coastalmanagement

Porpoise Bay Beach

Fine Scale Monitoring 2011/12

Prepared for **Environment Southland**

August 2012

Cover Photo: Porpoise Bay Beach - horse-riding and biking on the sand.

Bathers at Porpoise Bay Beach

Porpoise Bay Beach

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By

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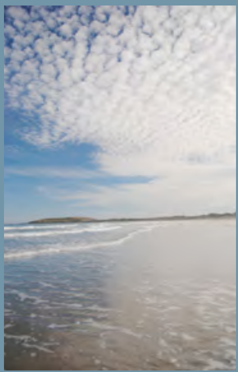
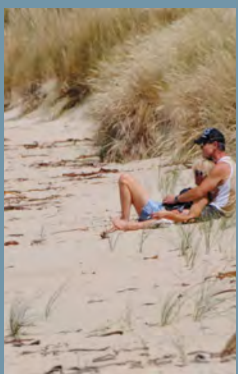
PORPOISE BAY BEACH - EXECUTIVE SUMMARY



This report summarises the results of the 2012 fine scale monitoring for Porpoise Bay Beach, a 5km long, semi-exposed and gradually sloping beach (intermediate/dissipative type) on the Catlins coast. 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 Porpoise Bay Beach for 2010, 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 30m wide marram foredunes with houses to the rear of them. The beach profile indicated accretion in the upper section of the beach in 2011 and 2012 compared to 2010, possibly as a consequence of sand mobilised following recent erosion from around Cooks Creek.
- **Sediment Type:** The beach was predominantly sand (>98.7% sand), with a very low mud content (1%). Grain size in 2010 and 2011 was similar.
- **Benthic Invertebrate Condition:** The benthic community condition was "balanced", with a typical exposed beach invertebrate community, dominated by crustaceans (isopods, amphipods), and moderate numbers of polychaetes. Because nutrients and organic matter were sparse on Porpoise Bay Beach, invertebrate numbers were low and consisted mainly of scavengers and predators. In 2012, there were no major differences compared to the 2010 and 2011 beach invertebrate monitoring results.
- **Sediment Oxygenation:** The Redox Potential Discontinuity (RPD) layer was relatively deep (>15cm depth) at all sites, indicating sediments were well oxygenated.



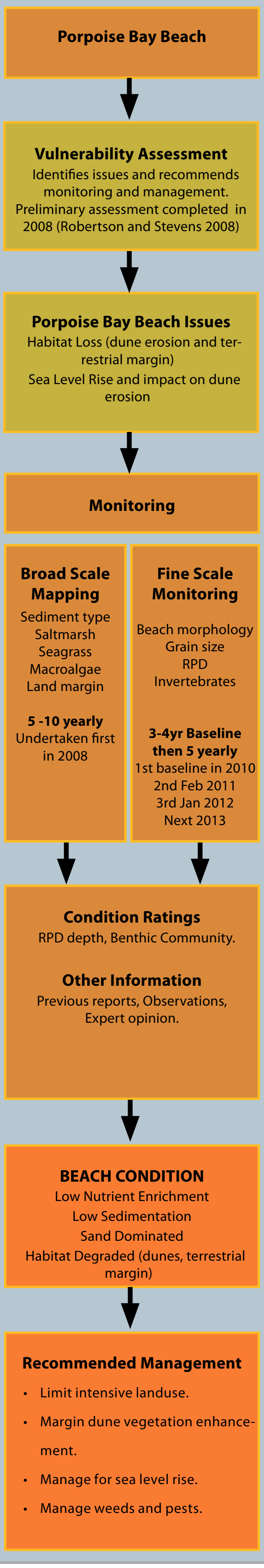
ESTUARY CONDITION AND ISSUES

Overall, the findings indicate a sandy beach which, compared with 2010, had gained sand in the upper shore in the vicinity of the transects in 2011 and 2012, following localised sand redistribution following storms. The beach invertebrate biota was relatively diverse and typical of exposed, nutrient-poor, sandy beaches. In the next 20-100 years changes to the beach fauna are likely, particularly in response to predicted erosion, and a likely steepening of the beach profile, as the effects of climate change take hold (i.e. increased wave climate, sea temperature and sea level rise).

RECOMMENDED MONITORING AND MANAGEMENT

In order to provide a baseline of beach condition on the Catlins coast (particularly in light of predicted accelerated sea level rise) it is recommended that the 4 year fine scale monitoring baseline be completed. After the baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on beach condition ratings. Although not directly monitored at Porpoise Bay Beach, the fine scale monitoring reinforced the need for management of dunes in the general area, as indicated in the Southland Coastal Vulnerability Assessment (Robertson and Stevens 2008). In particular, the current dominance of introduced marram grass as the main sand-binding species on the beach, which has inferior sand-binding and erosion control capabilities compared to the native sand-binders, should be managed. Maintenance of a healthy beach ecology is expected to be substantially enhanced by restoring the dunes to native sand-binding species (e.g. pingao).

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 moderate risk to soft sediment beach shore ecology on the Porpoise Bay coast through predicted accelerated sea level rise, sea temperature change, erosion, and habitat loss. To address this risk, and to provide information on Porpoise Bay beach ecology, annual long term monitoring of Porpoise Bay Beach (a representative intermediate/dissipative type beach ecosystem) was initiated in February 2010. 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. Porpoise Bay Beach tends more to 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.

Porpoise Bay is a partially sheltered, long curving bay with a broad, shallow gradient beach. The beach is backed by 4-5m high marram-covered, eroding sand dunes. The backdunes are generally grazed and dominated by flax, marram and grasses. At the northeastern end, near the mouth of the Waikawa Estuary, the dunes are taller, wider and more ecologically diverse and the beach is more exposed with a steeper gradient. The small settlement of Curio Bay is situated at the more gently sloping and sheltered southwestern end of the beach where the dunes have been developed for residential purposes.

Human use of the beach and associated rocky areas is high in a national context. It is used for walking, swimming, surfing, diving, scientific interest and inshore fishing. Public access is good and it is an important tourist destination. Commercial fishing boats are moored in Waikawa Estuary and access the open sea via Porpoise Bay. In 2008 the area was designated a mataitai reserve (see inset below for details).

Stormwater and sewage leachate from baches and motor camp drain towards the beach but it's impact on the beach ecology is expected to be relatively minor. Monitoring results for enterococci bacteria at Porpoise Bay Beach near the camping ground at the western end showed 100% compliance with bathing guidelines during 2007-2009 (ES water quality monitoring data). Cook Creek discharges to the bay via a small "tidal river mouth" type estuary (area ~1ha). The estuary is narrow and shallow (mean depth 0.5-1m) and situated in lowland grazed pasture and dunes. The estuary discharges onto the upper beach where it forms a shallow lagoon, the size of which varies depending on the extent of mouth constriction.

