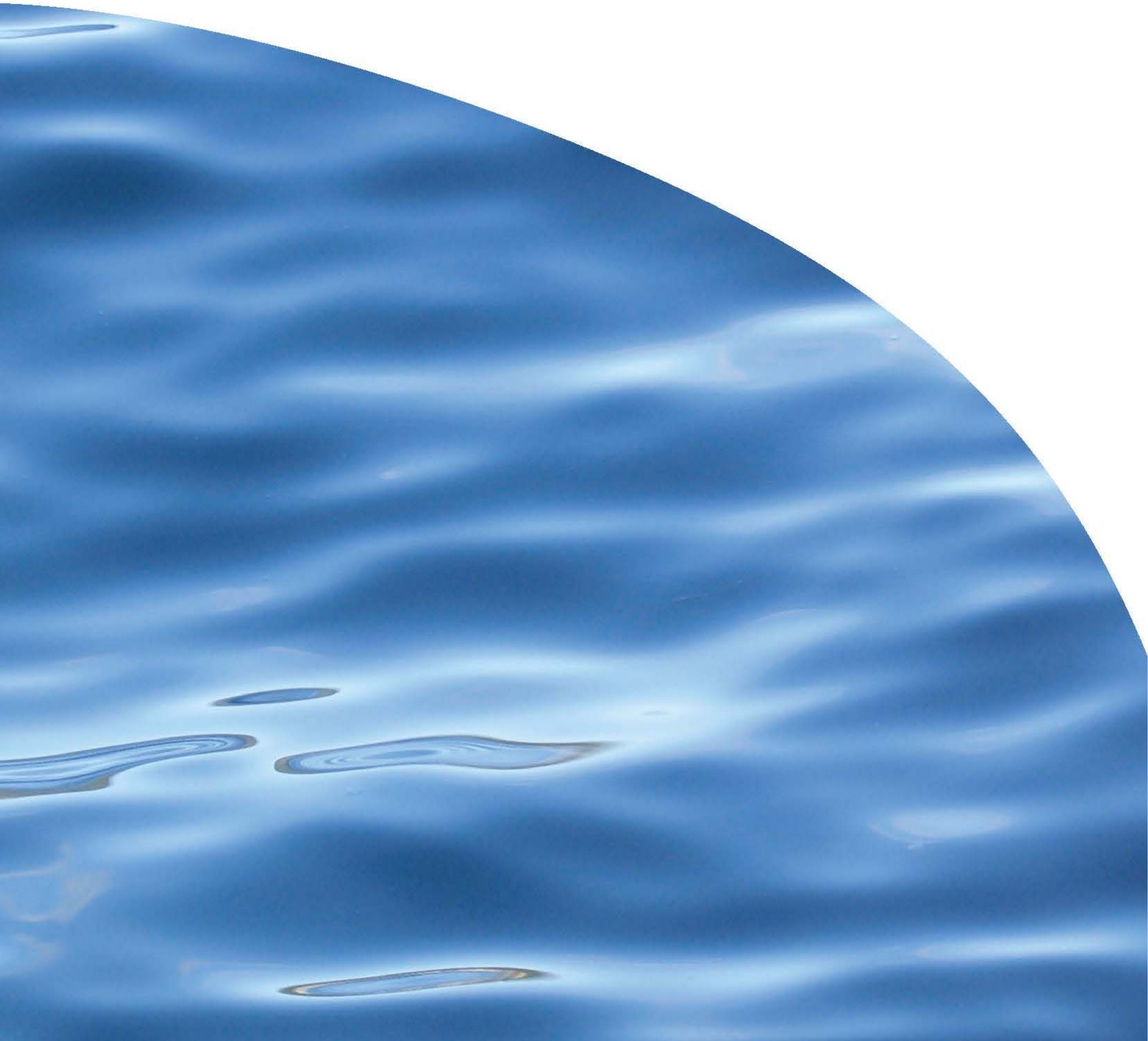
REPORT NO. 2081

TASMAN BAY STATE OF THE ENVIRONMENT BENTHIC ECOLOGICAL SURVEY: TASCAM SITE-2011-REVISED



TASMAN BAY STATE OF THE ENVIRONMENT BENTHIC ECOLOGICAL SURVEY: TASCAM SITE-2011 - REVISED

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EXECUTIVE SUMMARY

Background

Benthic characteristics were assessed at a station in western Tasman Bay (GPS coordinates 2517648E, 6014874N) in July 2006 in order to establish a point-in-time baseline for state of the environment (SOE) monitoring. Cawthron Institute was commissioned by the Tasman District Council to undertake the first repeat assessment of the baseline survey and report any significant changes detected after the five-year monitoring interval.

Methods

Seabed physical, chemical and biological properties were assessed according to procedures consistent with the 2006 baseline survey. These included field observations of indicators of sediment de-oxygenation, sediment particle size distribution, organic matter content, total nitrogen and phosphorus concentrations, and key identifiers of biological community structure. Survey results were compared with the 2006 baseline and other available information describing the greater Tasman Bay region.

Summary of results

Physico-chemical characteristics of the seabed observed at the Tasman Bay SOE monitoring site were typical of benthic environments affected by high rates of deposition of inorganic sediments. No indications of excessive organic or inorganic nutrient enrichment (*e.g.* sediment anoxia, H_2S production) were observed. With the exception of an unexplained reduction in total nitrogen concentration, changes observed between the 2006 and 2011 surveys were minor and can probably be attributed to normal temporal variation. The possibility must be acknowledged, however, that the nearby deployment of the TASCAM monitoring buoy, may have contributed to minor changes in seabed properties, through slight alterations of the hydrodynamic climate at the site.

The dominance of silt/clay sediment fractions and relatively low number of species and abundance of individuals at both sampling times indicates a continued low physical and biological habitat complexity at the monitoring site. The drop-off of fouling biota from the TASCAM buoy and mooring lines was the most likely cause of a slight increase in epifaunal diversity and abundance between 2006 and 2011.

Of particular interest was the observed 70% reduction (2006 *vs*. 2011) in density of the heart urchin, *Echinocardium chordatum*. This species was the dominant macrofaunal component during the 2006 survey and it is generally recognised as having an ecologically important functional role when present at high densities. Although still dominant in terms of biomass as of the 2011 survey, the lower abundance could suggest a change in the functional role of this species. This result may simply have been due to natural fluctuation over time, however more frequent and potentially wider-scale monitoring would be required to determine whether or not this single data point represents an on-going site-specific or a Tasman Bay-wide trend.

Recommendations

Continued monitoring of the Tasman Bay SOE site is recommended as a means of identifying/quantifying long-term changes in seabed habitat structure. However, since the SOE site also serves as a reference site for evaluating the effects of aquaculture activities in western Tasman Bay, there is a potential for coordination of SOE and industry consent monitoring efforts. This could provide interim results within the present five-year SOE monitoring interval thereby improving the understanding of shorter term (*e.g.* yearly fluctuations in benthic habitat characteristics) and enabling their evaluation in the context of long-term trends.

Important note

This report has been revised from the original report released in February 2012. It now includes data from revised laboratory results, so the following amendments have been made:

- Section 2.1.1: Table 1, Total Nitrogen (TN) description.
- Section 3.1: References to TN in main body of the report and in Figure 5
- Appendix 2: TN data.

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INTRODUCTION

1.1. Background

Cawthron Institute maintains a buoy-mounted oceanographic data collection facility (http://www.cawthron.org.nz/coastal-freshwater-resources/tascam.php) at a station in western Tasman Bay (Figure 1). This facility, which is referred to as TASCAM, is situated 6 km off the Motueka River mouth (GPS coordinates 2517648E, 6014874N), between the central and northern Tasman Bay aquaculture management areas (AMAs). The primary reason for deployment of the data collection buoy at this site was to assess the influence of the river plume on water column characteristics, however its location (1 km outside the boundaries of each of the northern and central AMAs) also provides a useful state of the environment (SOE) monitoring site for the assessment of changes in the benthic environment.

A baseline benthic ecological survey of the soft sediment environment at the TASCAM site was undertaken July 2006 (Gillespie & Keeley 2007) in order to begin compilation of a comparative SOE database. The objective was to provide a point-in-time description of the seabed habitat in terms of sediment physical, chemical and biological properties in order to enable detection of changes over time.

The present report describes the first repeat of the 2006 baseline survey carried out in July 2011.

This report has been revised from the original report released in February 2012. It now includes data from revised laboratory results which are: a clarification of Total Nitrogen (TN) results in Table 1, Figure 5 and Appendix 2, and amendments to references to TN in Section 3.1.

