Wriggle coastalmanagement

Castlepoint Beach

Fine Scale Monitoring 2013/14

Prepared for

Greater Wellington Regional Council

May 2014

Cover Photo: Castlepoint Beach looking north towards Whakataki Estuary.

Looking south-east along Castlepoint Beach towards Castlepoint township and Castle Rock.

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by

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Contents

List of Figures

List of Tables

All photos by Wriggle except where noted otherwise.

CASTLEPOINT BEACH - EXECUTIVE SUMMARY

This report summarises the results of the third year (2014) of fine scale monitoring at Castlepoint Beach, a semi-exposed, intermediate/dissipative type beach in the central section of the Wairarapa Coast. It is a key beach in the Greater Wellington Regional Council (GWRC) long-term coastal monitoring programme and uses sediment health as a primary indicator of beach condition. Beach condition is assessed through measures of: (1) beach morphometry or profile, (2) sediment grain size, and (3) the abundance and diversity of sediment dwelling animals at various tide levels on the beach. These indicators were chosen for their proven sensitivity to likely potential stressors (e.g. freshwater discharge and sediment supply alterations, sea temperature and sea level rises, increased wave climate, vehicle damage, bio-invaders, oil spills, toxic algal blooms, trampling, and erosion). Sediment oxygenation (Redox Potential Discontinuity (RPD) depth) was also measured, but as a secondary indicator (i.e. an indicator that is relatively easy to measure but with a low risk of being adversely impacted). The following section summarises results for two intertidal sites at Castlepoint Beach monitored on 23 January 2014.

FINE SCALE RESULTS

- **Beach Morphometry:** A relatively broad (40-60m) gradually sloping intertidal beach, steeper in the upper reaches and backed extensively by 20-30m wide marram-dominated dunes. The beach profiles show variable sand accretion and erosion from year to year. In 2014 there was an increase in sand on the high shore, a loss of sand on the low shore, and the presence of cusp and horn formations.
- **Sediment Type:** The beach was sand dominated (86.2%), with a very low mud content (0.9%). There was a slight increase in the proportion of gravel fractions (broken shell) at the low shore between 2009 and 2014 (from <0.1% to 16.6% - Site 4, 5 & 6 averages).
- **Sediment Oxygenation:** The Redox Potential Discontinuity (RPD) layer was relatively deep (>15cm) at all sites, indicating sediments were well oxygenated.
- **Benthic Invertebrate Condition:** The benthic community was typical of a semi-exposed beach with clean, coarse, well-oxygenated sand, a deep RPD, and low organic enrichment levels. The community present consisted of crustaceans (isopods, amphipods), polychaetes, dipterans and coleopterans, but species abundance and diversity was much lower in 2014 than in 2008 and 2009. The increase in coarse sediments on the lower part of the beach, and cusp and horn formations reflecting storm related changes in the beach, almost certainly indicate that physical disturbance is the primary cause of the reduced numbers of beach infauna present in 2014.

BEACH CONDITION AND ISSUES

Overall, the results of the third year of fine scale monitoring showed Castlepoint Beach had “very low” risk indicator ratings for sediment type and oxygenation, and supported a beach invertebrate biota typical of a semi-exposed, low organic enrichment level, beach.

The low level of human development at the site means direct human pressure is likely to be relatively minor. However, given the high likelihood of alterations to physical habitat predicted under future climate change scenarios (i.e. sea level rise, altered wave climate, storm events), and potential intensification in current land use, changes to the biotic community are expected in future. Establishing a robust baseline against which to measure such change on the Wairarapa Coast is therefore clearly important.

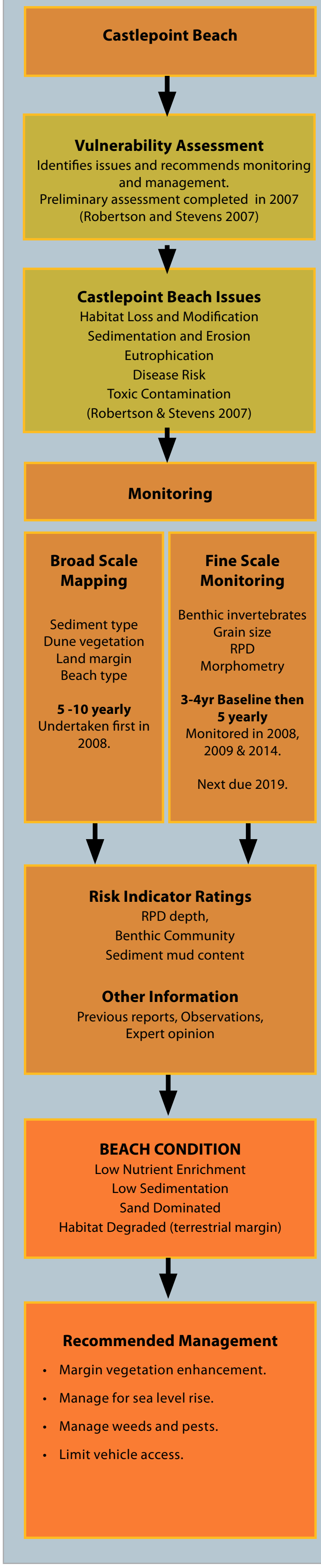
RECOMMENDED MONITORING AND MANAGEMENT

It is recommended that a new fine scale monitoring site be established in the less exposed region of the beach toward Castlepoint township, and a 3-4 year annual fine scale baseline of beach condition be established against which future change can be measured. After the baseline is completed, monitoring should be reduced to five yearly intervals or as deemed necessary based on beach risk indicator ratings. Given the current very low risk ratings, monitoring at a new site need not be undertaken immediately.

To protect the recognised high value of beaches on the Wairarapa Coast, it is important to manage beach habitat to maintain habitat diversity and a healthy beach ecology. To achieve this, it is recommended that GWRC:

1. Monitor catchment landuses likely to impact on key stressors, particularly sediment, nutrient and pathogen catchment load increases related to climate change, as well as freshwater flow diversions, and vehicle use.
2. Wherever possible, encourage and support territorial authorities to maintain and enhance the natural vegetation zone present above high water to provide a buffer between the beach and adjacent land development, and to incorporate predicted sea level rise into coastal planning and hazard assessments.

1. INTRODUCTION



Developing an understanding of the likely risks to coastal habitats is critical to the management of biological resources. The "Wairarapa Coastal Habitats - Mapping, Risk Assessment and Monitoring" report (Robertson and Stevens 2007) identified a moderate risk to soft sediment beach shore ecology on the Wairarapa Coast through predicted accelerated sea level rise, sea temperature change, erosion, and habitat loss. To address this risk, and to provide information on the Wairarapa Coast beach ecology, long term monitoring of Castlepoint Beach (a representative intermediate/dissipative type beach ecosystem) was initiated in January 2008 by GWRC. Wriggle Coastal Management was contracted to undertake the work with the monitoring site established ~2km south-west of Whakataki Estuary (Figure 1, Appendix 2), and monitored in 2008, 2009, and most recently in 2014.

Dissipative type beaches are relatively flat, and fronted by a moderately wide surf zone in which waves dissipate much of their energy. They have been formed under conditions of moderate tidal range, high wave energy and fine sand. Their sediments are well sorted fine to medium sands, and they generally have weak rip currents with undertows. The tidal flat is at the extreme end of dissipative beaches. Their ecological characteristics, when compared with other beach types, include the following:

- Generally intense interactions within and between species.
- Relatively high primary production, diversity and biomass of macrofauna.
- Exporters of organic matter.
- More highly regulated by biological interactions.

The relationships between stressors (both natural and human influenced), and changes to sandy beach communities, are complex and can be highly variable. However, there are clear links between the degradation of beach habitat through the combined effects of erosion, harvesting, vehicle damage, trampling, coastal development, introduced species, nutrient enrichment, sediment mud content, pathogen, and toxin inputs, as well as broader stressors such as climate change related effects of alterations to sea temperature, sea level, wave exposure, and storm frequency and intensity (e.g. McLachlan and Brown 2006) (Table 1).

Castlepoint Beach, situated between Whakataki River Estuary and Castle Rock, is ~5km long, and part of an extensive stretch of sandy beaches interspersed with rocky reefs and headlands that are present along much of the Wairarapa coast. Castlepoint Beach itself is a semi-exposed, moderate wave energy, gently sloping beach dominated by sand, with occasional rocky outcrops in the low tide and shallow subtidal zones. Castlepoint township is situated at the southern end of the beach where seawalls border the beach, and the terrestrial margin consists primarily of baches that are most commonly occupied during holiday periods. Land cover immediately inland of the township is primarily grassland used for sheep and beef grazing, with some exotic forestry. Further north toward Whakataki Estuary, the beach becomes more exposed, steeper, and high marram covered sand dunes border the beach. The intertidal sand flats are extensive (~40-80m wide) and, because of the exposed wave climate, beach sediments are mobile and subject to regular of erosion and accretion. Where natural sand movement is interrupted (e.g. over-stabilisation of dunes or construction of seawalls), erosion problems are likely to occur.

Human use of the beach and associated rocky areas at Castlepoint Beach is low-moderate in a national context, but is high in a local Wairarapa context. It is used for walking, quad-biking, surfing, diving, scientific interest and inshore fishing. Public access is generally good. Commercial fishing boats are launched off the beach at the south end of the beach (i.e. through the Gap).

