NAPIER PORT

PROPOSED WHARF AND DREDGING PROJECT

RESOURCE CONSENT APPLICATIONS: VOLUME 3

SPECIALIST REPORTS: APPENDIX H - L

PREPARED FOR PORT OF NAPIER LTD

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Allan Planning & Research Ltd

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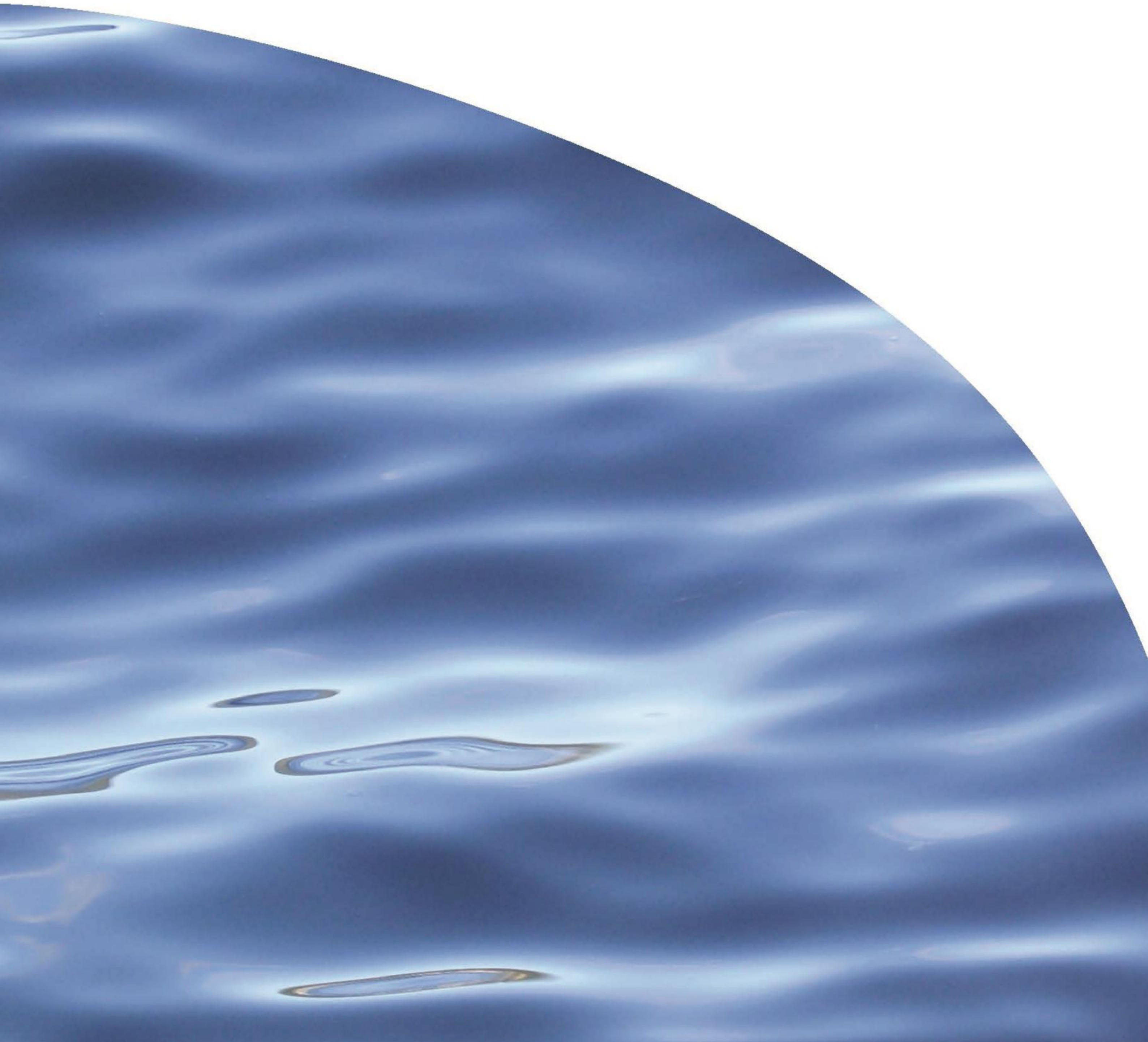
APPENDIX H

ASSESSMENT OF EFFECTS ON BENTHIC ECOLOGY AND FISHERIES RESOURCES FROM PROPOSAL DREDGING AND SPOIL DISPOSAL ENVIRONMENT

NAPIER PORT

REPORT NO. 2895

ASSESSMENT OF EFFECTS ON BENTHIC ECOLOGY AND FISHERIES RESOURCES FROM PROPOSED DREDGING AND DREDGE SPOIL DISPOSAL FOR NAPIER PORT



ASSESSMENT OF EFFECTS ON BENTHIC ECOLOGY AND FISHERIES RESOURCES FROM PROPOSED DREDGING AND DREDGE SPOIL DISPOSAL FOR NAPIER PORT

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EXECUTIVE SUMMARY

Port of Napier Limited (PONL) proposes to deepen and extend its existing approach channel to accept deeper draft vessels and establish a new (No.6) berth on the northern face of the main Port reclamation. The project will involve a schedule of staged dredging works, with approximately 3.2 million cubic metres of dredged material transferred to a proposed new spoil ground some 4 km offshore from Marine Parade Beach in approximately 20-23 m water depth. The dredging project will be completed by a combination of dredging methods; trailer suction hopper dredge (TSHD) for the central and outer Fairway, and back-hoe dredge (BHD) for the berth and Swing Basin. Cawthron Institute (Cawthron) were contracted to conduct an assessment of potential marine ecological effects from the proposed project.

The benthic environment and marine ecological resources of the area were characterised from a range of information sources. Extensive data for intertidal and benthic habitats within the vicinity of the Port were available from earlier surveys conducted by Cawthron and other specialists. This was augmented by further surveys conducted for the current investigation, with a focus on the ecology of Pania Reef. Continuous recording of surface water turbidity at two locations near Pania Reef was also initiated with the deployment of dedicated monitoring buoys with data telemetry. Fish and fisheries information for the wider inshore area was sourced from the Ministry for Primary Industry's *Warehau* data base as well as the scientific and fisheries literature.

Benthic habitats

The shallow-water benthic habitats in the vicinity of the Port primarily comprise fine soft sediments of high uniformity. This habitat extends across most of the 117 ha footprint of the berth development and dredging works although some low-relief mixed substrate is a current feature of the proposed Swing Basin area. Adjacent shoreline areas include the artificial hard substrates of the Port breakwaters and reclamation facing material as well as some natural fringing reef and cobble fields modified to varying extents by the presence of the Port and other structures. Further afield to the south is the more substantial Town Reef and offshore, the Pania Reef system extending for approximately 4 km north-east from a point 800 m from the Port's outer breakwater. The proposed new spoil ground is comprised of a flat and uniform soft sediment substrate of fine and very fine silty sand in 20–23 m water depth. Benthic communities are dominated by deposit-feeding invertebrates and no significant biogenic structures were evident.

The surveys of the Fairway, outer Swing Basin area and the proposed spoil ground identified no taxa or communities of special scientific or conservation interest; and these benthic habitats are not considered to be spatially limited in the wider area.

Pania Reef was identified as a key marine ecological receptor in the vicinity of the proposed project due to its proximity, high ecological, cultural and amenity values and the very limited occurrence and extent of such habitats in southern Hawke Bay. To accurately establish the topography and extent of Pania Reef, a multibeam echosounder (MBES) survey was

commissioned. The data were used to assist with the identification of eight suitable transect sites for dive surveys of Reef habitats and communities as well as additional remotely-operated underwater video. These surveys characterised the ecology of the Reef and indicated that Reef communities varied along gradients of depth, water motion and sedimentation. Diver observation and the survey photographic record suggested that fine sediment deposition is a significant ongoing process on the Reef, with the inshore and deeper sections most affected. However, the settlement of fine particulate material exists in equilibrium with a countervailing process of resuspension and dispersion via wave energy and hence the system is likely to be relatively insensitive to increased sediment supply.

Direct effects

Dredging will result in the loss of all benthic biota and communities within the approximately 117 ha area of the dredging footprint, including those within approximately 60 ha of previously undredged seabed. While recolonisation and ecological recovery of this area will occur quite rapidly following the cessation of dredging, the habitat will be slightly altered through deepening and furthermore be subject to periodic ongoing disturbance from maintenance dredging.

Similarly, the volume of dredged material to be deposited in the offshore spoil ground will result in the effective loss via burial of benthic communities across the spoil ground's 346 ha area. However, it is likely that many sediment-dwelling species will remain established in this area as dredge hopper loads loads are deposited incrementally over the course of the project. This, and the expected similarity of the bulk spoil to the native sediments of the spoil ground, is likely to facilitate its ecological recovery.

The soft sediment habitat and communities of both the dredge area and the spoil ground are considered to be typical of much larger areas of seabed in similar water depths in the wider Hawke Bay inshore region. Hence the temporary loss and/or alteration of habitat across these areas are not considered to be significant with respect to the marine ecology of the wider area. The dominant taxa of these communities are furthermore considered to be capable of relatively rapid recolonisation and re-establishment, a conclusion supported by the results of repeated previous monitoring of the Port's consented inshore spoil grounds.

Testing of sediments from the areas to be dredged has shown generally very low levels of contaminants; hence direct toxicity effects are not expected from its disturbance and disposal offshore.

Indirect effects

The primary mechanism by which ecological receptors outside the physical footprint of the works may be affected is through the generation and propagation of turbidity plumes comprising suspended sediment. Compiled turbidity data for the near-shore waters of Hawke Bay indicates variable ambient conditions with episodic high turbidity driven by riverine flood flows and wave resuspension events. Continuous monitoring of surface turbidity presently being conducted at two locations near Pania Reef is expected to provide a better indication of background variability and to potentially enable a useful correlation to be established between turbidity and suspended solids concentration (SSC).

Hydrodynamic modelling was undertaken by WorleyParsons Group Ltd to provide an indication of the propagation and strength of turbidity plumes generated by the dredging project. The model outputs indicated that spoil disposal operations will generate more extensive suspended sediment plumes than dredging. Since ambient water currents flow predominantly southwards, away from Pania Reef, there is only limited potential for plumes from spoil disposal activities to impinge upon Reef habitat. The one-month model simulations suggested that only very dilute plumes will reach the Reef, even when wind conditions cause currents over the spoil ground to be directed to the north-west, a situation which may occur for approximately 10% of the time. Taking into account wave turbulence effects, the modelling furthermore predicted no project-related sedimentation on Pania Reef from the one month simulations. Based on ambient turbidity data and consideration of the existing Reef communities, it was concluded that project-related increases in suspended sediment concentrations will not lead to adverse ecological effects at the Reef unless sustained for significantly longer than is predicted by the modelling outputs.

Other reef areas potentially affected by turbidity plumes from project components include Town Reef and the mixed boulder/cobble shoreline between the Port and Ahuriri Inlet. However, the modelling predicted that only the small western embayment adjacent to the Port would be exposed to dilute plumes (exceeding10 mg/L above background SSC) during dredging and that these exposures would be infrequent. Due to their greater natural exposure to shoreline resuspension processes, these sites are less likely to experience turbidity and sedimentation significantly exceeding normal background ranges and are more likely to recover rapidly.

While soft sediment habitats closer to the plume source will experience higher suspended sediment concentrations and settlement, benthic communities in these areas are already highly adapted to elevated near-bed turbidity and significant adverse effects are unlikely beyond tens to low hundreds of metres from the activity.

Fish and fisheries

The relatively shallow waters of Hawke Bay support a range of demersal and pelagic fish species, all of which are widespread in occurrence. With the possible exception of Pania Reef, no benthic habitats known or suspected to be of special importance to particular fisheries species, or any of their life stages, occur within the area potentially affected by the proposed project.

Commercial fishing within the near-shore areas of southern Hawke Bay is mostly targets flatfish and gurnard. Landed-catch data suggest that particular spatial concentrations of fishing effort do not occur in areas potentially affected by the proposed project. While these benthic species are able to avoid areas of direct disturbance, their preferred habitats also require them to be naturally tolerant of elevated turbidity.

Potential effects on paua, spiny lobster, surf clams and paddle crabs were considered in relation to their life histories and apparent distribution within the area. It was concluded that the project is very unlikely to result in significant adverse effects to local populations of these species.

Monitoring and management

It is recommended that monitoring of turbidity at points adjacent to Pania Reef should be continued throughout the dredging project, with a tiered system of trigger limits that ultimately require management of Project activities if it is indicated that they are resulting in significant stress to reef ecology.

It is also recommended that Pania Reef communities should be monitored directly in years where capital dredging has occurred. While time lags and determination of causality in the response of ecological receptors make them unsuitable to provide a basis for short-term management during dredging campaigns, monitoring will provide a basis for identification of any significant changes to baseline conditions over the course of the project.

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GLOSSARY

Term	Definition	Type
°C	Degrees Celsius	Unit
µm	Micron	Unit
ADCP	Acoustic Doppler Current Profiler	Acronym
ADL	Analytical Detection Limit	Acronym
AEE	Assessment of Environmental Effects	Acronym
AFDW	Ash Free Dry Weight	Acronym
ANZECC	Australia and New Zealand Environment and Conservation Council	Acronym
APHA	American Public Health Authority	Acronym
aRPD	apparent redox potential discontinuity	Acronym
As	Arsenic	Abbreviation
BHD	Back-hoe dredge	Acronym
Cd	Cadmium	Abbreviation
CD	Chart datum	Acronym
CELR	Catch effort landing returns	Acronym
cm	Centimetre	Unit
cm/s	Centimetres per second	Unit
Cr	Chromium	Abbreviation
Cu	Copper	Abbreviation
DDT	Dichlorodiphenyltrichloroethane	Abbreviation
DOC	Department of Conservation	Acronym
E	East	Acronym
EEZ	Exclusive Economic Zone	Acronym
FMA	Fisheries Management Area	Acronym
FSA	Fisheries Statistical Area	Acronym
g	Grams	Unit
g/m^3	Grams per cubic metre	Unit
GC-MS	Gas Chromatography - Mass Spectrometry	Acronym
GPS	Global Positioning System	Acronym
H’	Shannon-Weiner diversity index	Index
ha	Hectare	Unit
HBRC	Hawke’s Bay Regional Council	Acronym
Hg	Mercury	Abbreviation
HHS	Hunter Hydrographic Services Ltd	Acronym
ICP-MS	Inductively Coupled Plasma Mass Spectrometry	Acronym
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry	Acronym
ISQG	Interim Sediment Quality Guideline	Acronym
J'	Pielou’s evenness index	Index
km	Kilometre	Unit
LALLS	Low angle laser light scattering	Acronym
m	Metre or Metres	Unit
m/s	Metres per second	Unit
MBES	Multibeam echosounder system	Acronym
MDS	Multi-dimensional scaling	Acronym
MFish	Ministry of Fisheries	Acronym
mg/kg	Milligrams per kilogram (parts per million)	Unit
mg/L	Milligrams per Litre (parts per million)	Unit
mL	Millilitre	Unit
mm	millimetres	Unit

MSL	Mean Sea Level	Acronym
MW	Molecular Weight	Acronym
N	No. of individuals	Abbreviation
n	Number of replicates or samples	Variable
Ni	Nickel	Abbreviation
NIWA	National Institute of Water and Atmospheric Science	Acronym
NTU	Nephelometric turbidity unit	Acronym
NZMG	New Zealand Map Grid (map projection)	Acronym
NZST	New Zealand standard time	Acronym
OBS	Optical back-scatterance	Acronym
PAR	Photosynthetically active radiation	Acronym
Pb	Lead	Abbreviation
PIM	Particulate inorganic matter	Acronym
POM	Particulate organic matter	Acronym
PONL	Port of Napier Ltd	Acronym
PVC	Polyvinyl chloride	Acronym
QMA	Quota Management Area	Acronym
QMS	Quota Management System	Acronym
R^2	Coefficient of determination	Coefficient
S	Number of species (species richness)	Index
S.D.	Standard deviation	Acronym
SCUBA	Self-contained underwater breathing apparatus	Acronym
SE	Standard error of the mean	Acronym
SIMPER	Similarity percentage	Abbreviation
Sn	Tin	Abbreviation
SOP	Standard operating procedure	Acronym
SSC	suspended sediment concentration	Acronym
SVOC	Semi Volatile Organic Compound	Acronym
TACC	Total allowable commercial catch	Acronym
TOC	Total organic carbon	Acronym
TPH	Total Petroleum Hydrocarbons	Acronym
TPM	Total dry particulate matter	Acronym
TSHD	Trailer suction hopper dredge	Acronym
TSS	Total suspended solids	Acronym
USEPA	United States Environmental Protection Agency	Acronym
Zn	Zinc	Abbreviation

1. INTRODUCTION

Port of Napier Limited (PONL) is proposing to deepen the existing approach channel to accept deeper draft vessels and establish a new berth (No.6 berth) on the northern face of the main Port reclamation. This entails widening the current dredged channel and extending it seaward by approximately 1.3 km. The Swing Basin at the Port entrance will be extended approximately 120 m westwards and 220 m south and deepened to serve the new berth. It is proposed that the dredge spoil generated by the project will be deposited in a new 346 ha disposal area located approximately 3.3 km south-east of Pania Reef and 4 km offshore in water depths of 20–23 m. The spatial footprint for the dredging work and the proposed disposal area for the dredge spoil, in relation to the principal features of the coastline, are depicted in Figure 1.

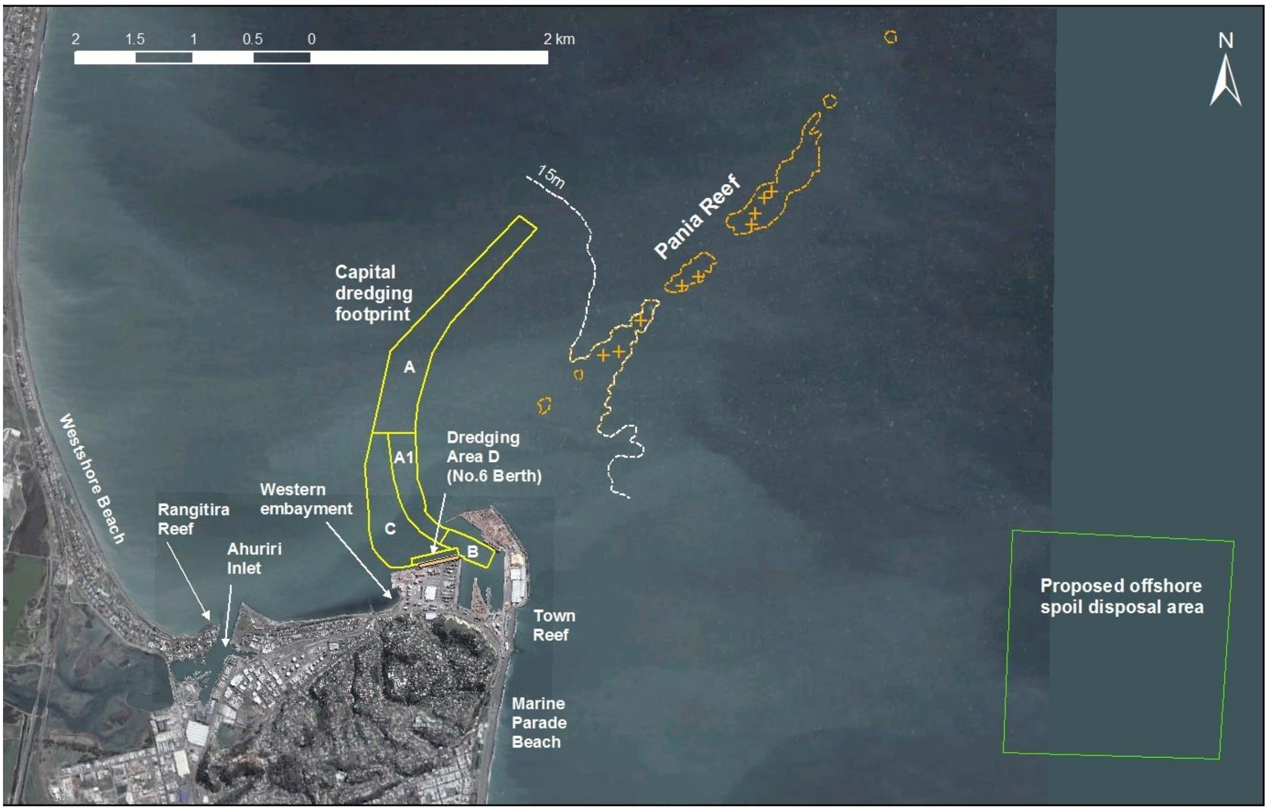

Figure 1. Composite aerial photograph of Port of Napier, showing the scale and layout of the proposed project elements.

Based on an expected combination of backhoe dredging and trailer suction hopper dredging, WorleyParsons Group has carried out sediment-plume modelling for the dredging project (Advisian 2017a). This simulated the potential water quality and depositional impacts associated with the dredging of the outer Fairway[1], Swing Basin and new berth, and the relocation of dredged material to the proposed disposal area (Figure 1).

As a component of the preparation of an Assessment of Environmental Effects (AEE), for the proposed development project, PONL contracted the Cawthron Institute (Cawthron) to conduct an investigation into potential marine ecological effects from the proposed project. This report presents the findings of the assessment of ecological effects, drawing upon historical and current survey data and the scientific literature.

1.1. Scope and objectives

The scope of this investigation and assessment was limited to effects on benthic, intertidal, fisheries and other marine ecological resources. Potential effects on marine mammals are being assessed in a separate report.

The objective is to provide a detailed assessment of the actual and potential impacts from each aspect of the proposed development on the benthic environment and marine ecological resources of the area. This was undertaken by characterising existing resources, establishing their relative ecological and fisheries importance and assessing to what extent each could be affected by the proposed development. A combination of approaches was used including:

- design and execution of surveys of sediment characteristics, intertidal and subtidal habitats, infauna and epifauna
- collation and comparison of data from previous surveys of the areas potentially affected
- desktop assessment of marine resources and potential impacts using available information sources
- assessment of the relative importance of habitats and marine resources lost or potentially altered by the proposed development
- assessment of the potential spatial extent of probable impacts.

[1] The term ‘Fairway’ in this report refers to the channel approach to the Port outside its breakwaters (areas A and A1 in Figure 1).

2. PROJECT DESCRIPTION

2.1. Dredging schedule

The total footprint area of the proposed dredging is approximately 117 ha. The capital dredging work is expected to be staged over a number of dredging campaigns, with the first used to deepen areas A, A1, B and C to the current channel depth of 12.5 m and the No. 6 berth pocket (area D) to its final level of -14.5 m (Figure 1).

The extended Swing Basin (area C) and channel (A, A1, B) will then be deepened in up to four subsequent stages at approximately 0.5 m increments (i.e. from -12.5 m to -14.5 m) over subsequent campaigns.

Dredging of areas B, C and D will be carried out by Backhoe Dredge (BHD), the current intention being to use two 240 m^3 barges. The dredged material will be taken to the proposed offshore disposal area. Areas A and A1 will be dredged by a trailer suction hopper dredge (TSHD) of 1,840 m^3 capacity. Estimates of dredging duration for each stage are provided in Table 1.

Table 1. Estimates of dredging duration (weeks) in each campaign, broken down by dredging area (refer Figure 1). Dredging of area D to the final depth of 14.5 m is proposed for campaign 1. Values from Advisian (2017a).

	Target	A / A1	B	C	D	Total
	Depth (m)	**TSHD**	**BHD**	**BHD**	**BHD**	**BHD**
Campaign 1	12.5	0.3	1.1	40.5	9.0	50.7
Campaign 2	13.0	1.0	1.5	6.7	-	8.2
Campaign 3	13.5	2.1	1.9	6.7	-	8.6
Campaign 4	14.0	2.5	2.1	6.8	-	8.8
Campaign 5	14.5	2.7	2.2	6.8	-	9.0

2.2. Disposal of dredged material

The dredge spoil is expected to comprise mostly fine to very fine silty sands at varying levels of consolidation. Estimates of spoil volumes to be placed in the proposed disposal ground are listed in Table 2.

Table 2. Estimates of spoil volumes (m^3) from the major dredging zones to be deposited in the proposed disposal area.

	Capital dredging zone				
	A	**A1**	**B**	**C**	**D**
Spoil volume (m^3)	874,480	341,528	161,802	1,666,467	176,030

2.3. Historical dredging activity

The Port of Napier currently holds a Resource Consent (CL970159D and Coastal Permit No. CPA0101) that allows for the disposal of up to 350,000 m^3 of dredged material over any 12 month period. Two designated dredge spoil disposal grounds are authorised by the Coastal Permit. The offshore site 'Ia' is located at and beyond the 10 m depth contour approximately 2 km NW of the Port, and the inshore site 'R extended' is located approximately 2 km WNW of the Port directly offshore from Westshore Beach in water depths between 2 m and 7.5 m (see Figure 2). These areas have been used intermittently in the past and physical and ecological effects have been monitored.

2.4. Wharf construction

A new wharf structure will be built for the No.6 berth. This will comprise a 700 mm thick continuous concrete deck supported on piles at approximately 6.5 m grid spacing in both offshore and shore-parallel directions. The wharf will be 350 m long and 34 m wide, with provision made for a future 50 m extension to the west. The slope beneath the wharf will be armoured.

The actual construction methodology has not yet been established. The components with potential to impact the coastal marine area are as follows:

- The wharf will be built from the edge of the existing reclamation.
- Pile casings will be driven to bedrock.
- A drill rig will be used to drill a pile socket into the bedrock at the base of the pile.
- Long-reach backhoes will trim the existing slope to the design lines before placement of armour.

3. NATURE OF THE PROJECT AREA

3.1. Wider-scale circulation and currents

Previous investigations have described the currents within Hawke Bay as having little tidally reversing flow but rather being dictated by a combination of wind, waves and the influence of the north-flowing Wairarapa Coastal Current and south-flowing East Cape Current (e.g. Ridgway 1960, 1962; Ridgway & Stanton 1969; Francis 1985; and Chiswell 2002). These two currents are reported to drive the general circulation within Hawke Bay which has previously been described as a bifurcating system whereby west flowing water masses enter the middle of the bay and diverge into north and south travelling shoreline flows. Francis (1985) quotes Ridgway (1960) as follows:

> *The main inflow takes place approximately along the mid-line of the bay. This current bifurcates, and the two currents thus formed follow the coastline and leave the bay at the northern and southern extremities.*

Haggitt and Wade (2016) noted that, on smaller scales, currents have been recorded travelling in many directions, with local conditions overridden by wind forcing.

Current data compiled from a series of deployments of single-point current meters in the vicinity of the Port in 2004-2005 were consistent with a relatively weak south-setting flow regime in the Napier area, although currents aligned with strong winds exhibited the greatest velocities. Further extended measurements undertaken at the Pania Reef south cardinal buoy over 2006-2007 also found currents to be generally weak and quite variable. However, an underlying south-easterly current set was identified, influenced by tidal state (generally stronger on the ebb) but frequently overridden by the influence of wind fields. Allowing for the influence of shoreline morphology and the possible formation of gyres, drogue drift tracks in the vicinity of the Port approaches were also consistently aligned with the co-occurring wind direction. (Cawthron unpublished data).

Based on current and wind data compiled for the Port Fairway area in 2016, Advisian (2017a) also found a direct association between stronger winds and greater directionally-aligned current velocities. They further reported that, although a tidal signal was evident from these current data, it was most evident when wind speeds were low.

3.2. Physical characteristics

1. The main Port breakwater begins at the northern extremity of the exposed open coastline of Marine Parade Beach. The approach channel and adjacent waters extend from the harbour entrance towards the west and further offshore to the

north and north-east. This area comprises a moderate- to high-energy shoreline with significant wave exposure and water movement. The waters offshore from Westshore Beach are also similarly exposed. The majority of the shallow coastal seabed surrounding the Port comprises mobile sands that are subject to continual movement and redistribution through wave action.

2. By design, the Port itself is semi-enclosed and well-protected from wave exposure. Dilution and dispersion processes in this area will be dominated by tidally reversing flows. Tidal range varies 1.1 m to 1.8 m (neap to spring). Water movement resulting from wind shear and vessel activity (propeller and ship movement turbulence) will also have an effect.

The presence of the Port confers additional shelter to shoreline areas immediately to the west. In particular, the main Port reclamation has created a small semi-sheltered embayment. Its semi-sheltered nature means that much of the time it is subject to only limited wave and tidal mixing. However, the embayment experiences periodic flushing and disturbance as a result of storm and swell events. Shoreline and shallow subtidal substrates of this area comprise natural and introduced boulder and cobble material which may extend up to 100 m seawards in the area of the west embayment. This habitat extends towards the Ahuriri Inlet to the immediate west and is interspersed with seasonally shifting medium sands.

In the wider surrounding area, Town and Pania reefs are disparate parts of a formerly continuous reef system that begins at the base of the main port breakwater and continues as a broken linear series of banks and pinnacles extending approximately 4 km offshore in a north-easterly direction. Pania Reef is the major seabed feature in southern Hawke Bay (Duffy 1992). Water depths over the Reef range from 3 m at Pania Rock to approximately 20 m where the reef meets the sand at its northern extremity. Its location makes it highly exposed to oceanic swells entering Hawke Bay as well as locally generated wind chop.

The most seaward point of Pania Reef is the steep pinnacle-like North Rock, which is isolated from the reef proper by a 700 m stretch of flat sand bottom. The north-western boundary of the reef system tends to be steeper than the south-western side which shelves off to boulder-strewn plateaus before descending on to a sand bottom.

The proposed new spoil disposal area is located 3.3 km south-east of Pania Reef in an area comprised of homogeneous soft sediments; these being predominantly fine and very fine silty sands. The bathymetry is relatively flat, gently sloping offshore in 20-23 m water depth and there are no significant high-relief features.

4. SURVEY METHODS

A range of methods was employed for the collection of the survey data used in this assessment. Benthic sample collection was carried out by divers at pre-established sample stations associated with specific soft-sediment seabed areas. Data collection for subtidal reef habitats employed dive transects at specific locations. This data was supplemented with several broad-scale and remote monitoring approaches. The principal survey methods are summarised as follows:

1. Samples from each benthic station collected by diver and any direct observations of substratum and biota recorded.
2. Collection of macrofaunal and sediment cores in soft sediment regions to characterise benthic sediments with respect to texture, organic enrichment, contaminants and ecology (Sections 4.1.2 and 4.2). The number and placement of sampling stations was based upon the need for adequate coverage of the sea bed, along with variations in depth profile and physical characteristics.
3. Use of an epifaunal research dredge to assess the distribution of epibiota over a broader area (Section 4.3).
4. Diver photoquadrat transects and ecological data collection (Pania Reef; Section 4.5.2).
5. Diver underwater video transects in areas of mixed benthic substrates
6. Remote-operated underwater drop-video transects (Pania Reef).
7. Limited broad-scale mapping of seabed features using side-scan sonar (Section 4.4).
8. Low-tide shoreline semi-quantitative survey of conspicuous intertidal biota and communities (Section 4.6).
9. Collection and analysis of a series of surface and seabed water samples at the inshore and offshore limits of Pania Reef over a two month period to gain an indication of suspended solids concentrations (SSC; Section 4.7.1).
10. Longer-term deployment of two telemetered buoy stations measuring continuous turbidity (NTU) and salinity in surface waters near Pania Reef (Section 4.7.2).

Figure 2 shows the general layout of historical and recent sample stations and other survey components relative to the Port, Pania Reef and the proposed areas of capital dredging and spoil disposal.

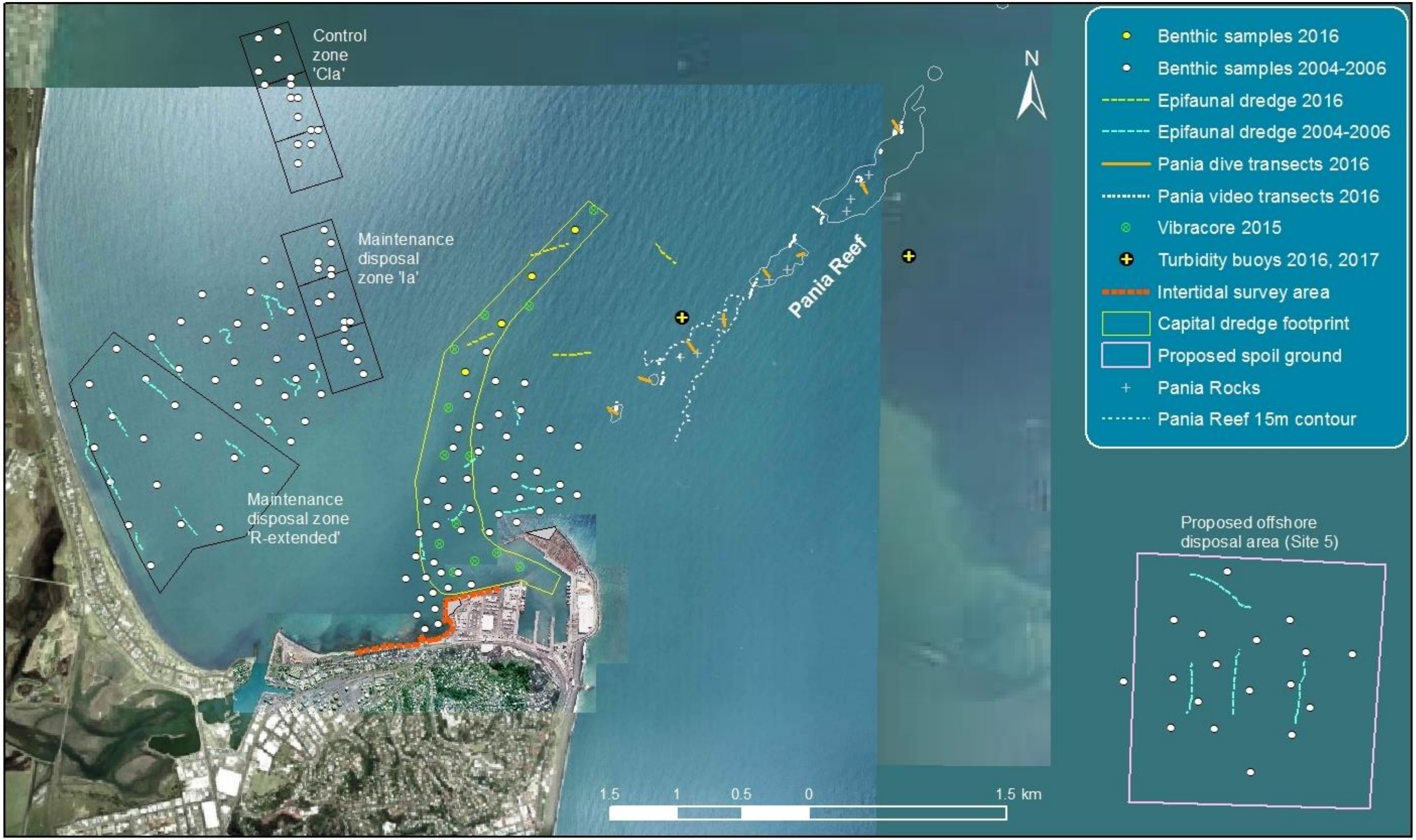

Figure 2. Overview spatial layout of benthic survey components for the Port of Napier, Westhsore Beach, Pania Reef to offshore Marine Parade.

4.1. Sediment characterisation

The principal physicochemical properties of seabed sediments that influence benthic ecological communities are grain size distribution, organic content and the concentrations of any toxicants present. Sediment grain size distribution defines the texture or coarseness of the substrate and is typically related to the depth and energy (waves and currents) of the overlying water column. The relative enrichment of sediments with organic material depends upon the size and proximity of input sources and also the depositional environment. In turn, both sediment texture and organic content play an important role in determining the capacity for adsorption and retention of contaminants. Chemical contaminants are primarily retained within fine sediments via adsorption to particulate surfaces and may accumulate over long time periods (Förstner 1995). Many contaminants preferentially bind to organic matter, although this association generally reduces its bioavailability (ANZECC 2000).

4.1.1. Sediment sampling

Across several surveys since 2004, sediment cores have been collected by divers at stations to the west and north of the Port, throughout the Central Fairway area and within the wider vicinity of the consented dredge spoil disposal grounds (Figure 2, Appendix 1). In 2005, eighteen cores were collected from an area of seabed located within the currently proposed spoil ground (Figure 2). For reference, areas corresponding to the sample code pre-fixes used are shown in Figure 3. Perspex^{TM} corers of 60 mm diameter were manually driven into the sediments to a depth of 10-15 cm, withdrawn and capped *in situ*, and returned to the survey vessel. Separate cores were collected at sample stations for which sediment chemical analyses were required. All cores were examined to qualitatively determine their texture, colour, and odour. Photographs were taken to document the relative degree of enrichment and the presence of an apparent redox potential discontinuity (aRPD) layer[2] that indicates the transition between oxidised and reduced conditions in the sediment profile.

4.1.2. Sediment analyses

All sediment samples were analysed for grain size distribution (as percentage gravel, sands, and mud) and organic content (as ash-free dry weight [AFDW] or total organic carbon [TOC]). Core samples from a number of stations were also analysed for trace contaminants including metals, organotin compounds and semi-volatile organic compounds (SVOCs). A summary of sediment analytical methods is given in Table 3 and a schedule of the survey and variables measured in each area is presented in Table 4.

[2] The aRPD refers to the often distinct colour change, between surface and underlying sediments. Its presence and distinctness is frequently related to the degree of organic enrichment, as oxygen is consumed by decomposition processes. This colour change is in reality continuous but may appear abrupt or be reduced to an average transition point (sediment depth) for descriptive purposes.

Where applicable, the sediment chemistry results were compared against the ANZECC (2000) Interim Sediment Quality Guidelines. These criteria provide trigger values representing two distinct threshold levels under which biological effects are predicted. The lower threshold (ISQG-Low) indicates a *possible* biological effect while the upper threshold (ISQG-High) indicates a *probable* biological effect.

Table 3. Summary of analytical methods used for characterisation of surficial sediments and a sample of stiff silt material from deeper in the sediment profile.

Analyte	Method Number	Description
Particle grain size – extended series (PGX)	Cawthron SOP No. 33074	Wet sieved through screen sizes: > 2 mm = Gravel < 2 mm to > 1 mm = Coarse Sand < 1 mm to > 500 µm = Medium Sand < 500 µm to > 250 µm = Medium/Fine Sand < 250 µm to > 125 µm = Fine Sand < 125 µm to > 63 µm = Very Fine Sand < 63 µm = Mud (Silt & Clay) Size classes from Udden-Wentworth scale
Organic Content (AFDW)	Luczak et al. 1997 (modified)	Sample dried at 105°C then ashed at 550°C. Gravimetric determination.
Total organic carbon (TOC) – 2016.	Hill Laboratories in-house method	Acid pre-treatment to remove carbonates if present, neutralisation, [Elementar combustion analyser].
Trace metals (As, Cd, Cr, Cu, Pb, Ni, Zn)	USEPA 2002 (modified)/APHA metals	Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) following aqua regia acid digestion
Mercury	USEPA 245.5 MOD	Flow Injection Mercury System (FIMS)—cold vapour atomic absorption spectrophotometer following HNO3/H2SO4 acid digestion with $KMnO_4$ and reduction with $SnCl_2$
Total recoverable tin and trace metals (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn) in 2016	USEPA 200.2	Nitric / hydrochloric acid digestion, ICP-MS (low level).
Semi-volatile organic compounds, (SVOC, BNA)	US EPA 3540, 3550, 3640 & 8270	Sonication or ASE extraction, GC-MS, full scan
Organotin compounds	Hill Laboratory in-house method	Methanol/acetic acid, sonication, ethylation, GC-MS
<u>Stiff silt sample only</u>		
Particle grain size distribution (sediment texture)	University of Waikato marine sediment by Low Angle Laser Light Scattering (LALLS).	Sample measured in aqueous suspension (with 0.1% Calgon dispersant) in a recirculating cell by Malvern Mastersizer 2000
Turbidity of sediment suspensions	APHA 20th Edn 2130B	Sonicated sample. Hach 2100N laboratory turbidimeter referenced to formazin standards
Total suspended solids of sediment suspensions	APHA 20th Edn 2540C	Gravimetric determination of sediments filtered (Whatman GF/C) from measured volume of agitated suspension

Table 4. Summary of number of stations sampled and analyses undertaken in benthic areas in or adjacent to Port of Napier approach channel since 2004.

	Entrance channel and surrounds	**Survey area 'B' north of breakwater**	**Survey area 'R' west of Port reclamation**	**Spoil Ground Vicinity [d]. Westshore**	**Proposed Spoil Ground**
Sample prefix code [a]	CD	B	R	RX, CS, Ia, CIa	S5
Approx. area covered (ha)	112	40	9.3	397	346
Depth range (m CD)	4–13	7–12	0–7	0–12	20–23
Sediment samples [b]					
Grain size distribution, organic content	26	2	6	59	18
Trace metals	16	-	-	-	-
Organotins / SVOCs [c]	4	-	-	-	-
Macrofauna samples	20	14	8	71	18
Epifauna dredge trawls	8	2	-	14	4

a. See map Figure 3
b. See Table 3 for analysis methods
c. Semi-volatile organic compounds
d. Sample numbers are those undertaken in Cawthron surveys. Repeat surveys required by PONL's spoil disposal coastal permit have been conducted in 2007 and 2012 (Smith 2008a, 2013)

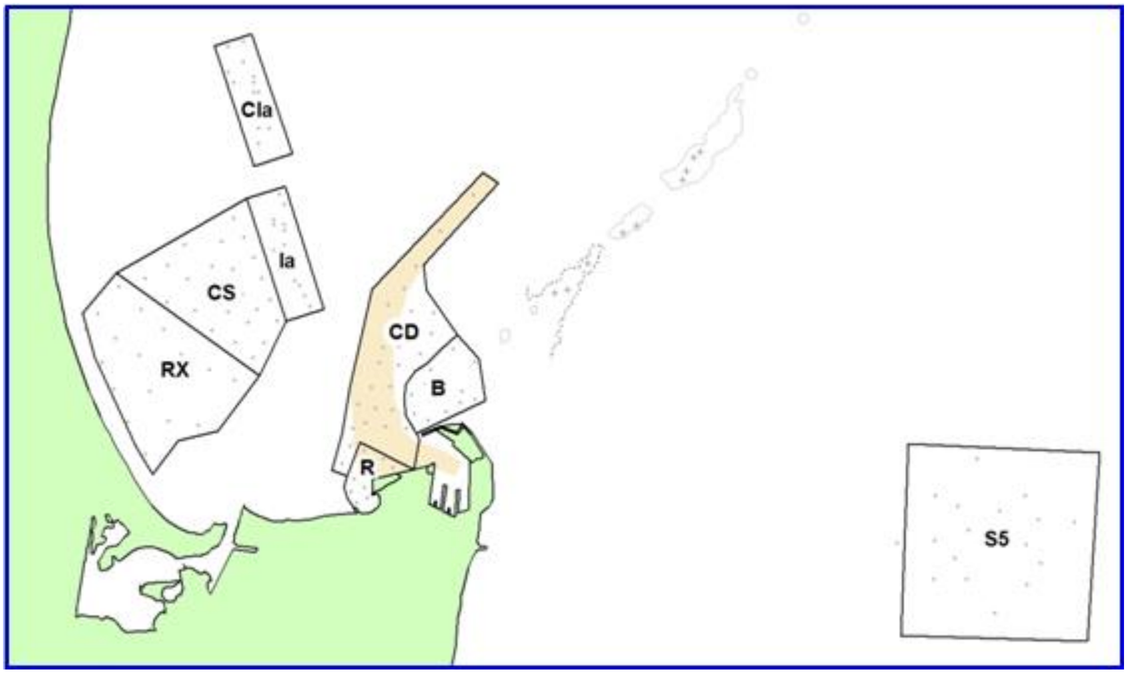

Figure 3. Key to areas corresponding to sample code pre-fixes for Port of Napier survey data.

Analysis of stiff silt material

An underlying cohesive stiff silt is likely to represent a significant proportion of the spoil from capital dredging of the Fairway. In 2007, a sample of this material was provided by PONL for analysis. Grain size analysis was carried out at Cawthron labs using the same wet-sieving technique used for surficial sediment samples (Table 3). However, to better establish the make-up of sub-63 µm (silt and clay) component, a sample was also sent to Waikato University for analysis by laser diffraction or Low Angle Laser Light Scattering (LALLS). This method works better in defining the relative proportions (by volume) of the very fine material. However, care must be taken in comparing results from the two methods as they are based on the measurement of different particle characteristics.

In order to investigate the relationship between suspended solids levels and turbidity for the stiff silt material, a series of suspensions was made up and analysed in the laboratory. Different weights of the stiff silt sample were added to 1 L of filtered (0.35 µm) seawater and mixed into suspension. These suspensions were then analysed for turbidity and total suspended solids (TSS). The samples were gently mixed and turbidity measurement carried out using a Hach 2100N bench turbidimeter. Suspended solids were determined gravimetrically by filtering (1.2 µm) a volume of the mixed suspension followed by drying and weighing of the filter paper.

Diver observations

Since benthic samples were largely collected by divers, there was opportunity for direct observation of the sea bed. However, diving conditions in the field (principally poor visibility) were such that spatial coverage was limited and photographic records were generally of poor quality. Notes were compiled for the survey areas and where necessary, voucher specimens were collected for later identification of biota. This information was used along with sample analyses and other survey data to compile a description of the benthic habitats and communities occurring within the area. Due to variability in benthic substrates occurring offshore from the western embayment adjacent to the Port entrance, six underwater video transects were conducted in this area (see Figure 23 on p. 63).

4.2. Benthic macrofaunal communities

The ecological assemblage of small animals living on the sediment surface or in the upper 10 cm of the sediments is generally referred to as macrofauna or macroinvertebrates, with the infauna being the subset of such animals inhabiting the sediment matrix[3]. By definition, these are sediment-dwelling animals retained on a 0.5 mm sieve mesh. Analysis of infauna communities has been used for several decades to assess human impacts in marine environments, since studies have demonstrated that they respond relatively rapidly to anthropogenic and natural stress

[3] The distinctions between these two groups are somewhat blurred and the terms are often used interchangeably.

(Pearson & Rosenberg 1978; Dauer et al. 1993; Borja et al. 2000). The presence or absence and density of different macroinvertebrate species provides a direct indication of the health of the benthic environment, and can also be used to predict likely impacts based on the relative sensitivity of the taxa represented. Since infaunal sampling uses a standardised and repeatable method, quantitative comparisons can be made both spatially and temporally.

An infaunal core sample was collected from the seabed at each of 18 stations in the approach channel area, 14 stations in survey area 'B' immediately north of the spur breakwater, 8 stations in survey area 'R' south-west of the port entrance and the 18 stations at the currently proposed spoil ground site (Table 4, Figure 3). The corers consisted of 130 mm diameter PVC tubes with a nylon 0.5 mm mesh bag fixed to the top to act as a sieve. Each core was manually driven into the sediments to a depth of 100 mm by the diver. The contents of the core were then emptied into the mesh sieve cover which was drawn closed for transport back to the survey vessel.

On board, each core was sieved by gently rinsing most of the fine sediments from the contents of the bag. The residue was then transferred to a sample container for preservation in a seawater solution of 3% glyoxol and 70% ethanol. In the laboratory, macrofauna within the preserved samples were identified and counted with the aid of a binocular microscope. Identifications were made to the lowest practicable taxonomic level. For some groups, species level identification is very difficult and, in such instances, infauna were grouped into recognisable taxa (morphologically similar groups).

Infauna data analysis

Infauna count data were analysed to ascertain levels of abundance (individual species density), species richness (diversity) and standardised indices of community diversity and evenness for each station (Table 5). These indices were compared between stations and significant differences interpreted with respect to key factors such as water depth and substrate characteristics.

The infaunal assemblages recorded at each site were contrasted using non-metric multidimensional scaling (nMDS; Kruskal & Wish 1978) ordination and cluster diagrams using Bray-Curtis similarities between samples in PRIMER v6 statistical software (v. 6.1.6 ©PRIMER-E 2000; Clarke & Warwick 1994; Clarke & Gorley 2001). Abundances were fourth-root transformed to de-emphasise the influence of the dominant species (by abundance). The major taxa contributing to the similarities of each grouping of benthic stations were then identified using analysis of similarities (SIMPER; Clarke & Warwick 1994; Clarke & Gorley 2001, 2006).

Table 5. Descriptions of macroinvertebrate (infauna) community indices.

Index	Equation	Description
No. species (S)	Count (taxa)	Total number of species in a sample.
No. individuals (N)	Sum (n)	Total number of individual organisms in a sample.
Evenness (J')	J' = H'/Log$_e$(S)	Pielou's evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.
Diversity (H' log$_e$)	H' = -SUM(P*i**log$_e$(P*i*))	Shannon-Wiener diversity index (log$_e$ base). A diversity index that describes, in a single number, the different types and amounts of animals present in a collection. Varies with both the number of species and the relative distribution of individual organisms among the species. The index ranges from 0 for communities containing a single species to high values for communities containing many species with each represented by a small number of individuals.

The sampling surveys for the consented dredge spoil grounds 'R extended' and 'Ia' and the reference area 'CIa' were repeated in 2007 and 2012 using a similar methodology and analysis (Smith 2008a, 2013).

4.3. Benthic epifauna

A small research dredge with a 250 mm x 500 mm throat and fitted with a 10 x 10 mm stainless steel wire mesh was used to sample benthic epifauna. The number and spatial distribution of dredge trawls depended upon area, substrate/habitat homogeneity and variations in bathymetry. Trawls were generally aligned along isobaths and the GPS track and start and finish depths were recorded in each case. Dredge contents were photographed, the taxa identified, and the number of individuals counted. Where identification was not possible in the field, voucher specimens were preserved in a solution of 70% ethanol and 3% glyoxol for later classification in the laboratory.

4.4. Side-scan sonar

Side-scan sonar enables detection of low-resolution changes in substrate texture on the seabed (e.g. a change from mud to cobble or reef substratum) and allows the extent of such areas to be effectively defined. As a survey method, when combined with suitable 'ground-truthing' data, it allows relatively large areas to be mapped relatively quickly.

Where water depth permitted, a Tritech™ sonar 'fish' was towed at a speed of approximately 2.4 knots, with a swathe width of 15 m either side of the vessel. GPS tracks were simultaneously logged with the side-scan sonar output to an onboard laptop computer using Tritech™ software, enabling the relocation of any areas of interest for later verification.

Side-scan sonar outputs enabled the broad-scale mapping of the seafloor topography in survey area 'R' to the west of the Port and south of the outer Swing Basin, where other survey methods had indicated the presence of a mix of substrates and habitats. Some limited side-scan coverage of the proposed spoil ground was undertaken in 2005 (Figure 2). Diver observations, sediment samples and dredge trawls were used to effectively ground truth the recorded outputs.

4.5. Pania Reef surveys

4.5.1. Multibeam imaging

Hunter Hydrographic Services (HHS) was contracted to survey and determine the extent and topography of Pania Reef. Heron Construction Ltd. was subcontracted by HHS to provide the multibeam echosounder (MBES) system and operating personnel. The following equipment was fitted to the survey vessel White Pointer:

- RESON Sebat 7125 Multi Beam Echo Sounder
- APPLANIX Pos MV Motion & Positioning System
- ODOM DIGIBAR PRO Sound Velocity Profiler
- RESON PDS2000 Acquisition Software
- Trimble SPS852 GNSS base station (PNL permanent installation).

The survey was completed over 12–13 April 2016. Position calibration was confirmed next to the end of No.3 Wharf (Port of Napier). Horizontal Datum - Hawkes Bay Circuit 2000. Vertical Datum confirmation was to zero of the Port of Napier tide board on the stairs at end of No.3 Wharf. Vertical datum ellipsoid residuals calculated as approximately 70 mm at the middle of the reef from the end of No.3 Wharf. NZVD2009 residuals were not applied to this survey. Sound Velocity Profile was gathered at the reef and applied to the system prior to data collection. A patch test was not carried out on this occasion. The values used for Roll, Pitch and Yaw were -0.75°, 0.07° and -0.86° as previously established for this setup on this vessel.

Site conditions and coverage

Conditions on the site were ideal for MBES survey; however, the abundance of kelp on the shoal areas of the reef inhibited the capture of true seabed profile and as such the measured depths over these areas were not accurate (always being shallower than the true surface). The survey endeavoured to achieve 100% coverage of the reef features. The number of soundings per square metre over the site were generally in excess of $10/m^2$. The site was surveyed using 400 KHz and swath generally set at 120 degrees.

Accuracy

The survey was carried out with a focus on determining relief (topography) and as such, certain techniques were employed to optimise this aspect. The estimated confidence level (spatial resolution) for this work was ± 0.5 m horizontally and ± 0.15 m vertically.

4.5.2. Reef ecological survey

Ecological survey data for Pania Reef was collected using a range of methods:

- diver assessment and quadrat photographs of substrate and epibiota[4]
- diver-operated underwater video transects of subtidal substrate and epibiota
- remote-operated video transects of subtidal substrata and epibiota.

Diver transect surveys

Diver surveys were undertaken for eight 100 m transects located at stations spanning the length of the reef system, each roughly perpendicular to its axis (i.e. SE-NW; refer Figure 27 on page 72) on 28–29 April 2016. Four of these transects (PR1–PR4) were selected to effectively repeat a similar survey conducted on the reef in 2005 and PR2 was also surveyed in 1991 (Duffy 1992). Data from previous surveys provides a useful comparison to assess temporal variability.

The transects were conducted by dropping the weighted end of the transect line at the shallowest point and running the remaining length of line out away until taut, from where the deeper end was lowered on a weighted shot line. Two divers swam along the transect line from the deepest point, taking video and quadrat photographs as well as recording notes on the benthic communities and mobile fauna. Four 41 cm x 61 cm ($0.25\ m^2$) rectangular photoquadrats were taken at each 10 m interval along the transects using a 10 megapixel digital SLR camera attached at a fixed distance from the quadrat. Diver-operated video footage was collected using a GoPro Hero camera. The ecological notes were also recorded at 10 m intervals along each transect and included a note of water depth as well as details of the habitat/substratum type, algal species and relative abundance, and conspicuous or common surface-dwelling fauna. Where necessary, voucher specimens were collected for later identification. This information was used to compile an accurate description of the habitat and the community of larger epibiota occurring within the area.

[4] Organisms living on or above the substratum surface.

Remote-operated video transects

Additional video transects of substrata and epibiota were conducted from the survey vessel at various locations along Pania Reef (refer Figure 27 in on page 72). These were obtained using a data-fed video monitor in the vessel, with the camera suspended just above the seabed. Transects ranged from 50 m to 200 m in length. The camera used was a Seaviewer 6000 Sea-drop 1080p HD-SDI underwater video camera. This information was used to compile further descriptions of habitat, and larger biota (where visible). In particular it was used to explore any major differences in species distributions between 2006 and 2016 as well as additional areas on Pania Reef that had not been surveyed by divers.

4.6. Intertidal survey

A semi-quantitative approach was used to describe the general habitat and communities of the intertidal zone of areas adjacent to the Port. The survey was conducted by two Cawthron Scientists over low tide on 28 November 2004. The survey encompassed a representative length of the port breakwater rock wall, the embayment adjacent to and immediately west of the main Port reclamation, and approximately 400 m of shoreline to the west towards the Ahuriri Inlet. In these areas, substrate and other habitat physical characteristics were recorded, along with conspicuous fauna and flora. Relative abundance and zonation patterns were assessed. Where identification of organisms was not possible in the field, voucher specimens were collected and preserved for later identification. Digital photographs were taken to support the observations made. Survey data was supplemented by, and compared to, that collected by Barter and Keeley (2002b) for an earlier reclamation proposal. Biological assemblages were assessed with respect to their distribution within the wider area and their relative sensitivity to disturbance.

4.7. Background suspended sediments and turbidity monitoring

4.7.1. Suspended sediments

To gain some indication of the natural background concentrations and variability of suspended solids in the water column in the vicinity of Pania Reef, a series of water samples were collected over November–December 2005 from two positions along the reef axis, one at the preferred channel marker at the inshore end of the reef, the other at the North Cardinal marker approximately 300 m north-east of North Rock (refer Figure 40 on page 96). A Van Dorn sampler was used to collect two 1 L samples from depths of 1 m beneath the surface and 1 m above the seabed respectively. Samples were collected on 16 occasions at different tidal and sea states and under a variety of wind conditions.

As the initial basis of a calibration between compiled turbidity data and suspended solids, grab samples are being collected at the site of the 'Pania West' monitoring buoy (see below) from the same depth as the turbidity sensor.

4.7.2. Turbidity monitoring

In order to establish a pre-dredge baseline of background turbidity at Pania Reef, water quality monitoring buoys have been installed by PONL The buoy selected was a Cawthron µWQ-700, consisting of a roto-formed polyethylene hull with near-surface mounted water-quality sensors (Figure 4).

