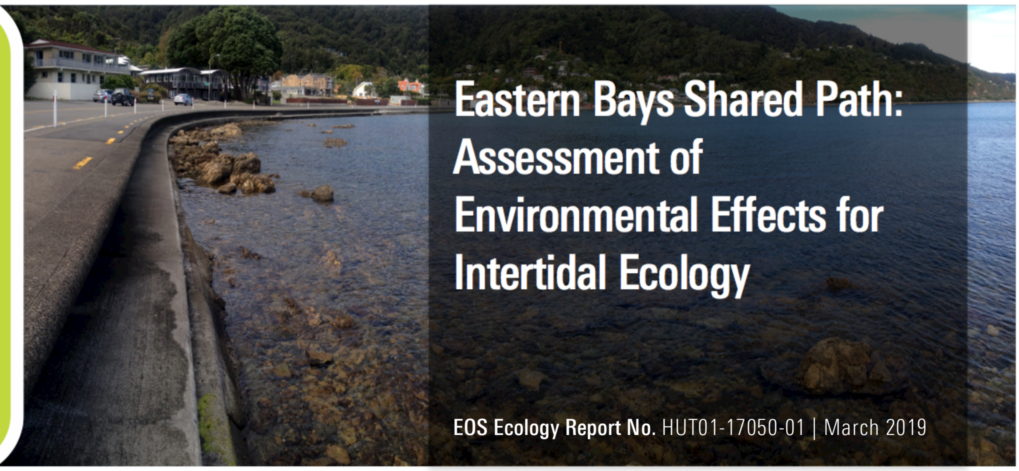
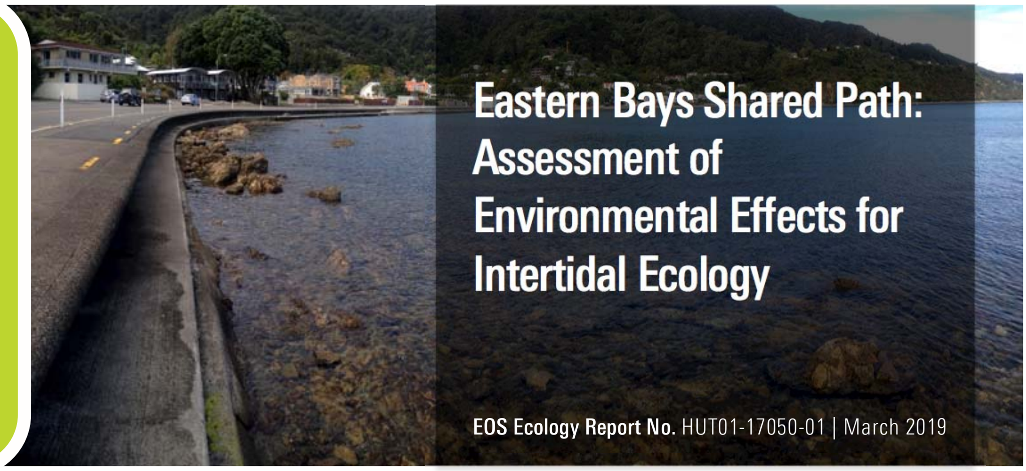


Eastern Bays Shared Path: Assessment of Environmental Effects for Intertidal Ecology

EOS Ecology Report No. HUT01-17050-01 | March 2019

SCIENCE + ENGAGEMENT



Eastern Bays Shared Path: Assessment of Environmental Effects for Intertidal Ecology

EOS Ecology Report No. HUT01-17050-01 | March 2019

Prepared for Hutt City Council

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EXECUTIVE SUMMARY

As part of the Hutt City Council (HCC) transport strategy the HCC is seeking to improve safety for pedestrians and cyclists along part of Marine Drive in the Eastern Bays of Wellington by creating a wider cycle/pedestrian path and replacing a number of seawalls to provide fit-for-purpose structures that are resilient to storm surges and to provide the first step towards adapting to future sea level rise. EOS Ecology was commissioned to provide an assessment of environmental effects that the proposed programme will have on intertidal ecology (specifically the benthic invertebrate and macroalgal communities).

Broad-scale habitat mapping and surveys of benthic invertebrates and macroalgae were undertaken in May 2016 and June 2017 to describe the nearshore intertidal environment. The intertidal habitat of the Eastern Bays area (i.e., Sorrento Bay to Windy Point) was found to be predominantly a moderately to very sheltered rocky reef with a substrate dominated by larger material (bedrock and cobble fields), as well as some beach areas of finer materials (gravel and sand).

A total of 60 invertebrate taxa were found in 71 epifauna quadrats, with the snail *Diloma aethiops,* the blue-banded periwinkle *Austrolittorina antipodum,* the limpet *Cellana radians,* the porcelain crab *Petrolisthes elongatus,* and chiton *Sypharochiton pelliserpentis* the most widespread taxa. No invertebrate taxa of conservation concern were recorded from the project area. Based on density data the community was dominated by the barnacle *Chamaesipho columna* (representing 86% of total abundance), with the snails *A. antipodum* (6.2% abundance), *D. nigerrimum* (2.2% abundance), and *M. aethiops* (2.1% abundance) the only other species representing more than 1% total abundance. There were few areas within the project area where it was possible to collect core samples to assess the infauna community. Of the eight core samples collected, a total of 28 invertebrate taxa were identified. Two polychaete taxa, *Aonides* sp. (27%) and *Prionospio* sp. (22%), as well as Gammaridae amphipods (21%) were the most abundant taxa overall, with *Aonides* and Gammaridae amphipods also being widespread. Macroalgae were of limited occurrence within the surveyed area with only 11 of the 71 epifauna quadrats containing any macroalgal species.

The community composition of the surveyed area was as would be expected for this general location (lower North Island) and rocky shore intertidal habitat, and is similar to the rocky shore communities found elsewhere in the Wellington Harbour. No taxa that are indicative of significant nutrient enrichment or fine sediment input were present in any great abundance. Tidal zone appeared to have the greatest influence on taxa richness and abundance of the avifaunal community. When comparing the areas proposed to be altered via seawall replacement to areas that will remain the same, there was no significant difference in community composition. Taxa richness was much lower on the existing seawall surface for areas designated for change, whilst taxa density was lowest on the seawall surface for areas not zoned for change. However, large error bars indicated a large within-sample variation.

Species of value as human food sources were neither abundant nor widespread within the surveyed intertidal areas. However observations of people gathering shellfish (cockles) along with remains of shellfish and kina on the shore indicates that some species may be present in greater abundance in the sub tidal area.

The proposed works include the construction of a shared path and seawall along 3.1 km (69%) of the 4.4 km stretch of shoreline between Sorrento Bay and the northern end of Eastbourne (excluding Days Bay beach area). The total area of new seawalls beyond the existing footprint will be 0.58 ha, which

includes areas within and outside of the coastal marine area (CMA). Within the project area, there will be 0.03 ha (5%) where the proposed seawall toe is behind the toe of the existing seawall, thereby providing a gain in foreshore area. For the length of new seawall that extends beyond the existing seawall toe, approximately 1.8 km (41%) is below the MHWS level and thus within the intertidal area of the CMA.

Approximately 87% of the project length already has a seawall. After completion of the proposed works, 93% of the project length will contain a seawall. Of the proposed seawall types, three types will occur within the intertidal zone: double curved seawall, triple curved seawall and revetment; whilst the single curved seawall is only used above the MWHS. Approximately half (55%) of the project length is planned to have a double or triple curved seawall, 10% revetment, 4% single curve wall, and 29% left in its current state. Approximately 1.4% of the project length consists of 17 discrete access points (steps, mini steps or ramps), which includes the replacement of three existing ramps.

Due to the losses of beach area to occupation of the shared path and seawall, beach nourishment has subsequently been proposed for three locations: Point Howard beach, Lowry Bay and York Bay. Recreation and amenity are the key reasons for this action, with improved coastal protection a secondary benefit. The potential effects of beach nourishment on intertidal and subtidal beach areas is provided in a supplementary report (McMurtrie & Brennan, 2019) and as such is not covered in this current report.

It is envisaged that in locations where the existing seawalls are to be replaced, the toe of the existing seawalls will be dug out to provide a footing for the seawall. Following the installation of poured concrete footing, the concrete seawall sections will be poured *in situ* using shaped formers and a textured surface applied to one of the curves using a form liner or void former. During the construction phase, there is expected to be an additional footprint to allow for the works. For the curved seawalls, the construction footprint will extend no more than five meters from the proposed toe of the seawall; for the revetment, the construction footprint will extend no more than three meters from the proposed toe of the seawall. The additional construction footprint will be approximately 1.50 ha, which will be temporary and staged over time and location.

The greatest risk during the construction phase relates to the release of any fine sediment material and the accidental release of water contaminated with cementitious-based products. A construction methodology has been provided that will form part of the construction and environmental monitoring plan. The construction zone will be limited to a length of no more than 20 meters per construction site (noting that there may be more than one construction site operating at the same time within a bay), will be isolated from the environment by a bund or other device, and weather conditions and tidal movements will be carefully considered. Dewatering of the construction area will be necessary to limit contamination of the receiving environment by sediment and/or cementitious products. A specific methodology for dealing with discharge from concreting activities is also proposed.

Due to the fact that the proposal is to primarily replace existing seawalls rather than create new seawalls where previously there were none, the replacement of the seawall per se is not envisioned to have a significant impact on intertidal ecology. There is some ecological benefit to the proposed curved seawalls over the existing angled seawalls, as the deep curve will provide shade and help to maintain humidity, which is necessary for biota survival during tidal exposure and the proposed addition of a textured surface to one of the curves will improve potential habitat. Thus the new seawalls are likely to provide a better habitat than some of the existing old seawalls.

However, for 10% of lineal length of the proposed works the new seawalls have a higher level of encroachment due to additional encroachment into the low-mid tide zone. A medium level of encroachment is expected along 47% of lineal length of the proposed works due to additional encroachment into the mid-high tide zone. Thus there are a number of recommended additional mitigation measures for these 'high' and 'medium' encroachment zones that will help to mitigate the effects of this additional encroachment. Overall, provided that all mitigation measures (those already proposed and our additional recommended measures) are implemented there should be a low net effect (or 'less than minor' effect in the context of the RMA) on the intertidal community currently found in the project area.

1 INTRODUCTION

As part of the Hutt City Council (HCC) transport strategy the HCC is seeking to improve safety for pedestrians and cyclists along part of Marine Drive in the Eastern Bays of Wellington by creating a wider cycle/pedestrian path and replacing a number of seawalls to provide fit-for-purpose structures that are resilient to storm surges and to provide the first step towards adapting to future sea level rise. This Eastern Bays Shared Path Project will provide a safe connection for residents in the Eastern Bays to workplaces, schools, shops and public transport facilities in the rest of Hutt City. It will also connect to the planned Wainuiomata Hill and Beltway Shared Paths and, in the future, through to Wellington City by joining up and connecting to planned new facilities by both the New Zealand Transport Agency and Wellington City Council.

The project focuses on Marine Drive, between Point Howard and the northern end of Days Bay, and the southern end of Days Bay (Windy Point) to Eastbourne (Muritai Road / Marine Parade intersection) (Stantec, 2019a). These bays are known collectively as the Eastern Bays and include (from north to south) Point Howard, Sorrento Bay, Lowry Bay, York Bay, Mahina Bay, Sunshine Bay, Days Bay, and Windy Point (in Eastbourne).

Along the length of the project extent, (approximately 4.4 km between Point Howard and Windy Point/Eastbourne, Figure 1), 69% of the existing road–harbour interface is proposed to be changed to allow for a 2.5–3.5 m width shared path and upgraded seawall. The proposed seawall types have been selected based on a multi-criteria assessment (MCA) by a range of technical experts encompassing intertidal ecology, avifauna ecology, terrestrial ecology, coastal processes, landscape and visual, civil design, recreation, planning and consenting, and engagement. The overall extent of works is approximately 3.1 km over 4.4 km of lineal shoreline length. Of the 3.1 km length of shoreline set to change, 84% will be curved seawalls (6% single, 68% double, 7% triple, 3% double/triple), followed by revetment (14%), and beach access (steps, mini steps and ramps) (2%) (Figure 2; Appendix 1). The proposed design plans (Stantec 2018) delineates either a 3.5 m or 2.5 m width pathway between the traffic lane and the shoreline meaning that there is the need to extend the existing footprint of the pathway seaward into the intertidal zone and Coastal Marine Area (CMA). Of the project works, 1.2 km are above the mean high water springs (MHWS) level and therefore outside the current intertidal zone.

Due to the losses of beach area to occupation of the shared path and seawall, beach nourishment has subsequently been proposed for three locations: Point Howard beach, Lowry Bay and York Bay. Recreation and amenity are the key reasons for this action, with improved coastal protection a secondary benefit.

HCC commissioned EOS Ecology to undertake an intertidal ecology assessment, to be included as part of the Assessment of Environmental Effects (AEE) in resource consent applications. The extent of this report is limited to an assessment of effects on the intertidal benthic ecology (epifauna and infauna invertebrates, and macroalgae), and excludes any detailed assessment of the effects on subtidal ecology, vegetation and avifauna assessments (covered in Overmars, 2019a), seagrass assessments (covered in Overmars, 2019b), coastal physical processes (covered in Allis, 2019), beach nourishment (covered in Reinen-Hamill, 2019 and McMurtrie & Brennan, 2019), freshwater fish passage (covered in James, 2019), or stormwater (which we have been asked to exclude due to it being a permitted activity under the Regional Plan). The potential effects of beach nourishment on intertidal and subtidal beach areas is provided in a supplementary report (McMurtrie & Brennan, 2019) and as such is not covered in this current report.

Figure 1 Area of proposed works for the Eastern Bays Shared Path in the Wellington area, as outlined in the Design Plans (Revision J) and associated files provided by Stantec 3 September 2018.

Figure 2 Proposed seawall treatment types as outlined in the design plans (Revision J) and associated files provided by Stantec 3 September 2018. A more detailed breakdown of the seawall types can be found in Appendix 1.

2 METHODS

2.1 Determination of Proposed Seawalls and Area of Works

Stantec provided plans containing information about the extent of the proposed seawalls to EOS Ecology as shapefiles derived from CAD files. Based on the previous tidal modelling undertaken by MWH in 2016, Stantec also provided shapefiles for low, mid, high and mean high water springs (MHWS) tide levels. All information was imported to ArcMap 10.2.2 for further interrogation. In addition, EOS Ecology determined the existing seawall types during site walkovers in May 2016 and June 2017, which was digitized as a GIS shapefile. Calculations from the derived shapefiles were accurate to approximately +/- 10 m and +/- 10 m^2 and are intended to provide a best estimate prior to detailed designs. The calculations for encroachment of the proposed seawalls was based on the point of greatest encroachment as indicated in the design plans, and as such is a slight overestimation of what the encroachment will be in reality. For example, revetment seawalls have the outer encroachment as the outward edge of the toe which following construction may be buried; whilst for curved seawalls the outer encroachment is based on the outward edge of the bottom-most curve which sits above the actual seafloor and overhangs the toe of the wall by approximately 0.2m (Jamie Povall, Stantec, pers. comm.) Calculation of proportion of length of proposed and existing seawalls was based on the project length as defined in Figure 1, and thus does not include the lineal length of foreshore that is not specified within that plan (i.e., the majority of Days Bay, and the promontory north of Days Bay).

2.2 Habitat Types – Broad Scale

The dominant habitat types of the intertidal environment were classified at a broad scale based on habitat type classes as described in Stevens *et al*. (2004). As this was the only habitat study undertaken in the project area, comparable habitat types were used for consistency. Stevens *et al* (2004) adapted the national estuarine habitat classification as developed by Ward & Lambie (1999) and taken from Atkinson (1985). The classifications of habitat type were further adapted in this study to best suit the Eastern Bays environment (e.g., the inclusion of a "concrete" habitat type class to account for existing seawalls). The differences between the classifications in Stevens *et al.* (2004) and this study are shown in Table 1.

Habitat types between Sorrento Bay and Days Bay were mapped from the road edge to the low tide zone during a site walkover on 3 May 2016, whilst the area between Days Bay and Windy Point was mapped on 8 June 2017 to match the extended project area. During the walkover, dominant habitat types were drawn on printed maps at a 1:500 scale (Figure 3) and then polygons created in ArcMap 10.2.2 (Appendix 2). The habitat types were chosen based on the predominant substrate type visible at the surface. In this dynamic environment, it is expected that some areas are likely to undergo changes over time. Photos were regularly taken as records of habitat types and landscape features (Figure 3). Total areas for habitat types were determined using the polygons created in ArcMap.

Table 1 Broad scale habitat classification system used by Stevens *et al.* (2004) with comparison to the classification used in this report.

Habitat types from Stevens *et al*. (2004)	Habitat types used in this report
Boulder field	Boulder field
Cobble field	Cobble field
Cobble field (Gravel field)	
Gravel field	Gravel field
Gravel field (Cobble field)	
Gravel field (Firm sand)	
Gravel field (Firm sand, Cobble field)	
Gravel field (Shell)	
Gravel field (Soft sand)	
Firm sand	Firm sand
Firm sand (Cobble field)	
Firm sand (Gravel field)	Firm sand (Gravel field)
Firm sand (Gravel field, Cobble field)	
Firm sand (Shell)	
Mobile sand	Mobile sand
Rock field	
Rock field (Cobble field)	
Rock-tx-cr-sg-rp	Bedrock
Soft mud	
	Cobble field (Bedrock)
	Concrete

(a) Marking up A3 site maps with habitat types

(b) Taking site photos

Figure 3 Habitat types were documented and mapped during the site walkovers by EOS Ecology.

2.3 Intertidal Ecology

Due to a lack of ecological information regarding the benthic fauna of the intertidal environment along the Eastern Bays area, field surveys were undertaken to determine the current state of the environment and to adequately assess the potential effects of proposed seawall replacements. The first round of surveys were based on the initial Eastern Bays Shared Path plan in 2016, but following alterations to the project plan in 2017, it was determined that additional sites needed surveying to incorporate the extension of the project area and the additional number of seawalls being replaced. The benthic fauna along the shoreline between Sorrento Bay and Windy Point were surveyed at 17 sites on the 4–6 May 2016 and 12 sites on 8–9 June 2017 (Figure 4). The site locations were chosen to ensure coverage of the broad-scale intertidal habitat types, as well as existing and proposed seawall types (Table 2; Appendix 3). Sites were included in areas where seawalls will be constructed (i.e., ‘impact’ sites) as well as in areas that will not undergo works (i.e., ‘control’ sites).

At each site, the epifauna and macroalgal community was assessed along transects extending out into the bay. A tape measure was run out from the white line of the road edge into the bay to near to the estimated low tide zone. A 0.5 m x 0.5 m quadrat was placed at two or three points along the transect (Figure 5) with at least one quadrat covering the seawall and one quadrat on the seafloor/harbour floor but within the likely operational or construction footprint.

Within each quadrat, epifauna invertebrates dwelling on the surface were identified and counted. Any coarse substrate was lifted (if possible) and the underside also inspected for biota. The relative substrate composition with the quadrat was recorded, based on aerial percentage cover of nine size substrate classes (concrete, bedrock, boulder, large cobble, small cobble, pebble, gravel, sand, and silt).

Prior to undertaking the search for biota within each epifauna quadrat, the percentage cover of macroalgal species within each epifauna quadrat was estimated by counting numbers of grid intersections (49 intersections in total) overlapping the algae, and converting this to a percentage cover value using the formula:

$$(N/49) \times 100$$

where N = number of grid intersection points

49 = maximum number of grid intersections

In addition to the epifauana quadrats, a free search was made along the entire site (extending out 2 m either side of the transect line) and any epifauna taxa not already identified in the quadrats were noted. The free search recorded the presence/absence and relative abundance of invertebrate taxa sighted.

Figure 4 The 29 survey sites where ecological information was collected on 4–6 May 2016 and 8–9 June 2017 by EOS Ecology. Refer to Appendix 3 for overlay of existing and proposed seawall types.

An avifauna quadrat along the base of an existing seawall.

An epifauna quadrat within a rocky shore area.

Extraction of an infauna core.

Assessing substrate within a quadrat.

Conducting a free search along the transect line.

Figure 5 Examples of survey methodology undertaken by EOS Ecology during the intertidal ecology survey of the Eastern Bays near-shore environment on 4–6 May 2016 and 8–9 June 2017.

Table 2 Percentage of total seawall length for the broad seawall treatment types, the number and percentage of survey sites that represent these treatment types, and whether the treatment types represent a change to the existing seawall (control vs. impact). Surveys undertaken by EOS Ecology on the 4-6 May 2016 and 8–9 June 2017. Appendix 3 provides an overlay of the survey sites and proposed seawall types.

Proposed seawall type	Control or impact site	Percentage of total length for each proposed seawall type	Total number of sites surveyed with the proposed seawall type	Percentage of total number of sites surveyed with the proposed seawall type
Curved seawalls	Impact	59.6	18	62
Revetment	Impact	9.8	3	10
Beach access	Impact	1.4	0	0
No change	Control	29.2	8	28
TOTAL			29	

Table 3 Breakdown of epifauna quadrats and infauna cores collected within each bay along the project area by EOS Ecology during surveys on the 4-6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29) (Figure 4).

Site No.	Bay	No. of epifauna quadrats	No. of infauna cores	Site No.	Bay	No. of epifauna quadrats	No. of infauna cores
1	Sunshine Bay	2		**16**	York Bay	2	1
2	Sunshine Bay	2		**17**	Mahina Bay	2	
3	York Bay	2		**18**	Days Bay	3	
4	York Bay	2	1	**19**	Windy Point	3	
5	York Bay	2	1	**20**	Days Bay	3	
6	Lowry Bay	3		**21**	Days Bay	2	
7	Sorrento Bay	2		**22**	Sunshine Bay	2	
8	Sorrento Bay	2	1	**23**	Sunshine Bay	3	
9	Lowry Bay	2	1	**24**	Mahina Bay	3	1
10	Lowry Bay	3	1	**25**	York Bay	3	
11	Mahina Bay	3	1	**26**	Mahina Bay	3	
12	Mahina Bay	2		**27**	Lowry Bay	3	
13	Mahina Bay	2		**28**	Lowry Bay	3	
14	Sunshine Bay	2		**29**	Sorrento Bay	3	
15	Sunshine Bay	2					

Infauna cores were collected at a subset of sites (i.e., eight sites, Table 3, Figure 4) where the substrate was amenable to core sampling. Due to the hard nature of the substrate (cobbles, bedrock or gravel substrate) at the majority of the sites, it was not possible to collect infauna cores at all survey sites. Where substrate was suitable, one infauna core was collected adjacent to an epifauna quadrat, with a total of eight infauna cores (from eight sites) collected. Infauna cores were 130 mm in diameter and were pushed into the sediment to a depth of 150 mm. Each infauna core was placed in a 500 micron mesh bag and washed on site in seawater, preserved in 70% IPA and taken to the laboratory for later processing. In the laboratory each infauna core sample was washed through a 500 micron sieve prior to processing. Processing involved the identification and counting of all invertebrates to the lowest practical level of classification using a full count procedure and stereo microscopes.

An additional visual survey of the subtidal area within the proposed construction footprint at north Lowry Bay (refer to Figure 38) was undertaken on the 26 July 2018 to confirm the presence/absence of *Macrocystis* (kelp) beds.

2.4 Sediment Contamination

There is some existing information for sediment contamination within the project area, although this is limited to samples from Lowry Bay by Stevens *et al*. (2004). This was used to provide an indication of sediment contaminant levels in the area.

2.5 Data Analysis

2.5.1 Epifauna

Biotic metrics (taxa richness and density) were plotted against a number of variables including tidal zone, substrate type and diversity, seawall vs. harbour floor, current wall type, and control vs. impact sites (Table 4), as well as comparing the dominant taxa. The following provides some additional information regarding each of the variables outlined in Table 4:

- Tidal zones were estimated based on the tidal level GIS layer provided by Stantec in 2017 including low, mid, high and MHWS.
- Substrate was classified based on the percentage substrate cover as assessed for each epifauna quadrat. Where one substrate accounted for more than 65% of the substrate cover then this was characterised as the dominant substrate type for that sample. Where only two substrate categories were present and no one category exceeded 65% cover then those two substrate types were used for the classification – in this case it was always a bedrock-cobble mix. Where three or more substrate categories were present and no one category exceeded 65% cover it was ascribed a 'mixed substrate' classification. This was usually a gravel, cobble, pebble mix and had a substrate diversity of three or more.
- The 'seawall vs. harbour floor' was used to differentiate between taxa richness and density on the seawall versus the wider intertidal area (i.e., the harbour floor).
- The control sites included areas where there is no planned change to the existing seawall (Figure 2). Impact sites were classed as locations where seawall construction works are proposed.
- The current wall types were based on assigning the wall types present at each survey site into one of five categories.

Distribution of the intertidal epifaunal community was examined using non-metric multidimensional scaling (NMS). NMS is non-metric statistical technique that condenses sample data (in this case epifaunal community data) to a single point in low-dimensional ordination space using some measure of community dissimilarity (Bray-Curtis metric in this instance). Interpretation is straightforward such that points on an x-y plot that are close together represent samples that are more similar in community composition than those further apart (Clarke & Gorley, 2006). Differences in epifaunal community composition between various groupings (e.g., tidal zone, seawall or harbour floor, seawall type, and control or impact) were tested using the analysis of similarities (ANOSIM) procedure, which is a non-parametric procedure applied to the similarity matrix that underlies the NMS ordination. ANOSIM is an approximate analogue of the standard ANOVA (analysis of variance) and compares the similarity between groups using the R test statistic. R=0 where there is no difference in the epifaunal community between groups, while R=1 where the groups have completely different communities. Where ANOSIM results showed significant or near-significant differences in epifaunal community compositions, the similarity percentages (SIMPER) procedure was used to determine which taxa where responsible. NMS, ANOSIM, and SIMPER were all carried out in PRIMER v6.1.5 (Clarke & Gorley, 2006).

2.5.2 Infauna

The eight infauna samples were plotted for taxa richness and density per site. There was insufficient sample replication to allow for any data analysis; however, the dominant taxa were identified.

Table 4 The 71 quadrats surveyed were separated into different variables below for data analysis. Surveys undertaken by EOS Ecology on 4-6 May 2016 and 8–9 June 2017.

Variable	No. Quadrats	Variable	No. Quadrats
Location along transect		Current Wall Type	
Harbour Floor	38	Concrete–smooth	28
Seawall	33	Concrete–aggregate	17
Tidal Zone		Concrete–smooth curved	13
Low	4	Revetment	6
Mid	21	Gabion baskets	0
High	34	None	7
Above high	12	Substrate	
Control vs. Impact		Bedrock	8
Control	18	Bedrock-cobble	2
Impact	53	Boulder	8
		Cobble	3
		Concrete	26
		Gravel	6
		Mixed substrate	15
		Sand	3

3 EXISTING STATE OF THE ENVIRONMENT

3.1 Existing Seawalls

The coastal edge of the Eastern Bays area from Sorrento Bay to Windy Point is a modified urban environment. The area immediately above the tidal zone (the foreshore) contains the main road (Marine Drive) that runs north-south and connects the Eastern Bays suburbs to the wider Hutt Valley. At the interface between the tidal zone and the urban environment a seawall currently exists that acts to protect (to varying degrees) the road from waves. The seawalls that currently exist can be categorised into two main materials– concrete or rock/boulders. These make up 87% of the total length of the project area. The other 13% contains an interface with no seawall (i.e. the harbour floor transitions through a beach area to the road surface, or consists of a vegetated or unvegetated bank). The concrete seawall category was further defined to represent the surface type: concrete–aggregate, concrete–smooth, concrete–smooth curved, as each type has features that may influence intertidal ecology (Table 5; Figure 6). Within the project area there are also sections of revetment seawall as well as one small length of gabion baskets. Of these seawall types concrete–smooth was the most abundant type (40% of total length), followed by concrete–aggregate (18%), revetment (17%) and gabion basket (1%) (Table 5). Concrete–smooth curved (10%) represented the relatively newly constructed seawalls, which are of a similar curved design to that proposed in the current plans. Each seawall type is described in the following sub-sections.

Table 5 Approximate length (and percentage of total length) of existing seawall types within the project area from Sorrento Bay to Windy Point, as determined during surveys undertaken by EOS Ecology on 3 May 2016 and 8 June 2017.

Existing seawall type	Length (m)	Percentage (%) of total length
Concrete-aggregate	795	18
Concrete-smooth	1,766	40
Concrete-smooth curved	425	10
Revetment	752	17
Gabion basket	60	1
None	593	13
Total length	**4,369**	

Figure 6 Categories of the seawalls that currently exist along the Eastern Bays shoreline as determined during surveys by EOS Ecology on 3-5 May 2016 and 8-9 June 2017.

