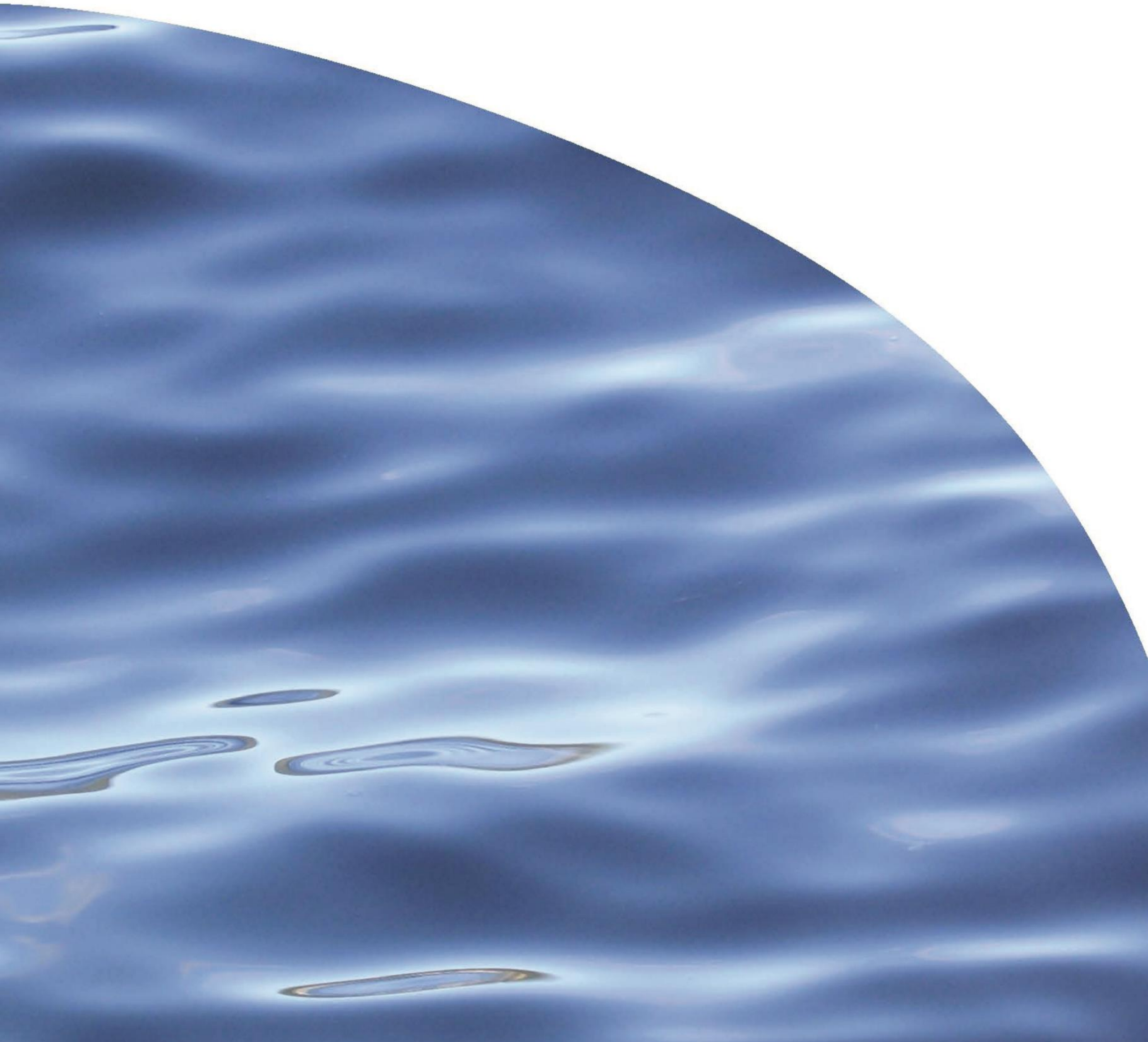
Appendix F: **Assessment of effects of different outfall options on the marine environment**

CAWTHRON
The power of science®

REPORT NO. 3380

PORIRUA WASTEWATER TREATMENT PLANT OUTFALL: ASSESSMENT OF EFFECTS OF DIFFERENT OUTFALL OPTIONS ON THE MARINE ENVIRONMENT



PORIRUA WASTEWATER TREATMENT PLANT OUTFALL: ASSESSMENT OF EFFECTS OF DIFFERENT OUTFALL OPTIONS ON THE MARINE ENVIRONMENT

DONALD MORRISEY, ANNA BERTHELSEN, DANA CLARK, SHAUN CUNNINGHAM, SCOTT EDHOUSE, LISA FLOERL, ROSS SNEDDON
ROBERTA D'ARCHINO (NIWA)

Prepared for Wellington Water Ltd

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Emma Newcombe

APPROVED FOR RELEASE BY:
Grant Hopkins

ISSUE DATE: 28 August 2019

RECOMMENDED CITATION: Morrisey D, Berthelsen A, Clark, D, Cunningham S, Edhouse S, Floerl L, Sneddon, R, D'Archino R 2019. Porirua wastewater treatment plant outfall: assessment of effects of different outfall options on the marine environment. Prepared for Wellington Water Ltd. Cawthron Report No. 3380. 53 p. plus appendices.

EXECUTIVE SUMMARY

Stantec New Zealand (Stantec) is assisting Wellington Water with an assessment of options for upgrading and re-consenting an existing discharge of treated wastewater to coastal water from the Porirua Wastewater Treatment Plant (WWTP). The options under consideration for the discharge are to coastal waters via:

- the existing short outfall at Rukutane Point, west of Titahi Bay (option 1)
- a new short outfall at Round Point, c. 500 m west of the existing outfall (option 3)
- a new offshore outfall, with a pipeline extending from the existing outfall to a diffuser c. 500 m offshore (option 5b).

To assist with the comparison of the three outfall options, Stantec engaged the Cawthron Institute to provide an assessment of coastal ecological values and potential effects of the three options. A preliminary review (presented in an earlier Cawthron report) identified a lack of site-specific ecological information on this part of the coast. This lack was addressed in the present study by ecological surveys of the intertidal and shallow-subtidal habitats in areas where the three potential outfalls would be located. In this report we present the results of the surveys, followed by an updated assessment of effects. The surveys also provide a baseline for future monitoring.

The existing outfall is located on an open, rocky coast at Rukutane Point, 500 m west of Titahi Bay. It lies opposite Mana Island, which is 3.2 km offshore. Mana Island is connected to the mainland by a submerged isthmus 4–10 m deep and known as *The Bridge*. The Bridge is designated as an Area of Important Conservation Value in the Greater Wellington Regional Council's Regional Coastal Plan for its *marine flora and fauna of national significance*. The existing outfall, and the option 3 outfall at Round Point, would discharge into similar habitats in the surf zone, consisting of intertidal and shallow subtidal patch reefs interspersed with sandy sediments. Outfall option 5b would run across the inshore reefs and across muddy fine sand out to a depth of 15 m (relative to Chart Datum).

Sidescan, drop-camera and diver surveys described the types of habitats and organisms present on the intertidal and shallow-subtidal reefs around each outfall option, including the existing outfall, and at a reference location east of the existing outfall. These habitats have an abundant and diverse algal flora and associated invertebrate fauna (limited numbers of fish were recorded, but the surveys were not designed to assess fish populations). The seabed along the route of the proposed offshore outfall (option 5b) is predominantly sandy sediment, marked by ripples nearer shore (indicating strong wave action). Sediments contained concentrations of organic carbon, nitrogen, phosphorus and trace metals typical of shallow coastal areas unaffected, or only mildly affected, by human activities.

The information obtained was used to refine the preliminary assessment of ecological effects of the three outfall options and will also provide baseline information for future monitoring. Information on the design and methods of construction of outfall options 3 (Round Point) and

5b (offshore) is currently limited and no modelling of potential dispersal and dilution of the discharge from them has been done. Consequently, although this assessment of effects has been refined from that presented in the preliminary report by incorporating the new ecological information, it is still constrained by lack of detail on the proposed activities.

There were no clear differences between the fauna and flora around the existing outfall and those at Round Point or the reference location, suggesting that the existing discharge has not had a marked ecological effect. We therefore assumed that the option 3 outfall, being in a similar environment and discharging the same quantity and quality of wastewater, would also have no marked effect. From previous studies of offshore WWTP outfalls that discharge into muddy or sandy sediments, we expect the proposed offshore outfall to cause localised changes in physicochemical properties of the sediment and the composition of its biological community. These effects are likely to be restricted to the area immediately around the outfall (tens of metres or less).

Risks from construction and operation of the proposed outfalls to the receiving environment were assessed. In view of the ecological and biodiversity values of subtidal rocky reefs, and their inclusion in Schedule F5 of the Wellington Proposed Natural Resources Plan as having high biodiversity value, we classified these as high-value habitats. The intertidal rocky areas and offshore sediments were classified as having moderate value. Based on the limited information currently available about the method of installation (in the case of options 3 and 5b) and operation of the three outfall options, the potential mechanisms of ecological effect were identified as:

- direct disturbance and destruction during construction of the pipeline
- deposition of sediment suspended during construction
- suspension and redistribution of sediment-related contaminants during construction
- long-term replacement or alteration of habitats due to the pipeline structure
- disturbance caused by access to the shore and seabed for maintenance
- nutrient enrichment due to the discharge of wastewater
- reduced salinity due to the discharge of wastewater.

We estimated levels of risk from each of these mechanisms for each of the valued ecological components. Levels of short-term risk to habitats and organisms on rocky and sandy substrata during the construction phase of outfall options 3 and 5b were assessed as ***negligible*** or ***less than minor***. Long-term risk of loss or alteration of habitat and effects of the discharge (nutrient enrichment and reduced salinity) from all three options were also assessed as ***negligible*** or ***less than minor***.

Given the low levels of risk, mitigation of adverse effects is not essential but, in the case of the offshore outfall option (5b), burial of the pipeline where it crosses sandy seabed would reduce effects on the surrounding environment. It would also reduce the risk of damage to the pipe and the consequent leakage of wastewater nearer shore. Management practices should be put in place to reduce the risk of spills of harmful materials, such as fuels, during the construction phase.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

GLOSSARY

Please refer to Cawthron Report Template Guide for instructions.

Term	Definition
°C	Degrees Celsius
µm	Micron
AEE	Assessment of Environmental Effects
AICV	Area of Important Conservation Value (in the Greater Wellington Regional Coastal Plan)
ANZG	Australia and New Zealand Guidelines for Fresh and Marine Water Quality (replacing the previous ANZECC (2000) guidelines)
As	Arsenic
Benthic	Relating to the seabed
BOD	Biological oxygen demand
Chl-*a*	Chlorophyll-*a*
cm	Centimetre
EPA	Environmental Protection Authority
GPS	Global Positioning System
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
kHz	Kilohertz
km	Kilometre
L/s	Litres per second
m	Metre or metres
MfE	Ministry for the Environment
mg/kg	Milligrams per kilogram (parts per million)
mm	Millimetres
N	Nitrogen
NIWA	National Institute of Water and Atmospheric Research
nMDS	Non-metric Multi-Dimensional Scaling, a multivariate statistical method that places samples in a two- or three-dimensional plot based on relative similarities among their faunal taxa (or other variables)
NZTM	New Zealand Transverse Mercator (map projection)
P	Phosphorus
psu	Practical salinity units
SIMPER	Similarity percentage (multivariate method in the statistical package PRIMER) that identifies taxa responsible for similarities between pairs of samples or groups of samples
Taxon (plural taxa)	General term for a level of classification of plants and animals (e.g., species)
TN	Total nitrogen
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency
UV	Ultra-violet (light)
WWTP	Wastewater treatment plant

1. INTRODUCTION

1.1. Purpose and scope of this report

Stantec New Zealand (Stantec) is assisting Wellington Water with an assessment of options for upgrading and re-consenting an existing discharge of treated wastewater to coastal waters from the Porirua Wastewater Treatment Plant (WWTP). To inform the options assessment, Stantec have engaged the Cawthron Institute to provide an assessment of coastal ecological values and potential effects of the three outfall options under consideration.

Currently the WWTP discharges to the coast south of Titahi Bay via a short outfall. Stantec are considering three outfall location options, all of which are adjacent to exposed, rocky-shore habitats (Figure 1):

- to coastal waters via an existing short outfall (option 1)
- to coastal waters via new short outfall at new location (option 3)
- to coastal waters via a new offshore outfall (option 5b).

The assessment of potential ecological effects on the coastal marine environment consisted of two phases:

- Phase one: a desktop assessment of existing coastal ecological values and potential adverse effects of the discharge (reported by Morrisey 2018)
- Phase two: a more detailed assessment, including field surveys, of ecological values and environmental effects of the current and potential outfalls, to inform the options assessment process and for inclusion in an assessment of environmental effects (AEE) and consent application (this report).

The existing outfall and its discharge have been operating with the present secondary (and UV irradiated) level of wastewater treatment since 1989 but there has been no assessment of its ecological effects, and no ecological monitoring conditions are attached to the discharge consent. As noted in the Phase one report, this lack of monitoring, and the general lack of site-specific ecological information on the rocky and soft-sediment coastal habitats around the outfall options, constrained assessment of effects of the present outfall and the alternative options.

The present study (Phase two) addresses this information gap through ecological surveys of the rocky shore and shallow subtidal area around the three outfall options, and of the soft-sediment seabed along the route of the pipeline and the diffuser of the potential offshore outfall. The results are presented in Section 2 of this report and provide a more detailed and site-specific description of the habitats and assemblages of marine plants and animals than was possible in the desktop assessment.

Section 3 of this report uses the new information to refine the assessment of ecological effects of the outfall options provided by the desktop assessment.

Assessments for the two new outfall options include potential short-term effects on the ecological values present from disturbance caused by construction activity. Potential long-term (*operational*) effects for all three outfalls include loss of habitat, due to the presence of the outfall structures, and effects of the discharged wastewater. The receiving environment consists of rocky intertidal and shallow-subtidal habitats, sediment habitats further from shore, and the water column in and around the area where the wastewater will be discharged.

Effects of the discharge on the receiving environment may include increased concentrations of nutrients and suspended solids, increased biochemical oxygen demand, and reduced salinity. The flora and fauna around the outfall will respond to the combination of these effects and our study took the approach of comparing the fauna and flora around the existing outfall with those at other inshore locations to identify any differences that indicated such a response.

Assessment of potential ecological effects of the discharge from the outfall are based on those observed at the existing outfall (if any). These surveys will also act as a baseline for future monitoring of effects of the new or existing short outfall (if either of these options is chosen), should monitoring be required by consent conditions.

1.1.1. Limits to the scope of the assessment of effects

Because of the dynamic nature of coastal waters, particularly on an open coast, one-off sampling of the water column does not provide a very useful representation of ecological conditions in the way that sampling of the seabed environment does. Although concentrations of contaminants in the water column may be elevated around outfalls, the ecological effects are much more diffuse and are difficult, or impossible, to detect. Any ecological effects of the discharge will be seen in the fauna and flora of the reefs and sediments around the outfall rather than the water column. Therefore, we did not include any water quality sampling in the survey. The presence of faecal indicator bacteria and pathogens in the discharge, and their implications for human health downstream of the outfall is, of course, an important issue but is beyond the scope of this report.

Information on the design and methods of construction of outfall options 3 and 5b is currently limited and no modelling of potential dispersal and dilution of the discharge from them has been done. Consequently, although this assessment of effects has been refined from that presented in the preliminary report (Morrisey 2018) by incorporating the new ecological information, it is still constrained by lack of detail on the proposed activities.

Note that an assessment of effects on fishing activities (including gathering of kai moana), on human-health risks and on birds are outside the scope of this study. Assessment of possible effects on birds is likely to require specialist local knowledge of their use of this part of the coast.

1.2. Description of the outfall options

1.2.1. Outfall locations and configuration

The outfall discharge options under consideration are (Figure 1, Table 1):

- to coastal waters via an existing short outfall at Rukutane Point, west of Titahi Bay (option 1)
- to coastal waters via a new short outfall at a new location near Round Point, c. 500 m west of the existing outfall (option 3)
- to coastal waters via a new offshore outfall, c. 500 m northeast of (and offshore from) the existing outfall and aligning with the existing outlet portal (option 5b).

The existing outfall is located on an open, rocky coast at Rukutane Point, 3.5 km southwest of the entrance to Porirua Harbour (Figure 1). The existing outfall and the option 3 (Round Point) outfall discharge into similar habitats in the surf zone of intertidal and shallow subtidal patch reefs interspersed with sandy sediments (Figure 2). Outfall option 5b would run across the inshore reefs and across muddy or gravelly sand out to a depth of 15 m (relative to Chart Datum: Figure 3).

Table 1. Locations of the three outfall options ('NZTM' – New Zealand Transverse Mercator). Information provided by Ron Havenhand (Beca) 30 April 2019.

Option	Location	NZTME	NZTMN	Latitude (S)	Longitude (E)
1	Rukutane Point	1753098.25	5447900.65	41.105760	174.823273
3	Round Point	1752595.66	5447759.98	41.107121	174.817326
5b	Offshore Rukutane Point (diffuser centre)	1752790.90	5448361.72	41.101667	174.819500

Figure 1. Location of the three outfall options. Location of the existing outfall (option 1) at Rukutane Point.

Figure 1., continued. Location of the alternative outfall options at Round Point (option 3) and offshore from the existing outfall (option 5b).

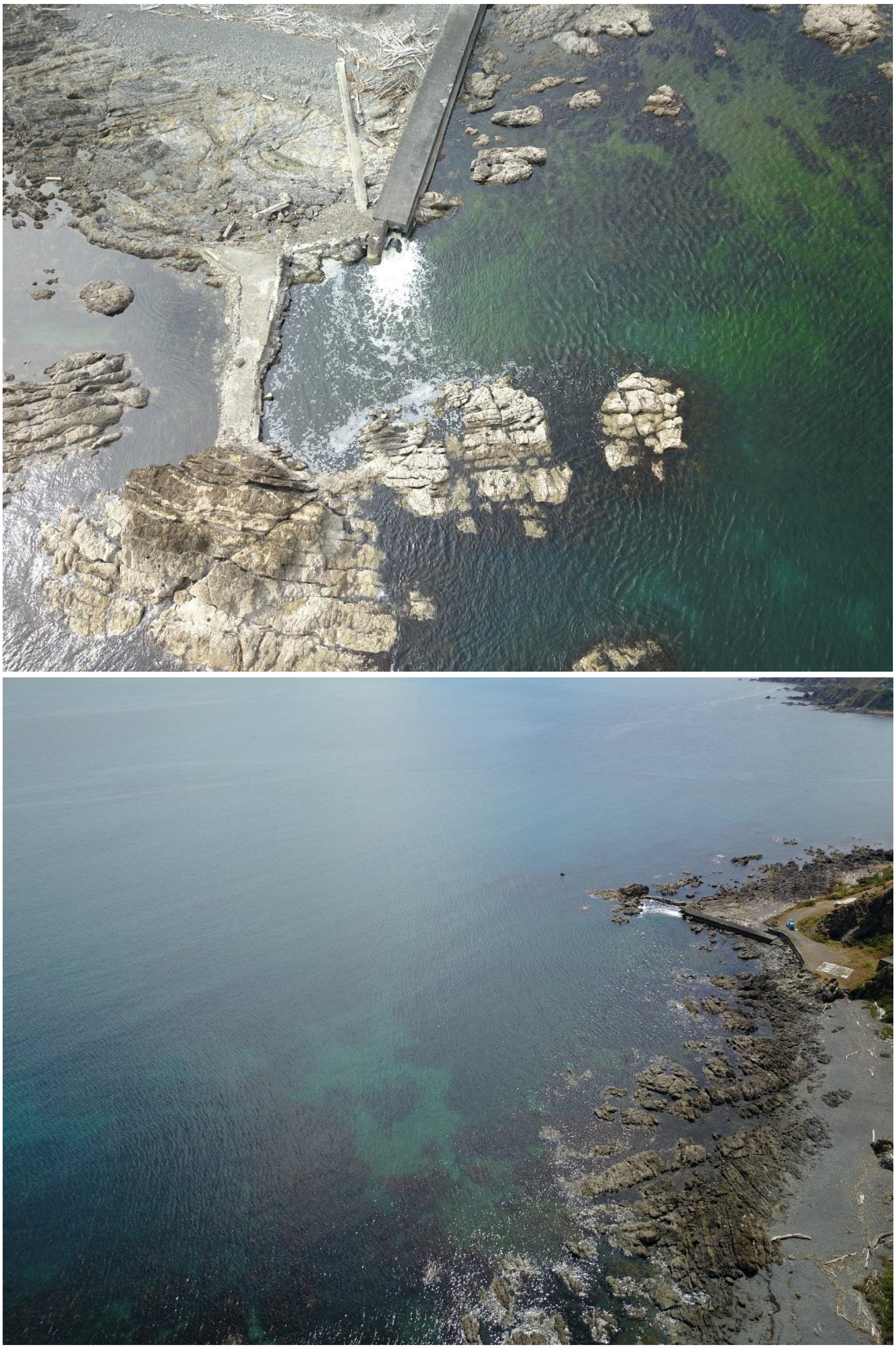


Figure 2. Aerial photographs showing the rocky coastline around the existing outfall. The presence of patches of shallow subtidal reef interspersed with patches of sand can be seen around the outfall (upper photograph) and extending offshore (lower photograph) (Images taken November 2017, courtesy of Paul Barter, Cawthron).

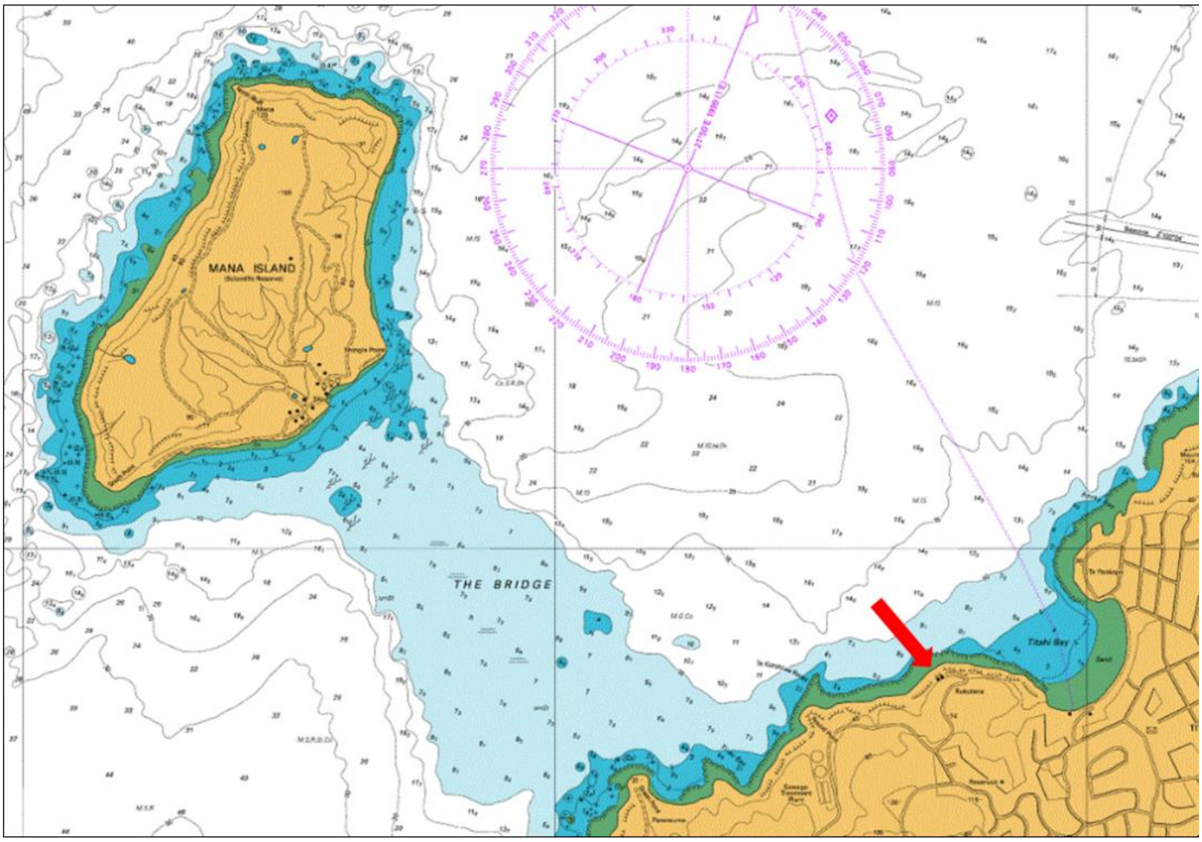


Figure 3. Detail from navigational chart NZ4632 showing the existing outfall of the Porirua WWTP (red arrow) and *The Bridge* between the mainland and Mana Island. Source: Land Information New Zealand (LINZ) and licenced by LINZ for re-use under the Creative Commons Attribution 4.0 International licence.

1.2.2. Wastewater characteristics

Available information on the wastewater characteristics was compiled and presented in the desktop assessment report (Morrisey 2018) but is repeated here for completeness. For the purposes of this assessment, the quality of the wastewater is assumed not to differ among the three outfall configurations.

The Porirua WWTP was upgraded to secondary treatment in 1989, resulting in decreased loads of suspended solids and biochemical oxygen demand (BOD) to the receiving environment (Steve Hutchinson, Wellington Water, pers. comm.). Ultraviolet disinfection was introduced in 2002, reducing the load of micro-organisms, including faecal coliform bacteria, in the wastewater.

The resource consent authorising the discharge (WGN980083) was granted in July 2000 and expires in July 2020. The consent allows an average discharge flow of 24,000 m^3/day and a peak flow of 92,800 m^3/day. The present average dry-weather flow to the WWTP is 220 L/s, the present maximum flow is 1,100 L/s and the proposed ('design') capacity for the WWTP is 1,500 L/s. Wastewater discharged through a short outfall into the surf zone on the coast at Rukutane Point, west of Titahi Bay and 3.5 km southwest of the entrance to Porirua Harbour (Figure 1).