1.2. Rationale for soft sediment sampling

Soft sediment habitats comprise a large percentage of the seabed habitat of Tasman Bay and are therefore a defining feature within the Tasman Bay ecosystem (Gillespie 2003). Because the majority of these habitats are inside the 30 m bathymetry line, they are exposed to sufficient sunlight to support photosynthetic activity. Benthic microalgal communities on the sediment surface, along with phytoplankton, are major contributors to food webs of most shallow coastal environments (Charpy-Raubaud & Sournia 1990). Due to their spatial dominance and ecological importance, soft sediment habitats play a major role in supporting the productivity of fish and shellfish resources in Tasman Bay (Gillespie 2003). Offshore mud habitats in western Tasman Bay have long been subjected to disturbances from riverine (catchment) influences (Gillespie & Rhodes 2006; Forrest *et al*. 2007, Gillespie *et al*. 2011a, Gillespie *et al*. 2011b), and trawling and dredging activities, however little attention has previously been given to establishing monitoring sites as a means of assessing long-term environmental change.

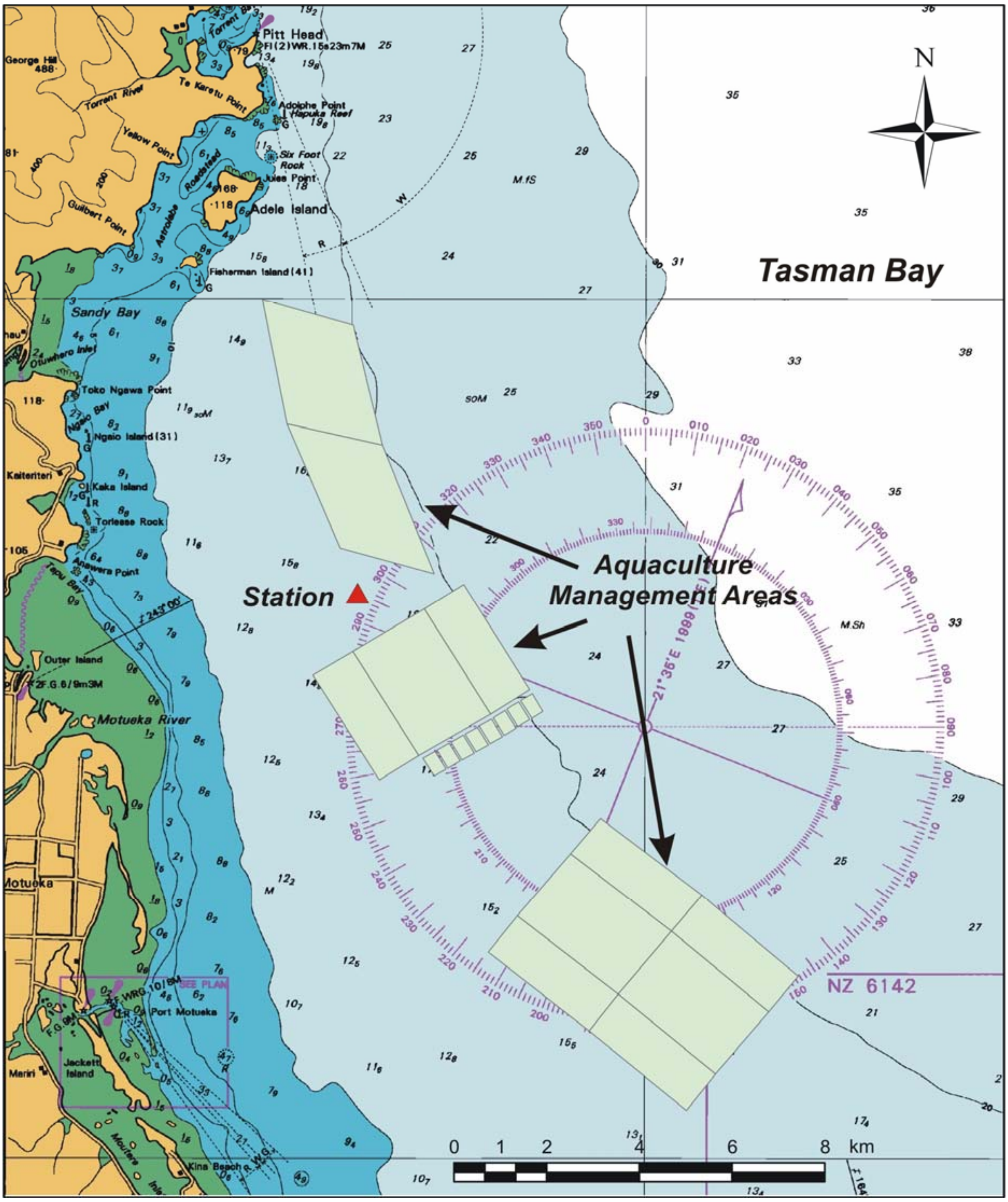

Figure 1. Location of the survey station and nearby aquaculture management areas.

2. SURVEY METHODS

2.1. Sampling and field analyses

Soft sediments were sampled by SCUBA divers on 5 July 2011 at locations randomly selected within 10 m of the TASCAM long-term data collection buoy. Because of their close proximity to the buoy site, the samples were considered as replicates that can provide information on within-site variation. A combination of techniques was used at each location in order to target specific benthic habitat characteristics. The characteristics assessed, and the survey techniques, were largely identical to those used during a soft sediment baseline assessment of the Horoirangi Marine Reserve in eastern Tasman Bay (Keeley *et al.* 2006) and the initial baseline survey undertaken in 2006 (Gillespie & Keeley 2007).

Six perspex tubes (62 mm internal diameter) were inserted into the sediment to obtain intact cores. Core profiles were assessed in terms of the depth of the redox potential discontinuity (RPD) layer, which represents the transition between oxidised and reduced conditions. The cores were then inspected for patches of sediment anoxia and sulphide odours and a representative core was photographed. The surface 20 mm of each core was removed to a sample container and stored on ice until analysed.

Six additional sediment cores (131 mm diameter by 100 mm deep, area = 0.0135 m^2) were collected for analysis of infauna community characteristics. The cores were gently washed through a 0.5 mm mesh sieve and the residue preserved with a solution of 3% glyoxal and 70% ethanol.

2.1.1. Sediment physical and chemical properties

Sediments were analysed for particle size distribution (as percentage gravel, sands, and mud), organic matter content (as ash free dry weight or AFDW), total nitrogen (TN) and total phosphorus (TP). A summary of the analytical methods is presented in Table 1.

Table 1. Analytical methods used for sediment characterisation.

Analyte	Method	Description
Particle grain size	Extended series (PGX), Cawthron SOP No. 33074	Wet sieving and calculation of dry weight percentage fractions*: >2 mm = Gravel <2 mm – >1 mm = Coarse Sand <1 mm - >500 µm = Medium Sand <500 µm - >250 µm = Medium/Fine Sand <250 µm - >125 µm = Fine Sand <125 µm - >63 µm = Very Fine Sand <63 µm = Mud (Silt and Clay)
Organic Content as Ash Free Dry Weight (AFDW)	Luczak *et al.* 1997 (modified)	Sample dried at 105°C then ashed at 550°C. Gravimetric determination.
Total Nitrogen (TN)	APHA 20th Ed. 4500N C	Due to an analytical procedural error, TN results had to be re-calculated to convert to dry weight basis using an assumed 49.2% average moisture content.
Total Phosphorus (TP)	ICP-MS Aqua Regia Digest	

*Six classes from the Udden-Wentworth scale.

2.1.2. *Infauna*

Infauna within the preserved samples were identified and counted with the aid of a binocular microscope. Identifications were made to the lowest practicable taxonomic level. For some groups, species-level identification is very difficult and, in such instances, infauna were grouped into recognisable taxa (morphologically similar groups). Results from the infauna samples were entered directly into Cawthron's marine database before being analysed to ascertain levels of abundance, species richness and diversity.

2.1.3. *Epibiota*

Conspicuous epibiota were quantitatively assessed from 16 photographic quadrats randomly positioned within an approximately 20 m radius of the site. The photographs were taken with an eight mega-pixel digital Canon Eos camera (Figure 2) which, upon each lowering, is designed to take a photograph with a set frame of reference (0.1 m^2) at a fixed distance directly above the seabed. The seabed images were initially collected 5 July 2011, but due to turbid conditions they were unsuitable for analysis and new images were collected 30 August 2011. Images were analysed on a high resolution computer screen and conspicuous biological features were identified (where possible) and enumerated. Benthic microalgal coverage and the degree of visible sediment reworking/bioturbation were assigned a value based on a relative scale of coverage from 1 to 5; *i.e.* 1= <10%, 2=11-30%, 3=31-60%, 4=61-90%, 5=>>90%. While these measurements are somewhat subjective, all images are held by Cawthron for direct comparison with baseline and subsequent monitoring results to reduce operator bias.

Figure 2. Quad cam apparatus for collecting seabed images.

