coastalmanagement

Orepuki Beach

Fine Scale Monitoring 2011/12

Prepared for
Environment Southland
August 2012

Cover Photo: Orepuki Beach.

Looking south along Orepuki Beach towards Monkey Island.

Orepuki Beach

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Prepared for
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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 two years (2011 and 2012) of fine scale monitoring for Orepuki Beach, an intermediate/dissipative type beach at the southeastern end of Te Waewae Bay. It is a key beach in Environment Southland's (ES) long-term coastal monitoring programme and uses sediment health as a primary indicator of beach condition. The primary indicators are i. beach morphometry or profile, ii. grain size, and iii. 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 sea 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 but with a low risk of being adversely impacted). The following section summarises monitoring results for the two intertidal sites at Orepuki Beach for 2011 and 2012.

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. The results of the beach profile analysis in 2012 showed a greater volume of sands than in 2011, and indicate sand deposition and erosion varies from year to year.
- **Sediment Type:** The beach was predominantly sand (97%), with a very low mud content (3%), similar to that reported previously (e.g. Keeley et al. 2002). Sand size fractions in 2012 were 68% fine sand (which provides important Toheroa habitat), 30% medium sand, and 0.5% coarse sand.
- **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 with 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 1986 beach invertebrate monitoring results (O'Shea 1986), in 2012 there were reduced numbers of toheroa and very few ghost shrimp. Possible reasons for this are changes to physical habitat through dynamic erosion/accretion processes, reduced fine sediment supply due to the Waiau River flow diversion, harvesting (legal and illegal), climate change (sea level rise, altered wave climate, storm events), and vehicle damage. Periodic diebacks of Toheroa are also known to occur (e.g. a 10-15% population reduction in July 2009).
- **Sediment Oxygenation:** The Redox Potential Discontinuity (RPD) layer was relatively deep >15cm depth) at all site, indicating sediments were well oxygenated.

BEACH CONDITION AND ISSUES

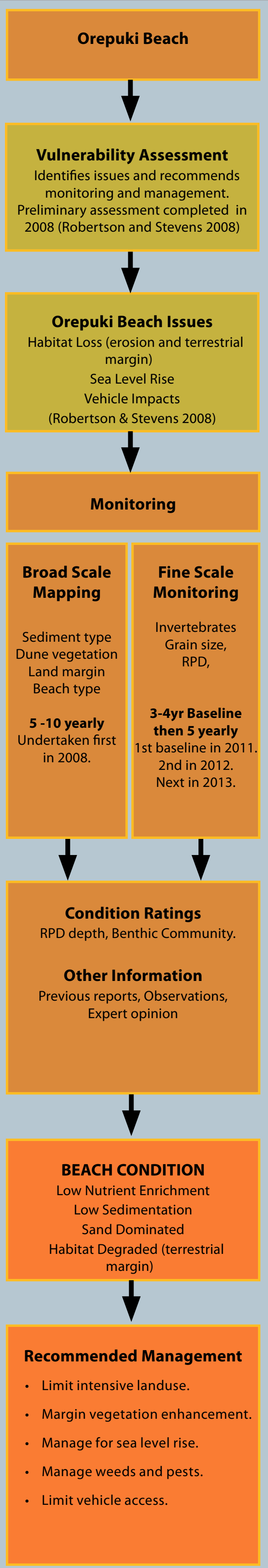
Overall, the findings indicate a sandy beach with the profile changing from year to year. Its invertebrate biota was relatively diverse and typical of exposed, nutrient-poor, sandy beaches, but has changed since 1986. Further changes to biota can be expected given the likelihood of continued changes to physical habitat, particularly through predicted erosion exacerbated by climate change (sea level rise, altered wave climate, storm events) and the Waiau River flow diversion.

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 the 4 year annual fine scale monitoring baseline continue until completed in 2014. After the baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on beach condition ratings. The next monitoring is scheduled for Jan/February, 2013.

The fine scale monitoring reinforced the need for management of the beach habitat. 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 by 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 the latter two stressors, 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, where not precluded by cliff areas.

1. INTRODUCTION



Developing an understanding of the condition and risks to coastal habitats is critical to the management of biological resources. The "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, sea 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. It extends 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 two years of intertidal fine scale monitoring of Orepuki Beach sites (first undertaken in February 2011 - see Robertson and Stevens (2011), and repeated in January 2012). The monitoring area was located approximately 300m east of Orepuki township (Figure 1). Monitoring was undertaken by measuring physical and biological parameters collected from the beach along two transects from the supratidal (the shore area immediately above the high-tide) to low water. The report is the second of a proposed series, which will characterise the baseline fine scale conditions in the beach over a 4 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 New Zealand beaches and dunes.

The key stressors of beaches and dunes are; changes in sediment supply, sea level and sea temperature rise, increased wave climate, vehicle use, introduced species (particularly 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. land clearance or trapping by 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 surrounding beach and its ecology by increasing erosion at the ends of seawalls 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 (e.g. 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, and 10-20% mortality of adults under vehicle tracks, with greater mortality in softer sand (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 dominant 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.

