix 2).

Graphs have been created using data collected at sites located within the inner harbour and the outer harbour in relation to the RNZ jetty by NRC between 2002 and 2016, plus the recent 2019 data collected for this assessment (see Appendix 2)[33]. Contaminant concentrations in the 2019

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[29] Aluminium and nickel are not analysed for NRC sediment monitoring purposes. Data collected by RNZ in 2019 are presented in Appendix 2 only.

[30] BTEX, OP, PAHs, TBTs, TPH

[31] Aluminium occurs ubiquitously in natural waters as a result of weathering of rocks that contain aluminium and is the most abundant naturally occurring metal (Boegman & Bates, 1981).

[32] Data supplied by Waikato Regional Council, via Mike Stewart at Streamlined.

[33] Where a contaminant was below laboratory detection limits, half the detection limit value has been used in order to be conservative.

survey were low and chromium below the maximum detected by NRC detected 2002-2016 (Appendix 2).

3.2.1 Sediment Grain Size

The subtidal seafloor beneath the RNZ jetty is a mixture of fine and medium grain sand with shell material also present at some sites. Photographs of the general nature of the substrate at sites RNZ1-4 and RNZ6-8 are shown below (Photograph 10 to Photograph 17).

Photograph 10: Site RNZ1 – 2019 Survey

Photograph 11: Site RNZ2 – 2019 Survey

Photograph 12: Site RNZ3 – 2019 Survey

Photograph 13: Site RNZ4 – 2019 Survey

Photograph 14: Site RNZ5 – 2019 Survey

Photograph 15: Site RNZ6 – 2019 Survey

Photograph 16: Site RNZ7 – 2019 Survey

Photograph 17: Site RNZ8 – 2019 Survey

Sediment grain size distribution at sites RNZ1-8 beneath and adjacent to the RNZ jetty, indicated that all sites are dominated by medium and fine sand fractions. Sites RNZ4-7 had slightly higher proportions of coarse sand compared to other sites (Figure 7).

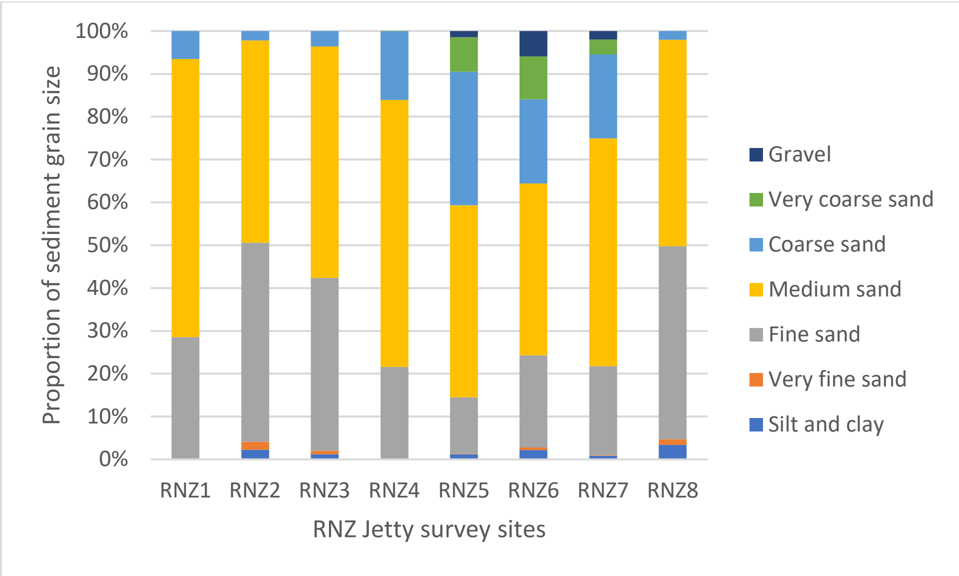


Figure 7: Proportion of sediment grain size at and adjacent to the RNZ jetty

The survey on Mair (sites M1-6) and Marsden Bank (sites M7-10) (Figure 9) revealed that sediments are typically dominated by fine sand, medium sand and shell/gravel (Figure 8), which is expected given that Mair and Marsden Bank are shell banks. Site M9 was in sand ripple habitat, and as such shell/gravel forms a small proportion (approximately 6%), whereas coarse sand was highest at this site (approximately 40%) (Figure 8).

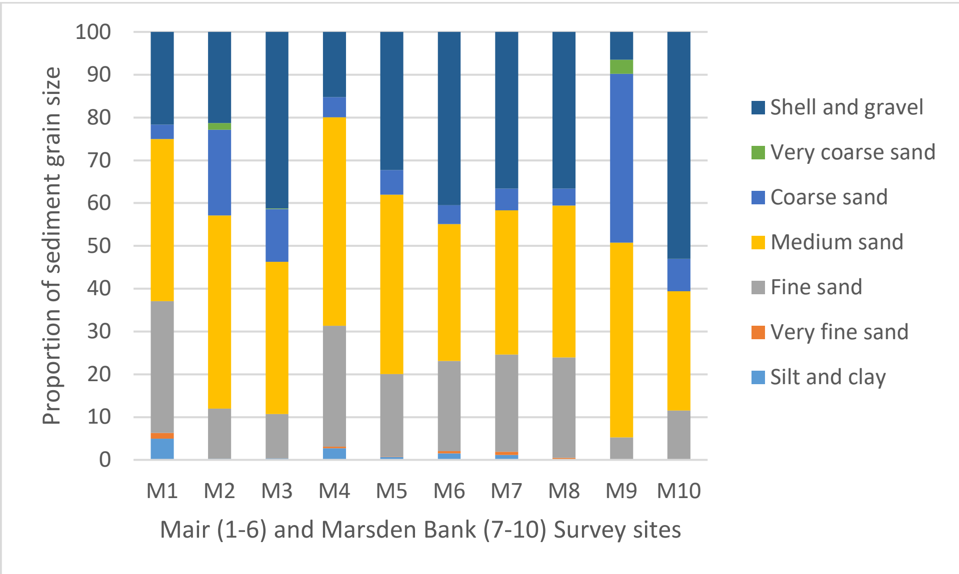
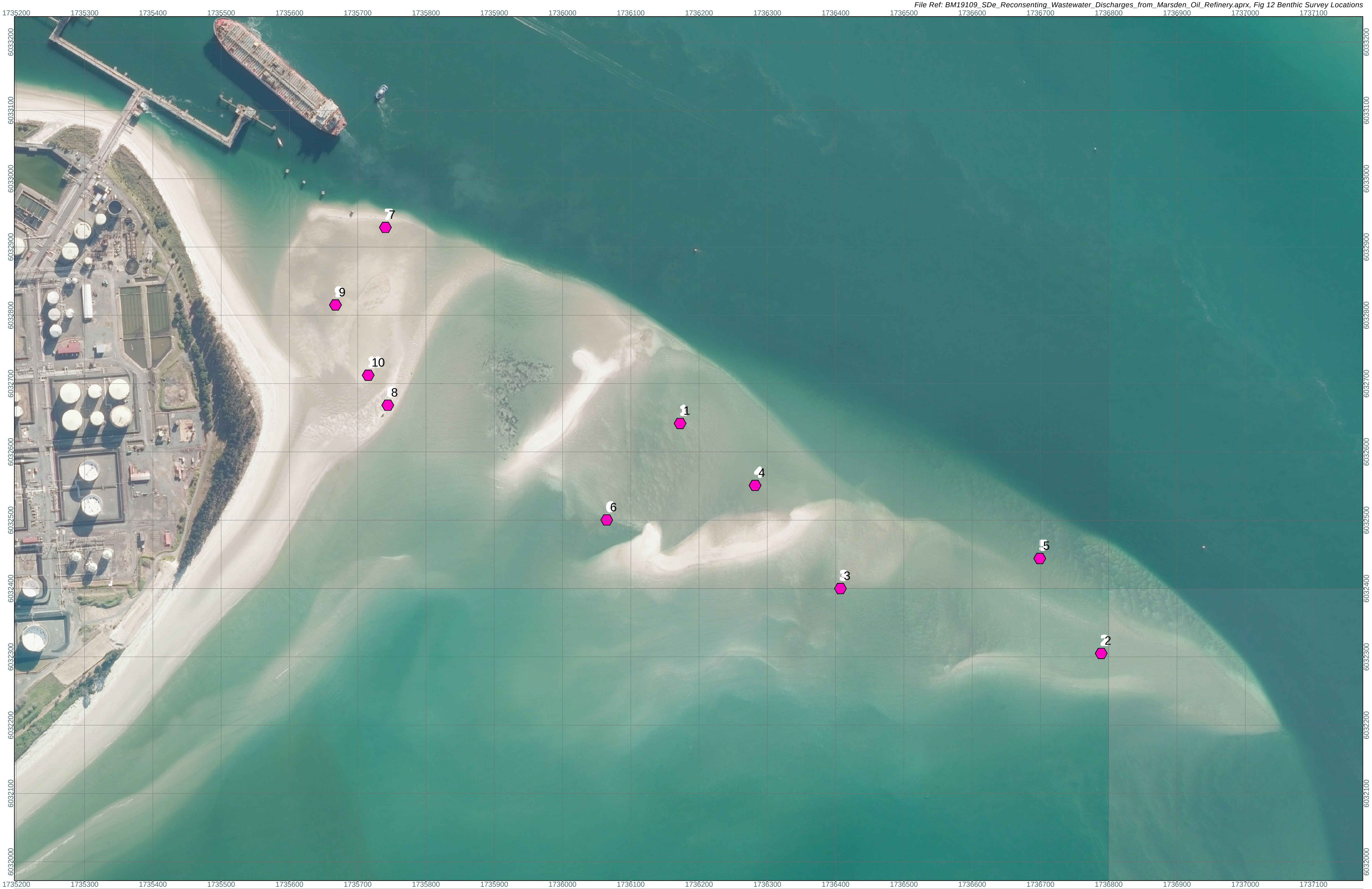


Figure 8: Proportion of sediment grain size at intertidal and shallow subtidal sites at Mair and Marsden Bank

File Ref: BM19109_SDe_Reconsenting_Wastewater_Discharges_from_Marsden_Oil_Refinery.aprx, Fig 12 Benthic Survey Locations



Boffa Miskell

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0 100 m

1:5,000 @ A3

Data Sources: LINZ, BML, Kerr and Associates

Projection: NZGD 2000 New Zealand Transverse Mercator

LEGEND

Benthic Survey Site

BM19109 RECONSENTING WASTEWATER DISCHARGES FROM MARSDEN OIL REFINERY

Mair and Marsden Bank Survey Locations

Date: 11 June 2020 | Revision: 0

Plan prepared by Boffa Miskell Limited

Project Manager: sharon.deluca@boffamiskell.co.nz | Drawn: MDu | Checked: SDL

Figure 9

3.3 Marine Ecology

3.3.1 Subtidal Benthic Invertebrates

In May 2019, five subtidal sediment core samples were collected at each of eight sites, four sites beneath the RNZ jetty (RNZ3-6), at the previous reasonable mixing zone boundaries (RNZ 2 and 7) and outside of the mixing zone boundary to the north-west and east (RNZ 1 and 8) (Figure 5). Cores were 138mm diameter and 150mm deep, sieved through a 0.5mm mesh and analysed for benthic invertebrate taxa (as per methodology used in Kerr (2016).

Benthic invertebrate data was analysed by abundance, species richness, Shannon-Wiener diversity index and taxa groups as proportions of abundance.

There was high variability in abundance among sites, with RNZ2, 3 and 8 having the highest number of individuals (approximately 250-270) and RNZ having the lowest abundance with 14 organisms per core (Figure 10).

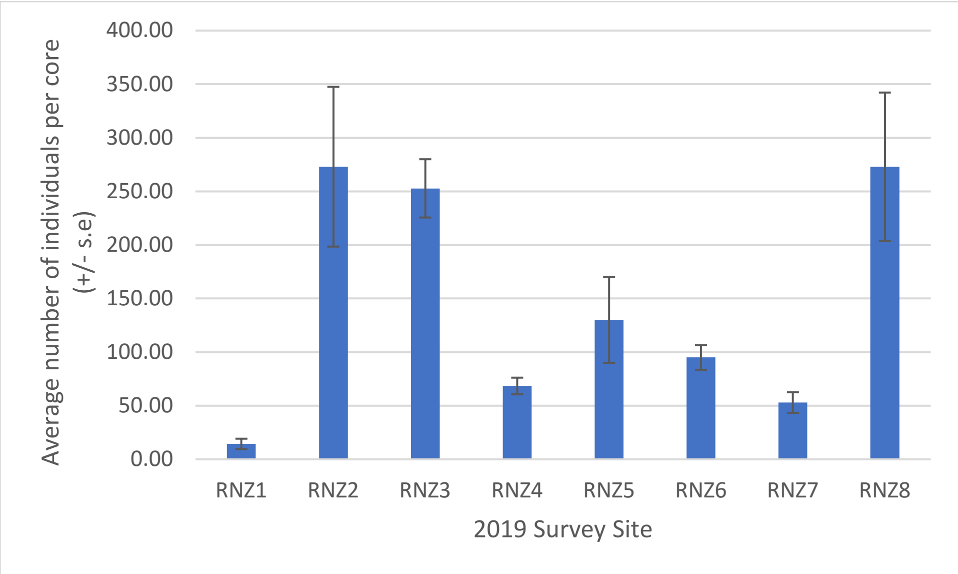

Figure 10: Average number of individuals

The number of taxa per core for most sites varied between 15 and 30, apart from RNZ1 which had approximately 7 taxa (Figure 11).

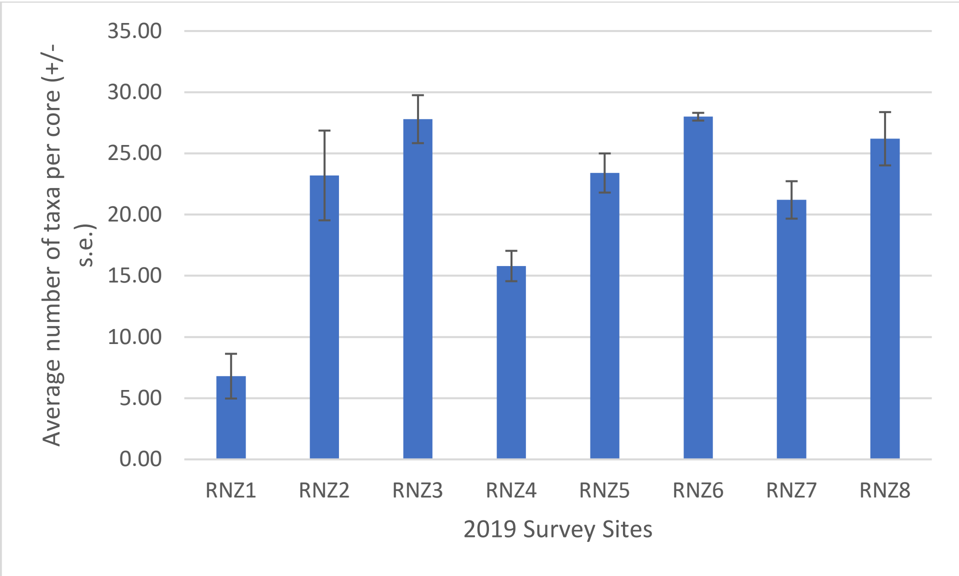

Figure 11: Average number of taxa

Shannon-Wiener Diversity Index (SW) is a measure of the evenness of the spread of abundance of organisms across the range of taxa present[34]. SW was highest within the reasonable mixing zone, with Site RNZ6 having the highest average SW (approaching 3) and lowest at site RNZ1 (c. 1.5) (Figure 12). Sites RNZ1 and RNZ2 had moderate diversity (1-1.5), whereas sites RNZ3-8 had high diversity (>2) (Figure 12).

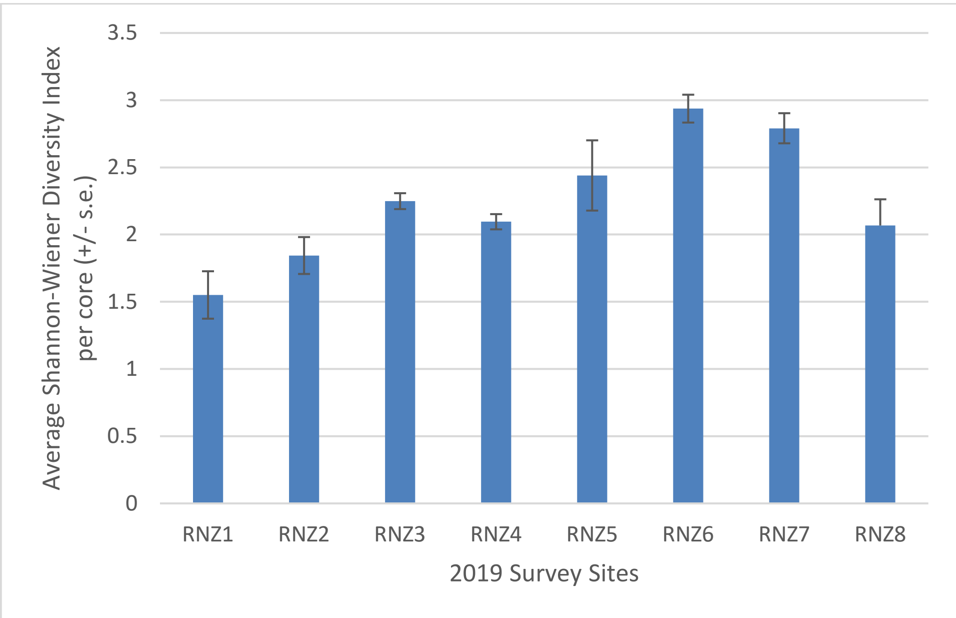

Figure 12: Average Shannon-Wiener Diversity Index

[34] Communities with a large number of species that are evenly distributed are the most diverse and communities with few species that are dominated by one species are the least diverse. In general terms, a diversity index of less than 1 indicates very low to low diversity, between 1 and 1.5 indicates moderate diversity, >1.5 indicates moderate to high diversity and >2 indicates high diversity.

The main taxa groups were similar across the sites, with ostracods, polychaete worms, bivalves and gastropod dominating the assemblages, with both sensitive (e.g. heart urchins (*Echinocardium cordatum*), a range of filter feeding bivalves, and spionid polychaete *Aonides trifida*) and tolerant (e.g. capitellid polychaetes *Capitella capitata* and *Heteromastus filiformis*, oligochaete worms) species present (Figure 13).

Within sites RNZ1-8, the most abundant organisms were juvenile snails from the Rissoidae family, the bivalve *Myllitella vivens vivens*, spionid polychaetes *Polydora* sp and *Pseudopolydora corniculata*, capitellid polychaete *Capitella capitata,* syllidae polychaetes, oweniid polychaete *Myriochele* sp., serpulidae polychate *Hydroides* sp., and ostrocods *Diasterope grisea*, *Parasterope quadrata*, *Phylctenophora zealandica*, *Scleroconcha* sp. (Figure 13).

Sites RNZ2[35], RNZ5 and RNZ8 had very high abundance of polychaete worms, with all three sites having a high abundance of the spionid polychaete *Polydora* sp[36]. Spionid polychaete worms are known to be common to extremely abundant in shallow water with fine sands. In addition, each site also had high abundances of other polychaete taxa, which were different among those sites (Figure 13).

The spionid polychaete *Pseudopolydora cornicula* and capitellid polychaete *Capitella capitata* were also present in high abundance at Sites RNZ2 and RNZ3 compared to all other sites. Capitellid polychaetes are typically known as tolerant of a range of environmental conditions (Figure 13).

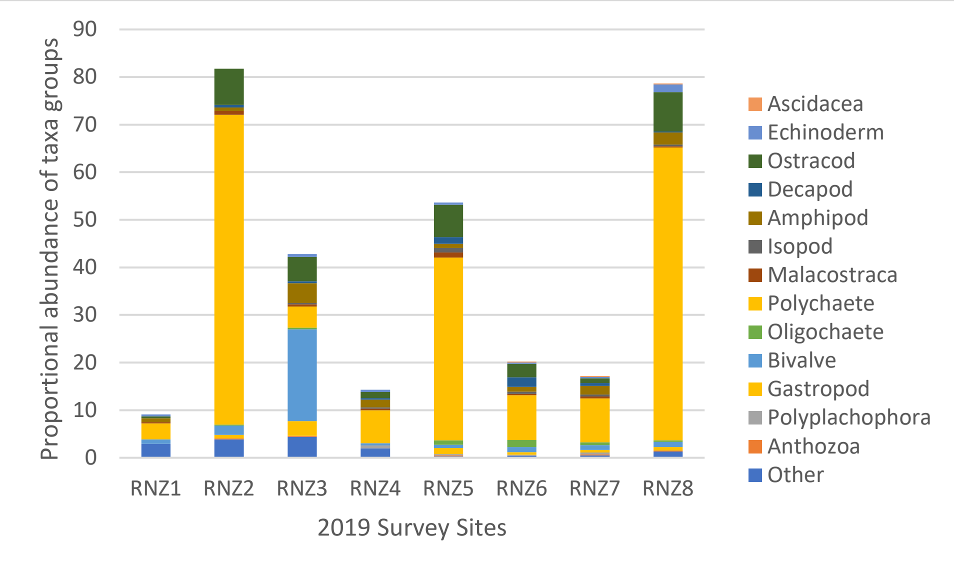

Figure 13: Proportion of abundance of main taxa groups

For the purposes of characterising the benthic invertebrate community in a wider area, as well as the 2019 data which is focused on the discharge area, within the mixing zone and outside of the mixing, we have selected seven sites that were surveyed in 2015 that were located in the general vicinity of the RNZ jetty and in similar habitats/hydrodynamic environments: three sites located up harbour (T11D, T11E, T11F), three sites located down harbour (T7B, T8B, T14B),

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[35] In January and February 2019, RNZ and Northport carried out maintenance dredging in the vicinity of the Port turning basin and the RNZ jetty. The approach to RNZ jetty 1 was dredged to maintain water depth. The dredged area included site RNZ2 (Figure 5)[35].

[36] Many *Polydora* species live in tubes in sand, whereas other species burrow into shells

and one site across the harbour (T9C) (Figure 5). We note it is not possible to statistically compare the 2015 and 2019 data as the samples were collected in different years, season, by different scientists etc. However, the 2015 data provides a characterisation of the types of benthic species and community composition in the wider area.

The assemblages adjacent to the RNZ jetty analysed in 2015 (V. C. Kerr, 2016) have a similar suite of taxa groups (Figure 16). The average number of individuals ranged between less than 20 to approximately 100 per core (Figure 14), and the average number of taxa detected ranged between less than five and approximately 20 per core (Figure 15)[37].

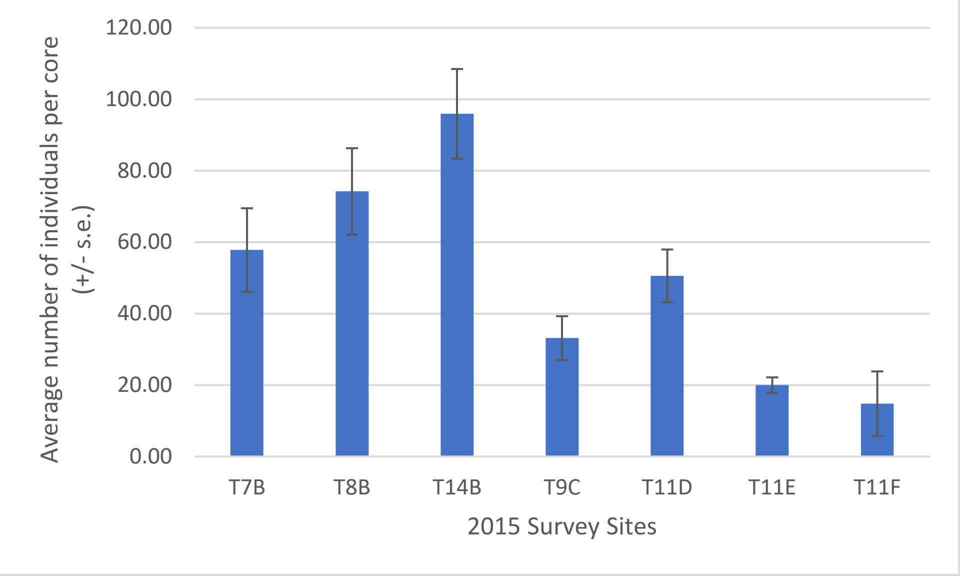

Figure 14: Average number of individuals

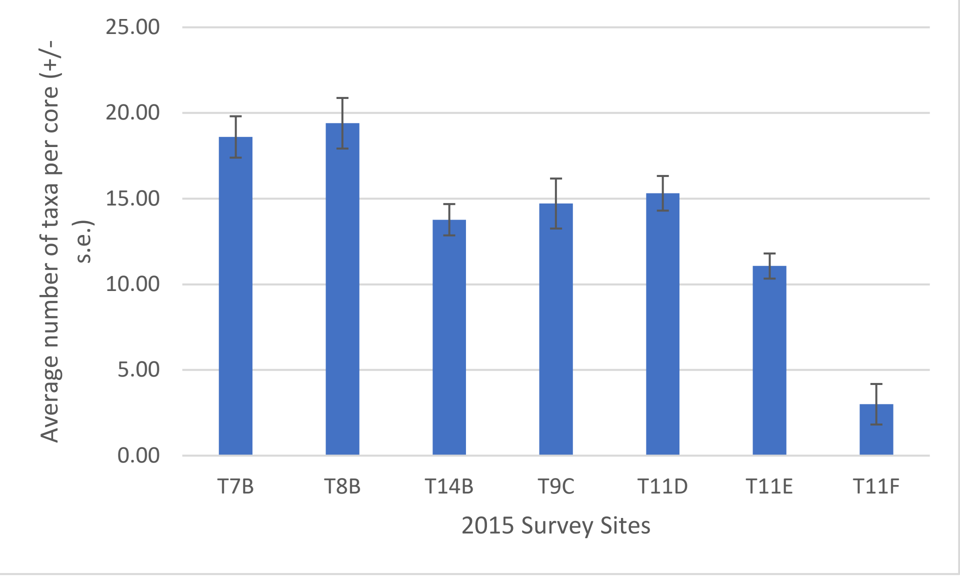

Figure 15: Average number of taxa

Common abundant taxa between the 2019 and the selected sites surveyed in 2015 included Rissoidae family juvenile snails, syllidae polychaetes, serpulidae polychaete *Hydroides* sp., and

[37] Noting again that the 2015 and 2019 data sets cannot be statistically compared due to being collected in different seasons and years.

ostracods (not identified to species level). Other species that were found in high abundance in 2015 at the selected sites but not in the 2019 data set included nematode roundworms, the bivalve *Ruditapes largillierti*, oligochaete worms, the spionid polychaete *Prionospio* sp., the syllid polychaete *Sphaeosyllis* sp., serpulidae polychaetes (not *Hydroides* sp.), and an unidentified amphipod.

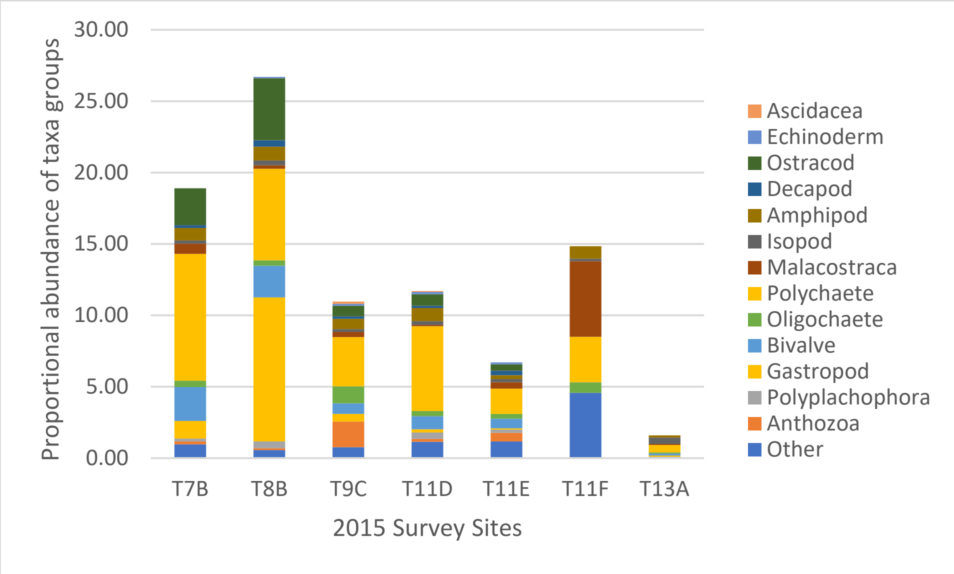

Figure 16: Proportion of taxa groups of abundance

The list of taxa detected in the 2015 survey and the 2019 survey was reviewed for the presence of species or groups of organisms that are known to have some sensitivity or tolerance to environmental perturbations (e.g. contaminants, sediment grain size, water quality) based on both New Zealand and overseas literature (see Appendix 3)[38]. There were approximately the same number of taxa or groups of organisms that have some sensitivity to contaminants, organic enrichment or silt and clay compared to those who are tolerant of contaminants, organic enrichment or silt and clay. The literature only provided information on approximately half the species or groups of taxa, but from the information available the community appears to have a balance of sensitive and tolerant species/taxa groups.