2.2. Biological data analysis

Analysing the data with an appropriate suite of univariate and multivariate statistical procedures can facilitate interpretation of spatial and temporal changes in biotic community structure over time. Relationships with other (*i.e.* physical and chemical) characteristics can also be explored in an effort to construct a general picture of the existing soft sediment habitats for application to a monitoring framework.

Raw data from infauna samples were summarised according to a suite of common univariate statistics, including: abundance, species richness, evenness and diversity (Table 2). The infauna community characteristics recorded during the present survey were compared with those recorded during the 2006 baseline survey using non-metric multidimensional scaling or MDS (Kruskal & Wish 1978) and ordination and cluster diagrams based on Bray-Curtis similarities in PRIMER v5, (Clark & Warwick 1994; Clarke & Gorley 2001).

Table 2. Descriptors of macro-invertebrate community characteristics.

Descriptor	Equation	Description
No. species (S)	Count (taxa)	Total number of species in a sample.
No. individuals (N)	Sum (n)	Total number of individual organisms in a sample.
Richness (d)	$d = (S-1)/\log_e N$	Margalef's richness index: A measure of the number of species present, making some allowance for the number of individuals. Values increase strongly with the number of species (H') and decrease with relative increases in the number of individuals.
Evenness (J')	$J' = H'/\mathrm{Log}_e(S)$	Pielou's evenness index: A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.
Diversity ($H' \log_e$)	$H' = -\mathrm{SUM}(P_i * \log_e(P_i))$	Shannon-Wiener diversity index ($\log_e$ base): A diversity index that describes, in a single number, the different types and amounts of animals present in a collection. Varies with both the number of species and the relative distribution of individual organisms among the species. The index ranges from 0 for communities containing a single species to high values for communities containing many species and each with a small number of individuals.

3. RESULTS AND DISCUSSION

3.1. Sediment physico-chemical properties

The sediments were generally pale brown and grey in colour (Figure 3) and there were no indications of elevated rates of oxygen depletion (*e.g.* sulphide odours or darkened anoxic RPD layers due to organic enrichment).

Figure 3. Representative sediment core images. Right-hand images are zoomed-in images of two of the cores from the left-hand photograph.

In 2006 and 2011, sediment textures were dominated by the silt/clay fraction (90 ± 2.4% and 93 ± 5.0%, respectively) with a minor sand component and small, but variable amounts of shell debris (Figure 4). The 2011 core No.5 contained a contrastingly high proportion of gravel (~15%) and the lowest recorded proportion of fine sands and silt/clay contents for the two surveys. This indicates low level patchiness and slightly increased variability at the site in 2011 compared to 2006, which exhibited slightly more homologous sediment characteristics. The full datasets of all sediment physico-chemical characteristics recorded during the surveys are listed in Appendix 2

The average sediment organic contents (Figure 5) remained relatively unchanged between the two surveys (*i.e.* 6.2 ±0.3% and 6.3 ±0.3%, respectively). In 2006 mean TP (891 ±40 mg/kg) and TN (1767 ±52 mg/kg) contents were reported to be “typical of those reported for numerous sites of similar particle size distribution in other regions of Tasman Bay.” The 2011 results showed similar mean TP concentrations of 820 ±59 mg/kg but comparatively lower mean TN concentrations of 1317 ±98 mg/kg (*i.e*. an ~25% reduction). Organic content and organic matter supply to the benthic environment are normally considered the main factors that control the magnitude of sediment nutrient flux (Cowan *et al.* 1996). The concentration of organics does not appear to have changed, however, the observed reduction in sediment TN concentration was clearly due to some other factor(s); *e.g.* increased sediment denitrification. The observed low molar N/P ratios (*i.e*. <~4 during 2011) are consistent with high sediment denitrification rates such as those previously reported for nearby sites in Tasman Bay (Christensen *et al.* 2003).

These physico-chemical characteristics indicate generally unenriched, fine-textured sediment habitats with moderate productive potential. With the exception of reduced sediment TN concentrations, no potentially ecologically significant changes were detected compared to the 2006 baseline results.

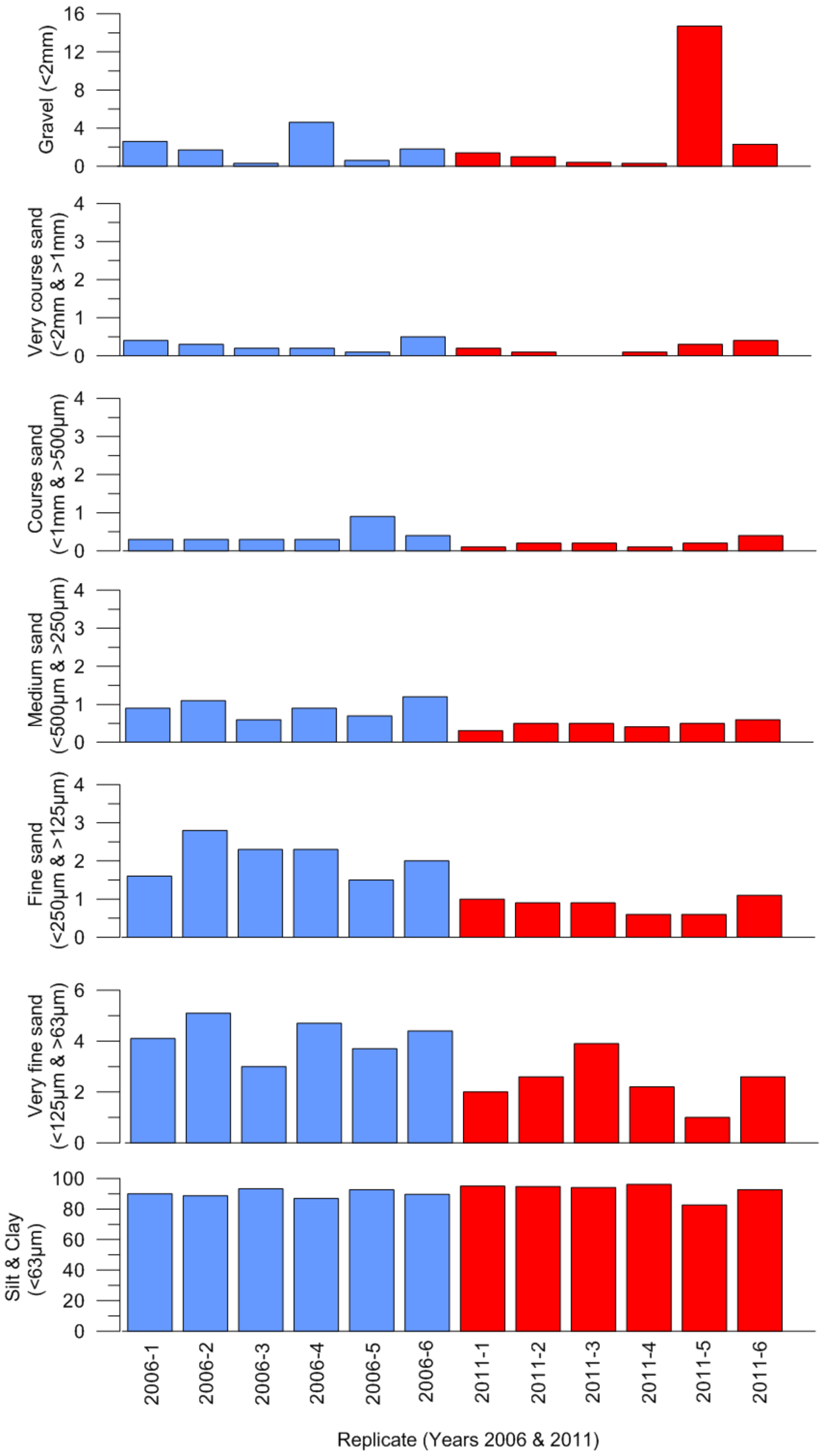

Figure 4. Sediment grain size characteristics (% dry weight) for 2006 and 2011. Note that the y-axis scales vary.