1. Introduction (Continued)

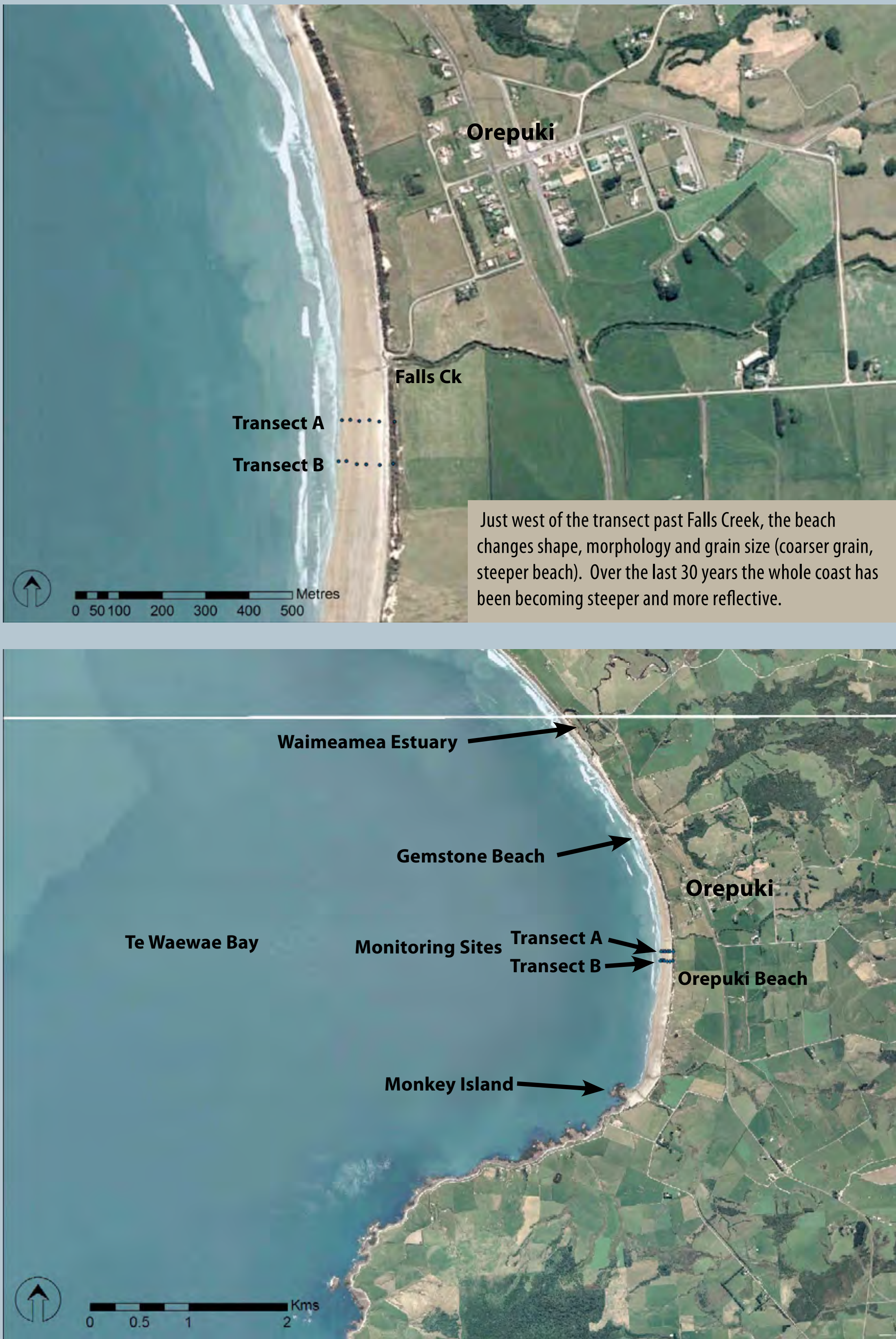


Figure 1. Location of fine scale monitoring sites at Orepuki Beach: close-up (top) and broad scale view (bottom). Photo: LINZ.

1. Introduction (Continued)

Table 2. Summary of broad and fine scale beach indicators (those used for Orepuki Beach fine-scale are shaded).

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*) 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 for 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. 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.

Location of fine scale sites at 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 both short and long term changes. 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 4 year baseline of annual monitoring has been recommended, after which a review will be undertaken and a likely shift to 5 yearly monitoring.

Sampling was undertaken by two scientists, during relatively calm sea conditions, on 23 January 2012 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 (supratidal zone).
- Sampling started in the supratidal zone at high tide, and continued into the intertidal zone following the receding water down the beach.
- Intertidal sampling was undertaken 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 (tied back to a fixed point for repeat surveys), 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 sediment (approx. 250gms) was collected from the top, middle and bottom of each replicate infauna core 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 used - the benthic community tolerance to organic enrichment, and the degree of sediment oxygenation as indicated by the redox discontinuity profile (RPD) (Appendix 2). It is recognised that on wave dominated beaches, physical disturbance is high, and conditions of elevated organic enrichment and low sediment oxygenation are generally uncommon. In addition, the number of coastal macrofauna species that have been assigned to enrichment and fine sediment tolerance groups is small. Therefore the interim ratings need to be interpreted in tandem with other observations (e.g. presence of organic matter on the sediment surface, frequency and magnitude of storm events, changes in sediment grain size).

3. RESULTS AND DISCUSSION

The results of the fine scale monitoring of two transects at Orepuki Beach on 23 January 2012 are presented below. Detailed results are presented in Appendix 3.

1. MORPHOMETRY

The morphometry of the Orepuki Beach transects for 2011 and 2012 is presented in Figure 2, along with historical data from O'Shea (1986). In 2012 the beach was backed by a 1-2m high x 5-7m wide foredune covered with marram grass. Immediately behind the foredune the ground rose steeply into 20m high, partially vegetated, sandstone cliffs. The intertidal area was 130-180m wide, with a gradual slope in the lower half and steeper in the upper. Shingle and cobble was present in sand on the upper shore.

Transects A and B both show an increase in sand deposition from 2011 (0.24-0.84m), with the profile at Transect A indicating the beach had more sand depth than reported by O'Shea (1986). These results show that sand deposition and erosion varies from year to year.

Beach profile information is limited at present as ES do not routinely measure beach profiles, but instead take aerial photos so they can analyse changes in dune width in the future. As such, the recommended monitoring will provide information that tests 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).