3.1.1 Concrete–Smooth

A concrete seawall with a smooth surface represents an older seawall that is either vertical, sloped or gently curved (Figure 7). Features of this seawall type include a smooth surface with few cracks and high exposure to sunlight (Figure 7). This seawall type represented 40% or 1,766 m of the total length within the project area, which is the largest proportion of any of the seawall types (Table 5). Of these existing seawalls 90% are due to be replaced.

A sloped concrete-smooth seawall at York Bay.

A slightly curved version of a concrete–smooth seawall at Sunshine Bay.

A vertical stepped seawall at Lowry Bay.

A vertical seawall along the southern part of Days Bay.

Figure 7 Examples of existing seawall type: concrete–smooth

3.1.2 Revetment

The existing revetment seawall type is characterised by boulder-sized material placed on a gradual slope from the road to the harbour floor. There may also be a mix of smaller substrate between the boulders. The existing revetment contains large gaps as well as small cracks between and within the material (Figure 8). Revetments have been used around the breakwalls of Whiorau Reserve and Point Howard, as well as in sections along Mahina and Sunshine bays (Figure 8). There is 752 m (or 17%) of revetment, including the lengths of breakwalls, of which 19% are due to be replaced.

Revetment at the southern end of Sunshine Bay.

Revetment at the southern end of Sunshine Bay.

Revetment breakwall at Whiorau Reserve.

Revetment features cracks, gaps and a large surface.

Figure 8 Examples of existing seawall type: revetment.

3.1.3 Concrete–Aggregate

The concrete-aggregate category includes seawalls that are sloping or vertical concrete with cobbles/boulders set into the concrete, or concrete that has been poured around rip rap or boulders/bedrock (Figure 9). The natural material used may have a rough surface and contain cracks but large gaps are limited. All of the existing 18% (795 m) of concrete-aggregate walls are due to be replaced.

Concrete–aggregate wall with large cobbles set in place with concrete at Sorrento Bay

Concrete–aggregate seawall at Mahina Bay where concrete has been poured around boulders

Figure 9 Examples of existing seawall type: concrete–aggregate.

3.1.4 Concrete–Smooth Curved

Within the project area, approximately 10% (425 m) of the shoreline has already undergone seawall replacement with single or double curved seawalls (Figure 10). These seawalls are located in Lowry and York bays and were replaced in 2007–2008. The double-curved seawalls are broadly similar to the double-curved seawall type that is the predominant seawall in the current proposed plans. While the surfaces of these walls are smooth, they differ from the concrete–smooth seawall type by providing shelter to biota from desiccation by virtue of the deep curve (Figure 10). The double curved seawall at York Bay will remain as it is, however the curved seawall at Lowry Bay will be replaced with double and triple seawalls to serve better shoreline protection.

Double curved wall at York bay

Double curved wall at Lowry Bay

Single curved wall at York Bay

Single curved wall at Sunshine Bay

Figure 10 Examples of existing seawall type: concrete–smooth curved.

3.1.5 Gabion Baskets

Southern Lowry Bay contains a 60 m section of gabion baskets (Figure 11). This type of seawall is vertical and stepped, containing various-sized boulders encased in wire baskets. These will be replaced with a double curved seawall.

Gabion baskets in southern Lowry Bay

Figure 11 Example of existing seawall type: gabion baskets.

3.1.6 None (No Seawall)

Along 593 m of the project area (approximately 13%), there is currently no seawall between the road and the shoreline. The longest stretch is in Lowry Bay where the road meets the gravel of the beach (Figure 12). In Sunshine Bay there is a low wooden retaining wall separating the road from the gravel beach, and there is a vertical vegetated/soil bank at the southern point of Mahina Bay and Windy Point (Figure 12). Generally speaking, these areas are found above the high tide mark and hence are not typically impacted by waves and storms. Of these lengths, approximately half (48%) are due to become seawalls, while the other half remains without a seawall.

No seawall above the high tide mark at Lowry Bay.

Small wooden barrier at Sunshine Bay.

Soil bank at the southern point of Mahina Bay.

Vegetated bank at Windy Point.

Figure 12 Examples of the locations where no seawall currently exists within the project area between Sorrento Bay to Windy Point.

3.2 Hydrodynamics and Sediment Transport

Wellington Harbour has a maximum tidal range of 1.5 m and an average tidal range of 0.75 m (neap tides) or 1.25 m (spring tides). Tidal zones for habitat can be classified as low, mid and high tide and is a significant factor in the determination of biological communities inhabiting intertidal habitats (Lachowicz, 2005). Approximately 45% of lineal length of the proposed project area lies within the low to high tide zone, 26% of lineal length is above the mean high water springs (MHWS) mark and 29% of the lineal length is not undergoing any change.

Wellington Harbour is well flushed with a flushing time of approximately ten days (Maxwell, 1956; Heath, 1976). Following intense rainfall events, the discharge from the Hutt River causes harbour waters to become more fresh and turbid, however for most of the time there is very little influence of fresh water on harbour salinities (Booth, 1975; Brodie, 1958). Tidal flow is generally in a clockwise direction on the flood tide and in an anticlockwise direction on the ebb tide (Brodie, 1958), however, this circulation is not always present and the circulation direction has been correlated to meteorological drivers (wind) and freshwater discharges from the Hutt River (Heath 1976, Allis 2019).

Sediment transport in the coastal zone of Wellington Harbour is primarily driven by waves, with the small tidal currents too weak to transport sediment on the seabed except within the Harbour mouth. The environment of the Eastern Bays is dynamic and the beaches undergo periods of accretion and erosion on a range of timescales from sub-daily (i.e. a tidal cycle) to interannual (Allis, 2019; GHD, 2015; Matthews, 1980), however the long-term trend of shoreline change suggests that the embayments north of Days Bay are relatively stable in terms of total beach volume and shoreline position. Beach erosion is common along the northern ends of the bays during southerly storms, although high tides combined with strong easterly winds also cause bay-wide erosion (Allis, 2019). Allis (2019) describes the sediment transport within the project area and the wider Eastern Bays region, stating that longshore drift, generally northwards, is the main influence on sediment supply in the project area.

Subtidal sediments along the Eastern Bays area of Wellington is generally described as sandy to very sandy due to the supply of marine sands from the Harbour entrance being deposited here during storm events (Figure 13, Booth, 1972; EHEA, 1998). Gravels are also deposited along the Eastern Bays from Cook Strait during large storms as well as from the erosion of adjacent rocky outcrops (EHEA, 1998), however gravel transport decreases from south to north with very little gravel transported north of Days Bay (Allis, 2019). Alluvial sediment is supplied during flood events from the Hutt River and other freshwater streams but does not accumulate on the Eastern Bays foreshore in substantial quantities due to the finer nature of these particles and the relatively exposed nature of the bays. In general, the supply from local terrestrial sources is small; the fine sediment fraction is either swept out to sea or settles on the harbour floor whilst the coarse sediment fraction is either extracted by mining at the mouth of the Hutt River (sands and gravels), or prevented from reaching the Eastern Bays by the breakwater at Seaview (Michael Allis, NIWA, pers. comm.).

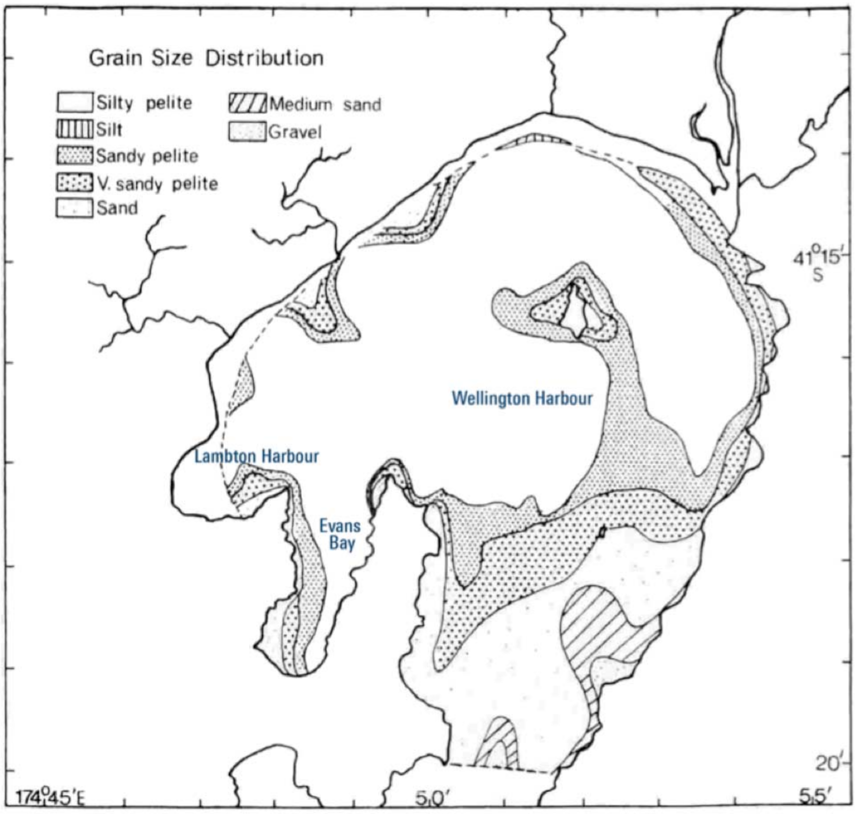


Figure 13 Particle size distribution in Wellington Harbour, as shown in Booth (1972). Note: "pelite" is an older geological term for clay-rick, fine-grained sedimentary rock.

3.3 Habitat Types – Broad Scale

3.3.1 Eastern Bays

The intertidal habitat of the Eastern Bays area (i.e., Sorrento Bay to Windy Point) has previously been described as having areas of moderately to very sheltered rocky reef, with a mix of substrate dominated by either bedrock, pebbles & boulders, or sand (EHEA, 1998). The broad-scale habitat assessment undertaken on 3 May 2016 and 8 June 2017 found similar habitat types as those described in EHEA (1998), albeit on a finer scale. The types of habitats mapped showed that while the dominant habitat type differed between some of the bays, all bays provided a similar mix of habitat types, meaning that no one bay was unique in its mix of habitat types (Table 6, Appendix 2). As the project area excludes the beach area of Days Bay, we have excluded this area in the broad scale-habitat assessment.

Of the area mapped, the predominant habitat type (32% of the total area mapped) was defined as a 'cobble field (bedrock)' mix (Table 6, Figure 13), and was present in every bay. This habitat type consists of cobble material (60–250 mm in diameter) interspersed with more stable bedrock material (Figure 14). The presence of the bedrock provides temporal stability, dissipating wave action and preventing the movement of the smaller substrate between the bedrock. The smaller cobble substrate provides diversity of habitat, with interstitial spaces between the large cobble substrate providing habitat for a diversity of invertebrate taxa. This habitat appears to be relatively stable over time.

Firm sand (gravel field) was the next most dominant habitat type covering 21% of the total project area, the majority of which exists in Lowry Bay. This habitat type characterises the "beach" areas and consists of sandy substrate, sometimes below a layer of mobile gravels (Figure 14). Often gravel is also found beneath a surficial sand layer. These areas are considered to be relatively active.

Areas of bedrock make up approximately 14% of the total area mapped (Table 6, Figure 14); these areas are where discrete patches of bedrock exist rather than interspersed with other material such as cobble (Figure 14). Discrete areas of bedrock were found in all bays except Lowry Bay, although the largest area of bedrock within the project area was mapped at the headland between Lowry Bay and Sorrento Bay. These areas of bedrock are the substrate forming the basis of the 'rocky reefs'. They perform a number of functions in the intertidal environment including provision of a permanent surface as habitat for a diverse range of rocky shore fauna and flora, a high tide roosting site for birds as it may be separated from land during high tides, a varied surface structure providing cracks and divots where creatures can hide and rock pools can form, and forming a barrier to break up the wave energy and allow stability of the surrounding smaller substrate and protection of areas from the forces of the sea.

Gravel field areas were found across the whole project area, representing 11% of the habitat types (Table 6, Figure 14), and were sometimes a transitional habitat type. As a smaller sized substrate, gravels are easily moved by waves especially during storm events, and so represent a more dynamic environment (Matthews, 1980). Gravel areas are typically found at the northern end of the bays due to these areas being depositional zones during large southerly winds and swells (GHD, 2015) and the northward migration of gravels from the entrance of Wellington Harbour (Matthews, 1980). The largest areas of gravel field were in Mahina and Sunshine Bays where the gravels were found between tidal zones (Appendix 2).

Cobble field (at 9%), like gravel field, was typically found in smaller sections within each bay and usually as a transitional area between habitat types (Appendix 2). The size of this habitat means that it can be mobilised during large storm events.

The concrete classification (Table 6, Figure 14) refers to seawalls of all types except 'revetment' and 'gabion baskets', and is characterised by the generally smooth nature of these surfaces. As a habitat type they are exposed surfaces and provide little protection from the waves. There were differences within the concrete habitat type including the presence of boulders, cracks, holes and edges; however, these were at a scale too fine for this broad-scale assessment.

Boulder field (Table 6, Figure 14) describes large substrate that is generally used for revetment seawalls and breakwalls, and represented 5% of the mapped area. This habitat type contains large spaces between boulders, and the roughness of the boulders is a key factor that improves its importance as intertidal habitat (Kostylev *et al*. 2005). The majority of boulder fields mapped included the start of the breakwall at Point Howard and the revetment along the southern end of Sunshine Bay. A cluster of concrete chunks placed in the mid–low tide zone of the north side of Mahina Bay were classed as boulder field as the pieces were broken into boulder-sized substrate and placed along a 65 m stretch of the bay.

Firm sand makes up the least dominant habitat type, representing 1% of the total area mapped (Table 6, Figure 14). Small areas of firm sand were found throughout the project area in between other substrate, but generally at a scale too fine for this assessment. Firm sand is transitional and may deposit and erode from areas depending on the hydrodynamics of area.

Table 6 Habitat types (in order of dominance) within the intertidal zone of the project area from Sorrento Bay to Windy Point (excluding Days Bay) as mapped by EOS Ecology for the broad scale habitat assessment undertaken 3 May 2016 (Sorrento Bay to Sunshine Bay) and 8 June 2017 (Eastbourne/Windy Point). The areas and percentage of each habitat type is shown, as is the percentage of each habitat type within each bay. Photographs of each of these habitat types is shown in Figure 14 while maps identifying areas of these habitat types are shown in Appendix 2.

				Percentage of habitat type in each bay					
Habitat type (in order of dominance)	Habitat code	Area mapped (m^2)	% of total area mapped	Sorrento Bay	Lowry Bay	York Bay	Mahina Bay	Sunshine Bay	Windy Point
Cobble field (bedrock)	CF/RB	13,134	32	13.6	30.2	46.0	37.0	38.9	27.4
Firm sand (gravel field)	FS/GF	8,607	21	28.7	38.9	17.2	13.7	14.3	6.9
Bedrock	RB	5,895	14	37.6	0.0	8.7	12.4	5.7	28.6
Gravel field	GF	4,335	11	1.0	9.6	7.5	18.2	15.8	11.6
Cobble field	CF	3,602	9	0.0	11.1	7.9	6.2	9.1	18.3
Concrete	CT	2,749	7	5.1	7.9	12.6	8.9	3.3	1.8
Boulder field	BF	2,165	5	14.1	0.6	0.0	3.6	12.2	2.9
Firm sand	FS	348	1	0.0	1.7	0.0	0.0	0.7	2.5

Cobble field (bedrock) (32% of area)

Firm sand (gravel field) (21% of area)

Bedrock (14% of area)

Gravel field (11% of area)

Cobble field (9% of area)

Concrete (7% of area)

Boulder field (5 % of area)

Firm sand (1% of area)

Figure 14 Examples of habitat types (and their percentage of total area mapped) as found on the broad scale habitat assessment along the project area on 3-5 May 2016 and 8-9 June 2017.

3.3.2 Comparison to the wider Wellington Harbour

According to the broad-scale mapping of EHEA (1998) and Stevens *et al*. (2004), habitat types south of Days Bay to Pencarrow Head are similar to that within the project area, with pebbles and boulders, sand, gravel, and rocky areas present. These areas are of a similar aspect as the project area but with a more dynamic hydrologic regime. There is a northward movement of gravel from Pencarrow Head to Eastbourne with the effects decreasing with distance from the entrance to Wellington Harbour (Matthews, 1980). Petone Beach is made up of sandy habitat with areas of pebbles and boulders, and the western shoreline from Horokiwi to Evans Bay is highly modified with rock and block shoreline protection with small areas of pebbles and boulders (EHEA, 1998). Oriental Bay provides an area of sand and pebbles. The Miramar Peninsula has sections of sandy, pebbly and rocky shore habitats on both the eastern and western sides of the peninsula (EHEA, 1998; Stevens *et al*., 2004).

3.4 Intertidal Ecology (Benthic Invertebrates and Macroalgae)

3.4.1 Epifauna

Taxa Overview

A total of 44 invertebrate taxa were identified from the 71 epifauna samples and a free search along the 29 site transects within the study area (Appendix 4), with seven taxa being found exclusively in the free search. Of these 44 taxa, the spotted topshell *Diloma aethiops* (recorded on 36 occasions), the blue-banded periwinkle *Austrolittorina antipodum* (28 occasions), barnacle *Chamaesipho columna* (28 occasions), the limpet *Cellana radians* (25 occasions), the porcelain crab *Petrolisthes elongatus* (25 occasions), and chiton *Sypharochiton pelliserpentis* (21 occasions) were the most widespread taxa (Figure 15). Other relatively widespread taxa include the bluish topshell *Diloma nigerrimum* (18 occasions), the common shore crab *Hemigrapsus sexdentatus* (15 occasions), the blue mussel *Mytilus galloprovincialis* (15 occasions), the oyster borer *Lepsiella scobina* (15 occasions), big handed crab *Heterozius rotundifrons* (14 occasions), green chiton *Chiton glaucus* (12 occasions), amphipods (10 occasions), black mussel *Xenostrobus neozelanicus* (10 occasions), and brown periwinkle *Austrolittorina cincta* (10 occasions). The remaining 45 taxa were recorded on less than 10 occasions.

Taxa richness varied from 0-12 taxa per epifauna sample, while densities ranged from 0–3033 individuals per sample. Densities greater than 1000/sample were found in epifauna samples where the barnacle *Chamaesipho columna* formed large colonies on the substrate. Of the 71 epifauna quadrats surveyed across 29 sites, 18 had no taxa in them at all. This included nine samples collected from the surface of existing seawalls, and nine from the wider intertidal area. Thirteen of the quadrats with no taxa present were also within the above high tide or high tide zones, while the other five were in the mid tide zone.

Of the 29,313 individuals found in the epifauna samples (Table 7), the barnacle *Chamaesipho columna* (Figure 15) was the most abundant taxon, representing 86% of the total individuals. This was not surprising given the large barnacle colonies that can form on stable substrate within the intertidal zone. The dominance of the intertidal community by this barnacle is reflected in a review of studies of Wellington Harbour by the EHEA (1998), where they described the intertidal ecology of the Eastern Bays from Sorrento Bay to Days Bay as being characterised by barnacles, along with clumps of blue and black mussels. The snails *A. antipodum* (6.2% relative abundance), *D. nigerrimum* (2.2% abundance), and *D. aethiops* (2.1% abundance) (Figure 15), were the next most abundant taxa. The remaining 33 taxa each comprised less than 1% of overall abundance (Table 7).

Chamaesipho columna:
Dominant (86%), widespread (28 occasions)

Austrolittorina antipodum:
Abundant (6.2%), widespread (28 occasions)

Diloma nigerrimum:
Abundant (2.2%), widespread (18 occasions)

Diloma aethiops:
Abundant (2.1%), widespread (36 occasions)

Cellana radians:
Widespread (25 occasions)

Petrolisthes elongatus:
Widespread (25 occasions)

Figure 15 The most abundant and widespread epifauna taxa found in the intertidal zone of project area (Sorrento Bay to Sunshine Bay). Determination of distribution was based on presence/absence data from epifauna quadrats and free searches along the site transect, whereas abundance was based on density data from epifauna quadrats only. Surveys undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Table 7 The average density (number per 0.25 m^2 quadrat), total number (sum), standard deviation (SD), and standard error (SE) for taxa recorded from the epifauna quadrats. The final column (#) represents the number of quadrats that each species was present in out of the 71 total. Epifauna quadrats were collected during surveys undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Faunal Group 1	Faunal Group 2	Taxa	Average	Sum	SD	SE	# (of 71)
Cnidaria	Anthozoa	*Actinia tenebrosa*	0.04	3	0.26	0.03	2
Crustacea	Amphipoda	Amphipoda	2.99	212	23.74	2.82	3
		Gammaridae	1.03	73	6.10	0.72	7
	Cirripedia	*Chamaesipho columna*	356.69	25325	774.51	91.92	21
	Decapoda	*Cyclograpsus lavauxi*	0.04	3	0.20	0.02	3
		Hemigrapsus crenulatus	0.07	5	0.31	0.04	4
		Hemigrapsus sexdentatus	0.11	8	0.43	0.05	5
		Heterozius rotundifrons	0.03	2	0.17	0.02	2
		Petrolisthes elongatus	3.31	235	12.94	1.54	16
Echinodermata	Asteroidea	*Patiriella* sp.	0.03	2	0.17	0.02	2
Mollusca	Bivalvia	*Austrovenus stutchburyi*	0.04	3	0.36	0.04	1
		Mytilus galloprovincialis	1.44	102	6.94	0.82	8
		Perna canaliculus	0.03	2	0.17	0.02	2
		Xenostrobus neozelanicus	0.15	11	0.58	0.07	7
	Chitonida	*Chiton glaucus*	0.06	4	0.29	0.03	3
		Sypharochiton pelliserpentis	0.62	44	2.00	0.24	9
	Gastropoda	*Atalacmea fragilis*	0.01	1	0.12	0.01	1
		Austrolittorina antipodum	25.49	1810	87.00	10.33	24
		Austrolittorina cincta	0.59	42	3.04	0.36	10
		Buccinulum linea	0.20	14	0.73	0.09	6
		Cellana ornata	0.46	33	2.98	0.35	6
		Cellana radians	1.10	78	5.50	0.65	12
		Cominella virgata	0.04	3	0.20	0.02	3
		Diloma nigerrimum	8.93	634	28.02	3.32	15
		Haustrum haustorium	0.01	1	0.12	0.01	1
		Lepsiella scobina	0.18	13	0.99	0.12	5
		Diloma aethiops	8.55	607	20.66	2.45	28
		Notoacmea sp.	0.30	21	1.41	0.17	4
		Onchidella nigricans	0.08	6	0.33	0.04	5
		Patelloida corticata	0.01	1	0.12	0.01	1
		Siphonaria australis	0.03	2	0.24	0.03	1
		Zeacumantus subcarinatus	0.06	4	0.29	0.03	3
		Diloma bicanaliculatum	0.01	1	0.12	0.01	1
		Benhamina obliquata	0.07	5	0.43	0.05	2
Platyhelminthes	Platyhelminthes	*Notoplana australis*	0.01	1	0.12	0.01	1
Polychaeta	Aciculata	*Glycera americana*	0.01	1	0.12	0.01	1
	Canalipalpata	*Scolecolepides benhami*	0.01	1	0.12	0.01	1
		TOTAL COUNT					**37**

The barnacle *C. columna* was found on all stable substrates, and thus was present in epifauna quadrats that were dominated by any substrate type larger than gravel (Figure 16). The species was also greatly influenced by tidal level, being more abundant in the mid to low tide zone, and much less abundant in the high tide zone (Figure 16). The next most abundant taxon, the blue-banded periwinkle *A. antipodum* was most abundant in the high and mid tide zones, followed by the above high tide zone, but was absent from the low tide samples and showed a preference for bedrock and concrete substrates (Figure 17).

The community composition along the surveyed area was as would be expected for this general location (lower North Island) and rocky shore intertidal habitat (Smith, 2013). No taxa that are indicative of significant nutrient enrichment or fine sediment input were present in any great abundance, with tidal zone and substrate seeming to be the main factors influencing the communities of this area. No invertebrate taxa of conservation concern (as listed in the threatened species list of Freeman *et al*. (2014)) were recorded from the project area.

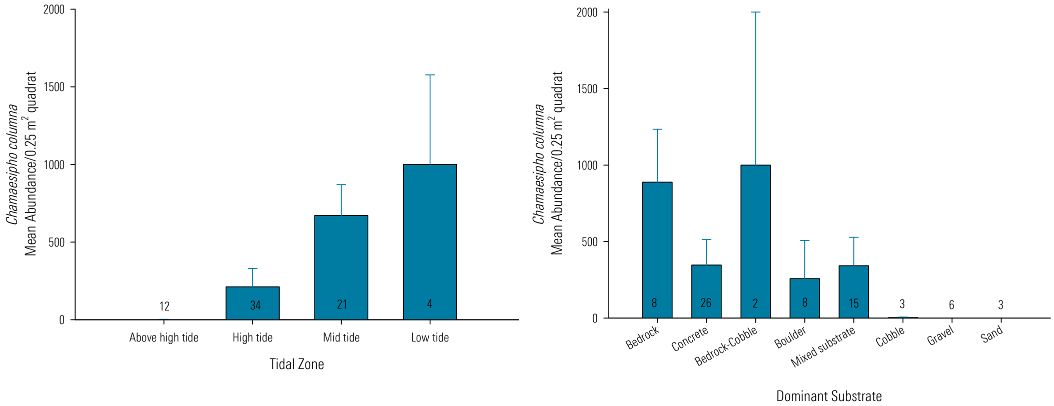


Figure 16 Mean abundance of the barnacle *Chamaesipho columna* with reference to tidal zone and dominant substrate type. Error bars are one standard error. The numbers on each bar represent the sample size for each category. Surveys undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

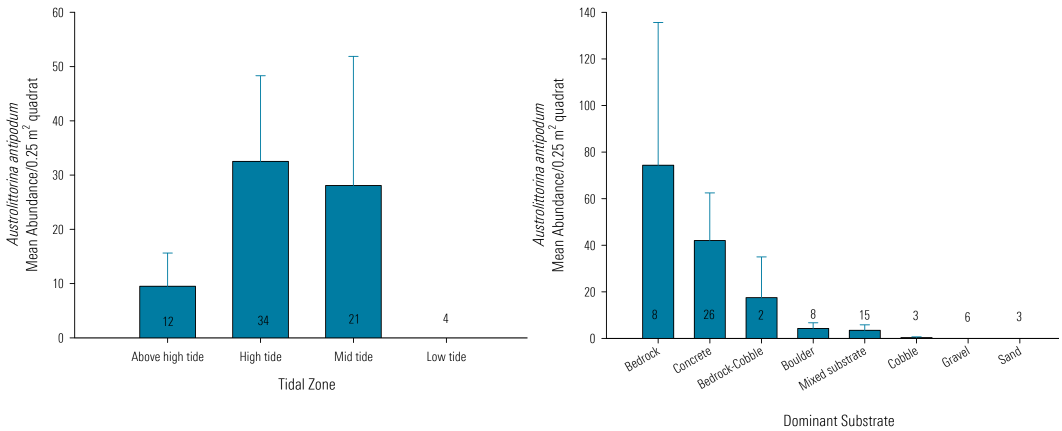


Figure 17 Mean abundance of the blue-banded periwinkle *Austrolittorina antipodum* with reference to tidal zone and dominant substrate type. Error bars are one standard error. The numbers on each bar represent the sample size for each category. Surveys undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Tidal Zone

Taxa richness and density increased along a gradient from above high tide to low tide (Figure 18). Very few taxa or individual animals were found in the above high-tide zone (Figure 18). There were significant differences in community composition across tidal zones (ANOSIM Global R=0.11, p=0.006), however with a Global R value near zero there is only a very weak separation among the tidal zone sample groups in terms of community composition. This is primarily the result of so many quadrats having no or very few taxa present, hence there are no distinct groupings or gradients on the NMS plot (Figure 19). Pairwise tests showed significant differences between high and mid tide zones (R=0.07, p=0.049), high and above high tide zones (R=0.13, p=0.041), mid and above high tide zones (R=0.29, p=0.001), and low and above high tide zones (R=0.24, p=0.007). More individuals of the barnacle *C. columna*, the limpet *C. radians*, the spotted topshell *D. aethiops,* and the porcelain crab *P. elongatus* were found lower down the shore, whereas individuals of the bluish top shell snail *D. nigerrimum* and the blue-banded periwinkle *A. antipodum* were more abundant in the high tide zone samples.