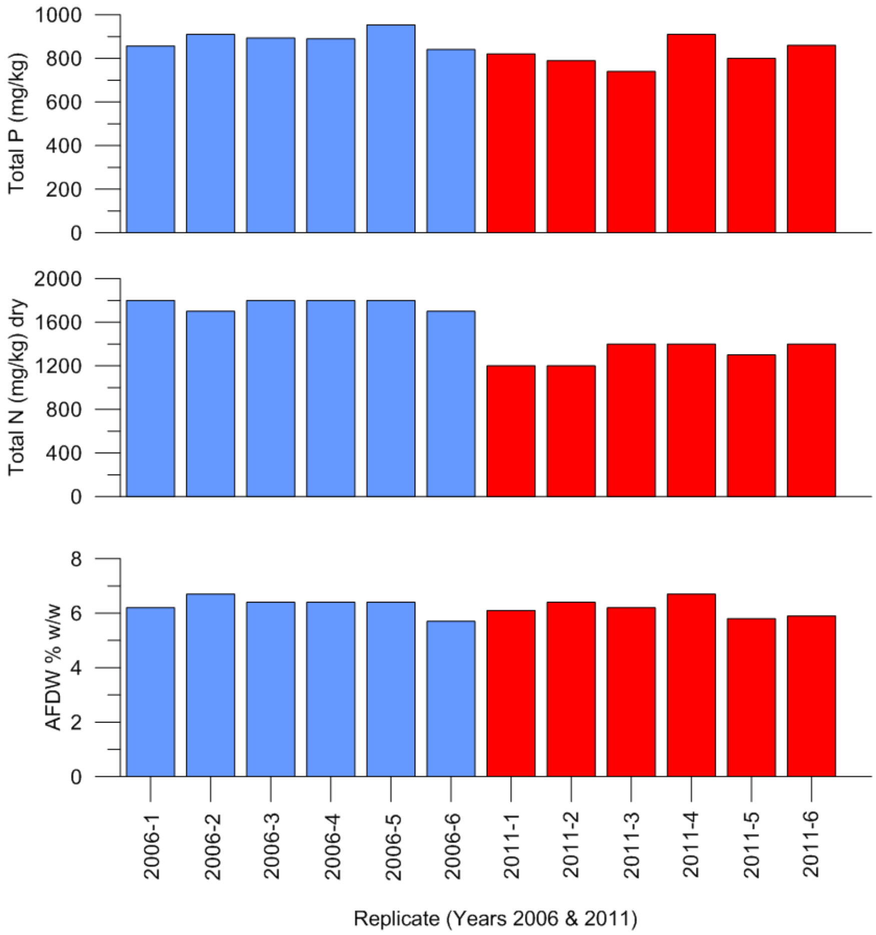

Figure 5. Sediment organic matter and nutrient concentrations for 2006 and 2011. NB: y-axis scales vary and TN concentrations for 2011are estimates based on an average moisture content of 49.2% calculated from similar Tasman Bay sediments.

3.2. Infauna community

A total of 28 taxa were identified from the six infauna cores collected during the 2011 survey and 29 taxa were identified during the previous 2006 survey (full species list in Appendix 4). Overall, the broad taxonomic groups between 2006 and 2011 remained very similar (Figure 6). The apparent reduction of the proportion of Nematoda is not considered noteworthy because, due to their small size, an unknown fraction of nematodes can pass through the 0.5 mm mesh filter.

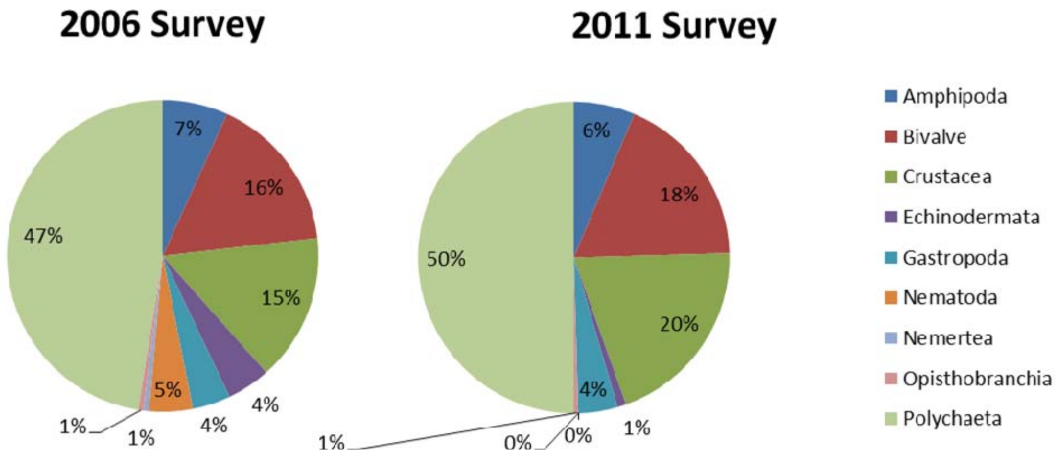

Figure 6. Pie charts comparing the calculated infaunal percentages of taxonomic groups for the 2006 and 2011 surveys.

In 2006, the site was dominated (in terms of biomass) by the heart urchin *Echinocardium cordatum*, (mean ± sd = 1 ± 0.6/core equating to 74 ±46/ m^2). The 2011 survey indicated a lower but still substantial abundance of *E cordatum* density of 22±38/m^2. The heart urchin is a relatively large-bodied deposit-feeding species. It is generally considered to be of ecological importance when present in significant densities due to its sediment mixing (bioturbation) activity (Lohrer 2003) and role as a food source for bottom-feeding fish. The apparent reduction in E. cordatum abundance suggests that there was also reduced sediment mixing activity in 2011 compared to 2006, however this may simply be indicative of natural temporal variation.

The similarity percentage (SIMPER[1])) between the 2006 and 2011 infaunal data sets was 52.9%, indicating that half the 2006 and 2011 communities were significantly similar. Significance was determined using ANOSIM[2] one-way analysis (0.2%). The average dissimilarity of the top six taxa between 2006 and 2011 (those greater than 2%), are listed below in Table 3. The overall trends for the taxa exhibiting the most dissimilarity between the 2006 and 2011 surveys were:

- Increased abundance of the polychaete *Cossura consimilis*, and the arthropod taxa, Ostracoda and Cumacea.
- Decreased abundance of Cirratulidae and *Aglaophamus sp.* worms.

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[1] SIMPER (similarity percentage) is a simple method for assessing which taxa are primarily responsible for an observed difference between groups of samples. The Bray-Curtis similarity measure is most commonly used with SIMPER.

[2] ANOSIM: (analysis of similarities) helps to determine the overall significance of the differences between groups of samples.

The species that showed the greatest level of dissimilarity between 2006 and 2011 was *Cossura consimilis* (Table 3). This polychaete worm is common to New Zealand port and estuarine soft sediment environments, and was noted as one of the most abundant species found in the second baseline survey at the Port of Nelson (Inglis *et al.* 2008). Although increased populations of this species, or polychaete abundance in general, can be related to organic enrichment *e.g.* (Guerra-Garcia & Garcia-Gomez 2004), such changes in similarity percentage may alternatively be due to natural temporal variation.

Table 3. Species showing the greatest average dissimilarity in abundance between the 2006 and 2011 surveys. Only species > 2% abundance are listed. Abundance data are fourth-root transformed.

	Group 2011	Group 2006		
Infaunal Taxa (< 2% AD)	**Average Abundance**	**Average Abundance**	**Average Dissimilarity (AD)**	**Dissimilarity SD**
Cossura consimilis	2.53	1.15	3.58	1.53
Ostrocoda	1.47	0.74	3.11	1.26
Cumacea	1.53	1.25	2.76	1.42
Nematoda	0	0.9	2.21	1.16
Cirratulidae	1.22	1.43	2.15	1.17
Aglaophamus sp.	1.19	2.02	2.05	1.95

Descriptors of infauna community structure (Figure 7) indicate a highly uniform biological habitat with a relatively low species diversity and abundance.