WAIKAWA/TUMU TOKA MATAITAI RESERVE

A mâtaitai reserve has been placed over waters within Waikawa Harbour, Porpoise Bay, Curio Bay and the lower section of the Waikawa River. Such a reserve has the following effect:

- Excludes commercial fishing;
- Does not exclude recreational fishing;
- Does not prevent access to beaches or rivers not on private land;
- Allows for bylaws governing fishing in the reserve to be made by the Minister of Fisheries.
- Any bylaws approved apply to all, with only one exception (the taking of seafood to meet the needs of a marae).

1. Introduction (Continued)

The current report documents the results of the third year of fine scale monitoring of Porpoise Bay Beach intertidal sites undertaken on 19/20 January 2012. The previous 2 years results are reported on in Robertson and Stevens (2010, 2011). The monitoring area was located at the southwestern end of the beach to provide a site that was accessible, representative of an intermediate/dissipative beach, and isolated from the localised influence of seawalls and discharges (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 third 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.

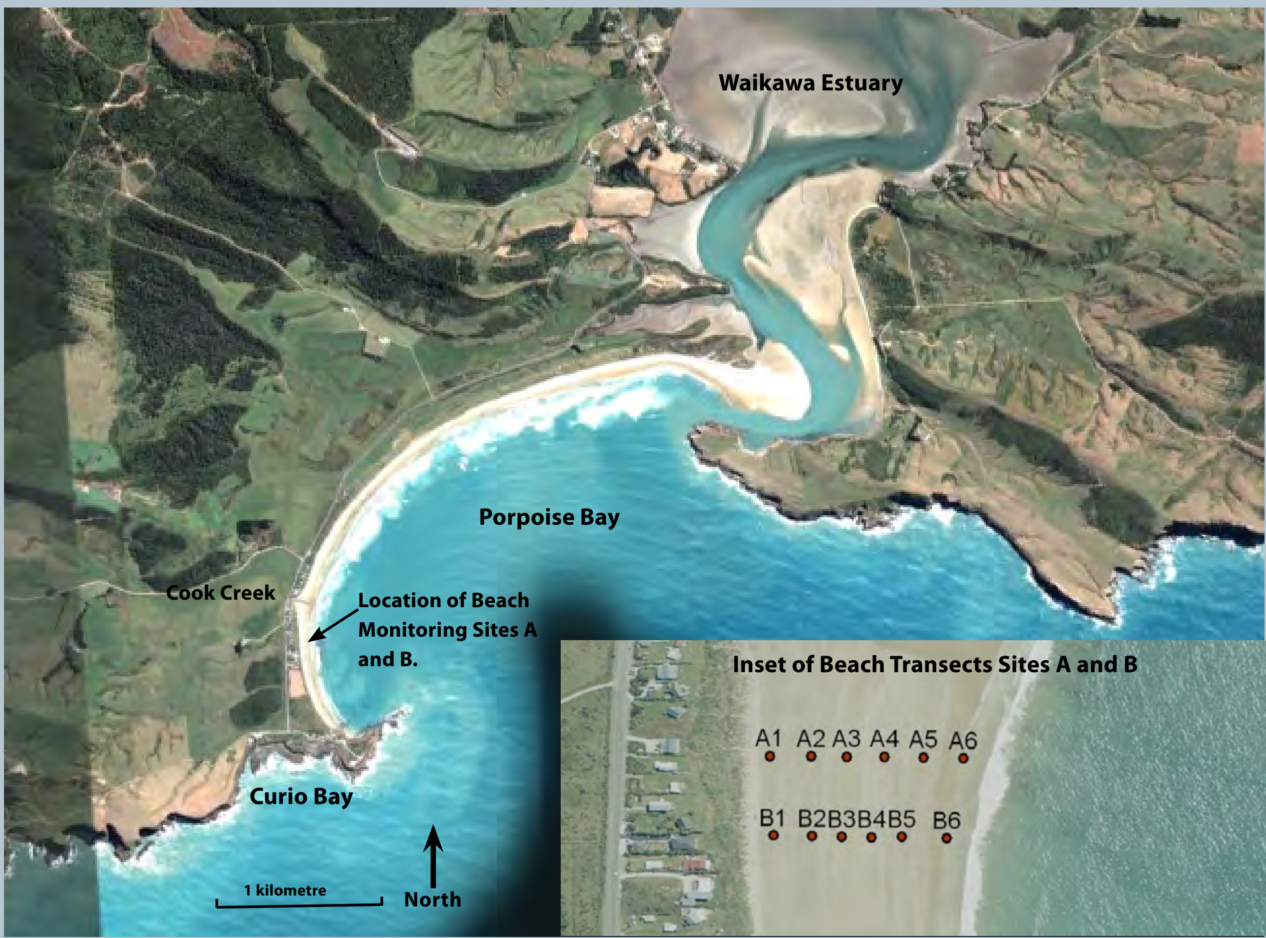
Toxicants.
If potentially toxic contaminant inputs (e.g. heavy metals, pesticides) are excessive, beach biodiversity is threatened and shellfish may be unsuitable for eating. Oil spills and toxic algal blooms are the main toxicant risks to New Zealand beaches.

1. Introduction (Continued)

Table 2. Summary of broad and fine scale beach indicators (those used for Porpoise Bay 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.

Figure 1. Location of fine scale monitoring sites at Porpoise Bay Beach.



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 19/20 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 Porpoise Bay Beach in 2010, 2011 and 2012 are presented below. Detailed results are presented in Appendix 3.

1. MORPHOMETRY

The morphometry of Porpoise Bay Beach transect A for 2010, 2011 and 2012 and transect B for 2010 and 2012 is presented in Figure 2 (the transect B profile was not measured in 2011). Figure 2 shows that the beach at the transect sites was backed by 2-3m high by 30m wide marram foredunes, with houses to the rear. The intertidal area was 100-110m wide, with a very gradual slope in the lower half, and steeper in the upper. At transect A the 2011 and 2012 profiles (particularly above the mid water area) were steeper than in 2010, showing a greater volume of sand on the upper beach (Figure 2 and Appendix 3). At transect B the 2010 and 2012 profiles are similar but again showing more sand deposited on the upper beach in 2012. The accretion at the transect sites since 2010 appears related to recent erosion and relocation of sand from further north along the beach (particularly after flood scouring of Cooks Creek estuary), although historically, it is understood that the area in general is eroding. However, beach profile information is limited as ES do not routinely measure beach profiles, but instead take aerial photos so they can analyse changes in dune width in the future, particularly in response to predicted increased erosion through climate change impacts of sea level rise and increased wave climate.

