coastalmanagement

Orepuki Beach

Fine Scale Monitoring 2010/11

Prepared for **Environment Southland**
August 2011

Cover Photo: Orepuki Beach Fine Scale Monitoring 2011 - Barry Robertson talking to local transport provider.

Looking east to Orepuki Beach.

Orepuki Beach

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By

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All photos by Wriggle except where noted otherwise.

OREPUKI BEACH - EXECUTIVE SUMMARY

This report summarises the results of the first year of fine scale monitoring for Orepuki Beach, an intermediate/dissipative type beach at the eastern end of Te Waewae Bay. It is a key beach in Environment Southland's (ES) long-term coastal monitoring programme and uses sediment health to assess beach condition. The primary indicators are; the beach morphometry or profile, grain size, and the abundance and diversity of sediment dwelling plants and animals at various tide levels on the beach. These indicators were chosen due to their proven sensitivity to likely potential stressors (e.g. freshwater discharge and sediment supply alterations, sea temperature and level rises, increased wave climate, vehicle damage, bio-invaders, oil spills, toxic algal blooms, trampling and erosion). Sediment oxygenation (RPD depth) was also measured, but as a secondary indicator (i.e. an indicator that is relatively easy to measure and a low risk of being adversely impacted). The following table summarises monitoring results for the two intertidal sites at Orepuki Beach for 2011.

FINE SCALE RESULTS

- **Beach Morphometry:** a broad intertidal area with a very gradual slope in the lower half and steeper in the upper - backed by 1-2m of marram foredunes and a 20m high sandstone cliff. Compared with the 1986 beach profile (O'Shea 1986), the 2011 beach profile was steeper, indicating a much lesser volume of sands on the beach. This supports observations that beaches in Te Waewae Bay are steepening and becoming coarser grained, possibly in response to reduced sediment loads from the Waiau River following damming and diversions in the catchment in 1969 (e.g. Kirk and Schulmeister 1994, Keeley et al. 2006).
- **Sediment Type:** The beach was predominantly sand (>98.7% sand), with very low mud contents (1.2%). Keeley et al. (2002) reported similar results in 2002 for Orepuki Beach. Because fine sand is important for Toheroa habitat, it is recommended that future grain size analyses differentiate between the different sand size fractions.
- **Benthic Invertebrate Condition;** the benthic community condition at both sites was "balanced", with a typical exposed, beach invertebrate community, dominated by crustaceans (isopods, amphipods), and moderate numbers of polychaetes and bivalves. Because nutrients and organic matter were sparse on Orepuki Beach, invertebrate numbers were low and consisted mainly of scavengers and predators. Compared with the 1986 beach invertebrate monitoring results (O'Shea 1986), there were some major differences. In particular; reduced numbers of toheroa and the complete absence of ghost shrimp. Several reasons could explain these results, including changes to physical habitat through erosion and vehicle damage.
- **Sediment Oxygenation;** the Redox Potential Discontinuity (RPD) layer was relatively deep >15cm depth) at all sites and therefore sediments were well oxygenated.

BEACH CONDITION AND ISSUES

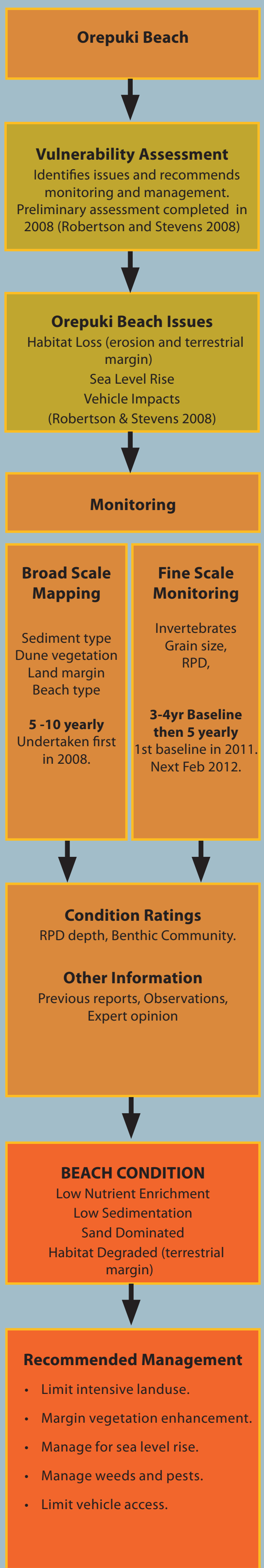
Overall, the findings indicate a sandy beach which is eroding, becoming steeper, and with its grain size possibly coarsening. Its invertebrate biota, which is relatively diverse and typical of exposed, nutrient-poor, sandy beaches, has changed since 1986. Further biota impacts can be expected, given the likelihood of continued changes to physical habitat through predicted erosion as a result of the Waiau River flow diversion, and from climate change (sea level rise and altered wave climate).

RECOMMENDED MONITORING AND MANAGEMENT

In order to provide a baseline of beach condition at Te Waewae Bay (particularly in light of predicted accelerated climate change effects and decreased sediment supplies from Waiau River) it is recommended that fine scale monitoring continues for three years. After the baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on beach condition ratings. The next fine scale monitoring is scheduled to take place in February, 2012.

The fine scale monitoring reinforced the need for management of the beach habitat, as indicated in the recent Southland Coastal Vulnerability Assessment (Robertson and Stevens 2008). Maintenance of a healthy beach ecology and increases in habitat diversity are expected to be substantially enhanced by limiting stressors (e.g. climate change, freshwater flow diversions, vehicle damage) and ensuring that the present low nutrient loads are maintained and that the beach is protected from excessive inputs of fine muds and pathogens. To help with this it is recommended that a natural vegetation zone above the high water line is encouraged to provide a buffer between the beach and the adjacent farmland.

1. INTRODUCTION



Developing an understanding of the condition and risks to coastal habitats is critical to the management of biological resources. The recent "Southland Coast - Te Waewae to the Catlins - Mapping, Risk Assessment and Monitoring" report (Robertson and Stevens 2008) identified a low-moderate risk to soft sediment beach shore ecology on the Te Waewae Bay coast through predicted accelerated sea level rise and temperature change, erosion and habitat loss. To address this risk, and to provide information on the Te Waewae Bay beach ecology, annual long term monitoring of Orepuki Beach (a representative intermediate/dissipative type beach ecosystem) was initiated in February 2011. Wriggle Coastal Management was contracted to undertake the work.

Dissipative-intermediate 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 have weak rip currents with undertows. The tidal flat is at the extreme end of dissipative beaches. Orepuki Beach tends more towards the intermediate type. Compared with other beach types their ecological characteristics include the following:

- Interactions within and between species are generally more intense.
- High level of primary production, diversity and biomass of macrofauna.
- Exporters of organic matter.
- More highly regulated by biological interactions.

The relationship between stressors (both natural and human influenced) and changes to sandy beach communities is 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, mud, pathogen and toxin inputs, as well as broader stressors such as climate change related effects of changes to sea temperature, sea level, wave exposure and storm frequency and intensity (McLachlan and Brown 2006) (Table 1).

Orepuki Beach is a very exposed, high wave energy, gently sloping sandy beach with some shingle and cobble patches extending from Monkey Island to the Waimeamea River Estuary, a distance of 3.25km. At low water mark, the intertidal sandflats extend in places 200m from high water. Because of the exposure, the foreshore is very mobile with the coast subject to erosion. Above high water, the terrestrial margin consists primarily of partially vegetated sandstone cliffs up to 20m high, but narrow sections of marram duneland occur in some areas at the toe of the cliffs (see photo on page 4). It is renown for its bent over trees and wild seas spraying mist high onto the cliffs which are thought to have been formed by the combination of tectonic uplift and marine erosion. Vegetation immediately inland of the cliffs is primarily grassland used for stock grazing, with stock fenced off from the beach and cliff areas.