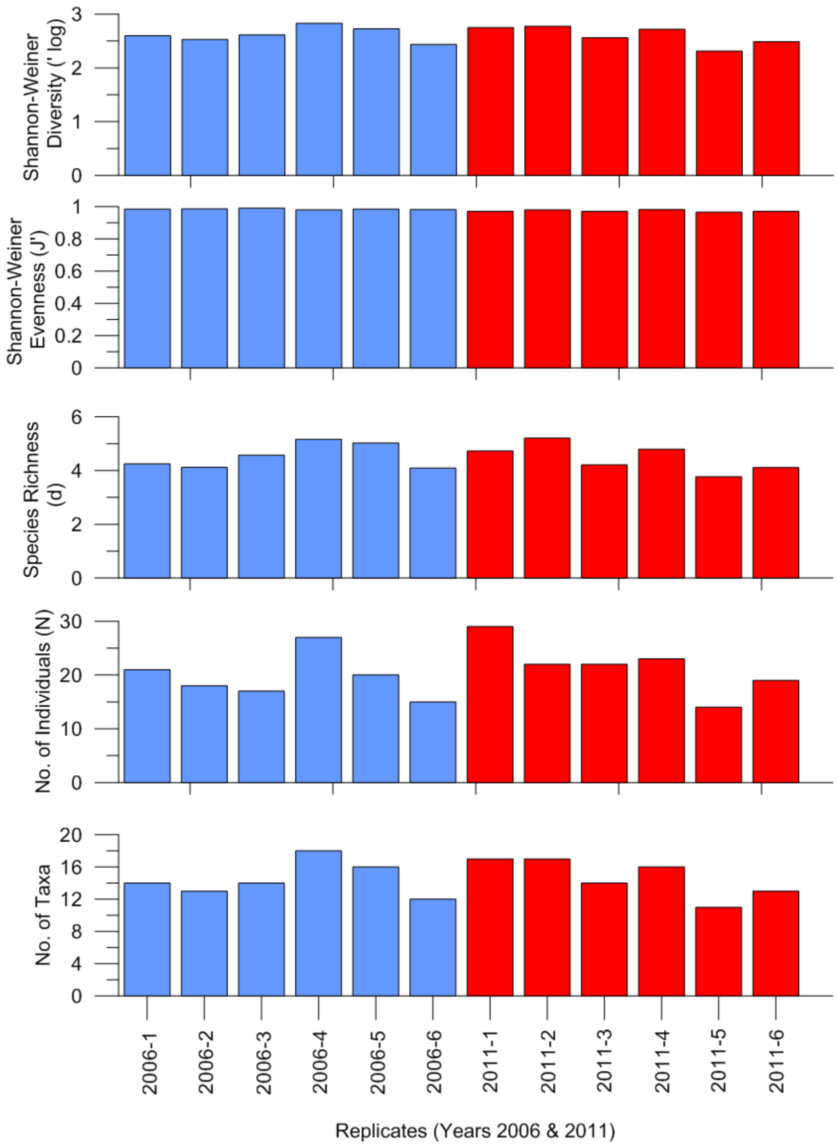

Figure 7. Descriptors of infauna community structure (based on a core area of 0.0135 m^2), calculated from 2006 baseline data and the current 2011 monitoring data. Note that the y-axis scales vary.

The multi-dimensional scaling (MDS) plot derived from the benthic infauna data shows homogenous grouping (at the 40% level of similarity) with three distinct groupings at the 50% level of similarity (Figure 8). The outlying 2006 replicate (2006-2) was caused by the complete lack of representation of amphipods, crustaceans and Ophiuroidea in that specific core (common in the majority of other replicates; see full species list Appendix 4).

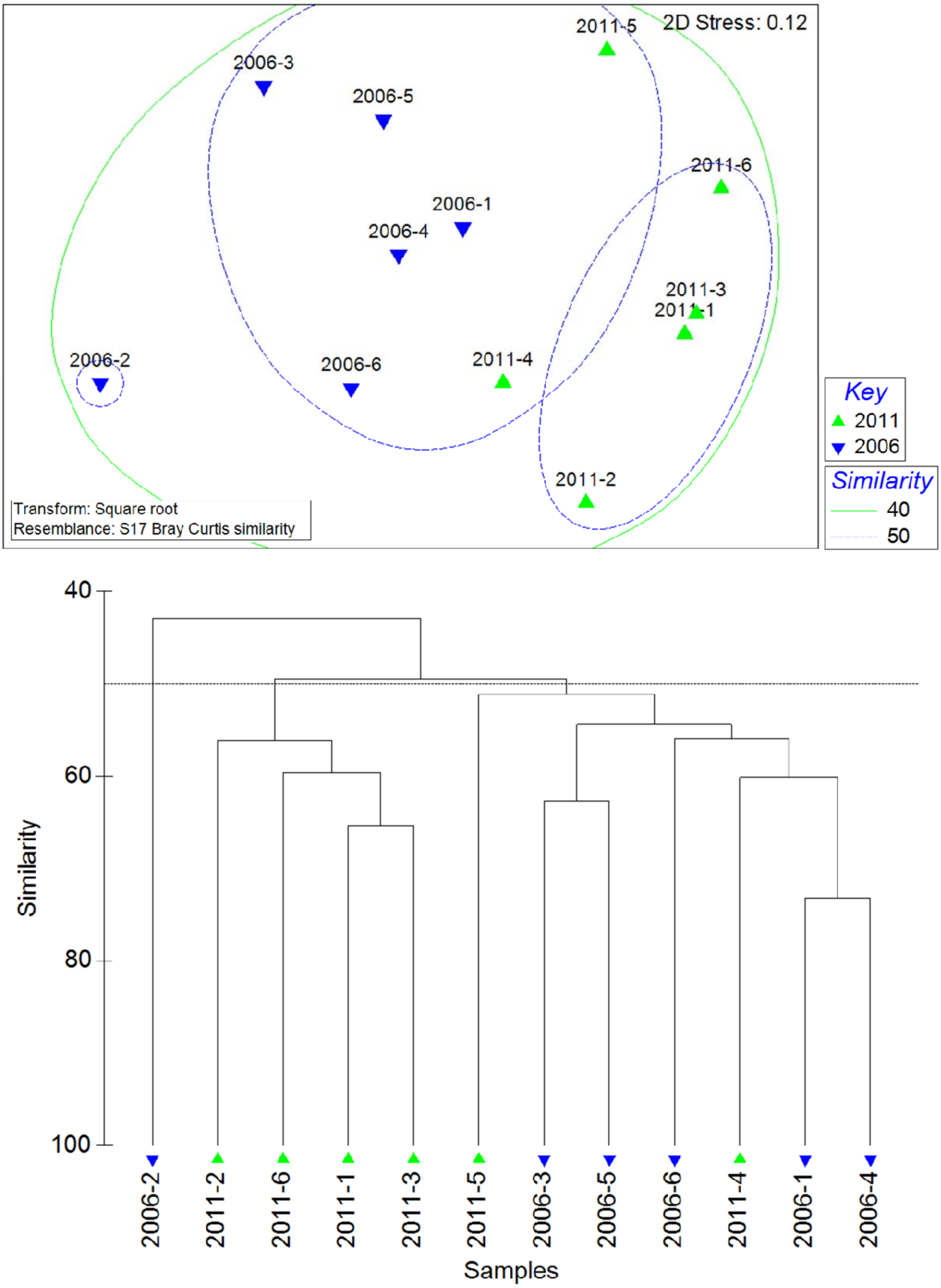

Figure 8. Multi dimensional scaling plot (MDS) and dendrogram (cluster diagram) of infauna sampled during 2011 and 2006 at the TASCAM buoy site. Data were square-root transformed count data, MDS clusters were formed at the 40% and 50% levels of similarity.

3.3. Conspicuous epibiota

The observed diversity of conspicuous animals on the surface of the seabed (epifauna) and their abundances remained low, but were slightly elevated compared to 2006 observations (Table 4, Appendix 1). Several large adult green-lipped mussels (*Perna canaliculus*) were observed growing attached to the empty shell of a horse mussel (Figure 9) and it is likely that these had become detached from the surface floats or mooring lines of the nearby long-term monitoring buoy. Divers noted the presence of more empty and living green-lipped mussels in a narrow area of the seabed surrounding the buoy when taking the photos.

In spite of the low epifauna densities, considerable animal activity (bioturbation) was evident in the form of worm and/or crustacean burrowing, surface grazing tracks, bio-deposits and sediment reworking. *Echinocardium chordatum*, a significant component of the infauna community, that is generally located just below the sediment surface (see Section 3.2), was detected in all seabed images (Figure 9), and much of the sediment reworking observed was attributed to this species.

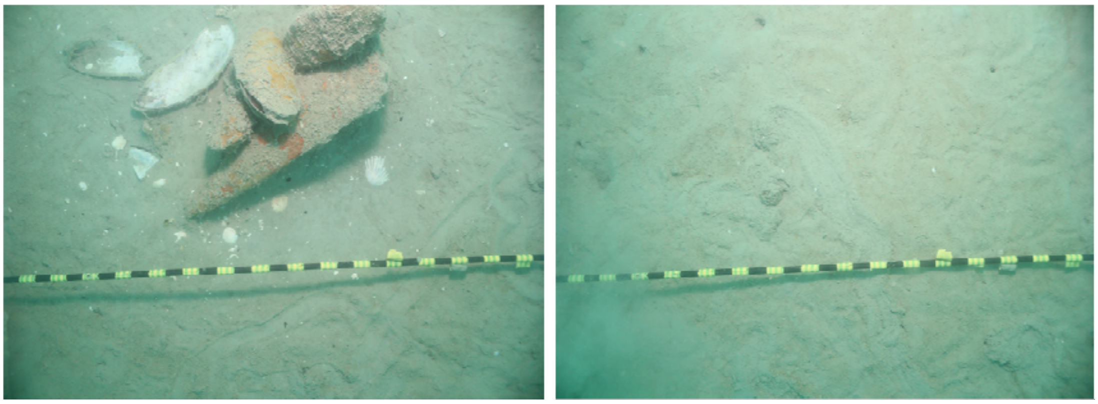

Figure 9. Representative seabed images. Left hand image: the bivalve mussel *Perna canaliculus* on top of the shell of the horse mussel, *Atrina zelandica*, and evidence of epifaunal track marks in the lower right corner. Right hand image: polychaete/crustacean burrows, epifaunal track marks and bioturbation evidence. A full set of seabed images, providing better resolution of detail, has been written to CD and appended to this report.

