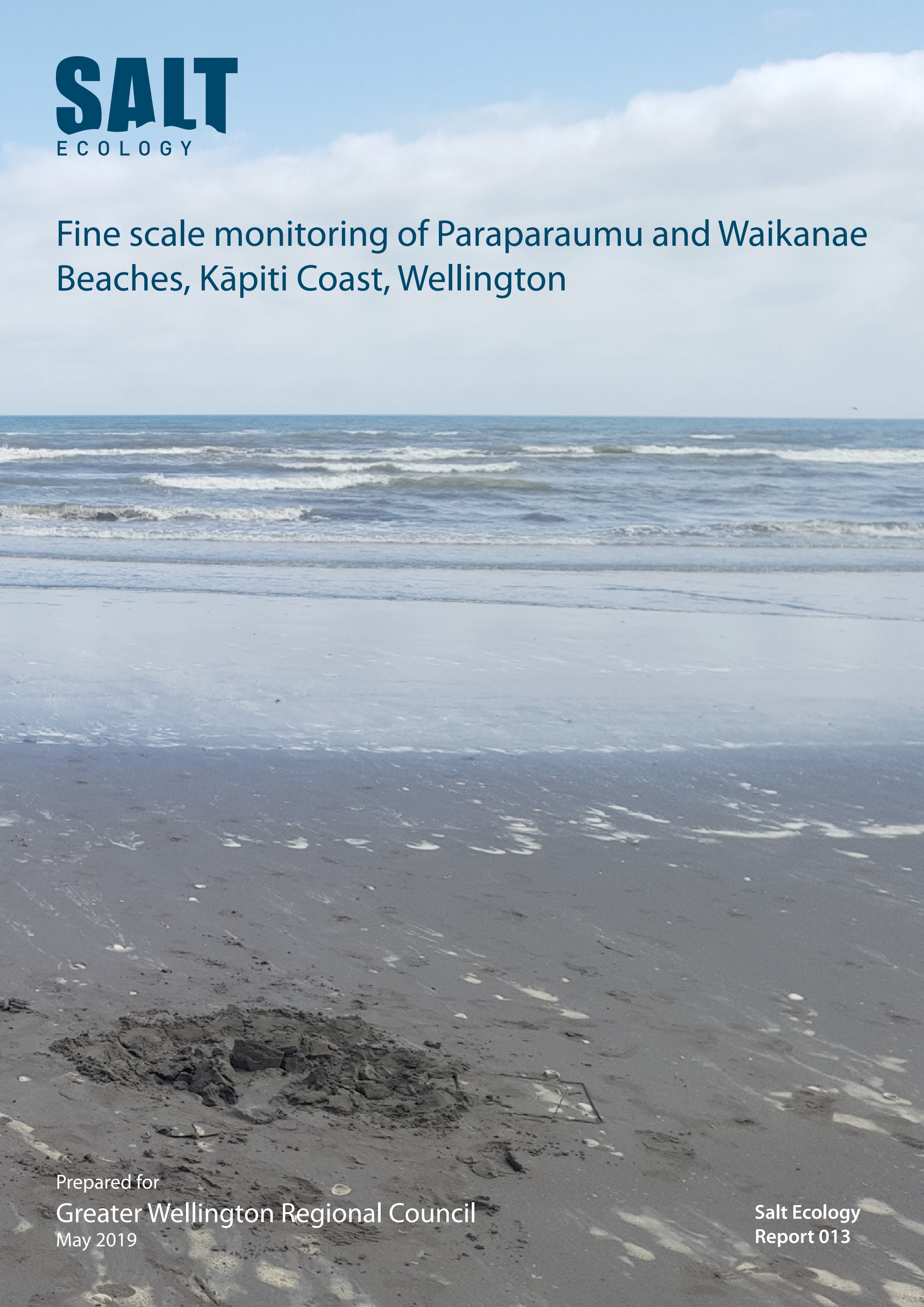
Fine scale monitoring of Paraparaumu and Waikanae Beaches, Kāpiti Coast, Wellington



Prepared for
Greater Wellington Regional Council
May 2019

Salt Ecology
Report 013

RECOMMENDED CITATION

Forrest BM, Stevens LM 2019. Fine scale monitoring of Paraparaumu and Waikanae Beaches, Kāpiti Coast, Wellington. Salt Ecology Report 013, prepared for Greater Wellington Regional Council, May 2019. 29p.

Fine scale monitoring of Paraparaumu and Waikanae Beaches, Kāpiti Coast, Wellington

Prepared by

Barrie Forrest
and Leigh Stevens

for

Greater Wellington Regional Council

May 2019

barrie@saltecology.co.nz, +64 (0)27 627 4631

www.saltecology.co.nz

ACKNOWLEDGEMENTS

Many thanks to Megan Oliver, Bryn Hickson Rowden and Evan Harrison (GWRC) for their assistance in the field, and to Megan for review of this report. We are also grateful to Salt Ecology staff Sabine O'Neill-Stevens and Sally O'Neill for field assistance and macrofauna sample processing, Gary Stephenson (Coastal Marine Ecology Consultants) for taxonomic identifications, Hayden Rabel (Salt Ecology) for assistance with R code development, and Charmayne King for editorial support.

The calculations of indices of beach health (AMBI, richness, abundance) were undertaken using an adjusted version of computer code and eco-groups prepared by the Cawthron Institute as part of the research programme Oranga Taiao Oranga Tangata, led by Massey University and funded by the Ministry of Business Innovation and Employment.

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

KEY FINDINGS

This report describes a baseline assessment and characterisation of two Kāpiti Coast beaches located at Paraparaumu and Waikanae, conducted in January 2019 by Salt Ecology for Greater Wellington Regional Council (GWRC). Sampling methods were based on recent previous beach surveys undertaken further north along the Kāpiti Coast at Peka Peka, at sites in Wellington Harbour, and on the Wairarapa coast. The approach consisted of monitoring key ecological health indicators along transects from the high tide zone to slightly deeper than the low spring tide zone.

The two beaches had broad intertidal zones with gently-sloping profiles, and were backed by vegetated dunes ~30-40m wide. The beach sediments consisted of clean well-flushed sands with a low to negligible mud and gravel content. There was no evidence of enrichment beyond very localised organic matter decay noted at one station on Paraparaumu Beach. Beach-cast macroalgae was in low abundance along the high tide strand line, although on the day of sampling at Paraparaumu Beach considerable densities of small crustaceans were being washed ashore.

At both beaches the sediment-dwelling macrofaunal assemblage had a very low richness of species (15 species in total; 1-7 species per sample). A few species occurred in moderate abundances, most notable of which were juvenile tuatua (*Paphies subtriangulata*) along the high tide shore zone, and a species of amphipod (*Waitangi brevirostris*) in the mid-shore. Although many of the species encountered remain poorly described, the main types of macrofauna present were typical of semi-exposed regional sandy beaches where the accumulation and retention of organic matter is low. Consistent with the physical conditions, the macrofauna was dominated by organisms that characterise clean, well-oxygenated sand with low enrichment levels, consisting of filter feeders (e.g. tuatua), and mobile omnivores, carnivores and scavengers.

Although the beach habitats sampled are subject to high human activity (foot traffic and/or vehicles), the low richness of species present is not necessarily linked to such activities, but conceivably reflects the semi-exposed environment and associated physical disturbances such as sand movement due to wave action. Across all of the indicators used, ecological health was rated as 'very good' or 'good' according to a four-tier condition rating assessment scale that was used. While the nature of the physical environment suggests that Kāpiti coast beaches are unlikely to be at high risk from future changes in key stressor inputs (i.e. fine muddy sediments and organic matter), there may be some risks including foot traffic and/or vehicles, coastal structures (seawalls) and stormwater outfalls.

Some considerations for long-term monitoring are discussed. To reliably measure change, and attribute change to probable causes, the indicators used in the present study 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 the best approach. The fact that the biota were relatively species-poor at each of the two locations surveyed means that apparent differences in biota from one survey to the next could reflect random sampling variation more than anything else.

With the establishment of a baseline of general ecological community composition at the two beaches, it is considered sufficient for on-going monitoring purposes to re-survey the sites every 5-years, at the same time of year and along the same transects, implementing methodological modifications to better characterise the occurrence of shellfish resources in the nearshore wadeable subtidal zone.

In intervening years it is recommended that beach sampling be extended to other parts of the coast to sample a more representative mix of beach types and disturbance levels, in particular sites representing different degrees of vehicle access, human use, and shoreline modification; e.g. coastal armouring, erosion prone areas, and sites with native versus introduced dune plantings. This approach would establish a more comprehensive picture of beach condition regionally, providing a sufficiently comprehensive dataset for informing a longer-term approach to monitoring and management.

1. INTRODUCTION

Developing an understanding of the state of coastal habitats is critical to the management of biological resources. The "Kāpiti, 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. Assessment and monitoring of these indicators will help determine the state of Wellingtons 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. over-harvesting 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 (Brown & McLachlan 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 or synoptic surveys in the GWRC region have been undertaken at various west coast beaches, including beaches on the Kāpiti Coast (Stevens & Robertson 2006; Robertson & Stevens 2015), Castlepoint Beach on the Wairarapa coast (Robertson & Stevens 2014), and various bays of Wellington Harbour and the south coast (Stevens et al. 2004; Stevens 2018). In 2018, GWRC contracted Salt Ecology to undertake fine-scale baseline assessment and characterisation of a further two beaches on the Kāpiti Coast, namely Paraparaumu and Waikanae beaches, located immediately south and north of Waikanae Estuary, respectively (Fig. 1). The selection of these locations reflected interest from GWRC and the wider community in their ecological health, given that they are popular for recreation, and potentially affected by direct physical disturbance (e.g. due to vehicle traffic) and outflow from Waikanae Estuary. This report describes the results of a survey conducted in late January 2019, and considers the utility of the survey locations for long-term monitoring.

2. METHODS

2.1 GENERAL APPROACH

The two beach sites were ~2km apart, and were surveyed by Salt Ecology and GWRC science and technical staff during calm to moderate (onshore sea-breeze) sea conditions over 16-18 January 2019. Reported tidal ranges for these dates differ widely depending on the reference station used. Based on the NIWA tide prediction model for Paraparaumu Beach (https://www.niwa.co.nz/services/online-services/tide-forecaster), tidal range was ~0.7-1m over the survey period. This compares with a minimum of ~0.4m and maximum of ~1.6m in the month either side. Hence, the survey period represents relatively neap tidal states, with a smaller tidal range by comparison with spring tide conditions during which the tide would recede further and uncover a greater amount of beach.