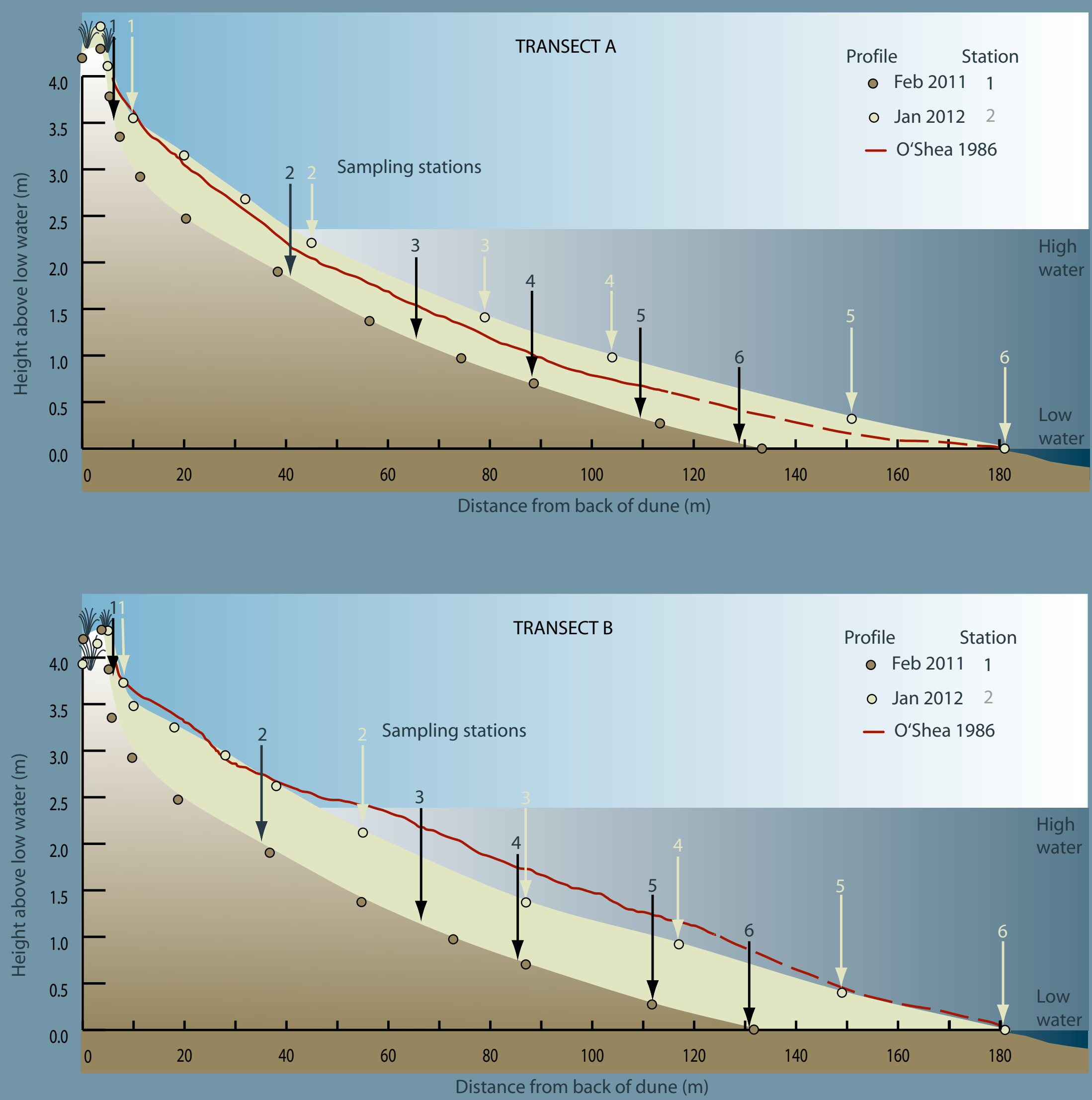


Figure 2. Cross-section of transects at Orepuki Beach, 1986, 2011 and 2012.

3. Results and Discussion (Continued)

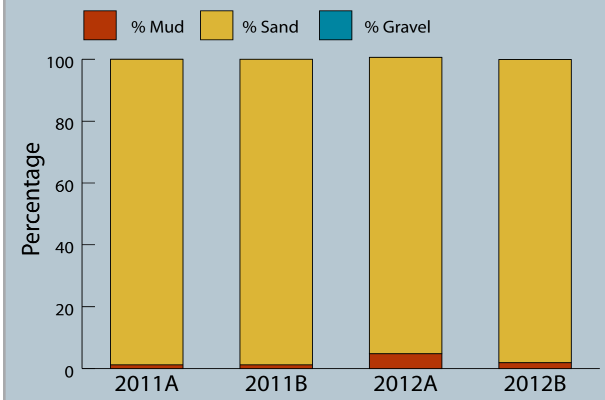


Figure 3. Grain size of sediments at Orepuki Beach, 2011 and 2012.

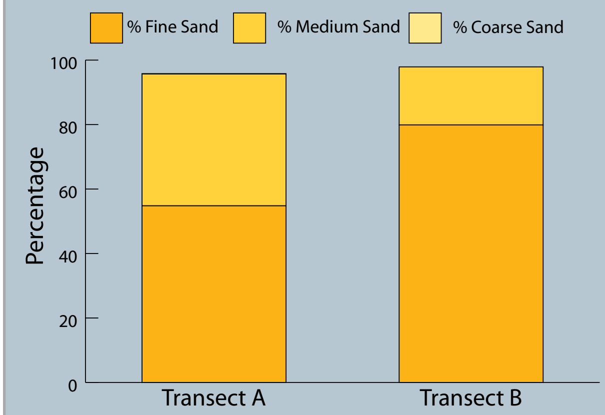


Figure 4. Sand size fractions at Orepuki Beach, 2012.

Collecting macrofauna

Table 3. Macrofauna results (means) for Orepuki Beach, 23 January 2012.

Site	Reps	Mean Total Abundance/m²	Mean Number of Species/Core
2011 Orepuki Beach A	18	76.2	3.2
2011 Orepuki Beach B	18	83.3	2.6
2012 Orepuki Beach A	18	55.1	2.4
2012 Orepuki Beach B	18	72.3	2.9

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).

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.

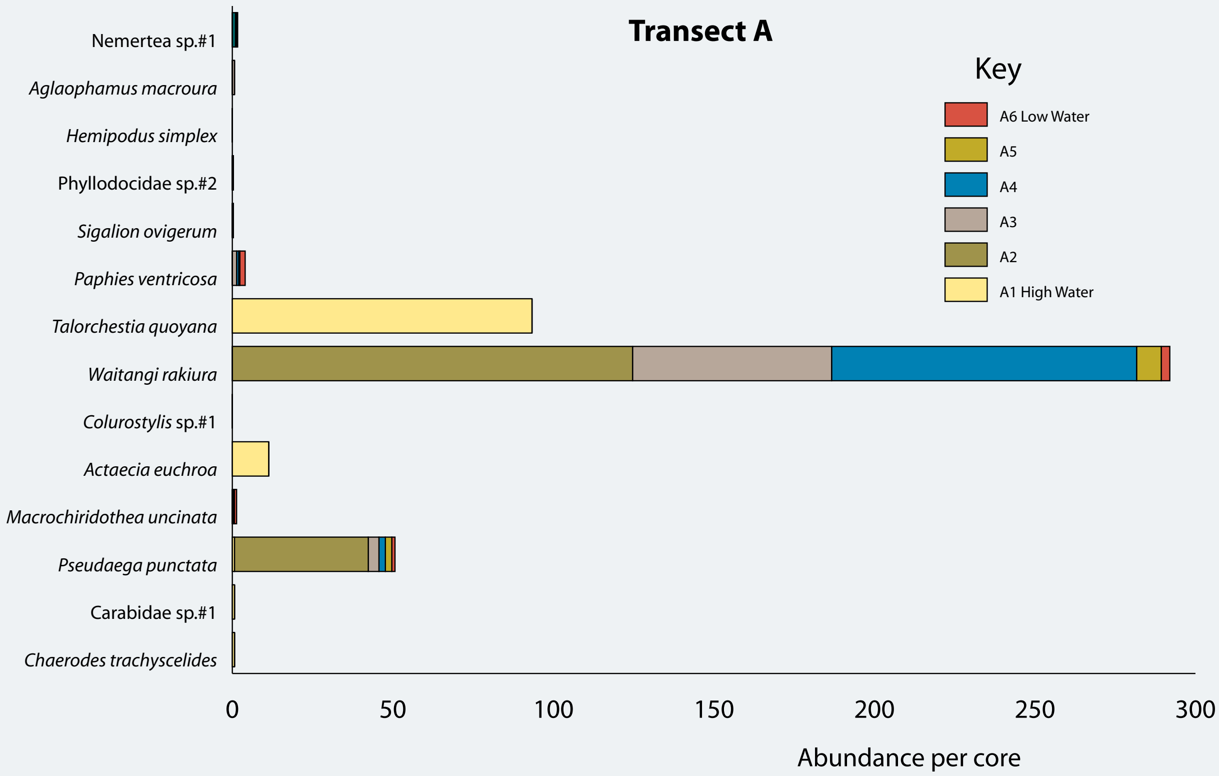
The Orepuki coastal environment, with its exposed nature and history of reduced sediment supplies from the Waiau catchment, is expected to be more at risk from the former of these stressors. Although the waters bathing the coastal areas during high rainfall periods tend to have a high suspended solids 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 2012 grain size monitoring results which showed that all sites were dominated by sandy sediments (97% sand), with very low mud contents (3%) (Figure 3). Analysis of the sand fraction (particles between 63µm and 2mm) showed the majority of the sand was in the fine sand category (68%), with moderate amounts in the medium (30%), and a very small amount in the coarse category (0.5%) - Figure 4.