1. Introduction (Continued)

An analysis of the major issues affecting NZ beaches (see Table 1), has identified the following as key monitoring indicators for assessing beach condition:

1. Broad scale habitat mapping
2. Sediment grain size
3. Beach morphometry
4. Beach macrofauna
5. Sediment oxygenation

Currently, GWRC undertake broad scale habitat mapping for all of their priority beaches every 10 years. These broad scale results have been used to subsequently select representative beaches on which to establish baseline measures of beach morphometry, grain size, macrofauna and sediment oxygenation. It is intended that the representative beaches be monitored at five yearly intervals to provide detailed information on these indicators of beach condition that are applicable to the wider coastline.

These measures will help determine the extent to which the Wellington coastline is affected, both in the short and long term, by the major environmental issues affecting NZ beaches. These include; habitat loss or modification, sediment, disease risk (addressed through GWRC's recreational water quality programme), eutrophication and toxic contamination (Table 1). The main stressors within these categories are climate change and sea level rise, over-collection of living resources, introduction of invasive species, and toxic contamination.

The present intertidal fine scale monitoring, undertaken in January 2014, follows 2 years of baseline monitoring undertaken in January 2008 and 2009 (see Robertson and Stevens 2008, 2009). It focuses on the key issues/stressors and indicators outlined in Table 1. Additional background information and rationale for indicator use is presented in Appendix 3, and the beach condition risk indicator ratings used are summarised in Table 2.

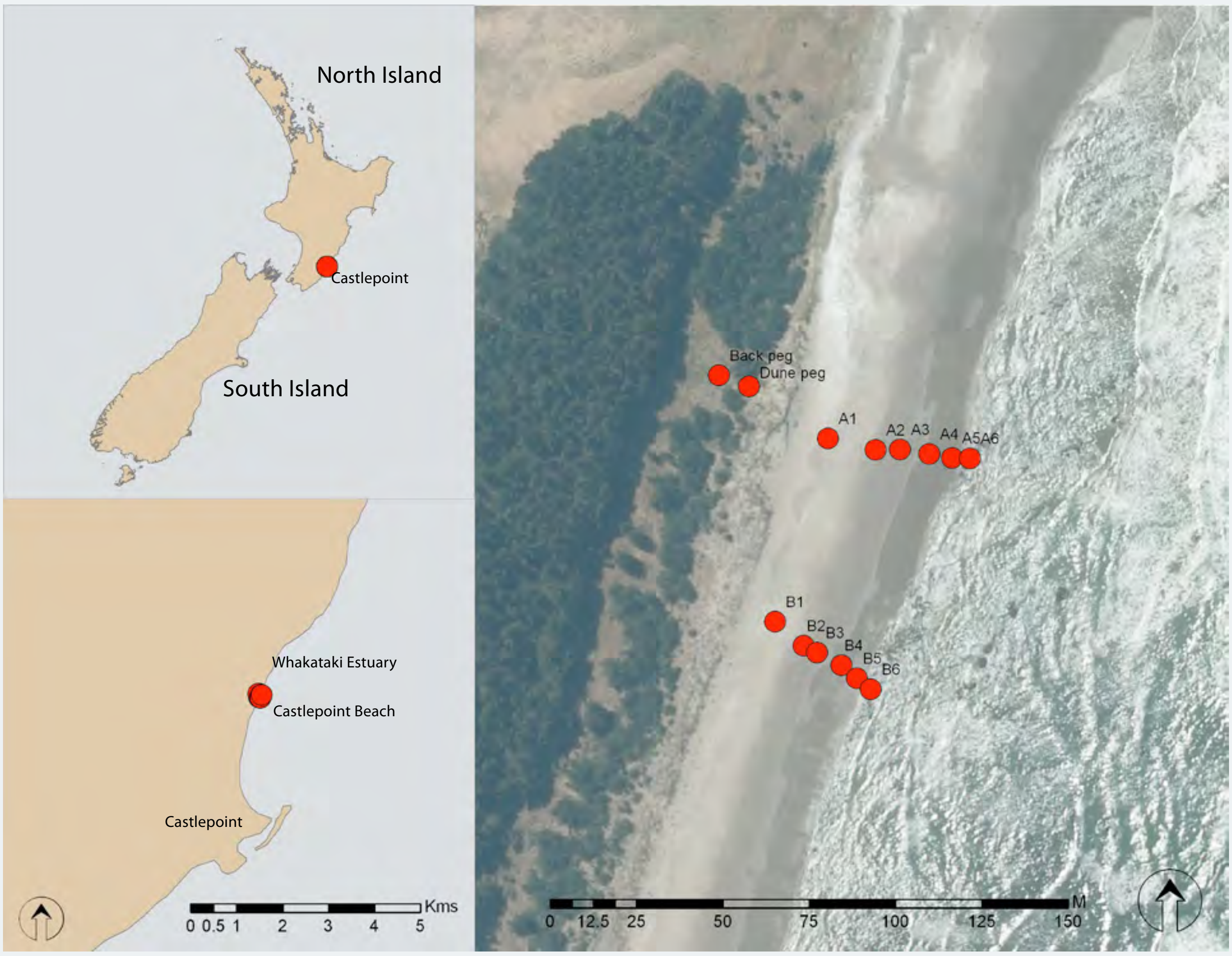


Figure 1. Location of fine scale monitoring sites at Castlepoint Beach.

Table 1. Summary of the major environmental issues affecting New Zealand beaches and dunes.

1. Habitat Loss or Modification: The key human-influenced stressors causing habitat loss or modification are:

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

Recommended Key Indicators:

Issue	Recommended Indicators
Erosion Temperature, Acidity, Sea Level Rise	Beach morphometry (measurement of beach profiles) Beach macrofauna Sea temperature and pH (monitored nationally)

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).

Issue	Recommended Indicators
Erosion Shoreline armouring	Beach morphometry GIS mapping of coastal structures

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

Issue	Recommended Indicators
Direct removal of living resources (e.g. shellfish)	Beach macrofauna Regulatory compliance (monitored through national agencies)

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

Issue	Recommended Indicators
Disturbance of beach and dune biota	Beach macrofauna Broad scale habitat mapping e.g. dune extent/composition (undertaken 10 yearly) Government or interest group wildlife surveys (e.g. DOC, OSNZ) Regulatory approvals and compliance (both regional and national agencies)

Table 1. Summary of major environmental issues affecting New Zealand beaches and dunes (continued).

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

Issue	Recommended Indicators
Coastal Development	Broad scale habitat mapping (undertaken 10 yearly) Coastal development and hazard planning (undertaken regionally and nationally)

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

Issue	Recommended Indicator
Stock Grazing	Broad scale habitat mapping of terrestrial margin landuse (undertaken 10 yearly)

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

In dune areas, introduced species are far more prevalent. Marram grass, initially introduced to NZ to limit coastal erosion and stabilise sand movement, has subsequently been found to have many drawbacks. Its ability to thrive in coastal areas results in marram dunes being generally taller, steeper, and larger than dunes dominated by native sand binding species (i.e. spinifex or pingao). Consequently, overstabilisation reduces the extent of active dunes able to release sand to the foreshore (helping buffer against storm erosion), while steep and reqular 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.

Issue	Recommended Indicators
Introduction of Invasive Species	Beach macrofauna Broad scale habitat mapping (undertaken 10 yearly) Port/harbour/terrestrial biosecurity surveys (undertaken regionally and nationally)

2. Sediment

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

Table 1. Summary of major environmental issues affecting New Zealand beaches and dunes (continued).

Issue	Recommended Indicators
Altered Sediment Loads	Catchment land use mapping (undertaken regionally and nationally) Rainfall/flooding frequency and intensity (undertaken regionally and nationally) Sediment grain size Beach macrofauna Beach morphometry

3. Disease Risk

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

Issue	Recommended Indicator
Disease Risk	Bathing beach and shellfish disease risk monitoring (Council or industry driven)

4. Eutrophication

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

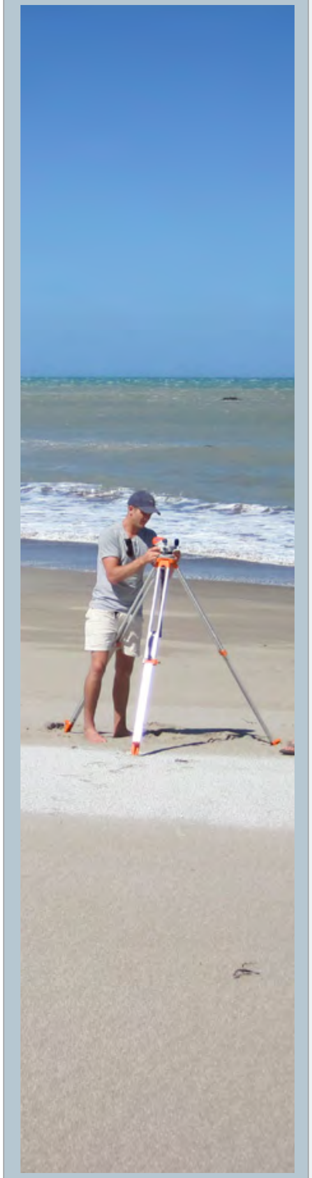
Issue	Recommended Indicators
Eutrophication	Broad scale habitat mapping (undertaken 10 yearly) Nuisance complaints (Council or public health agencies) Sediment oxygenation Sediment nutrients (only if elevated nutrient levels suspected) Beach macrofauna

5. Toxic Contamination

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

Issue	Recommended Indicator
Toxicity	Nuisance complaints (Council or public health agencies) Sediment contaminants (only if potential toxicity suspected) Beach macrofauna