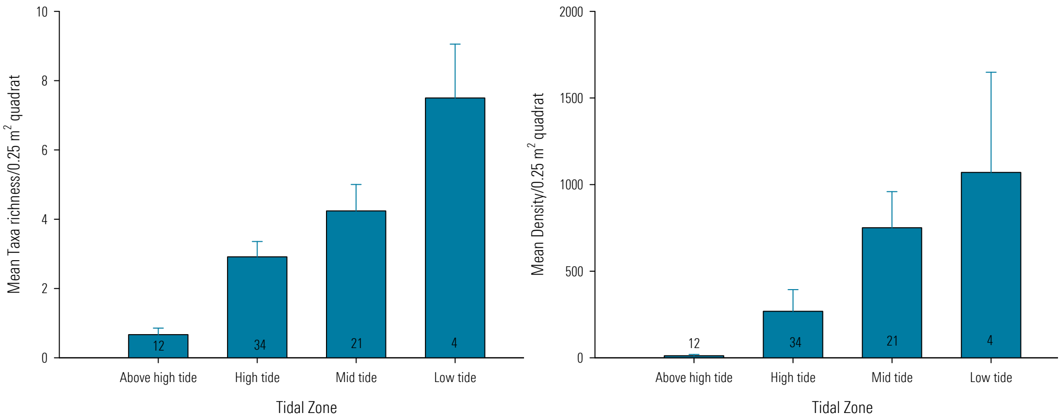


Figure 18 Taxa richness and density of all epifauna quadrats plotted against tidal zone. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

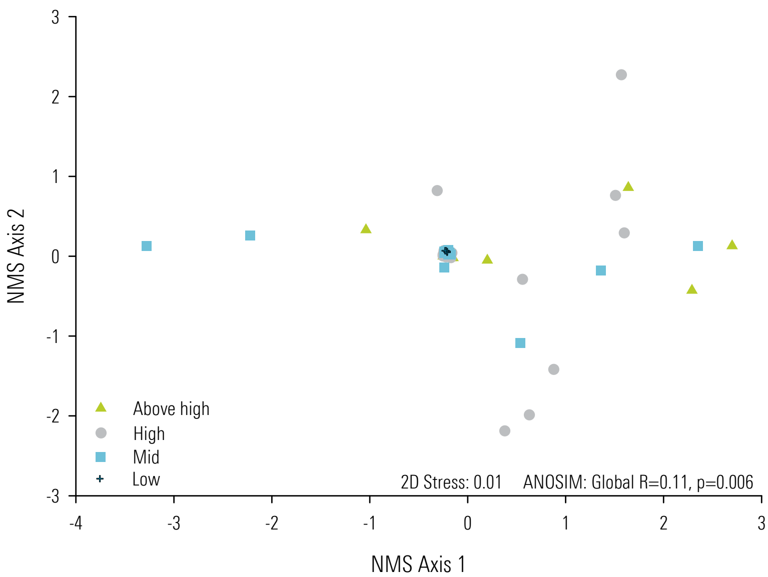


Figure 19 An NMS plot of tidal zone epifauna composition for the epifauna quadrats surveyed in the project area by EOS Ecology on 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Substrate

Larger, stable substrates (i.e., all sampled substrates except gravel and sand) tended to have higher taxa richness and densities (Figure 20). There was a lot of variability among these larger substrates as shown by the large error bars on Figure 20. The three sand samples and four of the gravel samples had no epifauna taxa present, with the other two gravel samples having only two taxa and two individuals present (an amphipod and a copepod). In the remaining substrate types there was a large variation in density between sites, indicating that substrate type as assigned here was not a significant deciding factor for density. Taxa richness was higher in quadrats with greater substrate diversity, however density was similar among the five levels of substrate diversity with the exception of those quadrats with three types of substrate, in which densities were lower (Figure 20). There is no ecological reason for this and this disparity is likely due to the vagaries of sampling. The high density of the barnacle *C. columna* at some sites was also responsible for the larger overall densities recorded from some of the samples (Figure 20).

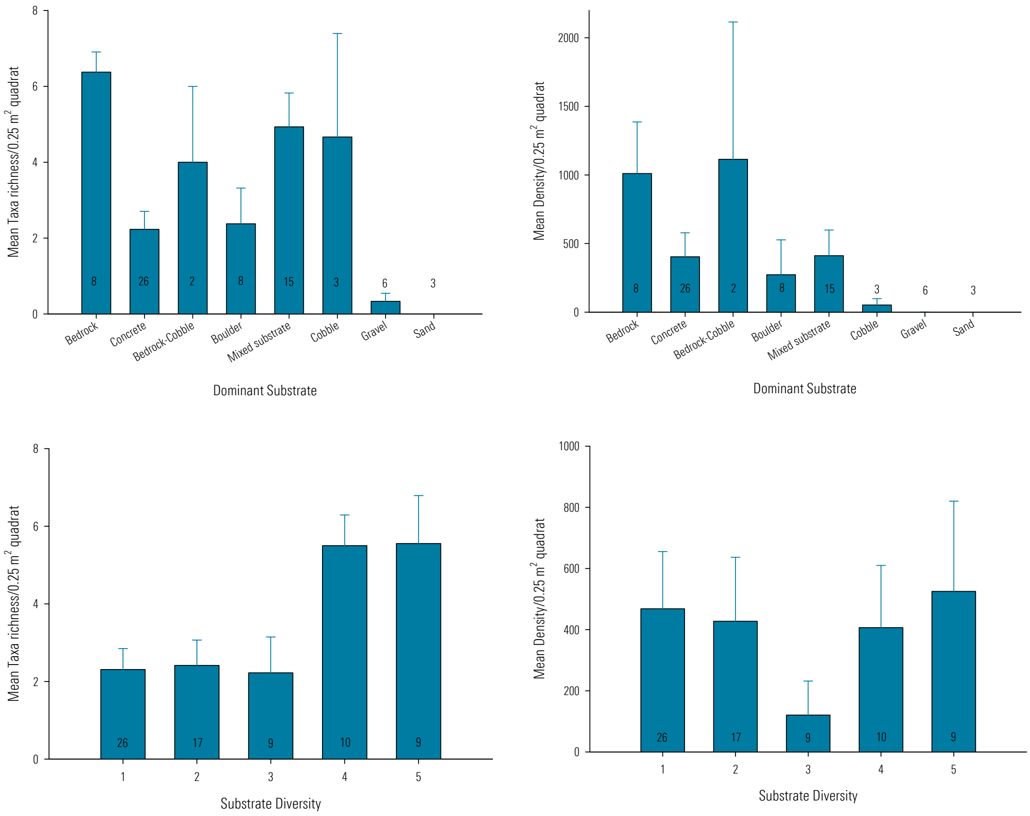


Figure 20 Mean taxa richness and density of all epifauna quadrats plotted against dominant substrate type and substrate diversity. Error bars are one standard error. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Seawall versus harbour floor

There was some difference in taxa diversity and density between epifauna quadrats collected from the surface of the seawall and other areas of intertidal habitat, with both taxa richness and density lower on the seawalls than they were in other sampled areas of intertidal habitat (although the large error bars indicate that there may be few statistically significant differences) (Figure 21). There was also a significant difference in community composition between samples collected from the seawall versus other intertidal habitat (i.e. harbour floor) (ANOSIM Global R=0.08, p=0.003), however the very low Global R value is indicative of very weak separation among sample groups. Harbour floor samples had higher densities of the barnacle *C. columna*, the snails (*D. aethiops* and *D. nigerrimum*), and the porcelain crab *P. elongatus*, with more of the blue-banded periwinkle *A. antipodum* on the seawall.

However, as the tidal level is a significant influencing variable on community composition, diversity and density, and is a confounding variable when comparing samples between the seawall and other areas, further analysis of community composition was undertaken on those epifauna quadrats collected from within the high tide zone only (as this was the only tidal height to span both harbour floor and seawall). When looking within this one tidal range there was no significant difference (ANOSIM Global R=0.01, p=0.338) in community composition between seawalls and other areas of habitat (Figure 22). This indicates that tidal location has a stronger influence on community composition than the seawall type per se.

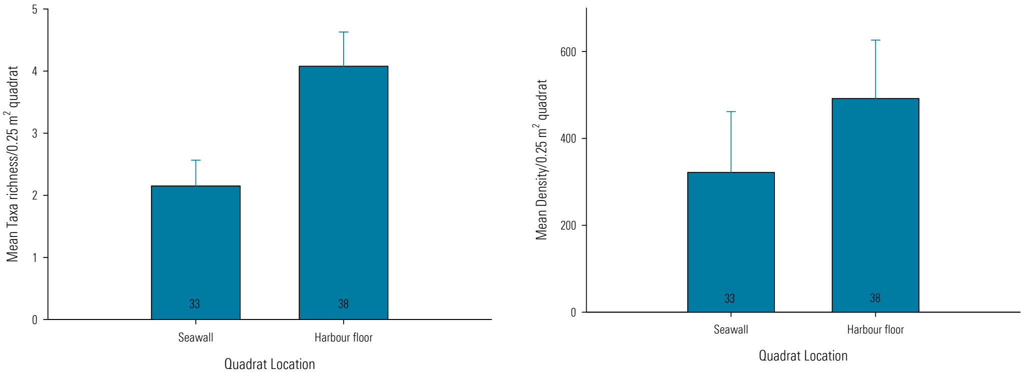


Figure 21 Mean taxa richness and density of all epifauna quadrats plotted against seawall versus other intertidal samples (harbour floor). Error bars are one standard error. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

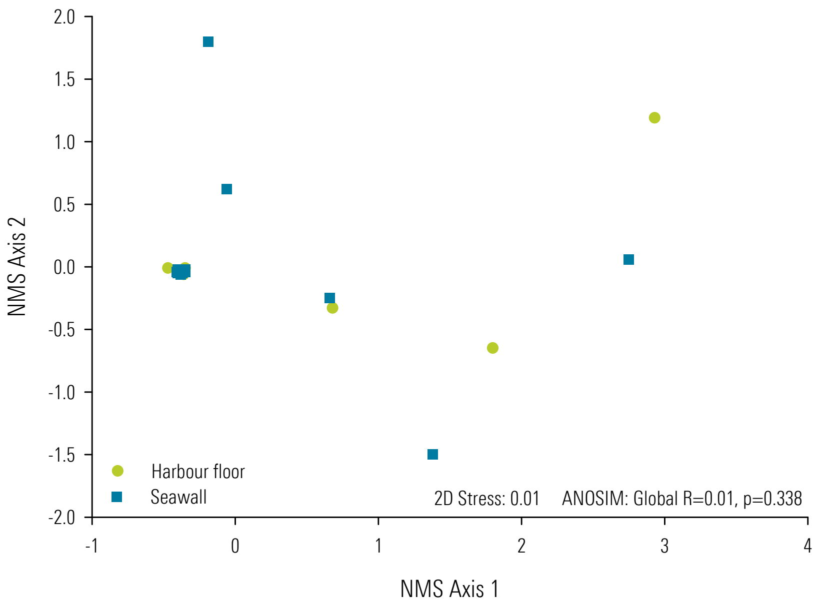


Figure 22 An NMS plot of epifauna composition between seawall and other habitat (harbour floor on the graph) within the high-tide zone, as surveyed in the project area by EOS Ecology on 4-6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Existing seawall types

There was some difference in taxa richness and density between the existing seawall types. Taxa richness tended to be higher on "revetment" and "concrete-smooth curved" types (although on average only had three or four taxa, respectively) and least on the "concrete-smooth" type (Figure 23). Densities were clearly higher on the three concrete seawall types than on revetments, although there was high variability among samples as shown by the large error bars on Figure 23. There were no significant epifaunal community composition differences among the existing seawall types (ANOSIM Global R=0.01, p=0.422) (Figure 24).

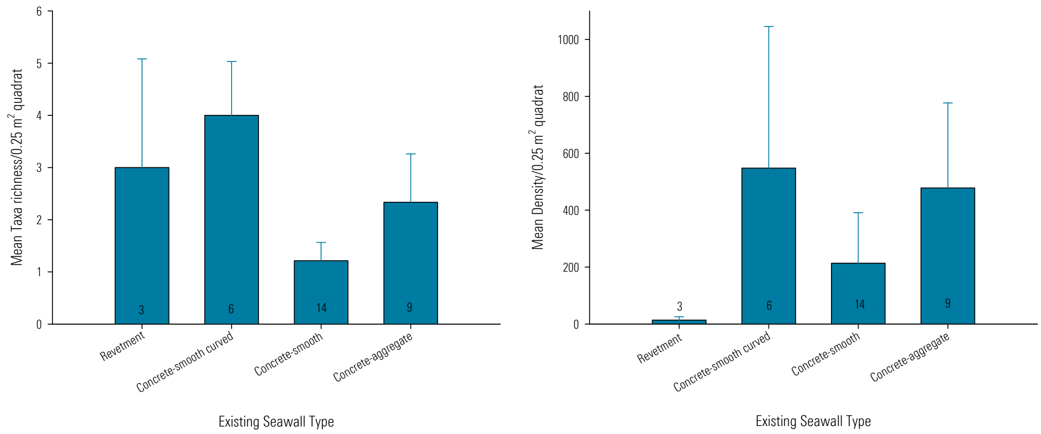


Figure 23 Mean taxa richness and density of all epifauna quadrats versus existing seawall types. Only samples collected from seawalls are included. Error bars are one standard error. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

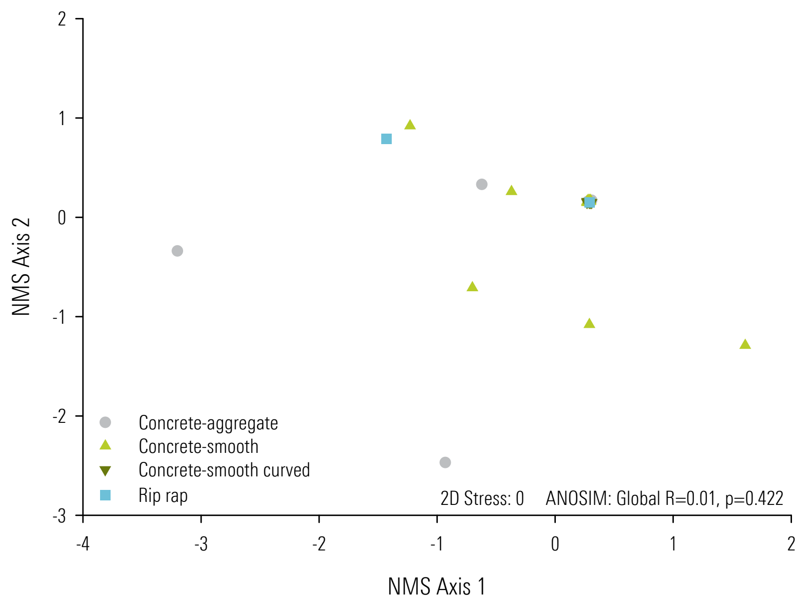


Figure 24 An NMS plot of epifauna composition between existing seawall type areas, as surveyed in the project area by EOS Ecology on 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29). Only samples collected from seawalls are included.

Future impact and control areas

A comparison was made between those surveyed sites that were within areas proposed to be changed as a result of the planned seawall upgrade (i.e., future impact sites) and those within areas where the seawall will not be altered (i.e., future control sites). Of the impact sites (sites where replacement of seawalls is proposed), taxa richness was less at the future impact sites compared to the future control sites for both seawall and harbour floor samples (Figure 25). However, for density, control sites were lower than impact sites for seawall and harbour floor samples. Note the large error bars, which are indicative of substantial variation among samples and mean that there is unlikely to be a significant difference where these error bars overlap.

There was no significant difference in terms of community composition between samples collected from the future control and impact sites (ANOSIM Global R=-0.01, p=561) (Figure 26).

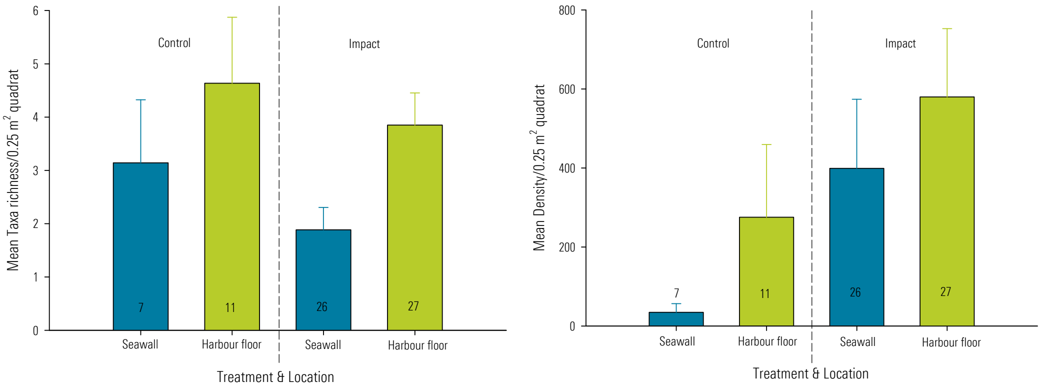


Figure 25 Mean taxa richness and density of all epifauna quadrats plotted against future impact and control sites. Samples collected within these areas from the seawall itself versus the wider intertidal area (harbour floor) have been separated for clarity. Error bars are one standard error. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

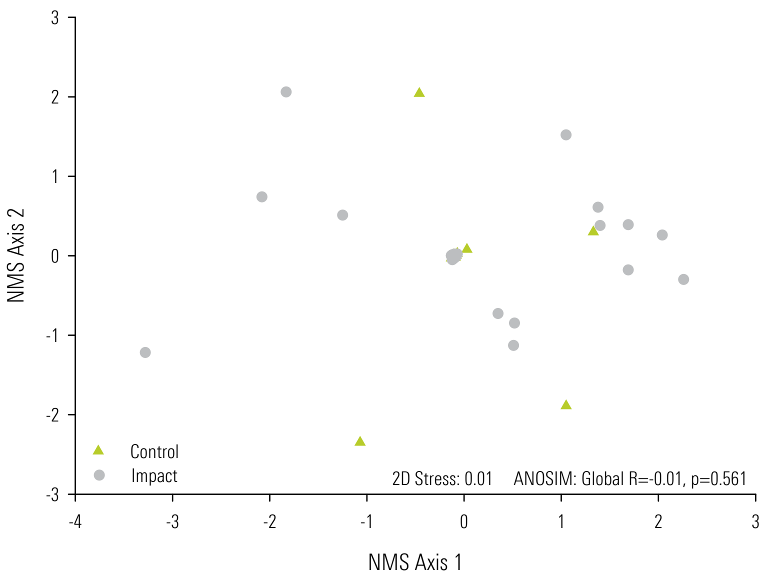


Figure 26 An NMS plot of epifauna composition between future impact and control sites, as surveyed in the project area by EOS Ecology on 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

Because of the larger footprint of the proposed revetment option, a further comparison was made between those epifauna quadrats collected within the footprint of proposed revetments and outside of this footprint. Because revetment treatments are only proposed for rocky shore areas (or at least areas containing larger substrate types) only areas with similar substrate types were included in this analysis (i.e. no gravel/sand beach areas were compared). Similarly, those epifauna samples collected within rocky shore areas but on the existing concrete seawalls were excluded so as to concentrate on the rocky shore habitat only. Taxa richness and taxa density were both lower in samples collected within the footprint of the proposed revetments compared to control areas for rocky shore habitats, although there was significant within-treatment variation for mean taxa density (Figure 27).

There was no significant difference in terms of community composition between samples collected within or outside of the revetment footprint within rocky shore habitats (ANOSIM Global R=0.155, p=0.089) (Figure 28).

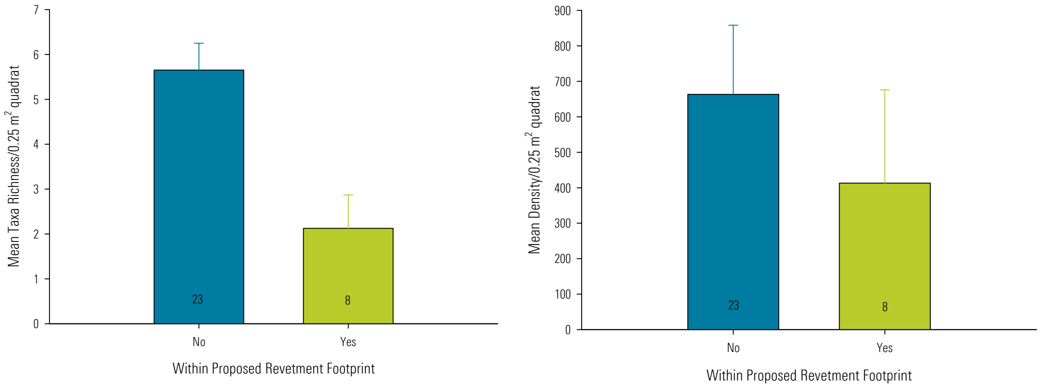


Figure 27 Mean taxa richness and density of those epifauna quadrats in rocky shore environments within or outside of the footprint for the proposed revetment seawall types. Error bars are one standard error. Numbers within bars denote the number of epifauna quadrats within that category. Surveys were undertaken by EOS Ecology on the 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

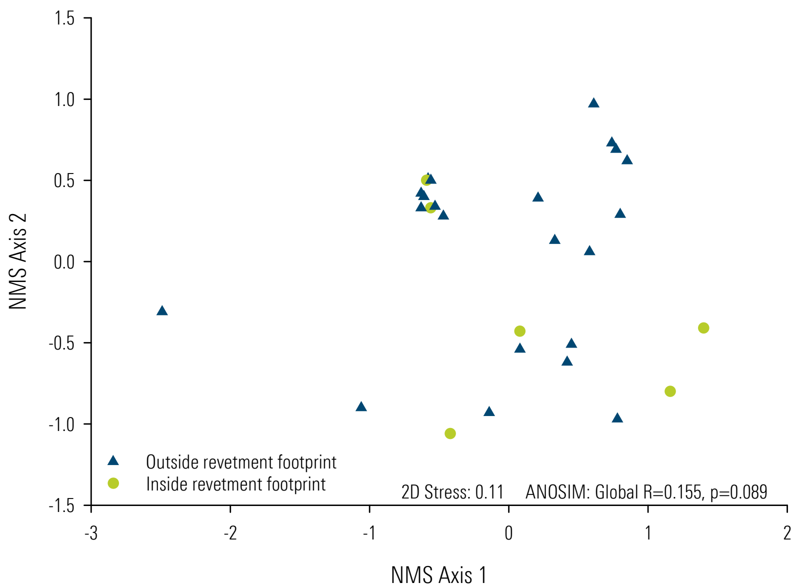


Figure 28 An NMS plot of epifauna composition between future revetment and control sites in rocky shore areas, as surveyed in the project area by EOS Ecology on 4–6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29).

3.4.2 Infauna

In general there were few areas within the project area where it was possible to collect core samples to assess the infaunal community, meaning that only eight samples in total were able to be collected. A total of 28 invertebrate taxa were identified from the eight infauna samples collected within the study area (Appendix 4). Of these, the polychaete *Aonides* sp. and amphipods (Gammaridae) were the most widespread taxa, being found in five of the eight infauna samples. These were followed by the pipi *Paphies australis* and the polychaete *Nereididae*, which were both found in three of the eight samples. Two polychaete taxa (*Aonides* sp. and *Prionospio* sp.) were the most abundant taxa, making up 27% and 22% of overall abundance, followed by gammarid Amphipoda (21% overall abundance). Each of the remaining 25 taxa made up less than 10% of total abundance.

The polychaetes *Aonides* sp. and *Prionospio* sp. have relatively broad habitat preferences, although *Aonides* is generally found in greater numbers in sandy substrates, and both are intolerant of mud content higher than 70-80% (with an optimum range of 0-5%; Needham *et al.,* 2014). Similarly, gammarid amphipods are generally found in areas with very coarse sediment and low mud content. *Aonides* in particular is a useful indicator of pollution as they are sensitive to copper, which is a contaminant often associated with stormwater discharges. Its dominance in the infauna community indicates that the infaunal habitat is in good condition.

Of the sites sampled, one site (Site 16) is located within an area that will not change with the proposed seawall upgrade, whereas the remaining samples were from areas where there are proposed changes to be made to the seawall.

3.4.3 Mahinga kai invertebrate species

A number of shellfish of potential value as mahinga kai were observed during the epifauna surveys, including (in order of occurrences) blue mussel (*Mytilus galloprovincialis;* sighted on 15 occasions), black mussel (*Xenostrobus neozelanicus;* sighted on 10 occasions), greenshell mussel (*Perna canaliculus;* sighted on nine occasions), pipi (*Paphies australis*; sighted on five occasions), and tuangi cockle (*Austrovenus stutchburyi* (sighted on three occasions) (Table 8). Clusters of mussels (mostly blue mussel, with some black mussel) were found between the mid–low tide zone along the project area where bedrock outcrops were present and attached to some rough seawall surfaces (Figure 29).

Both pipi and tuangi cockle found in these areas were small and sparsely distributed so would be difficult to collect and for little gain. It is possible that better conditions for both these species exist further into the subtidal zones of the bays surveyed.

There were some remains of rock oyster (*Saccostrea glomerata*) found on rocks during the epifauna surveys, and small shells of paua (*Haliotis iris* and *Haliotis australis*) seen along the strand line, but no live animals were found. There could be a number of reasons for the absence of any live rock oysters, such as predation/collecting, or that the search area was at the upper limit of the habitat range for this species. Live paua would naturally be limited to the subtidal zone, which is outside of the search area and project footprint.

During site visits and field surveys, people were observed collecting cockles in Lowry Bay. The discarded remains of a range of marine food species were also present at the promontory areas separating Days Bay and Sunshine Bay, Sunshine Bay and Mahina Bay, Mahina Bay and York Bay, and Windy Point (Figure 30). This included kina (*Evechinus chloroticus*), paua (*Haliotis iris* and *Haliotis australis*), greenshell mussel (*P. canaliculus*), tuangi cockle (*A. stutchburyi*), catseye (*Lunella smaragda*), turban shell (*Cookia sulcata*), and scallop (*Pecten novaezelandiae*). While these may have been dumped at these locations from people returning from further afield, it is likely that at least some of these would have come from food gathering from the Eastern Bays area. Greenaway & Associates (2019) reports on management for recreational fishing and shellfish gathering within the Wellington Harbour and notes that Sorento Bay has been non-compliant for recreational shellfish gathering water quality guidelines for *E. coli* levels during 2017. With the exception of cockles that were observed in the low tide area of NE Lowry Bay, the majority of these species would be found in the subtidal zone.

Table 8 **The number of occasions that mahinga kai species were observed during the epifauna surveys or in infauna samples collected during surveys by EOS Ecology on the 4–6 May 2016, including the sites and bays in which they were recorded.**

Common name	Scientific name	No. occasions sighted	Sites recorded at	Bays recorded at
Blue mussel	*Mytilus galloprovincialis*	15 (7 free search, 8 epifauna)	1, 3, 7, 11, 12, 17, 18, 19, 20, 21, 22, 26, 28, 29	All
Black mussel	*Xenostrobus neozelanicus*	10 (3 free search, 7 epifauna)	3, 12, 13, 16, 21, 23, 27, 28, 29	Sorrento, Lowry, York, Mahina, Sunshine, Days
Greenshell mussel	*Perna canaliculus*	9 (7 free search, 2 epifauna)	10, 11, 13, 16, 17, 21, 22, 27, 29	Sorrento, Lowry, York, Sunshine, Days,
Pipi	*Paphies australis*	5 (2 free search, 3 infauna)	4, 11, 13, 16	York, Mahina
Tuangi cockle	*Austrovenus stutchburyi*	3 (1 epifauna, 1 free search, 1 infauna)	10	Lowry

Mussels in the mid–low tide zone

Mussels attached to the base of a Lowry Bay seawall

Figure 29 **Clusters of the blue mussel found within the project area.**


Found on promontory between Sunshine and Mahina Bay. Found on promontory between Mahina and York Bay.

Empty shells at Windy Point, at the northern end of Eastbourne.

Figure 30 Photographs of discarded shellfish and kina observed along the shoreline during surveys undertaken by EOS Ecology on the 3-6 May 2016 and 8–9 June 2017.

3.4.4 Macroalgae

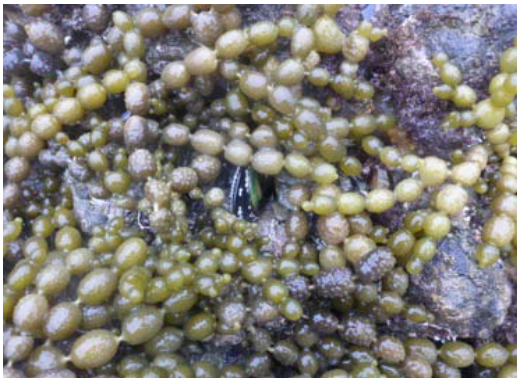
Macroalgae were generally not extensive within the 71 surveyed epifauna quadrats, with only 11 samples that included algae in the intertidal zone. Within these samples coverage was low, with only between 2 and 12% coverage confined to the permanent substrate types (bedrock and concrete) (Table 9, Figure 31). The most common algae recorded between the high–low tide zones were *Ulva* spp., although these were only found in seven of the 71 epifauna quadrats. Other macroalgae present included *Carpophyllum* (flapjack), *Corallina* (red, erect coralline) and *Hormosira banksii* (Neptune's necklace) (Figure 28).

