Fine Scale Monitoring of Petone Beach, Lyall Bay and Owhiro Bay, Wellington

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Salt Ecology Report 007

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Petone Beach looking across Wellington Harbour to Matiu/Somes Island.

RECOMMENDED CITATION

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EXECUTIVE SUMMARY

This report describes baseline assessment and characterisation of three beaches in Wellington Harbour conducted for Greater Wellington Regional Council (GWRC). These beaches were Petone, Lyall Bay and Owhiro Bay. Only the Petone beach assessment involved a comprehensive survey approach, whereas the focus of the Lyall Bay and Owhiro Bay surveys was a cursory characterisation of beach condition. The locations range from relatively wave-sheltered at Petone, to increasingly wave exposed at Lyall and Owhiro Bays, respectively.

The three beaches had intertidal zones ranging from a relatively broad gently-sloping profile with predominantly sandy sediments at Petone, to a narrower, steeper and predominantly gravel beach at Owhiro Bay. Lyall Bay was intermediate between these two. These differences are consistent with increased wave-exposure from Petone to Lyall and Owhiro Bays respectively. The apparent Redox Potential Discontinuity (aRPD) layer was relatively deep (>15cm) at all sites, indicating sediments were well-oxygenated, with no significant accumulation of organic matter. A cursory assessment of trace contaminants at Owhiro Bay did not reveal ecologically significant concentrations.

The beach infauna at all locations was relatively species-poor across most tidal elevations, but especially across the mid-shore zone. Similarly, abundances were generally low except for some of the high-tide stations where beach-cast seaweed supported sand hoppers. Additionally, some low shore or shallow subtidal stations harboured moderate densities of juvenile pipi (Petone) or amphipods (Owhiro). The biota present were typical of semi-exposed sandy beaches, where wave action limits the accumulation of fine organic detritus, and creates a harsh environment in which beach sediments are moved around and infauna organisms are subjected to regular or episodic disturbance. Overall, when infaunal results are considered together with other sediment indicators, the beaches were judged to be in “very good” or “good” condition, based on the condition rating system used.

Implications for ongoing monitoring are discussed. It is suggested that there would be little benefit in undertaking repeat surveys, except perhaps at intervals of c.5-years. Monitoring alternatives are suggested, including: (i) modifying the present design in terms of methods, in order to obtain a larger sample size; (ii) focusing more on the low tide and adjacent subtidal zones where a greater richness and abundance of biota would be expected; (iii) targeting just those species of particular interest (e.g. edible shellfish); and (iv) applying the present approach (or a modification of it) across more locations, in order to build up a more comprehensive picture of the state of the regions beaches, and better inform future monitoring needs.

1. INTRODUCTION

Developing an understanding of the state of coastal habitats is critical to the management of biological resources. The “Kapiti, Southwest, South Coasts and Wellington Harbour - Risk Assessment and Monitoring” report (Robertson and Stevens 2007) identified the nature and extent of risk from a range of stressors to the soft sediment shore ecology of beaches in the Wellington Region. Subsequent to that report, Greater Wellington Regional Council (GWRC) implemented a programme of broad-scale habitat mapping of priority beaches, and fine-scale baseline assessment and ongoing monitoring of a representative subset of those. The fine-scale programme uses key indicators of beach condition, whose selection was based on an analysis of the major issues affecting beaches in New Zealand (Appendix 1).

The main indicators used in the programme are beach morphometry (elevation profile), sediment grain size, sediment oxygenation, and the abundance and diversity of sediment-dwelling macrofauna (Appendix 2). Assessment and monitoring of these indicators will help determine the state of Wellington’s beaches and the extent to which they are affected by some of the common stressors described in Appendix 1. These include: habitat loss or modification (e.g. overharvesting of living resources, physical disturbance from vehicle activity), fine-sediment inputs, eutrophication, the introduction of invasive species, and chemical contaminants. Not all of these will be equally relevant or important at all locations. However, long-term monitoring also has value as a basis for assessing changes from processes that occur across broader spatial scales, such as sea temperature and sea level rise, changes in freshwater input and wave-climate (e.g. due to altered storm frequency or intensity), and ocean acidification.

Although the relationships between stressors (both natural and anthropogenic) and changes to sandy beach communities are complex, and can be highly variable, previous studies have established clear links between multiple stressors and the degradation of beach habitat (e.g. McLachlan and Brown 2006). The baseline assessment and monitoring programme put in place by GWRC is intended to provide a defensible, cost-effective way to help rapidly identify any degraded conditions at GWRC beaches, and will provide a platform for prioritising ongoing monitoring needs.

To date, fine-scale baseline assessments in the GWRC region have been undertaken at two beaches, one at Peka Peka beach near Waikanae on the Kapiti Coast (Robertson and Stevens 2015) and another at Castlepoint Beach on the Wairarapa coast (Robertson and Stevens 2014). The present report describes baseline assessment and characterisation of three beaches in Wellington Harbour: Petone Beach, Lyall Bay and Owhiro Bay (Figure 1), and considers their utility as locations for long-term monitoring. Only the Petone assessment involved a comprehensive survey approach, whereas the focus of the Lyall Bay and Owhiro Bay surveys was a cursory characterisation of beach condition. The locations range from relatively wave-sheltered at Petone, to increasingly wave exposed at Lyall and Owhiro Bays, respectively.

The selection of these locations for the 2018 surveys was primarily based on their popularity as swimming beaches and/or a GWRC and community interest in their health status. For the Petone Beach monitoring, comparative data are available from a 2004 Cawthron Institute study, which undertook similar sampling to the current study (Stevens et al. 2004).

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1. Regional map of survey locations.

Figure 2. Location of sampling transects and stations - Petone Beach (top), Lyall Bay (middle) and Owhiro Bay (bottom).

2. METHODS

2.1 GENERAL APPROACH

The beach surveys were undertaken by three scientists during relatively calm sea conditions in January 2018, the survey dates being as follows: Lyall Bay, 23 January 2018; Petone Beach, 25 January 2018; and Owhiro Bay, 27 January 2018. Tidal ranges over these sampling days increased from 0.85m on 23 January to 1.1m on 27 January, hence fell between the neap and spring tide ranges reported by LINZ for Wellington (neap 0.76m, spring 1.39m - Appendix 3).

The survey approach was based on that used by Aerts et al. (2004) in a study of macrofaunal community structure and zonation at a tropical sandy beach. It involved measuring the beach profile, and collecting samples of sediments and infaunal macroinvertebrates (i.e. macrofauna living within the sediment-matrix), along cross-shore transects extending from the supratidal (upper beach) to the low tide zone. In the present study, some additional infaunal samples were collected (by wading) from the shallow subtidal (~1.0–1.5m deep) at each site, mainly for comparative purposes with the intertidal component.

2.2 TRANSECTS AND SAMPLING STATIONS

Transects were established at each site on a representative part of the beach, perpendicular to the shoreline from the upper beach to the low tide zone (Figure 2). On each transect, a sampling station was located immediately above the high tide swash zone, and sampled (see sampling details below) at the time of high tide. Each subsequent hour from high to low tide, a new sampling station was established in the swash zone on each transect, following the receding water-line. This hourly sampling approach was used to distribute stations evenly across the tidal range. Each station was marked with a cane wand for easy relocation. The supplementary samples collected from the shallow sub-tidal zone were collected in a line with the intertidal markers. For the Petone survey, two cross-shore transects 50m apart were established in this way, whereas only one transect was surveyed at each of the other two beaches.

2.3 BEACH PROFILING

The cross-shore profile of each beach was measured along the transect lines (only transect A at Petone) using a total station theodolite surveying technique, tied back to a fixed point for repeat surveys. Where possible, the profile extended from the back of the dune system to below the low tide mark. These measures enabled the relative elevations of the sample stations to be derived, and will allow broad changes in the beach profile to be measured over time. Distances between all stations, and the GPS position of each station, were logged (Appendix 3).

2.4 QUANTITATIVE SAMPLING OF INFAUNA AND SEDIMENTS

Sediment cores were collected from each sampling station using a using a PVC tube (130mm diameter; area 0.0133m^2), which was manually driven to 150mm depth. Total numbers of cores per station and beach are summarised in Table 1. Sampling effort was greatest at Petone Beach, consistent with the comprehensive survey approach there, while the sampling was less at Lyall Bay, and least at Owhiro Bay. The approach was as follows:

- At Petone, three samples were collected at

Table 1. Summary of infaunal core sampling.

	Sampling stratum	Petone Beach	Lyall Bay	Owhiro Bay
INTERTIDAL	No. of transects	2	1	1
	Stations per transect	6	6	6
	Samples per station	3	1	1
	Cores per sample	2	9	3
	Total samples (total cores)	36 (72)	6 (54)	6 (18)
SUBTIDAL	No. of transects	1	1	1
	Stations per transect	2	1	1
	Samples per station	1	1	1
	Cores per sample	3	3	3
	Total samples (total cores)	2 (6)	1 (3)	1 (3)

each of 12 intertidal stations (six stations on each of two transects), and processed individually to provide a measure of within-station variation. The samples were spaced ~2m apart, with each sample itself consisting of two composited cores. At each of two subtidal depth stations, a single composite sample consisting of three cores was also collected.

- At Lyall Bay, single composite samples were collected at the six intertidal stations, each consisting of nine cores. A single composite sample was also collected subtidally, containing three cores.
- At Owhiro Bay, single composite samples were collected at the six intertidal stations, each consisting of three cores. As for Lyall Bay, a single composite sample of three cores was also collected subtidally at Owhiro.

Each core was extracted, emptied into a 1mm nylon mesh bag, and the contents sieved in nearby seawater. Material retained by the mesh bag was placed in trays and sorted in the field, with any infauna present placed into labelled plastic vials and preserved in a 70% isopropyl alcohol/seawater solution. Infauna samples were sent to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

A composite sample of sediment (~250g total) was collected from each sampling station from the top, middle and bottom core depth, for analysis of particle grain size distribution (mud ‹63µm, i.e. silt and clay; sand 63µm-2mm; gravel ›2mm). Sediment samples were composited at the station level, as it was of interest to only broadly characterise the grain size classes. In addition, at Owhiro Bay one composite sample was collected from the upper 20mm of sediment in the shallow subtidal zone at the end of the sampling transect, and another from the Owhiro Bay stream delta at low tide (Figure 2). These samples were analysed for total recoverable arsenic (As) and trace metals (Cd, Cr, Cu, Ni, Pb, Zn, Hg). This analysis provided a cursory check for the potential presence of contaminants from an adjacent/upstream landfill. Laboratory samples were sent to R J Hill Laboratories for analysis (methods available on request and summarised in Appendix 4) and tracked using standard Chain of Custody forms. Results were transferred electronically from R J Hill Laboratories to avoid transcription errors.

Quantitative sampling was supplemented with photographs and records of general site appearance, as well as notes on any significant site features and dominant dune plants. In addition, at each station along each transect the presence of any macroalgae or microalgal growth was noted, and the average apparent RPD (aRPD; see Appendix 3) depth was recorded as a secondary indicator. This indicator is relatively easy to measure, but in a sandy beach environment has a low likelihood of being appreciably altered by anthropogenic or natural stressors.

2.5 PRESENTATION AND ANALYSIS OF RESULTS

Beach profiles, sediment characteristics, and species richness and abundance patterns, are presented graphically and/or in Tables, in many instances using pooled samples in order to display general trends. Due to the different numbers of cores taken at each station, infaunal abundance data is scaled (based on #cores taken, as per Table 1) to the sampling effort in the Petone intertidal zone, to enable comparison among stations and beaches for the different analyses undertaken. Richness data cannot be reliably scaled in this way, thus richness results are interpreted within the context of sampling effort. Trace contaminant concentrations from Owhiro Bay subtidal samples were compared against ANZECC (2000) sediment quality guidelines.

Based on data aggregated within each tidal elevation, kite diagrams are used to illustrate relative patterns of species dominance along transects. For this purpose, taxonomic composition data were aggregated to the ten most common taxa across all sites, enabling easier comparison of differences among beaches and across tidal elevations. With the same aggregated data, non-metric multidimensional scaling (nMDS) was used to explore similarities in taxonomic composition patterns within and among tidal elevations and beaches, using the software Primer v7 (Clarke & Gorley 2015). Aggregation of replicates and transects for each tidal elevation at Petone Beach was considered reasonable based on exploratory analyses that revealed a high similarity in assemblage composition among transects at that site, and among individual within-station replicates.

