MONITORING OF BENTHIC EFFECTS OF THE WAIROA DISTRICT COUNCIL WASTEWATER TREATMENT PLANT OUTFALL DISCHARGE AT SITES IN THE LOWER WAIROA RIVER ESTUARY: 2011 SURVEY

PROJECT No.
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PREPARED FOR
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PREPARED BY
SHADE SMITH

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EAM - ENVIRONMENTAL CONSULTANTS
Level 1 Bowman Building, 3 Market Street PO Box 1154, Napier 4110
Phone 06 835 0248 **Fax** 06 835 0247 **Email** info@eam.co.nz **Web** www.eam.co.nz

Report prepared by:

Shade Smith
Principal Marine Scientist

Report reviewed by:

Jason Strong
Principal Environmental Scientist

Cover photo: Royal Spoonbills, Kotuku Ngutupapa (*Platelea regia*) resting on a tree washed down the river and held fast in the mud at a site approximately 100m upstream of the WDC outfall during the present survey.

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1. INTRODUCTION

The Wairoa District Council (WDC) Wastewater Treatment Plant consists of a two pond aerobic and anaerobic decomposition system and an outfall in the coastal marine area. Built in 1981, the oxidation ponds and outfall provide treatment of municipal sewage and disposal of effluent generated by Wairoa's approximately 4200 residents. Influent is firstly coarsely screened (<5mm) and then directed into a mixed primary pond (pond 1) which provides for facultative decomposition. The second stage of treatment occurs in a larger primarily anaerobic pond (pond 2), where some facultative decomposition occurs, but primarily pond 2 is described as a maturation pond. From the elevated situation of the ponds at Pilot Hill the treated effluent exits the final stage anaerobic pond and is gravity fed to the outfall discharge port. The discharge port is located at or about E2892440 N6228931 (NZTM NZGD2000), in the sub-tidal area of the lower Wairoa River Estuary, approximately 150m from the shoreline (opposite the entrance to Fitzroy Street, Wairoa) and approximately 800 m NE of the river estuary mouth which opens into northern Hawke Bay (Figure 1).

The outfall is constructed of high density black polyethylene (internal Φ 300mm) and has over time become buried in the sediment. The outfall discharge port is simply the terminus of the outfall pipe. Effluent discharge occurs into the overlying water column, which during typical discharge conditions (i.e. during ebb tide beginning 30mins after high tide and between 6pm and 6am) varies in depth between 1 – 2m. The area immediately above the outfall terminus is termed the 'boil' given that the upwelling effluent can at times be visible at the water's surface.

1.1 BACKGROUND

The resource consent WDC holds to discharge municipal wastewater into the Lower Wairoa River Estuary (CD940404W) does not specifically address monitoring of the receiving environment. However, when the consent was granted the issuing authority (Hawke's Bay Regional Council (HBRC)) noted that the 20 year period of the consent allowed ample time for the WDC to investigate options for upgrade to accommodate cultural issues and to provide a better level of treatment prior to discharge.

In 2006 a review of the Wairoa Wastewater Treatment Plant (WWTP) was completed by Opus International Consultants (Crawford, 2007) to ascertain whether or not some form of upgrade to wastewater treatment facilities would be required in the future. That review recommended the WWTP monitoring program be broadened to include: a characterisation of influent and effluent and associated pollutant loading, an assessment of unit process performance and an assessment of effects from the discharge to the receiving environment. In April 2007 EAM Ltd was contracted to carry out this expanded monitoring program. Since then influent and effluent quality have been monitored monthly while an assessment of ecological effects, incorporating high resolution dye dilution studies and a benthic survey and assessment of flatfish tissue have been undertaken (Barter 2007, Smith 2007).

Prior to these studies the estuarine/riverine environment in the vicinity of the Wairoa outfall has been the subject of only a limited number of studies over the last 20 years. These include a coarse dye dilution study, and benthic and water quality surveys conducted by Bioresearches Ltd. in 1996 at sites around the WWTP outfall (Larcombe 1996a). In an attempt to disentangle the effects of upstream discharges from that of the WDC outfall a dye dilution study, benthic and water quality assessment around the AFFCO freezing works outfall, located approximately 2km upstream of the WWTP outfall was also conducted around the same time (Larcombe 1996b).

These reports note that at times the estuary mouth can become partially or fully blocked heavily restricting river discharge into Hawke Bay and represents a worst case scenario for effluent discharge. This generally occurs during heavy sea conditions when the shingle bar is built up particularly during easterly generated swell. Although the consent requires WDC to store effluent during these periods the WWTP storage capacity is often exceeded and thus effluent has to be discharged into the estuary during these 'restricted flow' conditions. The first effluent dilution study in 2007 during this worst case scenario showed that the effluent plume did not disperse and remained close to the 'boil' with minimal transport, effected only by wind. Dilutions of 5:1 at the 'boil' where typical while the plume moved only a maximum of 150m from the 'boil' (Barter 2007). Under these conditions there is a significant human health risk when using the lower estuary for contact recreation, especially if these conditions persist for an extended period of time. During the second study and under normal flow conditions (i.e. where the estuary mouth was not blocked) effluent dilutions were 5:1 at the 'boil', 50:1 at 125m downstream and 250:1 at 350m downstream (Barter 2007). Under these conditions, effluent exits the estuary in a relatively short timeframe with the risk to human health moderate during discharge and less than minor at other times.

In terms of benthic effects, the 1996 survey found that the discharge had "no obvious effects on benthic biology or sediment quality" although nutrient enrichment of sediments was suggested as likely during 'restricted flow' conditions (Larcombe 1996a). The 2007 survey found that "discharge effects on benthic infaunal communities around the outfall are evident, and may continue to alter composition over time" and that "sediments at sites around the outfall have declined in quality over time". The 2007 survey also included an examination of trace metal concentrations in flatfish tissue, and found that levels were well within food safety limits with no evidence of accumulation. Overall, it was considered the scale of effects from the discharge were within the assimilative capacity of the receiving environment and that the presence of a sensitive bivalve species, *pipi* (*Paphies australis*), at sites around the outfall suggested effects were not large enough to constitute an undue adverse effect.

FIGURE 1: WAIROA RIVER ESTUARY SHOWING THE LOCATIONS OF THE WAIROA WWTP, THE OUTFALL IN RELATION TO THE MOUTH OF THE ESTUARY, 'IMPACT' MONITORING SITES A AND B AND 'REFERENCE' SITE C.

1.2 THIS STUDY

Given that the current discharge consent expires in 2019 and the need to be proactive in managing potential effects WDC have sought to incorporate the monitoring of benthic effects into the routine WWTP monitoring programme. Hence, following the 2007 benthic survey it was proposed that every four years monitoring of the effects of the treated effluent discharge on the macrobenthos and sediments be undertaken. Thus WDC engaged Environmental Assessments and Monitoring Ltd (EAM) to conduct a benthic survey of the receiving environment, including the following components:

- Assessment of sediment texture, organic content, trace metal and nutrient levels at outfall monitoring sites and at a suitable reference site.
- Assessment of benthic macroinfaunal communities at outfall monitoring sites and at a suitable reference site.

This report presents the findings of field survey work conducted in June 2011, subsequent data analyses, comparison to previous survey results and an assessment of effects. Where possible, the methods used in this survey were in keeping with those used in previous surveys. All methods used are fully detailed in the respective sections of this report.

1.3 RECEIVING ENVIRONMENT

The Wairoa River Estuary, commonly referred to as a barrier enclosed lagoon or drowned valley is classified, according to the New Zealand estuary classification system (Hume et al. 2007) as a category F estuary. Category F estuaries are characterised by a spit or shingle bar enclosing a large primary basin from which numerous arms lead off. This system gives rise to complex shoreline structure and supports extensive intertidal areas cut by deep channels. Wind mixing and wave driven re-suspension of sediments is generally minor given the limited fetch. Sediments tend to be muddier in the arms and sandier in the primary basin. The volume of river flow delivered over a tidal cycle is typically small compared to the total volume of the basin, and is generally less than the tidal volume entering the basin. Thus hydrodynamic processes tend to be dominated by the tides, meaning that these estuaries are poorly flushed.

The immediate receiving environment surrounding the outfall varies in depth considerably given that the outfall is located near the edge of the main channel. In 2007, prior to the start of the second dye dilution study, a coarse bathymetric survey across the main channel and in line with the outfall pipe, was completed (Figure 2). Those results show that under normal discharge conditions the effluent was discharging into around 1m of water and was around 40m shoreward from the edge of the main channel.

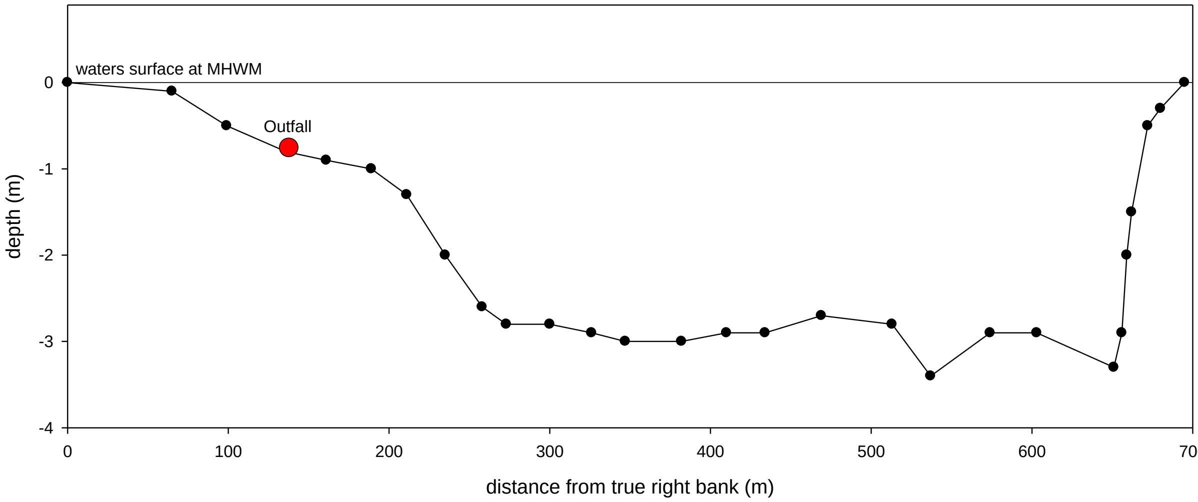

FIGURE 2: CROSS SECTION OF THE BATHYMETRY IN THE LOWER WAIROA RIVER ALONG THE LINE OF THE OUTFALL PIPE AS MEASURED DURING JUNE 2007.

Relevant literature that discusses the benthic habitat and epifauna of the area includes previous assessment reports of the outfall and also a report produced as part of the HBRC Estuarine State of the Environment (ESoE) monitoring program where in 2010 a Wairoa River Estuary site was included in the programme for the first time. The HBRC ESoE site is located approximately 600m upstream of the outfall. These studies reveal a patchy intertidal substratum of sandy mud with areas toward the main channel showing some rippled muddy sand while downstream of the outfall more muddy and upstream sites more sandy. These sediments support a moderately diverse array of infaunal and epifaunal organisms, including polychaete worms, various bivalve and gastropod species, and small crustacea, particularly Corophid amphipods, indicative of a low energy, low salinity estuarine setting(Conwell 2008). Complex habitat is limited with the occasional large tree or tree limb held fast in the mud providing some complex 3D structure. The area supports significant recreational and customary fishing effort with flatfish species, particularly yellow-bellied flounder (*Rhombosolea leporina*), using the immediate area around the outfall to forage (*pers obs*).

2. SEDIMENT CHARACTERISITICS

2.1 INTRODUCTION

Sediment characteristics can influence the distribution of benthic (bottom dwelling) invertebrates by affecting the ability of various species to burrow, build tubes or feed. In addition, demersal fish (fish that live on or near the bottom) are often associated with specific sediment types that reflect the habitats of their preferred prey. Both natural and anthropogenic factors affect the distribution, stability, quality and composition of sediments. Outfalls are one of many human derived (anthropogenic) factors that can directly influence the composition and distribution of sediments, and this occurs through the discharge of wastewater and subsequent deposition of a variety of compounds. In discharges from pulp mills the most common contaminants of concern are organic carbon in the form of wood fibres and fragments. Moreover, the presence of outfall pipes or associated structures can alter the hydrodynamic regime in the immediate area surrounding the outfall.