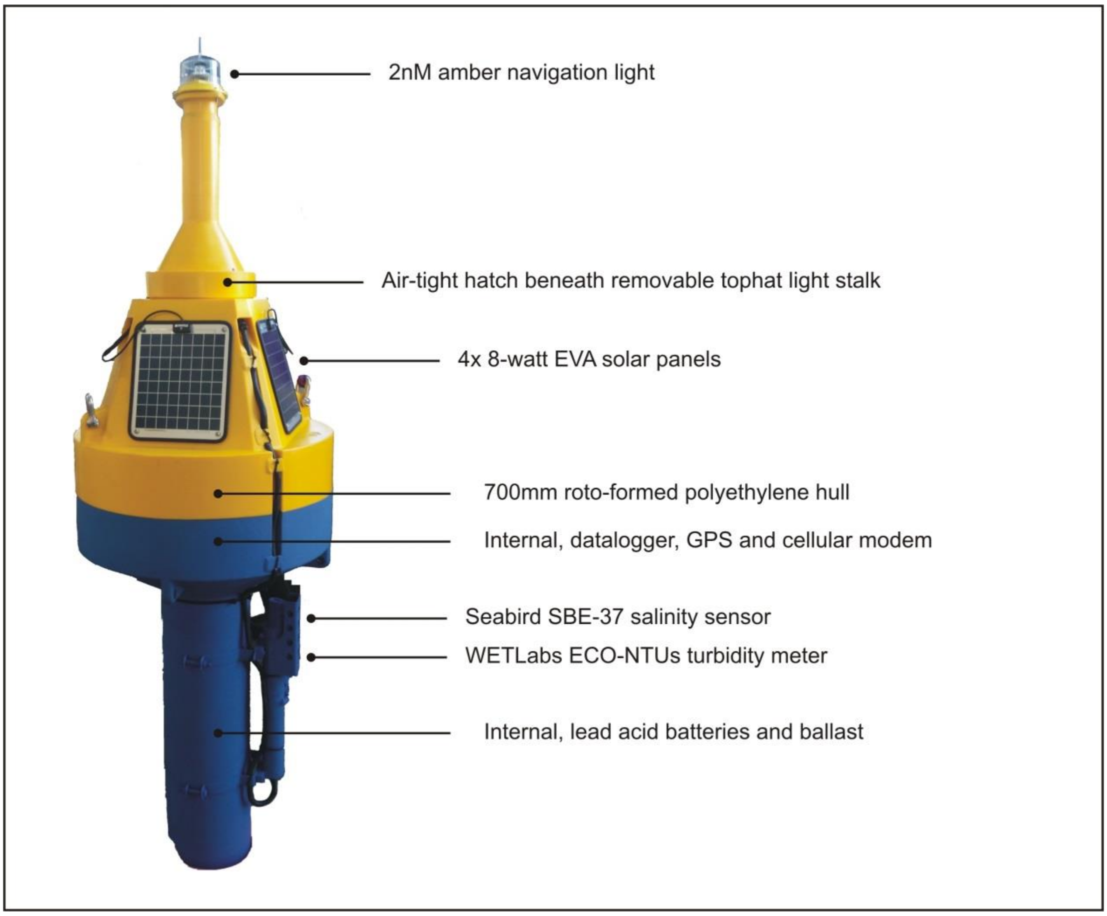

Figure 4. Telemetered turbidity monitoring buoy.

The first buoy ('Pania West') was installed on 18 April 2016 at a location immediately to the west of Pania Reef (39.4548 °S; 176.9297 °E; WGS84) in approximately 15 m of water (Figure 2). The site was selected to correspond with the most likely plume-path from dredging-related activities that might impinge upon Pania Reef according to the preliminary plume modelling (Advisian 2015).

The proposal to establish an offshore disposal ground south-east of the Pania Reef led to a decision to install a second identical turbidity monitoring buoy on the offshore (eastern) side of the Reef. The second buoy ('Pania East') was deployed in March 2017 at 39.4499°S, 176.9500°E (Figure 2).

Data collection from each of the buoy-mounted sensors is on a fifteen minute schedule with turbidity being an average of 30 readings collected at 1 Hz. Water quality and buoy performance data (i.e*.* solar recharge, battery level, position, leak alarm *etc*.) are logged internally and telemetered back to shore every 15 minutes via cellular communications.

The intention is to collect at least 12 months of baseline turbidity data and use this background information to establish an appropriate set of trigger levels to inform operational response during dredging.

5. FISH AND FISHERIES RESOURCES

The relatively shallow waters of Hawke Bay support a range of demersal[5] and pelagic[6] fish species, all of which are widespread in occurrence within the North Island coastal region. In a broad review of current and historical information on the marine coastal resources of the Hawke's Bay region, Haggitt and Wade (2016) described the region as supporting a mixed-species fishery with the predominant commercial fishing method being demersal trawling.

More than 30 important fish species are commercially or recreationally exploited in Quota Management Area 2 (QMA2, Central East; see Section 5.3 for a definition of QMAs). Many of these have a wide range of vertical distribution; some spend one or more stages of their life cycles in near-shore areas and others are more exclusively inshore in their distribution. Haggitt and Wade (2016) noted that there has been recent widespread concern over the current state of the fishery in Hawke Bay across all sectors (commercial, customary, and recreational), with indications that a number of historically abundant species are in decline.

5.1. Key inshore species

The 100 m depth contour is approximately 33 km offshore (ESE) from the Port of Napier, well beyond Cape Kidnappers. The 50 m contour is approximately 21 km offshore. Both these distances far exceed the expected range of significant turbidity plumes from the dredging operation. Hence consideration of fisheries stocks potentially vulnerable to dredging effects is limited to species whose major aggregations occur within the 30 m contour or where such shallower depths are important to one or more life stages or migratory behaviours.

Haggitt and Wade (2016) cite Stevenson et al. (1987) that targeted trawl species in southern Hawke Bay include moki and tarakihi out to a depth of 90 m, with tarakihi, barracouta, John Dory, and gemfish being targeted beyond that depth contour. It was noted that blue warehau spawn in Hawke Bay; however, the depths at which running ripe[7] fish have been recorded range from 50 m to 300 m (Morrison et al. 2014a).

In terms of commercial catch weight, the main inshore fisheries species are tarakihi, red gurnard, barracouta, trevally, flatfish and snapper, with blue moki and red cod also landed in significant quantities. Of these species, those for which shallow near-shore habitats are likely to be important are flatfish, gurnard, tarakihi and snapper. Other

[5] Living and feeding close to the sea floor.
[6] Living and feeding in the surface layers of oceanic and coastal waters.
[7] During the spawning period, females are referred to as 'ripe' when they have nearly-mature eggs scattered throughout their gonad and 'running ripe' once these mature eggs have ovulated and are ready for release.

species for which near-shore areas are likely to be important include elephant fish, rig and school shark.

5.2. Recreational fishing and customary harvest

Inshore Hawke Bay provides important recreational fisheries for red gurnard, tarakihi, snapper, kingfish, kahawai, and trevally. Haggitt and Wade (2016) noted that there are also small set net fisheries for butterfish (*Odax pullus*). Pania and Town reefs are fished for rock lobster and harvested for mussels. Pania Reef's status as a Mataitai means that commercial fishing is prohibited.

The Bay provides plentiful opportunities for shore-based fishing. Popular locations in southern Hawke Bay for surfcasting include the mouths of the Tukituki River at Haumoana; the Tutaekuri/Ngaruroro River at Clive and the Esk River. Targeted species include kahawai, kingfish, gurnard and rig, with trevally and blue moki also occasionally caught from shore. Local to Napier, Town Reef and Perfume Point are also notably popular for shore-based fishing. The mouth of the Tutaekuri/Ngaruroro River, and possibly those of the Tukituki and the Esk, is fished for flounder. Line fishing from recreational vessels targets red gurnard, tarakihi, snapper, kingfish, kahawai, häpuku/bass and trevally. Butterfish, moki and kahawai can be caught by set-net.

Haggitt and Wade (2016) reported that near-shore rocky reef habitat surrounding Napier (including Pania Reef, Town Reef and Tangoio Bluff) held significant customary and recreational value for the collection of green-lipped mussels, kina, paua, rock lobster, and various finfish species (including kahawai, gurnard and hapuka). While all finfish species caught in Hawke Bay have a high value to customary fishers, it was noted that taonga finfish species include blue moki, butterfish, blue warehou, rig, kahawai, hapuku/bass and tarakihi.

The Hawke's Bay Sport Fishing Club keeps a detailed record of catches from competition days (October–April). Of 18 species documented (HBSFC 2015), the following are identified as prevalent within or partly reliant upon shallow near-shore areas:

Gurnard	Snapper	Tarakihi	Trevally
Blue Cod	Red Cod	School Shark	Kahawai
Rig	Kingfish		

In regard to recreational fishing in Hawke Bay, Haggitt and Wade (2016) note that:

> *Currently the state of fisheries within Hawke's Bay is an extremely contentious issue due to very low catches, particularly within the recreational sector relative to previous decades.*

5.3. The Hawke Bay inshore fishery

5.3.1. Commercial fisheries context

New Zealand's quota management system (QMS) divides the exclusive economic zone (EEZ) into 10 fisheries management areas (FMAs; Figure 5). For each quota management species, separate stocks are defined by quota management areas (QMAs). The QMA may be the same as an FMA or a grouping of FMAs, depending on the geographical distribution of that fish stock. Commercial catch limits are set annually for each fish stock, as total allowable commercial catch (TACC).

Fisheries catch data has historically been collated from catch effort landing returns (CELR) into a Ministry of Fisheries (MFish, now Ministry for Primary Industries, MPI) database by Fisheries Statistical Area (FSA) within the EEZ. For each species or group, fishers reported catches to a unique FSA. For the last decade, such data have been recorded, for vessels longer than 6 m, at specific locations (latitude and longitude) instead of broad statistical areas.

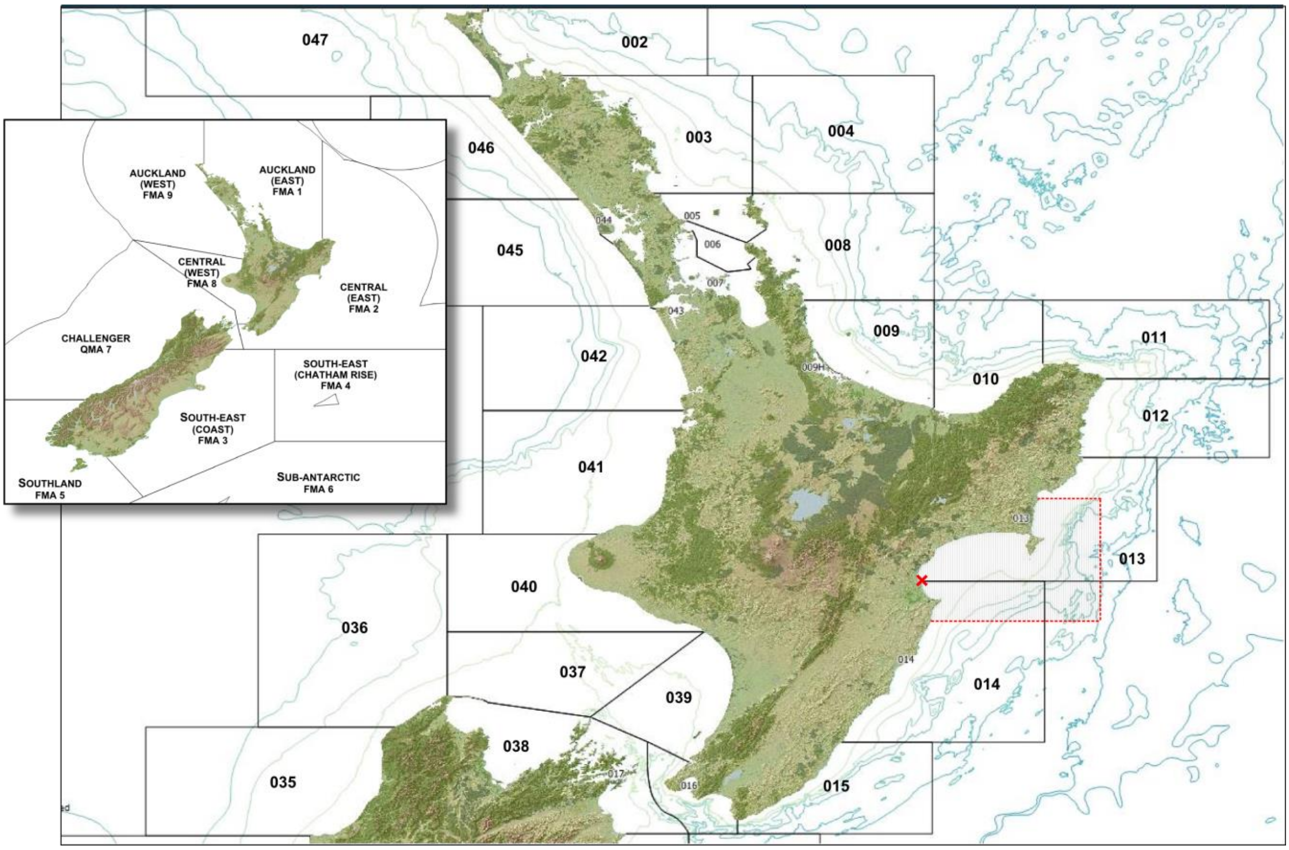

Figure 5. Fisheries management areas (FMAs, inset) and fisheries Statistical Areas (FSAs) for the North Island coastal regions. Location of the Port of Napier is designated by a red cross. The inshore region of Statistical Areas 013 and 014 covered by the Ministry for Primary Industries (MPI) data request is also shown.

The catch-effort database 'Warehou' is administered by MPI. The Port of Napier is situated on the boundary between Statistical Areas 013 and 014, within fisheries management area 2 (FMA 2; Figure 5). Commercial fishers land the majority of the finfish catch in FMA 2 by mid-water and bottom trawling, bottom long-lining and set netting methods.

5.3.2. Inshore Hawke Bay fishing restrictions

The principal commercial fishing restrictions in central to southern Hawke Bay are shown in Figure 6. Hawke Bay is part of larger inshore areas from East Cape to Castle Point within which bans are in place for pair trawling and fishing vessels larger than 46 m. Fears of the depletion of fish stocks through trawling and habitat damage in the area known as the 'Wairoa Hard' during the 1960s and 1970s led to the closure to commercial fishing of this large inshore area 26 km northeast of Napier in 1981 (Hashiba et al*.* 2014).

There is a prohibition on the use of Danish seine in Hawke Bay within 3 Nm of the shore. Additionally, Danish seine and the use of trawl nets by vessels larger than 13.5 m are prohibited within a line from Waipatiki Stream to Cape Kidnappers. Within lines between Ahuriri Bluff and either Petane Beach or Tukituki rivermouth, there is a prohibition on the use of any trawl net for commercial fishing. No commercial harvesting of paua or mussels is allowed within 1 km of the shoreline from Cape Runaway to Blackhead.

Two Mataitai areas are established in Hawke Bay. Moremore (a) extends 500 m from the shore and begins at Whirinaki Bluff, 11.6 km north of Port of Napier, and follows the coastline north-eastwards for approximately 18 km. Moremore (b) encompasses Pania Reef (Figure 6). In these areas, all commercial fishing is prohibited and amateur fishing regulations apply unless amended by appointed tangata tiaki/kaitiaki who can authorise customary food gathering.

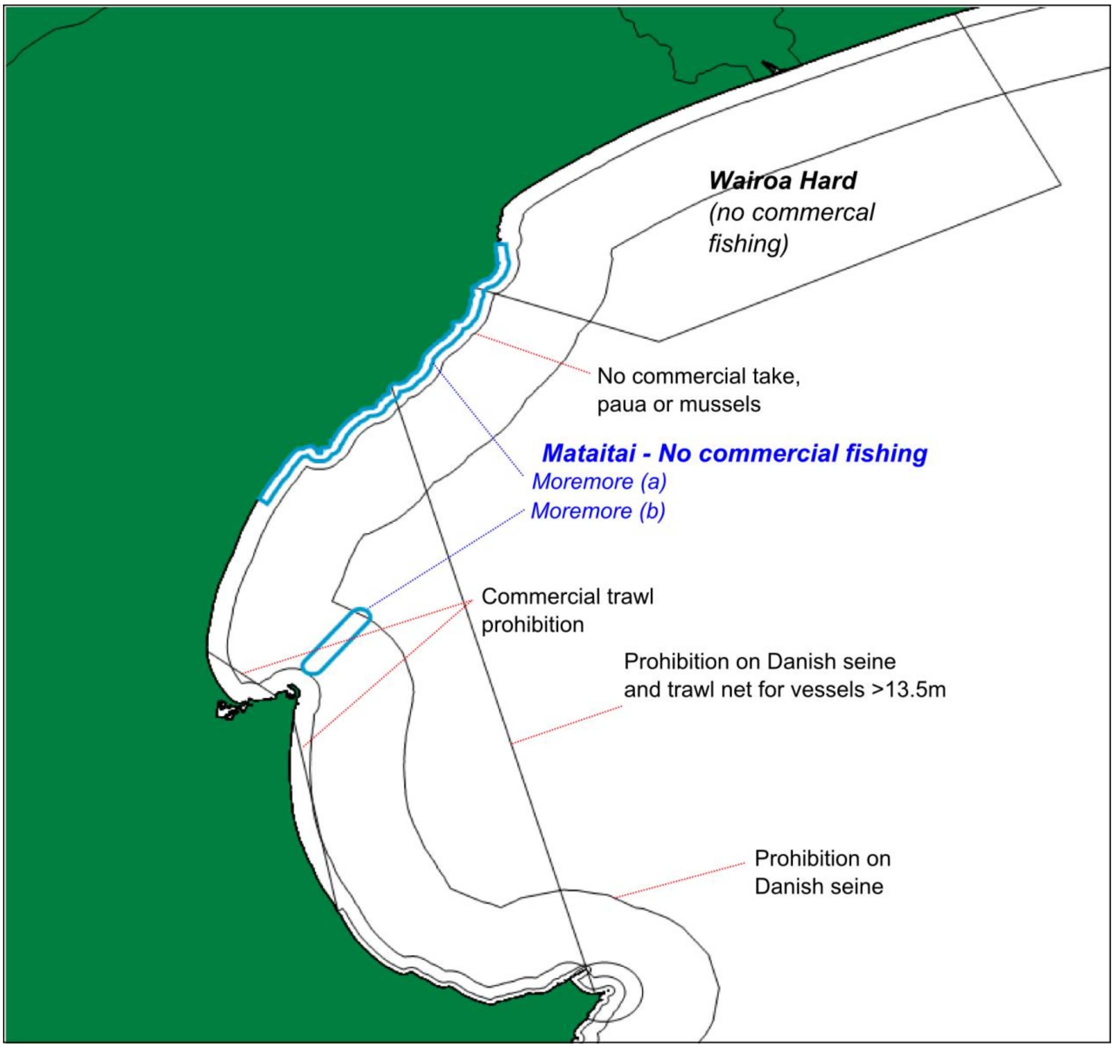

Figure 6. Commercial fishing restrictions in place for central and southern Hawke Bay (http://www.nabis.govt.nz/.).

5.3.3. Fisheries species important to inshore Hawke Bay

Principal target species by inshore trawling effort

In an effort to quantify benthic disturbance by trawl fishing within shallow inshore waters, Baird et al. (2015) analysed MPI data on fishing activity during fishing years 2008–2012 that used bottom-contact trawling methods (bottom trawls, bottom pair trawls, and midwater trawls within 1 m of the seafloor) in waters over the continental shelf. The data, which covered 48 target species, provide a good indication of the significance of particular demersal species in different areas nationally. Of 18 major target species, those for which trawl effort was concentrated within Hawke Bay included red gurnard, tarakihi, flatfish and snapper. Trawling effort for flatfish was concentrated in near-shore areas running south from Napier. Trawling effort targeting gurnard ranged from the near shore out to approximately the 100 m depth contour. In contrast, bottom trawl effort for tarakihi was concentrated between the 100 m and

250 m contours. The targeted snapper fishery is mainly north of East Cape, but within Hawke Bay, bottom trawling for this species is indicated to occur in an area of the southern Bay in around 50 m water depths from Napier to Cape Kidnappers. Species targeted in depths shallower than 50 m were generally limited to flatfish and elephant fish (median depth around 30 m). At 21 km offshore from the Port of Napier, the 50 m depth contour is considered to be well beyond the influence of sediment plumes arising from the proposed dredging project.

The following sections describe the relevant life-history, distribution and habitat preferences for the species most likely to be affected by disturbance to the near-shore region of southern Hawke Bay.

Flatfish

New Zealand's flatfish species are characterised by small size, rapid growth, short life-spans and relatively high fecundity. Flatfish are distributed widely throughout New Zealand, being frequently encountered in coastal inlets, embayments and estuaries. The ecology of juvenile flatfish is notable for the widespread use of specific nursery areas and low recruitment variability relative to other marine fish species. Inlets and lagoons functioning as nursery areas rely on being sufficiently open to the sea for recruitment to occur (Jellyman 2011). The flatfish fishery is comprised of eight species although typically only a few are dominant in any one QMA and some are not found in all areas. For management purposes all species are combined to form a unit fishery. The fishery is mainly confined to the inshore domestic trawl fleet except for a small incidental bycatch of soles, brill and turbot by offshore trawlers. The main fisheries landing flatfish as bycatch in FLA 2 target gurnard, snapper and trevally (MPI 2014).

New Zealand sole (*Peltorhamphus novaezeelandiae*)

Research trawls have caught New Zealand sole mainly around the northern North Island and east and west coasts of the South Island, including Tasman Bay, generally in water depths of less than 50 m. Only occasional individuals are found inside estuaries and harbours. No specific information is available on adult habitats, migrations and movements, spawning, or population connectivity (Morrison et al. 2014a). However, eggs of this species have been recorded from Pauatahanui Inlet and off the Otago coast from autumn to spring. Juveniles have been caught by trawlers in all areas where the species has been recorded, occurring inshore in less than 75 m depth. Hence key nursery areas, if they exist, have yet to be identified.

Sand flounder (*Rhombosolea plebeia*), yellow-belly flounder (*Rhombosolea leporine*)

Sand flounder are found in estuaries, embayments and shallow coastal regions (to a depth of 100 m) around the coast of New Zealand. Juvenile fish feed largely on amphipods, while decapods, sedentary polychaetes and cumaceans form the bulk of the adult diet (Morrison et al. 2014a).

Although both sand flounder (*R. plebeia*) and yellow-belly flounder (*R. leporine*) occupy similar depth ranges, the available literature indicates that the latter is the more inshore species of the two, favouring harbours and estuaries and generally slightly finer substrates. Both species are known to exhibit seasonality in their occurrence and distribution although their natural ranges overlap to a significant extent. Neither species is particularly specific in its food source and will take a variety of prey taxa that are known to be common within the wider area, particularly polychaete worms, crabs and molluscs.

Sheltered estuaries and harbours are typical nursery areas for sand flounder and juveniles are seasonally very abundant in such habitats around New Zealand. Juveniles are generally confined to the shallow tidal flats and along the shores near stream mouths (Morrison et al*.* 2014a). In the Ahuriri Estuary, yellow-belly flounder were the most prevalent of four flatfish species recorded by Kilner and Akroyd (1978).

Tagging surveys have demonstrated that sand flounder move to deeper waters to spawn during the late winter-spring months (Coleman 1978). Data from a number of regions support a long spawning period for sand flounder. From surveys of ichthyoplankton off Kaikoura, Hickford and Schiel (2003) recorded sand flounder larvae as being relatively common, and more so during sampling over full moon periods.

Colman (1976) showed that there were significant differences in mean number of fin rays in sand flounder between areas, concluding that stocks off the east and south of the South Island were clearly different from stocks in central New Zealand waters, and from those off the west coast of the South Island. Together with data from tagging studies, this generally suggests regionally localised populations with relatively limited movement.

Red gurnard (*Chelidonichthys kumu*)

Red gurnard are widely distributed around New Zealand. They occur from 10 m to 200 m water depths over muddy or sandy substrates. Although generally plentiful, red gurnard are more predominant in northern waters. Morrison et al*.* (2014a), citing Francis et al*.* (2002), described gurnard as *the most frequent species in the inshore assemblage* [with] *the widest latitudinal range and third greatest depth range* Although a major bycatch species of inshore trawl fisheries in most areas of New Zealand, including fisheries for red cod in the southern regions (MPI 2014), they comprise a significant targeted stock in Hawke Bay.

Red gurnard have a long spawning period that extends through spring and summer with a peak in early summer, although ripe, running ripe and spent fish are caught around most of New Zealand throughout the year. There are indications that fish move into deeper water as they get older and on a seasonal basis to spawn (Morrison et al*.* 2014a). However, spawning grounds appear to be widespread, there being no indications of any major geographical spawning aggregations or areas. Egg and larval development takes place in surface waters. Egg and larval development is pelagic with 8 days' drift before feeding begins. Recently settled juveniles are found in shallow harbours and estuaries between February and March, but in low numbers only, suggesting such habitats are of limited importance as nursery areas. It has been suggested that juveniles might occupy habitats not easily accessible to trawl and seine sampling such as rough ground. Research trawls have caught juvenile gurnard (0+ and 1+; 10–20 cm) around much of the coast of the North Island in depths less than 100 m, with highest catches in northern areas including the Hauraki Gulf, east Northland, Bay of Plenty, Hawke Bay and on the northern west coast (Hurst et al. 2000).

Tarakihi (*Nemadactylus macropterus*)

Tarakihi are a colder water species than snapper although they co-occur in many regions, including Hawke Bay. They are a demersal species that feeds on a wide range of small benthic invertebrates. Tarakihi are caught in coastal waters down to 400 m all around New Zealand and appear most abundant at depths greater than 100 m. There appears to be a broad pattern of tarakihi being found at shallower depths in more southern (and colder) waters (Morrison et al. 2014a).

The major commercial fishing grounds for tarakihi are west and east Northland, the western Bay of Plenty to Cape Turnagain, Cook Strait to Canterbury Bight and Jackson head to Cape Foulwind (Morrison et al. 2014a).

Tarakihi aggregate to spawn in a number of areas around New Zealand in summer-autumn. The pelagic larval and post-larval stages spend 9–10 months drifting in offshore waters before settling as juveniles. This extended larval phase allows significant spatial separation of spawning and nursery grounds (Morrison et al. 2014a). Large-scale movements during both larval and adult phases and lack of genetic isolation suggest that tarakihi around New Zealand are a single stock.

Tarakihi are noteworthy for juvenile associations with biogenic habitats. Vooren (1975) reported that tarakihi nursery areas featured a dense and varied invertebrate benthic epifauna dominated by sponges and small corals. Nationally, such nursery grounds occurred at depths of 20–100 m, and mostly between 10 km and 30 km from shore. Juveniles are thought to remain in particular nursery grounds for about three years before moving out into deeper waters. Vooren (1975) concluded that the major nurseries occurred in the South Island, and that these nurseries probably operated as sources of juveniles at the national scale. No specific nursery areas are indicated for Hawke Bay. Duffy (1992) recorded small numbers of juvenile tarakihi (about 50-70 mm) at reef sites south of Cape Kidnappers.

It is noted that tarakihi, as with snapper and many other species, have seasonal inshore-offshore migrations, as well as along-shore, which may or may not be part of spawning activities.

5.3.4. MPI fisheries data extract for Hawke Bay

A fisheries data request was submitted to MPI Data Management Group under the Official Information Act. This covered catch data over the most recent three-year time period to a spatial resolution of 0.1 ° (approximately 6 Nm). In order to optimise the data for assessment purposes, it was necessary to aggregate species within the data request. This is because MPI terms for the release of data include a 3 client / 3 vessel rule whereby, if fewer than 3 vessels or clients are represented within a defined cell and stratum, the data must be withheld as potentially commercially sensitive. Species aggregation is one way to minimise the information withheld by this rule, and was preferable in this case to decreasing the spatial resolution from the specified 0.1 ° grid size.

Two aggregates were established; one including all of the commercial flatfish species, the other including ten finfish and elasmobranch[8] species. This aggregation meant that effectively no catch-weight data were withheld for the years requested. The species selections were based on the fisheries literature and included those that are generally targeted (or are significant as by-catch) in waters of less than 50 m depth (Table 6).

While both barracouta and spiny dogfish typically represent a significant proportion of the landed catch, these species were excluded from the finfish aggregate. The rationale for this exclusion was based upon their regional ubiquity, wide depth-range preferences and non-specific benthic habitat requirements for crucial life stages. There was concern that the relatively large landed catch weights would obscure catch weight patterns for other species for which the shallow inshore waters may be more important. Additionally, catch weights for these species from both FSA013 and FSA014 have been relatively lower compared to values across all statistical areas, indicating that the region is not of national importance.

[8] A subclasses of cartilaginous fish which includes sharks, skates and rays.

Table 6. Fisheries species and FSA 13/14 catch weight (2013-2015 fishing years; kg) included to compile the aggregate data for Hawke Bay. The data extract for the flatfish aggregate also included catch information encoded to 'FLA', 'SOL', 'FLO' and 'SDF. DW = data withheld; NR = nil reported. FSA catch data for three important species not included in aggregates are also listed.

Aggregate / species code	Common name	Scientific name	FSA 013 Catch wt.	FSA 014 Catch wt.
FLAT	**Flatfish aggregate**			
FLA	Flatfish		*58,080*	*8,719*
BFL	Black flounder	*Rhombosolea retiaria*	*DW*	*DW*
BRI	Brill	*Colistium guntheri*	*1031*	*DW*
GFL	Greenback flounder	*Rhombosolea tapirina*	*DW*	*NR*
LSO	Lemon sole	*Pelotretis flavilatus*	*4,812*	*6,612*
ESO	New Zealand sole	*Peltorhamphus novaezeelandiae*	*93,259*	*85,890*
SFL	Sand flounder	*Rhombosolea plebeia*	*38,693*	*50,222*
TUR	Turbot	*Colistium nudipinnis*	*6,851*	*6,622*
WIT	Witch [a]	*Arnoglossus scapha*	-	-
YBF	Yellow-belly flounder	*Rhombosolea leporina*	*19,812*	*28,568*
FIN	**Finfish aggregate**			
RCO	Red cod	*Pseudophycis bachus*	*13,4540*	*152,017*
TAR	Tarakihi	*Nemadactylus macropterus*	*142,249 1*	*754,777*
GUR	Gurnard	*Chelidonichthys kumu*	*1,092,310*	*338,264*
MOK	Blue moki	*Latridopsis ciliaris*	*177,209*	*136,082*
TRE	Trevally	*Pseudocaranx dentex*	*282,736*	*153,896*
SNA	Snapper	*Pagrus auratus*	*335,025*	*31,456*
SCH	School shark	*Galeorhinus galeus*	*57,627*	*61,969*
ELE	Elephant fish	*Callorhinchus milii*	*7,566*	*50*
SPO	Rig	*Mustelus lenticulatus*	*126,708*	*38,459*
RSK	Rough skate	*Dipturus nasutus*	*33,967*	*36,343*
Additional species				
BAR	Barracouta	*Thyrsites atun*	*372,119*	*300,360*
SPD	Spiny dogfish	*Squalus acanthias*	*93,150*	*112,241*
JDO	John Dory	*Zeus faber*	*59,490*	*35,577*

a. Witch are distributed throughout New Zealand, though are more common around the South Island than the North. This species is not specifically targeted commercially.

The time frame covered by these data was from 1 October 2012 to 1 October 2015 (aggregated). Catch by all fishing methods was included. The area covered was defined as the inshore sections of Statistical Areas 13 and 14 out to longitude E178.5° and bounded by latitudes S38.75° and S39.8334°. Rounding rules were applied to align cell boundaries to 0.1 °, equivalent to a 6 Nm grid, with locality established by start position (e.g. of trawl track). The data outputs were represented spatially for each species aggregate using ArcGIS software (Figure 7 and Figure 8). Catch weight for each grid cell is given and represented by proportional symbols[9] to facilitate interpretation of the data.

Flatfish aggregate

An examination of the flatfish catch over the 2012–2015 fishing years shows that catch weight was relatively evenly distributed between Statistical Areas 013 and 014 for all species, although catch assigned to the generic FLA code was more prevalent for FSA013 (Table 6). The species most prevalent in catches across both areas were New Zealand sole (44%), sand flounder (22%) and yellow-belly flounder (12%), with the latter two species being slightly more prevalent in FSA014 (south of Napier).

For the defined area of the data extract, the total catch weight of flatfish was 384 tonnes, representing 94% of the total catch for Statistical Areas 013 and 014, underscoring the fact that flatfish are shallow-water species, generally found in waters less than 50 m depth (MPI 2014). This figure represents just 10% of the combined total of both aggregates, although the high value and exclusively near-shore distribution of the flatfish catch makes it potentially more important for consideration of effects from dredging activities. The flatfish catch for the three year period was relatively concentrated in the grid cells situated close inshore in the south-western end of the Bay with a secondary catch concentration in the north near Wairoa (Figure 7). Approximately 70% of the total catch of flatfish for the defined area came from the six grid cells surrounding Napier Port, most of this being from the coastal area south of Pania Reef and offshore from Hastings.

Finfish aggregate

At the level of fisheries Statistical Area, catch weights over the 2012–2015 fishing years for the ten finfish aggregate species show the relative importance of tarakihi and gurnard, being respectively 41% and 27% of the total combined weight for FSA013 and FSA014 (Table 6). For each of these species individually, catch weight was relatively lower for FSA104, being 35% (tarakihi) and 24% (gurnard) of the totals across both areas. This is consistent with the larger shallow inshore area of the Bay north of Napier being important for these species. While regionally much less significant in overall catch weight, the relative importance of FSA013 is more marked for snapper (91% in FSA013) and elephant fish (99%). At 0.1% of the combined aggregate finfish catch weight across both areas, elephant fish are a relatively insignificant component of the catch; however, like flatfish, this species is caught almost exclusively in shallow near-shore waters.

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[9] The Flannery compensation technique available in ArcMap™ v10 GIS has been used. This adjusts symbol sizes upwards to account for the fact that plot readers tend to underestimate the size of circular symbols.

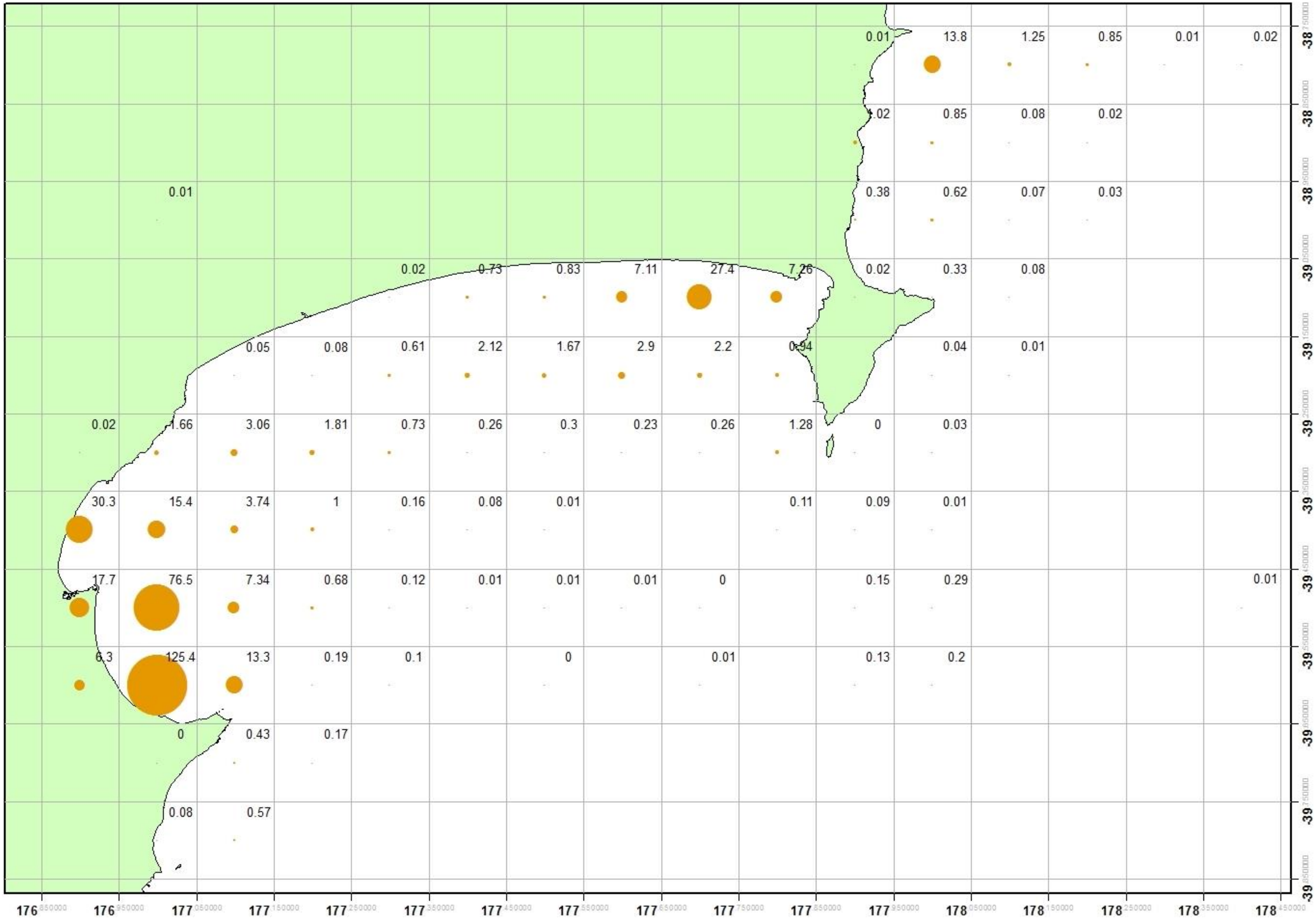

Figure 7. Recorded commercial catch weight (tonnes) for aggregated flatfish species in Hawke Bay (1 Oct 2012 to 1 Oct 2015) for 0.1 degree grid squares. Proportional symbols adjusted with Flannery compensation.

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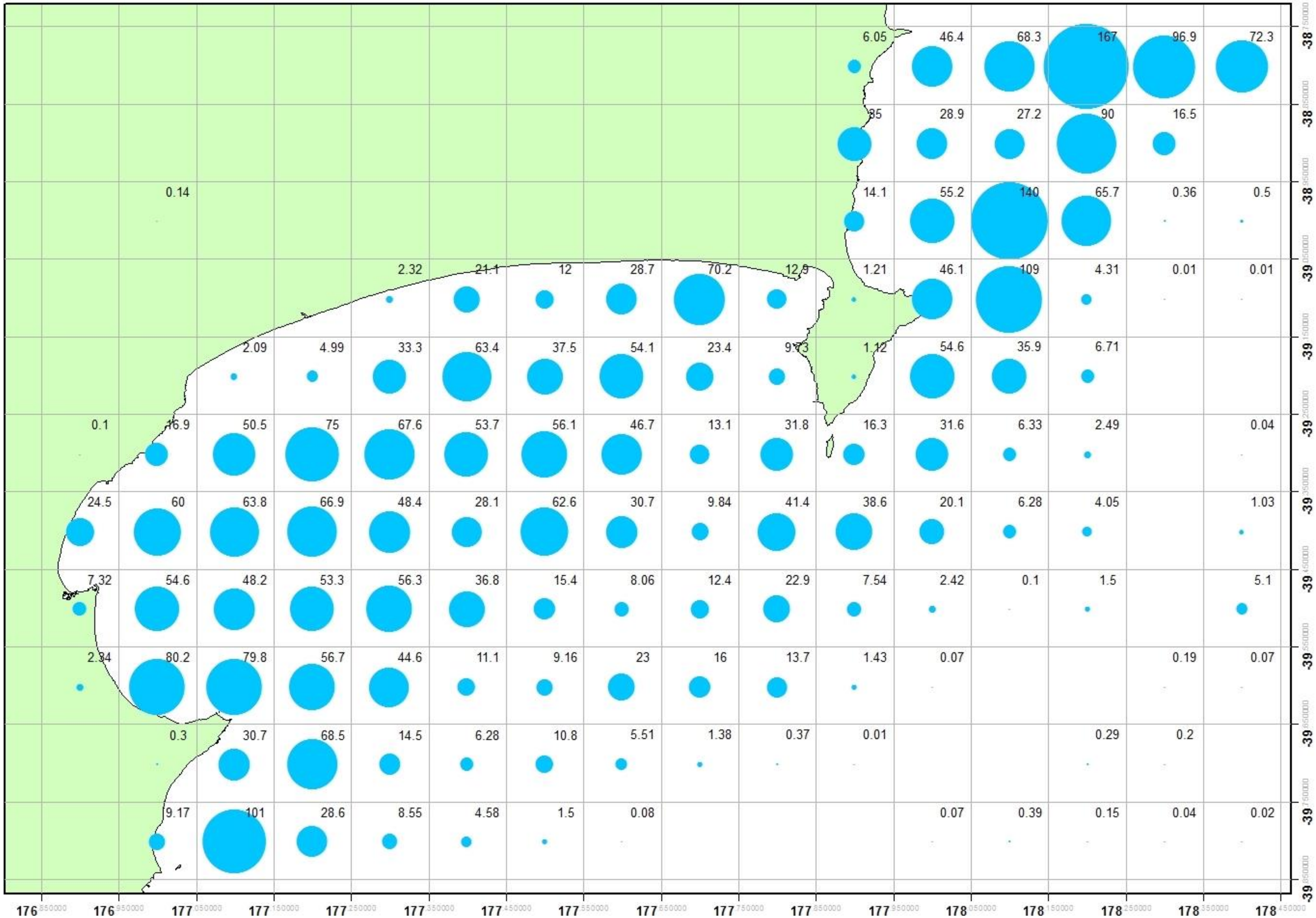

Figure 8. Recorded commercial catch weight (tonnes) for aggregated finfish species in Hawke Bay (1 Oct 2012 to 1 Oct 2015) for 0.1 degree grid squares. Proportional symbols adjusted with Flannery compensation.

For the defined area of the data extract, the total catch weight of the finfish aggregate was 3,505 tonnes, representing 65% of the combined total catch for these species over Statistical Areas 013 and 014 (Table 6). The spatial plot for the aggregated fin-fish species shows that landed catch weight over the period was relatively evenly distributed across the inshore area, but with higher catch weights generally north-east of Mahia Peninsula and, less markedly, around Cape Kidnappers (Figure 8). Catches for the two complete cells directly offshore from Port of Napier were reasonably typical of those spanning Hawke Bay in similar water depths. Similarly, the incomplete cells adjacent to the Port (those including a land component) showed catches generally proportionate to their sea area. This suggests that the waters within six nautical miles of the Port are not relatively more important for catches of these species.

5.4. Invertebrate species

There are a number of important invertebrate species that are fished in the Hawke Bay area. Of these, the two most sought-after on a national basis are blackfoot paua (*Haliotis iris*) and spiny rock lobster or crayfish (*Jasus edwardsii*). While less targeted generally, the New Zealand swimming crab (*Ovalipes catharus*) has been a significant if variable local fishery in the Napier area for several decades.

5.4.1. Paua

There was very little available information on the occurrence of paua in the Napier area. Paua are most common in clear water coastal situations, living from low water to 15 m. However, they tend to form large aggregations only in the upper part of this range. No paua were recorded from transect surveys of Pania Reef, and it is possible that its depth makes most of the Reef less than optimum habitat. Haggitt and Wade (2016) make reference to near-shore rocky reef habitat surrounding Napier (Tangoio Bluff, Pania Reef, Town Reef, Black Reef *etc.*) holding significant customary and recreational value for the collection of green-lipped mussels, kina, paua and rock lobster, but it is unclear whether Pania and Town reefs in particular supported local populations of paua. No commercial harvesting of paua is allowed within 1 km of the shoreline in Hawke Bay. Further notes on paua biology, life cycle and potential sensitivities are presented in Appendix 2.

5.4.2. Rock lobster

Rock lobsters are typically the largest and most abundant invertebrate predators on coastal rocky reefs throughout New Zealand. Two species are taken commercially, of which the packhorse lobster (*Sagmariasus verreauxi*) is limited mainly to the north of the North Island. Spiny rock lobsters (*J. edwardsii*) are more widely distributed and are often an important structural and functional component of rocky reef assemblages (MacDiarmid et al. 2013). Lobsters are common on Pania Reef where they are targeted by recreational fishers and divers. No commercial take occurs on the Reef due to its Mataitai status; however some commercial pots may be set on nearby Town Reef. Lobster distribution on the Reef appears to be related to the availability of suitable habitat and possibly to harvesting pressure. Based on the transect survey dives and on anecdotal information, they seem to be just as abundant on the inshore end of the Reef where higher turbidity and a greater level of settled fine sediment is typical, as on the offshore end.

The relevant statistical unit for southern Hawke Bay lobster fishery is Area 912 which extends from Waimarama, south of Cape Kidnappers to Wairoa. A query of MPI's NABIS website showed that catch weight for Statistical Area 912 over the three years up to and including 2015 was 110 t. This was significantly less than the 244 t for Statistical Area 911 (centered on Mahia Peninsula) or the 281 t for 913 (north Wairarapa coast) to the north and south, respectively. Further notes on rock lobster biology, life cycle and potential sensitivities are presented in Appendix 2.

5.4.3. New Zealand swimming crab (paddle crab)

Paddle crabs (*Ovalipes catharus*) are common within the Napier area and have been targeted commercially since 1977–78 when the stock was first exploited with catches off Westshore Beach. However, they are common off sandy beaches, and in harbours and estuaries throughout mainland New Zealand, the Chatham Islands, and east and south Australia, occurring from the intertidal zone to at least 10 m depth (MPI 2014).

A relatively large and fast-growing species, paddle crabs forage mainly in early evening and at night, moving into the shallow intertidal zone to feed mainly on either molluscs (especially surf clams) or crustaceans, but also on polychaetes, several fish species, cumaceans, and occasionally on algae (MPI 2014).

Although mating occurs in winter and spring in sheltered inshore waters, female crabs are believed to migrate to deeper water to spawn over the warmer months (September to March), after which the eggs are incubated until they hatch. A two month larval phase is thought to occur offshore in deeper water (to at least 700 m), after which the final (megalopa) stage migrates inshore to settle from January to May. This extended larval period is likely to ensure widespread dispersal and it is considered unlikely that biologically distinct stocks occur. MPI (2014) also suggests highly migratory adult behaviour based on tagging experiments.

Indications are that recreational take through direct targeting of paddle crabs is minimal, although they are taken as a bycatch of beach and estuarine seining and in set-nets throughout much of their geographical range.

MPI (2014) reports that there is no quantitative information available on non-fishing sources of mortality for this species.

From interviews conducted with customary, commercial, and recreational fishers Haggitt and Wade (2016) reported a reduction in paddle-crab numbers within Hawke Bay, However, MPI (2014) note that anecdotal information suggests a significant increase in paddle crab numbers since the 1970s, to the extent that concern has been expressed as to their potential impact on bivalve shellfish stocks. Haggitt and Wade (2016) also reported a perceived reduction of inshore and estuarine bivalve beds (particularly pipi and tuatua) in the Hawke's Bay region. MPI (2014) report that paddle crab landings have fluctuated significantly in most QMAs, mainly due to market variations. Additionally, while there are no reliable estimates of current and reference biomass, it is stated that paddle crabs are abundant throughout most of their range and the fishery is probably only lightly exploited.

Annual landed catch data for Statistical Areas 013 and 014 are presented in Table 7. There has been no consistent pattern to catches, and no apparent correlation between the two areas, which share a boundary at the latitude of Napier, placing the Westshore Beach area within FSA 013 (Figure 5). The catch in FSA 013 appears to have dropped off dramatically in 2014.

Table 7. Annual landed catch (in kilograms) for New Zealand swimming crab (*Ovalipes catharus*) in fisheries Statistical Areas 013 and 014 (Hawke's Bay region). Data from http://www.nabis.govt.nz/.

Fishing year	FSA 013	FSA 014
2009/10	11,948	65
2010/11	15,006	514
2011/12	14,094	21,533
2012/13	5,857	18,746
2013/14	Data withheld [a]	578
2014/15	Data withheld [a]	No catch reported
2015/16 (incomplete)	No catch reported	No catch reported

a. The likely reason for withholding data is that fewer than three vessels or fishers are represented within the area considered for that period.

5.4.4. Surf clams

Surf clams live in sediments seawards of low tide on open coasts around New Zealand. Due to the relative inaccessibility of this environment, they have not historically been targeted as a fisheries resource. This has changed in the last two decades, with some commercial efforts being made to exploit the resource. In 2004, seven surf clam species were added into the quota management system (Table 8). All seven occur within the wider area of Hawke Bay (Appendix 3) and there has been some interest in the viability of commercial harvest.

Table 8. The seven species of surf clam now included in the fisheries quota management system.

Common name	**Scientific name**	**Fisheries code**	**Family**
Deepwater tuatua	*Paphies donacina*	PDO	mesodesmatid
Fine (silky) dosinia	*Dosinia subrosea*	DSU	venerid
Frilled venus shell	*Bassina yatei*	BYA	venerid
Large trough shell	*Mactra murchisoni*	MMI	mactrid
Ringed dosinia	*Dosinia anus*	DAN	venerid
Triangle shell	*Spisula aequilatera*	SAE	mactrid
Trough shell	*Mactra discors*	MDI	mactrid

The NABIS online database identifies distributions of surf clams according to locations where they have been found, what is considered their normal range and 'hot-spots' where they are known to be particularly prevalent. Although all of the quota species are shown to occur along the full length of the Hawke Bay shoreline, the only species for which hot-spot status is accorded to the Napier region is the triangle shell (*Spisula aequilatera*), in a band which encompasses all of southern Hawke Bay, running continuously from Tongoio Bluff to Cape Kidnappers. Hot-spot status has been accorded to *Paphies donacina* and *Dosinia anus* for northern Hawke Bay east of Putorino and Mohaka, respectively (Appendix 3).

Surf clam species which have occurred in the Port of Napier survey samples (including the consented disposal grounds off Westshore Beach) include all those listed above except *Bassina yatei*, *Paphies donacina* and *Mactra murchisoni*. The occurrence of these species has been generally low, but the sampling methods used were not aimed at collecting larger organisms at the sediment depths at which surf clams generally live (up to 15 cm). Nonetheless, infaunal cores should collect the juveniles of these species in the upper sediment layers, where these are present. From the 166 individual infauna samples collected offshore from Westshore Beach across the three survey years (2004, 2007, 2012), the most commonly identified surf clams were the venerid species *Dosinia subrosea* and *D. anus*. However, the total counts for these two species were low (131 and 56, respectively). There were also low numbers of *Spisula aequilatera* (9 individuals in 2004 only) and *Mactra discors* (8 individuals in 2012 only).

Mortality and recruitment of surf clams are generally highly variable. Recruitment of spat can naturally vary greatly from year to year, and between beaches, with little or no recruitment occurring for several years on some beaches[10].

[10] http://www.fish.govt.nz/NR/rdonlyres/3FFE3A71-6FD6-4AD8-8F8F-24E972FB5FEA/0/clams_ipp.pdf

6. CHARACTERISATION OF BENTHIC ENVIRONMENTS

6.1. Fairway, outer Swing Basin and adjacent soft-sediment areas

The range and spatial coverage of sampling and survey methods conducted within and adjacent to the Port approaches is shown in Figure 9. Location data are listed in Appendix 1. The station label codes represent three generalised sampling areas. ’R’ refers to the near-shore area adjacent to the Port and immediately west of the main Port reclamation. ‘CD’ refers to the main northerly approach channel area. ‘B’ refers to the area adjacent and immediately north of the Port spur breakwater[11]. For a more general spatial key to sample label codes, refer to Figure 3.

6.1.1. Sediment grain size distribution

The seabed in the vicinity of the Central Fairway was composed predominantly of relatively fine-grained soft sediments (Figure 9, Figure 10). The dominant grain size fractions were fine and very fine sand, comprising on average, 51% and 31%, respectively, of the samples by weight (all ‘CD’ samples plus B13, B14). Together with the silt/clay component (13.5%), these fractions (representing particles < 250 μm) constituted an average of 95% of the sediment by dry mass.

The sample stations identified as being within areas which have previously been subject to maintenance dredging (principally the Central Fairway channel) were generally similar in grain size distribution to that of the surrounding seabed; however these sediments tended to have a slightly higher organic content and a slightly higher proportion of the silt and clay fraction (< 63 μm). This variation in sediment texture is likely to have resulted from the deepened channel section functioning as a sediment trap for deposited fine particulates, as well as potentially from the exposure (by dredging) of the underlying stiff silt material.

At generally less than 3% w/w AFDW, the sediments were not particularly organically enriched (Figure 10). Although some variability was observed, samples from shallower water depths (< 10 m) tended to show a slightly higher proportion of medium and coarse sands and slightly lower proportions of silts and clays. Diver observations indicated homogenous, well-sorted sands in the inshore parts of area B, north of the breakwater.

Outside of the maintained channel, sediment characteristics were found to vary little for stations in water depths greater than 10 m. The variability observed for stations inside the maintenance dredged areas may reflect the irregularity and limited spatial scales over which such dredging is required. Regardless, it is notable that the observed shift in sediment texture between undredged and dredged areas is small.

[11] While these labelling conventions were applied in the original sampling surveys, the areas have no distinct physical or operational boundaries in the context of the current proposal.

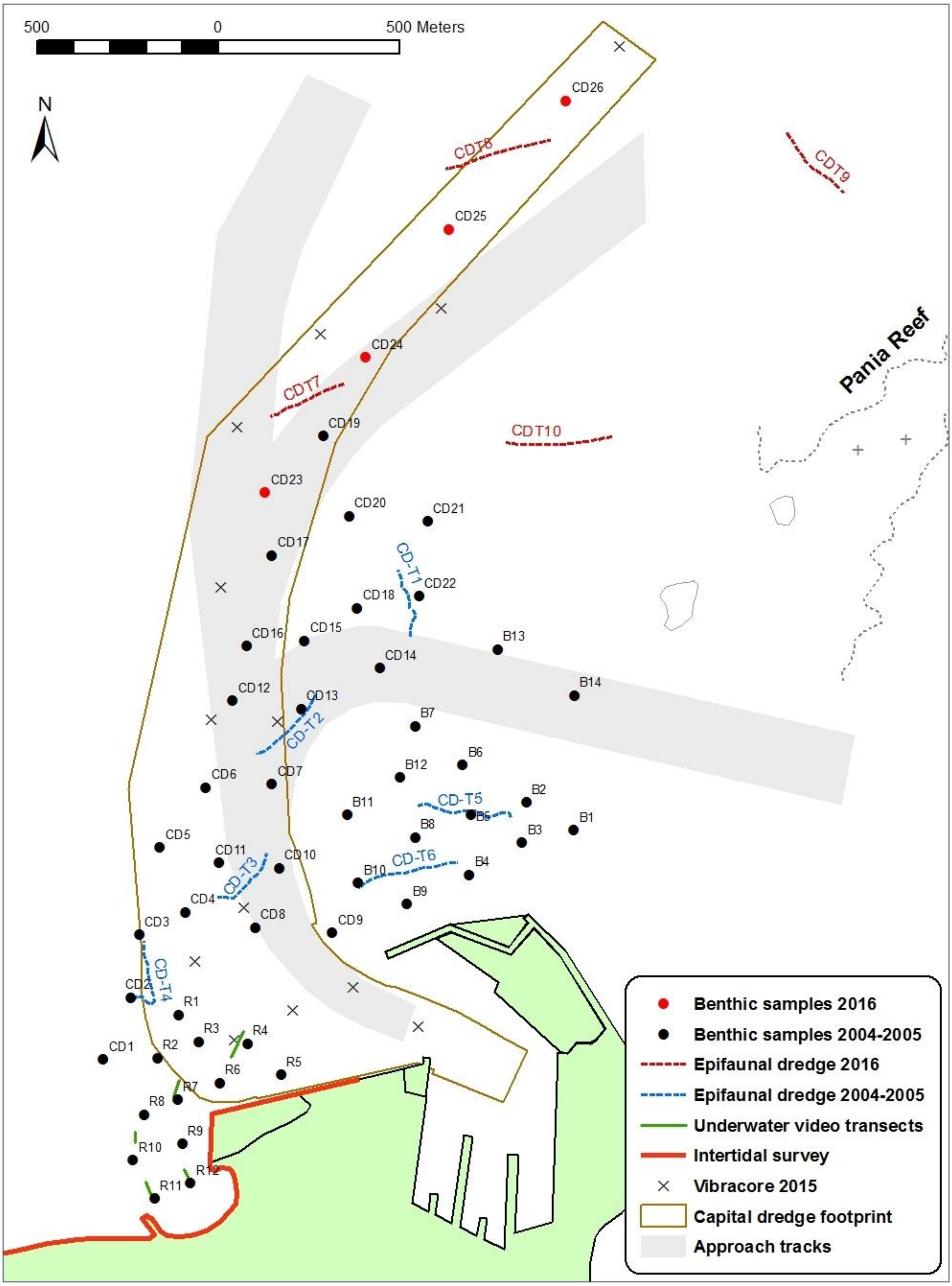

Figure 9. Schematic of Port of Napier and entrance channel overlaid with the proposed dredging area and showing components of benthic surveys.

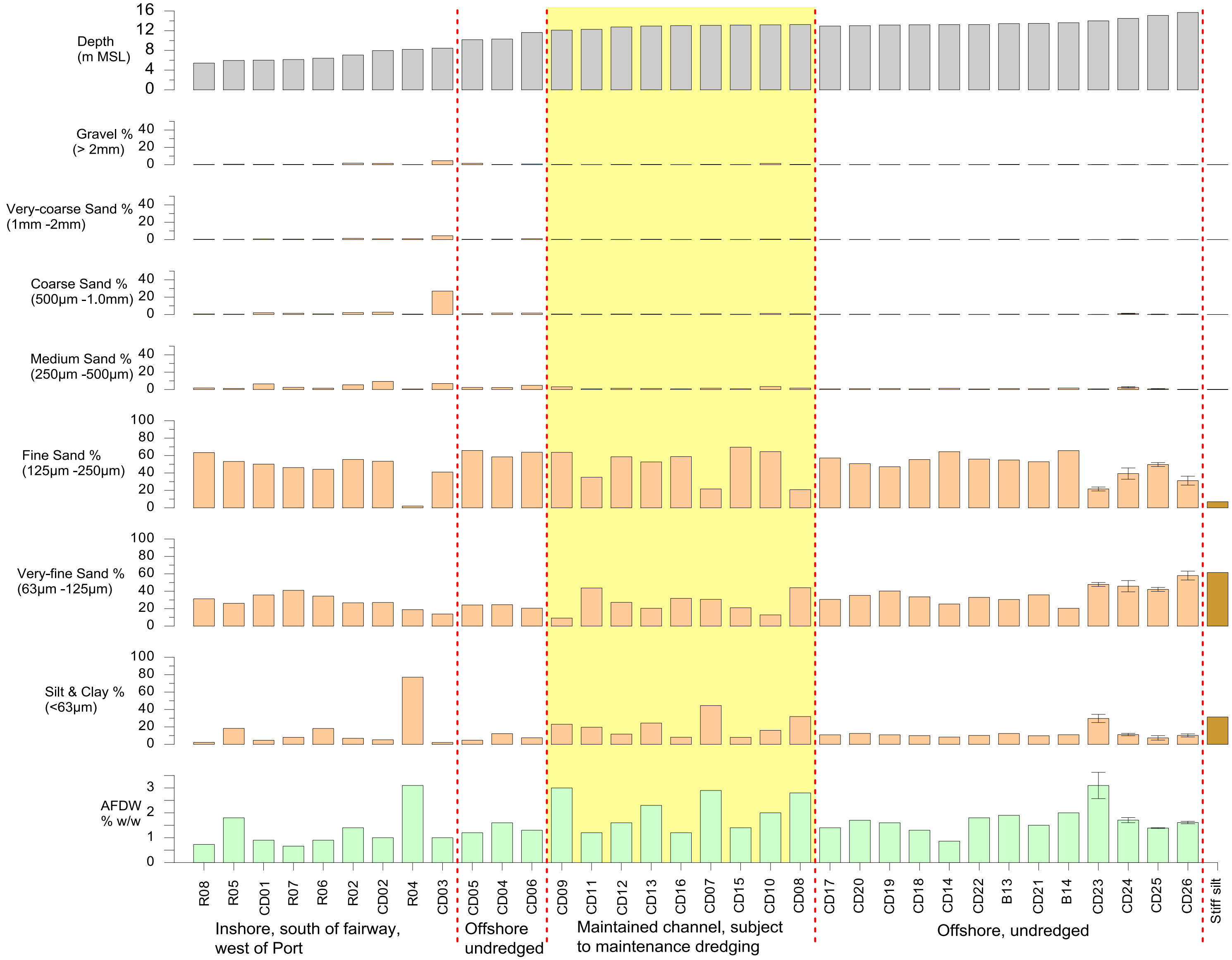

Figure 10. Grain-size distribution (% wt.) and organic content (as AFDW) of sediments collected in the vicinity of the approach channel. Those in areas subject to maintenance dredging are grouped (shaded yellow); otherwise order is by depth (mean sea level). Grain-size distribution for the stiff silt sample is also shown (AFDW not measured).