2. BEACH RISK INDICATOR RATINGS



The beach monitoring approach used by Wriggle has been established to provide a defensible, cost-effective way to help quickly identify the likely presence of the predominant issues affecting NZ beaches (i.e. eutrophication, sedimentation, disease risk, toxicity and habitat change; Table 1), and to assess changes in the long term condition of beach systems. The design is based on the use of primary indicators that have a documented strong relationship with water or sediment quality.
In order to facilitate this process, "risk indicator ratings" have been proposed that assign a relative level of risk of adversely affecting beach conditions (e.g. very low, low, moderate, high, very high) to each indicator (see Table 2). Each risk indicator rating is designed to be used in combination with relevant information and other risk indicator ratings, and under expert guidance, to assess overall beach condition in relation to key issues, and make monitoring and management recommendations.
When interpreting risk indicator results we emphasise:

- The importance of taking into account other relevant information and/or indicator results before making management decisions regarding the presence or significance of any beach issue.
- That rating and ranking systems can easily mask or oversimplify results. For instance, large changes can occur within a risk category, but small changes near the edge of one risk category may shift the rating to the next risk level.
- Most issues will have a mix of primary and secondary ratings, primary ratings being given more weight in assessing the significance of indicator results. It is noted than many secondary beach indicators will be monitored under other programmes and can be used if primary indicators indicate a significant risk exists, or if risk profiles have changed over time.
- Ratings for most indicators have not been established using statistical measures, primarily because of the extensive additional work and cost this requires. In the absence of funding, professional judgement, based on our experience from monitoring numerous NZ beaches, has been used in making initial interpretations. Our hope is that where a high level of risk is identified, the following steps are taken:
    1. Statistical measures be used to refine indicators and guide monitoring and management for priority issues.
    2. Issues identified as having a high likelihood of causing a significant change in ecological condition (either positive or negative), trigger intensive, targeted investigations to appropriately characterise the extent of the issue.
    3. The outputs stimulate discussion regarding what an acceptable level of risk is, and how it should best be managed.

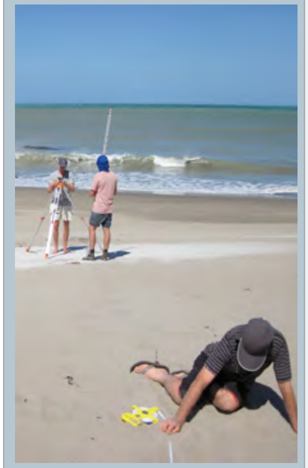
The indicators and risk ratings used for the Castlepoint Beach monitoring programme are summarised in the Table 2 and detailed background notes explaining the use and justifications for each indicator are presented in Appendix 3 and 4.

Table 2. Summary of beach condition risk indicator ratings used in the present report.

INDICATOR	RISK RATING				
	Very Low	Low	Moderate	High	Very High
Apparent Redox Potential Discontinuity (aRPD, cm)	>10cm depth below surface	3-10cm depth below sediment surface	1-<3cm depth below sediment surface	0-<1cm depth below sediment surface	Anoxic conditions at surface
Sediment Mud Content (% mud)	<2%	2-5%	5-15%	15-25%	>25%
Macroinvertebrate Enrichment Index (AMBI)	0-1.2 Intolerant of enriched conditions	1.2-3.3 Tolerant of slight enrichment	3.3-5.0 Tolerant of moderate enrichment	5.0-6.0 Tolerant of high enrichment	>6.0 Azoic (devoid of invertebrate life)

3. METHODS

FINE SCALE MONITORING



The beach monitoring approach is based on that used by Aerts et al. (2004) in a study of macrofaunal community structure and zonation of an Ecuadorian sandy beach. It involves measuring both the abundance and diversity of animals in cores collected from the beach along transects extending from the supratidal (upper beach) to low water zones, and measuring the cross-shore profile, as follows:

- Two transects are established ~50m apart in a representative part of the beach.
- On each transect, a sampling station is located on the dry beach immediately above the high tide swash zone and is sampled at high tide (see below for sampling details).
- Each hour after high tide for 5 hours, a new station is established in the swash zone on each transect, and marked with a cane wand. This hourly sampling is used to distribute stations evenly across the tidal range by following the receding water down the beach.
- At each station the following samples and field measures are taken:

Infauna (animals within sediments)

- Three replicate sediment cores (each ~2m apart) are collected using a 330mm square (area = $0.1089m^2$) stainless steel box corer.
- The box core is manually driven 150mm into the sediments, the core content removed with a spade, emptied into a 1mm nylon mesh bag, and the contents sieved in nearby seawater. Material retained by the 1mm mesh bag is then placed in trays and sorted with any infauna present collected. Infauna present are placed into a labelled plastic vials and preserved in a 70% isopropyl alcohol - seawater solution.

Physical and chemical measures

- The cross-shore profile of the beach is measured using a total station theodolite surveying technique (tied back to a fixed point for repeat surveys). Where possible this extends from the back of the dune system to the low tide mark. These measures enable the relative elevations of the sample stations to be derived, and changes in beach profile to be measured over time.
- Distances between all stations, and the GPS position of each station, are logged.
- Photographs are taken to record the general site appearance, and significant sites features and dominant dune plants recorded.
- At each station along each transect:
  - The presence of any macroalgae or microalgal growth is noted.
  - The average apparent RPD (aRPD; see Appendix 4) depth is recorded.
  - A composite sample of sediment (approx. 250g total) is collected from the top, middle and bottom of each replicate infauna core for analysis of particle grain size distribution (% mud, sand, gravel) - details in Appendix 1.
- Laboratory samples are tracked using standard Chain of Custody forms and results checked and transferred electronically to avoid transcription errors.
- Infauna samples are sent to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

Because these methods are designed for rapid, cost effective sampling, fauna situated in supra-tidal and sub-tidal areas are expected to be under-represented. Further, the dynamic nature of the beach means there will be both short and long term changes in the biological community. To minimise seasonal and spatial variation, monitoring is undertaken at a fixed time each year (e.g. January-February) and from cores positioned in habitat representative of the wider coastline. To account for year to year changes, a 3-4 year baseline of annual monitoring is recommended, followed by a review of monitoring, and a likely recommended shift to 5 yearly monitoring.

The current sampling was undertaken by four scientists, during relatively calm sea conditions, on 23 January 2014 within a wider programme of coastal monitoring being undertaken in the region.

4. RESULTS AND DISCUSSION

The results of the fine scale monitoring of two transects at Castlepoint Beach on 23 January 2014 are presented below. Detailed results are presented in Appendix 2 and 5.

1. MORPHOMETRY

The morphometry of Castlepoint Beach was measured once at Transect A as it was representative of the two transects, with 2009 and 2014 results presented in Figure 2. The beach was backed by an extensive, undulating 4m high x 20-30m wide dune system dominated by marram grass (see photo below), with scattered patches of tree lupin, pingao and spinifex also present (see lower left photo below). Landuse directly behind the dune system was dominated by established *Pinus radiata* and grassland (sheep and beef grazing). The intertidal zone was 40-60m wide, steepest in the upper half and extending to a gradual slope in the lower section of the beach.

Compared to 2009, a large build up of sand was evident on the beach in 2014, most pronounced on the upper shore and reducing in extent towards low tide. At the same time the low tide flats were ~10m closer inshore than in 2009, indicating the reworking of low tide sands up the beach. In addition, regular cusp and horn formations (finer and coarser sediments respectively) were present along the beach in 2014 (see lower right photo below). These cusp and horn forms, not evident in 2008 or 2009, are a common feature on steep reflective and intermediate beaches and primarily develop under mildly accretionary conditions, infilling to form a featureless berm when accretion persists (Almar et al. 2008), or when wave energy alters the beach dynamics.

The results described above are expected as variability in sand erosion and deposition at this scale is a common and natural feature on exposed sandy beaches, and can occur very rapidly, particularly during storm events. The beach infauna present will reflect these changes though their ability to tolerate both physical disturbance, and particularly changes in grain size. It is also noted that the response of some infauna to increased disturbance during storm events will be to temporally burrow deeper into the sediments, meaning that they may at times be undersampled using the methods described in Section 3.

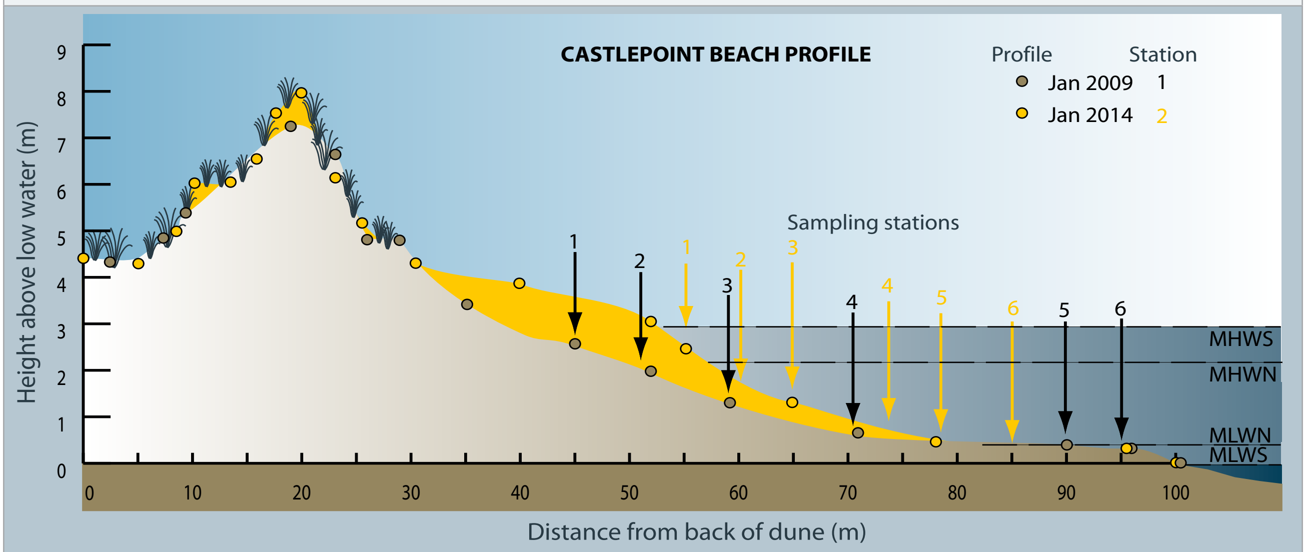


Figure 2. Cross-section of transect A at Castlepoint Beach, 2014.