The survey approach was based on that used in previous GWRC surveys, which in turn reflected methods 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 slope profile, and collecting samples of sediments and infaunal macroinvertebrates (i.e. macrofauna living within the sediment-matrix, such as shellfish and beach-hoppers), along cross-shore transects extending from the upper beach to the neap low tide zone. In the present study, additional macrofaunal samples were collected from the approximate spring low and shallow subtidal zones (~0.5-1m deep, respectively, at neap low tide), mainly for comparative purposes with the intertidal sampling

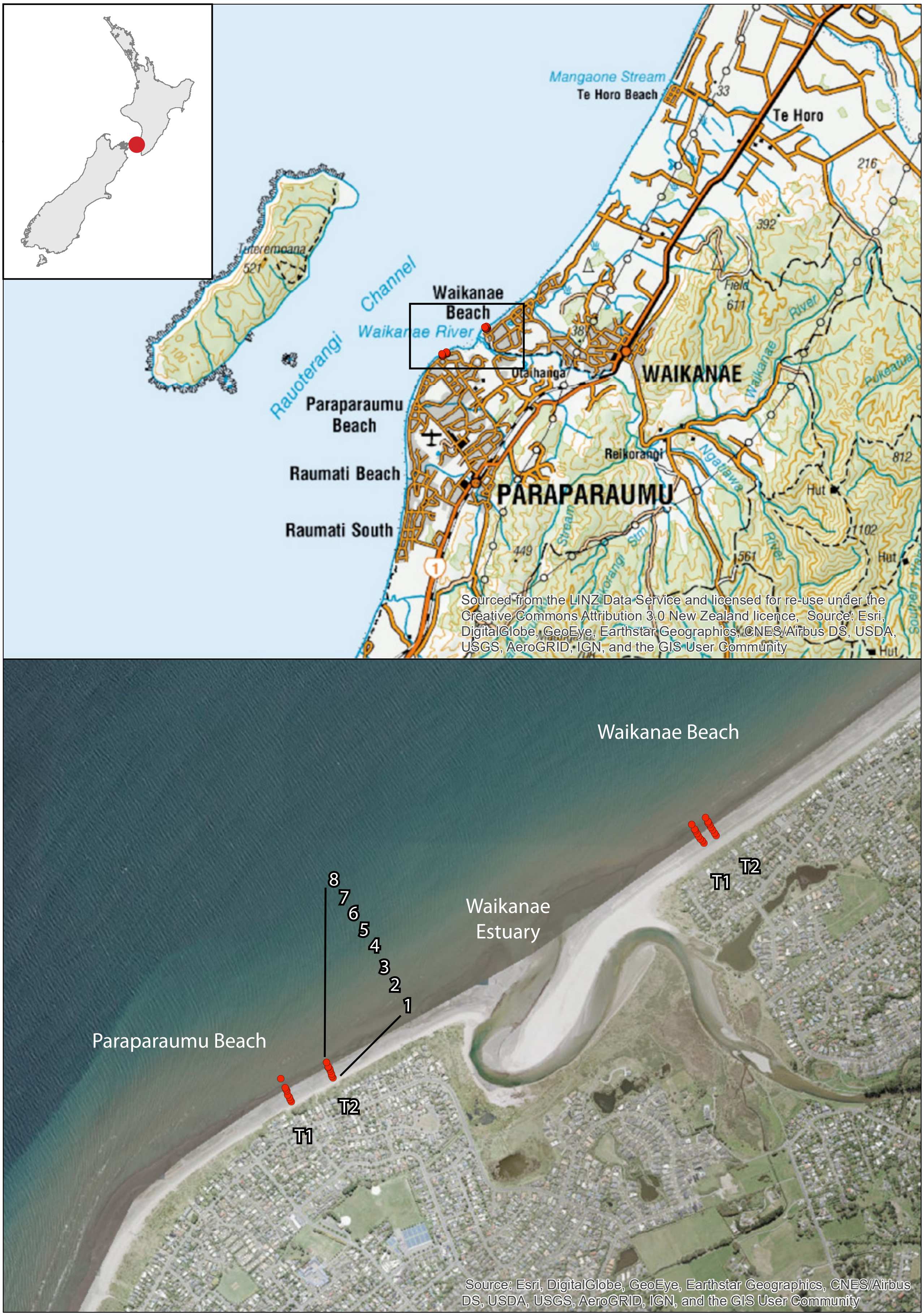


Fig. 1. Location of Paraparaumu and Waikanae beach survey locations, sampling transects and shore height stations.

component. The key indicators of beach condition that we assessed according to the methods below, are described in Appendix 2.

2.2 TRANSECTS AND SAMPLING STATIONS

Two transects were established at each site perpendicular to the shoreline on a representative part of the beach (Fig. 1). Transects were positioned 60m apart at Waikanae Beach and 175m apart at Paraparaumu Beach, the latter to minimise the possible influence of piped stormwater outfalls that discharge on the lower beach. On each transect, a sampling station was located at 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 flagged cane wand for easy relocation. The spring low and shallow subtidal stations were marked at the time of neap low tide, with the shallow subtidal stations 20-40m seaward of the low tide extent on the day of sampling in ~1m water depth. Sampling station positions are provided in Appendix 3.

Sampling stations were marked with flagged bamboo wands between the high tide zone and shallow subtidal.

2.3 BEACH PROFILING

The cross-shore profile in the location of each beach transect was measured using a theodolite. The profile extended from the back of the dune system to beyond the subtidal sampling station. These measures enabled the elevations of the sample stations to be derived relative to the mean level of the sea (MLOS), and will allow broad changes in the beach profile to be measured over time. Distances between all stations, and the GPS position of each beach sampling station, were logged.

Cross-shore profiles from the top of the dunes to the shallow subtidal were measured using a theodolite.

2.4 SAMPLING OF MACROFAUNA AND SEDIMENTS

Three replicate sediment samples were collected from each station using a using a square (330 x 330mm) stainless steel box core (sample area 0.1089m^2), which was manually driven 150 mm deep into the sand.

Macrofauna were sampled using a box corer.

Each sample was excavated from the corer using a spade or trowel, emptied into 1mm nylon mesh bag, and the contents sieved in the nearby seawater. Material collected within the mesh bag was retained for later sorting to pick out the macrofaunal organisms present. Extracted macrofauna were placed into labelled plastic jars, preserved in 70% isopropyl alcohol/seawater, and sent to a commercial laboratory (Gary Stephenson, Coastal Marine Ecology Consultants) for taxonomic identification and counting.

Example of macrofaunal organisms and detritus retained on a 1mm sieve.

Note that the samples from the two lowest stations (spring low and shallow subtidal) were collected by wading. As such, it was not possible to transfer all of the excavated sediment to the mesh bag without some loss of material. Samples from these deeper two stations should therefore be regarded as semi-quantitative, and probably underestimate the true richness and abundance of macrofauna present. However, they are useful for a broad comparison with the intertidal sampling.

To complement the macrofaunal sampling, a subsample of sediment was collected next to each box core from the top, middle and bottom core depth, and composited into a single sample (~250g total) for analysis of particle grain size (mud <63µm, i.e. silt and clay; sand 63µm-2mm; gravel >2mm). Samples were placed into ziplock bags and sent to RJ Hill Laboratories for analysis, based on methods in Appendix 4. The rationale for compositing sediment samples at the station level arose from recognition that particle grain size was likely to be relatively uniform across spatial scales of a few metres, such that sampling of discrete replicates with an associated tripling of analytical costs could not be justified.

The above 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 redox potential discontinuity (aRPD) depth was recorded as a secondary indicator. The aRPD is a subjective measure of the enrichment state of sediments according to the depth of visual transition between oxygenated surface sediments and deeper deoxygenated black sediments. The aRPD occurs closer to the sediment surface as organic matter loading increases, at least in susceptible environments. While this indicator is relatively easy to measure, in a sandy beach environment the aRPD has a low likelihood of being appreciably altered by anthropogenic or natural stressors, due to the generally porous and well-flushed nature of the sediments.

2.5 DATA RECORDING, QA/QC AND ANALYSIS

All sediment and macrofaunal samples were tracked using standard Chain of Custody forms, and results were transferred electronically as Excel sheets to avoid transcription errors. To minimise the risk of data manipulation errors, Excel sheets for the different data types were imported into the software R 3.5.3 (R Core Team 2019) and merged by common sample identification codes, and data summaries (e.g. means ±1SE) generated. Beach profiles were constructed from the theodolite data, and sediment grain size and macrofaunal species richness, abundance or composition patterns are presented graphically and/or in Tables. In some instances, pooled samples are presented in order to display general trends. Before macrofaunal analyses, the data were screened to remove species that were not regarded as a true part of the beach infaunal assemblage; these were epibiota, larval or planktonic life-stages, and non-marine organisms such as terrestrial beetles.

Based on data aggregated within each shore height, kite diagrams are used to illustrate relative patterns of dominance of the main taxonomic groups (e.g. bivalves, amphipods) along transects. For this purpose, taxon composition data were aggregated to seven higher groups. Based on species data, the multivariate non-metric multidimensional scaling (nMDS) ordination technique in the software Primer v7.0.13 (Clarke et al. 2014) was used to explore similarities in taxonomic composition patterns within and among shore heights (pooled across core and transect) and beaches. Pooling at this level was considered reasonable based on exploratory analyses that revealed a high similarity in assemblage composition among transects at each site. Prior to analysis, a triangular matrix of pairwise Bray-Curtis similarity index scores was generated, with abundance values 4th-root transformed to down-weight the influence on the nMDS ordination pattern of the most dominant species. The similarity percentages procedure (SIMPER) was used to explore the taxa that characterised the nMDS site groups, or discriminated groups from each other.

Values of the biotic index AMBI (Borja et al. 2000)

Table 1. Summary of subjective beach condition ratings referred to in the present report.

Ratings are based on apparent Redox Potential Discontinuity (aRPD) depth relative to the sediment surface, sediment mud content (%) and AMBI biotic index scores for macrofauna. See methods for further explanation.

Indicator	Unit	Very Good	Good	Moderate	Poor
Mud	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD	mm	≥ 50	20 to < 50	10 to < 20	< 10
AMBI	na	0 to ≤1.2	1.2 to ≤ 3.3	3.3 to ≤ 4.3	> 4.3
		Intolerant of enrichment	Tolerant of slight enrichment	Tolerant of moderate enrichment	Tolerant of high enrichment

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. AMBI scores were calculated based on standard international eco-group classifications (http://ambi.azti.es) where possible. However, to reduce the number of taxa with unassigned eco-groups, international data were supplemented with more recent classifications for New Zealand described by Berthelsen et al. (2018), which drew on prior New Zealand studies (Keeley et al. 2012; Robertson et al. 2015). For amphipods, we defaulted to the eco-group II designation used in the Berthelsen study. AMBI scores were not calculated for macrofaunal cores that did not meet operational criteria defined by Borja & Mader (2012), in terms of the percentage of unassigned taxa (> 20%), or low sample richness (< 3 taxa) or abundances (< 6 individuals). In such situations, cores were pooled within stations, or across transects for each shore height, and screened according to the same operational criteria.

To further assist in broadly characterising the health status of the beach biota, at least with respect to fine sediments and enrichment status, a 'condition rating' system was used to classify results for aRPD depth, the percentage mud in sediment samples, and infaunal AMBI scores (Table 1). This system classifies indicators into subjective classes between "very good" and "poor", and stems from a New Zealand Estuarine Trophic Index (ETI), which provides screening guidance for assessing where an estuary is positioned on a eutrophication gradient (Robertson et al. 2016a, b). We adopt the ETI thresholds for present purposes, except for aRPD, for which we modified the ratings based on the US Coastal and Marine Ecological Classification Standard Catalog of Units (FGDC 2012). The ratings should be regarded as a rough guide to beach health, in that they: were developed for estuaries; greatly over-simplify the results; are limited in terms of inferences that can be made with respect to stressors other than organic enrichment; and have been derived using expert judgement rather than comprehensive quantitative analyses.

3. KEY FINDINGS

3.1. BEACH PROFILES AND GENERAL FEATURES

The beach profiles were very similar at both beaches with 3-4m high steep faced dune systems extending 30-40m wide to residential housing. The back dunes were vegetated primarily with exotic species dominated by introduced marram grass, tree lupin, and introduced weeds, while the fore-dunes supported plantings of the native sand binder spinifex (Fig 3c). At Paraparaumu Beach, where erosion is evident, concrete seawalls have been installed in many places to protect coastal property.