Values of the AMBI biotic index (Borja et al. 2000) were calculated to provide scores of beach health based on the relative proportions of taxa assigned to one of five 'eco-groups' according to their tolerance to organic enrichment. Where eco-group designations were unavailable for a given species in the present study, but had been assigned in other studies to higher taxonomic classes of that species, the eco-group for the higher class was used as a proxy (Appendix 4). In order that numbers of taxa and/or abundances met performance guidelines for reliable AMBI calculation (Borja et al. 2012), it was necessary to pool infaunal data within each tidal elevation at Petone, and across the entire beach for each of Lyall and Owhiro Bays.

To further assist in broadly characterising the health status of the beach biota, at least with respect to enrichment status, a condition rating system has been used to classify results for aRPD depth, the percentage mud in sediment samples, and infaunal AMBI scores (Table 2). This system classifies indicators into subjective classes between "very good" and "poor". The ratings should be regarded as a rough guide to beach health in that they: greatly over-simplify the results; are limited in terms of inferences that can be made with respect to stressors other than enrichment; and have been derived using subjective expert judgement rather than comprehensive quantitative analyses.

Table 2. Summary of condition ratings used to assess fine sediment issues.

INDICATOR Condition Rating*	Very Good	Good	Moderate	Poor
Macroinvertebrate Enrichment Index (NZ AMBI**)	0-1.0 None to minor stress on benthic fauna	>1.0-2.5 Minor to moderate stress on fauna	>2.5-4.0 Moderate to high stress on fauna	>4.0 Persistent, high stress on benthic fauna
Sediment Mud Content (% mud)	<5%	5-10%	>10-25%	>25%
Sediment Oxygenation (aRPD depth cm)	>2cm (Very Good to Good)		0.5-2cm	<0.5cm

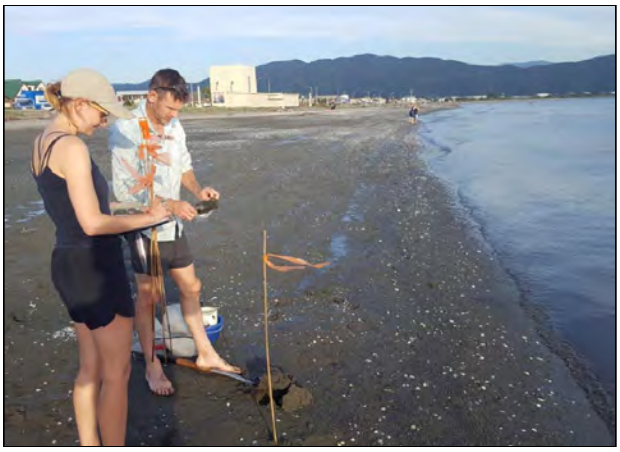
*see Robertson et al. (2016a,b, 2017) for supporting information on ratings. **Robertson et al. 2016.

Petone Beach

3. RESULTS AND DISCUSSION

3.1 BEACH MORPHOMETRY AND GENERAL FEATURES

The beaches consisted of sandy or coarse gravel sediments, with no visible biological growths (e.g. sea lettuce, microalgal mats) or other obvious symptoms that might indicate enriched or otherwise degraded conditions (Figure 3a-c). The only macroalgae evident were small amounts of drift material along parts of the high-tide strand-line at each location. At Petone, fine organic detritus and salps were conspicuous along the low-tide strand-line and adjacent shallows.



Petone Beach with gelatinous salps along the drift line.

The terrestrial fringe at Petone Beach and Lyall Bay was backed by a 5–10m wide and ~1m high undulating dune system. Dune vegetation at Petone was dominated by plantings of the native sand binders spinifex and pingao, while Lyall Bay was dominated by introduced marram grass, but also had extensive plantings of spinifex and pingao.

Spinifex and pingao dune at Petone Beach.

Owhiro Bay had occasional coastal shrubs (ngaio, flax) but no sand binders present.

Owhiro Bay showing gravel, beach cast seaweed and shrub dominated margin.

Urban development was the dominant land-use behind each beach, with concrete seawalls and roads the primary features of what would have historically been secondary dune areas.

The intertidal zones ranged from ~30-70m wide, with the slope very different between the three beaches (Figure 4), reflecting their different wave environments. The most wave-exposed site, Owhiro Bay, was the steepest, had the narrowest intertidal zone, and dropped away relatively steeply in the shallow subtidal. Lyall Bay, being slightly less exposed, was wider and less steep, with Petone being the most sheltered and least steep.

3.2 SEDIMENT PHYSICAL AND CHEMICAL CHARACTERISTICS

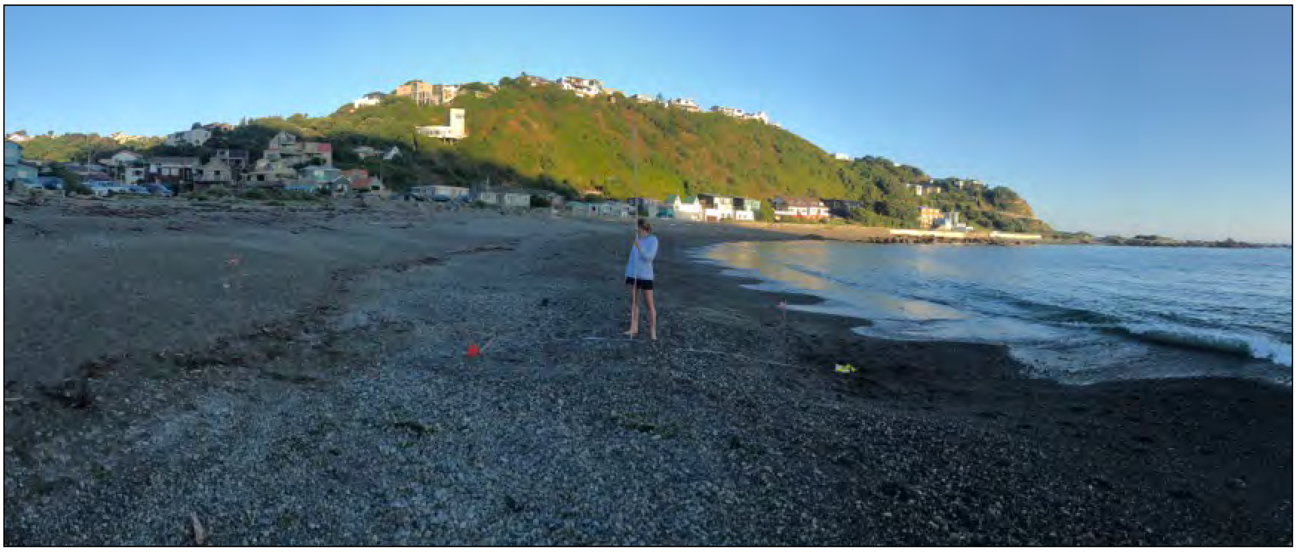
3.2.1 Sediment grain size

Sand was the dominant sediment grain size fraction at Petone Beach and Lyall Bay (Figure 5). With increased wave exposure the gravel fraction of the sediments increased from the lowest levels of ~5-10% at Petone, to being the dominant sediment fraction at Owhiro Bay (~60-80% gravel). The mud component at all beaches was <2%, and least at Owhiro Bay. Based on the Table 2 criteria, the beaches have a condition score of "very good", reflecting their very low mud content.

The major factors influencing the grain size distribution of beach sediments include: (i) wave exposure; (ii) the amount of sediment supply to beaches (e.g. reduced supply often leads to ero-

a. Petone Beach - gentle beach gradient with relatively fine sands and seaweed strand line adjacent to the narrow dune.

b. Lyall Bay - intermediate beach gradient with extensive gravel patches among finer sands.



c. Owhiro Bay - steep beach gradient domainted by gravel. Note the evenly spaced cusp and horn gravel formations along the waters edge highlighting the dynamic sediment environment at this site.

Figure 3. Photos of the three beaches surveyed in late January 2018.

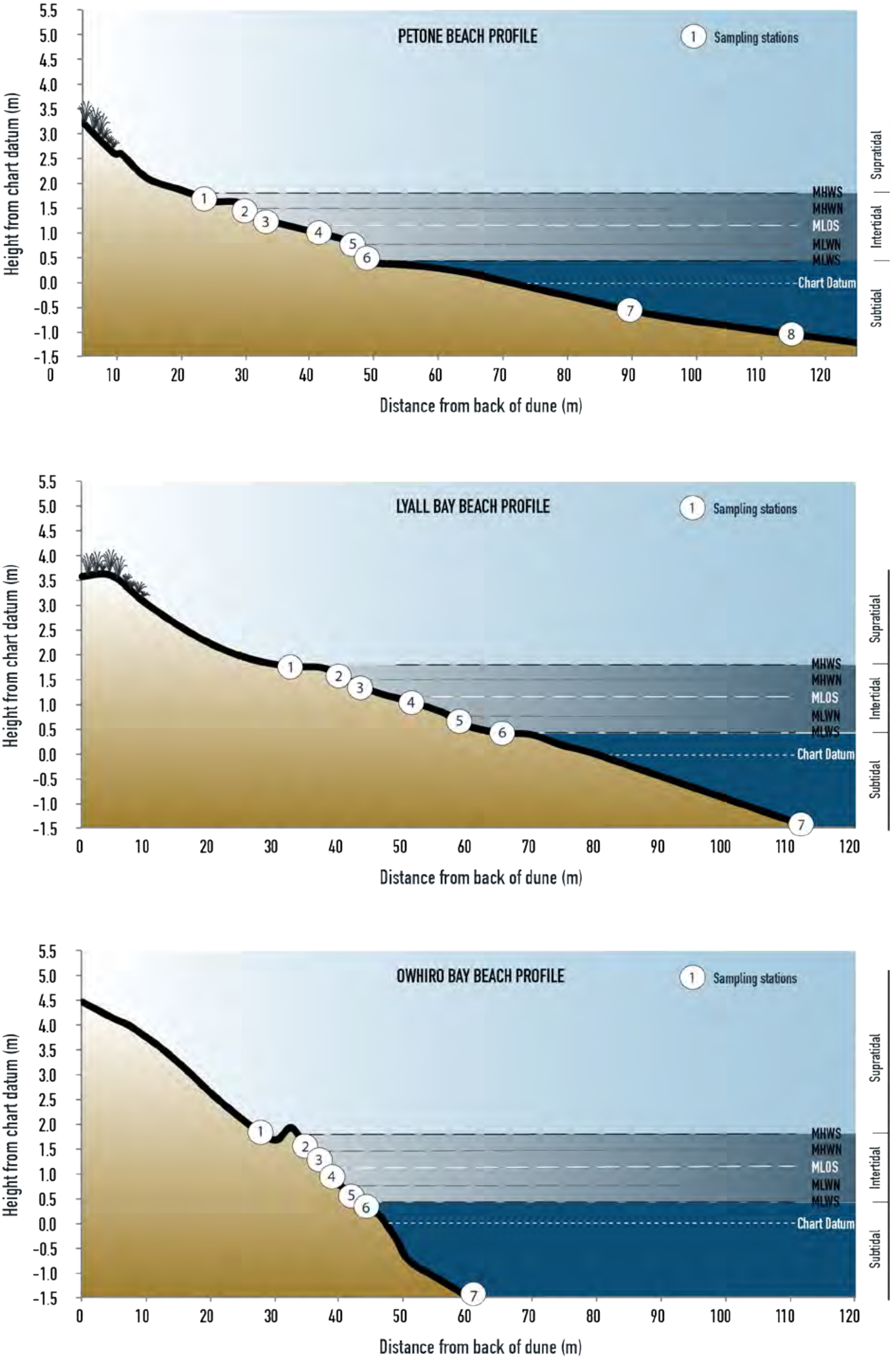
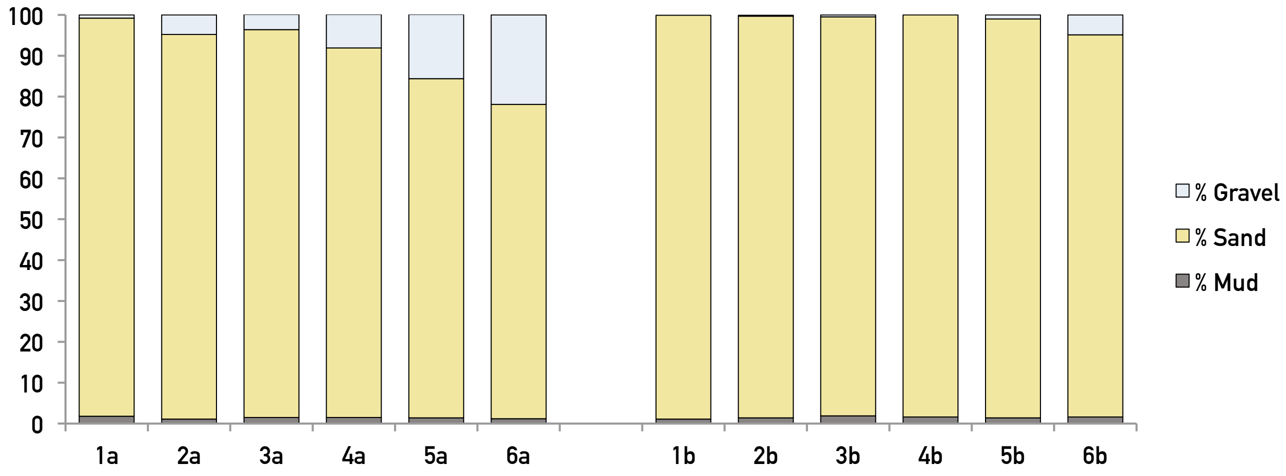
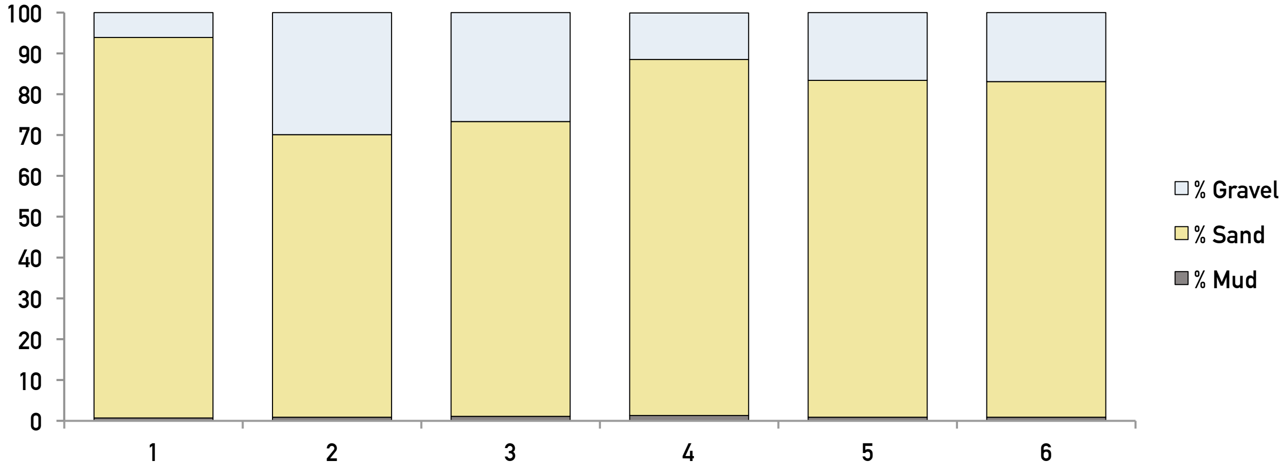