Dune and terrestrial margin at Transect B (Castle Rock in the background).

Regular cusp and horn formations along the upper shore.

4. Results and Discussion (Continued)

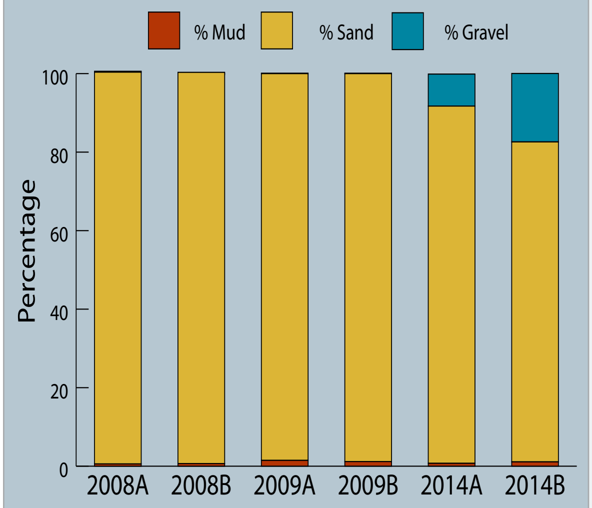


Figure 3. Mean sediment grain size (%, n=6), Castlepoint Beach, 2008, 2009 and 2014.

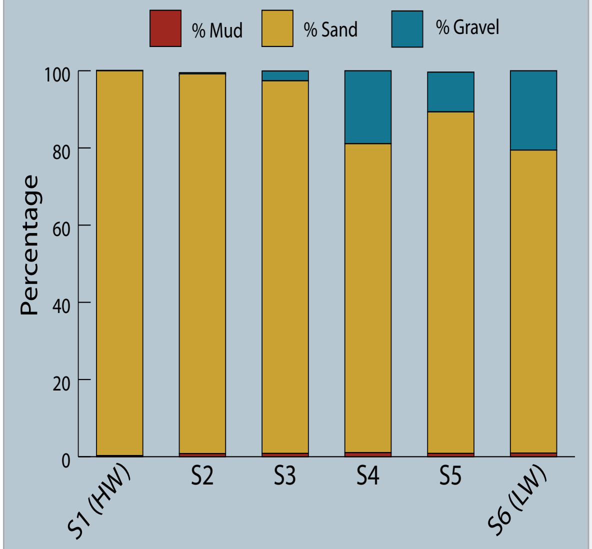


Figure 4. Mean sediment grain size (%, n=2) at each shore height, Castlepoint Beach, 2014.

2. SEDIMENT GRAIN SIZE

Sediment grain size is a major determinant of biological habitat. For example, a shift from fine to coarse sands can deter some shellfish from living there (e.g. toheroa and tuatua), while many species are displaced by high mud contents.

The major factors influencing the grain size distribution of beach sediments are: i. reduced sediment supply to beaches (often leading to erosion, coarser sediments, and steeper beaches in exposed situations), or ii. an increase in fine sediments as a result of increased suspended sediment runoff from developed catchments.

The Wairarapa coastal environment is not expected to be at risk of reduced sediment supply because of its semi-exposed nature, and its history of adequate sediment supplies from the surrounding catchment, and because climate change is likely to increase the mean supply of sediments if there is increased storm intensity or frequency.

The 2008, 2009 and 2014 results show that Castlepoint Beach is dominated by sand, with very little mud (<2% mud), a risk indicator rating of "very low". However, some changes are evident in the data. While samples were pooled to present average grain size per transect (Figure 3) after a one-way ANOVA test detected no statistically significant differences in % mud or sand within, or between, each transect in relation to shore height (i.e. all $P>0.01$), the proportion of the gravel fraction (predominantly broken shell) at both transect A and B significantly increased ($P<0.01$) from 2008 and 2009 compared to 2014 (Figure 3).

Figure 4 indicates the gravel fraction was predominantly found at low shore sites in 2014. A Tukey's HSD post-hoc multiple range test revealed gravel proportions at S4, S5 and S6 were significantly greater than those found at S1, S2 and S3 (i.e. $P<0.01$). This is typical of exposed sandy beaches where variable wind/wave action results in continual (natural) vertical cycling of fine sand across the shore profile.

3. REDOX POTENTIAL DISCONTINUITY (RPD)

On exposed beaches like Castlepoint, there are no major nutrient sources and the sands are well-flushed. Organic matter and nutrients within the sediments are likely to be very low and consequently the usual symptoms of beach eutrophication, e.g. macroalgal growths (e.g. sea lettuce) and microalgal blooms, sediment anoxia, elevated muddiness, and an enrichment tolerant benthic community, are very unlikely. In such a low risk situation, the number of primary fine scale indicators for eutrophication can therefore be limited to the easily measured aRPD depth. The depth of the aRPD layer provides a measure of whether nutrient enrichment, for example from sewage leachate or groundwater seepage to beach sediments from adjacent terrestrial areas, exceeds the level causing nuisance anoxic conditions in the surface sediments. Knowing if surface sediments are moving towards anoxia is important as anoxic sediments are toxic and support very little aquatic life.

The 2014 results showed that the aRPD depth at Castlepoint Beach was >15cm at all sites and therefore the sediments are likely to be well oxygenated. Such aRPD values fit the "very low" risk indicator rating and suggest that the benthic invertebrate community (investigated below) is likely to be exposed to healthy beach sediments, and will therefore not be expressing symptoms of eutrophication.

4. Results and Discussion (Continued)

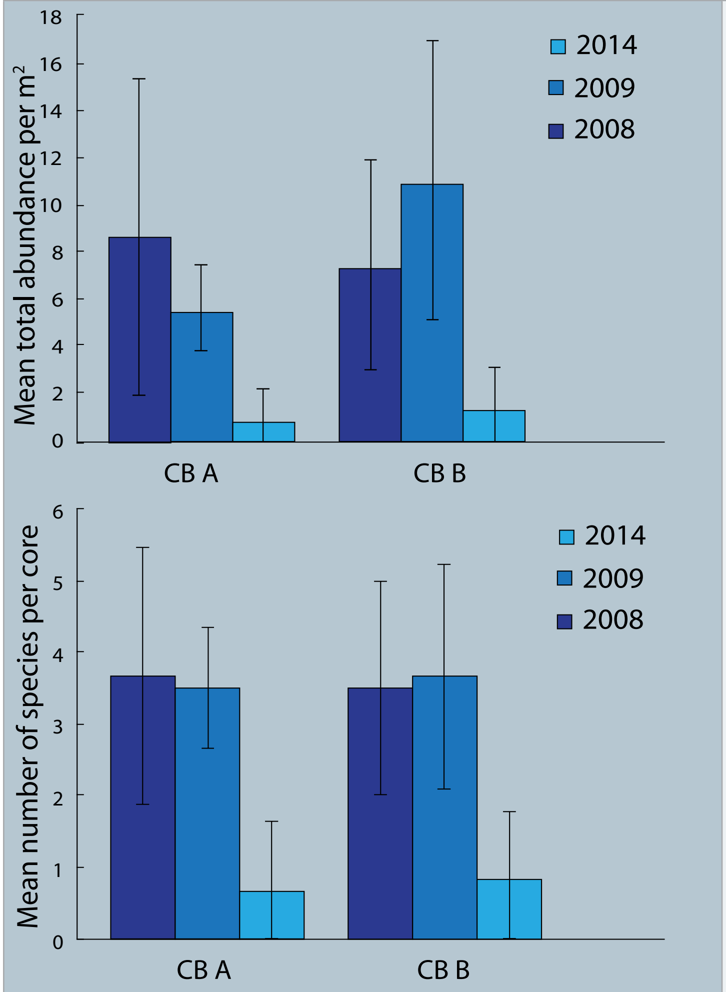


Figure 5. Mean macrofauna abundance (±SE, n=18), and number of species (±SE, n=18), Castlepoint Beach 2008, 2009 and 2014.

Table 3. Mean macrofauna abundance and number of species/core, Castlepoint Beach 2008, 2009 and 2014.

Site	Transect	Reps	Mean Abundance/ m^2	Mean Number of Species/Core
2008	A	18	8.5	3.7
	B	18	7.4	3.5
2009	A	18	5.5	3.5
	B	18	10.9	3.7
2014	A	18	0.8	0.7
	B	18	1.3	0.8

4. SEDIMENT BIOTA

The benthic invertebrate community at Castlepoint Beach was characterised using the standard indices of species richness and abundance. Low species numbers in 2014 preclude the use of community-level statistical analyses (e.g. non-metric multidimensional scaling (NMDS), and the AMBI organic enrichment risk rating (see Appendix 3) used in 2008 and 2009.

The 2014 results showed mean total abundance was 0.8/m^2 at Transect A and 1.3/m^2 at Transect B. These values were much lower than the ranges reported in 2008 (8.5-7.4/m^2) and 2009 (5.5-10.9/m^2) (Figure 5, Table 3), with very few organisms found in surface sediments on the low shore (Figures 6, 7 and 8).

