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Assessment of Ecological Effects on the Wairoa River Estuary from the Wairoa Wastewater Treatment Plant Outfall.

Client: Wairoa District Council
Project Reference: EAM042

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Cover page photograph of the Lower Wairoa River estuary, overlooking the area where the wastewater outfall is located (approximately 150m from the foreshore)

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1. Introduction

1.1 Background

The Wairoa District Council (WDC) has consent to discharge domestic, commercial and industrial wastewater into the Lower Wairoa River Estuary. This consent is due to expire May 2019. In granting the consent the issuing authority noted that the 20 year period of the consent allowed ample time for the council 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. This report and appendices describes the results of studies on effluent movement and dilution following discharge, sediment characteristics and benthic resources in the vicinity of the WWTP outfall located in the Lower Wairoa River Estuary, Wairoa (Fig. 1).

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 benthic survey and dye study of the WWTP outfall (Larcombe, 1996a) and a study of the AFFCO freezing works outfall (Larcombe, 1996b), approximately 2km upstream of the WWTP outfall. The previous study of the WWTP in 1996 is referred to continuously throughout this report to provide a comparison to the present findings.

1.2 Outfall History

The outfall was constructed in 1981, concurrent to the WDC Pilot Hill oxidation ponds. Effluent exits the final stage anaerobic pond and is gravity fed to the outfall discharge port. The discharge port is located sub-tidally, approximately 150m from the nearest shoreline (opposite the entrance to Fitzroy Street, Wairoa). 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.

1.3 This Study

This study was conducted between 24 April and 7 June 2007. The key components of the sampling programme included:

- Two effluent plume studies, examining plume movement and effluent dilution, the first representative of a worst case scenario where the river estuary outlet to the sea was heavily restricted and the second representative of normal tidal movement where the river estuary outlet to the sea was clear (Appendix 1)
- An examination of sediment characteristics including sediment composition and sediment quality focusing on trace metals, major nutrient species and total organic matter in sediments (Section 2)
- An examination of benthic macroinvertebrate infauna.(Section 3)
- An assessment of trace metal concentrations in Flounder (Section 4)

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.