Figure 4. Cross-shore profiles along beach transects from the sand dunes at the top of the shore to the shallow subtidal. Intertidal (1-6) and shallow subtidal (7, 8) sampling stations are shown.

a. Petone Beach



b. Lyall Bay



c. Owhiro Bay

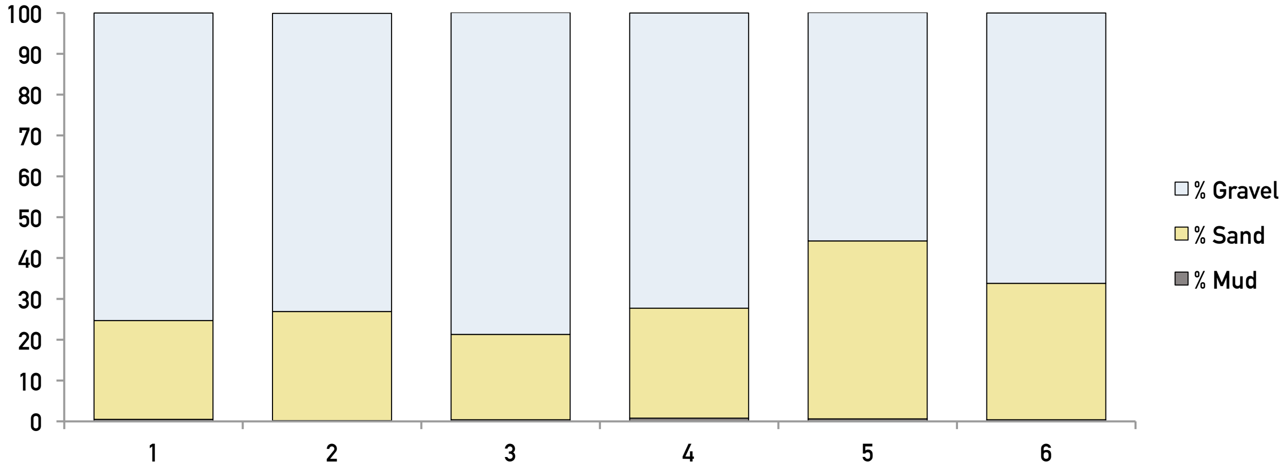


Figure 5. Sediment grain size from intertidal transects classified into three broad categories: mud ‹63μm; sand 63μm-2mm; and gravel ›2mm. Transects A and B at Petone beach are shown separately.

sion, coarser sediments, and steeper beaches in exposed situations), and (iii) the nature of the sediment supply (e.g. an increase in fine sediments due to increased suspended sediment runoff from developed catchments). The Wellington Harbour sites are unlikely to be at high risk from future changes in sediment inputs, because of their semi-exposed to exposed nature.

3.2.2 Redox potential discontinuity (aRPD) depth

The aRPD depth at all beaches was >15 cm, indicating that the sediments are well-oxygenated. These aRPD values fit the "very good" condition rating in Table 2. This finding is typical of beaches with high sand and/or gravel fractions in their sediments, which enables good flushing and limits any significant accumulation of organic detritus. The result is also consistent with the absence of obvious signs of degradation, despite the presence of detritus in the low tide fringe and shallow subtidal (as per Section 3.2.1). In such a situation, the aRPD depth provides a simple but useful indicator of any gross deterioration in enrichment status.

3.2.3 Contaminants at Owhiro Bay

Sediment samples from the subtidal Owhiro Bay transect station 7 and stream delta station 8 had very low concentrations of trace contaminants (Table 3). In composite samples from both areas, contaminant concentrations were substantially less that ANZECC (2000) Interim Sediment Quality Guideline (ISQG) "Low" trigger levels. Accordingly, concentrations were well below the levels at which ecological effects might be measurable. This result almost undoubtedly reflects the coarse nature of the sediments in the locations sampled. Trace contaminants adsorb primarily to very fine muddy sediments and organic matter. The very low mud content in the Owhiro Bay sediment samples (max 0.3 % mud, Table 3), combined with the strong flushing characteristics of the receiving environment, mean that shallow seabed sediments in this location are unlikely to be vulnerable to contaminant accumulation.

Owhiro Bay Stream where it flows over beach gravels below the road bridge toward the sea.

3.3 SEDIMENT BIOTA

3.3.1 Taxon richness and abundance

Raw infaunal data are given in Appendix 6. The

Table 3. Concentrations of arsenic and trace metals in sediments from two subtidal stations at Owhiro Bay. Contaminant concentrations are compared to ANZECC (2000) ISQG-Low trigger levels. Grain size classes are also shown.

Analyte		7. Subtidal Station	8. Owhiro Stream delta	ANZECC ISQG-Low
Trace elements (mg/kg dry weight)	Arsenic	8.8	4.2	20
	Cadmium	0.019	0.027	1.5
	Chromium	12.7	13.30	80
	Copper	8.9	8.0	65
	Lead	36.0	16.4	50
	Mercury	0.03	0.03	0.15
	Nickel	9.9	9.5	21
	Zinc	97	71	200
Grain size (% dry weight)	Mud	0.3	0.1	na
	Sand	1.2	67.3	na
	Gravel	98.6	32.6	na

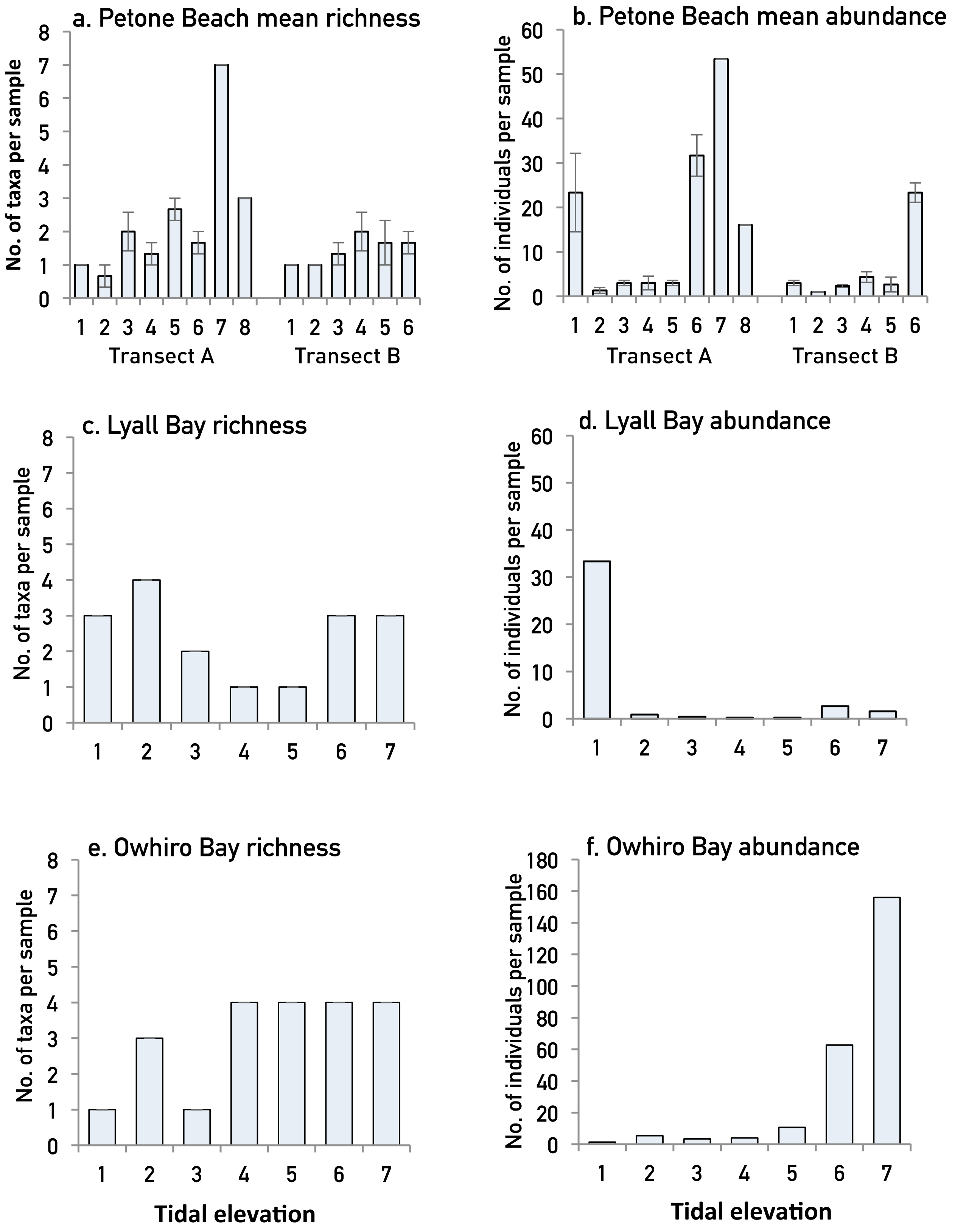


Figure 6. Taxon richness and abundance in composite core samples from Petone Beach (a, b), Lyall Bay beach (c ,d) and Owhiro Bay beach (e ,f). Petone intertidal (1-6) bars show mean values (± SE) from replicate samples (n = 3). All abundances are scaled to cores numbers for Petone intertidal samples (n = 2) to facilitate comparison among stations and beaches. Note different abundance scale for Owhiro Bay (f).