The 2019 data indicates that the benthic soft sediment assemblage beneath and adjacent to the RNZ jetty is abundant and diverse, containing both sensitive and tolerant taxa. The 2015 data indicates a similar suite of organisms are present in the wider area.

3.3.2 Marsden and Mair Bank Benthic Invertebrates and Sediment Grain Size investigation

At two hours either side of low tide on 31 August and 1 September 2019, surveys of intertidal and shallow subtidal benthic invertebrate assemblages and sediment grain size was undertaken at ten representative sites (four sites on Marsden Bank and six on Mair Bank) (Figure 9). Views of the banks, substrate types, and some of the survey sites are shown in Photograph 18 to Photograph 33. Sites M2, M5 and M6 were in shallow subtidal habitat and photographs were

[38] Not all species have been studied for sensitivity or tolerance to contaminants, sediment grain size or water quality.

not collected at those sites, but field observations were that the habitat type was similar to that at Site M1.

At each site, three replicate cores and a single surface (top 2-3cm) sediment sample were collected. Benthic invertebrate cores were 138mm diameter and 150mm deep, sieved through a 0.5mm mesh, preserved in ethanol and analysed for benthic invertebrate taxa by an independent taxonomist (as per methodology used in Kerr (2016)). Surface sediment samples were held on ice and shipped to University of Waikato for grain size analysis.

The invertebrate community differed between Mair and Marsden Bank despite the two sites having a similar sediment grain size profile (dominated by fine-coarse sand with variable (but generally high) proportion of shell/gravel), with Mair Bank have a highly diverse and abundant community and Marsden having moderate diversity and abundance (Figure 18 to Figure 22). Periodic accretion of sand has been observed on Marsden Bank, especially during south-easterly / easterly storms (Kerr pers. comm.) which, if deposited at a depth of greater than 10mm, may smother the benthic invertebrates and reset the community composition with early colonising species re-establishing first (e.g. oligochaete and polychaete worms, and amphipods). Stewart (2020) and Williams (2017) identify significant changes in sediment grain size composition on Marsden Bank in 2012, 2014 and 2016. In 2012, the composition was approximately 70% medium sand, 20% coarse sand and gravel, and 10% very fine and fine sand. In 2014, the composition had changed to 80% very fine and fine sand, 15% medium sand and 5% coarse sand and gravel. In 2016, coarse sand and gravel comprised 50% of the sediment, with very fine and fine sand forming 40% and medium sand 10%. This high variability in sediment grain size composition is consistent with the observations of changes to surface sediment texture on the bank (Kerr pers. comm; Williams, 2017) and is consistent with the hypothesis of the benthic community of Marsden Bank being made up of species that can cope with changing sediment profile and species that rapidly colonise disturbed environments.

Photograph 18: View from Marsden Bank to RNZ jetty.

Photograph 19: View from Marsden Bank across to Refinery, dolphins and jetty.

Photograph 20: View from Marsden Bank towards Mair Bank

Photograph 21: View from Marsden Bank towards Mair Bank

Photograph 22: Site M7 substrate on Marsden Bank

Photograph 23: Site M7 on Marsden Bank

Photograph 24: Site M9 substrate on Marsden Bank

Photograph 25: Site M9 on Marsden Bank

Photograph 26: Site M8 substrate on Marsden Bank

Photograph 27: Site M8 on Marsden Bank - broad sand ripple habitat

Photograph 28: Site M4 substrate on Mair Bank

Photograph 29: Site M4 on Mair Bank

Photograph 30: View from Mair Bank towards Marsden Bank and the refinery

Photograph 31: High density empty pipi shells on Mair Bank

Photograph 32: Site M1 on Mair Bank

Photograph 33: Site M3 on Mair Bank

The intertidal and subtidal soft sediment assemblages contain species that are known to be sensitive to contaminants and silt and clay (suspended and deposited) as well as species considered tolerant.

The abundance of benthic invertebrates was high on Mair Bank, markedly higher (361-1022 per core sample) than the abundance on Marsden Bank (19-107 organisms per core sample) (Figure 18). This difference in abundance was largely driven by Mair Bank samples having very high abundance of the Rissoidae (family) microsnails (1-2mm) (96-837 per core sample), which, while present in Marsden Bank samples, were in much lower abundance (0-59 per core sample) (Figure 18).

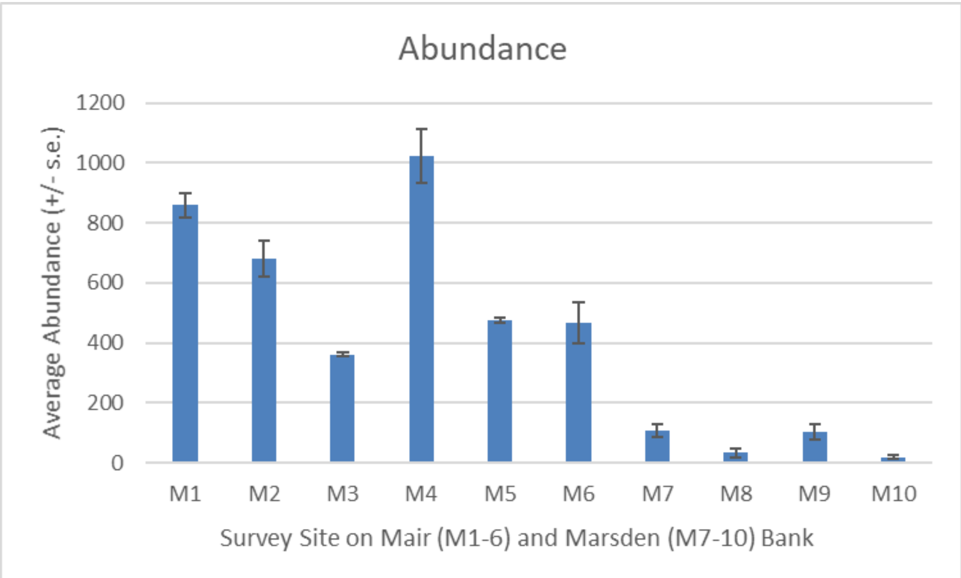

Figure 17: Average abundance of individual benthic invertebrates on Mair and Marsden Bank (+/- s.e.)

Mair Bank has a high number of taxa, higher (24-38 per core sample) than that detected at Marsden Bank (6-19 per core sample) (Figure 19).

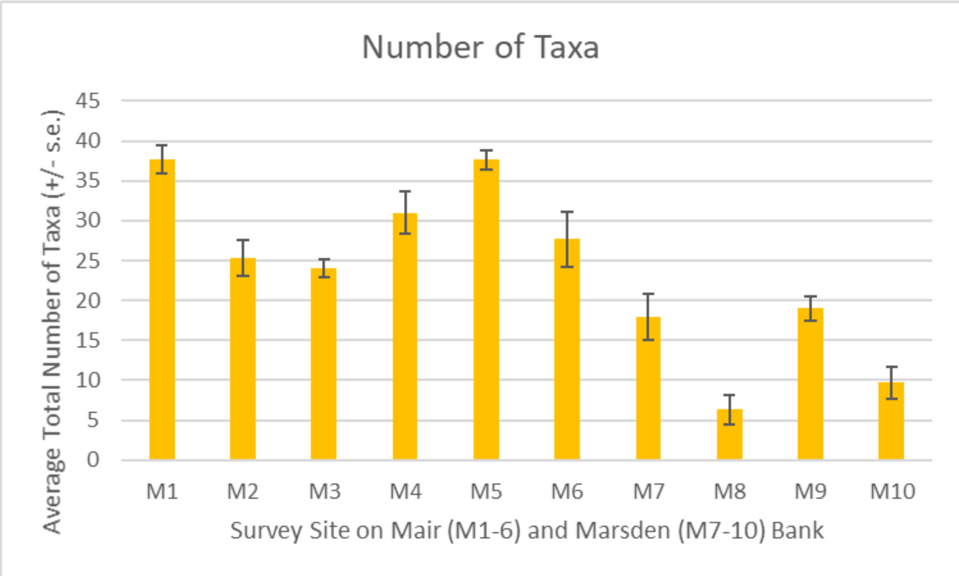

Figure 18: Average number of benthic invertebrate taxa on Mair and Marsden Bank (+/- s.e.)

The higher abundance of individual benthic invertebrates on Mair Bank compared to Marsden Bank is largely driven by Rissoidae microsnails, nematode worms and amphipods (Figure 20).

Some of the first organisms that are likely to colonise Marsden Bank after episodes of sand deposition are the smaller soft-bodied organisms with short life cycles e.g. polychaete, oligochaete and nematode worms, amphipods and isopods and copepods.

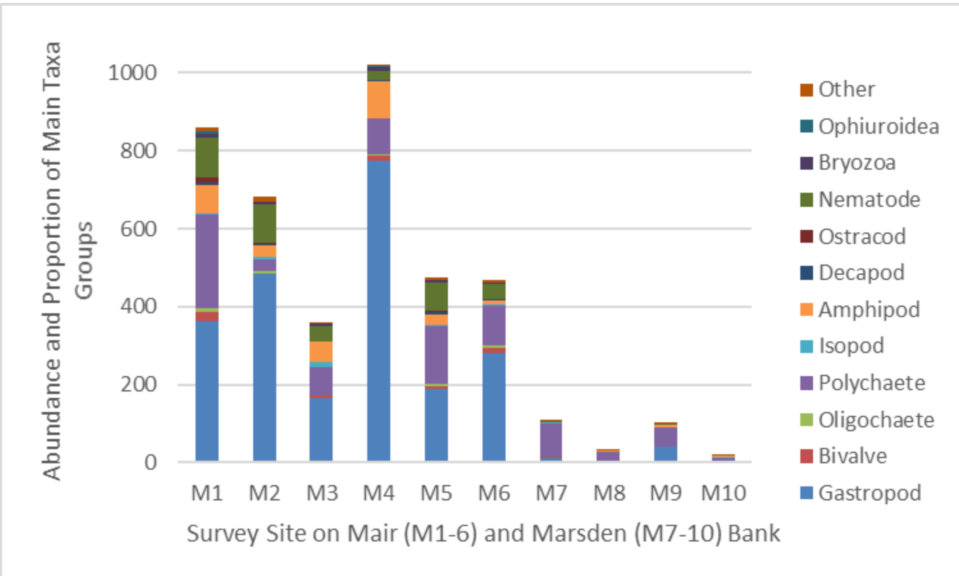

Figure 19: Proportion of main taxa group abundance at Mair and Marsden Bank

Shannon-Wiener diversity index was similar between sites on Mair and Marsden Bank, with indices ranging between just greater than 1 (moderate diversity) and just greater than 2 (high diversity) (Figure 21).

One pipi (*Paphies australis*) was found at Site M4 on Mair Bank and Site M10 on Marsden Bank. A single cockle (*Austrovenus stutchburyi*) was detected at Site M7 on Marsden Bank, whereas the thick lipped biscuit shell *Ruditapes largillierti* (which looks very similar to cockles) was detected at sites M1-M4 in reasonable abundance, but in very low numbers on Marsden Bank.

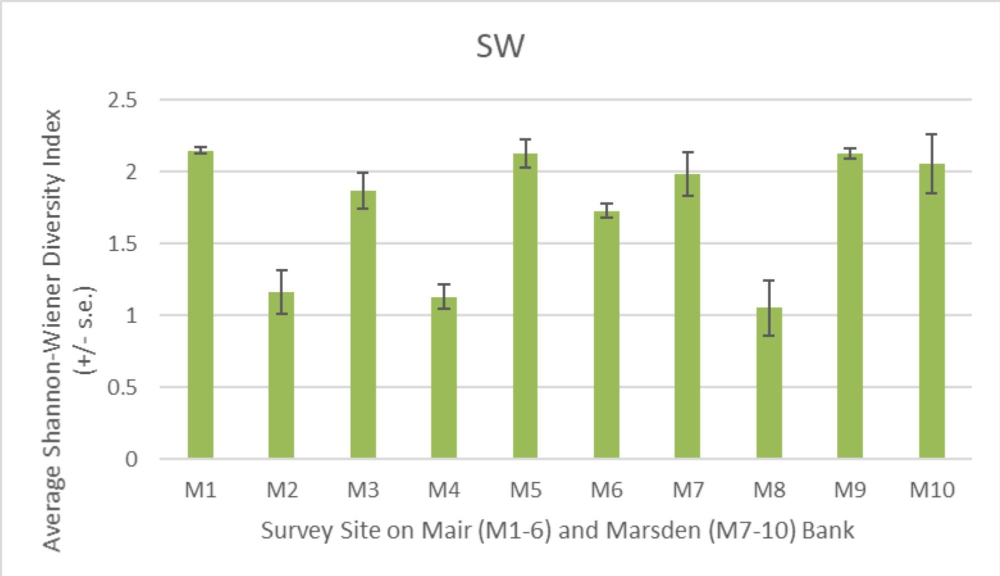

Figure 20: Average Shannon-Wiener Diversity Index for benthic invertebrate assemblages on Mair and Marsden Bank (+/- s.e.)

A non-metric multi-dimension scaling (n-MDS) plot was creating using Primer 7 software. The n-MDS plot shows the differences and similarities in benthic invertebrate assemblages in 2-dimensional space, with samples that are close together having similar assemblages and samples that are separated spatially have different assemblages. The plot clearly shows that the Mair Bank sites are all clustered close together and therefore are samples are similar to each other, whereas the Marsden Bank samples are distant from the Mair Bank samples, indicating that assemblages are different between the two Banks. Marsden Bank samples do not cluster together, with sites being quite distinct from each other. Site M8 samples are separated out, as are Site M10 samples, indicating that the assemblage at Site M8 is different to the other Marsden Bank samples, and that the assemblage at Site M10 is different to the other Marsden Bank samples. There is some similarity in assemblages between Site M9 and one sample collected at Site M7 (M7A), where the other two samples from Site M7 have different assemblages to all other samples collected (Figure 22).

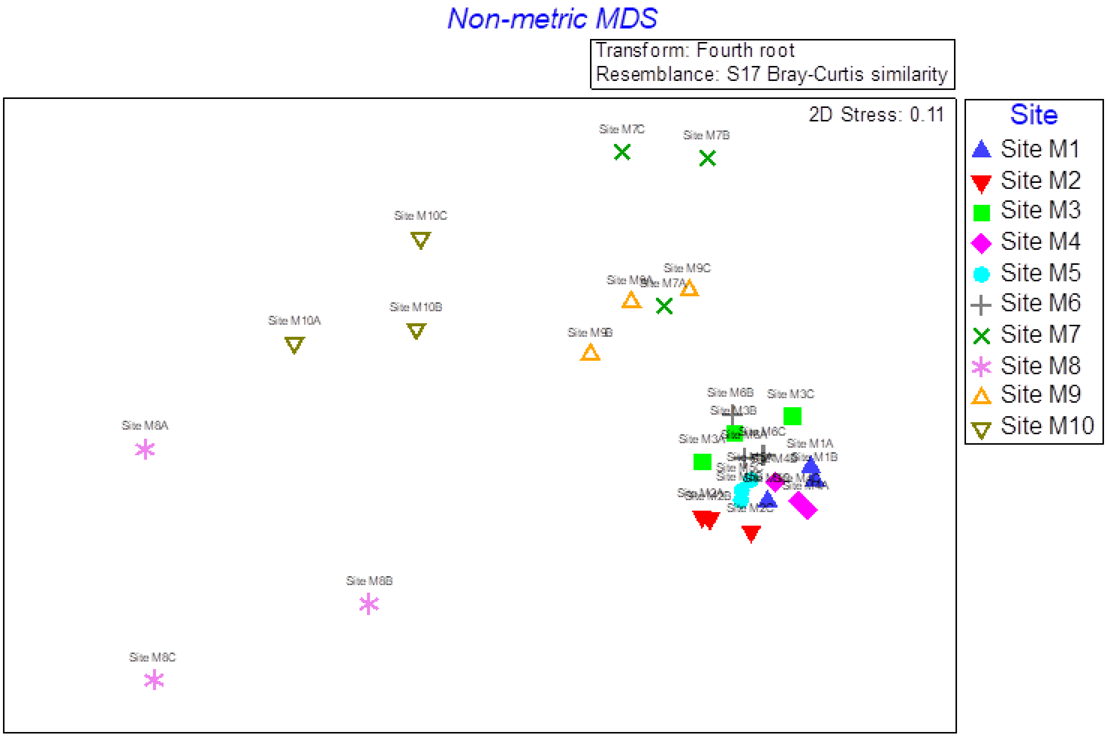

Figure 21: Non-metric multi-dimensional scaling (n-MDS) plot of benthic invertebrate assemblages at Mair (Sites M1-6) and Marsden (Sites M7-10) Banks.

Overall, it can be concluded that Mair Bank has a high species richness and abundance of benthic invertebrate organisms and relatively similar assemblages across sites, whereas Marsden Bank has a moderate species richness and abundance, with assemblages being relatively dissimilar between sites surveyed The greater variability between assemblages at Marsden Bank may reflect a pattern of repeated disturbance from periodic accretion of sand that has been observed on the Bank (Kerr pers. comm).

3.4 Shellfish Contaminant Body Burden

Pacific oysters (*Crassostrea gigas*) (c. 30 individuals at each site) were collected in May/June 2019 from structures at four sites[39] at or adjacent to the RNZ jetty (Figure 5, Photograph 34), in addition to three rocky shore reference sites distant to the jetty (Manganese Point, Little Munroe Bay, Urquharts Bay) (Figure 5, Figure 1). In September 2019, after obtaining permission from the Ministry for Primary Industry, shellfish were collected within the rahui area. Oysters were collected from A8 Dolphin, and pipi and mussels were collected from Mair Bank. Shellfish were shucked and the visceral mass (flesh) sent to Watercare Laboratory Services for the analysis of metals (including aluminium and nickel), organics (including polycyclic aromatic hydrocarbons (PAHs) and phenols), and total petroleum hydrocarbons (TPH) on replicate composite samples (three oyster, three mussel and two pipi).

The concentrations of individual PAHs were combined to form an assessment of total PAHs, three fractions of TPH were combined to form total TPH, and similarly methyl phenols, dimethyl

[39] The raw data sheets refer to Jetty A, B, C and D. To clarify, Jetty A is approximately located at RNZ 5, Jetty B is located at RNZ 7, Jetty C is located at RNZ 4 and Jetty D is located at RNZ 3 (Figure 4).

phenols, chlorophenols and phenol were combined to form an assessment of total phenols. Metals were assessed individually.

Oyster samples were collected from the three reference sites (Manganese Point, Little Munroe Bay and Urquharts Bay) and three sites at the RNZ jetty (Sites RNZ3-5) and analysed for body burden of fire-fighting foam contaminants that could be discharged via the canal system to the retention basin and SWB (Figure 5).

Where the concentration of a contaminant was below laboratory detection limits, the detection limit was used as the concentration in order to be conservative.

Photograph 34: Piers beneath the RNZ jetty (showing intertidal oysters attached to piers).

Photograph 35: Manganese Point (with oysters naturally present on the intertidal rocky shore).

Photograph 36: Little Munroe Bay (with oysters naturally present on the intertidal rocky shore).

Photograph 37: Urquharts Bay (with oysters naturally present on the intertidal rocky shore).

3.4.1 Literature on differences in uptake of contaminants among species

There are a number of studies that have compared the uptake of metals by various bivalve species. A study in New Zealand detected that blue mussel (*Mytilis edulis*) took up chromium and nickel more so than zinc, lead and copper (Brooks & Rumsby, 1965). That same study determined that *Ostrea sinuata*[40] (now *O. lutaria*) took up cadmium and zinc more so than chromium, copper, nickel and lead, and that scallops (*Pecten novae-zelandiae*) took up cadmium and chromium more so than zinc, nickel, lead and copper. Findings from a study in Wellington Harbour noted that there were differences in the uptake of copper, lead and zinc between blue mussel and green lipped mussel (*Perna canaliculus*) (Anderlini, 1992).

International studies also indicate differences in the uptake of contaminants between different bivalve species. Cadmium, copper and zinc were found to be higher in oysters (*Crassostrea rivularis*) compared to mussels (*Perna viridis*) and biscuit shell (*Ruditapes philippinarum*) (Fang, Cheung, & Wong, 2003). Those authors postulated that different habitats and feeding strategies contributed to the differences between species, with mussels and clams being intertidal, where the oyster they studied was a subtidal species. A study of heavy metals in mussels and oysters in Trinidad and Venezuela indicated that mussels accumulated cadmium, mercury and zinc from contaminated sediments more so than oysters (Rojas de Astudillo, Chang Yen, & Bekele, 2005). A study in the Sea of Japan, comparing the uptake of metals between mussels (*Crenomytilus grayanus*) and oysters (*Crassostrea gigas*) revealed a more pronounced accumulation of copper, lead and zinc by oysters compared to mussels (Shulkin, Presley, & Kavun, 2003). These data indicate that not only are there differences in the uptake of heavy metals between types of shellfish (i.e. between mussels and oysters), but that there are also differences in uptake between species of one type of shellfish (e.g. *Crassostrea rivularis* vs *Crassostrea gigas*).

3.4.2 Project body burden data

Interpretation of the shellfish contaminant data below, therefore, must consider differences between species in the uptake of heavy metals and different habitats (oysters are not in contact with sediment, whereas the mussel and pipi collected from Mair Bank are in contact with sediment). In addition, the Mair Bank pipi and mussel samples and the A8 Dolphin oyster samples were collected in a different season (spring) than the other oyster samples (winter), which can have an influence on proportion of lipids within gametes and consequently the accumulation of contaminants[41].

All samples collected had detectable concentrations of metals. Detection of individual PAHs and phenols varied among samples and sites, with some above laboratory detection limits and some below. For all samples analysed, chlorophenols and TPH were below laboratory detection limits and are not discussed further.

Total phenols were highest in oysters collected from Northport rocks (average approximately 250 ng/g), with RNZ 3, 4, 5 and 7 having the next highest concentrations (approximately average between 150-200 ng/g). Mair bank pipi and Urquharts Bay had the lowest concentration of total phenols (Figure 23). The two other reference sites (Little Munroe Bay and Manganese Point) had phenol concentration between 100-125 ng/g. Sentinel shellfish monitoring in 2005/2006 revealed a phenol concentration of 170 ng/g at the mixing zone boundary, which is similar to the 2019 data.

A number of laboratory studies have been carried out on the effect of phenols (at various concentrations in water and various exposure periods) on aquatic organisms. The mussel (*Perna viridis*) suffered slight impaired sperm morphology when exposed to phenol at 500 mg/L

[40] Foveaux Strait oyster

[41] Many contaminants accumulate in lipid rich tissue e.g. when gametes are ripening in spring and summer.

(Au, Chiang, & Wu, 2000), whereas the LC50 concentration for mud crab (*Panopeus herbstii)* was 52.8 mg/L (Key & Scott, 1986).

Surface water and ground water quality analyses for this Project revealed concentrations of phenols and PAHs below ANZECC guidelines (Table 6, Stewart 2020). Therefore, the primary source of these contaminants in oysters is unlikely to be RNZ. Phenols and PAHs are ubiquitous in the environment and are derived from a large range of sources. Phenols arise from industrial, agricultural, domestic and municipal waste, plus there are natural sources. PAHs can arise from pyrogenic (incomplete combustion), petrogenic (formed during crude oil maturation) and biological sources (Stewart, 2019).

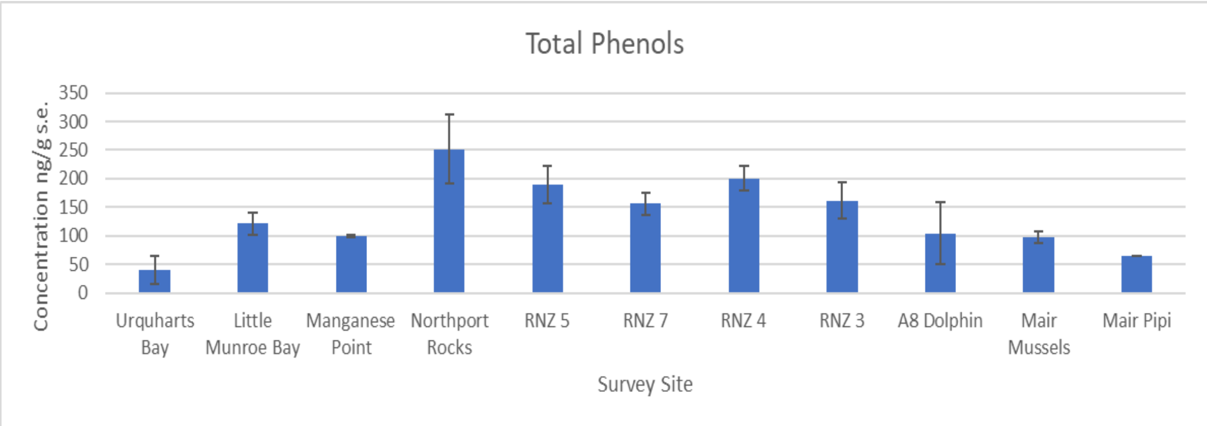

Figure 22: Concentration of total phenols in oyster flesh at various sites in Whangarei Harbour, and mussel and pipi flesh on Mair Bank.

PAHs were also highest at Northport Rocks (approximately 250 ng/g), but the three reference sites and RNZ3 and 5 jetty sites were close to the concentration detected at Northport Rocks (approximate range 200-235 ng/g). Mair Bank pipi and mussels had the lowest concentration of total PAHs (Figure 24).

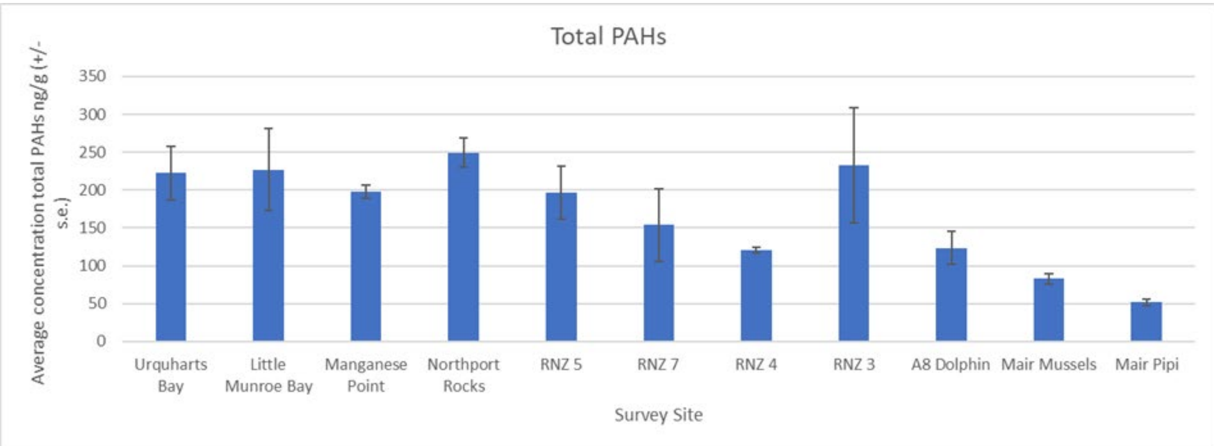

Figure 23: Concentration of total PAHs in oyster flesh at various sites in Whangarei Harbour, and mussel and pipi flesh on Mair Bank.