Stiff silt material

The results from both sieve analysis and laser diffraction showed that the main component of the underlying 'stiff silt' material that would be removed by capital dredging is very fine sand (< 125 µm and > 63 µm) rather than silt (< 63 µm). However, this sediment is likely to derive its cohesive properties from the 30% fraction in the sub-63 µm size class. It is notable that the stiff silt sample has a somewhat different grain size distribution compared even to that of the unconsolidated surface sediments in the periodically dredged approach channel (Table 9).

Table 9. Results of sieve analysis of stiff silt material compared to mean grain size distribution for surficial sediments from previously dredged and undredged areas. Samples wet sieved using Udden-Wentworth scale.

Particle size class	Sieve size	Proportion (% dry weight)		
		Stiff silt material	Surficial sediments	
			Dredged Channel [a]	Offshore undredged [b]
Gravel	> 2 mm	<0.1	0.6	0.1
V. Coarse Sand	< 2 mm & > 1 mm	0.1	0.5	0.2
Coarse Sand	< 1 mm & > 500 µm	0.1	0.9	0.4
Medium sand	< 500 µm & > 250 µm	0.1	2.4	1.0
Fine Sand	< 250 µm & > 125 µm	6.9	42.7	43.7
V. Fine Sand	< 125 µm & > 63 µm	61.5	24.2	41.9
Silt & clay	< 63 µm	31.4	28.9	12.8

a. Mean of four composite surface sediment samples (CD07-CD10) collected from the inner part of the dredged channel (Figure 9).

b. Mean values for sample stations to seaward of the maintained Central Fairway channel; comprising samples CD17, CD19-CD-21 and CD23-CD26 (Figure 9).

Results from the stiff silt sample analysed by laser diffraction (presented in Appendix 4) provide more detail on the sub-63 µm fraction and demonstrate that the grain-size distribution was in fact tri-modal, with frequency peaks at approximately 0.2 µm, 9 µm and 81 µm. Laser diffraction recorded 59% and 88% (by volume) of the material less than 63 µm and 125 µm, respectively, in contrast to 31% and 93% (by weight) for sieve analysis. The reasons for this disparity are likely to arise from factors related to particle density and/or shape. As noted in Section 4.1.2, the two techniques have only limited comparability, measuring essentially different properties of the material[12].

During preparation of seawater suspensions of the stiff silt material for turbidity and TSS analysis, it was found that the cohesive nature of the material was such that

[12] Sieve analysis gives a number-length mean (D[1,0]) by essentially measuring the second smallest dimension of the particle, whereas laser diffraction generates the equivalent volume mean (D[4,3]), which is identical to the weight equivalent mean only if particle density is constant.

sonication of the sample was required to disperse the clumps. The relationship between turbidity and TSS concentrations (up to 250 mg/L: Figure 11) for this material was found to be highly linear ($R^2 = 0.99$) over the relatively wide range of nominal concentrations prepared (0–2,000 mg/L). Because of relatively rapid settlement of the very fine sand fraction during the stabilisation of the turbidity reading (~15 sec), only the silt and clay fraction will have contributed to the turbidity and TSS measured.

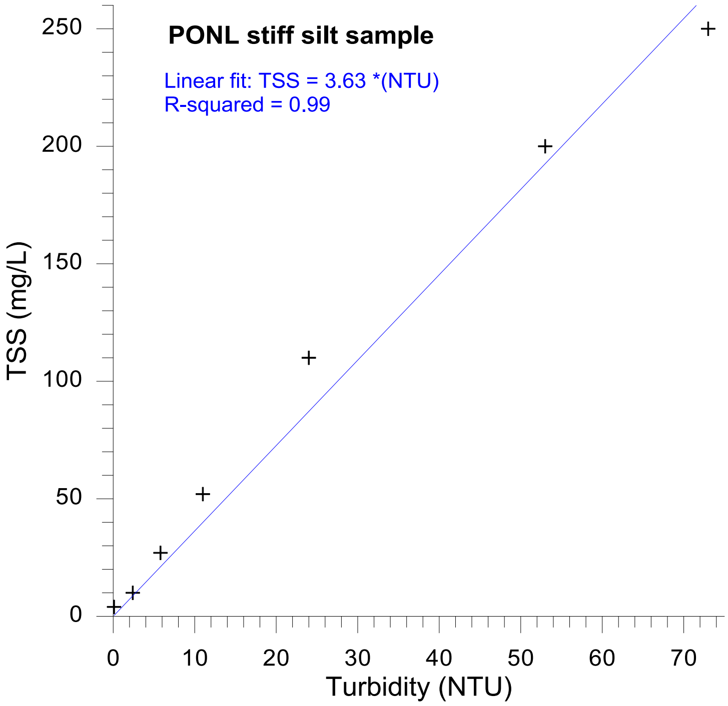

Figure 11. Relationship between turbidity (NTU; Hach 2100N bench turbidimeter) and total suspended solids for a series of suspensions in filtered seawater prepared using the stiff silt material. A linear trend line has been fitted to the data by least squares regression.

6.1.2. Sediment contaminants

Fairway and vicinity

Contaminant concentrations have been very low in all sediment samples collected from the Fairway area. All trace metals were at concentrations well below ANZECC (2000) ISQG-Low guideline values (Table 10). Semi-volatile organic compounds (SVOCs) and organotin compounds were all below detection limits for the four samples for which they were analysed (CD02, CD06, CD08, CD13 and the two vibracore samples; Appendix 5). These levels are very low compared to sediments analysed from other ports, both within New Zealand (e.g. Ports of Auckland Ltd 1990; Roberts & Forrest 1999; Keeley & Barter 2004) and internationally (e.g. Fowler 1990). The main reasons for this are likely to be that the Fairway sediments have a relatively low proportion of silts and clays and exist outside of the confined boundaries of the Port in a relatively high-energy, dispersive environment. The absence of vessel maintenance facilities at the Port is also notable as these can represent a significant source of contamination.

Table 10. Results of analyses for organic content (as ash-free dry weight) and trace metals in sediments from the vicinity of the Central Fairway. All metals concentrations expressed as mg/kg dry weight. Samples from areas that had been subject to maintenance dredging are shaded yellow. Depths corrected to mean sea level.

Sample station	***Depth (m)***	***AFDW (%w/w)***	***As***	***Cd***	***Cr***	***Cu***	***Pb***	***Hg***	***Ni***	***Sn***	***Zn***
CD01	6.0	0.9	< 5	< 0.1	8.5	1.3	4.1	< 0.05	4	0.3	20
CD02	8.0	1.0	< 5	< 0.1	8.3	1.4	3.6	< 0.05	4	0.3	14
CD05	10.2	1.2	< 5	< 0.1	10	1.2	3.3	< 0.05	5	0.3	15
CD06	11.6	1.3	< 5	< 0.1	8.4	1.6	3.8	< 0.05	5	0.3	22
CD08	13.3	2.8	< 5	< 0.1	9.8	2.7	5.5	< 0.05	6	0.4	17
CD09	12.1	3.0	< 5	< 0.1	10	2.8	5.6	< 0.05	6	0.4	25
CD10	13.2	2.0	< 5	< 0.1	9.6	2.1	4.7	< 0.05	6	0.4	25
CD13	12.9	2.3	< 5	< 0.1	12	2.8	8.0	< 0.05	7	0.4	37
CD14	13.2	0.86	< 5	< 0.1	7.8	1.8	4.7	< 0.05	5	0.4	22
CD17	13.4	1.4	< 5	< 0.1	11	2.4	5.5	< 0.05	8	< 1	28
CD20	13.4	1.7	< 5	< 0.1	8.8	2.5	5.7	< 0.05	6	< 1	32
B13	13.6	2.0	< 5	< 0.1	9.3	2.2	5.4	< 0.05	6	< 1	32
CD23	14.0	3.1	6.4	0.021	12.4	4.2	8	0.053	8.3	-	36
CD24	14.5	1.7	4.9	0.025	8.1	2	5.3	0.038	5.6	-	23
CD25	15.1	1.4	4.4	0.014	7.3	1.9	5.1	0.049	5.3	-	23
CD26	15.7	1.6	5.7	0.017	8.8	2.2	6.1	0.054	6.1	-	26
Vibracore 1 [a]	-	-	5.5	0.029	11.6	5.0	8.6	-	8.6	-	35
Vibracore 2 [b]	-	-	2.0	0.113	12.5	3.8	9.3	-	11.7	-	29
ISQG-Low [c]	-	-	20	1.5	80	65	50	0.15	21	-	200
ISQG-High [c]	-	-	70	10	370	270	220	1.0	52	-	410

a. Composite sample from 12 deep cores collected from the Fairway December 2015.
b. Surficial sample from single core collected from Port entrance/Swing Basin December 2015.
c. Interim Sediment Quality Guidelines (ANZECC 2000).

Toxicity testing (Microtox^{TM}) was carried out on a sediment sample composited from material obtained from 12 of the vibracore samples collected from within the Fairway in December 2015. The Microtox^{TM} test involves the preparation of elutriates by mixing 30 g of sediment with 10 mL of seawater in a rotary shaker, in complete darkness, for 24 hours. The suspension is then centrifuged and the supernatant subjected to the Microtox^{TM} bioluminescent bioassay procedure using the bacterium *Vibrio fischeri* (Beckman 1982). The test indicated no detectable toxicity and it was concluded that the sediment represented by the seabed sample may be considered 'non-toxic' for potential impacts on water column biota during dredging operations (Martin 2016).

Port Swing Basin

There is only limited available information regarding contaminant levels in benthic sediments from the Port of Napier Swing Basin and berth pockets; however PONL is required by its resource consent for maintenance dredge spoil disposal to ensure that there is no statistically significant toxicity to marine life from the dredged sediment. As a minimum, this involves annual Microtox^{TM} ecotoxicological testing of composite sediment samples from the berths, Swing Basin and Fairway, comprising sub-samples from seven, four and four stations, respectively (Figure 12). To date, this has been carried out by the National Institute of Water and Atmospheric Research (NIWA). Testing carried out since 2006 has reported no evidence of toxicity for any sediment sample.

Analysis of inner Harbour sediments associated with specific stormwater outfalls is carried out as required by PONL's stormwater discharge consent. Since these sediments are directly impacted by stormwater flows, they cannot be held to represent contaminant levels in bulk dredge spoil but provide information on relative inputs and loads as a worst-case scenario. As part of an investigation to support the stormwater consent application, Barter (2005) sampled sediments affected by run-off into the inner Harbour from six Port catchments. These were analysed for a range of contaminants including metals and SVOCs. Metals concentrations in these sediments were generally low, with no values exceeding ANZECC (2000) ISQG-High criteria. Cadmium exceeded ISQG-Low for three of these catchments and a single exceedance was recorded for each of lead and zinc. Only for zinc (at 330 mg/kg) was the exceedance more than marginal. Of the SVOC suite of analytes, polycyclic aromatic hydrocarbons (PAHs) made up the majority of compounds present above analytical detection limits and most of these were below ISQG-Low criteria. A single instance of the detection of the organochlorine pesticide DDT (0.1 mg/kg) was the only analyte to exceed the ISQG-High guideline value (0.046 mg/kg) and antifouling coatings were identified as a possible Port source (DDT has been historically added to some such paints and may still occur on foreign-flagged vessels). A paint-chip source would be consistent with both the discrete occurrence in sediments and the relatively high concentration.

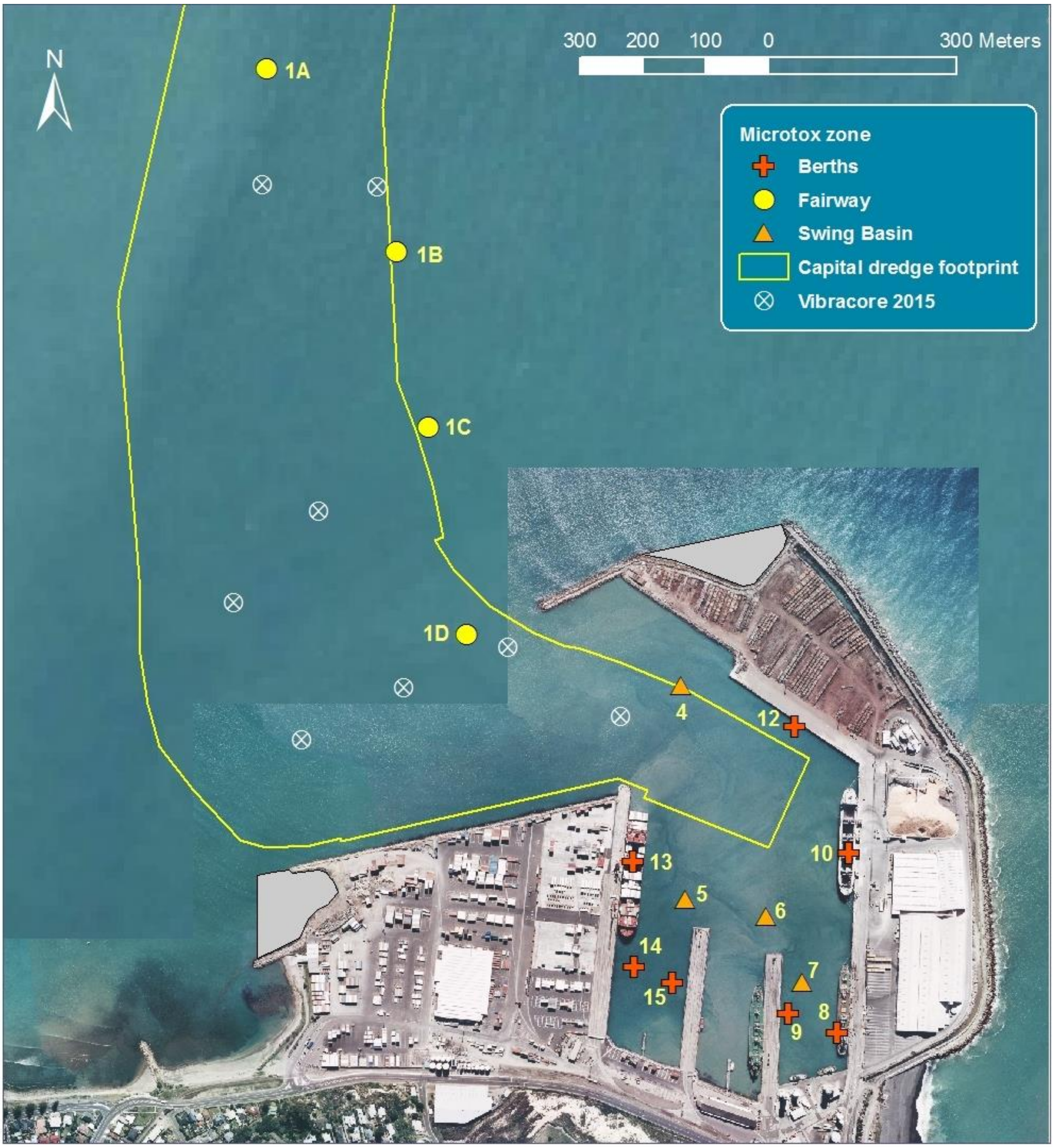

Figure 12. Locations of sample stations from which single composite sediment samples for Microtox™ testing are generated annually for the Berth Pocket, Swing Basin and Fairway zones.

Continuing bi-annual monitoring of five of the sediment sites associated with stormwater outfalls has been conducted for metal contaminants[13] and total petroleum hydrocarbons (TPH). Of the four monitoring occasions between 2006 and 2012, no metal analyte exceeded ISQG-Low and TPH has been consistently below analytical detection limits (Sneddon 2012a).

[13] The metals suite is cadmium, chromium, copper, lead, nickel and zinc.

Between 2013 and 2015, an extensive area of the inner Swing Basin was dredged, deepening it from an existing depth of 11.2 m to a depth of 12.0 m. The berth pockets were deepened from 11.8 m to 12.5 m. While these areas had been subject to periodic maintenance dredging, the capital nature of this recent work would have exposed virgin substrate over most of this area. This means that any accumulation of contaminants in sediments to be dredged as part of the current proposal will be effectively limited to inputs over the last 2 years.

6.1.3. Infaunal communities

A comparison of sediment infauna data from 34 sites from all surveys in the area of the Port approaches (the vicinity of the Fairway and adjoining areas) found significant spatial uniformity, particularly within individual depth strata. Infauna assemblages were dominated by amphipods, polychaetes, nemertean worms and ostracods (Table 11). Of these, amphipods and the deposit-feeding polychaetes, *Heteromastus filiformis* and two species of the genus *Prionospio*, were the most abundant.

The number of infauna taxa found in these areas ranged between 9 and 39 per core and the number of individuals varied, largely dependent upon the abundance of a few polychaete species that can occur in high densities. Infauna densities ranged between 22-527 individuals/0.013 m^2 core. Differences in infauna abundance, diversity and evenness between undredged and dredged areas were not large. However the samples from the maintained channel and the shallow area of mixed substrates west of the Port (prefix ‘R’; Figure 9) were notable for a greater variability in all characteristics and indices (Figure 13). For most samples that were analysed for both grain size and infauna, correlations were observed between the silt/clay content of the sediment and both abundance and community evenness (Figure 14). Although such changes are likely to result from a shift to finer substrates, both infauna indices and fines content are related, in this instance, to the level of physical disturbance to the seabed.

Table 11. List of the key infauna species that most contribute to the similarity of sites (SIMPER, Fourth-root transformed data, PRIMER v.5) in the Fairway and adjacent areas (survey areas CD and B; Figure 9). Top 80% of contributing species. Average similarity = 53%.

Species	Av.Abund.	Av.Sim.	Sim/SD	Contrib%	Cum.%
Prionospio sp.	12.74	7.86	0.95	26.96	26.96
Heteromastus filiformis	17.58	7.51	0.96	25.76	52.72
Amphipoda	9.78	4.46	0.82	15.30	68.02
Cumacea	3.00	1.55	0.95	5.31	73.33
Spiophanes modestus	2.42	1.41	0.52	4.85	78.18
Owenia petersenae	10.28	0.92	0.28	3.16	81.33
Prionospio aucklandica	7.84	0.72	0.32	2.46	83.79
Sigalionidae	0.88	0.53	0.58	1.81	85.60

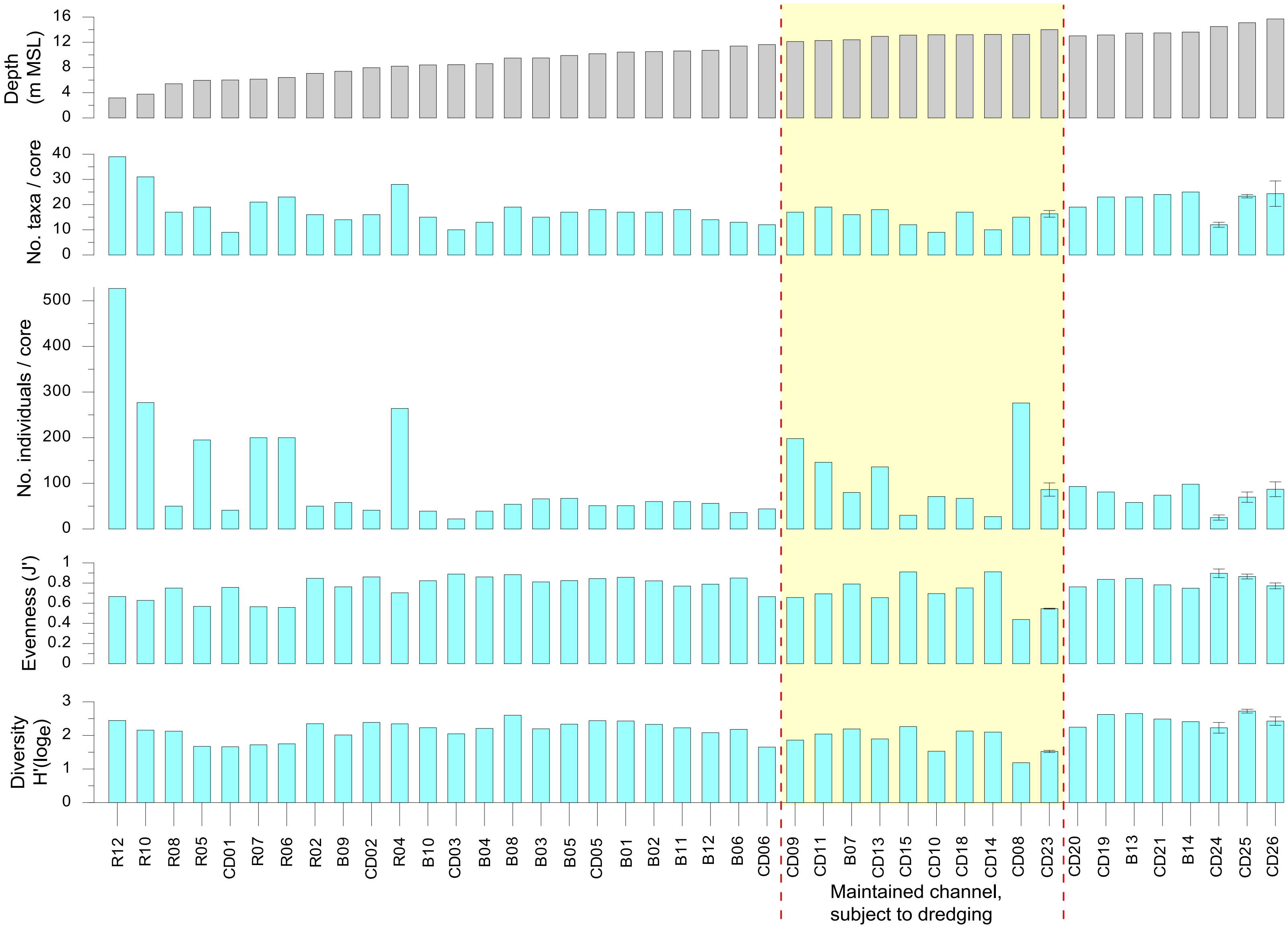

Figure 13. Sample depth, number of infauna taxa (species richness), infauna abundance, evenness (J') and diversity (H'_{loge}) from samples collected around the Fairway area. Samples collected from areas that were previously subject to maintenance dredging are grouped (and shaded yellow) to aid visual interpretation; otherwise order is by depth (referenced to mean sea level).

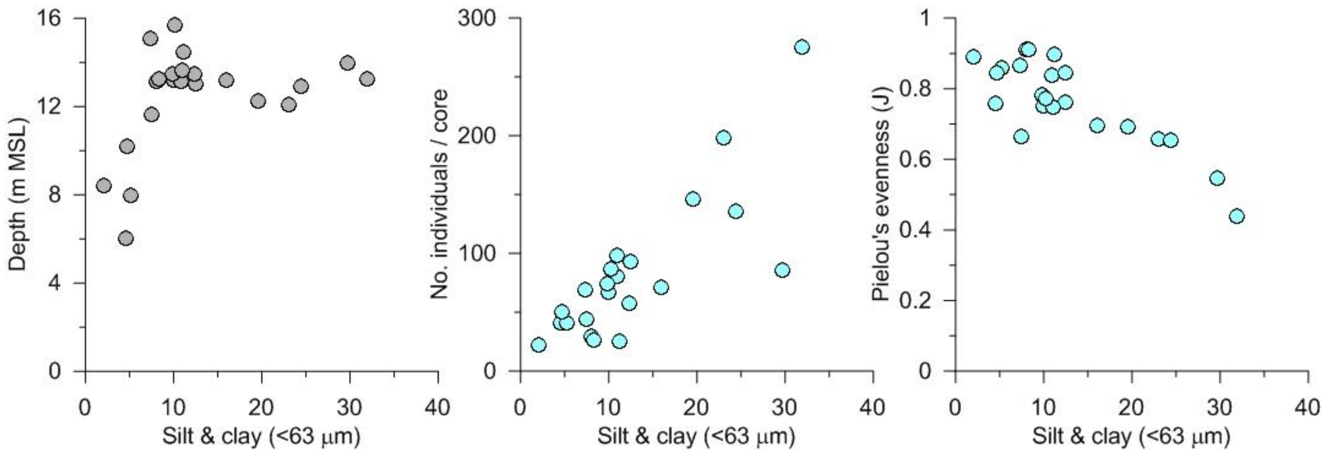

Figure 14. Relationships between silt and clay content of sediments with depth, infauna abundance and infauna community evenness.

The moderate stress value[14] of 0.21 associated with the multi-dimensional scaling (MDS) plot of the compiled infauna count data (Figure 15) indicates that the spatial arrangement of sample points does not represent the actual relative differences and groupings particularly well. However, the plot does serve to illustrate an apparent temporal shift in macroinvertebrate communities that has occurred since the 2004 survey. The factors contributing most to this change were a decrease in the abundance of the spionid polychaete *Prionospio aucklandica* and increases in cirritulid polychaetes and the capitellid *Heteromastus filiformis*. The presence of bivalve molluscs from the family Mactridae was also not reported from the earlier survey. While it is possible that some of these differences are attributable to the location of the 2016 samples further offshore, the spatial overlap of the two sample sets does not support this very well. Macrofaunal communities can be spatially patchy in otherwise fairly homogeneous environments as well as temporally variable. The decade-long temporal gap between the two sampling events means that such differences may be expected.

The weak resolution of 'In channel' and 'Near channel' groups in the MDS plot indicates that differences between communities within the dredged channel and those outside of it were relatively minor. Communities affected by maintenance dredging were largely dominated by the same types of organisms, and predominantly the same species.

[14] Distances on the MDS plot represent the relative similarity of the community assemblages (closer = more similar). These distances have only relative, not absolute, meaning. Thus the stress value is a dimensionless quantity and is a measure of the difficulty involved in compressing the sample relationships into two dimensions. A stress value of < 0.1 corresponds to a good ordination with no real prospect of a misleading interpretation, while a stress value of < 0.2 still gives a potentially useful 2-D picture. Stress values within the range of 0.2 to 0.3 should be treated with a great deal of scepticism, particularly if in the upper half of this range and for sample sizes of < 50.

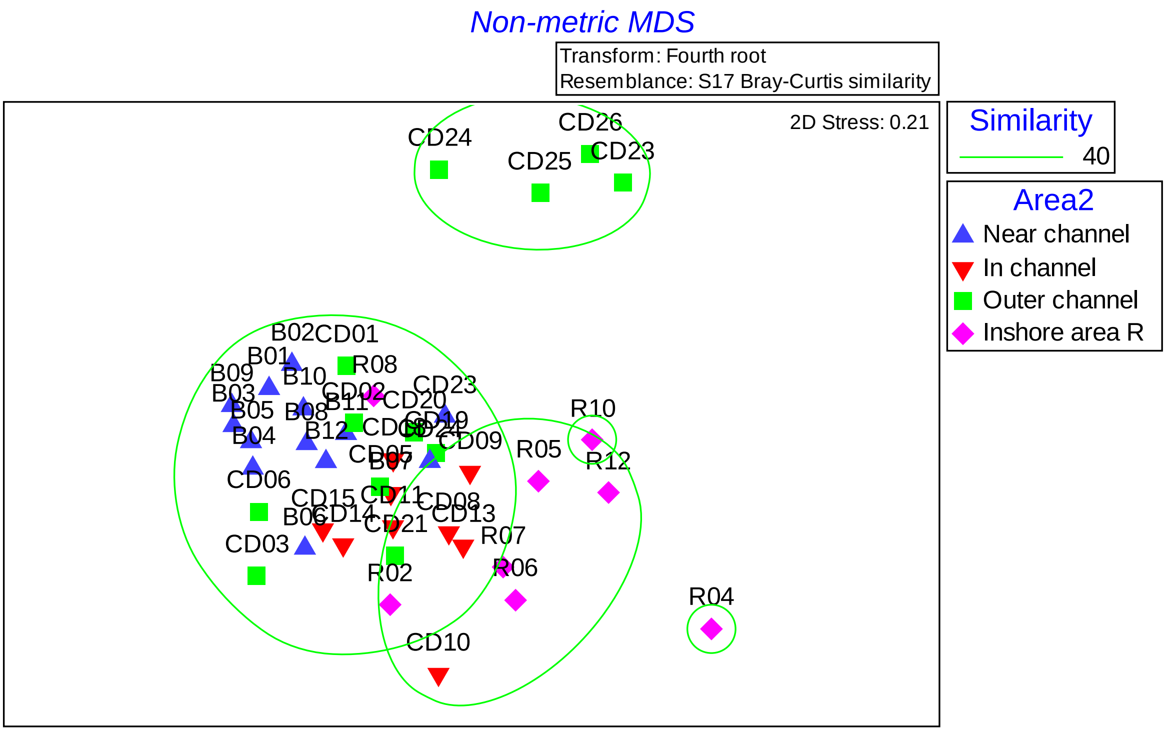

Figure 15. MDS plot of fourth root transformed infauna data from the Fairway area. Symbols group the samples according to generalised areas relative to the dredged Fairway channel.

Examination of the raw data for the 2004 sampling showed that, while differences between non-dredged and dredged areas were evident, these were mainly due to changes in the relative abundances of shared species, with densities mostly increasing in the disturbed areas. The most notable examples of this were the considerably higher densities of the opportunistic polychaetes *P. aucklandica* and *H. filiformis* at stations within the maintained channel. Less dramatic increases were evident in ostracods, nemertean worms and a number of other small polychaetes. Conversely, numbers of the polychaete *Spiophanes bombyx* were considerably lower in the dredged channel. Notable decreases were also evident in all three prevalent bivalve mollusc species (*Dosinia subrosea, Myadora striata, Soletellina siliqua*) and some polychaete species.

6.1.4. Epifauna dredge trawls

The epifaunal trawl data for the Fairway vicinity is listed in Table 12. Epifaunal communities outside and inside of the maintained channel may be inferred from comparison between the contents of trawls CDT1 and CDT4 and trawls CDT2 and CDT3, respectively. Another two trawls, CDT5 and CDT6, were carried out in the shallower survey area between the approach channel and the main breakwater (sample prefix ‘B’; see Figure 9).

Table 12. Epifauna recorded from research dredge trawls inside (shaded yellow) and outside of the dredged channel area. Refer to Figure 9 for locations of trawl tracks.

Trawl code		CDT1	CDT2	CDT3	CDT4	CDT5	CDT6	CDT7 [a]	CDT8	CDT9	CDT10
Trawl distance (m)		200	230	200	250	260	280	220	270	225	280
Trawl depth (MSL, m)		13.5	12.5	12.7	8.5	10.1	7.7	12.6	14.1	13.8	15.5
Year		2004	2004	2004	2004	2004	2004	2016	2016	2016	2016
Taxa	**Common name**										
Fellaster zelandiae	Sand dollar	327	4		196	34	105	85	40	248	55
Echinocardium cordatum	Heart urchin		7		2						
Patiriella regularis	Cushion star				3		3				
Unidentified brittle star	Brittle star		3								
Cominella adspersa	Speckled whelk				1						
Austrofusus glans	Knobbed whelk	2	1					2	9	8	5
Amalda australis	Olive shell	1			8			4		11	2
Atrina zelandica	Horse mussel		1								
Dosinia subrosea	Fine dosinia		1								
Dosinia anus	Ringed dosinia							1	4	1	
Pleurobranchaea maculata	Sea slug		1								
Owenia fusiformis	Polychaete worm		7								
Unidentified polychaete	Polychaete worm			2							
Paguridae	Hermit crabs	5		1		1		4	27	14	4
Hymenosoma depressum	Sea spider	3	23	2		2					
Ovalipes catharus	Common swimming crab					2					
Nectocarcinus antarcticus	Red swimming crab				2						
Neommatocarcinus huttoni	Policeman crab		1								
Unidentified crab	Crab								1		
Heterothyone ocnoides	Sea cucumber								30		45
Myadora striata	Large Myadora								4		
Rexithaerus spenceri	Wedge shell										1
Tanea zealandica	New Zealand moon snail									1	
Maorimactra ordinaria	Trough shell									1	
Peltorhamphus sp.	Sole								1		

a. CDT7 was located at the edge of the dredged area for dredging conducted in 2012. Trawl conducted in 2016.

The sand dollar, *Fellaster zelandiae*, was the predominant epifaunal species in undredged areas near the Fairway (CDT1 and CDT4-CDT6) but appeared to be effectively absent from within the channel. The highest densities were recorded at CDT1, with 163 retained per 100 m of tow (representing a nominal area of 50 m^2 of seabed). This is likely to be a conservative estimate due to expected trawl inefficiencies. Of the trawls conducted inside the dredged area, CDT3 was notable for the very sparse epifaunal abundances in the trawl, although a moderate amount of shell material was collected. The contents of trawl CDT2 also differed from those conducted outside the channel in that it recorded moderate densities of the sea spider crab (*Hymenosoma depressum*), low densities of brittle stars and heart urchins, a horse mussel (*Atrina zelandica*) and a policeman crab (*Neommatocarcinus huttoni*); however, this trawl appears to have spanned the edge of the channel (Figure 9) and may not be particularly representative. Species unique to the trawls outside the dredged channel included cushion stars (*Patiriella regularis*), the olive shell (*Amalda australis*) and the red and common swimming crabs (*Nectocarcinus antarcticus* and *Ovalipes catharus*, respectively). These species occurrences largely reflect the siltier nature of substrates within the dredged channel. The lower diversity of epifauna recorded from the two trawls in survey area B (CDT5 and CDT6) is thought to reflect the more mobile nature of benthic sediments in this shallower, higher-energy area adjacent to the Port's outer breakwater.

The trawls conducted further seawards in the Fairway area in 2016 produced a similar range of taxa to that of the 2004 sampling, with the addition of significant numbers of the holothurian *Heterothyone ocnoides* at two of the sites (CDT8, CDT10) and small numbers of several molluscs that had not been collected in 2004. *H. ocnoides* is very common in the wider area.

6.2. Offshore Westshore Beach

The consented spoil disposal areas 'R extended' and 'Ia' and the control site 'CIa' (Figure 16) are subject to 5-yearly benthic surveys. Five surveys have been carried out since 1997 with the most recent completed in 2012. An analysis of the multi-survey data-set was conducted by Smith (2013) including sediment texture and macrofaunal and epifaunal communities.

Site 'R extended' accepts material dredged from the outer Fairway only. To date it has accepted 414,000 m^3 of dredged material over 4 occasions since 1996 (Table 13). Site 'Ia', is located beyond the 10 m depth contour and has accepted a total of 730,500 m^3 of material spread over 13 occasions since 1996.

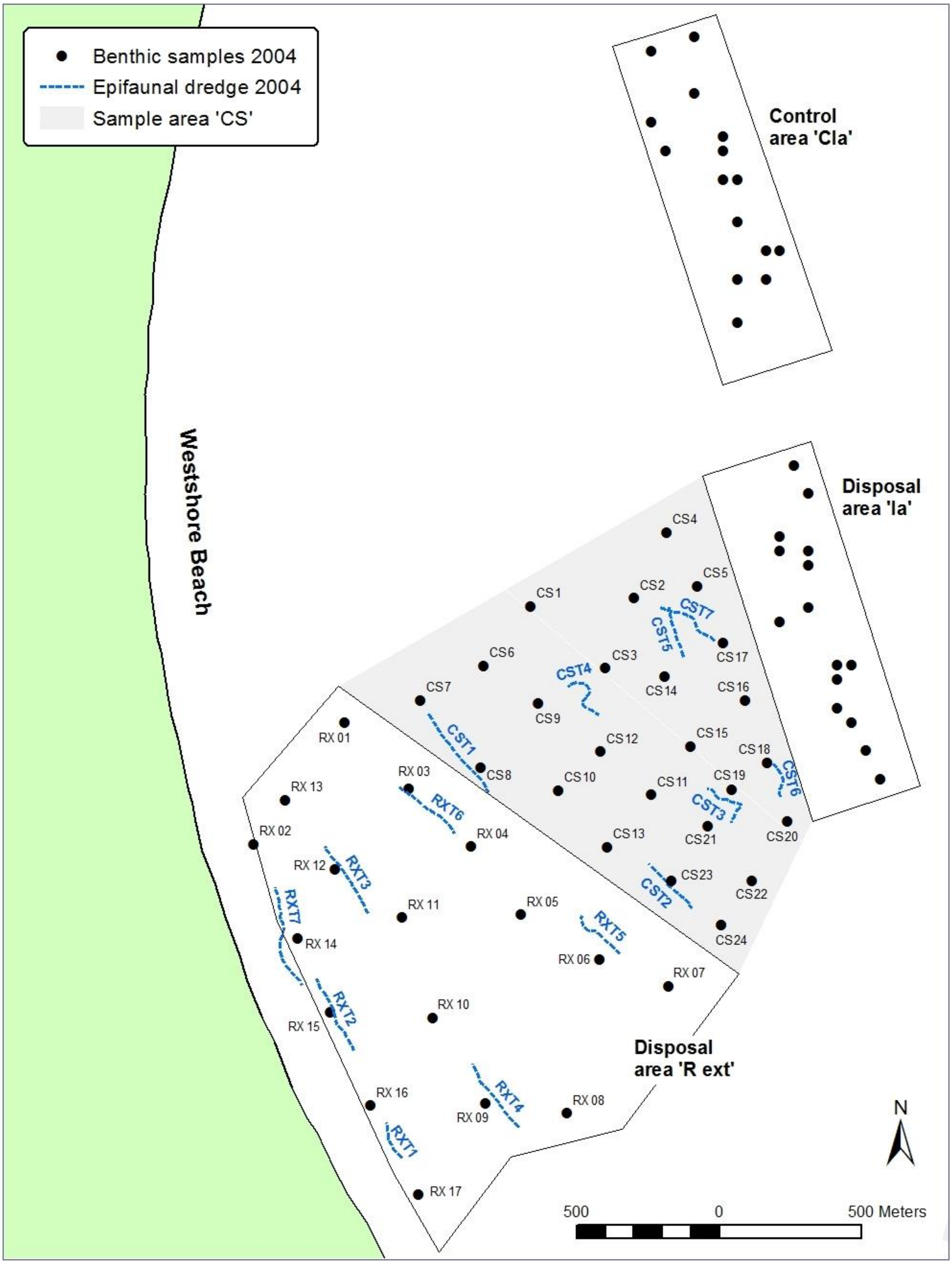

Figure 16. Schematic of the existing consented spoil grounds (and control area) offshore from Westshore Beach showing components of the 2004 benthic sampling surveys.

Spoil deposition history is presented graphically in Figure 17, along with the timing of the three most recent benthic surveys of these areas. The periods between spoil disposal and the subsequent survey were 14 months in 2004, 19 months in 2007 and 8 months in 2012. As well as representing the survey allowing the shortest period for benthic recovery, this most recent survey also followed the largest depositional loading to spoil ground 'Ia' (211,355 m^3).

Table 13. Volumes of dredge spoil deposited within the spoil grounds since 1995.

Year	Period	Spoil volume (m^3)	
		Ia	**R ext.**
1996	Jun95-Aug96	69,100	
1997	Dec	20,485	30,341
1998	May	9,020	
1999	May-Jun	17,900	
2000	July-Sep	27,750	
2003	Feb-Mar	36,950	95,370
2003	Jun-Sep	62,048	
2006	Feb-May	32,237	79,838
2008	Jun-Sep	30,166	
2009/10	Sep09-Jan10	68,100	
2012	Jan-Mar	211,355	130,965
2013/15	Oct13-Mar15	141,000	
2015	Jun-Jul	4,446	77,677

The area between the spoil grounds (CS in Figure 16) was surveyed in 2004 and represents approximately 140 ha of sea bed in depths ranging from 7 m to 12 m. Twenty four benthic samples were analysed for sediment texture and macrofaunal community structure. Additionally, the area was sampled with seven epifaunal dredge trawls.

6.2.1. Grain size analysis

The results of the 2004 sampling survey of the area between 'Ia' and 'R extended' (sample prefix 'CS' in Figure 16) showed that the seabed was comprised predominantly of fine sands that made up an average of 65% of the dry weight. Very fine sands were the next most dominant fraction, comprising, on average, 21% of samples, followed by silts and clays that made up approximately 9%. Sample variability was low, indicating the seabed was relatively uniform across the site (Figure 18). The homogenous core profiles indicated that sediments were also well mixed and devoid of near-surface anaerobic conditions. There was, however, a tendency for the deeper sites to contain a greater fraction of fine particulates (Figure 19). A side-scan sonar tow through the middle of the site (roughly south to north) confirmed that the area was effectively homogeneous.

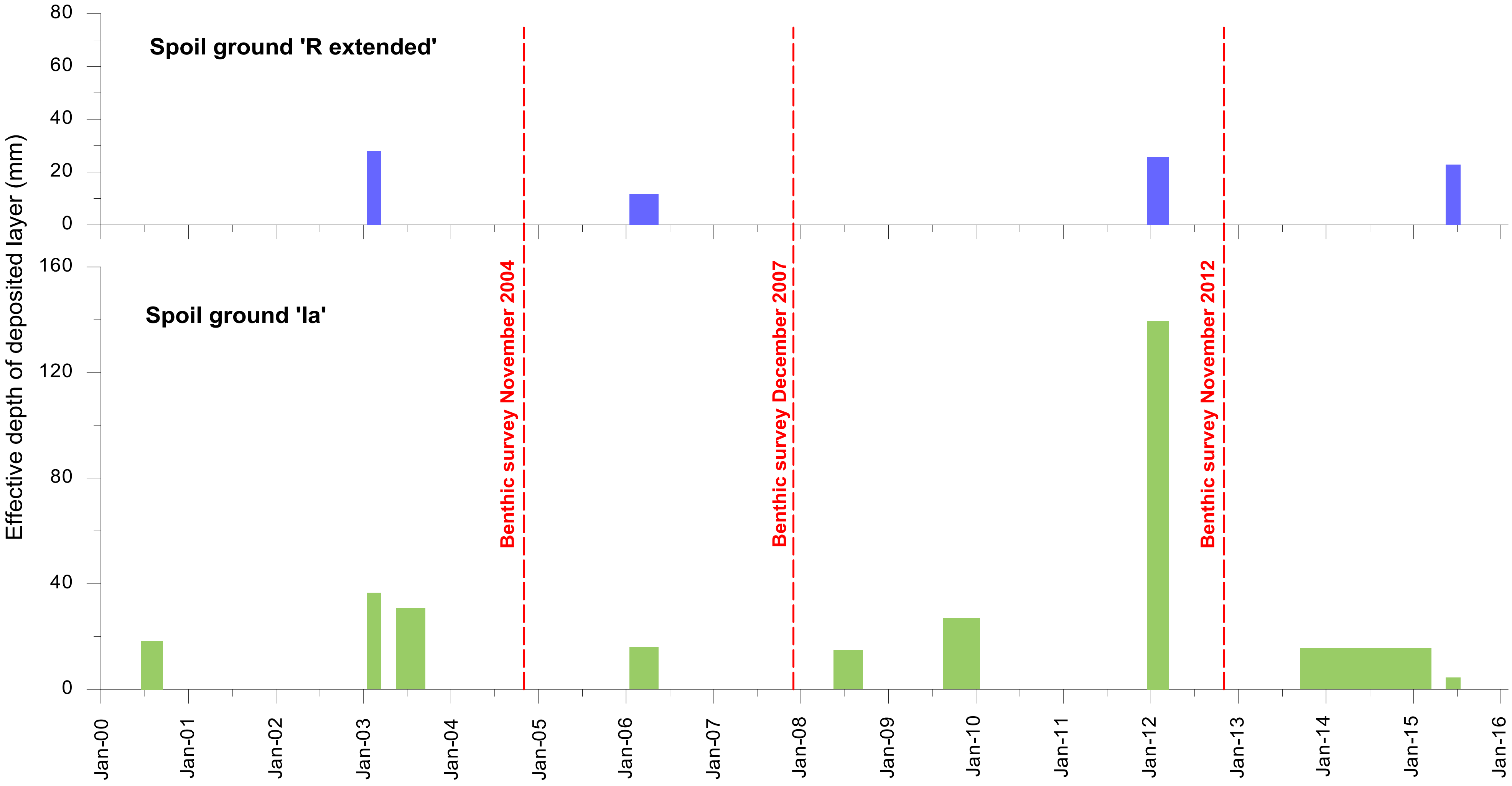

Figure 17. Graphical representation of the recent spoil deposition history of sites 'R extended' and 'Ia' in relation to the benthic surveys. Deposition events are presented as the depth of the deposited layer assuming the volume of spoil is spread evenly across the spoil ground area. A constant rate of deposition has been assumed for dredging campaigns across multiple months. Hence the area of each coloured bar is representative of the relative spoil volume deposited.

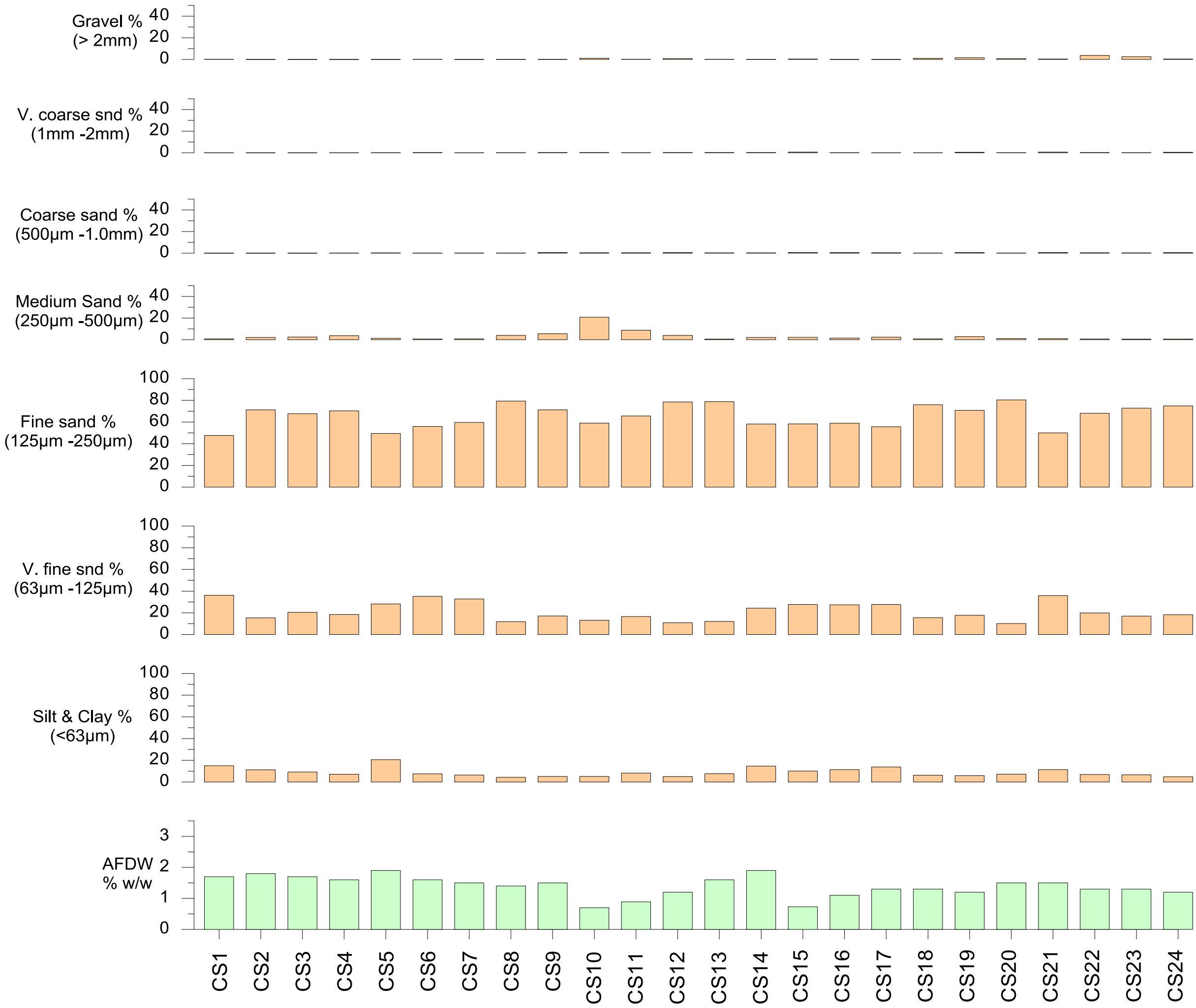

Figure 18. Ash-free dry weight and grain size composition (% wt) of sediments collected from the 24 sample stations between the established spoil grounds in 2004 (see Figure 16).

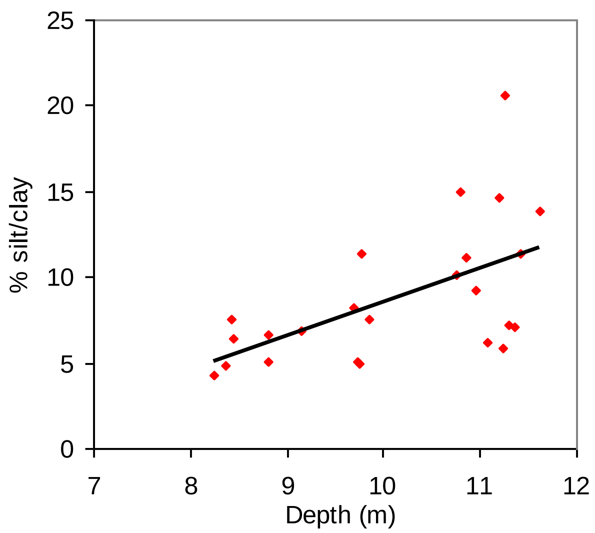

Figure 19. Relationship between water depth and silt/clay content for area 'CS' sediment samples.

The 2012 survey of sites 'Ia', 'CIa' characterised the sediments as predominantly fine and very fine, well sorted mobile sands. A discernible aRDP layer was recorded in 11 of 15 cores from 'Ia' only, at depths ranging 35 – 140 mm in the profile (Smith 2013). A pattern of increasing fine sand and decreasing very fine sand along a north to south gradient was observed across both sites but this gradient was more pronounced for samples from 'Ia'. Consistent with sediment texture coarsening generally towards the south, surficial sediments from 'CIa' averaged 9.2% compared to 4.0% for 'Ia'. Although a weak correlation between silt/clay content and depth was observed (Figure 19) no such north-south gradient in sediment texture was identified for the 2004 'CS' survey data.

Sediment texture (as defined mostly by relative proportions of fine and very fine sands) has been quite variable over the four survey years [1997, 2004, 2007, 2012; Smith (2013)]. However, in 2004 when the CS samples were collected, there was very little variation in mean values for the major fractions across the three sites ('R extended', 'CS', 'Ia') despite the depth gradient across them (Table 14). Assuming 'CS' and 'CIa' can act as suitable control sites, the data indicates no discernible effect on sediment texture from prior spoil deposition. However, deposition events were 20 months and 14 months prior to this sampling for 'R extended' (95,370 m^3) and 'Ia' (62,048 m^3), respectively (Table 13). All evidence suggests that this entire area off Westshore Beach is highly dispersive and these represent significant periods for recovery of shallow sediment habitats on an exposed coastline. It is likely, therefore, that ecological recovery from dredge spoil deposition was effectively complete well before these surveys were conducted.

Table 14. Mean values for the three major sediment grain size fractions across the three sample sites offshore from Westshore Beach (surveys November–December 2004).

Site	R ext.	CS	Ia	CIa
Depth (m)	6.0	10.1	11.6	11.8
Fine sand (%)	65	65	63	62
Very fine sand (%)	23	21	25	21
Silt/clay (%)	5.5	9	7.1	6.1

6.2.2. Benthic macrofaunal communities

Benthic macrofaunal communities at the inshore ('R extended') and offshore ('Cla' and 'la') sites were sampled in 2004 by Sneddon and Keeley (2005) and again in 2007 and 2012 by Smith (2008a, 2013). These reports can be referred to for greater detail regarding macrofaunal community characteristics at these sites. A survey of macrofaunal communities at the CS site (between 'la' and 'R ext'; Figure 16) was also conducted in 2004 by Cawthron, although these results have not previously been reported.

In an analysis of macrofaunal data across all of the consent-required surveys, Smith (2013) noted that, although distinct differences in community structure were discernible between sites, greater differences were observed between survey years. These temporal shifts were larger than those due to spatial, water depth and sediment textural differences across sites in any one survey. This is shown clearly by the nMDS plot in Figure 20 which includes the 2004 samples for the ‘CS’ area between the spoil grounds. Although apparent shifts may result from methodological differences when sampling and analysis is carried out by different parties, this does not apply to the 2007 and 2012 data, which show a similar separation in the nMDS plot.

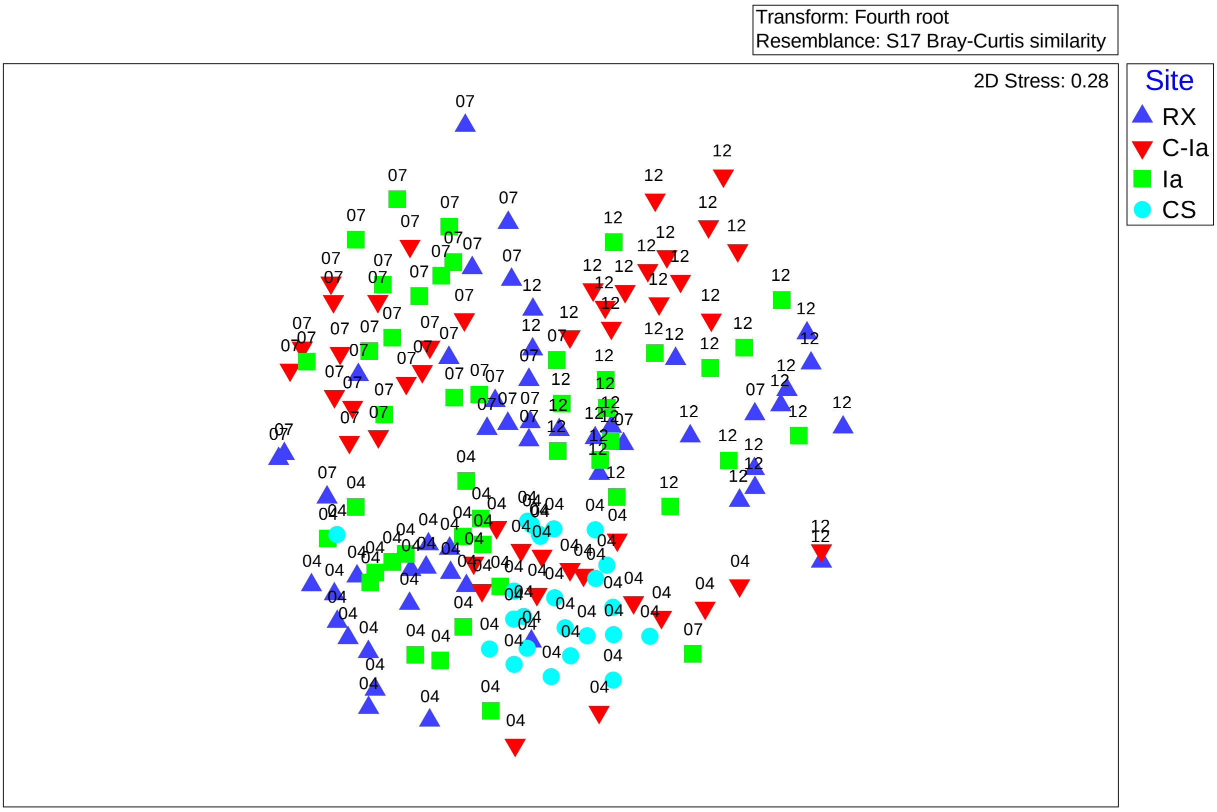

Figure 20. Non-metric MDS plot of fourth root transformed infauna data from three survey years for sampling sites off Westshore Beach, including the spoil grounds ‘Ia’ and ‘R extended’, the area between them (‘CS’) and the reference site ‘Cia’. Symbols group the samples according to these areas; numbers refer to survey year (20XX).

Differences between surveys

Investigating the pronounced temporal component of variability in benthic communities, Smith (2013) identified several species that exhibited consistently high variance between surveys, including juvenile mactrid bivalves, *H. filiformis*, the chaetognath *Sagitta* sp. and *P. aucklandica* at site ‘Ia’, and *P. aucklandica* and

H.filiformis at the control site ‘CIa’. In addition, it was noted that the spionid polychaete *Spiophanes bombyx* contributed to temporal variability in site ‘R extended’[15].