Gold and platinum were recovered from the area in the past and in 1986 alluvial deposits of possible commercial viability were found in the sediments and a mining company applied for the right to mine Orepuki Beach. There were concerns at the time of the impacts on the various infaunal species inhabiting these sediments especially the presence of both juvenile and adult populations of the toheroa *Paphies ventricosa,* but this proposal did not go ahead (O'Shea, 1986).

Human use of the beach is high from both a tourist and local context. It is particularly valued for its scenic qualities, and its natural character, and is used for walking, bathing, surfing, diving, horse riding, scientific interest, surf-casting, whitebaiting, inshore fishing, shellfish collection, picnicking, sitting, fossicking, gemstone collection and bird-watching. Hectors dolphins are often seen there. Vehicles are a common sight on the beach with access points at several locations along the beach.

1. Introduction (Continued)

The current report documents the results of the first year of intertidal fine scale monitoring of Orepuki Beach sites (undertaken on 26 February 2011). The monitoring area was located approximately 300m east of Orepuki township. Monitoring was undertaken by measuring physical and biological parameters collected from the beach along two transects from supratidal (the shore area immediately above the high-tide) to low water (Figure 1). The report is the first of a proposed series, which will characterise the baseline fine scale conditions in the beach over a 3 year period. The results will help determine the extent to which the beach is affected by major environmental pressures (Table 1), both in the short and long term. The survey focuses on providing detailed information on indicators of biological condition (Table 2) of the dominant habitat type in the beach (i.e. unvegetated intertidal sandflats).

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

The key stressors of beaches and dunes are; changes in sediment supply, sea level and temperature rise, increased wave climate, vehicle use, introduced marram grass, pathogens and stock grazing. Nutrients and toxicants are lesser risks.

Sediment Supply.
On coasts where the sediment supply from rivers is large, a change in sediment supply (e.g. from dams) can significantly alter beach topography. The introduction of seawalls, groynes and breakwaters can also cause changes to sediment supply and affect beach topography. If fine sediment inputs are excessive to sheltered beaches, the beach becomes muddier and the sediments less oxygenated, reducing biodiversity and human values and uses.

Sea Level Rise.
The general effect of sea level rise on beaches is that they erode. Most sandy beaches world-wide have recorded recession during the last century and the predicted accelerated sea level rise due to climate change will only increase erosion rates. A common response to accelerated erosion is to armour the beach with a seawall. Although this may protect terrestrial property, seawalls can cause damage to the beach and its ecology by eroding at the ends and causing accelerated erosion of the beach in front of the wall.

Vehicle Use.
Vehicle use on dunes and sandy beaches has been demonstrated to be highly damaging to plants and vertebrates, however the ecological impacts of beach traffic on invertebrates are not predictable at present because the specific responses (e.g., mortality rates) of potentially impacted species to varying intensities of traffic remain un-quantified. (Williams et al. 2004, Schlacher and Thompson 2009). Currently, a study is being undertaken on Oreti Beach looking at vehicle impacts on Toheroa. Initial results suggest up to 80 % mortality of juveniles under vehicle tracks (Greg Larkin, ES Coastal Scientist pers. comm.)

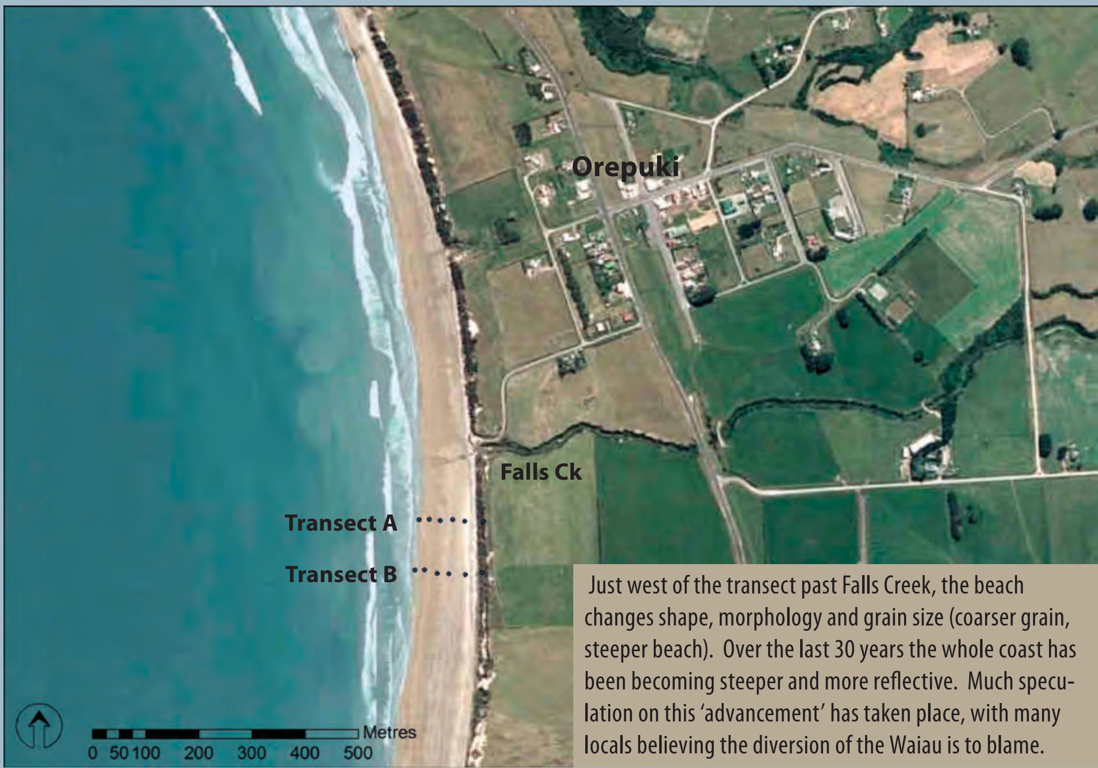
Stock Grazing.
The effect of stock grazing in dunes reduces the height of plants and encourages mobilisation of dunes. It also leads to a decreased organic and nutrient content of the duneland. Stock trampling also encourages sand mobilisation as does sheep rubbing against small blowouts. Low density stock grazing can be used to control weed growth in dunes, particularly in areas well back from the foredune, although excessive grazing leads to high levels of damage.

Marram Grass.
Introduced marram grass, although relatively successful at limiting coastal erosion and stabilising sand drift, does have drawbacks. In particular, marram dunes are generally taller, have a steeper front and occupy more area than dunes of either of the native sand binding species (spinifex or pingao). Consequently, they result in overstabilisation and a reduced ability of active dunes to release sand to the foreshore during storm erosion. They also tend to 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 move to remove existing, and minimise any further, marram grass invasion of active dunes, and to replant with native species.

Pathogens.
If pathogen inputs to the coastal area are excessive (e.g. from coastal wastewater discharges or proximity to a contaminated river plume), the disease risk from bathing, wading or eating shellfish increases to unacceptable levels.

Nutrients.
Eutrophication generally occurs only on very sheltered beaches when nutrient inputs are excessive (e.g. in the groundwater feeding a beach), resulting in organic enrichment, anoxic sediments, lowered biodiversity and nuisance effects for local residents.