During wet weather, flow to the WWTP exceeding 950 L/s currently bypasses the secondary treatment process in the plant but is screened on 2-mm milliscreens. The plant also has an emergency overflow that bypasses both the secondary treatment and 2-mm milliscreens. The milliscreened bypass flow, and occasional emergency overflow, re-join the treated wastewater downstream of the secondary treatment plant, and the combined flow passes through a UV-disinfection plant before discharging to the existing outfall. The UV plant has capacity for 1,000 L/s and any excess bypasses this plant. There were 50 bypass events during the period from September 2014 to November 2016, with an average frequency of c. 22 events per year (Stantec 2017). Most events occurred in winter (May–September) and were uncommon during January–March.

The WWTP will be upgraded during 2019/20 to provide a peak hydraulic capacity of 1,500 L/s and, based on current patterns of flow to the WWTP and other things being equal, bypass events will be eliminated. However, if upgrades to the sewage and stormwater network result in increased conveyance of storm flows to the WWTP, flows of more than 1,500 L/s could occur. The excess flow would bypass the secondary treatment but be milliscreened and possibly UV-disinfected. A further option under consideration is to use the existing outfall to discharge the secondary-treated effluent and the new shoreline or offshore outfall to discharge the storm flows more than 1,500 L/s (Ron Haverland, Beca, and Richard Peterson, Stantec, pers. comm.).

There are large differences in the values of wastewater-quality variables in the different components of wet-weather discharges (discussed in Section 3.3.1, below). These differences in quality may exert different types or magnitudes of effects on the receiving environment.

Stantec (2017) reviewed microbiological monitoring data during bypass discharges from sites located either side of the existing outfall. The results indicated that, in terms of suitability for recreation, water quality was 'poor' within Titahi Bay and 'very poor' closer to the outfall. However, Stantec (2017) noted that stormwater entering the bay via a stream and other outlets during wet weather was likely to be the primary cause of faecal contamination in the bay, rather than the WWTP bypass discharges. Nearer the outfall, however, stormwater was unlikely to be a significant source of faecal contamination and the WWTP discharge was the primary source.

2. DESCRIPTION OF THE RECEIVING ENVIRONMENT

2.1. Overview of existing information

Existing information was reviewed by Morrisey (2018) and is only summarised here. The three outfall options are located on open, rocky coast between Rukutane Point and Round Point, 500–1000 m west of Titahi Bay. They lie opposite Mana Island, which is located 3.2 km offshore. Mana Island is connected to the mainland by a submerged, 4–10 m deep isthmus known as *The Bridge*. *The Bridge* is designated as an Area of Important Conservation Value (AICV) in the Greater Wellington Regional Council's Regional Coastal Plan for its *marine flora and fauna of national significance*.

There is limited ecological information specific to this site. However, beds of kelp occur along this part of the Wellington coast on the exposed subtidal reefs and provide structurally and functionally important habitats. They contain a high biodiversity of other algae, fish and invertebrates, including recreationally and culturally important species such as pāua, kina and crayfish. The kelp beds support coastal food chains via direct grazing or by export of drift material to adjacent beaches and other habitats.

We are not aware of any specific, pre-existing information on the nature of the fauna and flora of the shallow-subtidal sediments around the outfall locations. The fauna is likely to consist of various species of polychaete worms, crustaceans, gastropod and bivalve molluscs, burrowing sea urchins and sea cucumbers.

2.2. Collection of additional ecological information

2.2.1. Introduction

The present study collected information on the biota of intertidal and shallow subtidal rocky reefs around the existing outfall at Rukutane Point (option 1) and at Round Point, where outfall option 3 would be located. Information was also collected at a location 300 m east of the existing outfall. This eastern site, and the site at Round Point, provided reference sites for comparison with the biota at Rukutane Point. This allowed assessment of effects of the existing discharge and, in turn, assessment of likely effects of option 3.

Information on the biota of the shore and shallow subtidal areas at Rukutane Point allowed assessment of the effects of construction of the offshore outfall (option 5b) on these habitats. We also collected information on the nature of the sediments along the route of the offshore outfall pipe, and of the organisms living on and in the sediments. This informed the assessment of the potential ecological effects of construction and operation of this outfall option.

Broad-scale and fine-scale surveys were used to collect information on the habitats and organisms of intertidal and shallow-subtidal reefs, as described in Appendix 1. Information on the nature of sediment habitats and organisms was collected along the route of the offshore outfall pipeline using sidescan sonar, drop camera and grab sampling (grab-sample locations are shown in Figure 4) to collect sediment samples (Appendix 1).

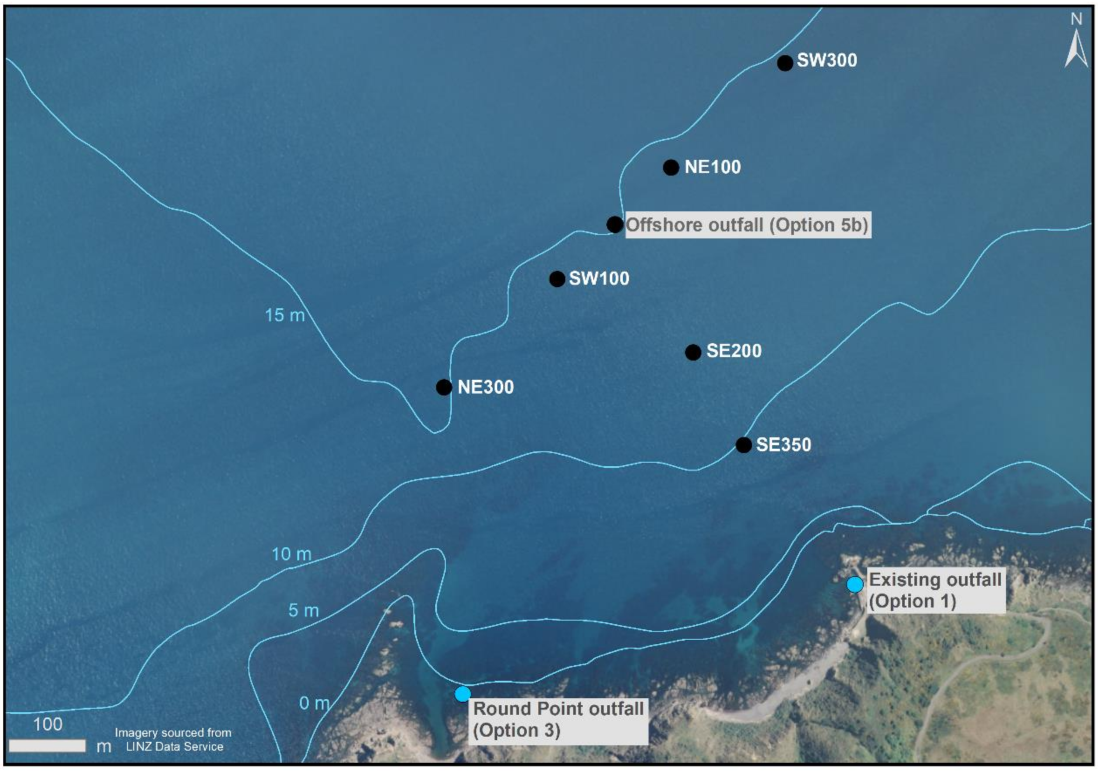


Figure 4. Locations of grab-sampling stations. The station referred to as 'DIFF' elsewhere in the report is at the offshore outfall.

2.2.2. Results and discussion

Broad-scale surveys of nearshore and offshore rocky and sediment habitats

Aerial photographs (Figure 1 and Figure 2) show that the intertidal habitat around the outfall options consists of a rocky shelf backed by pebble beaches and cliffs. The subtidal environment consists of patchy reefs interspersed with boulders, cobbles, pebbles and sand grading to sand-dominated habitat beyond about 150 m from shore, as shown in the sidescan images (Appendix 2).

Drop-camera images show the presence of bedrock, cobble and pebble, all with macroalgae growing on them, around the nearshore area at Round Point. Pebble and shelly sand dominated further from shore (Figure 5). Bedrock (with macroalgae) and patches of sand and pebble occur inshore at the existing outfall site (Figure 6). Macroalgae included bladed reds, the kelp *Ecklonia radiata*, the brown algae *Carpophyllum flexuosum* and *Zonaria aureomarginata* and the green algae *Ulva* sp. and *Caulerpa* sp. Not many animals were visible in the videos, probably because they were obscured by the dense macroalgal cover, but pink golf-ball sponges (species unidentified), 11-armed starfish (*Coscinasterias muricata*), spotties (*Notolabrus celidotus*) and blue cod (*Parapercis colias*) were recorded.

The sand-dominated habitat beyond c. 150 m from shore persisted out at least to the proposed offshore-outfall site (c. 500 m from shore). The sand surface is rippled out to c. 700 m from shore, indicating disturbance by wave action (Figure 6). Brown mats were present on the sediment surface at all the offshore sandy drop-camera stations and these are presumed to consist of benthic[1] diatoms (a type of microalga) (Figure 6). The brittle star *Ophiopsammus maculata* was common at three of the sites furthest from shore, and present at a fourth (Figure 6). Single individuals of the crab *Neommatocarcinus huttoni* and the cushion star *Patiriella regularis* were also recorded at the offshore stations. Although few animals were visible on the surface of the seabed, holes made by animals living in the sediment were present at all the stations.

[1] Relating to the seabed.

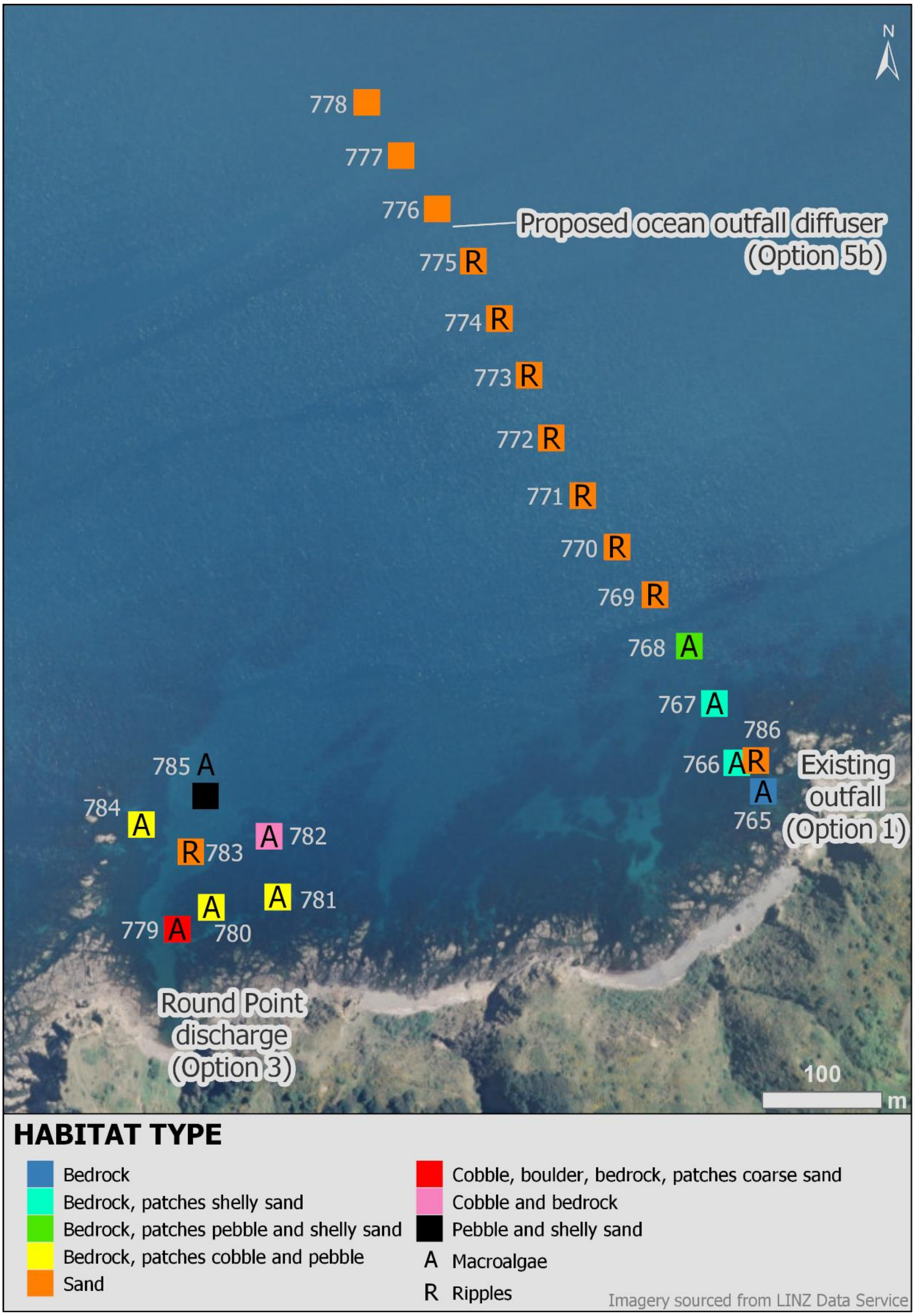


Figure 5. Seabed habitats identified from drop-camera videos. In addition to substratum type, the presence of macroalgae (A) on hard substrata, ripples (R) in sandy areas, and the way-point numbers are also shown.

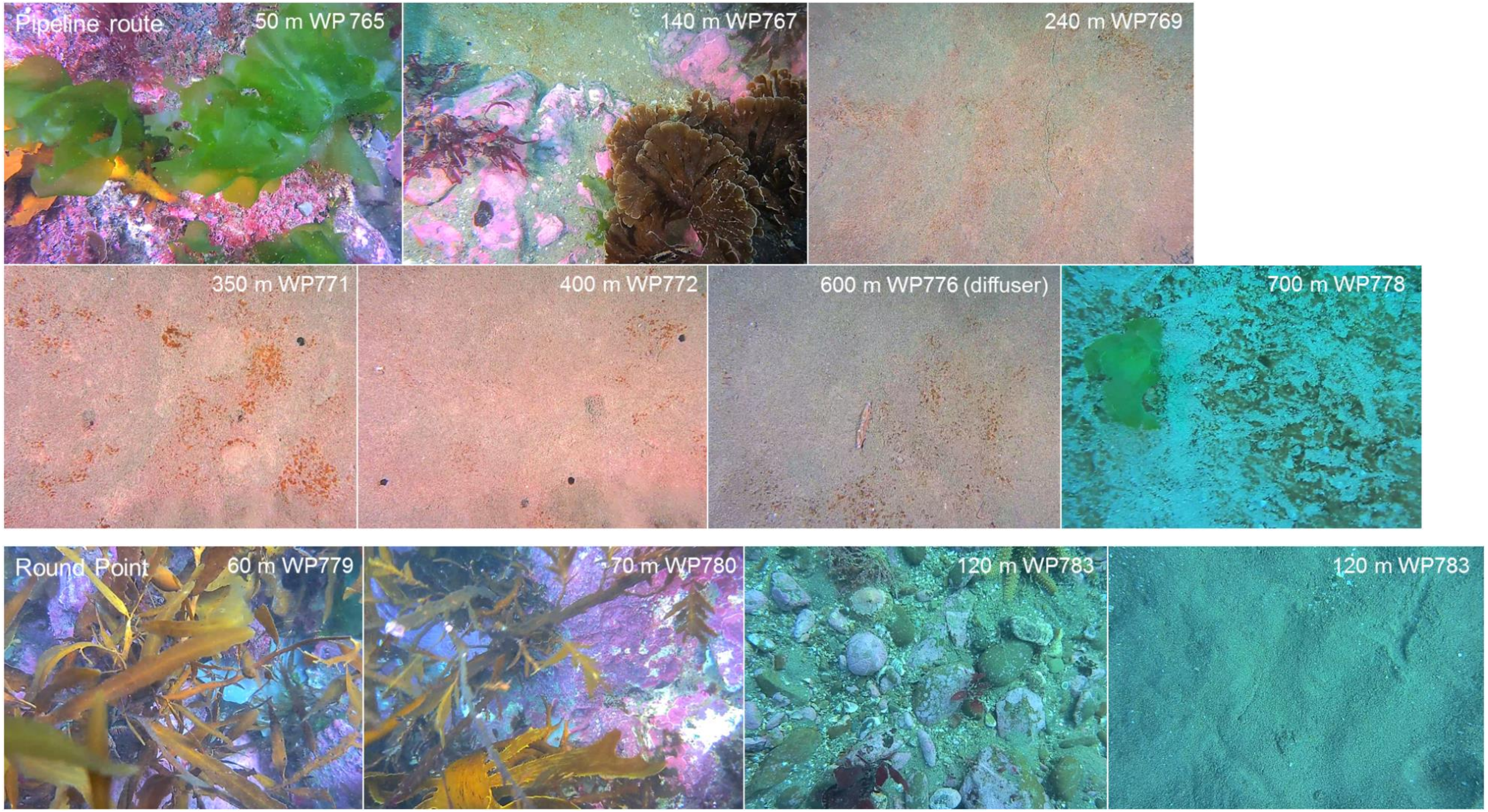


Figure 6. Representative images taken from drop-camera videos, showing examples of habitat present along the route of the proposed offshore outfall (including the existing outfall) and at Round Point. The shortest distance to the low-water mark and the waypoint number (WP) are shown. Diatom films can be seen on the surface of the sand at WPs 769, 771, 772, 776 and 778. The animal in the centre of the image from WP776 is the crab *Neommatocarcinus huttoni*.

Fine-scale surveys of intertidal and shallow-subtidal rocky habitats

The substratum along the intertidal transects consisted of bedrock at all three locations (Figure 7, Appendix 3). Quadrats in the upper intertidal area contained only two taxa, the barnacle *Chamaesipho* sp. and the blue-banded periwinkle *Austrolittorina antipodum* (Appendix 3, with representative images in Appendix 4). Encrusting coralline algae (ECA) and various green, brown and red algae were present closer to the low-water mark (Figure 8), accompanied by typical rocky-intertidal invertebrate taxa. The latter included two species of anemone, serpulid tubeworms, the snakeskin chiton *Sypharochiton pelliserpentis*, several species of limpets (*Cellana* spp. and *Siphonaria* sp.) and snails of the genera *Diloma* (herbivores) and *Haustrum* (predators). The little black mussel *Limnoperna pulex* was present at the outfall and reference locations.

Most of the subtidal transects ran across bedrock, with cobbles and boulders present intermittently at all three locations (Figure 7, Appendix 3). Encrusting coralline algae were present in most quadrats at all three locations, with up to 90% cover (Figure 8). Turfing corallines were consistently present in quadrats at Round Point but more variable at the other two locations (Figure 8). Macroalgal cover at all locations was dominated by the brown algae *Carpophyllum flexuosum* and *C. maschalocarpum* and *Ecklonia radiata*, with a range of smaller green, red and brown taxa living among them (Figure 8). The introduced kelp *Undaria pinnatifida*, common and widespread in Porirua and Wellington harbours, was only recorded at the shoreward end of transect 1 at Round Point.

Encrusting invertebrates on subtidal hard substrata included several types of sponge, the ascidian *Aplidium benhami*, bryozoans and anemones (*Oulactis muscosa*). Mobile invertebrates included various herbivorous snails (*Lunella smaragdus* and *Trochus* sp.), brittle stars (*Ophiopsammus maculata*), cushion stars (*Patiriella regularis*) and 11-armed starfish (*Coscinasterias muricata*) (see Appendix 5 for representative images from the subtidal transects). Kina (*Evechinus chloroticus*) were only recorded at Round Point, while a single individual of the large sea cucumber *Australostichopus mollis* was recorded at the existing outfall location. The most conspicuous invertebrates were pāua (*Haliotis iris*), which occurred at all three locations. They were most abundant at the outfall location, which is likely to reflect a reduced level of collecting by humans at this location (higher abundance around a wastewater outfall relative to nearby locations was also noted at the Karori West outfall on the south Wellington coast: Morrisey & D’Archino 2019). A single yellow-foot pāua (*Haliotis australis*) was also recorded at the outfall location.

Few fish were recorded by the divers along the transects. Triplefins were recorded at Round Point and the reference location. None were recorded at the outfall location but, given the small overall numbers, this is almost certainly due to chance rather than a real difference between this location and the others.

Percentage cover of encrusting coralline algae in the low-intertidal area on the two transects at the present outfall site was larger than at either of the other two sites (25% and 40% vs 0-15%: Figure 8, Appendix 3). However, there was no general indication of greater algal abundance at the present outfall site than at Round Point or the reference site, based on a comparison of total percentage cover for turfing coralline algae, brown, red or green macroalgae (Appendix 3). There was considerable variation in the cover of these taxa among locations and between transects within each location (particularly Round Point).

There were no clear differences in the extent of algal cover, nor in the algal taxa present, among the subtidal transects at the three locations (Appendix 3). There was no clear evidence of increased abundance of the green alga *Ulva* sp. around the outfall that might indicate a response to increased nutrient concentrations. Increased algal abundance would, in turn, be expected to support increased numbers of grazing invertebrates, such as snails. However, other than possibly increased abundances of pāua at the outfall location, there were no clear differences in the invertebrate of fish fauna between this and the other two locations.

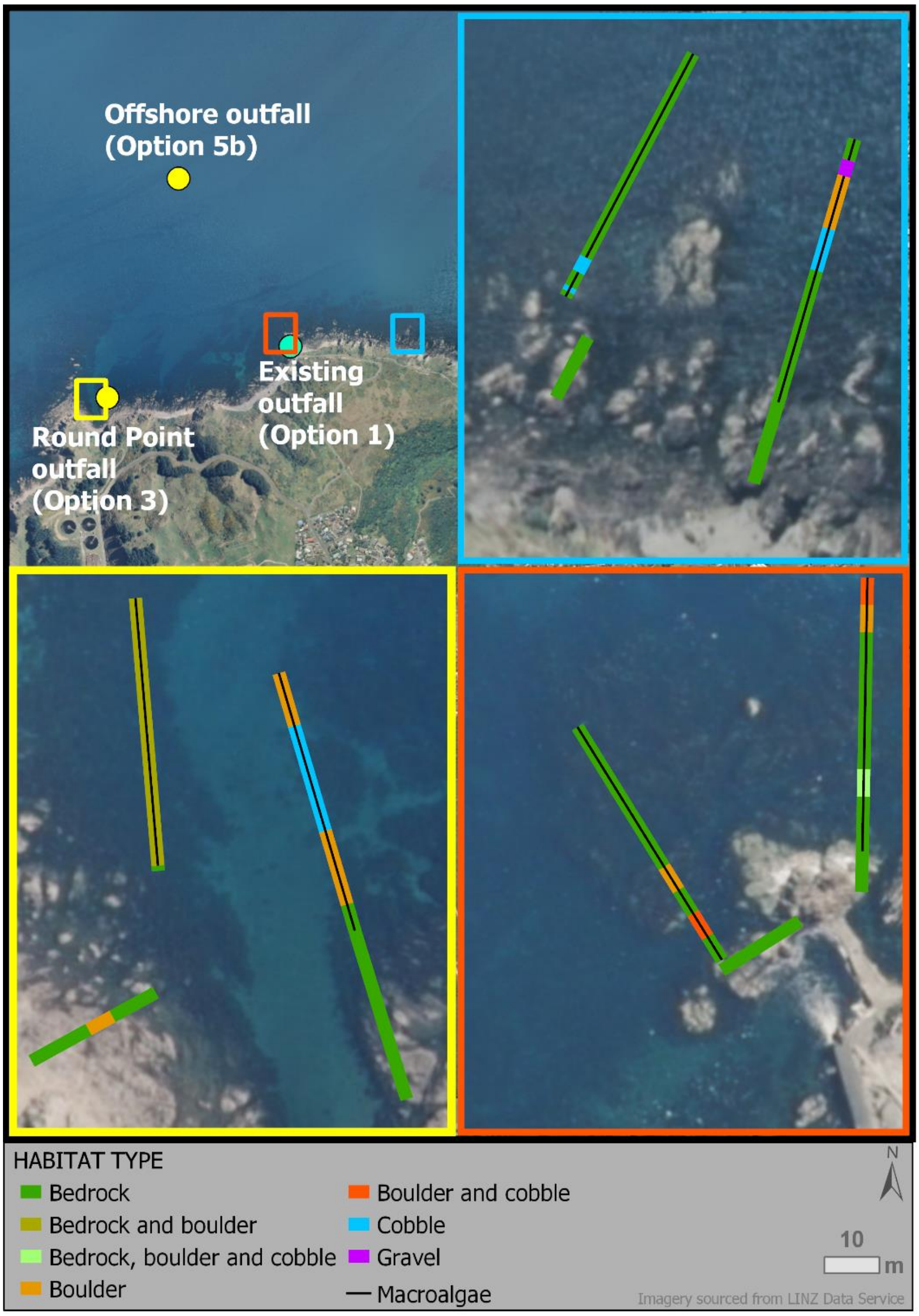


Figure 7. Types of habitat present along intertidal-subtidal transects at Round Point (bottom-left image), the existing outfall (bottom-right image) and the reference location (upper-right image). Black lines through the habitat bars indicate the presence of macroalgae.