Beach profiles from the toe of the fore-dune to low tide are plotted in Fig. 2, with the axes scaled to emphasise changes in beach profile . The 20-30m wide stretch of beach above station 1 had several small pre-cursor dunes and indicated sand accumulated in this zone. While this area remained dry on the days sampling was undertaken, it showed evidence of regular inundation by waves and is a very dynamic habitat.

Below station 1, the beach sloped gradually and relatively consistently from high to low tide. There were no major changes in gradient until the low tide mark (Station 6) where a shallow trough was present. This shallow subtidal zone extended several hundred metres offshore to a raised offshore sandbar.

There were no visible biological growths (e.g. sea lettuce, microalgal mats) or other obvious symptoms that might indicate enriched or otherwise degraded conditions. The only macroalgae evident were small amounts of drift material along parts of the strandline at each location (Fig. 3e). However, the amount of accumulated beach wrack was surprisingly low. At Paraparaumu, fine organic detritus and glass shrimps were abundant along the low-tide line and adjacent shallows on the day of sampling (Fig. 3f).

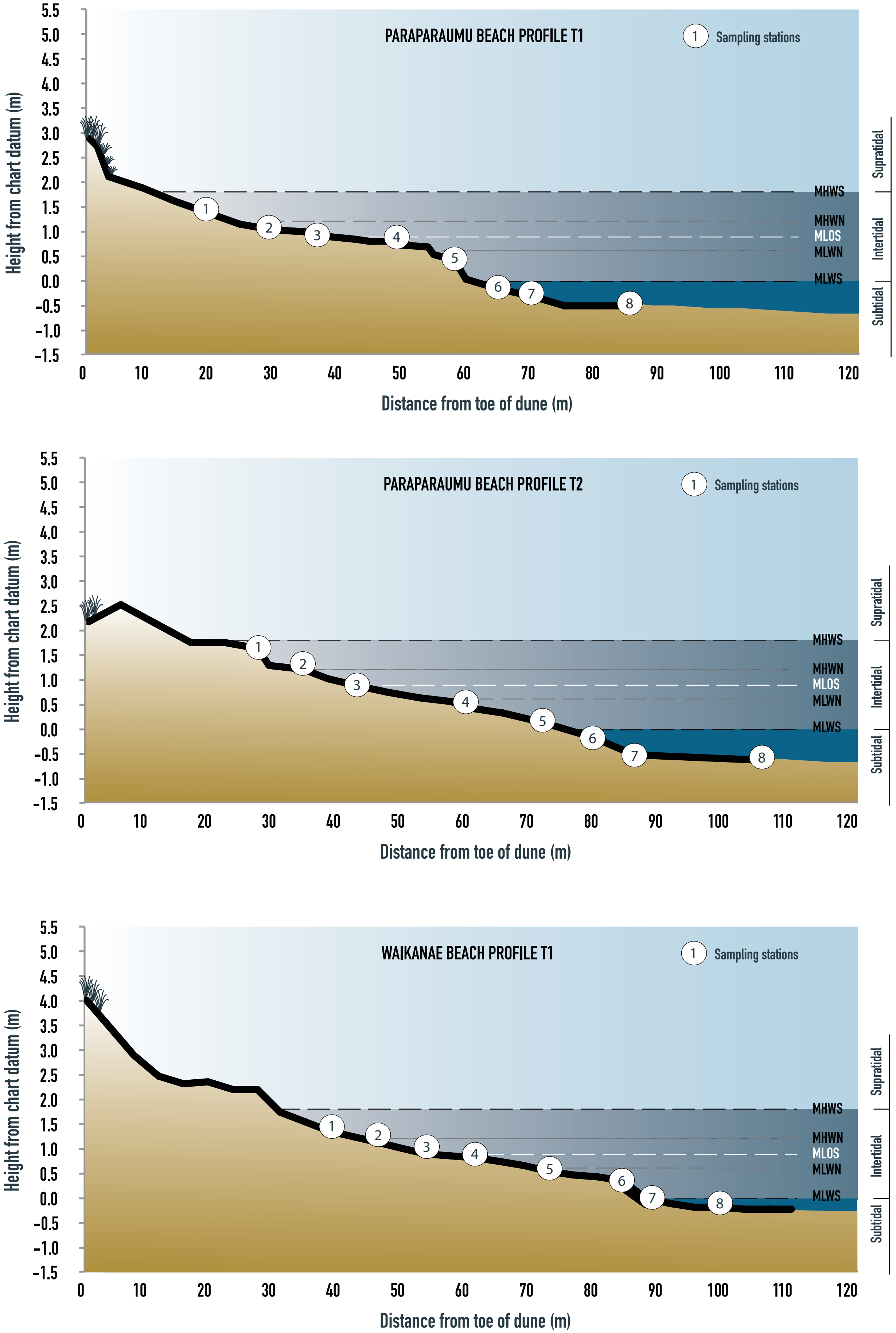


Fig. 2. Cross-shore beach transect profiles from the toe of sand dunes to the shallow subtidal.

Shore heights progress left to right from high shore (1) to low shore neap tide (6), low shore spring tide (7) and shallow subtidal (8).

3.2 SEDIMENT GRAIN SIZE AND aRPD DEPTH

The beaches consisted almost exclusively of sandy sediments, with a very low fine mud and coarse gravel component (Fig. 4, raw data in Appendix 4). The mud component was < 5% for all composite samples, except the deepest station (8) on Transect 1 (T1) at Paraparaumu for which the mud content was 6.9%. Hence, all stations are classified as "very good" in relation to the mud content thresholds in Table 1, with T1-8 classified as "good". The aRPD depth at all beach stations was > 15 cm, indicating that the sediments are well-oxygenated. The aRPD values fit the "very good" condition rating in Table 1. Despite this result, patches of mild enrichment were nonetheless noted in cores from Transect 2 (shore height 3) at Paraparaumu Beach, which reflected clumps of decaying organic matter. Aside from this, there were no obvious signs of degradation or enrichment, despite the presence of considerable detritus in the low tide fringe and shallow subtidal. In such a situation, the aRPD depth provides a simple but useful indicator of any gross deterioration in enrichment status.

Box corer hole showing clean sands with no enrichment visible.

Fig. 3. Selection of photographs illustrating key features of the beach and dunes.

A. Paraparaumu Beach showing eroding marram grass dunes.
B. Waikanae Beach.
C. Front of dunes behind beach showing a strip of the native sand-binder spinifex in front of tree lupins.
D. Central area of dunes behind beach showing marram grass, tree lupins and introduced weeds and grasses.
E. Very little macroalgae was present in the high tide strand line.
F. At Paraparaumu Beach, organic detritus and glass shrimps were abundant along the low-tide line and adjacent shallows on the day of sampling.

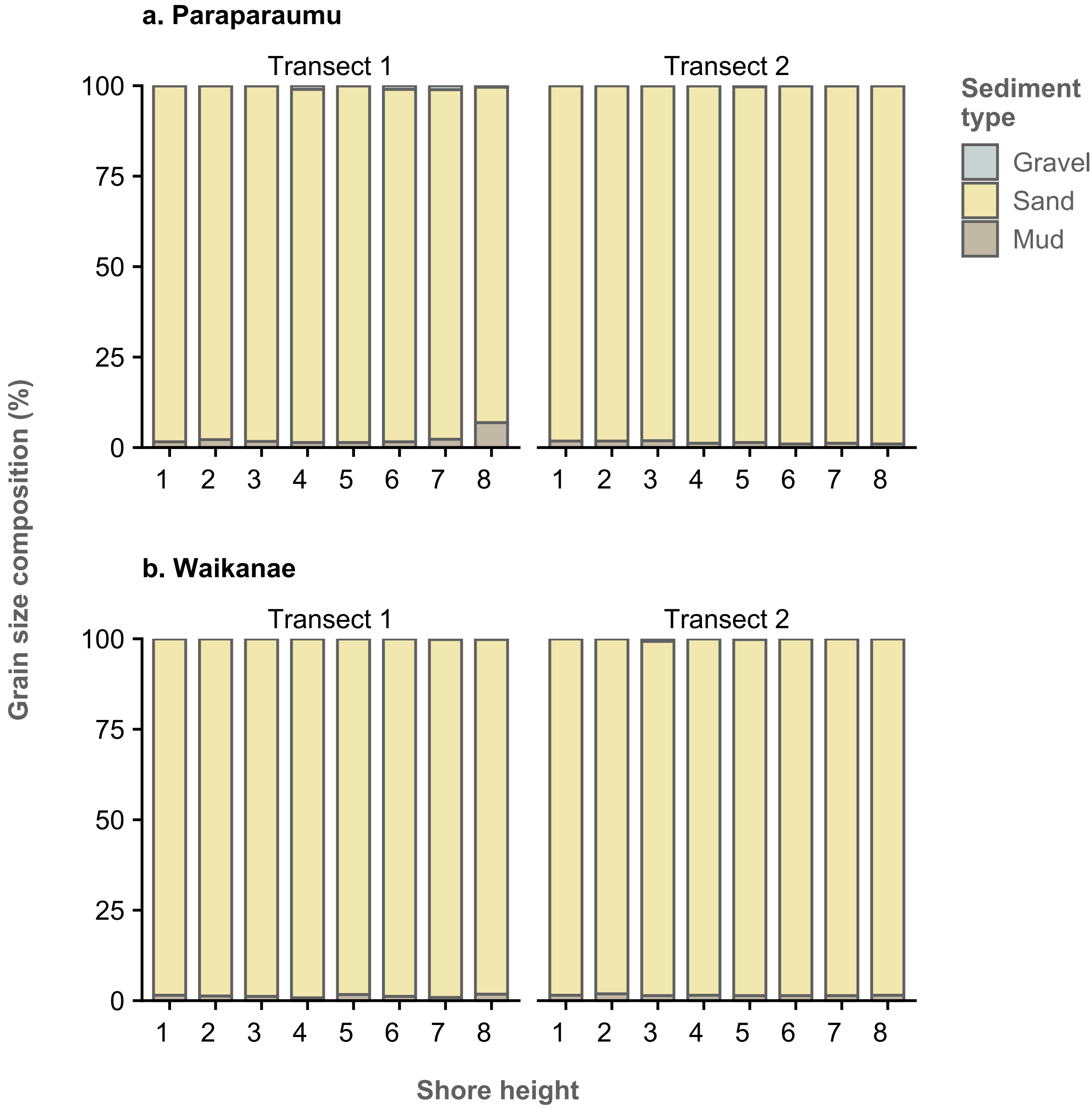


Fig. 4. Sediment grain size based on composite cores from each sampling station.

Grain size is classified into three broad categories: mud <63 µm (i.e. silt and clay); sand 63µm to ≤2 mm; and gravel >2 mm. Transects A and B are shown separately for each beach. Shore heights as described for Fig. 2.

3.3 SEDIMENT BIOTA

3.3.1 Taxon richness, abundance and composition

Raw macrofaunal data are given in Appendix 5. The macrofaunal assemblages at the two beaches were highly impoverished, with a total of 15 infaunal species or higher taxa recorded from Paraparaumu Beach, and 19 from Waikanae Beach. The only epibiota were a few juvenile sand dollars (*Fellaster zelandiae*) at Waikanae Beach in shallow subtidal cores (shore height 8). Background information on the dominant macrofaunal species we describe below is given in Table 2.