Toxicants.
If potentially toxic contaminant inputs (e.g. heavy metals, pesticides) are excessive, beach biodiversity is threatened and shellfish may be unsuitable for eating. Oil spills and toxic algal blooms are the main toxicant risks to New Zealand beaches.



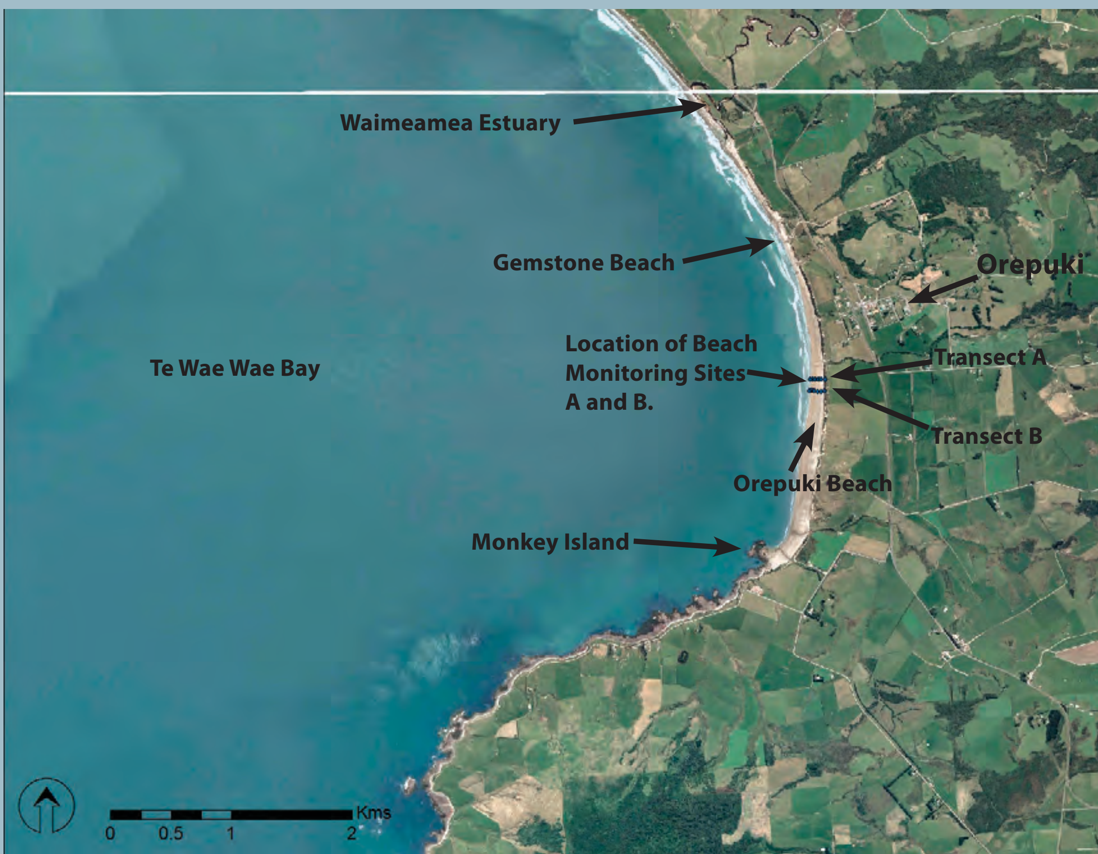


Figure 1. Location of fine scale monitoring sites at Orepuki Beach: close-up- top and broad scale view- bottom (Photo; LINZ).

1. Introduction (Continued)

Table 2. Summary of the broad and fine scale beach indicators.

Issue	Indicator	Method
Habitat Change	1. Morphometry	Measure beach slope along transects.
Sediment Type	2. Grain size	Physical analysis of beach sediment grain size - estimates the change in grain size over time.
All Issues	3. Benthic Community	Type and number of animals living in the upper 15cm of sediments. Relates the sensitivity of the animals present to different levels of pollution or disturbance.
Eutrophication	4. Redox Profile	Measurement of depth of redox discontinuity profile (RPD) in sediment estimates likely extent of deoxygenated, reducing conditions.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of any nuisance macroalgal growth (e.g. sea lettuce (*Ulva*, *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon in replicate samples from the upper 2cm of sediment. These indicators are only used in situations where nutrient enrichment is likely.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment. These indicators are only used in situations where metal contamination is likely.
Habitat Change	Dune, Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time. The back-shore profile and vegetation cover is also measured at the fine scale sites and therefore can be used as an indicator of local change.

Note: Shaded cells = indicators that were monitored at Orepuki fine scale.

Location of fine scale sites Orepuki Beach showing steep eroding cliffs with small area of duneland at base.

2. METHODS

FINE SCALE MONITORING

Fine scale monitoring involves measuring the abundance and diversity of plants and animals in cores collected from the beach along two transects from supratidal to low water tide ranges. The dynamic nature of the beach ecosystem means there will be change over both the short and long term. To minimise seasonal and spatial variation, monitoring is undertaken at a fixed time each year (January to March) and from cores that have been positioned in habitat that is representative of the wider coastline. To account for year to year changes, a 3-4 year baseline has been recommended (annual monitoring) after which a review will be undertaken and a likely shift to five yearly monitoring.

Sampling was undertaken by two scientists, during relatively calm sea conditions on 26 February 2011 when estuary monitoring was being undertaken in the region. The approach was similar to that used by Aerts et al. (2004) in a study of macrofaunal community structure and zonation of an Ecuadorian sandy beach as follows:

- Two transects were sampled 50m apart. Each transect was sampled at six stations: five stations were situated in the intertidal zone, while a sixth one was located on the dry beach.
- Sampling of the intertidal zone started at high tide, following the receding water down the beach.
- Sampling in the swash zone every 60 minutes to distribute stations evenly.
- The relative elevations of the stations were measured using the pole and horizon field surveying technique, distances between all sample sites were measured, and the GPS positions of each station were logged.

Physical and chemical analyses

- At each station along each transect the average RPD depth was recorded.
- At each station, a composite sample of the top 20mm of sediment (each approx. 250gms) was collected for analysis of grain size/particle size distribution (% mud, sand, gravel) - details in Appendix 1.
- Samples were tracked using standard Chain of Custody forms and results checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.

Infauna (animals within sediments)

- Three sediment cores (each 2m apart) were taken at each station using a 330mm square (area = $0.1089m^2$) stainless steel box corer.
- The box core was manually driven 150mm into the sediments, the sediments removed with a spade and emptied into a 1mm nylon mesh bag and the contents of the core sieved in nearby seawater. The infauna remaining were carefully emptied into a plastic container with a waterproof label and preserved in a 70% isopropyl alcohol - seawater solution.
- The samples were then transported to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

Condition Ratings

At present, there are no formal criteria for rating the overall condition of beaches in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers. Therefore, to help ES interpret their monitoring data, two interim beach "condition ratings" have been proposed. These are firstly, the benthic community organic enrichment condition and secondly, the degree of sediment oxygenation as indicated by the redox discontinuity profile (RPD) (Appendix 2). However, the benthic community organic enrichment rating for beaches is currently very limited because the number of species that have been assigned to appropriate tolerance groups is small. As a result, such ratings need to be interpreted in tandem with other observations (e.g. presence of organic matter on sediment surface, shallow RPD).