1.4 Study Site

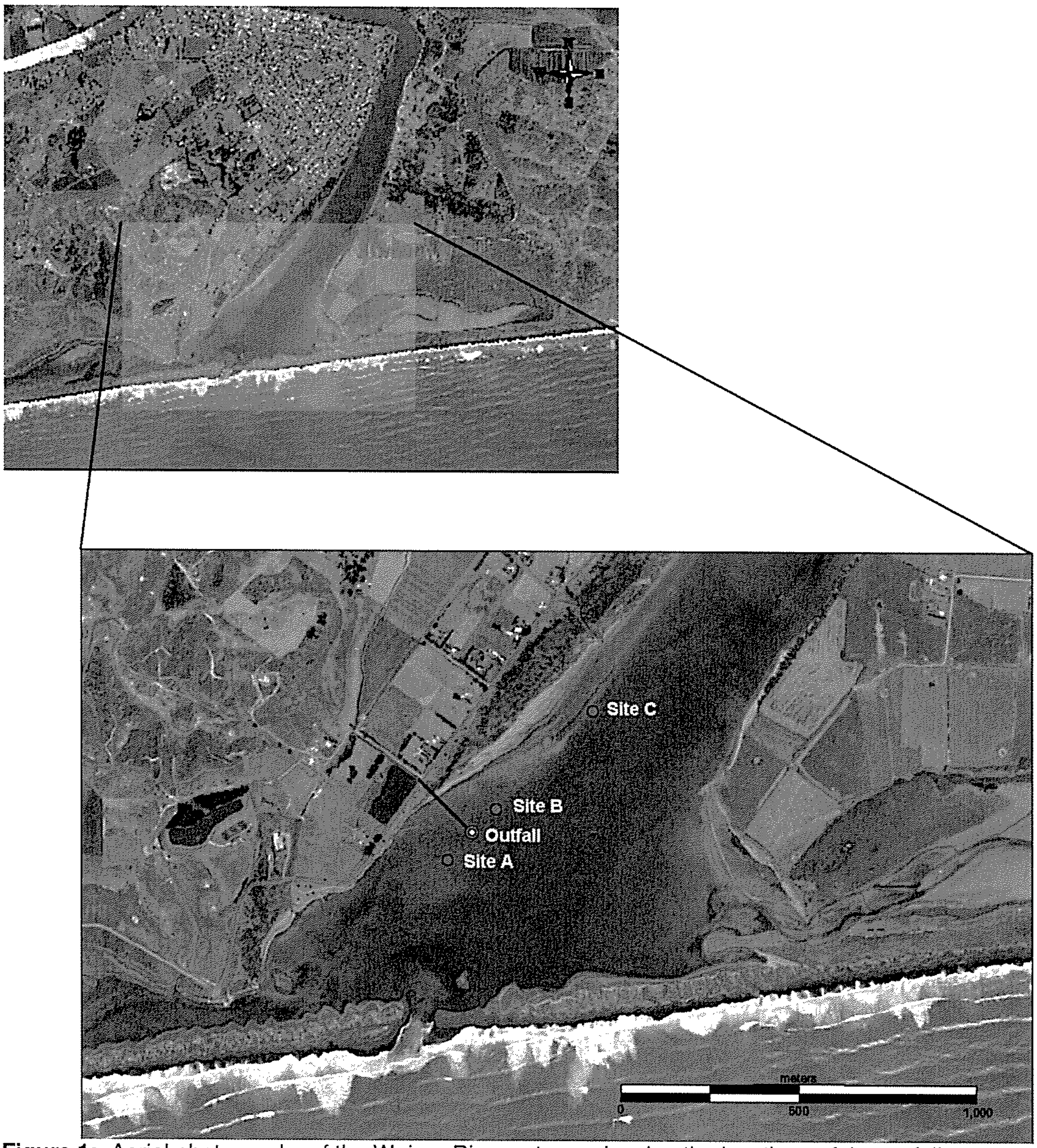

Figure 1: Aerial photographs of the Wairoa River estuary showing the locations of the outfall and its terminus and sampling locations.