This section presents a summary and analysis of sediment composition (grain size), organic matter, sediment trace metal and nutrient data collected in June 2011 in the vicinity of the WDC WWTP outfall. The aim was to assess the impact of the WWTP effluent discharge on the benthic environment by analysing spatial variability of the various sediment parameters and comparing the results to previous studies.

2.2 METHODOLOGY

2.2.1 SAMPLING SITES

The location of sampling sites in the present survey were consistent with those sampled in previous surveys in 1996 and 2007 (Figure 1, Table 1). Therefore, three sites were again sampled, two 'impact' sites in relatively close proximity to the terminus of the outfall (site A approximately 100m south-west or downstream and site B approximately 100m north-east or upstream of the outfall, and a control, or 'reference' site (site C approximately 500m north-east of the outfall. These sites are deemed representative of the benthic environment surrounding the outfall while the pattern of their siting, allows fine scale detection of the extent and magnitude of any outfall related effects in sediments.

Table 1: Location of WDC outfall monitoring sites sampled during the 2011 survey.

	NZTM (NZGD2000)	
Site	**East**	**North**
A	2892378	6228853
B	2892512	6228997
C	2892769	6229293

2.2.1 METHODOLOGY

A handheld Garmin eTrex GPS unit was used to locate each site (± 3m). Samples were collected at low tide on the 15th June 2011. At each site, five replicate sediment cores were collected using a PVC 60mm (internal Φ) x 150mm long corer. Cores were collected by pushing the corer into the sediment to a depth of 150mm and digging down the outside of the corer and placing a hand over the bottom of the corer when extracting the core from the surrounding sediment in order to maintain the integrity of the core profile. Cores were then ejected onto a clean white tray and split vertically. Each core was visually assessed for the presence/absence of anoxic areas within the core and the redox potential discontinuity (RPD) layer1 measured. Cores were then photographed and the top 5cm of sediment from each half of the core placed into separate pre-labelled resealable plastic bags and immediately stored on ice. Each replicate sediment core was analysed for chemical composition, while the sediment texture samples from each site were composited, and a single sub sample prepared

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[1] Redox Potential Discontinuity Layer (RPDL) - the brown coloured, oxygenated surface layer of sediments, distinct from the black anoxic layer beneath.

for analysis. Samples were transported on the same day to Hill Laboratories, Hamilton for analyses. A summary of the analytical methods used are presented in Table 2.

Table 2: Summary of analytical methods used for sediment analyses

Matrix	Parameter	Method	Description
Sediment	Particle Grain Size*	Malvern Mastersizer 2000 ver. 5.22 Laser Sizer.	Medium sand 300µm - 600µm Fine sand 150µm - 300µm Very fine sand 62.5µm -150µm Coarse silt 31µm - 62.5µm Medium silt 15.6µm - 31µm Fine silt 7.8µm - 15.6µm Very fine silt 3.9µm - 7.8µm Clay < 3.9µm
Sediment	Organic content: TVS	APHA 2540 G 20th Ed. 1998	Ignition in muffle furnace 550°C, 1hr, gravimetric.
Sediment	Trace metals: As,Cd,Cr,Cu,Hg,Ni,Pb,Zn	USEPA 200.2	Nitric/Hydrochloric acid digestion, ICP-MS (low level)
Sediment	Total Recoverable P	USEPA 200.2	Nitric/Hydrochloric acid digestion, ICP-MS
Sediment	Total N		Catalytic combustion (900°C, O_2), separation, thermal conductivity detector (Elementar Analyser)

2.2.3 DATA ANALYSIS

Trace metal results were compared against national sediment quality guidelines (ANZECC 2000). These guidelines or Interim Sediment Quality Guidelines (ISQG) consist of upper (ISQG-high) and lower (ISQG-low) thresholds above which biological effects can be expected. Where trace metal concentrations are below ISQG-low values then adverse biological effects are expected only on rare occasions. Trace metal concentrations falling between ISQG-low and ISQG-high are expected to cause adverse biological effects occasionally, while a result above the ISQG-high would be expected to cause adverse biological effects frequently.

In areas where anthropogenic influences are negligible, sediment trace metal concentrations largely reflect the surrounding geology. Sediments formed under these conditions, contain trace metals at levels described as 'baseline/background concentrations. Therefore trace metals were also compared against a set of relevant trace metal "Regional Background Concentration" (RBC) levels (Strong 2005). The RBC's were derived from sediment trace metal levels at 17 study areas, comprising 67 sites, located throughout Hawke's Bay's estuarine, riverine and lagoon systems. The RBC's provide a relevant regional basis for assessing the impact of a particular activity on sediment quality.

Spatial differences in TVS, nutrients and trace metals between sites in the present survey were explored visually and also using univariate statistical techniques (ANOVA) between sites. Similarly, temporal differences in sediment texture were also explored visually and subjected to a 2 factor ANOVA (site and year).

In order to prevent differences in sediment composition from affecting assessment of differences between sites sediment trace metal values, TVS and nutrients data were normalised[2] to the proportion of 'fines' (mud), i.e. the clay/silt fraction (particles <63µm) in each sample.

To compare TVS data against the previous 1996 study the values for % organic carbon presented in the 1996 report had to be converted to % organic matter, or TVS, by multiplying by 1.724 (Metson et al, 1971) before normalising.

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[2] Trace metals have been shown to preferentially adhere to fine sediments in the silt/clay fraction that have reactive surface properties. Therefore, differences in trace metal concentrations between sites may simply reflect differences in the proportion of sediments in this fraction. Normalising sediment contaminant data allows standardisation of sediment contaminants to sediment composition.

2.3 RESULTS

2.3.1 SEDIMENT TEXTURE

PRESENT SURVEY

Visual assessment of cores revealed some variability in RDPL depths between stations at 'impact' site A and to a lesser extent among stations at the reference site C (Table 3). RDPL depths indicate the extent of aeration and bioturbation in the estuary and the increased variability at sites A and C is likely a reflection of the increased amount of sand at stations A2 and C5 whereas most other sites were more muddy (see Appendix 1 for photos of sediment cores and Appendix 2 for measurements of RDPL depths). Average RDPL depths for all sites were relatively shallow with these measurements tending to suggest moderate sediment oxygenation. Below the RDPL layer the blackened anoxic zone at all sites had a distinctive smell of hydrogen sulphide. Few infauna reside in the anoxic zone and given the relatively shallow depth of the oxic zone the infaunal community is likely to be transitional and prone to fluctuations in abundance.

Table 3: Mean depth of the redox potential discontinuity layer (RDPL) at WDC outfall monitoring sites (± 1 SE)

Site	RPDL depth (mm)	Sediment matrix
A	43.6 ± 19.6	Mud
B	33 ± 6.8	Mud
C	35.6 ± 11.8	Sandy mud

In terms of sediment texture, all sites were predominantly characterised by mud, or 'fines'(<63µm) with course silt (31-63µm) the dominant fine sediment fraction at sites A and B (Figure 3). At the reference site C, sediments were sandier with a relatively higher component of fine sand (125-150µm) evident. Given the large amount of 'fines' comprising the sediments at all sites it was not surprising that the depth of the RDPL among sites was generally quite shallow. Although sites surrounding outfalls tend to show increased proportions of 'fines', in this case the increased amount of 'fines' at sites A and B compared to the reference site C is likely a combination of both the influence of the discharge and other site and temporal specific factors. The most significant of these factors is that the outfall is located in an area surrounded by expansive intertidal and shallow subtidal flats. These areas are often depositional and prone to accumulation of 'fines'. The large amount of 'fines' at all sites suggests that much of the river borne fine sediments deposit not only in the side arms of the estuary but on the expansive intertidal and shallow flats along the edge of the main channel.

INTER-SURVEY COMPARISON

The greatest change when comparing sediment texture among surveys to date (1996, 2007, 2011) was the increase in 'fines' among all sites over time and particularly between 2007 and the present (2011) (Figure 4). At site B this amounted to an increase of 3.8x in 'fines' between 2007 and 2011, whereas at sites A and C the increase over the same period was 1.2x and 1.4x respectively. Compared to 1996 the amount of 'fines' during the present survey at site B were 5.9x higher, while at site A levels where 2x higher and at site C levels were 1.4x higher. In general these results suggest the magnitude of increase in 'fines' across all sites is not consistent among sites, with the monitoring site downstream of the outfall (site A) relatively similar to the reference site (site C) while site B was much higher than both. At the site upstream of the outfall (site B) there appears to have been a major change in the hydrodynamics and thus sediment dynamics over time, which has resulted in this site becoming highly depositional as opposed to transitory as was the case in 1996 and 2007. Given the relative similarity in the magnitude of increase over time between sites A and C it is unlikely that the outfall discharge has majorly influenced the significant change evident at site B.

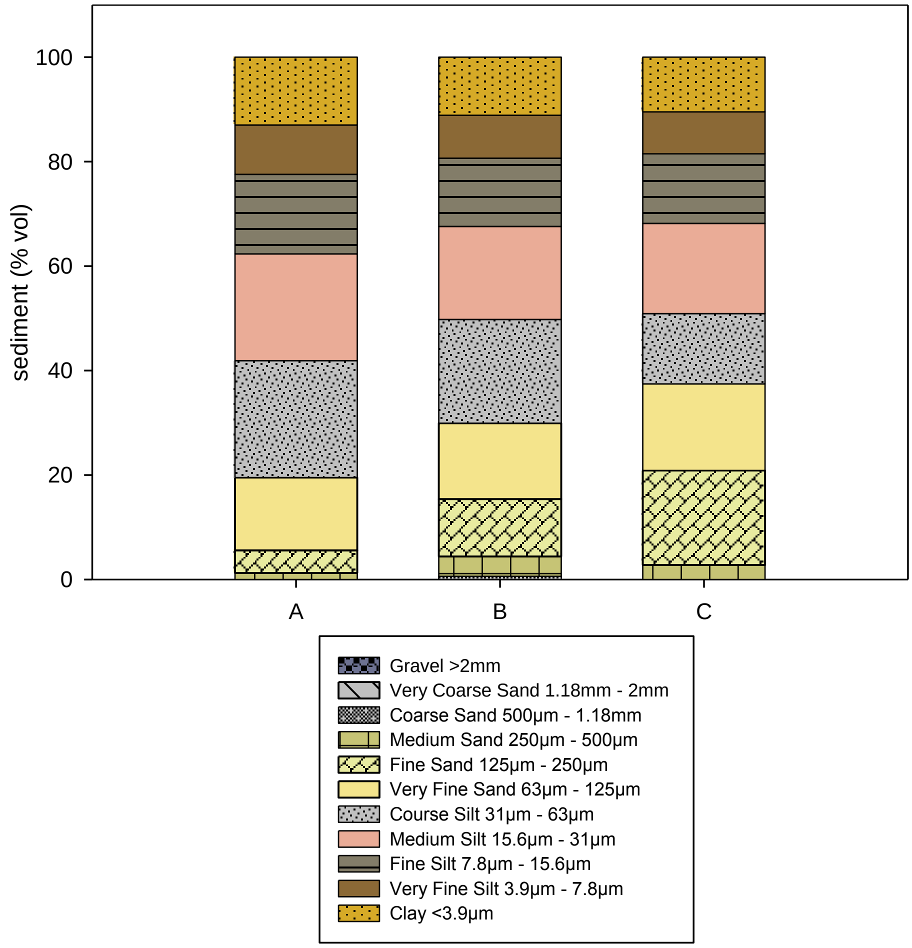

FIGURE 3: COMPARISON OF SEDIMENT TEXTURE AMONG WDC OUTFALL MONITORING SITES A, B ('IMPACT') AND C ('REFERENCE') DURING THE PRESENT (2011) SURVEY.