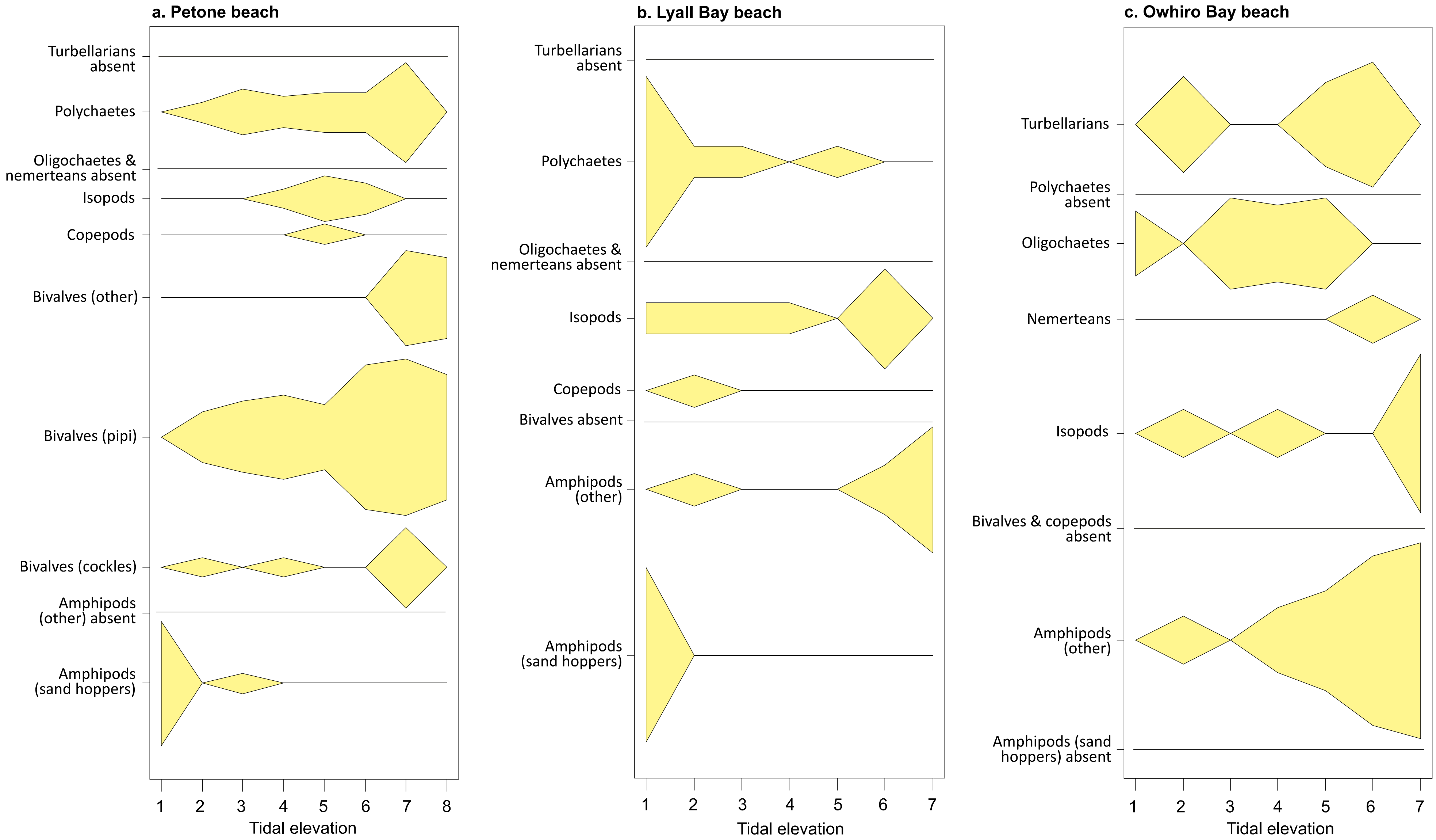


Figure 7. Kite diagrams showing the relative abundance (natural log transformed) and distribution of the main species and higher taxa at the three beaches. Tidal elevations progress from the high shore (1) to low intertidal (6) and into the shallow subtidal (7, 8).

infaunal assemblages at all beaches were relatively impoverished, reflected in the low taxon richness and abundance values evident at many sampling stations (Figure 6). Richness values in composite samples did not exceed more than four species or higher taxa at any station, except for subtidal station 7 (transect A) at Petone; seven taxa were recorded at that station (Figure 6a) despite the relatively low sampling effort there (i.e. 3 cores). There were no consistent trends among beaches in richness values from the high shore to shallow subtidal, nor among the two transects at Petone. Similarly, abundance trends along transects showed little overall consistency. However, at Lyall Bay and Petone (transect A only), elevated infaunal densities were evident at the highest tidal elevation (station 1), reflecting high numbers of the beach hopper Bellorchestia quoyana. This is a detrital feeding amphipod that is typical of the high tide strand line where seaweed and other organic detritus accumulates.

At most other intertidal stations, infaunal densities were typically ‹10 individuals per composite sample (Figure 6b, d, f). However, at the lowest intertidal station (station 6) and/or the shallow subtidal stations (station 7 and/or 8), densities were generally elevated, most notably at Owhiro Bay. At that location, infaunal densities where the greatest of all sites, reflecting numerous small mobile crustaceans (amphipods and isopods) in the low shore and shallow subtidal (Figure 6f).

At Petone, infaunal densities at low shore or shallow subtidal stations were moderately elevated, but in that location the increased densities were attributable to high numbers of juvenile pipi, Paphies australis (shell width typically ‹5mm). This is a suspension feeding bivalve also described to occur in relatively high abundance in a previous survey of the central-eastern end of Petone beach (Stevens et al. 2004). These high-density patches of juveniles probably support the more extensive beds that are anecdotally reported to be present in the deeper subtidal.

3.3.2 Taxon composition and dominance pat-

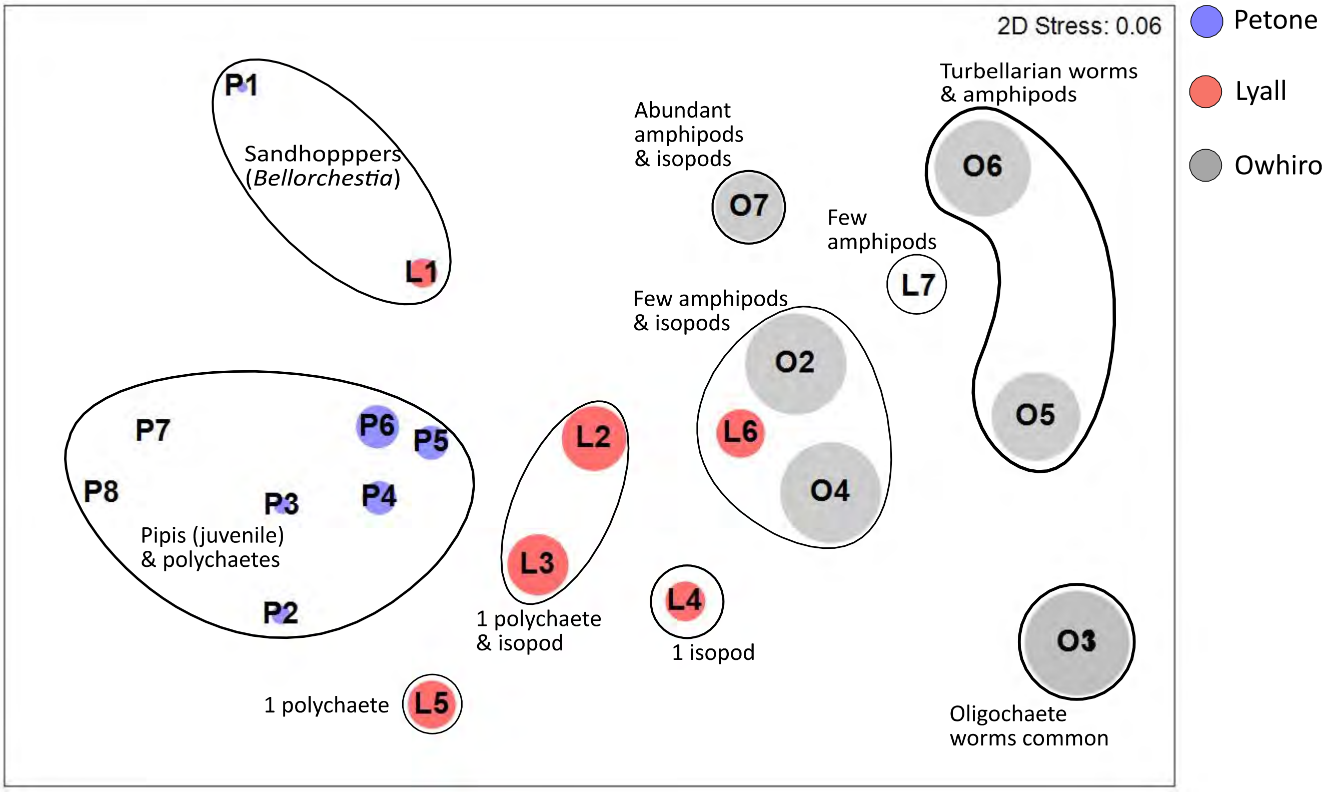


Figure 8. Biplot (nMDS) depicting the grouping of intertidal shore heights (1 to 7 or 8) among beaches according to their taxon composition; P = Petone, L = Lyall, O = Owhiro. Circled groups cluster at ›60% Bray-Curtis similarity. The main taxa or features characterising each cluster are shown. The filled bubbles overlaying each station are colour-coded by beach, and scaled to the gravel content (%) of the sediment. Note that sediment grain size was not analysed at P7, P8 or L7. A double square root transformation was applied to the data in order that the less common taxa had an influence on the ordination pattern.

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Patterns in the distribution of the dominant species or higher taxa are further evident in the kite diagrams in Figure 7. These diagrams are scaled using a natural log transformation to dampen the influence of the species that dominated the abundance patterns in Figure 6, and highlight patterns in less common taxa. At Petone, the dominance of the beach hopper, Bellorchestia quoyana, at the highest shore station is illustrated, as well as an increasing prevalence of small pipi towards lower tidal elevations (Figure 7a). However, occasional juveniles of other bivalve species were also evident at the subtidal stations, including cockles (Austrovenus stutchburyi) and wedge shells (Macomona liliana). Additionally, occasional polychaete worms were recorded across all but the highest shore station at Petone, which is consistent with the 2004 study.

Lyall Bay was similar to Petone in having a prevalence of beach hoppers on the high shore, but the polychaete worm Thoracophelia otagoensis (family Opheliidae) was co-dominant in this zone (Figure 7b, Appendix 2). By contrast with Petone, pipi and other bivalves were absent from the low shore and shallow subtidal at Lyall Bay, likely reflecting the dynamic nature of the physical environment there (i.e. the shifting of sand and gravel by wave action). Mobile crustaceans, in particular amphipods (but not sand hoppers) and isopods, were notable at lower tidal elevations at Lyall Bay, and these taxa were especially abundant at Owhiro Bay (Figure 7c). Also common at Owhiro Bay across a range of tidal elevations were oligochaete worms (the marine equivalent of an earthworm), nemertean ("proboscis") worms, and turbellarian flatworms, while polychaete worms evident at the other beaches were not recorded. Overall, the range of taxa sampled at Owhiro Bay were highly mobile amphipods and isopods, and worm groups that are reasonably tolerant of disturbed conditions.

The distribution and abundance patterns illustrated by the kite diagrams are largely reflected in the nMDS ordination biplot in Figure 8. The nMDS method cluster stations according to similarities in their taxon composition and abundance; in this instance the low "stress" value of the ordination (i.e. stress = 0.06) can loosely be interpreted to mean that tidal elevations lying nearest to each other (in a 2-dimensional biplot) are the elevations most similar in terms of their taxonomic composition. As well as reinforcing the main patterns evident from the kite diagrams, Figure 8 also highlights that many of the mid-shore sampling stations at Lyall Bay (2, 3, 4 & 5) were relatively species-poor. Furthermore, it is evident that most (but not all) tidal elevations tend to cluster within each beach, indicating that the environmental differences among beaches are probably a more important driver of assemblage composition that differences among tidal elevations within each beach.

In fact, by superimposing the sediment data onto the nMDS plot, it is apparent that the left to right clustering pattern from Petone to Lyall and Owhiro Bay follows the marked increase in gravel content of the sediment samples at those locations (see also Figure 5). This result is not to imply that gravel content is the key determinant of species composition. Rather, it more likely indicates the influence of other important correlated environmental factors such as wave-exposure.