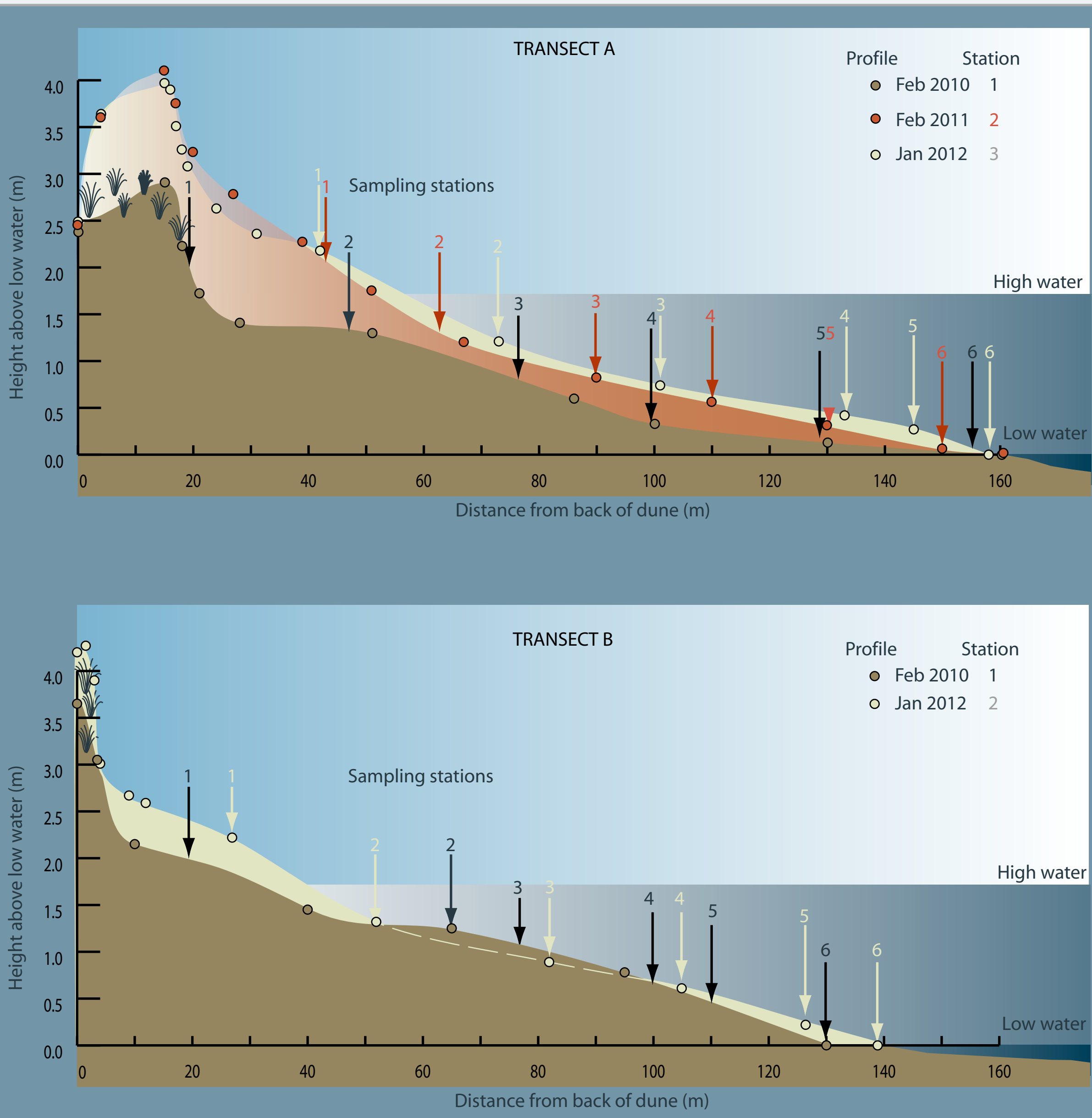


Figure 2. Cross-section of transects at Porpoise Bay Beach, 2010, 2011 and 2012.

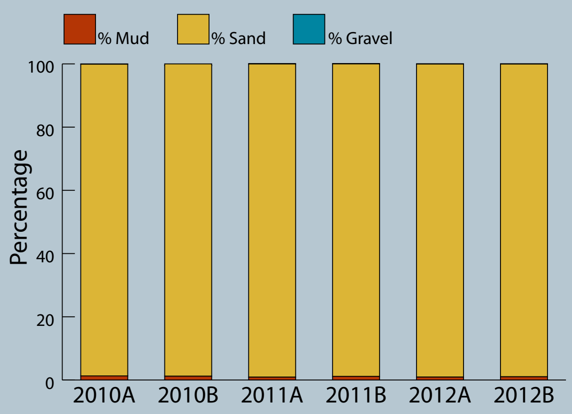


Figure 3. Grain size composition of sediments at Porpoise Bay Beach, 2010, 2011 and 2012.

Transect	Reps	Mean Total Abundance/m²	Mean Number of Species/Core
2010 Porpoise Bay A	18	79	2.6
2010 Porpoise Bay B	18	85	3.1
2011 Porpoise Bay A	18	97	3.6
2011 Porpoise Bay B	18	502	3.8
2012 Porpoise Bay A	18	372	3.8
2012 Porpoise Bay B	18	324	3.9

Table 3. Macrofauna results (means) for Porpoise Bay Beach, February 2010, 2011 and January 2012.

2. SEDIMENT GRAIN SIZE

Sediment grain size is a major determinant of biological habitat. For example, a shift from fine-medium sands to coarse sands can deter some polychaetes from living there (e.g. *Euzonus otagoensis*).

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 Porpoise Bay coastal environment, with its semi-exposed nature and history of erosion is expected to be more at risk from the former of these stressors. Although the waters bathing Southland coastal areas during high rainfall periods tend to have elevated suspended solids content as a result of catchment runoff, deposition of these solids tends to be offshore, or in sheltered embayments, beaches or estuaries. Porpoise Bay Beach, while impacted by floods in the Waikawa River, is both a semi-exposed beach and outside of major river plume deposition areas. It is therefore not expected to be at risk from excessive sedimentation of fine sediments. This was confirmed by the 2012 grain size monitoring results which showed that all sites were dominated by sandy sediments (>98.7% sand), with very low mud contents (1%) (Figure 3). Technically, "sand" refers to particles between 63µm and 2mm, and "fine sand" 125-250µm. The grain size analysis of Porpoise Bay Beach however, did not differentiate between the various sand fractions. It is recommended that this be undertaken in future monitoring in order to better assess the condition of this habitat for species like sediment dwelling polychaetes. Future monitoring will determine if the sediments are becoming coarser over time.