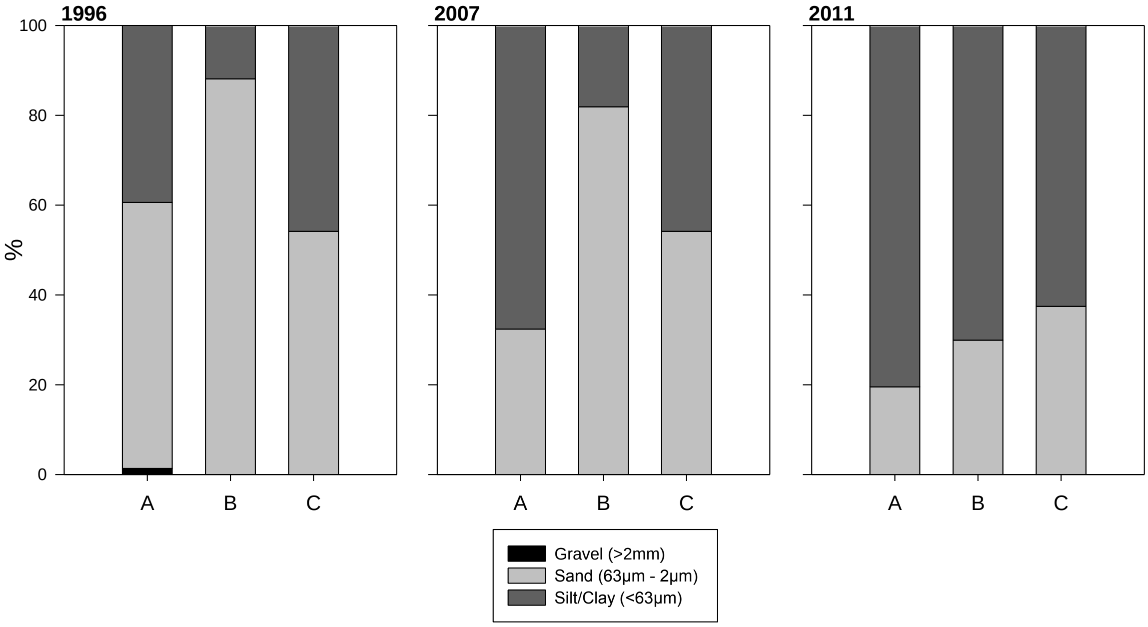

FIGURE 4: COMPARISON OF SEDIMENT TEXTURE AMONG OUTFALL MONITORING SITES A, B ('IMPACT') AND C ('REFERENCE') DURING SURVEYS IN 1996, 2007, AND THE PRESENT (2011). NB: 1996 RESULTS EXPRESSED AS % WET WEIGHT WHEREAS 2007 AND 2011 RESULTS EXPRESSED AS % VOLUME.

2.3.2 TOTAL VOLATILE SOLIDS

PRESENT SURVEY

Total volatile solids (TVS), also referred to as Ash Free Dry Weight (AFDW) represents the amount of organic matter present in the sediments. During the present survey the levels of organic matter where fairly low for estuarine sites (all sites ranged between 1.45% and 4.5%) although site A appeared slightly higher than the other sites (Figure 5a). However as levels of organic matter in sediments will tend to be higher in sites with a higher fines fraction, it is worthwhile normalising TVS results to 100% of the fines fraction for each site in order to more accurately compare between sites and reference estuarine sites. Statistical comparison of normalised data estimated no significant difference in TVS among sites.

INTER-SURVEY COMPARISON

Comparing normalised data for TVS over time, it appears that, apart from site B, levels have varied relatively little (Figure 5b). The sole significant difference in normalised results at sites over time (site B) was primarily a result of the small amount of 'fines' in 2007 compared to the present. These results for TVS are among the lower range of levels for organic matter among other estuaries nationally.

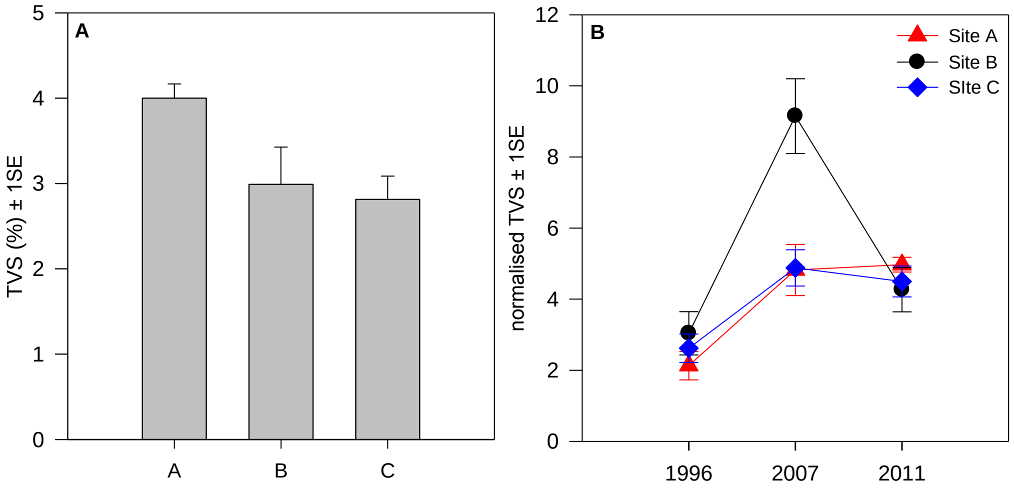

FIGURE 5: A) MEAN TOTAL VOLATILE SOLIDS (ORGANIC MATTER) AMONG WDC OUTFALL MONITORING SITES A, B ('IMPACT') AND C ('REFERENCE') DURING THE PRESENT (2011) SURVEY. **B)** MEAN NORMALISED TVS IN SEDIMENTS AMONG OUTFALL MONITORING SITES DURING SURVEYS IN 1996, 2007, AND THE PRESENT (2011). RESULTS NORMALISED TO 100% OF THE SILT/CLAY CONTENT AT EACH SITE.

2.3.3 SEDIMENT QUALITY - NUTRIENTS

PRESENT SURVEY

Site A had the highest concentration of both total nitrogen (TN) and total phosphorus (TP) followed by site C then site B (Figure 6). When compared against other Hawke's Bay and reference estuaries throughout New Zealand TN and TP concentrations at sites A, B and C are not significantly elevated, and lie in the mid range of values (Table 4). It is difficult to determine whether or not at these levels sediments could be classed as nutrient enriched as the survey was conducted during early winter when benthic algal production is typically at its lowest for the year. During summer nuisance algal growth can be evidence of sediment nutrient enrichment but given the time of year the survey was conducted (which was to be consistent with previous years) none was expected and indeed none was evident. Although levels are moderate compared to other estuaries an examination of monitoring sites during summer months for signs of nuisance algae would confirm whether sediments are nutrient enriched or not. As with TVS, levels of nutrients in sediments will tend to be higher in sites with a higher fines fraction and so to compare between sites levels were normalised to 100% of the mud/'fines' fraction. Comparisons show no significant differences in normalised TN between sites while normalised TP was significantly different among all sites (i.e. all sites different to each other, $p < 0.05$). In this case normalised levels at the reference site C were highest followed by site A then site B.

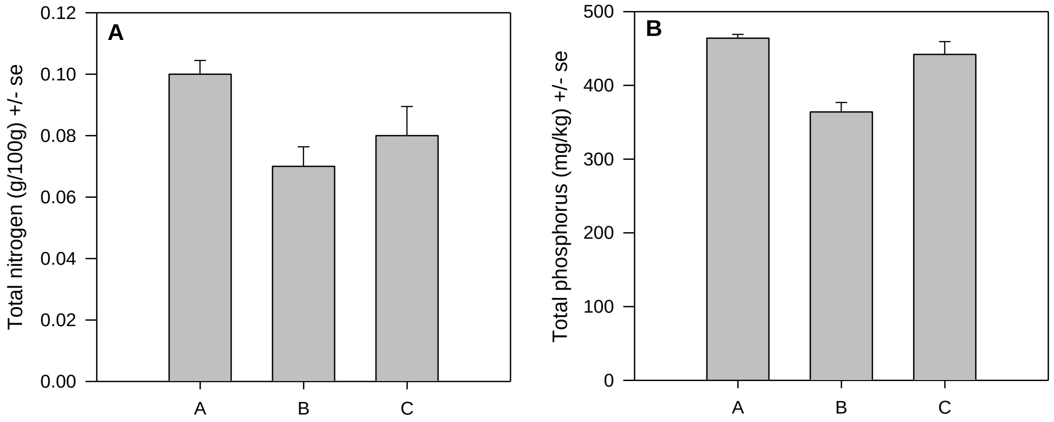

FIGURE 6: MEAN NUTRIENT CONCENTRATIONS **A)** TOTAL NITROGEN AND **B)** TOTAL PHOSPHORUS AMONG WDC OUTFALL MONITORING SITES A, B ('IMPACT') AND C ('REFERENCE') DURING THE PRESENT (2011) SURVEY.

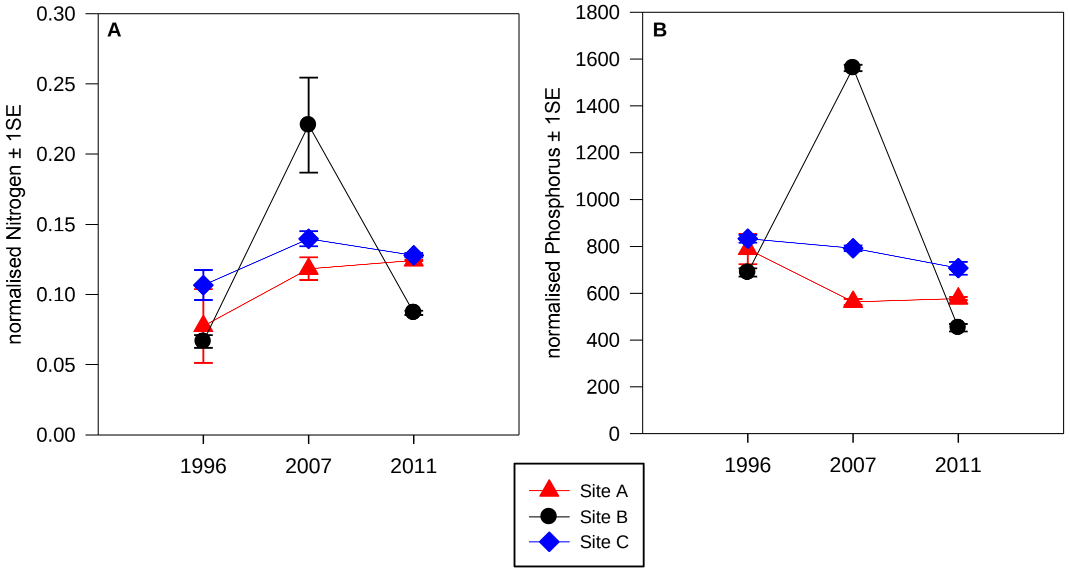

FIGURE 7: MEAN NORMALISED NUTRIENT LEVELS **A)** NITROGEN AND **B)** PHOSPHORUS IN SEDIMENTS AMONG OUTFALL MONITORING SITES A, B ("IMPACT') AND C ('REFERENCE') DURING SURVEYS IN 1996, 2007, AND THE PRESENT (2011). RESULTS NORMALISED TO 100% OF THE SILT/CLAY CONTENT AT EACH SITE. NB: 1996 NITROGEN RESULTS ARE TOTAL KJELDAHL NITROGEN (TKN).

Table 4: Range of Total Nitrogen (TN) and Total Phosphorus (TP) concentrations recorded at WDC outfall monitoring sites A, B and C during the present (2011) survey compared to the range of values at New Zealand estuary reference sites.

Site	TN (mg/kg)	TP (mg/kg)
A	900-1100	450-480
B	250-900	330-410
C	500-1000	410-500
Otamatea/Kaipara[1]	800-2400	443-619
Ohiwa[1]	250-1000	212-350
Ruataniwha[1]	250-700	330-580
Waimea[1]	250-1000	243-562
Havelock[1]	70-900	241-433
Kaikorai[1]	1500-2100	728-913
Avon-Heathcote[1]	250-600	298-355
Ahuriri[2]	790-840	320-810

1. (Robertson et al., 2002) 2. (Bennett, 2006)

INTER-SURVEY COMPARISON

Comparing normalised nutrient data among surveys, there were no significant differences in either TP or TN at site A between 2007 and the present but these where significantly lower than the 1996 result (*p* < 0.05) (Figure 7a,b). As Total Kjeldahl Nitrogen (TKN) was measured in 1996 rather than TN it is not appropriate that results be statistically compared, however given that TKN comprises the majority of TN it is worthwhile plotting the results to provide a broad comparison of how nitrogen has varied over time (Figure 7a). For both TN and TP the large increase in 'fines' at site B between 2007 and the present has likely resulted in the large reduction in the normalised results between these years. However, it is interesting to note that the present normalised results were only slightly lower than those reported in 1996 even though the sediment texture in 1996 was more similar to that observed in 2007. At site C there was no significant difference in TN between 2007 while for TP the present results were significantly different (lower), though only marginally, than both 1996 and 2007 normalised results.