Table 9 Macroalgae coverage (percentage) found in epifauna quadrats as surveyed by EOS Ecology on the 4–6 May 2016 and 8–9 June 2017. Coverage of macroalgae is determined by the proportion of intersections macroalgae is present across the 49 intersections within the quadrat. Site locations can be seen in Figure 4.

Location	Site No.	Quadrat No.	Tidal zone	Seawall or harbour floor	Dominant substrate	Coverage (%) across the quadrat					
						Gracilaria chilensis	*Ulva* sp.	*Carophyllum*	*Corrallina*	*Hormosira banksii*	*Bryopsis*
York Bay	3	1	High	Seawall	Concrete			2			
York Bay	3	2	Low	Harbour floor	Mixed					12	
York Bay	4	1	High	Seawall	Concrete		12				
Sorrento Bay	7	2	Mid	Harbour floor	Bedrock				2		
Days Bay	18	2	High	Seawall	Concrete		2				
Days Bay	20	3	Mid	Harbour floor	Mixed		2				6
Sunshine Bay	23	3	Mid	Harbour floor	Mixed		12				
Lowry Bay	27	3	Mid	Harbour floor	Bedrock					2	
Lowry Bay	28	2	Mid	Seawall	Concrete		22				
Sorrento Bay	29	2	High	Seawall	Concrete		5				
Sorrento Bay	29	3	Mid	Harbour floor	Bedrock	2	6				

Sea lettuce (*Ulva* sp.) at the base of a seawall.

Bryopsis present in mixed substrate at the southern end of Days Bay (Site 20, quadrat 3).



Neptune's necklace (*Hormosira banksii*).

Extensive coverage of macroalgae on the seawall at Lowry Bay, includes *Ulva* sp., *Gracilaria* and *Corrallina*.

Coralline algae (*Corallina*) in a rock pool.

A camouflage crab uses coralline algae as cover.

Figure 31 **Photographs of the macroalgae present in the intertidal zones of the Eastern Bays during surveys undertaken by EOS Ecology on the 3-6 May 2016 and 8–9 June 2017.**

Large beds of macroalgae were observed in the subtidal zone, outside the survey area and Wellington Harbour is known for its significant *Macrocystis* (kelp) beds (EHEA, 1998, MacDiarmid *et al.*, 2012, GWRC, 2015). The absence of kelp was able to be substantiated for the shallow subtidal area of north Lowry Bay where the construction footprint is proposed to extend (refer to Figure 38in later sections), as this was assessed via underwater viewer on the 26 July 2018. A shallow subtidal (up to 0.6-0.8 m deep at low tide) survey by Overmars (2019) for seagrass also confirmed the absence of kelp in Point Howard Beach, mid-south Lowry Bay and York Bay. Thus whilst a full subtidal survey was outside the scope of this intertidal ecology report, we can at least substantiate that kelp beds are not in the nearshore shallow subtidal areas of Point Howard Beach, Lowry Bay and York Bay. We do not believe that there are any significant kelp beds within the subtidal area of the project footprint (which includes the construction footprint for the seawalls[1]), on the basis of this information and given that there are only small areas of near-shore subtidal zone that the project footprint extends to within Lowry, Mahina and York Bays (Figure 38 in later sections) and the kelp beds grow at depths of three meters or more in Wellington Harbour (EHEA, 1998).

3.4.5 Comparison of Intertidal Ecology with the wider Wellington Harbour

A number of studies have investigated the intertidal ecology of Wellington Harbour; Bolton-Ritchie (2003) investigated the benthic ecology of inner Wellington Harbour (Lambton Harbour and Evans Bay); Lachowicz (2005) looked at the population of the three mussel species within Wellington Harbour; Palmer (2010) studied the role of the cushion star in intertidal cobble fields in Wellington Harbour; Tam (2012) investigated differences in intertidal assemblages between Cook Strait and Wellington Harbour, Stevens *et al.* (2004) collected infauna cores at Lowry Bay and Boffa Miskell (2015) produced a report containing results of a survey of intertidal ecology between Lower Hutt and Ngauranga. Tam (2012) provides the most extensive list of intertidal taxa for Wellington Harbour from sites in Evans Bay, Lambton Harbour, Seatoun and Inconstant Point; the latter two being most similar to the environments in this study. A total of 24 of the 44 invertebrate taxa we found in the eipfauna samples and free search were also listed in Tam (2012), who undertook a study of intertidal habitats within Cook Straight and Wellington Harbour. While Lachowicz (2005) focuses on the three species of mussels (*Perna canaliculus*, *Mytilus galloprovincialis* and *Aulacomya maoriana*), other rocky shore taxa are mentioned, many of which were also found in the Eastern Bays sites. Similarly, in the thesis by Palmer (2010), the focus species was the cushion star (*Patiriella* spp.) but other taxa were mentioned including mussels (*M. galloprovincialis* and *P. canaliculus*), and the barnacle *Chamaesipho columna*, which also dominated the intertidal epifauna samples from the Eastern Bays sites. Boffa Miskell (2015), in the intertidal surveys of an area between Lower Hutt and Ngauranga, similarly found an abundance of the barnacle *C. columna*, along with the little black mussel (*Xenostrobus neozelanicus*), two limpets (*Cellana ornata* and *Patelloida corticata*) and an unidentified whelk species. These species were all found across the sites in the project area. Of the infauna samples, our survey found six of the 17 invertebrate taxa recorded in Stevens *et al.* (2004).

In general, the intertidal ecology of Wellington Harbour has been found to fit the universal pattern of zonation as described by Stephenson & Stephenson (1949), Lachowicz (2005) and Tam (2012). This

1 Note that beach nourishment is not covered in this report. See McMurtrie & Brennan (2019) for potential effects of beach nourishment of subtidal beach areas.

concept generalises the types of organisms that inhabit the different tidal zones (high, mid, low) of a rocky shoreline based on the organisms' habitat requirements. Both Lachowicz (2005) and Tam (2012) refer to this universal zonation pattern and how it fits with Wellington Harbour. The zonation pattern described, which fits with the results from this survey, has snails in the high tide zone; mussels, barnacles and limpets in the mid tide zone; and macroalgae in the lower tidal zone. Ellis (2003) suggests using this zonation pattern as a measure of biodiversity recovery by having it represent the state of equilibrium following a disruption of the shoreline.

3.5 Sediment Contamination

Due to the input of urban and industrial stormwater runoff into Wellington Harbour, both historically and currently, contamination of sediments by heavy metals has been found to exceed a number of sediment quality guidelines, in particular in Evans Bay and Lambton Harbour (Stoffers *et al.,* 1986; Dickinson *et al.,* 1996; Pilotto *et al.,* 1998, Bolton-Ritchie, 2003; Stephenson *et al*., 2008; Oliver, 2013). Compared with sites in the main basin of Wellington Harbour, the studies have found surface sediments of these areas to contain elevated levels of heavy metals, particularly copper, lead and zinc. MWH (2003) and Bolton-Ritchie (2003) determined that there is a negative correlation between sediment heavy metal concentration and distance from a stormwater outlet.

There have been limited studies looking at sediment contamination of the intertidal area of the Eastern Bays. Stevens *et al.,* (2004) collected sediment samples from two intertidal sites (with three replicates per site) within Lowry Bay, and found them to be relatively free of contaminants (Table 10). They found that while there was a slight trend for both nutrients and heavy metals to be slightly enriched in the lower beach samples versus the high beach samples, the levels overall were not high. Levels of heavy metals (cadmium, chromium, copper, lead, nickel, and zinc) were all well below the ANZECC (2000) ISQG-low trigger levels, as well as the Auckland Council's more conservative Environmental Response Criteria for copper (<19 mg/kg), lead (<30 mg/kg) and zinc (<124 mg/kg) (ARC, 2004)(Table 10). They concluded that there was no sign of sediment contamination or sediment enrichment.

Heavy metals are typically bound to fine sediment particles and accumulate in sheltered areas. The intertidal zone of the Eastern Bays is relatively exposed for Wellington Harbour and experiences a dynamic and sometimes high energy hydrologic regime. During the site walkover and the site surveys we did not come across any depositional zones for fine sediment, with any fine sediment (mainly fine sand) limited to patches between substrate. These factors, combined with the fact that there is limited urban development in the area that discharge into these Eastern Bays, mean that it is probable that all of the bays within the Eastern Bays area have low sediment contaminant levels.

In comparison, testing of sediment contamination in two intertidal samples along the Hutt Road bordering the north-west side of Wellington Harbour by Boffa Miskell (2015) showed higher levels of copper (13.9-17.5 mg/kg) and lead (15-15.3 mg/kg) and similar levels of zinc (59-86 mg/kg) when compared to those found by Stevens *et al.* (2004) in the Eastern Bays area (Table 10). The higher concentrations (particularly for copper and lead) recorded for the intertidal area along Hutt Road is likely reflective of the larger urbanised catchment that discharges to the coastal environment in that area.

Table 10 Results from Stevens *et al*. (2004) for particle size (% wet weight), heavy metal (mg/kg) and nutrient (mg/kg dry) contamination in sediment samples collected from two sites within Lowry Bay. The ANZECC (2000) ISQG low/high and the Auckland Council's Environmental Response Criteria lowest 'green' (AC ERC) values have been added for comparison.

Variable	ANZECC low/high trigger	AC ERC	Rep 1	Rep 2	Rep 3	Mean	1 SD	Rep 1	Rep 2	Rep 3	Mean	1 SD
Ash free dry weight			0.9	0.7	0.9	0.8	0.1	1.2	1.3	1.3	1.3	0.1
Mud <63 µm			1.0	0.4	1.1	0.8	0.4	1.1	0.7	1.1	1.1	0.2
Sand <2mm			99.0	99.0	98.9	99.0	0.1	98.3	68.4	98.9	98.9	17.4
Gravel >2mm			<0.1	0.6	<0.1	0.2	0.3	0.7	30.9	<0.1	<0.1	17.6
Cadmium	1.5/10		<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	-
Chromium	80/370		5.8	5.0	5.4	5.4	0.4	7.1	6.2	6.0	6.4	0.6
Copper	65/270	<19	2.5	2.5	2.6	2.5	0.1	3.1	3.4	2.7	3.1	0.4
Lead	50/220	<30	15	7.9	7.9	10.3	4.1	9	12	9.5	10.2	1.6
Nickel	21/52		4.4	3.8	4.2	4.1	0.3	5.3	4.5	4.5	4.8	0.5
Zinc	200/410	<124	60	56	61	59.0	2.6	69	64	66	66.3	2.5
Total Nitrogen			190	140	170	166.7	25.2	230	140	190	186.7	45.1
Total Phosphorus			193	155	184	177.3	19.9	227	197	198	207.3	17.0

4 OVERVIEW OF DESIGN AND CONSTRUCTION METHDOLOGY

4.1 Proposed Seawalls and Shared Path Concept

According to the Design Features Report (Stantec, 2019a) the Eastern Bays Shared Path Project focuses on improving the connection and safety for pedestrians and cyclists as well as improving future resilience of the road and underground services along Marine Drive, Eastbourne between Point Howard and the northern end of Days Bay, and the southern end of Days Bay (Windy Point) to Eastbourne (Muritai Road / Marine Parade intersection). Seawalls already exist along 87% of the project length (Figure 6), however, most do not allow space for a shared path next to the road and many are not deemed acceptable to provide a safe barrier against storm surges into the future. Of the 13% (0.6 km) of the project length without an existing seawall, 52% (0.3 km) will remain without a seawall. This 0.3 km length remaining unchanged and without a seawall can be added to an additional 1 km of the project length that will also remain unchanged but already has a seawall. Therefore a total project length of 1.3 km (29%) will contain no seawall works, including the newly built curved seawall in York Bay, and existing revetment in southern Sunshine Bay (Figure 34). The 300 m section of relatively new curved (constructed in 2007-2008) seawall in York Bay already provides for a shared path that is consistent with the current designs, and is in good condition, so will remain. These seawalls and shared path areas are good examples of what the future replacements will look like (Figure 32).

The current design plans (Stantec, 2018) for the proposed seawalls were determined using multi-criteria analysis (MCA) following three workshops and several site visits by a panel of specialists across a range of disciplines (intertidal ecology, avifauna ecology, terrestrial ecology, coastal processes, landscape and visual, civil design, recreation, planning and consenting, and engagement), with the hierarchy of the selections based on providing for overtopping protection first and foremost, except in Lowry Bay where extra provision was made for intertidal and avifauna ecology. This approach for Lowry Bay was considered appropriate, given the close proximity of the subtidal zone in this area. The scores were differentiated between beach and non-beach areas and the groups' combined scores were weighted based on the disciplines. The preferred wall types were taken to the community for consultation then further expert discussions were undertaken, resulting in the final design plans. Two broad seawall types have been decided on (Figure 33, Figure 34), with minor details varying on a site-by-site basis and specialised designs for the transition zones between two seawall types (such as a revetment to curved seawall) to be further developed during the detailed design phase (Stantec, 2019a).

Excluding the project length where there will be no seawall change, of the proposed seawalls the design plans include (Figure 33, Figure 34):

» Curved concrete seawalls (84%) – double curved (68%), triple curved (7%), single curved (6%) and either double/triple curved (3%)

» Revetment (14%[2])

» Access points (2%)

2 This includes the transition zone from revetment to other seawall type.

At a total length of 2.7 km (or 60 % of the project length), the majority of the proposed seawalls will be curved concrete seawalls (Table 11, Figure 34). Of the two proposed seawall types the curved seawalls represent the smallest additional footprint into the harbour floor/beach areas, ranging from 0.1 m to 3.4 m beyond the toe of the existing seawalls (Table 11). The type of curved seawall is determined largely by height differential between the road surface and the harbour floor, with the double curve being the most common curved seawall type. The single curve wall is only used in southern Lowry Bay where they will form a low verge at the top of the existing beach area. The triple curve wall is proposed where greater shoreline protection is needed, or where there is greater drop down to the harbour floor from the road, at northern Lowry Bay, York Bay and Windy Point. The proportion of the curved seawall that will remain exposed after construction varies based on existing ground conditions and movement of beach gravels, and thus a conservative approach has been taken with the seawall height to ensure that the base of the seawall is not exposed over time (Stantec, 2019a).

The curved seawalls will be enhanced to improve intertidal habitat by being imprinted with a textured pattern during construction. A form liner or void former will be used to create a suitably textured surface (ca. 5 mm in depth) on the vertical curved face, whilst deeper depressions (ca 50 – 70mm in depth) will be formed on the flat step of the curved seawall (Stantec, 2019a) .These textures and depressions will increase surface area and complexity of the seawall providing additional habitat and protection for biota at different tidal zones. Some examples of seawall textures and depressions that have been used overseas are provided in Figure 35. These are indicative only, as the design of these textures will be developed during the detailed design of the seawalls and need to work from an engineering and landscape perspective as well as ecological perspective. Engineering constraints include the impact of drilling into the seawall to attach structures and the depth of depressions on the vertical and flat surfaces that would be possible with the underlying reinforcing structure (Jeremy Walters, Stantec, pers. comm.).

Table 11 Total lineal length and minimum and maximum encroachment distances beyond the existing seawall toe for the proposed seawall types, based on design plans and associated files provided by Stantec on 3 September 2018 (Stantec, 2018).

Seawall type	Total length proposed (m)/proportion of total project length (%)	Minimum encroachment (m)	Maximum encroachment (m)	Location for maximum encroachment
Curved seawall (single, double, triple)	2,650 m (59.6%)	0.1	3.4	Windy Point
Revetment*	430 m (9.8%)	2.0	6.6	Sunshine Bay
Access points (steps and ramps)	64 m (1.4%)	0.8	3.5	York Bay
No change	1,300m (29.2%)	N/A	N/A	

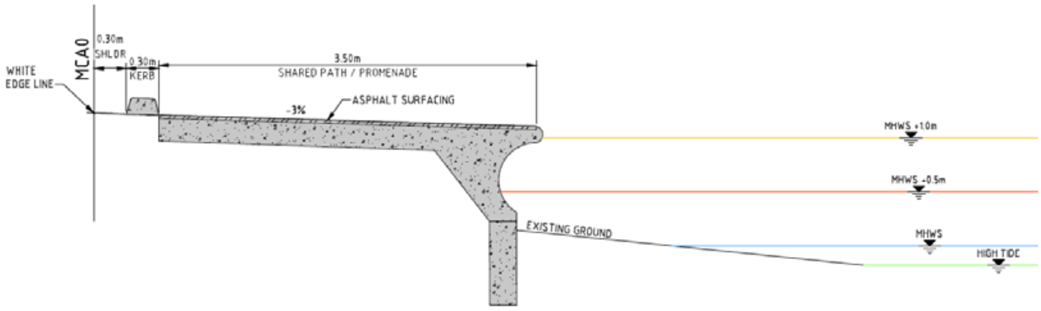
- Includes the transition zone between a revetment and other seawall treatments.


Single curved seawall (York Bay)

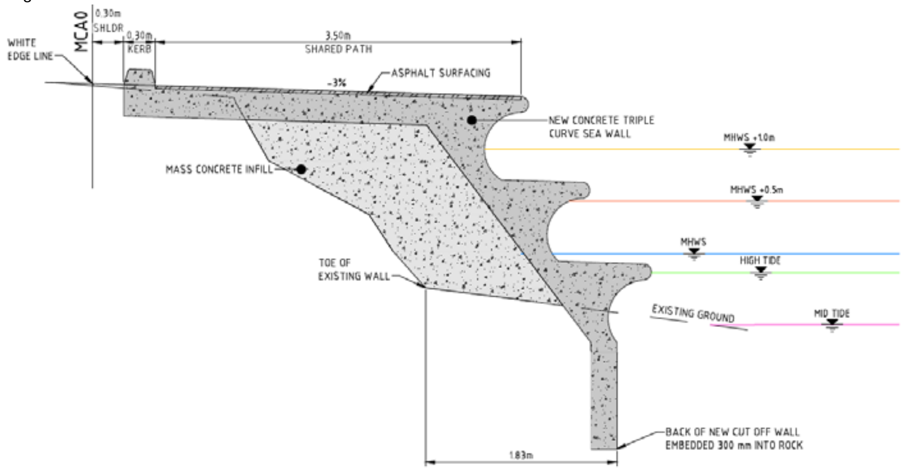

Double curved seawall (York Bay)


Recently constructed revetment seawall (Sunshine Bay)

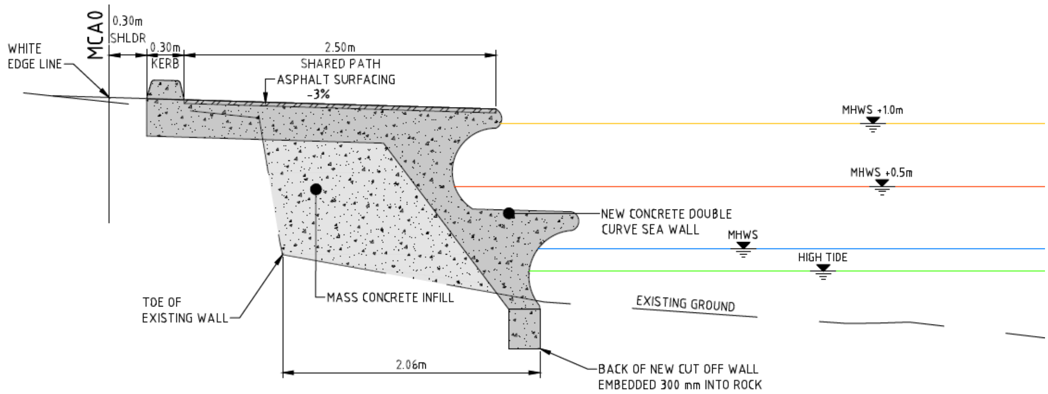
Figure 32 Photographs of the recently constructed single and double curved seawalls, with extended path for shared walking and cycling, which were constructed in 2007-2008, as well as revetment seawalls. These provide reasonable examples of what the proposed single curved, double curved and revetment seawalls would look like.



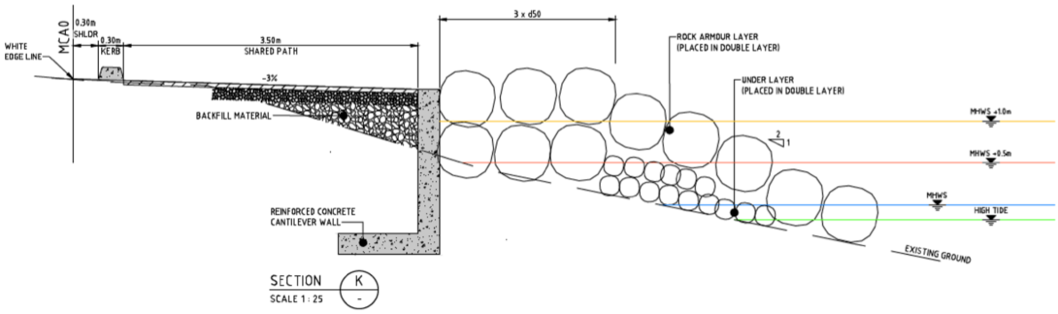
Single curved seawall



Triple curved seawall



Double curved seawall



Revetment

Figure 33 Examples of the designs plans for the proposed wall types for the Eastern Bays Shared Path (Stantec, 2019a) including current and future estimated tide lines for sea level rise of 0.5 and 1m. There will be minor variations on these designs on a site-by-site basis, including the width of the shared path. The tide levels shown are specific to a particular location.

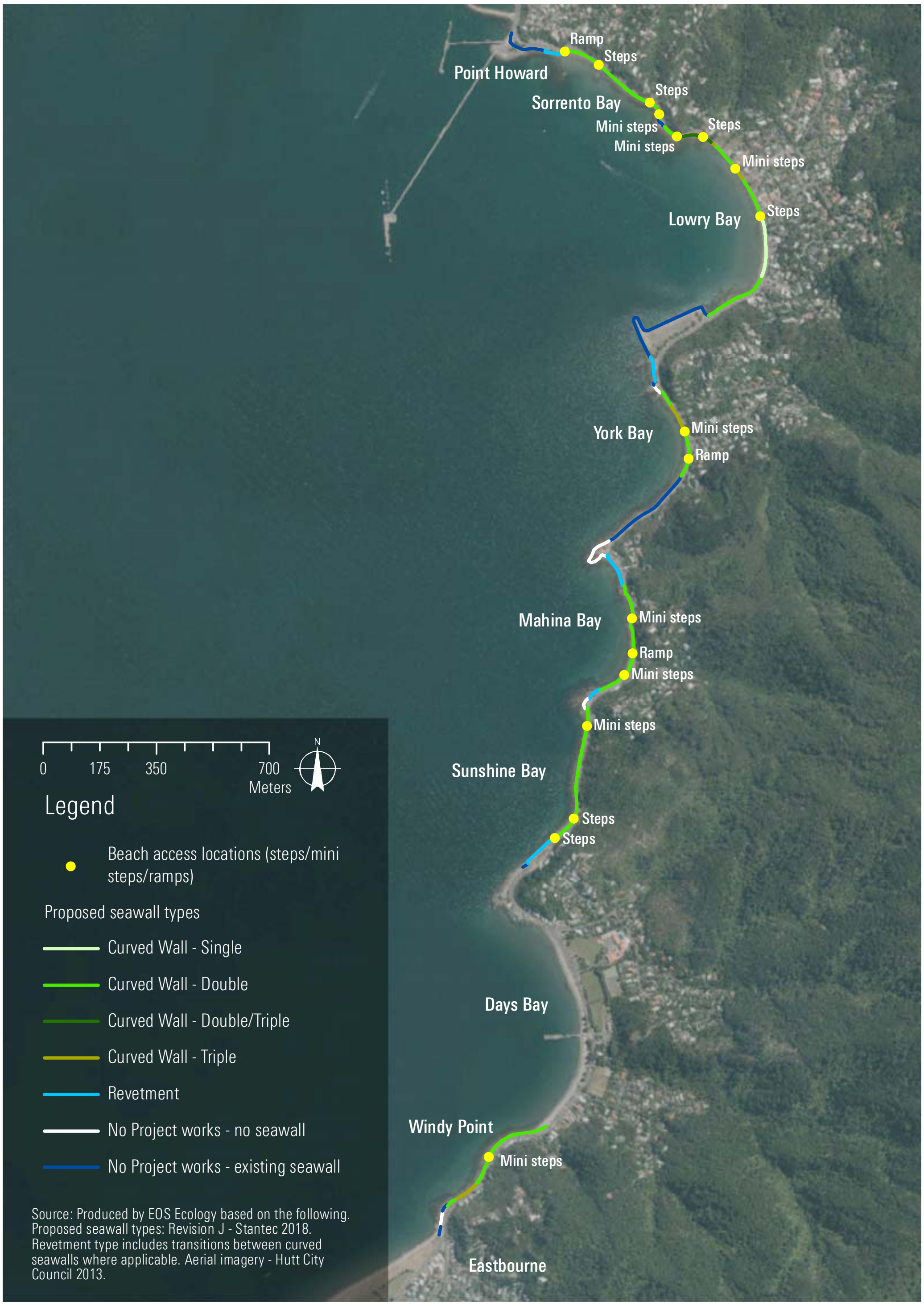
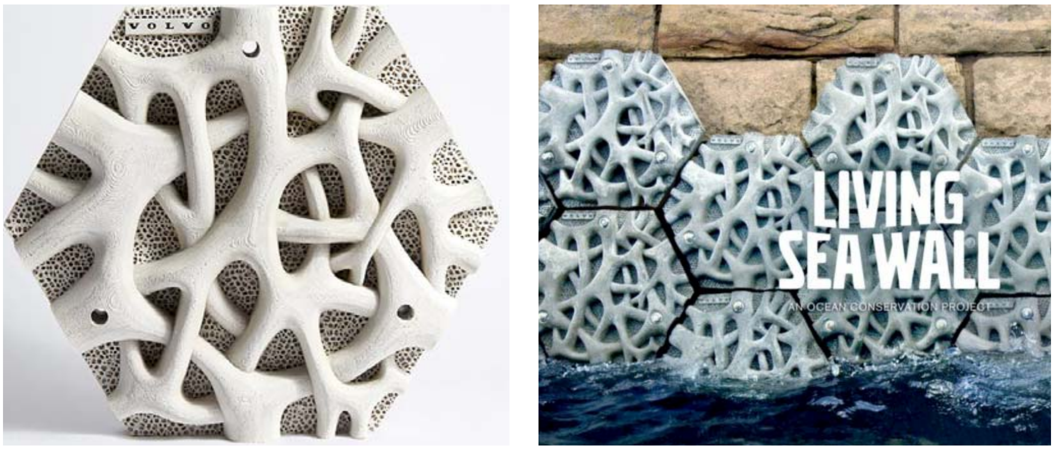


Figure 34 Proposed seawall types as outlined by the Design Plans and associated files (Revision J) provided by Stantec on 3 September 2018. Further breakdown of the curved seawall and access types is provided in Appendix 1.



A 3D printed seawall texture that is being trialled in the Sydney Harbour as a living seawall.
https://www.bloglovin.com/blogs/design-milk-31264/volvo-living-seawall-tiles-invite-shoreline-6778456417

Precast textured concrete panels used to enhance seawall habitat used in the Elliott Bay Seawall Project in Seatttle, Washington. Source: http://www.haddad-drugan.com/seawall-strata and
https://sdotblog.seattle.gov/2014/04/23/more-than-just-a-seawall-enhancing-habitat-in-elliott-bay-and-preserving-public-safety/

Example of small circular rock pools created in a 'bioblock' block surface as part of the URBANE habitat enhancement research project in Colwyn Bay, Wales. Source: http://urbaneproject.org/sites/colwyn-bay

Figure 35 Examples of textures applied to the vertical face of seawalls and small depressions created in horizontal surfaces implemented in coastal seawall enhancement projects overseas.

There are five small sections of proposed revetment seawalls that make up 430 m (10% of the project length) of the proposed seawalls (including the transitions between revetment and other seawall treatments) (Table 11, Figure 34). The proposed revetments extend between 2.0 m to 6.6 m from the toe of the existing seawalls (Table 11). They are limited to sections of the project where it was desirable to maintain a 'non-concrete' or 'non-seawall' shoreline, replace existing rock revetment, and/or where additional protection was required to reduce wave overtopping (Allis, 2019; Stantec, 2019a). In previous design plans, revetments were proposed in north and south Lowry Bay however, due to their encroachment into the subtidal zone, these have been removed or altered to reduce their footprint and thus encroachment into the CMA. Due to the dynamic nature of the coastal environment, the revetment seawalls require a double layer of competent rock that is hard wearing and in sufficient quantity for the new revetments (e.g. granite or andesite). We understand that the local *in situ* (i.e., rock excavated from the foundations of the new works) rock is of low quality, small size and insufficient quantity to be of use in the revetments (Michael Allis, NIWA, pers. comm.). However, whilst local greywacke quarries (e.g., Horokiwi Quarry) can provide material that would be suitable it is unlikely to be a sufficient volume for the project (Michael Allis, NIWA, pers. comm.). Consequently, revetment rock will probably need to be brought in from other regions. The final selection of rock material for the revetment will be addressed by the contractor.