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. These results indicate that changes in the grain size composition have not changed significantly over the past 10 years. Future monitoring will enable continued assessment of this important indicator.

3. SEDIMENT BIOTA

The benthic invertebrate community at Orepuki Beach in 2012 (Table 3, Figures 6 and 7, Appendix 4) was typical of a "normal" exposed beach community where inputs of nutrients or organic matter are low. It consisted of species that are usually present in low-moderate numbers, and included filter feeders, omnivores, carnivores and scavengers. The 2012 results showed that the mean total abundance per m² ranged from 55.1 at Transect A to 72.3 at Transect B. This was slightly lower than the range reported in 2011 (76.2 - 83.3). The abundance (10-2,750 animals per m²) was low at some sites and high at others, with low diversity (1-6 species per core) at both sites.

The community was dominated by organisms that prefer clean, well-oxygenated sand, a deep RPD, and low organic enrichment levels. The dominant organisms were crustaceans (isopods and amphipods) (Figures 6 and 7). The most sensitive species to both physical and chemical change is expected to be the toheroa.



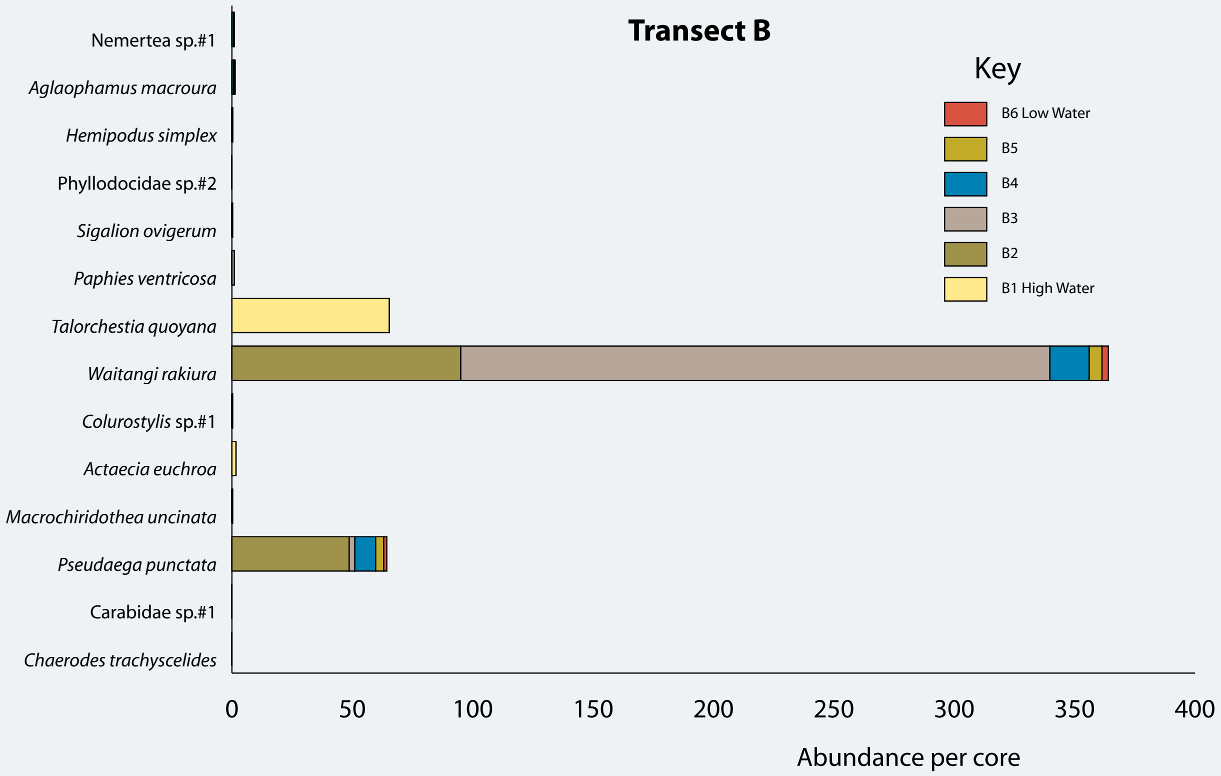
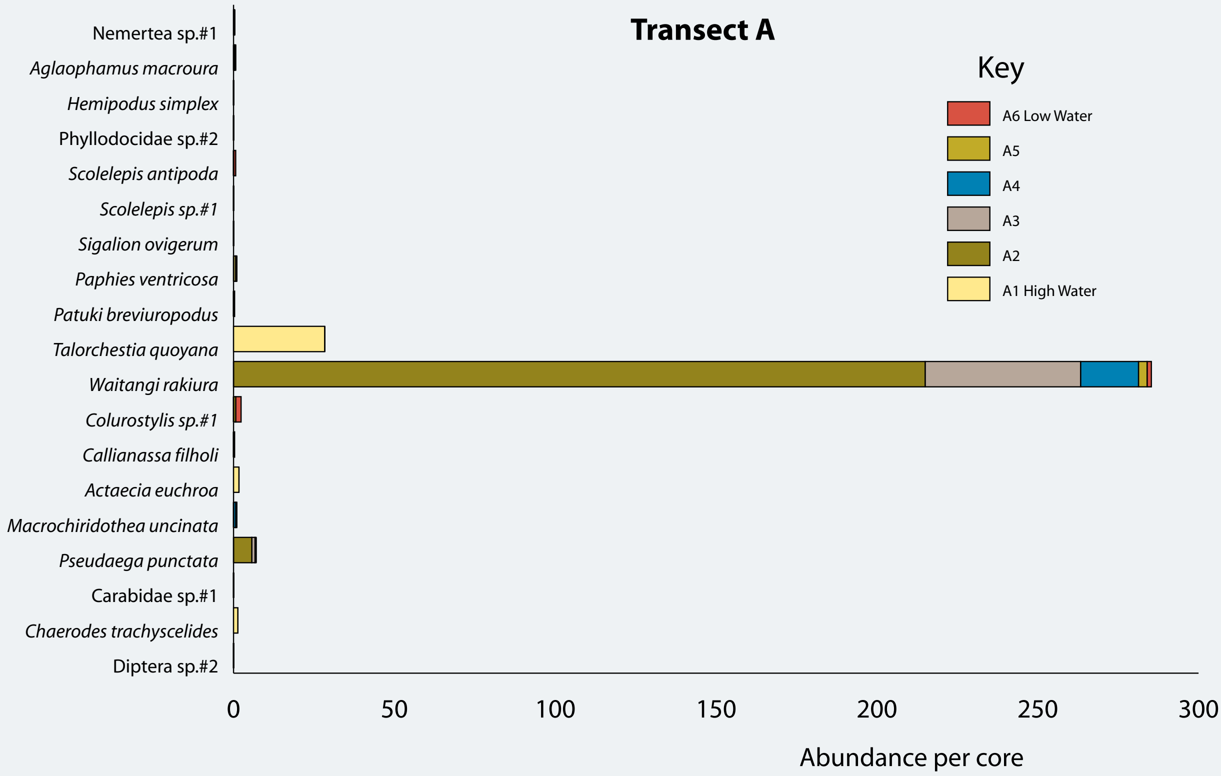


Figure 5. Mean abundance per core of macrofauna species at each site on Transects A and B Orepuki Beach - 26 February 2011.