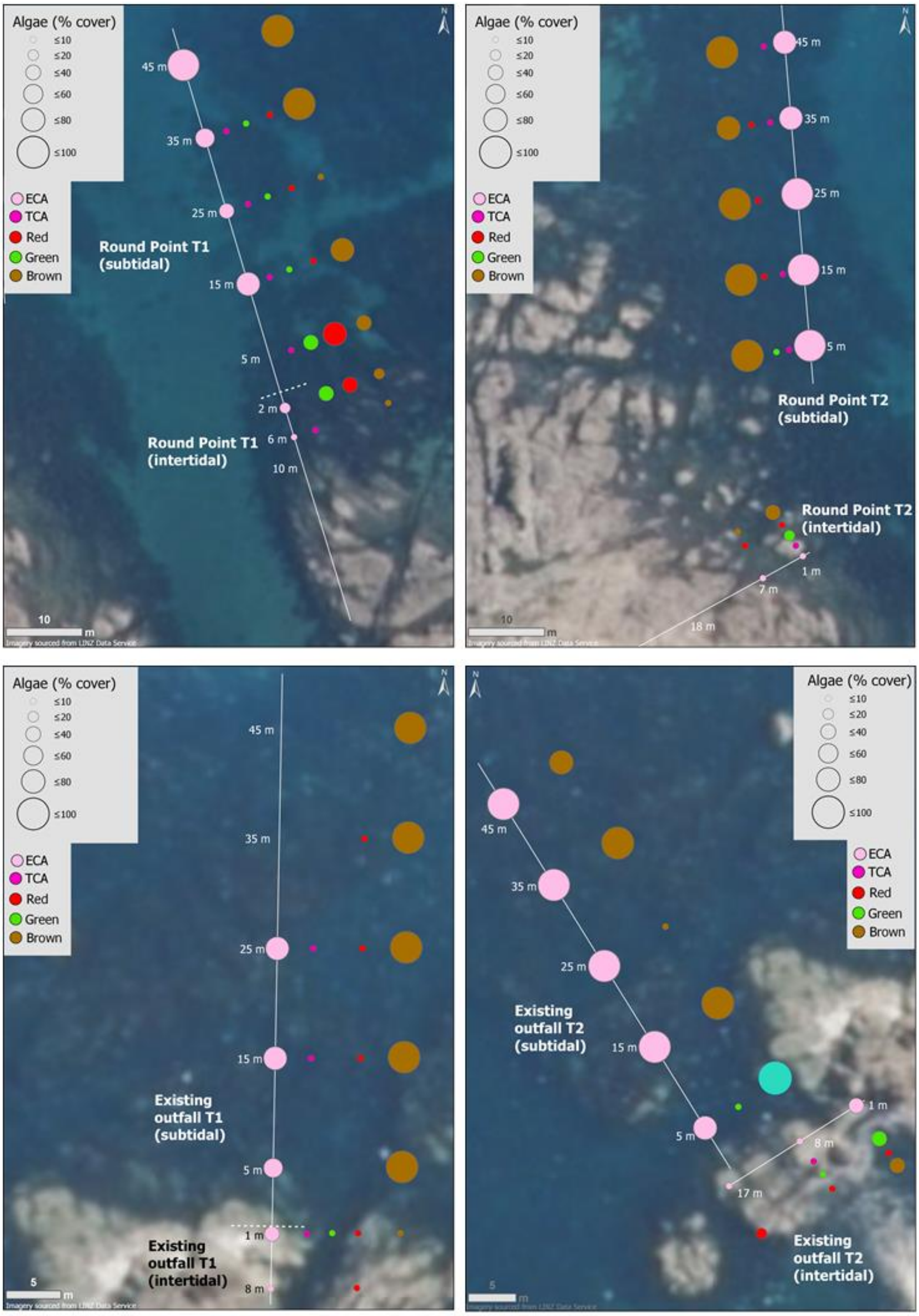


Figure 8. Bubble plots showing percentage cover of different types of algae along transects at Round Point (top) and the existing outfall (bottom). 'ECA' – encrusting coralline algae, 'TCA' – turfing coralline algae. See Figure 7 for locations of transects and Appendix 3 for source data.

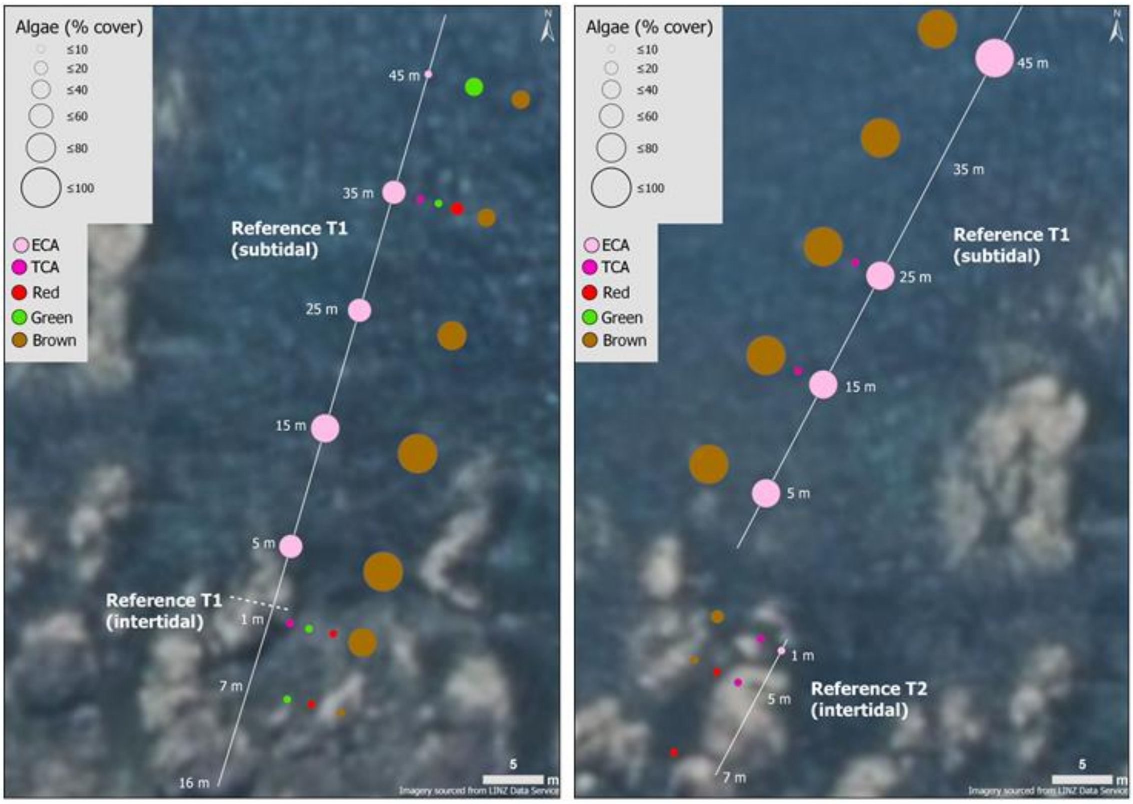


Figure 8, continued. Bubble plots showing percentage cover of different types of algae along transects at the reference location. 'ECA' – encrusting coralline algae, 'TCA' – turfing coralline algae. See Figure 7 for locations of transects and Appendix 3 for source data.

Grab-sampling along the route of the offshore-outfall

Water depths at the grab stations along the route of the offshore outfall ranged from 10–12 m at the station nearest the existing outfall (SE350) to 15.8 m at central point of the proposed diffuser (Table 2). The remaining stations were located along the 15-m depth contour to the southwest and northeast of the proposed diffuser.

Sediments at all stations consisted predominantly of very-fine or fine sand, with a small amount of mud. Pebbles and shell gravel were also present at station SW300 (Figure 9, Figure 10). Sediments at the offshore stations were dark-grey but none of the samples showed a distinct redox discontinuity. Sediments at SE200 and SE350 were grey-brown and were recorded by the divers as being siltier than the offshore samples, although this was not borne out by grain-size analysis (see below). Rather than silt, the appearance of these two samples probably reflects the relatively large percentages of very-fine sand in these samples. The percentage of very-fine sand was smallest, and the percentage of coarser material largest, at station SW300, furthest to the west. This is likely to be the result of relatively strong tidal currents in this location caused by acceleration as water passes over the shallow seabed of *The Bridge* (the 10-m depth contour that defines the eastern boundary of *The Bridge* lies 500 m west of SW300: Figure 3).

Table 2. Locations and water depths of the grab-sampling stations. Depths are the range among three replicate grabs and are not corrected for tidal state. 'NZTM' – New Zealand Transverse Mercator. 'NA' – not applicable because no redox discontinuity was visible in any core (maximum core depth was c. 8 cm).

Station	Depth (m)	NZTME	NZTMN	Latitude	Longitude	Redox depth	Appearance
SE350	10.2-12.3	1752956	5448079	41.104183	174.821533	NA	Finer than further offshore, grey-brown
SE200	12.2-12.3	1752891	5448198	41.103124	174.820727	NA	Finer than further offshore, grey-brown
NE300	15.8-15.9	1753009	5448569	41.099761	174.822044	NA	Dark grey sand
NE100	15.8-16.0	1752863	5448435	41.100997	174.820342	NA	Dark grey sand
Diffuser	15.7-15.8	1752791	5448362	41.101667	174.819500	NA	Dark grey sand
SW100	15.1-15.3	1752717	5448292	41.102311	174.818642	NA	Dark grey sand
SW300	15.4	1752572	5448153	41.103586	174.816941	NA	Dark grey sand with pebbles and shell

Concentrations of total organic carbon (TOC) in sediments were similar across all stations but slightly higher at NE300, the diffuser and SW300 (Figure 9, Figure 10). The relatively high concentration in the coarser sediment at SW300 may reflect higher inputs of organic material, such as drift algae, by water movement. The range of concentrations recorded (stations averages 0.12–0.15%[2]) is typical of unenriched coastal sediments (Mayer 1989).

Concentrations of total reactive phosphorus (TRP) were very similar at all stations (380–420 mg/kg: Figure 9, Figure 10) but highest at station SW300, probably for the same reason as TOC, i.e. inputs of drift algal material. As a general comparison, the TRP concentrations recorded are similar to those reported from sandy sediments at shallow-subtidal locations in the Canterbury Bight (Cawthron Institute unpublished data). Values up to 1000 mg/kg have been reported from highly enriched estuaries (Gillespie et al. 2012).

Concentrations of total nitrogen (TN) were in the range 0.02–0.03%[1] (by dry weight) across all but one sample. One replicate from station SE350 was below the analytical limit of detection (0.02%)[3]. Gillespie et al. (2012) reported concentrations in the range 0.02–0.19% from unenriched or moderately enriched estuarine sediments, so the present values suggest little or no enrichment.

The New Zealand Estuary Trophic Index protocol, developed to assist regional councils in assessing the vulnerability of estuaries to nutrient enrichment (Robertson et al. 2015), uses the following guidelines for sediment TOC and TN:

- TOC < 0.5% and TN < 0.025% indicate conditions not likely to stress aquatic organisms
- TOC 0.5–1%, TN 0.025–0.1% indicate conditions that may cause minor stress
- TOC > 1–2% and TN > 0.1–0.2% indicate conditions that may cause moderate stress
- TOC > 2% and TN > 0.2% indicate conditions that may cause significant stress.

Based on these criteria, concentrations of TOC and TN in sediments in the present study area are not likely to cause stress to aquatic organisms (or, in the case of TN, may cause only minor stress at most).

As discussed above, drop-camera images along the route of the proposed offshore outfall showed that the seabed was sandy with patches of brown material, assumed to be mats of diatoms (a type of microalga). Highest concentrations of chlorophyll-*a* among the sampling stations were recorded at the diffuser, SW100 and SW300 stations (Figure 9, Figure 10).

The chlorophyll-*a* concentrations recorded were in the range of those recorded at two subtidal stations (6–10 m water depth) in the lower Mahurangi Harbour (2.4–9.0 and 0.9–10.5 mg/kg: Halliday & Cummings 2009). They were at the lower end of the range

[2] Equivalent to g/100 g by dry weight of sediment.
[3] These data are not illustrated because, being at or just above the detection limit, any differences among samples or locations should be viewed cautiously.

of concentrations measured at 45 subtidal stations (1–9 m water depth) with predominantly sandy sediments in Tauranga Harbour during March–May 2016 (2.0–56.3 mg/kg, sand content 67–97%: Clark et al. 2016). These comparisons suggest that concentrations recorded in the present study are probably typical of shallow-subtidal, sandy sediments away from point-sources of nutrient enrichment.

As would be expected in coastal sediments with low mud content and dispersive water movements, concentrations of trace metals were low (Figure 11). Concentrations were generally similar among the sampling stations and all were well below concentrations at which adverse biological effects might be expected (ANZG 2018).

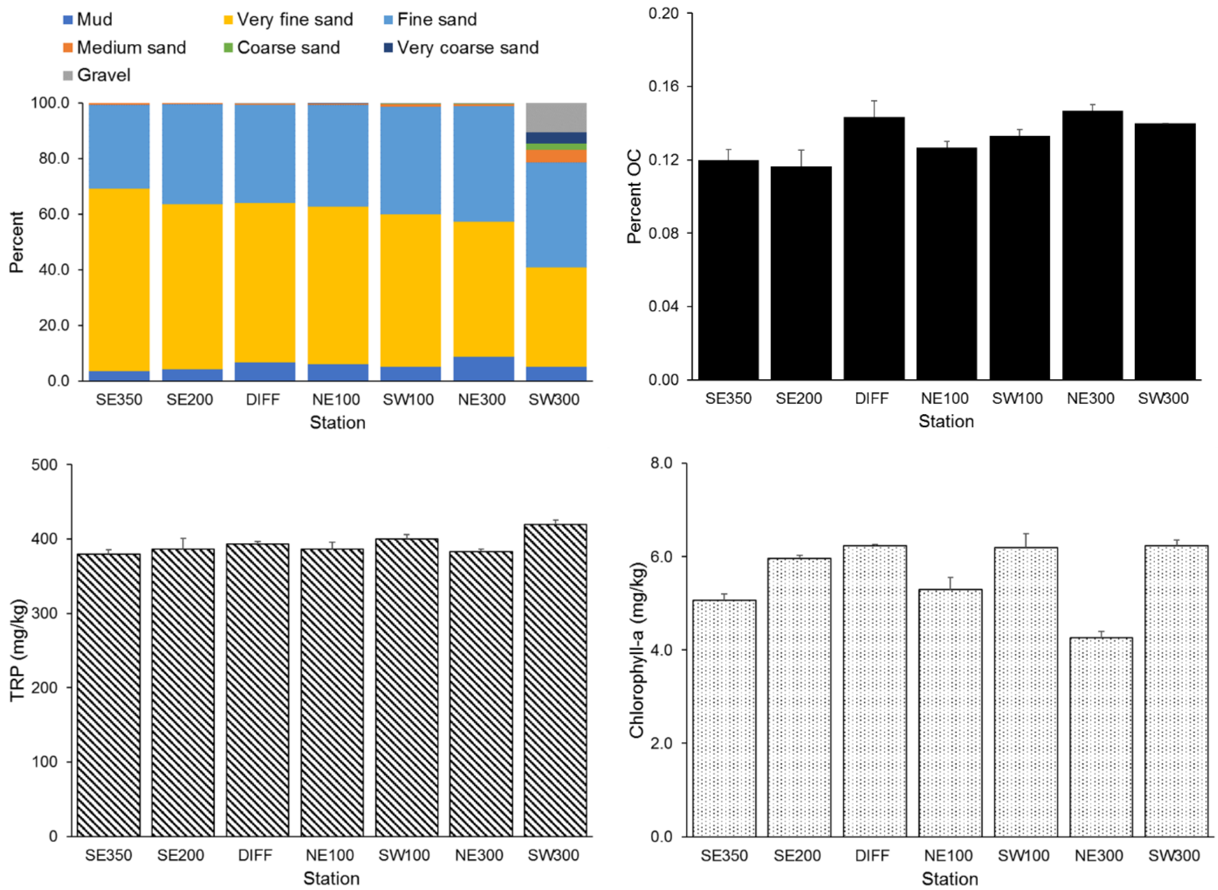


Figure 9. Sediment grain-size composition and concentrations of organic carbon (OC), total reactive phosphorus (TRP) and chlorophyll-*a* in sediments at the seven grab-sampling stations. Values are means (± SE for OC, TRP and chlorophyll-*a*) of three replicates. Note different y-axis scales for different determinands.

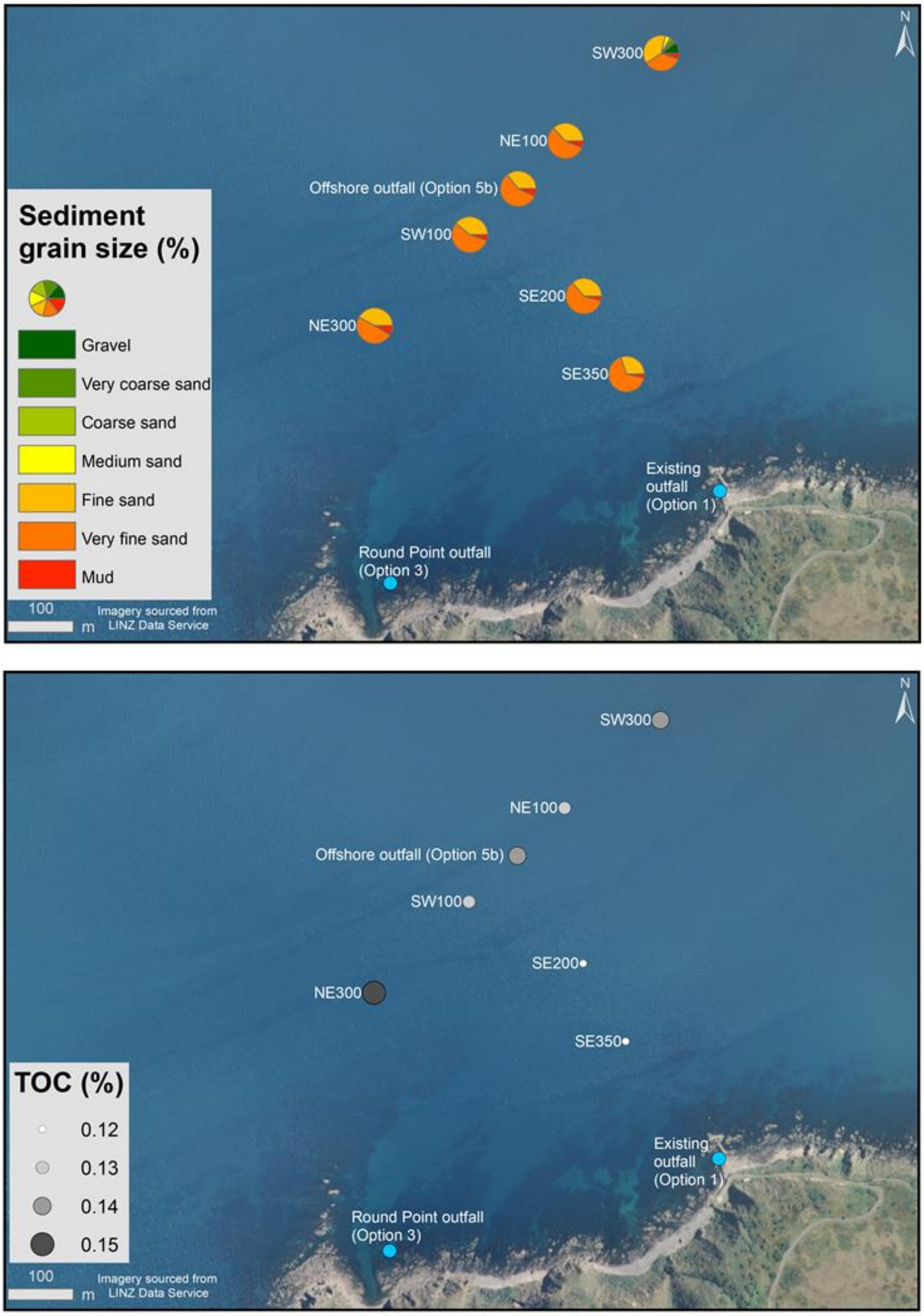


Figure 10. Sediment grain-size composition and concentration of organic carbon (TOC) in sediments at the seven grab-sampling stations. Concentration categories are based on 'natural breaks' that best group similar values and maximise differences among classes.

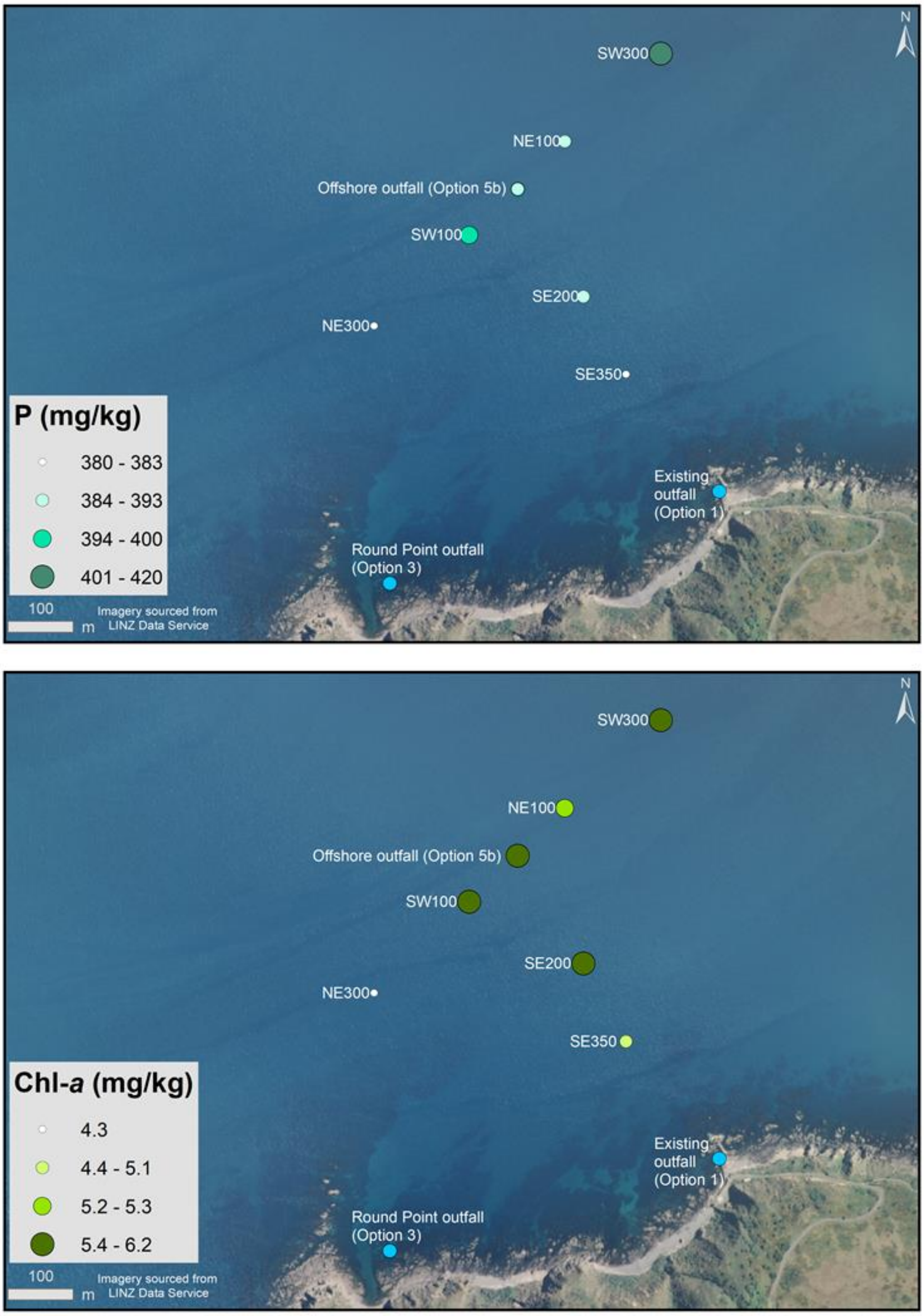


Figure 10., continued. Concentrations of total reactive phosphorus (P) and chlorophyll-*a* in sediments at the seven grab-sampling stations. Concentration categories are based on 'natural breaks' that best group similar values and maximise differences among classes.

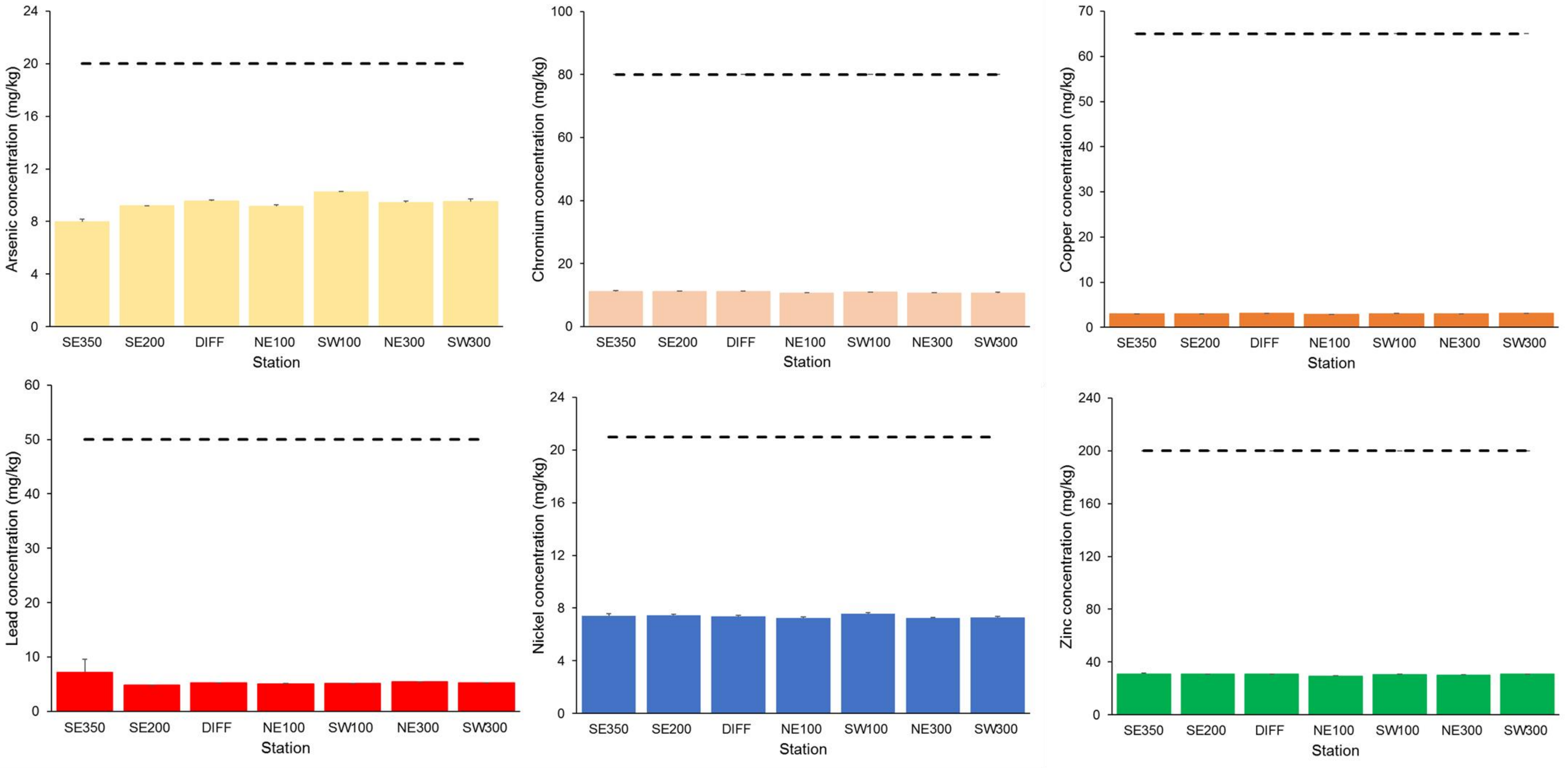


Figure 11. Concentrations of trace metals in sediments at the seven grab-sampling stations. Values are means (± SE) of three replicates. Dotted lines represent the ANZG (2018) default guideline values for sediment quality. Note different y-axis scales for different determinands.