To further examine broad trends across surveys for this report, averages for abundance and community indices were generated from a compiled multi-survey data set and are plotted in Figure 21. A listing of the 15 most abundant macroinvertebrate taxa overall is provided in Table 15 along with average abundances per core for each sampling area over the three spoil ground surveys.

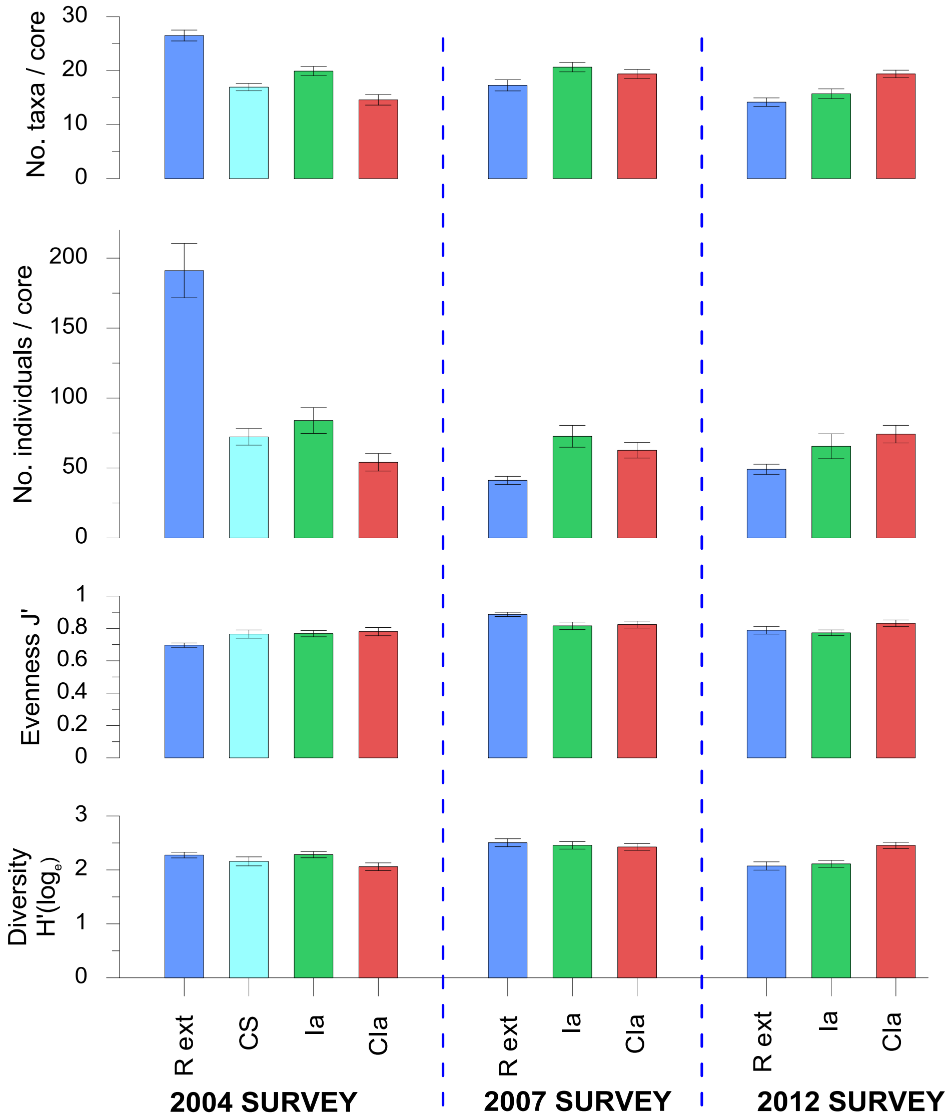

Figure 21. Mean community indices for macrofaunal data compiled for the three most recent benthic surveys of the Westshore Beach offshore sites. Error bars represent ±1SE.

[15] Due to possible taxonomic misidentification between surveys, *Spiophanes bombyx* and *Spiophanes multicrustata* were combined (as *Spiophanes* sp.) for statistical analyses for this report.

Table 15. Listing of the 15 most abundant taxa overall for the sampling areas off Westshore Beach, showing how relative dominance has varied across the 2004, 2007 and 2012 surveys. Values are mean abundance per core sample.

Survey year	**Taxonomic Group**	**2004**				**2007**			**2012**		
Site		**R ext**	**CS**	**Ia**	**CIa**	**R ext**	**Ia**	**CIa**	**R ext**	**Ia**	**CIa**
n		*17*	*24*	*15*	*15*	*17*	*15*	*15*	*17*	*15*	*15*
Period since deposition (mo.)		20	-	14	-	19	19	-	8	8	-
Prionospio sp.	Polychaeta: Spionidae	71.2	9.5	27.7	14.5	6.4	10.8	11.2	5.1	10.0	9.4
Amphipoda	Amphipoda	34.4	5.0	7.1	6.3	6.5	5.7	7.6	7.4	7.7	2.2
Heteromastus filiformis	Polychaeta: Capitellidae	13.6	9.2	8.7	2.9	3.5	5.5	11.2	2.1	5.0	2.7
Sagitta sp.	Chaetognatha	0.0	0.0	0.0	0.0	1.2	1.9	2.9	12.6	17.9	7.2
Spiophanes sp.	Polychaeta: Spionidae	7.7	6.8	5.9	5.8	1.7	2.1	3.9	0.7	3.9	0.6
Prionospio aucklandica	Polychaeta: Spionidae	1.3	19.4	1.5	9.3	0.2	0.3	0.1	1.0	1.0	2.1
Magelona dakini	Polychaeta: Spionidae	5.9	2.5	1.4	1.3	1.9	1.4	1.5	1.2	1.3	2.1
Unidentified bivalve (juv)	Bivalvia	0.0	0.0	0.0	0.0	0.0	16.7	1.4	0.4	0.4	0.5
Paracaudina chilensis	Holothuroidea	0.0	0.0	0.5	0.0	0.1	1.0	0.9	0.0	0.1	16.6
Cumacea	Cumacea	3.4	2.2	1.1	1.4	1.5	2.3	0.9	2.0	1.7	1.0
Paraonidae	Polychaeta: Paraonidae	3.6	1.6	1.0	0.3	0.5	0.3	0.2	1.9	3.2	4.7
Goniada sp.	Polychaeta: Goniadidae	2.4	1.9	1.4	1.2	1.8	1.2	0.4	1.4	1.5	1.4
Ostracoda	Ostracoda	2.5	0.9	1.8	1.3	0.6	1.3	0.9	0.4	2.3	1.9
Myllitella vivens vivens	Bivalvia	0.5	0.4	2.0	0.7	0.6	1.0	2.1	0.2	0.1	5.9
Nucula sp.	Bivalvia	0.4	0.3	1.8	0.9	1.2	5.6	1.3	0.1	0.4	0.7

The most notable feature of Figure 21 is the relatively much higher abundances in samples from ‘R extended’ in 2004. Very high abundances can indicate dominance, following disturbance, by just a few opportunistic or tolerant species. In this case, spionid and capitellid polychaetes and amphipods were primarily responsible for the increased numbers (Table 15). However, there were also a greater number of species overall identified from these samples, a factor which effectively counters the decrease in diversity (H’) and evenness (J) in these communities which would otherwise result. Coincident increases in both abundance and taxa richness are unlikely to be a consequence of significant disturbance or stress, especially following a recovery period of 20 months.

SIMPER analysis of the multi-survey data-set identified the taxa contributing most to community differences between 2004 and 2007 samples as the arrow worm (*Sagitta* sp.), the polychaetes *Prionospio aucklandica*, *Owenia petersenae*, cirratulidae and sigalionidae, the bivalve *Nucula* sp. and an unidentified juvenile bivalve which was notably prevalent in site ‘Ia’ in 2007 (Table 15). Those contributing most to differences between 2007 and 2012 samples were paraonid polychaetes, *Sagitta* sp., *Heteromastus filiformis*, cirratuldae, *Spiophanes* sp., the unidentified bivalve species and *Nucula* sp.

Differences between spoil ground and non-spoil ground sites

For samples from the 2004 survey, benthic communities within area ‘CS’ showed greater similarities to those from the other sites in the same year than to samples from any subsequent survey (Figure 20). However, considering just the 2004 data, the MDS plot in Figure 22 suggests a slight distinction between the areas that have received dredge spoil (‘Ia’ and ‘R extended’) and those which had not (‘CIa’ and ‘CS’).

While the relatively high stress value in Figure 22 (0.26) indicates that the distances between points should be treated with a degree of caution, the plot shows that macrofaunal communities generally clustered into three main groupings. One group comprised samples from ‘CIa’ and ‘CS’, while the other two consisted of those from ‘R extended’ and ‘Ia’, which were also relatively distinct from each other.

SIMPER analysis of the 2004 samples showed that the ten taxa contributing most to the dissimilarity between ‘CS’/’CIa’ and ‘R extended’ were (in order of influence) the polychaetes *Armandia maculate* and *Prionospio* sp., amphipods, *Prionospio aucklandica* and *Soletellina silique,* Glyceridae*, Aglaophamus macroura, Sagitta* sp.*, D. subrosea and* Mysidacea. All but the polychaete *P. aucklandica* were more abundant in the ‘R extended’ samples.

Of the taxa driving the dissimilarity between the ‘CS’/’CIa’ and ‘Ia’, *Heterothyone ocnoides, D. subrosea, Nucula* sp*., Myllitella vivens vivens* and Ostracoda were more abundant in ‘Ia’. Those more abundant in ‘CS’/’Cia’ were *P. aucklandica, Owenia petersenae,* Paraonidae, Cumacea and Sigalionidae.

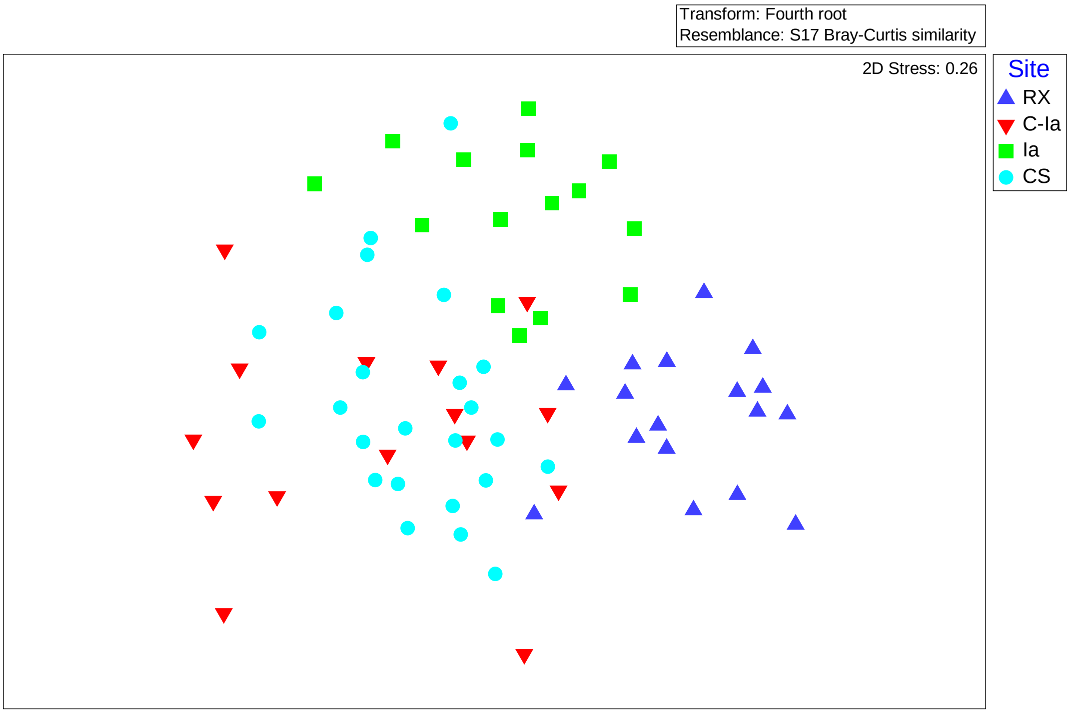

Figure 22. Non-metric MDS plot of fourth root transformed infauna data from the 2004 survey of sites off Westshore Beach, including the spoil grounds 'Ia' and 'R extended', the area between them ('CS') and the reference site 'C-Ia'. The coloured symbols group the individual samples according to these areas.

Sneddon and Keeley (2005) found very little evidence in 2004 for an effect from previous spoil deposition. However, Smith (2013) suggested that the 2012 data showed that community composition at 'Ia' was affected by spoil disposal history. Interpretation of the multi-survey data is confounded by the irregularity of spoil disposal events, both in volume and timing (Table 13) and the variability in recovery period prior to each benthic survey (Figure 17). Inclusion of the 'CS' data in the analysis generally supports the presence of a small spoil disposal effect at the 'R ext' and 'Ia' sites in 2004. However, the same three taxa, *Prionospio* sp., Amphipoda and *H. filiformis,* were dominant at all sites and it must be stressed that the differences overall were subtle and constitute at most a small but measureable shift in community structure rather than a clear adverse impact.

Changing patterns of dominance in soft sediment benthos are not unusual in shallow coastal areas. Certainly the consistent timing of the surveys over the November–December period does not suggest that seasonality would be a strong factor. Furthermore, the values and low variability of the diversity indices do not suggest a habitat under particular stress at the time the surveys were conducted. It is considered likely that the length of time between spoil deposition and each subsequent benthic survey has allowed near-complete recovery of these communities, a process undoubtedly facilitated by the dynamic nature of the seabed in this shallow exposed setting. It is concluded that, despite the noted changes in relative dominance by the more abundant taxa (Table 15), the community indices have been consistent across sites and show no long term trends which suggest a longer-term effect from dredge spoil disposal (Figure 21).

6.2.3. Epifaunal dredge trawls

Epifaunal communities at the ‘R-extended’ site were surveyed in 2004 by Sneddon and Keeley (2005) (sampling locations shown in Figure 16) and again in 2007 and 2012 by Smith (2008a, 2013). Smith (2013) compared epifaunal communities between surveys and noted no significant differences. It was concluded that a dredge spoil deposition effect was not discernible.

Trawl contents data for trawls carried out in area ‘CS’ in 2004 (Table 16) show that sand dollars (*F. zelandiae*) were the most abundant taxon, as was also observed for ‘R extended’ by Smith (2013). The next most abundant taxon was the wedge clam (*Myadora striata*), followed by hermit crabs (Paguridae) and olive shells (*Amalda australis*).

Table 16. Epifaunal diversity and abundance recorded from research dredge trawls in area ‘CS’.

Trawl code		**CST1**	**CST2**	**CST3**	**CST4**	**CST5***	**CST6**	**CST7**
Trawl distance (m)		340	220	210	220	190	170	250
Trawl depth – end (MSL, m)		8.0	8.6	10.1	10.2	11.1	10.4	11.3
Taxa	Common name							
Fellaster zelandiae	Sand dollar	506	552	318	145	3	46	2
Echinocardium cordatum	Heart urchin	1	2	4			1	
Patiriella regularis	Cushion star			2				
Austrofusus glans	Knobbed whelk				2		4	
Amalda australis	Olive shell	10	4		10			2
Sigapatella novaezelandiae	Circular slipper shell	1		6	13		4	
Myadora striata	Wedge clams	12	56	12	154		182	
Paguridae	Hermit crabs	8	15	6	2	1	2	
Hymenosoma depressum	Sea spider					5		1
Peltorhamphus novaezelandiae	Sole	1						

*Trawl efficiency was possibly compromised by higher speeds (~3kn) in a strong following wind.

Differences in epifaunal composition between the ‘CS’ and ‘R extended’ sites included the gastropod *Zethalia zelandicum,* which was present in high numbers in some shallow trawls near the shore, but was absent from trawls in the deeper parts of

'R extended' and all 'CS' trawls. The distribution of wedge clams also appeared to be predicated by depth, as it was more abundant in the deeper 'R extended' trawls and at the CS site. Paddle crabs (*Ovalipes cantharidus*) and the shrimp *Pontophilus australis* appeared to prefer shallower depths at the 'R extended' site and were absent from the deeper 'CS' site. Heart urchins (*Echinocardium cordatum*) were encountered more frequently at 'CS', although in low numbers. Taxa observed at 'CS' but not 'R extended' were; the circular slipper shell (*Sigapatella novaezelandiae*), the seastar (*Patriella regularis*), and the knobbled whelk (*Austrofusus glans*), however these taxa were relatively low in abundance. *S. novaezelandiae* is notable since it requires hard substrate, although this may often be limited to shell fragment material in otherwise sandy seabed environments.

6.3. Near-shore subtidal and intertidal mixed substrate habitats

The subtidal and intertidal reef substrates nearest to the area proposed for dredging are those adjacent to the Port on its western side. In addition to the artificial hard substrate of the Port breakwaters and seawalls, this includes a semi-protected embayment with a coarse sand beach and low-tide boulder reefs extending sub-tidally. The near-shore benthic environment supports a range of habitat types and communities predicated by depth, substrate and exposure to wave action. These habitats were surveyed in December 2004 and the findings from direct observation, photographic records, side-scan sonar imaging, and underwater video transect and benthic sampling data were used to compile an approximate broad-scale map comprising seven general habitat types based on substrate and tidal elevation (Figure 23).

6.3.1. Subtidal habitats and communities

The uniform soft sediment areas bordering the channel and Port approaches gave way, towards the south and east, to patches of cobbles and larger boulders and then to weed-covered boulder habitats with only pockets of coarse sediment. In shallower areas towards the small embayment formed by the existing Port reclamation, the boulder habitat became the predominant form and extended into the intertidal zone. A full list of the conspicuous fauna and flora observed during survey of these habitats is presented in Appendix 6.

Epifauna observed in the predominantly soft sediment habitat was very similar to that found in the wider inshore area; dominated by sand dollars (*F. zelandica*) with occasional olive shells (*Amalda australis*), knobbed whelks (*Austrofusus glans*), and hermit crabs.

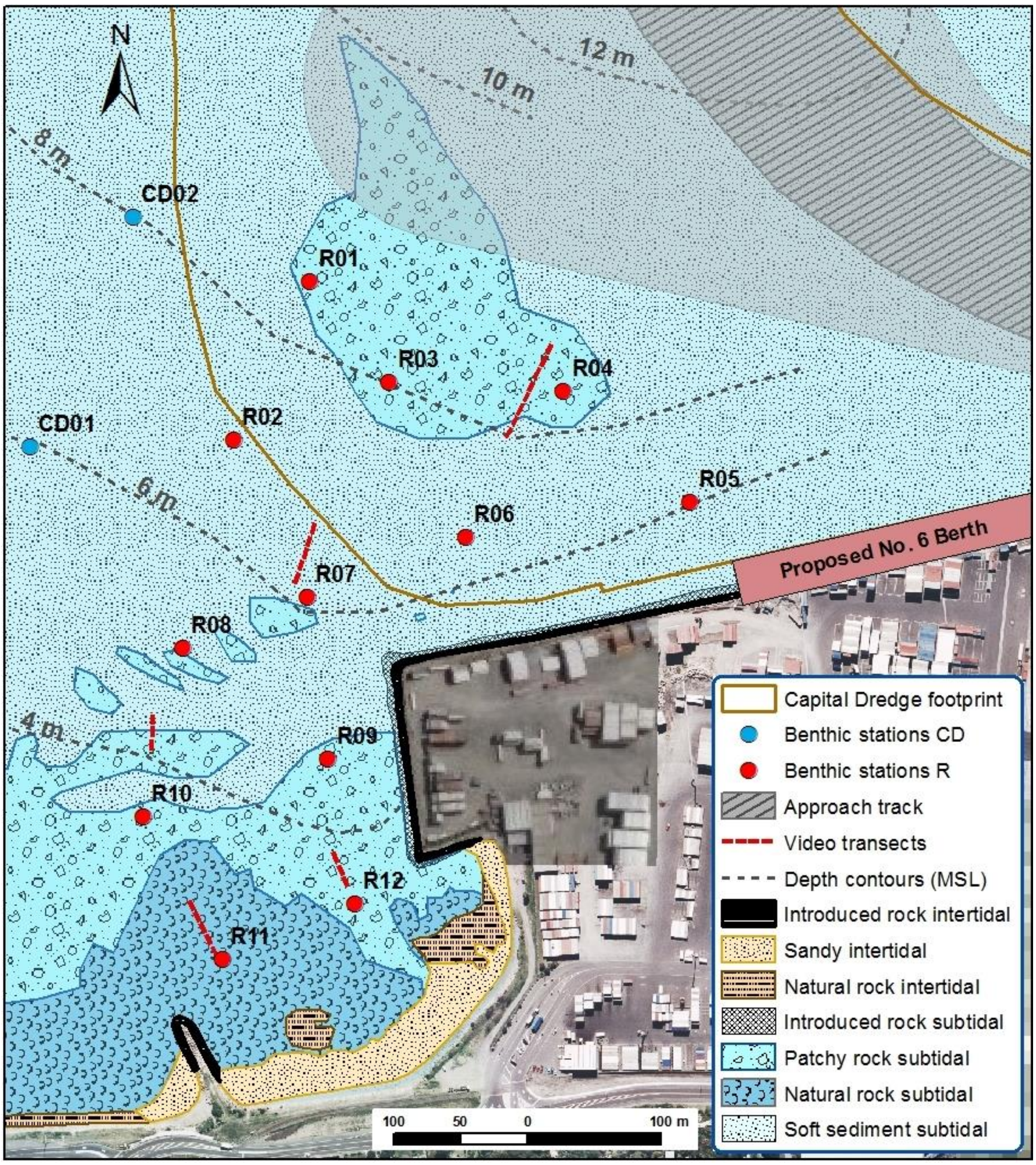

Figure 23. Approximate boundaries of the general habitat types identified immediately west of the Port of Napier from surveys in 2004. The grey shaded area indicates the footprint of limited capital dredging carried out in 2012, subsequent to the survey results depicted here. Depth contours (MSL) are approximate only.

Some areas of sandy seabed were interspersed with hard substrates such as partially buried cobbles and boulders, and in some instances diverse biogenic features (e.g. shell aggregations). This mixed habitat was broadly classified as ‘patchy rock reef’. Such an area identified west of the Port entrance (Figure 23) was found to comprise a combination of natural rock reef (boulders and cobble), sand and biogenic features. At Station R03, the sand substrate was modified in patches by dense aggregations of turret shells (*Maoricolpus roseus*). Very few large macroalgal species were present due to the absence of large rocks and the apparently variable levels of sand cover, but there were a variety of smaller red algae (e.g. *Rhodymenia* sp.), bryozoans, sponges and other invertebrates. At Station R02, sparse beds of horse mussels (*A. zelandica*) were observed. At the time of the survey, a heavy silt coating was evident on hard substrates and encrusting biota.

The patchy reef area situated further inshore to the immediate west of the Port reclamation was a transitional habitat between the offshore sand areas and the relatively permanent inshore rocky reef. As such, its hard substrates tended to be partially buried cobbles, rocks and boulders, sharing many encrusting species with the inshore reef. However, these areas were differentiated by their patchy nature, high silt occurrence, lack of large brown macrophytes and lower general diversity. These features are indicative that this habitat is subject to periodic inundations of sediment accompanying meteorological disturbances and the ecology of this habitat therefore appears limited by natural sediment transport processes.

The permanent natural reef identified in near-shore shallow subtidal areas was typical of shallow rocky reefs found along this section of New Zealand's coastline. This reef would be described as semi-sheltered due to the protection from large southerly (and to a lesser extent easterly) swells offered by its northerly aspect and the adjacent Port reclamation. Benthic cover was dominated by large brown algae (*Sargassum sinclairii, Cystophora* sp*., Carpophyllum maschalocarpum, Ecklonia radiata* and *Carpophyllum plumosum*) creating habitat for a wide variety of taxa including juvenile fish.

Shallow subtidal communities on the more exposed rock wall faces of the Port reflected the greater exposure to water movement and weaker influence of shifting sediments on this habitat. Dominant large macroalgae were *C. maschalocarpum* and *E. radiata*; however, coralline paint (*Lithophyllum/Lithothamnion* sp.) and coralline turf (*Corallina* sp.) were also abundant. Notable fauna in encrusting communities included the calcareous tubeworm *Spirobranchus cariniferus* and the ascidians *Botrylloides* spp. and *Pyura* sp. The catseye snail *Turbo smaragdus* was a prominent grazer and the sea stars *Pateriella regularis* and *Coscinasterias calamaria* were also commonly observed. The red rock crab (*Plagusia chabrus*) was the most prominent invertebrate scavenger/predator.

Barter & Keeley (2002a) described fish life during dives along the western sea wall, noting (in addition to the ubiquitous spotted wrasse and triplefins) sweep (*Scorpis lineolata*), marblefish (*Aplocdactylus arctidens*), butterfly perch (*Caesioperca lepidoptera*) and red moki (*Cheilodactylus spectabilis*). This assemblage is indicative of the greater water movement associated with the subtidal sea wall habitat and the shelter afforded by its more 3-dimensional structure.

6.3.2. Intertidal habitats and communities

The December 2004 survey found that intertidal substrates and habitat types on the western side of the Port varied from sand and gravel foreshore to boulder fields and rock wall habitats; however, the survey focused generally on the habitat characteristics and conspicuous biota of the sea wall substrate and the boulder reef within the west embayment and along the foreshore further west. The steep profile and limited access to the Port sea walls meant that communities were best assessed from the water and during shallow dives. Rock batter communities were examined on the spur breakwater/groyne on the western side of the west embayment and a representative length of the Port sea wall facing. Port sea wall communities were also previously described by Barter and Keeley (2002a, 2002b). A record of the taxa observed during the 2004 survey of intertidal reef communities is presented in Appendix 6 with corresponding relative abundance rankings.

Natural boulder reef

The intertidal boulder reef in the west embayment was observed to support communities of fairly high diversity and the species mix indicated a relatively sheltered, moderate energy environment. A wide range of marine algae were recorded. Among the most predominant were sea lettuce (*Ulva* sp.) and velvet weed (*Codium fragile*) with sporadic clumps of the brown algae *Ecklonia, Carpophylum plumulosum, Lessonia variegata* and *Cystophora* sp. The introduced algae *Undaria pinnatifida* was also in evidence and it is noted that this species was not recorded on this inshore reef in earlier surveys (Barter & Keeley 2002a, 2002b), although it was observed along the northern rock wall breakwater (NB Keeley, pers. comm.). The larger boulders at and below low tide supported fringing growths of *Rhodymenia dichotoma.*

Fauna recorded from the rocky intertidal substrates were also relatively diverse. Undersides of boulders provided shelter for a wide range of biota. The tube worm *Spirobranchus cariniferus* often formed dense communities. The anemone *Isactinia olivacea* was common as well as the transparent ascidian *Corella eumyota.* The half crab (*Petrolisthes elongates*) was particularly abundant though a range of other crab species was also recorded. The predominant grazing gastropod species recorded was *Diloma arida*, with *T. smaragdas, Atalacmea fragilis* and *Scutus breviculus* also fairly common. Chitons were also plentiful, the predominant species being *Sypharochiton pelliserpentis* with *Acanthochitona violacea* also represented*.* The sea stars *C. calamaria* and *Pateriella regularis* were observed on submerged rocks.

Rock batter communities

The introduced boulder rock of the sea walls and groyne differed physically from the more natural shoreline reefs, principally in its steeper gradient, more 3-dimensional structure and lower exposure to shifting sediments. The steepness results in only a narrow intertidal band of a few metres, compared to sometimes 30 m or greater for the low-tide boulder fields elsewhere along this shoreline. The structure also allows for plentiful overhangs, caves and crevices which provide shelter from solar radiation. At the same time, the gradient within the intertidal zone, the adjacent water depths and orientation of the sea walls makes this a higher energy environment, being generally more exposed to wave action.

While rock wall habitats were found to support a range of taxa similar to that of the surrounding reefs, communities tended to be less diverse due to the narrower range of substrate conditions (specifically absence of sediments). On exposed rock faces, the three barnacle species *Epopella plicata, Chamaesipha columna* and *Austrominius modestus* were abundant, along with the gastropods *Austrolittorina* sp. and *Haustrum scobina*, and the limpet *Patelloida corticata*. Vertical faces supported bands of rock velvet (*Codium adhaerens*) and the low tide surge zone featured abundant coralline turf (*Corallina* sp.) and the comb weed (*Pterocladia* sp.). At low tide level, encrusting communities were similar to those of the boulder reef habitat.

6.4. Proposed spoil disposal area

The layout of historical survey elements associated with the currently proposed dredged material disposal area are presented in Figure 24. The 2005 side-scan sonar output and diver observations recorded for this area indicated a flat and very homogeneous soft sediment habitat with no significant high-relief features or structures.

6.4.1. Sediment texture and organic content

All core samples collected from within the spoil disposal area in 2005 were entirely comprised of soft sediments; these being predominantly fine and very fine sands (greater than 75% of the dry weight). These sediments also featured a higher silt content (23%) than the shallower areas further inshore, consistent with the greater stability provided by deeper habitats. The three finest size fractions, comprising particles less than 250 µm, made up greater than 98% of the sediment samples (Table 17, Figure 25). Variability was relatively low, consistent with the observed uniformity of the seabed. Organic content, defined as Ash-Free Dry Weight (AFDW), was around 2%, indicating low overall levels of sediment enrichment (Figure 25). The homogenous core profiles indicated that sediments were also well mixed and near-surface anaerobic conditions were effectively absent.

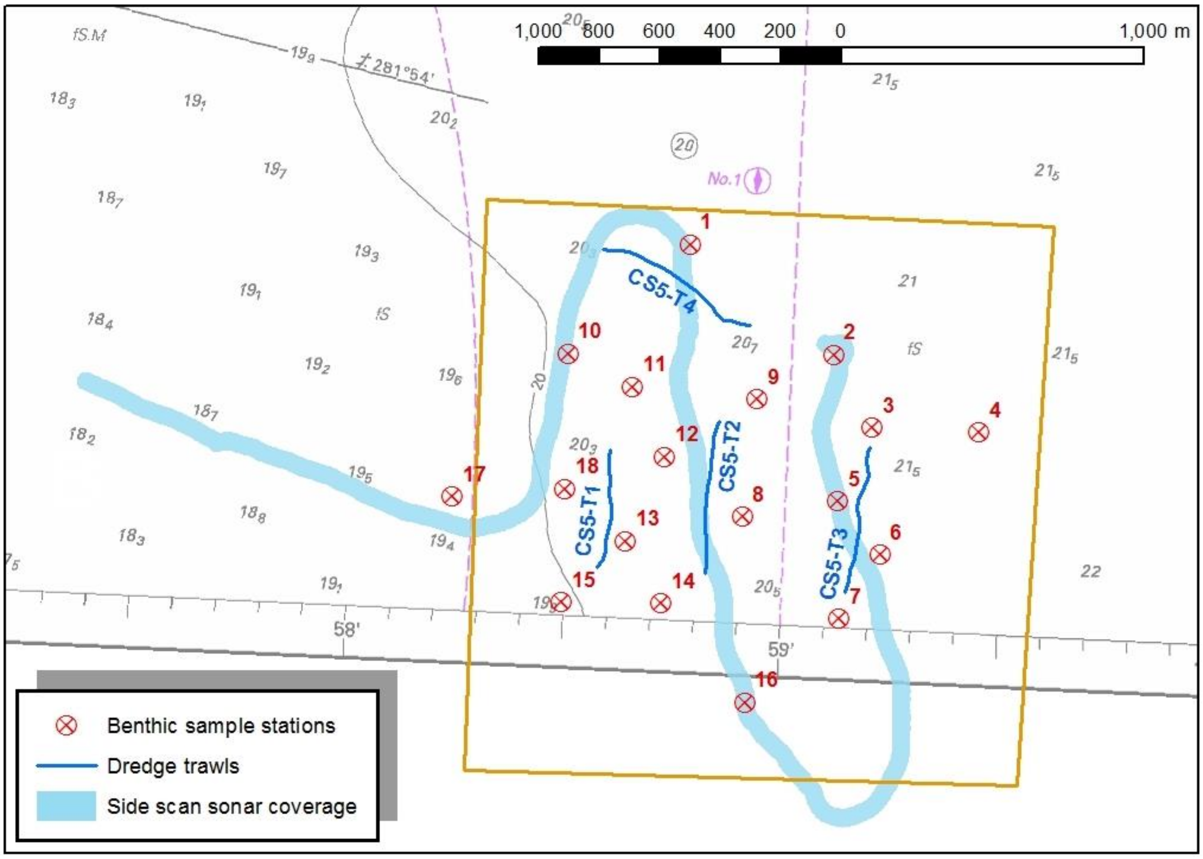

Figure 24. Layout of the 2005 survey elements in relation to the currently proposed offshore spoil ground overlaid on Part chart NZ5712a. The side-scan swathe width was 60 m.

Table 17. Summary table of mean grain-size distribution and organic content (as ash free dry weight) for the proposed offshore spoil disposal area.

	Mean value	Std error
Depth	20.8	0.08
Gravel	0.1	0.00
Very coarse sand	0.1	0.02
Coarse sand	0.1	0.01
Medium sand	0.3	0.05
Fine sand	46.2	2.76
Very fine sand	30.4	0.96
Silt/clay	23	2.27
Ash-Free Dry Weight	2.2	0.16

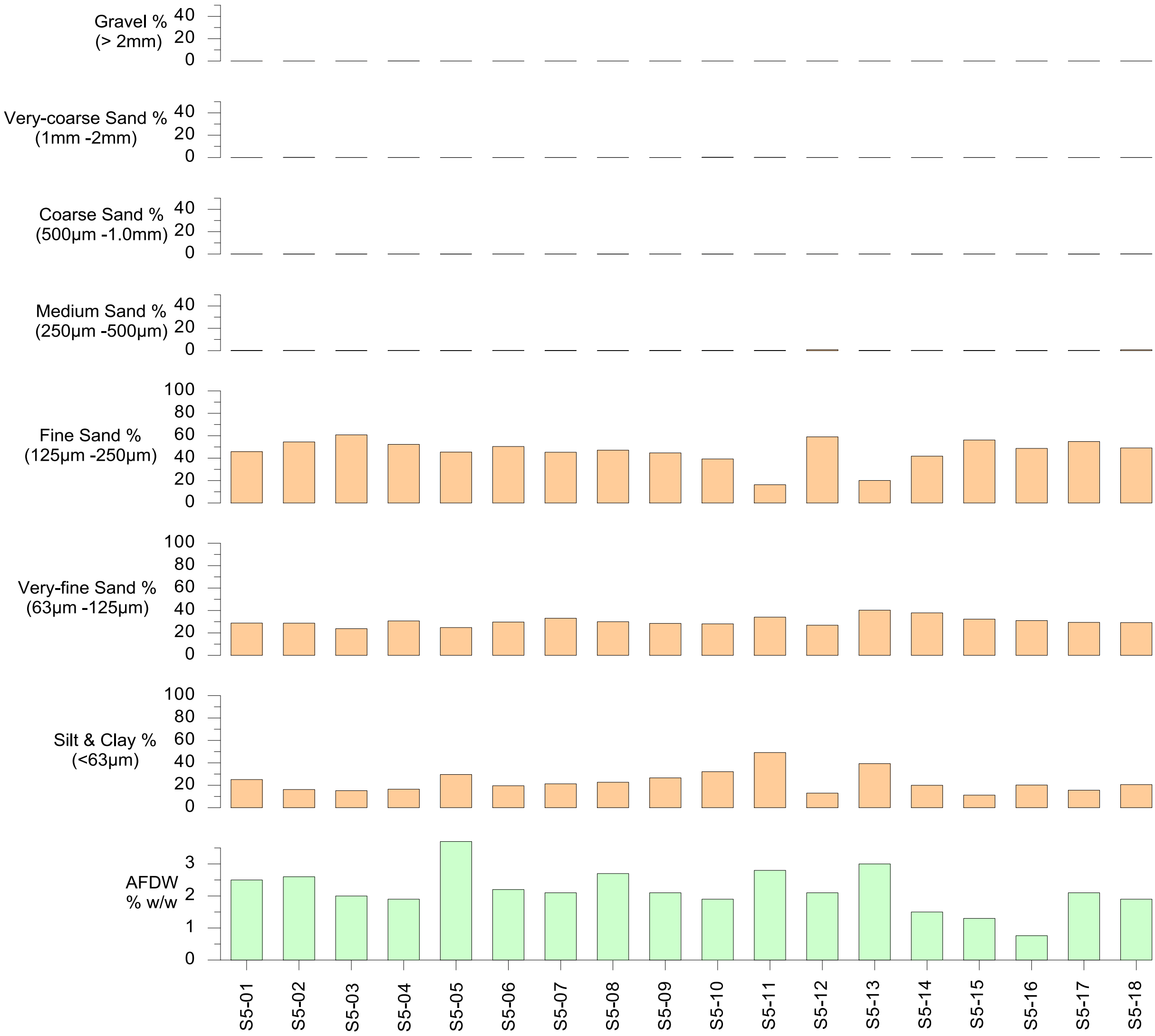

Figure 25. Organic content (ash-free dry weight) and grain size composition (% wt) of sediments collected from the 18 sample stations in the proposed offshore spoil disposal area.

6.4.2. Infauna cores

Infauna abundance at the proposed spoil ground was relatively variable in terms of infauna abundance, ranging between 6 and 93 individuals per core, with an average of 56 (Figure 26). Much of this variation was due to a few dominant species such as the polychaete *Heteromastus filiformis* and the small bivalve, *Nucula nitidula*, which are typically patchy, or aggregative, in their distribution (Table 18). Also related to such patchiness, the number of taxa in each core was similarly variable, ranging from 5 to 23 (Figure 26), 43 taxa recorded overall. In contrast, indices for the diversity and evenness of these communities are less variable across the site. High evenness indicates that any observed dominance by key taxa was relatively limited and suggests that the moderate diversity of the community was unlikely to represent a community under stress.

The species which tended to dominate the samples from the spoil ground site (in decreasing order of abundance) were *Nucula nitidula, Heteromastus filiformis, Prionospio* sp. and *D. anus*. The small holothurian *Heterothyone ocnoides* also featured in these samples. It is notable that the characteristic taxa from the site included two bivalve species (*N. nitidula* and *D. anus*). *D. anus* in particular, is typically associated with offshore stable sandy sediments.

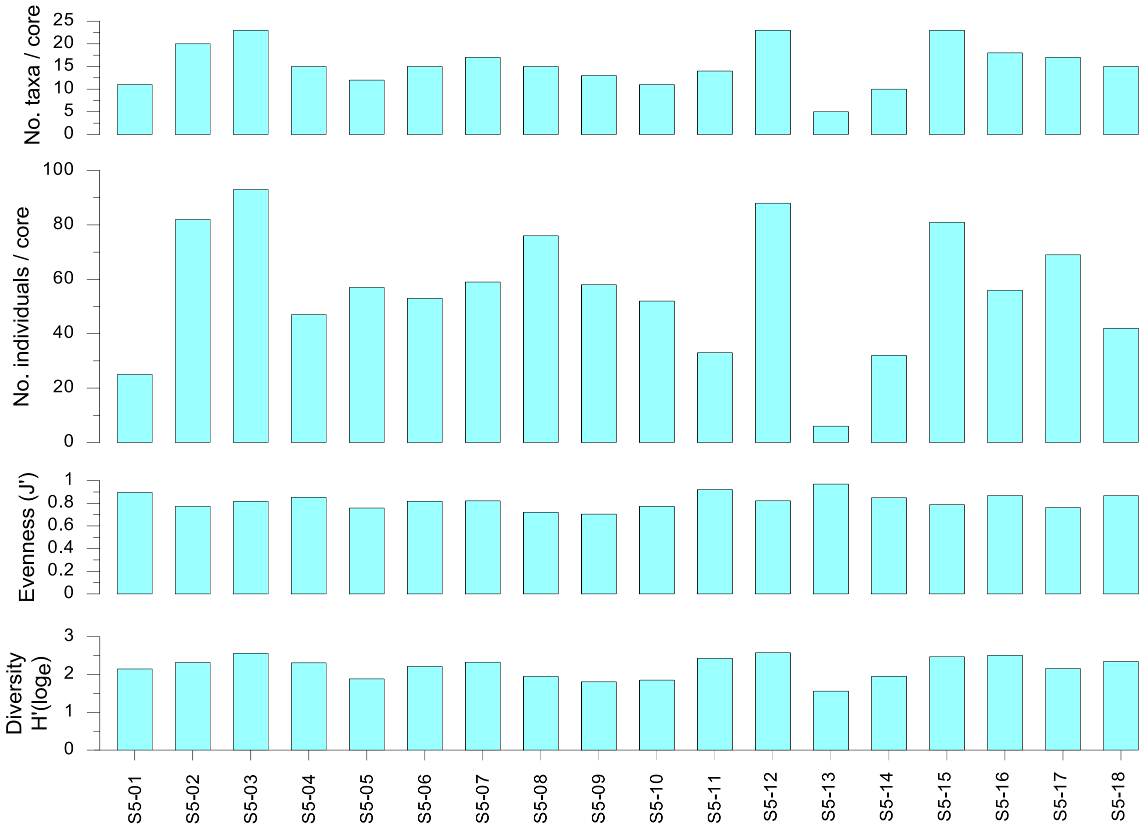

Figure 26. Infauna community indices from the proposed offshore spoil ground. Data based on a single 0.013 m^2 sediment core from each station.

Table 18. List of the most abundant infaunal taxa occurring at the proposed offshore spoil ground.

Group	**Taxa**	**Feeding**	**No./core**
Bivalvia	*Nucula nitidula*	Deposit feeder	14.1
Polychaeta: Capitellidae	*Heteromastus filiformis*	Deposit feeder	9.1
Polychaeta: Spionidae	*Prionospio* sp.	Surface deposit feeder	5.2
Bivalvia	*Dosinia anus*	Suspension feeder	3.1
Holothuroidea	*Heterothyone ocnoides*	Deposit feeder	2.8
Polychaeta: Nephtyidae	*Aglaophamus macroura*	Carnivore	2.6
Bivalvia	*Arthritica bifurca*	Deposit feeder	2.1

6.4.3. Epifauna dredge trawls

Benthic epifauna were sampled in four research dredge trawls within the proposed spoil ground; Figure 24). The biota collected in each trawl are listed in Table 19 below and photographs of the trawl contents are presented in Appendix 7.
The most numerous species collected at the site was the small holothurian *Heterothyone ocnoides.* These were collected in moderately large numbers and several of the related species *Heteromolpadia marenzelleri* were also found to be present. Other common but less abundant epifauna species within the trawl contents included the ostrich-foot whelk (*Struthiolaria papulosa*), knobbed whelk (*Austrofusus glans*), hermit crabs and sea spiders (*Hymenosoma depressum*).

Almost no debris or sediments were retained in the dredge from any trawl and it is thought that, due to the small size of most of the organisms collected relative to the dredge mesh size (10 mm), densities of species noted from both areas were possibly higher than is suggested by the recorded counts and trawl distances. There was little evidence from the trawl contents to suggest significant variation of habitat or community assemblage across the site. All of the species collected are relatively common to sandy coastal areas in the region at similar moderate depths.

Table 19. Epifauna species diversity and abundance recorded from research dredge trawls in the proposed offshore spoil ground area.

Trawl no.		T1	T2	T3	T4
Trawl distance (m)		382	502	483	561
Trawl depth (MSL, m)		20.8	21.0	21.5	21.1
Taxa	**Common name**				
Nemertea	Ribbon worms		1		
Aglaophamus macroura	Polychaete worm		1		
Prionospio sp.	Polychaete worm	1			
Struthiolaria papulosa	Kaikai-karoro	13			
Austrofusus glans	Knobbed whelk		20	3	12
Amalda australis	Olive shell				1
Spisula aequilatera	Triangle shell		5		1
Paguridae	Hermit crabs			10	5
Hymenosoma depressum	Sea spider		1	1	
Heteromolpadia marenzelleri	Sea cucumber		4	1	1
Heterothyone ocnoides	Sea cucumber	216	131	70	70

6.5. Pania Reef habitats and ecology

Pania Reef extends in a north-easterly direction beginning approximately 800 m from the Port of Napier. It is widest (about 400 m) at the south-western end, approximately 1 km north-east of the main Port breakwater, where the boulder and rock substrate emerges gradually from a 15 m deep sand bottom. Toward the seaward end, the topography becomes progressively steeper with large rocks fissured with crevices protruding from a sandy seabed at 18 m water depth.

At its closest points, the Reef is approximately 0.9 km south-east of the capital dredging footprint and 3.3 km north-west of the proposed offshore spoil disposal area.

6.5.1. Dive survey

An image generated from the multi-beam (MBES) survey is shown in Figure 27 overlaid with the components of the April 2016 dive survey. A detailed description of each transect dived, the prevalent biota and the general habitat types encountered is given in the following sections. Selected photographs of representative habitats along each transect are also provided. Note that the photographs have been digitally enhanced for visual purposes and therefore do not necessarily indicate the visibility and colour observed by the divers. A list of the conspicuous epibiota recorded for each transect are presented in Table 20 along with an assessment of relative abundance. Where applicable, brief comparisons with the 1991 and 2005 survey results are also provided.

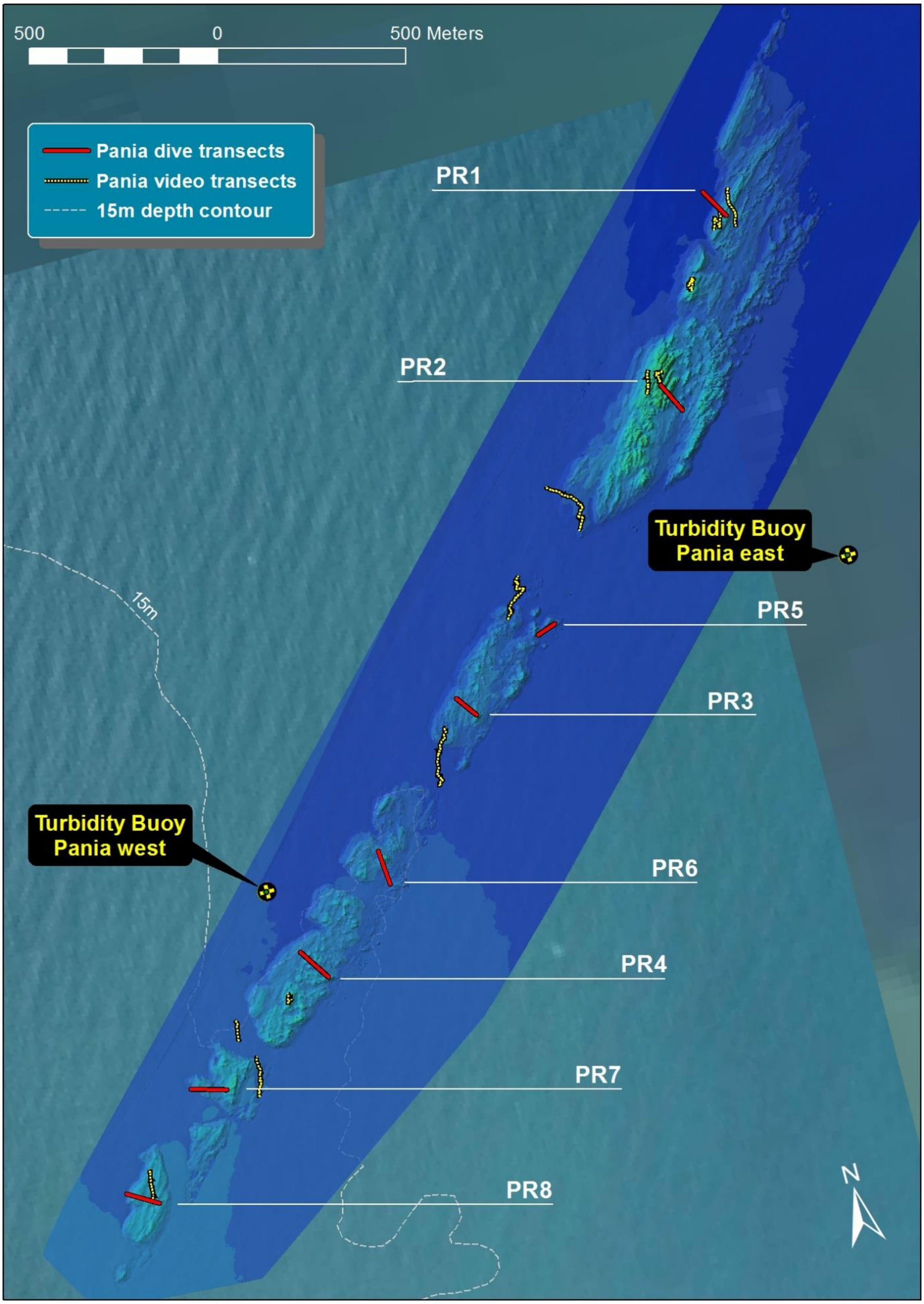

Figure 27. MBES image of Pania Reef showing locations of survey transects and monitoring buoys.

6.5.2. Description of ecological communities at each transect

Dive Transect PR1

Dive transect PR1 was situated on the northern end of the reef system. It began at a depth of 20 m and ran in a south-easterly direction to finish at a depth of 12 m (Figure 28).

The first 60 m of the transect was comprised of undulating bedrock overlaid with sand and fine silt. The ecological community comprised a variety of sessile invertebrates, dominated by the orange finger sponge (*Raspalia topsenti*), the yellow tubular sponge (*Ciocalypta* sp.), a hydroid (bushy hydroid—*Hydrozoa* sp.), clowns-hair bryozoan (*Catenicellidae* sp.) and erect bryozoan (c.f *Candidae* sp. A). Smaller organisms such as sea tulip (*Pyura spinosissima*), stony coral (*Culicea rubeola*), white striped anemone (*Anthothoe albocincta*), siphon whelk (*Penion sulcatus,* Figure 36), hermit crab (*Pagurus* sp.) and sea cucumber (*Australostichopus mollis*) were also present in low numbers. The red alga *Plocamium cirrhosum* was the only macroalga present.

From 60 m onwards along the transect, the reef typography steepened and kelp (*Ecklonia radiata*) forest became the dominant habitat. Although there was less silt, small amounts were still observed amongst the sessile epibiota. Many crevices and holes provided habitat for a plethora of sessile invertebrates including the grey massive sponge (*Ecionemia alata*), pink encrusting coralline paint (*Corallinales*), saddle squirt (*Cnemidocarpa* sp.), an unidentified bivalve, clowns hair bryozoan and orange finger sponge. As the profile became shallower (< 15 m depth), large patches of green-lipped mussels (*Perna canaliculus*), along with gastropods such as the green top shell (*Coelotrochus viridus*), tiger shell (*Calliostoma tigris*) and cooks turban (*Cookia sulcata*) were also present amongst the kelp. The sponge communities remained present in the troughs and under the overhangs.

Numerous demersal and semi-demersal fish species were encountered along the transect including blue cod (*Parapercis colias*), dwarf scorpion fish (*Scorpaena papillosa*), and a variety of triple fins (common–*Forsterygion lapillum*, variable–*Forsterygion varium* and yellow-black–*Forsterygion flavonigrum*). In the water column were butterfly perch (*C. lepidoptera*, Figure 36), leatherjackets (*Meuschenia scaber*), scarlet wrasse (*Pseudolabrus miles*) and spotties (*Notolabrus celidotus*).

Ecological communities in 2005 were similar although a notable difference was the absence of flapjack (*C. maschalocarpum*) in 2016. This is likely due to the slightly deeper depth (≤ 12 m) of the 2016 transect as surface-operated video footage confirmed the presence of flapjack at shallower depths near this station.

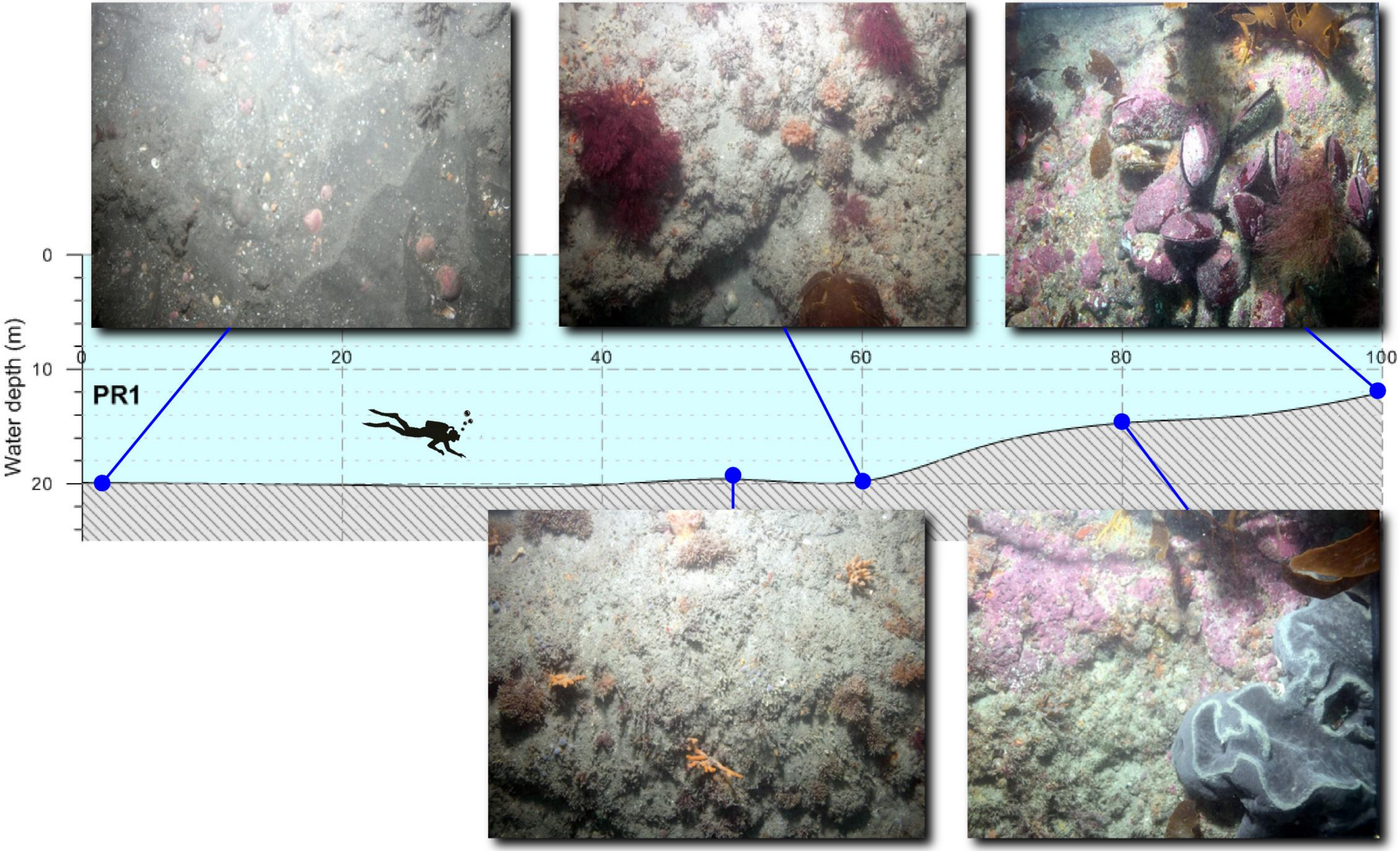

Figure 28. Depth profile with photographs of representative habitat along PR1. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive Transect PR2

PR2 was positioned on the south west side of Pania Rock. The transect began in 14.5 m water depth and progressed in a north-westerly direction towards the top of Pania Rock at 4 m depth (Figure 29). The substrate along the first 10 m of the transect was comprised of bedrock covered in sand patches and a fine layer of silt, after which there was a mix of cobble, boulder, bedrock and sand. At the shallowest depths, the silt layer had been largely washed away.

A variety of sponges was present along the first 50 m of the transect after which only the grey massive sponge and orange encrusting sponge (*Cliona* sp.) were present. Bryozoans (clowns hair, erect bryozoan), hydroids (feather hydroid–*Aglaophenia* sp. and mussel beard hydroid–*Amphisbetia bispinosa*), ascidians (saddle squirt, white colonial ascidian–*Eudistoma* sp., solitary ascidian–Acidiacea sp. A, and cream colonial ascidian–c.f *Didemnum* sp.) were also present along most (0–80 m) of the transect.

Green-lipped mussels were occasional between 30–60 m. Conspicuous mobile fauna included gastropods (green topshell, siphon whelk, circular saw shell – *Astraea heliotropium*, white rock shell – *Dicathias orbita*), kina (*Evechinus chloroticus*) and sea cucumber. Macrophyte communities were dominated by kelp (abundant) and coralline paint – Corallinales (common). However, these communities were relatively diverse with a variety of other brown (*Zonaria angustata*, *Carpomitra costata*) and red (*P. cirrhosum*, *Pterocladia capillacea*) seaweeds.

At 50 m the ‘reef proper’ began with some rock ledges and associated crevices as well as less overlying sediment. Kelp, flapjack (*C. maschalocarpum*) and coralline paint were common or abundant from 60 m onwards. Tightly packed beds of large green-lipped mussels were common from 70–100 m along the transect at depths shallower than 10 m.

Fish were present along the full transect length with scarlet wrasse and variable triplefins the most abundant. Other fish present included butterfly perch, spotted wrasse, blue cod, dwarf scorpion fish (*Scorpaena papillosa*) and blue eyed triplefin (*Notoclinops segmentatus*).

The ecological communities described above were generally similar to those at the same location in 2005 and 1991. However, green seaweed of the genus *Caulerpa* was common in 1991 and 2006 but absent in 2016. The hydroid tree (*Solandris ericopsis*) was occasionally present in 2006 but absent in 1991 and 2016.