3. SEDIMENT BIOTA

The benthic invertebrate community at Porpoise Bay Beach in 2012 was typical of a "normal" semi-exposed beach community where inputs of nutrients or organic matter are low. These conditions resulted in a low abundance (324-372 animals per m^2) and low diversity (3-7 species per core) community dominated by organisms that prefer clean, coarse, well-oxygenated sand, a deep RPD, and low organic enrichment levels.

As in 2010 and 2011, the dominant organisms included crustaceans (isopods and amphipods), and polychaetes (Figures 4, 5 and 6). However, the communities differed in that in 2012, there was an increase in the abundance of three species; the spionid polychaete, *Scololepis* sp #1, the amphipod *Patuki breviuropodus,* and the sand-hopper, *Talorchestia quoyana*. The isopod, *Actaecia euchroa* was present in reduced numbers and the polychaete, *Euzonus otagoensis* was absent in 2012. The results show a relatively diverse sandy beach community in which abundance and species vary from year to year (Figures 5 and 6).

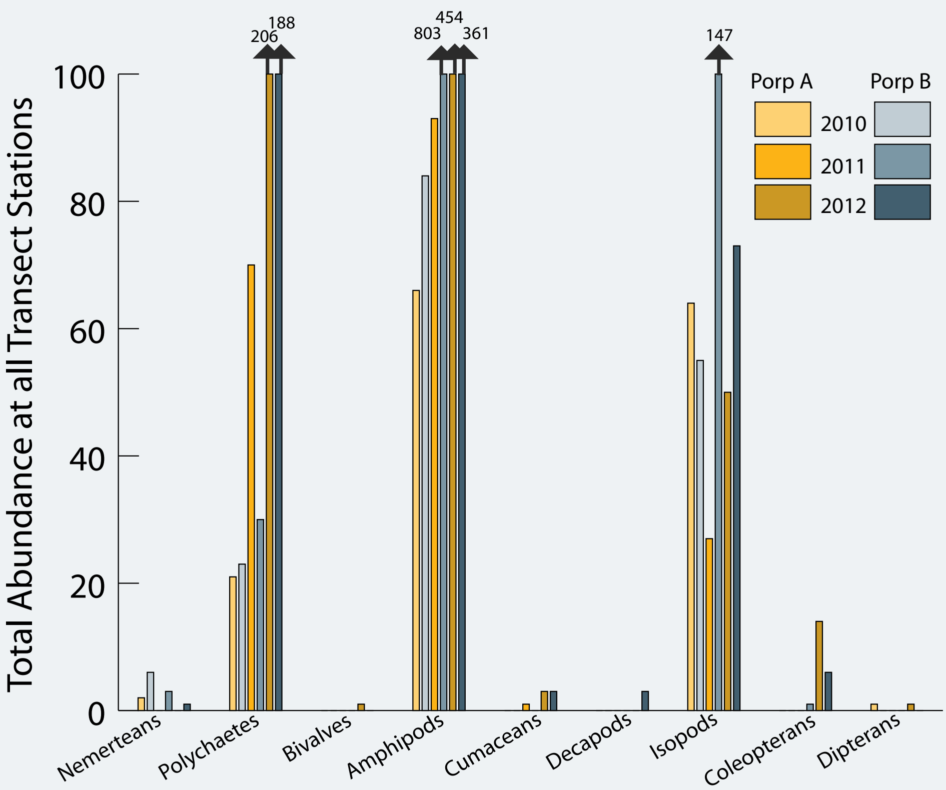
3. Results and Discussion (Continued)

At both transects in 2012, the sand hopper *Talorchestia quoyana* and the coleopteran beetle, *Chaerodes trachyscelides* which feed on organic material on the upper beach drift line, dominated the fauna at the high water stations. *Actaecia euchroa* was also present at the high water level. At mid to high water stations the spionid polychaete, *Scololepis* sp #1 was dominant with the predatory nemetean worm *Aglaophamous macroura* and the amphipod *Waitangi rakiura* present. At mid-low water levels, the dominant species included various sand-burrowing omnivorous amphipods, particularly *Patuki breviuropodus*. Also present was the isopod *Macrochiridothea uncinata*. At the low water level stations, species present included *Patuki breviuropodus, Aglaophamous macroura* and *Macrochiridothea uncinata,* and the spionid polychaete *Scololepis antipoda.*

Multivariate techniques have been used to further to explore differences in benthic invertebrate community composition and abundance at Transects A and B across the 3 years of monitoring at each of the 6 shore levels.

NMDS plots presented in Figure 7 show transects, when compared across shore levels, were generally paired together in years. This indicates that transects A and B are not significantly different from each other, but annual differences are evident in the samples collected. The raw data show this is related primarily to changes in species abundance, rather than a significant change in composition. The plots also show transects were most similar in 2010, with the spread between sites increasing in 2011 and 2012, something that may be in response to physical changes in the beach as reflected by the beach profiles described in Section 1.

Figure 4. Total abundance of macrofauna groups at Porpoise Bay Beach (sum of all 6 stations at each transect) 2010, 2011 and 2012.