3.3.3 AMBI biotic index and condition rating

Table 4 summarises the values of the AMBI biotic index, based on the different levels of sample aggregation indicated. According to the condition ratings from Table 2, only Lyall Bay would meet the "very good" rating, having an AMBI value of <1.2. Owhiro Bay and Petone Beach overall,

Table 4. Values for the biotic index AMBI calculated for infauna data. AMBI scores for individual stations at Lyall and Owhiro Bays did not meet operational criteria for index reliability, hence at those locations AMBI was calculated only for infaunal data pooled within beach.

Sampling level of AMBI calculation	AMBI score
Petone infauna pooled within each tidal elevation	Mean 1.62 (± SE 0.05), Range 1.5 – 1.88
Petone infauna pooled within beach	1.57
Lyall Bay infauna pooled within beach	0.83
Owhiro Bay infauna pooled within beach	1.58

as well as tidal elevations within Petone Beach, would be rated as "good". Given that Lyall Bay was generally the most species-poor and low abundance of the beaches sampled, at least across the mid-shore stations, the AMBI scores should be regarded with some caution and seen as a rough guide only. Even after aggregation, there were barely sufficient abundances of individuals, or species with assigned eco-groups, to meet performance criteria for reliable AMBI calculation (Borja et al. 2012).

4. SYNTHESIS OF RESULTS

The three beaches had intertidal zones ranging from a relatively broad gently-sloping profile with predominantly sandy sediments at Petone, to a narrower, steeper and predominantly gravel beach at Owhiro Bay. Lyall Bay was intermediate between these two. These differences are consistent with increased wave-exposure from Petone to Lyall and Owhiro Bays, respectively. The apparent Redox Potential Discontinuity (aRPD) layer was relatively deep (>15cm) at all sites, indicating sediments were well-oxygenated, with no significant accumulation of organic matter. A cursory assessment of trace contaminants at Owhiro Bay did not reveal ecologically significant concentrations.

The beach infauna at all locations was relatively species-poor across most tidal elevations, but especially across the mid-shore. Similarly, abundances were generally low except for some of the high-tide stations where beach-cast seaweed supported sand hoppers, and low shore or shallow subtidal stations that harboured moderate densities of juvenile pipi (Petone) or amphipods (Owhiro). This situation is typical of semi-exposed sandy beaches, where wave action limits the accumulation of fine organic detritus, and creates a harsh environment in which beach sediments are moved around and the biota are subjected to regular or episodic disturbance.

Overall, while to some extent having an impoverished infauna, when considered together with other sediment indicators, the beaches were judged to be in "very good" or "good" condition, based on the rating system used.

5. CONSIDERATIONS FOR MONITORING

The primary purpose of monitoring is to measure change over time. To reliably measure change, and attribute change to probable causes, the indicators used in the present study are considered to provide a useful suite for the cost-effective and rapid assessment of beaches. However, in the context of the present beaches, ongoing monitoring using the same methods is not necessarily useful or necessary. The fact that the biota is relatively sparse and variable across much of the beach at each location means that apparent differences in biota from one survey to the next could reflect random sampling variation more than anything else.

This issue could to some extent be mitigated by increased sampling effort (e.g. more cores and/or cores of large diameter) or modification of methods to target:

- Tidal elevations where a greater density and richness of taxa may be present: A logical approach would be focus on the low tide fringe and adjacent nearshore subtidal, as in such areas the biota would be expected to be less impoverished than the beaches themselves (e.g. subject to less human disturbance). Depending on depth, different methods may be required (e.g. dredging or grab sampling from a boat), which would increase the effort and cost of the surveys.
- Biota of particular interest: For example, the sampling design and methods could be modified to target important species such as pipi or other edible shellfish. Such a survey could seek to understand more about the occurrence (or otherwise) of such species in the beaches where they were not recorded, as well as their population size-structure. It would certainly be of interest to understand whether greater densities of shellfish, or shellfish of edible size, occur deeper in the subtidal adjacent to the beaches surveyed.

If the present approach is repeated, there would be little benefit in regular surveys. For example, it would be sufficient to conduct perhaps one survey every 5-years, at the same time of year and along the same transects. An additional point for GWRC is to consider the merits of undertaking synoptic surveys of other beaches, perhaps exploring some of the methodological modifications outlined above. This approach would establish a more comprehensive picture of beach condition and monitoring efficacy regionally, providing a sufficiently comprehensive dataset for informing a longer-term approach to monitoring.

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Lyall Bay

APPENDIX 1. A SUMMARY OF COMMON ENVIRONMENTAL STRESSORS AFFECTING NEW ZEALAND BEACHES

1. HABITAT LOSS OR MODIFICATION

The key human-influenced stressors causing habitat loss or modification are:

i. Climate Change and Sea level Rise.

Predicted climate change impacts on the NZ coastline include: warmer temperatures, ocean acidification, sea-level rise (with accelerated erosion), and increased storm frequency (Harley et al. 2006, IPCC 2007, 2014). These impacts are generally expected to alter the phenology, physiology, range and distribution, assemblage composition, and species interactions of various inhabitant beach biota (Jones et al. 2007). Long-term predictions, although spatially variable, include the loss of rare species, a reduction in species diversity, and the loss of entire communities in some situations (IPCC 2007, 2014). Low-gradient dissipative shores (i.e. NZ's dominant beach type), which support the greatest biodiversity, are at most risk due to their erosive nature and the much greater run-up of swashes on gentle gradients (Defeo et al. 2009).

ii. Shoreline Armouring.

A common response to coastal erosion is to artificially armour shorelines with hard barriers (e.g. seawalls, groynes) to protect terrestrial property including coastal housing, roads and recreation areas. Seawalls, in particular, damage beach and estuary ecology, destroy dunes, and prevent the natural migration of habitat landward in response to sea-level rise, particularly by increasing erosion at the ends of seawalls and causing accelerated erosion of the beach in front of the wall (Dugan et al. 2008). On unarmoured shorelines, sand and gravel from eroding areas and river plumes are transported by waves and currents and ultimately supply sediment to form and maintain the beaches and spits. These natural processes, important because they support vital functions like providing habitat for key species in the surf zone and intertidal areas of beaches, are compromised when shorelines are armoured e.g. Schaler et al. (2007).

iii. Over-collection of Living Resources.

Direct removal of living resources (e.g. shellfish) can cause major community level changes (e.g. Pérez and Chávez 2004) through disruption to natural predator-prey balances or loss of habitat-maintaining species e.g. commercial fishing may reduce densities of keystone predators (e.g. snapper), leading to subsequent changes to their target prey including crabs and shellfish. McLachlan (1996) showed clam populations depleted by recreational fisheries in a NZ beach between the mid-1960s and 1990 failed to recover following the closure of the fishery. In addition, although not widely practised on NZ beaches, harvesting of beach-cast seaweed can remove both protective habitat and vital food resources, resulting in species loss and greater exposure to natural disturbances (Kirkman and Kendrick 1997).

iv. Direct Physical Disturbance.

Human uses of beaches is high with subsequent disturbance to biological communities from recreation and tourism activities well documented (e.g. de Ruyck et al. 1997, Davenport and Davenport 2006). Grooming and cleaning is also undertaken on some beaches to remove litter and beach cast debris, including seaweed and driftwood. As well as direct disturbance, there are subsequent impacts from the loss of organic matter (i.e. an important food source for various fauna) and material important in naturally trapping sand and stabilising the beach from erosion (e.g. Llewellyn and Shackley 1996, Dugan et al. 2003). Mining and sand extraction also represent a generally localised but obvious source of disturbance (e.g. McLachlan 1996). Vehicles are also commonly used on beaches and dunes worldwide and cause damage that includes disturbing the physical attributes and stability of dunes and beaches by deeply rutting the sand surface and destroying foredunes (Schlacher and Thompson 2009), destroying dune vegetation that leads to lower diversity and less floral ground cover (Groom et al. 2007), and disturbing, injuring or killing beach fauna including shorebirds (Stephenson 1999, Schlacher et al. 2007, 2008, Williams et al. 2004).

v. Coastal Development.

Coastal development (e.g. modification through commercial and residential development, tourism, infrastructure - roading, boat ramps, marinas, stormwater and sewage outfalls) are all likely to intensify with expanding human populations and cause impacts at both local and regional scales. While mostly concentrated on coastal margins, the establishment of infrastructure without regard to appropriate coastal setbacks or planned retreats may in future create a public expectation for high value developments to be protected from erosion.

vi. Stock Grazing.

Excessive stock grazing in duneland causes dune mobilisation through trampling and grazing of sand binding plants, as well as direct habitat destruction and potential loss of native flora and fauna. Where stock alter vegetative cover, blowouts can occur causing accelerated erosion, adding support for artificial dune stabilisation (Hesp 2001). However, low density stock grazing can be used to control weed growth in dunes, particularly in areas well back from the foredune, though excessive grazing can lead to high levels of damage (ten Harkel and van der Meulen 2014). Dune grazing can also contribute to an increase in organic matter (manure), facilitating the growth of introduced weeds and grasses.

vi. Introduction of Invasive Species.

Global transport (i.e. hull fouling and ballast water discharges) is a major vector in the introduction of invasive or pest plants and animals. To date, very few invasive species have been reported on NZ's beaches. One example has been the introduction of the Asian date mussel to the Auckland Harbour, potentially via ballast water discharges (Nelson 1995). The mussel has subsequently spread to adjacent intertidal regions, where it is thought to have a small but consistently negative effect on species richness, and a much greater negative effect on species abundance (Creese et al. 1997). The potential dominance of opportunistic introduced taxa (and related displacement of native species or reduction in community diversity), can be enhanced following disturbance events (e.g. loss of fine sands).

In dune areas, introduced species are far more prevalent. Marram grass, initially introduced to NZ to limit coastal erosion and stabilise sand movement, has subsequently been found to have many drawbacks. Its ability to thrive in coastal areas results in marram dunes being generally taller, steeper, and larger than dunes dominated by native sand binding species (i.e. spinifex or pingao). Consequently, overstabilisation reduces the extent of active dunes able to release sand to the foreshore (helping buffer against storm erosion), while steep and regular dunes provide less natural wave dissipation during storms, can contribute to increased beach scouring by reflecting wave energy back onto the beach, and generally facilitate the establishment of terrestrial weeds and grasses. Such overstabilised dunes contribute to the loss of biodiversity and natural character (Hilton 2006). As a consequence of their invasive nature and threat to active dune function, as well as threats to ecology and biodiversity, there is now a growing effort to protect dunes dominated by native species, minimise the expansion of marram grass into active dune areas, and to replace marram dominated dunes with native species.

2. ALTERED SEDIMENT LOADS

Beaches and dunes are dynamic systems that require a supply of sand to build and maintain their form. Activities that alter this natural supply, either on land (e.g. dam construction, gravel extraction, land use changes), or at the coast (e.g. groynes or seawalls, dredging, dune overstabilisation or reclamation), can significantly change beach processes at both local and regional scales. Where changes occur to erosion and accretion patterns, particularly from factors that increase wave action and currents (e.g. shoreline armouring, groynes, and climate change impacts such as sea level rise and increased storm events), adverse consequences can be extreme (Willis & Griggs 2014). Furthermore, if fine sediment inputs to sheltered beaches are excessive, beaches can become muddier, contributing to less oxygenated sediments, reduced biodiversity, poor clarity, displacement of important shellfish species, and reduced and human values and uses. Although the exposed, dynamic nature of the majority of NZ's beaches means the risk from fine sediment inputs is relatively low (sediment is much more likely to settle offshore than in intertidal areas), predictions of an increased sediment supply to NZ's west coast under future climate change scenarios (Shand 2012), mean that sediment changes should be monitored.

3. DISEASE RISK (HUMAN HEALTH)

If pathogen inputs to the coastal area are excessive (e.g. from coastal wastewater discharges, proximity to a contaminated river plume, or direct farm runoff), the risk to bathing, wading and shellfish collection can increase to unacceptable levels. This results from the ability of many disease-causing organisms (including viruses, bacteria and protozoans) to survive for some time in the marine environment (e.g. Stewart et al. 2008). Human diseases linked to such organisms include gastroenteritis, salmonellosis and hepatitis A (Wade et al. 2003). High flushing and dilution mean disease risk is unlikely to be significant away from point source discharges, and public health reports of illness are likely to be the first indication of faecal bacterial issues directly impacting on human values and uses. Aside from serious health risks to recreational users and human consumers, pathogen contamination also causes economic loss due to closed shellfish beds, affecting an important industry in some beaches (e.g. Rabinovici et al. 2004). Again, such implications are likely to increase as human populations continue to grow.