3. RESULTS AND DISCUSSION

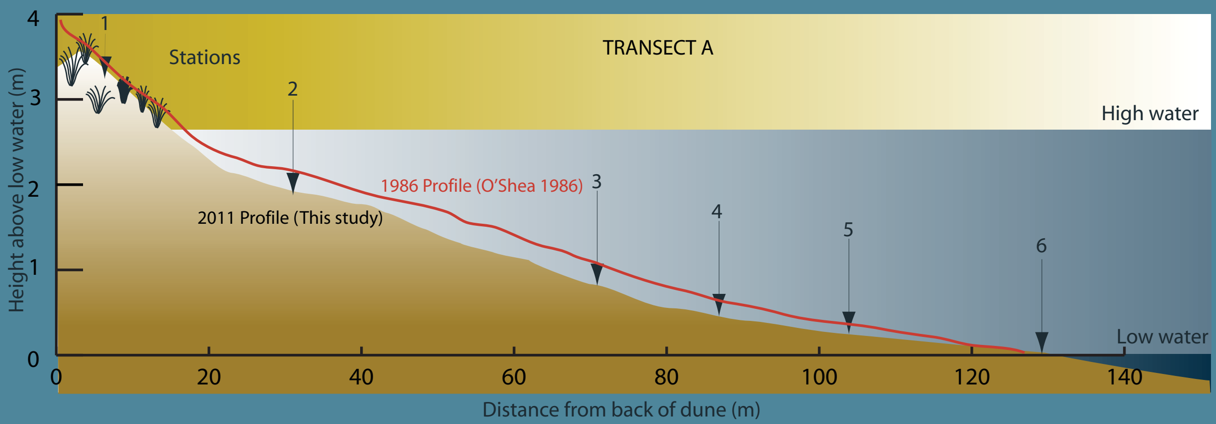
The results of the fine scale monitoring of two transects at Orepuki Beach on 26 February 2011 are presented below. Detailed results are presented in Appendix 3.

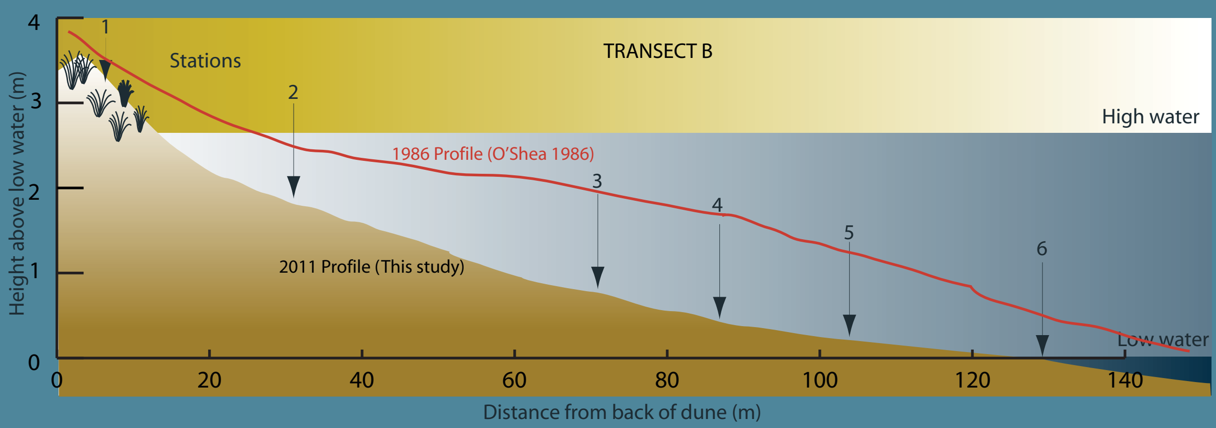
1. MORPHOMETRY

The morphometry of the Orepuki Beach transects for 2011 is presented in Figure 2. It shows that the beach was backed by a 1-2m high foredune which was covered with marram grass vegetation. The intertidal area was 130m wide, with a very gradual slope in the lower half and steeper in the upper. Immediately behind the foredune (5-7m wide) the ground rose steeply into 20m high, partially vegetated, sandstone cliffs. Figure 2 also shows the 1986 beach profile, when the beach was less steep, indicating a much greater volume of sands on the beach during this earlier period (O'Shea 1986). These findings support widely held beliefs that beaches in Te Waewae Bay are steepening and becoming coarser grained, possibly in response to reduced sediment loads from the Waiau River following damming and diversions in the catchment in 1969 (Kirk and Schulmeister 1994, Keeley et al. 2006).

In the future, these monitoring results will be useful as a means of assessing any further changes to the beach profile, particularly in light of predicted further declines in Waiau River sediment supplies to the coast (Kirk and Schulmeister 1994), and increased erosion through impacts of climate change (sea level rise and increased wave climate).

Figure 2. Cross-section of transects at Orepuki Beach, 26 February 2011.





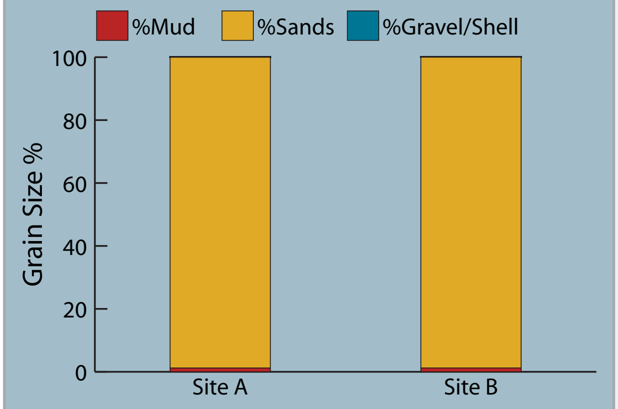


Figure 3. Grain size of sediments at Orepuki Beach, 2011.

Nemertean

Isopod

Polychaete *Aglaophamous macroura*

Amphipod

Toheroa *Paphies ventricosa*

Table 3. Macrofauna results (means) for Orepuki Beach, 26 February 2011.

Site	Reps	Mean Total Abundance/m²	Mean Number of Species/Core
Orepuki Beach A	18	76.2	3.2
Orepuki Beach B	18	83.3	2.6

2. SEDIMENT GRAIN SIZE

Sediment grain size is a major determinant of biological habitat. For example, a shift from fine sands, to coarse sands can deter some shellfish from living there (e.g. toheroa and tuatua).