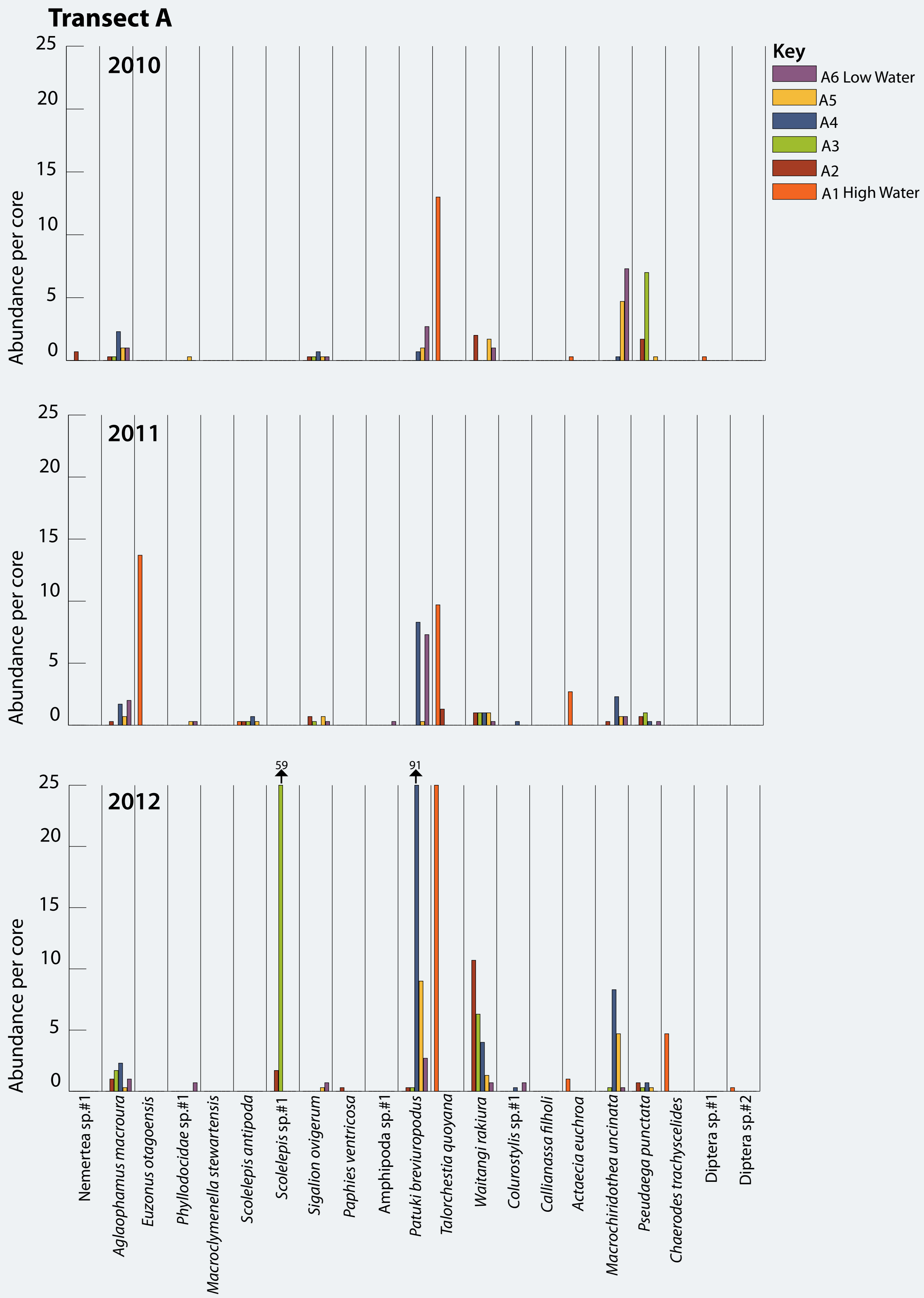


Figure 5. Mean abundance per core of macrofauna species at each station on Transect A - Porpoise Bay Beach 2010, 2011 and 2012.

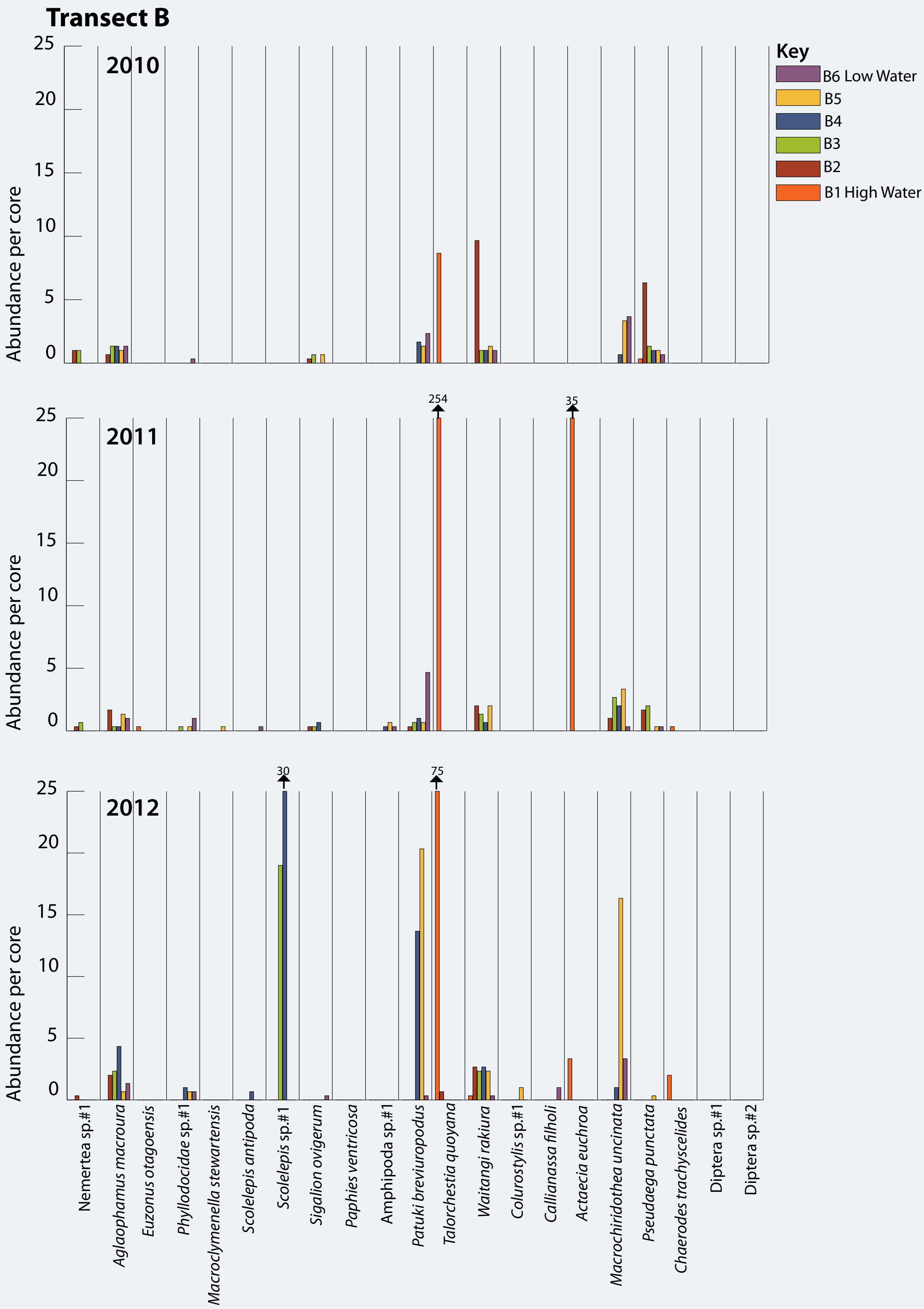


Figure 6. Mean abundance per core of macrofauna species at each station on Transect B - Porpoise Bay Beach 2010, 2011 and 2012.