2.3.4 SEDIMENT QUALITY – TRACE METALS

PRESENT SURVEY

Trace metals were present in the sediments at levels not exceeding ANZECC sediment quality guidelines (Figure 8). At these levels the contaminant load at each site would rarely be expected to induce adverse biological effects. No trace metals data was available from the 1996 study to compare against.

The results were also compared to a set of relevant RBC's developed for lagoonal and estuarine sites in the Hawke's Bay region (Strong 2005). For a selected number of trace metals, e.g. Pb, Zn, Cd, and Cu levels at sites A and C were within calculated background levels (± 1SE) levels while site B was consistently lower than the respective RBC. In terms of Cr all sites were below the RBC while for As, levels at sites A and C were slightly elevated. These results generally indicate that accumulation of trace metals is not occurring in the sediments surrounding the WWTP outfall.

To increase the accuracy of between site comparisons data were normalised to 100% of each sites silt/clay fraction. Normalisation[3] of data allows an accurate assessment of between site differences, and also allows comparison against other Hawke's Bay and New Zealand reference estuary sites (Table 5). The estuarine/lagoonal sediment background levels for Hawke Bay were also normalised to 100% of each sites silt/clay fraction to better illustrate trace metals at sites elevated compared to the respective background level (Table 5).

Between sites, normalised results at the reference site C for all 8 trace metals were consistently higher compared to both site A and B, with site B showing the lowest normalised results of all sites. Tukey HSD comparisons showed that for As, Cd, Cu, and Hg there was no significant difference between sites A and C but both were significantly higher than site B. For Cr and Ni there was no significant difference between site A and B but site C was significantly higher than both. Finally for Pb and Zn all sites were significantly different to one another with site C the highest, then site A then site B. Compared to other estuaries in Hawke's Bay and New Zealand the levels of trace metals at all sites are low to very low. Of note though is the high level of normalised As among all sites compared to the Ahuriri (Napier) estuary sites which suggests naturally elevated levels of As compared to background in the geology of the Wairoa River valley.

The large influx of fine sediment to site B as discussed in section 2.3.1 is likely to have acted to 'refresh' the sediments at this site.

These results indicate that the discharge does not have an observable effect on the sediment quality in the lower Wairoa River with respect to trace metals.

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[3] Trace metals have been shown to preferentially adhere to fine sediments in the silt/clay fraction that have reactive surface properties. Therefore, differences in trace metal concentrations between sites may simply reflect differences in the proportion of sediments in this fraction. Normalising sediment contaminant data allows standardisation of sediment contaminants to sediment composition.

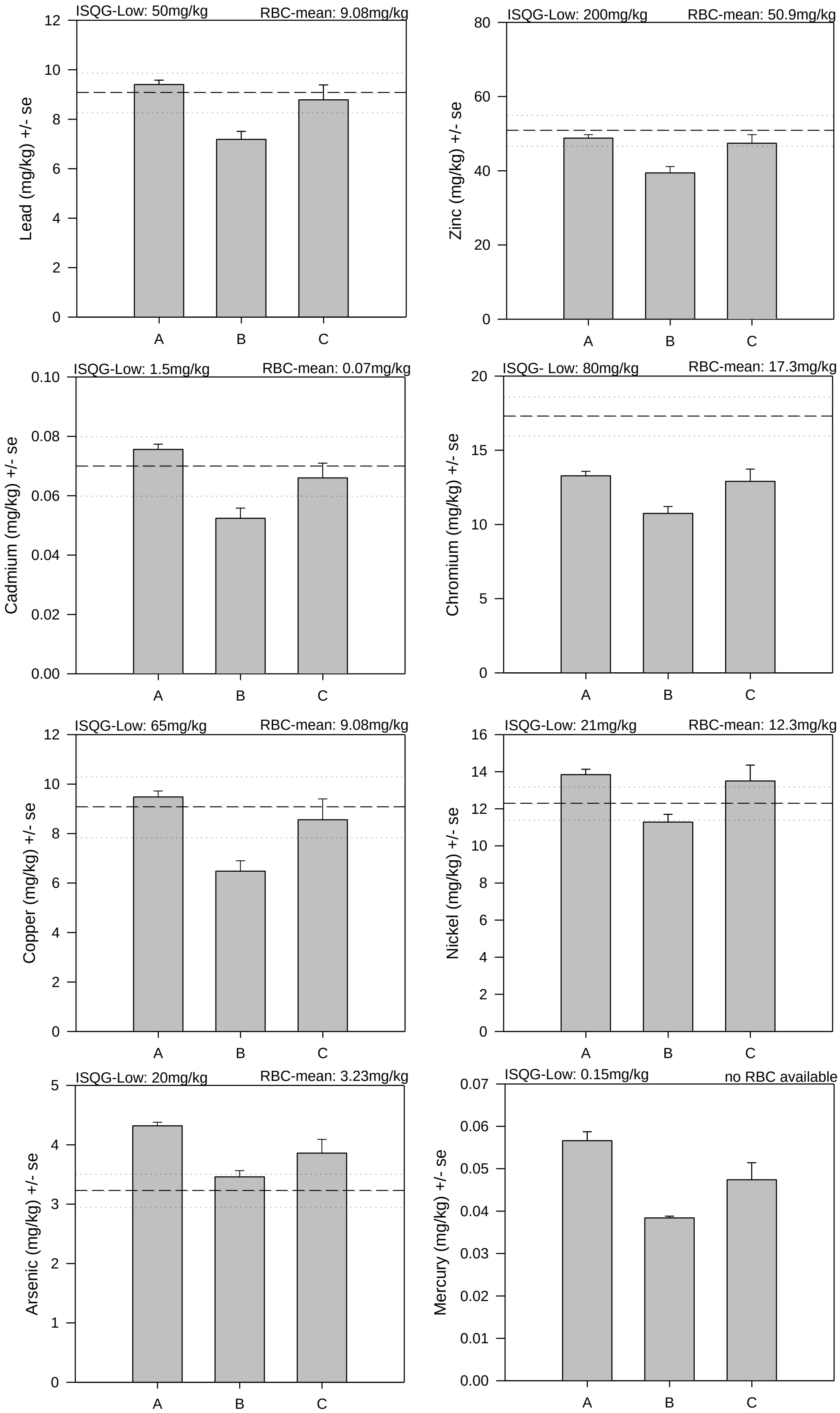

FIGURE 8: MEAN TRACE METAL CONCENTRATIONS (Pb, Zn, Cd, Cr, Cu, Ni, As, Hg) AT DISCHARGE MONITORING SITES A AND B ('IMPACT') AND C ('REFERENCE') IN THE WAIROA RIVER ESTUARY DURING THE PRESENT SURVEY. RESULTS EXPRESSED ON A DRY WEIGHT BASIS. GUIDELINES ARE INTERIM SEDIMENT QUALITY GUIDELINES – LOW (ANZECC 2000). REGIONAL BACKGROUND CONCENTRATIONS (RBC) ± 95%CI (STRONG 2005).

Table 5: Comparison of mean sediment trace metal levels **normalised** to 100% mud/fines content at outfall monitoring sites A, B in the Lower Wairoa River estuary and compared to a reference site within the estuary (site C). These are also compared to normalised Regional Background Concentrations (nRBC's) of trace metals from a regional study of Hawke's Bay lagoonal and estuarine sites (Strong 2005). Further comparisons include normalised data from the same monitoring sites in the previous survey in 2007 and a range of average values from New Zealand estuarine reference sites. Shaded cells indicate elevated levels compared to background levels for Hawke's Bay estuaries and lagoons

SITE	Total Recoverable Cadmium		Total Recoverable Chromium		Total Recoverable Copper		Total Recoverable Nickel		Total Recoverable Lead		Total Recoverable Zinc		Total Recoverable Arsenic		Total Recoverable Mercury	
		nRBC		nRBC		nRBC		nRBC		nRBC		nRBC		nRBC		nRBC
A 2011	**0.09**	0.09	**16.50**	21.50	**11.78**	11.28	**17.20**	15.29	**11.68**	11.28	**60.64**	63.25	**5.37**	4.01	**0.07**	ND
B 2011	**0.07**	0.10	**13.35**	24.68	**8.05**	12.95	**14.02**	17.55	**8.92**	12.95	**48.96**	72.62	**4.30**	4.61	**0.05**	ND
C 2011	**0.11**	0.11	**20.62**	27.66	**13.69**	14.52	**21.58**	19.66	**14.04**	14.52	**75.78**	81.37	**6.17**	5.16	**0.08**	ND
A 2007[1]	**0.07**	0.10	**16.17**	25.58	**8.72**	13.42	**15.23**	18.18	**9.49**	13.42	**57.69**	75.25	**5.09**	4.78	**0.05**	ND
B 2007[1]	**0.17**	0.39	**50.97**	95.42	**24.27**	50.08	**57.47**	67.84	**28.32**	50.08	**189.30**	280.75	**17.76**	17.82	**0.16**	ND
C 2007[1]	**0.11**	0.15	**22.30**	37.74	**11.82**	19.81	**24.35**	26.83	**13.1**	19.81	**85.82**	111.04	**7.11**	7.05	**0.06**	ND
Ahuriri (site GPC)[2]	0.55		59.42		59.68		33.84		68.69		944.89		0.55		ND	ND
Ahuriri (site PUR)[2]	0.36		45.21		35.95		28.06		44.86		463.89		0.36		ND	ND
Ahuriri (site AHU)[2]	0.32		66.75		33.13		44.59		46.50		346.80		0.32		ND	ND
Otamatea[3]	0.71		36.48		24.56		16.73		20.28		69.98		ND		ND	ND
Ohiwa[3]	0.49		36.82		20.02		19.4		16.92		137.81		ND		ND	ND
Ruataniwha[3]	1.09		260.87		77.17		148.91		51.09		407.61		ND		ND	ND
Waimea[3]	1.22		275.97		39.18		295.92		30.2		170.61		ND		ND	ND
Havelock[3]	1.57		255.49		56.02		138.74		29.32		225.13		ND		ND	ND
Avon-Heathcote[3]	1.85		288.89		59.26		122.22		116.67		709.26		ND		ND	ND
Kaikorai[3]	0.37		177.94		61.76		57.35		166.54		677.21		ND		ND	ND
New River[3]	5.88		652.94		223.53		294.12		41.18		1005.9		ND		ND	ND

[1] Smith (2007) [2] Smith (2010) [3] Robertson (2002)

INTER-SURVEY COMPARISON

Comparing normalised sediment trace metal levels between the 2007 survey and the present (sediments not analysed for trace metals during 1996 survey) it is evident that, except for site B, generally levels at the other sites have remained fairly stable over time, (Figure 9, Table 5). The large decrease in normalised results at site B, as previously mentioned, is likely a result of the increased levels of 'fines' (silt/clay) between the two surveys.

Comparison of normalised results at sites reiterated this general pattern of stability, particularly at site C, with the only significantly different result between years at site C (lower in 2011) in Zn ($p = 0.037$). Tukeys HSD comparisons suggested that at site A normalised levels of Cd, Cu, Ni, Hg, and Pb were significantly higher in 2011 than 2007 (all $p < 0.05$ or less).

These results suggest that over time normalised trace metal levels at the reference site C have varied little while at the downstream 'impact' site A there has been a slight increase in some trace metals. At the upstream 'impact' site B a major change in the sediment composition between years, going from a predominantly sandy site to a muddy site, precludes meaningful comparison of normalised results between years.