4. EUTROPHICATION

Eutrophication occurs when nutrient inputs are excessive and can stimulate the growth of fast-growing algae such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce (Ulva), Gracilaria), causing broad scale impacts over whole coastlines. Elevated nutrients have also been implicated in a trend of increasing frequency of harmful algal blooms (HABs) which can cause illness in humans and close down shellfish gathering and aquaculture operations (see Toxic Contamination below). High flushing and dilution mean most NZ beaches have a low risk from eutrophication, with poorly flushed ultra-dissipative areas or sheltered embayments most likely to show problems. Examples include regular phytoplankton blooms around the mouths of several Southland estuaries, while annual summer blooms of Ulva washing up on Mt Maunganui beach and in Tauranga Harbour present a significant nuisance problem. The accumulation of extensive organic matter can lead to major ecological, and occasionally deleterious impacts on water and sediment quality and biota (e.g. Anderson et al. 2002).

5. TOXIC CONTAMINATION

In the last 60 years, NZ has seen a huge range of synthetic chemicals introduced to the coastal environment through urban and agricultural stormwater runoff, industrial discharges, oil spills, antifouling agents, and air pollution. Many of them are toxic even in minute concentrations, and of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. When they enter the coastal environment these chemicals collect in sediments and bioaccumulate in fish and shellfish, causing health risks to humans and marine life. In addition, natural toxins can be released by phytoplankton in the water column, often causing mass closure of shellfish beds, potentially hindering the supply of vital food resources, as well as introducing economic implications for people depending on various shellfish stocks for their income. For example, in 1993, a nationwide closure of shellfish harvesting was instigated in NZ after 180 cases of human illness following the consumption of various shellfish contaminated by a toxic dinoflagellate, which also led to widespread fish and shellfish deaths (de Salas et al. 2005).

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APPENDIX 2. INDICATORS COMMONLY USED TO ASSESS THE PHYSICO-CHEMICAL AND BIOLOGICAL CONDITION OF SANDY BEACHES.

PRIMARY INDICATORS:

Listed in no particular order of priority and intended only as an indication of some common indicators for various coastal stressors.

1. Morphometry

Measuring the cross-shore profile of beaches provides information on changes in the beach contour in relation to wave, current and tidal action, as well as various anthropogenic pressures such as climate change-driven sea level rise, and the introduction of structures that may disrupt sediment transport (e.g. groyne or seawall construction, dredging, dune overstabilisation or reclamation). Knowledge of long-term changes directly informs hazard planning and the management of coastal structures, recreational activities, and environmental values. The approach uses well established methods e.g. Travers (2007), and is widely used both locally (e.g. Beach Profile Analysis Toolbox (BPAT) https://www.niwa.co.nz/our-science/coasts/tools-and-resources/tides/bpat) and overseas (e.g. Southern Maine Beach Profile Monitoring Program, Gold Coast Shoreline Management Plan - GCSMP) to investigate such changes.

USED TO ADDRESS ISSUES OF:
Climate change and sea level rise
Sedimentation/erosion
Coastal development

2. Sediment grain size

Measuring beach sediment grain size is important as distributional shifts can drive (and explain) large scale changes in biotic integrity and beach functionality. Reduced biotic integrity is most typically linked to beaches where sediments have become muddier (i.e. large sheltered embayments), or those which experience significant, yet predictable, cycles where fine sands build up and then erode following disturbance (e.g. storm) events - a regular occurrence on exposed NZ beaches. Data on sediment grain size distributions can therefore provide an early indication of whether the influence of the multiple anthropogenic pressures including climate change related impacts are affecting NZ's beaches.

USED TO ADDRESS ISSUES OF:
Sedimentation/erosion
Climate change and sea level rise
Eutrophication
Coastal development

3. Redox Potential Discontinuity (RPD) depth

Redox Potential Discontinuity (RPD) depth provides a good indicator of beach benthic health because it ultimately dictates which animals can reside under different (oxic or anoxic) sediment conditions (e.g. Pearson & Rosenberg 1978). It is readily obtained via visual assessment (e.g. Trites et al. 2005) and while it can vary extensively in time and space, it provides a robust primary indicator of the integrated influence of sediment grain size and organic matter input, temperature, wave action, photosynthesis, light intensity, dissolved oxygen, bacterial activity, and the presence of burrowing animals.

USED TO ADDRESS ISSUES OF:
Eutrophication

4. Benthic macroinvertebrate community

Macroinvertebrates are the primary biological indicator of beach health because they integrate the effects of multiple stressors. They are used extensively locally and internationally (e.g. European Union Water Framework Directive" (WFD) and the Beaches Environmental Assessment and Coastal Health (BEACH) Program (US EPA).

Macroinvertebrates are a sensitive indicator as their relatively long life-span and sedentary nature (and consequent direct contact with sediments), expose them to the integrated impacts of sediment and water column pollution over time (i.e. account for chronic effects). Further, their taxonomic diversity and variety of feeding types, trophic associations, and reproductive strategies, enable the assessment of their tolerance to different stressors (e.g. storm events, erosion and accretion, climate change-related increases in temperature and acidity, overcollection of living resources, invasive species, vehicle use, beach grooming, sediment compaction, eutrophication, and the delivery of fine sediments, toxicants and pathogens).

USED TO ADDRESS ISSUES OF:
Sedimentation/erosion
Climate change and sea level rise
Eutrophication
Coastal development
Toxic contamination
Habitat modification
Disease risk
Physical disturbance
Over-collection of living resources (i.e. shellfish)

SECONDARY INDICATORS:

5. Nuisance macroalgal cover

Certain macroalgal species (e.g. sea lettuce Ulva, Gracilaria) have a large capacity for nitrogen assimilation and storage over short time intervals. Such plants can rapidly assimilate event-driven nutrient pulses that can occur in coastal waters, and can retain a signature of the event in their tissues. As such, macroalgal tissues can be used to detect and integrate pulsed nitrogen inputs to coastal waterways that might be missed by routine water quality monitoring programmes. Macroalgal indicators are used extensively as a proxy for eutrophication (e.g. National State of the Environment Reporting, Estuaries and the Sea, Commonwealth of Australia). However, they are only applied in situations where nutrient enrichment is likely.

USED TO ADDRESS ISSUES OF:
Eutrophication

6. Sediment organic and nutrient enrichment

Sediment organic carbon and nutrients are derived from plant and animal detritus, bacteria or plankton formed in situ, or derived from natural and anthropogenic sources in catchments. Measurable changes to their associated concentrations are attributed to multiple drivers, but predominantly linked to the delivery of excessive catchment-derived nutrients, leading to the expression of eutrophic sediment conditions. These indicators, although developed primarily for assessing estuarine sediments, are adopted worldwide (e.g. 'Waterbody Assessment Tools for Ecological Reference Conditions and Status in Sweden' (WATERS), EC Water Framework Directive (WFD), Swedish Environmental Protection Agency) for beach use, but are only used in situations where nutrient enrichment is likely.

USED TO ADDRESS ISSUES OF:
Eutrophication

7. Sediment and bathing water contamination

When various agriculturally-, industrially- or domestically-derived chemical contaminants are found in the marine environment at levels that may harm living organisms, they are termed 'toxicants'. In the immediate areas of high concentration, toxicants in water or sediment can kill marine life (e.g. fish and invertebrates), which has knock-on implications for high trophic levels, including humans. There are, however, inherent limitations associated with measuring water column-based toxicant levels. The primary limitation being that contaminant concentrations in water are often below detection limits (i.e. those set by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)), and are highly variable both spatially and temporally. For this reason, sediments and inhabitant macrofauna, which both indicate and integrate toxicants, are used increasingly in toxicant assessment rather than the water column. Note: these indicators are only used in situations where contamination is likely.

USED TO ADDRESS ISSUES OF:
Toxicants

8. Loss of natural terrestrial margin

Coastal shoreline habitats function best with a natural vegetated margin which acts as a buffer from development and "coastal squeeze". This buffer protects against introduced weeds and grasses, naturally filters sediment and nutrients, and provides valuable ecological habitat. Broad scale habitat mapping of coastal features, including the terrestrial margin, is widely used to evaluate any changes over time to the extent of natural vegetated habitat.

USED TO ADDRESS ISSUES OF:
Coastal Development

9. Beach grooming

Grooming, a common practice on beaches heavily used for tourism (e.g. Southern California), clears beaches of macrophyte wrack (i.e. macroalgae and seagrasses), litter and other debris by raking and sieving the sand, often with heavy machinery. Consequently, grooming removes not only unwanted material, but also propagules of dune plants and other species, and it directly perturbs resident organisms through physical disturbance, as well as indirectly by removal of large quantities of fine sand, shifting sediment grain size towards less habitable, coarser grains. Beaches currently machine groomed in NZ include Paihia, Mt Maunganui, Matua, Papamoa and Ocean Beaches (Tauranga), with proposals made to groom many Auckland beaches on a regular basis. Intermittent manual cleaning of beaches occurs throughout NZ.

USED TO ADDRESS ISSUES OF:
Direct physical disturbance

10. Wildlife disturbance

Human activities impact beach wildlife, both directly (i.e. physical disturbance) and indirectly (i.e. behavioural disruptions). However, indicators of such impacts are yet to be developed. Ideally cost effective, basic observational indicators (e.g. expert opinion, ornithological observer reports of breeding/nesting disruptions) would be developed as initial screening tools, with more extensive population or physiologically based studies of human disturbance to wildlife applied only where necessary.

USED TO ADDRESS ISSUES OF:
Habitat modification
Direct physical disturbance

11. Over-collection of living resources

Recreational invertebrate fisheries are the most common form of exploitation on sandy beaches. Associated impacts can occur both directly through physical damage of organisms and indirectly when sediment disturbance lowers habitat quality and suitability. In NZ various shellfish taxa are targeted including toheroa, tuatua, tawera, pipi and cockle, with associated abundances generally declining as a function of a growing human population. Used as indicators, such taxa can provide information on population-level changes in relation to exploitation or disturbance over time.

USED TO ADDRESS ISSUES OF:
Habitat modification
Direct physical disturbance
Over-collection of living resources

12. Wave/storm frequency and intensity

Storm-driven wind and wave action represents the greatest natural hazard faced by sandy-shore animals, particularly on exposed beaches. During such events, both sand and animals are washed out to sea, while others are stranded upshore, where they die of exposure. Measuring both the frequency and intensity of storms therefore provides a reliable secondary indicator of beach condition.

USED TO ADDRESS ISSUES OF:
Habitat modification
Sedimentation/erosion
Climate change and sea level rise

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Trites, M., Kaczmarska, I., Ehrman, J.M., Hicklin, P.W., and Ollerhead, J. 2005. Diatoms from two macro-tidal mudflats in Chignecto Bay, Upper Bay of Fundy, New Brunswick, Canada. Hydrobiologia 544, 299–319.