Richness values in box core samples ranged from 1 – 7 taxa, with mean values correspondingly very low across all sampling stations (~2 to 6 taxa), being marginally higher at Waikanae Beach (Fig. 5). The mean richness values show no clear trends from high to low shore, as might be expected due to relatively harsh physical conditions higher on the shore (i.e. increased exposure to the elements during low tide). This result likely reflects a combination of core-to-core sampling variation due to the impoverished nature of the beach sands, as well as under sampling of biota at lower shores heights 7 and 8 (see methods). When the core-to-core variation is smoothed by aggregating cores within each shore height (i.e. pooling cores across stations and transects), there is a general trend for an increase in total richness from high to low shore (Table 3).

The main taxonomic groups are shown. Totals represent taxon richness and the sum of abundances pooled across six box cores (3 from each transect).

Despite the low richness values, macrofaunal abundances were quite high and high to low shore patterns were relatively consistent among transects and beaches (Fig. 6). Abundances at most

Table 2. Description of some of the dominant species. Shown here are species comprising ≥10% of the total abundance at any one of the sampling stations.

Except for Paphies subtriangulata, thumbnails are not the same species and are used to illustrate the general group.

Main group	Taxon	Description	Image
Amphipoda	*Waitangi brevirostris*	Amphipods are shrimp-like crustaceans. This species is from the family of phoxocephalid amphipods and inhabits sandy sediments.	
Amphipoda	*Diogodias littoralis*	Amphipods are shrimp-like crustaceans. This species is from the family of phoxocephalid amphipods and inhabits sandy sediments.	
Amphipoda	*Waitangi chelatus*	Amphipods are shrimp-like crustaceans. This species is from the family of phoxocephalid amphipods and inhabits sandy sediments.	
Bivalvia	*Paphies subtriangulata*	Edible bivalve known as tuatua, that feeds by filtering plankton particles from the water column. Distinguished from its close relative, the pipi (*Paphies australis*), by its asymmetric shell.	
Isopoda	Valvifera	A type of isopod, which is a small crustacean in the same group as sea lice and related to terrestrial slaters (woodlice). Probably an omnivorous scavenger.	
Isopoda	*Macrochiridothea uncinata*	A type of isopod, which is a small crustacean in the same group as sea lice and related to terrestrial slaters (woodlice)	
Nemertea	*Nemertea* sp. 1	Ribbon or proboscis worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions but can tolerate moderate enrichment.	
Polychaeta	*Hemipodia simplex*	A glycerid, or bloodworm, found in clean sand sites in estuaries and on clean sandy beaches. The glycerids in general are cylindrical, very muscular and active large predators and detritivores living in sands and sandy muds.	
Polychaeta	Spionidae	A type of bristle worm, with many species in this group being moderately tolerant of enrichment and other forms of disturbance	
Polychaeta	*Aglaophamus macroura*	A large, carnivorous, long-lived (5 years or more) intertidal and subtidal nephtyid bristle worm that prefers a sandier, rather than muddy habitat.	

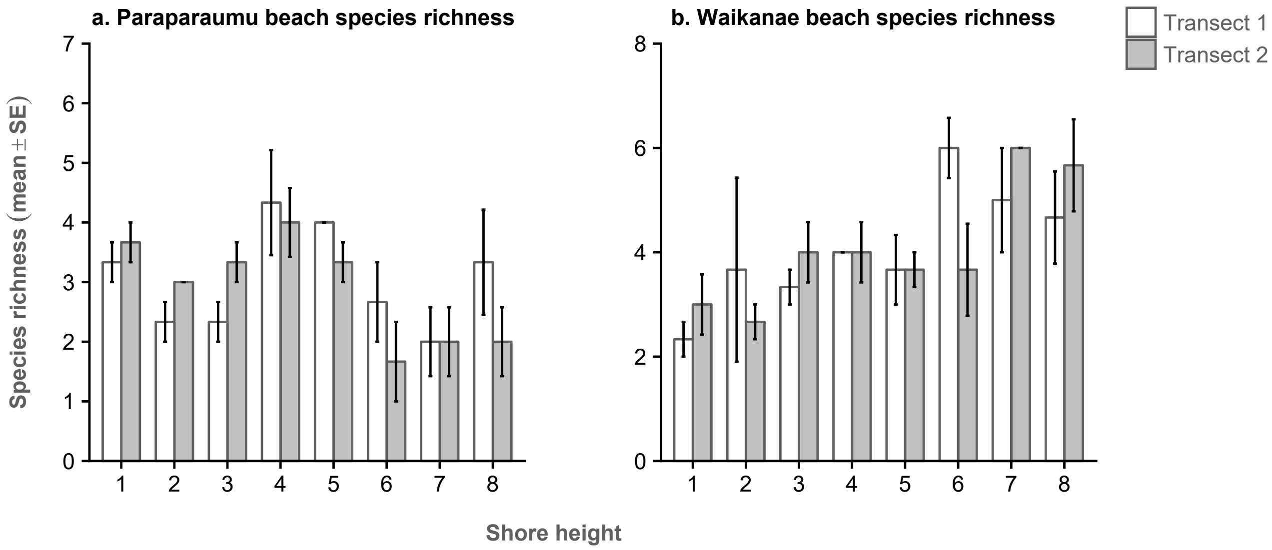


Fig. 5. Macrofaunal taxon richness in box core samples.

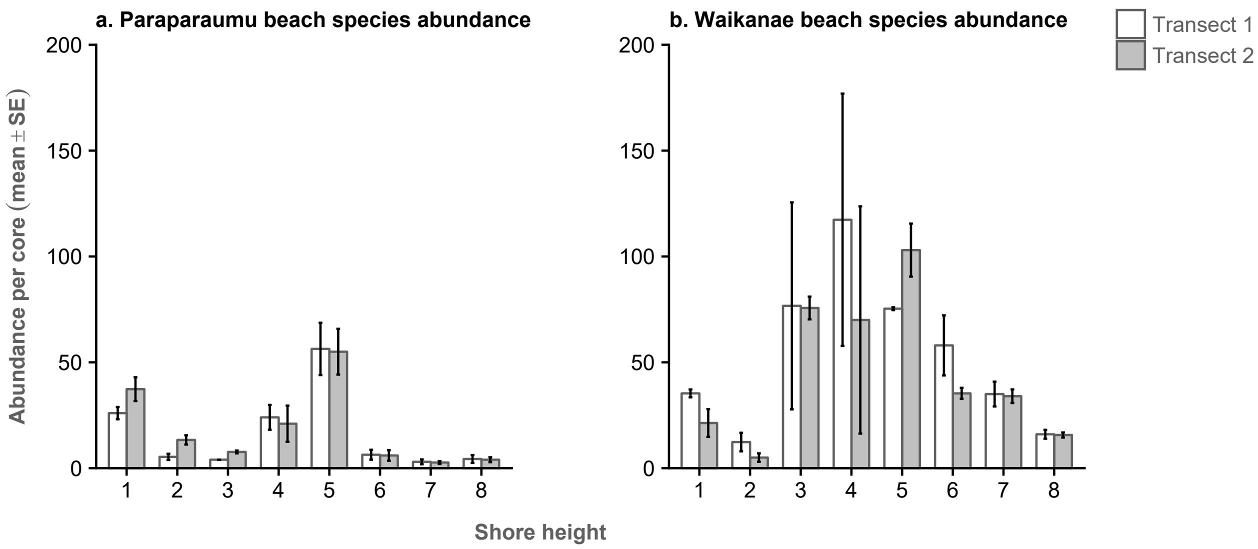


Fig. 6. Macrofaunal abundances in box core samples.

Values are means (± SE) of three samples. Shore heights as described for Fig. 2. Samples from heights 7 and 8 were collected by wading, and may underestimate true values (see methods).

shore heights were the greatest at Waikanae Beach. However, at both beaches there was a reasonably consistent bimodal pattern in the change in abundance values from high to low shore, with moderately elevated levels at the highest tidal elevation (shore height 1), and peak abundances at the mid-shore sampling stations that tapered to reduced values across the three lower shore zones (6 – 8). These abundance patterns primarily reflected juvenile bivalves (tuatua, *Paphies subtriangulata*) and to a lesser extent the polychaete ('bristle worm') *Hemipodia simplex* in the highest shore zone, while amphipods (most notably *Waitangi brevirostris*) dominated mid-shore stations (see images in Table 2). Of interest in the highest shore zone was a low prevalence of sand hoppers (amphipod, *Bellorchestia quoyana*), which is a reflection of the low prevalence of beach-cast seaweed along the strand line.

The dominance of these high and mid-shore species is reflected in the changing cross-shore abundance patterns of the higher taxa that they represent (i.e. bivalves, polychaetes, amphipods), which are summarised in Table 3 and illustrated as relative abundances in kite diagrams in Fig. 7. Despite the dominance of these taxa, other sub-dominant groups represented at both beaches were isopods (the marine equivalent of terrestrial slater bugs) and nemertean 'ribbon' worms, with a lesser prevalence

Table 3. Species abundances pooled across core and transect within each shore height at each beach.

Values are means (± SE) of six samples. Shore heights as described for Fig. 2. Samples from heights 7 and 8 were collected by wading, and may underestimate true values (see methods).

	Paraparaumu								Waikanae							
Taxa	P1	P2	P3	P4	P5	P6	P7	P8	W1	W2	W3	W4	W5	W6	W7	W8
Amphipoda (Amphipods)																
Bellorchestia quoyana	7	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-
Diogodias littoralis	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-
Waitangi brevirostris	-	-	10	113	313	26	8	2	1	33	427	531	517	252	115	43
Waitangi chelatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
Bivalvia (Bivalve shellfish)																
Paphies subtriangulata	106	26	-	3	9	4	5	10	111	7	11	1	5	4	7	2
Decapoda (Decapods)																
Biffarius filholi	-	-	-	-	-	-	-	-	-	-	-	1	-	5	-	2
Hemigrapsus crenulatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Isopoda (Isopods)																
Eurylana arcuata	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-
Macrochiridothea uncinata	-	-	-	-	-	-	1	2	-	1	-	-	-	-	57	4
Pseudaega melanica	-	-	-	-	3	2	-	-	-	4	9	8	-	1	7	-
Scyphax ornatus	10	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Valvifera	-	-	-	-	1	-	1	3	-	-	-	-	-	-	-	-
Nemertea (Ribbon worms)																
Nemertea sp. 1	-	6	12	8	3	-	1	-	-	1	3	2	3	3	2	1
Nemertea sp. 2	-	-	-	3	1	-	-	1	1	-	-	1	4	-	2	1
Ostracoda (Ostracods)																
Ostracoda sp. 1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Polychaeta (Bristle worms)																
Aglaophamus macroura	-	-	2	3	4	2	-	4	-	-	5	12	2	8	7	8
Hemipodia simplex	67	24	11	3	-	1	-	-	54	-	-	-	-	1	1	-
Magelona sp. 1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Orbinia papillosa	-	-	-	-	-	-	-	-	-	-	-	1	2	1	3	5
Pectinaria australis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Sigalion oviger	-	-	-	1	-	-	-	2	-	1	2	4	2	4	4	6
Spionidae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Total richness	4	3	4	8	7	6	6	8	5	9	6	10	7	10	12	10
Total abundance	190	56	35	135	334	37	17	25	170	52	457	562	535	280	207	95

of ostracods (small crustacea, aka 'seed shrimps'). Decapods (shrimps and crabs) were present in the occasional core taken from Waikanae Beach, but not Paraparaumu.