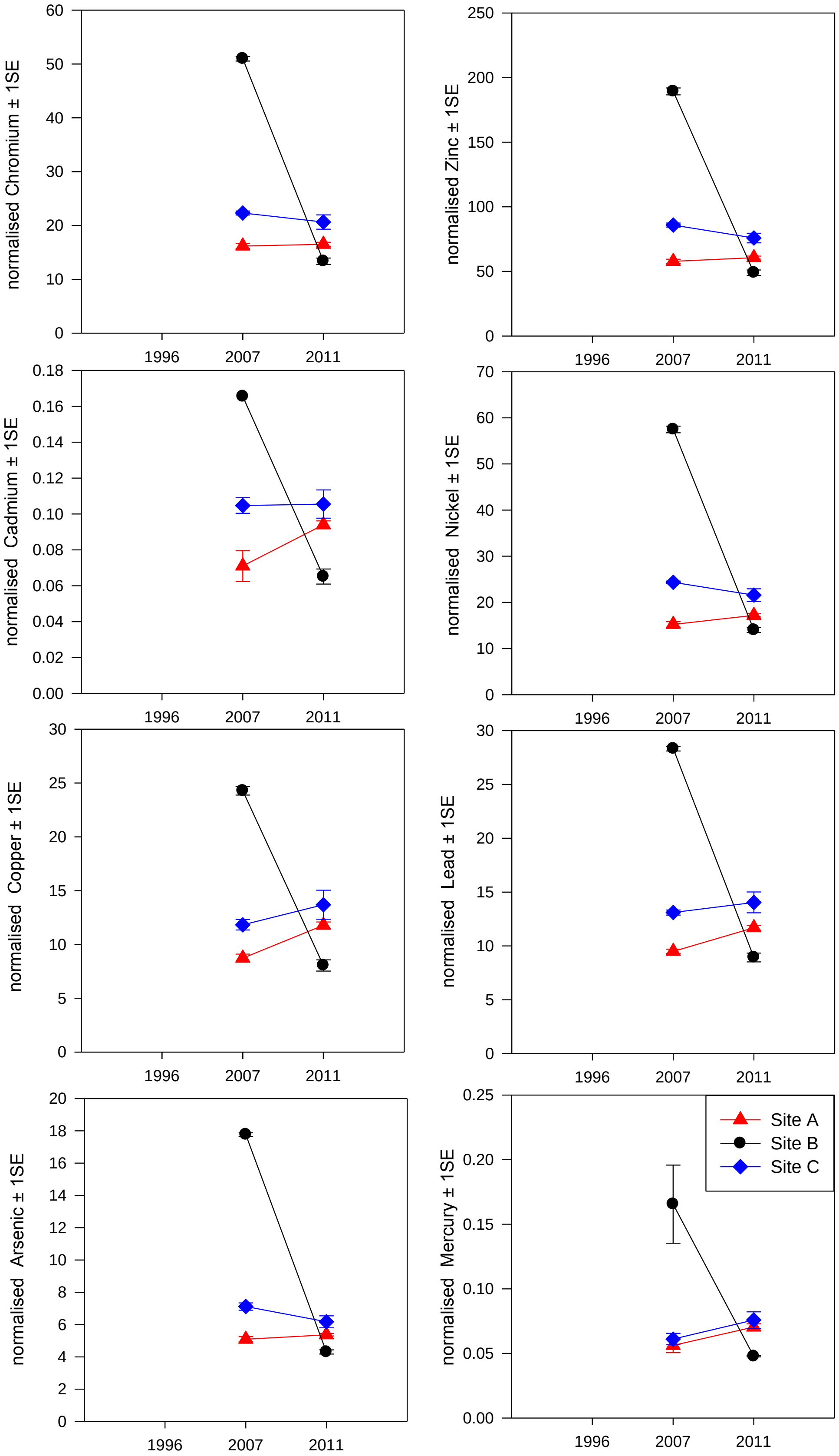

FIGURE 9: MEAN NORMALISED TRACE METAL CONCENTRATIONS (Pb, Zn, Cd, Cr, Cu, Ni, As, Hg) AT SITES A, B ('IMPACT') AND C ('REFERENCE') IN THE WAIROA RIVER ESTUARY IN 2007 AND THE PRESENT (2011). RESULTS NORMALISED TO 100% OF THE SILT/CLAY CONTENT AT EACH SITE.

2.4 SUMMARY

PRESENT SURVEY

- Average RDPL depth at all sites was relatively shallow suggesting only moderate sediment oxygenation occurs.
- The relatively shallow depth of the oxic zone suggests the infaunal community is likely to be transitional and prone to fluctuations in abundance.
- All sites predominantly characterised by mud, or 'fines'(<63µm) with sites A and B more muddy and site C more sandy.
- Average total volatile solids levels, or organic content, of sediments among all sites was generally low with inter-site variability very low.
- Compared against other reference estuaries throughout New Zealand, nitrogen and phosphorus levels at all sites lay in the mid range of values.
- There was no difference in normalised nitrogen between sites but phosphorus was significantly higher at reference site C followed by 'impact' site A then site B.
- Trace metals levels at all sites were low with all results below ANZECC sediment quality guidelines. and were, in general, within the limits of average background concentrations of Hawkes Bay estuarine and lagoonal systems.
- Compared to other estuaries in Hawke's Bay and New Zealand the levels of trace metals at all sites are low to very low.
- Reference site C generally had the highest normalised levels of trace metals followed by site A then site B.

INTER SURVEY COMPARISON

- Increased 'fines' (<63µm) at all sites over time and particularly between 2007 and the present (2011).
- Magnitude of increased 'fines' not consistent among sites, with the increase at the downstream 'impact' site A relatively similar to increase at the reference site C while the increase at the upstream 'impact' site B was much higher than both.
- Unlikely that the increased 'fines' between surveys is the result of outfall discharge.
- TVS, or organic matter content varied relatively little between surveys, except at site B where normalised levels have decreased.
- Proportions of TVS at sites among surveys are within the lower range compared to estuaries nationally.
- Sediment nitrogen levels at sites A and C have remained stable since the previous survey, whereas at site B normalised results have significantly decreased.
- Phosphorus levels at all sites appear to have decreased since 1996.
- Normalised sediment trace metals (Cd, Cu, Ni, Hg, Pb) at 'impact' site A increased slightly over time whereas at site B levels were generally lower in the present survey compared to initial 2006 survey results. Levels at the reference site C remained stable over time

3. BIOLOGICAL CHARACTERISITICS

3.1 INTRODUCTION

Benthic macroinvertebrates form diverse faunal communities that are important to the marine ecosystem. These animals serve vital functions in a wide variety of capacities, for example some species decompose organic matter, aiding nutrient cycling, other species filter particulate matter from the water, affecting water clarity. Many species of benthic macrofauna are also prey for fish and other organisms. Human activities such as wastewater disposal impact the benthos in a number of ways; including smothering, oxygen depletion, toxic contamination, and organic enrichment. Some macrofaunal species are highly sensitive to such effects and rarely occur in impacted areas, while other, more opportunistic species can thrive under altered conditions. Different species respond differently to environmental stress, so monitoring macrobenthic assemblages can help to identify anthropogenic impact. Also, since the animals in these assemblages are relatively stationary and long-lived, they integrate environmental conditions spatially and over time. Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which document both existing conditions and trends over time. The structure of benthic communities is influenced by many factors including sediment conditions (e.g., particle size and sediment chemistry), water conditions (e.g., temperature, salinity, dissolved oxygen, and current velocity), and biological factors (e.g., food availability, competition, and predation). Thus, both human activities and natural processes can influence the structure of benthic communities. Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have documentation of baseline or reference conditions for an area.

This section presents analyses and interpretations of the macrofaunal data collected at sites surrounding the WWTP during June 2011. Included are descriptions and comparisons of soft-bottom macrofaunal assemblages in the area, and analysis of benthic community structure. These data are compared against previous results of the 1996 and 2007 surveys.

3.2 METHODOLOGY

3.2.1 SAMPLING SITES

Infaunal sampling sites were the same as those described in section 2.2.1 (Figure 1).

3.2.2 METHODOLOGY

Sampling was carried out at the same time as respective sediment sample was collected. Although it was low tide, sites A and B were submerged, with a depth of approximately 50cm whereas site C was exposed. At each site five replicate infaunal cores were collected within a 5m radius of the sites GPS position. Infaunal cores were collected using a circular PVC 130mm (internal Φ) x 200mm long core (total area 0.013m^2). Samples were collected by pushing the core into the sediment to a depth of 150mm and digging down the outside of the core, placing a hand over the bottom, extracting the core and intact sample and ejecting the sample into a 0.5mm mesh bag, which was attached to the top of the core. The mesh bag was then detached from the core and a by pulling a drawstring on the bag the sample contents were contained in the bag. The sediment in the sample was gently washed through the bag, leaving only the infauna in the bag. Samples were washed into labelled jars with 80% ethanol and fixed in same. After transporting samples back to the lab a few drops of Rose Bengal solution was added to each sample, and left for several hours to allow the biota to uptake the stain. Samples were then poured into shallow trays and all biological material carefully picked out. The material was then examined under a dissecting microscope, and fauna enumerated and identified to the lowest possible taxonomic group.

3.2.3 DATA ANALYSIS

Infaunal data were described in terms of ranges and average values of abundance (N) and diversity indices (collectively called biological summary indices consisting of number of taxa (S), Shannon-Weiner diversity index (H'), Pielou's evenness (J') and Margalef's richness (d). Differences in these indices between sites and between years were explored by single or two factor ANOVA (STATISTICA 7), with post hoc analysis of individual terms by Tukeys HSD tests.

For benthic community assessment, data were analysed using a permutational multivariate analysis of variance (PERMANOVA) (Anderson 2005). This method of data analysis is regarded as a powerful way to test the significance of taxonomic compositional changes (Walters and Coen 2006).

The model was based on permutation of raw data for the fixed factor 'site' and or 'year'. Data were log(x+1) transformed before analysis, as this type of transformation scales down the effect of highly abundant species thus increasing the equitability of the dataset (variance standardisation). Data were also contrasted using non-metric multidimensional scaling (Kruskal and Wish 1978) ordination based on the Bray-Curtis distance matrix in PRIMER v5.

Major taxa contributing to the similarities of each site were identified using analysis of similarities (Clarke and Warwick 1994, Clarke and Gorley 2001).

Although the size of the infaunal samples collected in the 1996 survey was $0.05m^2$, compared to $0.013m^2$ used in the 2007 and present (2011) surveys, data were compared without scaling. The reason for not scaling results is that the number of species detected in a sample usually changes much more in relation to sample size or sampling intensity than the distribution of relative abundances (Huston 1997).

3.3 RESULTS

3.3.1 INFAUNAL SUMMARY INDICES

SPECIES ABUNDANCE, DIVERSITY, RICHNESS AND EVENNESS

PRESENT SURVEY

A complete list of benthic infaunal data from the present survey is included in Appendix 3.

Number of taxa (S), or species diversity in each core was low and did not vary significantly between sites. For all sites, S ranged between 2 – 5, with an average of 3.6 taxa $core^{-1}$ (Figure 10a).

Highest average abundance (N) was observed at the reference site C (89 ± 6.4 (1SE) individuals/core). This estimate was significantly higher ($p < 0.01$) compared to average abundances at 'impact' sites A and B (Figure 10b) where N did not differ significantly (45.2 ± 5.56 individuals/core).

The most abundant species at all three sites was the corophid amphipod *Paracorphium excavatum*, which accounted for 80.7% of total individuals. The next most abundant species among all sites was the omnivorous polychaete worm *Nicon aestuariensis* (13.5% of individuals) followed by another polychaete worm, the deposit feeding *Scolecolepides benhami* (2% of individuals).

Margalef's Richness (d) is a measure of biodiversity based on the number of species, adjusted for the number of individuals sampled, with values increasing with the number of species and decreasing with relative increases in number of individuals. In the present survey no significant differences were evident among any of the monitoring sites. Scores ranged between 0.23 – 1.1 averaging 0.65 (Figure 10c).

Pielou's evenness (J') is a measure of the similarity of the abundances of different species in a group or community, and the nearer values are to 1 the more even abundances are among species. In the present survey scores were again low, indicating the dominance in abundance of the corophid amphipods. There was no significant difference in J' among sites. Scores ranged between 0.36 – 0.72 averaging 0.5 (Figure 10d).