Aluminium was highest in mussels and pipi collected from Mair Bank (approximately 85-110 mg/kg), with the highest concentration in oysters was at Northport rocks (approximately 60 mg/kg). Relatively low concentrations were detected in oysters associated with the RNZ jetty (maximum approaching 40 mg/kg) (Figure 25).

Section 3.2.2 above summarises the ubiquitous nature of aluminium in marine sediments in Whangarei Harbour and other harbours. It is unlikely that aluminium is derived from RNZ.

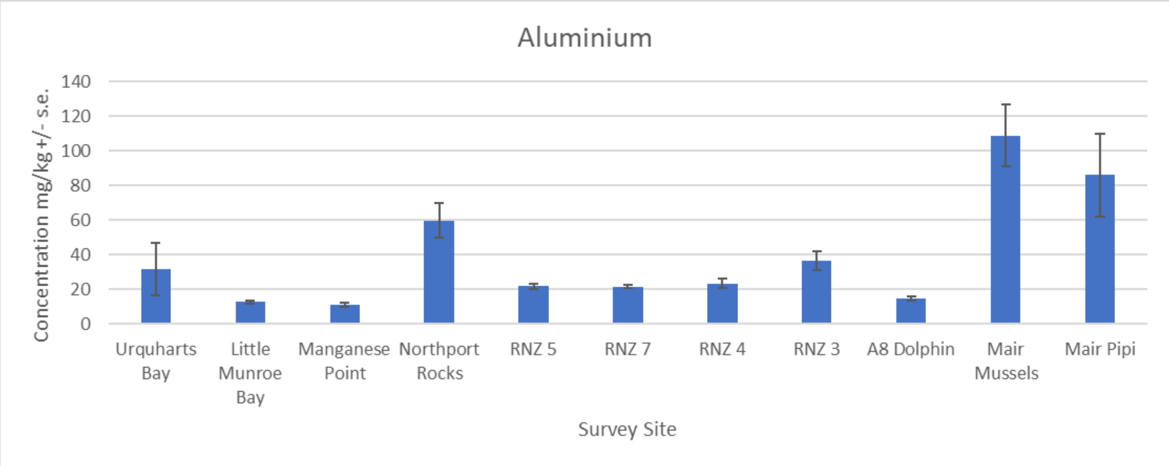

Figure 24: Concentration of aluminium in oyster flesh at various sites in Whangarei Harbour, and in mussel and pipi flesh on Mair Bank.

Arsenic concentrations in shellfish were fairly similar across all sites (2-3 mg/kg), with only Northport rocks (approaching 4 mg/kg) and A8 Dolphin (just above 3 mg/kg) recording concentrations above 3 mg/kg. RNZ4 had the lowest concentration of just below 2 mg/kg (Figure 26). NRC survey of shellfish body burden in 2012 revealed similar concentrations (2.3-5.6 mg/kg), with the highest concentration in cockles from Parua Bay.

The median concentration of arsenic in the RNZ discharge from the stormwater basin is 0.002 mg/L (Table 6, Stewart 2020). However, given that the distribution of arsenic is wide within harbour sediments (and highest at reference sites in the 2019 survey), it is unlikely that the source of arsenic in oysters at the sites surveyed is the RNZ discharge.

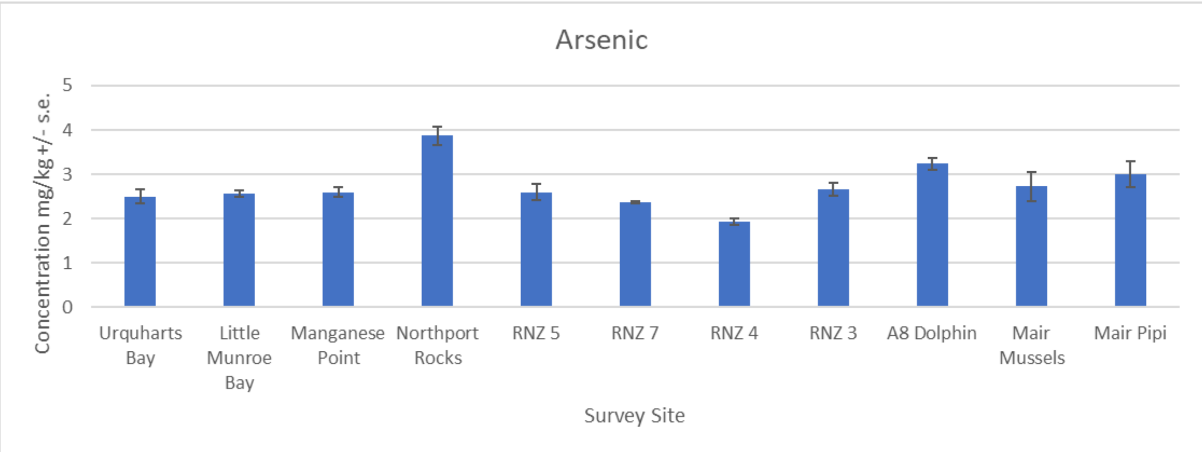

Figure 25: Concentration of arsenic in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

Chromium is a naturally occurring essential element (present in rocks, soil, plants and animals) and also has anthropogenic sources such as being contained in timber treatment products (e.g. copper chrome arsenic).

Chromium concentration was highest in mussels on Mair Bank (approximately 5.5 mg/kg), followed by Northport rocks (approximately 4.5 mg/kg) and pipi on Mair Bank (approximately 3.5 mg/kg). Chromium beneath the RNZ jetty and at reference sites was low (less than 1 mg/kg)

(Figure 27). NRC survey of shellfish body burden in 2012 revealed similar concentrations (0.1-4 mg/kg), with 4 mg/kg detected in pipi from Parua Bay. In 2005/2006 in sentinel shellfish, NRC detected chromium in very low concentrations 0.05-0.08 mg/kg.

Chromium is present within sediment collected from sites throughout the harbour (Bamford, 2016) at concentrations below the DGV of 80 mg/kg. Concentrations in sediment from the three reference sites (Little Munroe, Manganese Point and Urquharts Bay) were significantly higher than sites beneath and adjacent to the RNZ jetties in the 2019 survey. Chromium is present at low concentration within discharges from RNZ's stormwater basin, with a median of 0.0013 mg/L (Table 6, Stewart 2020). Modelling of RNZ's discharge from the stormwater basin does not indicate low dilution at Mair Bank nor Northport Rocks. Survey of groundwater seepage onto the foreshore near Mair Bank undertaken in November 2019 indicated that, at worst, chromium was detected at a concentration 40 times below ANZECC 80%[42] water quality guideline laboratory detection limits in groundwater. In addition, based on the harbour-wide distribution of chromium, it is unlikely that RNZ discharges are a significant contributor to the source of chromium in shellfish.

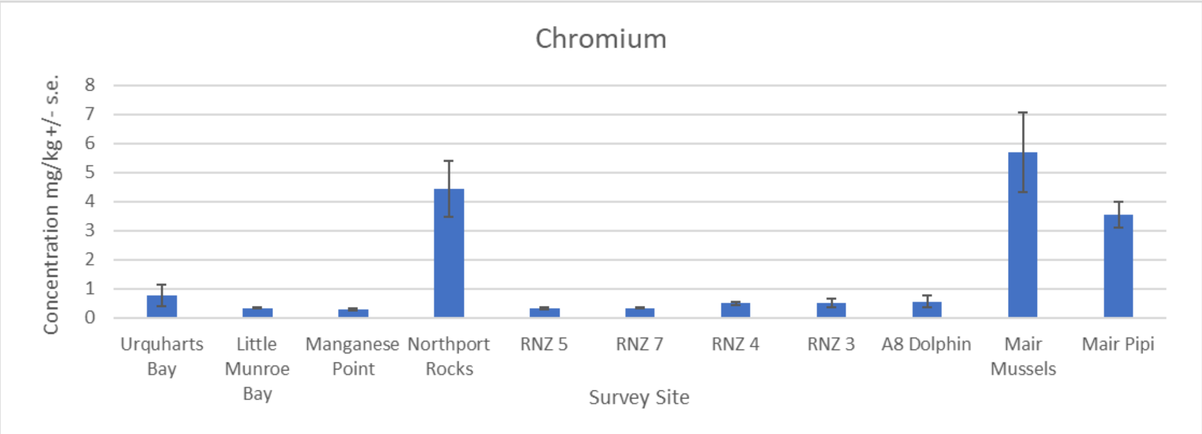

Figure 26: Concentration of chromium in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

The concentration of copper was highest in oysters from Manganese Point and Northport Rocks, with the lowest concentrations detected beneath the RNZ jetty and on A8 dolphin (Figure 28). Previous NRC shellfish body burden surveys revealed lower concentrations than those detected in 2019 (e.g. highest 2.97 in feral shellfish near to Mair Bank in 2008 and 0.72 mg/kg in sentinel shellfish in 2005/2006).

Copper is a common urban stormwater contaminant. Copper is elevated in sediment near Whangarei township, and is detectable at other sites surveyed by NRC (Bamford, 2016). The survey in 2019 revealed copper in sediment at reference sites (Manganese Point, Little Munroe Bay and Urquharts Bay) was significantly higher than beneath and adjacent to the RNZ jetties. Copper is present in low concentration in discharges from the RNZ stormwater basin, at a median concentration of 0.0027 mg/L (Table 6, Stewart, 2020). Given the wide distribution of copper throughout the harbour, it is unlikely that copper body burden detected below is related to discharges from the RNZ stormwater basin.

[42] The pNRP states at C.6.8.2(3) that 80% ANZECC (2000) water quality guidelines are appropriate for assessment of contaminants in groundwater.

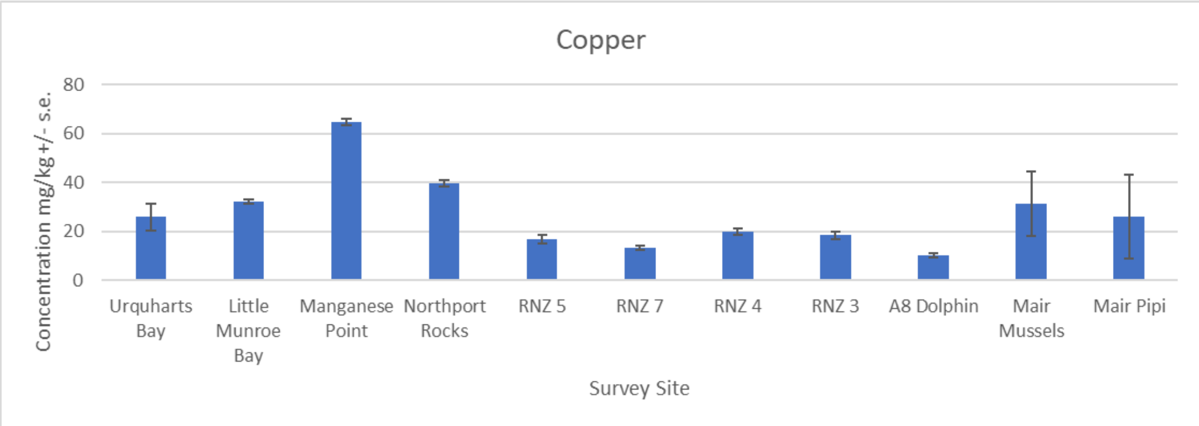

Figure 27: Concentration of copper in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

The concentration of lead was very low at all sites, with the highest concentration detected in mussels on Mair Bank (approximately 0.08 mg/kg), with most other sites having a concentration between 0.04 and 0.06 mg/kg (Figure 29). Previous body burden surveys by NRC have revealed relatively similar concentrations. In 2005/2006, NRC detected lead in sentinel shellfish at concentrations 0.04-0.05, whereas in 2008 lead was detected in pipi at 0.027 in pipi near Mair Bank.

Lead is a common urban stormwater runoff contaminant derived from tire wear, lubricating oil and grease, bearing wear and atmospheric fallout[43]. Lead is detectable in sediment throughout the harbour, with the highest concentration in sediments adjacent to Whangarei township (Bamford, 2016). Lead in marine sediment was significantly higher in the 2019 surveys at the three reference sites (Manganese Point, Little Munroe Bay and Urquharts Bay) compared to sites beneath and adjacent to the RNZ jetties. Lead is present in low concentration in discharges from the RNZ stormwater basin, with a median concentration of 0.006 mg/L (Table 6, Stewart 2020). However, given the wide distribution of lead within the Whangarei Harbour, it is unlikely that the source of lead within shellfish below is due to RNZ discharges.

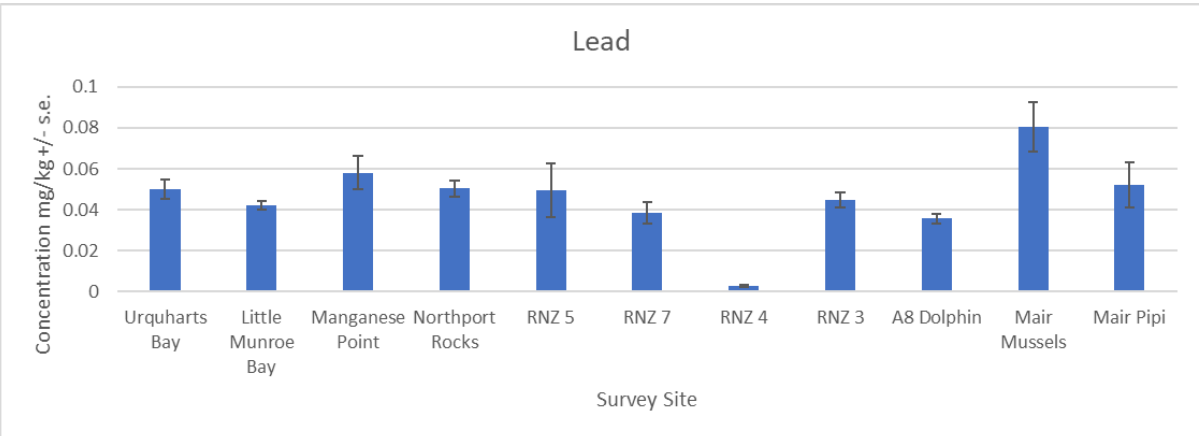

Figure 28: Concentration of lead in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

[43] Historically, also leaded fuels.

The concentration of mercury was highest in oysters from Manganese Point and Northport Rocks and lowest at RNZ jetty sites, A8 dolphin and mussels and pipi on Mair Bank (Figure 30). In past surveys, NRC detected mercury between 0.01 and 0.073 mg/kg, with the latter being in pipi at a site near Mair Bank.

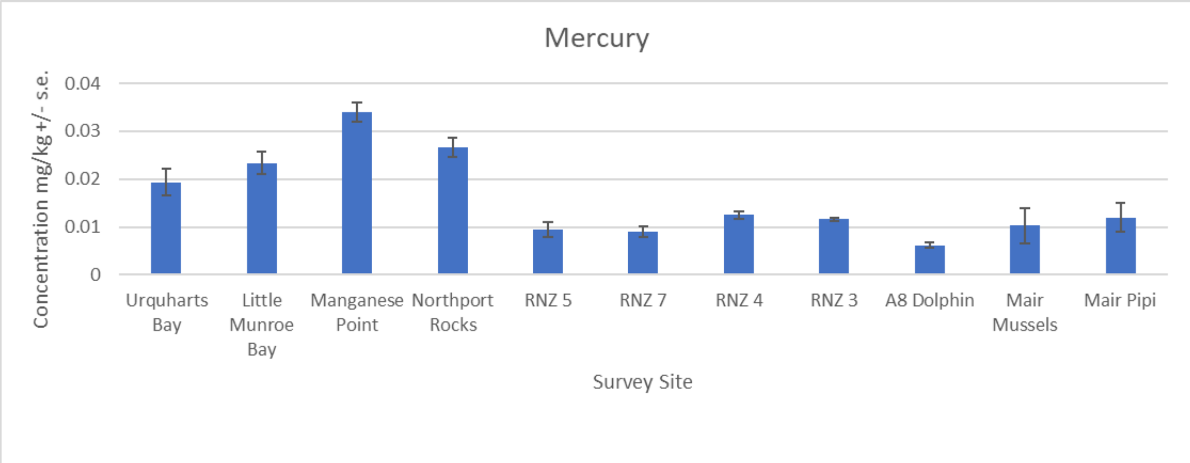

Figure 29: Concentration of mercury in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

Nickel concentration was highest in mussels from Mair Bank (approximately 4.5 mg/kg), with oysters from Northport rocks next highest (approximately 3.5 mg/kg) followed by pipi from Mair Bank (3 mg/kg) (Figure 31). These concentrations are similar to those detected in past NRC surveys e.g. 4mg/kg in pipi from Parua Bay in 2012.

Nickel is present in low concentration in the discharges from the RNZ stormwater basin, with a median concentration of 0.0013 (Table 6, Stewart 2020). A survey of groundwater seepage onto the beach near Mair Bank, carried out in November 2019, indicated nickel was below laboratory detection limits in groundwater and adjacent marine water samples (Table 5.3, Tonkin and Taylor (2020)). Nickel has been detected in marine sediments throughout the Whangarei Harbour, at concentrations below the Default Guideline Value (DGV) (ANZ, 2018) with the lowest concentration at Marsden Point in 2016 (0.8 mg/L) (Bamford, 2016). Based on the widespread distribution of nickel in Whangarei harbour sediments, the low concentration at Marsden Point, the lack of nickel in groundwater on the beach near Mair Bank and the low concentration in RNZ stormwater basin discharges, it is unlikely that the source of nickel in shellfish is due to RNZ activities.

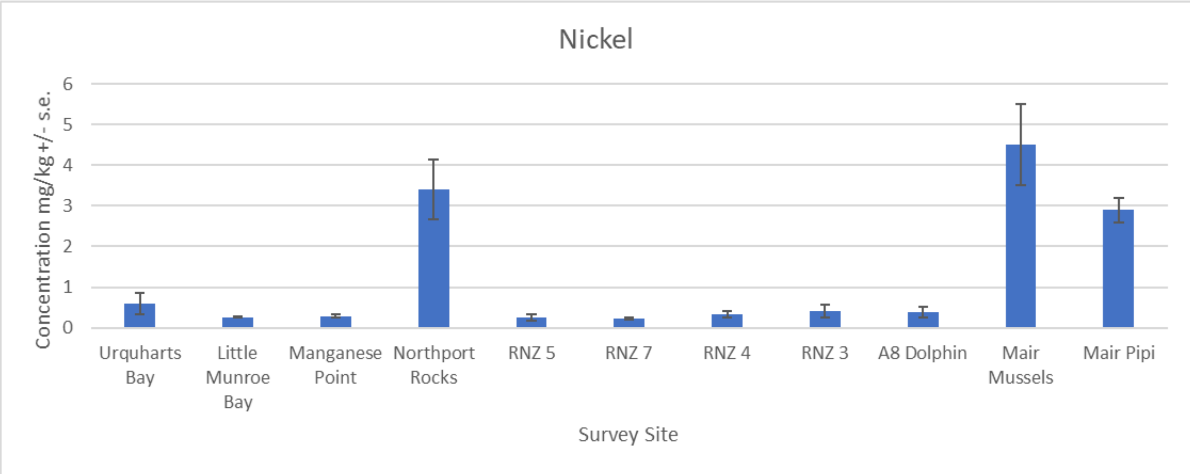

Figure 30: Concentration of nickel in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

Zinc is a common urban stormwater contaminant. Sources of zinc include from car tyres and runoff from galvanised rooves. Zinc was detected in highest concentrations in oysters from the three reference sites and Northport Rocks and in lowest concentrations in mussels and pipi from Mair Bank. Past surveys undertaken by NRC have revealed significantly lower body burden concentrations (maximum 14 mg/kg).

Zinc is present in discharges from RNZ stormwater basin in relatively low concentration (median of 0.042 mg/L). Zinc is present in sediment throughout the Whangarei Harbour largely below effects thresholds, but above DGV adjacent to the Whangarei township (Bamford, 2016). In the 2019 survey, zinc in marine sediments was significantly higher at the three reference sites (Manganese Point, Little Munroe Bay and Urquharts Bay) compared to sites beneath and adjacent to the RNZ jetties (Figure 32). Modelling indicates that at Marsden Bank, when tide and wind conditions coincide, zinc could be present in surface water at concentrations up to around 12-13% of the SWG (section 5.1.3 below).

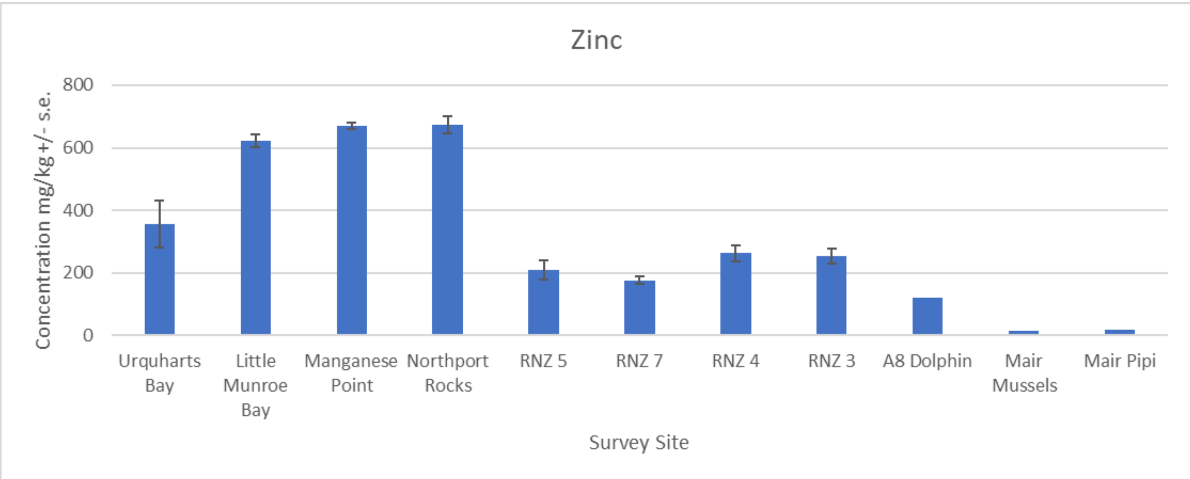

Figure 31: Concentration of zinc in oyster flesh at various sites in Whangarei Harbour, and in mussels and pipi on Mair Bank.

Analysis of fire-fighting foam contaminants (per- and polyfluoroalkyl substances (PFAS)) in oyster flesh samples collected from three locations beneath the RNZ jetty (RNZ 4, 5 and 7 – Figure 5) in July 2019 revealed concentrations below laboratory detection limits. This result is similar to tests carried out on pipi from Mair Bank on 14 June 2018 i.e. below laboratory detection limits.

4.0 Assessment of Effects on Marine Ecological Values

4.1 Assessment method

The method used to assess marine ecological values (based on the existing data and new investigations) is consistent with the EIANZ guidelines for undertaking ecological impact assessments (Roper-Lindsay, Fuller, Hooson, Sanders, & Ussher, 2018), whereby ecological values are assigned (Table 3)[44] and the magnitude of effects identified (

Table 4) in order to determine the overall level of effect of the proposal (Table 5). In Table 3, the shaded cells (Moderate, High and Very High) are considered to be more than minor effects that require avoidance, remedial actions or mitigation, whereas low and very low levels of effect are typically not of ecological concern (Roper-Lindsay, Fuller, Hooson, Sanders, & Ussher, 2018).

Table 3: Criteria for assigning ecological value to marine habitats.

ECOLOGICAL VALUE	CHARACTERISTICS
VERY LOW	• Benthic invertebrate community degraded with very low species richness, diversity and abundance. • Benthic invertebrate community dominated by tolerant organisms with no sensitive taxa present. • Marine sediments dominated by silt and clay grain sizes (>85%). • Surface sediment anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above GV threshold concentrations (Australian and New Zealand Governments, 2018) • Invasive, opportunistic and disturbance tolerant species highly dominant. • Vegetation/macroalgae absent. • Habitat extremely modified.
LOW	• Benthic invertebrate community degraded with low species richness, diversity and abundance. • Benthic invertebrate community dominated by tolerant organisms with few/no sensitive taxa present. • Marine sediments dominated by silt and clay grain sizes (>75%). • Surface sediment predominantly anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above GV threshold concentrations (Australian and New Zealand Governments, 2018). • Invasive, opportunistic and disturbance tolerant species dominant. • Vegetation/macroalgae provides minimal/limited habitat for native fauna.

[44] The 2018 EIANZ impact assessment guidelines do not include a method for assigning ecological value to marine habitats or taxa. Table 1 has been developed by Dr De Luca, improved and modified over time, and has been support through a number of the Boards of Inquiry and Environment Court hearings.

ECOLOGICAL VALUE	CHARACTERISTICS
	• Habitat highly modified.
MEDIUM	• Benthic invertebrate community typically has moderate species richness, diversity and abundance. • Benthic invertebrate community has both tolerant and sensitive taxa present. • Marine sediments typically comprise less than 75% silt and clay grain sizes. • Shallow depth of oxygenated surface sediment. • Contaminant concentrations in surface sediment generally below GV threshold concentrations (Australian and New Zealand Governments, 2018). • Few invasive opportunistic and disturbance tolerant species present. • Vegetation/macroalgae provides moderate habitat for native fauna. • Habitat modification limited.
HIGH	• Benthic invertebrate community typically has high diversity, species richness and abundance. • Benthic invertebrate community contains many taxa that are sensitive. • Marine sediments typically comprise <50% smaller grain sizes. • Surface sediment oxygenated. • Contaminant concentrations in surface sediment rarely exceed DGV threshold concentrations (Australian and New Zealand Governments, 2018). • Invasive opportunistic and disturbance tolerant species largely absent. • Vegetation/macroalgae provides significant habitat for native fauna. • Habitat largely unmodified.
VERY HIGH	• Benthic invertebrate community typically has very high diversity, species richness and abundance. • Benthic invertebrate community contains dominated taxa that are sensitive. • Marine sediments typically comprise <25% smaller grain sizes. • Surface sediment oxygenated with no anoxic sediment present. • Contaminant concentrations in surface sediment significantly below DGV threshold concentrations (Australian and New Zealand Governments, 2018). • Invasive opportunistic and disturbance tolerant species absent. • Vegetation/macroalgae sequences intact and provides significant habitat for native fauna. • Habitat unmodified.

Table 4: Criteria for describing magnitude of effect (Roper-Lindsay et al., 2018)

MAGNITUDE	DESCRIPTION
Very High	Total loss of, or very major alteration, to key elements/ features of the baseline conditions such that the post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether; AND/OR Loss of a very high proportion of the known population or range of the element / feature.
High	Major loss or major alteration to key elements/ features of the existing baseline conditions such that the post-development character, composition and/or attributes will be fundamentally changed; AND/OR Loss of a high proportion of the known population or range of the element / feature.
Moderate	Loss or alteration to one or more key elements/features of the existing baseline conditions, such that post-development character, composition and/or attributes will be partially changed; AND/OR Loss of a moderate proportion of the known population or range of the element / feature.
Low	Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible, but underlying character, composition and/or attributes of the existing baseline condition will be similar to pre-development circumstances/patterns; AND/OR Having a minor effect on the known population or range of the element / feature.
Negligible	Very slight change from existing baseline condition. Change barely distinguishable, approximating to the “no change” situation; AND/OR Having a negligible effect on the known population or range of the element / feature.

Table 5: Criteria for describing the level of effect (Roper-Lindsay et al., 2018)

LEVEL OF EFFECT		ECOLOGICAL AND / OR CONSERVATION VALUE				
		Very High	**High**	**Moderate**	**Low**	**Negligible**
MAGNITUDE	**Very High**	Very High	Very High	High	Moderate	Low
	High	Very High	Very High	Moderate	Low	Very Low
	Moderate	High	High	Moderate	Low	Very Low
	Low	Moderate	Low	Low	Very Low	Very Low
	Negligible	Low	Very Low	Very Low	Very Low	Very Low
	Positive	Net Gain	Net Gain	Net Gain	Net Gain	Net Gain

4.2 Summary of Marine Ecological Values

The marine ecological values within the receiving environment adjacent to the RNZ jetty comprise a diverse and abundant assemblage of invertebrates, low sediment contaminant concentrations, sandy grain sizes, high water quality and relatively limited habitat modification.