The distribution and abundance patterns illustrated by the kite diagrams are largely reflected in the species-level nMDS ordination biplot in Fig. 8. The nMDS method clusters stations according to similarities in their taxon composition and abundance. In this instance the moderate 'stress' value of the ordination (i.e. stress = 0.12) can be interpreted to mean that shore heights lying nearest to each other (in a 2-dimensional biplot) are reasonably similar in terms of their taxonomic composition. Fig. 8 reinforces the main patterns evident from the above analysis, including the compositional differences between high and mid-shore sites noted above.

The nMDS plot in Fig. 8 also reveals a few shore heights that remain discrete from the main clusters. In some instances this result reflects their species-poor nature (e.g. P2 & P3; shore heights 2 and 3 at Paraparaumu), but generally it reflects quite subtle differences among shore heights and beaches. These differences often reflect the absence or lower prevalence of species that characterise the adjacent clusters, but occasionally they reflects a slightly greater prevalence. For example, one of the ribbon worm (*Nemertea*) species was slightly more abundant at shore height 3 (mid-high shore) on both transects at Paraparaumu Beach. In the case of Transect 2, this finding is consistent with the fact that the box cores showed minor signs of localised and patchy enrichment, to which nemerteans are moderately tolerant.

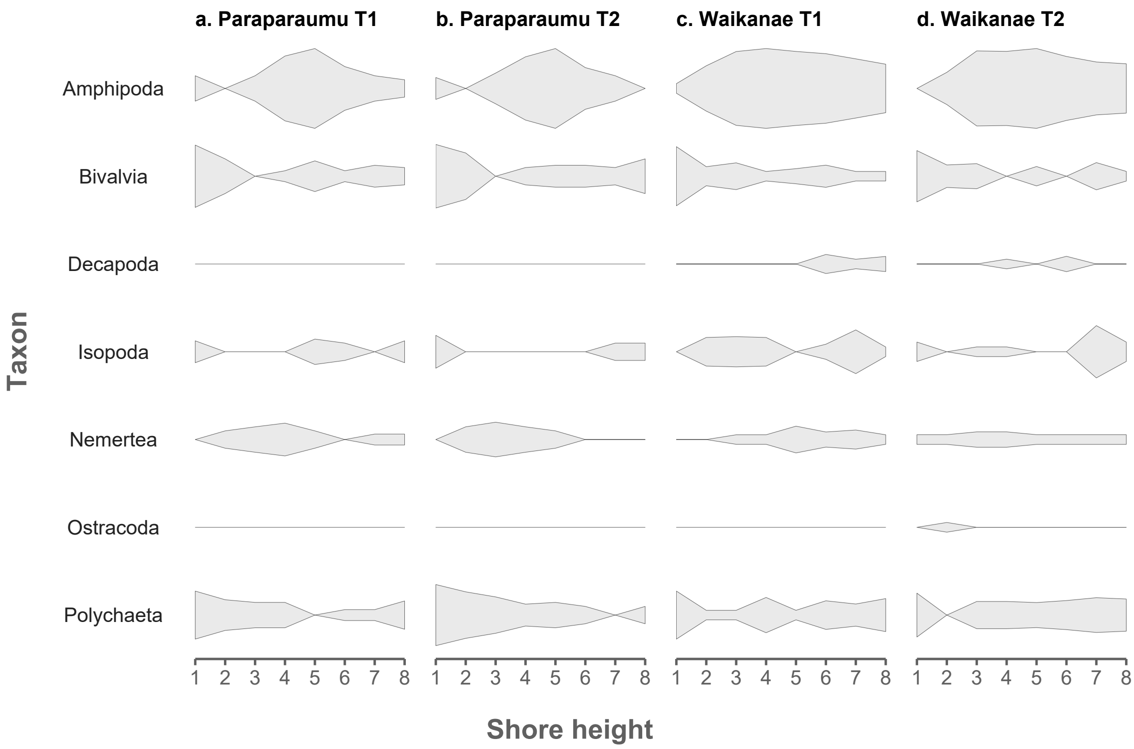


Fig. 7. Kite diagrams showing the relative abundance and distribution along each transect of main taxonomic groups shown in Table 3.

Abundance data were log10-transformed or order that the sub-dominant groups are not overwhelmed by high abundances of the most prevalent species. Shore heights as described for Fig. 2. Samples from heights 7 and 8 were collected by wading, and may underestimate true values (see methods).

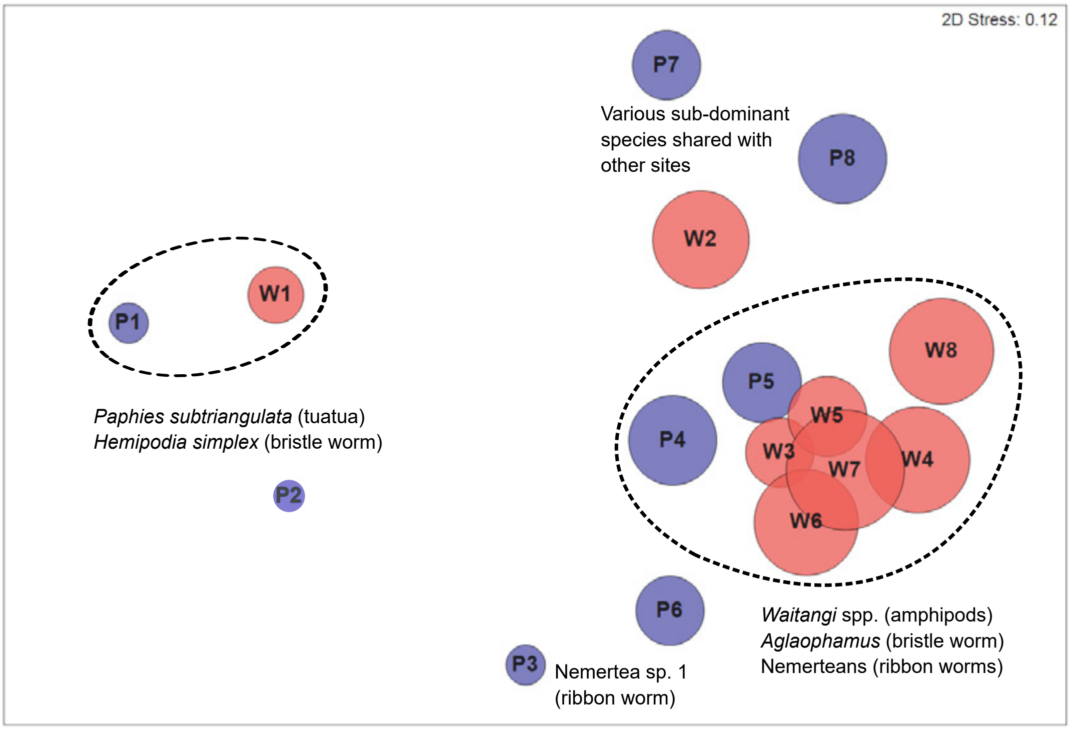


Fig. 8. Biplot (nMDS) depicting the grouping of shore heights according to their taxon composition.

P = Paraparaumu Beach, W = Waikanae Beach. Dotted circles enclose groups clustering at > 60% Bray-Curtis similarity, with the main taxa responsible for the groups clusters identified. The filled bubbles overlaying each station are colour-coded by beach, and scaled to taxon richness (the most species-rich sites are represented by the largest bubbles). A 4th-root transformation was applied to the data in order that the less common taxa had an influence on the ordination pattern.

3.3.3 AMBI biotic index

Table 4 summarises the values of the biotic index AMBI. As only 23% of core samples met operational criteria for reliable interpretation of AMBI scores, cores were aggregated within sampling station for the analysis. Even then only 34% of aggregated samples met AMBI operational criteria, with AMBI values ranging from 1.37 to 2.02. According to the condition rating thresholds in Table 1, beach health would be rated as 'good', with the macrofauna present 'tolerant of slight enrichment'. This index score reflects that all species present were in eco-groups ranging from I to III, spanning a spectrum from sensitive to moderately tolerant of enrichment (Appendix 5). Interestingly, when compared to the AMBI-specific classifications developed in Europe (i.e. not the New Zealand ETI), the AMBI scores in Table 4 would lead to classification of the beach health as either 'unbalanced' (Borja et al. 2000) or 'slightly disturbed (Borja et al. 2012).

The fact that 68% of the aggregated results failed to meet the recommended operational criteria for reliable AMBI interpretation (grey shading in Table 4), reflected that many species have unassigned eco-group scores (Appendix 5). This situation was also reported for Wellington Harbour beaches by Stevens (2018) and is due to the fact that the beach species encountered in the Wellington region are poorly described and understood. While the scores from stations in Table 4 failing to meet AMBI operational criteria should be interpreted with caution, they are generally similar to the scores that did meet the criteria, and the highest values (~2 at Paraparaumu Beach, shore height 3) are still well below the AMBI threshold of 3.3 that would move the overall status from 'good' to 'moderate' (i.e. moderately degraded). These higher scores reflected the occurrence of nemertean worms (eco-group III) in the cores from shore height 3 at Paraparaumu (i.e. where slightly enriched patches were evident, as noted above).

Table 4. Values for the biotic index AMBI calculated for macrofauna data for cores (n = 3) pooled within sampling station.

Shaded rows represent stations that met operational criteria for reliable AMBI calculation as defined by Borja & Mader (2012).

Station	Unassigned (UA) eco-groups (%)	Richness (S)	Abundance (N)	AMBI Score	Operational criteria met [1]
Para-01-T1	50	10	78	1.50	n
Para-01-T2	55	11	112	1.50	n
Para-02-T1	29	7	16	1.88	n
Para-02-T2	33	9	40	1.77	n
Para-03-T1	0	7	12	2.00	y
Para-03-T2	0	10	23	2.02	y
Para-04-T1	8	13	72	1.65	y
Para-04-T2	17	12	63	1.60	y
Para-05-T1	58	12	169	1.52	n
Para-05-T2	20	10	165	1.52	y
Para-06-T1	38	8	19	1.50	n
Para-06-T2	20	5	18	1.50	y
Para-07-T1	33	6	9	1.80	n
Para-07-T2	67	6	8	1.50	n
Para-08-T1	40	10	13	1.71	n
Para-08-T2	67	6	12	1.50	n
Wkne-01-T1	43	7	106	1.50	n
Wkne-01-T2	56	9	64	1.57	n
Wkne-02-T1	55	11	37	1.50	n
Wkne-02-T2	38	8	15	1.50	n
Wkne-03-T1	50	10	230	1.51	n
Wkne-03-T2	25	12	227	1.51	n
Wkne-04-T1	25	12	352	1.50	n
Wkne-04-T2	8	12	210	1.51	y
Wkne-05-T1	18	11	226	1.54	y
Wkne-05-T2	18	11	309	1.50	y
Wkne-06-T1	28	18	174	1.51	n
Wkne-06-T2	0	11	106	1.49	y
Wkne-07-T1	33	15	105	1.54	n
Wkne-07-T2	39	18	102	1.47	n
Wkne-08-T1	14	14	48	1.37	y
Wkne-08-T2	24	17	47	1.47	n

1. Operational criteria for reliable AMBI scores defined as UA > 20%, S < 3, N < 6. See methods.

4. SYNTHESIS OF RESULTS AND MONITORING CONSIDERATIONS

4.1 SYNTHESIS

The survey results are similar to other recent sandy beach studies in the wider region. The beach sites were almost exclusively clean sands, which appeared well-flushed, with no evidence of enrichment beyond very localised organic matter decay noted at one station on Paraparaumu Beach.