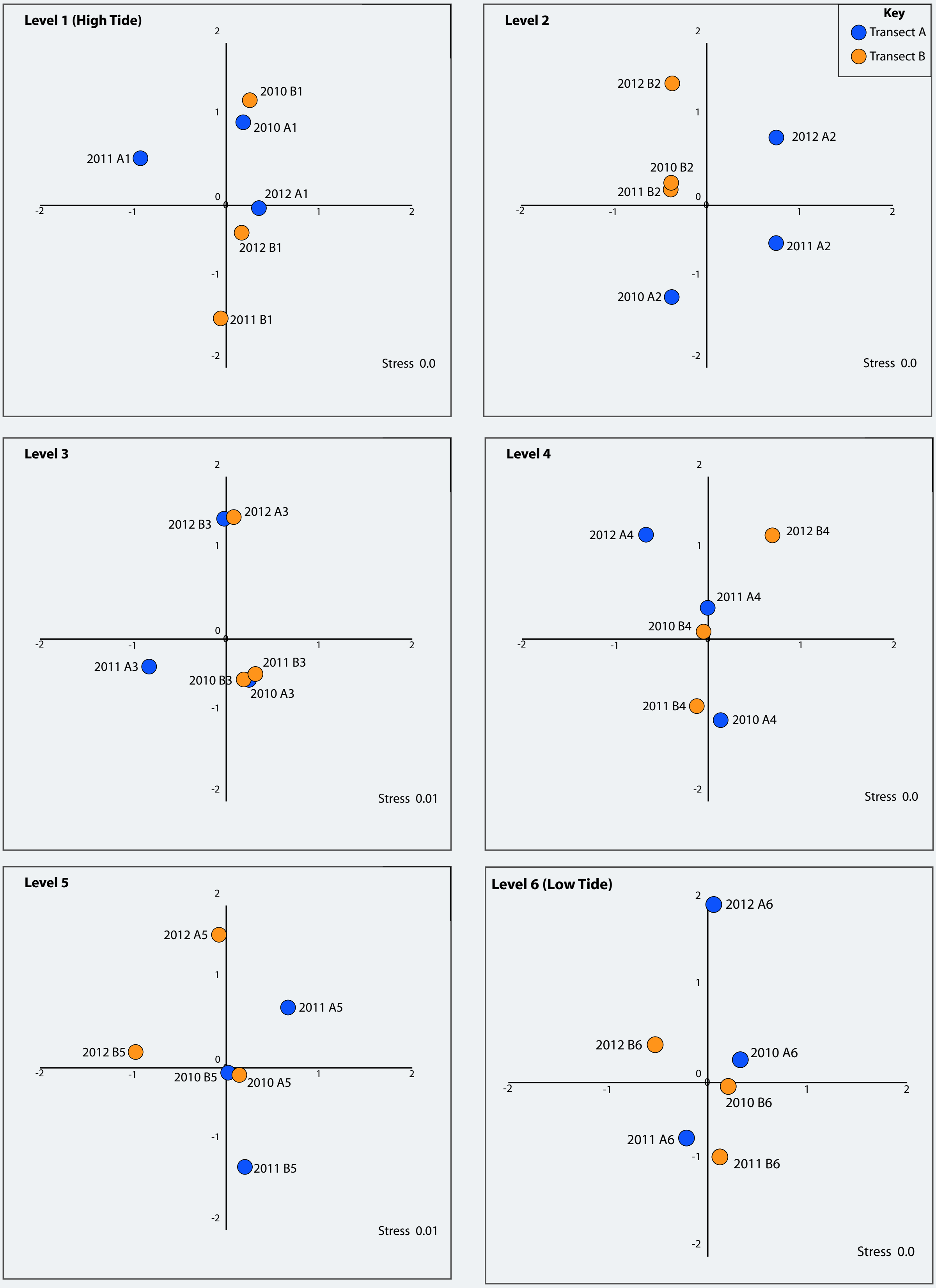


Figure 7. NMDS Plot for Porpoise Bay Beach: 2 transects, 6 sites on each - 2010, 2011 and 2012 (see page 11 for explanation).

3. Results and Discussion (Continued)

Explanation of NMDS plot for Porpoise Bay Beach (page 10).

Figure 7 shows the relationship among samples in terms of similarity in macro-invertebrate community composition at Transects A and B for the three years of sampling (2010, 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 non-metric 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.

As is typical for such beaches, the benthic invertebrate organic enrichment rating was in the "low to very low" category for 2010, 2011 and 2012 (Figure 8). 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.

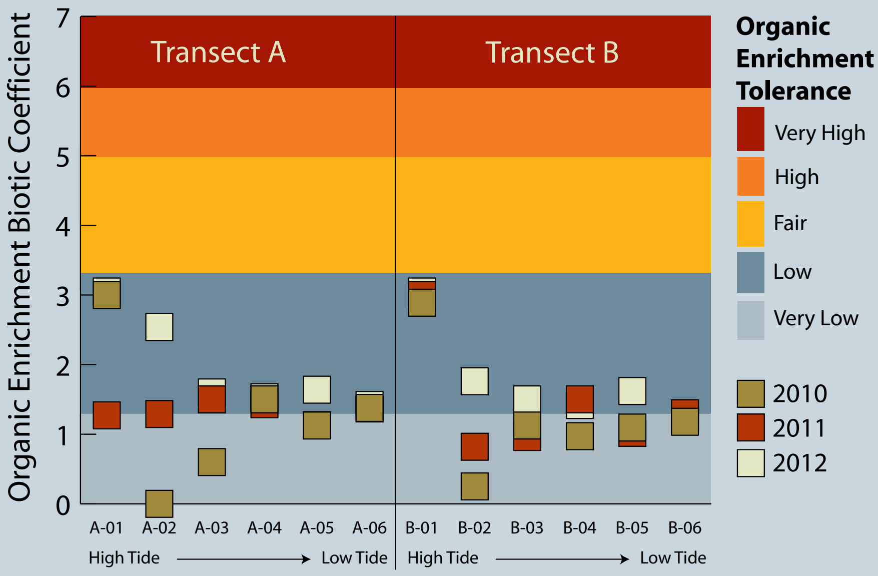


Figure 8. Benthic invertebrate organic enrichment rating, Porpoise Bay Beach, 2010, 2011 and 2012.