With reference to the marine characteristics identified in Table 3, the following apply to the soft sediment and hard-shore receiving environment beneath and adjacent to the RNZ jetty:

- Benthic invertebrate community typically has high[45] diversity, species richness and abundance (High).
- Benthic invertebrate community has both tolerant and sensitive taxa present (Medium).
- Marine sediments typically comprise <25% smaller grain sizes (Very High).
- Surface sediment oxygenated (based on observations, not direct measurement) (High).
- Contaminant concentrations in surface sediment significantly below DGV threshold concentrations (Very High).
- Invasive opportunistic and disturbance tolerant species largely absent (some invasive species present) (High).
- Vegetation/macroalgae provides significant habitat for native fauna (on adjacent rocky shores) (High).
- Habitat modification limited (Medium).

The body burden of contaminants in oysters from the RNZ jetty were, for the most part, lower than, or similar to, concentrations in oysters from reference sites and at Northport.

The marine ecological values characteristics range from medium to very high, with high characteristics being the most numerous. On balance, based on the guiding criteria and ecological expertise, it is considered that the marine ecological values at and adjacent to the RNZ jetty are high.

4.3 NZCPS

The New Zealand Coastal Policy Statement (NZCPS) contains several Policies that are relevant to an assessment of marine ecological effects associated with the Project (DOC, 2010).

<u>Policy 11: Indigenous Biological Diversity (biodiversity)</u>

Policy 11 is divided into two sections ((a) and (b)), where (a) requires avoidance of adverse effects and (b) requires avoidance of significant adverse effects and avoid, remedy or mitigation other adverse effects. I have applied the criteria in section (a) and (b) to the marine ecological values of the receiving environment for the Project.

Assessment of ecological values, species and habitats at the discharge point and in the wider receiving environment against the criteria contained in 11 (a) did not trigger a requirement to avoid adverse effects except at the Motukaroro Island marine reserve (criterion (vi)).

Assessment of ecological values, species and habitats at the discharge point and in the wider receiving environment against the criteria contained in 11 (b) trigger criteria (iii), (iv), (v) and potentially (vi). This policy requires significant adverse effects in the marine receiving environment to be avoided, and other effects to be avoided, remedied or mitigated.

<u>Policy 23: Discharge of Contaminants</u>

This policy requires consideration of the sensitivity of the receiving environment, the nature of the contaminants in the discharge and the capacity of the receiving environment to assimilate the discharge (23(1)(a)-(c)), which has formed an integral part of this assessment of effects on marine ecological values. With respect to 23(1)(d), it is my assessment that significant adverse effects beyond the existing defined reasonable mixing zone are avoided and with respect to 23(1)(f) effects within the mixing zone, they are minimised (not detected). I have not considered

[45] Apart from intertidal samples collected at Marsden Bank which are assessed as having moderate species richness and abundance of benthic invertebrates.

altering the size of the existing reasonable mixing zone in my assessment (23(1)(e) but note that I was not able to detect any measurable adverse effect on marine ecological values related to RNZ activities within the mixing zone.

Policy 23(4)(b) refers to reducing contaminant and sediment loadings in stormwater at source, through contaminant treatment and by controls on land use activities. I have considered this policy and have recommended that RNZ should continue to seek to improve the quality of treated wastewater and stormwater prior to discharge to the marine environment.

4.4 Assessment against RPS Appendix 5 Significance Criteria

Similar to the assessment against the NZCPS, the Motukaroro Island marine reserve is considered significant against the RPS criteria.

The pRP SEA areas linked to the Significant Ecological Marine Area Assessment Sheet that makes mention that Marsden and Mair Bank are mentioned as being recognised regionally and nationally as significant habitat for shellfish. However, the shellfish beds on the banks have significantly declined, have been largely absent over the past decade and show no signs of recovery. My assessment of Marsden/Mair banks against the RPS significance criteria indicates that Mair Bank is significant based on the high diversity and abundance of benthic invertebrates, whereas Marsden Bank is not significant and is quite distinct from Mair Bank with lower ecological values primarily due to significantly lower abundance and diversity of benthic invertebrates.

4.5 Discharge of treated stormwater and wastewater

4.5.1 Modelling of Discharge of Treated Stormwater and Wastewater

The spatial extent and dilution of the discharge of treated stormwater and wastewater has been modelled over a 5-day period for 13 actual rainfall events that occurred between August 2016 to December 2018 (MetOcean, 2020). During one of those events, the spillway opened and operated for approximately 90 minutes (rainfall event on 26 and 27th March 2017). Plots of average and maximum dilution were generated for each event. In addition, extreme events (100-year ARI) were modelled. Modelling of annual discharge from the diffuser (every 15 minutes) during El Niño and La Niña climate/weather patterns was also undertaken, with dilution assessed in surface water, bottom water and depth average. Consideration of the surface water and bottom water dilutions did not change the conclusions in Stewart (2020) nor in this report, therefore depth average dilution has been the focus of this assessment. The hydrodynamic modelling is summarised in section 5.1 (Stewart, 2020).

From the modelling data, plots of maximum and mean dilution of the discharge(s) were created. On the basis of those plots, it was possible to determine the spatial extent of discharged stormwater/wastewater and identify priority areas within the receiving environment where timeseries dilution data could be extracted to inform a conservative assessment of contaminant concentrations[46] (Stewart, 2020) (Figure 32). Timeseries data was also extracted from the four corners of the proposed reasonable mixing zone (sites C1-4) (Figure 6).

[46] Total phenol, total PAHs, BTEX, TPH, sulphides, BOD5, TSS, NH4-N, arsenic, cadmium, copper, lead, mercury, nickel, zinc and faecal coliforms.

To summarise, time-series dilution data for all modelled events was extracted from the modelling data at the following sites (Figure 6:

- Each of the four corners of the proposed reasonable mixing zone (C1-4)[47];
- Snake Bank (P1);
- Darch Point (P2);
- Lort Point (P3);
- Mair Bank (P4)[38];
- Home Point (P5);
- West of Marsden Bank (P6)[38];
- Northport (P7);
- Motukaroro Island (P8);
- Busby Head (P9).

Relevant contaminant concentrations at those locations were provided by Streamlined Environmental as median and worst-case values (5th percentile). These concentrations have been compared against maximum (not annual median) surface water quality guidelines and other relevant trigger levels[48] (where available[49]) (see section 5.1 (Stewart, 2020)). For ammonia, we have used the revised 95% trigger value of 0.46 mg/L recommended by Batley & Simpson (2009), which is more conservative than the 95% and 99% ANZECC guidelines (Batley & Simpson, 2009).

Table 6: Surface water quality guideline values used in this assessment

Parameter	Unit	Compliance metric	Value	Source
Ammonia	mg/L	Maximum	0.460	Batley & Simpson (2009)
Phenol	mg/L	Maximum	0.400	ANZ[50]
Arsenic	mg/L	Maximum	0.050	oNRP[51]
Cadmium	mg/L	Maximum	0.0020	oNRP[52]
Chromium (vi)	mg/L	Maximum	0.0044	ANZ[35, 53]
Copper	mg/L	Maximum	0.0013	ANZ[35,38]
Lead	mg/L	Maximum	0.0044	ANZ[35,38]
Mercury (inorganic)	mg/L	Maximum	0.0001	ANZ[35,54]

[47] C3, P4 and P6 are intertidal sites.

[48] All water contaminant concentration triggers are collectively referred to as surface water quality guidelines (SWQG).

[49] There are no surface water quality guidelines for total PAHs, BTEX, sulphides, BOD5 and faecal coliforms. BOD5 and faecal coliforms do not adversely affect marine organisms. In the absence of surface water quality guidelines for TPH and PAHs, it is noted that these contaminants generally associate with sediment not water. Sulphides and BTEX were always below the laboratory detection limit.

[50] 95% marine trigger value

[51] Insufficient data to derive a reliable ANZ marine trigger value

[52] oNRP more restrictive than ANZ (no data for pNRP)

[53] ANZ more restrictive than oNRP (no data for pNRP)

[54] No value in oNRP

Parameter	Unit	Compliance metric	Value	Source
Nickel	mg/L	Maximum	0.0700	ANZ[35,39]
Zinc	mg/L	Maximum	0.015	ANZ[35,36]

It is noted that RNZ's discharge NH4-N concentration data from early 2015 has been excluded from the data set, as a plant upgrade in 2015 resulted in an 8 fold decrease in concentration (see section 5.5.1 (Stewart, 2020) and the data from 2015 skews the data set and is not relevant with the plant upgrade in place.

4.5.2 Actual Rainfall Events Modelled Results

For both median and maximum concentrations during actual rainfall events, the concentrations of contaminants at sites C1-4 and P1-9 were low, significantly below the SWQG and therefore below effects thresholds.

The median and maximum concentration of contaminants during actual rainfall events (calculated by Stewart (2020)) was less than 10% of the SWQG at the proposed mixing zone boundary and at the nine points of interest around the harbour.

4.5.3 Extreme Rainfall Events Modelled Results

The median and maximum concentration of contaminants during 100-year ARI rainfall events at sites C1-4 and sites P1-9 were significantly (<10%) below the relevant SWQGs and therefore below effects thresholds. Stewart (2020) identified that modelling indicated the lowest dilution occurs at site C3 (at the mixing zone boundary) with a 175 times dilution (duration 1-3 hours) at 24 hours following an extreme rainfall event, which is not a concern for marine organism ecotoxicology.

4.5.4 El Niño and La Niña Modelled Results

The median and maximum concentration of contaminants over a year of modelling diffuser discharges under both El Niño and La Niña climate/weather conditions were significantly below SWQG and therefore below effects thresholds.

The median and maximum contaminant concentrations (calculated by Stewart (2020)) were below 10% of the SWQG and significantly below effects thresholds.

4.5.5 Ecotoxicology Tests on Discharge from the Stormwater Basin

As described above in section 3.2.1, of the three suites of ecotoxicology tests of the whole effluent on the four laboratory organisms (pipi, blue mussel, an amphipod and a microalga), all tests indicated that low dilution (approximately 1-9 times) was required to result in no effects on the test organisms, apart from a single test on blue mussel larvae that required a 256 times dilution in August 2019, which appears as an outlier or unusual result. The other three organisms tested in August 2019 required nil to very low dilution to be below effects thresholds. The water collected from the SWB was within test range parameters on that day. However, based on the ecotoxicology data, we have to assume that RNZ stormwater/wastewater, could in some circumstances, when diluted less than 256 times and exposure period was extended (e.g.

48 hours as per the ecotoxicology test), potentially cause adverse effects on shellfish larvae. The likelihood of the 5th percentile dilution being below 256 times coinciding with an exposure period around 48 hours is very unlikely.

If we look at the actual climatic and hydrodynamic data for a period of almost two years between 2010 and 2011 and 2015-2016, under La Niña and El Niño conditions respectively, we can see that for most sites the dilution of RNZ discharges are high (>99% of the time the dilution is above 256 times).

4.5.6 Suspended Sediment Modelled Results

Generally, the average annual TSS concentration across all NRC water quality monitoring sites is around 20 mg/L (Stewart, 2020). Modelling indicated extremely low concentrations of suspended sediment arising from RNZ stormwater, with worst case concentrations at the mixing zone boundary being 0.03 mg/L and at the sites of interest around the harbour, where time series contaminant data was extracted, being 0.02 mg/L. The magnitude of effect from suspended sediment (and subsequently deposited sediment) from the discharge of RNZ stormwater on background stormwater is likely to be negligible (section 5.3 (Stewart, 2020)).

4.5.7 Process chemicals

Daily use chemicals

The majority of process chemicals used at RNZ on a daily basis are assessed as having negligible effects on ecology of the receiving environment.

Cortrol OS7780 is a dissolved oxygen scavenger/metal passivator used in the western Accidentally Oil Contaminated (AOC) trench. Cortrol OS7780 does not come into contact with petroleum hydrocarbons as part of the refining process. It is applied at an average rate of 13.7 kg/day. The formulation has a pH of 7.5. Under worst-case dilutions and event scenarios (up to 5% of the time) and under least favourable conditions Cortrol OS7780 may be cause more than minor transitory effects outside the mixing zone. As a mitigation measure, Cortrol OS7780 is in the process of being replaced by RNZ with an alternative formulation (Cortrol OS5614). The use of Cortrol OS5614 will lead to a minor increase (0.048 mg/L) in NH_4-N to the SWB. Under normal-case scenario (i.e. most of the time) the additional NH_4-N load from Cortrol OS5614 is likely to have a negligible effect on water quality at the edges and outside of the mixing zone (Section 4.5.2, Stewart, 2020).

Other process chemicals used on a daily basis have been assessed as having a negligible effect on water quality (Embreak 2050, Optispearse ADJ5150, Embreak 2021, Spectrus NX1100, Inhibitor AZ8104, BetzDearborn, Crystalfloc Cationic Emulsions, Genguard GN8220, Spectrus BD1501E and Optisperse HP2650) (Section 4.5.2, Stewart, 2020) – the risk is negligible in the SWB, even before allowing for partitioning into oil or for dilution in the receiving environment, i.e. RQ1 < 1.

Accidental Spills

In 2018, there was an accidental spill of a product called DIPA. Similar to diethanolamine, minimal marine ecotoxicity data exists which results in a highly conservative PNEC being established. However, the European Chemical Agency (ECHA) do not consider that DIPA is acutely toxic to fish, invertebrates or algae. Stewart (2020) states that it is highly unlikely that there would have been any acute ecotoxicity effects as a result of the 2018 spill (Section 4.5.2, Stewart, 2020).

A spill of 100L of a product called ADIP-X, which contains methyldiethanolamine (MDA) has occurred within the past 15 years. Similar to diethanolamine and DIPA, due to minimal marine ecotoxicity data, a very conservative PNEC for MDA has been established for this product. MDA has low persistence in sediment and water and whilst having low biodegradability it does not bioaccumulate. Stewart (2020) considers that it is highly unlikely that the ADIP-X spill would have resulted in any acute ecotoxicity in the marine receiving environment (Section 4.5.2 (Stewart, 2020).

RNZ are currently reviewing and improving the process for mitigating the effects of accidental spill, involving stopping the flow of wastewater and recycling through the biotreater before discharge to the SWB.

<u>Chemicals used infrequently</u>

A fire-fighting foam (Solberg DoD3155) used infrequently at the fire training ground contains cocoamido propyl betaine (CPB) which has a low PNEC due to minimal ecotoxicology data. Stewart (2020) considers effects on marine organisms from the infrequent discharge of CPB would be negligible (Section 4.5.2 (Stewart, 2020)).

Overall, the magnitude of effect of the routine or accidental discharge of process chemicals on marine ecological values is assessed as low due to the rapid and high dilution afforded by the exchange of water beneath the RNZ jetty, low duration of exposure and low risk to marine organisms (Stewart, 2020).

4.5.8 Summary of effects of discharge of treated stormwater and wastewater

Modelling and subsequent contaminant concentration calculations indicate that, at the sites where time-series data was extracted (worst case sites based on lowest dilution) (Figure 32), contaminants contained in discharges from the diffuser, the diffuser bypass and the spillway are rapidly diluted to below effects thresholds.

Median contaminant concentrations for actual and extreme rainfall events plus the El Niño and La Niña were less than 1% of the SWQG values, strongly indicating that no effects on marine ecological values are expected.

Maximum contaminant concentrations for actual and extreme rainfall events plus the El Niño and La Niña were significantly below SWQG, with all measured contaminants at concentrations less than 10% of the SWQG.

The discharge of process chemicals (either daily use or rare accidental discharge) has been assessed by Stewart (2020) as having negligible effects on marine organisms.

Three suites of ecotoxicology tests carried out on water collected from the stormwater basin indicate that very low dilution (1-9 times) was required to avoid adverse effects on the sensitive test organisms. The exception is blue mussel larvae. In one of the three SWB samples tested, a dilution >256 times was required to avoid effects on blue mussel larvae. The hydrodynamic modelling data indicates that there are times (based on the 5%ile) when dilution of discharges from the diffuser can be below 256 times outside of the mixing zone (e.g. SE mixing zone boundary (C3), west of Marsden Bank, and Mair Bank). Together, the modelling and ecotoxicology studies indicate that under certain circumstances, bivalve larvae (or larvae of other sensitive species) could be exposed to SWB water at less than 256 times dilution and adverse effects on those individuals could occur. However, the duration of exposure to less than 256 times dilution was only 1-3 hours based on the timeseries modelling. It is expected that there would be no adverse effects on organisms at a population level. In addition, effects on marine ecological values are not expected to be greater than negligible. The ecological values at C3 and Mair Bank are high, which indicates that adverse effects on the assemblages are unlikely to be occurring or at least not having adverse effects on marine ecological values as a whole. Whilst there is no benthic ecology data for exactly site P6, located to the west of Marsden Bank, it is expected that, similar to Mair Bank and Marsden Bank, there are unlikely to be adverse effects on marine ecological values.

The impact of discharged suspended sediment and the potential for the discharge of process chemicals are expected to have negligible and low adverse effects on marine ecological values respectively.

Furthermore, we confirm that the data indicates contaminant concentrations in the proposed mixing zone are below effects thresholds. Sediment quality and benthic invertebrate assemblages (at all sites within and adjacent to the RNZ jetty, including C3, and Marsden and Mair Banks[55]) are in good health, which is also consistent with no adverse effects from the discharges of treated stormwater and wastewater based on the timeseries data from the hydrodynamic modelling of dilution.

The magnitude of effect of the discharge of treated stormwater and wastewater is assessed as negligible to low (*Table 4****). In combination with high marine ecological values, the level of ecological effect is determined to be very low to low (****Table 5****), which in RMA planning terminology is negligible to less than minor.***

4.6 Discharge of uncontaminated seawater

The discharge of uncontaminated warm seawater to the marine receiving environment occurs from the service pump that maintains pressure in the fire main, and from cooling of diesel pumps and overpressure valves, potentially when the firefighting system is activated. Seawater used in the service pump is discharged at approximately ambient temperature, whereas cooling water from intermittent use of diesel engines is discharged at temperatures above ambient.

The discharge of uncontaminated seawater is assessed as having a negligible magnitude of effect on marine ecological values as the rapid dilution beneath the RNZ jetty will quickly return discharged water to ambient temperature (in the intermittent situation where cooling water has elevated temperature on discharge).

The magnitude of effect of the discharge of uncontaminated seawater is assessed as negligible (*Table 4****). In combination with high marine ecological values, the level of effect is determined to be very low (****Table 5****), which in RMA planning terminology is negligible.***

4.7 Structures within the CMA (RNZ jetty and dolphins)

The RNZ jetty piers occupy approximately 33 m^2 of benthic habitat. In addition to the jetties, RNZ has breasting and mooring dolphins that are needed for the mooring of vessels visiting the Refinery, which occupy approximately 110m^2 of benthic habitat. The benthic substrate is medium-coarse sand, has a relatively high diversity and abundance of benthic organisms and is assessed as having high ecological value.

The area of Whangarei Harbour is 101.5km^2, with the jetty and dolphins occupying 0.00014% of the harbour. At the scale of the mouth of the Whangarei Harbour (as opposed to the entire

[55] Benthic assemblage data only, sediment contaminant samples were not collected.

harbour), from Darch Point/Northport to Mair Bank/Home Point, the area occupied by the jetty structures and dolphins remains very small (approximately 0.01%).

While occupying the high value benthic habitat, the structures provide additional hard shore habitat for sessile organisms. The invertebrate assemblages that occupy the structures are diverse and of high ecological value.

The magnitude of effect of the structures (jetty and dolphins) being located on/in benthic soft sediment habitat within Whangarei Harbour is assessed as negligible (**Table 4*****). In combination with high marine ecological values, the level of effect is determined to be very low (*****Table 5*****), which in RMA planning terminology is negligible.***

4.8 Cumulative Effects

Whangarei Harbour and Bream Bay receive a range of discharges from non-point source and point source locations. Stormwater is discharged from a large number of locations, including RNZ, Northport and urban stormwater discharges (many of which are untreated). Treated wastewater is discharged from the Whangarei wastewater treatment plant is also likely to be discharged to the marine receiving environment from the Ruakaka wastewater treatment plant in the future.

RNZ's treated stormwater and wastewater discharges occur in an area of high tidal flow, with rapid dilution occurring. The effect of the discharge adds to the background stormwater discharges, wastewater discharges and other runoff (e.g. rural). However, because of the hydrodynamic characteristics of the discharge location(s) (high current and tidal flow), discharges are rapidly diluted to below effects thresholds. The discharges from RNZ are unlikely to contribute to a more than negligible cumulative effect on marine ecological values in Whangarei Harbour or Bream Bay, which is supported by the presence of diverse marine intertidal and subtidal soft and hard-shore communities. Groundwater risk has been assessed in the CMA by Tonkin & Taylor (2020) and has not revealed any contaminants that are not naturally occurring nor likely to originate from the RNZ site.

Stewart (2020) identified that on rare occasions, process chemicals could combine with stormwater and wastewater and be discharged to the CMA (e.g. in the event of an accidental spill). The effect of such an event on marine organisms is assessed as potentially (at worst) minor but temporary or transient. There is no evidence of more than minor adverse effects on marine ecological values in the receiving environment.

There is scientific literature that indicates contaminants present in marine environments at concentrations below existing sediment guidelines may interact and result in adverse effects on marine organisms. The way we have assessed interactions between contaminants is through carrying out multiple ecotoxicology tests on sensitive laboratory organisms when exposed to the stormwater/produced water from RNZ which contains a mix of contaminants below effects thresholds. In addition, the ecological values within the areas of the receiving environment that modelling indicates dilute discharges extend to do not show signs of ecological degradation.

The magnitude of contribution to cumulative effect of the discharge of treated stormwater/wastewater, groundwater and process chemicals is assessed as low or negligible (**Table 4*****). In combination with high ecological values, the level of effect is determined to be low or very low (*****Table 5*****), which in RMA planning terminology is less than minor or de minimis.***

Occupation of a small area of benthic habitat for jetty piles/piers and dolphins adds to the cumulative loss of habitat within the harbour from structures and reclamations. However, the area occupied by RNZ structures is very small and is considered to have a negligible cumulative effect on the functioning of the Whangarei Harbour.

The magnitude of contribution to cumulative effect of occupation of the benthic habitat by jetty piles/piers and dolphins is assessed as negligible (*Table 4*). In combination with high ecological values, the level of effect is determined to be very low (*Table 5*), which in RMA planning terminology is negligible.

4.9 Patuharekeke's Cultural Effects Assessment and Matrix

Patuharekeke consider that there remains the potential for cumulative effects because there is the potential under certain conditions in shallow habitats for RNZ's discharges to be present at concentrations that have been found in one ecotoxicology test to have adverse effects on the larvae of blue mussel, and therefore could affect the larvae of other shellfish larvae and juvenile shellfish dispersal. However, the duration of exposure is very low (1-3 hours) compared to the exposure period of the ecotoxicology test on blue mussel larvae (48 hours). We remain of the opinion that cumulative effects are negligible.

We understand that Patuharakeke consider that there is still uncertainty around cumulative stressors on shellfish, including effects on juvenile dispersal. It is noted that the cause of the Mair Bank pipi decline has been studied (e.g. Williams and Hume, 2014) and remains unclear. In addition, none of the scientific data collected for this Project, and other RNZ projects, support a cause and effect link between the pipi decline at Mair Bank and the activities of RNZ. We remain of the opinion that RNZ discharges are not the cause of the pipi decline on Mair Bank.

Patuharakeke further state that the histology surveys carried out by Howell (2019 and 2020) indicated abnormalities of gills of pipi at Mair and Marsden Bank. Pipi from other sites were also surveyed for pipi health had similar histology, microbiology and presence of symbiotic bacteria. Howell (2019 and 2020) concluded that no cause and effect could be identified for the results observed.

With respect to biosecurity, Patukarakeke have requested that RNZ support the collaborative "Marine Biosecurity Toolbox" project that Patukarakeke are currently working with Cawthron on. We understand that RNZ are happy to discuss how it can best support this activity.

4.10 Summary of Potential Effects

If water quality and sediment quality at and adjacent to the RNZ jetty discharges or in areas where the discharge is moved to by current and tidal exchange was low, then we would expect to see benthic invertebrate assemblages that are dominated by tolerant species. However, from various observations and studies, we know that this is not the case - rather, that both water quality and sediment quality are high, and the benthic invertebrate assemblages are diverse and abundant.

One of the most significant ecological issues in the lower Whangarei Harbour is the collapse of pipi populations at Mair and Marsden Banks. Much of this collapse has happened over the last 10 years (Pawley, 2014; Williams & Hume, 2014). There are numerous potential drivers of bivalve population collapse. These include disease, the impact of climate on food availability (phytoplankton) or the supply of larvae to an area of adult habitat. Shellfish mass mortality events have become increasingly common in the last 10-15 years, with shellfish mortality events recorded throughout Northland, the Bay of Plenty and on the Horowhenua Coast (MPI, unpublished data). While the specific causes of these mortality events are unknown, disease has been suggested as a either a major driver, or a factor making shellfish vulnerable to other stressors (temperature, pollution, co-infection) which would not usually result in mortality (Ross et al. 2018).

It has been suggested by third parties that the disappearance of pipi is related to the activities of RNZ, either through dredging, or because of RNZ treated stormwater and wastewater being discharged into the harbour. There is little evidence to support the hypothesis that the decline of pipi is related to the activities of RNZ. RNZ has been operating at Marsden Point since 1964, yet the decline of pipi has only occurred in the last 10 years. This is a period where discharges from the refinery are likely to contain the lowest concentrations of contaminants over the 56 years of the refinery's operation. Given that there is no evidence of contaminants accumulating in the harbour and that pipi are unlikely to live for more than 10 years, if RNZ's discharges were going to cause a pipi population collapse it would have occurred in the decades after the refinery became operational, not half a century later. Furthermore, capital dredging projects at other ports, for example, Tauranga Harbour, have not precluded the recovery of pipi (Ross & Culliford 2018). There is no arguing that pipi populations have declined, but the limited evidence does not point to RNZ as the cause.

The marine environment has high ecological values. The magnitude of effect of the proposed discharges and occupation range from low to negligible. As such, the level of effect of the activities ranges between low and very low (Table 7).

Table 7: Summary of ecological values, magnitude of effect, and level of effect in EIANZ impact assessment guideline terminology and RMA planning terminology.

	ECOLOGICAL VALUE	MAGNITUDE OF ECOLOGICAL EFFECT	LEVEL OF ECOLOGICAL EFFECT	RMA PLANNING TERMINOLOGY	AVOIDANCE OR MITIGATION REQUIRED
Discharge of treated stormwater and wastewater	High	Low	Low	Less than Minor	No
Discharge of groundwater	High	Negligible	Very Low	De minimis	No
Discharge of process chemicals	High	Low	Low	Less than minor	No
Discharge of clean seawater	High	Negligible	Very Low	De minimis	No
Occupation of the seabed for structures associated with the jetty and dolphins	High	Negligible	Very Low	De minimis	No
Cumulative effects	High	Negligible	Very Low	De minimis	No

5.0 Conclusion

The marine ecological values at and adjacent to the RNZ Jetty are high. The potential effects assessed, being the discharge of treated stormwater and wastewater, the discharge of uncontaminated seawater, occupation of the seabed and cumulative effects of discharges and occupation, all were found to have a negligible or low magnitude of effect based on the robust data collected and data analysis. There is no evidence of adverse effects on marine ecological values within the receiving environment.

With the overall level of effect being low or very low, avoidance or mitigation is not required.

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Appendix 1: Laboratory Ecotoxicology Reports

NIWA
Taihoro Nukurangi

Toxicity Assessment of Three Storm-Water Samples

Prepared for Refining NZ, Marsden Maritime Holdings and Northport

September 2017

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Contents

Tables

Executive summary

Toxicity testing with three species was completed on grab storm-water discharge samples from the Refining NZ, Marsden Maritime Holdings and Northport. The three tests were 48-hour blue mussel bivalve (*Mytilus galloprovincialis*) embryo development, 96-hour wedge shell bivalve (*Macomona liliana*) survival and morbidity (reburial), and marine alga (*Dunaliella tertiolecta*) 72-hour growth.