The low macrofaunal richness combined with moderate abundances of a few dominant species is a similar finding to two earlier surveys of Peka Peka Beach (Robertson & Stevens 2015) a few kilometers to the north of the survey area. Interestingly that survey described moderate densities of tuatua in the second survey year, but not the peak at the highest shore zone described in the present study. This type of variability among locations and years likely reflects recruitment events in this species, with tuatua and other bivalves recruiting to high shore areas and migrating down the beach as they increase in size (Hannan 2014).

Although many of the species encountered remain poorly described, the general groups of macrofauna present were typical of a semi-exposed sandy beach where the accumulation and retention of organic matter is low. Consistent with the physical conditions, the macrofauna was dominated by organisms that characterise clean, well-oxygenated sand with low enrichment levels, consisting of filter feeders (e.g. tuatua), and mobile omnivores, carnivores and scavengers.

Although the beach habitats sampled are subject to high human activity (foot traffic and/or vehicles), the low richness of species present is not necessarily linked to such activities, but conceivably reflects the semi-exposed environment and associated physical disturbances such as sand movement due to wave action. While the nature of the environment suggests that Kāpiti coast beaches are unlikely to be at high risk from future changes in key stressor inputs (i.e. fine muddy sediments and organic matter), it may not be the case that these beaches are at no risk.

4.2 MONITORING CONSIDERATIONS

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 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 the best approach. The fact that the biota were relatively species-poor at each of the two locations surveyed means that apparent differences in biota from one survey to the next could reflect random sampling variation more than anything else.

To address such issues, Stevens (2018) suggested a number of modifications to the sampling approach. One of these was to take a greater sample volume than collected in the 2018 surveys, which we achieved with the box corer method (smaller corers were used in the 2018 synoptic surveys). Another suggestion was to undertake an assessment of biota in the very low shore and shallow subtidal. In the present study we undertook a preliminary assessment in these areas, although we recognised that the box corer method was inappropriate for a fully quantitative assessment, given the loss of sampled material due to wash from overlying water. Despite this limitation, our expectation was that we would find greater densities of shellfish and perhaps a higher richness of species in these deeper areas. Although there was some evidence of greater total richness, high density shellfish beds were not found.

Nonetheless, locals spoken to during the survey described tuatua beds at wadeable depths further seaward of our deepest sampling stations. Given the value placed on such resources, we consider that there would be merit in further investigation of these possible beds, using appropriate sampling methods (e.g. dredging from a boat), although this would increase the effort and cost of the surveys. However, such an extension to the GWRC monitoring programme would enable the occurrence of tuatua and other recreationally and culturally important species to be determined, and their population status to be assessed. .

With the establishment of a baseline of general ecological community composition at the two beaches, it is considered sufficient for on-going monitoring purposes to re-survey the sites every 5-years, at the same time of year and along the same transects, implementing some of the methodological modifications outlined above. In intervening years, it is recommended that beach sampling be extended to other parts of the coast to sample a more representative mix of beach types and disturbance levels, in particular sites representing different degrees of vehicle access, human use, and shoreline modification; e.g. coastal armouring, erosion prone areas and sites with native versus introduced dune plantings. This approach would establish a more comprehensive picture of beach condition regionally, providing a sufficiently comprehensive dataset for informing a longer-term approach to monitoring and management.

5. REFERENCES CITED

Aerts K, Vanagt T, Degraer S, Guartatanga S, Wittoeck J, Fockedey N, Cornejo-Rodriguez MP, Calderon J, Vincx M 2004. Macrofaunal community structure and zonation of an Ecuadorian sandy beach (Bay of Valdivia). Belgian Journal of Zoology 134(1): 17–24.

Berthelsen A, Atalah J, Clark D, Goodwin E, Patterson M, Sinner J 2018. Relationships between biotic indices, multiple stressors and natural variability in New Zealand estuaries. Ecological Indicators 85: 634-643.

Borja A, Franco J, Pérez V 2000. A Marine Biotic Index to Establish the Ecological Quality of Soft-Bottom Benthos Within European Estuarine and Coastal Environments. Marine Pollution Bulletin 40(12): 1100-1114.

Borja Á, Mader J, I. M 2012. Instructions for the use of the AMBI index software (Version 5.0). Revista de Investigación Marina, AZTI-Tecnalia 19(3): 71-82.

Brown AC, McLachlan A 2006. The Ecology of Sandy Shores, 2nd Edition. Academic Press, Burlington, Massachusetts. 392p.

Clarke KR, Gorley RN, Somerfield PJ, Warwick RM 2014. Change in marine communities: an approach to statistical analysis and interpretation, 3rd edition. PRIMER-E: Plymouth. Plymouth, PRIMER-E.

FGDC 2012. Coastal and Marine Ecological Classification Standard. Standard FGDC-STD-018-2012, Marine and Coastal Spatial Data Subcommittee, Federal Geographic Data Committee, June, 2012.. 343p. Available at: https://www.fgdc.gov/standards/projects/cmecs-folder/CMECS_Version_06-2012_FINAL.pdf.

Hannan DA 2014. Population genetics and connectivity in Paphies subtriangulata and Paphies australis (Bivalvia: Mesodesmatidae). PhD thesis, Victoria University of Wellington. 231p.

Keeley NB, Macleod CK, Forrest BM 2012. Combining best professional judgement and quantile regression splines to improve characterisation of macrofaunal responses to enrichment. Ecological Indicators 12: 154-166.

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

Robertson B, Stevens L 2014. Castlepoint Beach Fine Scale Monitoring 2014/15. Prepared by Wriggle Coastal Management for Greater Wellington Regional Council. 26p.

Robertson B, Stevens LM 2015. Peka Peka Beach Fine Scale Monitoring 2014/15. Prepared by Wriggle Coastal Management for Greater Wellington Regional Council. 27p.

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M 2016a. NZ Estuary Trophic Index Screening Tool 1: Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: C01X1420. 47 p.

Robertson BM, Stevens L, Robertson B, Zeldis J, Green M, Madarasz-Smith A, Plew D, Storey R, Hume T, Oliver M 2016b. NZ Estuary Trophic Index Screening Tool 2: determining monitoring indicators and assessing estuary trophic state. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68 p.

Robertson BP, Gardner JPA, Savage C 2015. Macrobenthic–mud relations strengthen the foundation for benthic index development: A case study from shallow, temperate New Zealand estuaries. Ecological Indicators 58: 161-174.

Stevens L, Robertson B 2006. Broad scale habitat mapping of sandy beaches and river estuaries on the western Wellington coast1035. 77 p.

Stevens LM 2018. Fine Scale Monitoring of Petone Beach, Lyall Bay and Owhiro Bay, Wellington. Salt Ecology Report 007. Prepared for Greater Wellington Council, May 2018. 33p.

Stevens LM, Robertson BM, Robertson B 2004. Broad Scale Mapping of Intertidal Habitat and Ecology of Sandy Beaches and River Estuaries Wellington Harbour and South Coast. Prepared by the Cawthron Institute for Greater Wellington Regional Council. Cawthron Report No. 913. 69p.

APPENDICES

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

(Source: extracted with minor modification from Stevens 2018).

1. HABITAT LOSS OR MODIFICATION

The key human-influenced stressors causing habitat loss or modification are outlined below.

i. Climate change and sea level rise

Predicted climate change impacts on the New Zealand 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. New Zealand'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. Schlacher 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 & 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 New Zealand beach between the mid-1960s and 1990 failed to recover following the closure of the fishery. In addition, although not widely practised on New Zealand 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 & 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 & 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 & 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 & 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 developments (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 & 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 (e.g. via hull fouling and ballast water discharges) is a major pathway for the introduction of invasive or pest plants and animals. To date, very few invasive species have been reported on New Zealand'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 New Zealand 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 over-stabilisation 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 New Zealand'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 New Zealand's west coast under future climate change scenarios (Shand 2012), mean that sediment changes should be monitored.

3. 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, as well as leading to adverse ecological effects, can cause illness in humans and close down shellfish gathering and aquaculture operations (see Toxic Contamination below). High flushing and dilution mean most New Zealand 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).

4. TOXIC CONTAMINATION

In the last 60 years, New Zealand 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 New Zealand 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).

REFERENCES

Anderson, D., Glibert, P., and Burkholder, J. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25, 704–726.

Creese, R., Hooker, S., Luca S de., and Wharton, Y. 1997. Ecology and environmental impact of Musculista senhousia (Moilusca: Bivalvia: Mytilidae) in Tamaki Estuary, Auckland, New Zealand. New Zeal J Mar Freshw Res 31, 225–236.

Davenport, J., Davenport, J.L. 2006. The impact of tourism and personal leisure transport on coastal environments; a review. Estuarine, Coastal and Shelf Science 67, 280–292.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M., and Scapini, F. 2009. Threats to sandy beach ecosystems: A review. Estuar Coast Shelf Sci 81, 1–12.

Dugan, J.E., Hubbard, D.M., McCrary, M.D. & Pierson, M.O. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine, Coastal and Shelf Science 58, 25–40.

Dugan, J.E., Hubbard, D.M., Rodil, I., Revell, D.L., and Schroeter, S. 2008. Ecological effects of coastal armoring on sandy beaches. Marine Ecology 29, 160–170.

Groom, J.D., McKinney, L.B., Ball, L.C., Winchell, C.S., 2007. Quantifying off-highway vehicle impacts on density and survival of a threatened dune-endemic plant. Biological Conservation 135, 119–134.

ten Harkel, M.J., and van der Meulen, F. 2014. Impact of grazing and atmospheric nitrogen deposition on the vegetation of dry coastal dune grasslands. J of Vegetation Science 7, 445–452.

Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F., Tomanek, L., Williams, S.L. 2006. The impacts of climate change in coastal marine systems. Ecology Letters 9, 500–500.

Hesp, P. 2001. The Manuwatu Dunefield: Environmental Change and Human Impacts. N Z Geog 57, 33–40.

Hilton, M.J. 2006. The loss of New Zealand's active dunes and the spread of marram grass (Ammophila arenaria). NZ Geographer 62, 105-120.

IPCC. 2007. Intergovernmental Panel on Climate Change web site. https://www.ipcc.ch/publications_and_data/ar4/wg1/ (accessed December 2009).

IPCC. 2013. Intergovernmental Panel on Climate Change web site. https://www.ipcc.ch/report/ar5/wg1/ (accessed March 2014).

Jones, A.R., Gladstone, W., and Hacking, N.J. 2007. Australian sandy-beach ecosystems and climate change: ecology and management. Australian Zoologist 34, 190–202.

Kirkman, H., and Kendrick, G.A. 1997. Ecological significance and commercial harvesting of drifting and beach-cast macro-algae and seagrasses in Australia: a review 9, 311–326.

Llewellyn, P.J. and Shackley, S.E. 1996. The effects of mechanical beach cleaning on invertebrate populations. British Wildlife 7, 147–155.

McLachlan, A. 1996. Physical factors in benthic ecology:effects of changing sand particle size on beach fauna. Marine Ecology Progress Series 131, 205–217.

Nelson, W.A. 1995. Nature and magnitude of the ballast water problem in New Zealand. In: The Royal Society of New Zealand. Ballast Water: a marine cocktail on the move. Proceedings of a national symposium, 27-29 June 1995, pp 13-19. SIR Publishing, Wellington.