APPENDIX 3. SAMPLING STATION DATA AND COORDINATES

LINZ tidal information for Wellington		Height (m)
Mean High Water Springs	MHWS	1.85
Mean High Water Neap	MHWN	1.49
Mean Low Water Neap	MLWN	0.73
Mean Low Water Springs	MLWS	0.46
Spring Range	SpringRange	1.39
Neap Range	NeapRange	0.76
Mean Sea Level	MSL	1.12
Highest Astronomical Tide	HAT	1.89
Lowest Astronomical Tide	LAT	0.4

Date	Site	High Water	Low Water	Height (m) Low-High (range)
23/1/18	Lyall	10.30h	16.57h	0.7-1.6 (0.9)
25/1/18	Petone	12.01h	18.19h	0.6 -1.6 (1.0)
27/1/18	Owhiro	13.40h	19.51h	0.6 -1.7 (1.1)

Date	Beach	Station	Comment	NZTM East*	NZTM North*	aRPD depth (cm)
25/01/2018	Petone	A0	Transect start	1757490	5434087	-
25/01/2018	Petone	A1	Supratidal	1757490	5434087	>15
25/01/2018	Petone	A2	High tide -1h	1757486	5434082	>15
25/01/2018	Petone	A3	High tide -2h	1757486	5434078	>15
25/01/2018	Petone	A4	High tide -3h	1757482	5434071	>15
25/01/2018	Petone	A5	High tide -4h	1757480	5434067	>15
25/01/2018	Petone	A6	High tide -5h	1757479	5434065	>15
25/01/2018	Petone	A7	Subtidal	1757467	5434042	>15
25/01/2018	Petone	A8	Subtidal	1757458	5434018	>15
25/01/2018	Petone	B1	Supratidal	1757437	5434106	>15
25/01/2018	Petone	B2	High tide -1h	1757435	5434101	>15
25/01/2018	Petone	B3	High tide -2h	1757434	5434098	>15
25/01/2018	Petone	B4	High tide -3h	1757430	5434089	>15
25/01/2018	Petone	B5	High tide -4h	1757428	5434082	>15
25/01/2018	Petone	B6	High tide -5h	1757426	5434080	>15
23/01/2018	Lyall	0	Transect start	1750007	5422902	-
23/01/2018	Lyall	1	Supratidal	1750033	5422878	>15
23/01/2018	Lyall	2	High tide -1h	1750038	5422873	>15
23/01/2018	Lyall	3	High tide -2h	1750041	5422871	>15
23/01/2018	Lyall	4	High tide -3h	1750047	5422865	>15
23/01/2018	Lyall	5	High tide -4h	1750053	5422859	>15
23/01/2018	Lyall	6	High tide -5h	1750059	5422855	>15
23/01/2018	Lyall	7	Subtidal	1750095	5422820	>15
27/01/2018	Owhiro	0	Transect start	1747123	5421509	-
27/01/2018	Owhiro	1	Supratidal	1747117	5421482	>15
27/01/2018	Owhiro	2	High tide -1h	1747118	5421476	>15
27/01/2018	Owhiro	3	High tide -2h	1747116	5421474	>15
27/01/2018	Owhiro	4	High tide -3h	1747115	5421471	>15
27/01/2018	Owhiro	5	High tide -4h	1747116	5421470	>15
27/01/2018	Owhiro	6	High tide -5h	1747116	5421467	>15
27/01/2018	Owhiro	7	Subtidal	1747116	5421449	>15
27/01/2018	Owhiro	8	Stream Mouth	1747054	5421434	>15
				*NZGD2000	*NZGD2000	

APPENDIX 3. PETONE BEACH PROFILE DATA

Petone Beach 25/01/2018 Station	Comment	NZTM East*	NZTM North*	Horizontal Distance (m)	Height above MLWS (m)
	Transect start	1757490	5434087	0	3.21
				5	2.59
	Toe of dune			6	2.59
				10	2.10
				15	1.87
A1, 12.01h	Supratidal	1757490	5434087	19	1.69
				20	1.62
				23.8	1.62
A2, 13.04h	High tide -1h	1757486	5434082	25	1.44
A3, 14.07h	High tide -2h	1757486	5434078	28.5	1.21
				30	1.20
	Mean Sea Level			32.5	1.12
				35	1.05
A4, 13.10h	High tide -3h	1757482	5434071	36.5	1.00
				40	0.88
A5, 16.13h	High tide -4h	1757480	5434067	42	0.75
A6, 17.16h	High tide -5h	1757479	5434065	44	0.49
				45	0.39
				50	0.35
				55	0.28
				60	0.18
	MLWS			65	0.03
				70	-0.12
				75	-0.27
				80	-0.42
A7, 18.19h	Subtidal	1757467	5434042	85	-0.57
				90	-0.69
				95	-0.79
				100	-0.88
				105	-0.97
A8, 18.22h	Subtidal	1757458	5434018	110	-1.06
		*NZGD2000	*NZGD2000		

Transect start is the top seaward edge of the concrete wall at the top of the beach.

APPENDIX 3. LYALL BAY PROFILE DATA

Lyall Bay 23/01/2018				Horizontal Distance (m)	Height above MLWS (m)
Station	Comment	NZTM East*	NZTM North*		
	Transect start	1750007	5422902	0	3.49
				5	3.49
				10	3.00
	Toe of dune			15	2.58
				20	2.22
				25	1.95
				30	1.77
1, 10:30h	Supratidal	1750033	5422878	35	1.67
				40	1.65
2, 11:35h	High tide -1h	1750038	5422873	43	1.49
				45	1.36
3, 12:40h	High tide -2h	1750041	5422871	46.5	1.27
	Mean Sea Level			50	1.12
4, 13:45h	High tide -3h	1750047	5422865	55	0.96
				60	0.76
5, 14:50h	High tide -4h	1750053	5422859	63	0.58
				65	0.46
6, 15:55h	High tide -5h	1750059	5422855	70	0.34
				75	0.31
				80	0.10
	MLWS			85	-0.06
				90	-0.26
				95	-0.47
				100	-0.67
				105	-0.88
				110	-1.08
				115	-1.29
7, 17.00h	Subtidal	1750095	5422820	120	-1.49
		*NZGD2000	*NZGD2000		

Transect start is the top step of the formed concrete stairs leading to the beach.

APPENDIX 3. OWHIRO BAY PROFILE DATA

Owhiro Bay 27/01/2018 Station	Comment	NZTM East*	NZTM North*	Horizontal Distance (m)	Height above MLWS (m)
	Transect start	1747123	5421509	0	4.41
	Storm surge zone			5	4.06
				10	3.74
	Cobble			15	3.22
				20	2.61
	Sand			25	2.07
1, 13.40h	Supratidal	1747117	5421482	27	1.89
	Bottom of dip			28.5	1.75
				30	1.73
	Top of rise			32	1.96
2, 14.42h	High tide -1h	1747118	5421476	34	1.60
				35	1.41
3, 15.44h	High tide -2h	1747116	5421474	36.5	1.28
	Mean Sea Level			37.5	1.12
4, 16.46h	High tide -3h	1747115	5421471	38.4	0.97
				40	0.74
5, 17.48h	High tide -4h	1747116	5421470	41	0.61
6, 18.50h	High tide -5h	1747116	5421467	42.5	0.32
	MLWS			45	0.27
	Shelf			48	-0.25
				50	-0.69
				55	-1.09
7, 19.52h	Subtidal	1747116	5421449	60	-1.49
		*NZGD2000	*NZGD2000		

Transect start is the top of the wooden marine reserve marker post concreted in the top of the beach.

APPENDIX 4. LABORATORY RESULTS

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

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Certificate of Analysis

Page 1 of 3

Client:	Salt Ecology Limited	**Lab No:**	1916026 SPv2
Contact:	Leigh Stevens C/- Salt Ecology Limited 21 Mount Vernon Place Washington Valley Nelson 7010	**Date Received:**	30-Jan-2018
		Date Reported:	26-Mar-2018 **(Amended)**
		Quote No:	90062
		Order No:	
		Client Reference:	GWRC 2018
		Submitted By:	Leigh Stevens

Sample Type: Sediment

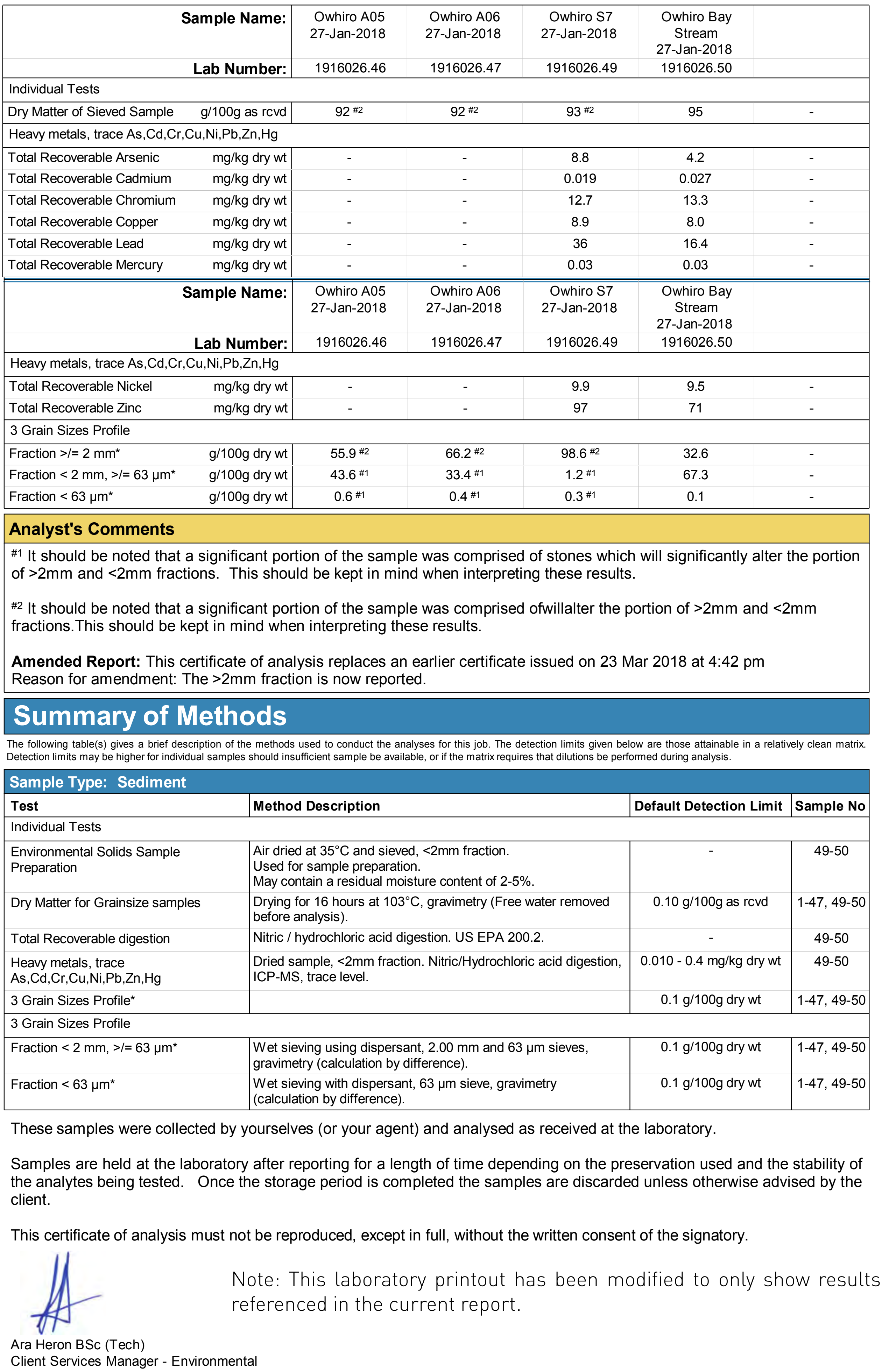
Sample Name:					Lyall A01 23-Jan-2018	Lyall A02 23-Jan-2018
Lab Number:					1916026.24	1916026.25
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd				87	89
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt				6.1	29.9
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt				93.2	69.2
Fraction < 63 µm*	g/100g dry wt				0.7	0.9

Sample Name:		Lyall A03 23-Jan-2018	Lyall A04 23-Jan-2018	Lyall A05 23-Jan-2018	Lyall A06 23-Jan-2018	Petone A01 25-Jan-2018
Lab Number:		1916026.26	1916026.27	1916026.28	1916026.29	1916026.30
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	84	84	87	83	85
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	26.7	11.4	16.6	16.9	0.8
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	72.2	87.2	82.5	82.2	97.4
Fraction < 63 µm*	g/100g dry wt	1.1	1.3	0.9	0.9	1.8

Sample Name:		Petone A02 25-Jan-2018	Petone A03 25-Jan-2018	Petone A04 25-Jan-2018	Petone A05 25-Jan-2018	Petone A06 25-Jan-2018
Lab Number:		1916026.31	1916026.32	1916026.33	1916026.34	1916026.35
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	83	80	80	82	83
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	4.8	3.7	8.2	15.7	21.9
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	94.1	94.9	90.4	83.0	76.9
Fraction < 63 µm*	g/100g dry wt	1.1	1.5	1.5	1.4	1.2

Sample Name:		Petone B01 25-Jan-2018	Petone B02 25-Jan-2018	Petone B03 25-Jan-2018	Petone B04 25-Jan-2018	Petone B05 25-Jan-2018
Lab Number:		1916026.36	1916026.37	1916026.38	1916026.39	1916026.40
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	86	80	78	78	78
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	0.2	0.5	< 0.1	1.0
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	98.8	98.3	97.6	98.4	97.6
Fraction < 63 µm*	g/100g dry wt	1.1	1.4	1.9	1.6	1.4