For compliance purposes, we report if the EC_{25} is greater than an 800-fold dilution or 0.125% (for Refining NZ) or a 200-fold dilution or 0.5% (for Northport and Marsden Maritime holdings). We have also reported the 'no toxicity dilution' of the storm-water samples; a dilution at which the sample would be expected to exhibit no toxicity to the organisms tested after a chronic exposure. Standard toxicity metrics including those used for consent compliance for the three tests are summarised in Table 1.

Table 1: Summary of toxicity test results on the storm-water grab samples. Bold indicates toxicity values used for consent compliance.

Organism	Sample	EC_{50}[a] (%)	EC_{25}[a] (%)	NOEC[b] (%)	LOEC[b] (%)	TEC[b] (%)	>25% Toxicity at specified compliance dilution[e]
Algae	Refining NZ	>25	**>25**	8[f]	16[f]	11.3	**No**
	Marsden Maritime Holdings	>20	**>20**	20	>20	n/a	**No**
	Northport	>20	**12.4**	8[f]	16[f]	11.3	**No**
Bivalve (*Macomona*)[c]	Refining NZ	>68	**>68**	68	>68	n/a	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	**No**
	Northport	>63	**>63**	63	>63	n/a	**No**
Bivalve (*Macomona*)[d]	Refining NZ	>68	**>68**	68	>68	n/a	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	**No**
	Northport	>63	**>63**	63	>63	n/a	**No**
Bivalve (blue mussel)	Refining NZ	>68	**>68**	50	68	58.3	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	**No**
	Northport	>63	**>63**	25	50	35.4	**No**

[a] EC_x= dilution required to cause an X% effect on the test organisms; [b]NOEC = No observed effect concentration; LOEC = Lowest observed effect concentration; TEC = threshold effect concentration (Geometric mean of NOEC and LOEC); [c]Acute 96-hour survival results; [d]Acute 96-hour morbidity (reburial) results; [e]Compliance condition: Refining NZ states 800-fold dilution (0.125%) and Marsden Maritime Holdings and Northport state a 200-fold dilution (0.5%). [f]Value determined with regards to method detection limit (section 3.2)

Using the EC_{25} as a comparative measure, the results for the 2017 Northport storm-water sample show more toxicity than the 2005 sample for the algal growth (EC_{25} was >32% in 2005 and 12.4% in 2017), but similar results to *Macomona* survival (i.e., LC_{25} was >63.5% in 2005 and >63% in 2017) (Martin, 2005). There are no results available for the blue mussel embryo development test in 2005 due to test failure. No previous results are available for Refining NZ and Marsden Maritime Holdings.

Based on the supplied storm-water samples from Refining NZ, Marsden Maritime Holdings and Northport, all the algae, wedge shell and blue mussel tests comply with the relevant section of the Northland Regional Council resource consents provided by 4Sight Consulting.

1 Introduction

NIWA was engaged by Refining NZ, Marsden Maritime holdings and Northport to undertake toxicity testing on a grab storm-water sample from each using Whangarei Harbour Seawater for dilution. No concurrent water quality data or testing of chemical contaminants was provided to or undertaken by NIWA as part of the testing.

The conditions for Refining NZ are as follows:

"Refining NZ. The same species and approach but taking into account the 800-fold dilution threshold…" (email from Mark Poynter (4Sight Consulting) to Karen Thompson (NIWA) 27/2/17).

Northport and Marsden Maritime Holdings consent conditions state:

"Monitoring of the toxicity of water within the stormwater treatment pond shall be carried out … On each monitoring occasion a single discrete water sample shall be taken … Water samples will be tested for toxicity using at least three marine species, including at least one algae (preferably Dunaliella tertiolecta – green algae), one invertebrate (preferably Fellaster zelandia – sand dollar), and one fish (preferably Rhombosolea plebeia – sand flounder). The final choice of toxicity test species, dilutions, test endpoints to be measured, and "toxicity effect" shall be submitted to the Council for approval at least twenty working days prior to stormwater sampling. The dilution water used for toxicity tests shall be an uncontaminated sample of Whangarei Harbour water, collected on an incoming tide at the harbour entrance, at a point agreed to by the Council. The toxicity testing shall be based on a dilution series that includes a 200-fold dilution. As stated in Condition 6 the 200-fold dilution sample shall not produce an adverse effect in more than 25% of the test species for the most sensitive of the test species used. Testing of the samples shall be carried out in accordance with the methodology outlined in the NIWA document entitled "Standard Methods for Whole Effluent Toxicity Testing: Development and Application" dated November 1998" (email from Mark Poynter (4Sight Consulting) to Karen Thompson (NIWA) 27/2/17).

A suite of tests was completed using three marine species, the blue mussel bivalve, *Mytilus galloprovincialis* (48-hour embryo development test), a wedge shell bivalve, *Macomona liliana* (96-hour survival and morbidity (reburial) test) and a marine alga, *Dunaliella tertiolecta* (72-hour growth test). Test species were selected on their availability at the time of testing.

Test results were used to determine if the samples comply with consent conditions by producing <25% toxicity at the specified compliance dilution and to produce a 'no toxicity dilution' factor.

2 Methods

Dilution and storm-water samples

Single use 2-litre food grade high density polyethylene (HDPE) bottles were supplied by NIWA for collection of the samples and dilution water. Samples were collected on July 24, during a high rainfall event and arrived at NIWA on July 26, 2017. Upon arrival at NIWA sample codes were assigned to the Whangarei Harbour dilution water (2614/QY1) and the 3 storm-water samples (2614/QY2-4) (Figure 1) and the physicochemical parameters of each were measured (Table 2). Samples were then stored in the dark at 4°C until testing commenced.

Figure 1: Dilution water and storm-water samples on arrival

Table 2: Physicochemical measurements of the samples upon arrival at NIWA (26 July, 2017).

NIWA Lab ID	Sample	Sample Date	pH	Salinity (ppt)	Dissolved Oxygen (mg L^{-1})	Temp (°C)
2614/QY1	Whangarei Harbour Seawater	24/7/17	8.18	32.9	10.9	10.6
2614/QY2	Refining NZ	24/7/17	7.90	6.3	9.4	10.5
2614/QY3	Marsden Maritime Holdings	24/7/17	7.94	0.2	9.8	5.7
2614/QY4	Northport	24/7/17	7.86	0.4	9.6	7.3

Toxicity testing methods

Tests were completed according to NIWA Standard Operating Procedures (SOP):

- NIWA SOP 33.0 – Marine algae 72-h chronic toxicity test for *Dunaliella tertiolecta*.
- NIWA SOP 58.0 – *Macomona liliana* 96-h acute toxicity test.
- NIWA SOP 21.2 - Blue mussel *Mytilus galloprovincialis* embryo 48-h chronic toxicity test.

A summary of test conditions and test acceptability information specified in each of the SOP manuals is provided in Appendix B.

Sample dilutions

Each test included a range of storm-water dilutions. The diluent for all the tests was the client supplied Whangarei Harbour Seawater.

The storm water samples were first adjusted to the required test salinities, as specified by the standard operating procedures. For the blue mussel and *Macomona* test, the storm-water sample salinities were adjusted using brine causing an effective dilution of the samples. This allowed for a maximum concentration of 68% for Refining NZ and 63% for Marsden Maritime Holdings and Northport.

For the algal test, the storm-water samples were adjusted to the required salinity of 26 ppt using 35 ppt dilution water (Whangarei Harbour Seawater) producing maximum concentrations of 25% for Refining NZ and 20% for Marsden Maritime Holdings and Northport.

Reference toxicant

Reference toxicant tests using zinc sulfate were undertaken concurrently using standard test procedures to measure the sensitivity and condition of the test organisms by comparing the results to the known sensitivity of the test organisms to zinc (NIWA, unpublished long-term database). The zinc sulfate stock concentration was validated by Hill Laboratories.

Test acceptability criteria

Each test has criteria that must be met for the test to be considered acceptable (Appendix B). For the blue mussel test the control embryos must have at least 80% normal development. In the *Macomona* test the control organisms must have greater than 90% survival and morbidity must be less than 10% in the reburial. In the algae test the increase in cell density in the control water must be greater than 16-fold and the coefficient of variation in the control replicates must be less than 20%.

Method detection limit

The method detection limit is a measure of the natural variability associated with each test calculated from our long-term database of test results. If the percent effect is smaller than the method detection limit than the effect may be due to natural variability in the test response.

Due to insufficient long-term data to produce a method detection limit for the *Dunaliella tertiolecta* algae test we have used the value established by another marine species (*Minutocellus polymorphus*) test. The method detection limit for *M.polymorphus* is 17.3% (NIWA, unpublished data).

Statistics

Statistical analyses were completed using CETIS v1.8.8.2 (Comprehensive Environmental Toxicity Information System) by Tidepool Scientific.

3 Results and Conclusions

Test results were used to determine if the samples comply with consent conditions by producing <25% toxicity at the specified compliance dilution and to produce a 'no toxicity dilution' factor.

Results are described in this section - raw data and detailed results from the statistical analyses are provided for all tests in Appendix A.

Table 3: Summary of toxicity test results on the storm-water samples. Bold indicates toxicity values used for consent compliance.

Organism	Sample	EC_{50}[a] (%)	EC_{25}[a] (%)	NOEC[b] (%)	LOEC[b] (%)	TEC[b] (%)	No Toxicity Dilution[e]	>25% Toxicity at specified compliance dilution[f]
Algae	Refining NZ	>25	**>25**	8[g]	16[g]	11.3	8.8x	**No**
	Marsden Maritime Holdings	>20	**>20**	20	>20	n/a	<5x	**No**
	Northport	>20	**12.4**	8[g]	16[g]	11.3	8.8x	**No**
Bivalve (*Macomona*)[c]	Refining NZ	>68	**>68**	68	>68	n/a	<15x	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	<16x	**No**
	Northport	>63	**>63**	63	>63	n/a	<16x	**No**
Bivalve (*Macomona*)[d]	Refining NZ	>68	**>68**	68	>68	n/a	<15x	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	<16x	**No**
	Northport	>63	**>63**	63	>63	n/a	<16x	**No**
Bivalve (blue mussel)	Refining NZ	>68	**>68**	50	68	58.3	1.7x	**No**
	Marsden Maritime Holdings	>63	**>63**	63	>63	n/a	<1.6x	**No**
	Northport	>63	**>63**	25	50	35.4	2.8x	**No**

[a] EC_x= dilution required to cause an X% effect on the test organisms; [b]NOEC = No observed effect concentration; LOEC = Lowest observed effect concentration; TEC = threshold effect concentration (Geometric mean of NOEC and LOEC); [c]Acute 96 hour survival results; [d]Acute 96 hour morbidity (reburial) results; [e]No toxicity dilution calculated as follows: chronic test = (1/TEC)*100; and acute test = $(1/(LC_{50}/10))*100$; [f] Compliance condition: Refining NZ states 800-fold dilution (0.125%) and Marsden Maritime Holdings and Northport state a 200-fold dilution (0.5%). [g]Value determined with regards to method detection limit (section 3.2)

3.1 No toxicity dilution

We have reported the 'no toxicity dilution' for this study, a dilution at which the sample would be expected to exhibit no toxicity in the above toxicity tests (Table 3). The 'no toxicity dilution' value is commonly used if no resource consent compliance conditions are provided. The no toxicity dilution is calculated from chronic data by multiplying the inverse of the TEC by 100 and from acute data by multiplying the inverse of the $(LC_{50}/10)$ by 100. The conversion factor of 10 for acute toxicity data provides a chronic toxicity estimate from the acute LC_{50} measurement (ANZECC 2000). The most sensitive test was the algae test which resulted in a definitive no toxicity dilution of 8.8-fold for the Refining NZ and Northport storm-water samples.

3.2 Algae chronic toxicity test

Controls

The cell density of algae grown in the control water met the test acceptability criteria with coefficient of variations between 6.5-12% and 25-32-fold increases in cell density.

Toxicity

Exposure to the storm-water sample from Refining NZ caused significant (α=0.05) toxicity to algal cell growth at 1% (14% reduction in growth) and higher tested concentrations however, only the reduction in algal cell density in the 16 and 25% samples was greater than the 17.3% method detection limit. For this reason, the lowest observed effect concentration (LOEC) for this test is considered to be 16% and the no observed effect concentration (NOEC) is 8%. There was a maximum of 20% reduction in cell density compared to controls in the highest tested concentration (25%).

No significant (α=0.05) toxicity was observed in the highest tested concentration (20%) of Marsden Maritime Holdings storm-water sample.

Significant (α=0.05) toxicity was observed in 1% (12% reduction in growth) and higher tested concentrations of the Northport storm-water however, only the reduction in algal cell density in the 16 and 20% samples was greater than the method detection limit. For this reason, the LOEC for this test is considered to be 16% and the NOEC is 8%. The 20% Northport sample showed a 28% reduction in cell density relative to the control. Some of the toxicity observed could be attributed to the high colour of the sample (as seen in Figure 1) reducing the light availability for algal growth.

Compliance

The EC_{25} values did not detect any significant toxicity in the supplied Refining NZ storm-water sample at an 800-fold dilution (0.125% concentration), or any significant toxicity in the Marsden Maritime Holdings or Northport storm-water samples at a 200-fold dilution (0.5% concentration).

3.3 *Macomona* survival and morbidity (reburial) test

Controls

Mean control survival was 100%, with all replicates having greater than 90% survival and less than 10% morbidity, therefore the test met the acceptability criteria.

Toxicity

There was no significant toxicity on survival or morbidity in the highest tested concentration of Refining NZ storm-water (68%), with a mean survival of 93%. There was no significant toxicity on survival and morbidity in the highest tested concentration of Marsden Maritime Holdings and Northport storm-waters (63%), with mean survivals of 97% and 93% respectively.

Compliance

The EC_{25} values did not detect any significant toxicity in the supplied Refining NZ storm-water sample at an 800-fold dilution (0.125% concentration), or any significant toxicity in the Marsden Maritime Holdings or Northport storm-water samples at a 200-fold dilution (0.5% concentration).

3.4 Blue mussel embryo development chronic toxicity test

Controls

Mean control survival was 93% and all replicates had greater than 80% normal development therefore the test met the acceptability criteria.

Toxicity
Exposure to the storm water sample from Refining NZ caused significant (α=0.05) toxicity to blue mussel embryos at the highest tested concentration of 68% resulting in a 10.7% reduction in normal embryo development compared to control embryos. The reduction in normal embryo development was greater than the 7.2% method detection limit.

No significant (α=0.05) toxicity was observed in the highest tested concentration (63%) of Marsden Maritime Holdings storm water sample.

Significant (α=0.05) toxicity was observed in 50% and higher tested concentrations of the Northport storm water. The 50% Northport sample showed a 5.5% reduction relative to the control which is below the detection limit however, the 63% sample showed a 11.3% reduction in normal embryo development.

Compliance
The EC_{25} values did not detect any significant toxicity in the supplied Refining NZ storm-water sample at an 800-fold dilution (0.125% concentration), or any significant toxicity in the Marsden Maritime Holdings or Northport storm-water samples at a 200-fold dilution (0.5% concentration).

3.5 Reference toxicant

The EC_{50} value of zinc sulfate for *D. tertiolecta* 0.12 mg Zn^{2+} L^{-1} was within the expected range of the long-term mean 0.13±0.12 mg Zn^{2+} L^{-1} (±2 standard deviations (S.D.), n=5).

The results for blue mussel embryos exposed to zinc sulfate (EC_{50} = 0.14 mg Zn^{2+} L^{-1}), were within the expected range of the long-term mean, 0.19±0.05 mg Zn^{2+} L^{-1} (±2 standard deviations (S.D.), n=21). The results for *Macomona* exposed to zinc sulfate for survival (EC_{50} = 2.63 mg Zn^{2+} L^{-1}) and morbidity (EC_{50} = 1.48 mg Zn^{2+} L^{-1}) were within the expected ranges of the long-term means, 2.84±1.93 mg Zn^{2+} L^{-1} (n=21) and 1.53±0.74 mg Zn^{2+} L^{-1} (n=21) respectively.

By using three test species (*D. tertiolecta, M. liliana,* and *M. galloprovincialis*) that exhibit such sensitivity to zinc, the results from this suite of toxicity tests provide a moderate degree of confidence in assessing the toxic hazard of the sample. However, care must be taken when extrapolating these results for protection of organisms present in a particular receiving water environment.

3.6 Summary

- The highest definitive no toxicity dilution for the Refining NZ and Northport samples was 8.8-fold based on the algae test. The highest indicative no toxicity dilution for the Marsden Maritime Holdings sample was <16-fold based on the *Macomona* test after application of an acute to chronic conversion factor of 10 as per ANZECC (2000) recommendations.
- Samples from Refining NZ, Marsden Maritime Holdings and Northport (24/7/17) comply with the relevant sections of the Northland Regional Council resource consents. The EC_{25} values did not detect any significant toxicity for algae growth, Macomona survival or morbidity or blue mussel embryo development at the specified dilutions (Refining NZ 0.125% and Marsden Maritime Holdings and Northport 0.5%).

4 References

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Cawthron Institute, Ecotoxicology

6 June 2019

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CAWTHRON REPORT NO. 3341

RESULTS FROM TOXICITY TESTS CONDUCTED ON REFINING NZ PRODUCED WATER SAMPLE

Project Number: 17253

Client: Refining NZ
Attention: Riaan Elliot

Sample details

Sample ID (client labelled)	Receiving 1	Receiving 2	Producing 1	Producing 2	Receiving water 1	Receiving water 2	Producing water 1	Producing water 2
Collected by	A.M	A.M	A.M	A.M	A.M	A.M	A.M	A.M
Date sampled	20/05/19 10:00	20/05/19 10:00	20/05/19 10:00	20/05/19 10:00	21/05/19 10:30	21/05/19 10:30	21/05/19 10:30	21/05/19 10:30
Date received	21/05/19 09:25	21/05/19 09:25	21/05/19 09:25	21/05/19 09:25	22/05/19 09:00	22/05/19 09:00	22/05/19 09:00	22/05/19 09:00
Physico-chemical parameters (at reception)								
Temperature (°C)	16.2	16.1	16.6	16.3	16.0	16.1	16.0	16.6
Dissolved oxygen (mg/L)	9.43	9.60	7.68	8.19	9.77	9.87	7.29	7.83
Salinity (PSU)	35.8	35.7	9.6	9.8	36	36.2	10.62	10.45
pH	8.19	8.21	7.83	7.83	8.21	8.20	7.76	7.76

Produced water samples and Receiving water samples were pooled to obtain composite samples.

Summary of the Results on Produced water

Test species	EC_{50} (%) (95%CI)	NOEC (%)	LOEC (%)	TEC (%)	No toxicity dilution
Green algae	> 87	87	-	> 87	≥ 1.15
Amphipod	> 91	91	-	> 91	≥ 1.10
Pipis (survival)	> 81	81	-	> 81	≥ 1.23
Pipis (1h reburial)	n/c	n/c	n/c	n/c	n/c
Blue mussel	> 81	81	-	> 81	≥ 1.23

n/c: non conclusive – none of the individuals from controls and tests reburied after 60min

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Summary of the results on Receiving water (RW) (average ± standard deviation)

Test species	Control	RW (mod.)	RW 100%
Algae (Nbr × 1,000)/mL	489 ± 18	475 ± 94	499 ± 23
Amphipod (% survival)	98 ± 4	87 ± 9	75 ± 6
Pipis (% survival)	100	-	100
Blue mussel (% survival)	86 ± 3	-	90 ± 4

-: not determined, * : significantly different from Control ($P < 0.05$)

Comments: Produced water and receiving water did not have any significant impacts on the tested organisms.

Reviewed by

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Ecotoxicologist
Cawthron Institute

Louis Tremblay, PhD
Environmental toxicologist
Cawthron Institute

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Methods and exposure parameters:

	Green micro-algae	Bivalve	Amphipods	Bivalve - embryo larval development
Test start – end dates	24-28/05/2019	23-27/05/2019	23-27/05/2019	22-24/05/2019
Standard –	ASTM E1218-04 (2012)	n/a	ASTM E1192-97 (2014)	ASTM E724-98 (2012)
Cawthron SOP	ETX 4.33.1	ETX 4.34.3	4.34.1	ETX 4.32.1
Test species	*Dunaliella tertiolecta*	*Paphies australis*	*Paracorophium excavatum*	*Mytilus galloprovincialis*
Source	Laboratory culture (CS-175)	Delaware Estuary	Delaware Estuary	Tennyson Inlet
Density, number per container	$12.3 \pm 4.8 \times 10^3$ /mL	3	10	~400
Test containers	96 well plate	750 mL glass container	80 mL glass container	20 mL glass vials (28 × 61 mm)
Exposure time (hrs)	96	96 + 1 for reburial	96	48
Sample pre-treatment	0.22 µm filtration Addition of brine seawater or Type I water to adjust salinity	Addition of brine seawater or Type I water to adjust salinity	Addition of brine seawater or Type I water to adjust salinity	Addition of brine seawater to raise salinity of produced water
Concentrations tested (%)	0, 0.2 to 87%	0, 1.56 to 81% (reburial with clean seawater)	0, 0.78 to 91%	0, 0.4 to 81%
Replicates	10 for controls, 5 for treatments	6 for controls, 3 for treatments	10 for controls, 3 for treatments	5 for controls, 5 for treatments
Light	Continuous 70 µmol/m²/sec	14h:10h	None	None
Temperature (°C)	21	18	17	17
Dilution water	Artificial seawater	Natural seawater (CAP)	Natural seawater (CAP)	Artificial seawater
Aeration	None	Continuous	None	None
Parameter (at beginning) Salinity (PSU) / DO (mg/L) / pH	26.3 / n/m / 8.2	34 / 9.14 / 8	21 / 9.4 / 8	32.4 / 9.83 / 8.2
Parameter (at end) Salinity (PSU) / DO (mg/L) / pH	n/m / n/m / n/m	33.8±0.5 / 7.4±0.3 / 8	21.7±0.6 / 7.4±0.3 / 8	n/m / n/m / n/m
Endpoint	Growth inhibition	Survival/reburial	Survival	Survival
Sensitivity (EC_{50}) (mg/L)	0.167 (0.0.145–0.190) (Cu^{2+})	n/m	1973 (1647-2299) (Zn^{2+})	0.105 (0.103–0.108) (Zn^{2+})
Control quality for sensitivity (mean with 2SD) (mg/L)	0.166 (0.112–0.219) (*n* = 17)	n/a	1829 (595-3063) (*n* = 24)	0.08 (0.021–0.143) (*n* = 30)
Test acceptability (in controls)	CV < 20%, 16-fold increase	< 10% mortality	< 10% mortality	> 70% survival
Test compliance to procedure	☑		☑	☑
Note	Age of culture: 5 days	Collection date: 14/05/2019	Collection date: 14/05/2019	Collection date: 14/05/2019 Spawning method: thermal stimulation

n/m: not measured, n/a: data not available

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APPENDICES

Appendix 1. Raw data for the algae growth, amphipod survival and mussel embryo-larval development assays

Table A1.1 Algal density (number of algal cells ×10^3 /mL) in the produced water sample.

Control	Sample (%)									
0	0.20	0.39	0.78	1.56	3.13	6.25	12.5	25	50	87
478.1	436.8	453.7	459.2	503.4	513.9	506.3	480.4	476.7	481.4	505.2
454.8	462.4	482.0	504.4	524.1	526.6	526.6	462.8	490.3	518.3	515.4
476.0	694.4	392.9	485.2	704.1	491.7	469.4	509.0	805.6	576.1	492.2
454.6	662.0	468.0	449.5	453.6	769.7	449.8	470.2	502.3	466.9	494.9
444.8	472.7	488.5	506.1	454.6	496.5	510.2	515.0	531.9	530.1	565.8
453.9										
505.8										
493.4										
433.9										
470.1										

Quantification method: particle counter (Multisizer 4e Coulter Cell Analyzer – Beckman Coulter)

Table A1.2 Algal density (number of algal cells ×10^3 /mL) in the receiving water samples at 73% (26 PSU) and at 100% (36 PSU).

Control	RW (73%)	RW (100%)
512.3	470.3	492.7
488.4	405.4	523.7
477.3	690.3	504
512	436.4	520.8
481	454.2	455.1
493.1	438.4	476.8
490.1	451.3	496.2
460.6	447.3	535.4
493.8	472.3	519.8
507.2	449.9	488.2
495	435.8	495.8
493.8	421.9	478.1
452.5	459.2	
	428	
	440.9	
	761.9	
	457.2	
	425.6	

Table A1.3. Survival rate (%) of the burrowing amphipod (*Paracorophium excavatum*) exposed to a serial dilution of the produced and receiving water samples at 91% (21 PSU) and at 100% (36 PSU).

Control	Sample (%)								Receiving water (%)	
0	**0.78**	**1.56**	**3.13**	**6.25**	**12.5**	**25**	**50**	**91**	**91**	**100**
100	90	100	100	100	100	80	100	80	88	80
100	90	100	70	100	100	100	100	100	100	80
100	100	100	90	100	100	30	91	100	90	67
90									78	80
100									80	70
100										
100										
90										
100										
100										

Table A1.4. Survival rate (%) of the pipis (*Paphies australis*) exposed to a serial dilution of the produced water sample and in receiving water sample.

Control	Sample (%)							Receiving water
0	**1.56**	**3.13**	**6.25**	**12.5**	**25**	**50**	**81**	
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100	100
100								100
100								100
100								100

Table A1.5. Reburial rate (%) of the pipis (*Paphies australis*) exposed to a serial dilution of the produced water sample and in receiving water sample.

Control	Sample (%)							Receiving water
0	**1.56**	**3.13**	**6.25**	**12.5**	**25**	**50**	**81**	
0	33	33	0	0	0	0	0	0
0	33	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0								0
0								0
0								0

Table A1.6. Survival rate (%) of blue mussel (*Mytilus galloprovincialis*) D-larvae (D-yield) exposed to a serial dilution of the produced water sample and in the receiving water sample.

Control	Sample (%)									Receiving water
0	**0.39**	**0.78**	**1.56**	**3.13**	**6.25**	**12.5**	**25**	**50**	**81**	
82	90	86	87	85	84	91	87	87	91	85
86	95	n/m	92	83	88	81	85	83	79	87
85	91	87	88	86	87	83	87	86	87	91
87	86	84	86	84	85	86	88	90	82	91
89	90	90	90	85	88	89	91	93	90	95

n/m: not measured

Appendix 2. Statistical analysis

Calculation of the EC_{50} (the concentration which produces an effect on 50% of the test organisms), with associated 95% confidence intervals (CI), were done with R (R Core Team, 2019) using bootstrap resampling with the 'drc' package (Ritz & Streibig 2005). Hypothesis testing (level of statistical significance of $P < 0.05$) was based on the method described in Hall and Golding (1998). Statistical analyses were conducted with Statistica 13 (TIBCO Inc., USA).

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Appendix 4. Acronyms and definitions

Acronym	Definition
ASTM	American Society for Testing and Materials
ASW	Artificial seawater
CAP	Cawthron Aquaculture Park
CI	Confidence Interval (95%)
CV	Coefficient of Variation
Cu	Copper
DO	Dissolved Oxygen
DTA	Direct Toxicity Assessment
EC	Effective Concentration
LOEC	Lowest Observed Effect Concentration
NOEC	No Observed Effect Concentration
PSU	Practical Salinity Unit
SD	Standard Deviation
TEC	Threshold Effect Concentration
Zn	Zinc (trace metal)

$EC_{x\text{-}t}$	**Effective Concentration** is the generic term for a concentration of substance or material that is estimated to cause some defined effect on a proportion (x%) of the test organisms after a defined period of exposure (t). This kind of endpoint allows the classification and the comparison of the toxic potency or intensity of different chemicals. More terms can be derived to describe specific effects (*e.g.* lethality, inhibition): **$LC_{x\text{-}t}$** (Lethal Concentration) is the concentration of substance or material that is estimated to be lethal to a proportion (x%) of the test organisms after a defined period of exposure (t). This is an acute toxicity indicator (for the blue mussel and the wedge shell); **$IC_{x\text{-}t}$** (Inhibitory Concentration) is the concentration of substance or material that is estimated to have an inhibitory effect (*e.g.* algal growth) on a proportion (x%) of the test organisms after a defined period of exposure (t). This is a chronic toxicity indicator (for the diatom).
LOEC	**Lowest Observed Effect Concentration** is the lowest concentration of a test substance or material which is observed to have a statistically significant adverse effect on the test organisms for a defined time of exposure and under the test conditions, relative to the control.
NOEC	**No Observed Effect Concentration** is the highest concentration of a test substance or material which is observed not to have a statistically significant adverse effect on the test organisms for a defined time of exposure and under the test conditions, relative to the control.
Practical salinity unit	It is a unit based on the properties of sea water conductivity to measure salinity. It is equivalent to parts per thousand or (‰) or to g/kg.
Reference toxicant	Chemical used to assess the constancy of response of a given species of test organisms to that chemical. It is assumed that any change in sensitivity to the reference substance will indicate the existence of some similar change in degree of sensitivity to other chemicals/effluents whose toxicity is to be determined.
TEC	Threshold Effect Concentration is the geometric mean of the NOEC and the LOEC. It represents the lowest concentration that should not cause any effect for the related measured endpoint.