3. Results and Discussion (Continued)



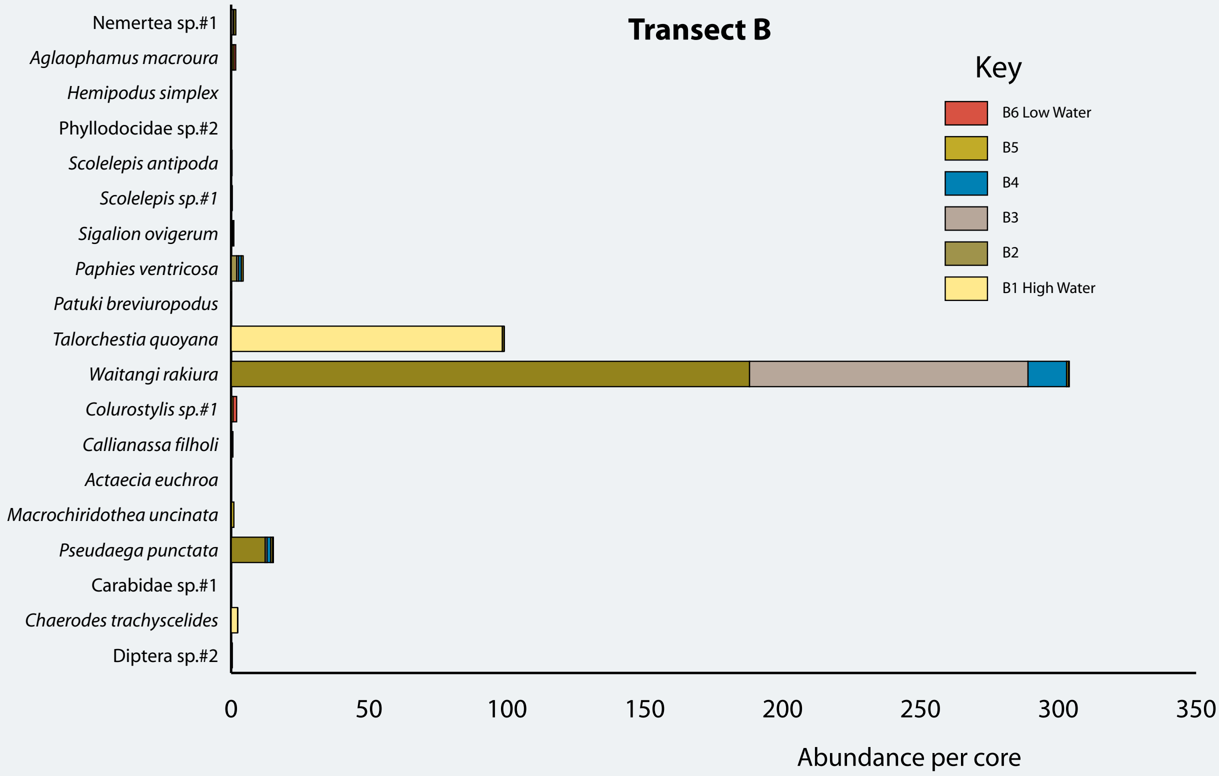


Figure 6. Mean abundance per core of macrofauna species at each site on Transects A and B Orepuki Beach - 23 January 2012.

The phoxocephalid amphipod *Waitangi rakiura* and the sand hopper *Talorchestia quoyana* dominated the fauna at the mid to high water sites, with the scavenging isopod *Pseudaega punctata* present in small numbers. 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 in very low numbers at low tide sites. Its presence was noted in surveys in 1986 and 1997 (Robertson 1997) and yet it was not recorded in 2011. A number of potential stressors could explain this finding, including reduced fine sediment supply, sediment mobility, toxicity (toxic algal blooms), vehicle crushing, and competition. One hypothesis presented by Peterson (1977) is that *Paphies* and *Callianassa* compete with each other for space and food in the intertidal zone, both feeding on the diatom *Chaetocerus armatus*, but given the low numbers of *Paphies,* it is an unlikely explanation here.

Toheroa (*Paphies ventricosa*) were present at 20% of Transect A, and 50% of Transect B mid to low tide sites. When present, densities were low (approximately 1-2 per 0.1m^{-2} quadrat), and most were juveniles. This reflects a reduction to that reported by O'Shea (1986) who recorded 1986 densities of juveniles at 3 per 0.1m^{-2} or more, with adults rarely exceeding 3-6 per m^{-2}. This reduction may be a result of bed patchiness, and periodic diebacks of Toheroa are also known to occur (e.g. a 10-15% population reduction in July 2009 - Greg Larkin, ES Coastal Scientist pers. comm. 2012). However, a recent survey (Futter and Moller 2009) concludes that declines have been accelerated due to the combined effect of reduced Waiau River flows combined with some other ecological factor that has also operated regionally to depress the population at both Te Waewae Bay and Oreti Beach. It could be attributed to a number of stressors including: storm events, harvesting (legal and illegal), pollution and crushing by vehicles (Keeley et al. 2002). A recent pilot study undertaken on Oreti Beach looking at vehicle impacts on Toheroa indicated up to 80% mortality of juveniles under vehicle tracks, and 10-20% mortality of adults under vehicle tracks, with greater mortality in softer sand (Greg Larkin, pers. comm. 2012). 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.

Multivariate techniques have been used to further to explore differences in benthic invertebrate community composition and abundance at Transects A and B across the 2 years of monitoring at each of the 6 shore levels. The NMDS plot presented in Figure 8 shows that, as expected, benthic invertebrate community composition was clearly related to tidal height, with the supratidal site (level 1) obviously distinct from the 5 intertidal level stations. Transects A and B grouped closely together indicating little difference between the transects. Once the baseline is completed the data will be analysed for any trends showing differences between the years.