The PCA analysis (Figure 12) combines the values of the physico-chemical variables to provide a visual representation of differences among samples. The plot shows a separation of samples from station SW300 from other samples, reflecting their relatively coarse texture and high concentrations of TRP. Sample SW300 A appears distinct from the other two replicates, due to relatively small percentages of coarser sediment fractions and correspondingly larger percentages of fine and very-fine sand (Appendix 6).

Given the natural variability of TOC, TN, TRP and chlorophyll-*a* in sediments (Zaiko et al. 2018), interpretation of differences among stations at this stage should be cautious. Their present concentrations suggest that the area sampled is currently unenriched, and the data provide a basis for identifying future change should the offshore-outfall option be chosen.

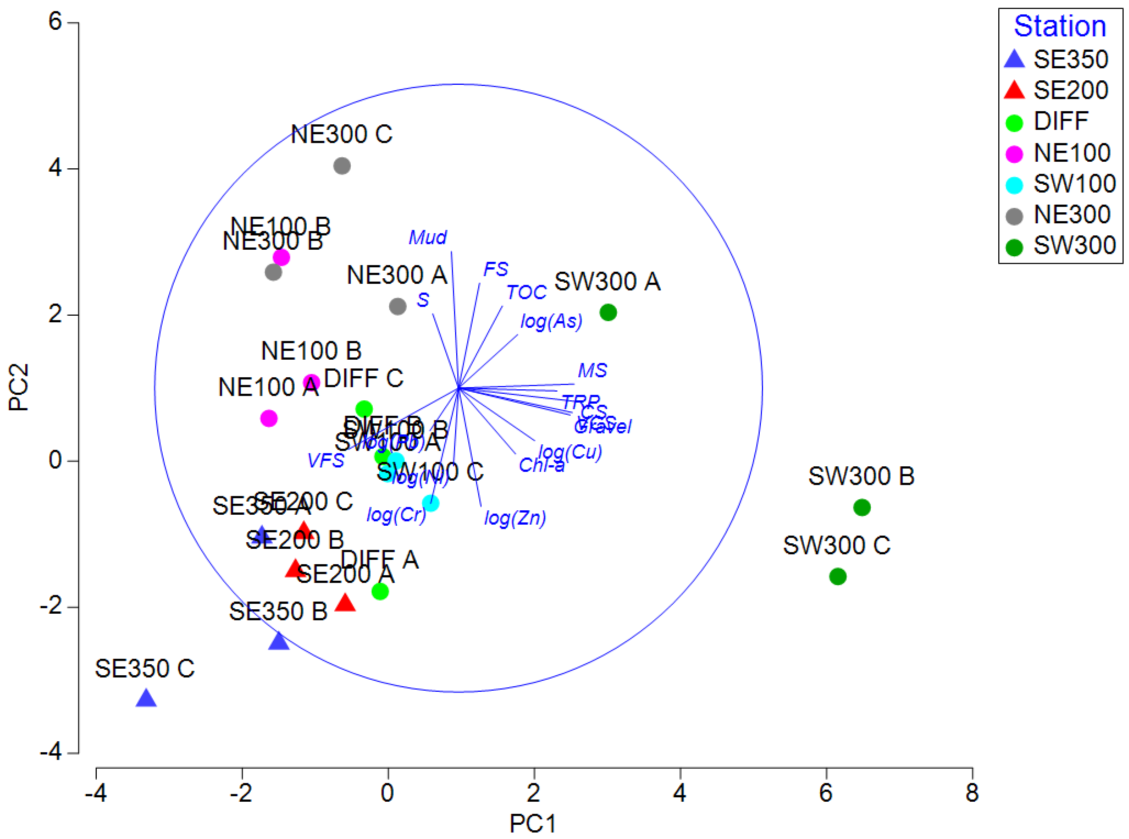


Figure 12. Principal components analysis comparing the physico-chemical characteristics of sediments from three replicate samples from each station. The length and direction of the vectors (blue) indicate the influence of that variable on the position of samples in the plot. 'VFS' – very-fine sand, 'FS' – fine sand, 'MS' – medium sand, 'CS' -coarse sand, 'VCS' – very-coarse sand, 'S' – total sulphides, 'TOC' – total organic carbon, 'TRP' – total recoverable phosphorus. Metals data log-transformed.

Average numbers of individual macrofauna per sample ranged from 105 at the station nearest shore (SE350) to 293 at SW300 (Figure 13, Figure 14)[4]. The smallest number of taxa per sample was 23 at SE350 and the largest was 32 at SW300, with a range of 26-27 among the other stations (Figure 13, Figure 14).

There was considerable variation in numbers of animals among replicate samples at station SW300, as shown by the relatively large standard error (Figure 13). Examination of the data show that this was due to a large number of sabellid polychaete worms in one sample relative to others at SW300 (416, 20 and 4 individuals) or other stations[5]. Because of this dominance by a single taxon (the next most abundant taxon in this sample was represented by 40 individuals), the values for evenness and diversity were relatively small[6] at SW300 (Figure 13).

[4] Raw infaunal data are provided in Appendix 7.
[5] For this reason, a relatively strong transformation ($\log_{(x+1)}$) was applied to the infaunal data.
[6] The maximum potential value for the Shannon-Weiner diversity index (H) is dependent upon the number of categories or species sampled for a given data set. Values typically range between 0 (indicating low community complexity) and 4 (indicating very high complexity). The evenness value (J′) ranges from 0 (highly irregular distribution of individuals among taxa) to 1 (regular distribution). While a range of values for the Shannon-Weiner Diversity Index (H') are possible for soft sediment communities in relatively unimpacted marine systems, experience suggests that these typically exceed 1.0. Similarly, values of Pielou's evenness (J') less than 0.4 would suggest some form of adverse impact.

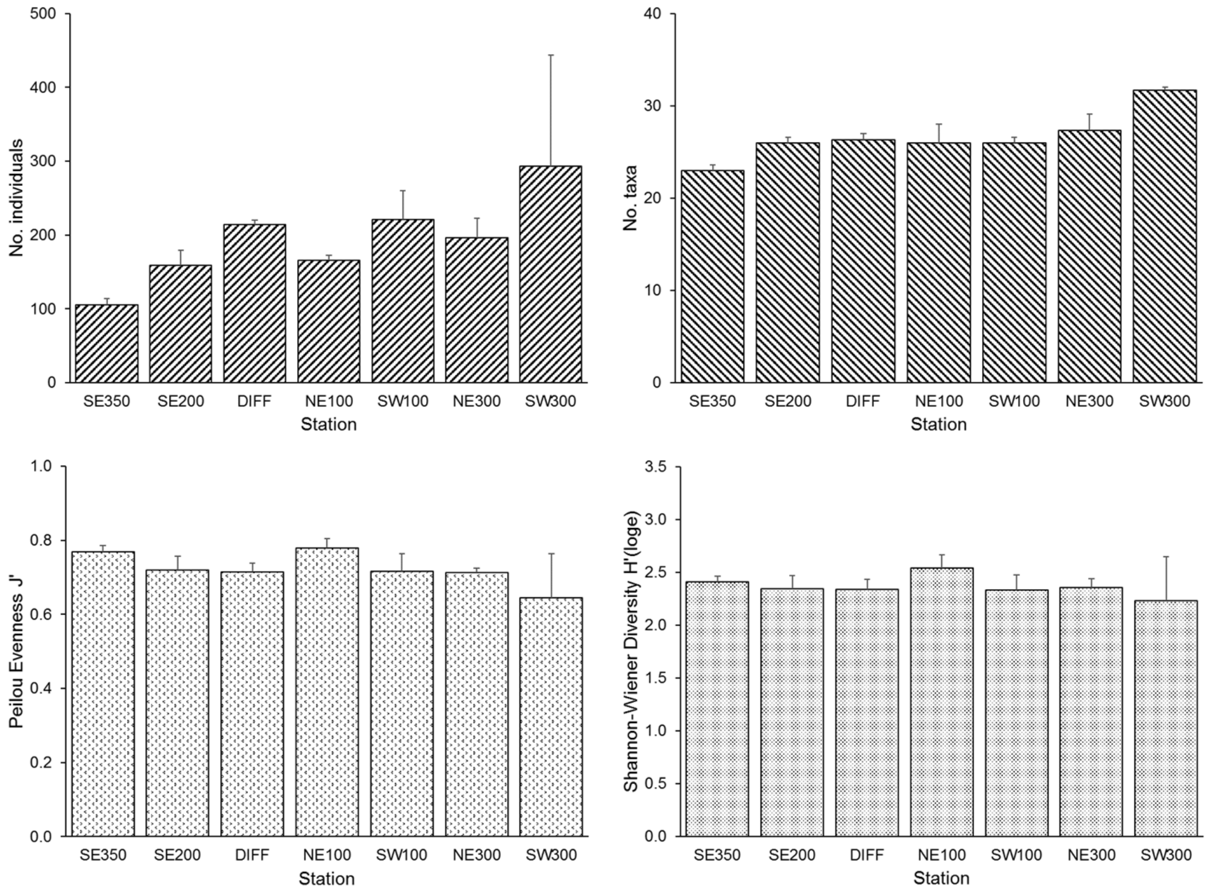


Figure 13. Macrofaunal abundance and diversity (number of taxa, Pielou's evenness and Shannon-Wiener diversity) in sediments at the seven grab-sampling stations. Values are means (± SE) of three replicates. Note the different y-axis scales on the different graphs.

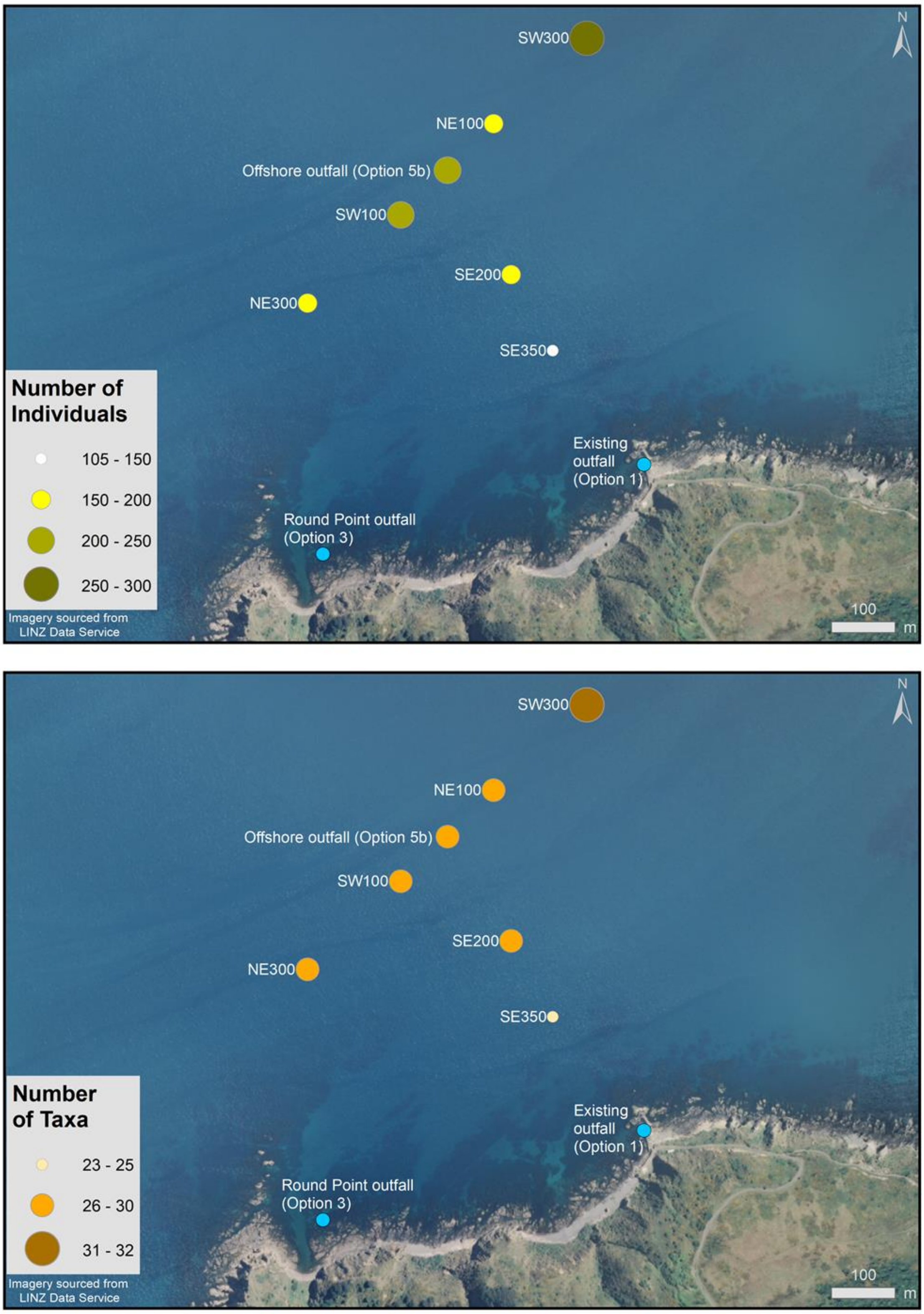


Figure 14. Macrofaunal abundance and number of taxa in sediments at the seven grab-sampling stations. Categories for numbers of individuals are based on ‘defined intervals’ that best group similar values and maximise differences among classes, and those for numbers of taxa were derived manually.

The infauna was dominated by small polychaete worms, amphipod, cumacean, ostracod and tanaid crustaceans and small bivalves. Three taxa, the polychaetes *Myriochele* sp. and *Euchone* sp. and cumacean crustaceans, were present in every sample across all stations, and 20 taxa were present in at least 50% of samples (Table 3). The three ubiquitous taxa were also among the four most abundant across all samples (the third most abundant being an unidentified sabellid polychaete), and were among the five most abundant taxa at all sampling stations (Table 3). The unidentified sabellid was present in low numbers at SW100 and NE300 but, as noted above, was very abundant at SW300.

The dominance of sabellids in samples from SW300 is shown by the separation of these samples, and particularly replicate A, from others in the nMDS plot (Figure 15, upper plot). Samples from SE350 also appear relatively distinct in this plot, and this is emphasised further when the date are log-transformed to reduce the influence of the dominant sabellids (Figure 15, lower plot). Among the remaining stations, separation among samples from a particular station is similar to that among samples from different stations, reflecting relative similarity in their infauna.

Table 3. Summary of the most widespread and abundant taxa in grab samples across all stations and by individual station. The left side of the table shows taxa present in ≥ 50% of all samples (maximum value = 21), the middle shows taxa with total abundances of ≥ 21 individuals across all samples, and the right shows abundances by station (total number across three replicates, minimum, maximum and average number per replicate).

Most widespread taxa			**Most abundant taxa overall**		**Most abundant taxa by station**					
Taxon	**Group**	**No. samples**	**Taxon**	**Total abundance**	**Station**	**Taxon**	**Total**	**Min**	**Max**	**Ave**
Myriochele sp.	Polychaete	21	*Myriochele* sp.	1099	SE350	*Myriochele* sp.	90	25	38	30.0
Euchone sp.	Polychaete	21	*Euchone* sp.	593		*Euchone* sp.	64	15	34	21.3
Cumacea	Crustacean	21	Sabellidae	461		Cumacea	30	6	15	10.0
Cirratulidae	Polychaete	20	Cumacea	369	SE200	*Myriochele* sp.	150	40	65	50.0
Ostracoda	Crustacean	20	Haustoriidae	177		*Euchone* sp.	105	22	60	35.0
Haustoriidae	Amphipod	19	Phoxocephalidae	176		Cumacea	50	15	18	16.7
Phoxocephalidae	Amphipod	19	Urothoidae	106	DIFF	*Myriochele* sp.	216	59	88	72.0
Urothoidae	Amphipod	18	Cirratulidae	99		*Euchone* sp.	104	23	51	34.7
Parasterope quadrata	Crustacean	18	*Parasterope quadrata*	80		Cumacea	67	14	31	22.3
Prionospio tridentata	Polychaete	17	*Nucula nitidula*	76	NE100	*Myriochele* sp.	137	37	57	45.7
Owenia petersenae	Polychaete	17	*Owenia petersenae*	62		Cumacea	48	15	17	16.0
Nucula nitidula	Bivalve	16	*Prionospio tridentata*	57		Phoxocephalidae	48	15	17	16.0
Tanaidacea	Crustacean	16	Tanaidacea	56		*Euchone* sp.	45	14	16	15.0
Tawera spissa	Bivalve	15	Aoridae	54	SW100	*Myriochele* sp.	220	32	108	73.3
Spiophanes modestus	Polychaete	15	Ostracoda	54		*Euchone* sp.	113	29	48	37.7
Aglaophamus sp.	Polychaete	15	*Tawera spissa*	45		Cumacea	71	19	27	23.7
Aricidea sp.	Polychaete	14	*Antisolarium egenum*	41	NE300	*Myriochele* sp.	216	49	98	72.0
Ophiuroidea	Brittle star	14	Nuculidae	40		Cumacea	65	13	31	21.7
Munnidae	Isopod	13	*Aglaophamus* sp.	30		Haustoriidae	54	6	32	18.0
Aoridae	Amphipod	13	*Spiophanes modestus*	29		Phoxocephalidae	47	15	16	15.7
			Ophiuroidea	28		*Euchone* sp.	42	5	20	14.0
			Aricidea sp.	27	SW300	Sabellidae	440	4	416	146.7
			Munnidae	25		*Euchone* sp.	120	36	44	40.0
			Paraonidae	24		*Myriochele* sp.	70	10	39	23.3
						Cumacea	38	5	18	12.7

Figure 15. Non-metric MDS plot based on untransformed (upper plot) and $\log_{(x+1)}$-transformed infaunal abundance data. There are three replicate samples (A, B, C) from each station. Stress values indicate how well the two-dimensional plot represents the multi-dimensional data (the values above indicate reasonably good representation).

Values for the average *similarities within stations* show that replicate samples from SE200 and NE100 are most consistent in their faunal composition (i.e. have the highest values in Table 4). The average values for *dissimilarity among stations* (Table 5), which underlie the nMDS, show that station SW300 is the most dissimilar to any of the other stations (values range from 54.9–65.3%), reflecting the separation seen in the nMDS plot (Figure 15). Station SE350 is the next most distinct, also reflecting the pattern seen in the nMDS plot (42.3–60.6%: Table 5). Average dissimilarities among the remaining five stations range from 31.7–39.0%.

Identification of the taxa that contribute most to the similarity among samples from the same station, or dissimilarity among samples from different stations[7], shows that the same three taxa dominate in both types of comparison for most of the stations (based on untransformed data: Table 4 and Appendix 8). The polychaetes *Myriochele* sp. and *Euchone* sp. and cumacean crustaceans each contributed > 10% of the similarity among samples at five of the stations. *Myriochele* sp. and *Euchone* sp. also characterised samples from NE300 (together with cumaceans and phoxocephalid amphipods) and SW300. Sabellid polychaetes (other than *Euchone* sp.) contributed the largest percentage dissimilarity between samples from SW300 and those from other stations (Appendix 8). The distinctiveness of samples from SE350 derives not so much from differences in taxa present, although this station contained the lowest number of taxa, but in their relative numbers, with *Myriochele* sp. and *Euchone* sp. less abundant at SE350 than other stations (Table 3 and Appendix 8).

[7] Using the PRIMER routine SIMPER.

Table 4. Taxa contributing at least 10% to the similarity among replicate samples from each of the seven sampling stations. Average similarities among replicates from each station are also shown in the first column. 'Av.Abundance' – average abundance at that station, 'Av.Sim' – average similarity among pairs of samples from that station, 'Contrib%' – contribution of taxon to the average similarity, 'Cum.% - cumulative contributions. Values were derived from untransformed data using the SIMPER routine.

Station	**Species**	**Av.Abund**	**Av.Sim**	**Contrib%**	**Cum.%**
SE350	*Myriochele* sp.	30.00	24.47	37.88	37.88
Ave sim = 64.59	*Euchone* sp.	21.33	14.28	22.11	60.00
	Cumacea	10.00	6.59	10.21	70.21
SE200	*Myriochele* sp.	50.00	26.28	35.96	35.96
Ave sim = 73.07	*Euchone* sp.	35.00	14.11	19.31	55.27
	Cumacea	16.67	9.89	13.54	68.81
DIFF	*Myriochele* sp.	72.00	29.11	42.83	42.83
Ave sim = 67.95	*Euchone* sp.	34.67	11.80	17.36	60.19
	Cumacea	22.33	7.79	11.46	71.66
NE100	*Myriochele* sp.	45.67	23.62	32.90	32.90
Ave sim = 71.79	Cumacea	16.00	9.27	12.92	45.82
	Phoxocephalidae	16.00	9.26	12.90	58.71
	Euchone sp.	15.00	8.67	12.08	70.79
SW100	*Myriochele* sp.	73.33	21.25	32.54	32.54
Ave sim = 65.33	*Euchone* sp.	37.67	14.34	21.95	54.48
	Cumacea	23.67	9.64	14.75	69.23
NE300	*Myriochele* sp.	72.00	28.19	42.13	42.13
Ave sim = 66.90	Cumacea	21.67	7.89	11.79	53.92
	Phoxocephalidae	15.67	7.85	11.73	65.66
SW300	*Euchone* sp.	40.00	15.27	37.63	37.63
Ave sim = 40.58	*Myriochele* sp.	23.33	5.11	12.60	50.23

Table 5. Average dissimilarities among replicates from each station. Values were derived from untransformed data using the SIMPER routine.

	SE200	DIFF	NE100	SW100	NE300	SW300
SE350	42.3	51.0	47.4	51.5	52.9	60.6
SE200		32.3	34.6	37.6	36.7	54.9
DIFF			36.4	33.6	32.7	56.0
NE100				39.0	31.7	62.2
SW100					37.0	56.8
NE300						65.3

2.3. Summary and conclusions

The intertidal area at all three locations consisted of bedrock, with a typically sparse fauna and flora at the top of the shore but with a greater diversity of plants and animals near the low-water mark. Subtidal habitat consisted of rocky reefs, interspersed or overlain by cobbles and boulders. These hard substrata were dominated by encrusting coralline and brown algae but also contained a range of red and green macroalgae, together with encrusting and mobile invertebrates. There was no clear difference in the abundance of macroalgae or invertebrates between the present outfall location and Round Point or the reference location, indicating that the existing outfall is not having an obvious effect on the shallow-subtidal flora and fauna. Although total recorded numbers of pāua were higher at the outfall location than at either of the other locations, this is more likely to reflect reduced human predation at this location rather than any direct effect of the outfall.

Sediments beyond the fringing reefs consisted of fine sands with organic carbon, phosphorus, nitrogen and chlorophyll-*a* concentrations typical of unenriched coastal sediments. Concentrations of trace metals were well below guidelines for the protection of aquatic life.

The infauna of the sediments is composed mainly of small worms, crustaceans and bivalves and is generally homogeneous across the area sampled. The coarser sediments nearest to *The Bridge* (at station SW300) contained a similar fauna to other stations but with an additional dominant taxon (sabellid polychaetes) and had the highest (though spatially variable) abundance and the largest number of taxa. There was no evidence of beds of large shellfish living in the sediment and none of the drop-camera videos contained horse mussels, scallops or other ecologically or culturally important taxa. Based on the drop-camera images, animals living on the surface of the sediment were scarce, with only the brittle star *Ophiopsammus maculata* being common. Surface films of what appeared to be diatoms were a notable feature of the subtidal sediments.

The surface of the seabed at stations nearer to the shore was marked by ripples, suggesting that it is regularly disturbed by wave action. This, and the fact that the fauna is dominated by small, probably short-lived organisms suggests that the fauna of these areas is likely to be resilient to disturbance of their habitat.

3. ASSESSMENT OF ECOLOGICAL EFFECTS ON THE COASTAL MARINE ENVIRONMENT

Information on the design and methods construction of outfall options 3 and 5b is currently limited and no modelling of potential dispersal and dilution of the discharge from them has been done. Consequently, although this assessment of effects has been refined from that presented in the preliminary report (Morrisey 2018) by incorporating the new ecological information, it is still constrained by lack of detail on the proposed activities.

3.1. Methods for assessing effects

3.1.1. Assessing the 'value' of organisms and habitats

The 'value' of organisms and habitats was determined using, as a first stage, the Ecological Impact Assessment New Zealand (EIANZ 2015) value method (Table 6 and Table 7). As far as we are aware, no marine invertebrates listed as *threatened* or *at risk* under the New Zealand Threat Classification System (Freeman et al. 2014) are present in the survey area. The present survey area, and the scope of the present study, did not extend into the terrestrial (including coastal) habitats considered by the national priority habitat types (MfE 2007).

Table 6. Assigning value to species/taxa for assessment purposes (EIANZ 2015).

Determining factors	Value
Nationally threatened – critical or vulnerable	Very high
Nationally at risk – declining	High
Nationally at risk – recovering, relict or naturally uncommon	Moderate–high
Locally uncommon/rare, not nationally threatened or at risk	Moderate
Not threatened nationally, common locally	Low

Table 7. Assigning value to habitat for assessment purposes (EIANZ 2015).

Determining factors	Value
Supporting more than one national priority type*	Very high
Supporting one national priority type or naturally uncommon ecosystem	High
Locally rare or threatened, supporting no threatened or at-risk species	Moderate
Nationally and locally common, supporting no threatened or at- risk species	Low

* *Refer MFE, DOC (MfE 2007) Protecting Our Places. National Priority One: To protect indigenous vegetation associated with land environments (defined by Land Environments of New Zealand at Level IV) that have 20% or less remaining in indigenous cover. National Priority Two: To protect indigenous vegetation associated with sand dunes and wetlands; ecosystem types that have become uncommon due to human activity. National Priority Three: To protect indigenous vegetation associated with 'originally rare' terrestrial ecosystem types not already covered by priorities 1 and 2.*

Determination of habitat value also refers to Policy P40 of the Wellington Proposed Natural Resources Plan to protect and restore ecosystems and habitat types with significant biodiversity values in the coastal marine area, identified in Schedule F5 of the Plan. These include subtidal rocky reefs and giant kelp (*Macrocystis pyrifera*) beds. Consequently, these habitats are considered to be of ***high*** value in our assessment. Although giant kelp occurs on rocky, open coasts in the southern North Island, no plants were recorded in the survey area and we have not considered it in the assessment of ecological effects.