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

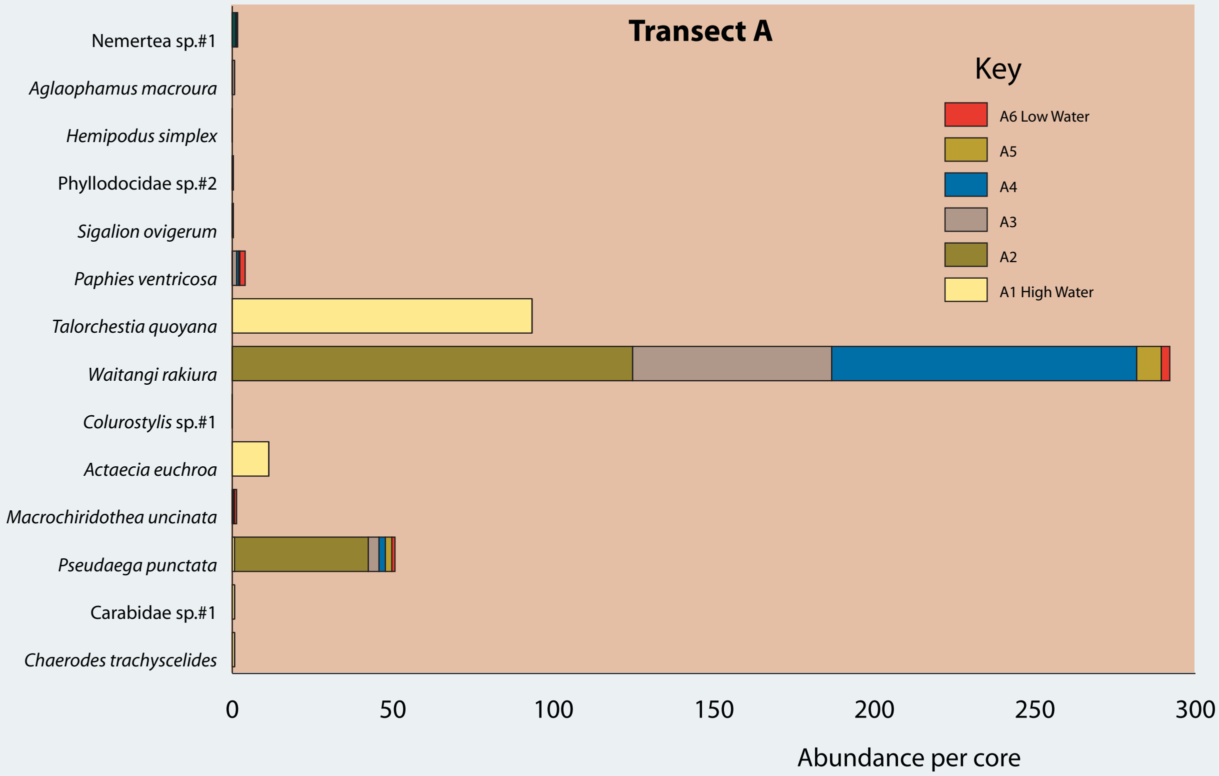
The Orepuki coastal environment, with its exposed nature and history of reduced sediment supplies from the Waiau catchment, is expected to be more at risk from the former of these stressors. Although the waters bathing the coastal areas during high rainfall periods tend to have a high suspended solids content as a result of catchment runoff, deposition of these solids tends to be offshore, or in sheltered embayments, beaches or estuaries. Orepuki Beach, being an exposed beach is not expected to be at risk from excessive inputs of fine sediments. This was confirmed by the 2011 grain size monitoring results which showed that all sites were dominated by sandy sediments (>98.78% sand), with very low mud contents (1.2%) (Figure 3). Technically, "sand" refers to particles between 63µm and 2mm. The grain size analysis of Orepuki Beach did not differentiate between the various sand fractions within this range and it is recommended that this be undertaken in future monitoring in order to better assess the condition of this habitat for species like Toheroa.

Given the historical erosion of Orepuki Beach, it is useful to compare the 2011 results with past grain size monitoring information. Keeley et al. (2002) reported similar results in 2002 for Orepuki Beach, but also showed that the beach was a mix of coarse and fine grained particles. Evidently, historical grain size monitoring was also undertaken in 1969 at Orepuki Beach by D. H. Wood as referenced in O'Shea (1986), but to date we have not been able to trace this reference.

Future monitoring will determine if the sediments are becoming coarser over time.

3. SEDIMENT BIOTA

The benthic invertebrate community at Orepuki Beach (Table 3 and Appendix 4) in 2011 was typical of a "normal" exposed beach community where inputs of nutrients or organic matter are low. The results showed that the abundance (40-3,210 animals per m²) was low at some sites and high at others with low diversity (2-5 species per m²) at both sites. The community was dominated by organisms that prefer clean, coarse, well-oxygenated sand, a deep RPD and low organic enrichment levels. The dominant organisms were crustaceans (isopods and amphipods) (Figures 4 and 5).



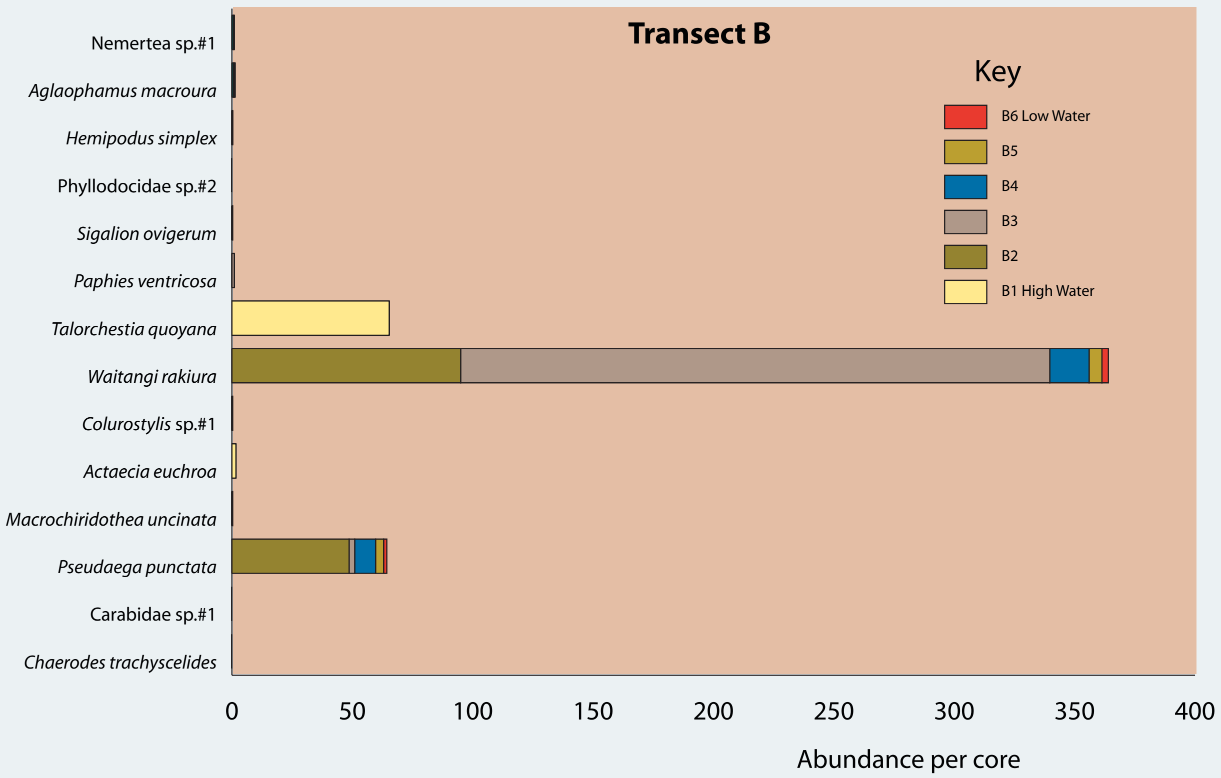


Figure 4. Mean abundance per core of macrofauna species at each site on Transects A and B Orepuki Beach - 26 February 2011.

3. Results and Discussion (Continued)

The phoxocephalid amphipod *Waitangi rakiura* and the scavenging isopod, *Pseudaega punctata* dominated the fauna at the mid to high water sites. At mid-low water levels, small numbers of the nephtyid and scaleworm polychaetes, *Aglaophamous macroura* and *Sigalion ovigerum* (both very active carnivores that live in the sands) were present. The ghost shrimp *Callianassa filholi* was present at these intertidal sites in 1986 and also in Jan 1997 (Robertson 1997) and therefore it is interesting to note its complete absence in 2011. A number of potential stressors could explain these findings including reduced fine sediment supply, sediment mobility, toxicity (toxic algal blooms), vehicle crushing and competition. A hypothesis has been presented that both *Paphies* and *Callianassa* compete for both space and food (Peterson 1977) in the intertidal zone, both feeding on the diatom *Chaetocerus armatus*, but given the low numbers of *Paphies,* that is an unlikely scenario.