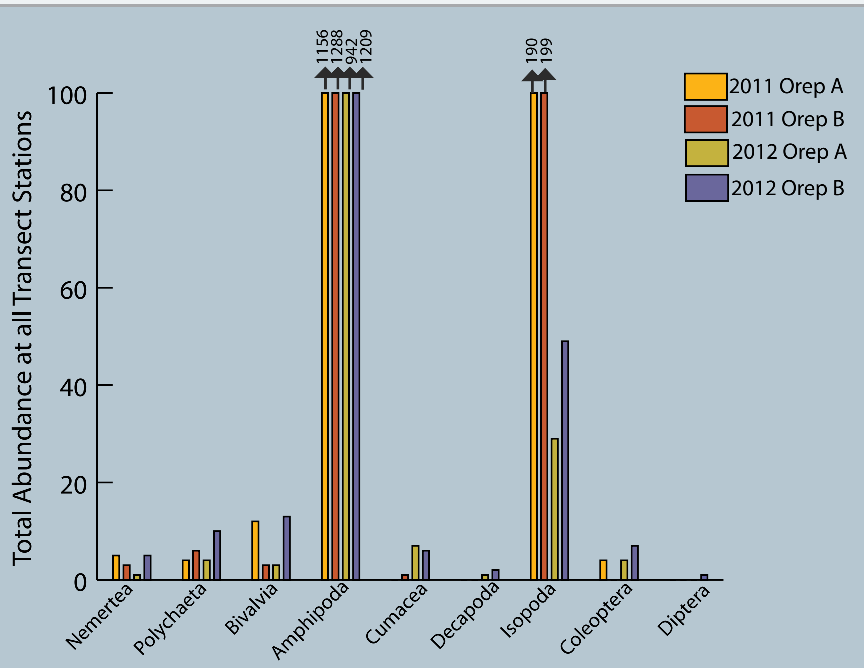


Figure 7. Total abundance of macrofauna groups at Orepuki Beach (sum of all 6 stations at each site), 2011-12.

3. Results and Discussion (Continued)

Figure 8 shows the relationship among samples in terms of similarity in macro-invertebrate community composition at Transects A and B for the two years of sampling (2011 and 2012). The plot shows the means of the 3 replicate samples for each tide level station and is based on Bray Curtis dissimilarity and square root transformed data. The approach involves multivariate data analysis methods, in this case nonmetric multidimensional scaling (NMDS) using PRIMER vers. 6.1.10. The analysis basically plots the site and abundance data for each species as points on a distance-based matrix (a scatterplot ordination diagram). Points clustered together are considered similar, with the distance between points and clusters reflecting the extent of the differences. The interpretation of the ordination diagram depends on how good a representation it is of actual dissimilarities i.e. how low the calculated stress value is. Stress values greater than 0.3 indicate that the configuration is no better than arbitrary and we should not try and interpret configurations unless stress values are less than 0.2.

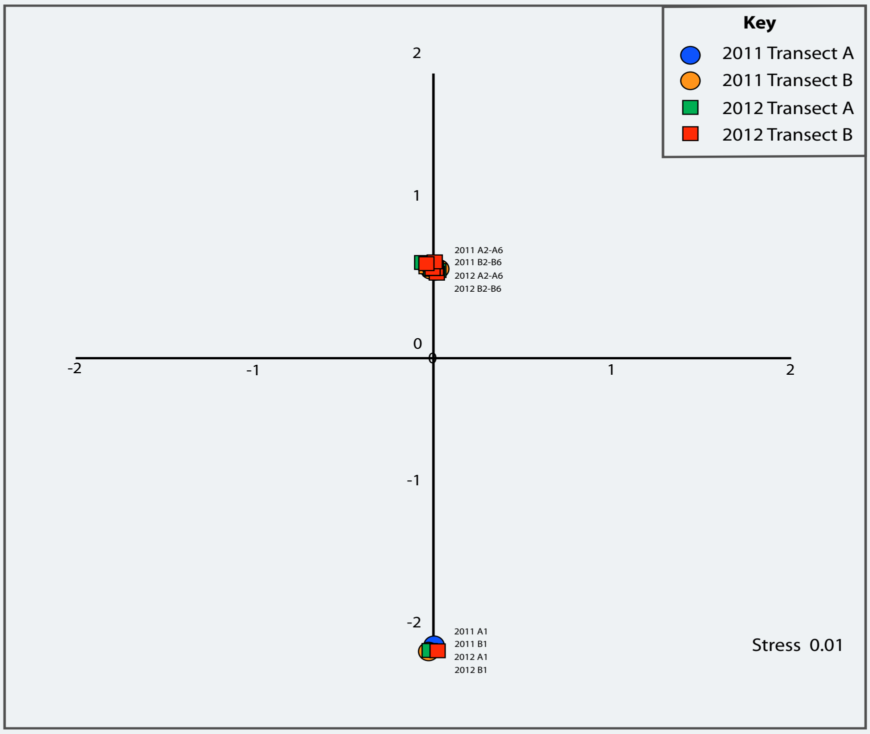


Figure 8. NMDS plot for Orepuki Beach macroinvertebrates, 2011-2012.

As is typical for exposed sandy beaches, the benthic invertebrate organic enrichment rating was in the "low to very low" category for 2012 (Figure 9). 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.

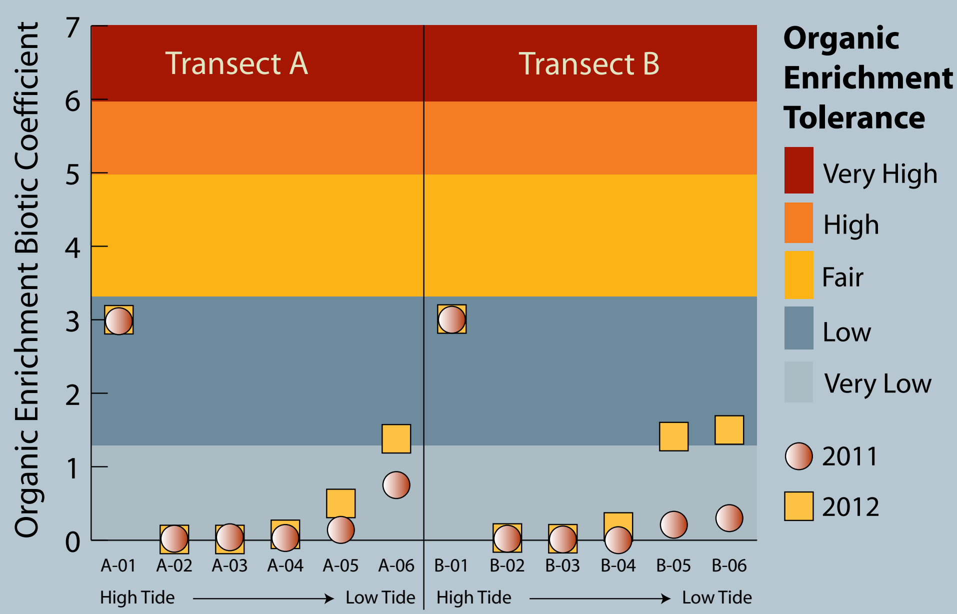


Figure 9. Benthic invertebrate organic enrichment rating, Orepuki Beach, 2011-2012.