In more general ecological terms, 'value' was also assessed on relative abundance and diversity of organisms in a given habitat compared with other habitats present in and around the survey area. Habitats or assemblages of known ecological importance, including macroalgal (not necessarily kelp) beds, were assessed as being of ***high*** ecological value. The less diverse intertidal rocky areas were assessed as being of ***moderate*** value. The infaunal assemblages of the sediments along the route of the offshore outfall option were considered to be of ***moderate*** ecological importance in comparison with more uniformly muddy sediments that are generally found in deeper areas offshore.

Note that this assessment excludes birds, marine mammals (both of which, although very important, are outside the scope of this report) and fish. According to habitat-modelling studies, species richness and diversity of reef fish are likely to be generally high around the exposed headlands of Mana Island and the adjacent coast (see MacDiarmid et al. 2012). There does not appear to be any detailed information on fish populations specific to the study area and this situation has not changed as a result of the present surveys (one-off surveys are unlikely to provide adequate information and for this reason were not attempted).

3.1.2. Assessing the level of risk

The approach to risk assessment was based on modified versions of those proposed by EIANZ (2015) and Burgman (2005). The levels of risk were derived from the sequential consideration of the following factors (the categories of each factor are shown in Table 8 and Table 9:

- the ecological value of the organisms or habitats affected
- the spatial scale and duration of the effect
- the magnitude, or consequences, of the effect occurring.
- the likelihood of the effect occurring.

The level of ecological risk is derived from a combination of the value of the ecological feature and the magnitude of the effect (Table 8). If the expected level of risk was more than minor, mitigation options were identified and the residual risk estimated after mitigation.

Table 8. Level of risk of an adverse effect.

		Ecological Value			
		Very high	**High**	**Moderate**	**Low**
Magnitude	High / severe	Significant	Significant	More than minor	Minor
	Moderate / medium	Significant	More than minor	Less than minor	Negligible
	Low / minor	Minor	Less than minor	Less than minor	Negligible
	Negligible	Less than minor	Negligible	Negligible	Negligible

3.2. Short-term effects of pipeline construction (options 3 and 5b)

3.2.1. Methods of construction[8]

Because information on methods of construction and on the nature of infrastructure to be installed, is currently limited, the information below is only indicative.

Existing shoreline outfall

For present purposes it is assumed that no construction or modification work would be required for continued operation of the existing outfall.

Shoreline outfall at Round Point

This option would require a new pipeline from the outlet structure of the WWTP ultra-violet treatment plant and down the steep slope to the eastern side of the bay at Round Point. An energy-dissipating system would be required to control the flow

[8] Preliminary information on outfall design options provided by email from Ron Haverland, Beca 23 July 2019.

because of the high head provided by the elevation of the plant. This would probably be achieved with control valves that would be installed in a fenced compound in the bay at Round Point.

The outfall pipe would have an outside diameter of 0.8–1.0 m and be constructed from polyethylene. It would run in a rock trench, with back-filling of the trench and reinstatement of the foreshore area after construction. The coastal frontage at this location is particularly steep, with limited access to the foreshore for the pipeline itself and for its construction. Installation would probably require the construction of temporary trestle supports and rails anchored into the rock to provide access for construction.

The current outfall has a concrete ‘causeway’ between the shore reef and an offshore reef immediately to the east (Figure 2), presumably to push the discharge offshore to prevent it dispersing along the shore to the east. No such causeway is proposed at Round Point because there is likely to be limited benefit from it.

Offshore outfall

The new outfall would connect to the existing outlet system at the tunnel portal structure at Rukutane Point. The inlet to the pipeline will need to be below low-water level at all tides, requiring the invert of the inshore end of the outfall pipeline to be 2.5–3 m lower than the present outlet from the portal structure. The inlet to the outfall pipeline will require a new de-aeration structure with an excavation to 7 m below ground into rock. The inshore section of the pipeline will require excavation into the outer extent of the rock shelf where it can emerge in the sediment seabed (c. 120 m). Work would involve trenching in rock, or tunnelling through it, to beyond the nearshore reef. Trenching through the intertidal foreshore would require a temporary trestle support to provide access.

The offshore section of the pipeline could be a polyethylene pipeline weighted with concrete collars and incorporating diffuser components at the seaward end. It may be installed on the seabed or placed in an excavated trench and backfilled depending on the potential for interference with boating and trawling activities. Construction of the c. 600 m seaward section could be achieved by a float-and-sink of the pipeline. The pipe could be assembled on the temporary trestle for the launch, or alternatively towed to site from an assembly and storage area in Porirua Harbour.

3.2.2. Effects of construction on intertidal and shallow-subtidal hard substrata

Ecological effects on hard substrata may arise from the following sources:

- direct disturbance during construction, including from vehicles and machinery
- disturbance and deposition of sediments and any associated contaminants during construction.

Other effects of construction, such as accidental spillage of fuel from construction vehicles and equipment, are possible and could be significant but their likelihood is unknown. Assessment of the risks of effects is consequently not very useful at this stage but mitigation measures to reduce them are discussed in Section 3.4.

Direct disturbance

The construction process will involve disturbance from access of equipment and vehicles across the intertidal rock platform and destruction of intertidal and subtidal habitat along the pipeline corridor. In the case of the Round Point option, this will perhaps affect an area 3–4 m wide and 80 m long (taking it to the edge of the inshore reef). It is not currently known how this area would be reinstated following pipeline installation, but the worst-case scenario is that the affected area would be converted to artificial material (concrete or similar).

Construction effects of the offshore outfall would probably be limited to a 30 m wide corridor, depending on the actual methodology, over c. 120 m of intertidal and subtidal rocky habitat. Effects will include disturbance from access of equipment and vehicles across the intertidal rock platform and destruction of intertidal and subtidal habitat along the pipeline corridor. Excavation of the trench through rock and sand will temporarily suspend sediment in the water column.

Temporary loss of habitat, and destruction of organisms living in the areas affected, during installation of the pipe is certain to occur. The spatial scale of disturbance and habitat alteration could be hundreds or thousands of square metres (e.g., an area 120 m × 30 m for the offshore outfall). However, given the predominance of rocky intertidal and shallow-subtidal habitat in this region (rocky reefs and headlands interspersed with pebbly beaches run south from Titahi Bay for about 30 km to Cape Tarawhiti), the proportion of rocky shore and subtidal reef affected is small. The disturbance will last weeks to months. The resultant level of risk is ***less than minor*** (Table 9).

Sediment deposition

Trenching of the pipeline through rock will suspend sediments into the water column. As in the case of sediment habitats, suspended sediment may interfere with feeding activities of some animals, particularly filter feeders, and reduce the amount of light reaching the seabed, potentially reducing net photosynthesis. However, the duration of suspended sediment events will be short, probably that of a working day, and sediment will then settle or disperse overnight, to increase again the following day for the period of trenching activity (assuming that work does not take place around the clock). This coastal offshore environment naturally experiences frequent storms that will suspend sediment and the organisms present are presumably tolerant of this, even over periods of several days. Consequently, the risk from the various hazards related to deposition of sediments on intertidal and subtidal hard substrata is ***negligible*** (Table 9).

3.2.3. Effects of construction on soft-sediment habitats

Construction effects of the offshore outfall would probably be limited to a 30 m wide corridor, depending on the actual methodology, over 600 m of subtidal, sandy sediment. As discussed in Section 2.2.2, the sediment environment is dynamic, and the organisms present are likely to be tolerant of physical disturbance. Consequently, the effects of disturbance caused by construction of the pipeline are likely to be short-lived and disturbed areas are expected to be recolonised fairly rapidly (perhaps months to a few years). The resultant level of risk is therefore ***less than minor*** (Table 9).

Construction activity will also suspend sediments, and any associated toxic contaminants, into the water column. As in the case of hard substrata, suspended sediment may interfere with feeding activities of some animals, particularly filter feeders, and reduce the amount of light reaching the seabed, potentially reducing net photosynthesis. It is conceivable, although unlikely, that higher concentrations of contaminants occur in deeper layers than near the surface. Excavation of these deeper sediments, and subsequent deposition on the surface of the seabed around the disturbed area, might expose organisms to higher concentrations. Suspension of sediment may also cause contaminants to change from the sediment-bound phase to the more bioavailable dissolved phase.

However, the duration of suspended sediment events will be short, probably for the duration of a working day, and will then disperse overnight, to increase again the following day for the period of trenching activity (assuming that work does not take place around the clock). This coastal offshore environment naturally experiences frequent storms that will suspend sediment and the organisms present are presumably tolerant of this, even over periods of several days. The very low concentrations of metal contaminants measured in the grab samples indicates that exposure to toxic contaminants is very unlikely to pose an ecological risk. Consequently, the risk from the various hazards related to suspension of seabed sediments is ***negligible*** (Table 9).

3.3. Long-term effects of the outfalls

3.3.1. Mechanisms of effect

Loss of habitat and on-going disturbance

The natural hard substrata removed during construction are likely to be replaced by artificial materials, such as concrete. The fauna that colonises these artificial substrata will probably be different to, and less diverse than, that present on natural substrata (Connell 2001; Connell & Glasby 1999). Furthermore, artificial substrata can be more vulnerable to colonisation by non-indigenous species (Cordell et al. 2013; Ling et al. 2012), although this is not always the case (e.g., Gittenberger & van Stelt 2011).

The likelihood of leakage from the pipe upstream of the outfall is presumably very limited unless the pipe is breached and, if it did occur, would be of short duration. This effect can therefore be ignored for present purposes.

Discharge of nutrients and other contaminants

As noted in Section 1.2.2, the outfall currently discharges secondary-treated and UV-disinfected wastewater but during periods of heavy rainfall excess flows bypass the secondary-treatment plant and are discharged as milliscreened and UV-disinfected wastewater. When flow to the WWTP exceeds 1,000 L/s the excess flow also bypasses the UV-treatment. The quality of wastewater, and the environmental effects produced, will differ among these different types of discharge and are discussed separately. Whether the wastewater has been UV-disinfected affects the risk to human health rather than its marine ecological effects and the comparison of effects is therefore limited to those of milliscreened wastewater versus secondary-treated.

The discharge from the WWTP outfall may potentially affect the ecology of the receiving environment by increasing concentrations of nutrients (notably compounds of nitrogen and phosphorus) and suspended solids, including organic material, and by reducing salinity. The type of treatment used at the Porirua WWTP (and other WWTPs in the Wellington Region) under normal flow conditions generally produces a final effluent of near-neutral pH and achieves very effective reduction in BOD, suspended solids and bacteria but less effective removal of nutrients (Barter et al. 2005). Under normal flow conditions, therefore, nutrients are likely to be the main factor in any ecological effects of the discharge.

Concentrations of trace metals, metalloids and organic contaminants in secondary-treated wastewater are generally low and below the ANZG (2018) water-quality criteria for receiving waters (Barter et al. 2005). In the case of the Karori West WWTP discharge, Barter et al. (2005) noted that

> Comparison against ANZECC (2000)[9] water quality criteria shows that, in general, concentrations of these contaminants were very low and in most cases were below the most stringent ANZECC (99% protection level) guidelines for receiving waters. In other words, even without dilution, the effluent itself would meet stringent receiving water criteria for the protection of aquatic ecosystems.

Nutrients from the WWTP may potentially make their way into the local ecosystem. Dudley (2007) used the relative proportions of stable isotopes of carbon and nitrogen to trace the uptake of nutrients derived from the Porirua WWTP outfall by macroalgae and herbivorous invertebrates. He demonstrated the uptake of dissolved inorganic nitrogen from sewage by *Carpophyllum maschalocarpum* and a herbivorous isopod

[9] Predecessors of the ANZG 92018) guidelines, but unchanged in most cases.

crustacean (*Amphoroidea media*), and the uptake of carbon from suspended particulate organic matter by the filter-feeding crab *Petrolisthes elongatus*.

Increased nutrient concentrations may cause increased abundances and biomass of planktonic algae (phytoplankton) and benthic micro- and macroalgae. These increases may, in turn, result in increased abundances of herbivorous zooplankton and benthic invertebrates, such as grazing gastropods. Very large increases in biomass of macroalgae can smother the seabed, adversely affecting other species, and may be dislodged and carried to more sheltered areas (such as Titahi Bay) where they accumulate and decompose, creating adverse ecological effects and a nuisance for human users of the area.

Increased concentrations of phytoplankton and of suspended solids from the discharge reduce water clarity. In addition to causing a visual impact, this can reduce light penetration to the seabed and reduce the depth range of benthic algae. It may also affect the feeding ability of fish and invertebrates that hunt visually. Decomposition of suspended solids, and of phytoplankton when they die, can lead to increased BOD and reduced concentrations of dissolved oxygen in the water column and on the seabed. As suspended material settles out onto the seabed it can smother algae and sessile animals. Conversely, moderate concentrations of suspended organic material may provide a food source for filter-feeding animals and, after deposition, for deposit-feeders.

Modelling studies for the present WWTP discharge (DHI 2018) show that salinity will be reduced below the ambient concentration of 32 psu in the coastal area between Green Point and the north side of Titahi Bay under average discharge rates and in the area from Green Point to the mouth of Porirua Harbour under design discharge rate (Figure 16). The predicted reduction in salinity to 25–29 psu caused by the average rate of discharge in an area c. 200 m either side of the outfall is likely to be ecologically significant. However, it should be noted that this reduction applies to the surface plume of the discharge and will only impact on the seabed in the area immediately below the discharge and for short periods in the intertidal area as the tide rises and falls.

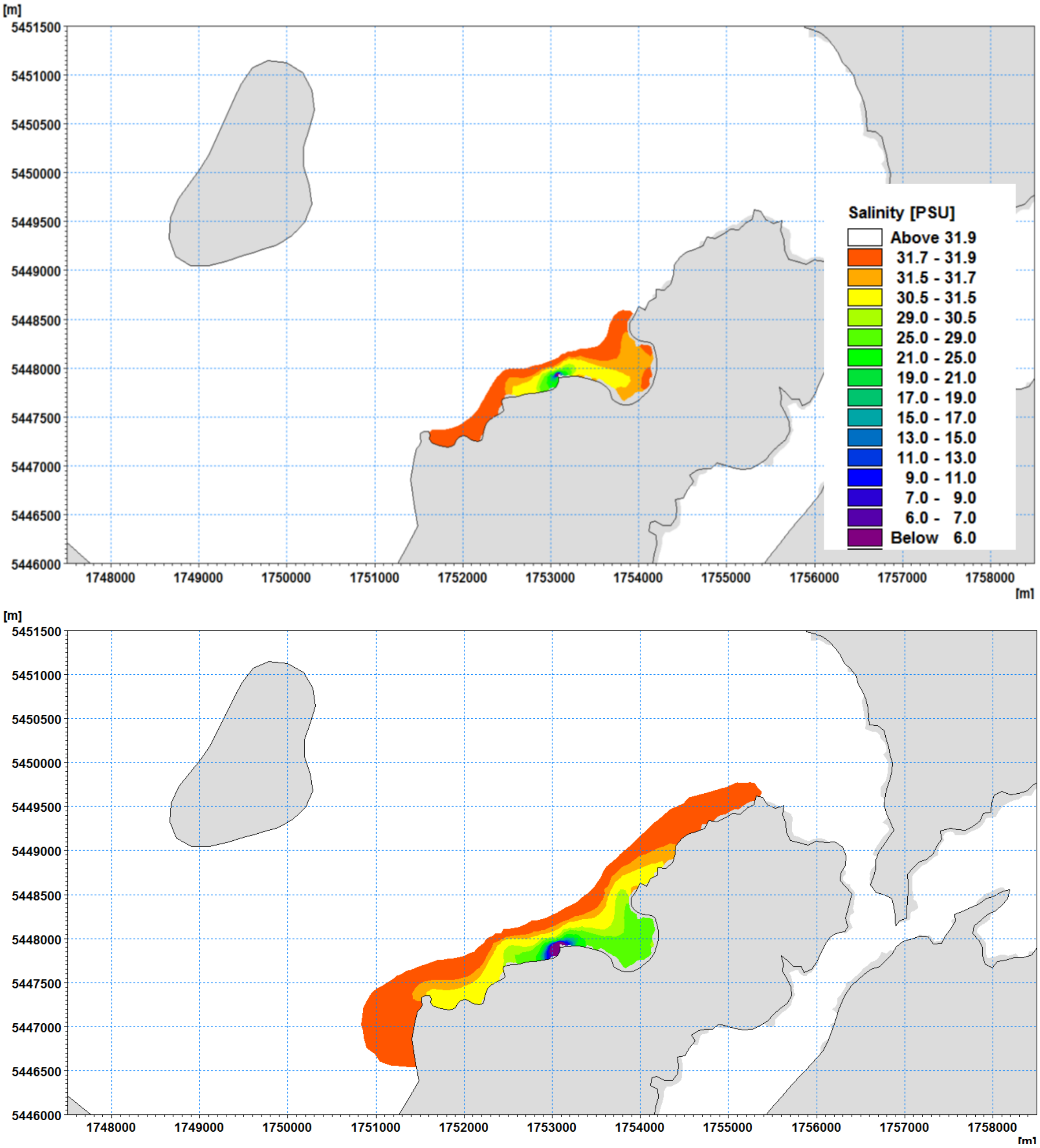


Figure 16. Predicted mean salinities for the average discharge rate from the existing Porirua WWTP discharge (300 L/s: upper figure) and for the design discharge rate (1500 L/s). Source: DHI (2018).

Modelling suggests that 1:100 dilution of the effluent (based on median concentrations) will be achieved at c. 500 m west of the outfall and 750 m east (reaching the middle of Titahi Bay beach) under average flow rate (Figure 17: DHI 2018). Under peak ('design') discharge rate (1,500 L/s), this level of dilution is predicted to occur c. 1 km from the outfall.

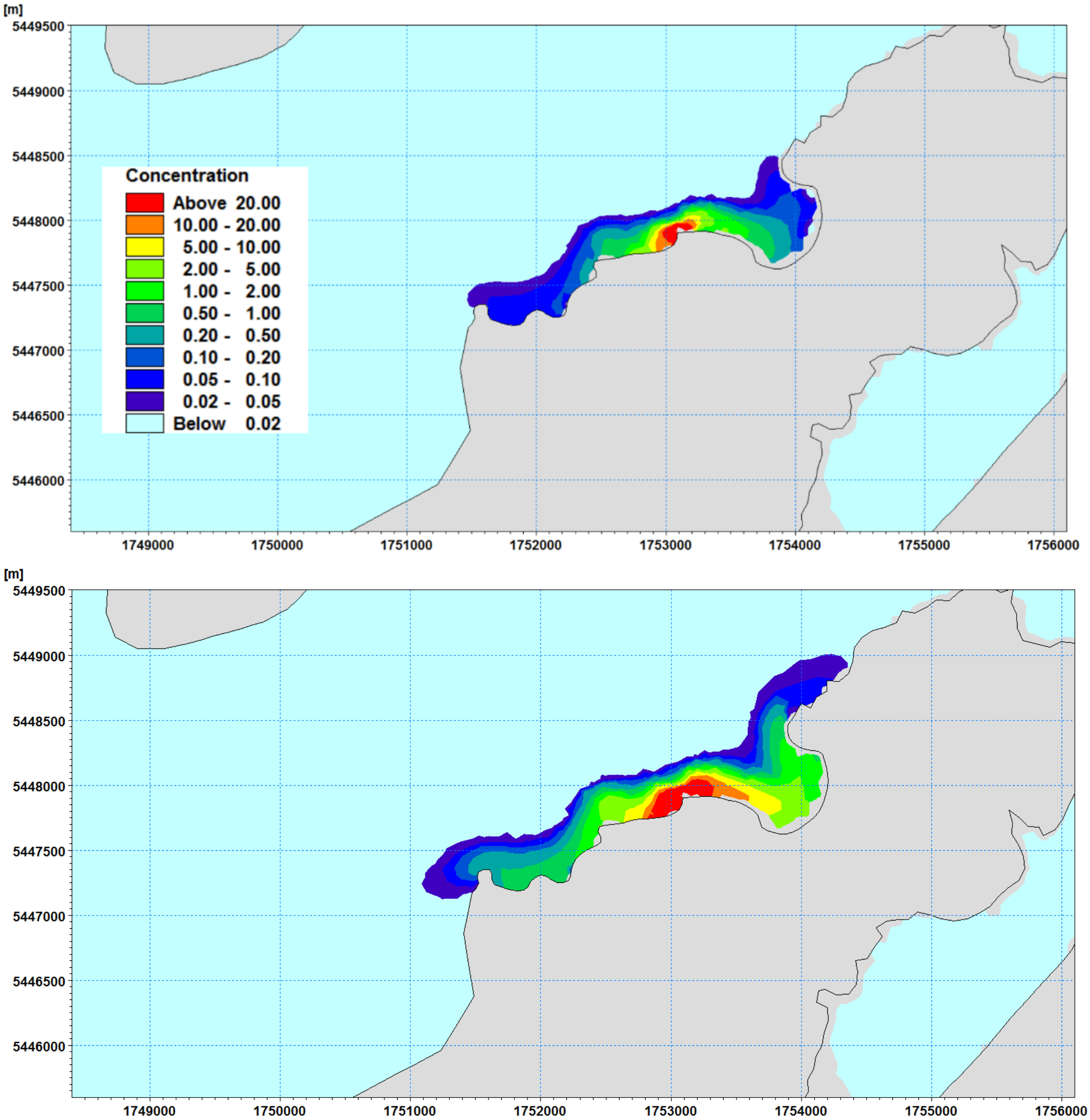


Figure 17. Predicted median concentration of wastewater for the average discharge rate from the existing Porirua WWTP discharge (300 L/s: upper figure) and for the design discharge rate (1500 L/s). Source: DHI (2018).

The majority of wastewater discharged from the Porirua outfall is expected to be secondary treated. During the period 19 November 2014 to 16 November 2016 there were a total of 50 bypass events, with an average of 22 per year (Stantec 2017). The average duration of these events was 10 h, and the events occurred c. 2.5% of the time. The longest duration and largest volume events occurred during winter (May–September). The largest number of bypass events occurred in May 2015, with a total duration of 62 h (8% of the time). However, despite upgrades to the WWTP in 2015/16, the frequency of bypass events has exceeded that anticipated at the time the present consent was granted. The upgrade to the WWTP planned for 2019/20 will increase the hydraulic capacity to 1,500 L/s and, as noted in Section 1.2.2, is expected to eliminate bypass discharges. However, increased frequency of storm flows due to climate change, or increased conveyance of storm flows to the WWTP due to upgrades to the sewage and stormwater network, could potentially generate flows exceeding 1,500 L/s. Consequently, despite the intended upgrade, these events could still occur under extreme conditions. In terms of ecological (rather than human health) effects, such discharges could cause temporary reductions in water clarity and deposition of organic matter.

3.3.2. Intertidal and shallow-subtidal hard substrata

Loss of habitat and on-going disturbance

The ecological effects of changes to intertidal and subtidal flora and fauna resulting from conversion of natural to artificial substrata along the pipeline trench after construction are likely to be persistent for the reasons discussed in Section 3.3.1. The resultant level of risk to both intertidal and subtidal habitats is, however, ***less than minor*** (Table 9).

Under options 1 and 5b, disturbance to the intertidal area from access to the pipe for on-going maintenance will presumably be no different from that caused by human access to the intertidal area that already occurs and can be ignored in terms of additional risk. Access for maintenance under option 3 (Round Point) may create a small increase in disturbance to the intertidal area at this location but this is presumed to be infrequent and minor, and the associated risk is ***negligible*** (Table 9).

Effects of the discharge

A preliminary prediction of probable ecological effects was made for the Porirua WWTP discharge based on the general similarities between the quality of wastewater and the nature of the receiving environments among the three outfalls (Bluff Point, Karori West and Porirua) (Morrisey 2018). The prediction took the form of an assessment of the integrated effect of relevant wastewater characteristics (nutrient and total suspended solids loads, and reduced salinity) as evidenced by the response of the benthic fauna and flora around the outfall.

The survey (Barter et al. 2004) of the Bluff Point outfall in 2004 following installation of secondary treatment found that although there was some evidence of deposition of solids at shallower depths on the transect closest to the discharge, they were much reduced in degree and extent compared to those reported in 1998, prior to the upgrade. Consistent with the observed improvement in water quality, in 2004 macroalgae appeared healthier, more varied and more abundant on the transect closest to the outfall than in 1998. By 2004, the overall species diversity of the survey transects closest to the outfall *appeared largely indistinguishable from that of transects further away* (Barter et al. 2004). The fauna near the outfall also showed evidence of recovery in 2004, with species of anemones and ascidians present that were not recorded in 1998 and abundances of other species larger in 2004. The large numbers of mysid shrimps that had formerly been present feeding on suspended solids were absent in 2004. Pāua were present, and in some places very abundant, in both surveys, probably because of the absence of fishing pressure around the outfall. A subsequent survey at Bluff Point in 2014 (Dunmore & Peacock 2015) found that surface water was still discoloured but there was no evidence of deposition of suspended solids. *Carpophyllum maschalocarpum* remained abundant on the transects closest to the outfall and other algae had also increased in abundance and diversity.

The survey of shallow subtidal area immediately around the outfall at Karori West (Barter et al. 2005) found evidence of mild nutrient enrichment at depths < 2 m. The macroalgal community was lush and diverse relative to nearby control sites, and the additional nutrients were apparently encouraging the wide range of taxa found in this part of the coast to thrive. Numbers of herbivorous fish and grazing invertebrates were also more abundant closer to the outfall (again, in the case of pāua this may have reflected reduced fishing pressure rather than, or in addition to, enhanced food supply). Reefs at 2–5 m depth near the outfall showed little sign of outfall-related enrichment. This suggested that the communities living on them are rarely exposed to elevated concentrations of nutrients, probably because of high levels of mixing and dispersion by water movement and redirection of the wastewater back into shore by wave action upon being discharged (Barter et al. 2005).