A detailed breakdown of the species present over the beach profile at Transects A and B is shown in Figure 6. Despite the low recorded abundance and diversity in 2014, the dominant organisms present were amphipods and isopods, polycheates, and coleopterans as found in previous years.

The similar species composition, but much lower numbers in 2014, indicates a large and consistent reduction in most beach organisms, but no clear shift in community composition. That is, as in 2008 and 2009, the species present in 2014 prefer clean, coarse, well-oxygenated sand, a deep RPD, and low organic enrichment levels and indicate a "normal" exposed beach community (see Figures 7 and 8).

Combined with an increase in coarse sediments on the lower part of the beach, and cusp and horn formations reflecting storm related changes in the beach, these results almost certainly indicate that physical disturbance is the primary cause of the reduced numbers of beach infauna identified in 2014.

This is further supported by the majority of taxa sampled in 2014 being mobile, scavenging organisms found primarily in the high shore, where wind/wave action is less pronounced and grain size composition remained unchanged. On the lower shore, only the

4. Results and Discussion (Continued)

muscular and mobile predatory polychaeate worm *Hemipodus simplex,* and the scavenging isopod *Pseudaega tertia,* were found. Because continual vertical movement of sands means habitat for sand-preferring macroinvertebrate taxa will be intermittently reduced (Defeo & Mclachlan 2005, Forgie et al. 2013), the variance in the results between 2008, 2009, and 2014, is expected, and in this case, attributed to natural processes.

The three years of monitoring has also highlighted that the site initially selected is more physically exposed than first envisaged and, as a consequence, is prone to frequent storm disturbance and thus the community present expresses large natural short-term variation.

While increased storm frequency is predicted under most climate change models, the high physical disturbance at the current site reduces its effectiveness as an indicator of other key stressors at both local scales (e.g. beach armouring, vehicle use, trampling, harvesting, contaminants), and global scales (e.g. ocean acidification). It is therefore recommended that a second site be established in a less exposed area of the beach (i.e. near Castlepoint township) for sampling in subsequent years. This will build off the established baseline, but ensure that adequate macrofaunal data is captured for community-level statistical analyses so that the effects of major issues facing beaches (identified in Table 1) can be more reliably measured.

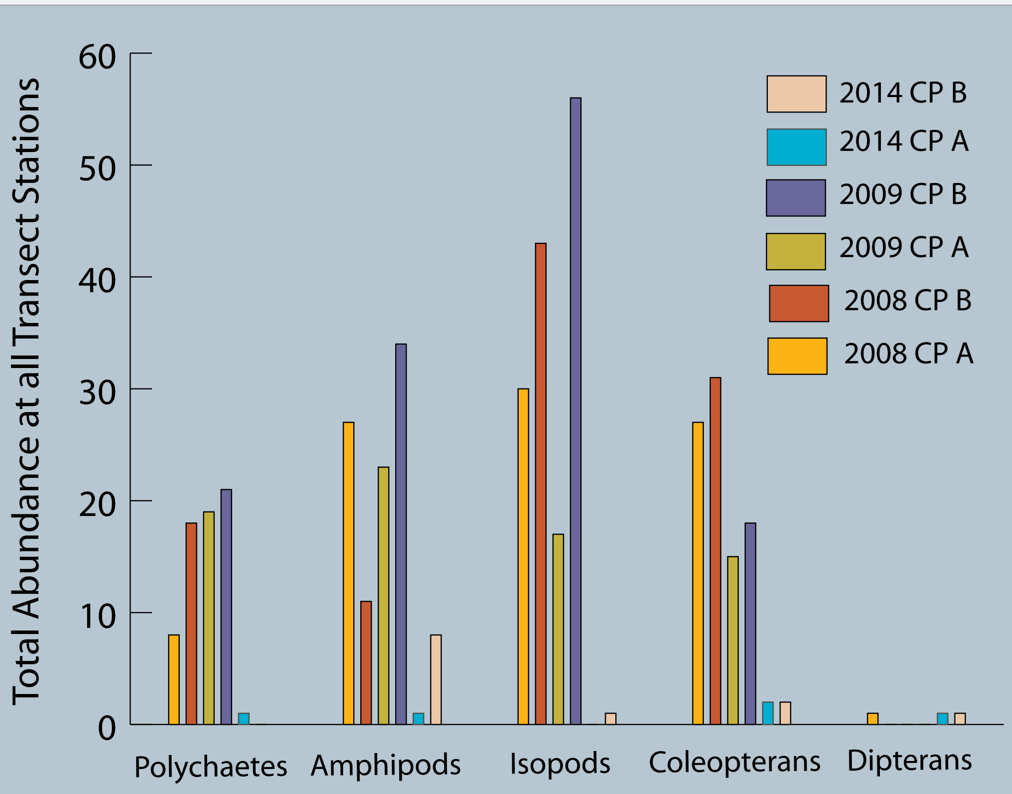


Figure 6. Total abundance of macrofauna groups (summed by transect), Castlepoint Beach, 2008, 2009, 2014.

Sorting macrofauna from the sand and shell fractions retained by the 1mm mesh sieves.

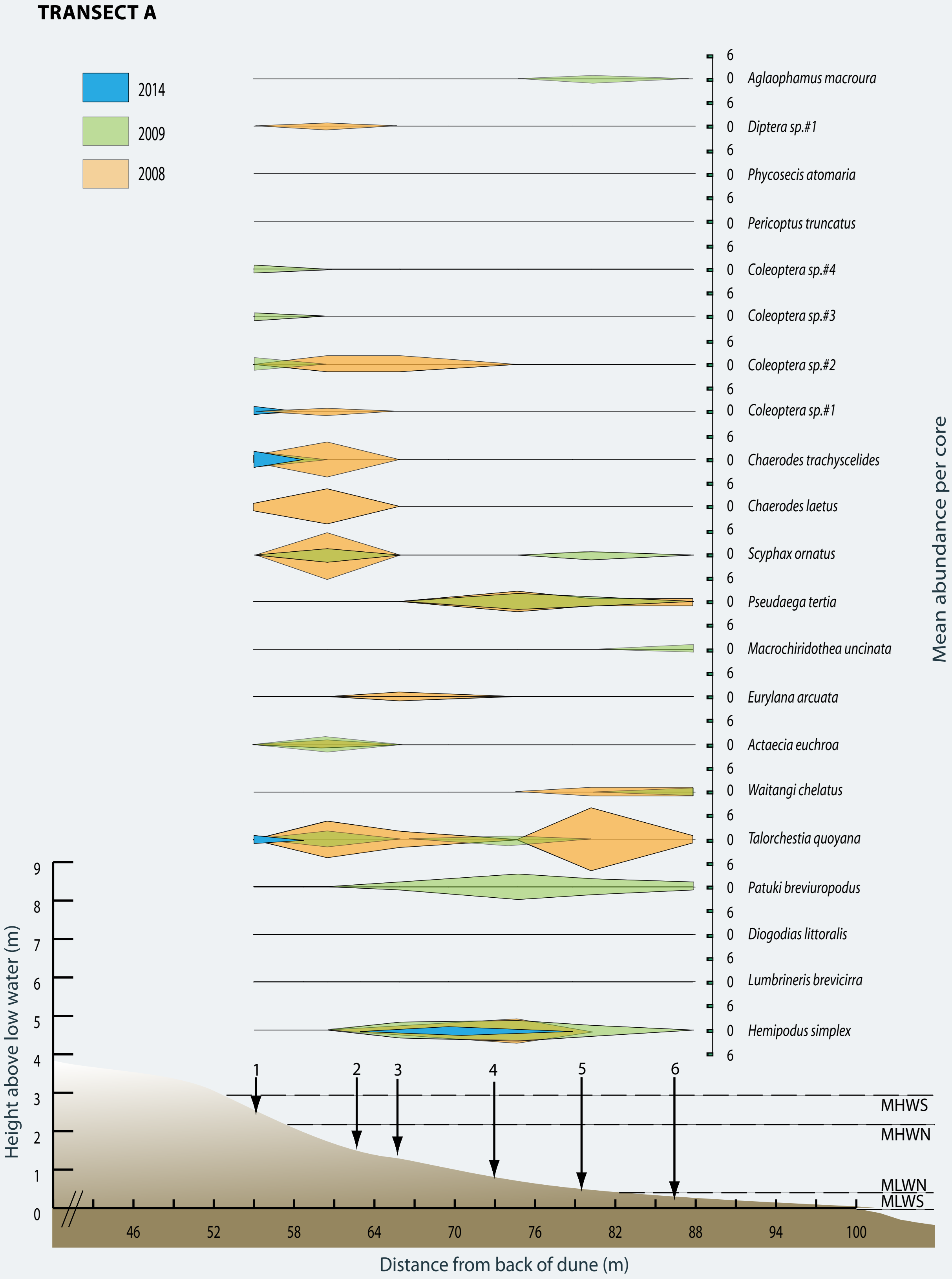


Figure 7. Kite diagram showing macrofauna distribution across Transect A, Castlepoint Beach, 2008, 2009 and 2014.