Pérez, E.P. and Chávez, J.E. 2004. Modelling short-term dynamic behaviour of the surf clam (Mesodesma donacium) fishery in Northern Chile using static and dynamic catchability hypotheses. Interciencia 29, 193–198.

de Ruyck, A., Soares, A.G., McLachlan, A. 1997. Social carrying capacity as a management tool for sandy beaches. Journal of Coastal Research 13, 822–830.

de Salas, M.F., Rhodes, L.L., Mackenzie, L.A., and Adamson, J.E. 2005. Gymnodinoid genera Karenia and Takayama (Dinophyceae) in New Zealand coastal waters. New Zeal J Mar Freshw Res 39,135–139.

Schlacher, T.A., Dugan, J., Schoeman, D.S., Lastra, M., Jones, A., Scapini, F., McLachlan, A., Defeo, O. 2007. Sandy beaches at the brink. Diversity and Distributions 13, 556–560.

Schlacher, T.A., Thompson, L.M.C., and Walker, S.J. 2008. Mortalities caused by off-road vehicles (ORVs) to a key member of sandy beach assemblages, the surf clam Donax deltoides. Hydrobiologia 610, 345–350.

Schlacher, T.A. and Thompson, L.M.C. 2009. Changes to dunes caused by 4WD vehicle tracks in beach camping areas of Fraser Island. In Proceedings of the 2009 Queensland Coastal Conference, S. Galvin, Editor. 2009, SEQC: Brisbane, Australia.

Shand, R.D. 2012. Kāpiti Coast Erosion Hazard Assessment Update. A report prepared for the Kāpiti Coast District Council.

Stephenson, G. 1999. Vehicle impacts on the biota of sandy beaches and coastal dunes: a review from a New Zealand perspective. Science for Conservation, 121, 1173–2946. Retrieved from http://www.cabdirect.org/abstracts/20000704352.html.

Williams, J.A., Ward, V.L., and Underhill, L.G. 2004. Waders respond quickly and positively to the banning of off-road vehicles from beaches in South Africa. Wader Study Group Bulletin 104, 79–81.

Willis, C.M. and Griggs, G.B. 2014. Reductions in Fluvial Sediment Discharge by Coastal Dams in California and Implications for Beach Sustainability. J Geol 111, 167–182.

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

Source: Stevens (2018) with minor modification.

The indicators below are listed in no particular order of priority and are intended only as a guide to some of the common and easy-to-measure indicators for various coastal stressors.

PRIMARY INDICATORS

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 over-stabilisation 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 New Zealand 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 New Zealand's beaches.

USED TO ADDRESS ISSUES OF:

Sedimentation/erosion

Climate change and sea level rise
Eutrophication
Coastal development

3. Apparent Redox Potential Discontinuity (aRPD) depth

The apparent Redox Potential Discontinuity (aRPD) 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 macrofaunal community

Macroinvertebrates (macrofauna) 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 and toxicants).

USED TO ADDRESS ISSUES OF:
Sedimentation/erosion
Climate change and sea level rise
Eutrophication
Coastal development
Toxic contamination
Habitat modification
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 agriculture, industrial or domestic-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 very low and are highly variable both spatially and temporally. For this reason, sediments and inhabiting macrofauna, which both indicate and integrate toxicants, are used increasingly in toxicant assessment.

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, 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 New Zealand 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 New Zealand.

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 New Zealand various shellfish taxa are targeted including toheroa, tuatua, tawera, pipi and cockles, 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

APPENDIX 3. SAMPLING STATION DATA AND COORDINATES.

Site	Transect	Station	Position	NZTM East	NZTM North	aRPDcm
WKNE	1	1	Supratidal	1769326	5473876	>15
WKNE	1	2	High Tide -1h	1769319	5473886	>15
WKNE	1	3	High Tide -2h	1769312	5473898	>15
WKNE	1	4	High Tide -3h	1769306	5473907	>15
WKNE	1	5	High Tide -4h	1769301	5473917	>15
WKNE	1	6	High Tide -5h	1769296	5473924	>15
WKNE	1	7	High Tide -6h	1769296	5473929	>15
WKNE	1	8	Subtidal	1769286	5473944	>15
WKNE	2	1	Supratidal	1769280	5473848	>15
WKNE	2	2	High Tide -1h	1769274	5473857	>15
WKNE	2	3	High Tide -2h	1769267	5473865	>15
WKNE	2	4	High Tide -3h	1769261	5473873	>15
WKNE	2	5	High Tide -4h	1769254	5473885	>15
WKNE	2	6	High Tide -5h	1769248	5473895	>15
WKNE	2	7	High Tide -6h	1769245	5473901	>15
WKNE	2	8	Subtidal	1769234	5473917	>15
PARA	1	1	Supratidal	1767904	5472977	>15
PARA	1	2	High Tide -1h	1767900	5472985	>15
PARA	1	3	High Tide -2h	1767898	5472992	>15
PARA	1	4	High Tide -3h	1767893	5473002	>15
PARA	1	5	High Tide -4h	1767891	5473010	>15
PARA	1	6	High Tide -5h	1767886	5473017	>15
PARA	1	7	High Tide -6h	1767885	5473020	>15
PARA	1	8	Subtidal	1767879	5473034	>15
PARA	2	1	Supratidal	1767749	5472889	>15
PARA	2	2	High Tide -1h	1767745	5472897	>15
PARA	2	3	High Tide -2h	1767741	5472905	>15*
PARA	2	4	High Tide -3h	1767736	5472915	>15
PARA	2	5	High Tide -4h	1767733	5472928	>15
PARA	2	6	High Tide -5h	1767730	5472935	>15
PARA	2	7	High Tide -6h	1767727	5472940	>15
PARA	2	8	Subtidal	1767709	5472974	>15

*enriched site due to localised presence of organic matter

APPENDIX 4. RJ HILL ANALYTICAL METHODS AND RESULTS FOR SEDIMENTS.

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SPv1

Client:	Salt Ecology Limited	**Lab No:**	2112668
Contact:	Leigh Stevens	**Date Received:**	23-Jan-2019
	C/- Salt Ecology Limited	**Date Reported:**	21-Feb-2019
	21 Mount Vernon Place	**Quote No:**	96903
	Washington Valley	**Order No:**	
	Nelson 7010	**Client Reference:**	GWRC-Paraparaumu Beach
		Submitted By:	Leigh Stevens

Sample Type: Sediment

Sample Name:		1 Para Well - 1 - T1 18-Jan-2019	2 Para Well - 2 - T1 18-Jan-2019	3 Para Well - 3 - T1 18-Jan-2019	4 Para Well - 4 - T1 18-Jan-2019	5 Para Well - 5 - T1 18-Jan-2019
Lab Number:		2112668.1	2112668.2	2112668.3	2112668.4	2112668.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	86	79	76	75	76
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	< 0.1	1.0	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	98.4	97.8	98.3	97.6	98.6
Fraction < 63 µm*	g/100g dry wt	1.6	2.2	1.7	1.4	1.4

Sample Name:		6 Para Well - 6 - T1 18-Jan-2019	7 Para Well - 7 - T1 18-Jan-2019	8 Para Well - 8 - T1 18-Jan-2019	9 Para Well - 1 - T2 18-Jan-2019	10 Para Well - 2 - T2 18-Jan-2019
Lab Number:		2112668.6	2112668.7	2112668.8	2112668.9	2112668.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	72	73	85	76
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	1.0	1.1	0.4	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	97.5	96.7	92.7	98.2	98.2
Fraction < 63 µm*	g/100g dry wt	1.6	2.3	6.9	1.8	1.8

Sample Name:		11 Para Well - 3 - T2 18-Jan-2019	12 Para Well - 4 - T2 18-Jan-2019	13 Para Well - 5 - T2 18-Jan-2019	14 Para Well - 6 - T2 18-Jan-2019	15 Para Well - 7 - T2 18-Jan-2019
Lab Number:		2112668.11	2112668.12	2112668.13	2112668.14	2112668.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	75	75	76	74	74
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	< 0.1	0.3	0.1	0.1
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	98.0	98.7	98.4	98.9	98.7
Fraction < 63 µm*	g/100g dry wt	1.9	1.2	1.4	1.0	1.2

Sample Name:		16 Para Well - 8 - T2 18-Jan-2019				
Lab Number:		2112668.16				
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	75	-	-	-	-
3 Grain Sizes Profile						
Fraction >/= 2 mm*	g/100g dry wt	< 0.1	-	-	-	-
Fraction < 2 mm, >/= 63 µm*	g/100g dry wt	99.0	-	-	-	-
Fraction < 63 µm*	g/100g dry wt	1.0	-	-	-	-

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.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

ilac-MRA IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-16
3 Grain Sizes Profile			
Fraction >/= 2 mm*	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-16
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	1-16
Fraction < 63 µm*	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-16

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.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Salt Ecology Limited	**Lab No:**	2112669 SPv2
Contact:	Leigh Stevens	**Date Received:**	23-Jan-2019
	C/- Salt Ecology Limited	**Date Reported:**	02-May-2019 **(Amended)**
	21 Mount Vernon Place	**Quote No:**	96902
	Washington Valley	**Order No:**	
	Nelson 7010	**Client Reference:**	GWRC-Waikanae Beach
		Submitted By:	Leigh Stevens

Interim Report

This is an interim report, prepared before all test results are completed. As all final Q.C. checks may not have been possible, it is not regarded as an official certificate of analysis. The final, official report will be issued upon completion of all tests.

Sample Type: Sediment

Sample Name:		1 Wkne - 1 - T1 16-Jan-2019	2 Wkne - 2 - T1 16-Jan-2019	3 Wkne - 3 - T1 16-Jan-2019	4 Wkne - 4 - T1 16-Jan-2019	5 Wkne - 5 - T1 16-Jan-2019
Lab Number:		2112669.1	2112669.2	2112669.3	2112669.4	2112669.5
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	78	75	75	76	76
3 Grain Sizes Profile						
Fraction >/= 2 mm	g/100g dry wt	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	98.5	98.7	98.8	99.2	98.3
Fraction < 63 µm	g/100g dry wt	1.5	1.3	1.2	0.8	1.7

Sample Name:		6 Wkne - 6 - T1 16-Jan-2019	7 Wkne - 7 - T1 16-Jan-2019	8 Wkne - 8 - T1 16-Jan-2019	9 Wkne - 1 - T2 16-Jan-2019	10 Wkne - 2 - T2 16-Jan-2019
Lab Number:		2112669.6	2112669.7	2112669.8	2112669.9	2112669.10
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	77	76	73	81	73
3 Grain Sizes Profile						
Fraction >/= 2 mm	g/100g dry wt	< 0.1	0.2	0.2	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	98.8	98.9	98.0	98.5	98.1
Fraction < 63 µm	g/100g dry wt	1.2	0.9	1.8	1.5	1.9

Sample Name:		11 Wkne - 3 - T2 16-Jan-2019	12 Wkne - 4 - T2 16-Jan-2019	13 Wkne - 5 - T2 16-Jan-2019	14 Wkne - 6 - T2 16-Jan-2019	15 Wkne - 7 - T2 16-Jan-2019
Lab Number:		2112669.11	2112669.12	2112669.13	2112669.14	2112669.15
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	74	76	76	78
3 Grain Sizes Profile						
Fraction >/= 2 mm	g/100g dry wt	0.7	< 0.1	0.2	< 0.1	< 0.1
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	97.9	98.5	98.4	98.5	98.5
Fraction < 63 µm	g/100g dry wt	1.4	1.5	1.4	1.4	1.4

Sample Name:		16 Wkne - 8 - T2 16-Jan-2019				
Lab Number:		2112669.16				
Individual Tests						
Dry Matter of Sieved Sample	g/100g as rcvd	76	-	-	-	-
3 Grain Sizes Profile						
Fraction >/= 2 mm	g/100g dry wt	< 0.1	-	-	-	-
Fraction < 2 mm, >/= 63 µm	g/100g dry wt	98.6	-	-	-	-
Fraction < 63 µm	g/100g dry wt	1.5	-	-	-	-

Analyst's Comments

Amended Report: This certificate of analysis replaces an earlier report issued on 21 Feb 2019 at 1:40 pm
Reason for amendment: The sampling dates have been amended.