The preliminary risk assessment for the present outfall at Rukutane Point (Morrisey 2018) assumed that effects were likely to be similar to those of the discharges of secondary-treated wastewater, and periodic bypass events, at Bluff Point and Karori West. However, the current surveys of the intertidal and shallow subtidal hard-substrata around the existing outfall at Rukutane Point, and of equivalent areas away from it (500 m in the case of Round Point and 300 m in the case of the reference location), did not provide any clear evidence that the current discharge has resulted in increased growth of algae, or abundances of grazer invertebrates, as a consequence of increased nutrient availability.

This lack of observed effects suggests that dispersion and dilution of the discharge at Rukutane Point is sufficient to reduce concentrations of nutrients to ecologically acceptable levels. Modelling suggests that, under average flow conditions, by the time the discharge plume reaches the reference location and Round Point, concentrations will be reduced by factors of about 10 and 100, respectively (Figure 17). The receiving environment at Round Point is similar to that at Rukutane Point in terms of habitat types and exposure to wind-driven and tidal currents. The expected ecological effects of the discharge on hard-substratum habitats at Round Point would therefore be expected to be similar. The proposed location of option 3 is, however, sheltered to the west by a reef extending c. 150 m out from the shore, and by the relatively shallow waters of *The Bridge*. This may reduce water movement around the outfall under certain tidal, wind and wave conditions and inhibit the dispersion and dilution of contaminants. This extension of the dilution footprint could, in turn, extend the area of ecological effect. However, given the moderate level of effect observed around the existing outfalls at Bluff Point and Karori West, this effect is not expected to be large. At worst the discharge at Round Point might result in increased abundances of macroalgae and grazing invertebrates in shallow habitats adjacent to the outfall, as at Karori West. Because this expectation is based on observed differences at existing outfalls, it integrates effects of both normal and high-flow discharges and of the effects of nutrient inputs and reduced salinity. The risk to hard-substratum habitats from discharges at Round Point or Rukutane Point is therefore considered ***less than minor*** (Table 9).

3.3.3. Soft-sediment habitats

Loss or alteration of habitat and on-going disturbance

As noted above, soft-sediment habitats and organisms are expected to recover relatively rapidly and completely from the disturbance caused by construction of the offshore outfall option once the trench has been back-filled. The level of risk is ***negligible*** (Table 9).

The pipe itself is presumed to be an 'inert' presence in the environment once construction is complete. However, unintentional leakages of wastewater could occur from incompletely sealed joints or due to accidental damage. At present it has not been decided whether the pipe will be completely buried. If this is not the case, there will be 'passive' effects on water movement around the pipe and, thereby, on sediment stability and properties. Scouring of the sediment by water currents is likely around the pipe and its supports, with consequent changes to the nature of seabed (height and sediment texture). The pipe is likely to be colonised by a different fauna to surrounding area as seen, for example, on the risers of the outfall in Lyall Bay of Wellington City Council's Moa Point waste-water treatment plant (Morrisey 2018). This fauna may, in turn, affect the fauna of surrounding sediments by enhancing numbers of predators, such as fish and crabs. Effects are likely to be very localised and the level of risk is ***less than minor*** (Table 9).

Effects of the discharge

From previous studies of offshore outfalls that discharge into muddy or sandy sediments on the west coast (e.g., Whanganui: Berthelsen & Morrisey 2017), we might expect localised (tens of metres or less) changes in physicochemical properties of the sediment and the composition of the biological community. The former may include increased concentrations of organic matter and sulphides, higher proportions of fine sediment, and increased concentrations of trace metals (though these would not be expected to exceed sediment-quality criteria). The fauna may include relatively larger numbers of species tolerant of increased organic matter, such as capitellid polychaete worms, and small decreases in faunal diversity.

The survey of sediment physico-chemical character and infaunal composition at and around the proposed offshore outfall showed that this area is not enriched with nutrients or metal contaminants at present. The sandy nature of the sediment, and the presence of ripples on the surface of the seabed suggests that it is subject to reasonably strong water movement. The environment is therefore likely to be conducive to the dispersion and dilution of particulate and dissolved contaminants from the discharge. The extent of any effects is likely to be restricted to the area immediately around the outfall (tens of metres or less). The risk is ***less than minor*** (Table 9).

3.4. Mitigation measures

Policy P138 of the Wellington Proposed Natural Resources Plan requires that new structures, or alteration to a structure, shall be avoided in coastal habitats listed in Schedule F5 of the Plan, including subtidal rocky reefs. Exclusions to this requirement include where the structure is necessary to enable the development, operation or maintenance and upgrade of regionally significant infrastructure, but only if there are no practicable alternative methods of providing for the activity. In the present context there does not appear to be any possibility of placing the new outfall options where effects on shallow subtidal reefs can be completely avoided. Obviously, the continued operation of the existing outfall will not introduce any new effects. Aerial photographs (e.g., Figure 1) suggest that there is a sandy channel leading out from the shore at Round Point, but it is not known whether the sand is deep enough to accommodate the pipeline.

None of the predicted risks from any of the outfall options were ranked above *less than minor* and consequently mitigation is not essential. However, there are measures that could be taken to minimise any residual risk of unwanted environmental effects and, in the case of possible spills of fuel or other toxic materials, should be taken to protect the environment around the outfalls.

Burying the pipe below seabed will avoid long-term effects on water movement and sediment transport, and reduce the area available for colonisation by hard-substratum taxa. The only potential residual risk of adverse ecological effects after construction is that from major accidental leakage from the pipe due, for example, to rupture caused by boat anchoring or dredging. Burial of the pipe will reduce this risk and presumably methods will be put in place to detect, and rapidly fix, breakages.

Spillage of fuel or other toxic materials during construction of the new outfall options could have adverse effects on intertidal or shallow-subtidal habitats and organisms.

This risk can be minimised by best-practices relating to operation of machinery and the transfer and storage of fuel and other potentially harmful liquids or solids.

3.5. Summary

Using the approaches to assessing risk proposed by Burgman (2005) and EIANZ (2015), levels of short-term risk to habitats and organisms on rocky and sandy substrata during the construction phase were identified as ***negligible*** or ***less than minor*** (Table 9). Long-term risk from loss or alteration of habitat and effects of the discharge (nutrient enrichment and reduced salinity) were also identified as ***negligible*** or ***less than minor*** (Table 9).

Given the low levels of risk, mitigation of adverse effects is not essential but, in the case of the offshore outfall option (5b), burial of the pipeline where it crosses sandy seabed would reduce effects on the surrounding environment. It would also reduce the risk of damage to the pipe and the consequent leakage of wastewater nearer shore. Management practices should be put in place to reduce the risk of spills of harmful materials, such as fuels, during the construction phase.

Table 9. Summary of potential ecological effects of the proposal. See Section 3.1.1 for derivation of 'value' and Section 3.1.2 for 'level of risk'.

Potential environmental effect	Ecological feature	Outfall options	Value	Spatial scale of effect	Duration of effect	Magnitude of effect	Likelihood of effect	Level of risk
Direct disturbance during construction	Biota of intertidal rocky substrata	3, 5b	Moderate	Medium	Moderate	Low / minor	High	Less than minor
	Biota of subtidal rocky substrata	3, 5b	High	Medium	Moderate	Low / minor	High	Less than minor
	Biota of sandy sediments	5b	Moderate	Medium	Short	Low / minor	High	Less than minor
Sediment deposition during construction	Biota of intertidal rocky substrata	3, 5b	Moderate	Small	Short	Negligible	Moderate	Negligible
	Biota of subtidal rocky substrata	3, 5b	High	Small	Short	Negligible	Moderate	Negligible
	Biota of sandy sediments	5b	Moderate	Small	Short	Negligible	Moderate	Negligible
Contaminant deposition during construction	Biota of sandy sediments	5b	Moderate	Small	Persistent	Negligible	Moderate	Negligible
Contaminant dissolution	Biota of sandy sediments	5b	Moderate	Small	Short	Negligible	Moderate	Negligible
Long-term habitat loss or alteration	Biota of intertidal rocky substrata	1, 3, 5b	Moderate	Medium	Persistent	Low / minor	High	Less than minor
	Biota of subtidal rocky substrata	1, 3, 5b	High	Medium	Persistent	Low / minor	High	Less than minor
	Biota of sandy sediments: habitat loss (removal and replacement of sediment)	5b	Moderate	Medium	Short	Negligible	High	Negligible
	Biota of sandy sediments: habitat alteration	5b	Moderate	Medium	Persistent	Low / minor	High	Less than minor
Access for maintenance	Biota of intertidal rocky substrata		Moderate		Short	Negligible	Low	Negligible
Nutrient enrichment	Biota of intertidal rocky substrata	1, 3, 5b	Moderate	Small	Persistent	Low / minor	Moderate	Less than minor
	Biota of subtidal rocky substrata	1, 3, 5b	High	Small	Persistent	Low / minor	Moderate	Less than minor
	Biota of sandy sediments	5b	Moderate	Small	Persistent	Low / minor	Moderate	Less than minor
Reduced salinity	Biota of intertidal rocky substrata	1, 3, 5b	Moderate	Medium	Persistent	Low / minor	Moderate	Less than minor
	Biota of subtidal rocky substrata	1, 3, 5b	High	Medium	Persistent	Low / minor	Moderate	Less than minor
	Biota of sandy sediments	5b	Moderate	Medium	Persistent	Low / minor	Moderate	Less than minor

Definition of terms used in table:

Spatial scale of effect: Small (tens of metres), Medium (hundreds of metres), Large (> 1 km)

Duration of effect: Short (days to weeks), Moderate (weeks to months), Persistent (years or more)

Magnitude of effect: Negligible (no or very slight change from existing conditions), Low / Minor (minor change from existing conditions, minor effect on population or range of the feature), Moderate / Medium (loss or alteration to key element(s) of existing conditions, moderate effect on population or range of the feature) , High / Severe (major or total loss of key element(s) of existing conditions, large effect on population or range of the feature)

Likelihood of effect: Low (< 25%), Moderate (25–75%), High (> 75%)

Level of risk: Negligible (effect too small to be discernible or of concern), Less than Minor (discernible effect but too small to affect others), Minor (noticeable but will not cause any significant adverse effects), More than Minor (noticeable that may cause adverse impact but could be mitigated), Significant (noticeable and will have serious adverse impact but could be mitigated)

4. ACKNOWLEDGEMENTS

Identification of infaunal samples was done by Cawthron's taxonomy laboratory. Thanks also to Gretchen Rasch for editing this report.

5. REFERENCES

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Toxicant default guideline values for sediment quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants. Accessed 5 June 2019.

Barter P, Keeley N, Hopkins S 2005. A survey of effluent dilution/dispersion and subtidal marine ecology around the Karori West short ocean outfall Cawthron Report No. 1095. Prepared for MWH New Zealand Ltd. 35 p. plus appendices.

Barter P, Sneddon R, Keeley N 2004. A survey of effluent dilution/dispersion and subtidal marine ecology around the short ocean outfall at Bluff Point. Cawthron Report No. 887. Prepared for Hutt City Council. 24 p. plus appendix.

Berthelsen A, Morrisey D 2017. Whanganui wastewater outfall: 2017 benthic survey. Prepared for Whanganui District Council. Cawthron Report No. 3063. 26 p. plus appendices.

Burgman M 2005. Risks and decisions for conservation and environmental management. Cambridge: Cambridge University Press.

Clark D, Taiapa C, Sinner J, Taikato V, Culliford D, Battershill C, Ellis J, Gower F, Borges H, Patterson M 2018. 2016 Subtidal ecological survey of Tauranga harbour and development of Benthic Health Models. OTOT Research Report No. 4. Massey University, Palmerston North. 54 p. plus appendices.

Clarke KR, Warwick RM 1994. Changes in marine communities: An approach to statistical analysis and interpretation. Plymouth Marine Laboratory. Plymouth, UK.

Clarke KR, Gorley RN 2001. PRIMER v5: User manual/tutorial. Plymouth Marine Laboratory, United Kingdom.

Connell SD 2001. Urban structures as marine habitats: an experimental comparison of the composition and abundance of subtidal epibiota among pilings, pontoons and rocky reefs. Marine Environmental Research 52: 115-125.

Connell SD, Glasby TM 1999. Do urban structures influence local abundance and diversity of subtidal epiobiota? A case study from Sydney Harbour, Australia. Marine Environmental Research 47: 373-387.

Cordell JR, Levy C, Toft JD 2013. Ecological implications of invasive tunicates associated with artificial structures in Puget Sound, Washington, USA. Biological Invasions 15: 1303-1318.

DHI 2018. Titahi Bay outfall modelling. Prepared for Wellington Water Ltd. DHI Water and Environment Ltd. 64 p. plus appendices.

Dudley BD 2007. Quantitative ecological impact assessments using natural abundance carbon and nitrogen stable isotope signatures. Victoria University of Wellington unpublished PhD thesis. 141 p. plus appendices and references.

Dunmore R, Peacock L 2015. Bluff Point ocean outfall: subtidal marine ecology survey. Prepared for MWH New Zealand Ltd. Cawthron Report No. 2673. 23 p. plus appendix.

EIANZ 2015. Ecological Impact Assessment (EcIA) EIANZ guidelines for use in New Zealand: terrestrial and freshwater ecosystems. March 2015. Environment Institute of Australia and New Zealand Inc. 88 p. plus appendices.

Freeman D, Schnabel K, Marshall B, Gordon D, Wing S, Tracey D, Hitchmough R 2014. Conservation status of New Zealand marine invertebrates, 2013. New Zealand Threat Classification Series 9. Department of Conservation, Wellington. 20 p.

Gillespie P, Clement D, Clark D, Asher R 2012. Nelson Haven fine-scale benthic baseline 2012. Prepared for Nelson City Council. Cawthron Report No. 2209. 22 p. plus appendices.

Gittenberger A, van der Stelt RC 2011. Artificial structures in harbors and their associated fauna. Aquatic Invasions 6: 413-420.

Halliday J, Cummings V 2009. Mahurangi Estuary ecological monitoring programme – report on data collected from July 1994 to January 2009. Auckland Regional Council Technical Report No. TR2009/120. 69 p. plus appendices.

Ling SD, Johnson CR, Mundy CN, Morris A, Ross DJ 2012. Hotspots of exotic free-spawning sex: man-made environment facilitates success of an invasive seastar. Journal of Applied Ecology 49(3): 733-741.

MacDiarmid A, Nelson W, Gordon D, Bowden D, Mountjoy J, Lamarche G 2012. Sites of significance for indigenous marine biodiversity in the Wellington region. Prepared for Greater Wellington Regional Council. NIWA Client Report No. WLG2012-19. 85 p.

Mayer LM 1989. The nature and determination of non-living sedimentary organic matter as a food source for deposit feeders. In: Lopez G, Taghon G, Levinton J (eds) Ecology of marine deposit feeders. Springer-Verlag, New York, pp 98-113.

MfE 2007. Protecting our places – Information about the Statement of National Priorities for Protecting Rare and Threatened Biodiversity on Private Land. Ministry for the Environment and Department of Conservation Report No. ME805. 51 p.

Morrisey D 2018. Porirua Wastewater Treatment Plant outfall: Preliminary assessment of ecological values and effects of different outfall options. Prepared for Stantec New Zealand. Cawthron Report No. 3220. 26 p.

Morrisey D, D'Archino R 2019. Karori West ocean outfall: 2019 ecological survey. Prepared for Wellington Water Ltd. Cawthron Report No. 3311. 23 p. plus appendices.

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Oliver M 2016. NZ Estuary Trophic Index Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420. 68 p.

Stantec 2017. Porirua WWTP bypass discharge review. Stantec New Zealand final report. Prepared for Wellington Water. 10 p. plus appendix.

Zaiko A, Berthelsen A, Cornelisen C, Clark D, Bulmer R, Hewitt J, Stevens L, Stott R, McBride G, Hickey C, Banks J, Hudson N 2918. Managing upstream: estuaries state and values – methods and data review. Stage 1B report. Prepared for the Ministry for the Environment. NIWA Client Report No. 2017415HN. 74 p. plus appendices.

6. APPENDICES

Appendix 1. Methods used in the surveys of rocky and soft-sediment habitats.

Broad-scale surveys of nearshore and offshore rocky and sediment habitats

The broad-scale survey used sidescan sonar and drop-camera video images to describe the seabed along the coast between Round Point and the reference location east of Rukutane Point. The seabed along the inshore area from Round Point to 300 m east of Rukutane Point (i.e. the location of the reference station), and the route of the offshore outfall option, was surveyed using sidescan along a series of tracks (‘swaths’). The sidescan images provide a map of the types of seabed present, such as areas of bedrock, boulders, cobbles, coarse and fine sediments, distinguished by their different acoustic reflectances.

One swath followed the line of the coast as close to shore as water depth allowed (see Section 2.2.2 for details). Three other swaths ran parallel to the shore, with overlap between adjacent swaths. Both sides of the proposed offshore pipeline route were also surveyed, with the vessel travelling in opposite directions on each side.

Surveying was done using a Lowrance Structurescan HD® system with side-scanning sonar (455 kHz frequency). The vessel travelled at 5-6 knots and had a swath width of c. 40 m (20 m either side). GPS position tracks were logged simultaneously with bathymetric data and the side-scan sonar output on the onboard chart plotter. Starts and ends of tracks, and any features of interest, were marked as waypoints. This enabled the relocation of such areas for subsequent inspection and verification using the drop-camera (see below).

Sonar imagery was processed using the Reefmaster 2.0 software package to convert the sonar files to geo-referenced .kml files. Outlines of benthic features were traced in ArcMap to create a coarse habitat map where appropriate.

A drop video camera was deployed in the same areas as the sidescan to verify the features seen in the sidescan images and to obtain a record of organisms living on the surface of the seabed.

Fine-scale surveys of intertidal and shallow-subtidal rocky habitats

The fine-scale surveys documented habitats and dominant, habitat-forming organisms along transects perpendicular to the shore. Counts or estimates of percentage cover were also made in quadrats at points along these transects. Two transects were run across the shore and shallow-subtidal area at each of the two potential coastal outfall locations (Rukutane Point and Round Point) and the reference location. The intertidal transects started at the low-water mark and ran up the shore until the steep topography at the top of the shore made it impossible to continue. The subtidal transects started at the low-water mark and ran perpendicular to the shore for 50 m.

The intertidal observer recorded a general description of the type of substratum (bedrock, boulder, cobble, etc.) along the transect, noting distances from low water of any transitions from one type to another. They also recorded the percentage by area of each type of substratum, and of sessile organisms, in each of two quadrats (1 m × 1 m) at each of three points along the transect. The three points were selected to represent the range of shore heights traversed by the transect and the types of substratum present. Numbers of individuals of mobile species were also recorded.

The subtidal transects were surveyed by two observers using SCUBA. One observer ran a tape measure out to 50 m from shore and swam back along it, noting the distance from low water of transitions between types of substratum and the dominant organism present (principally seaweeds). The observer also videoed the transect. The second observer recorded percentage cover of each type of substratum and of sessile organisms, and numbers of individuals of mobile species, in each of two quadrats (1 m × 1 m) at each of five points along the transect. Quadrats were placed at 5, 15, 25, 35 and 45 m from the low-water mark.

Grab-sampling along the route of the offshore-outfall

The nature of the seabed, and of the animals living in and on it[10], along the route of the offshore outfall option were determined by collecting samples of sediment using a van Veen grab (maximum bite depth c. 20 cm, area 0.096 m^2). Samples were collected at three stations along the route and at two stations at distances of 100 m and 300 m either side of the diffuser and in the same depth of water (Figure 4, Table 2).

The sediments samples were analysed for a suite of physico-chemical variables that might be expected to change in response to the presence of an outfall and affect the fauna of the sediments. These included sediment texture and the concentrations of organic compounds and trace-metal contaminants that might derive from the discharge. Animals present in the sediments were identified and counted. Concentrations of chlorophyll-*a* were also measured to allow assessment of potential increased abundances of microalgae living on the sediment caused by increased concentrations of nutrients derived from the discharge.

Three replicate grab samples were collected at each of the seven stations. Each grab sample was sub-sampled as follows (laboratory analytical methods are given in the table below):

[10] Animals living in or on the sediment that are retained by a 0.5-mm mesh are collectively referred to as ‘macrofauna’. They are divided into the ‘infauna’ living within the sediment, and the ‘epifauna’ living on its surface.

- a sediment core sample (6.3 cm diameter) was taken using a clear, Perspex® corer and photographed to show the sediment structure, colour and depth of the redox-potential discontinuity (if present, as an indicator of organic enrichment[11])
- the surficial 3 cm of the core sample was then removed and placed in chilled containers, for analysis of the following variables (by Hill Laboratories Ltd, Hamilton):
    - grain size (seven size categories: gravel, very-coarse sand, coarse sand, medium sand, fine sand, very-fine sand, mud)
    - total organic carbon (TOC, a component of treated wastewater that can provide additional food for macrofauna or, by encouraging microbial activity, result in reduced concentrations of oxygen in the receiving environment)
    - total nitrogen (TN, a component of treated wastewater and the nutrient that most commonly limits primary productivity in marine environments)
    - total reactive phosphorus (TRP, a component of treated wastewater and required for primary productivity, though not usually limiting in marine environments)
    - total recoverable trace metals / metalloids (arsenic, cadmium, chromium, copper, lead, nickel and zinc: potentially present in treated wastewater and stormwater but also naturally present in the coastal environment)
    - concentration of chlorophyll-*a* (the primary photosynthetic pigment for green plants, commonly used as a surrogate for microalgal biomass)
- a subsample of the surficial 3 cm of the core sample was kept chilled and analysed for total free sulphides on the day after collection (concentrations of sulphides reflect levels of organic enrichment: samples analysed by the Cawthron Institute)
- a 10-cm deep core (surface area[12] 106 cm^2) was taken and sieved through a 0.5-mm mesh to collect macrofauna. Each sample was preserved in 95% ethanol with 5% glyoxal and returned to Cawthron's taxonomy laboratory for identification and enumeration of macrofauna to the lowest practicable level of identification (species level where possible).

Macrofaunal and physico-chemical data were analysed using the multivariate statistical package PRIMER v7 (Clarke & Gorley 2001). Principal component analysis (PCA) was used to compare samples and stations based on their sediment physico-chemical characteristics. The PCA combines the data to create plot axes that best

[11] Organic enrichment encourages microbial activity in the sediment, depleting oxygen and resulting in the production of black iron sulphides below the redox discontinuity, apparent as a change in sediment colour. The depth of the discontinuity beneath the sediment surface is inversely related to the degree of enrichment.

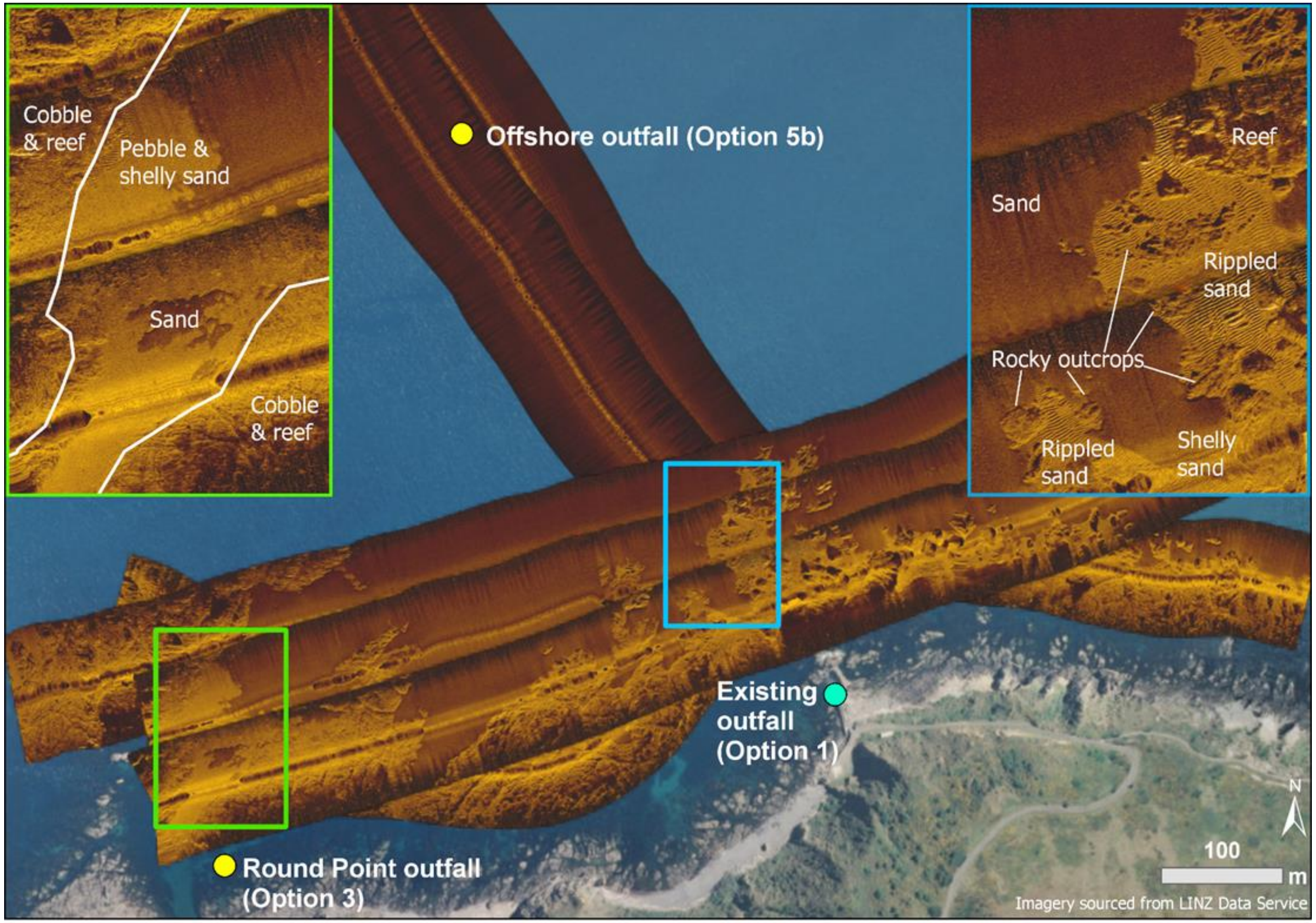
[12] The core tube consisted of a section of 13-cm diameter pipe squashed laterally to allow it to be inserted through the doors on the top of the grab. The resulting tube has an elliptical cross-section, the area of which is 80% of that of the equivalent circular cross-section (133 cm^2).

represent the differences among samples. The untransformed infaunal count data for each replicate sample were analysed first and then reanalysed following $\log_{(x+1)}$ transformation to de-emphasise the influence of the dominant species (by abundance). Untransformed and transformed data were analysed using non-metric multidimensional scaling ordination (nMDS) and cluster analyses, both based on Bray-Curtis similarities among the infauna of the samples (Clarke & Warwick 1994). The nMDS attempts to place samples in a 2-dimensional plot according to the similarities and differences in their fauna. The closer two samples are in the plot, the more similar are their fauna. A 'stress statistic' provides a measure of how well the plot represents the differences between all the individual samples. The taxa contributing to the similarities among samples from the same station and dissimilarities among samples from different stations were identified using analysis of similarities (SIMPER; Clarke & Warwick 1994).