The current revetment design has an average rock diameter of 500 mm, an approximate 1.5 m level area (roughly three times the average rock diameter) at the top of the slope, and a revetment slope of 2:1 (Stantec, 2019a). The indicated footprint of the proposed revetments allows for some additional drop-off due to the sloping shoreline and additional room to key in the revetment to the underlying strata (Stantec, 2019a). Thus the final footprint may vary slightly depending on the site-specific conditions of the existing foreshore, but is not expected to be enlarged from that shown in the preliminary design plans.

Previous design plans showed a large revetment at northern Lowry and a curved wall plus revetment at southern Lowry. These were proposed due to the extra protection required in these areas from wave overtopping, however, this meant that these new seawalls would extend into the subtidal zone. Due to the encroachment of these into the CMA and the protection of subtidal rocky reefs under Schedule F5 of the Proposed Natural Resources Plan (GWRC, 2015), the proposed seawalls have been changed to double and triple curved seawalls to reduce their footprint. Over time, as a result of sea level rise and climate change ,if revetment additions are needed to protect the road from overtopping events then additional intervention (i.e., creation of a revetment in front of the proposed curved seawalls) could still be possible with the proposed design.

Path widths along the length of the project vary between 2.5 and 3.5 m, with 3-3.5 m the preferred widths. The path widths will be constructed to ensure safety standards and to maintain the pathway as effective and useable for the activities in this area, such as bike riding, dog walking, jogging, etc.

Making up 64 m and 1% of the total project length beach access will be provided at 17 points within the project area, generally providing a minimum of two access points per beach (Stantec, 2019a). Beach access types include steps (standard and mini) and ramps, and have, where possible, been designed to minimise the area of encroachment into the intertidal area (Table 11, Figure 34). To do this, they have been designed to run parallel to the seawall and (in the case of ramps) display a steeper grade of 1V:4H (instead of 1V:8H), incorporating them into transition zones between revetment and curved seawall treatments, and using smaller steps for more informal access points. In general these access points encroach over the existing seawall/access point toe by 0.8–3.5 m (Table 11).

4.2 Overview of Construction Methodology

The Design Features Report (Stantec, 2019a) describes the construction methodology for the project, including the programme timeline, activities and management. We understand that this will be incorporated into the Construction and Environmental Management Plan (CEMP), which will form part of the consent conditions for the project. The following is a brief overview of key construction activities taken from the Stantec (2019a) report.

The programme for construction will be delivered over six years from 2019, with the intention to complete the works in stages and bay by bay. Each construction of each stage is dependent on funding availability and is expected to take 3–6 months, depending on bay length and complexity. Stantec (2019a) gives the following construction order for the project, with completion of each stage over separate financial years:

» Windy Point

» Point Howard/Sorrento Bay

» Lowry Bay

» Other bays to follow.

In general, the construction of the seawalls will entail the removal of the existing seawall to provide access to construct the new wall base, which will be undertaken using an excavator and/or breaker from the road. Where space does not allow, machinery will be operated from the beach. In these cases, the use will be minimized, the machinery will not be stored on the beach and movements will be across weight-bearing mats to reduce impact and constrain movement. Construction of the seawalls requires a minimum working distance that has been currently estimated at around 3 m for revetment, and 5 m for curved walls beyond the toe of the new seawall, to allow for the excavation and burying of the toe of the new seawalls.

Demolition of material is to be undertaken within a contained area via the use of silt fences and/or behind the seawall. Excavation of material for the base of the seawall will generally be shallow (<1 m) however, in some locations (Sorrento Bay (50 m), Lowry Bay (585 m), York Bay (450 m), Mahina Bay (220 m), Sunshine Bay (250 m)) seawall foundations may need to extend up to 5 m below the existing beach level. Larger natural weathered rock material colonised by intertidal biota that has been excavated will be stockpiled nearby so that they can be replaced in suitable areas following construction.

Site works are constrained by tidal effects and shoring will be required in some locations, with the details of these determined in the CEMP. Weather conditions and tide forecasts will be part of the construction considerations and will form part of the CEMP to prevent storm events or high tides from overtopping and risking contamination of the receiving environment.

Site dewatering and holding is likely to be required for the excavations and construction. A settlement tank or large container that will allow sediment to settle and/or be filtered out (via a filter placed over the discharge pipe) has been suggested in the Design Features Report (Stantec, 2019a). The treated water will then be discharged either to the sea or to the sewer to limit sediment release into the receiving environment. To limit sediment discharge and wave overtopping, continuous lengths of seawall being constructed will be limited to a 20 m length (although there may be more than one construction site operating at the same time within a bay).

Concrete foundations for the seawalls will be poured *in situ* as it is considered to provide improved strength and ease over precast concrete methods. Following completion of the foundations, the lower level of the seawall will also be poured *in situ* in sections using shaped formers, with a similar approach then being used for the upper level/s (for the double and triple curved walls). It is assumed that the machinery used to pour the concrete will be retained on the road verge, with mainly personnel working within the intertidal/beach area. Specific criteria are outlined for ensuring wet cementious products are not discharged into the receiving environment, which is detailed in Stantec (2019a).

Construction of the revetment includes a "reinforced concrete cantilever retaining wall supporting the shared path (likely to be poured concrete *in situ*), and the rock rip rap which is typically placed in front of this structure on a geofabric and AP65 granular bedding layer. Geofabric may only be necessary when placed on unconsolidated sediment (beach, cobbles and gravels). Placement of geofabric over rock platforms may not be required as it will depend on the bedding material. If geofabric is placed, the edge and tails of the geotextile is to be hidden beneath the rock" (Stantec, 2019a). Material to be used for the revetment is "competent weathered rock". Again, machinery will be operated from the road verge where possible.

The potential for beach nourishment at three bays (Point Howard beach, Lowry Bay and York Bay) is considered in a separate report (McMurtrie & Brennan, 2019).

5 ASSESSMENT OF ENVIRONMENTAL EFFECTS

5.1 Construction Effects

5.1.1 Effects from Sedimentation

During seawall construction activities, sediment generation may occur from multiple sources of unconsolidated sediments. Earthmoving necessary to construct seawall footing is expected to mix and suspend any fine sediment present in the beach gravel, with terrestrial runoff and/or seawater. Imported material used for road construction and widening will be clean of fines, with less chance of fine sediment release.

Although sedimentation is a natural process along the Eastern Bays, excavation of material below the current natural beach surface and introduction of foreign building materials and sediments could entrain fine sediment within coastal waters. Anticipated sedimentation issues associated with construction activities include:

» Temporary disturbance of existing beach sediment and beach profile by machinery working from the beachfront and excavating unconsolidated beach deposits.

» The introduction of terrigenous (i.e., land-derived) sediment to the near shore environments from the addition of material during earthmoving and seawall construction activities.

» Potential for unanticipated fine sediment deposits below seawall footing.

Increased inputs of terrigenous sediment to marine environments can result in increased turbidity and suspended sediment concentrations. Increased turbidity reduces light penetration into the water column, impacting primary production of pelagic phytoplankton and benthic macrophytes (algae that live in or on the sediments) and thus reducing a key food component to suspension feeders, herbivorous benthic grazers and deposit feeders (Gibbs & Hewitt, 2004). Suspended sediments can also interrupt feeding and respiration by clogging gill structures of filter feeders, and can cause reduced oxygen levels as oxygen in the water column is consumed by microbes that break down the organic content in the sediment. Optical effects of suspended sediment are particularly prevalent when particles have a fine grain size. Once settled from the water column, sedimentation can negatively impact benthic environments. Shoaling, embeddedness and other physical modification of habitat can result from sudden changes in sediment supply.

The Eastern Bays of Wellington Harbour support *Macrocystis* (kelp) beds/forests, which are representative habitats at the northern extent of this habitat type in New Zealand (EHEA, 1998). Kelp beds have a high biodiversity value with major threats including sedimentation, increases in turbidity and increases in storminess (MacDiarmid *et al*. 2012). While unlikely given the small area of the construction, harbour-wide sediment plumes over an extended time (a number of days) can potentially have a detrimental impact on these beds. It should be noted that these areas would already be exposed at times to low light conditions during storm events where Wellington Harbour experiences significantly higher turbidity from its catchments (James *et al*. 2015). *Macrocystis* beds are reported to occur along the eastern bays area (between Point Howard and Hinds Point) (GWRC, 2015), however current exact locations have not been determined, other than the confirmed absence of them within the shallow (< 0.8m) subtidal area of Point Howard Beach, Lowry Bay, and York Bay. The construction footprint extends into the shallow subtidal area within Lowry Bay, Mahina Bay and York Bay (refer to Figure 38).

The current construction methodology includes a number of measures that will help to control and minimise sediment release (see Section 6.1.1). The greatest risk of sediment release therefore comes from the five areas where the construction footprint is within the subtidal area (Figure 38) and in the three beach nourishment areas. Because these areas will be in the permanently wetted zone, it will be more challenging to install and maintain sediment control measures, meaning there will be an increased risk of sediment release.

In the event terrigenous sediment should become suspended in the near shore water column during construction of the Eastern Bays seawall, effects will likely be short lived. Grain-size analysis of Eastern Bays beach deposits shows that all particles are in a size range greater than fine sand (GHD, 2015). Particles of this size require high energy to remain suspended. Once settled the natural water movement occurring along the Eastern Bays near-shore environment will rapidly disperse any accumulated sediment. Thus while there is likely to be a small (albeit undefined) increase in sediment inputs during earthwork and construction activities, it is equally likely that the biota in the receiving environment will be tolerant of some temporary increase in suspended and settled sediment since similar situations result from storm events. It is not anticipated that the potential volumes of sediment generated during this project would be sufficient to cause any modification to local habitat. The short continuous working lengths (of up to 20 m within a construction site) will also limit the potential for the release of contaminated sediment, as it will minimise the extent and duration that a site is exposed (and the site will be easier to maintain than a larger site).

5.1.2 Effects from Other Contaminants

Release of *In Situ* Contaminants

Excavation of material is required for the pouring of seawall foundations. In most cases this will be less than one metre deep, but in some locations (Sorrento Bay (50 m), Lowry Bay (585 m), York Bay (450 m), Mahina Bay (220 m), Sunshine Bay (250 m)), foundations may need to extend to five metres deep. There is the potential for contaminants associated with fine materials to be released into the environment during this process. Based on the (albeit limited) existing information on sediment contamination in the area, it appears that sediment contamination and nutrient enrichment is low (based on data available for Lowry Bay). Combined with the fact that fine particles are not particularly abundant in the area, it is unlikely that the proposed construction will have any observable contaminant-related impacts.

Release of Cementitious Products

The biggest risk of construction is the release of cementitious products during any in-situ pouring of the concrete seawalls and footings. In-situ concrete construction has been determined to be the best method from an engineering and constructability perspective, however, it does come with a higher risk of environmental contamination.

Concrete or cementitious (mortar, grout, plaster, stucco, cement, slurry) washout wastewater is caustic and considered to be corrosive with a pH over 12 (www.concretewashout.com/index.php/industry_problems/concrete_washwater/). Despite the strong buffering capacity of seawater, increases in pH can occur via natural (photosynthesis) or anthropogenic means, with subsequent effects on marine biota. The pH of the open ocean usually ranges from 7.5 to 8.5, with pH in inshore areas (including tidepools, bays, and estuaries) sometimes decreasing to 7.0 (Calabrese & Davis, 1966), thus the acceptable pH range is considered to be 7.0 – 8.7 pH units (Locke, 2008). pH levels higher than this can have detrimental effects on aquatic biota, from mortality of biota through to alterations in growth, photosynthesis, feeding and immune response (Locke, 2008 (review); Calabrese & Davis, 1966; Ringwood & Keppler, 2002 (bivalves); Chen & Durbin, 1994 (marine phytoplankton)). Changes in pH can also increase the bioavailability of heavy metals and can reduce recruitment rates for particular benthic species (ANZECC, 2000; Calabrese & Davis, 1966; Loyless & Malone, 1997; Ringwood & Keppler, 2002; Shaw, 1981). pH is a logarithmic measure of acidity, meaning that small changes in pH values can have large impacts.

The release of untreated cement-contaminated water into the intertidal zone of the construction sites could locally alter pH and cause detrimental effects on the local ecosystem, particularly if it is concentrated in intertidal areas (i.e., tide pools, etc.) during low tide. This is considered the greatest risk of the proposed construction activities on the intertidal benthic ecology.

The construction methodology (Stantec, 2019a) includes a number of measures to reduce construction effects relating to the release of contaminants (see Section 6.1.1 for a full list). In summary these measures include isolating the construction area from the marine environment using bunds or other devices, and weather and tide monitoring. There is also specific controls required for the pouring of concrete, including the preference to only pour concrete in dry conditions, or where this is not possible, to contain the contaminated water and pump it to the wastewater network (where it will be treated) or to a treatment device for treatment of pH to suitable levels prior to discharge to the receiving environment during high tide (when there is a greater dilution factor). The planned short working lengths (of up to 20 m continuous length within a construction site, although there may be more than one construction site operating at the same time within a bay) will also limit the potential for cementitious contamination, as it will help to minimise the extent and duration that a site is exposed (as the site will be easier to maintain than a larger site).

On the basis of the proposed construction measures to isolate, contain, and treat water potentially contaminated by wet cementitious products, the effects should be able to be kept within a 'less than minor level, provided that the contractor establishes a good system for control and monitoring, and maintains vigilance throughout the *in situ* pouring and curing of cement. This will be particularly important in areas where there are nearby rock pools where a small amount of pH altered water discharged at low tide could kill all resident biota. There is also greater risk relating to cementitious products for six locations where a portion of the construction zone may extend within the subtidal area, in particular a ca 32 m section in northern Lowry Bay (Figure 38). Having a construction footprint below the low tide may make it harder to maintain a dry site, keep water ingress to a minimum, or to maintain effective controls, and thus may increase the risk of an effect.

Other Contaminants

There is the risk that other contaminants associated with the machinery to be used in the intertidal area (i.e., petroleum-based products). However, it is expected that the use of the excavator on the beach would be minimised, and all machinery would use biodegradable hydraulic fluids and be stored and refuelled away from the beach.

5.1.3 Effects from Habitat Disturbance

Where construction of the shared path and seawalls occurs, a temporary construction zone from the bottom of the seawall will be required to enable construction, which may include the use of machinery in the foreshore area to assist in the excavation of materials prior to installation of the new seawalls. Construction of the seawalls requires a minimum working distance of three meters for revetment, and five meters for curved walls beyond the toe of the new seawall, to allow for the excavation and burying of the toe of the new seawalls. In total, the construction footprint is estimated to be 1.50 ha. Within the CMA, this construction zone represents an additional 1.20 ha of localised disturbance beyond of the actual footprint of the proposed seawalls.

The construction activity itself may locally impact on the environment through the disturbance of the intertidal habitat through compaction of material and crushing of biota. The assemblage making up the intertidal ecology of the Eastern Bays project area is typical of a rocky shore community and typical of what is found in the Wellington area. If habitat is available, recruitment of species will be dependent on the larval influx from adjacent intertidal areas and from pelagic influences (Schiel, 2004). The design features report (Stantec, 2019a) also outlines the stockpiling of any excavated rocky material that is inhabited by intertidal biota for the possible re-use in the area after construction, thereby further facilitating recolonisation.

It is thus likely that any localised effect on the benthic community will be short-lived, with an abundant colonist source from the adjacent areas and lower tidal area available to re-colonise the part of the foreshore within the construction footprint following construction. However, it would be relevant to check any rock pools within the construction area for fish (i.e., such as rock fish) and relocate them outside of the construction zone prior to commencing works.

Kelp beds (*Macrocystis pyrifera*) have been found in Wellington Harbour growing at depths 3–15 m (EHEA, 1998). No kelp beds were found in the shallow subtidal are of Point Howard Beach, Lowry Bay or York Bay, and is unlikely to be in the shallow subtidal area of Mahina Bay based on their known depth preferences. However, Overmars (2019b) has identified shallow subtidal and intertidal seagrass beds in central and Southern Lowry Bay[3]. Thus refer to Overmars (2019a, 2019b) for consideration of effects on seagrass.

5.2 Operational Effects

The proposed works include the construction of a shared path and seawall along 3.1 km (69%) of the 4.4 km stretch of shoreline between Point Howard and the northern end of Eastbourne (excluding Days Bay beach area).

Currently, approximately 87% of the shoreline within the project length (which excludes Days Bay) already has a seawall, made of some form of angled or curved concrete, or rock revetment. Of the remaining 13% of the project length containing no seawalls, 52% will remain without a seawall. For this project, the works will involve the creation of 2.7 km curved concrete seawalls (single, double, or triple) (60% of project length), 0.4 km of rock revetments (10% of project length), 0.06 km of access points (1% of project length), whilst 1.3 km of shoreline will be left as it is (29% of project length). Approximately 2.8 km (64%) of the project length is below the MHWS level, however 1 km (23%) of this is behind the existing seawall toe. Therefore, 1.8 km (41%) of the project length is below the MHWS level and beyond the existing seawall toe and thus forms the basis of this assessment.

[3] As vascular plants, seagrass has been dealt with in the Avifauna and Vegetation technical report by Overmars (2019a, 2019b).

The long-term effects to the intertidal ecology within the project area relate to changes in habitat type of the seawall; encroachment into the existing intertidal area; hydrodynamics within the local area that effect wave exposure, tidal inundation, and sedimentation (details covered in Allis, 2019), as well as stormwater runoff (not covered in this AEE). The potential effects of beach nourishment on subtidal areas are covered in McMurtrie & Brennan (2019).

5.2.1 Altered Habitat

The Eastern Bays area is representative of a modified intertidal environment, with manmade seawalls existing along 87% of the project length. The evidence is unequivocal that artificial seawalls support less biodiversity than natural rocky shore environments, a major factor in this being loss of heterogeneity of the surface (Kostylev *et al.* 2005; Moreira *et al.*, 2006; Moreira *et al.*, 2007; Browne & Chapman, 2011; Chapman & Underwood, 2011; Firth *et al.,* 2013, Ravinesh & Bijukumar, 2013). The steeper aspect that is characteristic of artificial seawalls (such as the proposed and existing curved and otherwise steep concrete seawalls structures) can also lead to more significant changes in community structure and functioning over smaller spatial scales (Chapman & Underwood, 2011). This is due to the reduction in the space between tidal levels on a near vertical surface, meaning not only less space for biota at a particular tidal height, but the interaction of species from different tidal levels that might not otherwise interact on more gently sloping shores. Results from this study are in line with the literature, in that the current seawalls support a lower diversity of taxa compared to that found on the harbour floor (although this pattern may have been confounded by tidal level) (Figure 21). For the Eastern Bays however, where 87% of the project length already has a manmade seawall, the likely changes to the intertidal community at the seawall will be less than if the area was changing from a natural rocky shore to a seawall environment. In general it was found that the areas where an upgraded seawall is proposed there was lower taxa richness than in areas where seawalls will not be undergoing any change, although taxa density was greater than on the seawalls to remain. After the completion of the project works, 93% of the project length will contain seawalls.

We found that taxa richness was lowest on the smooth concrete seawalls (which at 40%, represents the greatest proportion of existing seawall type), with greater taxa richness and density on the concrete–smooth curved and the concrete–aggregate walls (Figure 23). It is likely that this is related to the habitat complexity of the aggregate and the additional shade protection (and thus higher humidity) provided by the curved seawall as opposed to the smooth angled seawalls that would be subject to greater sunlight exposure (and thus drying). Shade, humidity and wave exposure are key factors influencing the taxa that can survive in the higher intertidal zones of rocky shore environments (Bertness *et al.*, 1999; Tomanek & Helmuth, 2002; Schiel, 2004; Smith, 2013). Thus in relation to shading and humidity, the proposed curved seawalls will provide an improved habitat compared to the existing smooth angled seawalls and thus may result in an increased diversity of taxa colonising these new walls.

Microhabitats created by a varying the surface (i.e., increasing heterogeneity) and an increased surface area has been found to increase the richness and density of species in that environment (Kostylev *et al.*, 2005; Lam *et al.* 2009; Ravinesh & Bijukumar, 2013; Chapman & Browne, 2014). This was evidenced on site by intertidal taxa taking advantage of small variations in the existing seawall surfaces within the Eastern Bays area (Figure 35). The proposed addition of the textured surface to the curved seawalls as indicated in Stantec (2019a), will, if designed appropriately, provide microhabitats along the length of the curved seawalls allowing for an increased surface area and small-scale surface heterogeneity. Textured seawalls are being increasingly implemented as a means of improving intertidal seawall habitat around the globe (Figure 35).

Larger substrate embedded in the toe of the existing new curved wall at York Bay provides additional habitat for biota.

A weep hole in the surface of the existing new curved seawall at York Bay provides additional refuge areas for taxa when the tide is out.

Periwinkles, found in the high tide zone can find habitat in the smallest of places protecting them from exposure

Figure 36 Examples of small variations in surface texture of seawalls found within the project area that have been exploited by intertidal taxa.

In discussions with Stantec it is understood that currently the textured surface may only be applied to one (currently the bottom) curve of the curved seawall face, although this is not specified in the Design Features report (Stantec, 2019a). It will be important to ensure that this texture is applied to any curved seawall surface that is below the MHWS mark, with application of the texture on seawalls above this providing for future sea level rise. Location within the tidal zone has the greatest impact on potential for intertidal biodiversity, with biodiversity increasing from high to low tide zone. The indicative cross-sections provided in the Design Features Report (Stantec, 2019a) (some of these are shown in Figure 33) indicate that generally the current MHWS level should remain below the bottom step of all but the triple curved seawalls, but they also indicate potential future MHWS levels under SLR where the tide will reach higher on the walls. It must be noted however that these specific cross-section points may not be indicative of the entire foreshore length.

The proposed addition of shallow depressions in the flat step of the curved seawall will also help to provide habitat for some biota, provided that they are in sufficient density and at the right tidal level. Firth *et al.,* (2013) found that artificial structures can be modified to provide rock pools that promote biodiversity, with the effect of these rock pools more pronounced at mid than higher tidal levels. Recent work in Sydney, Australia has also shown that incorporating water-retaining features (that mimic rock pools) into seawalls can dramatically increase the diversity of colonising epibiota (Chapman & Blockley, 2009; Browne & Chapman, 2011 – both censu Firth *et al*., 2013).

Sloping revetment options provide a greater potential area available for intertidal biota compared to steeper/vertical seawalls as they allow more space between tidal zones, thereby decreasing competition and predation pressures between and within species, and better mimicking a more gradual natural shoreline. However, this is dependent on the rock type and habitat created by the revetment material. Invertebrate samples collected from the existing revetment seawall types were limited to three quadrats where taxa richness was similar to other existing seawall types, but where taxa density was much lower. The revetment seawalls are likely similar in structure to the proposed revetment wall type. It is probable that the use of the harder rock (needed for durability and therefore longevity) are not ideal habitat for many intertidal species due to the lack of cracks and surface roughness, which can limit biodiversity (Chapman & Underwood, 2011). In contrast, the local *in situ* rock in the rocky shore habitats is softer, weathering over time to provide micro-habitats suitable for colonisation by various intertidal biota. The erosion of the softer rock, substrate heterogeneity and varied slope profile also means that rocky shore habitats typically have rock pools, where they can support greater biodiversity and different communities than the surrounding emergent rock habitat (see Firth *et al.,* 2013). Such features are less frequent on artificial structures. It is therefore possible that the revetment rock material itself will not provide the same quality of habitat as the *in situ* rocky shore habitat for intertidal biota. However, the type of habitat created, with the greater voids within the rock face will ensure cover for larger species during a range of tidal cycles, and in particular during tidal inundation, including for fish species.

Those taxa found in the upper tidal zones will be more susceptible to desiccation, due to prolonged periods of exposure during tide cycles. Thus there are individual species that may benefit more by the works long term; such as the blue-banded periwinkle (*A. antipodum),* which is found in the high tide zone and more associated with seawall samples in the area than the harbour floor samples. *A. antipodum* is found throughout much of New Zealand, and is abundant on rocky shores from the top of the littoral fringe to the upper part of the barnacle zone (Reid & Williams, 2004). They are more common on exposed shores and on vertical cliffs, but favour shaded rock faces over sunny faces (Reid & Williams, 2004). It is anticipated that *A. antipodum* will do well on the modern curved seawalls, with the curved nature providing the shade that will benefit this species in exposed parts of the coastline.

Ultimately, the long term environmental effects of the creation of new seawalls along 69% of the project length on the intertidal benthic community is considered to be less than minor based on the following:

- There were no unique or rare species of invertebrates found in the surveys and the fauna is similar to that of the wider area.
- Seawalls currently exist along the majority of the shoreline, and consist primarily of angled concrete seawalls (smooth/smooth-curved/aggregate) (68% of the existing project length) that support low species diversity or richness.
- The majority of the proposed seawalls are curved seawalls (60% of the total project length). These will replace mostly existing old angled concrete seawalls. The curved seawall will provide additional protection from desiccation during tidal exposure, whilst the addition of the texture to (one of) the vertical curved surfaces and small depressions in the flat step of the seawall will provide more habitat for intertidal biota than what currently exists on the current seawall faces. However, we acknowledge that the limitation of this to one seawall curve could limit its habitat potential for some locations.
- Rock revetments, while occupying a larger footprint, represent a small proportion of the overall project length (10%). Compared to angled concrete walls, revetments provide greater habitat heterogeneity and surface area due to the variety of material with many gaps and crevices as well as the slope.
- The project works will be staged by bay to completion over a number of years meaning that relatively small areas will be disturbed at once, facilitating recolonisation of fauna from adjacent undisturbed areas.

5.2.2 Encroachment into the CMA

The planned shared path works occur adjacent to and within the coastal marine area (CMA). The coastal marine area is defined as being below the mean high water spring (MHWS) level. According to the design plans issued 3 September 2018, approximately 2.0 km (45% of the total project length, or 65% of those areas undergoing change) will have new seawalls that will exist within the CMA once constructed, and of these, 1.8 km (41% of the project length, or 58% of those areas undergoing change) will be where the new seawalls have an additional encroachment into the CMA than currently exists (Table 12, Figure 37). This additional encroachment equates to 0.4 lineal km and 0.15 ha of intertidal area lost for the revetment treatment and 1.4 lineal km and 0.15 ha of intertidal area lost for curved seawall treatments (Table 12). There will also be 0.04 lineal km and 0.003 ha of additional intertidal area lost for the access points (Table 12). We note that there is also a small area of gain of intertidal zone through setting back of the seawall toe compared to the existing seawall, equating to 0.4 lineal km and 0.03 ha of gain of seafloor. Thus on balance there is a total of 1.8 km (i.e., 41% of the project length) and 0.30 ha (i.e., 51% of new seawall area) of additional encroachment overall within the CMA.

Because the construction footprint is larger than the footprint of the final seawall, additional encroachments into the subtidal zone is possible during the construction phase. From the estimated construction extents, there is likely to be 106 m and 0.01 ha of additional encroachment into the subtidal zone. These include the following estimated lengths and locations (Figure 37): 32 m in northern Lowry Bay; 18 m in southern Lowry Bay; 16 m in York Bay; 16 m in northern Mahina Bay; and 24 m in southern Mahina Bay.

The design plans (Stantec, 2018) have been resolved to provide the appropriate shared path width, ensure the safety of the road from storm surges and to minimise, where possible, encroachment into the CMA. Stantec undertook an assessment of the feasibility of moving the road corridor towards the landward edge to minimize or remove the need to encroach into the CMA (Stantec, 2019b). However, they found that the "coastal edge" option was more favourable due to the following reasons:

- It is not economically viable or desirable by HCC for property acquisition to enable the road corridor to be moved landward.
- Widening on the landward side would require major earthworks and cuts, especially on the headlands, which would result in significant effects to the environment.
- Opportunities exist to enhance environmental outcomes through providing a modern seawall and treatment options that respond to environmental effects such as fish passage, natural character and intertidal ecology.
- A coastal option enables public access to be enhanced and have recreational benefits.
- Existing footpaths and shoulders on the landward side are inappropriate for use as a road corridor due to safety at driveway entrances and perceived car and pedestrian/cycle conflicts.

Where encroachment into the CMA could be minimised this was done through orientating beach access steps and ramps parallel to the seawall, the use of a single instead double curved seawalls in some beach locations, and the use of mini steps at intervals between the larger steps. The previously proposed large revetment in northern Lowry Bay and the curved wall plus revetment treatment type in southern Lowry Bay have also been changed to curved seawall types to reduce their encroachment into the subtidal zone. The triple and double curved seawalls should provide some protection from wave overtopping events in the short to medium term, with the ability to retrofit other options in the longer term for sea level rise. Stantec (2019a) also states that there may be some locations where beach material transportation is not as great, and thus where it may be possible to reduce the seawall height and encroachment (by approximately 600 mm per seawall curve) by reducing the number of curves on a seawall (i.e., changing a double curve seawall to a single curve seawall). Such opportunities will be further investigated during the detailed design phase.