Toheroa (*Paphies ventricosa*) were present at some low to mid tide sites at moderate densities, with the majority in the juvenile size range (0.7-2.5cm) and a few adults (2.6-11.8cm). These numbers (approximately 0-2 per 0.1m^2 quadrat) reflect a reduction since a 1986 survey which showed densities of adults rarely exceeding 3-6 m^{-2} and juveniles at 30m^{-2} or more (O'Shea 1986) at these sites. This reduction may be a result of bed patchiness, but a recent survey (Futter and Moller 2009) concludes that declines have been accelerated due to the combined effect of the reduced Waiau flow and some other ecological factor. This other factor has also operated regionally to depress the population at both Te Waewae Bay and Oreti Beach and could be attributed to a number of stressors including: storm events, harvesting, pollution and crushing by vehicles (Keeley et al 2002). Currently, a study is being undertaken on Oreti Beach looking at vehicle impacts on Toheroa. Initial results suggest up to 80 % mortality of juveniles under vehicle tracks (Greg Larkin, ES Coastal Scientist pers. comm.)

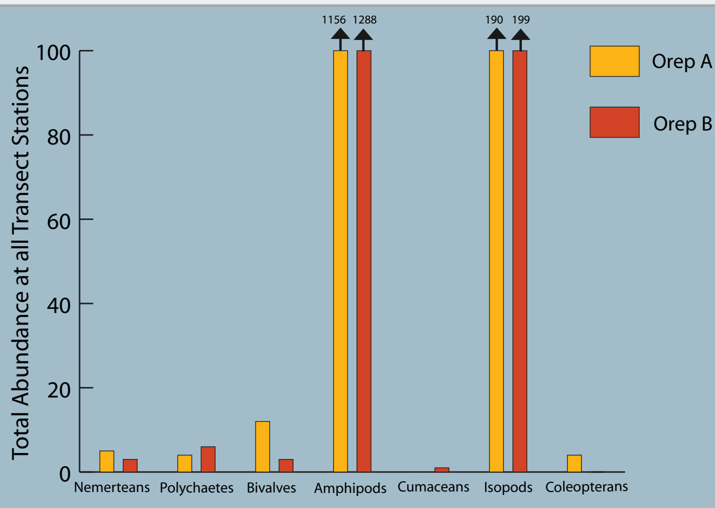


Figure 5. Total abundance of macrofauna groups at Orepuki Beach (sum of all 6 stations at each site) - February 2011.

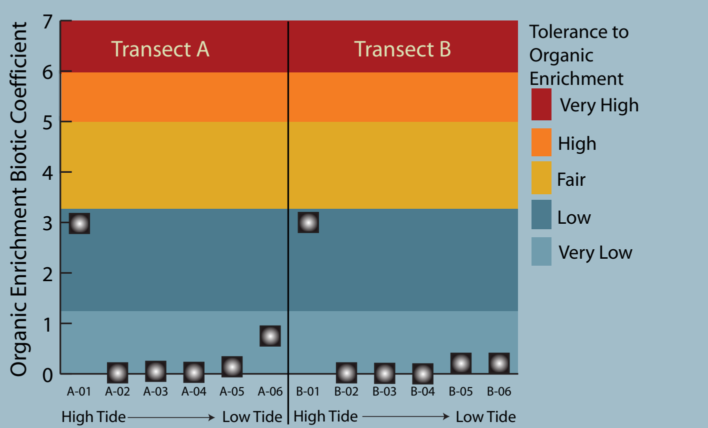


Figure 6. Rating of macro-invertebrate tolerance to organic enrichment, Orepuki Beach, 2011.

As is typical for such beaches, the benthic invertebrate organic enrichment rating was in the "low to very low" category for 2011 (Figure 6). Such a rating reflects the predominantly low sediment nutrient concentrations, the sand dominated nature of the beach, and the presence of species that prefer low levels of organic matter. The highest enrichment ratings were recorded at the supra tidal levels on each transect where most organic material accumulates e.g. beach cast seaweed, driftwood and decaying organic matter. The monitoring will provide a baseline against which future change can be measured, the importance of which is clearly demonstrated by the obvious changes which have occurred since the 1986 survey.

The sand hopper *Talorchestia quoyana* dominated the fauna at the high water sites despite the fact that the drift line contained very little organic detritus on the day of sampling. Small numbers of the isopod, *Actaecia euchroa* were present at high water and the toheroa, *Paphies ventricosa* was found at mid-low water particularly at Transect A.

In general the community consisted of species that are usually present in low-moderate numbers, and include filter feeders, omnivores, carnivores and scavengers. The most sensitive species to both physical and chemical change is expected to be the toheroa.

3. Results and Discussion (Continued)

4. REDOX POTENTIAL DISCONTINUITY (RPD)

On exposed beaches like Orepuki Beach, 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. macro-algal (e.g. sea lettuce) and micro-algal blooms, sediment anoxia, increasing muddiness, and benthic community changes are unlikely. In such a low risk situation, the number of fine scale indicators for eutrophication is therefore limited to the easily measured RPD depth. The depth of the RPD layer (Figure 7) provides a measure of whether nutrient enrichment, for example from sewage leachate or groundwater from pasture above the cliff, seeping through beach sediments, exceeds the trigger leading to nuisance anoxic conditions in the surface sediments. Knowing if the surface sediments are moving towards anoxia is important as anoxic sediments are toxic and support very little aquatic life.

Figure 7 shows the sediment profiles and RPD depths for the Orepuki Beach transect sampling sites (also Appendix 3) and indicates the likely benthic community that is supported at each site based on the measured RPD depth (adapted from Pearson and Rosenberg 1978). The 2011 RPD results showed that the depth of the RPD at Orepuki Beach was >15cm at all sites and therefore likely to be well oxygenated. Such RPD values fit the "very good" condition rating and indicate that the benthic invertebrate community was likely to be in a "normal" state.