Laboratory methods used in analyses of sediment physic-chemical properties.

Analyte	Method Number	Description
Particle grain size	Hill Lab in-house method	Wet sieved through screen sizes: > 2 mm = Gravel < 2 mm to > 1 mm = Very-coarse sand < 1 mm to > 500 µm = Coarse sand < 500 µm to > 250 µm = Medium sand < 250 µm to > 125 µm = Fine sand < 125 µm to > 63 µm = Very-fine sand < 63 µm = Mud (silt and clay)
Total organic carbon and total nitrogen		Acid pre-treatment to remove carbonates present followed by catalytic combustion (900°C, O_2), separation, Thermal Conductivity Detector [Elementar Analyser].
Total recoverable phosphorus	EPA 200.2.	Dried sample sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level.
Total recoverable metals (trace analysis)	USEPA 200.2	Dried sample sieved as specified (if required). Nitric/Hydrochloric acid digestion. Detected by ICP-MS, trace level.
Chlorophyll-*a*	NIWA, Hamilton in-house method	Extraction with 95% Ethanol, Spectroscopy. Subcontracted to NIWA, Hamilton.
Total free sulphides	Cawthron protocol 60.102	Sediments solubilised in a high-pH solution containing a chelating agent and an anti-oxidant. Sulphide concentration measured with a sulphide specific electrode. The electrode output was measured by a millivolt meter and calibrated using sulphide standards. The sulphide standard was checked for purity using a United States Pharmacopoeia method.

Appendix 2. Sidescan images from the survey area.



Appendix 3. Percent cover and numbers of individuals of macroalgae and invertebrates in quadrats from intertidal and subtidal quadrats. Distances from the low-water mark are shown in the first column and water depth (at the time of sampling, not corrected for tidal height) in the second column. 'ECA' and 'TCA' – encrusting coralline algae and turfing coralline algae, respectively. Cover was determined for the substratum (encrusting and turfing taxa), the under-canopy (greens, browns and reds) and the over-canopy (the large browns *Carpophyllum* spp. and *E. radiata*), so total cover can sum to > 100%.

Round Point T1 Distance (m)	**Depth (m)**	**Substratum**	**Algae**	**Invertebrates**	**Algal cover % ECA**	**% TCA**	**% brown**	**% red**	**% green**
10	Inter	Bedrock 100%		*Chamaesipho* sp. <1%	0	0	0		0
6	Inter	Bedrock 100%	ECA <1%, *Porphyra* 3%, TCA <1%, encrusting brown alga <1%	*Chamaesipho* 70%, *Austrolittorina antipodum* 240, *Cellana ornata* 1	<1	<1	<1		0
2	Inter	Bedrock 100%	ECA 15%, *Ulva sp.* 25%, filamentous red 10%, encrusting brown alga 5%, *Caulacanthus ustulatus* 5%, *Lophothamnion hirtum* 5%, *Hormosira banksii* 5%, *Lophurella caespitosa* 3%, *Scytothamnus* sp. 2%, *Splachnidium rugosum* <1%, *Petalonia binghamiae* <1%	*Chamaesipho* sp. 20%, *Diloma* sp. 4, *Cellana radians* 1, *Sypharochiton pelliserpentis* 1	15	0	14	25	25
5	0.3	Bedrock 100%	Red filamentous alga 70%, *Ulva* sp. 25%, *Carpophyllum maschalocarpum* 20%, *Undaria pinnatifida* 10%, turfing coralline 1%, *Cystophora scalaris* 1%		0	1	31	70	25
15	2.1	Bedrock 100%	ECA 80%, turfing coralline 10%, *Carpophyllum flexuosum* 50%, *Ecklonia radiata* 20%, *Ulva* sp. 2%, Zonaria sp. 1%, *Dictyota kunthii* 1%, *Polysiphonia aterrima* 1%	*Haliotis iris* 1, triplefin 2	80	10	72	1	2
25	3.3	Cobble 100%	ECA 40%, turfing coralline 7%, encrusting brown alga 5%, *Ulva* sp. 5%, *Halopteris* sp. 2%, *Aeodes* sp. 1%, *Carpophyllum flexuosum* 1%, red filamentous alga <1%	*Patiriella regularis* 1, triplefin 4	40	7	8	2	5
35	3.6	Cobble 60%, boulder 40%	ECA 60%, turfing coralline 10%, *Carpophyllum flexuosum* 80%, *Ecklonia radiata* 20%, *Ulva* sp. 1%, *Zonaria* sp. 1%, *Euptilota formosissima* 1%	*Lunella smaragdus* 3	60	10	100	1	1
45	4.2	Boulder 90%, cobble 10%	ECA 90%, *Carpophyllum flexuosum* 80%, *Ecklonia radiata* 20%, *Zonaria* sp. 1%	*Trochus* sp. 1, *Ophiopsammus maculata* 1, triplefin 2, encrusting yellow sponge <1%, encrusting orange sponge 1%, *Aplidium benhami* 1%	90	0	100	0	0

Round Point T2					Algal cover				
Distance (m)	**Depth (m)**	**Substratum**	**Algae**	**Invertebrates**	**% ECA**	**% TCA**	**% brown**	**% red**	**% green**
18	Inter	Bedrock 100%		*Austrolittorina antipodum* c.400	0	0	0	0	0
7	Inter	Bedrock 100%	ECA 1%, encrusting brown <1%, *Caulacanthus ustulatus* <1%, *Porphyra* sp. 5%	*Chamaesipho* sp. 80, *Austrolittorina antipodum* 480	1	0	<1	6	0
1	Inter	Bedrock 100%	ECA 5%, TCA 5%, encrusting brown 1%, *Cystophora scalaris* 15%, *Codium* sp. 10%, *Hormosira banksii* 5%, *Ulva* sp. 5%, *Caulacanthus ustulatus* 2%, *Champia novae-zelandiae* 1%, *Splachnidium rugosum* <1%, *Lophurella caespitosa* <1%	*Chamaesipho* sp. 1%, *Pomatoceros* sp. <1%, *Oulactis muscosa* 4, *Lunella smaragdus* 1, *Cellana radians* 1, *Haustrum haustorium* 1	5	5	22	4	15
5	1.4	Bedrock 95%, cobble 5%	ECA 90%, turfing coralline 10%, *Ulva* sp. <1%, *Carpophyllum maschalocarpum* 60%, *Ecklonia radiata* 30%	*Ophiopsammus maculata* 1, triplefin 1, *Oulactis muscosa* 3	90	10	90	0	1
15	1.7	Bedrock 100%	ECA 90%, turfing coralline 5%, *Carpophyllum flexuosum* 90%, *Ecklonia radiata* 10%, *Zonaria* sp. 1%, *Cladhymenia oblongifolia* 1%	*Patiriella regularis* 1, *Oulactis muscosa* 5	90	5	100	1	0
25	2	Bedrock 100%	ECA 90%, *Carpophyllum flexuosum* 100%, *Zonaria* sp. 5%, *Polysiphonia aterrima* <1%	*Patiriella regularis* 4, triplefin 3, *Oulactis muscosa* 3	90	0	100	1	0
35	2	Bedrock 100%	ECA 80%, turfing coralline 10%, *Carpophyllum flexuosum* 50%, *Ecklonia radiata* 30%, *Polysiphonia aterrima* <1%	*Evechinus chloroticus* 2, triplefin 2	80	10	80	1	0
45	2.2	Bedrock 100%	ECA 80%, turfing coralline 10%, *Carpophyllum maschalocarpum* 80%, *Ecklonia radiata* 10%, *Zonaria* sp. 3%	*Evechinus chloroticus* 1, *Patiriella regularis* 3, *Oulactis muscosa* 2	80	10	93	0	0

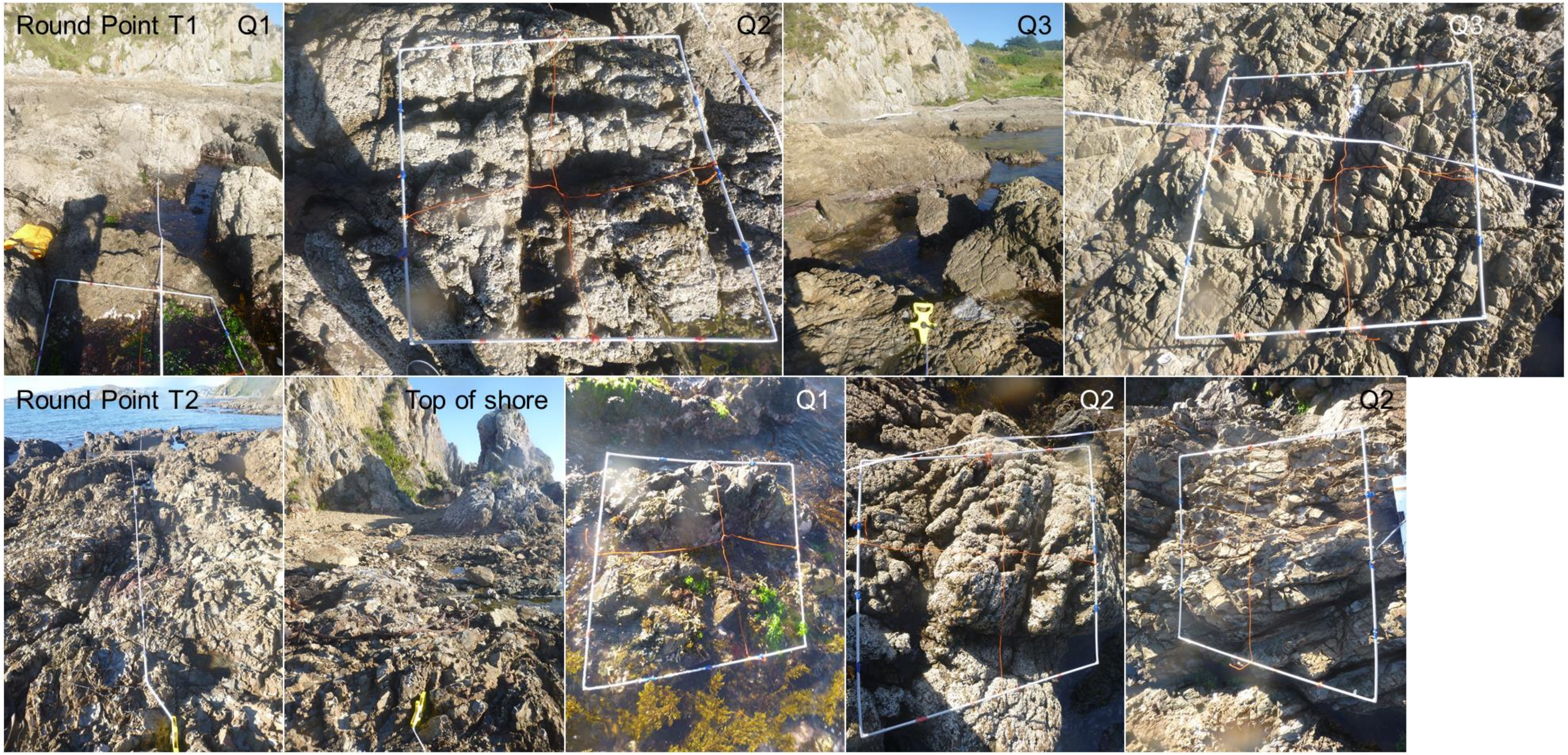
Outfall T1 Distance (m)	Depth (m)	Substratum	Algae	Invertebrates	Algal cover % ECA	% TCA	% brown	% red	% green
10	Inter	Bedrock 100%		*Chamaesipho* sp.20%, *Austrolittorina antipodum* c.300	0	0	0	0	0
8	Inter	Bedrock 100%	ECA 10%, *Lophurella caespitosa* 5%, *Porphyra* sp. <1%	*Chamaesipho* sp.80%, *Limnoperna pulex* 1%, *Austrolittorina antipodum* 360, *Siphonaria* sp. 1%, *Sypharochiton pelliserpentis* 2	10	0	0	6	0
1	Inter	Bedrock 100%	ECA 25%, TCA 1%, encrusting brown 5%, *Lophurella caespitosa* 5%, Zonaria 1%, *Codium* sp. 1%, *Petalonia binghamiae* 1%, *Carpophyllum maschalocarpum* <1%	*Chamaesipho* sp.20%, *Cellana radians* 5, *Siphonaria* sp. 10, *Haustrum scobina* 2	25	1	8	5	1
5	2.5	Bedrock 100%	ECA 50%, *Carpophyllum maschalocarpum* 30%, *Ecklonia radiata* 70%, *Zonaria* sp. 10%	*Haliotis iris* 14, *Coscinasterias muricata* 1, encrusting orange sponge 1%	50	0	100	0	0
15	0.5	Bedrock 100%	ECA 80%, turfing coralline 5%, *Carpophyllum maschalocarpum* 80%, *Ecklonia radiata* 20%, *Zonaria* sp. 1%, *Pterocladia* sp. 5%		80	5	100	5	0
25	1.3	Bedrock 100%	ECA 80%, turfing coralline 1%, *Carpophyllum maschalocarpum* 80%, *Ecklonia radiata* 10%, *Zonaria* sp. 5%, filamentous red alga 1%	Encrusting orange sponge 1%	80	1	95	1	0
35	2.1	Bedrock 100%	*Carpophyllum maschalocarpum* 70%, *Ecklonia radiata* 30%, *Zonaria* sp. 1%, filamentous red alga 1%	Encrusting blue/grey sponge 5%, *Haliotis iris* 1, *Anchorina alata* 20%	0	0	100	1	0
45	5.2	Bedrock 100%	*Carpophyllum flexuosum* 20%, *Ecklonia radiata* 80%	*Patiriella regularis* 5, encrusting orange sponge 10%, *Tethya* sp. 3, encrusting orange bryozoan 1%	0	0	100	0	0

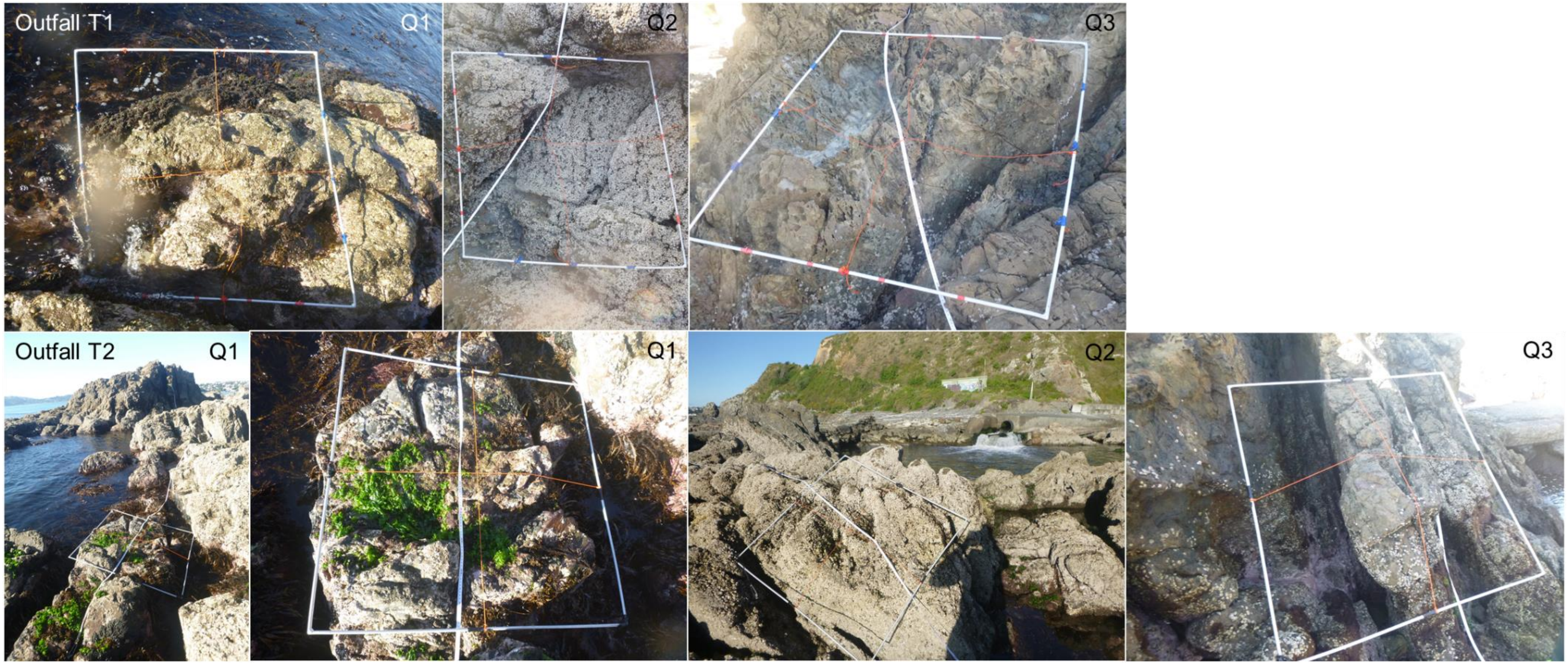
Outfall T2 Distance (m)	Depth (m)	Substratum	Algae	Invertebrates	Algal cover % ECA	% TCA	% brown	% red	% green
17	Inter	Bedrock 100%	ECA 5%, *Gelidium* sp. 15%	*Limnoperna pulex* <1%, *Chamaesipho* sp.21%, *Austrolittorina antipodum* 75, *Cellana ornata* 14, *Cellana radians* 6, *Sypharochiton pelliserpentis* 3, *Haustrum haustorium* 1	5	0	0	15	0
8	Inter	Bedrock 100%	ECA 2%, TCA <1%, *Ulva* sp. 1%, *Gelidium* sp. 10%	*Limnoperna pulex* 2%, *Chamaesipho* sp.87%, unid. barnacle <1%, *Oulactis muscosa* <1%, *Anthopleura* sp. <1%, serpulid <1%, *Cellana ornata* 20, *Cellana radians* 1, *Siphonaria* sp. 2, *Sypharochiton pelliserpentis* 9, *Haustrum scobina* 3, *Leptograpsus variegatus* 1	2	<1	0	10	1
1	Inter	Bedrock 100%	ECA 40%, *Carpophyllum maschalocarpum* 25%, *Ulva* sp. 25%, Codium sp. 7%, *Gelidium* sp. 1%, *Colpomenia* sp. <1	*Chamaesipho* sp.2%, *Galeolaria* sp. <1%, *Actinia tenebrosa* 1, *Cellana ornata* 6, *Siphonaria* sp. 12, *Sypharochiton pelliserpentis* 1, *Haustrum haustorium* 1	40	0	26	1	32
5	3.1	Bedrock 100%	ECA 80%, *Carpophyllum maschalocarpum* 90%, *Ecklonia radiata* 10%, *Zonaria* sp. 20%, *Cladophora* sp. 1%		80	0	100	0	1
15	1.7	Bedrock 100%	ECA 90%, *Carpophyllum maschalocarpum* 60%, *Ecklonia radiata* 20%, *Zonaria* sp. 2%		90	0	82	0	0
25	1.1	Bedrock 100%	ECA90%, *Halopteris* sp. 5%	*Haliotis iris* 1	90	0	5	0	0
35	2.4	Bedrock 100%	ECA 90%, *Carpophyllum maschalocarpum* 100%, *Ecklonia radiata* 5%, *Halopteris* sp. 3%	*Trochus* sp. 1	90	0	100	0	0
45	1.9	Bedrock 100%	ECA 90%, *Carpophyllum maschalocarpum* 2%, *Ecklonia radiata* 50%, *Zonaria* sp. 5%, *Carpomitra costata* 11%	Encrusting orange sponge 1%, *Haliotis australis* 2, *Australostichopus mollis* 2	90	0	68	0	0

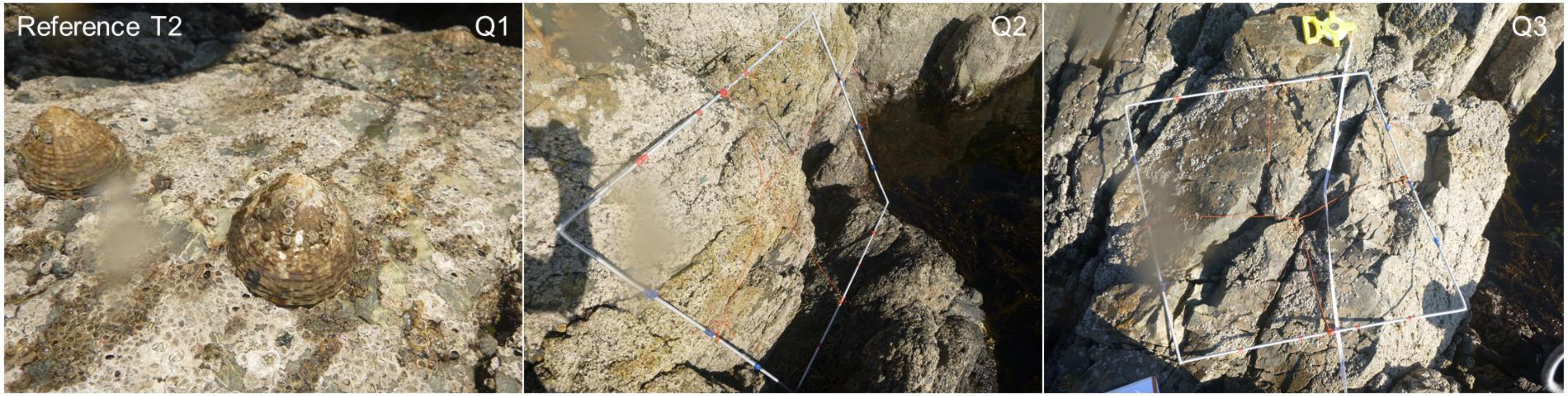
Reference T1 Distance (m)	Depth (m)	Substratum	Algae	Invertebrates	Algal cover % ECA	% TCA	% brown	% red	% green
16	Inter	Bedrock 100%	*Porphyra* sp. <1%	*Limnoperna pulex* <1%, *Chamaesipho* sp.40%, *Austrolittorina antipodum* 20, *Cellana radians* 1, *Austrolittorina cincta* 5	0	0	0	<1	0
7	Inter	Bedrock 100%	*Caulacanthus ustulatus* <1%, *Ulva* sp. <1%, *Hormosira banksii* 5%	*Chamaesipho* sp.75%, *Lunella smaragdus* 1, *Diloma* sp. 1, *Cellana ornata* 4, *Cellana denticulata* 4	0	0	5	<1	<1
1	Inter	Bedrock 100%	Filamentous brown <1%, *Ulva* sp. <1%, *Hormosira banksii* 35%, *Cystophora scalaris* 3%, *Cystophora torulosa* 40%, Codium 1%, TCA <1%, encrusting red <1%, *Caulerpa germinata* 1%, *Splachnidium* sp. <1%	*Patiriella regularis* 1	0	<1	79	<1	3
5	1.7	Cobble 10%, boulder 90%	ECA 60%, *Carpophyllum flexuosum* 90%, *Ecklonia radiata* 10%	*Patiriella regularis* 2	60	0	100	0	0
15	2.1	Bedrock 100%	ECA 80%, *Carpophyllum flexuosum* 90%, *Zonaria* sp. 10%	*Lunella smaragdus* 1, *Tethya* sp. 1	80	0	100	0	0
25	3.8	Cobble 10%, bedrock 80%	ECA 50%, *Carpophyllum flexuosum* 10%, *Carpophyllum maschalocarpum* 20%, *Ecklonia radiata* 10%, *Zonaria* sp. 30%	Triplefin 1, orange encrusting sponge 1	50	0	70	0	0
35	3.8	Cobble 50%, bedrock 50%	ECA 60%, turfing coralline 2%, encrusting brown alga 5%, *Ulva* sp. 1%, *Carpophyllum flexuosum* 5%, *Ecklonia radiata* 5%, filamentous red alga 10%, *Zonaria* sp. 10%, *Halopteris* sp. 1%, *Pterocladia* sp. 2%	*Patiriella regularis* 3, triplefin	60	2	21	12	1
45	4.8	Sand 98%, boulder 2%	ECA 1%, *Ulva* sp. 40%, *Ecklonia radiata* 20%, *Zonaria* sp. 1%	Encrusting blue/grey sponge 70%	1	0	21		40