Table 12 Summary of the *additional* encroachment for the proposed seawalls within the CMA. Revetment treatments include the transition zone between these and another seawall type. Percentage values are based on the total project length or area of the proposed new seawalls. Refer to Figure 39for a spatial overview.

Seawall type	Additional encroachment into the CMA – LENGTH		Additional encroachment into the CMA – AREA	
	kilometres	% of project length	hectares	% of new seawall area
Curved seawall (single, double, triple)	1.4	32	0.15	26
Revetment	0.4	8	0.15	25
Access points (steps and ramps)	0.04	0.8	0.003	0.6
Total new seawalls	**1.8**	**41**	**0.30**	**51**

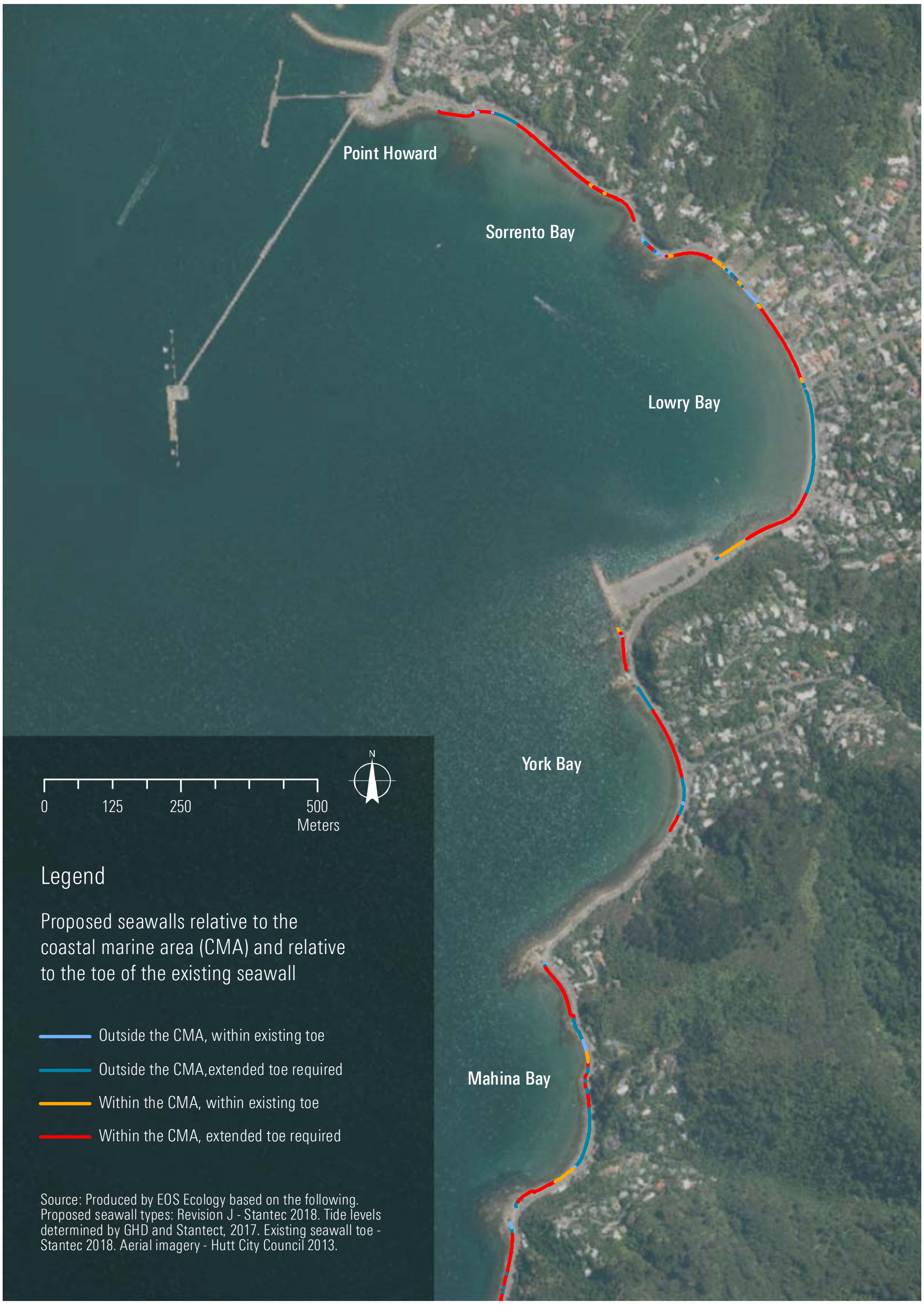


Figure 37 Proposed shared path and seawall works that, once constructed, will extend into the intertidal zone, relative to the existing seawalls (northern extent).

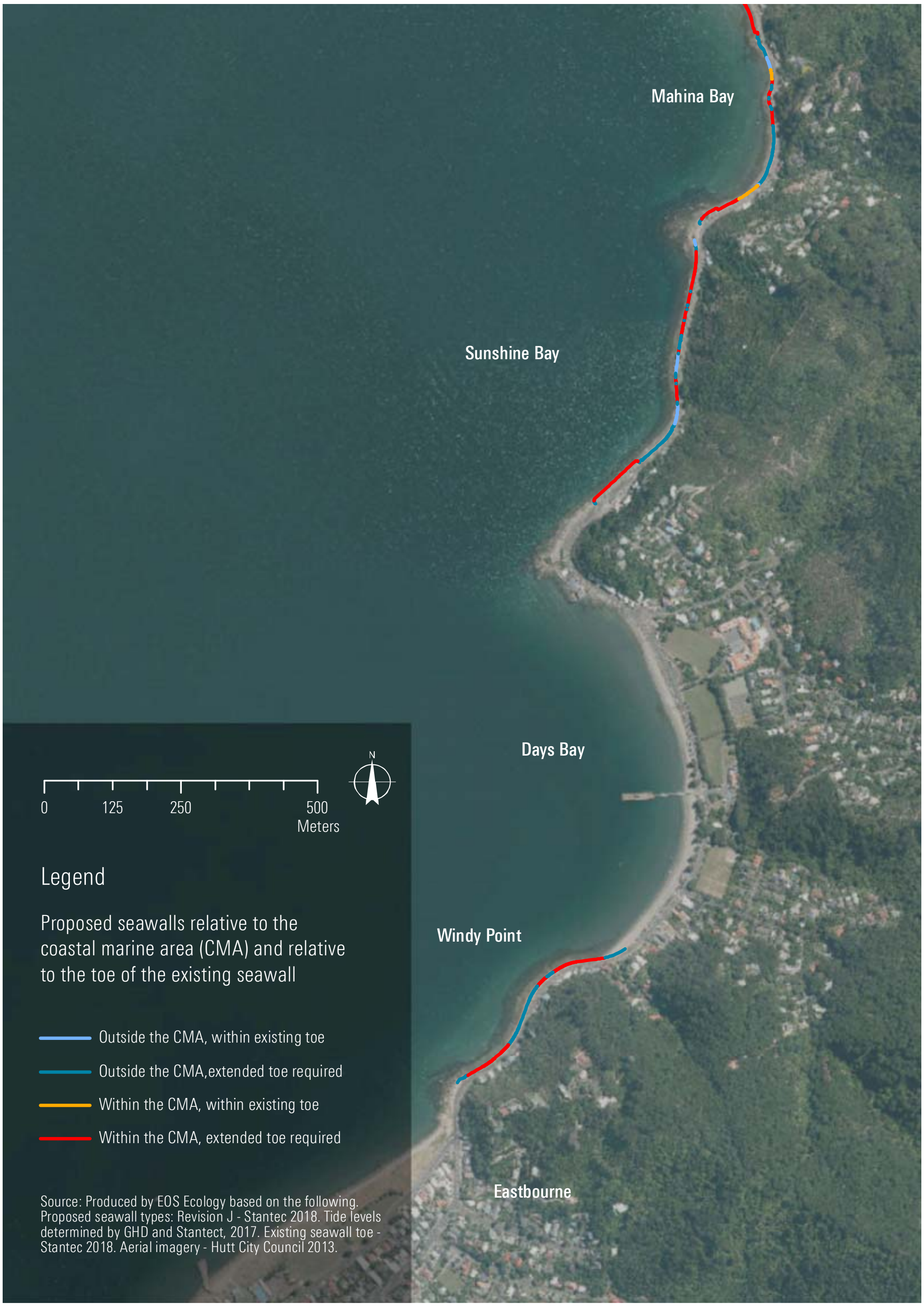
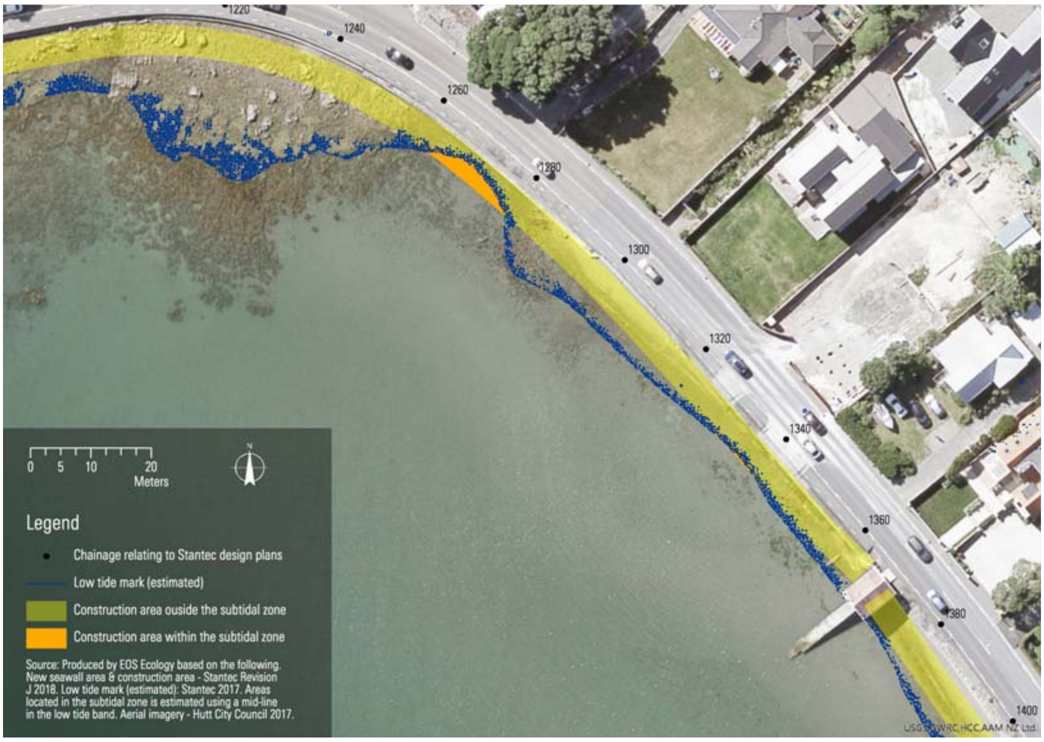
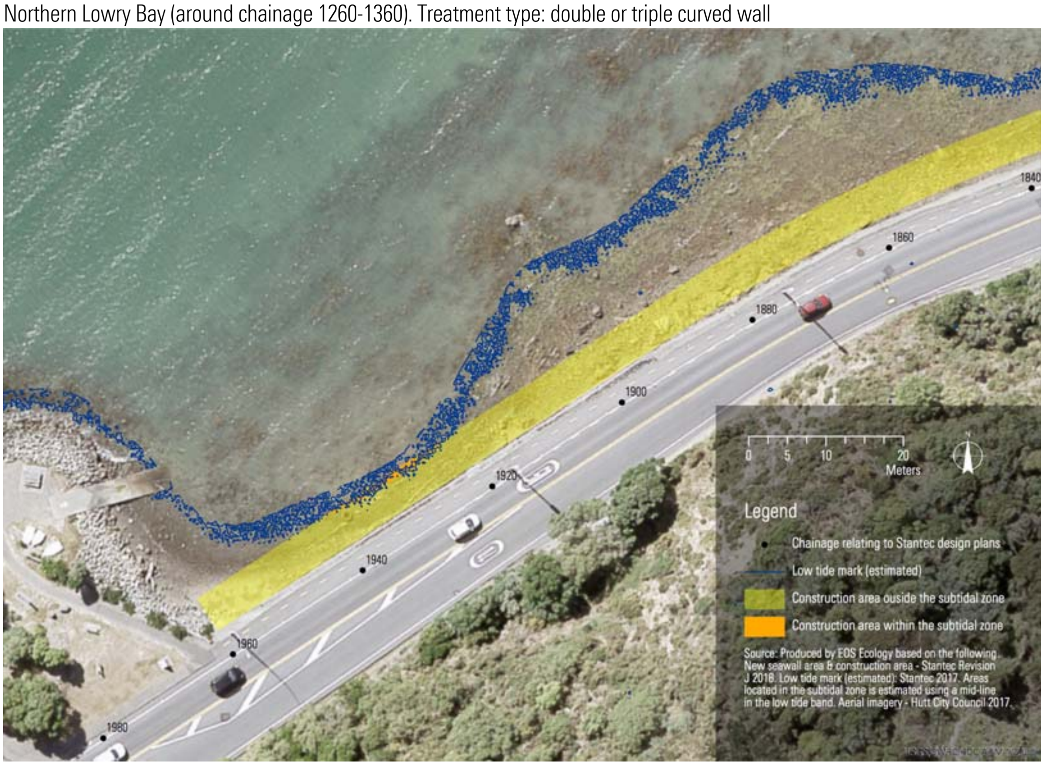


Figure 37 (cont.) Proposed shared path and seawall works that, once constructed, will extend into the intertidal zone, relative to the existing seawalls (southern extent).



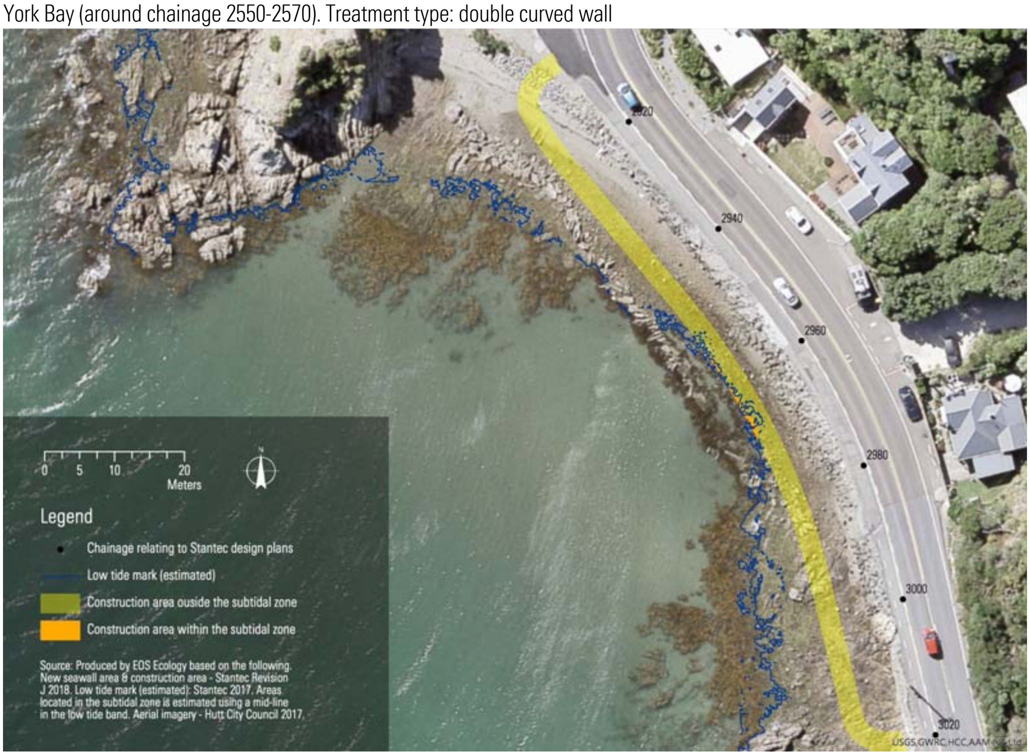
Northern Lowry Bay (around chainage 1260-1360). Treatment type: double or triple curved wall



Southern Lowry Bay (around chainage 1920-1940). Treatment type: double curved wall

Figure 38 Maps showing the five locations where the construction zone may extend into the subtidal zone (orange areas). Low tide level determined by digitisation of aerial imagery by Stantec.

York Bay (around chainage 2550-2570). Treatment type: double curved wall



Northern Mahina Bay (around chainage 2950-2970). Treatment type: revetment

Figure 38 (cont.) Maps showing the five locations where the construction zone may extend into the subtidal zone (orange areas). Low tide level determined by digitisation of aerial imagery by Stantec.

Southern Mahina Bay (around chainage 3330-3370). Treatment type: double curved wall

Figure 38 **(cont.) Maps showing the five locations where the construction zone may extend into the subtidal zone (orange areas). Low tide level determined by digitisation of aerial imagery by Stantec.**

Tidal zonation patterns are known to have a significant impact on intertidal communities, with both taxa richness and abundance decreasing with increasing distance up the shore (i.e., from low tide to high tide zones) (Lachowicz, 2005; Wolcott, 1973; Tomanek & Helmuth, 2002; Harley & Helmuth 2003). This pattern was also borne out in the Eastern Bays area, with both invertebrate taxa richness and density in epifauna quadrats decreasing from the 'low tide' to 'above high tide' zones. Thus we ranked the proposed seawalls based on their proposed footprint extent and encroachment into the existing intertidal area (Figure 39). A high encroachment rank (and thus higher potential level of impact on intertidal ecology) was given to seawalls encroaching beyond the existing seawall footprint into the more productive low-mid tide zone, where taxa diversity and density is at its greatest (and thus represents the greatest loss). Each bay within the project contains some sections ranked 'high', totalling 0.3 km or 10% of the project works (Table 13). The majority of these were where the proposed seawalls are revetment type (Table 12, 72%), which have the largest footprint of the proposed seawall types. Seawalls that extend beyond the toe of the existing seawall into the mid-high tide zone were given a medium encroachment rank, and represent 74% of the project works length (1.5 km, Table 13). These are generally curved seawall types (88%, Table 13). The low encroachment rank was given to seawall locations within the intertidal zone but with no expected encroachment beyond the existing seawall footprint (5%, Table 13). Seawalls located above the MHWS (outside the CMA) were given an 'N/A' rank and account for 38% of the project works length (Table 13).

Given the already highly modified environment along the Eastern Bays area, a change from one seawall type to another is likely to have less impact (cf Section5.2.1) than a change in the footprint of the proposed seawall, with a resultant loss of intertidal habitat with a greater encroachment footprint. Factors for consideration in regards to the level of impact for the proposed additional encroachment include the following:

- The areas of greatest encroachment occur where the revetment treatment types are proposed. For these rocky shore environments both the taxa richness and taxa density was lower in the rocky shore habitat within the proposed revetment, compared to areas outside of the encroachment, whilst there was no difference in community composition
- More generally, the intertidal invertebrate community of the harbour floor habitat within areas where the seawalls are proposed to change is not dissimilar to that found in areas that will remain the same.
- The intertidal taxa found within the project area is representative of the wider Wellington Harbour area and contain no biota of conservation concern (as listed in Freeman *et al*., 2014).
- The revetment treatment type, whilst representing the greatest level of encroachment, still creates a rocky sloped shore that will at least be available for intertidal biota to colonise (providing that the habitat is suitable).
- Notwithstanding the previous statements, the size of the area of additional encroachment within the CMA (0.30 ha over a 4.4 km project length) is a reasonable area of existing intertidal habitat that will be lost to additional encroachment. For the curved seawalls, the level of additional encroachment within the CMA is 0.15 ha, (or 26% of new seawall area) represents a complete loss of intertidal habitat, as this will be in-filled behind the vertical seawall. For the revetment option the 0.15 ha of additional encroachment within the CMA (or 25% of new seawall area) will provide a gently sloped intertidal habitat, which will remain available to intertidal biota. Whilst this more natural gradient is preferred, the rock type may not be as suitable for colonisation by intertidal biota due to its 'hard wearing' nature compared to the *in situ* rocky shore material.
- No kelp beds were found within the construction footprint within Lowry Bay or York Bay, and based on the depth preference for kelp it would be unlikely to be in the construction footprint for Mahina Bay. However, it is not known whether kelp is present in deeper water close to these areas. Seagrass was found by Overmars (2019b) in the shallow (<0.8 m at low tide) subtidal and intertidal zone of central and southern Lowry Bay (although seagrass considerations are covered by Overmars 2019a).

Thus on balance, those areas ranked as a 'high' or 'medium' for CMA encroachment in Figure 39 (and summarised in Table 11) are likely to require some additional measures to mitigate the effect of encroachment into the intertidal area (see Section 6).

Table 13 Lineal length (m) of seawall that falls into the four different levels of encroachment into the intertidal zone, as displayed in Figure 39. Refer to Figure 39 for further information on the encroachment levels.

Seawall type	High	Medium	Low	N/A	Grand Total
Access points		24		41	65
Curved	84	1,306	161	1,097	2,677
Single				190	190
Double	70	1,055	123	908	2,156
Double/Triple		74	25	5	104
Triple	14	192	15	7	227
Revetment	215	153	9	54	431
Grand Total	**299**	**1,483**	**170**	**1,191**	**3,174**

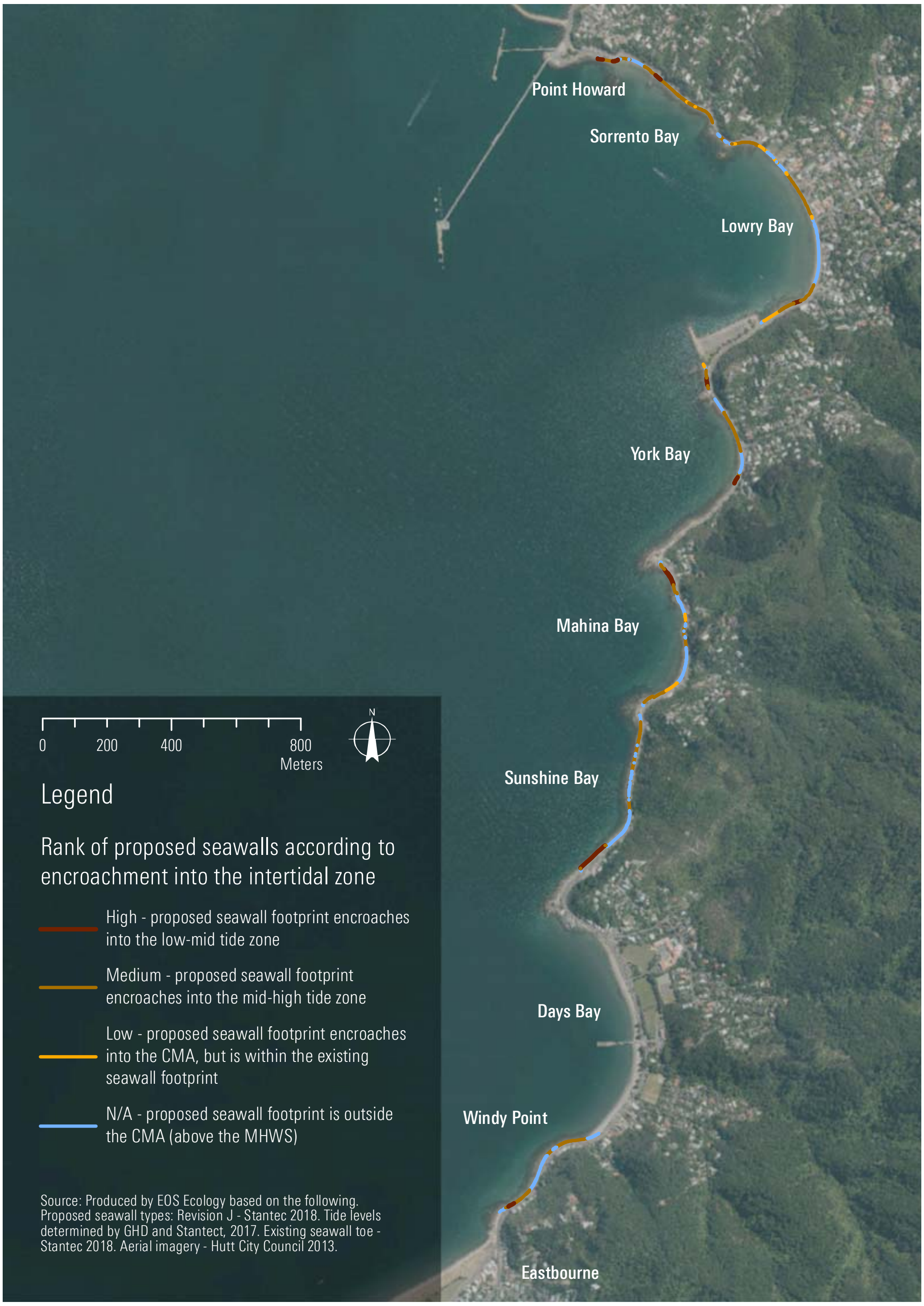


Figure 39 Proposed seawalls were ranked according to their encroachment into the intertidal zone. Those seawalls encroaching into the more productive low-mid tide zone were given a 'high' impact rank, those encroaching on the mid-high tide zone were given a 'medium' rank, those within the intertidal zone but with no encroachment were given a 'low' impact rating, and those above the CMA were given an 'N/A' rating. Note that this does not take into account the existing or proposed seawall types or areas of beach nourishment (that also effects intertidal ecology), which has been assessed in the Section 5.2.1.

5.2.3 Changes Related to Altered Hydrodynamics

Allis (2019) considers that effects with regard to nearshore hydrodynamics and sediment movement will be minor, primarily due to the already altered state of this coastal area and small overall change to the coastline by the project (i.e., creation of seawalls and subsequent loss of beach sediment has already occurred over the last 100 years). Allis (2019) stated that there could be a potentially moderate effect on nearshore hydrodynamics leading to either an accumulation or erosion of sediment at the locations where transitions between wall types occur, although it was noted that with good design it should be possible to further mitigate this through detailed design.

Sediment generation and transport is a naturally occurring process in the Eastern Bays portion of Wellington Harbour (Booth, 1975; Lachowicz, 2005, Matthews, 1980). During storm (rainfall and wind-wave events) events, longshore drift, terrigenous supply and wave action will temporarily suspend fine particulate matter in the water column (Booth, 1975; Lachowicz, 2005). Such natural events cause brief periods of high turbidity and increased sediment flux to near-shore environments.

Seawalls are installed to protect modified coastlines from natural depositional and erosional processes. Changing the size and shape of protective structures in the coastal margin has the potential to effect natural processes that influence sediment supply and transport. However, when considering the proposed Eastern Bays seawall replacements, due to existing seawall structures being in place, and only minor changes in scaling and position between the existing and proposed structures, the operational effect of the proposed shared path will have a minor effect on fine sediment generation (Allis, 2019). Allis (2019) highlighted the existing double curved seawall at York Bay allowed sediment movement, accumulation and transport by waves, indicating a minor impact on coastal processes for a double curved seawall design in this area. Thus where suspended sediment and sedimentation is concerned, the changes to the hydrodynamic regime should have a negligible effect (Allis, 2019).

Based on the information available at this time (i.e., Allis, 2018), the substrate of the Harbour floor below the seawall is not anticipated to change greatly, although there could be local erosion or sediment accumulation changes due to minor changes in hydrodynamics along the harbour floor below the seawall. The environmental effects of this are likely to be localised, within the natural variability in sediment composition on the foreshore, and based on the small magnitude of change to seawall proposed. Small shifts in community composition/dominant species may occur at some locations as a response to changes to substrate size and altered hydrodynamics, but it is unlikely to greatly change the overall community composition of the intertidal area due to the localised nature of the changes in substrate size and the already dynamic nature of the nearshore environment.

5.2.4 Stormwater Runoff

We have not been asked to deal with stormwater discharges as, according to HCC the stormwater from roads abutting the CMA is a permitted activity under the Regional Plan and will not change as a result of the proposed programme.

6 RECOMMENDED MITIGATION

6.1 Construction Phase Mitigation Measures

6.1.1 Proposed Mitigation Measures

The Design Features Report (Stantec, 2019a) outlines the measures to be incorporated during construction to reduce the environmental effects of the construction phase. In general the document covers a large number of mitigation measures that will help to keep the construction footprint to a minimum, control contaminants (in particular sediment and wet cement products), and facilitate recolonisation. The following is a summary of those measures outlined in Stantec (2019a) that will help to minimise the environmental effects of the construction phase:

» "Up to 20 metre lengths of seawall would be exposed at any one-time during replacement to retain small increments of potential discharge of sediments and reduce the risk of wave overtopping." We understand this to mean that construction sites will be only 20 m long but there can be more than one construction site per bay. This staging of the construction works by bay and limiting any continuous section of wall under construction to 20 m will enable the contractor to better manage their site, meaning less risk of accidental discharges etc.