A visually evident, yellow-brown microalgal film (often referred to as the microphytobenthos or MPB) covered an estimated 20-60% of the seabed (see example Figure 9), however the colouration of this film was much less intense than observed during 2006 which may indicate a comparatively reduced diatom biomass. In addition to providing an important food source for epifaunal grazers, deposit feeders and suspension feeders, Christensen *et al.* (2003) reported that MPB production, at depths less than 30 m in Tasman Bay, has an important stimulatory effect on microbial denitrification rates due to oxygenation of the surface sediments.

Benthic diatoms that comprise the MPB can also affect the physical integrity of the water-sediment boundary layer due to production of polysaccharide materials that glue sediment particles together. Unfortunately single point-in-time assessments of diatom biomass or coverage are not sufficient to identify long-term trends due to the high seasonal and spatial variability (Gillespie 2003). Nonetheless it is possible that increased suspended sediment (SS) concentrations and related light limitation at the sediment-water interface could impact on MPB production with follow-on effects to sediment animal communities (Gillespie 1997).

Table 4. Summary values for epifauna quadrat observations (n=16). Bracketed values = standard error. Relative 1-5 scale: 1= <10%, 2=11-30%, 3=31-60%, 4=61-90%, 5=>90%.

Epifauna (average/0.1 m^2)	
Perna canaliculus	0.27 (0.21)
Echinocardium cordatum	2.27 (0.37)
Austrofusus glans	0.07 (0.07)
Amalda mucronata	0.13 (0.09)
Animal activity	
# Holes-A (large, average/0.1 m^2)	2.20 (0.44)
# Holes-B (small, average/0.1 m^2)	4.80 (0.47)
Sediment reworking (1-5 scale)	3+
Microalgal coverage (1-5 scale)	3*

* Very light coverage in all quadrats

3.4. The greater Tasman Bay region

The present survey results describing sediment physico-chemical properties within sites of similar depths in the western Tasman Bay region (*i.e.* grain size distribution, organic matter content and TP concentration) were within similar ranges recorded during two previous investigations (Forrest 2007; Forrest *et al.* 2007) and unpublished information describing reference sites assessed during 2010 consent monitoring of mussel farm impacts within the central AMA (R. Forrest, Cawthron, pers. comm.). However TN concentrations observed during the present survey were ~ 58% lower than reported for the two earlier surveys cited and ~47% lower than those recorded in 2010. The reason for the reduced TN concentrations at the 2011 SOE monitoring site are unclear but there is some indication, based on comparison amongst the different sampling dates, that it may be a general phenomenon throughout the region.

Benthic biological communities were also typical of other regions of Tasman Bay; *e.g.* six sites of depths 15-20 m on the western side of the Bay (Gillespie *et al.* 2011b) and six of seven sites on the eastern side of the Bay (Keeley *et al.* 2006). Such community characteristics are consistent with a generally stressed benthic environment throughout much of the Bay due to high rates of deposition of suspended sediments originating from adjacent catchments (Gillespie *et al.* 2011b). Such stress-related conditions have likely been exacerbated as a result of physical disturbance of the seabed from a long history of dredging and bottom trawling activities (Gillespie & Rhodes 2006).

3.5. Potential controlling factors

3.5.1. River plume suspended sediment (SS) deposition

Since the study site was located within an area influenced by the Motueka River plume (Forrest *et al*. 2007), it is subjected to episodic flood-related SS discharges from the catchment (Gillespie *et al*. 2011b). Consequently, if large temporal changes in benthic habitats are detected, interpretation of potential contributing factors should consider the frequency and intensity of historical storm events during the periods leading up to each survey.

The frequency of flood events in the Motueka River >400 m^3/s during the 12 months leading up to the 2006 SOE survey (Figure 10) was considerably lower than that leading up to the 2011 survey; *i.e*. three *vs.* 11 respectively (Figure 11). However the benthic communities did not appear to be altered significantly as a result. This may be because the effects can be longer-term and potentially cumulative with regard to flood events. For example, Gillespie *et al*. (2011b) reported a particularly high SS discharge associated with a major flood in March 2005. This flood was considered to represent a “threshold event” whereby SS initially deposited within the river contributed to SS flushed into Tasman Bay during successive smaller rainfall events thereby potentially affecting the composition of benthic habitats, over an extended period (*e.g*. years). Observations of a fluctuating and sometimes persistent near-bottom high turbidity layer in river plume-affected regions of Tasman Bay (Gillespie & Rhodes 2006) suggest that on-going sediment resuspension can also affect benthic habitat characteristics for extended periods.

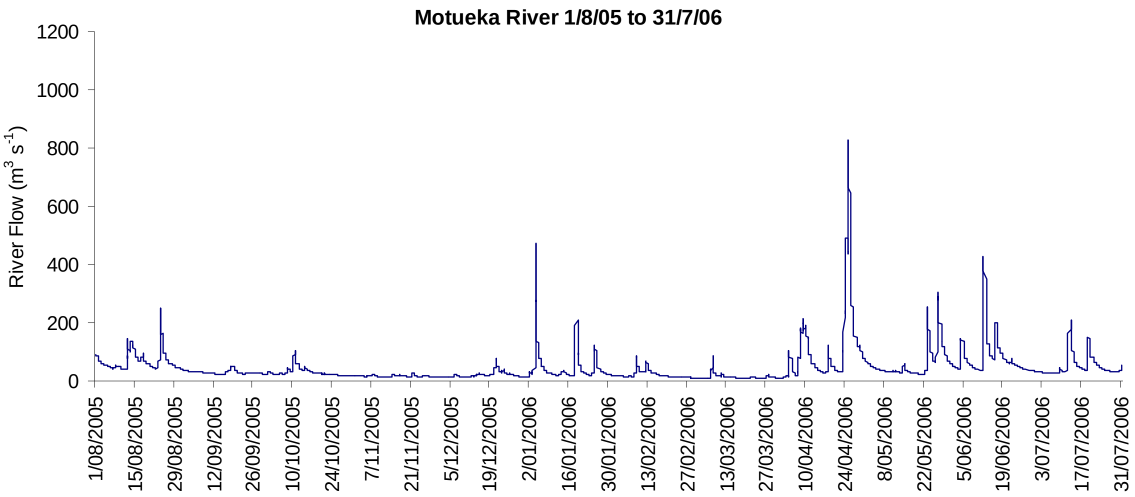

Figure 10. Motueka River flow during the 12 month period leading up to the 2006 SOE monitoring survey.

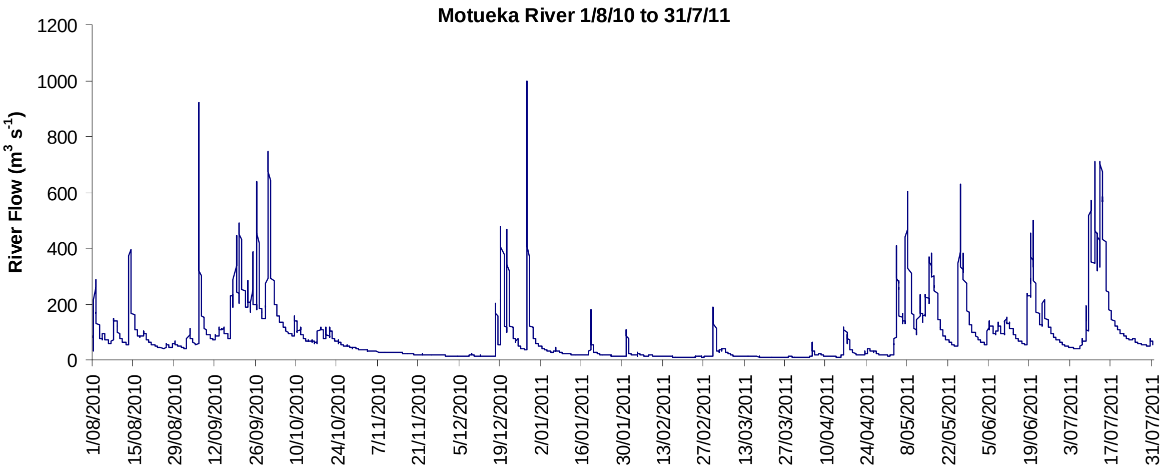

Figure 11. Motueka River flow during the 12 month period leading up to the 2011 SOE monitoring survey.