Reference T2 Distance (m)	Depth (m)	Substratum	Algae	Invertebrates	Algal cover % ECA	% TCA	% brown	% red	% green
7	Inter	Bedrock 100%	*Porphyra* sp. <1%	*Chamaesipho* sp.15%, *Austrolittorina antipodum* 320	0	0	0	1	0
5	Inter	Bedrock 100%	*Hormosira banksii* 10%, TCA <1%, *Caulacanthus ustulatus* 5%	*Chamaesipho* sp.85%, *Pomatoceros* sp. <1%, *Diloma* sp. 3	0	<1	10	5	0
1	Inter	Bedrock 100%	ECA 5%, TCA <1%, encrusting brown alga 5%, *Carpophyllum maschalocarpum* 10%	*Chamaesipho* sp.40%, *Haustrum scobina* 1, *Diloma* sp., 2, *Cellana denticulata* 6, *Cellana radians* 4, *Sypharochiton pelliserpentis* 1	5	<1	15	0	0
5	1.1	Bedrock 90%, boulder 10%	ECA 80%, *Carpophyllum maschalocarpum* 100%, *Zonaria* sp. 1%	*Haliotis iris* 2	80	0	100	0	0
15	1.7	Bedrock 100%	ECA 80%, turfing coralline 5%, *Carpophyllum maschalocarpum* 100%	Triplefin 1, *Tethya* sp. 2	80	5	100	0	0
25	2.5	Bedrock 80%, boulder 20%	ECA 70%, turfing coralline 5%, *Carpophyllum maschalocarpum* 50%, *Ecklonia radiata* 50%, *Zonaria* sp. 2%	*Lunella smaragdus* 1, *Haliotis iris* 2, *Patiriella regularis* 3, triplefin 2	70	5	100	0	0
35	3.8	Bedrock 100%	*Carpophyllum flexuosum* 50%, *Carpophyllum maschalocarpum* 50%, *Ecklonia radiata* 20%, *Zonaria* sp. 3%	Encrusting blue/grey sponge 1%, triplefin 2, encrusting orange sponge 5%, *Tethya* sp. 4	0	0	100	0	0
45	4.7	Bedrock 100%	ECA 90%, *Carpophyllum flexuosum* 40%, *Ecklonia radiata* 60%	Encrusting blue/grey sponge 5%, encrusting orange sponge 1%, *Patiriella regularis* 4	90	0	100	0	0

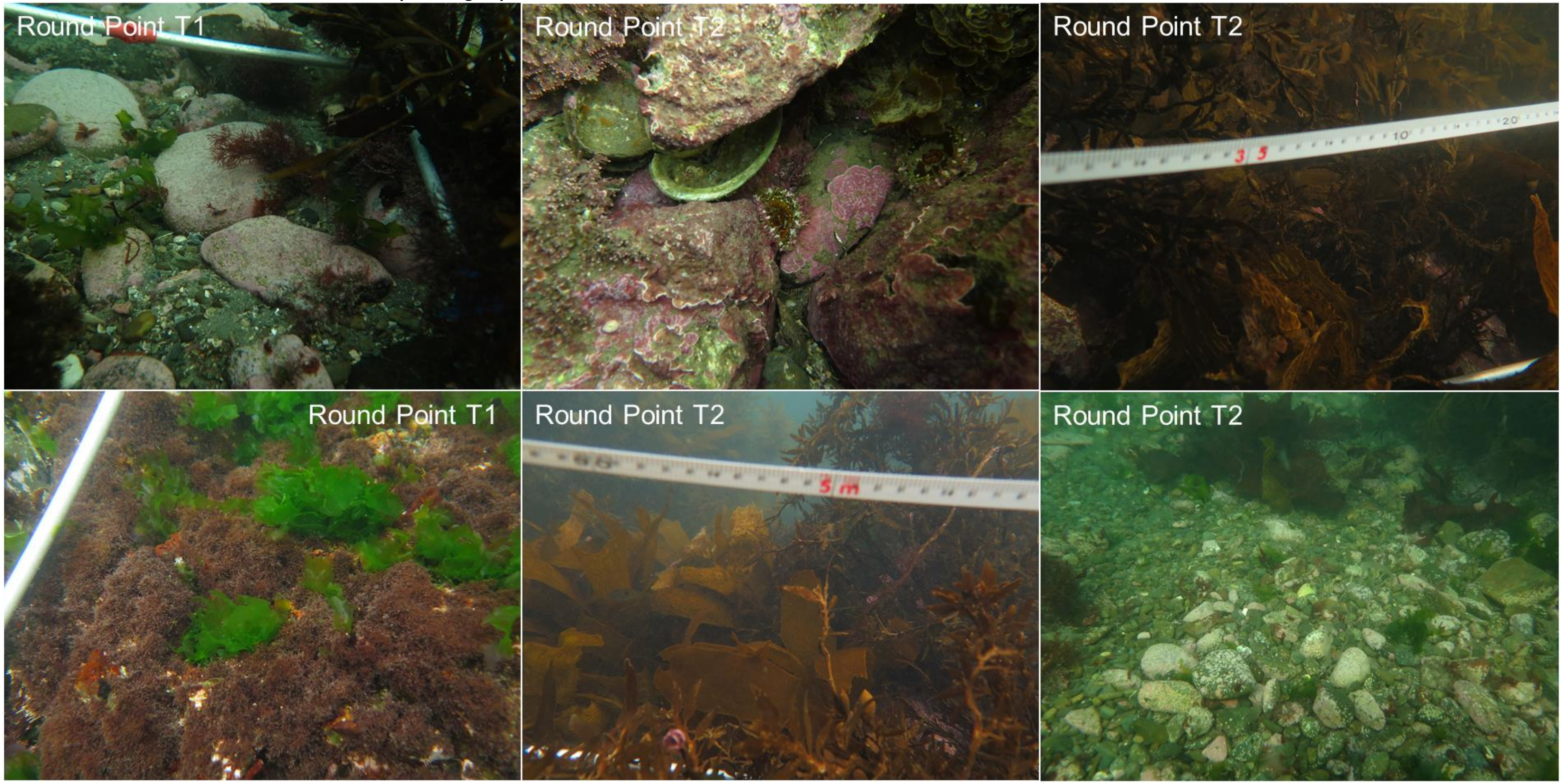
Appendix 4. Images from the intertidal transects and quadrats from Round Point (option 3), the existing outfall location at Rukutane Point (option 1) and the reference location. No photographs were taken of the first transect at the reference location.

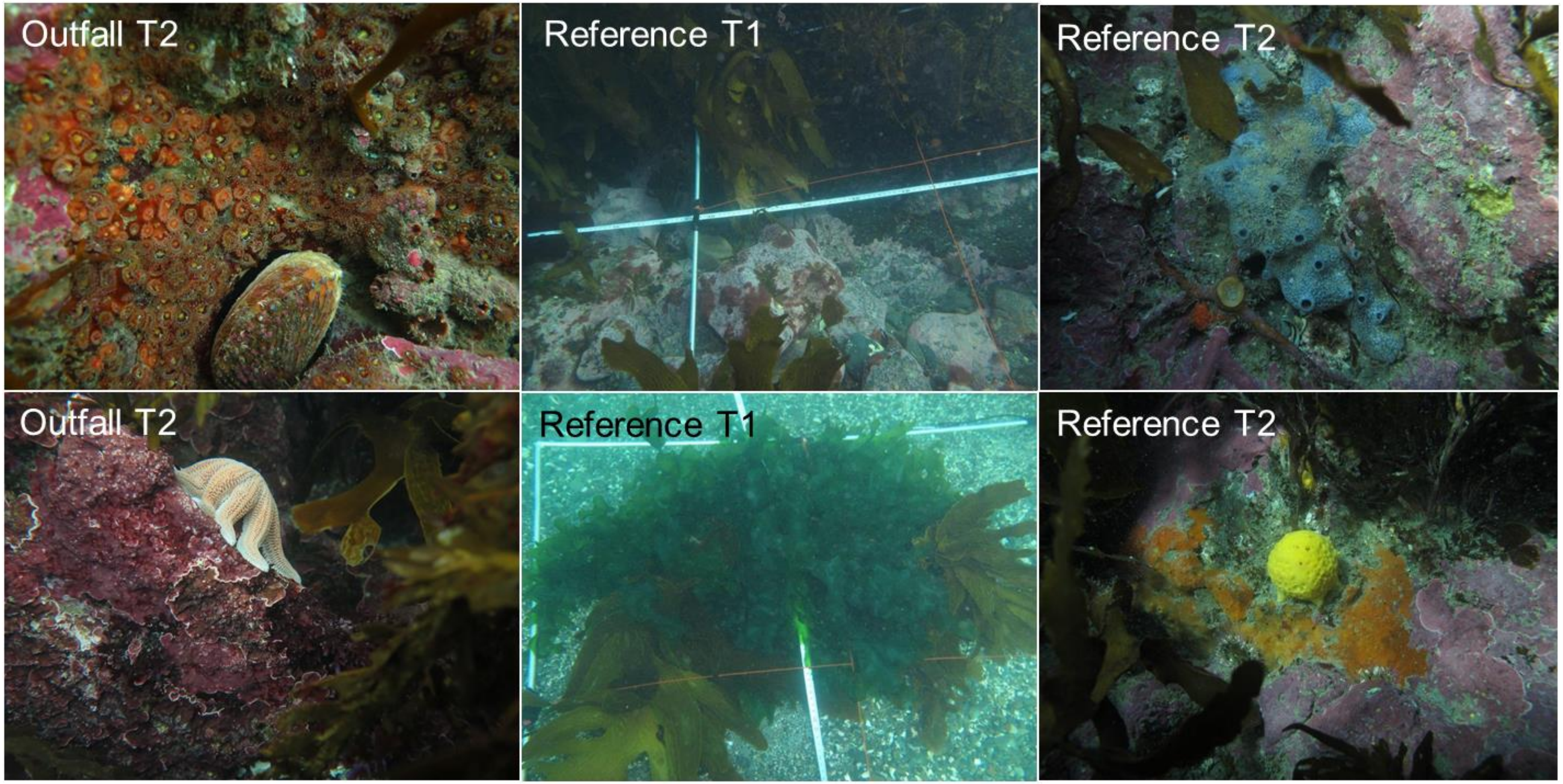



Outfall T1
Q1
Q2
Q3
Outfall T2
Q1
Q1
Q2
Q3


Reference T2
Q1
Q2
Q3

Appendix 5. Images from the subtidal transects and quadrats from Round Point (option 3), the existing outfall location at Rukutane Point (option 1) and the reference location. No photographs were taken of the first transect at the outfall location.




Outfall T2
Reference T1
Reference T2
Outfall T2
Reference T1
Reference T2

Appendix 6. Values of physic-chemical variables for individual samples. 'TRP' – Total Recoverable Phosphorus, 'TN' – Total Nitrogen, 'TOC' – Total Organic Carbon.

	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 B	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
TRP (mg/kg dw)	390	380	370	410	390	360	400	390	390	370	400	390	390	400	410	380	380	390	410	430	420
TN (%)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
TOC (%)	0.11	0.13	0.12	0.1	0.12	0.13	0.13	0.16	0.14	0.13	0.13	0.12	0.14	0.13	0.13	0.15	0.14	0.15	0.14	0.14	0.14
Arsenic (mg/kg dw)	8.0	8.3	7.6	9.2	9.2	9.2	9.7	9.6	9.4	9.2	8.9	9.3	10.3	10.2	10.2	9.5	9.2	9.6	9.3	9.9	9.4
Cadmium (mg/kg dw)	<0.010	0.011	<0.010	<0.010	0.01	0.011	<0.010	0.011	<0.010	0.011	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	0.011	0.011	<0.010	0.014	0.014
Chromium (mg/kg dw)	10.5	10.8	11.9	11.1	11.3	10.9	11.5	10.8	11	10.9	10.4	10.5	10.7	11	11	10.6	10.8	10.4	10.2	10.7	11
Copper (mg/kg dw)	3.0	3.0	2.8	3.0	2.9	3.0	3.2	3.1	3.0	2.8	2.8	2.9	3.0	3.1	3.0	3.1	2.9	2.8	3.0	3.1	3.2
Lead (mg/kg dw)	4.7	4.8	12.1	4.9	4.8	4.9	5.3	5.3	5.2	5.2	5.0	5.0	5.1	5.1	5.2	5.4	5.5	5.5	5.1	5.3	5.3
Nickel (mg/kg dw)	7.2	7.7	7.3	7.4	7.3	7.6	7.5	7.4	7.2	7.2	7.2	7.4	7.7	7.4	7.6	7.3	7.3	7.1	7.3	7.2	7.4
Zinc (mg/kg dw)	30	32	31	31	31	31	31	31	30	30	29	29	30	30	31	31	30	29	30	31	31
Grain size (% dw):																					
Gravel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.2	0.1	0.1	0.1	0.3	0.1	<0.1	2.2	13.2	16
Very-coarse sand	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.4	5.1	5.9
Coarse sand	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	0.2	0.2	0.2	0.2	0.1	0.1	1.2	2.8	2.5
Medium sand	0.7	0.5	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.4	0.6	0.4	0.8	0.9	0.8	1.0	0.6	0.7	4.4	4.9	4.5

	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 B	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
Fine sand	28.2	30.9	31.3	37.3	32.4	38.4	34.5	33.6	37.6	34.7	35.7	39.6	37.8	37.2	41.0	44.8	36.8	43.3	45.5	37.2	30.6
Very-fine sand	66.8	64.9	65.3	58.9	62.5	56.6	59.2	58.7	54.4	58.2	56.7	54.8	56.4	55.9	52.2	45.3	53.5	46.9	38.5	33.3	35.3
Mud	4.3	3.6	3.0	3.4	4.7	4.5	5.6	7.1	7.1	6.6	6.8	4.9	4.5	5.6	5.6	8.3	8.8	8.9	6.8	3.5	5.2
Chl-*a* (mg/kg ww)	5.2	5.2	4.8	6.1	5.9	5.9	6.2	6.2	6.3	5.8	5.0	5.1	6.2	5.7	6.7	4.4	4.0	4.4	6.4	6.3	6.0
Sulphides (µM)	<71	<71	<71	<71	<71	<71	<71	<71	<71	<71	153	<71	<71	<71	<71	<71	131	<71	<71	<71	<71

Appendix 7. Abundances of infauna from grab samples. Values of Pielou's evenness and Shannon-Wiener diversity indices are also shown.

Group	Taxa	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 C	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
Anthozoa	Anthozoa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthozoa	Ceriantharia	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nemertea	Nemertea	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Nematoda	Nematoda	0	0	1	0	0	0	1	0	0	1	0	0	0	2	0	0	0	0	1	2	0
Gastropoda	Gastropoda (micro snails)	0	1	0	0	0	0	0	0	0	1	0	4	0	1	0	0	0	0	0	0	0
Gastropoda	Gastropoda Unid.	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	Naticidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Gastropoda	*Amalda* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gastropoda	*Antisolarium egenum*	0	0	0	0	0	0	0	9	4	8	2	7	3	0	2	1	1	0	4	0	0
Gastropoda	*Cantharidus* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Gastropoda	*Euterebra tristis*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	*Sigapatella* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Bivalvia	Bivalvia indent.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	Bivalvia Unid.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Bivalvia	Bivalvia Unid. (juv)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	Nuculidae	0	0	0	0	0	1	0	0	0	0	5	15	12	6	1	0	0	0	0	0	0
Bivalvia	Tellinidae (juvenile)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Bivalvia	Thraciidae	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0
Bivalvia	Veneridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Bivalvia	*Corbula zelandica*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Bivalvia	*Divalucina cumingi*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Bivalvia	*Dosinia* sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	*Dosinia* sp. (Juvenile)	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bivalvia	*Gari* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Bivalvia	*Neolepton* sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Bivalvia	*Nucula nitidula*	1	6	3	1	1	1	4	7	20	8	0	0	0	0	0	1	8	4	6	4	1
Bivalvia	*Pratulum pulchellum*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Group	Taxa	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 C	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
Bivalvia	*Scalpomactra scalpellum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bivalvia	*Solemya parkinsoni*	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0
Bivalvia	*Soletellina* sp. (Juvenile)	0	1	3	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Bivalvia	*Tawera spissa*	0	0	0	0	1	0	2	2	3	0	2	2	2	2	3	1	1	1	9	13	1
Bivalvia	*Trichomusculus barbatus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Oligochaeta	Oligochaeta	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta: Pectinariidae	*Lagis* sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0
Polychaeta: Paraonidae	Paraonidae	1	0	0	0	1	1	3	0	0	0	3	0	0	0	2	0	2	2	0	6	3
Polychaeta: Paraonidae	Aricidea sp.	0	0	0	1	3	3	2	0	2	0	1	1	1	1	0	0	6	2	1	2	1
Polychaeta: Spionidae	*Paraprionospio* sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta: Spionidae	*Prionospio australiensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Polychaeta: Spionidae	*Prionospio* sp.	4	0	3	0	0	0	1	0	0	0	0	0	3	0	0	1	1	0	3	1	0
Polychaeta: Spionidae	*Prionospio tridentata*	0	1	0	4	5	5	7	1	5	2	5	5	0	1	0	5	3	4	1	2	1
Polychaeta: Spionidae	*Spio* sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta: Spionidae	*Spiophanes modestus*	0	1	3	1	3	4	1	1	2	0	2	2	0	0	0	1	0	1	3	3	1
Polychaeta: Magelonidae	Magelonidae	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	0	0	0
Polychaeta: Capitellidae	*Barantolla lepte*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta: Capitellidae	*Notomastus* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polychaeta: Maldanidae	Maldanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0
Polychaeta: Opheliidae	*Armandia maculata*	0	0	0	0	0	1	0	1	0	0	0	1	0	1	4	1	1	0	1	1	0

Group	Taxa	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 C	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
Polychaeta: Sigalionidae	Sigalionidae	1	1	2	0	1	0	0	1	0	0	1	0	2	0	0	0	0	0	0	1	0
Polychaeta: Syllidae	Exogoninae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polychaeta: Syllidae	Syllidae	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polychaeta: Goniadidae	Goniadidae	0	0	0	0	1	0	0	0	1	0	2	0	1	0	1	2	0	0	1	1	1
Polychaeta: Nephtyidae	*Aglaophamus* sp.	4	1	0	2	2	0	2	3	1	2	1	0	2	2	0	0	0	1	1	2	4
Polychaeta: Dorvilleidae	Dorvilleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Polychaeta: Dorvilleidae	*Ophryotrocha* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Polychaeta: Oweniidae	Myriochele sp.	25	27	38	40	65	45	59	88	69	57	43	37	108	80	32	49	69	98	39	21	10
Polychaeta: Oweniidae	*Owenia petersenae*	0	0	0	1	2	4	10	3	5	1	4	1	1	1	4	2	3	0	6	10	4
Polychaeta: Cirratulidae	Cirratulidae	2	6	5	2	0	2	10	1	2	3	7	5	7	11	8	3	11	7	4	2	1
Polychaeta: Cirratulidae	*Chaetozone* sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaeta: Flabelligeridae	Flabelligeridae	1	0	0	1	1	0	1	0	0	0	0	1	1	0	0	1	0	0	1	1	1
Polychaeta: Terebellidae	Terebellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Polychaeta: Sabellidae	Euchone sp.	34	15	15	22	60	23	51	23	30	15	16	14	48	36	29	17	5	20	40	44	36
Polychaeta: Sabellidae	Sabellidae	0	0	0	0	0	0	0	0	0	0	0	0	7	0	11	1	1	1	416	20	4
Crustacea	Nebaliacea	0	0	1	2	0	0	1	0	0	0	0	0	2	2	0	0	0	4	0	0	0
Crustacea	Tanaidacea	2	2	4	6	2	4	7	4	0	2	0	0	5	1	2	0	2	4	8	1	0
Crustacea	Mysidacea	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Cumacea	Cumacea	15	6	9	18	17	15	14	22	31	16	17	15	25	19	27	13	31	21	15	5	18
Isopoda	Munnidae	0	1	0	0	2	2	2	3	3	1	0	1	0	1	0	2	3	0	3	0	1
Isopoda	Anthuridae	1	0	1	0	3	3	0	0	0	0	1	0	0	0	3	0	0	0	1	1	2
Isopoda	Natatolana sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Aoridae	2	0	5	1	1	0	2	1	3	1	0	0	26	0	0	2	0	4	0	3	3
Amphipoda	Caprellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Group	Taxa	SE350 A	SE350 B	SE350 C	SE200 A	SE200 B	SE200 C	DIFF A	DIFF B	DIFF C	NE100 A	NE100 B	NE100 C	SW100 A	SW100 B	SW100 C	NE300 A	NE300 B	NE300 C	SW300 A	SW300 B	SW300 C
Amphipoda	Haustoriidae	5	2	6	10	5	9	14	0	7	8	16	16	10	5	8	16	6	32	1	0	1
Amphipoda	Isaeidae	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Ischyroceridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Liljeborgiidae	0	0	0	1	0	0	5	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Amphipoda	Lysianassidae	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	Oedicerotidae	0	1	0	0	0	0	0	0	1	2	0	0	1	0	0	3	3	0	1	0	2
Amphipoda	Phoxocephalidae	1	3	0	2	6	2	0	10	14	17	15	16	12	14	10	15	16	16	3	2	2
Amphipoda	Urothoidae	0	0	0	8	8	5	4	11	5	2	5	14	6	2	6	6	8	6	6	2	2
Amphipoda	Liljeborgia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Decapoda	Diogenidae	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	5	0	1	0	0
Decapoda	Paguridae	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Decapoda	*Alpheus novaezealandiae*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda	*Ebalia laevis*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Decapoda	Anomura	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Decapoda	Decapoda ident.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	Diasterope grisea	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	1	0	0	0
Ostracoda	*Neonesidea* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Ostracoda	*Parasterope quadrata*	0	0	0	3	2	3	4	4	5	3	5	9	3	3	2	1	2	8	5	5	13
Ostracoda	Ostracoda	3	0	2	1	2	3	6	3	2	1	4	2	6	1	2	1	1	3	7	2	2
Bryozoa	Bryozoa (encrusting)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hemichordata	Hemichordata	6	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroidea	Ophiuroidea	2	0	4	2	0	3	3	1	2	1	0	1	2	0	3	0	0	1	2	0	1
Holothuroidea	*Taeniogyrus dendyi*	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
	No. Individuals	115	89	112	133	198	147	218	203	222	157	160	180	298	197	167	152	195	243	593	163	123
	No. Taxa	23	24	22	25	26	27	27	25	27	24	24	30	27	26	25	30	28	24	31	32	32
	Evenness	0.74	0.78	0.79	0.74	0.65	0.77	0.75	0.67	0.73	0.73	0.80	0.81	0.70	0.64	0.81	0.73	0.72	0.69	0.41	0.77	0.76
	Diversity	2.31	2.49	2.43	2.38	2.12	2.54	2.46	2.15	2.40	2.32	2.54	2.75	2.30	2.10	2.59	2.47	2.41	2.19	1.40	2.66	2.64

Appendix 8. Taxa contributing more than 10% to the average dissimilarity among stations. ‘Av.Abundance’ – average abundance at each of the two stations compared, ‘Av.Diss’ – average dissimilarity among samples from the two stations, ‘Contrib%’ – contribution of taxon to the average dissimilarity, ‘Cum.% - cumulative contributions. Values were derived from untransformed data using the SIMPER routine.

Comparison	Taxon	Av.Abund 1	Av.Abund 2	Av.Diss	Diss/SD	Contrib%	Cum.%
SE350 vs	*Myriochele* sp.	30.00	50.00	7.27	1.77	17.18	17.18
SE200	*Euchone sp.*	21.33	35.00	6.67	1.32	15.76	32.94
SE350 vs	*Myriochele* sp.	30.00	72.00	13.27	2.73	26.02	26.02
DIFF	*Euchone* sp.	21.33	34.67	5.22	1.42	10.24	36.25
SE200 vs	*Myriochele* sp.	50.00	72.00	6.51	1.45	20.17	20.17
DIFF	*Euchone* sp.	35.00	34.67	4.32	1.17	13.39	33.56
SE350 vs	*Myriochele* sp.	30.00	45.67	6.00	1.48	12.64	12.64
NE100	Phoxocephalidae	1.33	16.00	5.41	10.73	11.41	24.05
SE200 vs	*Euchone* sp.	35.00	15.00	5.76	1.16	16.63	16.63
NE100	Phoxocephalidae	3.33	16.00	3.98	4.07	11.48	28.11
DIFF vs	*Myriochele* sp.	72.00	45.67	6.95	1.67	19.08	19.08
NE100	*Euchone* sp.	34.67	15.00	5.14	1.57	14.11	33.18
SE350 vs	*Myriochele* sp.	30.00	73.33	12.73	1.56	24.72	24.72
SW100	*Euchone* sp.	21.33	37.67	5.23	1.87	10.15	34.87
SE200 vs	*Myriochele* sp.	50.00	73.33	8.96	1.91	23.82	23.82
SW100	*Euchone* sp.	35.00	37.67	4.55	2.08	12.09	35.91
DIFF vs SW100	*Myriochele* sp.	72.00	73.33	6.93	1.68	20.62	20.62
NE100 vs	*Myriochele* sp.	45.67	73.33	9.01	1.95	23.14	23.14
SW100	*Euchone* sp.	15.00	37.67	5.71	4.47	14.66	37.80
SE350 vs NE300	*Myriochele* sp.	30.00	72.00	13.34	2.33	25.23	25.23
SE200 vs	*Myriochele* sp.	50.00	72.00	6.94	1.37	18.93	18.93
NE300	*Euchone* sp.	35.00	14.00	5.65	1.12	15.42	34.35
DIFF vs	*Euchone* sp.	34.67	14.00	5.06	1.44	15.50	15.50
NE300	*Myriochele* sp.	72.00	72.00	4.80	1.40	14.69	30.18
NE100 vs NE300	*Myriochele* sp.	45.67	72.00	7.30	1.53	23.05	23.05

Comparison	Taxon	Av.Abund 1	Av.Abund 2	Av.Diss	Diss/SD	Contrib%	Cum.%
SW100 vs	*Myriochele* sp.	73.33	72.00	7.82	1.63	21.15	21.15
NE300	*Euchone* sp.	37.67	14.00	5.60	2.61	15.15	36.30
SE350 vs SW300	Sabellidae	0.00	146.67	22.94	0.83	37.83	37.83
SE200 vs	Sabellidae	0.00	146.67	21.02	0.81	38.30	38.30
SW300	*Myriochele* sp.	50.00	23.33	8.04	1.37	14.66	52.96
DIFF vs	Sabellidae	0.00	146.67	19.34	0.80	34.53	34.53
SW300	*Myriochele* sp.	72.00	23.33	12.05	1.68	21.52	56.05
NE100 vs	Sabellidae	0.00	146.67	20.77	0.81	33.42	33.42
SW300	*Myriochele* sp.	45.67	23.33	7.03	1.25	11.31	44.73
	Euchone sp.	15.00	40.00	6.47	2.61	10.40	55.13
SW100 vs	Sabellidae	6.00	146.67	18.60	0.77	32.74	32.74
SW300	*Myriochele* sp.	73.33	23.33	11.70	1.38	20.60	53.34
NE300 vs	Sabellidae	1.00	146.67	19.65	0.79	30.09	30.09
SW300	*Myriochele* sp.	72.00	23.33	12.25	1.62	18.75	48.84
	Euchone sp.	14.00	40.00	6.26	2.09	9.58	58.42