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Cawthron Institute, Ecotoxicology

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Nelson, 7042
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11 September 2019

CAWTHRON REPORT NO. 3401

RESULTS FROM TOXICITY TESTS CONDUCTED ON REFINING NZ EFFLUENT AND RECEIVING WATER SAMPLES

Project Number: 17353

Client: Refining NZ
Attention: Riaan Elliot

Sample details

Sample ID (client labelled)	Effluent 1	Effluent 2	Effluent 3	Effluent 4	Receiving water (4 composited containers)
Collected by	A.M	A.M	A.M	A.M	A.M
Date/Time sampled	21/08/19 08:00	21/08/19 08:00	21/08/19 08:00	21/08/19 08:00	21/08/19 09:00
Date received	23/08/19 06:00	23/08/19 06:00	23/08/19 06:00	23/08/19 06:00	23/08/19 06:00
Temperature (°C)	12.4	12.2	12.1	12.1	12.9
Dissolved oxygen (mg/L)	8.2	7.8	8.4	8.6	8.3
Salinity (PSU)	2.4	2.5	2.5	2.5	35
pH	7.7	7.7	7.7	7.7	8.2

Effluent samples and receiving water samples were pooled to obtain composite samples.

Summary of the Results on Effluent

Test species	EC_{50} (%) (95%CI)	NOEC (%)	LOEC (%)	TEC (%)	No toxicity dilution
Green algae	n/d*	6.25*	12.5*	8.84*	11.3 × *
Amphipod	> 86.7	86.7	> 86.7	> 86.7	< 1.15 ×
Pipis (survival)	> 77.2	77.2	> 77.2	> 77.2	< 1.3 ×
Pipis (1h reburial)	> 77.2**	77.2**	> 77.2**	> 77.2**	< 1.3 ×**
Blue mussel	0.43 (0.41-0.44)	< 0.39	0.39	< 0.39	> 256 ×

* algal growth stimulation (n/d not determined)
** only partial reburial in control and no trend related to concentration observed.

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Summary of the results on Receiving water (RW) (average ± standard deviation)

Test species	Control	RW (modified*)	RW (100% - 35PSU)
Green algae (Nbr × 1,000)/mL	216 ± 13	219 ± 24	228 ± 18
Amphipod (% survival)	95 ± 8	95 ± 8	91 ± 9
Pipis (% survival)	100	-	100
Pipis (% reburial)	18	-	58
Blue mussel (% survival)	85 ± 9	-	86 ± 13

-: did not required RW salinity modification
*: (RW modified to 26 PSU for algae (74%) and 20 PSU for amphipods (58%))

Comments:

- The effluent had a significant impact on the blue mussel embryo-larval development.
- Receiving water did not have any significant impacts on the tested organisms.

Reviewed by

Olivier Champeau, PhD
Ecotoxicologist
Cawthron Institute

Louis Tremblay, PhD
Environmental toxicologist
Cawthron Institute

Methods and exposure parameters:

	Green micro-algae	Bivalve	Amphipods	Bivalve - embryo larval development
Test start – end dates	23-27/08/2019	23-27/08/2019	23-27/08/2019	23-25/08/2019
Standard – Cawthron SOP	ASTM E1218-04 (2012) – MfE ETX 4.33.1	n/a ETX 4.34.3	ASTM E1192-97 (2014) 4.34.1	ASTM E724-98 (2012) ETX 4.32.1
Test species	*Dunaliella tertiolecta*	*Paphies australis*	*Paracorophium excavatum*	*Mytilus galloprovincialis*
Source	Laboratory culture (CS-175)	Delaware Estuary	Delaware Estuary	Tennyson Inlet
Density, number per container	$10.1 \pm 2.5 \times 10^3$ /mL	3	10	~400
Test containers	96 well plate	750 mL glass container	80 mL glass container	20 mL glass vials (28 × 61 mm)
Exposure time (hrs)	96	96 + 1 for reburial	96	48
Sample pre-treatment	0.45 µm filtration Addition of brine seawater or Type I water to modify salinity	Addition of brine seawater or Type I water to modify salinity	Addition of brine seawater or Type I water to modify salinity	Addition of brine seawater to raise salinity of produced water
Concentrations tested	0, 0.2 to 82.3%	0, 3.13 to 77.2% (reburial with clean seawater)	0, 0.78 to 86.7%	0, 0.39 to 77.7%
Replicates	10 for controls, 5 for treatments	6 for controls, 3 for treatments	10 for controls, 3 for treatments	5 for controls, 5 for treatments
Light	Continuous 180 µmol/m²/sec	14h:10h	None	None
Temperature (°C)	21	18	17	17
Dilution water	Artificial seawater	Natural seawater (CAP)	Natural seawater (CAP)	Artificial seawater
Aeration	None	Continuous	None	None
Parameter (at beginning) Salinity (PSU) / DO (mg/L) / pH	26.3 / n/m / 8.2	33.3 / 9.8 / 8	20.5 / 10.2 / 7.7	33.4 / 8.4 / 7.9
Parameter (at end) Salinity (PSU) / DO (mg/L) / pH	n/m / n/m / n/m	33.8±0.5 / 7.4±0.3 / 8	20.7±0.1 / 7.3±0.5 / 7.8	n/m / n/m / n/m
Endpoint	Growth inhibition	Survival/reburial	Survival	Survival
Sensitivity (EC_{50}) (mg/L)	0.2 (0.167–0.233) (Cu^{2+})	> 100 (Zn^{2+})	2.47 (2.06-2.88) (Zn^{2+})	0.121 (0.119–0.123) (Zn^{2+})
Control quality for sensitivity (mean with 2SD) (mg/L)	0.164 (0.107–0.222) (*n* = 19)	n/a	1.85 (0.62-3.09) (*n* = 25)	0.084 (0.024–0.144) (*n* = 32)
Test acceptability (in controls)	CV < 20%, 16-fold increase	< 10% mortality	< 10% mortality	> 70% survival
Test compliance to procedure	☑		☑	☑
Note	Age of culture: 6 days	Collection date: 21/08/2019	Collection date: 23/08/2019	Collection date: 21/8/2019 Spawning method: thermal stimulation

n/m: not measured, n/a: data not available

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APPENDICES

Appendix 1. Raw data for the algae growth, amphipod survival and mussel embryo-larval development assays

Table A1.1 Algal density (number of algal cells ×10^3 /mL) in the produced water sample.

Control	Sample (%)									
0	**0.20**	**0.39**	**0.78**	**1.56**	**3.13**	**6.25**	**12.5**	**25**	**50**	**82**
216	180	188	222	193	198	197	254	228	243	233
250	230	195	202	260	207	247	251	224	259	273
219	196	224	219	207	205	235	226	242	238	272
206	172	226	230	227	228	225	253	244	247	275
220	201	197	205	195	209	214	238	245	229	267
210										
183										
201										
177										
216										

Quantification method: particle counter (Multisizer 4e Coulter Cell Analyzer – Beckman Coulter)

Table A1.2 Algal density (number of algal cells ×10^3 /mL) in the receiving water samples at 74% (26 PSU) and at 100% (35 PSU).

Control	RW (74%)	RW (100%)
211.7	194.0	225.4
192.9	278.9	261.7
223.5	218.8	204.9
210.1	211.7	225.0
224.7	199.5	236.3
227.4	208.2	209.1
198.3	192.3	256.1
217.8	206.8	207.5
201.8	221.9	210.6
209.0	215.8	234.5
200.6	243.1	236.8
223.3	233.3	223.2
213.8		
219.4		
224.5		
255.2		
217.9		
212.8		
217.7		
218.1		

Table A1.3. Survival rate (%) of the burrowing amphipod (*Paracorophium excavatum*) exposed to a serial dilution of the produced and receiving water samples at 58% (20 PSU) and at 100% (35 PSU).

Control	Sample (%)								Receiving water (%)	
0	0.78	1.56	3.13	6.25	12.5	25	50	87	58	100
100	100	100	100	100	100	90	90	100	100	89
100	100	91	100	90	100	100	100	100	100	78
100	100	100	100	90	100	89	100	100	100	100
80									90	100
100									80	91
82									100	89
100										
100										
100										
92										

Table A1.4. Survival rate (%) of the pipis (*Paphies australis*) exposed to a serial dilution of the produced water sample and in receiving water sample.

Control	Sample (%)						Receiving water
0	3.13	6.25	12.5	25	50	77	
100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100
100	100	100	100	100	100	100	100
100							100
100							100
100							100

Table A1.5. Reburial rate (%) of the pipis (*Paphies australis*) exposed to a serial dilution of the produced water sample and in receiving water sample.

Control	Sample (%)						Receiving water
0	3.13	6.25	12.5	25	50	77	
0	25	25	0	0	25	25	25
33	25	25	0	25	50	0	75
0	25	75	25	50	25	25	100
25							50
25							50
25							50

Table A1.6. Survival rate (%) of blue mussel (*Mytilus galloprovincialis*) D-larvae (D-yield) exposed to a serial dilution of the produced water sample and in the receiving water sample.

Control	Sample (%)					Receiving water
0	0.39	0.78	1.56	3.13	6.25	
88.4	34.4	4.2	0.0	0.0	0.0	85.4
89.9	40.2	1.1	0.0	0.0	0.0	95.0
85.1	65.3	9.7	0.0	0.0	0.0	91.7
69.7	45.2	1.1	0.0	0.0	0.0	63.0
92.3	82.0	7.0	0.0	0.0	0.0	94.3

Appendix 2. Statistical analysis

Calculation of the EC_{50} (the concentration which produces an effect on 50% of the test organisms), with associated 95% confidence intervals (CI), were done with R (R Core Team, 2019) using bootstrap resampling with the 'drc' package (Ritz & Streibig 2005). Hypothesis testing (level of statistical significance of $P < 0.05$) was based on the method described in Hall and Golding (1998). Statistical analyses were conducted with Statistica 13 (TIBCO Inc., USA).

Appendix 3. References

ASTM 1998. E724-98 2012 - Standard guide for conducting static acute toxicity tests starting with embryos of four species of saltwater bivalve molluscs. West Conshohocken, PA, ASTM International. 20 pp.

ASTM 2012. E1218-04 - Standard guide for conducting static toxicity tests with microalgae. West Conshohocken, PA, ASTM International. Pp. 14.

ASTM 2014. E1192-97 - Standard guide for conducting acute toxicity tests on aqueous ambient samples and effluents with fishes, macroinvertebrates, and amphibians. West Conshohocken, PA, ASTM International. Pp. 14.

Hall JA, Golding LA 1998. Standard methods for whole effluent toxicity testing: development and application. Report no. MfE80205. NIWA report for the Ministry for the Environment Wellington, New Zealand. 53 pp.

R Core Team 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ritz C, Streibig JC 2005. Bioassay Analysis using R. Journal of Statistical Software:12(5): 16.

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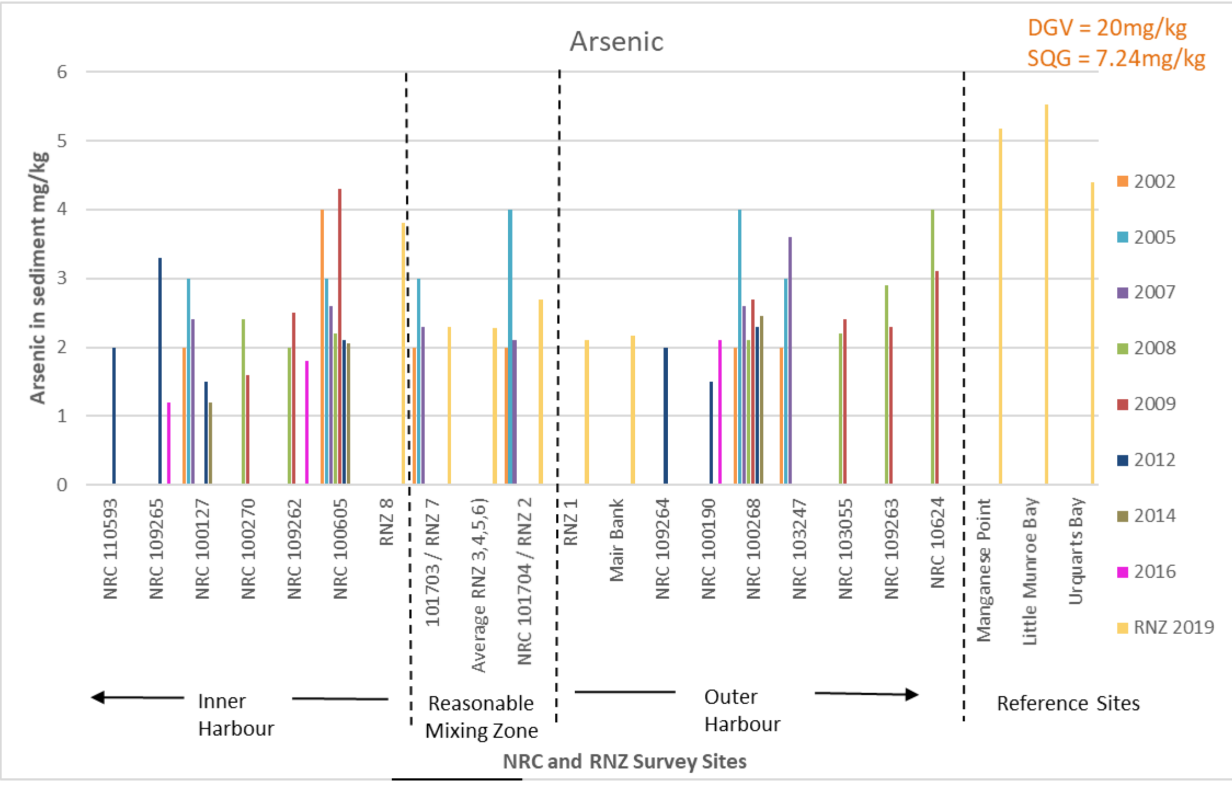
Appendix 4. Acronyms and definitions

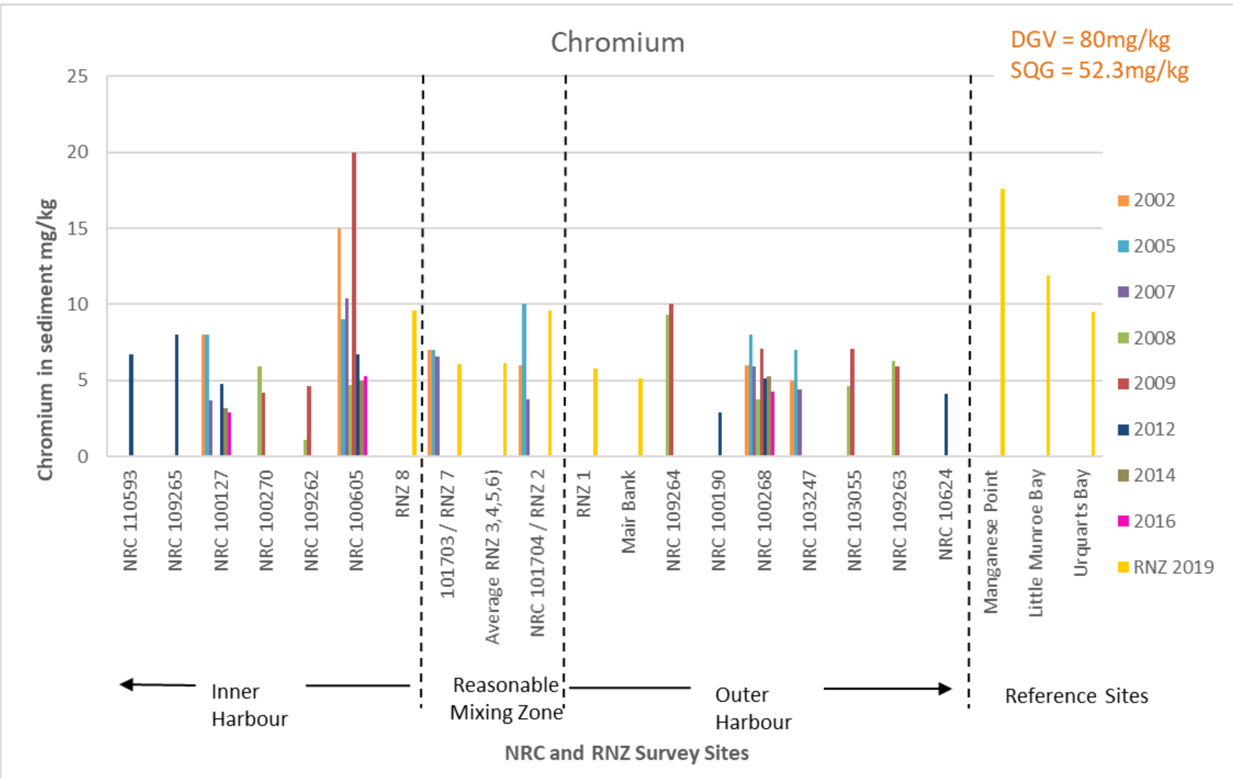
Acronym	Definition
ASTM	American Society for Testing and Materials
ASW	Artificial seawater
CAP	Cawthron Aquaculture Park
CI	Confidence Interval (95%)
CV	Coefficient of Variation
Cu	Copper
DO	Dissolved Oxygen
DTA	Direct Toxicity Assessment
EC	Effective Concentration
LOEC	Lowest Observed Effect Concentration
NOEC	No Observed Effect Concentration
PSU	Practical Salinity Unit
SD	Standard Deviation
TEC	Threshold Effect Concentration
Zn	Zinc (trace metal)

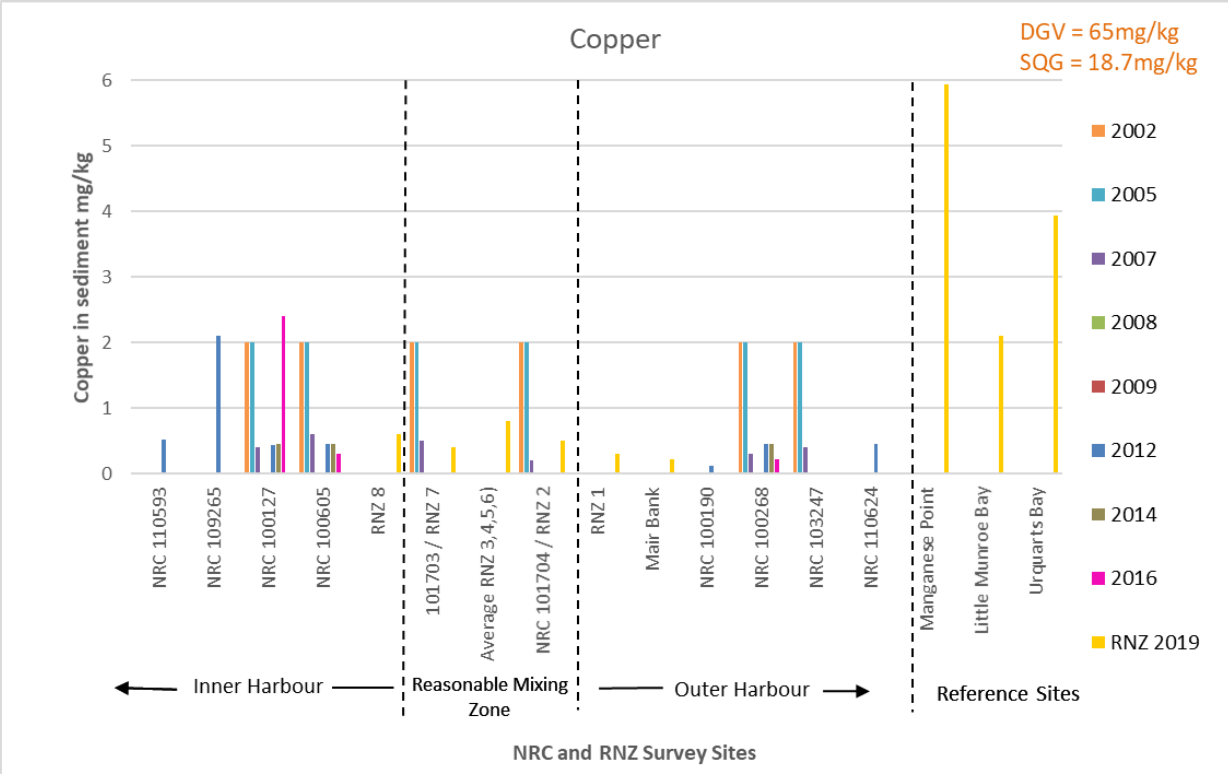
$EC_{x\text{-}t}$	**Effective Concentration** is the generic term for a concentration of substance or material that is estimated to cause some defined effect on a proportion (x%) of the test organisms after a defined period of exposure (t). This kind of endpoint allows the classification and the comparison of the toxic potency or intensity of different chemicals. More terms can be derived to describe specific effects (*e.g.* lethality, inhibition): **$LC_{x\text{-}t}$** (Lethal Concentration) is the concentration of substance or material that is estimated to be lethal to a proportion (x%) of the test organisms after a defined period of exposure (t). This is an acute toxicity indicator (for the blue mussel and the wedge shell); **$IC_{x\text{-}t}$** (Inhibitory Concentration) is the concentration of substance or material that is estimated to have an inhibitory effect (*e.g.* algal growth) on a proportion (x%) of the test organisms after a defined period of exposure (t). This is a chronic toxicity indicator (for the diatom).
LOEC	**Lowest Observed Effect Concentration** is the lowest concentration of a test substance or material which is observed to have a statistically significant adverse effect on the test organisms for a defined time of exposure and under the test conditions, relative to the control.
NOEC	**No Observed Effect Concentration** is the highest concentration of a test substance or material which is observed not to have a statistically significant adverse effect on the test organisms for a defined time of exposure and under the test conditions, relative to the control.
Practical salinity unit	It is a unit based on the properties of sea water conductivity to measure salinity. It is equivalent to parts per thousand or (‰) or to g/kg.
Reference toxicant	Chemical used to assess the constancy of response of a given species of test organisms to that chemical. It is assumed that any change in sensitivity to the reference substance will indicate the existence of some similar change in degree of sensitivity to other chemicals/effluents whose toxicity is to be determined.
TEC	Threshold Effect Concentration is the geometric mean of the NOEC and the LOEC. It represents the lowest concentration that should not cause any effect for the related measured endpoint.

Appendix 2: Sediment Contaminant Graphs[56]

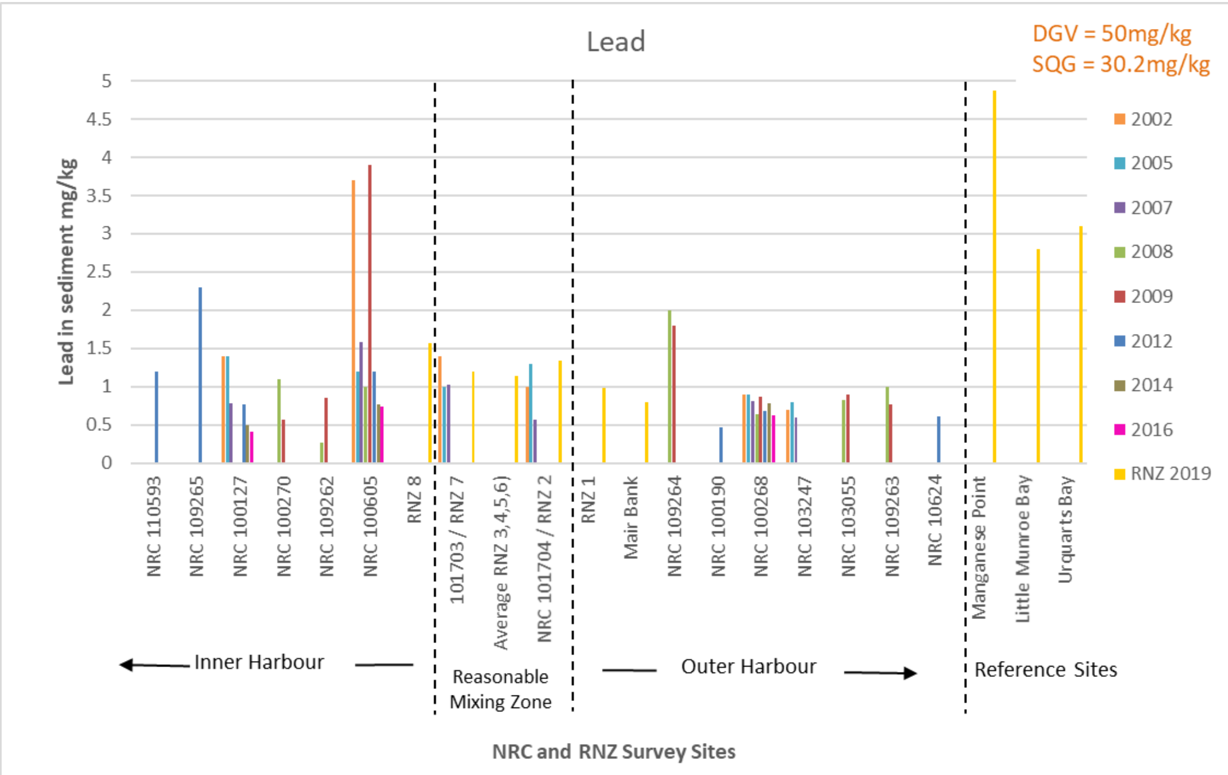
[56] Where concentrations were below laboratory detection limits, the detection limit has been used as the concentration in order to be conservative.