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.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Dry Matter for Grainsize samples	Drying for 16 hours at 103°C, gravimetry (Free water removed before analysis).	0.10 g/100g as rcvd	1-16
3 Grain Sizes Profile			
Fraction >/= 2 mm	Wet sieving with dispersant, 2.00 mm sieve, gravimetry.	0.1 g/100g dry wt	1-16
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	1-16
Fraction < 63 µm	Wet sieving with dispersant, 63 µm sieve, gravimetry (calculation by difference).	0.1 g/100g dry wt	1-16

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

APPENDIX 5. MACROFAUNAL ABUNDANCES IN BOX CORE SAMPLES.

Main group	Taxa	EG	P5T1a	P5T1b	P5T1c	P5T2a	P5T2b	P5T2c	P6T1a	P6T1b	P6T1c	P6T2a	P6T2b	P6T2c	P7T1a	P7T1b	P7T1c	P7T2a	P7T2b	P7T2c	P8T1a	P8T1b	P8T1c	P8T2a	P8T2b	P8T2c
Infauna																										
Amphipoda	*Bellorchestia quoyana*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Diogodias littoralis*	II	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Waitangi brevirostris*	II	41	39	77	37	73	46	1	6	6	5	-	8	-	3	1	2	-	2	1	-	1	-	-	-
Amphipoda	*Waitangi chelatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bivalvia	*Paphies subtriangulata*	-	2	2	2	-	1	2	-	1	-	3	-	-	-	1	2	-	1	1	1	-	1	4	2	2
Decapoda	*Biffarius filholi*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda	*Hemigrapsus crenulatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Eurylana arcuata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Macrochiridothea uncinata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-
Isopoda	*Pseudaega melanica*	-	1	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Scyphax ornatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	Valvifera	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	2	-
Nemertea	*Nemertea* sp. 1	III	1	1	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Nemertea	*Nemertea* sp. 2	III	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Ostracoda	*Ostracoda* sp. 1	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Aglaophamus macroura*	II	-	-	-	1	2	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	3	1	-	-
Polychaeta	*Hemipodia simplex*	II	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Magelona* sp. 1	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Polychaeta	*Orbinia papillosa*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Pectinaria australis*	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Sigalion oviger*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-
Polychaeta	Spionidae	III	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	Infaunal richness per core		**4**	**4**	**4**	**4**	**3**	**3**	**2**	**4**	**2**	**3**	**1**	**1**	**1**	**3**	**2**	**1**	**2**	**3**	**3**	**2**	**5**	**3**	**2**	**1**
	Infaunal abundance per core		**45**	**43**	**81**	**40**	**76**	**49**	**2**	**10**	**7**	**9**	**1**	**8**	**1**	**5**	**3**	**2**	**2**	**4**	**3**	**2**	**8**	**6**	**4**	**2**

Epibiota

None recorded

Main group	Taxa	EG	W5T1a	W5T1b	W5T1c	W5T2a	W5T2b	W5T2c	W6T1a	W6T1b	W6T1c	W6T2a	W6T2b	W6T2c	W7T1a	W7T1b	W7T1c	W7T2a	W7T2b	W7T2c	W8T1a	W8T1b	W8T1c	W8T2a	W8T2b	W8T2c
Infauna																										
Amphipoda	*Bellorchestia quoyana*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Diogodias littoralis*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Amphipoda	*Waitangi brevirostris*	II	70	73	74	126	86	88	69	64	23	31	39	26	36	21	15	15	17	11	8	10	12	6	4	3
Amphipoda	*Waitangi chelatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	7	4	9
Bivalvia	*Paphies subtriangulata*	-	1	1	-	1	-	2	2	1	1	-	-	-	-	-	1	2	1	3	1	-	-	-	-	1
Decapoda	*Biffarius filholi*	I	-	-	-	-	-	-	-	1	2	1	-	1	-	-	-	-	-	-	-	1	1	-	-	-
Decapoda	*Hemigrapsus crenulatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Eurylana arcuata*	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Macrochiridothea uncinata*	-	-	-	-	-	-	-	-	-	-	-	-	-	8	2	11	9	15	12	1	-	-	1	1	1
Isopoda	*Pseudaega melanica*	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	5	-	-	-	-	-	-	-
Isopoda	*Scyphax ornatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	Valvifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemertea	*Nemertea* sp. 1	III	1	-	1	-	1	-	-	1	1	-	1	-	-	1	1	-	-	-	-	1	-	-	-	-
Nemertea	*Nemertea* sp. 2	III	1	2	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	1
Ostracoda	*Ostracoda* sp. 1	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Aglaophamus macroura*	II	-	-	-	-	1	1	2	1	1	2	-	2	-	-	3	3	-	1	3	-	1	-	2	2
Polychaeta	*Hemipodia simplex*	II	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-
Polychaeta	*Magelona* sp. 1	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Orbinia papillosa*	I	-	-	-	-	1	1	1	-	-	-	-	-	1	-	-	2	-	-	1	-	2	-	2	-
Polychaeta	*Pectinaria australis*	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Sigalion oviger*	II	1	-	-	1	-	-	1	-	1	1	-	1	-	-	-	2	1	1	-	-	3	1	1	1
Polychaeta	Spionidae	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Infaunal richness per core		**5**	**3**	**3**	**3**	**4**	**4**	**6**	**5**	**7**	**4**	**2**	**5**	**4**	**4**	**7**	**6**	**6**	**6**	**6**	**3**	**5**	**4**	**6**	**7**
	Infaunal abundance per core		**74**	**76**	**76**	**128**	**89**	**92**	**76**	**68**	**30**	**35**	**40**	**31**	**46**	**26**	**33**	**33**	**40**	**29**	**17**	**12**	**19**	**15**	**14**	**18**
Epibiota																										
Echinoidea	*Fellaster zelandiae*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2

Stations coded by beach (P = Paraparaumu, W = Waikanae), shore height (1 = neap high to 8 = shallow subtidal), transect (T1, T2) and box core replicate (a – c). Samples from heights 7 and 8 were collected by wading, and may underestimate true values (see methods).

Main group	Taxa	EG	P1T1a	P1T1b	P1T1c	P1T2a	P1T2b	P1T2c	P2T1a	P2T1b	P2T1c	P2T2a	P2T2b	P2T2c	P3T1a	P3T1b	P3T1c	P3T2a	P3T2b	P3T2c	P4T1a	P4T1b	P4T1c	P4T2a	P4T2b	P4T2c
Infauna																										
Amphipoda	*Bellorchestia quoyana*	II	2	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Amphipoda	*Diogodias littoralis*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Waitangi brevirostris*	II	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	1	4	1	11	20	28	27	1	26
Amphipoda	*Waitangi chelatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bivalvia	*Paphies subtriangulata*	-	12	15	24	28	15	12	1	7	-	6	10	2	-	-	-	-	-	-	-	-	1	1	1	-
Decapoda	*Biffarius filholi*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda	*Hemigrapsus crenulatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Eurylana arcuata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Macrochiridothea uncinata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Pseudaega melanica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Scyphax ornatus*	-	2	1	-	4	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	Valvifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemertea	*Nemertea* sp. 1	III	-	-	-	-	-	-	1	-	1	2	1	1	1	1	2	4	2	2	1	1	3	1	1	1
Nemertea	*Nemertea* sp. 2	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-
Ostracoda	*Ostracoda* sp. 1	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Aglaophamus macroura*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1	1	-	-	-
Polychaeta	*Hemipodia simplex*	II	10	5	5	15	17	15	1	1	4	8	4	6	2	-	2	2	1	4	-	1	-	1	-	1
Polychaeta	*Magelona* sp. 1	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Orbinia papillosa*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Pectinaria australis*	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Sigalion oviger*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Polychaeta	Spionidae	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Infaunal richness per core		**4**	**3**	**3**	**4**	**4**	**3**	**3**	**2**	**2**	**3**	**3**	**3**	**3**	**2**	**2**	**3**	**3**	**4**	**3**	**6**	**4**	**5**	**4**	**3**
	Infaunal abundance per core		**26**	**21**	**31**	**48**	**35**	**29**	**3**	**8**	**5**	**16**	**15**	**9**	**4**	**4**	**4**	**7**	**7**	**9**	**13**	**26**	**33**	**31**	**4**	**28**

Epibiota

None recorded

Main group	Taxa	EG	W1T1a	W1T1b	W1T1c	W1T2a	W1T2b	W1T2c	W2T1a	W2T1b	W2T1c	W2T2a	W2T2b	W2T2c	W3T1a	W3T1b	W3T1c	W3T2a	W3T2b	W3T2c	W4T1a	W4T1b	W4T1c	W4T2a	W4T2b	W4T2c
Infauna																										
Amphipoda	*Bellorchestia quoyana*	II	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Diogodias littoralis*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda	*Waitangi brevirostris*	II	1	-	-	-	-	-	5	13	7	6	2	-	167	11	36	81	71	61	36	70	225	173	20	7
Amphipoda	*Waitangi chelatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bivalvia	*Paphies subtriangulata*	-	19	30	24	6	4	28	-	3	-	2	1	1	4	1	1	2	-	3	1	-	-	-	-	-
Decapoda	*Biffarius filholi*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Decapoda	*Hemigrapsus crenulatus*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Eurylana arcuata*	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Macrochiridothea uncinata*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	*Pseudaega melanica*	-	-	-	-	-	-	-	3	1	-	-	-	-	2	-	6	1	-	-	-	3	4	1	-	-
Isopoda	*Scyphax ornatus*	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopoda	Valvifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemertea	*Nemertea* sp. 1	III	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	1	1	1	-	-	-	-	1
Nemertea	*Nemertea* sp. 2	III	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Ostracoda	*Ostracoda* sp. 1	I	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Aglaophamus macroura*	II	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	1	4	1	3	1	2	1
Polychaeta	*Hemipodia simplex*	II	14	9	9	10	8	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Magelona* sp. 1	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polychaeta	*Orbinia papillosa*	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Polychaeta	*Pectinaria australis*	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Polychaeta	*Sigalion oviger*	II	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	1	3	-	-	-
Polychaeta	Spionidae	III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Infaunal richness per core		**3**	**2**	**2**	**3**	**2**	**4**	**3**	**7**	**1**	**3**	**2**	**3**	**3**	**4**	**3**	**4**	**3**	**5**	**4**	**4**	**4**	**5**	**4**	**3**
	Infaunal abundance per core		**34**	**39**	**33**	**18**	**12**	**34**	**9**	**21**	**7**	**9**	**3**	**3**	**173**	**14**	**43**	**86**	**73**	**68**	**42**	**75**	**235**	**177**	**24**	**9**
Epibiota																										
Echinoidea	*Fellaster zelandiae*	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Stations coded by beach (P = Paraparaumu, W = Waikanae), shore height (1 = neap high to 8 = shallow subtidal), transect (T1, T2) and box core replicate (a – c). Samples from heights 7 and 8 were collected by wading, and may underestimate true values (see methods).

SALT ECOLOGY

www.saltecology.co.nz