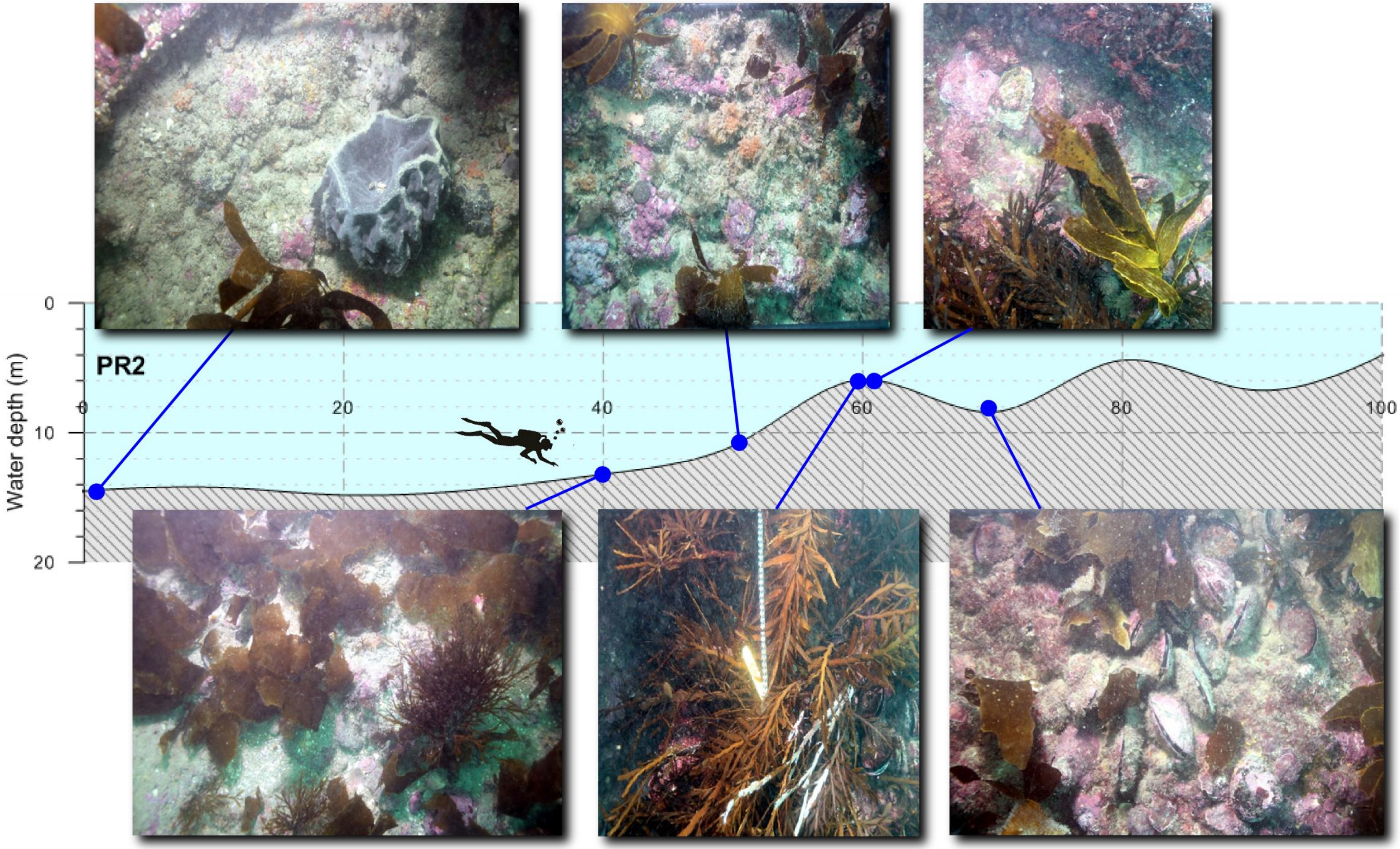

Figure 29. Depth profile with photographs of representative habitat along PR2. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive Transect PR5

PR5 was situated on the eastern side of the middle section of Pania Reef and ran in a south-easterly direction. The transect profile was relatively flat, fluctuating between a water depth of 17–15.5 m (Figure 30). The substrate was dominated by bedrock covered in silt, with the occasional sandy patch halfway along the transect. The silt layer was noticeably thicker compared to that at transects PR1 and PR2.

Seafloor communites were generally consistent across the full transect length. The macroalgae community was relatively sparse, comprising red algae (*P. cirrhosum*, small red blade algae–Rhodophyta) and kelp which were rarely encountered. Sessile epibiota communites were present, consisting mainly of grey massive and yellow tubular sponges, erect bryozoan, orange tube hydroid (*Steginoporella neozelandica*) and grey colonial and saddle squirt ascidians. Horse mussels (*A. zelandica*) were also encounted between 30–40 m, and green-lipped mussels at 50 m, along the transect. Mobile epifauna comprised of siphon and lined whelks (rarely encountered) and hermit crabs (common at the 30 m mark).

Butterfly perch were the only fish commonly encountered although a numer of other species were present including: leather jacket, red moki, blue cod, dwarf scorpion fish and variable and common triplefin.

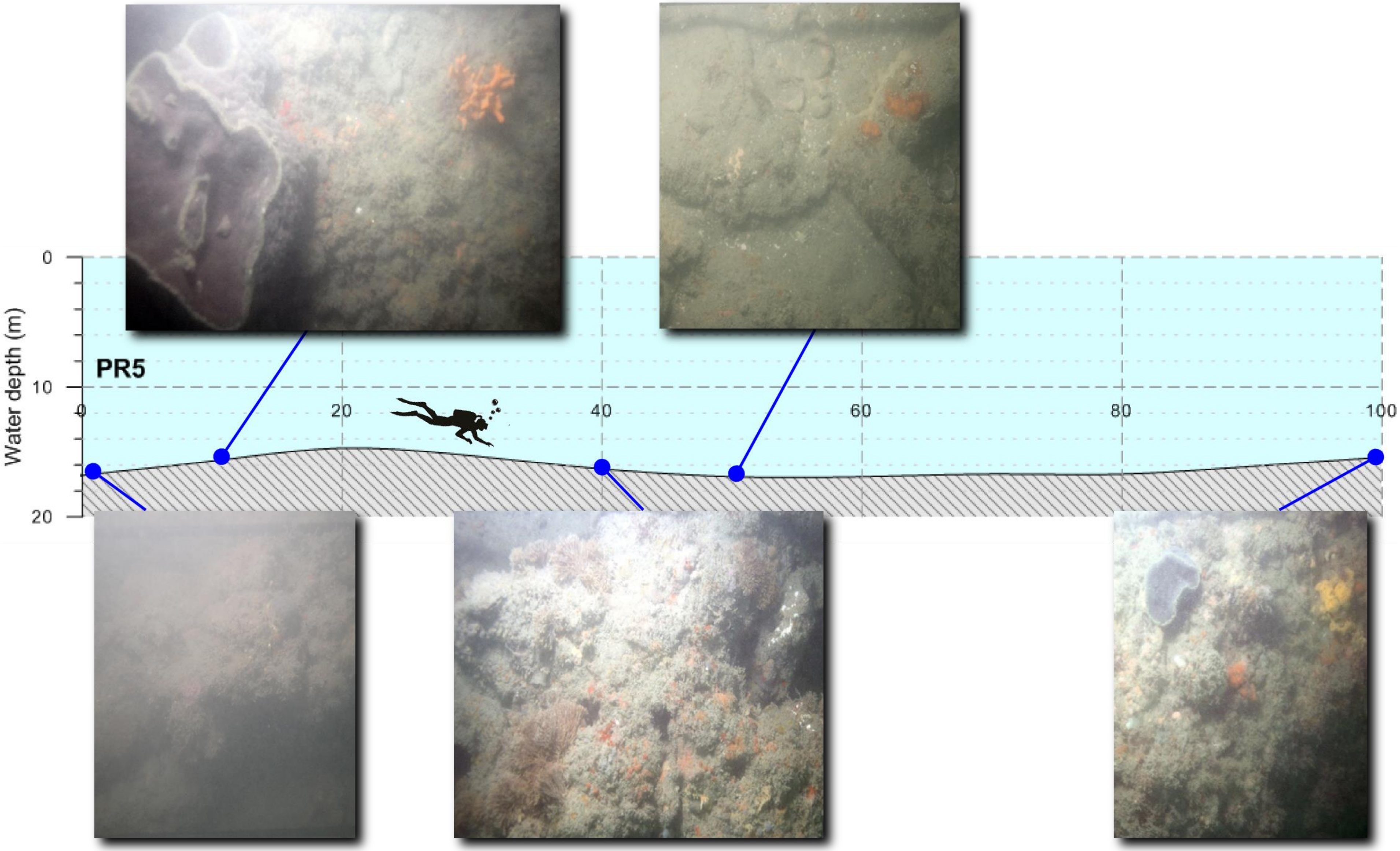

Figure 30. Depth profile with photographs of representative habitat along PR5. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive transect PR3

PR3 was positioned on the north-west side of Pania Reef and ran in a south-easterly direction from a depth of 15 m up onto a shallow rock to 8.7 m depth near the middle of the reef (Figure 31). The seafloor substrate along the first 50 m of the transect comprised bedrock, boulders and sand patches with overlying silt in 15–13.5 m of water. From 60 m onwards the profile rose gradually and the seafloor changed to bedrock and overlying silt with the rare patch of sand. Between 90–100 m the reef gradient rose more steeply to a depth of 8.7 m and the substrate was relatively clean of silt.

Between 0–70 m macroalgae communities consisted largely of kelp, which was abundant, as well as red algae (*P. cirrohum*, coralline paint). Sessile invertebrate communities included a variety of sponges (orange finger, yellow tubular, orange golf ball–*Tethya burtoni*, pink thick encrusting–Demospongia sp. C, and grey massive), bryozoans (clowns hair, erect bryozoan), the feather hydroid (*Aglaophenia* sp.) and saddle squirt ascidian. Mobile epifauna included gastropods (siphon whelk, Cunninghams top shell–*Calliostoma selectum*, tiger shell, circular saw shell and swollen trumpet shell–*Argobuccinum pustulosum*), hermit crab and the 11-armed seastar (*Coscinasterias muricata*).

After 80 m there were fewer sessile invertebrates (e.g. sponges, ascidians and bryozoans) although mussel beard hydroid, stony coral (*Culicea rubeola*) and the grey massive sponge were present. Epibiotic communities were instead dominated by macroalgae, mostly kelp but also coralline paint and *P. cirrhosum,* and green-lipped mussels which were common to abundant. The clown nudibranch (*Ceratosoma amoenum* Figure 36) was also present.

Fish encountered along the transect included: butterfly perch, sweep (*Scorpis lineolata*), spotted wrasse and variable triplefin. At the start (deeper end) of the transect blue cod, leather jacket and dwarf scorpion fish were observed. At shallower depths (< 12 m) depths scarlet wrasse, red moki (*C. spectabilis*), banded wrasse, hiwihiwi (*Chironemus marmoratus*), marblefish (*Aplodactylus arctidens*) and oblique triplefins (*Forsterygion maryannae*) also occurred.

In 2005, kelp occurred as only a sparse canopy while in 2016 this macroalgal species was abundant along most of the transect. Flapjack and coralline turf were also present in 2005 but absent in 2016. A number of conspicuous invertebrate taxa including sea cucumber, sea stars (*P. regularis*) and horse mussels were also observed in 2005 but not in 2016. Otherwise, ecological communities were generally similar between these two years.

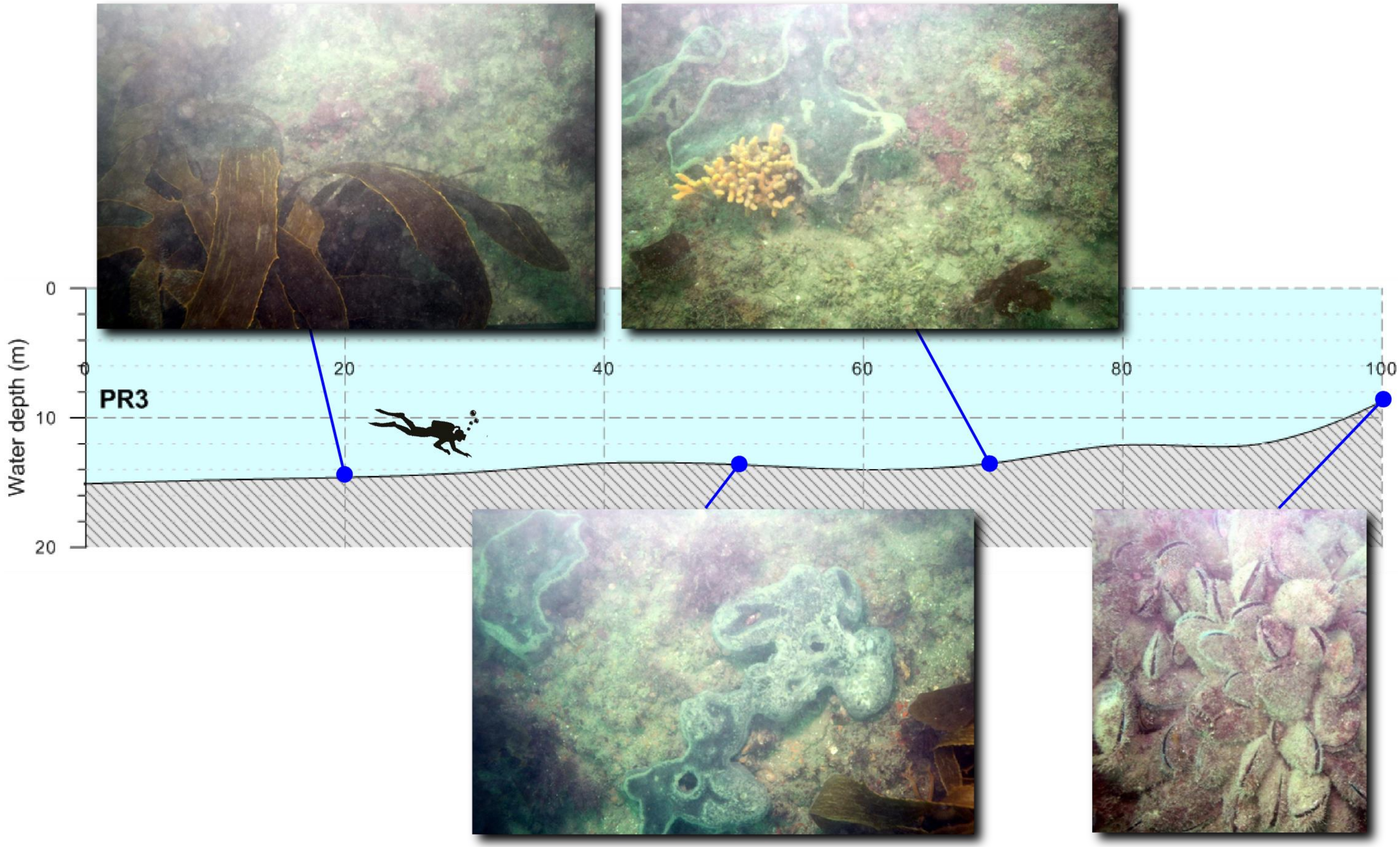

Figure 31. Depth profile with photographs of representative habitat along PR3. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive Transect PR6

PR6 was situated on the north eastern side of the southern section of Pania Reef. The transect ran in a south-easterly direction and for the first 50 m the profile was relatively flat and at its deepest depth (16 m) (Figure 32). After this it rose sharply to its shallowest depth of 9.8 m at the 70 m mark and then fell back down to approximately 14 m depth at the end. The substrate was dominated by bedrock, which was covered in sandy patches and silt along the first half and near the end of the transect. Noticeably less silt covered the substrate between 60–70 m when the profile was at its shallowest.

Between 0–40 m along the transect macroalgal communities were sparse and restricted to red algae (*P. cirrhosum* and coralline paint). Sessile invetebrate communities comprising of sponges, bryozoans, hydroids and ascidianc were present with taxa including: grey massive sponge, yellow lumpy sponge–Demospongia sp. E, purple tubular sponge–c.f *Thorecta* sp., erect bryozoan, orange tube hydroid, bushy hydroid, saddle squirt and grey and white colonial ascidians. Mobile invertebrates, present in small numbers, were siphon whelk, hermit crabs and sea cucumbers.

Between 70–80 m some sessile biota were less prevalent although these were again encountered at the 90–100 m mark. The only mobile taxa observed after 40 m was the butterfly chiton (*Cryptochonchus porosus*). Kelp was present after 50 m and was common from 70 m onwards. Red algae (*P. cirrhosum* and coralline paint) were also present.

A variety of fish were encountered including: butterfly perch, blue cod, leather jacket, red moki, spotted wrasse, tarakihi (*Nemadactylus macropterus*), sweep, dwarf scorpion fish, banded wrasse, variable triplefin, spectacled triplefin (*Ruanoho whero*) and scarlet wrasse.

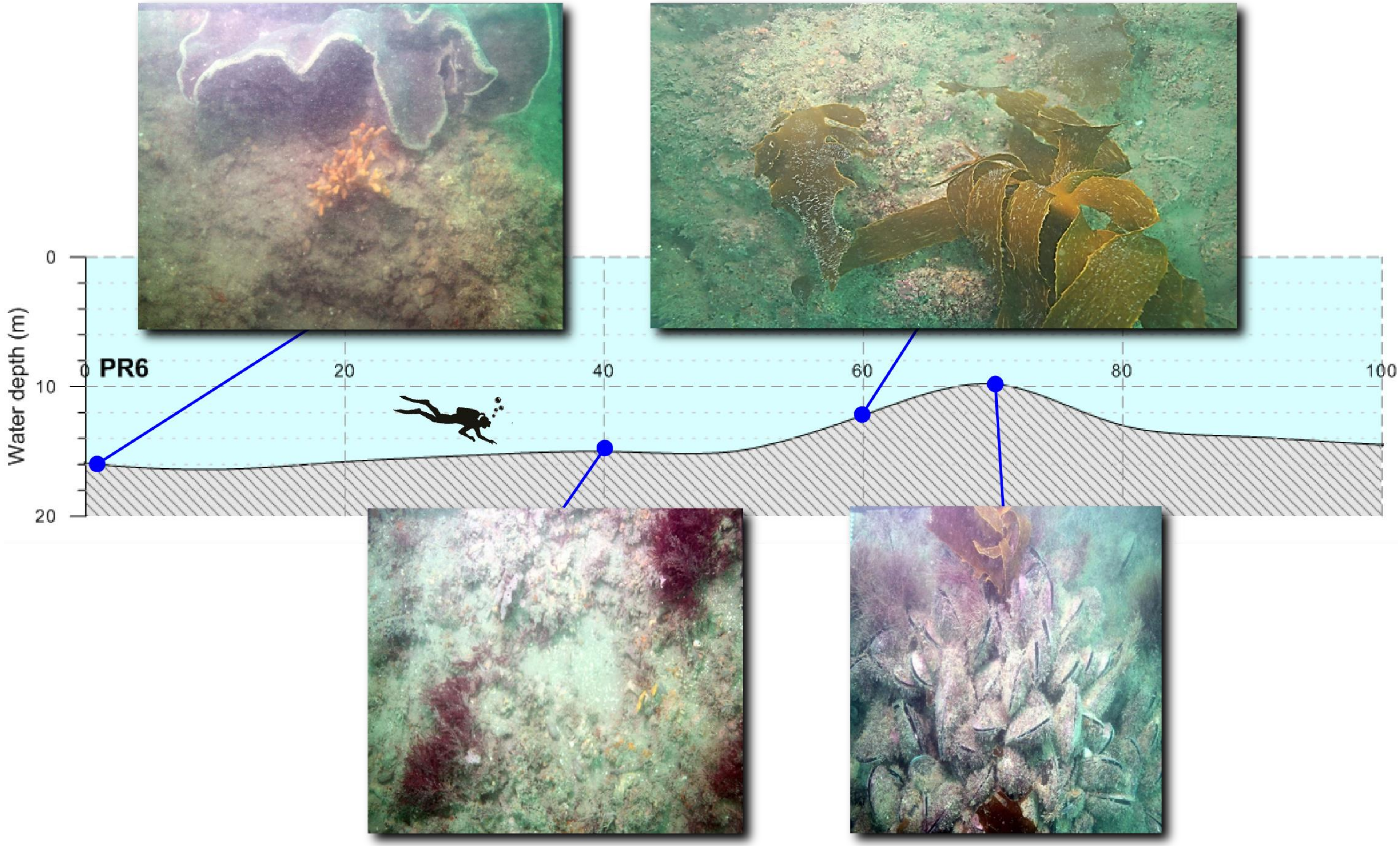

Figure 32. Depth profile with photographs of representative habitat along PR6. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken. .

Dive Transect PR4

PR4 was located on the north-westerly side of the most southern section of Pania Reef and ran in a south–easterly direction. The transect profile was relatively flat, fluctuating between 13.4–11 m water depth (Figure 33). The substrate along most of the transect was comprised of bedrock, except for between 70–90 m where cobble and sand overlaid the bedrock. Silt was prevalent along the full transect length.

Seafloor communities were relatively consistent along the transect and included sponge gardens comprising a variety of sessile biota. The commonest of these were the sponges (grey massive, orange finger, yellow tubular and orange golfball), bryozoans (clowns hair, erect), the feather hydroid (*Aglaophenia* sp.) and ascidians (saddle squirt, white colonial ascidian and white didemnum). Macroalgae included kelp (occasional to common) as well as red algae (*P. cirrhosum*, red blade algae and coralline paint). Mobile epifauna included gastropods (siphon whelk, green top shell and Cunninghams top shell), hermit crabs and sea cucumbers. Green-lipped mussels were occasionally encountered in the final 10 m of the transect. Fish communities comprised butterfly perch, spotties, blue cod, dwarf scorpion fish, variable triplefin, leather jacket, scarlet wrasse and an eagle ray (*Myliobatis tenuicaudatus*).

In 2005, a bed of well-established green-lipped mussels encrusted the entire top of a large boulder at the shallow end (≤ 10 m depth) of the transect. Clusters of ascidians (genus *Pyura*) colonised the boulder and flapjack was also present. The 2016 transect profile was deeper than 10 m, which likely explains why mussels were only occasionally encountered and flapjack was absent.

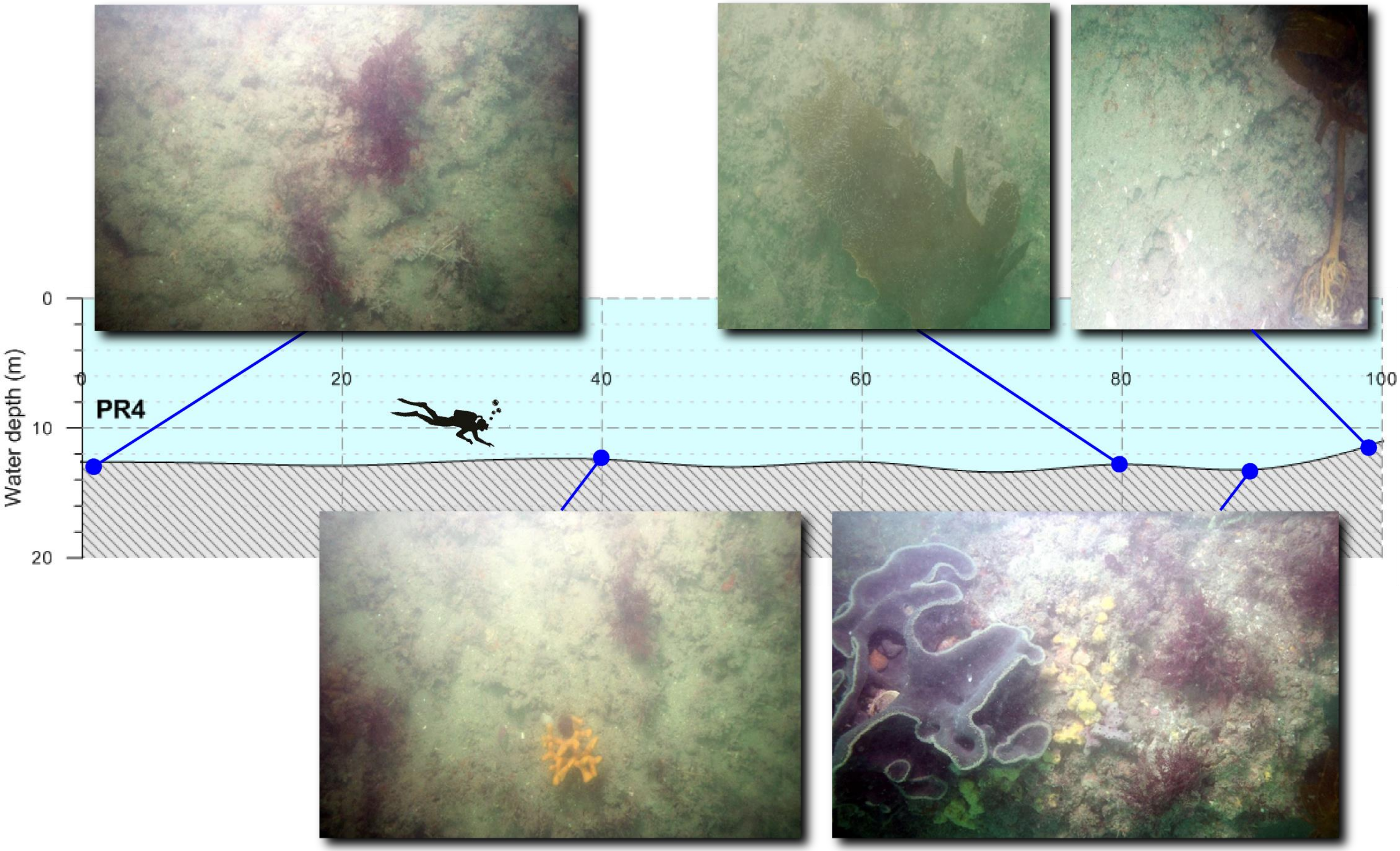

Figure 33. Depth profile with photographs of representative habitat along PR4. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive Transect PR7

PR7 was located on the north-eastern side of Pania Reef and ran in a south-easterly direction. The transect profile undulated between 12.8–14.6 m water depth for the first 80 m, before rising to 11 m depth at the end (Figure 34). The substrate was dominated by bedrock overlaid with a heavy covering of silt, and the occasional patch of sand in the middle of the transect. Silt was less prevalent from 90 m onwards where the transect was slightly shallower.

Macroalgal communities along the full transect length included red algae (*P. cirrhosum* and red blade algae) which were only rarely or occasionally encountered. From 10 m onwards, kelp was also occasionally or commonly present. Sessile biota communities were prevalent along most of the transect, including sponges (grey massive, pink golf ball–*Tethya bergquistae*, yellow tubular, orange finger, lilac–Demospongia sp. D, yellow lumpy and purple tubular), bryozoans (clowns hair, erect), hydroids (feather, orange tube), cnidarians (white striped anemone–*Anthothoe albocincta*, common soft coral–*Alycyonium* c.f *aurantiacum*) and ascidians (saddle squirt, grey and white colonial). Oysters (Ostreidae sp.) were observed between 10-30 m.

From 90 m onwards, a reduced variety of sessile invertebrates were observed including: sponges (grey massive, yellow tubular, lilac and pink golf ball), bushy hydroids and grey colonial ascidians. Green-lipped mussels were present from 50 m, and common from 70 m, onwards. Conspicuous mobie epifauna along the transect included: siphon and lined whelks, tiger shells, hermit crabs, sea cucumber and the 11-armed seastar. A variety of fish were encountered with butterfly perch and blue cod the most common. Variable triplefin, banded triplefin (*Forsterygion malcomi* Figure 36), scarlet wrasse and dwarf scorpion fish were also present.

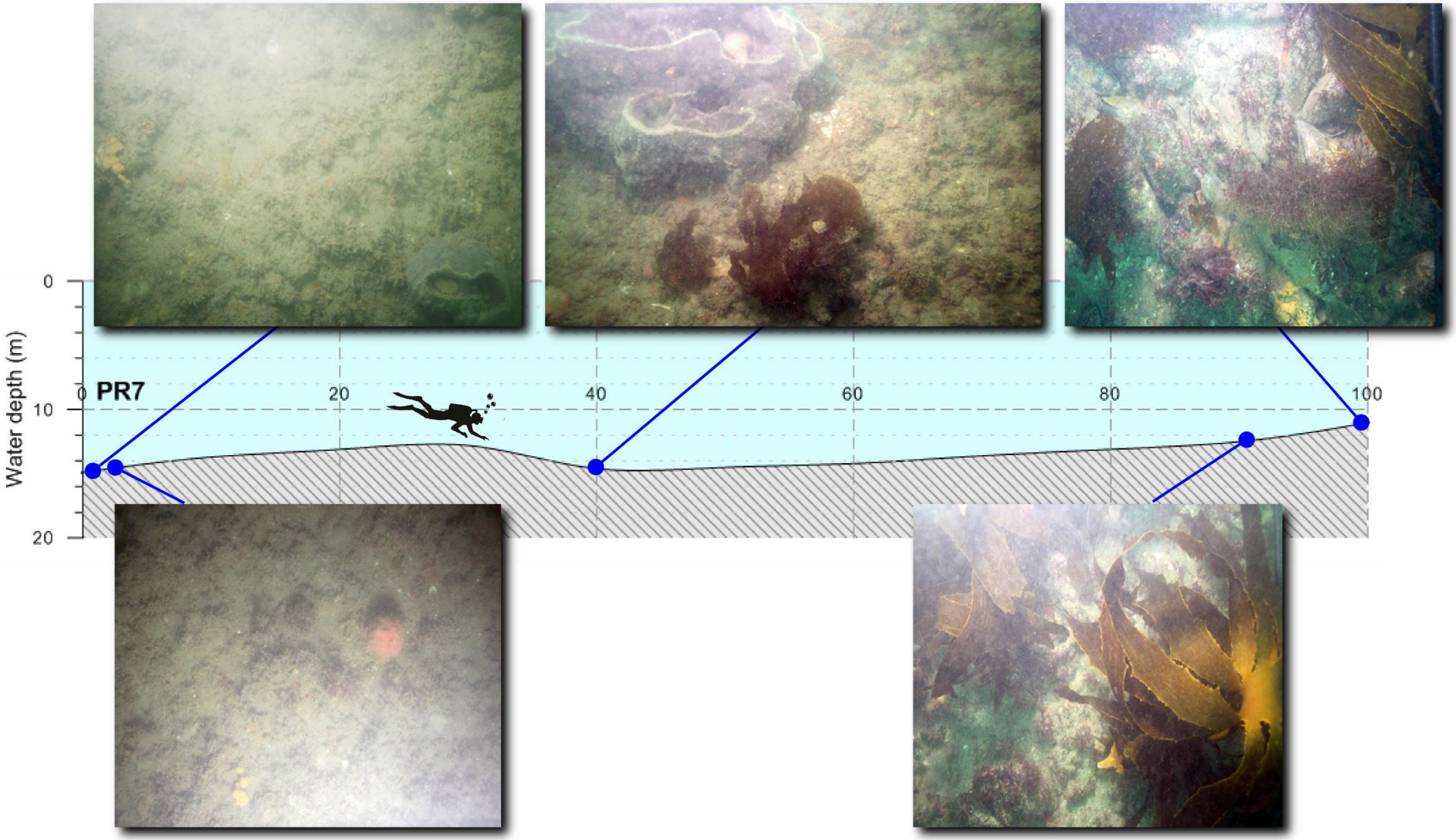

Figure 34. Depth profile with photographs of representative habitat along PR7. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Dive Transect PR8

PR8 was the southernmost transect (closest to the shore) on Pania Reef and ran in a south-easterly direction. The transect profile began at 16 m depth. From the 30 m mark it rose to 13 m depth after which it was relatively flat, fluctuating between 13-11.6 m depth (Figure 35). Along the first 10 m, the substrate was dominated by silty sand after which silt-covered bedrock (with sand at 70 m) became abundant. Silt layers were relatively thick along the full transect length.

No conspicuous biota were encountered in the sandy habitat at the start of the transect. After 10 m, macroalgal communities, restricted to red algae (*P. cirrhosum* and coralline paint) and small red blade algae (from 60 m onwards), were present. Diverse communities of sessile biota were present, with the most common being sponges (grey massive, orange golf ball, yellow tubular, orange finger, lilac, yellow lumpy, orange massive), hydroids (feather, orange tube), the white striped anemone and ascidians (sea tulip, saddle squirt, grey and white and cream colonial ascidians and white didemnum). The hydroid tree (*Solandris ericopsis*) was also encountered. Horse mussels and oysters were present between 10–20 m and green-lipped mussels encountered at the 50 m mark.

A range of mobile invertebrates occurred in low numbers including siphon whelk, Cunninghams topshell, clown nudibranch, beaded topshell (*Calliostoma puntulatum*), sea cucumber and hermit crab. Spiny rock lobster (*Jasus edwardsii,* Figure 35, Figure 36) were present between the 40–50 m marks.

Butterfly perch and blue cod were the most common fish observed along the transect. Spotted wrasse, variable triplefin, scarlet wrasse and blue moki were also present.

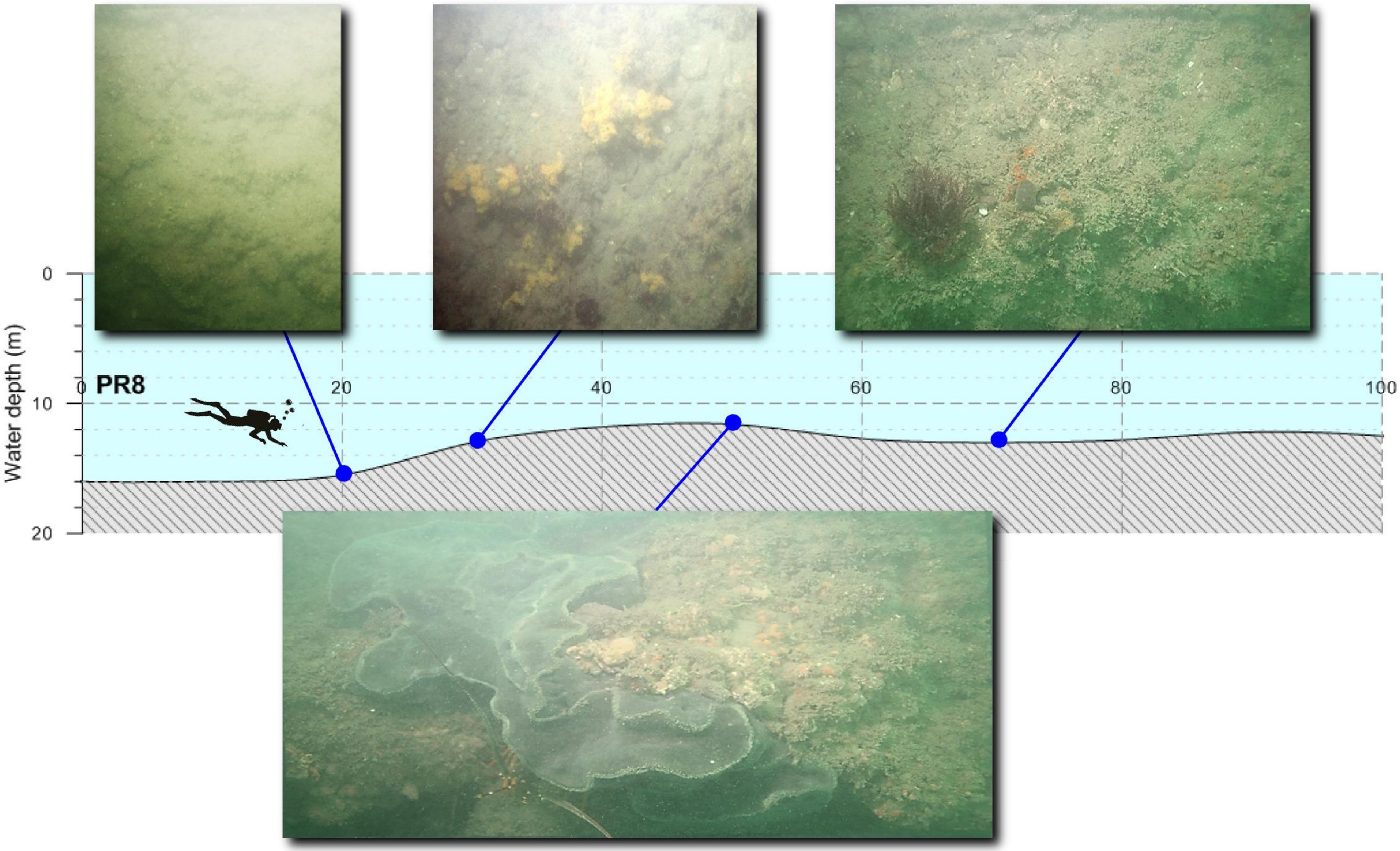

Figure 35. Depth profile with photographs of representative habitat along PR8. The photographs are aligned with the transect profile to indicate representative habitat along the transect and the blue lines indicate the exact location at which they were taken.

Table 20. Epibiota taxa list and the range of abundance rankings along the eight transects surveyed on Pania Reef in 2016. N = not present, R = rare, O = occasional, C = common, A = abundant. For visual purposes, a blank cell indicates a complete absence all along the transect (i.e. N). Transects are listed in the order of increasing distance from the seaward end i.e. along the wave exposure gradient.

Scientific name	**Common name**	**PRI**	**PR2**	**PR5**	**PR3**	**PR6**	**PR4**	**PR7**	**PR8**
Phaeophyceae	**Brown algae**								
Ecklonia radiata	Kelp	N-A	A	N-R	O-A	N-C	R-C	N-C	
Carpophyllum maschalocarpum	Flapjack		N-A						
Halopteris sp.		N-R	N-C						
Zonaria angustata			N-C						
Carpomitra costata			N-C						
Rhodophyta	**Red algae**								
Plocamium cirrhosum		N-C	N-C	N-O	R-A	N-O	C	R-C	N-C
Corallinales	Coralline paint	N-C	N-A		C	N-C	N-O		N-R
Pterocladiella capillacea			N-O						
Rhodophyta sp.	Small red blade algae			N-R	N-O		C	R-O	N-C
Porifera	**Sponges**								
Ecionemia alata	Grey massive sponge	N-C	N-C	N-C	N-C	N-O	C	R-O	N-C
Cliona sp.	Orange encrusting sponge		N-C	N-R			N-R		
Polymastia sp.						N-R			
c.f Hymeniacidon sp.	Orange massive sponge		N-R			N-O			N-C
Tethya bergquistae	Pink golf ball sponge	N-R	N-R			N-R	N-O	N-O	N-R
Ciocalypta sp.	Yellow tubular sponge	N-C	N-O	N-C	N-O	N-O	N-C	N-C	N-C
Raspalia topsenti	Orange finger sponge	N-R	N-R	N-C	N-O	N-O	R-O	N-O	N-C
Tethya burtoni	Orange golf ball sponge	N-R		N-R	N-O		N-O		N-O
Demospongia sp. A	White/green massive sponge		N-R	N-R		N-R			
Demospongia sp. B	Grey massive sponge		N-R	N-R					N-R
Demospongia sp. C	Pink thick encrusting sponge				N-O				
Demospongia sp. D	Lilac sponge				N-R	N-O	N-C	O-C	N-O
Demospongia sp. E	Yellow massive lumpy sponge			N-O		N-O	N-R	N-O	N-O
c.f *Thorecta* sp.	Purple tubular sponge					N-O	N-R	N-O	N-O
Demospongia sp. F	Maroon massive sponge					N-R			
Latrunculia sp.			N-R				N-R		
Bryozoa									
Catenicellidae sp.	Clowns hair/moss bryozoan	N-C	N-C	N-O	N-O	N-O	N-O	N-R	N-R
c.f Candidae sp. A	Erect bryozoan	N-O	N-C	N-C	N-C	N-O	N-O	N-O	
c.f Candidae sp. B	Erect fan bryozoan					N-R			

Table 20, continued

Scientific name	Common name	PRI	PR2	PR5	PR3	PR6	PR4	PR7	PR8
Cnidaria	**Hydroids, anemones, corals**								
Aglaophenia sp.	Feather hydroid	N-R	N-C	N-O	N-O		N-O	R-O	N-C
Solandria ericopsis	Hydroid tree								N-R
Steginoporella neozelandica	Orange tube hydroid	N-R		N-C		N-O	N-R	N-O	N-O
Amphisbetia bispinosa	Mussel beard hydroid		N-O		N-A	N-C			
Hydrozoa sp.	Bushy hydroid	N-C		N-O		N-C	N-R	N-O	
Ectopleura sp.									N-R
Bougainvilliidae	Encrusting hydroid			N-O		N-R			
Culicea rubeola	Stony coral	N-R		N-R	N-C				
Anthothoe albocincta	White-striped anemone	N-O	N-C					R-O	N-O
Anthozoa sp.	Unid. red subtidal anemone						N-R	N-R	
Alcyonium c.f aurantiacum	Common soft coral							N-O	
Monomyces rubrum	Stony coral								N-R
Ascidiacea	**Tunicates, sea squirts**								
Pyura spinosissima	Sea tulip	N-R	N-R				N-R		N-C
Cnemidocarpa sp.	Saddle squirt	N-O	N-O	N-C	N-O	N-O	O	N-O	N-C
c.f Synoicum otagoensis	Grey colonial ascidian			N-C		N-O	N-O	O-C	N-O
Eudistoma sp.	White colonial ascidian		N-O	N-O		N-O	N-O	N-O	N-C
Ascidiacea sp. A	Solitary ascidian		N-R						
c.f *Didemnum* sp.	Cream colonial ascidian		N-R				N-O		N-O
Didemnum sp.	White didemnum						N-O		N-O
Alcyonium aurantiacum									N-O
Bivalvia									
Perna canaliculus	Green-lipped mussel	N-C	N-C	N-R	N-A	N-A	N-O	N-C	N-R
Atrina zelandica	Horse mussel			N-O					N-R
Bivalvia sp.	Unid. attached bivalve	N-O							
Ostreidae sp.	Oyster							N-R	N-R
Polyplacophora	**Chitons**								
Cryptoconchus porosus	Butterfly chiton					N-R			
Gastropoda	**Snails, limpets**								
Coelotrochus viridus	Green top shell	N-R	N-O				N-R		
Penion sulcatus	Siphon whelk	N-R	N-R	N-R	N-O	N-O	N-O	N-O	N-R
Calliostoma selectum	Cunninghams top shell				N-R		N-R		N-R
Calliostoma tigris	Tiger shell	N-R			N-O			N-R	
Cookia sulcata	Cooks turban	N-O							
Dicathias orbita	White rock shell		N-C						
Buccinulum linea	Lined whelk		N-O	N-R		N-O		N-R	
Ceratosoma amoenum	Clown nudibranch	N-R			N-R				N-R

Table 20, continued

Scientific name	Common name	PRI	PR2	PR5	PR3	PR6	PR4	PR7	PR8
Calliostoma punctulatum	Beaded top shell								N-R
Astraea heliotropium	Circular saw shell		N-O		N-R				
Argobuccinum pustulosum	Swollen trumpet shell				N-R				
Crustacea	**Crabs, lobster, barnacles**								
Jasus edwardsii	Rock lobster								N-R
Pagurus sp.	Hermit crab	N-O		N-C	N-R	N-O	N-R	N-R	N-C
Cirripedia sp.	Unid. barnacle		N-O						
Echinodermata									
Australostichopus mollis	Sea cucumber	N-R	N-O		N-O	N-R	N-R	N-O	N-R
Evechinus cloroticus	Kina		N-O						
Coscinasterias muricata	11-armed seastar				N-R			N-R	
Osteichthyes	**Fish**								
Meuschenia scaber	Leather jacket	N-O	N-C	N-R	N-O	N-R	N-R		
Caesioperca lepidoptera	Butterfly perch	N-C	N-C	N-C	O-A	N-A	N-C	N-O	N-C
Cheilodactulus spectabilis	Red moki		N-R	N-R	N-O	N-O			
Notolabrus celidotus	Spotted wrasse	N-O	N-O	N-R	N-C	N-R	N-R		N-R
Nemadactylus macropterus	Tarakihi	N-R				N-C			
Parapercis colias	Blue cod	N-O	N-R	N-R	N-O	N-O	N-O	N-O	N-O
Scorpis lineolata	Sweep		N-O		N-C	N-O			
Scorpaena papillosa	Dwarf scorpion fish	N-O	N-O	N-R	N-R	N-R	N-R	N-R	
Notolabrus fucicola	Banded wrasse		N-O		N-O	N-O		N-R	
Forsterygion varium	Variable triplefin	N-O	N-O	N-R	N-O	N-O	N-R	N-R	N-R
Forsterygion lapillum	Common triplefin	N-R		N-R					
Forsterygion flavonigrum	Yellow-black triplefin	N-R							
Pseudolabrus miles	Scarlet wrasse	N-O	N-O		N-O	N-O	N-R	N-R	N-R
Chironemus marmoratus	Hiwihiwi				N-R				
Latridopsis ciliaris	Blue moki				N-R				N-R
Notoclinops segmentatus	Blue-eyed triplefin		N-R						
Aplodactylus arctidens	Marble fish				N-R				
Forsterygion maryannae	Oblique triplefin				N-O				
Myliobatis tenuicaudatus	Eagle ray						N-R		
Ruanoho whero	Spectacled triplefin					N-R			
Forsterygion malcomi	Banded triplefin					N-R		N-R	

6.5.3. Environmental factors

Overall, 82 animal taxa and nine macroalgal taxa were recorded from the eight Pania Reef transects (Table 20). Environmental factors typically influence the distribution of rocky reef organisms and ecological communities on Pania Reef exhibited strong patterns in relation to position along the longitudinal axis of the reef, depth and level of sedimentation.

Figure 36. A selection of mobile epibiota and fish encountered at Pania Reef: siphon whelk (top left), clown nudibranch (top right), dwarf scorpion fish (middle left), butterfly perch (middle right), banded triplefin (bottom left), rock lobster (bottom right).

Depth can influence community composition due to its effect on the magnitude of other environmental factors e.g. light availability and water motion are typically higher at shallower depths. Depths along the eight Pania Reef transect profiles ranged between 4 m and 20.3 m. Most transect profiles were deeper than 10 m. The exceptions were PR2, PR3 and PR6, which were shallower than 10 m for at least part of their profiles.

Wave exposure can impact reef organisms through direct physical force. It can also influence other environmental factors. For example, it can resuspend and disperse deposited fine sediment or increase food availability for filter feeders and planktivores.

Pania Reef is located at an angle to the shore, extending into deeper waters. It also features greater relief in its topography towards its seaward end. This potentially creates a gradient in wave energy along the length of the reef, with the most seaward stations (PR1 and PR2) being the most exposed to water movement. There is also a gradient in water movement down the reef profile, with shallower habitats being subject to greater wave energy.

Although fine deposited sediment (silt veneer) was evident at all Pania Reef transects, it was correlated positively with depth and negatively with distance from the seaward end of the reef. This is likely due to the influence of these two factors on water motion which resuspends and disperses fine sediment from the reef. There was also a persistent benthic turbidity layer in the water column at the transects closest to shore with water clarity generally greater at the transects furthest from shore. The degree of sedimentation is likely to fluctuate in response to sea state. Long period swell is likely to be an important factor contributing to the resuspension of sediments from the seabed surrounding the reef. Conditions were calm with minimal swell during the 2016 survey.

Patterns in ecological communities

In terms of average depth-related ecological patterns, a transition was observed to occur at approximately 11 m. Above this transition zone, communities were characterised by relatively abundant brown seaweeds (kelp and flapjack), coralline paint, grey massive sponges, clowns hair bryozoan, green-lipped mussels and butterfly perch (Figure 37, Figure 38). These taxa likely benefitted from the greater water movement (as filter feeders and planktivores) and associated lower levels of settled sediment (many encrusting organisms) and higher light availability (photosynthesizing macroalgae) at the shallower depths. It should be noted, however, that transects did not often run into shallow depths and therefore it is possible that the actual distributions of taxa at shallow depths may be underrepresented.

Communities at greater water depths (> 11 m) were characterised by a range of taxa that were present, but generally not abundant, including encrusting invertebrates such as sponges (yellow massive, orange finger, orange golf ball, lilac sponge), a bryozoan (erect), ascidians (grey colonial, ascidian spp. and *Cnemidocarpa* sp. A), a hydroid (feather) and fish (scarlet wrasse, blue cod) and a red seaweed (*P. cirrhosum*) (Figure 37, Figure 39). With the exception of flapjack, all of the taxa characteristic of shallower communities were present at these greater depths, although not as abundant. Some encrusting invertebrates such as sponges can tolerate sedimentation (Bell et al*.* 2015), do not typically require high light levels and likely benefit from lower competition for space from macroalgae (Cárdenas et al*.* 2012).

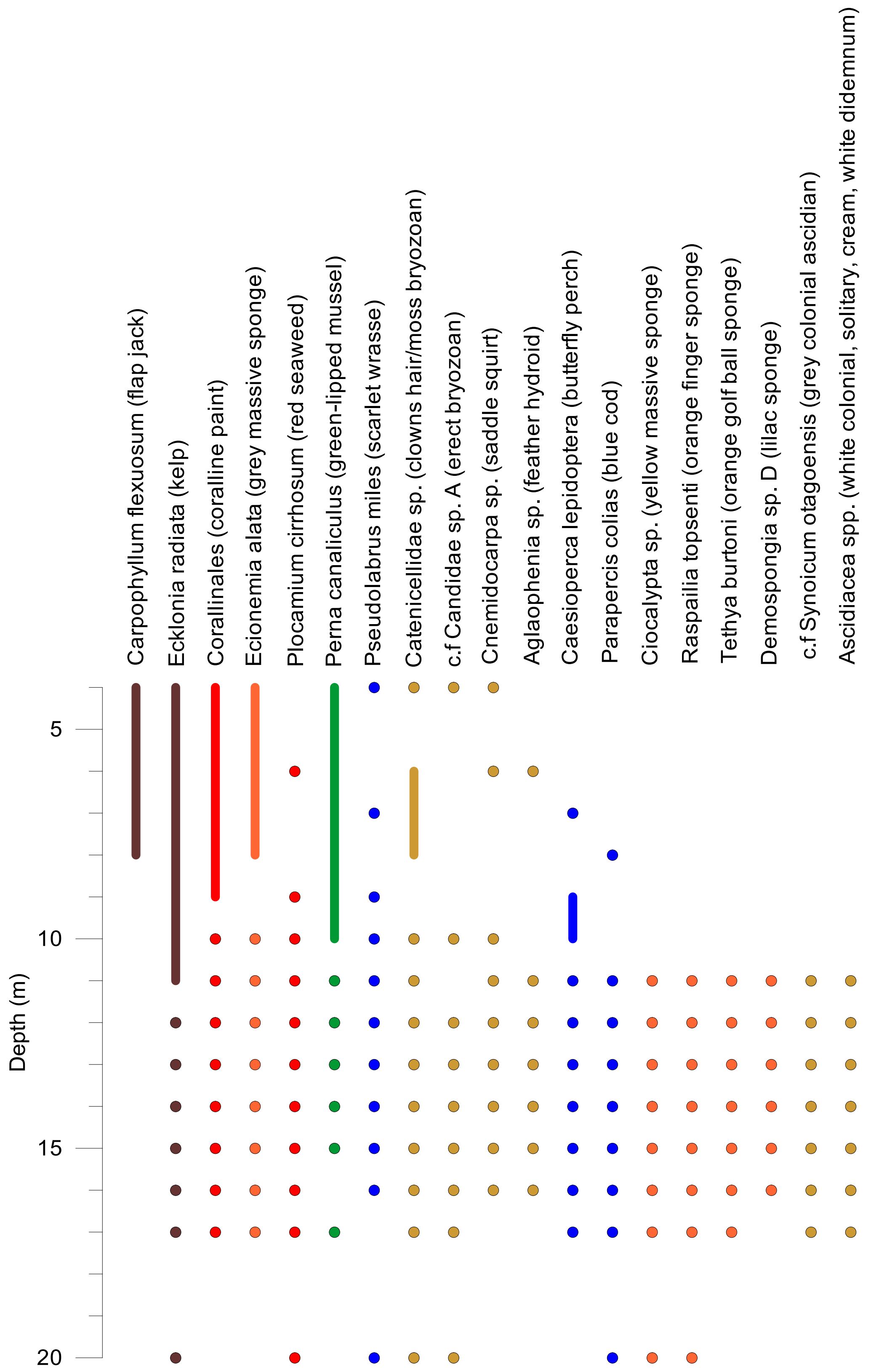

Figure 37. Depth distribution patterns of some of the more common taxa on Pania Reef. Average common/abundant distribution is represented by a solid line and average rare/occasional distribution is represented by a circle.

Figure 38. Reef taxa characteristic of shallower communities subject to higher water motion and less sedimentation.

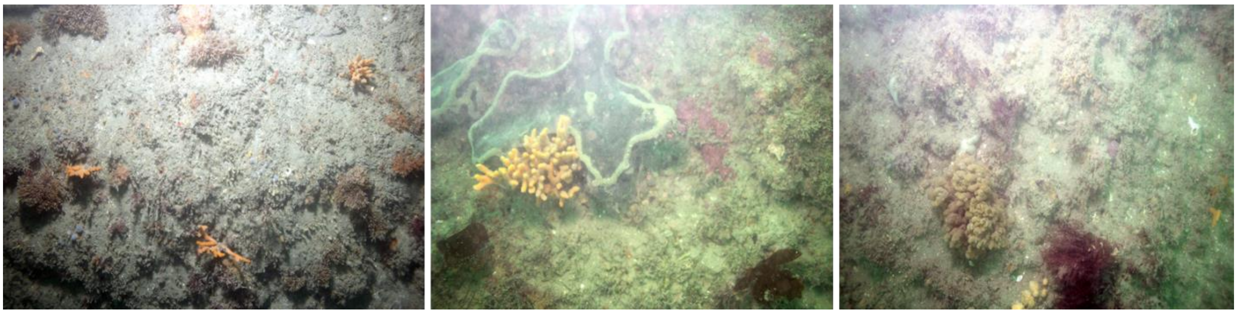

Figure 39. Reef taxa characteristic of deeper communities subject to less water motion and higher sedimentation.

Depth-related patterns were more pronounced than those relating to longitudinal distance along the Reef. However, ecological communities at the two outermost /seaward stations (PR1 and PR2) generally supported a higher diversity of brown macroalgae than the generally siltier inshore transects. Settled sediment can adversely affect the growth and recruitment of brown macroalgae such as *E. radiata* (Lees 2001), and these were totally absent at PR8 (the innermost transect). Inner station communities also featured a lower prevalence of coralline paint and a higher diversity of sessile benthic invertebrates (e.g. sponges). Fish diversity and abundance was also observed to be lower at the two innermost transects (PR7 and PR8). The effects of sedimentation at these transects were pronounced, and it is clear that the established community is adapted to withstand greater settlement rates of fine particulate material.

6.6. Background suspended sediments

Results from the analysis of water samples collected at the two Pania Reef monitoring stations (P1, P3; Figure 40), are presented in Table 21. Although relatively limited in terms of defining background levels and variability, the data indicates a logical pattern in terms of expected turbidity with the highest levels measured in samples from the inshore site near the seabed and the lowest suspended solids generally near the surface beyond the outer end of the reef (P1B > P3B > P1T > P3T). The results were also logically consistent with wave and wind conditions; higher TSS coincided generally with greater wave height and onshore wind directions. Swell is likely to be an important factor contributing to the resuspension of bottom sediments from the seabed surrounding Pania Reef.

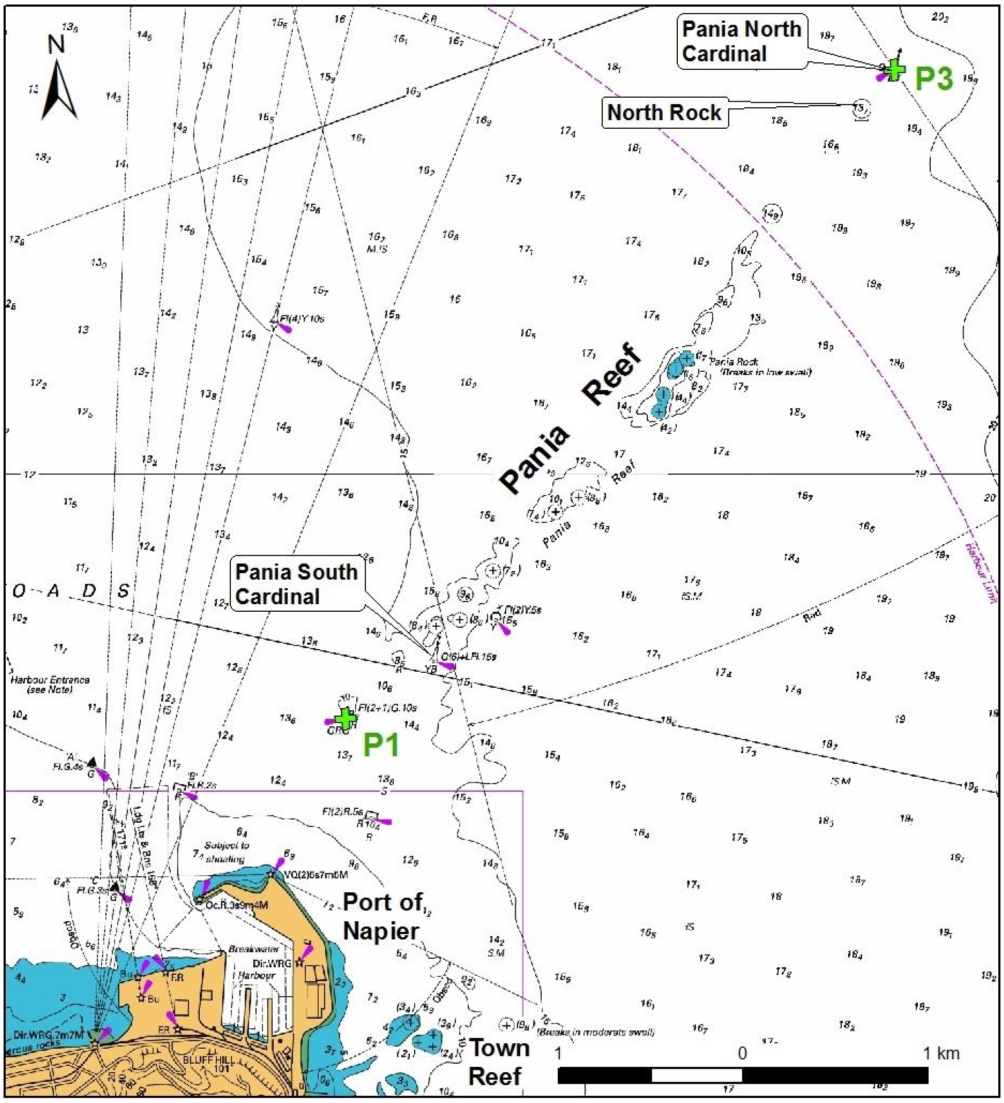

Figure 40. Part of Chart NZ 5712 showing locations of sampling points (P1 and P3) for background total suspended solids (TSS).