» "Excavated beach material is to be stockpiled nearby and replaced on the beach after construction of each section of wall as appropriate. This will only relate to suitable natural weathered material that has been colonised by intertidal biota for subsequent reintroduction and relates mainly to larger rock material that can be placed in front of the new seawalls rather than sandy/gravel beach material. The stockpiling and placement only refers to natural beach materials."

» "Sediment generation would be kept to a minimum through the use of crushed material that is clean of fines in the construction of the widened road. Sediments introduced as part of the construction would not incorporate fines smaller than sand particles, to promote quick settling of suspended particles."

» "Earthworks and construction activities (including beach nourishment) will be sensitive to tide timing and tidal height to avoid movement of sediment potentially containing fine sediment in a wet environment. Storm events will very likely overtop any sediment control mechanism used. During overtopping, sediment will likely be shifted into the excavated seawall footing area. A site plan for sediment removal would be developed. Site management will monitor weather conditions to anticipate any weather and high tide events that may lead to high seas and plan mitigation measures accordingly. These details will be addressed in the CEMP for the specific sections of seawall."

» "Any excavation in areas where it is predominantly gravel/sand beach zone (as opposed to the rocky shore areas) would also be undertaken using methods that cause the least amount of sediment to be released from the construction area. This would include bunding / shuttering that will effectively contain and isolate the construction area from the incoming tide until construction is completed. This bund could be built from clean beach gravel sourced from the excavated area, or could be achieved via the use of sheet piling. Such a structure would need to be large enough to allow construction to continue 'in the dry' while the tide is in and strong enough to withstand waves and the incoming tide."

» "In areas where the material in the construction footprint is of larger material (i.e., rocky shore habitats) or where seawall works occur close to the mid tide mark, alternative sediment control devices will be provided. These may include sand filled geotextile containers or tubes (sand to be locally sourced) that can be easily removed following completion of the works."

» "The area of disturbance would be kept to the absolute minimum required to undertake the construction. Where there is adequate space, machinery would work from the road verge rather than from the beach/foreshore, meaning that there will be less area outside of the direct excavation zone that is subject to construction plant."

- "There would be no exposure of non-native backfill material to sea (to be enclosed by seawall and silt fences)."
- "Machinery working in the foreshore/harbour floor would track across weight-bearing mats to reduce compaction of softer/looser substrate and help to protect the intertidal surface structure within the beach areas. It will also provide a defined road for the machinery to work from, further reducing unnecessary impact to the beach/harbour floor substrate."
- "The use of the excavator on the beach would be minimised to limit damage to the beach area. The excavator would not be stored overnight nor maintained or refueled on the beach."
- "The construction zone will be clearly demarked to include a minimum working distance beyond the toe of the new seawall to allow for excavation of the bed to construct and bury the seawall edge. Demarcating the allowable area for access on the beach floor/intertidal area will also help to minimise encroachment of the construction on adjacent areas."
- Machinery working on the beach floor/intertidal area would use biodegradable hydraulic fluids and will not be stored ore refuelled on the beach. A spill kit will be maintained on site at all times, to contain any accidental spills relating to machinery working in the area.
- Dewatering is likely and any discharges are proposed to be treated for sediment and cementitious products, and either discharged to the sewer or pumped directly back to the sea. Details of the dewatering activities are specified in the construction methodology.
- "A methodology for ensuring that wet cementitious products are not discharged to the environment will include:
  - Pouring of concrete *in situ* to be done in the dry.
  - If it is not possible to undertake the works in dry conditions then the following steps will be followed:
  - Contain the potentially contaminated water, and pump to the wastewater network.
  - Contain the potentially contaminated water and pump to a treatment structure where the water can be treated to get pH to a level suitable for the local receiving environment; determining the suitable level may require sampling pH in the bay during times when it would be expected that discharges would occur.
  - If discharging suitably treated water to the environment (either directly or indirectly via the stormwater network) then this is to be done at high tide when there is the greatest level of dilution. The pH of any water on site is to be monitored to ensure compliance with this requirement."

6.1.2 Additional Recommended Mitigation Measures

Given the comprehensive list of criteria listed in the proposed construction methodology (Stantec, 2019a), we would only recommend the following additional mitigation measures to ensure the net effect of construction on the intertidal community is low. We understand that these additional mitigation measures have been agreed to be implemented.

- For any construction areas where there are intertidal rock pools or loose rocky material in the intertidal zone, check in rock pools and under rocks within the construction area for fish (i.e., such as rock fish) and relocate them outside of the construction zone prior to commencing works. Provided that there is a qualified ecologist to provide initial training and guidance to the contractors at the start of the project, then it should be possible for contractors to undertake this activity.

There are six locations where the construction footprint may extend into the subtidal zone (Figure 38), each being between 16-32 m lengths at discrete locations within Lowry, York and Mahina Bays. These areas will be more susceptible during construction purely from the point of view that they will be permanently wetted and thus it will be comparatively more challenging to work within and will have a greater risk of contamination during the pouring of wet concrete. We would therefore recommend the following for these zones:

» Prior to construction demarcate the actual location of the low tide line and determine if the subtidal zone is in fact within the 5 m construction width. This is necessary because the low tide line referred to in this report was established via digitisation of aerial imagery and thus has some variation in its accuracy.

» If the subtidal zone is confirmed to extend into the 5 m construction width than narrow the construction width such that all construction activity remains outside of the subtidal zone.

» If it is not possible to narrow the construction zone sufficiently to remain outside of the subtidal zone then undertake measures to isolate the construction site from the subtidal area such that the site is effectively contained should a release of concrete (or other contaminants) in the worksite occur. Surficial large rocks in the subtidal area within the construction site that have been colonised with biota should be removed from the site and placed in the adjacent subtidal zone.

» Allow for the ability to extend the length of a construction zone beyond the proposed 20 m length, if this allows for a single subtidal area to be contained in the one site (rather than having to contain the subtidal area over two adjacent sites). The estimated lineal distance for two sections identified in Figure 38 are longer than 20m; namely a 32 m length in northern Lowry Bay and a 24 m length in Southern Mahina Bay.

Refer to Overmars (2019a, 2019b) in relation to seagrass beds during construction.

6.2 Operational Phase Mitigation Measures

6.2.1 Proposed Mitigation Measures

The following are design features that have been incorporated into the curved seawall design.

Additional habitat on curved seawalls:

» “Texture is to be incorporated into the concrete surfaces of the seawalls, to provide opportunities to establish biota habitat.” … “A form liner/void former can be used to create a suitably textured surface on the vertical curved faces (ca 5mm in depth) and on the flat step of the curved seawall (ca 50 – 70mm in depth). Details of these features are to be provided in the Landscape and Urban Design Plan, where there will be input from the design ecologist, engineer, landscape architect and urban designer.” Stantec (2019a). In discussions with Stantec it is understood that currently the textured surface will be applied to the bottom curve of the double and triple curved seawall face within the intertidal zone, and the slightly deeper holes to the bottom flat step of the double and triple curved seawalls.

» Part of the engineering design to provide for drainage through the otherwise impermeable concrete wall is the creation of 75 mm diameter weep holes every 2 m along length of curved seawalls. They will be vertically placed immediately above the lowest step of the curved wall (so they will drain across the top surface of the step), and also above the second step for the triple-curved option. Whilst they are being included as part of the engineering design they will also provide some small habitat feature, where the weep holes are within the intertidal zone. The proposed weep holes are slightly larger and placed more often than those in the new curved seawall in York Bay, that are being utilised by biota (Figure 36).

Reuse of colonised rock material:

» In rocky foreshore areas, excavated larger natural weathered rock material that has been colonised by intertidal biota will be stockpiled nearby, and replaced on the beach in front of the new seawalls after construction of each section (Stantec, 2019a).

» The reuse of this material will not only facilitate colonisation of the new surfaces and disturbed construction footprint area, but will also help to create new habitat immediately in front of the new seawalls, and is recommended as a means of improving habitat values of existing seawalls (Department of Climate Change and Water, 2009).

6.2.2 Additional Recommended Mitigation Measures

There are a number of additional mitigation measures to be implemented during the design and construction phase that will help to improve habitat complexity and thus biota diversity and/or density on the new seawalls, so as to ensure the net effect on the intertidal community is low (or 'less than minor' in the RMA context). We understand that these additional mitigation measures have been agreed to be implemented. It is acknowledged that the design of some interventions must take into account maintaining structural integrity of the seawalls which may limit the breadth of the designs. However where there is scope for enhancements to be made, then even minor changes can improve intertidal ecology, and they may even become a focal point of interest for public engagement about intertidal ecology.

Curved Seawalls

Further criteria regarding textures on the curved wall surface:

» Design the proposed texture to apply to the curved surface of the seawall in conjunction with an ecologist (with an understanding of intertidal ecology) and engineer during the detailed design phase. Ensure that the design is sufficient to provide some additional intertidal habitat on the curved surface whilst not compromising on the structural integrity of the curved walls.

» The texture should be applied to curved sea walls within the 'high' and 'medium' encroachment sections as identified in Figure 39. Table 13 outlines the lineal distance of curved wall type that this would apply to. For double or triple curved sea walls the texture should be applied to any curve that is within 200 mm of the MHWS mark (i.e., any curve that is wholly or partly within the current intertidal zone. At a minimum (based on only one curve being textured) this would equate to 0.09 ha of textured surface.

» Based on an effects level approach there is an insufficient level of effect to require that the textured surface be applied to areas identified as 'low' within Figure 39, as the seawall is within the same footprint as the existing seawall). However, by including a texture on these seawalls (as per the condition specified above) then at a minimum (i.e., based on only one curve being textured) this would add an additional 0.01 ha of textured surface; and a total of 0.1 ha, which is 68% of the estimated 0.15 ha of intertidal area that would be lost under the curved seawall encroachments. Thus the texture applied to the 'low' encroachment ranking will help to offset the existing intertidal area lost to the 'high' and 'medium' encroachments.

- Based on an effects level approach there is an insufficient level of effect to require that the textured surface be applied to areas identified as 'NA' within Figure 39 as they are above the current CWMS level).
- Whilst from an effects level consenting point of view a texture is not required on the curved surfaces outside of the two criteria specified above (i.e., not within the 'high', 'medium', or 'low' encroachment sections where the curved wall is within 200 mm of the MWHS mark), or within the 'NA' encroachment sections, any consent should not preclude the option to do textures here should there be a desire to do so. This would provide a more cohesive landscape design approach, and in particular provide future ecological resilience to sea level rise; with the textures on the higher curves currently above the MHWS mark becoming the future intertidal zone under sea level rise scenarios.

Further criteria regarding textures (small depressions) on the flat step:

- Design the proposed shallow depressions for the flat step of the curved seawall in conjunction with an ecologist (with an understanding of intertidal ecology) and engineer during the detailed design phase. Ensure that the design is sufficient to provide some additional intertidal habitat on the curved surface whilst not compromising on the structural integrity of the curved walls.
- These 'holes/depressions' should be applied to any bottom flat step of double curved seawalls and any bottom and middle flat step of triple curved seawalls that are within 200 mm of the MHWS mark, within the 'high' and 'med' impact sections as identified in Figure 39. Table 13 outlines the lineal distance of curved wall type that this would apply to. At a maximum this equates to approximately 0.13 ha of horizontal surface with depressions applied, although the final area will be less than this as not all bottom and middle flat steps will be below (or within 200 mm of) the MWHS mark.
- It would not be suitable to apply depressions to the top flat step (i.e., any single curved sea walls and the top step for double and triple curved sea walls) as this will be at road height and thus above the MHWS level and also within the walking zone for walkway users.
- Based on an effects level approach there is an insufficient level of effect to require that the textured surface be applied to areas identified as 'low' (i.e., the new seawall is within the same footprint as the existing) or 'NA' (i.e., above the current CWMS level) within Figure 39. Whilst from a consenting point of view the depressions are not needed on the flat step within these areas, any consent should not preclude the option to do textures here should there be a desire to do so. This is due to the same reasons as specified for the curved seawall textures.

Reuse of colonised rock material:

- Such material should be stockpiled in a similar intertidal zone during construction and ideally redistributed in front of the new seawall under supervision of a qualified intertidal/coastal ecologist.

Rock pools on vertical face of curved seawall:

- Install purpose-made 'plant pot/window box' structures that can be added to the surface of the curved seawall following completion of construction. Structures that are added to an otherwise smooth seawall can increase surface area, microhabitat and complexity (Browne & Chapman, 2014; Department of Climate Change and Water, 2009; Goff, 2010). These structures will not limit the function of the seawall and add many benefits for intertidal environments.
- A number (ca. 10-15) could be placed in several (up to five) locations where the bottom seawall curve is within the mid-tide area and the seawall is less exposed to storm surge. If the structures prove

successful in terms of longevity then it would be possible to investigate adding more of them if relevant at a later time (i.e., outside of this project).

- Figure 40 shows an example of a low-tech 'window box', although the design for Eastern Bays would need to take into account the curved nature of the vertical surface and the height between the seabed and the top of the curve. As this will vary along the length of the project we recommend that these structures are designed and installed upon completion of the seawalls, so that actual site conditions can be taken into account. A key criteria would be that the structures are designed in conjunction with a project engineer and landscape architect, along with an ecologist (with an understanding of intertidal ecology), so as to ensure that the features also meet the wider project requirements. However, any conditions should not preclude the ability for this to be undertaken as a university research project or similar.
- As with other ecological interventions, the consent conditions should not preclude the option to install more 'window boxes' should there be a desire to do so.

Encroachment:

- Stantec (2019a) states that "There may be some beach locations where material transportation is less active and therefore a single curve wall may suffice. It is noted that using a single rather than double curve can avoid an additional 600 mm horizontal beach encroachment". Thus our expectation is that it should be possible at some locations at least, to reduce the level of encroachment for the curved seawalls during the detailed design phase.

Figure 40 Example of a 'window box' rock pool on a flat vertical face from Chapman & Browne (2014).

Revetments

Revetment seawall types extend the furthest beyond the existing seawall footprint and were generally placed in the 'high' encroachment ranking (Figure 39). That said the sloped angle of the seawall provides a greater intertidal zone, which helps to reduce predation and competition, and better mimics a natural shore profile. Revetments also provide for greater future-proofing for intertidal change with sea level rise - as the gently angled slope will maintain a similar intertidal zone width as the sea level moves up the revetment (this is in contrast to more vertical seawalls where the intertidal zone is reduced to a smaller width as the sea level moves from the sloped shoreline to the more vertical seawall surface). However, as the rock proposed for the revetment is hard-wearing it is unlikely to wear over time to create a heterogeneous surface texture more amenable to colonisation. On the balance of these considerations some additional mitigation measures are required for the revetment treatment types to ensure the net effect on the intertidal community is low (or 'less than minor' in the RMA context). We understand that these additional mitigation measures have been agreed to be implemented.

- Use natural rock/cobble substrate within the construction area that would otherwise be removed during construction or lost beneath the seawall. We note that to maintain the integrity of the revetment that this natural rock could not be used as bulk fill within revetments. However, this 'won' rock can be reused in various ways onsite, including being deposited on rock platforms to be broken/dispersed by waves, or manually placed into voids in the rock revetment as habitat. This material can be stockpiled and then placed following completion of the rock revetment, and should maximise the range of rock sizes.
- Do not excavate out *in situ* rock to replace with revetment rock if it can be avoided.
- Drill core some rock pools into the surface of some of the hard revetment rock within the mid-tide area of the seawall (Figure 41). This can be done following construction of the revetments, and should concentrate mostly on the mid-low tide zone.
- Look at reducing the footprint of the revetment seawall types through the following options, where it is possible to do so without irrevocably compromising on structural integrity of the seawall, overtopping protection, or coastal processes:
  - Increasing the slope of the revetment.
  - Reducing the rock size (to reduce the width of flat area at the top of the revetment).
  - Reducing the width of the flat area at the top of the revetment to be two rock diameter instead of three.

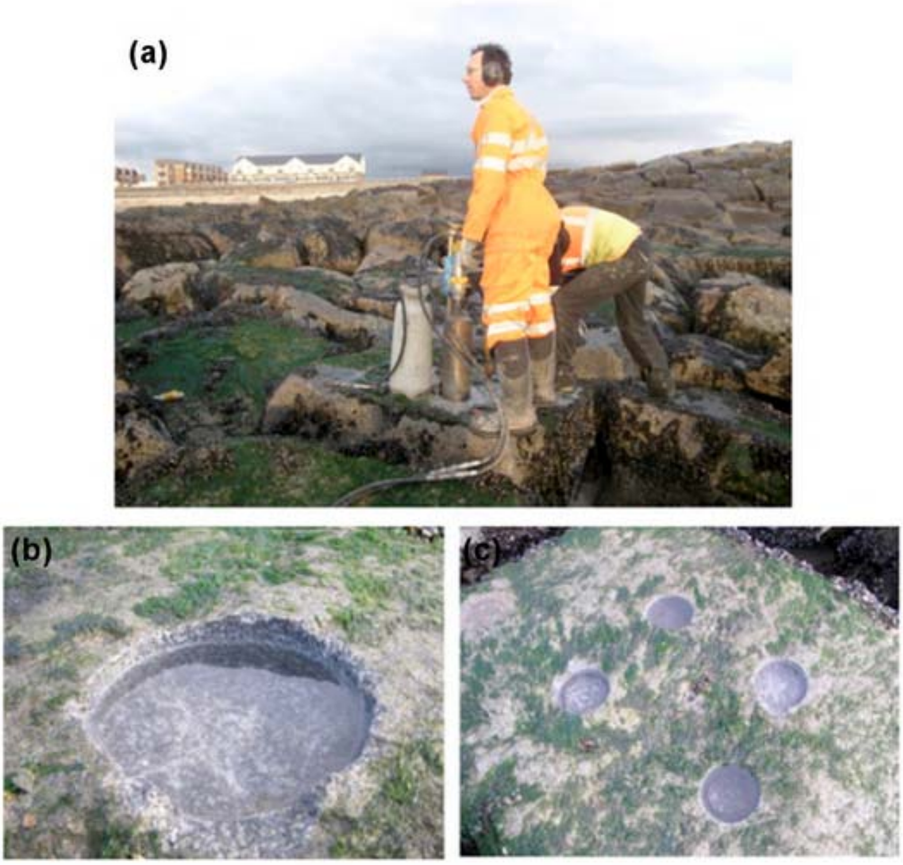


Figure 4.11 Drill-cored rock pools at Tywyn, Wales. (a) Contractors drilling the pools in November 2011. (b) Shallow (5 cm deep) pool. (c) Four pools on the surface of a boulder. *All photographs by L. Firth.*

Figure 41 Example of rock pool depressions being drill-cored into revetment rock. Source: Zanuttigh *et al*., 2015.

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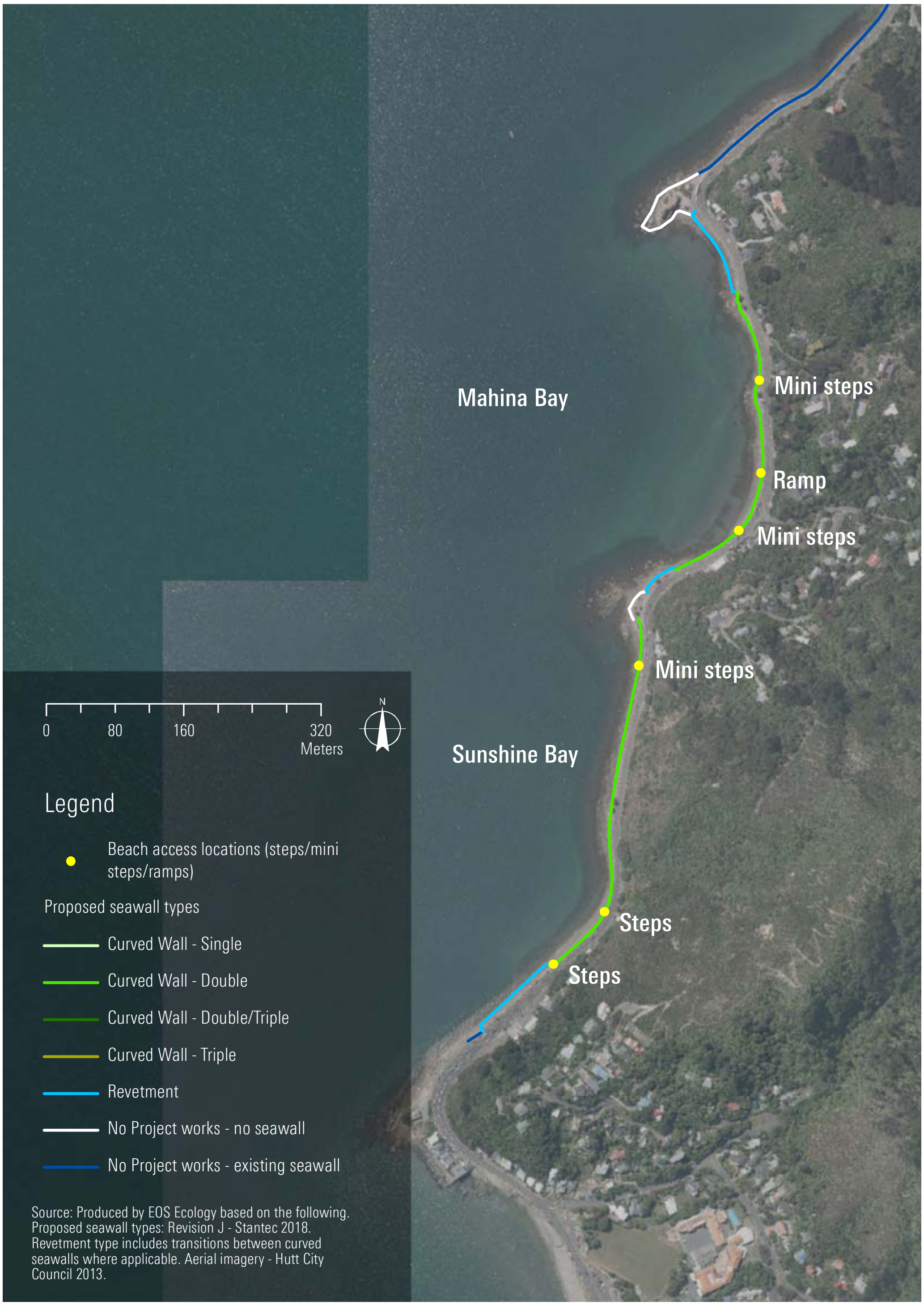
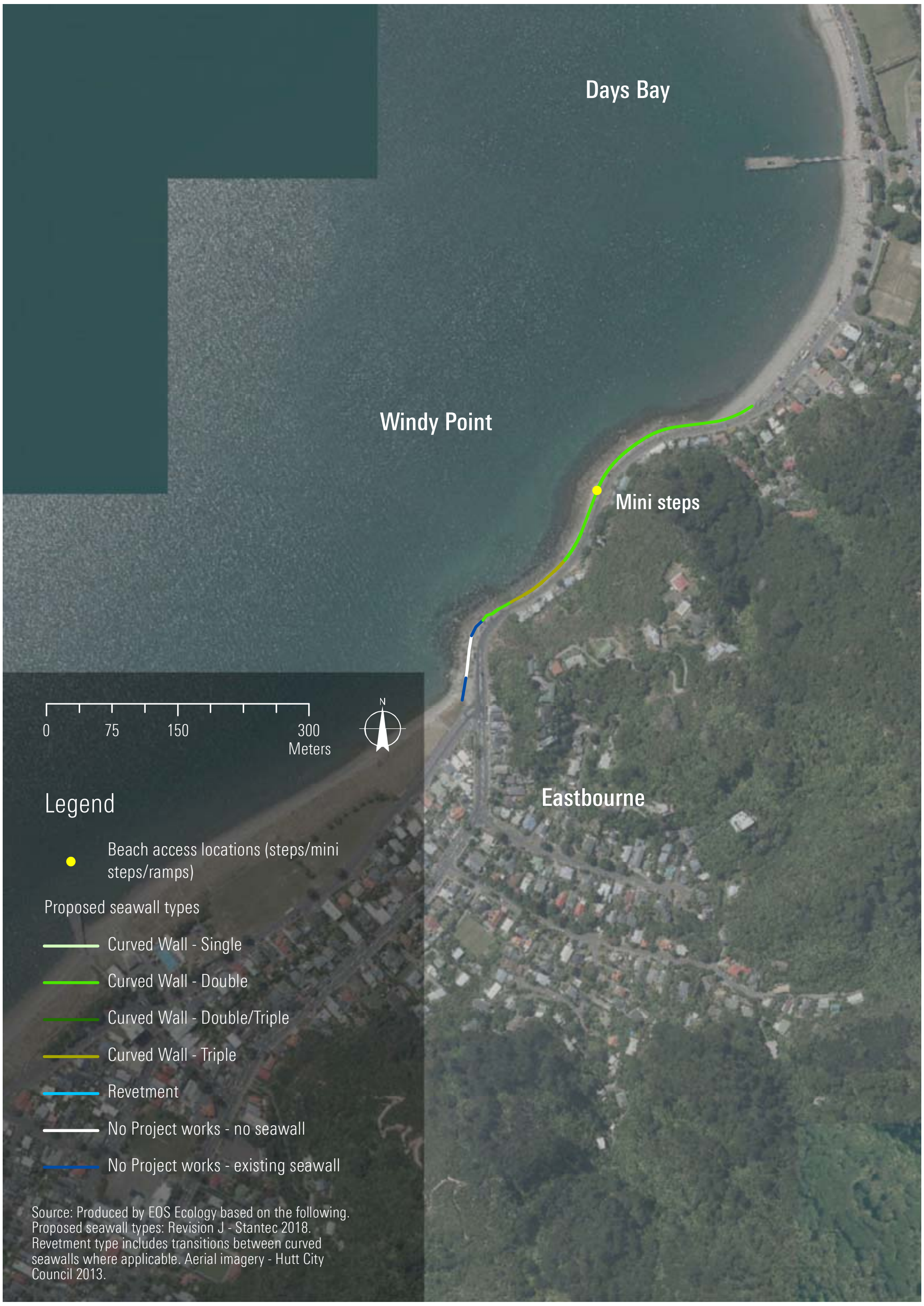
9 APPENDICES

9.1 Appendix 1 – Detailed Map of Proposed Seawall Types

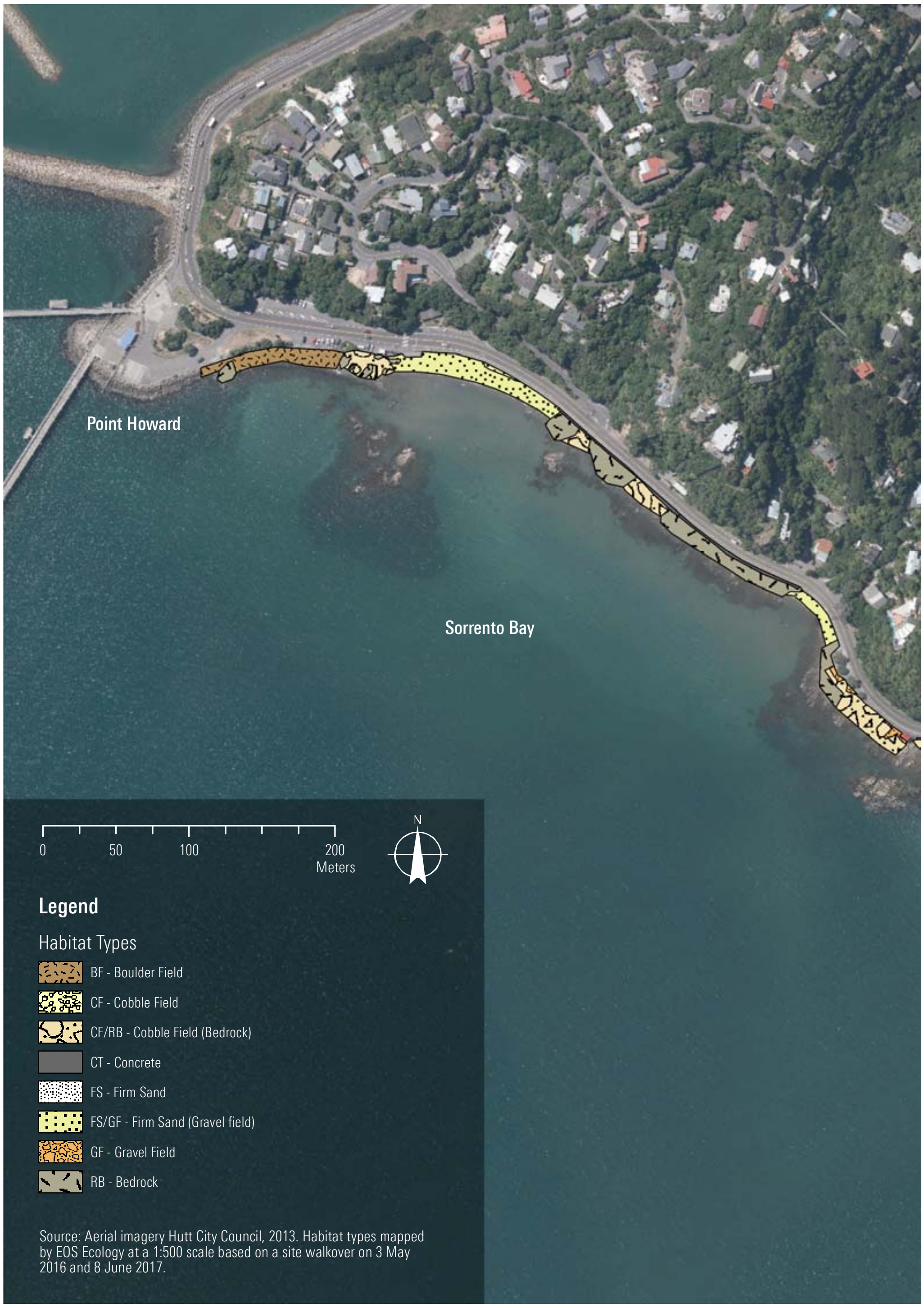
The proposed detailed seawall types as per the Design Plans and associated files from Revision J (Stantec 2018).