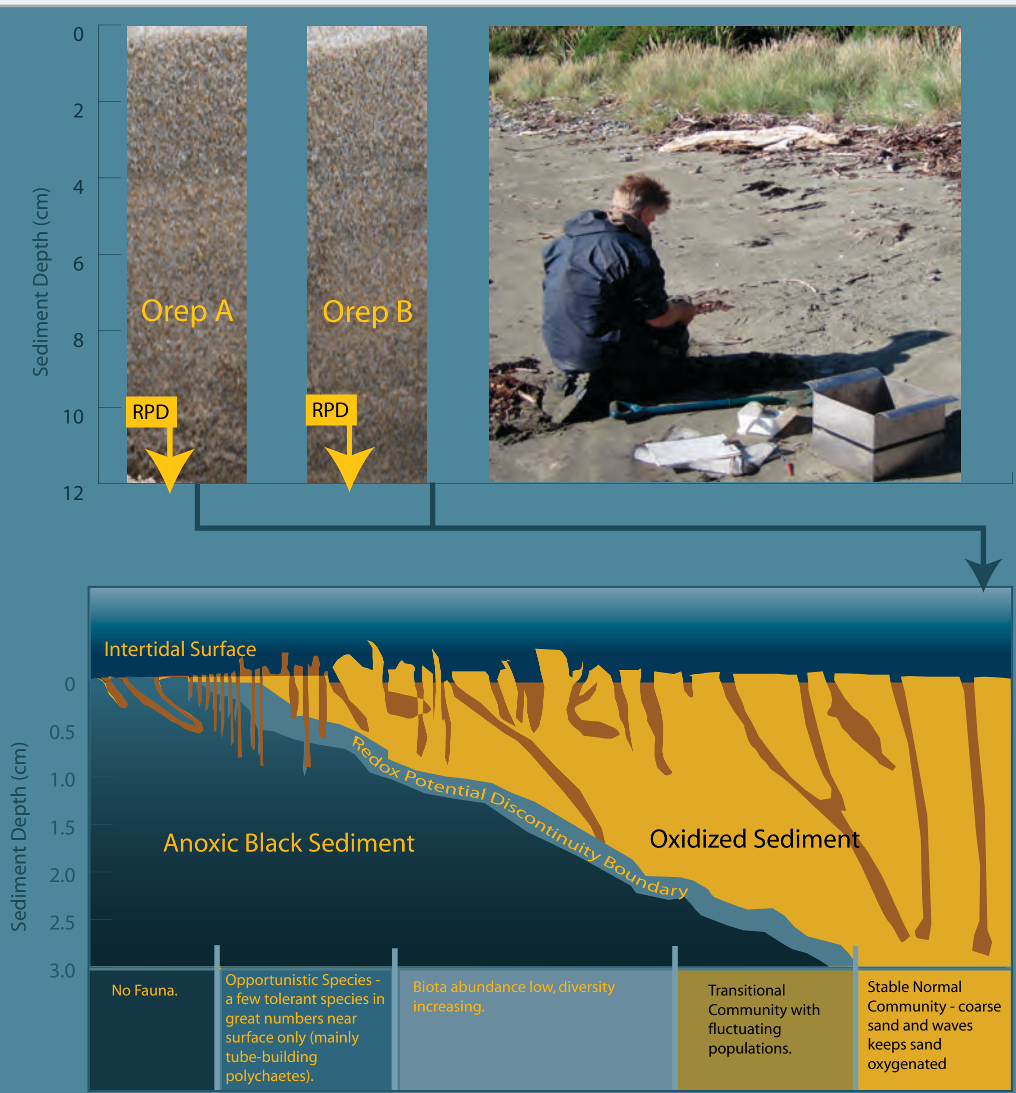


Figure 7. Sediment profiles, depths of RPD and predicted benthic community type, Orepuki Beach.

4. CONCLUSIONS

The results of the first year of fine scale monitoring for Orepuki Beach, an intermediate/dissipative type beach at the eastern end of Te Waewae Bay indicated the following;

- **Beach Morphometry:** a broad intertidal area with a very gradual slope in the lower half and steeper in the upper - backed by 1-2m of marram foredunes and a 20m high sandstone cliff. Compared with the 1986 beach profile (O'Shea 1986), the 2011 beach profile was steeper, indicating a much lesser volume of sands on the beach. These findings support widely held beliefs that beaches in Te Waewae Bay are steepening and becoming coarser grained, possibly in response to reduced sediment loads from the Waiau River following damming and diversions in the catchment in 1969 (Kirk and Schulmeister 1994, Keeley et al. 2006).
- **Sediment Type:** The beach was predominantly sand (>98.7% sand), with very low mud contents (1.2%). Keeley et al. (2002) confirmed similar results in 2002 for Orepuki Beach. Because fine sand is important for Toheroa habitat, it is recommended that future grain size analyses differentiate between the different sand size fractions.
- **Benthic Invertebrate Condition;** the benthic community condition at both sites was "balanced", with a typical exposed beach invertebrate community, dominated by crustaceans (isopods, amphipods), and moderate numbers of polychaetes and bivalves were also present. Because nutrients and organic matter were sparse on Orepuki Beach, invertebrate numbers were low and consisted mainly of scavengers and predators. Compared with the 1986 beach invertebrate monitoring results (O'Shea 1986), there were some major differences, in particular; reduced numbers of toheroa and the complete absence of ghost shrimp. Several reasons could explain these results, including changes to physical habitat through Waiau River flow diversion and vehicle damage.
- **Sediment Oxygenation;** the Redox Potential Discontinuity (RPD) layer was relatively deep >15cm depth) at all sites and therefore sediments were well oxygenated.

Overall, the findings indicate a sandy beach which is eroding, becoming steeper and its grain size possibly coarsening. Its invertebrate biota, which is relatively diverse and typical of exposed sandy beaches, has changed since 1986. Further biota impacts can be expected, given the likelihood of changes to physical habitat through predicted continuing erosion as a result of both the Waiau River flow diversion, climate change (sea level rise and altered wave climate) and vehicle damage.

5. MONITORING

Orepuki Beach has been identified by ES as a priority for monitoring, and is a key part of ES's coastal monitoring programme being undertaken in a staged manner throughout the Southland region. Based on the 2011 monitoring results, it is recommended that monitoring continue as outlined below:

- **Fine Scale Monitoring**. Complete the four years of the scheduled baseline monitoring at Orepuki Beach. Next monitoring is scheduled for February 2012. After the baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on beach condition ratings.

6. MANAGEMENT

The fine scale monitoring at Orepuki Beach reinforced the need for management of the beach habitat. Maintenance of a healthy beach ecology and an increase in habitat diversity is to be encouraged by minimising the likely detrimental effects of stressors (e.g. control on vehicle access to the beach to prevent impacts to Toheroa, climate change, and reduced sediment supplies from the Waiau River). Also, by encouraging a riparian strip of native vegetation between the beach and the adjacent farmland at the base and top of the cliffs would enhance species diversity.

7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with organising and editing from Greg Larkin (Coastal Scientist, Environment Southland).

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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	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric.	N/A

* 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. INTERIM CONDITION RATINGS

The condition ratings are designed to be used in combination with each other and with other information to evaluate overall beach condition and deciding on appropriate management responses. Expert input is required to make these evaluations. The ratings are based on a review of monitoring data, use of existing guideline criteria (e.g. ANZECC (2000) sediment guidelines, Borja et al. 2000), and expert opinion. They indicate the type of condition the monitoring results reflect, and also include an "early warning trigger" so that ES is alerted where rapid or unexpected change occurs.

Benthic Community Index (Organic Enrichment)

Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in N and S hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation. In particular, 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, in low-salinity locations and naturally enriched sediments.

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 in Appendix 2 and 3.

BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING			
ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE
Very Low	Intolerant of enriched conditions	0-1.2	Monitor at 5 year intervals after baseline established
Low	Tolerant of slight enrichment	1.2-3.3	Monitor 5 yearly after baseline established
Moderate	Tolerant of moderate enrichment	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
High	Tolerant of high enrichment	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Very High	Azoic (devoid of invertebrate life)	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Trend to slight enrichment	>1.2	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and 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. In addition, nutrient availability in beaches is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process.

RPD CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan (ERP)

APPENDIX 3. 2011 DETAILED RESULTS

Station Locations

Orepuki Beach A						
Station	A1	A2	A3	A4	A5	A6
NZTM East NZGD2000	1194273	1194238	1194215	1194192	1194171	1194152
NZTM North NZGD2000	4860369	4860369	4860372	4860370	4860373	4860372

Orepuki Beach B						
Station	B1	B2	B3	B4	B5	B6
NZTM East NZGD2000	1194270	1194239	1194208	1194186	1194162	1194144
NZTM North NZGD2000	4860272	4860269	4860270	4860271	4860278	4860277

Physical and chemical results for Orepuki Beach, 26 February 2011.