Table 21. Background total suspended solids data collected for two sample stations on Pania Reef over the period November to December 2005.

Date	Time		TSS* (g/m^3)				Wave data			Wind data		Tide
	P1	P3	P1B	P1T	P3B	P3T	Hs (m)	T peak (sec)	Dir'n (°True)	Vel. (kn)	Dir'n (°True)	Flood + Ebb -
15/11/05	11:50	11:30	9	7	7	7	0.6	12	125	6	70	0.25+ -
16/11/05	15:00	14:45	16	9	6	8	0.5	10.5	112	9	55	0.7+
21/11/05	14:55	14:30	9	9	9	7	0.55	12	70	20	340	0.7-
22/11/05	11:20	11:00	10	10	8	7	0.6	11	155	12	210	1.7+ -
23/11/05	15:45	15:30	12	6	12	7	0.65	10	130	10	110	0.6 -
24/11/05	12:00	11:45	13	9	8	7	0.8	10	125	10	200	1.65 + -
25/11/05	8:45	8:30	9	5	20	3	0.8	11	125	10	240	0.85 +
29/11/05	12:40	12:00	54	41	55	23	2.4	11	95	13	140	0.85 +
30/11/05	19:20	19:10	53	19	20	9	1.4	10	90	10	120	0.80 -
1/12/05	14:30	14:15	26	13	23	12	1.1	11	110	9	130	0.95 +
2/12/05	12:00	11:50	41	10	26	8	0.75	10	110	10	120	0.2 +
5/12/05	12:20	12:00	23	7	23	5	0.4	12	50	22	320	0.85 -
7/12/05	15:30	15:00	8	6	17	8	1.1	14	130	10	120	0.4 -
9/12/05	10:40	10:15	18	9	14	6	0.65	8	110	8	60	1.75 +
15/12/05	16:50	16:30	14	7	8	9	0.9	6	100	15	70	1.55 +
19/12/05	12:55	12:30	20	10	12	7	0.5	10	100	8	90	0.7 -
Mean			21	11	17	8						
Median			15	9	13	7						
Maximum			54	41	55	23						
Minimum			8	5	6	3						

* Total Suspended Solids: The suffix 'B' refers to a sample collected 1 m above the seabed, while 'T' refers to a sample collected 1 m beneath the sea surface.

Instantaneous wind speed did not appear to correlate with higher levels of TSS, but this may be misleading as data for the period preceding sampling are possibly more important in this respect. The full range of effects from wind and sea state is possibly also understated in these data due to sampling in more extreme conditions being precluded for safety reasons. Rainfall in the preceding 12 hours is potentially also a factor in generating a turbidity plume from the Esk River which may extend as far as the Pania Reef area (see Section 6.7 below). Other terrestrial runoff may also be significant in this regard.

Despite the limitations of the dataset, it indicates that suspended solids load in the waters surrounding Pania Reef is highly variable and dependent upon sea state and other environmental factors.

6.7. Turbidity monitoring

A plot by calendar quarter (three monthly) of the 15 minute surface salinity, sea temperature, and turbidity (as NTU) data collected by the Pania West monitoring buoy since April 2016 is presented in Figure 41. The gaps in the turbidity time series in January and March 2017 show periods when the buoy was ashore for unscheduled maintenance. The turbidity signal shows little or no drift from biofouling and very low 'noise' which can often be a feature of the output from these types of sensors.

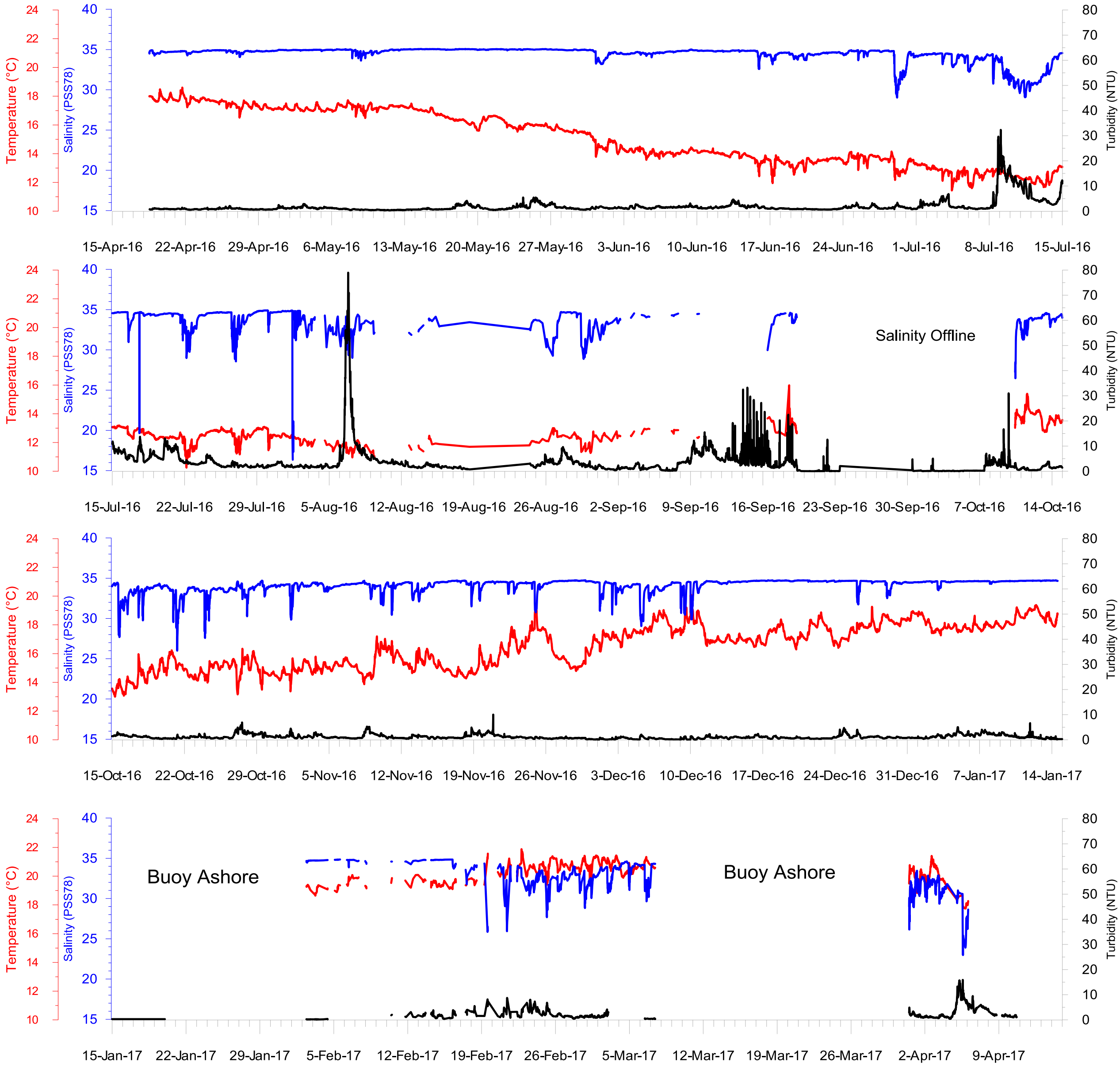

Figure 41. Time series plot of turbidity (black), sea temperature (red), and salinity (blue) collected at the Pania West buoy since April 2016.

Turbidity levels to date have been generally low (< 10NTU) which indicates relatively clear surface waters with two distinct periods of increased turbidity in early July and early August where values in excess of 30 NTU were recorded. Both of these events lasted more than two days, with the maximum peaks of shorter duration—lasting several hours to a day. Apart from these events, it is noted that the 2016 winter in Hawke Bay was otherwise generally mild in terms of weather and the dataset may not yet represent the full range of expected turbidity.

Comparison against the salinity signal and significant wave height (from one of PONL's wave buoys) over time will also help determine to what degree rain and storm events directly affect the clarity of surface water at the Reef. For example, both the high-turbidity events noted above coincided with increases in discharge flows from the main rivers that feed into Hawke Bay (the Esk, Tutaekuri, Ngaruroro, and Tukituki) as well as increased wave heights.

Interestingly, the more pronounced and sustained drop in surface salinity at the end of June 2016 corresponded with a smaller rain event than the 7 August storm which featured more than double the river flow (Figure 42). The likely reason for this is that the second storm was characterised by much larger and longer period waves (P. Frizzell, PONL, pers. comm) which would have mixed the surface waters more vigorously, dispersing the freshwater layer more rapidly.

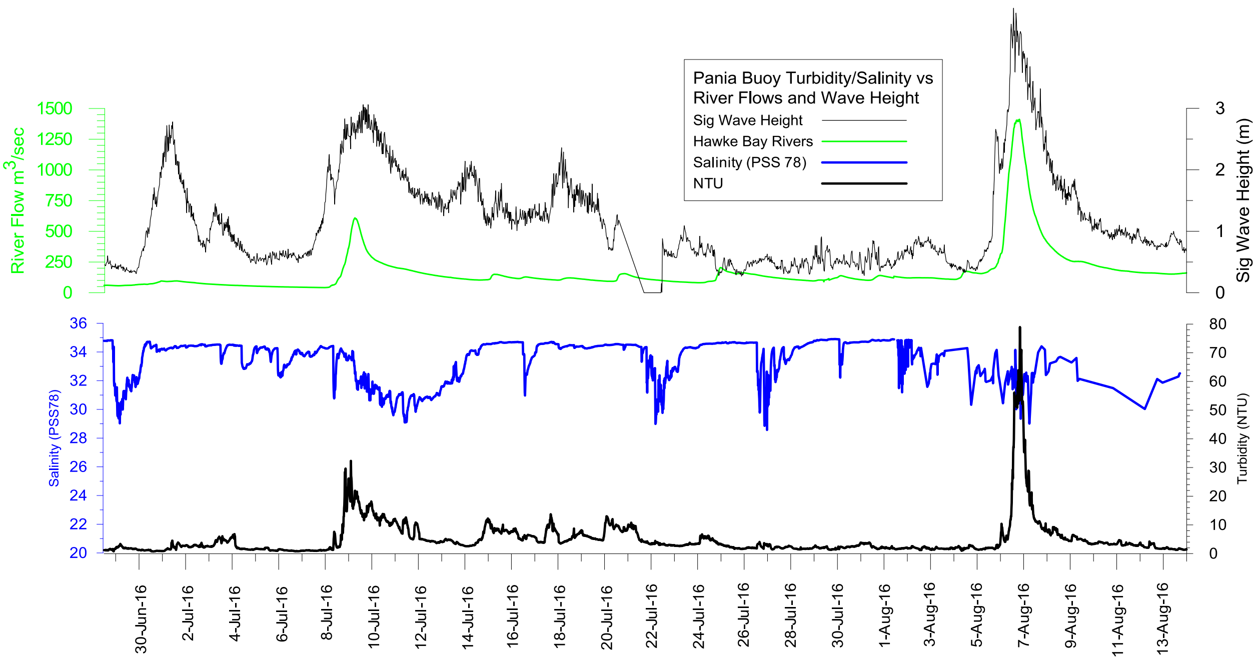

Figure 42. Expanded time series plot of logged water quality data from the Pania West Buoy covering late June to mid-July 2016 and aligned with hydrographs for the rivers flowing into southern Hawke Bay.

Analysis of the turbidity and salinity data from the Pania West Buoy following these events demonstrates clearly the influence on background water clarity from riverine inputs and terrestrial runoff as well as sediment resuspension via waves.

The Pania East buoy had been deployed for only a few weeks prior to the production of this report so the combined turbidity dataset is limited. However, a single storm event in early April 2017 allows the evaluation of differences in turbidity response between the two locations. The turbidity readings from each buoy can be seen to track one another reasonably well (Figure 43) both before and during the storm event. The increase in turbidity at Pania West preceded the response at the further offshore Pania East location by several hours, but the magnitude and duration of the event were almost identical. This demonstrates that it should be possible to track a more spatially limited event, such as a dredge plume, that may affect only one location or present a greater time-lag between the onset of a change in turbidity.

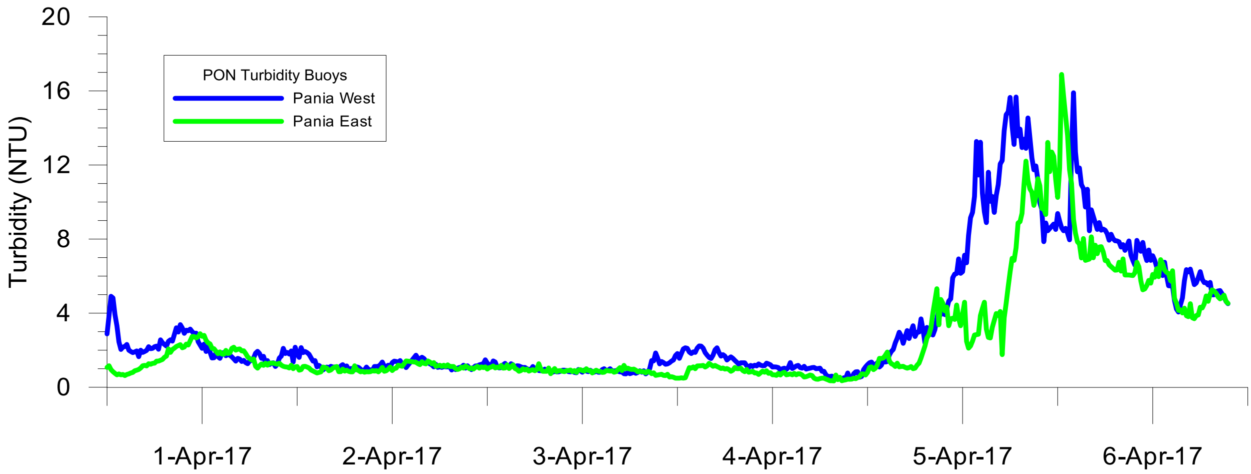

Figure 43. Comparison of turbidity data from Pania East and Pania West buoys for early April 2017.

A plot of the distribution of turbidity values for the current dataset indicates the potential frequency distribution of background turbidity. This takes the form of a leptokurtic, right skewed Gaussian distribution, resulting from long periods of relatively low turbidity punctuated by episodic peaks of highly turbid water (Figure 44). The histogram is shown overlaid with a normal Gaussian fit and alongside a box-whisker plot showing the quartiles and minimum/maximum values. For the compiled dataset, the median turbidity value was 1.3 NTU with a maximum of 79 NTU recorded on 7 August 2016. The respective 95th and 99th percentile values were 6.8 NTU and 13.2 NTU.

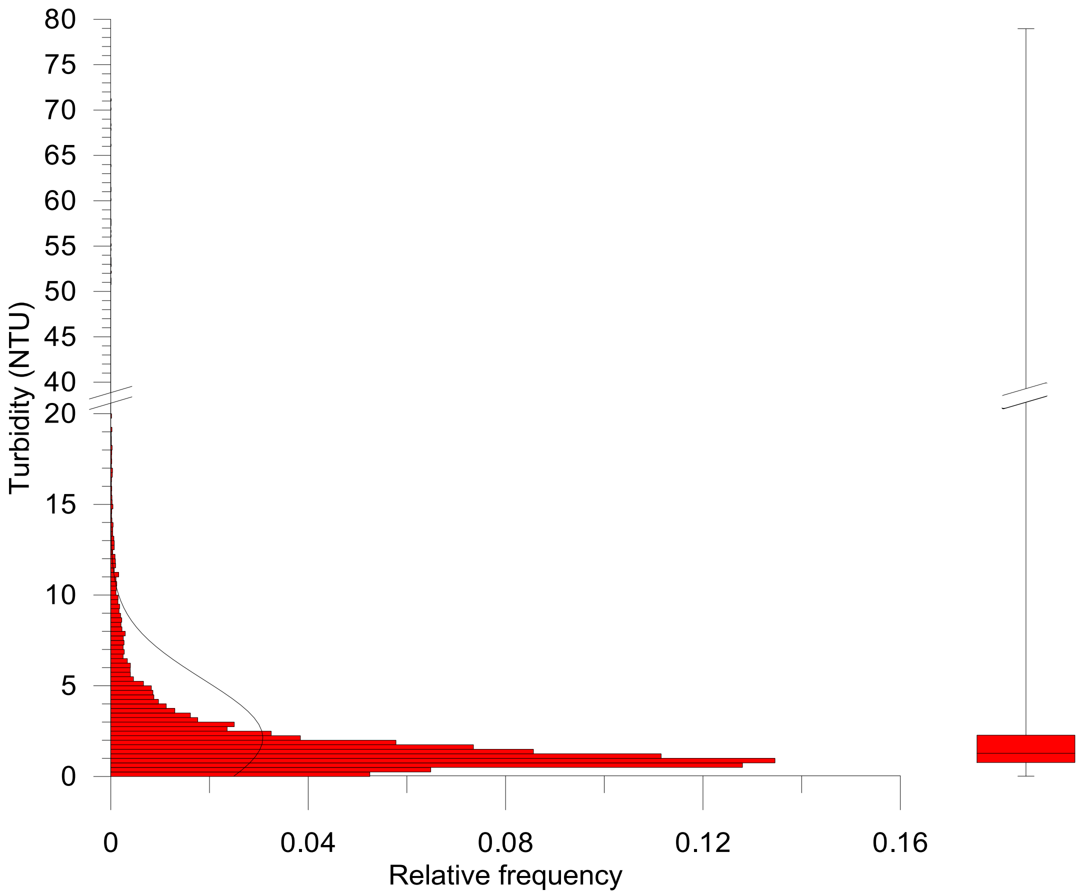

Figure 44. Histogram of turbidity data collected 18 April to 10 April 2017, alongside a box-whisker plot of the same dataset. Box shows median and quartiles; whiskers represent total range of data.

To date, a total of ten seawater grab samples have been collected at the Pania West Buoy from the same depth as the turbidity sensor and analysed for TSS (Table 22). A correlation between TSS and the corresponding NTU reading at the buoy shows a reasonably good linear relationship (TSS = 1.6xNTU+1.0; r^2 = 0.94; Figure 45) although the data points are not evenly distributed across the range represented. The range itself is limited compared to that of the complete turbidity data set, with only one sample corresponding to a turbidity exceeding 8 NTU.

The TSS vs NTU dataset will continue to be collected during the baseline period and, while it is expected that the turbidity range over which a correlation can be derived will be extended, it is recognised that there are obvious limitations to the capture of extreme conditions due to the need to sample from, a small vessel. It is further proposed that these data will be supplemented with data from a tank test using dredge sediments and an identical turbidity sensor.

Table 22. Comparison of total suspended solids (TSS) in seawater grab samples to corresponding turbidity reading at the Pania West Buoy. To calculate the mean, the analytical detection limit (ADL) for TSS (3 mg/L) was assumed for the sample where this was not exceeded.

Date	Time (NZST)	Pania W Buoy (NTU)	TSS gm/m^3
5/05/2016	12:00	1.44	4
24/05/2016	15:15	1.75	5
24/05/2016	15:20	2.42	7
1/07/2016	11:35	2.47	6
12/07/2016	11:40	4.40	8
16/07/2016	12:30	5.70	8
26/07/2016	12:15	1.85	<3
9/09/2016	11:15	7.97	13
10/09/2016	8:10	13.95	26
11/09/2016	9:45	7.08	10
Mean		*4.90*	*9.0*
Median		*3.44*	*7.5*

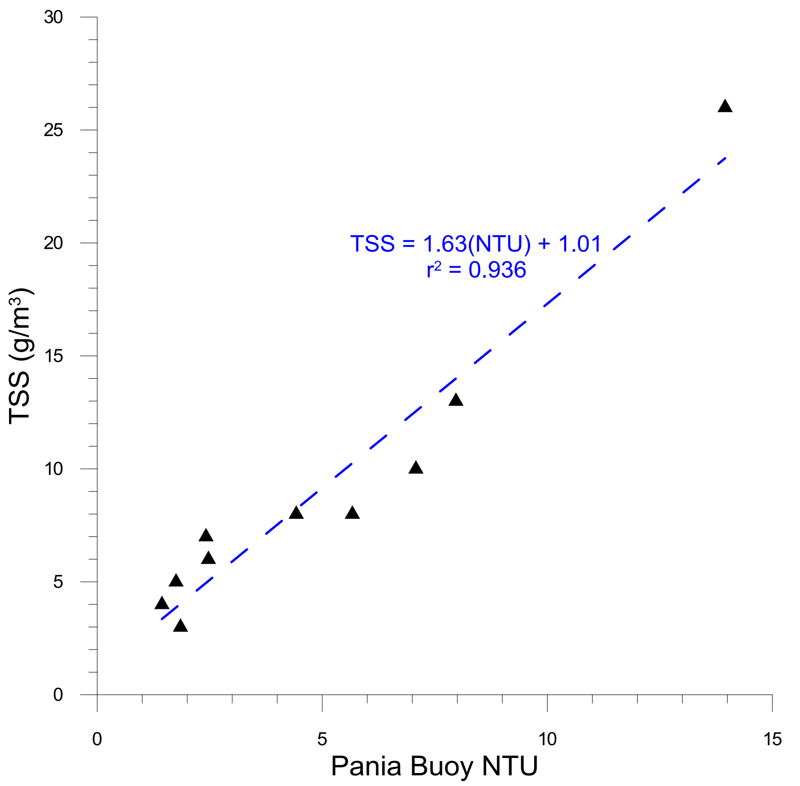

Figure 45 Relationship between TSS samples (in g/m^3) and NTU at the Pania West Buoy. In the one instance where TSS was below the analytical detection limit (ADL), the value was set equal to ADL (3 g/m^3).

7. ASSESSMENT OF ECOLOGICAL EFFECTS

The activities of dredging and spoil disposal have a direct impact upon the benthic areas where they are undertaken. The environmental significance of this impact depends upon the size of the area affected, the ecological or other values with which the area is associated and the ability of the habitat to recover. However, there is also potential for indirect effects on surrounding environments in the form of turbidity plumes and contaminant release from resuspended sediments. The significance of these effects depends on the nature of the dredged sediments and the physical and biological nature of the specific receiving environment. Often it is the indirect effects which become a major focus due to the potentially much larger areas or more valuable receptors that may be affected.

7.1. Direct disturbance: Loss or alteration of habitat

Dredging for navigation has the objective of bringing about a lasting change to a benthic area in the form of greater water depths. This can result in an altered hydrodynamic environment and depositional regime that in turn bring about a change in the texture of the sediment substrate. Since water depth and the nature of surficial sediments are key factors in the variability of benthic communities in shallow coastal areas, pronounced and potentially lasting effects within the specific area of dredging are unavoidable. The need to maintain depths into the future furthermore requires a programme of ongoing maintenance dredging, representing a substantial regular disturbance that may result in a benthic community held in an intermediate successional stage of recovery.

Direct physical disturbance from dredging occurs within a specific identified area. Where access to an established port is deepened, the major proportion of this area is likely to be already subject to ongoing disturbance in the form of regular maintenance dredging and hull and propeller turbulence from shipping movements.

In the case of the Port of Napier channel extension, the area that will be directly affected by the proposed capital dredging is approximately 117 ha, in water depths varying from 6 m to 14.5 m (at Chart Datum). The benthic substrate within this area is for the most part relatively uniform, comprising fine and very fine sands with a smaller but significant silt fraction.

7.1.1. Fairway areas

The Fairway area within which capital dredging is proposed features a relatively uniform benthic habitat that is part of a much larger area of such substrates in inshore Hawke Bay. The surveys of this area identified no taxa or communities of special scientific or conservation interest, and the benthic habitat is not considered to be limited in spatial distribution. The effective loss of this habitat by dredging is therefore not expected to have a discernible effect on the ecological functioning and productivity of the wider inshore area.

The benthic communities typically inhabiting soft sediment areas in the vicinity of the Fairway are generally quite resilient to disturbance. The predominant infauna taxa (polychaete worms, amphipods, nemertean worms, ostracods) have short life cycles and are able to rapidly recolonise affected areas where conditions remain suitable. The survey data indicate that, over the longer term, dredging disturbance and any associated substrate changes will result in only a relatively small shift in infauna community structure, with differences between non-dredged and dredged areas relating to patterns of relative dominance rather than the communities being fundamentally different. However, the change to sediment texture is expected to make the area less suitable for some epifaunal species (e.g. sand dollars, some bivalve molluscs).

The area of the proposed capital dredging footprint that has not been previously dredged is approximately 60 ha, of which roughly half is comprised of the section extending offshore (Figure 9). This affected area is relatively very small in relation to similar habitats in the general area. Furthermore, based on the analysis of the survey data, the deepening by capital dredging of areas already actively maintained at navigable depths is not expected to significantly affect the nature of their benthic communities.

7.1.2. Outer Swing Basin and Port entrance

The benthic habitat occurring within the enlarged outer Swing Basin to the immediate west and north-west of the proposed No.6 berth (Figure 23) is largely a continuation of the subtidal soft sediments of the wider inshore area. However, the survey of this area conducted in 2004 indicated the presence of some existing hard substrate, albeit of generally low diversity and ecological productivity compared to the more permanent reef further inshore to the south. It is furthermore likely that this low-relief reef habitat is somewhat ephemeral, experiencing partial or complete burial in occasional sediment accretion events, a situation that substantially limits its ability to support stable communities.

The nature of the benthic environment within the area of the Port entrance is not considered to be of significant importance to the marine ecological resources of the wider region. The proposal to further increase access depths within this area is assessed as being largely equivalent, in terms of ecological impact, to current periodic maintenance dredging.

7.1.3. Spoil deposition

Deposition of dredge spoil upon the seabed represents a direct disturbance in the form of a smothering impact over the whole of the spoil ground and, to some extent, around its margins. This impact is inherent in the activity and is, as such, unavoidable. The main mitigating factors are:

- the limited ecological and scientific importance of spoil ground benthic habitats; in particular their prevalence within the wider area
- the similarity between the deposited and native sediments
- the ability of such habitats to recover following deposition and the rate at which this occurs.

Other important considerations are:

- mechanisms by which impacts to habitats outside the disposal area may occur
- the potential extent, severity and persistence of effects on habitats within a spreading zone outside the disposal area boundary.

The total area of the proposed offshore spoil ground, located 4 km east of the Port, is approximately 346 ha. Assuming the full projected volume of dredged material from the project (3.2 million cubic metres) is spread evenly over this area, a nominal deposited layer thickness of 0.93 m will result. In reality, a number of factors will influence this value (including dispersion during deposition and consolidation of deposited material); hence this calculated value should be treated as contextual only.

Based on the modelling of hydrodynamic conditions contributing to resuspension of sediments and bed-load transport, Advisian (2017b) characterised the disposal area as *mildly dispersive for silt, and weakly dispersive for fine and medium sand*. This contrasts with the shallower consented spoil ground area off Westshore Beach which represents a more dynamic sediment environment.

The observed uniform nature of the seabed in the vicinity of the disposal area, together with similarities to substrate and communities sampled from other inshore sites, indicates the relative ubiquity of this benthic habitat in the wider area. None of the benthic fauna sampled from the site have been identified as being of special scientific or conservation interest.

Comparison between spoil material and native sediments

The sample of underlying stiff silt material from the Fairway area analysed in 2008 (Sections 4.1.2 and 6.1.1) was used in earlier assessments as being fairly representative of the bulk spoil generated from capital dredging. It was found to be finer than the mean sediment texture at the currently proposed disposal area, with very fine sand and silt/clay fractions of 62% and 31% compared to 30% and 23% for the disposal site. However, its cohesive nature[16] suggested that a significant proportion of this material may be deposited in the spoil ground as clumps with limited friability.

Estimates of bulk spoil characteristics have been updated more recently with the collection of deep vibracore samples across a wider area of the dredging footprint (Figure 9). Information from these samples was used to define a generalised spoil grain-size distribution for non-cohesive sediment transport modelling by Advisian (2017b). This defined the spoil material as follows:

- approximately 20% finer than 100 µm
- approximately 70% between 100 µm and 200 µm
- approximately 10% coarser than 200 µm.

Although the particle diameter criteria are slightly different to those of the sieve analysis carried out for the disposal area samples, it can be seen that this estimate is a reasonable match for the sediments occurring within the proposed spoil ground. In particular, the median (50% passing) particle diameter from the vibracore sample analysis was given as 125 µm. This corresponds well with the average 46% of the disposal area sediments coarser than 125 µm (Table 17).

While the dispersive nature of the spoil ground site will act to grade the deposited sediments over time towards a natural equilibrium texture, the expected similarity between the spoil and native sediments (both in texture and marine origin) should represent little impediment to the process of recovery towards pre-deposition benthic communities.

Impacts on benthic ecology

For the benthic habitat within the offshore spoil ground, the deposition of dredge spoil will result in substantial smothering effects on the existing benthic communities. While the scale of deposition means that complete loss of these communities can be assumed for the area within the spoil ground boundaries, individual benthic taxa are unlikely to actually disappear from the site, even temporarily. This is due to both the resilience of many sediment-dwelling organisms and the nature of the depositon occurring. Infauna and some epifaunal species will have varying degrees of tolerance to smothering impacts, based mostly on vertical mobility within the sediments. The steady incremental rate of spoil deposition over an extended period, as well as the staged nature of the project, will give many fauna time to migrate vertically within the spoil layer. Highly motile rapid burrowers, quick tube-builders and rapid colonisers are likely to survive as remnant populations and facilitate the rapid re-establishment of the benthic community. In this way, a steady state of successional recovery is likely to be

[16] It was noted by the laboratory analysing the stiff silt sample that sonication of the sample was required to disperse the clumps before grain-size analysis could be performed.

attained within the project time-scale, as opposed to recovery commencing from an effectively abiotic base state at the cessation of the project.

Soft sediment community resiliance to impacts from sediment inundation has been observed for naturally dispersive benthic environments, including the consented spoil grounds for Port of Napier off Westshore Beach. Benthic monitoring carried out as a requirement of PONL's existing Coastal Permit for dredge spoil disposal has not identified any significant adverse ecological or other effects to spoil ground habitats as a result of spoil deposition since 1996 (see Section 6.2; Stephenson 1997; Sneddon & Keeley 2005; Smith 2008a, 2013). While these results provide useful context, the more dispersive nature of these shallower inshore environments must be taken into account when making comparisons to potential outcomes for the proposed offshore site.

In a study of the effects of long-term dredge spoil disposal on benthic macrofauna in Tasman Bay, Roberts and Forrest (1999) attributed a lack of discernible adverse impact, even after 30 years of sea disposal of Port Nelson maintenance dredge spoil, to the dynamic nature of the sedimentary environment in the disposal area. While in shallower water than proposed Port of Napier disposal site, the Tasman Bay spoil ground has a less energetic wave climate, resulting in a benthic environment comparable in terms of dispersivity. In the Tasman Bay case, there was, however, a notable and persistent change in sediment texture and heterogeneity within the spoil ground, resulting in a localised increase in ecological diversity (Sneddon 2012b). Depending upon the physical differences between the dredge spoil and native sediments at the site, such an effect may be observable, at least initially, at the Port of Napier offshore spoil ground.

A spreading zone of altered substrate and community characteristics may also be evident adjacent to the spoil ground following completion of dredging campaigns. This is due to a proportion of the finer spoil particulate material settling or being subsequently transported across the site boundaries, or impacts from elevated levels of suspended sediments at the seabed during a campaign. However, as noted above, spoil and native sediments are likely to be generally similar. Furthermore, based on grain-size analysis of the substrate (Figure 25), benthic community analysis (Sections 6.4.2 and 6.4.3) and diver observations, it is considered that the benthic community in the vicinity will already be adapted to high levels of suspended sediment. Hence while spreading zone effects may be discernible within a margin around the spoil ground, these are likely to be relatively subtle and transient.

7.2. Contaminants

The results of chemical analysis of sediment samples collected in 2004 and 2016 indicate that key contaminants were not elevated in the approach channel sediments of either previously dredged or undredged areas and that organic enrichment was similarly low. Since sediments tend to integrate contaminant inputs over time and the nature and scale of Port operations has not changed significantly since the earlier survey, the current contaminant status of these sediments is expected to be very similar. This assessment is supported by the ongoing annual direct toxicity (Microtox^{TM}) testing of sediments from the inner Swing Basin and Fairway.

A standard caveat provided by NIWA with the Microtox^{TM} test results states that:

> *A single species assessment cannot provide a comprehensive assessment of the potential for adverse effects on biota in the receiving water environment, and care must be taken when extrapolating the results of the Microtox^{TM} elutriate test for protection of other organisms present in a particular receiving water environment.*

As such, this test must form part of a weight-of-evidence approach to assessment rather than confirmation of the absence of significant contamination. Nonetheless, the effective absence of elevated levels of indicative contaminants in the 2004 and 2016 Fairway sediment samples and the uniformly low levels in the sediments specifically associated with Port stormwater outfalls support a conclusion of minimal contaminant risk from the dredging of these sediments. This is additionally supported by the ongoing periodic monitoring of benthic communities in the consented spoil grounds, which has consistently indicated no effects attributable to the toxicity of dredged sediments (e.g. Smith 2013).

With regard to the potential total contaminant loading from the larger volume of spoil and extended duration of the project, it is worth noting that the capital dredging component will be cutting into deeper sediments unaffected by anthropogenic inputs, including those of the Harbour entrance which were deepened with capital dredging in 2012. These underlying substrates are not expected to carry contaminants of ecological significance. This is supported by the chemical analysis of deep vibracore samples from the Fairway in 2015 (Section 6.1.2).

7.3. Turbidity and suspended sediments

Expressed in nephelometric turbidity units (NTU), turbidity is an optical quality of water whereas suspended solids concentration (SSC) is a physical parameter. While turbidity may be directly related to the attenuation of light reaching the seabed, it is a less useful parameter in the assessment of the potential for smothering or inundation effects. SSC is also the parameter used in plume modelling. The principal reason why turbidity is generally the monitored variable is that it can be measured and recorded continuously, whereas SSC cannot. But the relationship between turbidity and SSC is often problematic, since it involves the calibration of an optical quality to a physical quantity. Because turbidity is dependent upon the nature of the particles in suspension as well as the quantity, the relationship between the two is likely to be site-, event-, or source-specific[17] and a generalised correlation will be unreliable (Davies-Colley & Smith 2001). For inshore Hawke Bay, the relationship between turbidity and SSC may be different for a plume arising from a flooded river versus that from wave resuspension of sediments, algal bloom or from spoil disposal operations. However, as long as these limitations are allowed for, there is still potential for a correlation derived on a site-specific basis to be usefully applied to *in situ* monitoring with optical sensors.

7.3.1. Significance of turbidity from dredging

The scale of the capital dredging project and the anticipated volume of spoil produced mean that the production of turbidity plumes and their subsequent movement with ambient currents will be the principal mechanism by which stressors may act upon ecological receptors outside the area of direct disturbance. The silt/clay component of dredged sediments will be easily resuspended by disturbance from the dredge, entrained at high concentrations within hopper overflow water and will be slow to settle out of the water column.

The severity of ecological effects from high turbidity and suspended sediments depends on a number of factors, including:

- the nature of the suspended matter (composition, size range, reactivity *etc.*)
- concentration within the water column
- duration of the turbidity event and the rate of dilution and dispersion
- rate of settlement of suspended particulates out of the water column
- the level of background turbidity to which ecological communities are naturally adapted.

The last factor, relating to the inherent tolerance of marine communities to high turbidity/suspended solids, is an important consideration. For benthic communities, this depends to an extent upon the nature of the existing substrate. Those living on or within fine soft sediments will be inherently tolerant of near-seabed turbidity layers resulting from natural resuspension processes and relatively high rates of deposition. In contrast, reef communities may be less tolerant, especially at sites where clear water is the norm.

Although significant resuspension can occur during dredging operations, very high SSC tends to be localised to the activity, decreasing sharply with distance. The greater density of highly sediment-laden water results in downward turbidity currents which carry high-strength plumes to the seabed and act to limit their spatial extent. At

[17] The suspended solids component in most natural waters includes a wide range of particulate materials from biogenic to mineral.

lower concentrations, such density gradients are less significant and plumes are advected by ambient currents. Modern trailer suction dredges may be set up to release hopper overflow water with high suspended solids at depth, which can significantly limit propagation of turbidity plumes via surface currents.

The recent vibracore sampling of the capital dredge area indicates that the underlying sediments may be quite variable; however, the earlier analysis of the stiff silt material indicates that this extensive underlying substrate does not comprise a significantly greater proportion of fine material (< 63 µm) than the overlying recent and infill sediments (Section 6.1.1). It is unlikely, therefore, that the rate of fine sediment resuspension from capital dredging will significantly exceed that from the disturbance of unconsolidated surface sediments which comprise much of the spoil removed periodically by maintenance dredging.

7.3.2. Background suspended solids and turbidity

While turbid conditions are common in the near-shore waters of Hawke Bay, there has been only limited quantitative data available with which to define the receiving environment in this regard.

In attempting to model turbidity effects in southern Hawke Bay, Ellison (1995) found wind speed to be an important factor influencing near-shore turbidity. Even strong offshore north-westerly and westerly winds with little swell have been observed to produce significant inshore turbidity, leading to the suggestion that during strong offshore winds, a vertical current circulation cell may be set up perpendicular to the general shoreline and bringing sediment-laden benthic water to the surface.

Over three synoptic surveys carried out between April and August 1995, Ellison (1995) found background turbidity[18] in southern Hawke Bay to range between 0-25 NTU, with the higher levels generally associated with near-shore areas of up to 15 m water depth and especially in the vicinity of the river mouths. A two week period (May–June 1995) during which surface water turbidity was continuously logged at the location of the consented spoil ground ('Ia') off Westshore Beach featured two peaks in values up to 20 NTU sustained for two and three days, respectively.

Sources of suspended sediment and turbidity

The amount of sediment resuspended during dredging operations for the No.6 Berth project will be substantially less than that delivered to the near-shore coastal waters by rivers such as the Esk, Tutaekuri and Tukituki. Ellison (1995) cites White (1994) that the total sediment contribution to the near-shore zone of Hawke Bay from the Esk, Ngaruroro, Tutaekuri and Tukituki rivers is estimated to be in the vicinity of 2.7 million tonnes/year. It has also been reported that turbidity produced by the three rivers to the South of Napier can extend northwards towards the Port area (P. Frizzell,

[18] As recorded using Greenspan TS100 OBS turbidimeters.

Coastal Zone Management Ltd, pers. comm). These three rivers deliver a combined silt loading far greater than the Esk River alone. However, Ellison (1995) reported that waves were considered to be the dominant mechanism by which fine bed sediment may be entrained and retained in suspension and cited White (1994) that waves of one metre and greater occur more than 240 days each year in Hawke Bay. It follows that many of the high turbidity events occurring naturally in the area of Pania and Town reefs arise principally from wave-induced resuspension of benthic sediments. Therefore, it is reasonable to expect a measure of similarity, in the nature of suspended particulates, between the background and that generated by dredging and spoil disposal operations in the local area.

Turbidity at Pania Reef

The suspended solids data compiled from analysis of Pania Reef water samples in 2005 (16 occasions, 2 locations, surface and seabed) covers a relatively short time period (November–December 2005; see Table 21). The median values for TSS recorded for the southern end of the Reef were 15 mg/L at the seabed and 9 mg/L at the surface. Maximum values were 54 mg/L and 41 mg/L, respectively. Since the TSS data was collected only during conditions conducive to small boat operations, it is possible that the data-set represents the lower end of the natural range of values.

The limited TSS/turbidity dataset collected for the Pania West monitoring buoy location (Figure 45, n = 10) gives a preliminary relationship between suspended solids[19] (mg/L) and turbidity (NTU) of TSS = 1.6 x turbidity+1.0; (R^2 = 0.94). This is reasonably consistent with a similar relationship [TSS = 1.5 x turbidity; (R^2 = 0.94)] derived for dredging in Port Nelson where samples were taken directly from the plume adjacent to the dredge (Cawthron Institute 2006; unpublished data). The linear relationship demonstrated for the stiff silt sample (Section 6.1.1) cannot be used for comparison since it employed a nephelometric turbidimeter (Hach 2100N) as opposed to an instrument measuring optical back-scatterence (OBS)[20].

The record to date (April 2016–April 2017) for surface turbidity at the Pania West monitoring buoy (Figure 44) gives median and 95th percentile values of 1.3 NTU and 6.8 NTU, respectively. It indicates that turbidity is variable with periods of elevated turbidity associated with specific events. The application of the preliminary correlation between turbidity and suspended solids results in estimated values for median and 95th percentile TSS for the monitoring period of 3.1 mg/L and 12.1 mg/L, respectively.

[19] Despite the grammatical implication of a technical difference between the terms total suspended solids (TSS) and suspended sediment concentration (SSC), the difference is typically methodological only and they are often used interchangeably.

[20] Turbidity units have no intrinsic value. Their accuracy and usefulness is defined by the instrument design and measurement method. For this reason, comparisons must be based on identical instruments or at least the use of comparable meter designs. The widespread use of the units NTU for turbidity derived from other than nephelometric instruments is also technically erroneous.

It is the experience of local divers that highly turbid conditions can persist on Pania Reef for up to several weeks (Hayden Moffit, Ocean Adventures HB Ltd, pers. comm.). During the diving surveys conducted in November 2005, an attempted transect dive on North Rock at the offshore extremity of the reef was aborted due to high turbidity resulting in zero visibility below 15 m water depth. Conditions for the dive were otherwise calm with winds below 10 knots.

Figure 46 shows aerial photographs of turbidity effects in the Napier coastal region. The first photograph (Figure 46A) shows an extensive turbid plume in the immediate vicinity of the Port. Conditions on the day of the photograph were ENE winds at 5-6 kn with a significant wave height of 0.5 m; mean period 5-6 seconds, mean true direction east. While the source of the turbidity is not clear, the image is consistent with modelling results suggesting that sediment resuspended in the Port area may form a plume that can propagate over the inshore sections of Pania Reef. The frequency of such occurrences is uncertain but the observations of sediment veneers on Reef surfaces during transect dives, together with other anecdotal observations, suggest that such effects are not uncommon.

The second aerial photograph (Figure 46B) shows a turbidity plume apparently generated by waves breaking over Pania Rock at the center of Pania Reef. It appears, from the relative clarity of the surrounding water, that the source of the plume is sediment resuspended from the reef top itself rather than the deeper soft sediment areas on either side. This is again consistent with diver observations of natural silt deposition upon Reef surfaces.

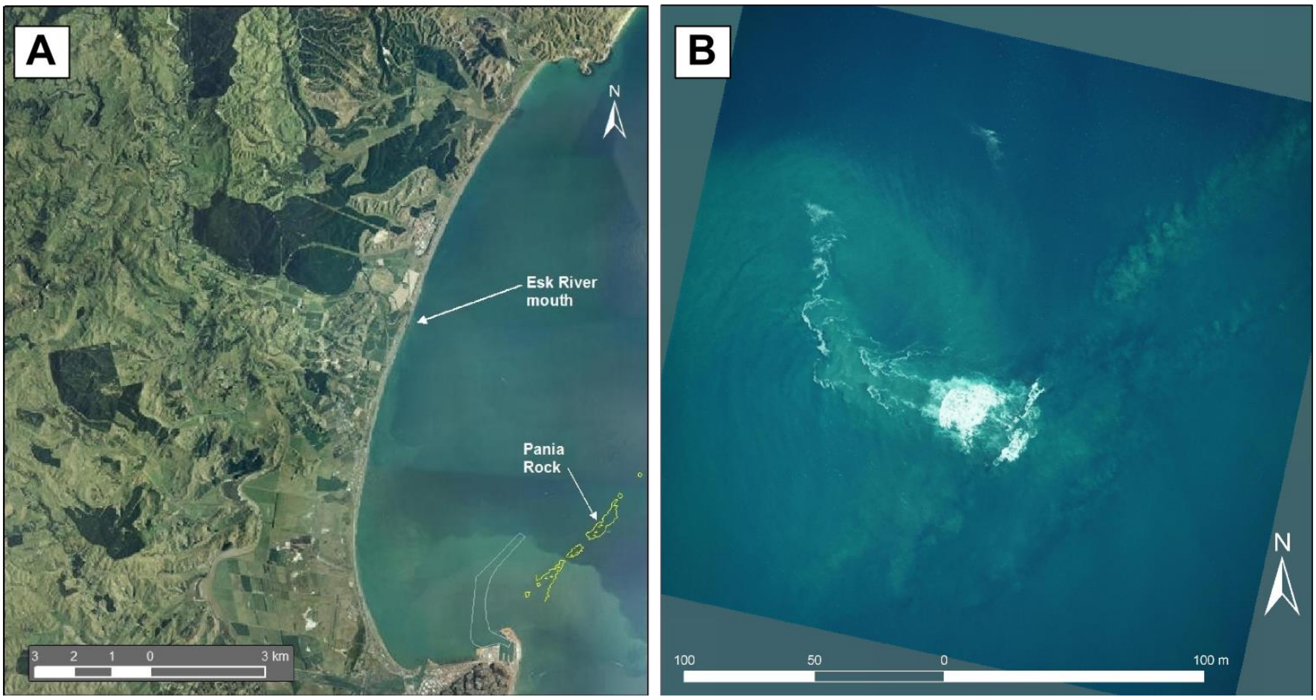

Figure 46. Aerial photographs of Napier coastal turbidity effects. A**:** Port and Westshore Beach area showing a turbid plume in the region of the Port. The position of Pania Reef and the outline of the proposed capital dredge area are overlain for reference (LINZ orthophoto taken 10 January 2004). B**:** Wave breaking on Pania Rock in heavy swell conditions (1040 hrs 24 March 2001: Tide = 0.35 m CD; H_s = 2.5 m; T_p = 13 sec; swell direction = 95°T; wind speed = 4 kts; wind direction ENE). Photo has been rotated to align with true north.

7.3.3. Implications from hydrodynamic modelling results

Hydrodynamic modelling has been undertaken by WorleyParsons Group to provide an indication of the propagation and strength of sediment plumes generated by the dredging project (Advisian 2017a). The modeling was based on the proposed use of a combination of backhoe dredging and trailer suction hopper dredging (TSHD) over five separate dredging campaigns (Table 1). Model parameters assumed the use of a 1,840 m^3 TSHD for dredging the inner (A1) and outer (A) Fairway areas[21]. To put the size of this TSHD in context with historical Port operations, this compares to the use of the TSHDs *New Era* (850 m^3 capacity) and *Pelican* (965 m^3 capacity) for maintenance and some capital dredging (Appendix 8).

The model was calibrated with, and validated against, current data collected from a downward-facing acoustic Doppler current profiler (ADCP) located on the western edge of the Fairway. A particle tracking model coupled to the hydrodynamic model to predict plume behavior incorporated fall velocity distribution data generated for sediments from vibracore samples from nine locations near the navigation channel. A

[21] The estimated total volume to be dredged by TSHD is 1.2 million m^3 (Table 2), with a further 2.0 million m^3 to be removed from the inshore sections by back-hoe and barge.

conservative approach assumed no flocculation of fine resuspended particles. This resulted in calculated settling velocities lower than would likely occur in reality.

The particle tracking model was set up to allow for deposition and resuspension of particulates, with inputs from both current and wave model simulations. The model was run for simulations of Campaigns 1 and 5, to capture high overall dredging volumes and relatively greater dredging of the outer Fairway, respectively. Conditions over the relatively stormy period[22] of July 2016 were used in the model as a reasonable worst case for re-suspension and transport of dredged sediments. This period included major wind events when compared to measured wind data between 2005 and 2015, including strong westerly winds. However, the period was considered to be representative of the full range of conditions that could be expected during the proposed capital dredging campaigns (Advisian 2017a).

Modelling outputs

The model considered only sediments put into suspension by dredging and spoil disposal activities, which means that all results are to be considered *in addition to* ambient conditions of SSC and sedimentation. Model outputs in the form of percentile exceedance envelopes indicated that plumes generated from spoil deposition at the proposed disposal site would be more extensive than those generated at the dredge sites, for all scenarios run. Modelled sediment deposition showed similar spatial patterns to those of SSC. However, no potential for deposition of fine silts or clays over the footprint of Pania Reef was identified for the dredging campaigns modeled based on these scenarios. The following model outcomes were noted for the two modelled campaigns.

For the one month Campaign 1 simulation:

- There was no potential for Pania Reef to be affected by increases in total suspended sediment concentrations above 10 mg/L at any time
- Taking into account sediment stirring by wave-generated currents (which would result in re-suspension of any fine sediment that may be deposited on the Reef), no deposition on the Reef was predicted by the model.
- Time-series outputs of near-surface sediment concentrations, averaged over a 500 m grid area for points at the outer, middle and inner sections of Pania Reef, indicated that SSC would remain less than 5 mg/L above background values and with only isolated peaks above a 1 mg/L increase. Minor peaks in SSC on the Reef would coincide with periods where currents in the vicinity of the disposal area were directed toward the north-west.

For the one month Campaign 5 simulation:

[22] Strong westerly winds were predominant over this period.

- Similar to Campaign 1, there was no potential for Pania Reef to be affected by increases in total suspended sediment concentrations above 10 mg/L at any time.
- Taking into account sediment stirring by wave-generated currents, no deposition on the Reef was predicted by the model.
- Suspended sediment concentrations were slightly higher for Campaign 5 but—averaged over a 500 m grid area—remained less than 7 mg/L (and with only isolated peaks above 1 mg/L) above background values for the three nominal locations on the Reef.

Suspended sediment concentrations

The ADCP (current data) record for the Fairway area showed no evidence of stratification occurring within the water column and generally well-mixed conditions are expected for this area. Advisian (2017a) reported that sediment concentrations within plumes (from both dredging and spoil deposition sources) will be spread relatively evenly over the water column at far-field receptors[23].

In addition to showing more substantial plumes generated from spoil disposal than from dredging, the model outputs predicted the greatest plume concentrations occurring during TSHD usage when the deposition rate at the disposal area was at a maximum. Hence the minor peaks in project-related SSC at Pania Reef occurred when the TSHD phase of a campaign coincided with wind conditions that caused the normally south-east-setting currents to be directed instead to the north-west. Advisian (2017a) noted that this occured for less than 2% of the time over the simulation period. It was further noted by Advisian (2017b) that currents at the proposed disposal area are almost exclusively southerly, with those directed towards Pania Reef (WNW to N) occurring approximately 10% of the time[24].

The duration of TSHD dredging for an individual campaign is not expected to exceed 3 weeks (Table 1). For the reasonable worst-case conditions of July 2016, model outputs indicate that suspended sediment concentrations over the Reef are expected to reach the range of 2–5 mg/L above background for a period of approximately one day over the month[25]. The limited SSC dataset in Table 21 suggests that background concentrations on the order of 10 mg/L may be reasonably typical of Reef waters, but also that this level may be considerably exceeded during high swell or run-off events and remain elevated for several days[26]. This suggests that, unless sustained for significantly longer than is predicted by the model, a project-related increase in SSC of less than 7 mg/L is very unlikely to lead to adverse ecological effects at the Reef.

[23] This contrasts with general observations that ambient turbidity levels frequently exhibit an increase near the seabed, a situation that can sometimes have a marked effect on underwater visibility at Pania Reef, even when surface conditions are good.

[24] Based on ADCP meter deployment 9 December 2016 to 16 January 2017.

[25] The 2% exceedance from a 98th percentile exceedance plot over a month represents 15 hours duration.

[26] The recently compiled background turbidity dataset from the telemetered Pania Buoy is in NTU (Section 6.7) and will require calibration against TSS over an appropriate range of conditions to place such levels in better context.

Modelling of resuspension at, and transport from, the proposed disposal area under storm wind conditions using extremely conservative assumptions (very severe wave height and period) indicated that the potential for plume effects at Pania Reef exists only for westerly quarter winds (Advisian 2017b). Even here, the maximum SSC expected over parts of the Reef would be 2 mg/L and 4–6 mg/L above background for surface and benthic water column layers, respectively. Allowing for a significantly elevated background turbidity under such conditions, this potential contribution from spoil ground sediments is considered to be less than minor.

Sedimentation

The modelling conducted by Advisian (2017a) predicted no sedimentation of fine silt fractions on Pania Reef. This was largely due to the direction of prevailing currents being toward the east, resulting in sediment plumes from the disposal site moving offshore and away from the Reef. It was further noted that wave-induced near-bed currents would result in re-suspension of any sediment that may be deposited on the Reef. This underscores a general distinction that should be made between sedimentation (as accumulation) and depositional flux for which settled material quantities are inherently ephemeral in wave-exposed environments.

Since the model includes only the sediment introduced by dredging activities, the background depositional flux of sediments is not part of the model outputs. This means there is no real context for deposition from project-generated plumes. The observed sediment on reef surfaces (Section 6.5.2) indicates that natural sediment deposition may be significant, especially at deeper points of the inshore Reef sections, but this background cannot be quantified with the available information. However, some degree of proportionality can be assumed between ambient turbidity levels and natural sedimentation of fine particulate material. Hence it follows that project plumes would add only incrementally to existing background deposition.

The amount of sedimentation occurring naturally on the Reef will furthermore be in equilibrium with resuspension from episodic swell events that lift and disperse fine material that has settled in calm periods (e.g. Figure 46B). Hence, while any short-term increases in suspended sediment supply may result in temporary increases in the thickness of deposited silt veneers under calm conditions, it is important to acknowledge that such layers occur naturally and do not persist over longer time-scales.

Exposure of other shoreline receptor sites

The percentile exceedance plots from modelling suggest that the exposure of Town Reef to SSC and depositional effects will be greater than that predicted for Pania Reef; however, its inshore setting means that its background exposure to elevated SSC will also be considerably higher. Suspended sediment concentrations are not predicted to exceed 10 mg/L above background at Town Reef at the 98th percentile level; i.e. for less than 15 hours over the month-long simulations for Campaigns 1 and 5. Corresponding deposition is indicated to exceed 1 mm only at the 98th percentile level for each of these campaigns.

The model outputs further suggest that, despite its proximity to the dredging operation, the shoreline immediately west of the Port will be little more exposed to plumes than Town Reef, with exceedance of 10 mg/L above background occurring only in the western embayment adjacent to the Port at the 98th percentile level and then only for Campaign 1 over the one month simulation. The 1 mm 98th percentile depositional contour for Campaign 1 extends some way over the western shoreline but not as far as Ahuriri Inlet. This suggests that near-shore areas further west (such as Rangitira Reef) and north [Mataitai area of Moremore (a) (Figure 6)] are unlikely to be exposed to significant plume effects.

7.4. Habitat sensitivity to suspended sediment plumes

The introduction of suspended sediment from human activities is increasingly recognised as a significant environmental stressor in many aquatic ecosystems (Gray 1997). An important consideration in the establishment of site assessment criteria for dredging and spoil disposal operations is the proximity to areas of special scientific or biological importance as well as to habitats with sensitive receptors (DEWHA 2009).

While the key marine ecological receptor in the vicinity of the proposed project is Pania Reef, shoreline reef areas are also potentially vulnerable by virtue of proximity to plume propagation paths (Town Reef) or limited flushing characteristics (the embayment immediately west of the Port reclamation). While no soft sediment benthic habitats have been identified as being unique or limited in the wider area, these are potentially locally important as foraging grounds for recreationally and/or commercially targeted fisheries species.

The wide range of background values for different coastal environments means that assessment must be approached on a site-specific basis. However, a range of adverse ecological effects can occur when suspended sediment concentrations are sustained in excess of background concentrations. Knowledge of the specific sensitivities of different classes of organism is relatively limited; hence consideration of the background levels to which communities are naturally adapted becomes an important component of any assessment.

7.4.1. Soft sediment benthos

The near-shore soft sediment benthic habitats of southern Hawke Bay are characterised by fine sediments that are subject to resuspension by wave-induced shear. Smith (2013) noted that seabed sand ripples were a characteristic typical of the monitored areas in 10–12 m of water off Westshore Beach, indicating a dynamic seabed environment. Since fine material is a significant component of these bed sediments, there is a persistent near-bed layer of high turbidity, producing the consistently very-limited to absent underwater visibility observed by divers. The benthic communities occurring in this environment must consequently be well-adapted to sustained conditions of high suspended-sediment loadings, including the increased deposition rates which this engenders. This is consistent with the assemblages of epifauna and sediment dwelling infauna identified from sampling (Sections 6.1, 6.2 and 6.4) with all taxa considered highly tolerant of sustained high suspended sediment levels.

Suspension- and deposit-feeding molluscs can be affected by high suspended sediment levels. Gibbs and Hewitt (2004) found that horse mussels (*Atrina zelandica*) exhibit increasing stress at increasing suspended sediment levels and wedge shells (*Macomona liliana*) were adversely affected at levels above 300 mg/L. However, as well as being significantly higher than the concentrations predicted for all but the immediate areas of dredging and spoil disposal (Advisian 2017a), these studies concerned the introduction of terrigenous rather than the marine sediments to which resident species will be accustomed.

Light penetration at the seabed is expected to be naturally very low in near-shore sediment habitats and mobile substrates are not conducive to the establishment of benthic algae, so elevated surface and mid-water turbidity following spoil deposition are not expected to result in significant effects associated with any reduction in photosynthetically active radiation (PAR)[27] reaching the seabed.

7.4.2. Reef habitats

Key to the assessment of potential suspended sediment effects on reef ecosystems is an understanding of the relative sensitivity of reef communities. However, only very limited information exists concerning actual sensitivity thresholds for key taxonomic groups. Rather it is the distribution of these taxa across the spectrum of suspended sediment conditions which provides an insight into individual tolerances.

The transect surveys of Pania Reef found its ecological communities to vary along gradients of depth, water motion and sedimentation (Section 6.5). Community assemblages reflected the high-energy exposed setting of the Reef. However, both direct observation and available water quality data indicate that these are generally adapted to cope with frequent periods of moderate to high turbidity, particularly at the southern inshore end. The communities were characterised by a range of epibiota and fish taxa and relatively low macroalgal diversity.