The Shannon-Weiner diversity index (H') is a measure of the likelihood that the next individual will be the same species as the previous individual, the higher the number the more diverse the sample. At all sites in the present survey H' was low with no significant difference in $\log_e$ transformed scores between sites. Transformed index scores ranged between 0.4 – 0.9, and averaged 0.61 (Figure 10e).

INTER-SURVEY COMPARISON

Comparing data on number of taxa (S) between years (within sites) it is evident that in general there has been a decline through time (Figure 11a). At both 'impact' sites A and B there was an overall significant reduction in S (all $p < 0.05$ or less) with Tukey's individual comparisons estimating these reductions were due to a significant difference between 1996 and the present (2011) only (both $p < 0.04$). Although there was no overall significant difference between years at the reference site C, the Tukeys individual comparisons between years revealed that the 1996 results were significantly lower ($p < 0.046$) than the present (2011).

Examining number of individuals (N) within sites over time, at 'impact' sites it is evident that variability is high, with abundance increasing between 1996 and 2007 and then decreasing between 2007 and the present (2007) (Figure 11b). Accordingly individual Tukeys comparisons at site A estimate no significant difference in N between 1996 and 2011 while the 2007 result was significantly higher than both 1996 and 2011 ($p < 0.001$). At site B, the same pattern was evident but all years were significantly different to each other ($p < 0.01$). In comparison at the reference site C there has been little difference between 2007 and the present but these results were significantly lower than those observed in the initial 1996 survey (Figure 11b). The variability at 'impact' sites over time appears to be primarily a result of a change in the dominant species from the polychaete worm *Scolelepis* sp. and the snail *Potamopyrgus antipodum* to the corophid amphipod *P. excavatum* and the polychaete *S. benhami* between 1996 and later surveys. At site C the differences over time is a result of the loss of *P. antipodum* in great numbers in latter surveys.

The only significant difference between years and within sites for Margalef's richness (d) was at the 'impact' site A (Figure 11c). At site A the 1996 result was significantly higher than both the 2007 and present (2011) results ($p < 0.02$, 0.004 respectively).

Similarly in terms of evenness (J'), again there has been little overall variation between years within respective sites, except at site A. At site A there was an inverse pattern to that observed for N such that the 1996 and 2011 results were significantly higher than the 2007 results (both $p < 0.001$ or less) but not different to each other (Figures 11d).

Comparison of the Shannon-Weiner diversity index (H') scores between surveys and within sites revealed few significant differences, with 'impact' site A the only site where H' was estimated to be significantly different between years ($p < 0.01$) (Figure 11e). This was primarily due to the high numbers of *P. excavatum* in the 2007 survey, compared to the other two years, depressing the H' score for that year. site where a significant difference was estimated.

In general scores for species diversity (S) are decreasing at all sites, abundance (N) is highly variable at 'impact' sites and possibly decreasing at the reference site C. Margalef's richness (d) is decreasing at site A, but fairly stable at the upstream 'impact' site B and reference site C. Similarly evenness scores at sites B and C are relatively stable while at site A evenness is highly variable through time. Finally the Shannon-Weiner diversity index scores (H') at sites B and C are also relatively stable but highly variable at site A. These results provide some evidence that overall conditions in the Lower Wairoa River Estuary provide for a transitional community, prone to variability. Given the decreased species diversity there is some evidence that overall conditions in the river estuary are deteriorating over time. Additionally the WDC discharge is also a measurable contributing stressor to infaunal communities, particularly at the downstream 'impact' site A, and this is in evidence as an increased level of variability among the summary indices compared to the other monitoring sites.

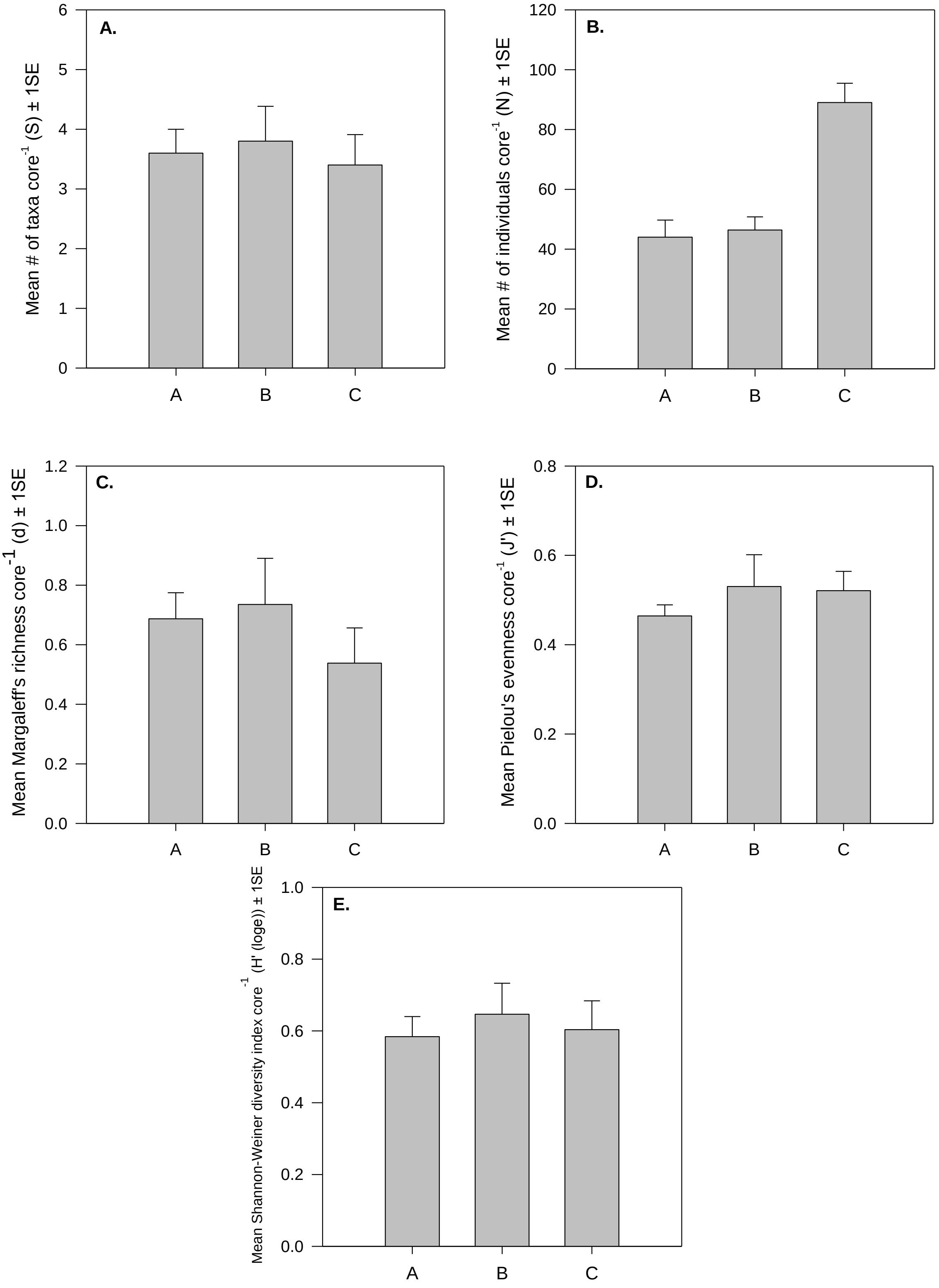

FIGURE 10: PLOTS COMPARING MEANS OF **A)** TAXA RICHNESS, **B)** INDIVIDUAL ABUNDANCE **C)** MARGALEF'S RICHNESS, **D)** PIELOU'S EVENNESS AND **E)** SHANNON-WEINER DIVERSITY INDEX OF BENTHIC MACROINFAUNAL COMMUNITIES FROM THE PRESENT (2011) SURVEY AT WDC OUTFALL MONITORING SITES.

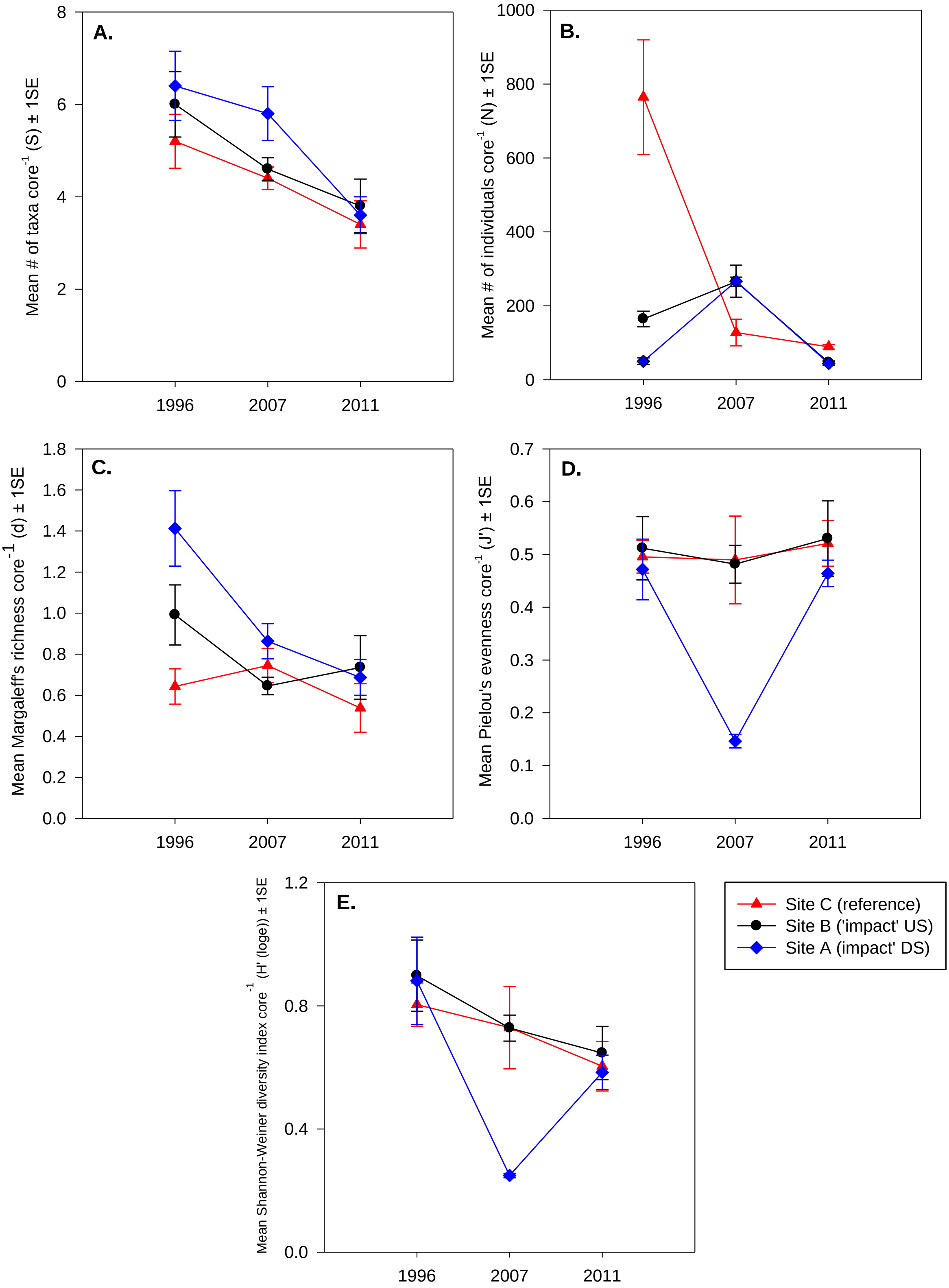

FIGURE 11: PLOTS COMPARING MEANS OF **A)** TAXA RICHNESS, **B)** INDIVIDUAL ABUNDANCE **C)** MARGALEF'S RICHNESS, **D)** PIELOU'S EVENNESS AND **E)** SHANNON-WEINER DIVERSITY INDEX OF BENTHIC MACROINFAUNAL COMMUNITIES AT WDC OUTFALL MONITORING SITES BETWEEN THE 1996, 2007, AND PRESENT (2011) SURVEYS. ERROR BARS ± 1SE.