Arsenic
DGV = 20mg/kg
SQG = 7.24mg/kg
Arsenic in sediment mg/kg
0
1
2
3
4
5
6
NRC 110593
NRC 109265
NRC 100127
NRC 100270
NRC 109262
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 109264
NRC 100190
NRC 100268
NRC 103247
NRC 103055
NRC 109263
NRC 10624
Manganese Point
Little Munroe Bay
Urquarts Bay
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites

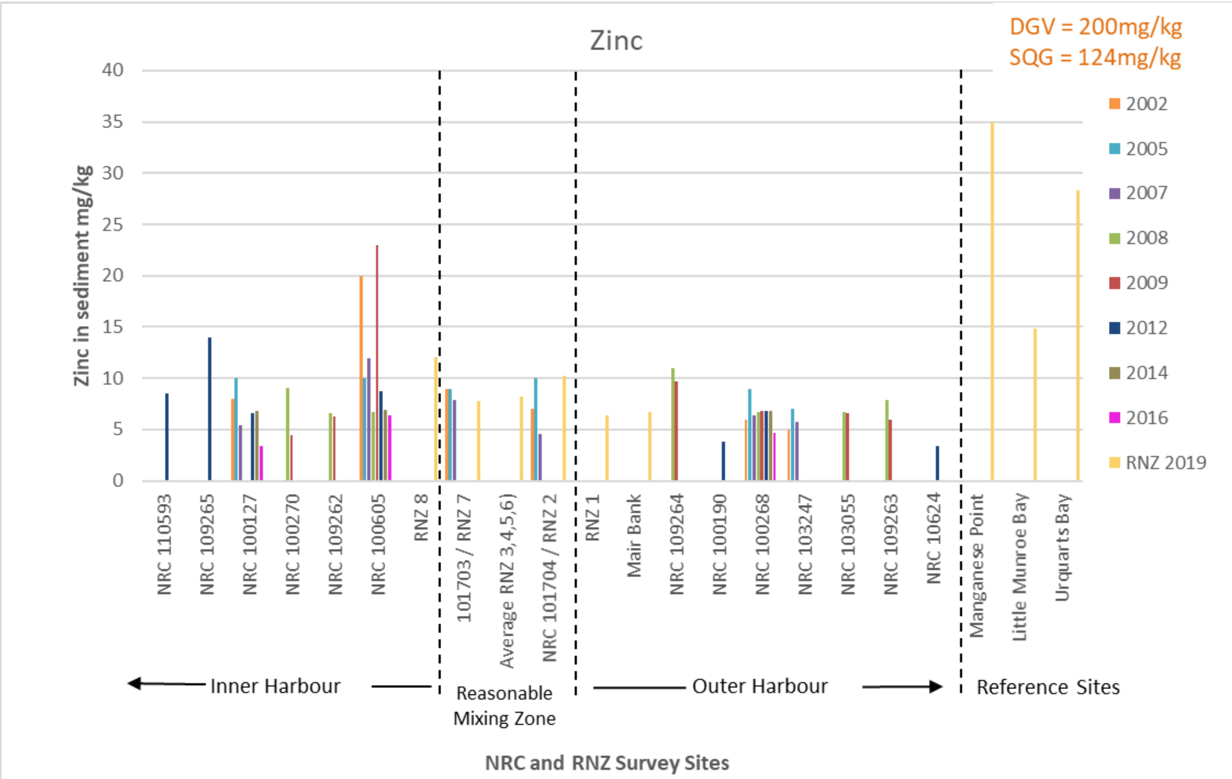

Chromium
DGV = 80mg/kg
SQG = 52.3mg/kg
Chromium in sediment mg/kg
0
5
10
15
20
25
NRC 110593
NRC 109265
NRC 100127
NRC 100270
NRC 109262
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 109264
NRC 100190
NRC 100268
NRC 103247
NRC 103055
NRC 109263
NRC 10624
Manganese Point
Little Munroe Bay
Urquarts Bay
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites

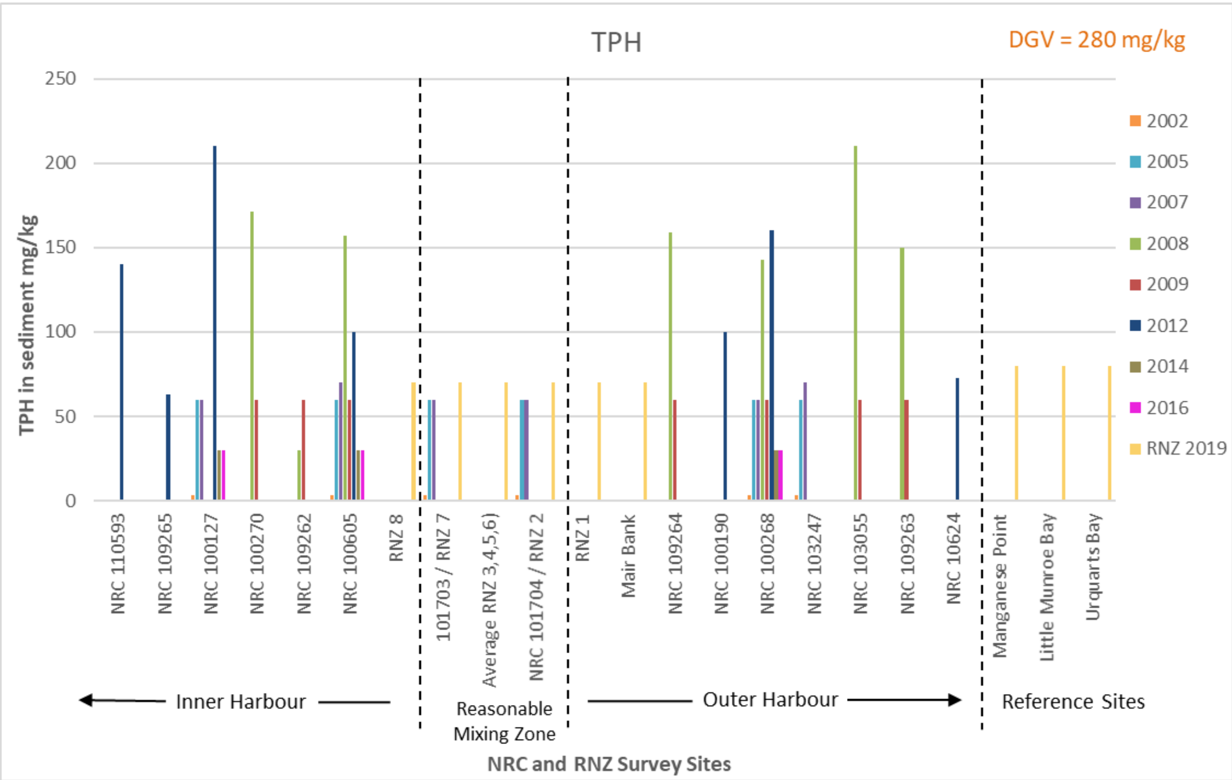


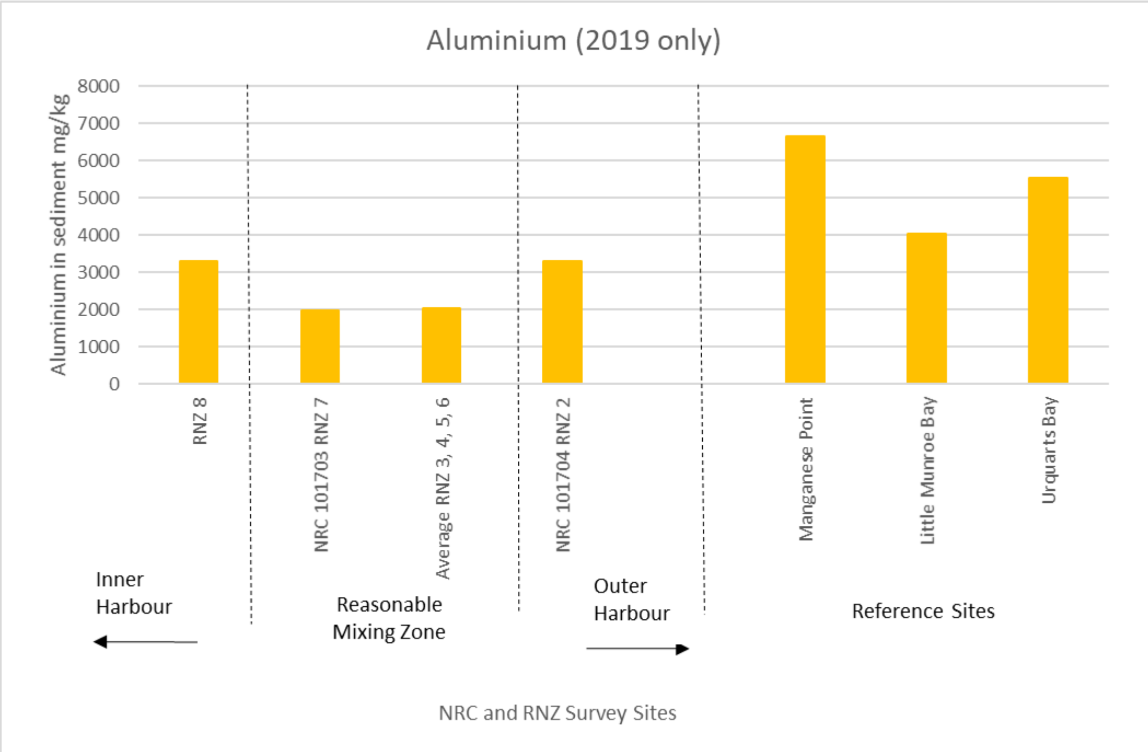
Copper
DGV = 65mg/kg
SQG = 18.7mg/kg
Copper in sediment mg/kg
6
5
4
3
2
1
0
NRC 110593
NRC 109265
NRC 100127
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 100190
NRC 100268
NRC 103247
NRC 110624
Manganese Point
Little Munroe Bay
Urquarts Bay
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites

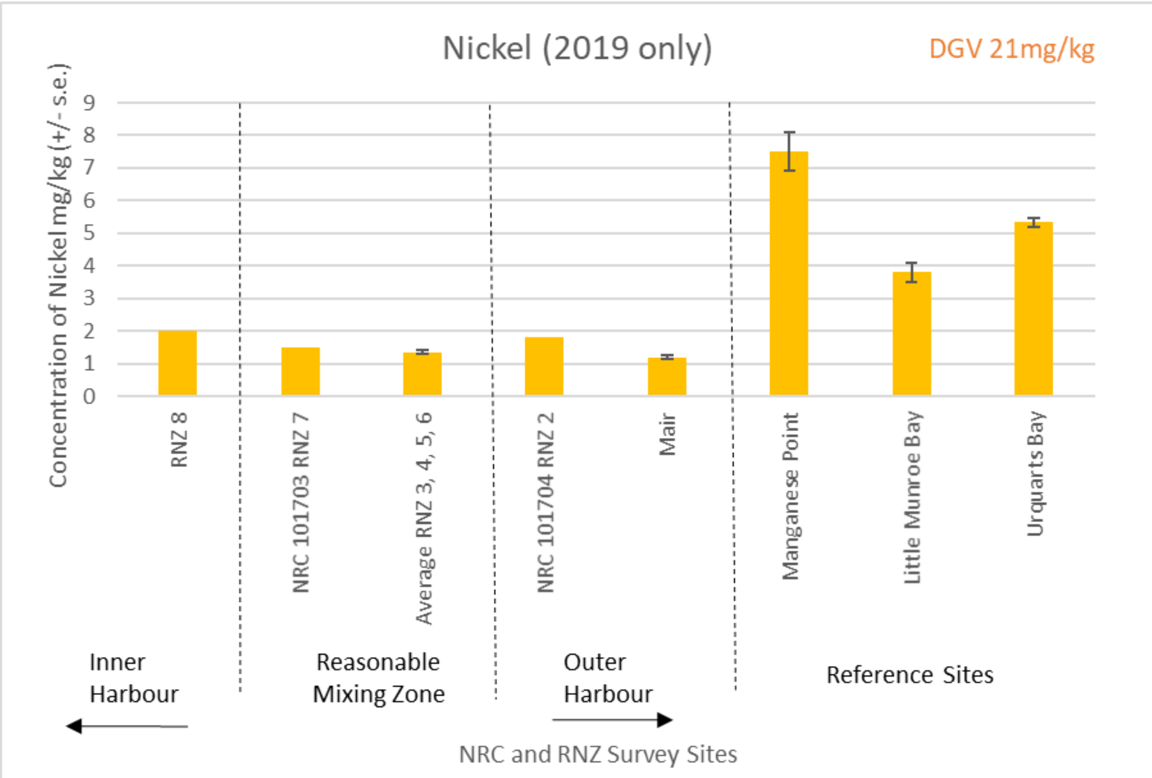


Lead
DGV = 50mg/kg
SQG = 30.2mg/kg
Lead in sediment mg/kg
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
NRC 110593
NRC 109265
NRC 100127
NRC 100270
NRC 109262
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 109264
NRC 100190
NRC 100268
NRC 103247
NRC 103055
NRC 109263
NRC 10624
Manganese Point
Little Munroe Bay
Urquarts Bay
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites


Zinc
DGV = 200mg/kg
SQG = 124mg/kg
Zinc in sediment mg/kg
40
35
30
25
20
15
10
5
0
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
NRC 110593
NRC 109265
NRC 100127
NRC 100270
NRC 109262
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 109264
NRC 100190
NRC 100268
NRC 103247
NRC 103055
NRC 109263
NRC 10624
Manganese Point
Little Munroe Bay
Urquarts Bay
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites


TPH
DGV = 280 mg/kg
TPH in sediment mg/kg
250
200
150
100
50
0
2002
2005
2007
2008
2009
2012
2014
2016
RNZ 2019
NRC 110593
NRC 109265
NRC 100127
NRC 100270
NRC 109262
NRC 100605
RNZ 8
101703 / RNZ 7
Average RNZ 3,4,5,6)
NRC 101704 / RNZ 2
RNZ 1
Mair Bank
NRC 109264
NRC 100190
NRC 100268
NRC 103247
NRC 103055
NRC 109263
NRC 10624
Manganese Point
Little Munroe Bay
Urquarts Bay
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites


Aluminium (2019 only)
Aluminium in sediment mg/kg
8000
7000
6000
5000
4000
3000
2000
1000
0
RNZ 8
NRC 101703 RNZ 7
Average RNZ 3, 4, 5, 6
NRC 101704 RNZ 2
Manganese Point
Little Munroe Bay
Urquarts Bay
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites


Nickel (2019 only)
DGV 21mg/kg
Concentration of Nickel mg/kg (+/- s.e.)
9
8
7
6
5
4
3
2
1
0
RNZ 8
NRC 101703 RNZ 7
Average RNZ 3, 4, 5, 6
NRC 101704 RNZ 2
Mair
Manganese Point
Little Munroe Bay
Urquarts Bay
Inner Harbour
Reasonable Mixing Zone
Outer Harbour
Reference Sites
NRC and RNZ Survey Sites

Appendix 3: Benthic Invertebrate Tolerance/Sensitivity Information

Table 1: Invertebrate Sensitivity Characteristics (sources below)

		Tolerance to Organic Enrichment	Tolerance to Mud	Tolerance to Contaminants	Details
Amphipod	*Paracorophium sp.*	**Indifferent**	**Tolerant**		A tube-dwelling corophioid amphipod. Two species in NZ, *P. excavatum* and *P. lucasi*. Both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area. *P. excavatum* has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum range 95-100% mud, distribution range 40-100% mud. Often present in estuaries with regularly low salinity conditions.
	Phoxocephalidae sp.	**Sensitive**	**Tolerant**		A family of amphipods.
	Talitridae				A family of Amphipods which includes all terrestrial amphipods as well as some marine and semi-terrestrial species.
	Torridoharpinia hurleyi		**Sensitive**		
	Waitangi brevirostris		**Sensitive**		*Waitangi chelatus* is known to prefer a very low mud content of 0-5% and has been shown to be sensitive to lead contamination. If the sediment becomes muddier and/or polluted the abundance of *Waitangi chelatus* is likely to decline.
	Corophiidae	**Tolerant**	**Tolerant**		*Corophiidae* is a family of amphipods. They tolerate a sediment mud content of 40-100%, with an optimum range of 95-100%. Therefore, they are usually found in very muddy habitats. Corophiid amphipods can also tolerate organic enrichment and pollution. Corophiids is likely to increase when the sediment mud content increases (exceeding 40-50%) and/or becomes polluted or organically enriched.
	Caprellidae				Refered to as skeleton shrimps, have been found fee living within fine red algae (Morton 2004).
	Haustoriidae				Known to colonise quickly after disturbance (Posey and Alphin 2002).
	Lysianassidae				
	Phoxocephalidae				
	Amphipoda Unid.				
Anemone	*Anthopleura aureoradiata*		**Sensitive**		Mud flat anemone, attaches to cockle shells and helps to reduce the rate at which cockles accumulate parasites. It can also grow in small vertical shafts of its own an inch or more deep, fastened to small stones. Grows up to10mm, intolerant of low salinity, high-turbidity and increasing silt/clay sediment content (Norkko et al., 2001). It has green plant cells in its tissues that convert solar energy to food (Robertson and Stevens, 2016). Optimum range 5-10% mud, distribution range 0-15% mud.
	Edwardsia sp.	**Indifferent**	**Tolerant**		A tiny elongate anemone adapted for burrowing; colour very variable, usually 16 tentacles but up to 24, pale buff or orange in colour. Fairly common throughout New Zealand. Prefers sandy sediments with low-moderate mud. Intolerant of anoxic conditions.
Anthozoa	*Anthozoa Unid.*				
	Anthopleura aureoradiata		Sensitive		Often colonises the sheel of Austrovenus stutchburyi (Cook 2010). Has a negative effect of increasing sediment and mud content on predictions of occurance (Thrush et al 2003). Limited to sediment mud concentrations <50%, preference for 23.8-43.8% (Robertson et al 2015).
	Edwardsia sp.		Sensitive		Optiumum range of 7–33.3% mud content, upper limit <40% mud (Robertson et al 2015).
Ascidia	*Didemnum sp. (White)*				
	Molgula sp.				
	Ascidian (solitary)				
	Pyura sp.				
Asteroidea	*Patiriella regularis*				

Bivalve	*Arcuatula (Musculista) senhousia*		**Tolerant**		*Musculista senhousia* is a small invasive mussel originating from Asia and growing up to 35mm. It can live on both hard and soft substrates in the intertidal and shallow subtidal zones to 20 m depth and often occurs in dense patches.
	Arthritica sp.	**Tolerant**	**Tolerant**		A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds. Optimum range 55-60% or 20-40% mud, distribution range 0-70% mud.
	Austrovenus stutchburyi	NA	**Sensitive**		The cockle is a suspension feeding bivalve with a short siphon - lives a few centimetres from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer. Has average mobility. Is sensitive to depth of sediment deposited. Can be considered to have average overall tolerance to sedimentation. Prefers sand with some mud (optimum range 5-10% mud or 0-10% mud), distribution range 0-85% mud.
	Hiatula (Soletellina) siliquens	**Sensitive**	**Sensitive**		Soletellina is a genus of bivalve molluscs in the family Psammobiidae, known as sunset shells. Intolerant of eutrophic or muddy conditions (Robertson and Stevens, 2016).
	Macomona liliana	NA	**Sensitive**		A surface deposit feeding wedge shell. This species lives at depths of 5-10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer. Prefers a sandy substrate. Has moderate mobility, and has average tolerance to depth and duration of sediment deposition. Prefers sand with some mud (optimum range 0-5% mud), distribution range 0-40% mud.
	Nucula hartvigiana	**Tolerant**	**Sensitive**		The nut clam of the Family *Nuculidae*, is endemic to NZ. It is found intertidally and in shallow water, especially in *Zostera* sea grass flats. It is often found together with the New Zealand cockle, *Austrovenus stutchburyi*, but is not as abundant showing a preference for mud. Like *Arthritica* this species feeds on organic particles within the sediment. Not very mobile. Intolerant of depth and duration of sediment deposition. Optimum range 0-5% mud, distribution range 0-60% mud.
	Paphies australis	NA	**Sensitive**		The pipi is endemic to NZ. Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents. They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7m. Prefer sandy substrates. Highly mobile suspension feeders. Intolerant of depth of sediment deposition. Adults optimum range 0-5% mud, distribution 0-5% mud. Juveniles often found in muddier sediment.
	Arthritica bifurca	**Tolerant**	Tolerant	Tolerant	Deposit feeder. Optimum range of 1-90% mud (Robertson et al 2015). Considered to be an enrichment tolerant taxa (keeley et al 2014). Species tolerant of elecated contaminant loadings included the deposit feeding bivalve A. bifuca (Ellis et al 2015).
	Thraciidae		tolerant		Family of thraciidae shells of light build, dull surfaced, granulose or smooth, and never pearly within, inequivalve, the more convex right valave slightly overlapping the left. Jurassic to recent, most seas, usually in deep water, buried in mud or silty sand (Powell 1979).
	Corbula zelandica		tolerant		Low water to about 50 fathoms, in mud or very fine sand. Very abundant in the north in shallow water. (Powell 1979). Habitat sandy mud to fine silty sand and gravel, in which is shallowly buries itself. Usually in semi-protected to sheletered waters, though often occurs in the presence of moderate currents, e.g. in the fine gravel substrata of tidal channels. Low intertidal to 80m (Cook 2010).
	Dosinia subrosea		Sensitive		Habitat: Semi-protected to open shore, where it buries itself in moderately fine sand. Can tolerate a limited amount of silt (Cook 2010).
	Felaniella zealandica				Habitat: buried shallowly in muddy sandy, in sheltered waters. Low intertidal to 60m. (Cook 2010).
	Gari lineolata				Habitat: buried 10-20cm deep in silty sand to coarse or slightly gravelly sand in protected to semi-protected situations. Low intertidal to 140m; most abundant above 30m. (Cook 2010)
	Gari stangeri				Habitat: buried the surface in fine sand to gravel, where there is reasonable water flow. Occurs from the low intertidal to at least 80m, though is most often collected in less thatn 30m of water. (Cook 2010).
	Myadora antipodum				Habitat: Fine, clean sand off open coasts. Recorded from 20m to at least 200m depth (Cook 2010).
	Myllitella vivens vivens				
	Nucula nitidula		Tolerant		Habitat: Shallowly buries itself in fine muddy sediments, though tending towards slighlty cleaner situation compared with nucula hartvigiana. Found in low to moderatly-low energy environments. Where N. hartvigiana is likely to be found in muddy sand flats, N. nitidula may be found futher away from the shore, particulary towards a channel or stronger tidal flow. This species is co-dominant with the Amphiura aster, in well-defined subtidal benthic community that occurs in Hawke Bay, from 10-45m. Depth range: below the low-water mark to over 60m (Cook 2010)

Bivalvia	*Paphies subtriangulata (juvenile)*		Sensitive		The shell may be discoloured brown or green, particulary towards the truncated posterior end, or may even have a asmall crop of algae or encrusting incertebates, e.g. hydrois, indicating that the animal lives very close to the substratum surface. Juveniles of the two species of tuatua may be difficult to separate on shell characters alone, but can be identified by the colour of their adductor muscles. (Cook 2010) Habitat: A or just below the surface of clean sand, as on open beaches. Usually at and below low water mark but juveniles and sometimes larger individuals may be found in the lower mid-shore. Found in lower mid-intertidal to shallow subtidal, seldom much deeper than spring low-water mark. (Cook 2010)
	Purpurocardia purpurata		Tolerant		Purple cockle. Habitat: buried at the surface of sandy mud to silty coarse sand, or sometimes with shell debris or gravel. Found on moderately sheletered to semi-exposed coasts, probably preferring moderate water movement. This species is co-dominant with the venerid tawera spissa in a subtidal benthic community that is widespread around New Zealand. Low intertidal to over 100m. (cook 2010).
	Ruditapes largillierti		Tolerant		Shallow burrowing venerid clam found 50-70mm below the sediment surface. It is common thoughout NZ occuring in both mudddy and sandy locations (Gribben et al 2002). Buried near the surafce in fine, muddy to clean sand or fine gravel, on protected to semi-protected shoes and in harbours and estuaries where there is moderate water movement, e.g. tidal channels. May also occur in seagrass. Live in the low intertidal to at least 20m (Cook 2010).
	Solemya parkinsoni				Deposit feeder. Habitat: Firm sandy mud where it buries itself 10-60cm deep, in harbours and estuaries, often in assocaition with seagraa. Larger individuals are usually found more deeply buried. Low intertidal to over 60m. (Cook 2010). Burrow with the anterior end downwards and does not maintain an opening to the surface. deeply buried in thick mud. (Powell 1979).
	Saccostrea glomerata				Auckland rock oyster. Habitat: Hard substrata in harbours and estuaries, and on mre sheletered sections of the open coast. Occurs in dense climps, with individuals often atached to one another. In suitable habitats, a dense zone forms across the shore. Mid-intertidal.
	Tawera spissa		Sensitive		Habitat: Just below the surface in fine to coarse sand, in some water movement, e.g., tidal channels and open beaches. Able to tolerant some silt. Often the dominant species. Just below the low tide mark oto at least 200m. (Cook 2010).
	Tawera spissa (Juveniles)				
	Theora lubrica		Tolerant	Tolerant	Lives in billions in shallow-water muddy substrates around the hatbour edges and is one of the few oganisms that thrives in highly disturbed and polluted environments under wharves and marinas (Hayward 1997). The mud kills off the original sand-dwelling organisms and provides a completely new environment for a different biota (e.g. Theora lubrica, pers. obs.). is perhaps the most pollution-tolerant mollusc in the harbour. Living in contaminated sediments of the westhaven marina (Hayward 1997). Habitat: shallowly buried in fine sand and mud (Cook 2010).
	Thracia vegrandis				A small but modertaly solid shell, with subparallel dorsal and vental margins, the beaks near to the posterior end, and there is a minute crescentic lithodesma, only 1.2mm (Powell 1979).
	Varinucula gallinacea				Present in the s'sub-tidal walls' in central waitemata Harbou (Hayward 1999)
	Zenatia acinaces		Sensitive		Razor clam. Habitat: buried in fine sand off open, semi-exposed to exposed beaches. Subtidally, it also occurs in sand mud substrata in more sheltered situations where there is sufficent water movement. In some sheltered harbour areas, this species is the dominanant mollusc, in combination with an assemblage of polychaete worms. From low intertidal to at least 40m. (Cook 2010).
Bryozoa	*Bryozoa (encrusting)*				filter feeding.
Cephalocordata	*Epigonichthys hectori*		Sensitive		New Zealand lancelet. Habitat is sandy, well irrigated bottom deposits, where it deeds by passing ciliary currents through its mouth and out through the atriopore. (Crossland 1979).
Chaetognatha	*Chaetognatha*				Arrow worms. Small, marine planktonic hunters,

Cirriped	*Austrominius modestus*		-		Small acorn barnacle. Capable of rapid colonisation of any hard surface in intertidal areas and prefers sheltered shores. *Austrominius modestus* tolerates lower salinity and higher temperatures than most other native barnacles however, this species cannot survive in permanent low salinity. *A. modestus* accumulates zinc and other heavy metals yet its use as a biomonitor is not yet agreed.
	Austrominius modestus				
	Balanus sp.				
Copepod	*Copepod*		-		Very small crustaceans usually having six pairs of limbs on the thorax. The benthic group of copepods (Harpactacoida) have worm-shaped bodies.
Crustacea	*Nebalia sp.*				Species of crustacean.
Cumacea	*Colurostylis lemurum*	NA	**Sensitive**		A cumacean and semi-pelagic detritus feeder. Some species of cumacea can survival in brackish water. Most species live only one year or less, and reproduce twice in their lifetime. Cumaceans feed mainly on microorganisms and organic material from the sediment. Species that live in the mud filter their food, while species that live in sand browse individual grains of sand. Optimum range 0-5% mud, distribution range 0-60% mud.
	Cumacea		Sensitive		
Decapod	*Austrohelice crassa*	NA	**Tolerant**		Surface deposit feeder and predator/scavenger. Prefers a muddy substrate, is very mobile and tolerant of sedimentation. Overall considered relatively insensitive. Optimum range 95-100% mud, distribution range 5-100% mud.
	Callianassa filholi				Thalassinidean shrimps construct and occupy burrows in a variety of soft-sediment environments in tropical and temperate regions, with their presence often evident in the form of conspicuous mounds of expelled material on the sediment surface. Berkenbusch and Rowden 1999
	Decapoda (larvae Unid.)				
	Halicarcinus cookii	**Tolerant**	Tolerant		Optimum mud is 2.6-12.3%, optimum nutrient range (TN mg/kg) 265-590 and (TP mg/kg) 105-204. Metal (CU mg/kg) 0.5-1.1 (Pb mg/kg) 1.5-2.8. (Ellia et al 2017). Tolerant to eccess mud and organic enrichment (Wriggle 2017)
	Halicarcinus whitei	**Tolerant**	Tolerant		Tolerant to eccess mud and organic enrichment (Wriggle 2017)
	Liocarcinus corrugatus		Sensitive		Dwarf swimming crab. Widely distributed around the world, in northern and central New Zealand. On sandy and gravel bottoms, sandy tidal flats, and rock pools. Caught in set nets and dredges. Intertidal to 140 m. (Naylor et al 2015).
	Notomithrax minor		Tolerant		Lives on sand or mud between the immediate subtidal region to about 40m depth (Webber and Wear 1981). The carapcae is comonly adorned with sponged and branchhing algae. Commonly found on sand, mus and coarse shell reefs in shelteted areas such as bays and harbours. Also found in high densities on and around artifical substrates such as wharf pilings and mussel aquaculture structures. (van de Ven 2007).
	Paguridae				Hermit crabs. is one of the most morphologically and ecologically diverse groups of reptant decapod crustaceans (Forest et al 2000).
	Pagurus sp.				Hermit crab.
	Palaemon affinis		Tolerant		Common prawn in intertidal habitats in both the NI and SI including rock pools, estuaries and mangrove areas. (Day 2001).
	Pariliacantha georgeorum		Tolerant		Burrows on exposed or semi-exposed clean to muddy fine-sand beaches from the lowest tide level to about 50 m depth. Burrows of P. georgeorum are usually found at or below the lowest spring-tide level. Burrows of *P. georgeorum* appear to have a single entrance with an initial vertical shaft of three to four body lengths after which the burrow may change direction. Morton & Miller (1968) reported burrows of *P. georgeorum* (misidentified as *Squilla armat* a) to a depth of about 1 m. All specimens were found singly, rather than in pairs. (Ahyong 2012).
	Philocheras australis		Tolerant		Sand shrimp. Sandy/muddy intertidal to soft-bottom subtial. Scavenger feeder. Common in harbours, inlets and bays in the intertidal zone to a depth of 20m. Feeds on organic detriturs at the surface of the sediment. (Marine species.org).
	Philocheras sp.		Tolerant		Crangonid shrimp genus. These small, often cryptic sand shrimp inhabit mud or sand in shallow to bathyal waters. (Taylor 2010>).
	Pilumnus novaezealandiae				
	Pinnotheres atrinocola				