[27] PAR designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis.

The following sections consider the main mechanisms by which adverse impacts may occur from the impingement on reef areas of turbidity plumes and discuss the likely sensitivity or resilience of these habitats.

Sedimentation by settlement from the water column

Impacts to reef communities can result when sediment deposition occurs to the extent of covering over encrusting, sedentary or less-mobile biota. The amount of deposition required to lead to significant adverse effects will vary with the specific habitat and community assemblage. However, such smothering impacts generally do not occur in areas of high wave energy.

Working in Kaikoura, Schiel et al. (2006) found that even a fine layer of sediment greatly reduced the attachment of germlings of the macroalgae *Hormosira banksii* and *Durvillaea* sp., and a slightly thicker layer entirely prevented attachment. However, despite the presence of patchy sand habitats that occurred just below the *Durvillaea* zone, they noted that neither sand nor other sediments was observed to accumulate on the high-energy sites in the intertidal zone. It was concluded that, while deposited sediment can cause high levels of mortality if burial is deep and prolonged, these effects were more likely to occur along the shorelines of sheltered harbours and sites of lower wave exposure.

The greatest observed gradient in sedimentation on Pania Reef was with depth. Relatively heavy silt veneers were observed in deeper sections of all transects. This depth gradient is common to turbid environments exposed to significant wave energy since conditions become more quiescent with depth and deposited sediment is more likely to stay in place. The reef-top and its associated macroalgal canopy was notably free of sediment despite very calm conditions. During a transect dive at the same location as transect PR2 (running south-east from Pania Rock), Duffy (1992) noted that a sand patch in the reef at 16 m was raised into ridges 25 cm high. The magnitude of this effect at such a depth suggests that the mechanical flushing effects of oceanic swells frequently reach significant depths on the Reef; hence the prevalence of deposited silt is likely to be quite variable.

Greater levels of sedimentation were observed by divers at the transects closer to shore along Pania Reef. This increased siltation of Reef surfaces is likely to derive mostly from generally greater turbidity in the near-shore region. This in turn is likely to have several predominant sources, including increased wave resuspension of benthic sediments in shallower waters, wave induced abrasion of beach substrates and along-shore propagation of riverine discharge plumes. The flatter profile of the reef in its southern sector may also result in less turbulence at the seabed, allowing more sediment to stay in place

Pania Reef communities are accustomed to periodically elevated turbidity, but the exposure of the Reef to persistent wave action also ensures that sediments tend to remain in suspension until settlement can occur in quiescent zones in deeper waters. Even where silt veneers deposit on Reef surfaces during periods of high turbidity and calm conditions, these will be easily resuspended and removed by subsequent wave events (Figure 46B). Hence, variable silt conditions are part of the natural conditions of the Reef. This mechanism will prevent or limit the build-up of settled silt even under increased sediment loading from dredging plumes. At peak levels of suspended solids (from all sources), silt veneers may be more prevalent at lower energy sites on the Reef, but these will still be rapidly resuspended and dispersed by swell events.

A slight increase in sediment supply in the form of elevated SSC is unlikely to increase the thickness of deposited veneers at open coastal locations except during atypical periods of low wave energy. This is because the amount of sedimentation is mediated by the amount of water movement, but is likely to be relatively less sensitive to the amount of sediment in suspension. In this way, the system may be self-limiting to a certain extent. But in times of very settled conditions, there would be some potential for an increase in deposition if SSC is significantly greater than normal background levels. While the risk of ecologically significant increases in deposition is considered very low, comparison of the results of the more detailed plume modelling for reef areas against a comprehensive and calibrated turbidity data set should enable the assessment of potential deposition from anticipated turbidity shifts to be refined.

Furthermore, a sustained increase in the flux of suspended sediment may favour the establishment or increased prevalence of psammophytic (sediment tolerant) algae such as red filamentous and turfing forms, which are not only capable of adjusting to sediment stress, but also trap and bind sediment (Airoldi 2003). However, the suspected high variability in background SSC and the limited duration of individual dredging campaigns make it very unlikely that such a fundamental shift could occur within project time-frames.

Interestingly, turfing forms of algae (specifically common coralline forms) were absent from the transects surveyed on Pania Reef. Instead, there was a greater prevalence and diversity of sponges recorded from areas of greater siltation further inshore. In a review of sediment impacts on sponges, Bell et al. (2015) found little consistency in the findings of published studies and concluded that the relationship between sponges and sediment was complex. However, they did note that it had been hypothesised that sponges persisted in highly sedimented areas because of reduced competition with algae. While this is consistent with our observations on Pania Reef, the prevalence of algae did not appear great enough for clear competitive interaction to occur and it is likely that other factors are involved.

Light attenuation

High turbidity reduces light levels (as photosynthetically active radiation—PAR) reaching the seabed. When this is sustained, photosynthetic organisms can be adversely affected. On reefs, a reduction in PAR may affect structurally and trophically important seaweeds. Shears and Babcock (2007) noted that light penetration is an important factor explaining vertical distribution and variation in algal communities in rocky reef habitats.

Hence the depth zonation of marine algae may be principally dependent upon light attenuation effects and the depths at which a particular species can be found will vary with mean ambient water clarity. Where there are sustained shifts in the background turbidity, a thinning of the canopy of large macrophytes at depth will result as light conditions decrease below optimum levels for individual species. Eventually, a decrease in the depth at which such species begin to establish and thrive will be observable, with encroachment by species tolerant of lower light conditions. Significant changes in macrophyte prevalence and cover in reef habitats will in turn result in indirect effects on the wide range of organisms which rely on them for food and habitat.

Some indication of prevailing light attenuation (and hence water clarity) at Pania Reef is given by the depth at which sponge gardens are seen to take over from brown macrophytes as the predominant cover. The dive transects (described in Section 6.5.2) show this change generally occurring at the 15 m level for *Ecklonia* on the outer sections of the Reef, but there was a noticeable thinning out of this species and further depth restriction to 10-12 m for the inshore sections. The southernmost transect (P8) recorded no *Ecklonia* at all. These depths are relatively shallow compared to ranges for *Ecklonia* in other parts of the New Zealand coastline that have generally clearer waters and it is considered that light is the major limiting factor.

However, light attenuation is highly variable in most coastal regions and relatively long-lived species such as *Ecklonia* (Novaczek 1981) must be able to survive sustained and repeated low light episodes due to storm and swell resuspension events and the effects of riverine sediment plumes. The rate of response of different species to shifts in light availability will vary with species. Desmond et al. (2015) recorded seasonal changes in biomass for a mixed macrophyte community at 2 m and 10 m depth strata. It was noted that peak biomass occurred during summer, declining in autumn and winter then increasing again during spring. Biomass varied by a factor of greater than two seasonally at 2 m depth but very little change was recorded for the reduced standing biomass at 10 m depth, suggesting that, while macroalgae will respond readily to light availability, they are generally resilient to the effects of low levels on these time-scales.

The transect data indicate that the distribution of large brown macroalgae on Pania Reef is affected by ambient turbidity and/or sedimentation gradients. Populations of the most prevalent macroalgal species occurring at Pania Reef are also found at locations where turbidity is significantly higher (such as inshore Pegasus Bay on the South Island east coast). While a response in biomass is likely with a significant and sustained shift in light levels, recovery would be expected on seasonal time-scales with a return to prior conditions.

Effects on feeding mode

Reef-dwelling suspension feeders vary in their tolerance to suspended inorganic particulates based on their ability to selectively remove organic food particles to maintain growth. The predominant filter feeders observed on Pania Reef were green-lipped mussels (*Perna canaliculus*), ascidians and sponges, most of which are relatively tolerant of elevated concentrations of inorganic particulates. This is supported by the reported presence of mussels in harvestable quantities at Town Reef on the adjacent shoreline (Haggitt & Wade 2016) and the greater prevalence of sponges at the southern end of Pania Reef. It was noted for the 2005 transect dive at PR1, towards the seaward end of the Reef, that the effects of sedimentation on reef surfaces were pronounced at 15 m depth. However, there was a dense and apparently healthy community of encrusting organisms including filter feeders such as cup sponges (*Ancorina* sp.), golf ball sponges (*Tethya* sp.) and ascidians despite a persistent veneer of silt.

All filter-feeding bivalves are affected by the quality and quantity of seston[28]. Mussels are relatively tolerant of high levels of suspended particulates, but feeding efficiency will be affected if the proportion of useable organic particulates relative to the inorganic fraction drops below a certain level. During turbidity events, *P. canaliculus* is able to raise its feeding rates and has been found to select for nutritious particles when particulate organic matter was reduced to ≤ 16% (Teaioro 1999). However, increased feeding rates are accompanied by higher respiration, resulting in lower overall growth rates if such conditions are sustained.

Hawkins et al. (1999) reported that rates of filtration and ingestion in *P. canaliculus* continued to rise as the total dry particulate mass (TPM) of available seston increased up to (the relatively very high) level of 1000 mg/L. Only above this level did a decline in filtration rate suggest any physical overloading of feeding mechanisms. They noted that;

> *A high capacity for filtration and the ability to adjust clearance rate enabled P. canaliculus to optimize particle selection and absorption efficiencies at levels that maintained organic absorption rate independent of the reduction in organic content of available seston as TPM increased to at least 1000 mg/L.*

In reference to a related tropical species, *Perna viridis*, Wong and Cheung (1999) reported that;

> … *feeding processes of green mussels appear well adapted to cope with changes in food quantity and quality. At high particle*

[28] The total particulate matter suspended in the water column and including plankton, organic detritus (collectively particulate organic matter or POM), and inorganic material (PIM).

concentrations but simultaneous low food values in the water column, green mussels have high rates of seston filtration and pseudofaeces production, together with preferential organic ingestion act to compensate for the dilution of organic matter in suspension.

Where exposure is prolonged, effects on mussel physiology may occur at lower particulate concentrations than is indicated by these studies. However, the available information suggests that, in order for suspended sediments to have an adverse effect upon farmed mussels, levels would need to be substantially higher and more sustained than is likely to be the case for the proposed capital dredging project.

Negative effects from sedimentation on the abundance of gastropod grazers have been documented in numerous observational and manipulative studies (Airoldi & Hawkins 2007). Deposited sediment can impair the movement and attachment of grazers. Reduction in grazing activity can be caused either by direct physical interference or indirectly via increases in the cover of turf-forming algae that they are unable to consume (Jenkins et al*.* 1999). Additionally, larval mortality rates of both paua and urchins increase in response to sedimentation early in development (Phillips & Shima 2006; Walker 2007). The reduction in grazing activity by sedimentation has been postulated as one of the mechanisms through which sedimentation controls algal structure on rocky shores (Airoldi & Hawkins 2007).

Sedimentation in the form of silt layers is already a prominent feature of much of Pania Reef. Only the reef top in shallower water of 4–8 m appears relatively free of settled silt via persistent exposure to wave shear. Few urchins and no paua were recorded along the dive transects although the reasons for this were not clear. A range of gastropod grazers were recorded (Table 20).

Abrasive or scouring effects

The scouring effect of deposited and suspended sediments in high energy zones can adversely affect the more delicate encrusting organisms in reef environments. Atalah and Crowe (2010) found that the cover of two types of crustose algae (crustose coralline algae and *Ralfsia* sp.) can be negatively affected by sedimentation and considered this most likely due to the abrasive and scouring effects of sediment moved by wave action, rather than smothering.

In extreme cases of scour, the high suspended sediment loads toward the seabed can maintain rocks in a largely abiotic state although cycles of periodic accretion may also contribute to such effects. In the case of Pania Reef, the community assemblages noted during the transect dives appeared somewhat acclimated to these effects and the signs of scour were minimal, suggesting that sediment loads are generally sub-critical in this regard. It is expected that suspended sediments reaching Pania Reef from dredging or spoil disposal operations will be dominated by fine silts, and that these are unlikely to attain levels resulting in significant abrasive effects.

Potential cumulative effects from a sustained shift in background SSC

Sedimentation plays a significant role in structuring rocky reef communities, both intertidal and subtidal. However, it is important to recognise that gradients in sedimentation rates and water turbidity are a natural feature of coastal systems. Specific areas of the New Zealand coast feature naturally large sediment loads (e.g. South Canterbury) and, increasingly, natural inputs are augmented by those associated with catchment modification.

The preliminary plume modelling suggests that Pania Reef will not experience suspended sediment concentrations from dredging and spoil disposal at greater than 10 mg/L above natural background levels. This is unlikely to exceed the highest levels experienced by the Reef from storm conditions or riverine flood flows. It is therefore unlikely that such plumes will result in acute stressor events. Rather, any observable changes in reef communities, should they occur, are likely to be subtle, resulting from a shift in the background levels of turbidity and suspended sediments over the duration of dredging operations. Potential changes in community structure may include the following:

- an increase in the prevalence and cover of psammophytic taxa at the expense of those more sensitive to suspended or deposited sediments
- a decrease in the cover of erect canopy-forming macrophyte species
- a decrease in the depth to which canopy-forming and other macrophytes extend
- changes in the prevalence and community structure of grazers.

The degree to which these changes may occur depends upon the concentration of the plume and the duration for which these conditions persist. It is impossible to establish the precise extent to which the Reef communities are controlled by sediment fluxes as opposed to other factors, but observations suggest that sediment is a key driver. This in turn suggests that the communities are in equilibrium with, and will respond to changes in, the background sediment supply. But because suspended sediment conditions are naturally variable, there must also be a degree of resilience to change. This means that where the level of stress is not acute, community response will be gradual and, ultimately, reversible following a return to more typical conditions.

Furthermore, the physical configuration of the Reef and the sediment and turbidity gradients already observable along its length mean that such effects would have to be quite pronounced to be measureable. It is unlikely, therefore, that monitoring of the reef communities could unequivocally establish causality in the event of an observed change in an ecological parameter or index, especially as such values may undergo natural oscillations on a seasonal basis (e.g. macroalgal standing biomass). The exposure of the Reef to high turbidity is naturally event-driven. While a full year of background turbidity data should capture seasonal variation, an indication of inter-annual variability will need to be inferred from the frequency and severity of captured events such as storms, rainfall and oceanic swell.

The circulation patterns in Hawke Bay bring about a weak underlying southward set to water flow off Napier. Plume modeling by Advisian (2017a) indicated that dredging activity would not result in a significant increase in SSC over Pania Reef, even with a TSHD operating in the outer Fairway (Section 7.3.3). For spoil deposition at the proposed offshore disposal area, currents carrying plumes towards Pania Reef are indicated to operate only around 10% of the time (Advisian 2017b) and even when these occur, elevation of SSC above background over the Reef is predicted to be less than 10 mg/L (Advisian 2017a). Hence there appears little potential for a project-related increase in SSC at Pania Reef of a magnitude and duration that is ecologically significant.

7.4.3. Pania Reef

It is difficult to rank the taxa observed on Pania Reef with respect to sensitivity to turbidity or sedimentation effects. Because Reef communities are intrinsically in balance with existing conditions, the categorisation of organisms particularly sensitive to suspended sediments suggests that their status may already be marginal. This marginal status in turn decreases their importance to overall community structure.

The most critical elements of many reef communities are the habitat-forming species. In the case of Pania Reef, these are the canopy-forming macroalgae (especially *Ecklonia*), green-lipped mussels *P. canaliculus* (as a species which forms dense beds) and to some extent sponges, although these were not found to attain high rates of coverage, even where they were prevalent. The most sensitive of these to suspended sediment is likely to be the macroalgae, and their distribution on the Reef will be predicated to a significant extent by both turbidity-related light attenuation (controlling depth range) and sediment deposition (affecting prevalence along the Reef axis). Since gradients in the distribution and condition of *Ecklonia* are apparent, the implication is that this species will respond to changes in ambient suspended sediment. As discussed above, such changes are unlikely to be rapid unless conditions reach levels of acute stress, but changes in standing biomass on at least seasonal time-scales have been established. Conversely, sustained changes in turbidity for durations on the order of weeks are unlikely to result in a measureable response.

7.4.4. Other reef habitats

Although Pania Reef is of particular concern due to its location, extent and recreational and cultural importance, there are other hard-substrate areas that are considered on the basis of proximity to the proposed project. These are Town Reef and the shoreline between the Port and Westshore Beach, including the semi-sheltered embayment immediately west of the main Port reclamation.

Town Reef

Town Reef is located adjacent to the base of the main Port breakwater at the northern end of Marine Parade Beach. It is approximately 2 km to the south of the proposed Fairway dredging operations and represents a well-flushed, high-energy environment due to considerable exposure to both wave action and along-shore currents. While not surveyed for this assessment, the ecological communities it supports are expected to be well-adapted to highly turbid conditions. Natural sediment transport processes operating at this exposed location are expected to be significant, with considerable volumes of shoreline and near-shore sediments likely to move through the area.

The orientation of the currents identified in the vicinity of the Port Fairway makes inshore areas more likely to experience elevated turbidity from the proposed dredging than Pania Reef, and this is a notable feature of the modelling outputs (Advisian 2017a). However, Town Reef is at sufficient distance from the proposed dredging and spoil disposal operations that the SSC exceedance envelopes show potential exposure which is unlikely to be ecologically significant relative to expected background levels for this location (Section 7.3.3).

The shoreline morphology at this location indicates no potential for sediment plumes to be entrained and trapped within the area of Town Reef and its shallow, wave exposed nature is expected to preclude the accumulation of settled fine sediments. However, periodic event-driven accretion and erosion of coarse sediments is likely to be a notable feature of the near-shore margin. For these reasons, additional stress to Town Reef from any project-associated plumes is expected to be relatively minimal.

Western embayment

The small western embayment adjacent to the Port is protected to a significant extent by the existing reclamation and breakwaters. However, it does not receive complete shelter from wave energy and would experience periodic flushing and disturbance as a result of storm and swell events. It is characterised by mixed substrates, including natural and introduced cobble and boulder material which extend up to 200 m seawards of the sand beach (Section 6.3). These intertidal and shallow subtidal habitats continue for much of the shoreline to the Ahuriri entrance at Perfume Point. Dilution and dispersion processes in this area would be expected to be moderate; however, it is likely that a small gyre operates in this vicinity during some wind conditions (Advisian 2015), a situation that may make it potentially vulnerable to plume impingement effects.

The benthic surveys of these areas indicate that moderate levels of sediment deposition, accretion and erosion are significant existing processes. As well as persistent inshore wave resuspension effects, there are sediment inputs from natural run-off and riverine loads (Ellison 1995) and deposited fine sediments were observed to be a consistent feature (Section 6.3). The established benthic communities are therefore adapted to tolerate sediment stresses at ambient levels, including those associated with periodic storm events, which have the capacity to transport substantial quantities of sediment in shallow near-shore areas via wave-mediated resuspension and bed-load transport. The flushing effect of significant storm wave events means that deposited fine sediments will not persist in this area at greater than existing levels.

Even the relatively well-established reef habitat of the low tide boulder field in the western embayment (Section 6.3.2) is likely to be relatively variable over intermediate time periods due to event-driven processes. For this reason, while there is potential for short-term adverse ecological effects from increased fine sediment deposition to these areas if such conditions are sustained, shifts in community structure are unlikely to exceed those associated with natural perturbations and recovery is likely to occur within seasonal timeframes.

As noted in Section 7.3.3, the modelling results reported by Advisian (2017a) appeared to show that plumes at concentrations greater than 10 mg/L above background would impinge upon the western embayment at the 98th percentile level (i.e. less than one day duration) for the one month simulation of Campaign 1. This level of plume exposure is very unlikely to be ecologically significant for this location.

Rangitira Reef

Immediately west of the entrance to Ahuriri Inlet, Rangitira Reef is a broader area (approximately 5.5 ha) of shelf and cobble reef and has been ecologically characterised by Smith (2008b). It is the closest significant reef area to the consented dredge spoil disposal sites and was a key factor in the establishment of the south-eastern boundary of site ‘R extended’, 750 m to the north-west (Figure 2). With respect to habitats and biodiversity, it reflects a continuation of the near-shore reef environments east of the Ahuriri entrance but with slightly greater exposure to swell wave energy. Smith (2008b) described the subtidal environment as being highly dynamic and prone to disturbance from waves and swell. Despite considering the role of spoil disposal operations in a number of limited prior studies of the Reef, Smith did not link the findings of his survey to effects from prior use of the spoil grounds. The near-shore exposed environment of Rangitira Reef means that, similar to the shoreline to the east, it is likely to be resilient to any sediment plume effects arising from the project. Plume modelling conducted by Advisian (2017a) indicated that this location would be unlikely to be exposed to SSC exceeding 10 mg/L above background (Section 7.3.3).

7.5. No.6 Berth construction

7.5.1. Habitat alteration

Given that the site of the proposed No.6 berth is at the Port entrance and completely within the zone of proposed capital dredging, the only additional direct loss of habitat caused by its construction will be current sea wall rip-rap facing extending down the existing batter slope. This is entirely an introduced substrate and will be replaced with a similar substrate during construction of the berth. The habitat will differ, however, due to the greater water depth and the establishment of the wharf structure above, which will significantly alter the light regime. There will also be ongoing disturbance from vessels using the berth (especially propeller wash) and periodically required maintenance dredging of the berth pocket. Such alterations to the physical environment will alter the ecological suitability of benthic habitat and therefore the communities present.

The wharf piles represent the introduction of a significant expanse of new hard substrate for colonisation by encrusting biota. Although the mechanism is not well understood, wharf piles are known to create a habitat for epibiotic assemblages distinct from those of intertidal reefs or floating pontoons (Connell 2001). Wharf pile surfaces are already a significant intertidal and subtidal substrate within the Port; hence the No. 6 Berth development represents an incremental change in extent rather than an entirely new habitat.

7.5.2. Construction effects

There are no significant discharges that are intrinsically associated with the anticipated construction process and the potential for accidental discharges is expected to be minimised through implementation of appropriate management practices through a Construction Management Plan.

Piling and drilling operations, trimming of the batter slope and the placement of armour all have the potential to generate turbidity plumes but these are likely to be more localised in extent and less sustained than those arising from dredging.

Consequently, any disturbance to habitats outside of the capital dredging footprint resulting from wharf construction activity will be very localised and is not expected to exceed that from dredging operations.

8. FISH AND FISHERIES ASSESSMENT

The critical factors associated with the capital dredging project that may have the potential to affect fisheries resources in the Napier region are considered to be;

1. the permanent alteration of benthic areas by dredging and the ongoing disturbance of these areas from maintenance dredging,
2. the temporary loss of benthic habitat represented by inundation and disturbance at the proposed spoil ground and areas immediately adjacent to its boundaries and
3. the elevated suspended sediments concentrations and poor water clarity within turbidity plumes potentially generated by dredging and spoil disposal activities.

8.1. Significance of seabed areas directly impacted

8.1.1. Benthic habitat

As benthic habitats, neither the proposed capital dredge area or spoil ground have been identified as being of special ecological or conservation importance; however, the wider areas of inshore Hawke Bay are of some importance as recreational and commercial fisheries areas. In particular, the area running south of Napier appears to be productive for the flatfish trawl fishery (Section 5.3.4). The area potentially impacted exists inside an area where trawling is prohibited for vessels greater than 13.5 m (Figure 6). Most trawling occurring inside the 30 m depth contour is expected to be targeting flatfish and gurnard.

The relative importance to fisheries species of seabed habitat lost, altered or temporarily disturbed as a result of the proposed activities depends to an extent upon the proportion of similar habitat within the surrounding region.

Capital dredging area

The extended Fairway proposed for capital dredging represents an area that will be effectively permanently altered from its natural state due to the ongoing need for periodic dredging to maintain depths. The total area to be dredged is approximately 117 ha with around 60 ha previously undredged. The survey data for this area does not identify it as a habitat that would be spatially limited in the wider inshore area; hence, in terms of the area of productive seabed directly affected, its potential loss to fisheries species is considered less than minor.

Sediment areas in transition zones around reef habitats can have particular importance for species such as snapper and tarakihi. However, the 1 km distance between the dredged Fairway and Pania Reef is considered an adequate buffer to avoid changes in foraging behavior for these species.

Proposed dredge spoil disposal area

The 2005 survey of the area currently proposed as a spoil ground found the seabed to be entirely composed of relatively homogeneous soft sediments. The sediment infaunal community was dominated by deposit-feeding invertebrates and was considered typical of sandy coastal areas at moderate depths that are periodically subjected to high turbidity and ocean swells. The site did not encompass physical habitats or biogenic features which significantly differentiated it from much of southern Hawke Bay in similar depths. Hence there is little evidence to suggest that this specific area has an importance to certain fisheries species that sets it apart from other areas in similar water depths.

The proposed location of the disposal area is within an area of inshore southern Hawke Bay representing around 60% of the total commercial flatfish catch (Figure 7). However, the limited size of the site relative to similar habitat in this wider area means that any temporary impact on benthic macroinvertebrate communities as a result of dredge spoil disposal is likely to have minimal impact on general populations of fish species such as flatfish and gurnard which may include it in their foraging range. These species tend to be wide-ranging and may avoid the immediate area during spoil deposition activities. Other commercial species such as snapper and tarakihi also exhibit high mobility over a wide range of feeding areas, and are known to consume a highly varied diet (Godfraiux 1974a, 1974b, 1974c; Morrison et al*.* 2014a).

Periodic benthic monitoring surveys have indicated that the long-term use for spoil disposal of sites off Westshore Beach has not resulted in changes to seabed communities which would compromise - more than temporarily - their use for foraging by fish populations (Section 6.2). The greater water depth of the proposed disposal area means that it is less dispersive than the near-shore sites. The greater total spoil volume of the capital dredging project is also relevant, but spoil deposition will be spread over five dredging campaigns. Effective recovery of the benthic community is expected to occur relatively rapidly (over a period of months) following deposition events.

8.2. Fish movements and critical habitats

While recent efforts at compiling present knowledge have sought to address information gaps in the life-cycles and habitat preferences of key species (e.g. Morrison et al*.* 2014a, 2014b), Haggitt and Wade (2016) noted that there still remain large gaps in our understanding of the importance of various habitat types in supporting fishery production and different life history stages of fished species.

With the possible exception of Pania Reef, benthic habitats known or suspected to be important to particular fisheries species do not occur within the area potentially affected by the proposed project. Morrison et al*.* (2014b) noted that reefs with macroalgae forests support large numbers of small fish (mainly wrasses) but few large benthic-feeding fishes. Large carnivorous species such as tarakihi, blue moki and blue cod are likely to occur in significantly higher densities over sandy bottom with small patch reefs with sparse algae. Pania Reef has a mix of such habitats and the transect dives conducted support such a distribution, although no large aggregations of fisheries species have been consistently reported for the Reef.

8.2.1. Migration

Although a number of species are known to move from inshore estuarine and harbour environments to offshore areas on a seasonal basis for spawning or as part of a change of habitat preference with development from juvenile to adult stages, there is no information which suggests that the Napier area represents a relatively more important location in this regard.

The Ahuriri Estuary is utilised by several migratory species including flatfish and whitebait (Kilner & Akroyd 1978). The seasonal offshore movement of sand and yellow-belly flounder is relatively well documented but the available data support long spawning periods for both. These species are noted for high fecundity and low recruitment variability (Morrison et al*.* 2014a). In any case, the proposed dredging, spoil disposal and construction activities are not considered to represent a barrier to fish movement, especially as the Ahuriri already features high levels of turbidity from the input of terrigenous (land-based) sediments (Madarasz 2006).

8.2.2. Spawning and nursery areas

There are no specific areas potentially affected by the project which are known or suspected to be important spawning or nursery grounds for fisheries species. While the Ahuriri Estuary almost certainly functions as a nursery area for several species and possibly a spawning area for whitebait, its potential exposure to project-associated stressors is limited to the incursion of dilute turbidity plumes only. The project is not considered to be a significant source of contaminants (Section 7.2). As noted above, the current exposure to suspended sediments from catchment inputs is likely to far exceed that from the tidal entrainment of dredging or spoil disposal plumes.

As noted, both locally common species of flounder move into deeper waters annually to spawn, as do gurnard, kahawai and blue moki. Red gurnard are believed to spawn over inner and mid-shelf areas (Hurst et al*.* 2000). While rig aggregate annually in spring and summer in shallow coastal waters to breed, specific areas of importance are not documented. Both this species and school shark are ovoviviparous[29] and highly mobile. It has been noted that pregnant female rig can travel large distances in

[29] Mode of reproduction whereby eggs are hatched within the body, so that the young are born alive but without placental attachment.

a short time (www.nabis.govt.nz lineage document; spawning rig). Since these species do not require specific habitats for egg-laying, they are likely to avoid the immediate areas of benthic disturbance without significant disruption to the life cycles of local populations.

Elephant fish (*Callorhinchus milii*) were the only fisheries species identified as utilising shallow near-shore waters for spawning. Eggs are laid in spring, in water depths of 5-30 m, and take 5-8 months to hatch. The exact distribution of egg-laying sites of *C. milii* is not known but Hawke Bay is near the northern extent of the range of this species and represents a very small proportion of the total landed catch (Section 5.3.4). The inshore area around Napier is unlikely to be a spawning area important to the fisheries stock.

The semi-sheltered inshore area of mixed substrate adjacent to the Port and expanded Swing Basin is considered to be too limited in extent to be critical to the life cycles of wide-ranging species. The majority of fisheries species are distributed in off-shore areas and are not considered to be reliant upon the limited habitats identified in the Port area.

The mixed substrate areas of the Wairoa Hard and Clive Hard are associated with both the adult and juvenile phases of several fisheries species including John Dory, tarakihi and snapper (Morrison et al*.* 2014a), but both these areas are at substantial distances from the project area.

The macroalgal habitats of Pania Reef may be of limited and localised importance to the juvenile stages of some species such as blue moki, although there is no available evidence to support a status of critical nursery area.

8.3. Effects on fish from suspended sediment

As noted for marine ecosystems generally, the most significant mechanism for potential far-field exposure to dredging-related stressors will be via the generation and propagation of turbidity plumes. The dredged material is expected to be generally very low in contaminants. It is also very unlikely to carry elevated nutrients and organic material. Therefore, tolerance and behavioural responses to potentially high suspended solids concentrations are the key issues in considering effects on fish populations.

Variable and sometimes elevated background turbidity is a natural feature of inshore Hawke Bay. Occasionally very high levels of suspended sediment concentrations will occur in shallow regions near the coast as a result of storm events and riverine inputs (Figure 42). The severity of suspended particulate matter as a potential stressor is related to the size distribution and composition of particulates as well as their concentration. The documented effects of terrigenous sediments with high clay fractions are considered to arise at least partly from their difference to native sediments to which local marine communities are adapted. Turbidity plumes generated by dredging and spoil disposal activities will comprise marine sediments from local sources which are similar to those continually resuspended by natural processes. Therefore, a degree of natural tolerance to resuspension events is expected in local fish populations, especially benthic species such as flatfish and gurnard.

Potential impacts to finfish from high suspended solids concentrations include the following:

- gill clogging and abrasion
- egg smothering and abrasion
- reduced foraging success
- increased vulnerability to predation.

It was noted by Wilbur and Clarke (2001) that many fish thrive in turbid conditions and that increased turbidity can be favorable to some species where it confers protection from predation and cover from which to hunt their prey. In their review of published studies of biological effects from suspended sediments, they also reported that, for spawning salmonids, the greatest mortality rates (> 75%) were elicited by suspended sediment dosages that exceeded those typically generated by hydraulic cutterhead dredges. It is likely that most if not all demersal species utilising near-shore areas are similarly adapted to such levels, although the total duration of exposure may be a factor in exceeding such tolerance.

The inshore and estuarine species of flatfish are inherently tolerant of high concentrations of suspended sediments. The yellowbelly flounder has a preference for very muddy environments and it is suggested to be a predominantly nocturnal non-visual feeder (Morrison et al*.* 2014a).

In considering the potential duration of exposures to high SSC, it is worth noting that finfish are generally very mobile and are able to avoid areas of localised stress or disturbance. However, where areas of very high turbidity are significant in extent or completely cover suitable habitat or territory, adverse effects on populations may arise. Most investigations of the effects of suspended solids on fish and shellfish species have focused on riverine or estuarine habitats where subsequent dispersal of turbidity plumes is constrained and the potential for avoidance by local populations is limited.

In the case of the relatively unconstrained areas of inshore Hawke Bay, there will be substantial attenuation of plume strength with distance from the source (Advisian 2015). Plumes of suspended sediments with concentrations high enough to be of concern are not expected to extend more than a few hundred metres from the point of suspension. Avoidance of areas of particularly high suspended solids is likely to be the principal response of finfish species to increasing stress.

8.4. Invertebrate fisheries species

8.4.1. Paua

The occurrence and distribution of paua (*Haliotis iris*) within the Napier region is unknown. No individuals were recorded during the transect dives on Pania Reef but this may be due to limited reef area at suitably shallow depth. Anecdotal evidence suggests they have been historically harvested in the Napier area, although no commercial harvesting of paua is allowed within 1 km of the shoreline in Hawke Bay, so the stock has no commercial significance. Barter and Keeley (2002) reported finding isolated small clusters of paua along the outer breakwater of the Port. Due to the known spatial distribution of suitable habitat, the only mechanism by which reef populations may be potentially affected by the project is via the propagation of turbidity plumes.

Early life stages of paua are particularly vulnerable to toxicants and other stressors; however, few published studies have examined the effects of suspended sediments in the water column on larval stages of marine invertebrates. Phillips and Shima (2006) examined the effects of suspended sediments from terrestrial runoff on larval development, survival, and settlement of kina (*Evechinus chloroticus*) and paua. Results indicated that kina larvae appeared to tolerate exposure to suspensions of terrigenous sediment better than those of paua. For both species, however, short term exposure to high sediment loads was generally worse if exposure occurred early rather than later in larval life. The mechanism by which exposure to sediment increased mortality in both species was not determined but it is important that a distinction should be made between terriginous sediments and resuspended marine sediments to which paua may be better adapted.

Elevated turbidity may also affect the settlement success of invertebrates such as paua. However, it is noted that paua occur abundantly in very turbid waters elsewhere such as the coast of Banks Peninsula and within Lyttelton Harbour. Healthy populations of paua occur along the northern shoreline of outer Lyttelton Harbour within the long-utilised spoil disposal grounds for Lyttelton Port's maintenance dredging program (Cawthron unpublished data).

Sediment deposition upon substrates favoured by paua may limit larval settlement and post-settlement survival. Freeman (2006) reported that sedimentation or shifts in sand deposits could cause significant post-settlement mortality in juvenile paua.

Adult paua may be somewhat resilient to deposition events. Macpherson (2013) studied the recovery of a section of the Te Angiangi Marine Reserve in southern Hawke Bay after it was subjected to a large-scale sedimentation event in April 2011. Catastrophic coastal landslides had inundated the immediate intertidal platform adjacent to the hillside, including significant paua and kina habitat. The landslide debris immediately began to be eroded by wave action into fine-sized particles and transported offshore but the number of adult paua within the reserve remained high after the sedimentation event. Five to eight months after the event, the marine reserve populations began to recover where habitats had been smothered even though significant erosion of the residual landslide debris was still occurring.

8.4.2. Spiny lobster

Spiny lobster (*Jasus edwardsii*) are widespread around the New Zealand coastline but the southern Hawke Bay lobster fishery (Statistical Area 912) appears relatively less productive than adjacent rocky coastal areas to the north and south. However, Pania Reef represents a locally productive recreational and customary fishery for this species

Lobster occur over a broad range of natural turbidity but information regarding the effects of suspended solids on this species is very sparse. It is considered that direct effects of turbid plumes on adult individuals are likely to be minimal. However, any prolonged impingement of rocky reefs by high strength plumes has the potential to result in a reduction in the depth of the photic zone, which may in turn impact on fish and lobster populations in these areas through reduction in macroalgal cover. Nonetheless, lobster were commonly observed within the southern section of the Reef where macroalgal cover is notably sparse.

In a technical review of the application by Trans-Tasman Resources Ltd to conduct iron ore extraction and processing in the South Taranaki Bight, Huber et al*.* (2014) concluded that the impacts of turbidity plumes on lobster larval phases were likely to be minor due to the highly localised geographic extent of the source and the variable oceanic conditions (including variations in suspended sediments) tolerated by larvae prior to settlement within inshore areas.

Juvenile rock lobster were recorded during a 2004 dive survey of patchy subtidal reef inshore of the Port outer Swing Basin. The importance of this small embayment to the wider lobster fishery is unknown, but in view of its very limited spatial extent it is considered very unlikely to be even locally significant.

8.4.3. Paddle crabs

Although there appears to be an intermittent fishery along Westshore Beach for the New Zealand swimming crab or paddle crab (*Ovalipes catharus*), the species is a highly mobile scavenger occurring over a wide range of conditions that suggest it is inherently tolerant of elevated turbidity. What is known of its biology and life history does not suggest that the stock within Hawke Bay will be particularly vulnerable to stressors arising from the No.6 Berth project. Localised elevated turbidity is unlikely to significantly affect the highly mobile adult crabs and recruitment of larval megalopa will remain unaffected following any temporary increase in physical stressors.

8.4.4. Surf clams

There is no current commercial harvest of surf clams in the vicinity of the proposed project although there is some interest in the future exploitation of this resource in Hawke Bay. Only general information is available concerning the distribution of commercial species in the region and this mostly indicates that the areas of interest would be in northern rather than southern Hawke Bay (Section 5.4.4, Appendix 3).

The highly dynamic environment of the surf zone means that species occurring in this habitat are well adapted to significant disturbance, including high levels of sediment resuspension and deposition during wave and storm events. The plume modelling outputs suggest that suspended sediment concentrations for the near-shore environment will be relatively localised and will not be sustained at levels of more than 10 mg/L above background. Such concentrations are expected to be well within levels to which these near-shore soft sediment habitats are regularly exposed

Harvest of surf clams will most likely be undertaken using hydraulic methods whereby the surface layer of sediment is fluidised through the injection of water. This will have the effect of resuspending all of the fine sediments and producing plumes which are carried by near-shore currents. Since this material will be suspended within the shellfish beds themselves, there is a high probability that quite high levels of TSS will be experienced in directly adjacent areas. Since there is some evidence that such methods achieve sustainable yields where commercial harvest occurs, it is considered unlikely that the sediment plumes expected from the No.6 berth project will have more than a minimal effect on the surf clam resource in the vicinity of Napier.

8.4.5. Other species

There is anecdotal evidence that cockles (*Austrovenus stutchburyi*) are gathered within an arm of the Ahuriri Inlet behind Westshore Beach, but the inherent turbidity tolerance of this species coupled with the distance from dredging and construction activities means that significant effects to these beds would not be expected.

9. CONSIDERATIONS FOR MONITORING AND MANAGEMENT

Allowing for the unavoidable direct effects on habitats within the dredging and spoil-deposition footprints, the principal mechanism by which adverse ecological effects may result within the wider area will be via the propagation of plumes of resuspended sediments. However, hydrodynamic modelling for the dredging project has identified only very limited potential for sediment plumes to impinge upon the key high-value receptor site of Pania Reef.

The magnitude of adverse effects from plumes largely depends on the degree to which they fall outside the natural range of conditions in terms of concentration and duration. Information on the existing spatial and temporal variability of background turbidity for surface waters is currently being collected and compiled for two locations in the Reef vicinity (Section 6.7).

The staged implementation proposed for the dredging project lends itself to a precautionary approach to monitoring and management of risk, giving the opportunity to provide validation of both modelling and assessment findings so that timely action may be taken, if appropriate, in relation to subsequent dredging campaigns. The duration of individual stages, and especially the relative brevity of any combined BHD/TSHD operations, allows an opportunity early in the project for validation of both the model predictions and the expected absence of significant ecological effects on key receptors.

Risk is primarily related to the uncertainty within both the model predictions and the nature of background turbidity conditions; hence it is considered that monitoring should aim to provide the following:

1. validation of the modelling outputs in terms of actual turbidity/SSC conditions during dredging and spoil disposal
2. assurance that significant ecological effects attributable to the activity are not occurring on Pania Reef.

9.1. Turbidity monitoring

Validation that project activities have not resulted in more than minor changes to background levels of water column SSC can be addressed using the two established continuous turbidity monitoring stations in the vicinity of Pania Reef (Section 6.7). The compiled turbidity data may be analysed to provide turbidity trigger values based upon high-order percentiles of the background. Exceedance of the trigger values would prompt actions along a tiered framework of investigative and operational responses.

The measurement of turbidity (as NTU) as a surrogate for sediment-related attenuation of light and/or deposition/smothering of epibenthic biota is a commonly used adaptive management tool, especially in Australia where sediment impingement upon coral reefs and/or seagrass beds has been a particular focus of concern (e.g. SKM 2013, Rio Tinto Alcan 2015). Turbidity monitoring, with accompanying trigger levels, is also being used for compliance and adaptive management as part of the Port of Otago (Next Generation) capital dredge project.

9.1.1. Data smoothing - EWMA

What these programs all have in common is the use of a data smoothing function for turbidity data, usually an Environmentally Weighted Moving Average (EWMA), for comparison against prescribed trigger values (e.g. Envirometrics 2007). The EWMA approach overcomes much of the ‘spikiness’ and noise inherent in turbidity monitoring data and allows it to be more effectively used in applying environmental triggers. It is beyond the scope of this report to explain how the EWMA approach works and readers are directed to documents such as Envirometrics (2007) for detail. However, the application of EWMA for compliance monitoring is both tested and widely accepted for similar programmes and is therefore the recommended approach in this instance.

9.1.2. Derivation of recommended turbidity trigger limits

There is very little in the way of useful published guidelines for turbidity or suspended sediments in natural waters. The reason for this is that there is a very wide range of natural conditions, even within individual regions. ANZECC (2000) lists a suggested range for default trigger values of 0.5–10 NTU for turbidity in south-east Australian waters (which is recommended as a default reference also for New Zealand). For aquaculture species, a guideline trigger value for suspended solids of 10 mg/L is suggested; however, New Zealand’s main aquaculture species (green-lipped mussels) can thrive in conditions which frequently substantially exceed this level (Section 7.4.2).

As noted, there have been several instances where turbidity trigger levels have been applied to the monitoring of capital dredging projects in New Zealand and Australia. Trigger levels derived for EWMA data from telemetered monitoring stations for three relatively recent projects are listed in Table 23. The recommended triggers are typically habitat-specific, both to be protective of specific ecological receptors and in recognition of the fact that turbidity conditions can vary naturally between habitats. Limits for seagrass beds, for example, are designed around the protection of clarity to allow sufficient light penetration for photosynthesis. As the key habitat-forming macroalgal species at Pania Reef, populations of *Ecklonia* may be similarly affected by increased turbidity (Section 7.4.2) but, due to the greater depth range over which it occurs, *Ecklonia* is arguably less sensitive to reduced light conditions, especially over shorter time frames (weeks rather than months).

Table 23. Comparable New Zealand and international studies where turbidity lmits based on an Environmentally Weighted Moving Average (EWMA) have been adopted. ERL = environmental response limit.

		NTU triggers and Limit 6-Hour EWMA			Long-term Environmental Limit	
Location / study	Ecological receptor / Habitat	Trigger1 (NTU)	Trigger2 (NTU)	ERL (NTU)	NTU	Term
Port Otago Ltd	Seagrass Habitats	12	17	25	15	14 Day Moving Avg
	Other Eco Habitats	19	24	35	50	10 Day Mean
	Cockle Habitats	35	50	70	---	
Port of Gladstone	Dry Weather Season	17	27	---	---	
	Wet Weather Season	30	48	---	---	
Port Philip Bay	Fish	35	50	70		
Port of Melbourne	Seagrass	12	17	25	15	14 Day Moving Avg
	Benthic Invertebrates	19	24	35	---	
	Seabirds + Seagrass	9	14	17	---	

Based on the relatively low background surface turbidity at Pania Reef, a conservative approach is recommended, with the three-tier system of triggers adopted for the protection of seabirds and seagrass in Port Phillip Bay being a suitable starting point.

Comparison of these turbidity values with a composite dataset of 6-hour EWMA from the two Pania monitoring buoys over a one year period shows that the two response levels (9 NTU and 14 NTU) would be exceeded by natural perturbations in the background (Figure 47). However, this would occur for short durations at a relatively low frequency. The 9 NTU response level would have been triggered seven times during the 14 month baseline period for an average duration of less than a day (maximum 2.8 days). An environmental response level (ERL) of 17 NTU would have been exceeded on two occasions of 10 hours and 25 hours, respectively. Based on the dataset in Figure 47, the two response triggers (9 NTU and 14 NTU) correspond to the 98th and 99th percentiles of the EWMA record, respectively.

9.1.3. Duration component of triggers

Brief periods of elevated turbidity occur naturally and therefore have very little associated ecological risk. Therefore, the duration of an exceedance is an important component of the turbidity trigger levels and has been applied in the monitoring programmes of other large projects such as Port of Gladstone in Queensland. A conservative approach would utilise an exceedance interval on the order of 24 hours for trigger level 1 (9 NTU) and 12 hours for level 2 (14 NTU) before the initiation of a response would be required.

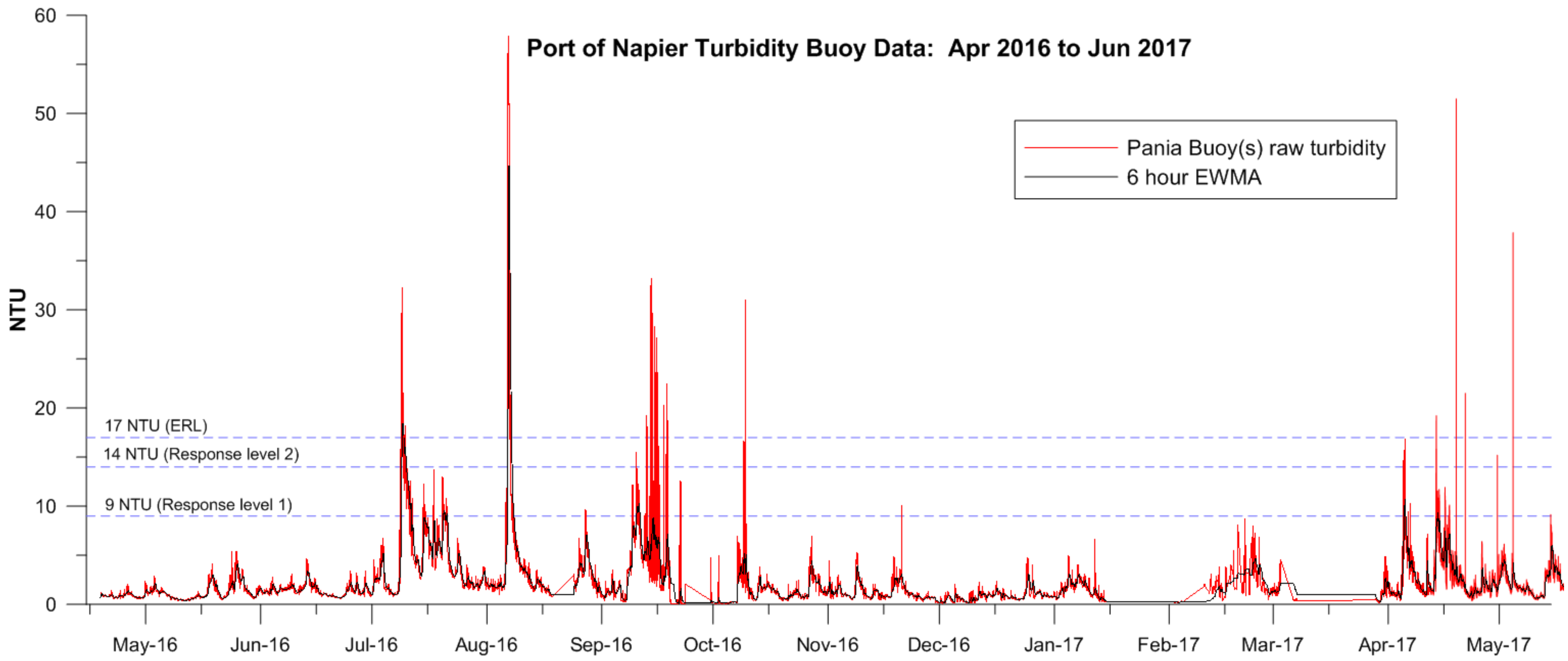

Figure 47. Turbidity data set derived from both Pania (East and West) buoys over a one year period between May 2016 and May 2017. Both the raw data and 6-hour exponentially weighted moving average (EWMA, λ = 0.6) are shown relative to the recommended trigger levels. Exceedance of recommended environmental response level (17 NTU) occurred on 9 July and 6 August 2016. Exceedance of the recommended response level 1 (9 NTU) occurred on a further five occasions during the period.

9.1.4. Establishing a causal link with dredging

The first response to the exceedance of a trigger should be an investigation of the primary cause. Because turbidity is naturally variable, one of the principal difficulties in applying the triggers in a dredging situation lies in establishing the contribution—if any—of dredging and spoil deposition activities to the measured turbidity. While the spatial separation of the two Pania buoys is likely to provide some indication of whether elevated turbidity is generalised in the near-shore area, it is quite conceivable that both monitoring buoys may be affected simultaneously by localised plumes. Therefore, it is likely that a degree of judgement will be required, based on a weight of evidence approach, to determine if an exceedance is primarily dredge-related rather than from natural external drivers.

With sufficient background data to establish the behaviour of the natural system, statistical methods may be applied to quantify the influence of factors such as wind speed and direction, rainfall, river flow, and wave and swell characteristics. Spot measurements of turbidity at reference sites may also be employed as part of a response to trigger exceedance. Satellite imagery will often clearly illustrate the provenance and extent of near-shore turbidity although, due to cloud cover, this cannot always be relied upon for validation.

The modelling by Advisian (2017a) indicated increases in SSC due to dredging activities of no more than 10 mg/l on Pania Reef. The model outputs further indicate a likelihood that such events would occur only under certain current conditions. While even a small additional sediment load could result in a trigger level being exceeded if the background was already close to the trigger, it would be less likely that turbidity would remain elevated for a period such that a management response was required unless an obvious external driver (such as flood river flows or swell) was also in play.

9.1.5. Use of turbidity data: management vs compliance

With 15-minute telemetry of turbidity values, the 6-hour EWMA can be calculated at each step. However, it is recognised that there needs to be a minimum period to effectively establish compliance status and 6 hours (noting that suggested trigger durations are multiple of 6 hours) is considered a workable period in the context of both operational constraints and ecological relevance. Nonetheless, calculation at 6-hourly intervals would give little visibility of impending exceedance. Hence the ability to establish EWMA trends over shorter time periods is valuable from a management perspective to learn how the system responds and maintain a suitable state of preparedness if triggers are approached.

Allowance for missing data

Minor loss of turbidity data can be handled by stipulation within conditions of how much information is required to meet QA/QC requirements. For example the Port Philip Bay dredging project used 20% missing data as the criterion for assessing a valid EWMA calculation (PoMC 2008). For monitoring at Pania Reef, this stipulation would equate to five missing 15-minute readings every six hours. Longer term missing or invalid data could be addressed via collection of grab samples or other methods.

9.1.6. Overview of suggested turbidity monitoring and compliance approach

A suggested framework for the consent conditons around turbidity monitoring and compliance is provided in Table 24. A conceptual decision tree for the process is presented in Figure 48.

Investigative responses to trigger exceedance would begin with interpreting and reporting information concerning key external drivers of turbidity (e.g. high wave or riverine outflow events) in relation to the current exceedance. They could, however, also prompt more detailed investigation of project activities, involving discrete plume mapping surveys, if required.

Table 24. Framework for a recommended approach to monitoring and compliance for continuously recorded turbidity data in the vicinity of Pania Reef. ERL = environmental response limit.

Response trigger level		**Compared against:**	**Duration after which exceedance is established**	**Response to exceedance**	
				Management (internal)	**Regulatory / reporting**
1	9 NTU	6 hr EWMA	24 hrs	**Investgate** most probable cause **Record / report** response taken to manage / mitigate (if any) **Review** and **modify** dredge operations as necessary	None
2	14 NTU	6 hr EWMA	12 hrs		**Notify** consenting authority within 1 working day. **Report** on whether exceedance was project-related.
ERL	17 NTU	6 hr EWMA	Immediately	**Investigate / record / report / review** (as above) plus **modify / curtail** dredge operations if necessary	**Notify / report** (as above) within 12 hours (if dredge – related) or 1 working day (if non-dredge-related). **Seek consenting authority approval** to re-commence activity if dredge-related

For most exceedance situations, it will be clear before exceedance occurs that the background turbidity is rising (or will rise) due to external drivers. It is unlikely to be the case that a wholly unanticipated natural turbidity event will occur. However, establishing (and adjudicating on) relative contributions to a turbidity exceedance may sometimes present difficulties.

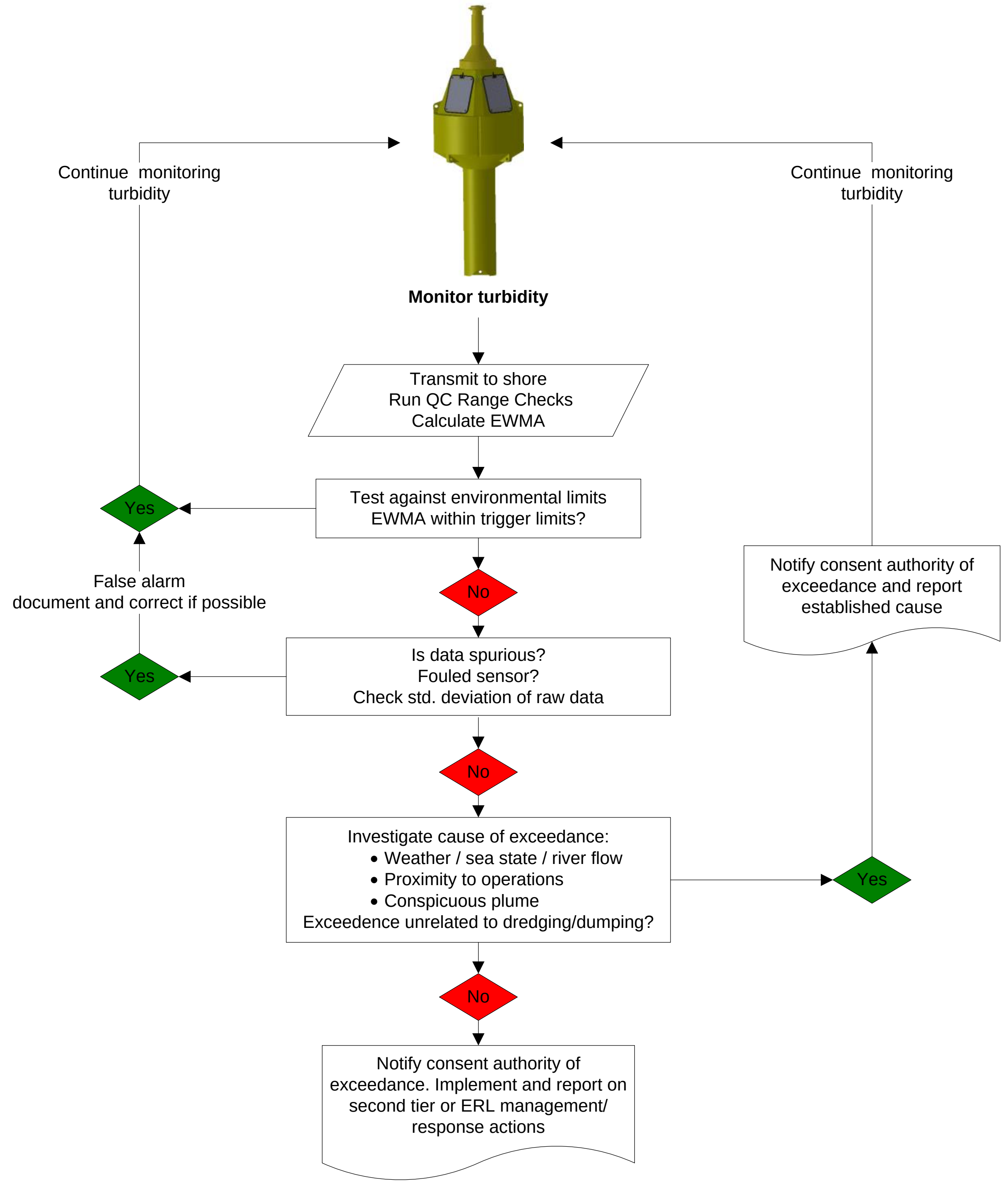

Figure 48. Decision tree showing how 2nd tier and ERL turbidity trigger level(s) could be used for assessing and managing compliance of capital dredge operations.

9.2. Direct monitoring of ecological receptors

Ecological monitoring would involve periodic surveys of ecosystem condition, with Pania Reef being the principal focus. Such monitoring would focus on changes potentially related to impacts from an increase in SSC. Such monitoring does not, however, lend itself very well to an adaptive management approach for the following reasons:

- The wide range of potential ecological responses to suspended sediments means the prior establishment of specific triggers or limits is impractical.
- It is unlikely that natural variability in key ecosystem parameters could be unequivocally established due to the operation of longer-term variability and/or natural cycles and trends.
- The establishment of strict causality for any observed change in condition is very challenging. Interpretation would need to take a weight-of-evidence approach and a degree of uncertainty would need to be accommodated.
- It is likely that ecological responses to turbidity-related stressors would involve a significant time lag following a change in ambient conditions. This means that even where causation is established, any management responses would be limited to time-scales between dredging campaigns, rather than within them.

Such ecological monitoring would, however, serve the following functions:

a) To identify any more serious or distinct effects where causation is rather more obvious (aided by time-series data from turbidity buoy/s)
b) To provide assurance that the actual condition of the prime receptor of concern is being monitored during the project, regardless of prior assessment findings.

The staging of the dredging project theoretically allows the possibility that any significant findings from ecological monitoring may be able to inform the management of the subsequent dredging campaigns.

10. SUMMARY AND CONCLUSIONS

Together with other available information sources, the survey data compiled for this assessment represent a comprehensive characterisation of the benthic areas in the vicinity of the proposed Port of Napier wharf and dredging project. The survey data covers a 12-year time period up to 2016, with a significant proportion collected in 2004-2005; however, as much as possible this has been checked against more recent data to verify its continued accuracy and relevance.