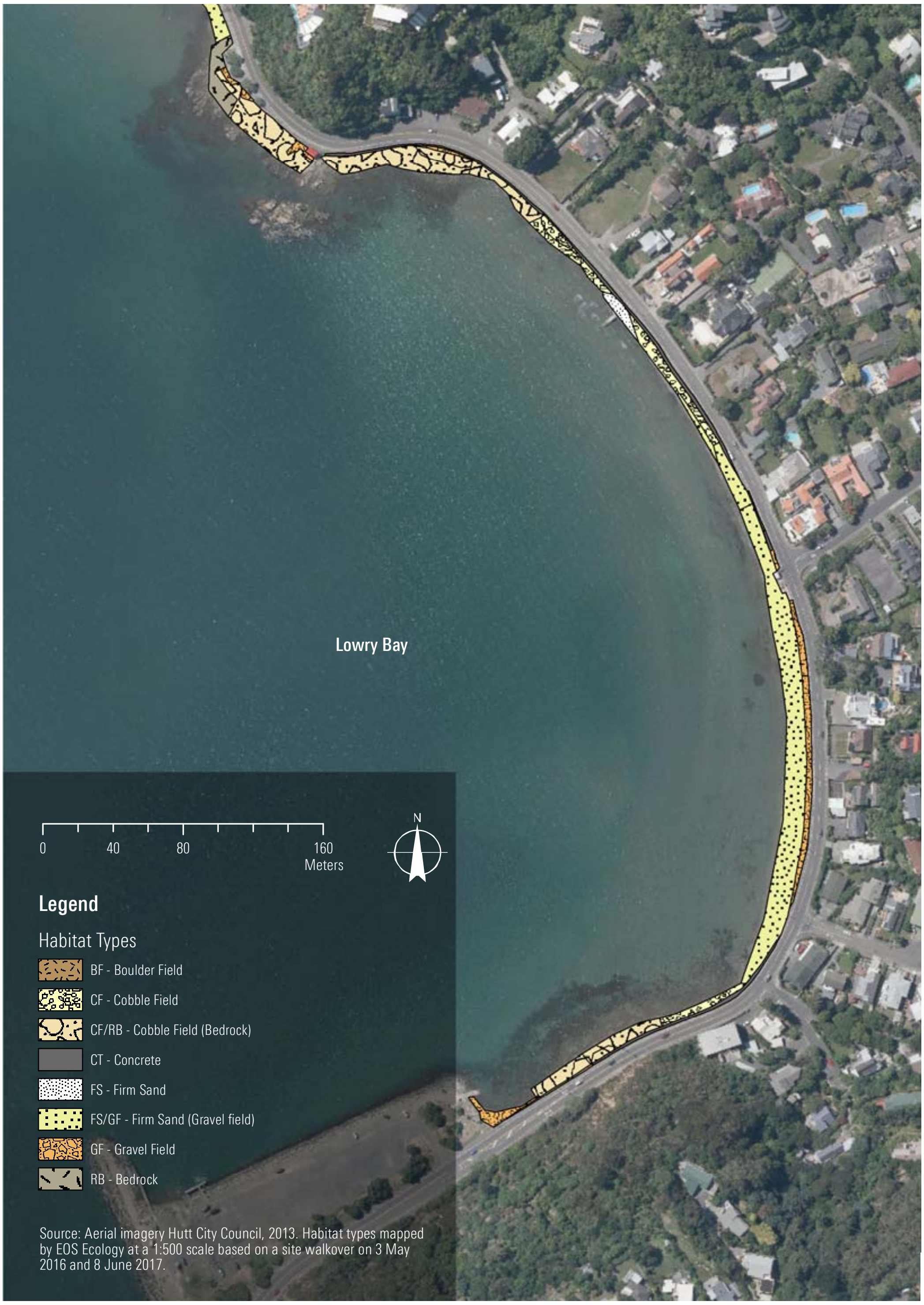

Mahina Bay
Mini steps
Ramp
Mini steps
Mini steps
Sunshine Bay
Steps
Steps
0
80
160
320
Meters
N
Legend
Beach access locations (steps/mini steps/ramps)
Proposed seawall types
Curved Wall - Single
Curved Wall - Double
Curved Wall - Double/Triple
Curved Wall - Triple
Revetment
No Project works - no seawall
No Project works - existing seawall
Source: Produced by EOS Ecology based on the following. Proposed seawall types: Revision J - Stantec 2018. Revetment type includes transitions between curved seawalls where applicable. Aerial imagery - Hutt City Council 2013.


Days Bay
Windy Point
Mini steps
Eastbourne
0
75
150
300
Meters
N
Legend
Beach access locations (steps/mini steps/ramps)
Proposed seawall types
Curved Wall - Single
Curved Wall - Double
Curved Wall - Double/Triple
Curved Wall - Triple
Revetment
No Project works - no seawall
No Project works - existing seawall
Source: Produced by EOS Ecology based on the following. Proposed seawall types: Revision J - Stantec 2018. Revetment type includes transitions between curved seawalls where applicable. Aerial imagery - Hutt City Council 2013.

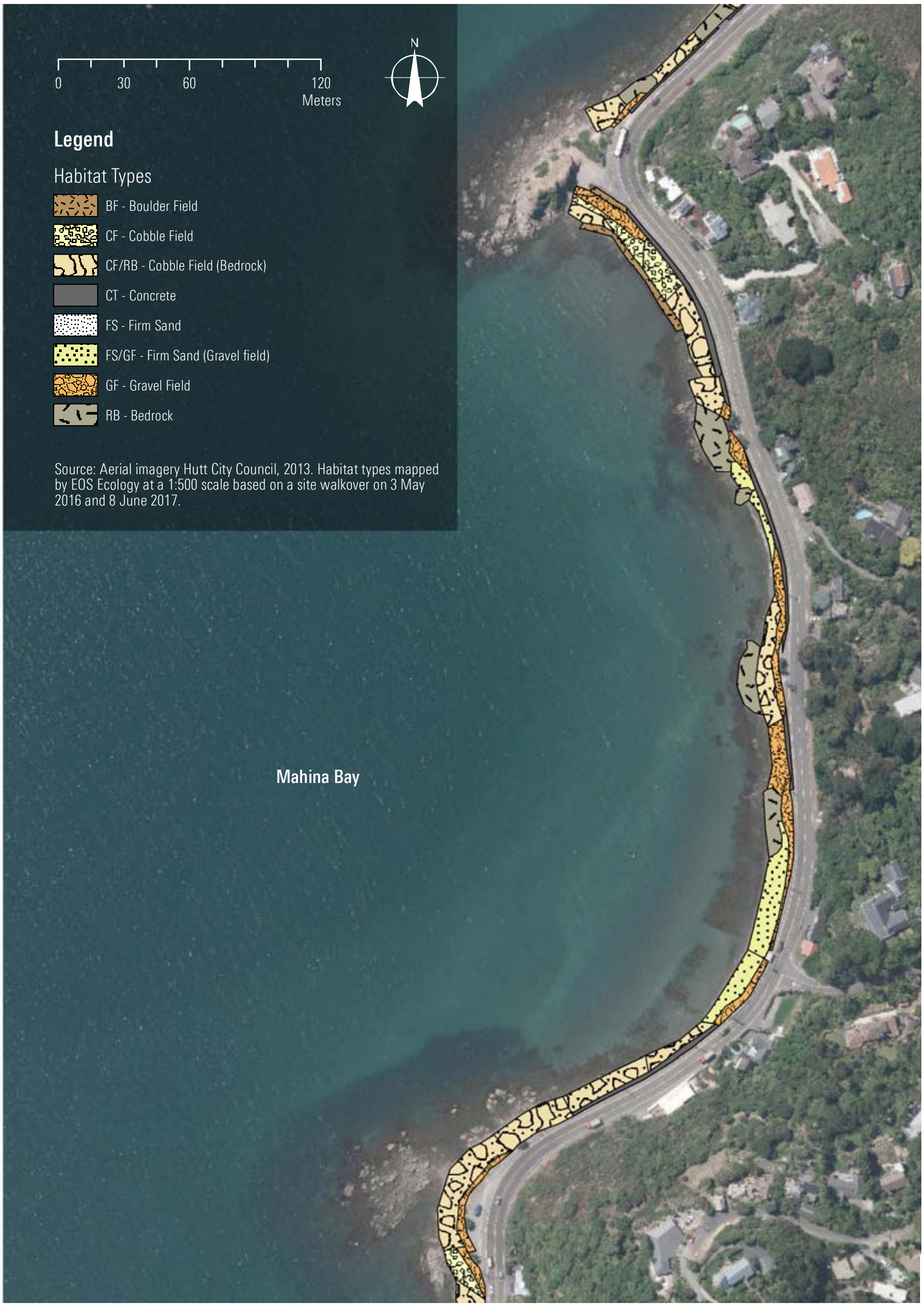
9.2 Appendix 2 – Habitat Maps – Broad Scale Assessment

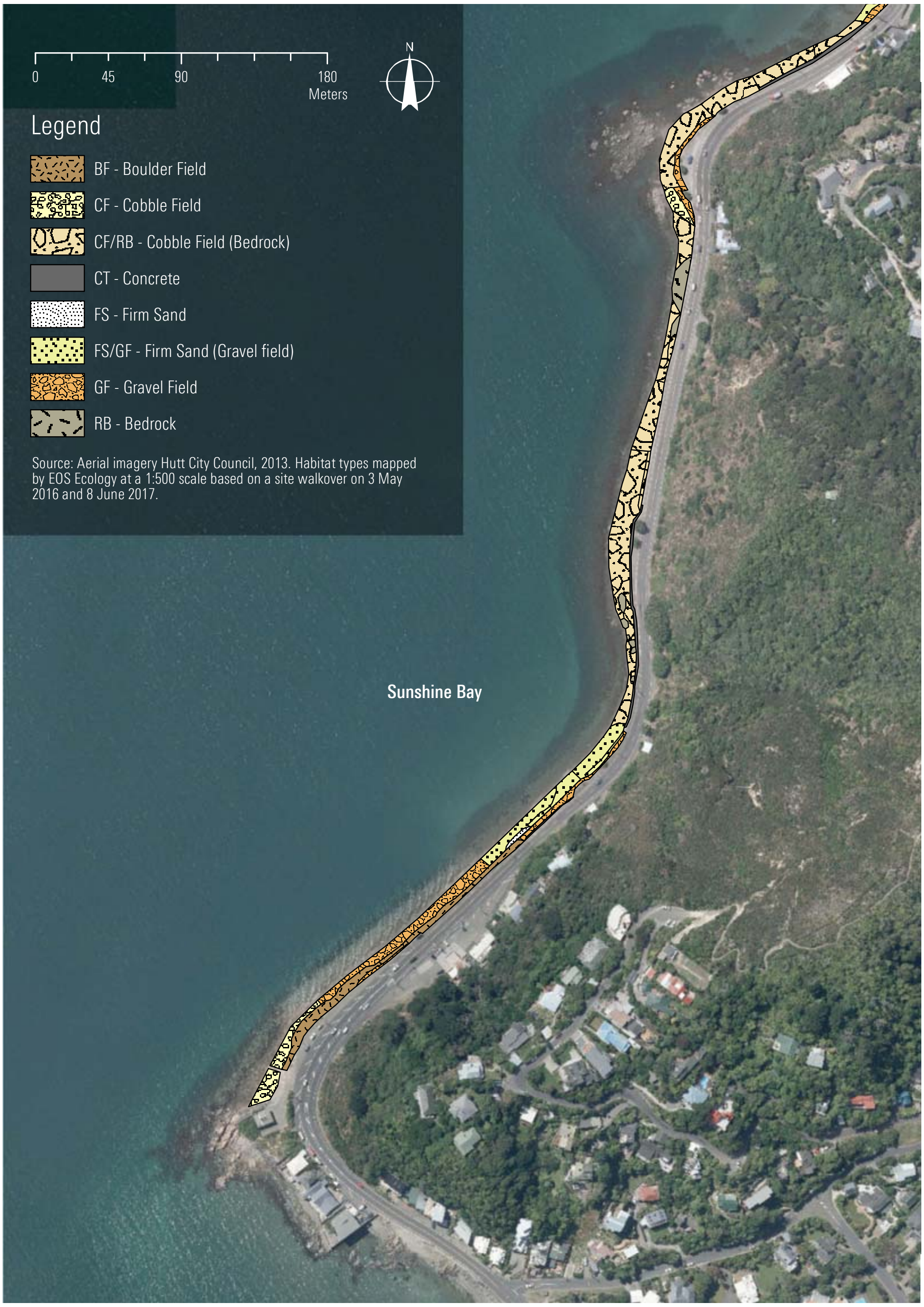
The broad scale assessment of habitat types was undertaken on 3 May 2016. The maps provide habitat types adapted from Stevens *et al.* (2004) at a 1:500 scale. Note that Days Bay was excluded from the habitat mapping as it falls outside of the project area.




Lowry Bay
0
40
80
160
Meters
N
Legend
Habitat Types
BF - Boulder Field
CF - Cobble Field
CF/RB - Cobble Field (Bedrock)
CT - Concrete
FS - Firm Sand
FS/GF - Firm Sand (Gravel field)
GF - Gravel Field
RB - Bedrock
Source: Aerial imagery Hutt City Council, 2013. Habitat types mapped by EOS Ecology at a 1:500 scale based on a site walkover on 3 May 2016 and 8 June 2017.


0
40
80
160
Meters
N
Legend
Habitat Types
BF - Boulder Field
CF - Cobble Field
CF/RB - Cobble Field (Bedrock)
CT - Concrete
FS - Firm Sand
FS/GF - Firm Sand (Gravel field)
GF - Gravel Field
RB - Bedrock
Source: Aerial imagery Hutt City Council, 2013. Habitat types mapped by EOS Ecology at a 1:500 scale based on a site walkover on 3 May 2016 and 8 June 2017.
York Bay

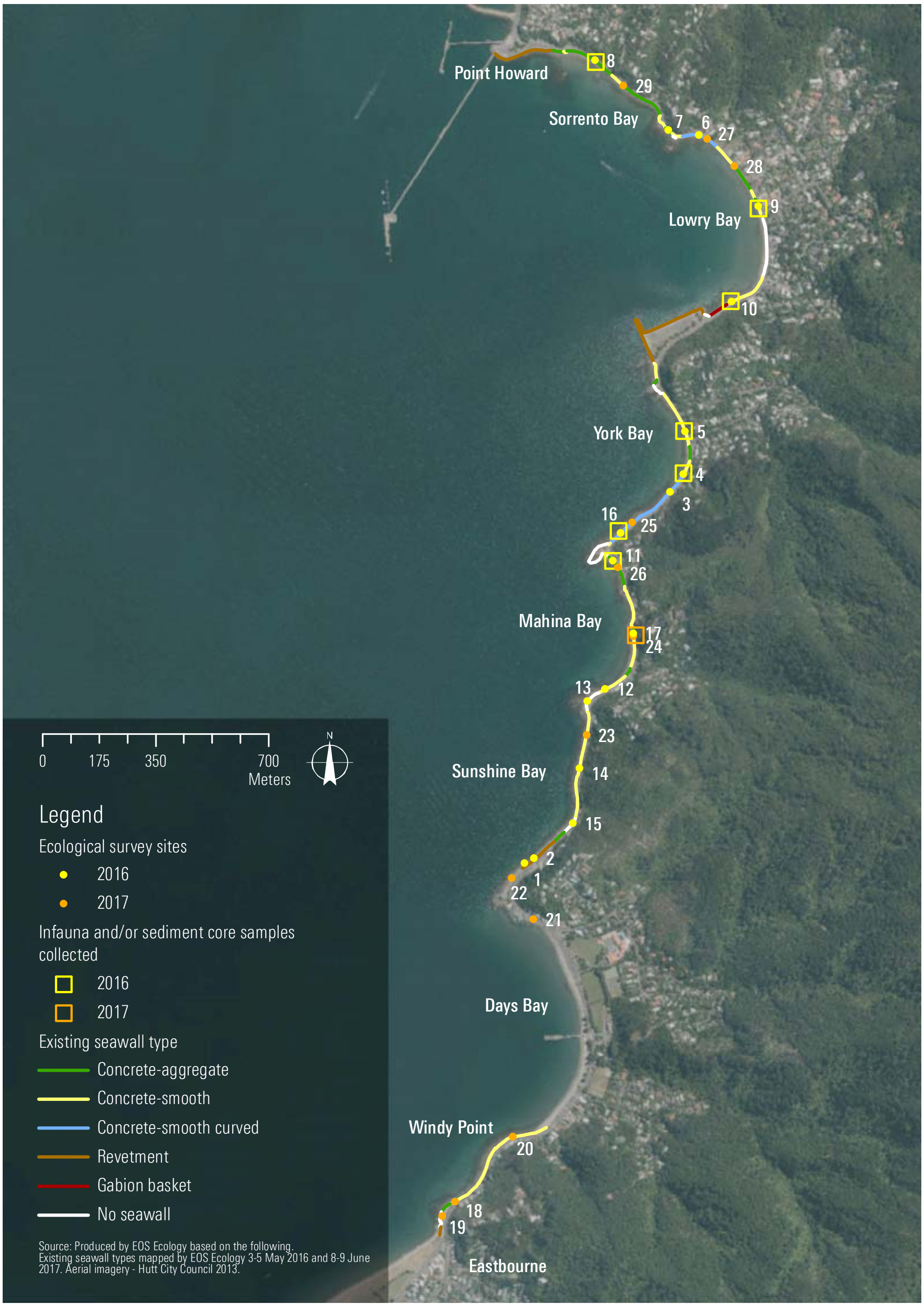

0
30
60
120
Meters
N
Legend
Habitat Types
BF - Boulder Field
CF - Cobble Field
CF/RB - Cobble Field (Bedrock)
CT - Concrete
FS - Firm Sand
FS/GF - Firm Sand (Gravel field)
GF - Gravel Field
RB - Bedrock
Source: Aerial imagery Hutt City Council, 2013. Habitat types mapped by EOS Ecology at a 1:500 scale based on a site walkover on 3 May 2016 and 8 June 2017.
Mahina Bay

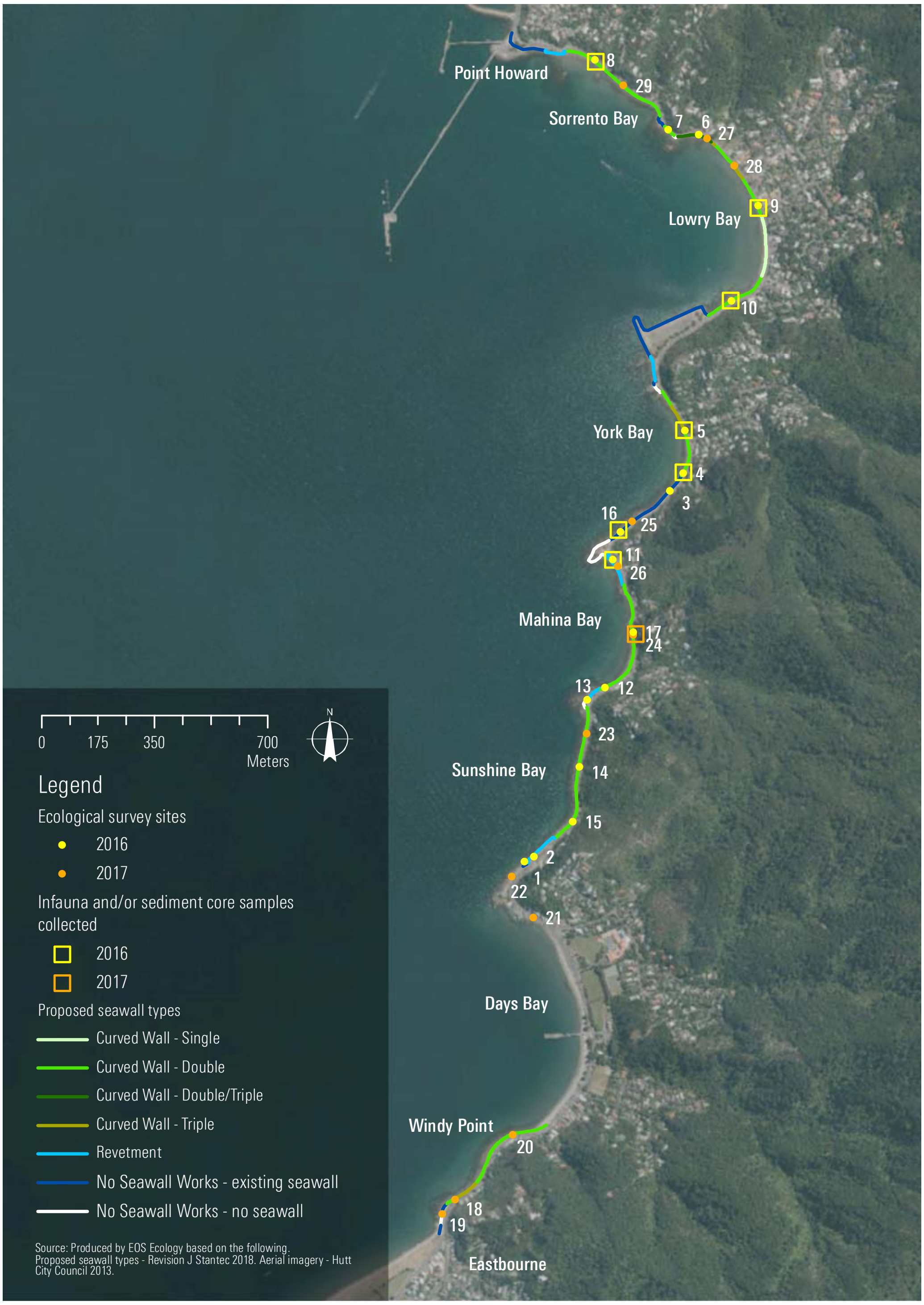

0
45
90
180
Meters
N
Legend
BF - Boulder Field
CF - Cobble Field
CF/RB - Cobble Field (Bedrock)
CT - Concrete
FS - Firm Sand
FS/GF - Firm Sand (Gravel field)
GF - Gravel Field
RB - Bedrock
Source: Aerial imagery Hutt City Council, 2013. Habitat types mapped by EOS Ecology at a 1:500 scale based on a site walkover on 3 May 2016 and 8 June 2017.
Sunshine Bay


0
30
60
120
Meters
N
Legend
BF - Boulder Field
CF - Cobble Field
CF/RB - Cobble Field (Bedrock)
CT - Concrete
FS - Firm Sand
FS/GF - Firm Sand (Gravel field)
GF - Gravel Field
RB - Bedrock
Source: Aerial imagery Hutt City Council, 2013. Habitat types mapped by EOS Ecology at a 1:500 scale based on a site walkover on 3 May 2016 and 8 June 2017.
Days Bay
Windy Point
Eastbourne

9.3 Appendix 3 – EOS Ecology Ecological Survey Sites

EOS Ecology ecological surveys (including infauna and sediment cores) were conducted 4-6 May 2016 and 8-9 June 2017. The following two maps overlay these sites with the existing seawalls and the proposed seawalls (Revision J).




Point Howard
Sorrento Bay
Lowry Bay
York Bay
Mahina Bay
Sunshine Bay
Days Bay
Windy Point
Eastbourne
8
29
7
6
27
28
9
10
5
4
3
16
25
11
26
17
24
13
12
23
14
15
2
1
22
21
20
18
19
0
175
350
700
Meters
N
Legend
Ecological survey sites
2016
2017
Infauna and/or sediment core samples collected
2016
2017
Proposed seawall types
Curved Wall - Single
Curved Wall - Double
Curved Wall - Double/Triple
Curved Wall - Triple
Revetment
No Seawall Works - existing seawall
No Seawall Works - no seawall
Source: Produced by EOS Ecology based on the following. Proposed seawall types - Revision J Stantec 2018. Aerial imagery - Hutt City Council 2013.

9.4 Appendix 4 – Benthic Invertebrate Fauna Overview

Number of samples (from 71 epifauna quadrats, 8 infauna cores and a free search along the 29 site transects) that benthic invertebrates were recorded from during 4-6 May 2016 (Site 1–17) and 8–9 June 2017 (Site 18–29) surveys. Note that only new taxa not already identified in epifauna quadrats from that site were recorded in the free searches. While 71 epifauna quadrats were collected, 18 had no taxa present.

Faunal Group 1	Faunal Group 2	Taxa	Epifuana	Free search	Infauna Core	Grand Total
Chordata	Actinopterygii	*Acanthoclinus fuscus*		5		5
Cnidaria	Anthozoa	*Actinia tenebrosa*	2	3		5
Crustacea	Amphipoda	Amphipoda	3	1		4
		Gammaridae	7	3	5	15
	Cirripedia	*Chamaesipho columna*	21	7		28
	Copepoda	Copepoda			1	1
	Decapoda	*Austrohelice crassa*			1	1
		Cyclograpsus lavauxi	3	1		4
		Hemigrapsus crenulatus	4	3		7
		Hemigrapsus sexdentatus	5	10		15
		Heterozius rotundifrons	2	12	2	16
		Pagurus sp.		1		1
		Palaemon affinis		1		1
		Petrolisthes elongatus	16	9	2	27
	Isopoda	Flabellifera			2	2
	Ostracoda	Ostracoda			1	1
Echinodermata	Asteroidea	*Patiriella* sp.	2	6		8
	Echinodermata	Echinodermata			1	1
Mollusca	Bivalvia	*Arthritica* sp.			1	1
		Austrovenus stutchburyi	1	1	1	3
		Mytillidae			1	1
		Mytilus galloprovincialis	8	7		15
		Paphies australis		2	3	5
		Perna canaliculus	2	7		9
		Tawera spissa			1	1
		Xenostrobus neozelanicus	7	3		10
	Chitonida	*Chiton glaucus*	3	9		12
		Sypharochiton pelliserpentis	9	12		21
	Gastropoda	*Atalacmea fragilis*	1	5		6
		Austrolittorina antipodum	24	4		28
		Austrolittorina cincta	10			10
		Benhamina obliquata	2	1		3
		Buccinulum linea	6	2		8
		Cellana ornata	6	3		9
		Cellana radians	12	13	2	27
		Cominella glandiformis		2		2
		Cominella virgata	3	5		8
		Dicathais orbita		1		1

		Diloma bicanaliculatum	1	8		9
		Diloma nigerrimum	15	3	1	19
		Haustrum haustorium	1	6		7
		Lepsiella scobina	5	10		15
		Diloma aethiops	28	8	1	37
		Notoacmea sp.	4	1		5
		Onchidella nigricans	5			5
		Patelloida corticata	1			1
		Potamopyrgus sp.			1	1
		Siphonaria australis	1			1
		Lunella smaragda		5		5
		Zeacumantus subcarinatus	3		2	5
Nemertea	Nemertea	Nemertea			1	1
Platyhelminthes	Platyhelminthes	*Notoplana australis*	1		1	2
Polychaeta	Aciculata	*Glycera americana*	1		1	2
		Nereididae			3	3
		Perinereis vallata			1	1
	Canalipalpata	*Aonides* sp.			4	4
		Oweniidae			1	1
		Prionospio sp.			2	2
		Scolecolepides benhami	1			1
	Scolecida	*Capitella* sp.			2	2
		Heteromastus filiformis			2	2
No. of occurrences			**226**	**180**	**47**	**453**
No. of taxa			**41**	**40**	**44**	**61**

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