4. Redox Potential Discontinuity (RPD)

On semi-exposed beaches like Porpoise Bay 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 9) provides a measure of whether nutrient enrichment, for example from sewage leachate or groundwater from pasture 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 9 shows the sediment profiles and RPD depths for the Porpoise Bay 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 Porpoise Bay 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.

3. Results and Discussion (Continued)

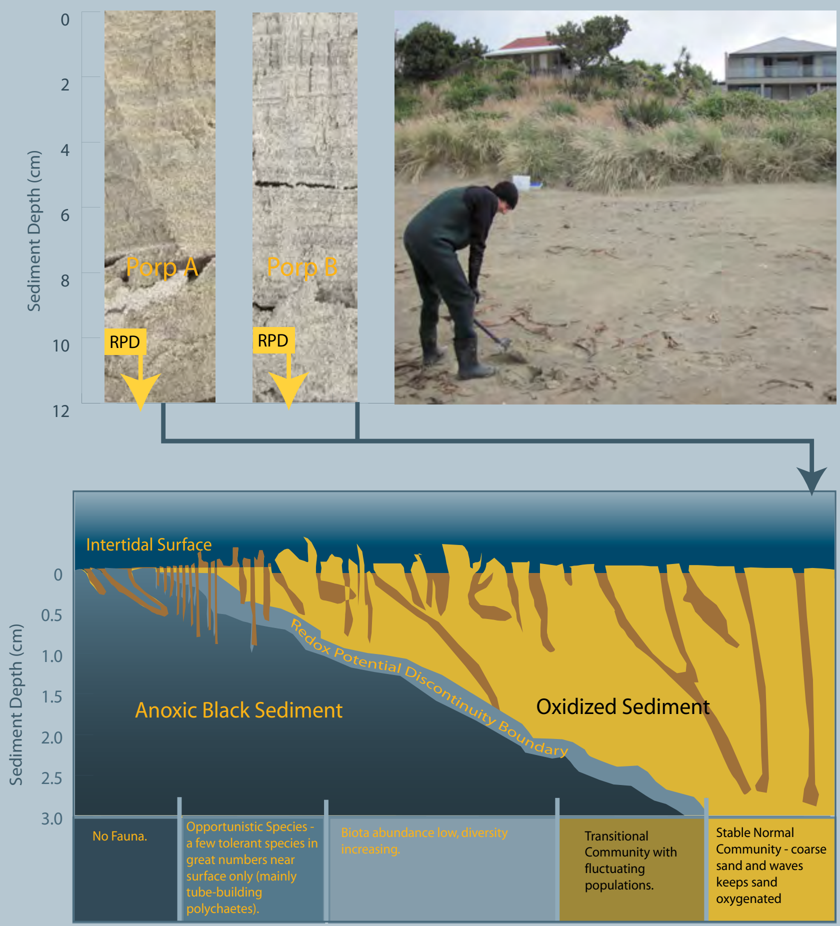


Figure 9. Sediment profiles, depths of RPD, and predicted benthic community type, Porpoise Bay Beach 2012.

4. CONCLUSIONS

The results of the third year of fine scale monitoring of Porpoise Bay Beach, an intermediate/dissipative type beach 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 30m wide marram foredunes with houses to the rear of them. The beach profile indicated accretion in the upper section of the beach in 2011 and 2012 compared to 2010, possibly as a consequence of sand mobilised following recent erosion from around Cooks Creek.
- **Sediment Type:** The beach was predominantly sand (>98.7% sand), with a very low mud content (1%). Grain size in 2010 and 2011 was similar.
- **Benthic Invertebrate Condition;** the benthic community condition was "balanced", with a typical exposed beach invertebrate community, dominated by crustaceans (isopods, amphipods), and moderate numbers of polychaetes. Because nutrients and organic matter were sparse on Porpoise Bay Beach, invertebrate numbers were low and consisted mainly of scavengers and predators. In 2012, there were no major differences compared to the 2010 and 2011 beach invertebrate monitoring results.
- **Sediment Oxygenation;** the Redox Potential Discontinuity (RPD) layer was relatively deep (>15cm depth) at all sites, indicating sediments were well oxygenated.

Overall, the findings indicate a sandy beach which had gained sand in the upper beach area in the vicinity of the transects in 2011 and 2012, compared with 2010. Its invertebrate biota was relatively diverse and typical of exposed, nutrient-poor, sandy beaches. In the next 20-100 years changes to the beach fauna are likely, particularly in response to ongoing erosion, and a likely steepening of the beach profile, as the effects of climate change take hold (i.e. increased wave climate, sea temperature and sea level rise).

5. MONITORING

Porpoise Bay 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 2012 monitoring results, it is recommended that monitoring continue as outlined below:

- **Fine Scale Monitoring**. Complete the scheduled 4 years of baseline monitoring at Porpoise Bay 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

Although not directly monitored at Porpoise Bay Beach, the fine scale monitoring reinforced the need for management of dunes in the general area. In particular, the current dominance of introduced marram grass as the main sand-binding species on the beach, which has inferior sand-binding and erosion control capabilities compared to the native sand-binders. Maintenance of a healthy beach ecology, particularly in relation to predicted accelerated sea level rise, is substantially enhanced by restoring the dunes to native sand-binding species (i.e. pingao).

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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

TOLERANCE 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

Porpoise Bay Beach A							
Station	**Dune Peg**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
NZTM East NZGD2000	1301755	1301785	1301829	1301858	1301889	1301897	1301916
NZTM North NZGD2000	4825742	4825743	4825745	4825741	4825742	4825737	4825731

Porpoise Bay Beach B							
Station	**Top Step**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**
NZTM East NZGD2000	1301777	1301792	1301828	1301857	1301880	1301898	1301915
NZTM North NZGD2000	4825645	4825649	4825649	4825650	4825649	4825647	4825645

Physical and chemical results for Porpoise Bay Beach, 20 January 2012.

Transect	Station	RPD	Salinity	Mud	Sands	Gravel
		cm	ppt		%	
Porp A	1	>15	33	0.2	99.8	< 0.1
	2	>15	33	1	99	< 0.1
	3	>15	33	1.1	98.8	0.1
	4	>15	33	1.1	98.8	< 0.1
	5	>15	33	1	98.9	< 0.1
	6	>15	33	1.1	98.9	< 0.1
Porp B	1	>15	33	0.7	99.3	< 0.1
	2	>15	33	1	99	< 0.1
	3	>15	33	1.2	98.8	< 0.1
	4	>15	33	1.2	98.7	0.1
	5	>15	33	1	98.9	< 0.1
	6	>15	33	1.1	98.8	< 0.1

APPENDIX 3. 2012 DETAILED RESULTS (CONTINUED)

Porpoise Bay Beach Profile Results - 2010, 2011, 2012.