3.3.2 INFAUNAL COMMUNITY STRUCTURE

PRESENT SURVEY

Multivariate analysis of infaunal data allows a comparison of community structure between sites, and years. Similarities in species abundance between sites and years are expressed on a two dimensional plane called a non-metric multi-dimensional scaling (MDS) plot (Figure 12, 14). The plot comparing infaunal communities between sites in the present survey shows some separation, although subtle, with reference site C located at the top of the plot (Figure 12). Additionally the spread of replicates at 'impact' sites appears to be higher relative to the reference site.

Despite the subtle degree of graphical separation observed in the plot, PERMANOVA results do not confirm a significant difference in community structure, even though the pPERM = 0.01, the more relevant pMC = 0.057 (better estimate provided when the number of replicates is relatively small) suggests only weak evidence of a significant difference (Table 6). Pair-wise *a posteriori* comparisons revealed that despite there being no overall significant difference in community structure between sites, there was a significant inter-site difference between sites B and C (pMC = 0.044).

A SIMPER analysis and species correlation plot are used to assist identification of species associations that account for the observed differences in community structure between sites and are shown in Figure 13 and Table 7. The SIMPER analysis confirms that the two key species driving the community similarity at sites are *Paracorphium excavatum* and *Nicon aestuariensis.*

Given the low species diversity and numerical dominance of a few species these results suggest indicate that the strength of the relationship between community structure and either direction or proximity to the outfall is weak, (i.e. the outfall discharge has a limited influence on community structure compared to other effects).

Table 6: PERMANOVA results examining the effect of site on benthic macroinfauna during the present (2011) survey. All data were ln(x+1) transformed, and analysis was based on Bray-Curtis similarities. P (perm) indicates the permutational p-value, P(MC) indicates the Monte Carlo p-value.

Source	df	SS	Mean Square	F-Value	P (perm)	P (MC)
Site	2	1398.234	699.117	2.22	0.01	0.057
Residual	12	3778.817	314.901			
Total	14	5177.051				

'*' indicates significant result

Table 7: List of infauna species that contribute most to the similarity among WDC outfall monitoring sites during the present (2011) survey. (SIMPER log(x+1) transformed data, PRIMER). Top 90% of species at each site contributing to observed similarity listed.

Site	Species	Av. abund	Av. Sim	Sim/SD	Contrib %	Cum%
Site A (av. sim. 69.95%)	*Paracorphium excavatum*	35.4	51.12	14.62	73.07	73.07
	Nicon aestuariensis	4.6	13.99	1.11	20	93.08
Site B (av. sim. 78.3%)	*Paracorphium excavatum*	36.8	48.3	10.02	61.69	61.69
	Nicon aestuariensis	7.6	28.12	7.24	35.92	97.61
Site C (av. sim. 83.3%)	*Paracorphium excavatum*	72.2	48.06	11	57.67	57.67
	Nicon aestuariensis	12.2	27.91	9.75	33.49	91.16

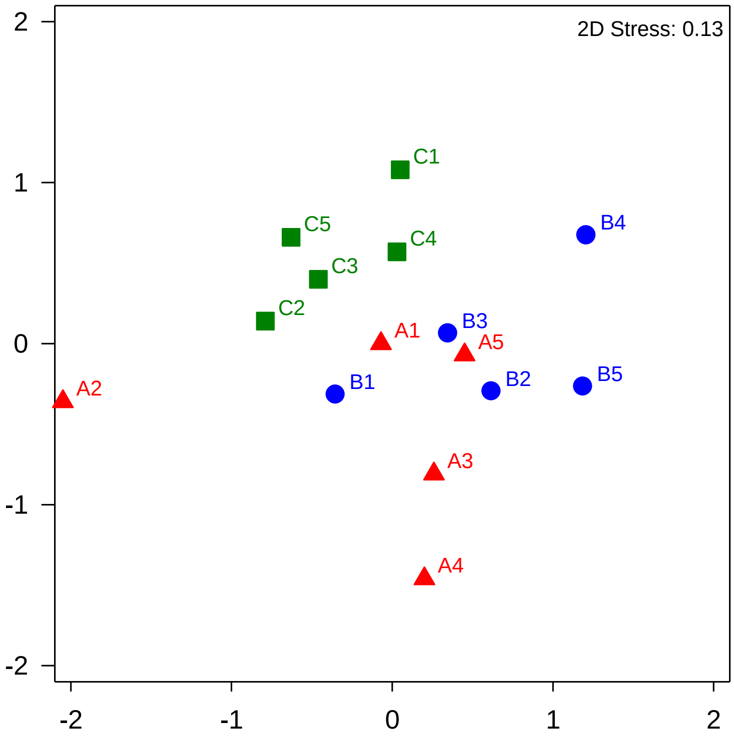

FIGURE 12: NON-METRIC MDS PLOT OF BENTHIC MACROINFAUNA DATA FROM THE PRESENT (2011) SURVEY AT 'IMPACT' MONITORING SITES A (RED ▲), AND SITE B (BLUE ●) AND REFERENCE SITE C (GREEN ■) OF THE WDC OUTFALL. DATA WERE SQUARE ROOT TRANSFORMED PRIOR TO ANALYSIS AND GROUPINGS ARE BASED ON BRAY-CURTIS SIMILARITIES.

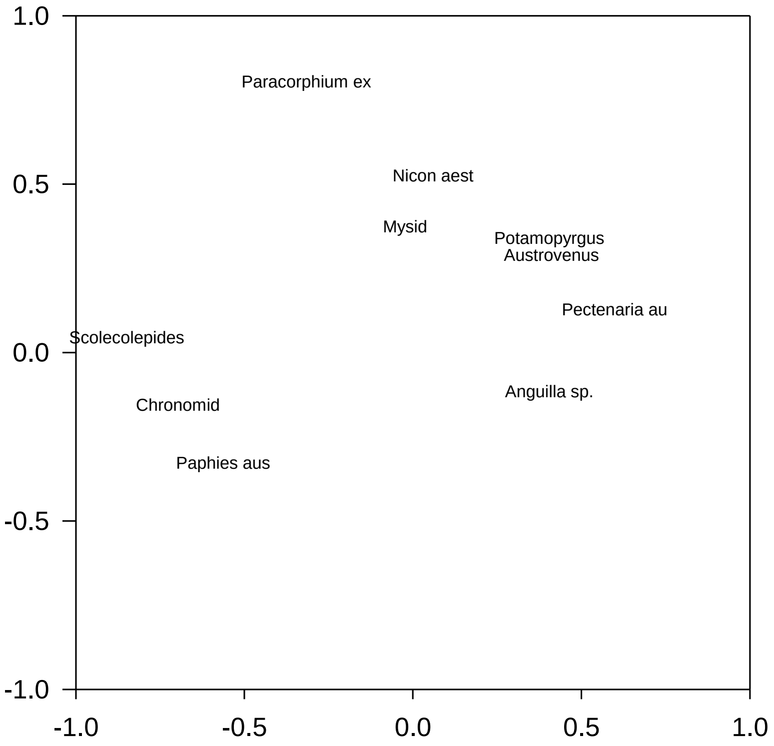

FIGURE 13: CORRELATIONS BETWEEN INFAUNAL SPECIES ABUNDANCES AND NON-METRIC MDS AXES FROM PREVIOUS PLOT AT WDC OUTFALL MONITORING SITES DURING THE PRESENT (2011) SURVEY.

INTER-SURVEY COMPARISON

Distinct temporal differences in community structure are apparent among monitoring sites, as displayed by the separation of at least 3 groups explainable by survey year (Figure 14). The relative closeness between the 2007, and 2011 group and relative distance of this group to the 1996 group suggest that the community structure in the present survey is more similar to the 2007, survey than to 1996 surveys.

The PERMANOVA confirms these observations by indicating both site and year are significant factors estimating infaunal community structure, however evidence of a significant interaction term (year*site) indicates these differences are not consistent between either years or sites (Table 8). To investigate the source of this inconsistency pairwise *a posteriori* comparisons between years (within sites) and between sites (within years) were conducted. These comparisons indicated that communities vary temporally, i.e. between years, within sites but that the similarity in community structure evident in the present survey (2011) was counter to the pattern of inter-survey differences evident among the earlier two surveys. Thus spatial differences appear to have reduced over time. These results generally suggest communities vary greatly temporally and spatially, however the temporal aspect seems especially strong. The lack of a spatial difference in the present survey may be a reflection of some other influence, such as a fresher (i.e. flow of > 3x median) that has resulted in the observed similar community structure.

Table 8: PERMANOVA results examining the effect of site and year on site infauna data. All data were transformed ln(x+1), and analysis was based on Bray-Curtis dissimilarities. P (perm) indicates the permutational p-value, P(MC) indicates the Monte Carlo p-value. Significant results denoted by asterisk.

Source	df	SS	Mean Square	F-Value	P (perm)	P (MC)
Year	2	11195.75	5597.87	22.51	0.01	0.01
Site	2	34343.89	17171.94	69.05	0.01	0.01
Residual	4	10315.82	2578.95	10.37	0.01	0.01
Year x Site	36	8952.46	248.67			
Total	44	64807.93				

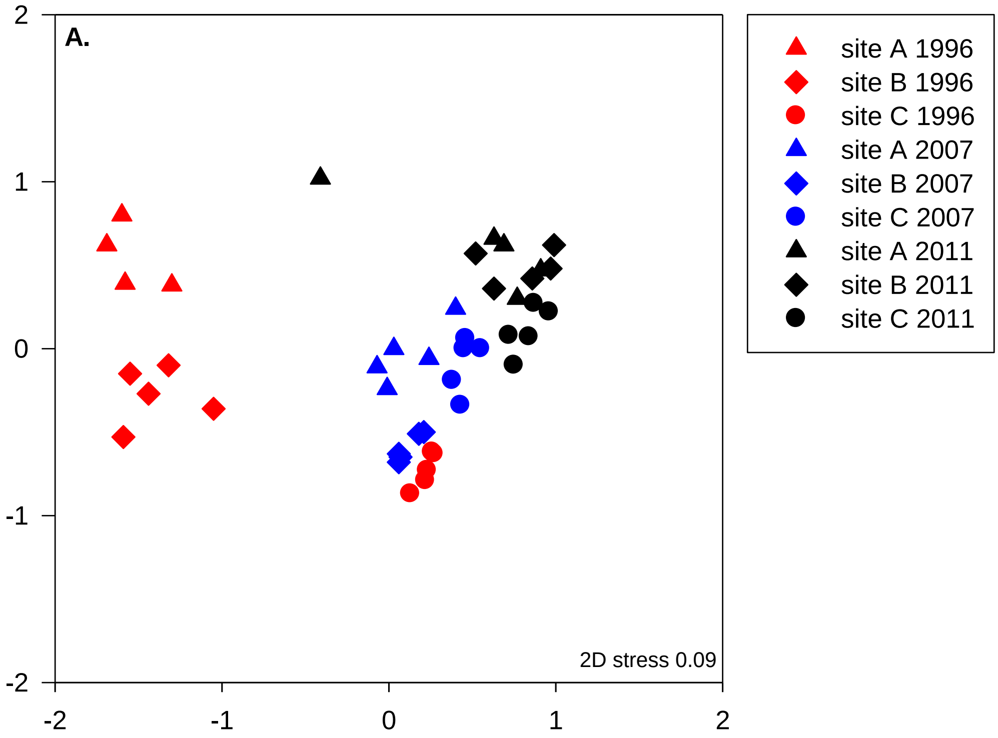

FIGURE 14: NON-METRIC MDS PLOTS OF BENTHIC MACROINFAUNA DATA FROM THE 1996, 2007 AND PRESENT (2011) SURVEYS AT MONITORING SITES SURROUNDING THE WDC OUTFALL. DATA WERE TRANSFORMED LOG(X+1) PRIOR TO ANALYSIS AND GROUPINGS ARE BASED ON BRAY-CURTIS SIMILARITIES

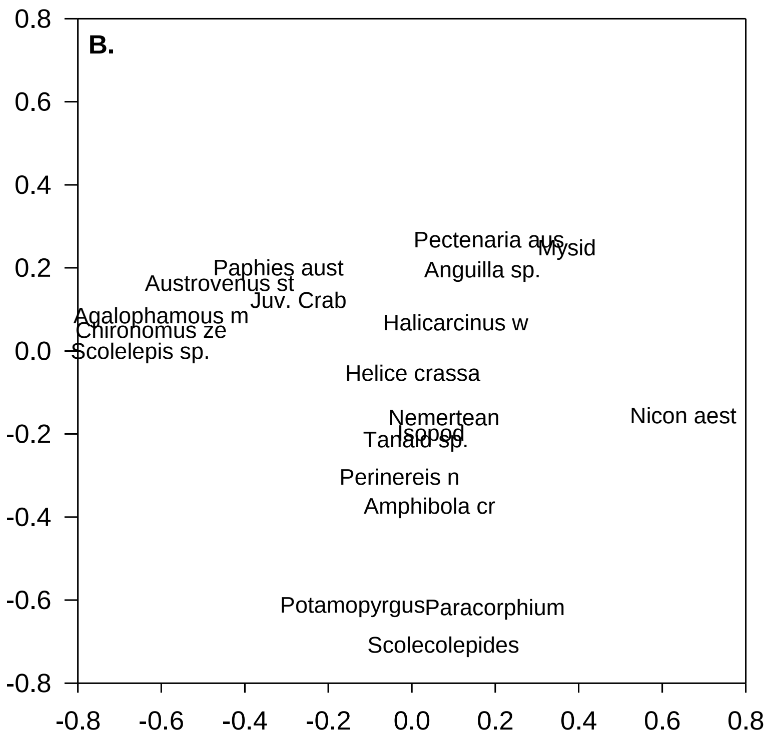

FIGURE 15: CORRELATIONS BETWEEN INFAUNAL SPECIES ABUNDANCES AND NON-METRIC MDS AXES FROM PREVIOUS PLOT AT WDC OUTFALL MONITORING SITES DURING 1996, 2007 AND THE PRESENT (2011) SURVEY.