Transect	Station	RPD	Salinity	Mud	Sands	Gravel
		cm	ppt		%	
Orep A	1	>15	33	1.3	98.6	< 0.1
	2	>15	33	1.6	98.4	< 0.1
	3	>15	33	1.1	98.9	< 0.1
	4	>15	33	1.1	98.9	< 0.1
	5	>15	33	1.2	98.8	< 0.1
	6	>15	33	0.9	99.1	< 0.1
Orep B	1	>15	33	1.1	98.9	< 0.1
	2	>15	33	1	99	< 0.1
	3	>15	33	1.1	98.9	< 0.1
	4	>15	33	1.3	98.7	< 0.1
	5	>15	33	1.8	98.2	< 0.1
	6	>15	33	1.1	98.9	< 0.1

Beach Profile Results for Orepuki Beach, 26 February 2011.

Site (both A and B)	Height Above Low Water (mm)	Distance from Base of Cliff (m)
A6	0	131
A5	270	111
A4	700	86
A3	970	72
	1370	54
A2	1900	36
	2470	18
	2920	9
A1	3150	5
Foredune	3670	3
Base of Cliff (hind-dune)	3420	0

APPENDIX 3. 2011 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.1089m² core) - Orepuki Beach Transects A and B (26 Feb 2011) (Note: NA = Not Assigned)

	Species	AMBI	A1a	A1b	A1c	A2a	A2b	A2c	A3a	A3b	A3c	A4a	A4b	A4c	A5a	A5b	A5c	A6a	A6b	A6c
NEMERTEA	Nemertea sp.#1	III				2	1					1							1	
POLYCHAETA	*Aglaophamus macroura*	II								1	1									
	Hemipodus simplex	II																		
	Phyllodocidae sp.#2	II															1			
	Sigalion ovigerum	II																	1	
BIVALVIA	*Paphies ventricosa*	II							1	2	1	2				1			2	3
CRUSTACEA AMPHIPODA	*Talorchestia quoyana*	III	97	142	41															
	Waitangi rakiura	I				81	171	122	167	6	13	172	51	62	8	2	13	5	2	1
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	NA																		
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA	9	16	9															
	Macrochiridothea uncinata	II										1			1			2		
	Pseudaega punctata	I		1	1	29	57	39	4	5	1	3	1	2	2	1	3		2	1
INSECTA COLEOPTERA	*Carabidae* sp.#1	NA		1	1															
	Chaerodes trachyscelides	NA		2																
	Total species in sample		2	5	4	3	3	2	3	4	4	5	2	2	3	3	3	2	5	3
	Total individuals in sample		106	162	52	112	229	161	172	14	16	179	52	64	11	4	17	7	8	5

	Species	AMBI	B1a	B1b	B1c	B2a	B2b	B2c	B3a	B3b	B3c	B4a	B4b	B4c	B5a	B5b	B5c	B6a	B6b	B6c
NEMERTEA	Nemertea sp.#1	III					2										1			
POLYCHAETA	*Aglaophamus macroura*	II					2				1					1				
	Hemipodus simplex	II															1			
	Phyllodocidae sp.#2	II																		
	Sigalion ovigerum	II																	1	
BIVALVIA	*Paphies ventricosa*	II							2		1									
CRUSTACEA AMPHIPODA	*Talorchestia quoyana*	III	15	74	107															
	Waitangi rakiura	I				73	101	111	186	319	229	6	9	34	7	2	7	3	3	2
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	NA																1		
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA	2	2	1															
	Macrochiridothea uncinata	II																		1
	Pseudaega punctata	I				43	57	46	4	2	1	11	7	8	3	6	1	1	2	1
INSECTA COLEOPTERA	*Carabidae* sp.#1	NA																		
	Chaerodes trachyscelides	NA																		
	Total species in sample		2	2	2	2	4	2	3	2	4	2	2	2	2	3	4	3	3	3
	Total individuals in sample		17	76	108	116	162	157	192	321	232	17	16	42	10	9	10	5	6	4

AMBI Sensitivity to Stress Groupings (from Borja et al. 2000)

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.

APPENDIX 4. INFAUNA CHARACTERISTICS

Group	Species	AMBI Group	Details
Nemertea	Nemertea sp.	III	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions.
Polychaeta	*Aglaophamous macroura*	II	An intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate. Feeding type is carnivorous.
	Hemipodus simplex	II	A glycerid, or bloodworm, found in clean sand sites in estuaries and on clean sandy beaches. Are cylindrical, very muscular and active large predators and detritivores.
	Phyllodocidae	II	The phyllodocids are a colourful family of long, slender, and very active carnivorous worms characteristically possessing enlarged dorsal and ventral cirri which are often flattened and leaf-like (paddleworms). They are common intertidally and in shallow waters.
	Sigalion ovigerum	II	A polychaete worm belonging to the Suborder Phyllodicidae, Family Sigalionidae. Sigalionids are predatory scale worms found burrowing in sands and muds. Classified as a subtidal species (see NIWA's Worm Register, http://www.annelida.net/nz/Polychaeta/Family/F-Sigalionidae.htm.
Bivalvia	*Paphies ventricosa*	II	A large bivalve mollusc of the family Mesodesmatidae, endemic to New Zealand. It is found in both the North and South Islands, but the main habitat is the west coast of the North Island. The best grounds are wide fine-sand beaches where there are extensive sand-dunes, enclosing freshwater, which percolates to the sea, thereby promoting the growth of diatoms and plankton.
Crustacea	*Actaecia euchroa*	NA	A very small isopod which makes shallow burrows in the supralittoral zone. The species may be active during the day on damp sand and if disturbed rolls itself up into a ball.
	Macrochiridothea uncinata	II	An idoteid isopod from the lower intertidal of exposed beaches.
	Pseudaega punctata	i	An isopod of the Family Eurydicidae, a scavenger that is fiercely carnivorous, biting any animal it comes upon including humans. When the tide is in it actively swims about hunting food, but while the tide is out it lies buried in the sand. Often a numerically dominant component of the middle and upper intertidal on New Zealand exposed sandy beaches. Common on Stewart Island beaches. Fills a similar niche to the Northern hemisphere *Eurydice pulchra* and on this basis is conservatively classified as highly intolerant of excessive sediment, synthetic chemicals, nutrients and low oxygen conditions (Fincham 1973, Budd 2007).
	Colurostylis sp #1	II	A cumacean that prefers sandy environments - 0-5% mud with range 0-60% mud**. Cumacea is an order of small marine crustaceans, occasionally called hooded shrimp. Their unique appearance and uniform body plan makes them easy to distinguish from other crustaceans.
	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 (slight unbalance situations).
	Waitangi rakiura	I	A phoxocephalid amphipod that inhabits the intertidal, especially of exposed beaches. Is a sand-burrowing omnivore.
Insecta	*Chaerodes trachyscelides*	NA	A highly specialised, flightless burrowing coleopteran beetle confined to the narrow strip of sand at and just above high water level on sandy marine beaches in New Zealand.
	Carabidae sp #1	NA	A large, cosmopolitan family of ground beetles, with more than 40,000 species worldwide. They are often shiny black or metallic and are found under the bark of trees, under logs, or among rocks or sand by the edge of ponds and rivers. Most species are carnivorous and actively hunt for any invertebrate prey they can overpower.