4. SUMMARY AND RECOMMENDATIONS

Physico-chemical characteristics of the seabed observed at the Tasman Bay SOE monitoring site were typical of benthic environments affected by high rates of deposition of inorganic sediments. No indications of excessive organic or inorganic nutrient enrichment (*e.g.* sediment anoxia, H_2S production) were observed. Changes in these characteristics observed between the 2006 and 2011 surveys were minor, with the exception of an unexplained ~25% reduction in TN concentration, which may be attributed to normal temporal variation. The possibility must be acknowledged, however, that the nearby deployment of the TASCAM monitoring buoy may have contributed to minor changes in seabed properties, due to slight alterations in the hydrodynamic characteristics of the site.

The dominant sediment silt/clay fraction and relatively low number of species and abundance of individuals indicated continued low physical (and related biological) habitat complexity at the monitoring site. Of particular interest was the observed 70% reduction (2006 vs. 2011) in density of the heart urchin, the dominant macrofaunal component. Although this may simply have been due to natural fluctuation over time, we propose continued evaluation of long-term trends in the abundance of this species as a potentially important indicator of ecological change.

An observed slight increase in epifaunal diversity and abundance at the SOE site between 2006 and 2011 was attributed to the drop-off of fouling animals that had settled on the nearby TASCAM buoy and mooring lines.

Continued monitoring of the Tasman Bay SOE site is recommended as a means of identifying/quantifying long-term changes in seabed habitat structure. However, since the SOE site also serves as a reference site for evaluating the effects of aquaculture activities in western Tasman Bay, there is a potential for coordination of SOE and industry consent monitoring efforts. A coordinated approach would provide a greater spatial context for the SOE results and would greatly improve the temporal resolution of the data, thereby improving the understanding of shorter term (*e.g*. yearly) fluctuations in habitat characteristics while allowing them to be placed in the context of long-term variation.

5. ACKNOWLEDGEMENTS

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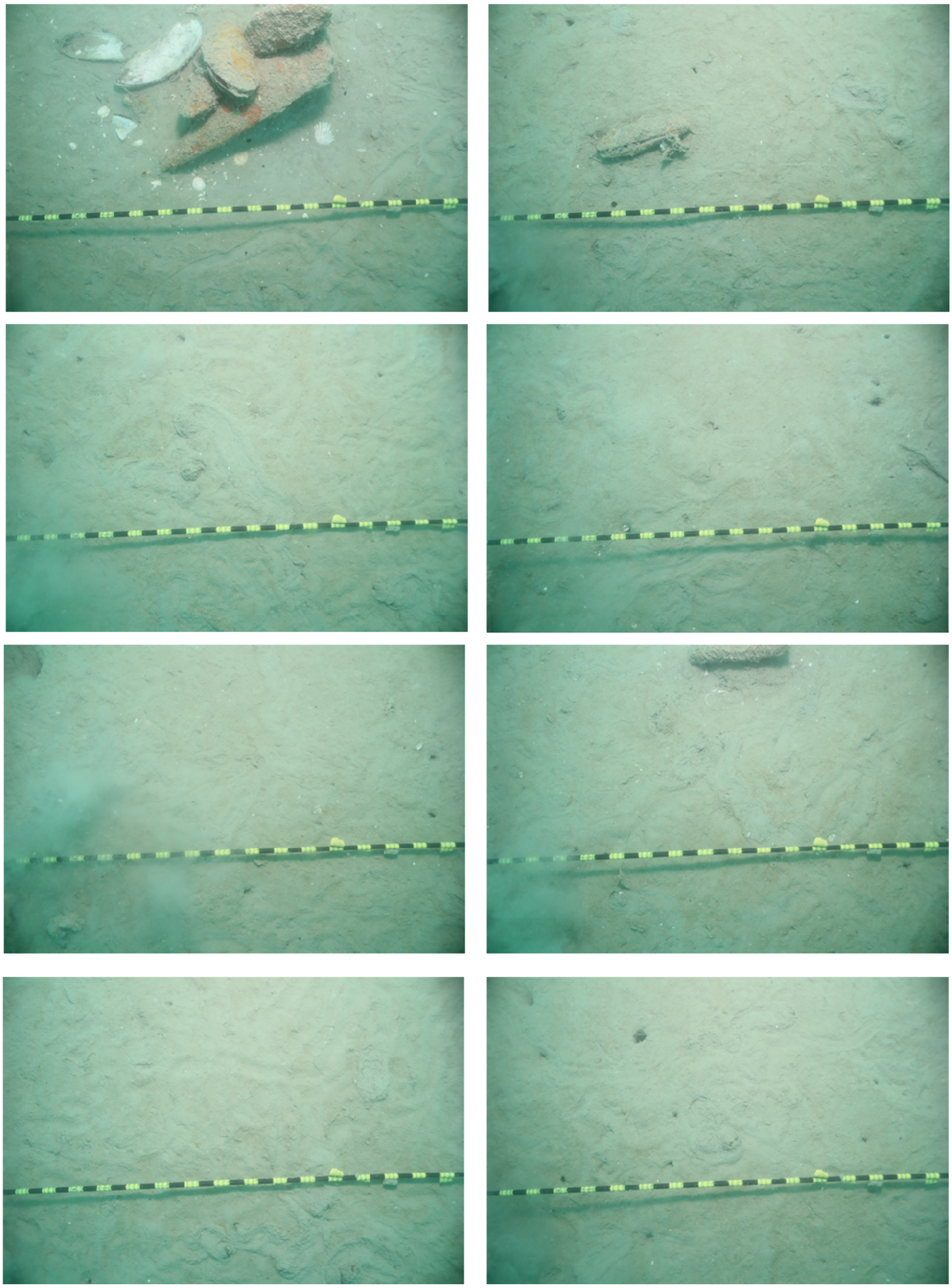
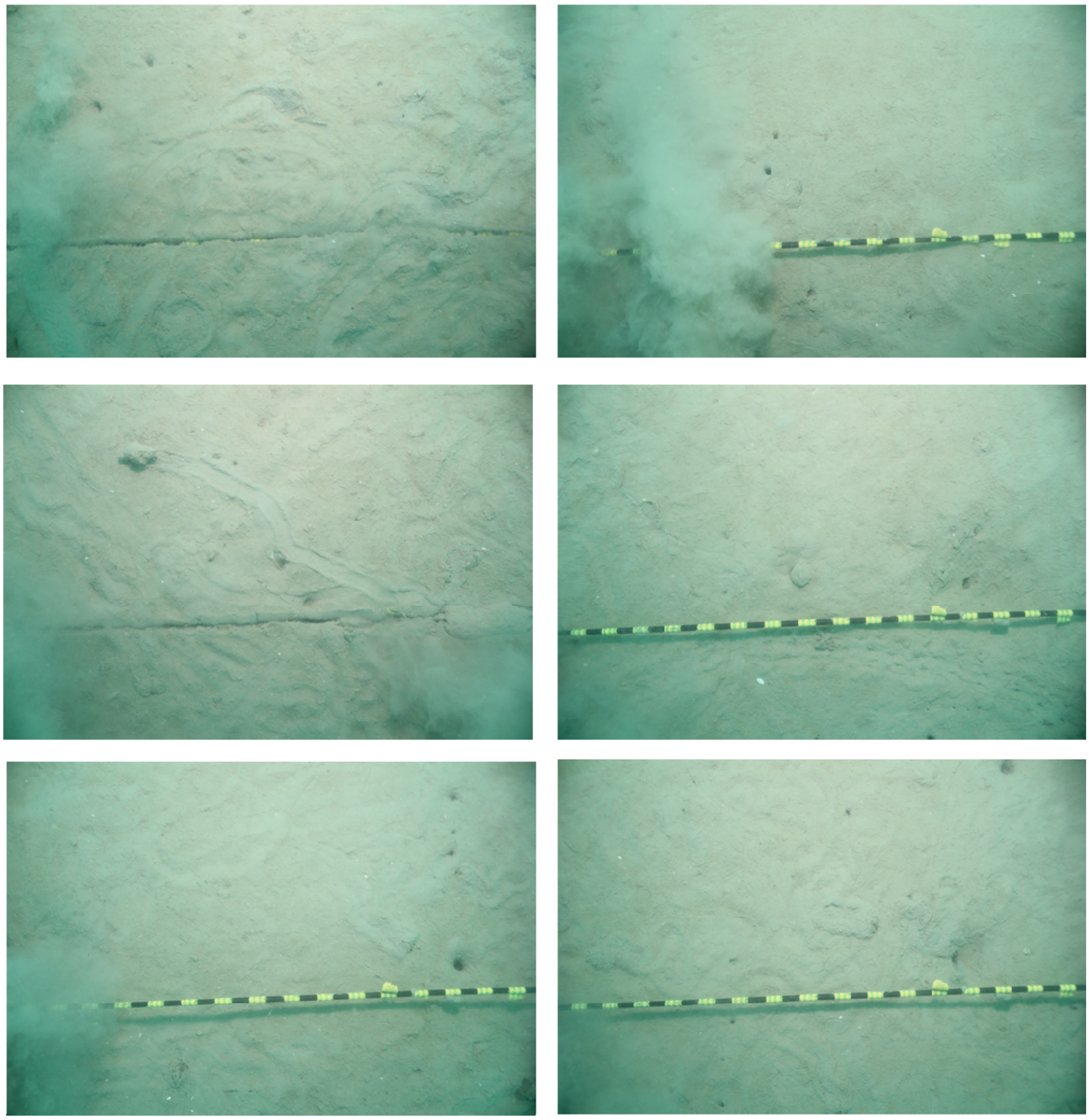
7. APPENDICES

Appendix 1. Seabed Quad cam images (also supplied on CD, providing greater resolution of features).