3.4 SUMMARY

PRESENT SURVEY

- Infaunal abundances were relatively high and not significantly different across all sites, with the corophid amphipod *Paracorphium excavatum* the most abundant taxa at all sites.
- Scores of infaunal diversity, richness and evenness indices for 'impact' sites were not significantly different to the reference site and all were low indicating low a low diversity community.
- Infaunal community structure at 'impact' sites A and B were not significantly different to the reference site C.
- Key infaunal species influencing community structure among sites were *Paracorphium excavatum* and *Nicon aestuariensis*.

INTER SURVEY COMPARISON

- Species abundance (N) has shown high variability between years, primarily as a result of the dominance and high numbers of amphipods and in the past snails.
- Number of taxa have declined fairly consistently at all sites over time.
- Diversity and evenness index scores that account for number of individuals are relatively stable at the reference site C and 'impact' site B.
- At the downstream impact site A indices have varied significantly over time indicating a transitional community predominates, particularly at this site.
- Significant spatial and temporal variability among infaunal communities over time, but not consistent between either years or sites.
- However given the similarity in community structure in the present survey spatial differences have reduced over time.
- The lack of a spatial difference in the present survey may be a reflection of some other influence, such as a fresher (i.e. flow of > 3x median), or deterioration of general conditions throughout the main body of the estuary.

4. SUMMARY

The WDC outfall discharge is an existing activity subject to compliance with a number of resource consent conditions set out in the discharge permit CD940404W.

The Council is not required by the consent to undertake monitoring of sediments and biological communities at sites surrounding the outfall diffuser, however WDC have proactively engaged in work to determine the level and magnitude of any effects occurring as a result of the discharge. This report forms a part of this work.

SEDIMENT CHARACTERISTICS

Discharges of sewage into coastal systems can result in increases to the fine portion of the sediment fraction resulting from increased inputs of organic material, and increases in sediment levels of nutrients and trace metals resulting from the discharge itself.

The current study observed an increase in the portion of fine sediments compared to previous studies, however these increases were observed at both the 'impact' and 'reference' sites. At the upstream 'impact' site (site B) there appears to have been a major change in the hydrodynamics. This is likely the cause of the changes in the sediment texture observed, as the site appears to have become highly depositional, rather than being transitory in nature as it was in previous years.

The large amount of 'fines' at all sites suggests that much of the river borne fine sediments deposit not only in the side arms of the estuary but on the expansive intertidal and shallow flats along the edge of the main channel.

These levels of organic material within the sediments were consistent among the impact and control sites, and are among the lower range of levels for organic matter among other estuaries nationally.

Levels of total nitrogen within the sediments were not significantly different between sites once sediment texture was accounted for, however total phosphorus was observed to be higher at the upstream control site, indicating that upstream sources were contributing phosphorus to the sediments at a higher rate than the discharge.

Levels of trace metals within the sediments at all sites were well within environmental guidelines (ANZECC 2000) indicating that no adverse ecological effects would be expected as a result of the discharge. In most cases trace metal levels were similar to those described as background by Strong (2005), the exception to this was arsenic which was slightly elevated compared to regional background concentrations at all sites, suggesting a geological influence. The lower than average levels at site B are likely to reflect the input of 'clean' sediments caused by deposition.

In general there is no evidence in the sediment texture or chemistry to suggest that the WDC discharge is having an adverse effect on the receiving environment surrounding the discharge port.

BENTHIC COMMUNITY

With the exception of the number of individuals (N), there were no significant differences in the biotic indices between the 'impact' and the 'reference' sites. In general species diversity was low, and the results observed highlight the dominance of the corophid amphipod, *Paracorphium excavatum,* at all of the sites sampled.

The results indicate a reduction in species richness overtime at all sites, and while this only appears to be statistically significant for sites A and B, site C returned a statistically significant reduction between the 1996 and current surveys and therefore has only not returned an overall statistically significant difference due to the results in 2007 falling within the errors of the 1996 and current surveys.

All other biological indices indicate variability in the assemblage, but in general the results are similar between all surveys (excepting species richness at site A).

An analysis of the community assemblage between sites (PERMANOVA) did not detect any significant differences in the community assemblages between sites suggesting that there is little evidence of a relationship between community structure and either direction or proximity to the outfall (i.e. the outfall discharge has a limited influence on community structure compared to other effects

Both site and year appear to be significant factors influencing infaunal community structure. The ordination highlights the overwhelming influence of 'year' on community structure; however spatial variation (between sites) is also evident. The predominant grouping by year rather than by site indicates that proximity to the discharge is not as important a driving factor in the benthic community make up as year. This indicates the role of recruitment and turnover in the formation of benthic communities.

The current survey showed the lowest level of inter-site variability observed to date. It appears as though spatial differences have reduced overtime (i.e. all sites within 2011 are more similar than all sites within 1996 and 2007).

These results generally suggest communities vary greatly temporally and spatially, however the temporal aspect seems especially strong. The lack of a spatial difference in the present survey may be a reflection of some other influence, such as a fresher (i.e. flow of > 3x median) that has resulted in the observed similar community structure.

There is no evidence that would suggest that the Wairoa District Council sewage discharge is having any adverse effect on the benthic biota adjacent to the outfall.

5. CONCLUSION

Examination of the sediment texture and chemistry results, combined with the benthic infaunal characteristics indicates that there is currently no evidence to suggest that the outfall is having any adverse effect on the receiving environment.

Sediment texture and chemistry reveals no indication of a discharge related effect, and results are similar to those observed at the upstream reference site, site C. Assessment and analysis of the biota living in the sediments surrounding the outfall did not detect any significant differences in the community assemblages between sites suggesting that the outfall discharge has a limited influence on community structure.

6. RECOMMENDATIONS

While not specifically required by the resource consent currently held by Wairoa District Council, monitoring of the receiving environment has provided important information on the effects of the discharge on the local receiving environment. It is recommended that monitoring continue in order to ensure that any changes arising either from cumulative effects, or changes in the discharge (i.e. either load or quality) are detected quickly. The current frequency of 4-yearly is considered appropriate.

The current methodology (similar to that used in 1996 survey, and the same as that used in 2007) is providing a sound and robust basis for intra and inter-survey comparison, therefore it is recommended that future surveys continue to use the same methodology outlined in the present survey.

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APPENDIX ONE

SEDIMENT CORE PROFILES

FIGURE A2-1: SEDIMENT CORE PROFILES AT WDC OUTFALL MONITORING SITES DURING THE PRESENT (2011) SURVEY.

APPENDIX TWO

SEDIMENT COMPOSITION DATA

Site	Clay <3.9µm	Very fine silt 3.9 – 7.8µm	Fine silt 7.8 – 15.6µm	Medium silt 15.6 - 31µm	Coarse silt 31 - 63µm	Very Fine Sand 63 - 125µm	Fine Sand 125 - 250µm	Medium Sand 250 - 500µm	Coarse Sand 500µm – 1.18mm	Very Coarse Sand 1.18 - 2mm	Gravel >2mm
A	12.99	9.43	15.24	20.45	22.36	13.96	4.36	1.2	0.01	0	0
B	11.13	8.22	13.06	17.82	19.86	14.51	11.01	3.78	0.48	0.13	0
C	10.47	8.02	13.34	17.26	13.46	16.57	18.11	2.77	0	0	0

SEDIMENT TRACE METAL, NUTRIENT AND ORGANICS DATA

Station	As mg/kg dry wt	Cd mg/kg dry wt	Cr mg/kg dry wt	Cu mg/kg dry wt	Hg mg/kg dry wt	Ni mg/kg dry wt	Pb mg/kg dry wt	Zn mg/kg dry wt	N mg/kg dry wt	P mg/kg dry wt	TVS g/100g dry wt
A1	4.2	0.078	12.5	8.9	0.055	13.2	9	47	900	450	4.3
A2	4.5	0.078	14.3	10.3	0.05	14.8	10	52	900	480	4.5
A3	4.2	0.075	12.9	9.1	0.057	13.3	9.1	47	1100	460	3.7
A4	4.3	0.069	13.4	9.5	0.063	14.1	9.4	49	1000	470	3.7
A5	4.4	0.078	13.3	9.6	0.058	13.8	9.5	49	1100	460	3.8
B1	3.1	0.042	9.5	5.2	0.039	9.9	6.2	34	<500	330	1.45
B2	3.4	0.051	10.2	6.2	0.039	11	6.9	38	600	360	3.1
B3	3.5	0.05	10.7	6.5	0.039	11.4	7.4	39	600	360	4
B4	3.6	0.057	11	6.7	0.037	11.6	7.2	42	700	360	3.6
B5	3.7	0.062	12.3	7.8	0.038	12.5	8.2	44	900	410	2.8
C1	4.5	0.079	15.5	11	0.06	15.9	10.4	54	1000	500	2.7
C2	3.4	0.067	12.8	8.1	0.038	13.4	8.5	47	700	410	3.4
C3	4.2	0.071	13.7	9.5	0.047	14.4	9.6	50	1000	460	2.8
C4	3.9	0.064	11.9	8.3	0.052	13.1	8.6	46	800	430	3.3
C5	3.3	0.049	10.6	5.9	0.04	10.7	6.8	40	500	410	1.87

APPENDIX THREE

INFAUNAL DATA

		Site A					Site B					Site C				
General group	**Taxa**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Bivalvia	*Paphies australis*		1	1			1						1			
Bivalvia	*Austrovenus stutchburyi*									1						
Gastropoda	*Potamopyrgus antipodum*									1						
Polychaeta: Nereidae	*Nicon aestuariensis*	9		5	2	7	6	10	8	5	9	8	15	15	12	11
Polychaeta: Spionidae	*Scolecolepides benhami*	1			1		1						4	3		8
Polychaeta: Spionidae	*Scolelepis* sp.		11													
Polychaeta: Pectinaridae	*Pectinaria australis*									1	1					
Diptera: Chironomidae	*Chironomis zelandica*		1													
Mysidacea	*Mysid shrimp*	1	1			2		2			1	4	1	2		
Amphipoda: Corophidae	*Paracorphium excavatum*	46	40	41	23	37	51	24	41	43	25	101	59	61	67	73
Osteichthyes	*Anguilla* sp.										1					
	NO OF TAXA	**4**	**5**	**3**	**3**	**3**	**4**	**3**	**2**	**5**	**5**	**3**	**5**	**4**	**2**	**3**
	NO OF INDIVIDUALS	**57**	**54**	**47**	**26**	**46**	**59**	**36**	**49**	**51**	**37**	**113**	**80**	**81**	**79**	**92**

APPENDIX FOUR

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