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. macroalgal (e.g. sea lettuce) and microalgal blooms, sediment anoxia, increasing muddiness, and benthic community changes are unlikely. In such a low risk situation, the number of primary fine scale indicators for eutrophication is therefore limited to the easily measured RPD depth. The depth of the RPD layer (Figure 10) 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 10 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 2012 RPD results showed that the depth of the RPD at Orepuki Beach was >15cm at all sites and therefore the sediments are 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.

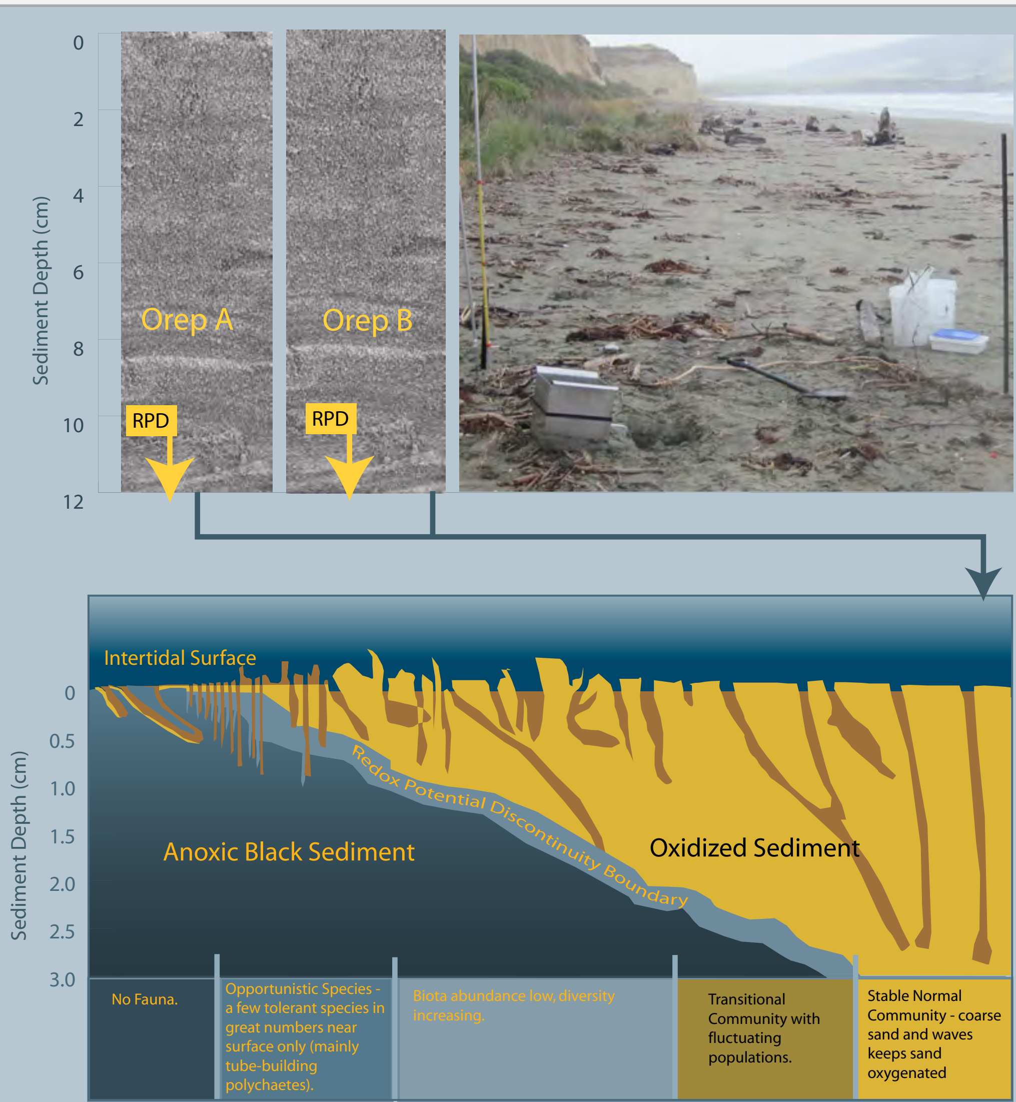
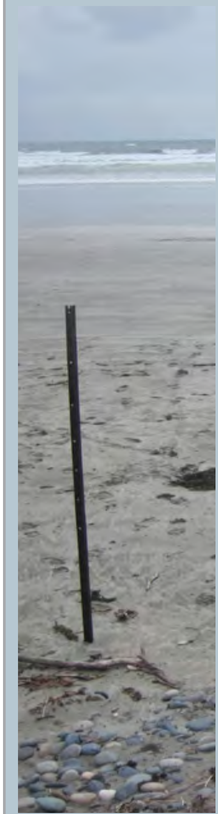


Figure 10. Sediment profiles, depths of RPD, and predicted benthic community type, Orepuki Beach.

4. CONCLUSIONS



The results of the second year of fine scale monitoring for Orepuki Beach, an intermediate/dissipative type beach at the southeastern 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. In 2012, both transects showed an increase in sand deposition (0.24-0.84m) from 2011, and at Transect A the profile has more depth than shown in the 1986 beach profile (O'Shea 1986). These findings show that sand accretion and erosion vary from year to year.
- **Sediment Type:** The beach was predominantly sand (97% sand), with very low mud contents (3%), similar to that reported previously (e.g. Keeley et al. 2002). Sand size fractions in 2012 were 68% fine sand (which provides important toheroa habitat), 30% medium sand, and 0.5% coarse sand.
- **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 with 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 1986 beach invertebrate monitoring results (O'Shea 1986), in 2012 there were reduced numbers of toheroa and very few ghost shrimp. Possible reasons for this are changes to physical habitat through dynamic erosion/accretion processes, reduced fine sediment supply due to the Waiau River flow diversion, harvesting, climate change (sea level rise, altered wave climate, storm events), vehicle damage.
- **Sediment Oxygenation:** The Redox Potential Discontinuity (RPD) layer was relatively deep (>15cm) at all sites, indicating sediments were well oxygenated.

Overall, the findings indicate a sandy beach with the profile changing from year to year indicating the movement of large volumes of sand. Its invertebrate biota was relatively diverse and typical of exposed, nutrient-poor, sandy beaches, but has changed since 1986. Further changes to biota can be expected given the likelihood of continued changes to physical habitat, particularly through predicted erosion exacerbated by climate change (sea level rise, altered wave climate, storm events) and the Waiau River flow diversion.

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 and 2012 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 2013. 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 reinforced the need for management of the beach habitat, as indicated in the 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 by 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 the latter two stressors, it is recommended that a natural vegetation zone be encouraged above high water to provide a buffer between the beach and the adjacent farmland, where not precluded by cliff areas.

7. ACKNOWLEDGEMENTS

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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 Tolerance to 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 TOLERANCE 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. 2012 DETAILED RESULTS

Station Locations

Orepuki Beach A							
Station	**Back Peg**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
NZTM East NZGD2000	1194275	1194266	1194239	1194205	1194179	1194134	1194104
NZTM North NZGD2000	4860370	4860371	4860369	4860372	4860381	4860385	4860390

Orepuki Beach B							
Station	**Back Peg**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
NZTM East NZGD2000	1194282	1194275	1194232	1194198	1194165	1194127	1194090
NZTM North NZGD2000	4860272	4860273	4860277	4860281	4860281	4860288	4860289

Physical and chemical results for Orepuki Beach, 23 January 2012.