Sample Name:		Petone B06 25-Jan-2018	Owhiro A01 27-Jan-2018	Owhiro A02 27-Jan-2018	Owhiro A03 27-Jan-2018	Owhiro A04 27-Jan-2018
Lab Number:		1916026.41	1916026.42	1916026.43	1916026.44	1916026.45
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	79	98 [#1]	98	97 [#2]	95 [#2]
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	4.9	75.3 [#1]	73.0 [#2]	78.8 [#2]	72.3 [#2]
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	93.5	24.2 [#1]	26.7 [#1]	20.9 [#1]	26.9 [#1]
Fraction < 63 µm*	g/100g dry wt	1.6	0.5 [#1]	0.2 [#1]	0.4 [#1]	0.8 [#1]



Sample Name:	Owhiro A05 27-Jan-2018	Owhiro A06 27-Jan-2018	Owhiro S7 27-Jan-2018	Owhiro Bay Stream 27-Jan-2018	
Lab Number:	1916026.46	1916026.47	1916026.49	1916026.50	
Individual Tests					
Dry Matter of Sieved Sample g/100g as rcvd	92 #2	92 #2	93 #2	95	-
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Arsenic mg/kg dry wt	-	-	8.8	4.2	-
Total Recoverable Cadmium mg/kg dry wt	-	-	0.019	0.027	-
Total Recoverable Chromium mg/kg dry wt	-	-	12.7	13.3	-
Total Recoverable Copper mg/kg dry wt	-	-	8.9	8.0	-
Total Recoverable Lead mg/kg dry wt	-	-	36	16.4	-
Total Recoverable Mercury mg/kg dry wt	-	-	0.03	0.03	-

Sample Name:	Owhiro A05 27-Jan-2018	Owhiro A06 27-Jan-2018	Owhiro S7 27-Jan-2018	Owhiro Bay Stream 27-Jan-2018	
Lab Number:	1916026.46	1916026.47	1916026.49	1916026.50	
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg					
Total Recoverable Nickel mg/kg dry wt	-	-	9.9	9.5	-
Total Recoverable Zinc mg/kg dry wt	-	-	97	71	-
3 Grain Sizes Profile					
Fraction >/= 2 mm* g/100g dry wt	55.9 #2	66.2 #2	98.6 #2	32.6	-
Fraction < 2 mm, >/= 63 µm* g/100g dry wt	43.6 #1	33.4 #1	1.2 #1	67.3	-
Fraction < 63 µm* g/100g dry wt	0.6 #1	0.4 #1	0.3 #1	0.1	-

Analyst's Comments

#1 It should be noted that a significant portion of the sample was comprised of stones which will significantly alter the portion of >2mm and <2mm fractions. This should be kept in mind when interpreting these results.

#2 It should be noted that a significant portion of the sample was comprised ofwillalter the portion of >2mm and <2mm fractions.This should be kept in mind when interpreting these results.

Amended Report: This certificate of analysis replaces an earlier certificate issued on 23 Mar 2018 at 4:42 pm
Reason for amendment: The >2mm fraction is now reported.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	49-50
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-47, 49-50
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	49-50
Heavy metals, trace As,Cd,Cr,Cu,Ni,Pb,Zn,Hg	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.010 - 0.4 mg/kg dry wt	49-50
3 Grain Sizes Profile*		0.1 g/100g dry wt	1-47, 49-50
3 Grain Sizes Profile			
Fraction < 2 mm, >/= 63 µm*	Wet sieving using dispersant, 2.00 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-47, 49-50
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-47, 49-50

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Note: This laboratory printout has been modified to only show results referenced in the current report.

APPENDIX 5. ECO GROUP CLASSIFICATIONS

Name in datasheet	Eco-group name used in analysis	Comment
Actaecia euchroa	NA	Isopoda has no EG
Amphipoda sp1	Amphipoda	EG II
Amphipoda sp2	Amphipoda	EG II
Amphipoda sp3	Amphipoda	EG II
Amphipoda sp4	Amphipoda	EG II
Arthritica sp.	Arthritica bifurca	EG IV
Austrovenus stutchburyi	Austrovenus stutchburyi	EG II
Bellorchestia quoyana	Amphipoda	EG II
Boccardia (Paraboccardia) syrtis	Boccardia	EG II
Copepoda sp.	Copepoda	EG II
Copepoda sp1	Copepoda	EG II
Diogodias littoralis	Amphipoda	EG II
Exosphaeroma sp.	NA	Isopoda has no EG
Glycera lamelliformis	Glyceridae	EG II; pooled to Glyceridae
Glyceridae	Glyceridae	EG II; pooled to Glyceridae
Hiatula sp.	NA	Hiatula and Bivalvia have no EG
Isopoda sp1	NA	Isopoda has no EG
Isopoda sp2	NA	Isopoda has no EG
Macomona liliana	Macomona liliana	EG II
Nemertea sp1	Nemertea	EG III
Nereididae	Nereididae	EG III
Oligochaeta sp1	Oligochaeta	EG III
Paphies australis	Paphies australis	EG II
Pectinaria australis	Pectinaria	EG III
Perinereis vallata	Perinereis	EG III
Polychaeta	NA	Polychaeta has no EG
Pseudaega melanica	NA	Isopoda has no EG
Tainokia iridescens	Onuphidae	EG II
Thoracophelia otagoensis	Opheliidae	EG I
Turbellaria sp1	Platyhelminthes	EG II
Waitangi brevirostris	Amphipoda	EG II
Waitangi chelatus	Amphipoda	EG II

APPENDIX 6. RAW DATA

Infaunal raw data for Petone (Pet), Lyall Bay (Lya) & Owhiro Bay (Owh). Tidal elevations listed as 01, 02, etc. A Petone, transects are denoted A & B, and sample replicates a, b, c.

General group	Taxon	PetA01a	PetA01b	PetA01c	PetA02a	PetA02b	PetA02c	PetA03a	PetA03b	PetA03c	PetA04a	PetA04b	PetA04c	PetA05a
Amphipod	Amphipoda sp1													
Amphipod	Amphipoda sp2													
Amphipod	Amphipoda sp3													
Amphipod	Amphipoda sp4													
Amphipod	Bellorchestia quoyana	20	40	10						1				
Amphipod	Diogodias littoralis													
Amphipod	Waitangi brevirostris													
Amphipod	Waitangi chelatus													
Bivalve	Arthritica sp													
Bivalve	Austrovenus stutchburyi													
Bivalve	Hiatula sp													
Bivalve	Macomona liliana													
Bivalve	Paphies australis				2	2		3	2		2	1	5	1
Copepod	Copepoda sp													
Copepod	Copepoda sp1													
Isopod	Actaecia euchroa													
Isopod	Exosphaeroma sp													1
Isopod	Isopoda sp1													
Isopod	Isopoda sp2													
Isopod	Pseudaega melanica													
Nemertean worm	Nemertea sp1													
Oligochaete worm	Oligochaeta sp1													
Polychaete worm	Boccardia syrtis													
Polychaete worm	Glycera lamelliformis													
Polychaete worm	Glyceridae												1	
Polychaete worm	Nereididae							1		1				
Polychaete worm	Pectinaria australis													
Polychaete worm	Perinereis vallata									1				1
Polychaete worm	Polychaeta													
Polychaete worm	Tainokia iridescens													
Polychaete worm	Thoracophelia otagoensis													
Turbellarian worm	Turbellaria sp													

General group	Taxon	PetB03a	PetB03b	PetB03c	PetB04a	PetB04b	PetB04c	PetB05a	PetB05b	PetB05c	PetB06a	PetB06b	PetB06c	LyaA01
Amphipod	Amphipoda sp1													
Amphipod	Amphipoda sp2													
Amphipod	Amphipoda sp3													
Amphipod	Amphipoda sp4													
Amphipod	Bellorchestia quoyana													78
Amphipod	Diogodias littoralis													
Amphipod	Waitangi brevirostris													
Amphipod	Waitangi chelatus													
Bivalve	Arthritica sp													
Bivalve	Austrovenus stutchburyi						1							
Bivalve	Hiatula sp													
Bivalve	Macomona liliana													
Bivalve	Paphies australis	2	3	1	6	3	1		4	1	23	19	25	
Copepod	Copepoda sp								1					
Copepod	Copepoda sp1													
Isopod	Actaecia euchroa													1
Isopod	Exosphaeroma sp					1		1						
Isopod	Isopoda sp1													
Isopod	Isopoda sp2													
Isopod	Pseudaega melanica													
Nemertean worm	Nemertea sp1													
Oligochaete worm	Oligochaeta sp1													
Polychaete worm	Boccardia syrtis													
Polychaete worm	Glycera lamelliformis										2			
Polychaete worm	Glyceridae					1							1	
Polychaete worm	Nereididae													
Polychaete worm	Pectinaria australis													
Polychaete worm	Perinereis vallata			1										
Polychaete worm	Polychaeta								1					
Polychaete worm	Tainokia iridescens													
Polychaete worm	Thoracophelia otagoensis													71
Turbellarian worm	Turbellaria sp													

APPENDIX 6. RAW DATA

Infaunal raw data for Petone (Pet), Lyall Bay (Lya) & Owhiro Bay (Owh). Tidal elevations listed as 01, 02, etc. A Petone, transects are denoted A & B, and sample replicates a, b, c.

General group	Taxon	PetA05b	PetA05c	PetA06a	PetA06b	PetA06c	PetA07	PetA08	PetB01a	PetB01b	PetB01c	PetB02a	PetB02b	PetB02c
Amphipod	Amphipoda sp1													
Amphipod	Amphipoda sp2													
Amphipod	Amphipoda sp3													
Amphipod	Amphipoda sp4													
Amphipod	Bellorchestia quoyana								2	4	3			
Amphipod	Diogodias littoralis													
Amphipod	Waitangi brevirostris													
Amphipod	Waitangi chelatus													
Bivalve	Arthritica sp						6							
Bivalve	Austrovenus stutchburyi						4							1
Bivalve	Hiatula sp							2						
Bivalve	Macomona liliana						1	2						
Bivalve	Paphies australis	2	1	22	32	39	61	20					1	
Copepod	Copepoda sp													
Copepod	Copepoda sp1													
Isopod	Actaecia euchroa													
Isopod	Exosphaeroma sp	1	1	1	1									
Isopod	Isopoda sp1													
Isopod	Isopoda sp2													
Isopod	Pseudaega melanica													
Nemertean worm	Nemertea sp1													
Oligochaete worm	Oligochaeta sp1													
Polychaete worm	Boccardia syrtis						5							
Polychaete worm	Glycera lamelliformis						2							
Polychaete worm	Glyceridae	1												
Polychaete worm	Nereididae											1		
Polychaete worm	Pectinaria australis						1							
Polychaete worm	Perinereis vallata													
Polychaete worm	Polychaeta													
Polychaete worm	Tainokia iridescens													
Polychaete worm	Thoracophelia otagoensis													
Turbellarian worm	Turbellaria sp													

General group	Taxon	LyaA02	LyaA03	LyaA04	LyaA05	LyaA06	LyaS07	OwhA01	OwhA02	OwhA03	OwhA04	OwhA05	OwhA06	OwhS07
Amphipod	Amphipoda sp1					1	1		1		1	1		
Amphipod	Amphipoda sp2										1	6	55	
Amphipod	Amphipoda sp3												21	153
Amphipod	Amphipoda sp4													29
Amphipod	Bellorchestia quoyana													
Amphipod	Diogodias littoralis	1					4							
Amphipod	Waitangi brevirostris					1								
Amphipod	Waitangi chelatus						2							
Bivalve	Arthritica sp													
Bivalve	Austrovenus stutchburyi													
Bivalve	Hiatula sp													
Bivalve	Macomona liliana													
Bivalve	Paphies australis													
Copepod	Copepoda sp													
Copepod	Copepoda sp1	1												
Isopod	Actaecia euchroa													
Isopod	Exosphaeroma sp													
Isopod	Isopoda sp1								1		1			1
Isopod	Isopoda sp2													51
Isopod	Pseudaega melanica	1	1	1		10								
Nemertean worm	Nemertea sp1												1	
Oligochaete worm	Oligochaeta sp1							2		5	3	5		
Polychaete worm	Boccardia syrtis													
Polychaete worm	Glycera lamelliformis													
Polychaete worm	Glyceridae													
Polychaete worm	Nereididae													
Polychaete worm	Pectinaria australis													
Polychaete worm	Perinereis vallata													
Polychaete worm	Polychaeta													
Polychaete worm	Tainokia iridescens				1									
Polychaete worm	Thoracophelia otagoensis	1	1											
Turbellarian worm	Turbellaria sp								6			4	17	