Appendix 1. Seabed Quad cam images, *continued.*



Appendix 2. Physical and chemical properties of sediments from 2006 and 2011.

		2006 (mg/kg)							
Site		**1**	**2**	**3**	**4**	**5**	**6**	Mean	(+1 Std)
Gravel (>2mm)	% w/w	2.6	1.7	0.3	4.6	0.6	1.8	1.9	1.6
Very coarse sand (2mm & >1mm)	% w/w	0.4	0.3	0.2	0.2	0.1	0.5	0.3	0.1
Coarse sand (<1mm & >500µm)	% w/w	0.3	0.3	0.3	0.3	0.9	0.4	0.4	0.2
Medium Sand (<500 µm & >240 µm)	% w/w	0.9	1.1	0.6	0.9	0.7	1.2	0.9	0.2
Fine sand (<250 µm & >125 µm)	% w/w	1.6	2.8	2.3	2.3	1.5	2	2.1	0.5
Very fine sand (<125 µm & >63 µm)	% w/w	4.1	5.1	3	4.7	3.7	4.4	4.2	0.7
Silt & clay (<63 µm)	% w/w	90	88.7	93.3	86.9	92.6	89.6	90.2	2.4
AFDW	% w/w	6.2	6.7	6.4	6.4	6.4	5.7	6.3	0.3
Total N	mg/kg (dry)	1800	1700	1800	1800	1800	1700	1766.7	51.6
Total P	mg/kg	857	910	894	890	954	841	891.0	40.0
Molar N/P	mg/kg	4.7	4.1	4.5	4.5	4.2	4.5	4.4	0.2

		2011 (mg/kg)							
Site		**1**	**2**	**3**	**4**	**5**	**6**	Mean	(+1 Std)
Gravel (>2mm)	% w/w	1.4	1.0	0.4	0.3	14.7	2.3	3.4	5.6
Very coarse sand (2mm & >1mm)	% w/w	0.2	0.1	0.0	0.1	0.3	0.4	0.2	0.1
Coarse sand (<1mm & >500µm)	% w/w	0.1	0.2	0.2	0.1	0.2	0.4	0.2	0.1
Medium Sand (<500 µm & >240 µm)	% w/w	0.3	0.5	0.5	0.4	0.5	0.6	0.5	0.1
Fine sand (<250 µm & >125 µm)	% w/w	1.0	0.9	0.9	0.6	0.6	1.1	0.9	0.2
Very fine sand (<125 µm & >63 µm)	% w/w	2.0	2.6	3.9	2.2	1.0	2.6	2.4	0.9
Silt & clay (<63 µm)	% w/w	95.0	94.8	94.1	96.2	82.7	92.7	92.6	5.0
AFDW	% w/w	6.1	6.4	6.2	6.7	5.8	5.9	6.2	0.3
Total N	mg/kg (dry)	620	620	700	730	660	720	675.0	48.9
Total P	mg/kg	820	790	740	910	800	860	820.0	59.0
Molar N/P	mg/kg	1.7	1.7	2.1	1.8	1.8	1.9	1.8	1.8

Appendix 3. Summary of descriptors of infauna community structure (based on a core area of 0.0135 m^2). See Table 2 for definitions of these statistics).

Sample	No. of Taxa	No. of Individuals (N)	Margalef richness index (d)	Pielou's evenness index (J')	Shannon-Weiner diversity index H'($\log_e$)
2006-1	14.0	21.0	4.3	1.0	2.6
2006-2	13.0	18.0	4.1	1.0	2.5
2006-3	14.0	17.0	4.6	1.0	2.6
2006-4	18.0	27.0	5.2	1.0	2.8
2006-5	16.0	20.0	5.0	1.0	2.7
2006-6	12.0	15.0	4.1	1.0	2.4
2006 Mean	14.5	19.7	4.5	1.0	2.6
(+1 Std)	2.2	4.2	0.5	0.0	0.1
2011-1	17.0	29.0	4.7	1.0	2.8
2011-2	17.0	22.0	5.2	1.0	2.8
2011-3	14.0	22.0	4.2	1.0	2.6
2011-4	16.0	23.0	4.8	1.0	2.7
2011-5	11.0	14.0	3.8	1.0	2.3
2011-6	13.0	19.0	4.1	1.0	2.5
2011 Mean	14.7	21.5	4.5	1.0	2.6
(+1 Std)	2.4	4.9	0.5	0.0	0.2

Appendix 4. Merged infauna taxa and abundance data (individuals/core) for 2006 and 2011.

			Jul-2011						**Jul-2006**					
GROUP	**TAXA**	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Gastropoda	Gastropoda (white rissoid like)		1	2	1			1						
Gastropoda	Gastropoda (unident.)									1				
Gastropoda	*Austrofusus glans*			1		1			3		1	1	1	
Bivalve	*Arthritica bifurca*									3	2		1	
Gastropoda	Struthiolaria papulosa	Kaikai-karoro					1							
Gastropoda	*Turbonilla sp.*			1										
Opisthobranchia	*Philine auriformis*	White slug		1						1				
Bivalve	*Melliteryx parva*		4	3										
Bivalve	*Mysella unidentata*	Small bivalve				3	1							
Bivalve	*Nemocardium pulchellum*	Purple cockle						4						
Nemertea	Nemertea													1
Nematoda	Nematoda								1	4	2	1		
Bivalve	*Nucula gallinacea*	Nut shell	1			1							1	
Bivalve	*Dosinia lambata*									2	1	1	1	
Bivalve	*Ennucula strangei*								1			1		
Bivalve	*Leptomya retiaria retiaria*									1				
Bivalve	*Neilo australis*												1	
Bivalve	*Theora lubrica*	Window shell	6	4	5	5	1	2	3	2	1	2	4	1
Polychaeta: Paraonidae	Paraonidae		1	1		3	1	1		1	2	1		1
Polychaeta: Spionidae	*Cossura consimilis*		6	4	9	3	9	9	2	3		3	1	1

			Jul-2011						Jul-2006					
GROUP	**TAXA**	**COMMON NAME**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
Polychaeta: Cossuridae	*Prionospio multicristata*					1								
Polychaeta: Capitellidae	*Capitella capitata*		2		1									
Polychaeta: Capitellidae	*Heteromastus filiformis*		3	1				1						
Polychaeta: Sigalionidae	Sigalionidae		5	1	3	5	1		3	4	1	5	1	4
Polychaeta: Nephtyidae	*Aglaophamus sp.*		2	1	3	1	1	1	6	3	3	5	5	3
Polychaeta: Lumbrineridae	Lumbrineridae			1		2		1	2	2		2		1
Polychaeta: Dorvilleidae	Dorvilleidae				1									
Polychaeta: Cirratulidae	Cirratulidae		6			3	2	3	2		2	4	3	4
Polychaeta: Flabelligeridae	Flabelligeridae		1			1								
Polychaeta: Terebellidae	Terebellidae		1	1	4	1		2			1	1		1
Polychaeta: Terebellidae	*Terebellides stroemi*								1					
Crustacea: Malacostraca	Cumacea	Hooded shrimp	3	6	4	4	1		5			8	2	1
Amphipoda	Amphipoda[1]		4		1	1	3	1	1		3	2	2	
Amphipoda	Phoxocephalidae[2]		1		1		1	1	2		1		1	
Crustacea: Decapoda	*Macrophthalmus hirtipes*	Stalk-eyed mud crab		1	1	1								
Crustacea	Ostrocoda		13	1	5			4	3			3	1	
Crustacea: Malacostraca	Mysidacea											1		
Crustacea: Malacostraca	*Tanaid sp.*										1	2		
Echinodermata	Ophiuroidea												1	1
Echinodermata	*Echinocardium cordatum*	Heart urchin		1	1					1	1	2	1	1
TOTAL ABUNDANCE			60	31	40	36	22	31	35	28	22	45	27	20

[1] Incl. Corophiidae, Oedicerotidae, Amphipoda B and Amphipoda C

[2] Amphipoda A