Transect A	12-Feb-10		9-Feb-11		20-Jan-12	
Distance from Dune marker (m)	Site	Hgt above low water (m)	Site	Hgt above low water (m)	Site	Hgt above low water (m)
0		2.38		2.44		2.49
4				3.59		3.64
15		2.91		4.09		3.97
16						3.9
17				3.74		3.51
18		2.23				3.26
19						3.08
20				3.22		
21	A1	1.73				
24						2.63
27				2.77		
28		1.41				
31						2.36
39			A1	2.26		
42					A1	2.18
45	A2					
51		1.3		1.74		
62			A2			
67				1.19		
73					A2	1.21
76	A3					
86		0.6				
90			A3	0.81		
100	A4	0.33				
101					A3	0.74
110			A4	0.55		
130	A5	0.13	A5	0.3		
133					A4	0.42
145					A5	0.27
150		0.04	A6	0.05		
158					A6	0
160	A6	0		0		

Transect B	12-Feb-10		9-Feb-11		20-Jan-12	
Distance from Dune marker (m)	Site	Hgt above low water (m)	(not surveyed)		Site	Hgt above low water (m)
0		3.65				4.20
1.5						4.27
3						3.9
3.5		3.05				
4						3.01
9						2.67
10		2.15				
12						2.59
20	B1					
27					B1	2.22
40		1.45				
50	B2					
52					B2	1.32
65		1.25				
70	B3					
82					B3	0.89
90	B4					
95		0.78				
105					B4	0.61
110	B5					
126					B5	0.22
130	B6	0				
139					B6	0

Infauna (numbers per 0.1089m² core) - Porpoise Bay Beach Transects A and B (19/20 January 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.	III																		
POLYCHAETA	*Aglaophamus macroura*	II				2		1	4		1	2	3	2		1		1	1	1
	Euzonus otagoensis	I																		
	Macroclymenella stewartensis	I																1	1	
	Phyllodocidae sp.#1																			
	Scolelepis antipoda	III																		
	Scolelepis sp.#1	III				1	2	2	11	40	126									
	Sigalion ovigerum	II													1			2		
BIVALVIA	*Paphies ventricosa*	II						1												
CRUSTACEA AMPHIPODA	Amphipoda sp.#1	NA																		
	Patuki breviuropodus	II					1			1		71	89	113	16	6	5	4		4
	Talorchestia quoyana	III	24	28	23															
	Waitangi rakiura	I				4	18	10	7	9	3	4	3	5	1		3		2	
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	II											1					1		1
CRUSTACEA DECAPODA	*Callianassa filholi*	NA																		
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA		2	1															
	Macrochiridothea uncinata	II							1			6	10	9	13	1			1	
	Pseudaega punctata	I				1	1			1		1		1			1			
INSECTA COLEOPTERA	*Chaerodes trachyscelides*	NA	2		12															
INSECTA DIPTERA	Diptera sp.#1	NA																		
	Diptera sp.#2	NA	1																	
	Total species in sample		3	2	3	4	4	4	4	4	3	5	5	5	4	3	3	5	4	3
	Total individuals in sample		27	30	36	8	22	14	23	51	130	84	106	130	31	8	9	9	5	6

Taxa	Species	AMBI	B1a	B1b	B1c	B2a	B2b	B2c	B3a	B3b	B3c	B4a	B4b	B4c	B5a	B5b	B5c	B6a	B6b	B6c
NEMERTEA	Nemertea sp.	III					1													
POLYCHAETA	*Aglaophamus macroura*	II				1	3	2		2	5	6	7		1		1	3	1	
	Euzonus otagoensis	I																		
	Macroclymenella stewartensis	I										1	1	1	1	1			1	1
	Phyllodocidae sp.#1																			
	Scolelepis antipoda	III										1		1						
	Scolelepis sp.#1	III							23	9	25	18	47	24						
	Sigalion ovigerum	II																	1	
BIVALVIA	*Paphies ventricosa*	II																		
CRUSTACEA AMPHIPODA	Amphipoda sp.#1	NA																		
	Patuki breviuropodus	II										10	8	23	13	17	31			1
	Talorchestia quoyana	III	71	94	59	2														
	Waitangi rakiura	I		1		2	4	2	4	1	2	2	4	2	4	2	1		1	
CRUSTACEA CUMACEA	*Colurostylis* sp.#1	II													1	1	1			
CRUSTACEA DECAPODA	*Callianassa filholi*	NA																2	1	
CRUSTACEA ISOPODA	*Actaecia euchroa*	NA		4	6															
	Macrochiridothea uncinata	II										2	1		46	1	2	2	1	7
	Pseudaega punctata	I														1				
INSECTA COLEOPTERA	*Chaerodes trachyscelides*	NA	2		4															
INSECTA DIPTERA	Diptera sp.#1	NA																		
	Diptera sp.#2	NA																		
	Total species in sample		2	3	3	3	3	2	2	3	3	7	6	5	6	6	5	3	6	3
	Total individuals in sample		73	99	69	5	8	4	27	12	32	40	68	51	66	23	36	7	6	9

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.
	Euzonus otagoensis	I	An opheliid polychaete. Most *Euzonus* species inhabit intertidal sandy beaches consisting of well-sorted, medium to fine sands. Intolerant of enriched conditions.
	Macroclymenella stewartensis	I	Belongs to the Maldanidae, Bamboo worms. *Macroclymenella* sp., a sub-surface deposit-feeder found in tubes of fine sand or mud to depths of 15cm and has a key role in the re-working of sediment. This worm may modify the sediment conditions, making it more suitable for other species (Thrush et al. 1988). *Macroclymenella* is common in estuaries. Intolerant of anoxic conditions.
	Scololepis antipoda and *Scololepis* 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	*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.
	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.
	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).
	Amphipoda sp #1	NA	An unidentified amphipod.
	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	Talitrid amphipod found on the backshore of NZ 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	Diptera sp.#1 and #2	NA	Unidentified flies.
	Chaerodes trachyscelides	NA	A highly specialised, flightless burrowing beetle confined to the narrow strip of sand at and just above high water level on sandy marine beaches.

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, such 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.