10.1. Loss or alteration of benthic habitat

The surveys of the Fairway, outer Swing Basin area and the proposed disposal area identified no taxa or communities of special scientific or conservation interest and these benthic habitats are not considered to be spatially limited in the wider area.

10.1.1. Capital dredge area

As with all capital dredging programmes, significant seabed disturbance will occur within the approximately 117 ha area of the dredging footprint, effectively representing the loss of all benthic biota and communities. This will include approximately 60 ha of previously undredged seabed.

While the recolonisation of the Fairway and Swing Basin with benthic fauna will begin at the completion of each dredging pass, this deepened area is likely to represent an altered physical habitat with finer substrate. Hence benthic communities may be kept in an intermediate successional stage by disturbance from shipping traffic and ongoing maintenance dredging. However, these communities will not be fundamentally different to those of surrounding benthic areas and many of the same taxa will be represented.

10.1.2. Disposal area

The proposed offshore disposal area for the project is comprised of a flat and uniform soft sediment substrate of fine and very fine silty sand in 20–23 m water depth. Benthic communities were observed to be dominated by deposit-feeding invertebrates and no significant biogenic structures were evident.

Due to the overall volume of spoil to be deposited over the 346 ha area, the complete loss of benthic communities via burial has been assumed. However, it is likely that many sediment-dwelling species will remain established in this area as dredge spoil loads are deposited incrementally over the course of the project. The site is described as being only mildly dispersive, but the existing benthic community is characteristic of a moderately dynamic sediment environment.

Analysis of deep core samples from within the dredging footprint has indicated that bulk spoil properties will be similar to the native sediments of the disposal area. Hence there should be little impediment to recolonisation and ecological recovery of the site. The key taxa are furthermore considered to be relatively tolerant of disturbance and such recovery is likely to be relatively rapid. Allowing for the difference in water depth, this is supported by the results of periodic benthic monitoring carried out at the Port's consented spoil grounds off Westshore Beach since 1996, which has identified no significant adverse ecological or other effects to benthic habitats.

10.2. Wider area effects

10.2.1. Contaminants

Elevated concentrations of contaminants and organic matter were not a feature of the Fairway sediments in samples collected in 2004. Recent additional sediment sampling, chemical and ecotoxicological analysis and spoil ground community structure all indicate that this remains the case. Hence contaminant effects from the dredging project are not anticipated.

10.2.2. Turbidity plumes

The scale of the capital dredging project and the anticipated volume of spoil produced mean that the production of turbidity plumes and their subsequent movement with ambient currents will be the principal stressor for the local marine environment beyond the areas of direct disturbance. While turbid conditions are common in the near-shore waters of Hawke Bay, there has been only limited historical quantitative data available with which to define the receiving environment in this regard. Continuous monitoring of surface turbidity presently being conducted at two locations near Pania Reef is expected to provide a better indication of background variability and potentially enable a useful correlation to be established between turbidity and suspended solids concentration (SSC).

The quantity of fine sediment material resuspended by the dredging and spoil disposal operation is likely to be much less than that delivered to Hawke Bay inshore waters by riverine inputs. Quantities resuspended near the shoreline by wave action are also considered to be substantial. Hydrodynamic modelling conducted by WorleyParsons Group has indicated that spoil disposal operations will generate more extensive suspended sediment plumes than dredging.

The location of the proposed offshore spoil ground to the south-east of Pania Reef benefits from ambient water currents that flow predominantly to the south, away from the Reef. Plume modelling outputs indicate there is only limited potential for dilute plumes from the project to impinge upon Pania Reef. This is the case even when wind conditions cause currents over the spoil ground to be directed to the north-west, a situation which may occur for approximately 10% of the time.

The plume modelling used conservative assumptions regarding particulate settling rates, dredging scenarios and weather and current conditions. Reasonable worst-case weather conditions from July 2016 were utilised in a simulation of two dredging campaigns involving simultaneous BHD and TSHD operations. Model outputs indicated that SSC over the Reef would be expected to reach the range of 2–5 mg/L above background for a period of approximately one day over the month.

Historical sampling data suggest that calm weather background concentrations on the order of 10 mg/L may be reasonably typical of Pania Reef waters. This level may be considerably exceeded during high swell or run-off events and remain elevated for several days. This suggests that, unless sustained for significantly longer than is predicted by the modelling outputs, project-related increases in SSC will not lead to adverse ecological effects at the Reef.

Other reef areas potentially affected by turbidity plumes from project components include Town Reef and the mixed boulder/cobble shoreline between the Port and Ahuriri Inlet. However, only the small western embayment adjacent to the Port was predicted by modelling to exceed 10 mg/L above background SSC over the one month simulation, and then only for a period of less than a day during Campaign 1. Due to their greater natural exposure to shoreline resuspension processes, these sites are less likely to experience turbidity and sedimentation significantly exceeding normal background ranges and are more likely to recover rapidly.

10.2.3. Habitat sensitivity and impact mechanisms

Shallow water soft sediment benthic habitats in the vicinity of the Port are subject to continual resuspension of fine bed sediments and the communities inhabiting this environment are adapted to these conditions. Except in the immediate vicinity of disturbance (tens to low hundreds of metres), it is unlikely that turbidity plumes from dredging or spoil disposal activities would exceed the inherent tolerance to suspended sediments of these communities.

The ecological survey of Pania Reef indicated that hard substrate benthic communities varied along gradients of depth, water motion and sedimentation. Community assemblages reflected the high-energy exposed setting of the Reef. However, direct observation, anecdotal evidence and available water-quality data indicate that these are generally adapted to cope with frequent periods of moderate to high turbidity.

The main mechanisms by which adverse impacts may occur from the impingement of turbidity plumes on reef areas are as follows:

- sedimentation/smothering of reef surfaces and encrusting/sessile biota
- light attenuation stresses on photosynthesising biota (especially macroalgae)
- interference of suspended and settled particulates with feeding modes (especially suspension/filter feeding biota).
- abrasive or scouring effects of suspended sediments with wave motion.

Of these mechanisms, sedimentation and light attenuation are the most likely to affect Pania Reef communities.

Sedimentation

Sedimentation is currently a highly visible condition of much of the Reef, with only the shallowest sections being effectively clear of silt films and accretion. However, the plume modelling predicted no additional project-related sedimentation on Pania Reef from the one month simulations. The status of most of the Reef with respect to accumulated sediments is considered to be controlled to a large extent by the frequency and severity of high-wave events and in this regard, the reef/hydrodynamics system is likely to represent a dynamic equilibrium. Hence a slight increase in sediment supply in the form of elevated SSC is unlikely to increase the thickness of deposited veneers on Reef surfaces except during atypical periods of very low wave energy.

Light attenuation

On reefs, a reduction in photosynthetically active radiation due to increased turbidity may affect structurally and trophically important seaweeds. On Pania Reef, the depth at which sponge gardens replace brown macrophytes (principally *Ecklonia*) as the predominant cover is less than at other reef locations with higher water clarity. Conversely, the depth limit for *Ecklonia* at more turbid coastal locations such as South Canterbury is significantly less again. It follows that this important habitat-forming species will respond to sustained changes in light regime. However, light attenuation is highly variable in most coastal regions and relatively long-lived species such as *Ecklonia* must be able to survive sustained and repeated low light episodes. Consequently, macroalgae at Pania Reef are expected to be generally resilient to the relatively small and temporary shifts in available light which may result from the project.

Filter feeders

It is considered that the most structurally important filter feeding organism on Pania Reef is the green-lipped mussel (*Perna canaliculus*), which can form very dense beds on the reef tops. The information available on this species indicates that it is very resilient to increases in suspended sediments, tolerating values of SSC substantially greater than will potentially occur during the proposed project.

10.2.4. Potential effects

Pania Reef

Where turbidity-associated parameters (such as light) are limiting for key taxa, changes in community structure will begin to occur if high turbidity levels are sustained beyond background variability. Considering that such changes already occur naturally with seasonal and inter-annual cycles, temporary perturbations beyond background variability are unlikely to result in lasting impacts unless they are substantial and sustained.

Potential shifts in community structure may be measureable with repeated reef surveys. Possible ecological shifts include the following:

- an increase in the prevalence of sediment-tolerant organisms
- a decrease in the cover and depth distribution of macroalgae
- changes in the prevalence of grazers.

However, based on the plume modelling, it is very unlikely that Pania Reef will experience project-related sediment plumes at concentrations which place reef communities under the acute level of stress that would be required to bring about such changes over project time-scales. Where ecological shifts are observed, it is also unlikely that strict causality could be established, outside of natural variability, unless turbidity measured at the Reef has substantially exceeded that currently predicted by plume modelling.

Other benthic habitats

Since fine material is a significant component of the bed sediments of inshore Hawke Bay, there is typically a persistent layer of highly turbid water just above the seabed. Benthic communities must consequently be well-adapted to sustained conditions of high suspended-sediment loadings, including the increased deposition rates which this engenders. This is consistent with the assemblages of epifauna and sediment-dwelling infauna identified from sampling, with all taxa considered highly tolerant of sustained high suspended sediment levels. While soft sediment communities immediately adjacent to dredging and spoil disposal activities may be impacted by very high levels of SSC, these zones will be spatially very limited in extent.

10.3. Construction of the new wharf

While the berth pocket and wharf structure represent a heavily modified environment and introduced substrates, they will be established at a site already modified by the Port reclamation structure. This modified habitat and the ongoing disturbance of associated operations represent only an incremental expansion of existing Port facilities. The construction of the berth occurs entirely within the footprint of capital dredging and encompasses activities for which marine environmental effects are expected to be highly localised[30]. With effective environmental management, effects to marine ecology in the wider area are expected to be minimal.

10.4. Fish and fisheries

Neither the area of proposed capital dredging nor the proposed offshore spoil disposal ground have been assessed as being benthic habitats that are spatially limited in the wider area and no features have been identified which indicate a particular importance as foraging areas for fisheries species.

Nor has the project area been identified as including specific areas involved in significant fish migration pathways. While the Ahuriri Estuary is frequented by several migratory species, the proposed dredging, spoil disposal and construction activities are not considered to represent a barrier to fish movement from this source. With the possible exception of Pania Reef, benthic habitats known or suspected to be important to particular fisheries species, or any of their life stages, do not occur within the area potentially affected by the proposed project.

The project area is within a zone where trawling by vessels larger than 13.5 m is prohibited. It is likely that species targeted within this zone are primarily flatfish and gurnard. Landed-catch data for the most recent three complete fishing years suggest that particular concentrations of fishing effort do not occur in areas potentially affected by the proposed project.

Based on inshore substrates and observed benthic turbidity in soft sediment areas, a degree of natural tolerance to resuspension events is expected in local fish populations, especially benthic species such as flatfish and gurnard.

Data from three benthic surveys conducted since 2004 have shown a level of consistency in the abundance and diversity of macroinvertebrate communities in areas both within and outside of the currently consented spoil grounds. This suggests that there has been no longer-term degradation of the food resource for benthic-foraging species in the area as a result of spoil disposal activities. While the greater spoil volume and spoil-ground water depth need to be considered, these factors are mitigated by the staged nature of the project and the predicted similarity between dredged material and existing sediments within the proposed disposal area.

While turbidity plumes with sediment concentrations high enough to be of concern to fish are not expected to extend more than a few hundred metres from the point of suspension, avoidance of these areas is likely to be the principle response of finfish species to increasing stress.

[30] Note that effects on marine mammals and marine avifauna are being covered by separate assessment reports.

The importance of reef areas in the Napier area to paua stocks is not clear. Although they have been known to occur in the area, none were recorded from Pania Reef, which may have limited habitat at suitable depths. There is evidence that adult paua may be somewhat resilient to sediment deposition events. While the larvae may be more sensitive to sedimentation (which may limit recruitment success if heavy), it is noted that healthy populations occur in more turbid environments than Napier.

Pania Reef appears to represent a locally productive recreational and customary fishery for spiny lobster; however, its status as a Mataitai reserve means all commercial fishing is prohibited. From a review of lobster life history, it is considered that direct effects of dilute turbid plumes on adult individuals are likely to be minimal and that recruitment of perulus larvae will be similarly unaffected.

While it is understood that a limited fishery for paddle crabs exists in the Napier area, including offshore from Westshore Beach, this species is known to occur in areas prone to very high wave resuspension of sediments. There is nothing in its known life history or habitat preferences that suggests a particular sensitivity to increases in turbidity.

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12. APPENDICES

Appendix 1. Location and depth data for benthic sample stations and other survey components.

NB: Benthic sampling stations used for the monitoring of the existing (maintenance dredge) spoil grounds (R extended, Ia and Cia) off Westshore Beach are randomised for each monitoring round. Readers are directed to individual monitoring reports for these locations. Mapped points in Figure 16 are derived from the 2004 monitoring round (Sneddon & Keeley 2005).

Table A1.1. Position coordinates and water depths for benthic stations in the vicinity of the Port of Napier and approaches.

Station	Date sampled	NZ Map Grid coordinates NZMG E	NZMG N	Depth (MSL)
CD1	25/11/2004	2846061	6185015	6.0
CD2	25/11/2004	2846136	6185185	8.0
CD3	25/11/2004	2846160	6185359	8.4
CD4	25/11/2004	2846287	6185420	10.3
CD5	25/11/2004	2846216	6185599	10.2
CD6	25/11/2004	2846343	6185764	11.6
CD7	25/11/2004	2846527	6185774	13.1
CD8	25/11/2004	2846480	6185378	13.3
CD9	25/11/2004	2846692	6185364	12.1
CD10	25/11/2004	2846546	6185543	13.2
CD11	25/11/2004	2846381	6185557	12.3
CD12	25/11/2004	2846419	6186005	12.8
CD13	25/11/2004	2846607	6185981	12.9
CD14	25/11/2004	2846824	6186094	13.2
CD15	25/11/2004	2846617	6186169	13.1
CD16	25/11/2004	2846456	6186155	13.0
CD17	7/12/2004	2846527	6186405	12.9
CD18	7/12/2004	2846763	6186259	13.2
CD19	7/12/2004	2846668	6186735	13.2
CD20	7/12/2004	2846739	6186513	13.0
CD21	7/12/2004	2846956	6186499	13.5
CD22	7/12/2004	2846932	6186292	13.2
CD23	29/04/2016	2846508	6186579	14.4
CD24	29/04/2016	2846786	6186952	14.5
CD25	29/04/2016	2847017	6187304	15.0
CD26	29/04/2016	2847339	6187659	15.6
R1	26/11/2004	2846269	6185137	9.1
R2	26/11/2004	2846211	6185019	7.1
R3	26/11/2004	2846326	6185063	8.0
R4	26/11/2004	2846459	6185058	8.2
R5	26/11/2004	2846551	6184972	6.0
R6	26/11/2004	2846382	6184949	6.4
R7	26/11/2004	2846266	6184903	6.1

Table A1.1. continued

Station	Date sampled	NZ Map Grid coordinates NZMG E	NZMG N	Depth (MSL)
R8	26/11/2004	2846174	6184862	5.4
R9	26/11/2004	2846280	6184781	4.7
R10	26/11/2004	2846143	6184737	3.8
R11	26/11/2004	2846202	6184631	1.6
R12	26/11/2004	2846301	6184674	3.2
B1	24/11/2004	2847359	6185647	10.4
B2	24/11/2004	2847229	6185723	10.5
B3	24/11/2004	2847217	6185612	9.5
B4	24/11/2004	2847072	6185524	8.6
B5	24/11/2004	2847075	6185689	9.9
B6	24/11/2004	2847052	6185827	11.4
B7	24/11/2004	2846922	6185934	12.4
B8	24/11/2004	2846922	6185627	9.5
B9	24/11/2004	2846899	6185443	7.4
B10	24/11/2004	2846765	6185501	8.4
B11	24/11/2004	2846734	6185689	10.6
B12	24/11/2004	2846880	6185792	10.7
B13	7/12/2004	2847149	6186146	13.4
B14	7/12/2004	2847361	6186019	13.6

Table A1.2. Position coordinates (finish point) and water depths for research dredge trawls conducted in the vicinity of the Port of Napier and approaches.

Trawl	Date	NZ Map Grid coordinates NZMG E	NZMG N	Depth (MSL)
CDT1	29/11/2004	2846872	6186362	13.5
CDT2	29/11/2004	2846484	6185857	12.5
CDT3	29/11/2004	2846375	6185461	12.7
CDT4	29/11/2004	2846133	6185183	8.5
CDT5	29/11/2004	2846926	6185713	-
CDT6	29/11/2004	2846763	6185485	7.7
CDT7	30/04/2016	2846700	6186900	12.9
CDT8	30/04/2016	2847300	6187500	14.3
CDT9	30/04/2016	2848100	6187400	15.7
CDT10	30/04/2016	2847500	6186700	13.9

Table A1.3. Position coordinates and water depths for benthic sample stations and research dredge trawls (finish point) for the area (CS) between the spoil grounds off Westshore Beach.

Station	Date	NZ Map Grid coordinates NZMG E	NZMG E	Depth (MSL)
CS1	24/11/2004	2844515	6187169	10.8
CS2	24/11/2004	2844878	6187197	10.8
CS3	24/11/2004	2844779	6186952	11.0
CS4	24/11/2004	2844991	6187428	11.4
CS5	24/11/2004	2845099	6187239	11.3
CS6	24/11/2004	2844350	6186961	9.9
CS7	24/11/2004	2844128	6186839	8.5
CS8	24/11/2004	2844340	6186603	8.2
CS9	24/11/2004	2844543	6186829	9.7
CS10	24/11/2004	2844614	6186523	8.8
CS11	24/11/2004	2844939	6186509	9.7
CS12	24/11/2004	2844760	6186660	9.8
CS13	24/11/2004	2844783	6186325	8.4
CS14	24/11/2004	2844986	6186923	11.2
CS15	24/11/2004	2845076	6186678	10.8
CS16	24/11/2004	2845269	6186839	11.4
CS17	24/11/2004	2845189	6187041	11.6
CS18	24/11/2004	2845344	6186622	11.1
CS19	24/11/2004	2845222	6186528	11.2
CS20	24/11/2004	2845415	6186415	11.3
CS21	24/11/2004	2845137	6186400	9.8
CS22	24/11/2004	2845292	6186207	9.1
CS23	24/11/2004	2845010	6186207	8.8
CS24	24/11/2004	2845184	6186052	8.4
Trawl		**Finish point**		
TCS1F	29/11/2004	2844365	6186512	8.0
TCS2F	29/11/2004	2845078	6186105	8.6
TCS3F	29/11/2004	2845132	6186527	10.1
TCS4F	29/11/2004	2844651	6186881	10.2
TCS5F	29/11/2004	2845052	6186990	11.1
TCS6F	29/11/2004	2845342	6186638	10.4
TCS7F	29/11/2004	2844961	6187173	11.3

Table A1.4. Position coordinates for transects dived on Pania Reef (refer Figure 27).

Transect	Point	NZ Map Grid coordinates NZMG E	NZMG E
PR1	Start	6188499	2849751
	Reef	6188421	2849795
PR2	Start	6187946	2849548
	Reef	6188024	2849510
PR3	Start	6187361	2848770
	Reef	6187305	2848810
PR4	Start	6186817	2848194
	Reef	6186734	2848250
PR5	Start	6187485	2849074
	Reef	6187468	2849024
PR6	Start	6186930	2848472
	Reef	6187022	2848464
PR7	Start	6186541	2847820
	Reef	6186514	2847912
PR8	Start	6186316	2847583
	Reef	6186270	2847661

Table A1.5. Details of the two sampling sites used to collect background suspended solids data. These positions are represented in Figure 40.

Sample station	Position coordinates NZMG E	NZMG N	Depth* (m)	Description
P1	2847636	6186213	10	Preferred channel marker [Fl.(2+1)G.10s]
P3	2850774	6189595	20	Pania Reef north cardinal marker [Q]

* At chart datum

Appendix 2. Compiled notes on paua and lobster biology, life cycle and distribution.

Paua (*Haliotis iris*)

Paua can refer to three New Zealand species but the main species harvested commercially and recreationally is *Haliotis* iris. They are herbivores, feeding to a large extent upon drift algae, and can form large aggregations on reefs in shallow subtidal coastal habitats. Their range of movement is over a sufficiently small spatial scale that they may be considered effectively sedentary. Paua are broadcast spawners and spawning is thought to be annual (late summer-autumn). Paua larval dispersal longevity is relatively short, with the non-feeding veliger larvae settling after between three to ten days. This means that the larval population can undergo only limited dispersal from the spawning adult population (Freeman 2006).

Newly settled larval paua live in reduced flow environments, mostly on crustose coralline algae habitats, where they can attach and grow. Once they become juveniles (40 to 45 mm in shell length) they move to and live in cryptic habitats, such as beneath rocks and boulders, until they are between 60 to 70 mm in shell length (3-5 years old) and have reached sexual maturity. They then prefer relatively exposed situations and are found generally in water depths less than 5 m, but up to 10 m (Freeman 2006). Hence habitat-related factors are an important source of variation in the post-settlement survival of paua. Growth, morphometrics, and recruitment can vary over short distances and may be influenced by factors such as wave exposure, habitat structure, availability of food and population density. The NABIS lineage document for *H. iris* notes that paua are most common in clear water coastal situations, living from low water to 15 m.

Rock lobster (*Jasus edwardsii*)

Mating in *J. edwardsii* takes place after moulting in autumn. After the eggs hatch in spring, a long (1-2 years) pelagic larval phase begins wherein the larvae pass through three pre-settlement stages; the short-lived naupliosoma, a phyllosoma larval stage of at least 12 months and the final phyllosoma stage. The phyllosoma larvae metamorphose into the puerulus which settles on reef substrates mainly at depths less than 20 m. Settlement indices measured on collectors can fluctuate widely from year to year (MPI 2012).

Adult lobsters have a strong site association. Foraging occurs at night and is typically spatially limited although foraging distances on rocky reefs have been observed to increase with body size. In some places, at certain times of the year, larger males may migrate offshore across sand flats to feed on shellfish. Egg-brooding females are more active toward the end of the 3.5 month brooding season around September and October and may also form offshore aggregations in areas of high water current in spring at the time of larval hatching (MacDiarmid et al*.* 2013). Additionally, long distance mass migration of juvenile or sub-adult red rock lobsters is well documented around the southern coasts of the South Island although the numbers moving varies from year to year (Booth 1997).

It is not known if such migrations are a feature of the Hawke Bay area. In tagging studies, Freeman et al*.* (2009) found that lobster movement patterns were sex- and size-dependent, but nearly all recaptured individuals were found on the same rocky reef on which they were tagged, indicating that lobsters were reluctant to cross muddy sediments between reefs.

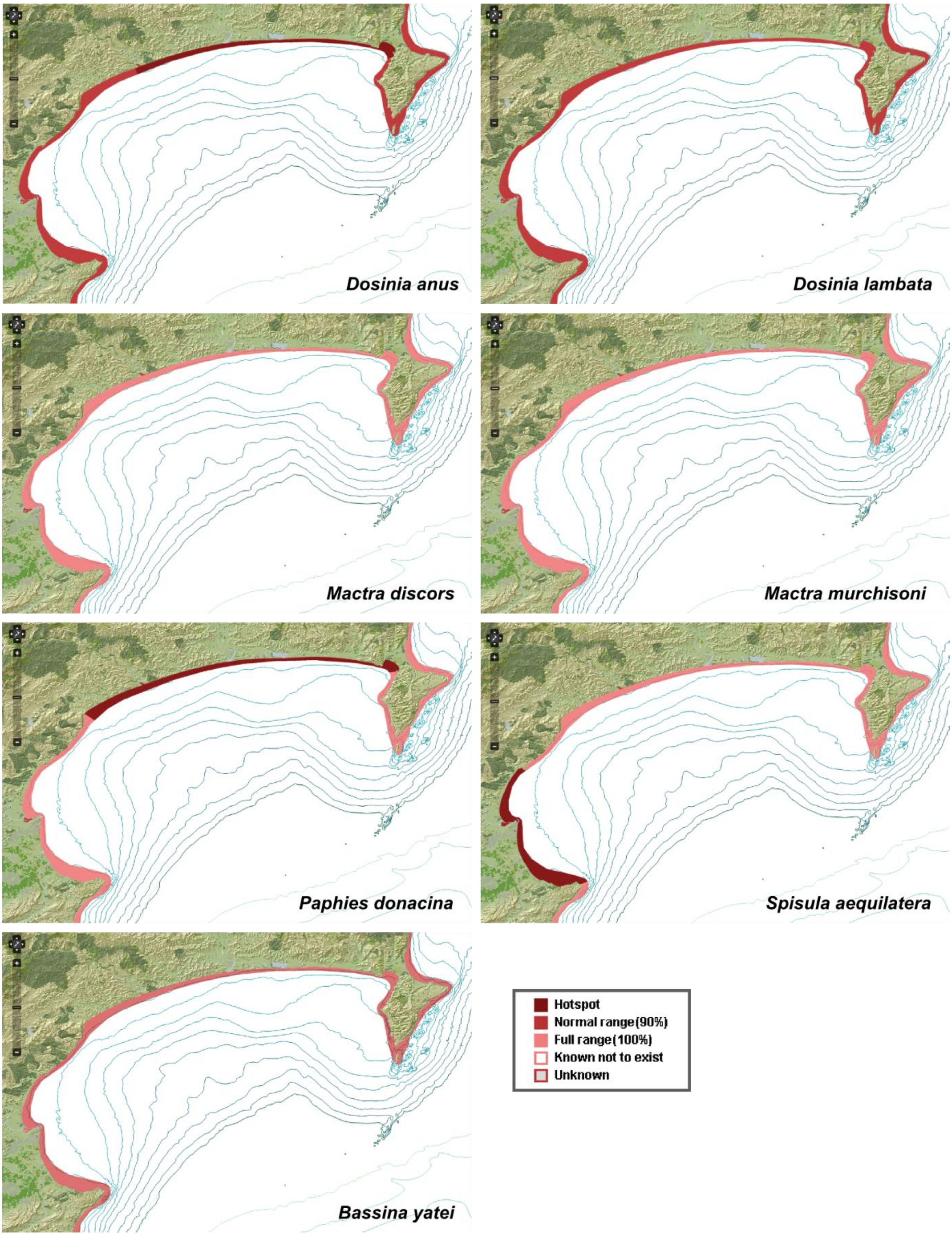
A long pelagic phase allows lobster larvae to be carried hundreds or thousands of kilometres by oceanic currents. However, in some situations large offshore eddies may maintain the larvae close to their source populations. Hence populations may have varying degrees of connectivity based on larval dispersion patterns. This connectivity was explored by Chiswell & Booth (2008) using ocean current data to numerically model larval tracks for different source locations and evaluate statistically where such larvae were likely to settle (i.e. larval sinks), as well as assigning the likely origins (sources) of existing populations.

Freeman et al. (2012) noted that because the long larval lifespan of this and many other marine species results in larvae potentially settling thousands of kilometres from their source, recruitment and adult abundance are consequently decoupled. MPI (2012) reported that there is no evidence for genetic subdivision of lobster stocks within New Zealand based on biochemical genetic and mtDNA studies. It was further noted that the observed long-distance migrations in some areas and the long larval life probably result in genetic homogeneity among areas.

Rock lobster are taken by potting on or near rocky shores or rocky reefs and seabed from the shallows and out to at least 100 m depth if the substrate remains suitable. The fishery is highly seasonal, with the main catches taken in the winter months of July and August. Catch data for *J. edwardsii* are available only on a fishing statistical area basis, and as so few fishermen are involved in this commercial fishery the data cannot be partitioned on a smaller spatial scale. Relatively low landed catch weights for lobster than for many finfish species are balanced by much higher market value per kilogram.

The Catch Effort and Landing return (CELR) data for spiny lobster show that it is most abundant in the southeast of the North Island, northeast of the South Island, in Fiordland and western Foveaux Strait, around Stewart Island, and at the Chatham Islands (NABIS lineage for *J. edwardsii*).

Appendix 3. Distribution of seven surf clam species in Hawke Bay ([http://www.nabis.govt.nz/:](http://www.nabis.govt.nz/) accessed November 2016).



Appendix 4. Analysis reports for Low Angle Laser Light Scattering (LALLS) tests (in triplicate) on the sample of stiff silt provided by PONL in 2007.

MALVERN INSTRUMENTS

MASTERSIZER 2000

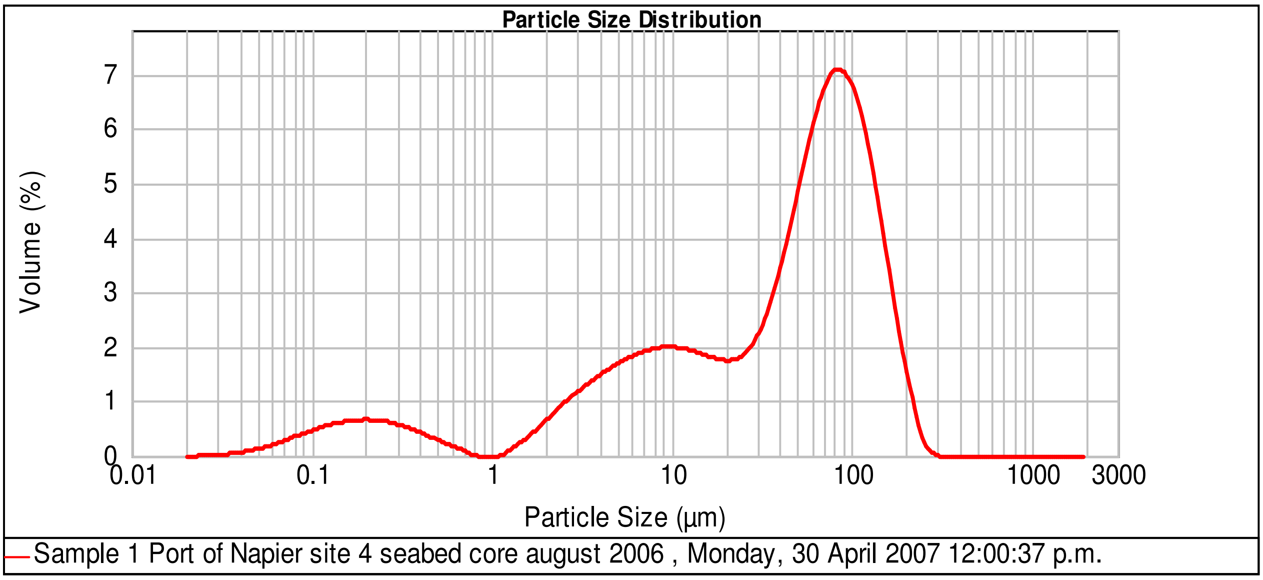
Result Analysis Report

Sample Name:	SOP Name:	Measured:
Sample 1 Port of Napier site 4 seabed	Marine Sediment	Monday, 30 April 2007 12:00:37 p.m.
Sample Source & type:	**Measured by:**	**Analysed:**
	jacinta	Monday, 30 April 2007 12:00:38 p.m.
Sample bulk lot ref:	**Result Source:**	
	Measurement	

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	Hydro 2000G (A)	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	12.17 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	0.415 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.0233 %Vol	2.578	0.844	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
3.66 m²/g	1.640 um	59.105 um	

d(0.1): 2.449 um **d(0.5): 50.764 um** **d(0.9): 133.320 um**



Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %	Size (μm)	Volume In %
0.050	0.18	0.980	1.10	37.000	3.95	105.000	6.98	300.000	0.00	840.000	0.00
0.060	1.72	2.000	4.71	44.000	5.57	125.000	5.53	350.000	0.00	1000.000	0.00
0.120	2.88	3.900	7.93	53.000	6.47	149.000	3.70	420.000	0.00	2000.000	
0.240	2.37	7.800	8.86	63.000	6.94	177.000	2.08	500.000	0.00		
0.490	0.46	15.600	8.37	74.000	7.99	210.000	0.80	590.000	0.00		
0.700	0.04	31.000	3.05	88.000	7.98	250.000	0.12	710.000	0.00		
0.980		37.000		105.000		300.000		840.000			

Operator notes:

MALVERN INSTRUMENTS

MASTERSIZER 2000

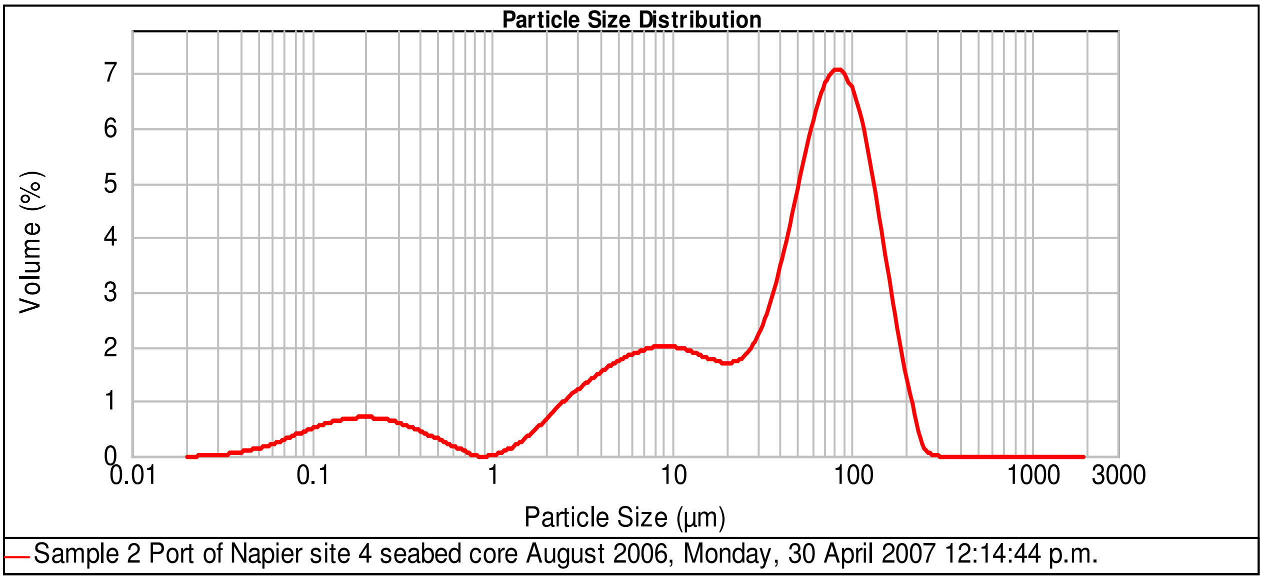
Result Analysis Report

Sample Name: Sample 2 Port of Napier site 4 seabed	**SOP Name:** Marine Sediment	**Measured:** Monday, 30 April 2007 12:14:44 p.m.
Sample Source & type:	**Measured by:** jacinta	**Analysed:** Monday, 30 April 2007 12:14:45 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 12.81 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.363 %	**Result Emulation:** Off

Concentration: 0.0239 %Vol	**Span :** 2.593	**Uniformity:** 0.851	**Result units:** Volume
Specific Surface Area: 3.89 m²/g	**Surface Weighted Mean D[3,2]:** 1.544 um	**Vol. Weighted Mean D[4,3]:** 57.702 um	

d(0.1): 2.187 um **d(0.5): 49.577 um** **d(0.9): 130.726 um**



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0.050	0.20	0.980	1.21	37.000	3.98	105.000	6.85	300.000	0.00	840.000	0.00
0.060	1.84	2.000	4.85	44.000	5.64	125.000	5.36	350.000	0.00	1000.000	0.00
0.120	3.06	3.900	8.09	53.000	6.54	149.000	3.52	420.000	0.00	2000.000	
0.240	2.51	7.800	8.83	63.000	6.99	177.000	1.92	500.000	0.00		
0.490	0.48	15.600	8.18	74.000	7.99	210.000	0.67	590.000	0.00		
0.700	0.04	31.000	3.05	88.000	7.92	250.000	0.06	710.000	0.00		
0.980		37.000		105.000		300.000		840.000			

Operator notes:

MASTERSIZER 2000

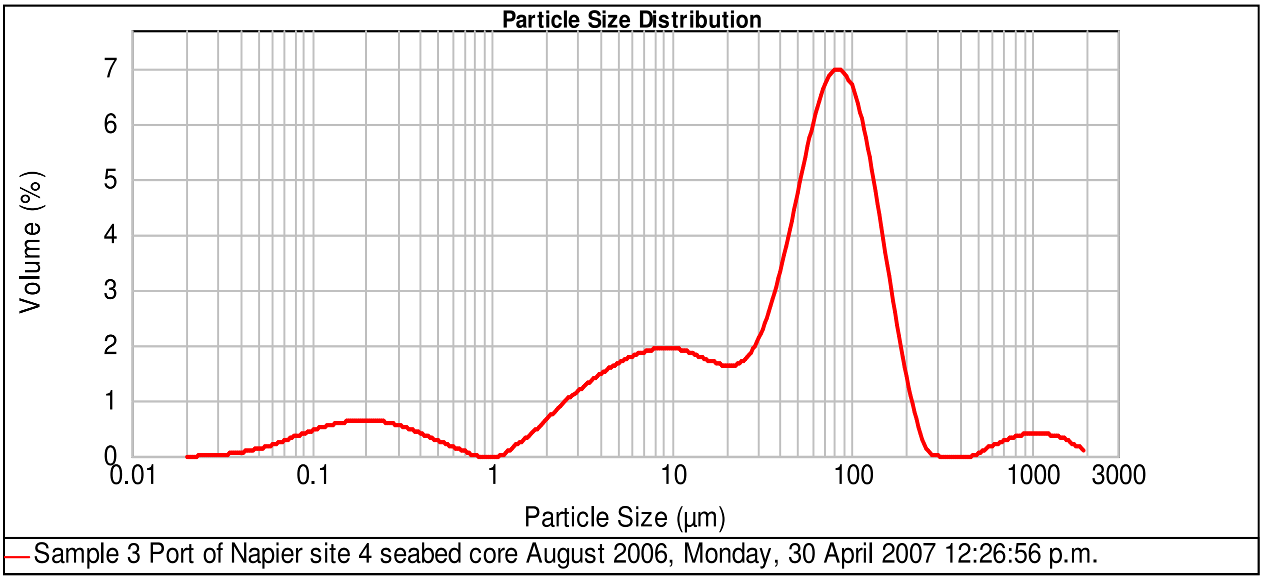
Result Analysis Report

Sample Name: Sample 3 Port of Napier site 4 seabed	**SOP Name:** Marine Sediment	**Measured:** Monday, 30 April 2007 12:26:56 p.m.
Sample Source & type:	**Measured by:** jacinta	**Analysed:** Monday, 30 April 2007 12:26:57 p.m.
Sample bulk lot ref:	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 11.63 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.363 %	**Result Emulation:** Off

Concentration: 0.0226 %Vol	**Span :** 2.643	**Uniformity:** 1.29	**Result units:** Volume
Specific Surface Area: 3.58 m²/g	**Surface Weighted Mean D[3,2]:** 1.678 um	**Vol. Weighted Mean D[4,3]:** 85.739 um	

d(0.1): 2.540 um **d(0.5): 53.087 um** **d(0.9): 142.873 um**



Size (µm)	Volume In %
0.050	0.18
0.060	1.68
0.120	2.81
0.240	2.29
0.490	0.43
0.700	0.03
0.980	

Size (µm)	Volume In %
0.980	1.10
2.000	4.69
3.900	7.84
7.800	8.59
15.600	7.85
31.000	2.92
37.000	

Size (µm)	Volume In %
37.000	3.84
44.000	5.48
53.000	6.40
63.000	6.87
74.000	7.89
88.000	7.85
105.000	

Size (µm)	Volume In %
105.000	6.81
125.000	5.35
149.000	3.53
177.000	1.94
210.000	0.74
250.000	0.06
300.000	

Size (µm)	Volume In %
300.000	0.00
350.000	0.00
420.000	0.00
500.000	0.10
590.000	0.28
710.000	0.37
840.000	

Size (µm)	Volume In %
840.000	0.45
1000.000	1.41
2000.000	

Operator notes:

Appendix 5. Additional sediment chemical data.

Table A5.1. Results of analyses for semivolatile organic compounds (SVOCs) and organotin compounds in sediments from the capital dredge area (refer Figure 9). All values are as mg/kg dry wt (organotins as mg Sn/kg).

Laboratory note: The apparent difference in detection limits between samples from CD2 and CD6 and samples from CD8 and CD13 relates to a difference in the dry-matter (or moisture) content of the samples as-supplied to the lab since analysis is performed on equal quantities of samples as-received.

	Benthic Station			
Analyte	**CD2**	**CD6**	**CD8**	**CD13**
Semi-volatile organic compounds				
Bis(2-chloroethyl)ether	< 0.06	< 0.06	< 0.08	< 0.08
1,3-Dichlorobenzene	< 0.06	< 0.06	< 0.08	< 0.08
1,4-Dichlorobenzene	< 0.06	< 0.06	< 0.08	< 0.08
1,2-Dichlorobenzene	< 0.06	< 0.06	< 0.08	< 0.08
Bis(2-chloroisopropyl)ether	< 0.06	< 0.06	< 0.08	< 0.08
N-nitrosodi-n-propyl amine	< 0.06	< 0.06	< 0.08	< 0.08
Hexachloroethane	< 0.06	< 0.06	< 0.08	< 0.08
Nitrobenzene	< 0.06	< 0.06	< 0.08	< 0.08
Isophorone	< 0.06	< 0.06	< 0.08	< 0.08
Bis(2-chloroethoxy)methane	< 0.06	< 0.06	< 0.08	< 0.08
1,2,4-Trichlorobenzene	< 0.06	< 0.06	< 0.08	< 0.08
Naphthalene	< 0.06	< 0.06	< 0.08	< 0.08
Hexachlorobutadiene	< 0.06	< 0.06	< 0.08	< 0.08
2-Methylnaphthalene	< 0.03	< 0.03	< 0.04	< 0.04
2-Chloronaphthalene	< 0.03	< 0.03	< 0.04	< 0.04
Acenaphthylene	< 0.03	< 0.03	< 0.04	< 0.04
2,6-Dinitrotoluene	< 0.1	< 0.1	< 0.2	< 0.2
Acenaphthene	< 0.03	< 0.03	< 0.04	< 0.04
Dibenzofuran	< 0.06	< 0.06	< 0.08	< 0.08
2,4-Dinitrotoluene	< 0.1	< 0.1	< 0.2	< 0.2
Fluorene	< 0.03	< 0.03	< 0.04	< 0.04
4-Chlorophenylphenylether	< 0.06	< 0.06	< 0.08	< 0.08
N-Nitrosodiphenylamine	< 0.06	< 0.06	< 0.08	< 0.08
Hexachlorobenzene	< 0.06	< 0.06	< 0.08	< 0.08
Phenanthrene	< 0.03	< 0.03	< 0.04	< 0.04
Anthracene	< 0.03	< 0.03	< 0.04	< 0.04
Carbazole	< 0.06	< 0.06	< 0.08	< 0.08
Fluoranthene	< 0.03	< 0.03	< 0.04	< 0.04
Benzo[a]pyrene	< 0.03	< 0.03	< 0.04	< 0.04
Pyrene	< 0.03	< 0.03	< 0.04	< 0.04
Benzo[a]anthracene	< 0.03	< 0.03	< 0.04	< 0.04
Chrysene	< 0.03	< 0.03	< 0.04	< 0.04
Benzo[b]fluoranthene	< 0.03	< 0.03	< 0.04	< 0.04
Benzo[k]fluoranthene	< 0.03	< 0.03	< 0.04	< 0.04
Indeno(1,2,3-c,d)pyrene	< 0.03	< 0.03	< 0.04	< 0.04
Dibenzo[a,h]anthracene	< 0.03	< 0.03	< 0.04	< 0.04
Benzo[g,h,i]perylene	< 0.03	< 0.03	< 0.04	< 0.04
3,3'-Dichlorobenzidine	< 0.3	< 0.3	< 0.4	< 0.4
Dimethylphthalate	< 0.1	< 0.1	< 0.2	< 0.2

Table A5.1, continued

	Benthic Station			
Analyte	**CD2**	**CD6**	**CD8**	**CD13**
Diethylphthalate	< 0.1	< 0.1	< 0.2	< 0.2
Di-n-butylphthalate	< 0.1	< 0.1	< 0.2	< 0.2
Bis(2-ethylhexyl)phthalate	< 0.3	< 0.3	< 0.4	< 0.4
Di-n-octylphthalate	< 0.1	< 0.1	< 0.2	< 0.2
Butylbenzylphthalate	< 0.1	< 0.1	< 0.2	< 0.2
Di-(2-ethylhexyl)adipate	< 0.1	< 0.1	< 0.2	< 0.2
Alpha BHC	< 0.06	< 0.06	< 0.08	< 0.08
Beta BHC	< 0.06	< 0.06	< 0.08	< 0.08
Gamma BHC (Lindane)	< 0.06	< 0.06	< 0.08	< 0.08
Delta BHC	< 0.06	< 0.06	< 0.08	< 0.08
Heptachlor	< 0.06	< 0.06	< 0.08	< 0.08
Aldrin	< 0.06	< 0.06	< 0.08	< 0.08
Heptachlor epoxide	< 0.06	< 0.06	< 0.08	< 0.08
Endosulfan I	< 0.1	< 0.1	< 0.2	< 0.2
4,4'-DDE	< 0.06	< 0.06	< 0.08	< 0.08
Dieldrin	< 0.06	< 0.06	< 0.08	< 0.08
Endrin	< 0.06	< 0.06	< 0.08	< 0.08
Endrin Aldehyde	< 0.1	< 0.1	< 0.2	< 0.2
Endosulfan II	< 0.1	< 0.1	< 0.2	< 0.2
4,4'-DDD	< 0.06	< 0.06	< 0.08	< 0.08
Endosulfan sulphate	< 0.1	< 0.1	< 0.2	< 0.2
4,4'-DDT	< 0.1	< 0.1	< 0.2	< 0.2
Phenol	< 0.1	< 0.1	< 0.2	< 0.2
2-Chlorophenol	< 0.1	< 0.1	< 0.2	< 0.2
2-Methylphenol (o-cresol)	< 0.1	< 0.1	< 0.2	< 0.2
3 & 4-Methylphenol (m- + p-cresol)	< 0.1	< 0.1	< 0.2	< 0.2
2-Nitrophenol	< 0.1	< 0.1	< 0.2	< 0.2
2,4-Dimethylphenol	< 0.1	< 0.1	< 0.2	< 0.2
2,4-Dichlorophenol	< 0.1	< 0.1	< 0.2	< 0.2
4-Chloro-3-methylphenol	< 0.1	< 0.1	< 0.2	< 0.2
2,4,6-Trichlorophenol	< 0.1	< 0.1	< 0.2	< 0.2
2,4,5-Trichlorophenol	< 0.1	< 0.1	< 0.2	< 0.2
Organotin compounds				
Monobutyltin	< 0.002	< 0.002	< 0.002	< 0.002
Dibutyltin	< 0.002	< 0.002	< 0.002	< 0.002
Tributyltin	< 0.001	< 0.001	< 0.001	< 0.001
Triphenyltin	< 0.001	< 0.001	< 0.001	< 0.001

Appendix 6. Benthic epibiota associated with mixed substrate habitats in the vicinity of the Port.

Table A6.1. Summary of incidence and relative abundance of conspicuous intertidal and subtidal epibiota in near-shore subtidal and intertidal mixed substrate habitats (refer habitat map in Figure 23). Relative abundance code: A = abundant; C = common; O = occasional; R = rare.

Taxa	Common name	Sandy subtidal	Patchy rocky subtidal	Natural rocky subtidal	Artificial rocky sustidal	Rocky intertidal
FLORA						
Chlorophyta	**Green algae**					
Ulva sp.	Sea lettuce	O	A	A	O	A
Codium fragile	Velvet weed		O	C	O	C
Codium adhaerens	Rock velvet			O		A
Phaeophyta	**Brown algae**					
Sargassum sinclairii	Sargassum weed		O	A		
Lessonia variegata				O		
Cystophora sp.				C		O
Ecklonia radiata	Kelp		O	C	O	
Carpophyllum maschalocarpum	Flapjack		O	C	C	O
Carpophyllum plumosum				C		C
Undaria pinnatifida			O	O	O	
Halopteris novaezelandiae			R			
Rhodophyta	**Red algae**					
Lithophyllum / Lithothamnion sp.	Coralline paint		A	A	A	A
Corallina sp.	Coralline turf		C	A	A	A
Pterocladia sp.	Comb weed			O		C
Zonaria turneriana			O	A		O
Dictyota sp.						O
Rhodymenia dichotoma			C	C	O	C
Rhodymenia sp.		O	O	C		
Gigartina sp.			C	C		O
FAUNA						
Cirripedia	**Barnacles**					
Epopella plicata	Surf barnacle					A
Chamaesipho columna	Columnar barnacle					A
Austrominius modestus	Estuarine barnacle		C	C	A	A
Actiniaria	**Sea anemones**					
Isactinia olivacea	Olive anemone					C
Phlyctenactis tuberculosa	Wandering anemone					R
Ascidiacea	**Sea squirts**					
Corella eumyota	Transparent sea squirt					O
Botrylloides spp.				O		
Pyura sp				O	O	
Cnemidocarpa sp.			O	C	O	
Bryozoans						
Colonial - Unid.				O		
Porifera						
Tethya ingalli	Purple golf ball sponge		C	C		
Polychaeta	**Segmented worms**					
Pomatoceros caeruleus	Spiny tube worm					A

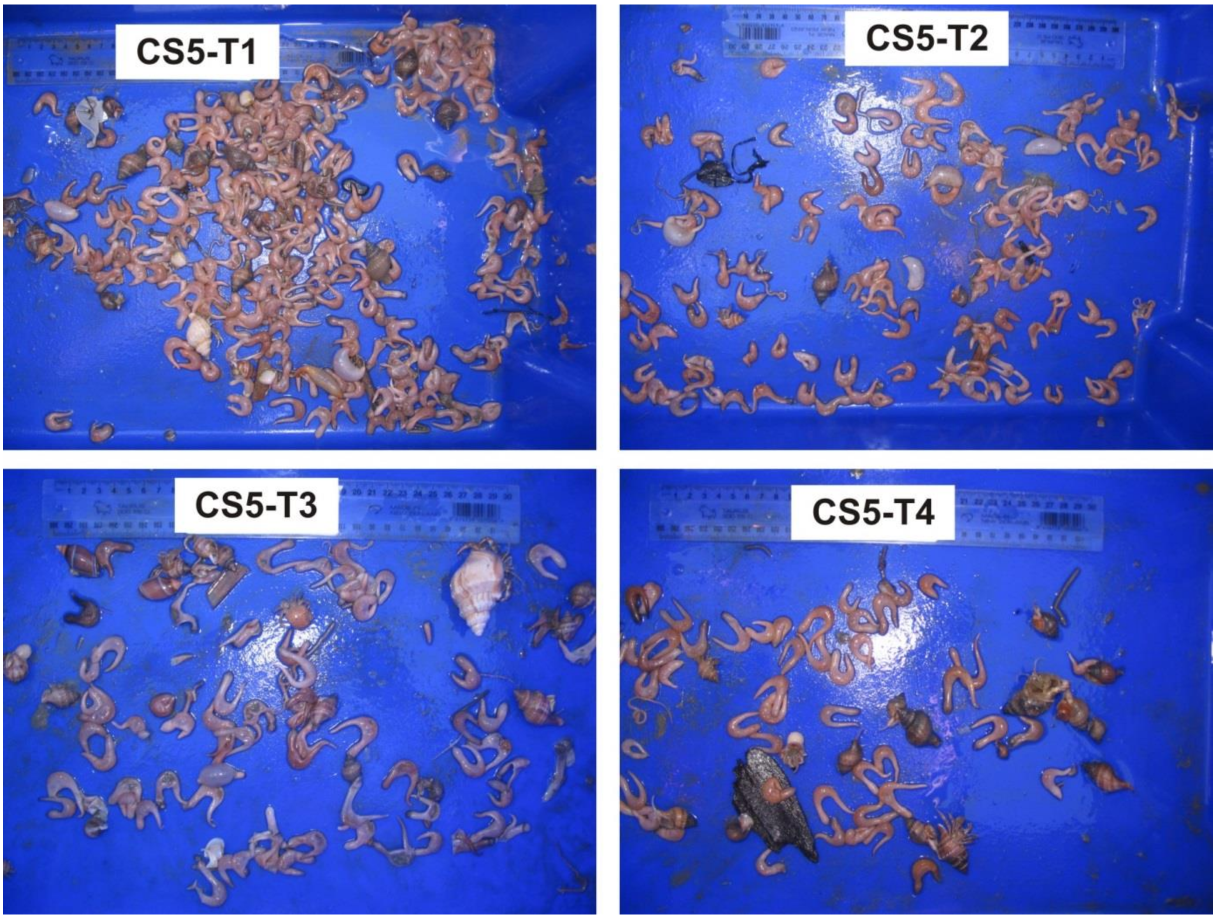
Table A6.1, continued

Taxa	Common name	Sandy subtidal	Patchy rocky subtidal	Natural rocky subtidal	Artificial rocky subtidal	Rocky intertidal
FAUNA, Polychaeta, cont.	**Segmented worms**					
Sabellidae				O	O	
Nereidae						O
Spirorbis sp.	Spiral worm		O	C		
Flabelligera affinus						C
Echinodermata						C
Australostichopus mollis	Sea cucumber	C	O			
Patiriella regularis	Cushion star	C	A	C	C	C
Fellaster zelandica	Sand dollar	C	O			
Coscinasterias calamaria	Eleven-armed star			O	O	O
Echinocardium cordatum	Heart urchin	C				
Decapoda	**Crabs, shrimps, crayfish**					
Paguridae	Hermit crabs	O	C	C	O	C
Palaemon affinis	Common shrimp					C
Petrolisthes elongatus	Half crab					A
Hemigrapsus edwardsi	Common rock crab					O
Ozius truncatus	Black finger crab					Shells
Helice crassa	Tunneling mud crab					O
Plagusia chabrus	Red rock crab			O	O	
Eurynolambrus australis	Triangle crab					O
Jasus edwardsii	Crayfish		O	O		
Bivalvia	**Clams, mussels**					
Aulacomya maorianus	Ribbed mussel					O
Zelithophaga truncata	Rock borer clam					Shells
Perna canaliculus	Green-lipped mussel			R	O	
Dosinula zelandica				O		
Dosinia subrosea		O				
Atrina zelandica	Horse mussel	O				
Gastropoda	**Whelks, limpets, paua**					
Haliotis iris	Paua					Shells
Zeacumantus sp.	Horn shell					C
Nerita atramentosa	Black nerita					O
Diloma arida	Dark top shell					A
Haustrum haustorium	Dark rock shell					C
Dicathais orbita	White rock shell				O	C
Lepsiella scobina	Oyster borer					A
Turbo smaragdus	Cat's eye snail, Ataata			C	O	C
Atalacmea fragilis	Fragile limpet					C
Austrolittorina sp.	Periwinkle					A
Cellana ornata	Limpet, Ngakihi				C	O
Cominella maculosa	Speckled whelk	O	O	O	O	R
Scutus breviculus	Shield shell					O
Patelloida corticata						C
Buccinulum lineum	Lined whelk			O	O	
Maoricolpus roseus	Turret shell	C				
Polyplacophora	**Chiton**					
Eudoxochiton nobilis	Noble chiton			O	O	C
Sypharochiton pelliserpentis	Snakeskin chiton				O	C

Table A6.1, continued

Taxa	Common name	Sandy subtidal	Patchy rocky subtidal	Natural rocky subtidal	Artificial rocky subtidal	Rocky intertidal
Polyplacophora, cont.	**Chiton**					
Cryptoconchus porosus	Butterfly chiton					C
Acanthochitona violacea						C
Cephalopoda	**Octopus, squid**					
Pinnoctopus cordiformis	Common octopus			R		R
Fish	**Fish**					
Forsterygion sp.	Common triplefin		C	C	A	
Forsterygion varium	Variable triplefin		O	C	C	
Caesioperca lepidoptera	Butterfly perch			O		
Arripis trutta	Kahawai			O		
Aplocdactylus arctidens	Marblefish			O		
Scorpis lineolata	Sweep			C	O	
Notolabrus celidotus	Spotty		O	C	C	
Cheilodactylus spectabilis	Red moki		O	O		

Appendix 7. Benthic epifauna collected in the four dredge trawls conducted within the area of the proposed offshore spoil ground in 2005.



Appendix 8. Record of dredging and spoil disposal to sites Ia and R extended for Port of Napier and approaches since 1995.

Year	Dredge	Period	Spoil volume (m^3)		Dredging area and notes
			Ia	R ext.	
1996	Kotuku Kimihia	Jun95-Aug96	69,100		No.1 berth; hard 23,200 soft 15,900. Berths, Swing Basin; mud pap, limestone, sand.
1997	Pelican	Dec	20,485	30,341	No.2 berth 1,010 m^3 mud & silt Fairway east and west 49816m^3 fine sand and silt
1998	Tasman Bay	May	9,020		No 2 Berth. mud and silt
1999	Kimihia	May-Jun	17,900		Removed piles No.4 Wharf. Dredging between 2-3, 4-5, off end No.4 wharf. Mud, silt, mudstone
2000	Kimihia	July-Sep	27,750		No.2, 5 & 3 Berths, Swing Basin. Between ¾ Fairway off spur
2003	New Era	Feb-Mar	36950	95,370	Fairway – East & West and Inner
2003	Kimiha	Jun-Sep	62,048		Swing Basin, Berths 1A, 1B, 2, & 5.
2006	New Era	Feb-May	32,237	79,838	Fairway, Swing Basin, Berths
2008	Heron Backhoe	Jun-Sep	30,166		Between 3 and 4 Berths and from under 4 Wharf Associated with 3-4 Wharf Development Contract
2009 2010	Kimihia Backhoe	Sep09-Jan10	68,100		4 Berth Capital and maintenance – all berths and Swing Basin – vicinity spur BW. Calculated Vol. – Combine hard and soft
2012	BRAGE	Jan-Mar	211,355	130,965	Fairway maintenance & capital and deepen Josco Channel
2013 2015	Kimihia	Oct13-Mar15	141,000		Inner Swing Basin and Berths - Outer Turning Basin – Swing Basin entrance Nth and Sth side.
2015	Pelican	Jun-Jul	4,446	77,677	Fairway, Josco, Sth Pania Channel