4. Results and Discussion (Continued)

TRANSECT B

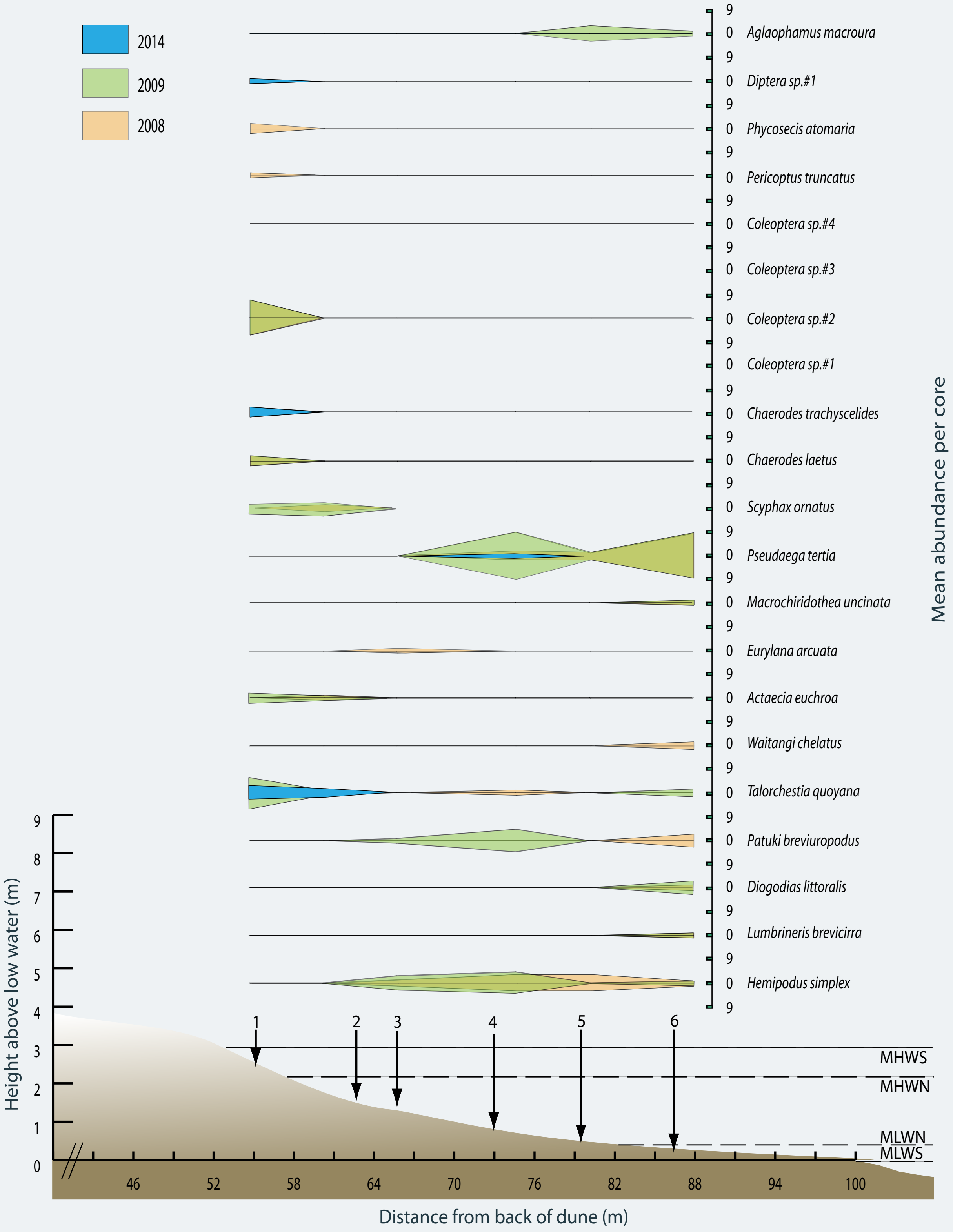


Figure 8. Kite diagram showing macrofauna distribution across Transect B, Castlepoint Beach, 2008, 2009 and 2014.

5. SUMMARY AND CONCLUSIONS

The results of the third year of fine scale monitoring at Castlepoint Beach, a semi-exposed, intermediate/dissipative type beach in the central section of the Wairarapa Coast, indicated the following;

- **Beach Morphometry:** A relatively broad (40-60m) gradually sloping intertidal beach, steeper in the upper reaches and backed extensively by 20-30m wide marram-dominated dunes. The beach profiles show variable sand accretion and erosion from year to year. In 2014 there was an increase in sand on the high shore, a loss of sand on the low shore, and the presence of cusp and horn formations.
- **Sediment Type:** The beach was sand dominated (86.2%), with a very low mud content (0.9%). There was a slight increase in the proportion of gravel fractions (broken shell) at the low shore between 2009 and 2014 (i.e. from <0.1% to 16.6% - Site 4, 5 & 6 averages).
- **Sediment Oxygenation:** The Redox Potential Discontinuity (RPD) layer was relatively deep (>15cm) at all sites, indicating sediments were well oxygenated.
- **Benthic Invertebrate Condition:** The benthic community was typical of a semi-exposed beach with clean, coarse, well-oxygenated sand, a deep RPD, and low organic enrichment levels. The community present consisted of crustaceans (isopods, amphipods), polychaetes, dipterans and coleopterans, but species abundance and diversity was much lower in 2014 than in 2008 and 2009. The increase in coarse sediments on the lower part of the beach, and cusp and horn formations reflecting storm related changes in the beach, almost certainly indicate that physical disturbance is the primary cause of the reduced numbers of beach infauna present in 2014.

Overall, the results of the third year of fine scale monitoring showed Castlepoint Beach had “very low” risk indicator ratings for sediment type and oxygenation, and supported a beach invertebrate biota typical of a semi-exposed, low organic enrichment level, beach.

The low level of human development at the site means direct human pressure is likely to be relatively minor. However, given the high likelihood of alterations to physical habitat predicted under future climate change scenarios (i.e. sea level rise, altered wave climate, storm events), and potential intensification in current land use, changes to the biotic community are expected in future. Establishing a robust baseline against which to measure such change on the Wairarapa Coast is therefore clearly important.

6. MONITORING

The Wairarapa Coast has been identified by GWRC as a priority for monitoring, and is a key part of GWRC’s coastal monitoring programme being undertaken in a staged manner throughout the Greater Wellington region. It is recommended that monitoring continue as outlined below:

- **Fine Scale Monitoring**. Establish a new fine scale monitoring site in the less exposed region of the beach toward Castlepoint township. At this new site, establish a 3-4 year annual fine scale baseline of beach condition against which future change can be measured. After the baseline is completed, monitoring should be reduced to five yearly intervals or as deemed necessary based on beach risk indicator ratings. Given the current very low risk ratings, monitoring at a new site need not be undertaken immediately.

7. MANAGEMENT

To protect the recognised high value of beaches on the Wairarapa Coast, it is important to manage beach habitat to maintain habitat diversity and a healthy beach ecology. To achieve this, it is recommended that GWRC:

1. Monitor catchment landuses likely to impact on key stressors, particularly sediment, nutrient and pathogen catchment load increases related to climate change, as well as freshwater flow diversions, and vehicle use.
2. Wherever possible, encourage and support territorial authorities to maintain and enhance the natural vegetation zone present above high water to provide a buffer between the beach and adjacent land development, and to incorporate predicted sea level rise into coastal planning and hazard assessments.

8. ACKNOWLEDGEMENTS

This survey and report has been undertaken with the support and feedback from Dr Megan Oliver (Environmental Scientist, Greater Wellington Regional Council). Thanks to Greg Larkin for assistance with fieldwork.

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Analytical Laboratory	Method	Detection Limit
Infauna Sorting and Identification	Gary Stephenson*	Coastal Marine Ecology Consultants	N/A
Grain Size (%mud, sand, gravel)	R.J Hill Laboratories	Wet sieving, gravimetric (calculation by difference)	0.1 g/100g dry wgt
Redox Potential Discontinuity (RPD)	-	Visual assessment (refer to Appendix 4)	-
Salinity	-	Handheld YSI meter (YSI Professional Plus)	-

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

APPENDIX 2. 2014 DETAILED RESULTS

Station Locations

Castlepoint Beach A

Station	Back Peg	A1 (high shore)	A2	A3	A4	A5	A6 (low shore)
NZTM East NZGD2000	1871596	1871628	1871642	1871649	1871658	1871664	1871669
NZTM North NZGD2000	5469801	5469783	5469780	5469780	5469779	5469777	5469777

Castlepoint Beach B

Station	Back Peg	B1 (high shore)	B2	B3	B4	B5	B6 (low shore)
NZTM East NZGD2000	1871596	1871614	1871621	1871625	1871632	1871637	1871641
NZTM North NZGD2000	5469801	5469730	5469723	5469721	5469717	5469714	5469710

Physical and chemical results for Castlepoint Beach, 23 January 2014.

Transect	Station	RPD	Salinity	Mud	Sand	Gravel
		cm	ppt		%	
CP A	1	>15	33	0.3	99.7	<0.1
	2	>15	33	0.8	98.7	0.5
	3	>15	33	0.8	98.1	1.1
	4	>15	33	0.7	81.7	17.6
	5	>15	33	0.8	87.1	11.5
	6	>15	33	1	80.9	18.1
CP B	1	>15	33	0.3	99.7	<0.1
	2	>15	33	0.8	98.1	1.2
	3	>15	33	0.9	95	4
	4	>15	33	1.4	78.4	20.2
	5	>15	33	0.9	89.9	9.1
	6	>15	33	0.9	76.1	23

APPENDIX 2. 2014 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.1089m² core) - Castlepoint Beach Transects A and B (23 January 2014)

(Note: NA = Not Assigned)

Taxa	Species	AMBI	A1a	A1b	A1c	A2a	A2b	A2c	A3a	A3b	A3c	A4a	A4b	A4c	A5a	A5b	A5c	A6a	A6b	A6c
POLYCHAETA	*Hemipodus simplex*	I										1								
CRUSTACEA AMPHIPODA	*Talorchestia quoyana*	III			1															
	Pseudaega tertia	I																		
INSECTA DIPTERA	*Diptera sp. #1*	II		2																
	Diptera sp. #2	II		1																
INSECTA COLEOPTERA	*Chaerodes trachyscelides*	NA																		
Total species in sample				2	1							1								
Total individuals in sample				3	1							1								

Infauna (numbers per 0.1089m² core) - Castlepoint Beach Transect B (23 January 2014)

Taxa	Species	AMBI	B1a	B1b	B1c	B2a	B2b	B2c	B3a	B3b	B3c	B4a	B4b	B4c	B5a	B5b	B5c	B6a	B6b	B6c
POLYCHAETA	*Hemipodus simplex*	I																		
CRUSTACEA AMPHIPODA	*Talorchestia quoyana*	III	4	1		2		1												
	Pseudaega tertia	I										1								
INSECTA DIPTERA	*Diptera sp. #1*	II			2															
	Diptera sp. #2	II																		
INSECTA COLEOPTERA	*Chaerodes trachyscelides*	NA			1															
Total species in sample			1	1	2	1		1				1								
Total individuals in sample			4	1	3	2		1				1								

APPENDIX 3. BEACH INDICATORS

Primary indicators used to assess the physicochemical and biological condition of sandy beaches.
Note: These indicators were used in the present report.