	Stomatopoda				Mantis shrimps. exclusively predatory lineage of malacostracan crustaceans. Stomatopods occupy a wide range of continental shelf or slope habitats, from the shore down to about 1500 m. They are common and conspicuous on coral reefs and abundant on soft, level substrates. Although most speciose in tropical and subtropical waters, some stomatopods occur in temperate and even subantarctic waters. New Zealand spans subtropical/warm temperate through to subantarctic waters, and stomatopods occur throughout this range. (Ahyong 2012).
	Upogebia sp.				Mud shrimp.
Diptera	*Dolichopodidae larvae*				Long-legged flies.
	Muscidae				House fly.
	Orthocladiinae				The subfamily Orthocladiinae is poorly known in New Zealand; most species have been described only from adults, and the immature stages are unknown or undescribed (Boothroyd 1999).
	Psychodidae (larvae)				Moth flies.
	Tanypodinae				Sub-family of chironomid midges.
Echinoder m	*Trochodota dendyi*				A soft bodied sea cucumber that is worm-like in appearance and burrows up to 20cm into sand - a deposit feeder and sediment disturber.
Echinoidea	*Echinoidea (Juvenile spat)*				sea urchin
Gastropod	*Amphibola crenata*		**Tolerant**		A pulmonate gastropod endemic to NZ. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria. Juveniles prefer finer sediment than adults.
	Caecum digitulum				Tusk shell. found under stones in the upper tidal zone (Powell 1979).
	Cominella adspersa		**Tolerant**		Speckled whelk. Habitat: mudflats adjacent to rocks and stones, in semi-shelted to protected localities. Mid-intertidal to at least 20m (Cook 2010).
	Cominella virgata				Red-mouthed whelk. Habitat: beneth rocks and stock, and on corallina hormosira flats in tide pools in sheltered to exposed locations (Cook 2010)
	Maoricrypta youngi				Slipper limpet. Habitat: lives attached to the shells of living gastropods. Abudance is rare and local. Low intertidal down to approximately 90m. (Cook 2010)
	Sigapatella tenuis				Habitat: Clean sands in open localities. Lives attached to the inside of gastropod or bivalve shalls, the underside of rocks or other hard substrata. (Cook 2010).
	Sigapatella novaezelandiae				Circular slipper limpet. Habitat: rocky reefs in shelteted to semi-protected localities, liviing attached beneath rocks, to the inside of gastropod or bivalve shells, or to other smooth and hard surfaces. Mid-intertidal to 50m or more. (Cook 2010).
	Cylichna thetidis				Canoe shell. Habitat: clean sand substratam in sheltered localities. Most abundant where the substratum is fine, but tolerates coarse sand. Low intertidal (where most common) to 55m depth.
	Taron dubius				Habitat: rocky reefs, on algal turf and under stones in sheltered and semi-exposed localities. Mit to low intertidal. (Cook 2010). Imposex has been observed in the species (Stewart et al 1992).
	Chiton glaucus	**Indifferent**			The green chiton, is a marine polyplacophoran mollusc in the Family *Chitonidae*, the typical chitons. It is the most common chiton species in NZ. The shell, consisting of eight valves surrounded by a girdle, is fairly large, up to 55mm in length.
	Cominella glandiformis	NA	**Sensitive**		Endemic to NZ. A carnivore living on surface of sand and mud tidal flats. Has an acute sense of smell, being able to detect food up to 30 metres away, even when the tide is out. Intolerant of anoxic surface muds. Optimum range 5-10% mud, distribution 0-10% mud.
	Cominella sp.				
	Cominella quoyana				(listed at Cominella quoyana quoyana). Habitat: clean, medium to coarse substrata, at or just below the surface, on open (rarely semi-protected) localities. (Cook 2010).
	Marginella sp				Carnivorous marine gastrpods. Living on soft and hard substrata. (marshall 2004).

	Maoricolpus roseus roseus		**Tolerant**		Turret shell. Habitat: from sheltered muddy localities with small stones nd shells, to cleaner shelly substrata. Sometimes a dominant species, particularly in areas of moderate-to-strong curent such as harbour channels. Subtidally, it is recognised as co-dominant with the bivalve nucula hartvigiana. Low intertidal to 130m. (Cook 2010). Suspension feeding, occuys a wide range of substrates from soft sediments to rocky ools from the low intertidal to depths of around 200m (Donald & Spencer 2015).
	Notoacmaea helmsi	NA	**Sensitive**		Endemic to NZ. Small limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds. Optimum range 0-5% mud, distribution range 0-10% mud.
	Notoacmea scapha		**Sensitive**		Endemic to NZ, a small grazing limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds and sensitive to pollution.
	Notoacmea sp.				genus of true limpets.
	Rissoidae				Tiny snails. Very numerous. Most are known from subidal grounds, but any collection of algal washings from tide pools will produce perhaps a dozen of long list of posisble species. Are adapated to so many slightly different ecological niches (Morton & Miller 1968)
	Potamopyrgus estuarinus				Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds.
Hemichordata	*Hemichordata*				Shallow-water marine, worm-like vertebrates that possess gill slits, relating them to the chordates. There are two classes: Enteropneusta (acron worms) and Pterobranchia. Most hemichordates are acre acorn worms. The body of acron worms I divided into three distrinct regions, an anterior proboscis, a collar region and a trunk. Most epceis for U-shaped burrows in soft sediments, through some are found under algal holdfasts, rocks and shells (Cook 2010).
Hexapod	*Collembola*				Collembola are mostly of terrestrial origin and are one of the most abundant arthropods found in wetland communities. Some species live on water surfaces. Little is known of Collembola.
Holothur oidea	*Chiridota nigra*				sea cucumber. An offshore species usually in 9-270m. Habitat: Mud. (Pawson 1970)
	Trochodota dendyi				Sea-cucumber. puts out worm like casting as it burrows into sediment. DISTRIl3UTIO, : Trochodota dendyi is widespread on the New Zealand coa t and has been recorded from intertidal and shallow local ities at Auckland, Wellington, and Stewart I sland (Mortensen, 1 925), also from J OO miles north-west of Auckland. BATHYMETRIC RANGE: 0-126m HABITAT : M ud, sand, and shell. (Pawson 1970).
Hydrozoa	*Hydroida (thecate)*				Hydroid colony.
Isopod	*Exosphaeroma planulum*		-		Small seaweed dwelling isopod. Prey species for birds and fish. Little is known about the Exosphaeroma genera.
	Exosphaeroma waitemata		-		Small seaweed dwelling isopod. Prey species for birds and fish. Little is known about the Exosphaeroma genera.
	Anthuridea				
	Asellota				
	Eurylana cookii				have been located in the mouth of the Avon-Heathcote Estuary in fine sand, within shifting sand at the mouth or in stable areas high in the intertidal zone just inside the estuary. (Jansen 1981).
	Exosphaeroma sp.				
	Isocladus armatus				upper limit HWS. Lower limit rise with increasing wave action. (Jansen 1971)
	Pseudosphaeroma campbellensis				Most common in intertidal pools and intertidal algal turs in sheltered habitats. (Poor 1981) . Habitat: under stones, in pools, on algae: often in or near freshwa ter (Hurley & jansen 1977).
Mysid shrimp	*Mysidacea sp.*	**Indifferent**			Mysidacea is a group of small, shrimp-like creatures. They are sometimes referred to as opossum shrimps. Wherever mysids occur, whether in salt or fresh water, they are often very abundant and form an important part of the normal diet of many fishes.

Nemertea	*Nemertea*	**Tolerant**	Tolerant		ribbion or probiscis worms. Tolerant to excess mud and organic enrichment. Mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions. (Wriggle 2017).
Oligochaete worm	*Oligochaete sp.*	NA	**Tolerant**		Segmented worms - deposit feeders. Classified as very pollution tolerant by AMBI (Borja et al., 2000) but a review of literature suggests that there are some less tolerant species. Many oligochaete species prefer sand and then mud. Tolerant of depth of sedimentation and time exposed. Optimum range 95-100% mud, distribution range 0-100% mud.
Ophiuroidea	*Ophiuroidea*		Tolerant		brittle stars. Are the largest group of extant echinoderms, with 2064 described speiceis found in all oveans from the intertidal to the greatest depths. The mahorit lve on the seafloor, buried in mud or hidden in crevices snad holes in rocks and coral. Some sepcies are epizoic, living on a variety of hosts such as corals, sea urchins. (Stoher at al 2012).
Opisthobranchia	*Heterobranchia Unid.*				One of the msot species rich groups within gastropoda.
Ostracoda	*Diasterope grisea*				
	Euphilomedes agilis				
	Leuroleberis zealandica		Sensitive		Giant ostrocod. Lives in the coarse sand bottom, during darkness variable number may be found free-swimming in the water above. (Fenwick 1984)
	Neonesidea sp.				
	Parasterope quadrata				
	Phylctenophora zealandica				
	Scleroconcha sp.				This genus is widespread. (Kornicker 1979).
Phoronida	*Phoronis sp.*				Horseshoe worm.
Platyhelminthes	*Platyhelminthes*				Flatworms.
	Aglaophamus macroura	**Sensitive**	Sensitive		A large, long-lived (5 yrs or more) intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate. Feeding type is carnivorous. Significant avoidance behaviour by other species. Feeds on *Heteromastus filiformis*, *Orbinia papillosa* and *Scoloplos cylindrifer* etc.
	Aonides trifida		**Sensitive**		Small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10cm. *Aonides* is free-living, not very mobile and strongly prefers to live in fine sands; also very sensitive to changes in the silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds. Optimum mud range 0-5% and distribution between 0-5%.
	Aricidea		**Tolerant**		Slender burrowing worms that are probably selective feeders on grain-sized organisms such as diatoms and protozoans. *Aricidea sp.*, a common estuarine paranoid, is a small sub-surface, deposit-feeding worm found in muddy-sands. These occur throughout the sediment down to a depth of 15cm and appear to be sensitive to the changes in the mud content of the sediment. Some species of *Aricidea* are associated with sediments with high organic content.

Armandia maculata	**Sensitive**			Common subsurface deposit-feeding/herbivore. Belongs to Family Opheliidae. Found intertidally as well as subtidal in bays and sheltered beaches. Prefers fine sand to sandy mud at low water. Does not live in a tube. Depth range: 0-1,000m. A good coloniser and explorer. Pollution and mud intolerant.
Asychis		-		-
Boccardia (Paraboccardia) syrtis and acus	**Sensitive**	**Sensitive**		Small surface deposit and suspension feeding spionids. Prefers low-moderate mud content but found in a wide range of sand/mud. It lives in flexible tubes constructed of fine sediment grains and can form dense mats on the sediment surface. Prefers sandy sediment to muddy. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds. Intolerant of elevated TSS for more than six days. Sensitive to sediment deposition. Optimum range 10-15% mud, distribution 0-50% mud.
Capitella capitata	**Opportunistic**	**Tolerant**		A blood red capitellid polychaete which is very pollution tolerant. Common in sulphide rich anoxic sediments. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud, based on *Heteromastus filiformis*.
Chaetopterus sp.				Tube worm. Habitat: Rocky shore. Soft shore. Sheltered to open beaches. Sand to shell gravel Depth range: 0-60 (m). Salinity regime: Marine only. Microhabitat: Epifaunal (or part buried) in aggregated mats. Tube: Soft parchment tube with 2 openings, opaque and encrusted except at openings. Subsurface filter-feeder. Lives in a variety of subtidal habitats and may extend into intertidal under stones or overhangs. Newly abundant in Auckland region since 1997. Mats of tubes may be habitat-excluder for other species (scallops). Cryptogenic (origin unknown, possibly alien introduction). (annelida.net.nz)
Cirratulidae sp.	**Opportunistic**	**Sensitive**		Subsurface deposit feeder that prefers sands. Small sized, tolerant of slight unbalanced situations. Optimum range 10-15% mud, distribution range 5-70% mud.
Cossura consimilis		**Sensitive**		*Cossura consimilis* is usually found in habitats which are sandier rather than muddy. *Cossura consimilis* also shows sensitivity to copper contamination. Where estuarine sediments become muddier (exceeding their optimum range) and/or polluted (particularly with copper), the abundance of Cossura consimilis is likely to decline. *Cossura consimilis* tolerates a sediment mud content of 5 to 65%, with an optimum range of 20-25%.
Dorvilleidae				Distributions, lifestyle, and habitat:, occurring both in the intertidal and across the continental shelf. A Dorvillea species occurs in algal holdfasts and other crevice habitats provided by rock and sessile marine plants and animals. Species of other genera have been collected free-swimming at night but their habitat is unknown. Microscopic dorvilleids occur in coarse sands. Dorvilleids occur throughout New Zealand. Nothing is known regarding restricted distributions of particular species. (ANNELIDA.NET.NZ)
Euchone sp.		**Tolerant**		-
Eunicidae				large carnivores or scavengers. Distribution: Throughout New Zealand in the intertidal, and subtidal to continental shelf depths. Amongst encrusting growths and in crevices, and rarely in soft sediments unless also under rocks. Marphysa depressa is common in muddy rock crevices.
Glyceridae	**Indifferent**	**Sensitive**		Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15 cm. They are distinguished by having four jaws on a long eversible pharynx. Intolerant of anoxic conditions. Often present in muddy conditions. Intolerant of low salinity.
Goniada sp.	**Indifferent**	**Sensitive**		Slender burrowing predators (of other smaller polychaetes) with proboscis tip with two ornamented fangs. The goniadids are often smaller, more slender worms than the glycerids. The small goniadid *Glycinde dorsalis* occurs low on the shore in fine sand in estuaries. Optimum mud range 50-55%, distribution range 0-60% mud.
Hesionidae sp.	**Indifferent**			Fragile active surface-dwelling predators somewhat intermediate in appearance between nereidids and syllids. The New Zealand species are little known.
Heteromastus filiformis	**Opportunistic**	**Sensitive**		Small sized capitellid polychaete. A sub-surface, deposit-feeder that lives throughout the sediment to depths of 15cm and prefers a sandy-muddy substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do. Relatively tolerant of sedimentation and not very mobile. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud.
Hydroides elegans			Tolerant	calcareous tubeworm. The family Serpulidae are intertidal to deep sea throughout New Zealand. (anelida.net.nz). Fouling species on both natural and artifiical structures. Found subtidally and is highly tolerant of contaminated waters. (Inglis et al 2010).
*Hydroides sp **				
Macroclymenella stewartensis		**Sensitive**		A sub-surface, deposit-feeder that is usually found in tubes of fine sand or mud. This species is found throughout the sediment to depths of 15cm and potentially has a key role in the reworking and turn-over of sediment. This worm may modify the sediment conditions, making it more suitable for other species (Thrush et al., 1988). Common at low water in estuaries. Intolerant of anoxic conditions.

Polychaete worm	*Magelona dakini*		**Sensitive**		A small, thin and shovel-nosed (shield like head) burrower and subsurface deposit feeder. Adults grow up to 70mm long. Magelonids are most abundant in sandy habitats and are highly sensitive to lead contamination. Where estuarine sediments become polluted and/or very muddy, the abundance of magelonids is expected to decline.
	Maldanidae				Bamboo worms. Feed as bulk consumers of sediment using a balloon-like probiscis. Large, deep burrowing species. Most bamboo worms live below the surface in flimsy sediment tubes. They process copious amounts of sediment and deposit it in earthworm-like surface casts. During calm weather the accumulating casts become conspicuous on intertidal sands of sheltered harbours. (annelida.net.nz)
	Myriochele sp.				occurs infrequently in offshore sediments. From family Oweniidae (annelida.net.nz)
	Myriowenia sp.				occurs infrequently in offshore sediments. From family Oweniidae (annelida.net.nz)
	Neanthes sp. A				Active, omnivorous worms. Family nereididae: found throughout NZ from freshwaters and the upper intertidal to the deep sea offshore. (annelida.net.nz)
	Nereis cricognatha				Neanthes cricognatha (worms: marinspecies.org). Lives in algal holdfasts and algal turf (annelida.net.nz).
	Nicon aestuariensis	**Tolerant**	**Tolerant**		A nereid (ragworm) that is tolerant of freshwater and is a surface deposit-feeding omnivore. Prefers to live in moderate to high mud content sediments. Optimum range 55-60% or 35-55% mud, distribution range 0-100% mud.
	Notomastus zeylanicus	**Tolerant**	Tolerant		Family Capitellidae. Thread-like sediment dwellers that live in unlined, rambling burrows and are considered to be relatively non-selective particle feeders. They are long, fragile and difficult to collect intact. Family live mid-intertidal to coninental shelf depths throughout New Zealand. Family is common and can locally be very desnse around organic effiient discharges. Noto mastus sp. are much largerr subtidal capitellids (Annelida.net.nz).
	Onuphis aucklandensis		Tolerant		Large scavenging tube-dwelling worms with a cluster of five long annulated head antennae. Onuphis sp. build thick mud tubes very like maldanids, but usally thinly lined with a tough transparent section. Family is present throughout NZ from low intertidal and subtidal to deep sea. Onuphis aucklandensis is probably the commonest shallow-water onuphid and is found only in muddy substrata. (annelida.net.nz)
	Orbinia papillosa	**Sensitive**	**Sensitive**		Long, slender, sand-dwelling unselective deposit-feeders which are without head appendages. Found in fine and very fine sands (occasionally mud) and can be uncommon. Pollution and mud intolerant. Sensitive to time and depth of deposition. Optimum range 5-10% mud, distribution range 0-40% mud.
	Owenia petersenae	**Indifferent**			Members of the Oweniidae have characteristic tubes which are considerably longer than the animal and are composed of shell fragments and sand grains which are stacked on top of each other. Oweniids often remain intact within their tubes and must be carefully removed for proper examination. *O. fusiformis* is currently thought to include a variety of species. Normally a suspension feeder, but is capable of detrital feeding. Is a cosmopolitan species frequently abundant on sandflats. Are classified as intermediate type species along organic enrichment gradients (Pearson and Rosenberg 1978).
	Paraonidae sp.				Slender burrowing worms, which selectively feed on grain-sized organisms such as protozoans and diatoms.
	Pectinaria australis	**Sensitive**	**Tolerant**		Subsurface deposit-feeding herbivore. Lives in a cemented sand grain cone-shaped tube. Feeds head down with tube tip near surface. Prefers fine sands to muddy sands. Mid tide to coastal shallows. Belongs to Family *Pectinariidae*. Often present in NZ estuaries. Density may increase around sources of organic pollution and eelgrass beds. Intolerant of anoxic conditions.
	Perinereis vallata		**Sensitive**		An intertidal soft shore nereid (which are common and very active omnivorous worms). Prefers sandy, muddy sand, sediments. Sensitive to large increases in sedimentation.
	Phyllodocidae	**Indifferent**			The phyllodocids are a colour family of long, slender, and very active carnivorous worms characteristically possessing enlarged dorsal and ventral cirri which are often flattened and leaf-like (paddleworms). They are common intertidally and in shallow waters.
	Platynereis australis				Active, omnivorous worms. Lives in algal holdfasts and algal turf along the coast. Soft shore species. (annelida.net.nz)
	Polydora sp.		Sensitive		Family Spionidae. Spionids are very common polychaetes in all sandy substrata and rather infrequently on rocky shores. The Polydora group specialise in boring into shells. (annelida.net.nz). Polydora-groupu a speciose group of small spionid worms, may of which have hte ability to on and in mollusc shalls. (Read 2010).

	Polynoidae				Scale worms. Lower intertidal and subtidal to deep sea throughout New Zealand. Polynoids generally occur crawling on various firm surfaces, including shelly substrata. Lepidonotus spp. and more rarely Euphione squamosa, may be found creeping along under unsedimented boulders in rocky shore pools and amongst algal holdfasts. However, Disconatis accolus is sand-dwelling, sharing the tube of the common intertidal maldanid polychaete Macroclymenella stewartensis. Disconatis accolus is also occasionally found in tubes of other polychaetes and was first described associated with the lugworm Abarenicola affinis. Lepidastheniella comma was described from terebellid tubes. (annelida.net.nz)
	Prionospio aucklandica		**Tolerant**		Common at low water mark in harbours and estuaries. A surface deposit-feeding spionid that prefers living in muddy sands but is very sensitive to changes in the level of silt/clay in the sediment.
	Prionospio multicristata	**yes**	Sensitive		surface deposit feeder and filter feeder. High abundance of P. multicristata around the outfall, but numbers were low at other sites suggesting this is a localise effect of the outfall. This pattern did not relate to sediment composition. Both the spionid polychaete Prionospio multicristata and the polychaete Magalona dakini were observed in high abundances at sites around both the existing and extended outfalls. These species are tube-dwelling, surface deposit feeders that collect organic material onto palps that extend into the water column, but also pick up matter from the seabed surface. They are common in fine-very fine sand areas, but are generally lacking from sediments with very high levels of mud (Mitchell Daysh 2017).
	Prionospio tridentata				Spionidae family: Small burrowers or surface tube-dwellers or crevice- and algal turf-dwellers, or shell-borers with one pair of deciduous feeding palps, and multiple pairs of segmental gills. surface deposit feeder and filter feeder. (annelida.net.nz).
	Prionospio yuriel				Spionidae family: Small burrowers or surface tube-dwellers or crevice- and algal turf-dwellers, or shell-borers with one pair of deciduous feeding palps, and multiple pairs of segmental gills. surface deposit feeder and filter feeder. Occurs subtidally in harbours (annelida.net.nz).
	Pseudopolydora corniculata				Spionidae family: Small burrowers or surface tube-dwellers or crevice- and algal turf-dwellers, or shell-borers with one pair of deciduous feeding palps, and multiple pairs of segmental gills.. surface deposit feeder and filter feeder. (annelida.net.nz)
	Pygospio sp.				Spionidae family: Small burrowers or surface tube-dwellers or crevice- and algal turf-dwellers, or shell-borers with one pair of deciduous feeding palps, and multiple pairs of segmental gills.. surface deposit feeder and filter feeder. (annelida.net.nz)
	Sabellidae				Fan worms. Large dwellers in leathery tubes or tiny 'naked' crawling forms with a 'feather-duster' crown of two semicircular fans of stiff filaments. THe largest sabellids are subtidal and found amongst sessil marine growths, in crevices etc. Can be common on wharf piles, and harbours. Most sabellids are subtidal. A number of small, inconspicuous, unstudied species occur in sands and muds intertidally and subtidally, and amongst algal turf. Little is known about them. (annelida.net.nz).
	Scolecolepides benhami	**Tolerant**	**Tolerant**		A surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. Optimum range 25-30% mud, distribution range 0-60% mud.
	Scoloplos cylindrifer	**Sensitive**	**Sensitive**		Belongs to Family *Orbiniidae* which are thread-like burrowers without head appendages. Common in intertidal sands of estuaries. Long, slender, sand dwelling unselective deposit feeders. Optimum range 0-5% mud, distribution range 0-60% mud.
	Serpula sp.				Family serpulidae: Colonial 'feather-duster' crowned dwellers in calcareous tubes, the opening of which is blocked by an ornamented plug. The small serpulids include several Serpula species with flower-like opercular funnel, amongst which is Serpula maorica (Benham, 1927), and various Hydroides species with a second tier of spines above the funnel. Members of these genera are amongst the commonest ship-fouling serpulids and in New Zealand probably include some previously foreign species that have arrived as hitchhikers on ship hulls.(annelida.net.nz)
	Sigalionidae		Tolerant		Long, usually rectangular-bodied predators protected by a number of large overlapping scale-like plates. Found burrowing in sand or mud. Present throughout NZ, intertidal to continental shelf. Some species found in beds of seagrass, other in soft sediments ofshore. THere are no rocky shore or crevice-dwelling sigalionid species. (annelida.net.nz)
	Sphaerosyllis sp.	**Indifferent**	**Sensitive**		Belongs to Family *Orbiniidae* which are delicate and colourful predators. Very common, often hidden amongst epifauna. Small and delicate in appearance. Prefers sandy sediments. Optimum range 25-30% mud, distribution range 0-40% mud.
	Spio readi				Spionidae family: Small burrowers or surface tube-dwellers or crevice- and algal turf-dwellers, or shell-borers with one pair of deciduous feeding palps, and multiple pairs of segmental gills.. surface deposit feeder and filter feeder. (annelida.net.nz)

	Spirobinae				Family: serpulidae. Colonial 'feather-duster' crown dweller in calcareous tubbes, the opening of which is blocked by an ornamented plug.
	Syllidae	**Indifferent**	**Sensitive**		Belongs to Family *Syllidae*. Delicate and colourful predators. Very common, often hidden amongst epifauna. Small size and delicate in appearance. Prefers mud/sand sediment. Optimum range 25-30% mud, distribution range 0-40%.
	Terebellidae sp.	**Indifferent**	NA		Large tube or crevice dwellers with a confusion of constantly active head tentacles and a few pairs of anterior gills.
	Travisia olens novaezealandiae		**Sensitive**		Belong to the Opheliids. Short-bodied, cigar-shaped, muscular sand burrowers. Opheliids are deposit feeders, but probably selective in their intake of particulate material. The large, fat, bad smelling, grey-white coloured scalibregmatid Travisia olens is found on open to semi-protected sand beaches. Optimum range 0-5% mud, distribution range 0-5%.
Polyplacophora	*Chiton glaucus*				commonly found under stones. Intertidal and shallow subtidal from exposed open shores to sheletered, estuarine sites. In the former, it is found under cobbes and stones and in the latter, on stones or bivalve shells, particulary cockles. Cryptic by dau, it emerges at night to feed on open rock or tops of cobbles. From high on the shore to about 5m subtidally. (Cook 2010).
	Ischnochiton maorianus				Habitat: under cobblesor small boulders resting on or partially buried in gravel, sand or silt, from exposed open coasts to sheltered harbours. They often aggregate in large numbers around the edges of cobbles at, or just below, the sediment lin. This fast moving chiton often curls up and falls of overturned rock. It rarely venture onto the top surface of rocks, preferring to feed on an drift or detrital plant material that accumulates around or underneath rock. Occurs from the high intertidal to at least 10m depth. (Cook 2010).
	Leptochiton inquinatus				Habitat: under cobbles, boulders or occasionally old shells, resting on silty and often anaerobic sediment. Almost always underthe the centre of a boulder and rarely seen on the sides of boulder or on open bedrock. From low intretidal to at least 30 m subtidally. (Cook 2010).
	Rhyssoplax sp.				Chiton.
Porifera	*Sponge (bread)*				Sponges feed by filtering water using specialised cells, which propel a one-directional water current through the sponge body.
	Sponge (finger)				
	Sponge (white Encrusting)				
Pycnogonida	*Pycnogonid (unid.)*				sea spiders. Present from the shoreline to great depths.Predominatnly bnthic organisims and some are known to be parasitic in invertebrates wither as juveniles or permanently.
Ribbon worm	*Nemertea sp.*	**Tolerant**	**Tolerant**		Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions. Optimum mud range 55-60%, but distribution between 0-95%.
Tanaidacea	*Tanaidacea*			Sensitive	Small benthic crustacean. Furthermore, because of tanaidaceans' sensitivity to pollutants and to physicochemical variations in water, this Order has been considered a potential indicator of pollution in water quality monitoring studies (Ferreira 2015). Can be found living within seagrass, with some species adapted to live small used rissoid shalls.
	202 taxa in total	11 Tolerant 8 Sensitive	38 Tolerant 39 Sensitive	3 Tolerant 1 Sensitive	

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