Transect	Station	RPD	Salinity	Mud	Fine Sand	Medium Sand	Coarse Sand	Gravel
		cm	ppt			%		
Orep A	1	>15	33	2.6	70.4	26.9	0.1	< 0.1
	2	>15	33	1.8	63.8	34.5	< 0.1	< 0.1
	3	>15	33	9.9	58.1	32	< 0.1	< 0.1
	4	>15	33	4.7	52.6	42.7	< 0.1	< 0.1
	5	>15	33	3.2	53.7	43	0.1	< 0.1
	6	>15	33	2.7	30.3	66.3	0.7	< 0.1
Orep B	1	>15	33	5.4	83.3	11.1	< 0.1	0.3
	2	>15	33	1	97.9	1.1	< 0.1	< 0.1
	3	>15	33	0.8	94.8	4.4	< 0.1	< 0.1
	4	>15	33	0.9	84.2	14.8	< 0.1	< 0.1
	5	>15	33	1.9	65	33	< 0.1	< 0.1
	6	>15	33	1.4	54.2	43.7	0.7	< 0.1

APPENDIX 3. 2012 DETAILED RESULTS (CONTINUED)

Beach Profile Results for Orepuki Beach 2011 and 2012.

Transect A	26 February 2011		23 January 2012	
Distance from Dune Marker (m)	Site	Height above low water (mm)	Site	Height above low water (mm)
0		4295		4235
3.6		4295		4535
5	A1	3870		4110
7		3350		
11		2920	A1	3550
20		2470		3150
32				2680
38	A2	1900		
45			A2	2210
56		1370		
74	A3	970		
79			A3	1410
88	A4	700		
104			A4	980
113	A5	270		
151			A5	320
133	A6	0		
181			A6	0

Transect B	26 February 2011		23 January 2012	
Distance from Dune Marker (m)	Site	Height above low water (mm)	Site	Height above low water (mm)
0		3935		3930
3				4150
5	B1	4295		4290
7		3870		
8			B1	3730
9		3350		
10				3480
13		2920		
18				3250
22		2470		
28				2950
38	B2			2620
40		1900		
55			B2	2120
58		1370		
67	B3			
76		970		
87			B3	1370
90	B4	700		
115	B5	270		
117			B4	920
135	B6	0		
149			B5	400
181			B6	0

APPENDIX 3. 2012 DETAILED RESULTS (CONTINUED)

Infauna (numbers per 0.1089m² core) - Orepuki Beach Transects A and B (23 Jan 2012)

(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
NEMERTEA	Nemertea sp.#1	III						1												
POLYCHAETA	*Aglaophamus macroura*	II									1						1			
	Hemipodus simplex	II																		
	Phyllodocidae sp.#2	II																		
	Scolelepis antipoda	III																1	1	
	Scolelepis sp.#1	III																		
	Sigalion ovigerum	II																		
BIVALVIA	*Paphies ventricosa*	II				1	1					1								
CRUSTACEA AMPHIPODA	*Patuki breviuropodus*	II																1		
	Talorchestia quoyana	III	37	24	24															
	Waitangi rakiura	I				189	197	259	72	62	11	18	22	14	3	2	3	2		2
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	NA														2		1	3	1
CRUSTACEA DECAPODA	*Callianassa filholi*	III																	1	
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA	4	1																
	Macrochiridothea uncinata	II										1		1		1				
	Pseudaega punctata	I				6	8	3			3			1						
INSECTA COLEOPTERA	*Carabidae* sp.#1	NA																		
	Chaerodes trachyscelides	NA	2	2																
	Total species in sample		3	3	1	3	3	3	1	1	3	3	1	3	1	3	2	4	3	2
	Total individuals in sample		43	27	24	196	206	263	72	62	15	20	22	16	3	5	4	5	5	3

Taxa	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	1	1				
POLYCHAETA	*Aglaophamus macroura*	II									1						2	1		1
	Hemipodus simplex	II																		
	Phyllodocidae sp.#2	II																		
	Scolelepis antipoda	III																	1	
	Scolelepis sp.#1	III					1													
	Sigalion ovigerum	II											1		1					1
BIVALVIA	*Paphies ventricosa*	II				2	1	3	1	1		3			1		1			
CRUSTACEA AMPHIPODA	*Patuki breviuropodus*	II																		
	Talorchestia quoyana	III	66	109	120	2														
	Waitangi rakiura	I				166	139	259	238	4	61		21	21	2				1	
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	NA													2			2	2	
CRUSTACEA DECAPODA	*Callianassa filholi*	III															1	1		
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA																		
	Macrochiridothea uncinata	II													3					
	Pseudaega punctata	I				18	6	13	1		1	1	2	1	1		1		1	
INSECTA COLEOPTERA	*Carabidae* sp.#1	NA																		
	Chaerodes trachyscelides	NA	4		3															
INSECTA DIPTERA	Diptera sp.#2				1															
	Total species in sample		2	1	3	4	4	3	4	2	3	2	3	3	7	1	4	3	4	2
	Total individuals in sample		70	109	124	188	147	275	242	5	63	4	24	23	11	1	5	4	5	2

APPENDIX 4. INFAUNA CHARACTERISTICS

	Group and 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.
	Scolelepis antipoda	III	A spionid wom typically found in the intertidal zone at the water's edge.
	Scolelepis sp.#1	III	A small, common, intertidal spionid. Can handle moderately enriched situations******. Tolerant of high and moderate mud contents. Found in Waiwhetu Estuary (black sulphide rich muds), Fortrose Estuary (5% mud).
	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	*Patuki breviuropodus*	II	A oedicerotid amphipod that inhabits the intertidal, especially of semi-exposed beaches. Is a sand-burrowing omnivore. Common on very clean semi-exposed beaches at Stewart Island and therefore is expected to be pollution intolerant.
	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 unbalance situations).
	Waitangi rakiura	I	A phoxocephalid amphipod that inhabits the intertidal, especially of exposed beaches. Is a sand-burrowing omnivore.
	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. Highly intolerant of excessive sediment, synthetic chemicals, nutrients and low oxygen conditions.
	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.
	Callianassa filholi	III	Biffarius (previously Callianassa) filholi is a ghost shrimp of the family Callianassidae, endemic to New Zealand, which grows up to 60 millimetres (2.4 in) long. Ghost shrimp, Decapoda, endemic to NZ. Makes long, semi-permanent burrows between low water of neap and spring. Up to 5cm long it is pale milk white with coral pink. Can't walk on a firm surface. A male and a female normally occupy a burrow. When feeding the shrimp moves close to one of the entrances. Prefers sand isand is usualy found in protected sand beaches near low water.
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.

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.