	Indicator	Rationale	Issue(s)
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 overstabilisation or reclamation). Knowledge of long-term changes directly informs hazard planning and the management of coastal structures, recreational activities, and environmental values. The approach uses well established methods e.g. Travers (2007), and is widely used both locally (e.g. Beach Profile Analysis Toolbox (BPAT) https://www.niwa.co.nz/our-science/coasts/tools-and-resources/tides/bpat) and overseas (e.g. Southern Maine Beach Profile Monitoring Program, Gold Coast Shoreline Management Plan - GCSMP) to investigate such changes.	• Climate change and sea level rise • Sedimentation/erosion • Coastal development
	2. Sediment grain size	Measuring beach sediment grain size is important as distributional shifts can drive (and explain) large scale changes in biotic integrity and beach functionality. Reduced biotic integrity is most typically linked to beaches where sediments have become muddier (i.e. large sheltered embayments), or those which experience significant, yet predictable, cycles where fine sands build up and then erode following disturbance (e.g. storm) events - a regular occurrence on exposed NZ beaches. Data on sediment grain size distributions can therefore provide an early indication of whether the influence of the multiple anthropogenic pressures including climate change related impacts are affecting NZ's beaches.	• Sedimentation/erosion • Climate change and sea level rise • Eutrophication • Coastal development
	3. Redox Potential Discontinuity (RPD) depth	Redox Potential Discontinuity (RPD) depth provides a good indicator of beach benthic health because it ultimately dictates which animals can reside under different (oxic or anoxic) sediment conditions (e.g. Pearson & Rosenberg 1978). It is readily obtained via visual assessment (e.g. Trites et al. 2005) and while it can vary extensively in time and space, it provides a robust primary indicator of the integrated influence of sediment grain size and organic matter input, temperature, wave action, photosynthesis, light intensity, dissolved oxygen, bacterial activity, and the presence of burrowing animals.	• Eutrophication
	4. Benthic macroinvertebrate community	Macroinvertebrates are the primary biological indicator of beach health because they integrate the effects of multiple stressors. They are used extensively locally and internationally (e.g. European Water Framework Directive" (WFD) (European Union 2000) and the Beaches Environmental Assessment and Coastal Health (BEACH) Program (US EPA 2009). 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, over-collection of living resources, invasive species, vehicle use, beach grooming, sediment compaction, eutrophication, and the delivery of fine sediments, toxicants and pathogens).	• Sedimentation/erosion • Climate change and sea level rise • Eutrophication • Coastal development • Toxic contamination • Habitat modification • Disease risk • Physical disturbance • Over-collection of living resources (i.e. shellfish)

APPENDIX 3. BEACH INDICATORS (CONTINUED)

Secondary indicators commonly used to assess the physicochemical and biological condition of sandy beaches. Note: These indicators were not used in the present report.

	Indicator	Rationale	Issue(s)
Secondary Indicators	**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.	• Eutrophication
	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.	• Eutrophication
	Sediment and bathing water contamination	When various agriculturally-, industrially- or domestically-derived chemical contaminants are found in the marine environment at levels that may harm living organisms, they are termed 'toxicants'. In the immediate areas of high concentration, toxicants in water or sediment can kill marine life (e.g. fish and invertebrates), which has knock-on implications for high trophic levels, including humans. There are, however, inherent limitations associated with measuring water column-based toxicant levels. The primary limitation being that contaminant concentrations in water are often below detection limits (i.e. those set by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC)), and are highly variable both spatially and temporally. For this reason, sediments and inhabitant macrofauna, which both indicate and integrate toxicants, are used increasingly in toxicant assessment rather than the water column. Note: these indicators are only used in situations where contamination is likely.	• Toxicants
	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.	• Coastal development
	Beach grooming	Grooming, a common practice on beaches heavily used for tourism (e.g. Southern California), clears beaches of macrophyte wrack (i.e. macroalgae and seagrasses), litter and other debris by raking and sieving the sand, often with heavy machinery. Consequently, grooming removes not only unwanted material, but also propagules of dune plants and other species, and it directly perturbs resident organisms through physical disturbance, as well as indirectly by removal of large quantities of fine sand, shifting sediment grain size towards less habitable, coarser grains. Beaches currently machine groomed in NZ include Paihia, Mt Maunganui, Matua, Papamoa and Ocean Beaches (Tauranga), with proposals made to groom many Auckland beaches on a regular basis. Intermittent manual cleaning of beaches occurs throughout NZ.	• Direct physical disturbance

APPENDIX 3. BEACH INDICATORS (CONTINUED)

Secondary indicators commonly used to assess the physicochemical and biological condition of sandy beaches. Note: These indicators were not used in the present report.

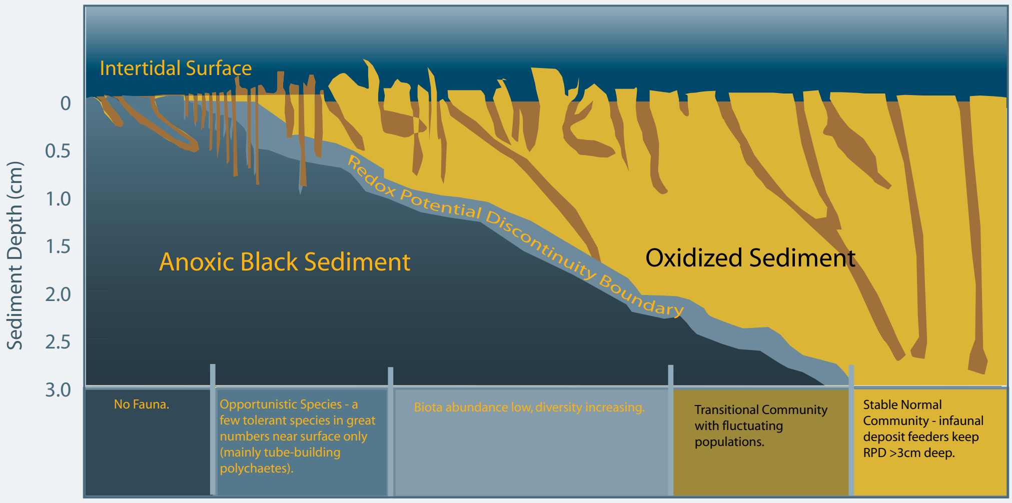
Indicator		Rationale	Issue(s)
Secondary Indicators	**Wildlife disturbance**	Human activities impact beach wildlife, both directly (i.e. physical disturbance) and indirectly (i.e. behavioural disruptions). However, indicators of such impacts are yet to be developed. Ideally cost effective, basic observational 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.	• Habitat modification • Direct physical disturbance
	Over-collection of living resources	Recreational invertebrate fisheries are the most common form of exploitation on sandy beaches. Associated impacts can occur both directly through physical damage of organisms and indirectly when sediment disturbance lowers habitat quality and suitability. In NZ various shellfish taxa are targeted including toheroa, tuatua, tawera, pipi and cockle, with associated abundances generally declining as a function of a growing human population. Used as indicators, such taxa can provide information on population-level changes in relation to exploitation or disturbance over time.	• Over-collection of living resources
	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.	• Habitat modification • Sedimentation/erosion • Climate change and sea level rise

APPENDIX 4. BEACH CONDITION RISK RATINGS - BACKGROUND

REDOX POTENTIAL DISCONTINUITY (RPD) DEPTH

Redox Potential Discontinuity (RPD) depth measures the transition between oxygenated sediments near the surface and deeper anoxic sediments. It is a primary condition indicator as it is a direct measure of whether nutrient and organic enrichment exceeds levels causing nuisance (anoxic) conditions. Anoxic sediments contain toxic sulphides, which support very little aquatic life, and as the RPD layer gets close to the surface, a “tipping point” is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and worsen sediment conditions. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments. The tendency for sediments to become anoxic is much greater if the sediments are muddy.

The RPD layer is an effective ecological barrier for most, but not all, sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. Pearson and Rosenberg (1978) developed a useful organic enrichment tool that indicates the likely benthic macrofauna community that is supported at a particular site based on the measured RPD depth (see Figure below for summary). This tool has been used extensively to date to help interpret intertidal monitoring data in New Zealand and its relationship to organic enrichment. However, it is important to note that this tool was based primarily on studies conducted in stable subtidal sediments of coastal estuaries and embayments rather than the more unstable intertidal sediments of beach habitat or shallow, well-flushed estuaries commonly found in NZ.



An indication of the likely benthic community supported at measured RPD depths **(adapted from Pearson and Rosenberg 1978).**

In addition, a recent study (Gerwing et al. 2013) describe two common methods for measuring RPD as follows:

- **Visual assessment** (often by digital imaging e.g. Munari et al. 2003) based on the assumption that in the absence of oxygen, ferrous sulphides produced by microbial sulphate reduction precipitate as Fe-sulphides, which produce a grey or black coloration of the sediment, which signifies the RPD depth (Valdemarsen et al. 2009). When redox measurements (Eh) are not considered simultaneously, the RPD is termed the apparent RPD (aRPD) (Birchenough et al. 2012).
- **Redox potential (Eh) measurements** represent a bulk measurement that reflects the occurrence of multiple redox equilibria at the surface of an electrode and reflects a system’s tendency to receive or donate electrons. Electrodes are inserted either vertically or horizontally at different depths (Rosenberg et al. 2001, Diaz & Trefry 2006) into the sediment. The depth of the RPD is identified as the zone where conditions change from oxidizing to reducing or the transition from positive to negative mV readings (Birchenough et al. 2012).

Gerwing et al. (2013) compared the methods and found similar results for stable subtidal (Rosenberg et al. 2001) and deep sea sediments (Diaz & Trefry 2006), but different results for relatively dynamic intertidal sediments.

Such findings, indicate two important points:

1. The use of the Pearson-Rosenberg (1978) approach for assessing macrobenthic response to organic enrichment in dynamic, shallow intertidal sediments (i.e. the dominant habitats in most NZ estuaries and beaches) has yet to be proven, and
2. The appropriate RPD method for use in such intertidal sediments and its relationship with biotic indicators needs to be identified.

APPENDIX 4. BEACH CONDITION RISK RATINGS - (CONTINUED)

RECOMMENDED RESEARCH

Clearly, there is an urgent requirement for a direct comparison between both RPD methods (visual and redox) for intertidal estuary and beach habitats in NZ, and particularly the relationship between the RPD depth measured by each and other indicators, especially biotic factors such as macroinvertebrates and macroalgal cover. This is to be included as part of proposed PhD research by Ben Robertson commencing in mid 2014.

RECOMMENDED RPD RISK RATING (INTERIM)

In the interim period prior to the results of the proposed PhD research by Ben Robertson being available, it is recommended that the RPD risk rating be based on aRPD results and predicted ecological response bands similar to those proposed by Pearson-Rosenberg (1978) as follows.

Beach Condition Risk Indicator Rating (Interim): Apparent Redox Potential Discontinuity (aRPD) Depth

Risk Rating	Very Low	Low	Moderate	High	Very High
aRPD depth (cm)	>10cm	3-10cm	1-<3cm	0-<1cm	Anoxic at surface

References

Birchenough S., Parker N., McManus E, and Barry J. 2012. Combining bioturbation and redox metrics: potential tools for assessing seabed function. Ecological Indicators 12, 8–16.

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Jorgenson N., and Revsbach N.P. 1985. Diffusive boundary layers and the oxygen uptake of sediments and detritus. Limnology and Oceanography 30, 111-112.

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Pearson T. H., and Rosenberg R. 1978. Macrobenthic succession in relation to organic enrichment and pollution in the marine environment. Oceanography and Marine Biology: an Annual Review 16, 229-311.

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Veldemarsen T., Kristensen E., and Holmer M. 2009. Metabolic threshold and sulfide-buffering in diffusion controlled marine sediments impacted by continuous organic enrichment. Biogeochemistry 95, 335-353.

APPENDIX 4. BEACH CONDITION RISK RATINGS - (CONTINUED)

BENTHIC MACROINVERTEBRATES

Because of their proven ability to indicate and integrate environmental conditions, soft sediment macrofauna can be used to represent benthic community health and provide a beach condition classification (if representative sites are surveyed).

Unfortunately, direct sediment macroinvertebrate/environmental condition relationships and thresholds have not yet been developed for NZ beaches. In the interim period, prior to the development of such thresholds, it is recommended that the AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) be used for the interpretation of NZ beach macrofauna data. The AMBI has been verified in relation to a large set of coastal environmental impact sources (Borja, 2005) and geographical areas (in N and S hemispheres) and so is potentially relevant. However, because the development of the AMBI does not include data from NZ beaches in its dataset, its use for NZ beaches can result in a relatively high error in the final result. In addition, its robustness can be reduced when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample.

The equation to calculate the AMBI Biotic Coefficient (BC) is as follows;

$$BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100.$$

The characteristics of the ecological groups (GI, GII, GIII, GIV and GV) are summarised as follows:

- Group I. Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.
- Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.
- Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalanced situations). They are surface deposit-feeding species, as tubicolous spionids.
- Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.
- Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.

The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with 5 levels, from 0 to 6.

RECOMMENDED RESEARCH

Undertake studies to develop direct sediment macroinvertebrate/environmental condition relationships for NZ beaches.

RECOMMENDED MACROINVERTEBRATE RISK RATING (INTERIM)

In the interim period, prior to the development of direct sediment macroinvertebrate/environmental condition relationships for NZ beaches, it is recommended that the use of the AMBI (Borja et al. 2000) would provide a reasonable indicator of beach risk to organic enrichment as follows.

Beach Condition Risk Indicator Rating (Interim): Macroinvertebrate Enrichment Index (AMBI)

Risk Rating	Very Low	Low	Moderate	High	Very High
Macroinvertebrate Enrichment Index (AMBI)	0-1.2 Intolerant of enriched conditions	1.2-3.3 Tolerant of slight enrichment	3.3-5.0 Tolerant of moderate enrichment	5.0-6.0 Tolerant of high enrichment	>6.0 Azoic (devoid of invertebrate life)

References

Borja, A., Franco, J., and Perez, 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, 1100–1114.

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APPENDIX 4. BEACH CONDITION RISK RATINGS - (CONTINUED)

SEDIMENT MUD CONTENT (% MUD)

Most NZ beaches are dominated by sandy substrates due to their relatively high wave exposure. However, if fine sediments accumulate, detrimental and difficult to reverse changes in biotic community composition are likely to occur, and human uses and values are likely to be adversely impacted (e.g. through reduced water clarity and increased muddiness). The relationship between beach sediment mud content and the benthic macrofaunal community has not yet been directly developed into a biotic indice that could be used to predict biotic impacts of a shift in grain size. However, in a widespread study of NZ estuarine habitats that included sandy intertidal flats similar to dissipative beach type tidal flats, Robertson (2013) found that the estuarine sediments with low to intermediate mud concentrations (i.e. 2-25% mud) were more likely to have a diverse and abundant macroinvertebrate assemblage and low organic enrichment (<1% TOC) than muddier sediments. In addition, these sediment-macroinvertebrate-mud thresholds were similar to those reported by Van Hoey et al. (2004) in a study investigating multiple exposed sandy beaches in Belgium. Such findings indicate that in the interim, prior to the development of direct sediment-macroinvertebrate-mud thresholds for NZ beaches, the use of the estuary sediment-macroinvertebrate-mud thresholds (adapted from Robertson 2013) would provide a reasonable indicator of beach response.

RECOMMENDED RESEARCH

Undertake studies to develop direct sediment-macroinvertebrate-mud content thresholds for NZ beaches.

RECOMMENDED SEDIMENT MUD CONTENT RISK RATING (INTERIM)

In the interim period, prior to the development of direct sediment-macroinvertebrate-mud content thresholds for NZ beaches, it is recommended that the use of the estuary sediment-macroinvertebrate-mud thresholds (adapted from Robertson 2013) a would provide a reasonable indicator of beach response as follows.

Beach Condition Risk Rating (Interim): Sediment Mud Content

Risk Rating	Very Low	Low	Moderate	High	Very High
Sediment Mud Content (% mud)	<2%	2-5%	5-15%	15-25%	>25%

References

Hoey, G.Van., Degraer, S., and Vincx, M. 2004. Macrobenthic community structure of soft-bottom sediments at the Belgian Continental Shelf. Estuarine, Coastal and Shelf Science 59, 599–613.

Robertson, B.P. 2013. Determining the sensitivity of macroinvertebrates to fine sediments in representative New Zealand estuaries. Honours dissertation, Victoria University of Wellington - Note: In preparation for journal publication.

APPENDIX 5. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Polychaeta	*Hemipodus simplex*	I	A glycerid, or bloodworm, found in clean sand sites in estuaries and on clean sandy beaches. They are cylindrical, very muscular and active large predators and detritivores.
Crustecea	*Talorchestia quoyana*	III	This talitrid amphipod is found on the backshore of New Zealand sandy beaches and is dependent on drift for food. Individuals of this species are great consumers of algal and other organic material stranded on the beach. They are typical of wave-washed sandy shores, i.e. beaches that have low anthropogenic effects and with low sediment (sand) metal concentrations. Although they are found in large numbers near sources of rich organic material, they are not present in permanently eutrophic, low oxygen sediments. In this case, *Talorchestia* has been assigned in the group of species tolerant to excess organic matter enrichment (Group III). These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slightly unbalanced situations).
	Pseudaega tertia	I	An isopod typically found in the midlittoral zone of exposed, sandy/pebbly beaches.
Insecta	*Chaerodes trachyscelides*	NA	A highly specialised, sand-burrowing beetle, likey to be rare and intolerant of harsh sediment conditions.
	Diptera sp.#1	II	An unknown dipteran or fly larvae.
	Diptera sp.#2	II	An unknown dipteran or fly larvae.

AMBI Sensitivity to Stress Groupings (from Borja et al. 2000, and further validated for NZ taxa in Robertson 2013)

Group I. Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.
Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.
Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids.
Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.
Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.
The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with 5 levels, from 0 to 6.