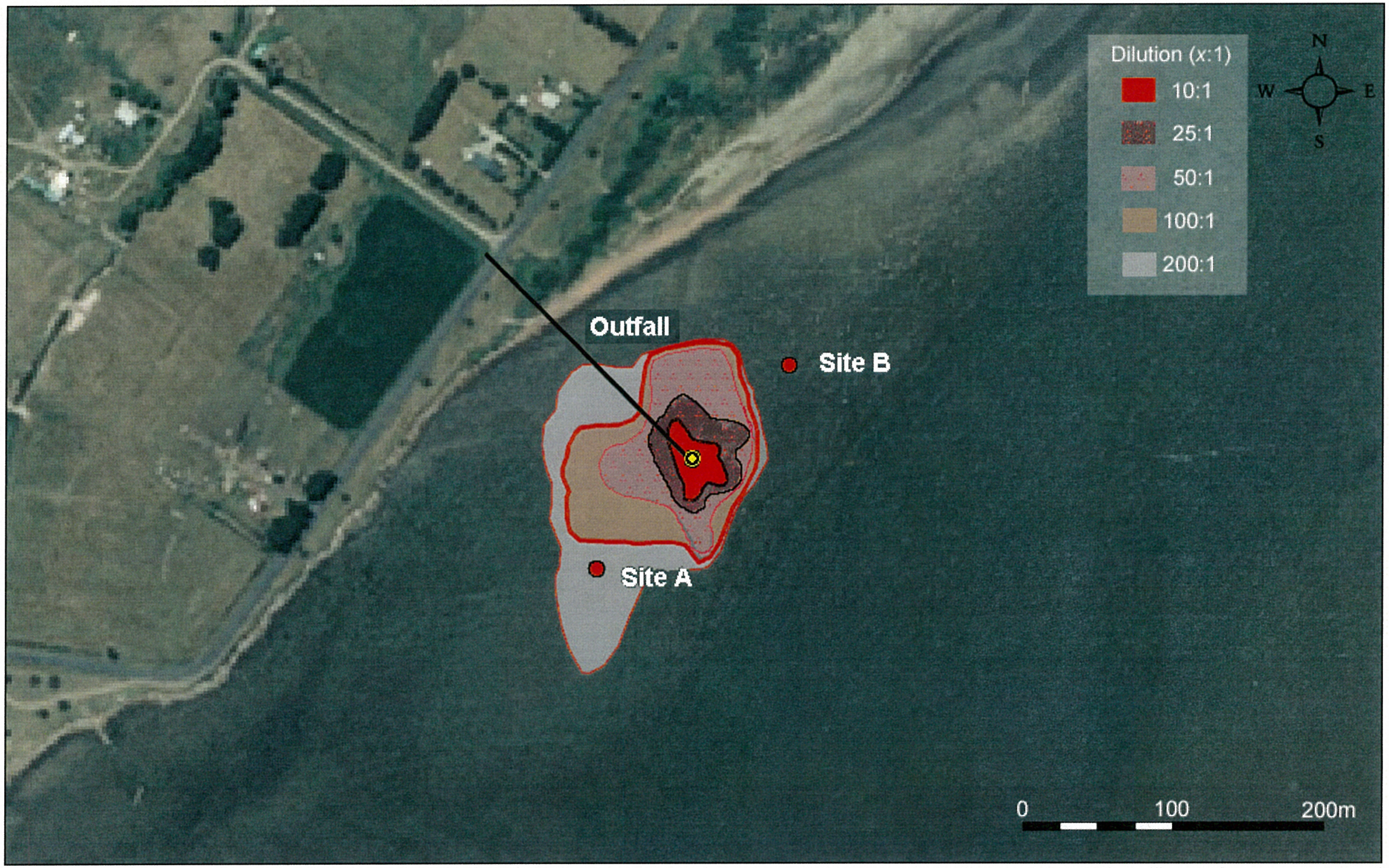

Figure 2: Aerial Photograph of the Wairoa River estuary showing WWTP outfall, sampling sites A and B, and dilution contours of the effluent plume, representative of worst case discharge conditions during a period of minimal tidal and river flows (restricted river bar conditions on 24th April 2007)

2. Sediments Characteristics

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. (Gray, 1981, Snelgrove, 1994) 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 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 organic and inorganic compounds. Some of the most commonly detected compounds discharged via outfalls are trace metals, pesticides, and various organic compounds (e.g., organic carbon, nitrogen, sulfides). Moreover, the presence of outfall pipes or associated structures can alter the hydrodynamic regime in the immediate area surrounding the outfall (*see* appendix 1 for description of effluent plume).

The analysis of various sediment parameters (e.g., particle size and percentages of sand, silt and clay) can provide useful information relevant to wave action, current velocity and sediment stability. Chemical composition of sediments can be affected by both natural and anthropogenic influences. For example, sediment erosion from hills and cliffs, and the flushing of sediment particles and terrestrial debris down streams and rivers, contribute to the composition of metals and organic content within an area. Concentrations of these materials within marine sediments generally increase with increasing amounts of fine particles chiefly as a result of adsorption.

This section presents a summary and analysis of sediment composition (grain size) and chemistry data collected in May 2007 in the vicinity of the Wairoa River estuary outfall. The aim was to assess the possible impact of wastewater discharge on the benthic environment by analysing spatial variability of the various sediment parameters and comparing the results to previous studies and sediment quality guidelines.

2.2 Sampling Sites and Methodology

2.2.1 Sample sites

Sample sites were chosen to align with those used in a previous study of this outfall, (Larcombe, 1996a) in order to maximise the robustness of comparisons. 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 and site **B** approximately 100m north-east of the outfall (Fig. 2)), and a control, or 'reference' site (site **C** approximately 500m north-east of the outfall (Fig. 1)).

2.2.2 Methodology

Sampling was carried out at low tide on the 14th May 2007. At each site, five replicate sediment cores were collected using a Perspex 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) layer[1] 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 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 1.

Table 1: 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)	

* Modified Wentworth scale

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

2.2.3 Data Analysis

Currently there are no guidelines for assessing the effects of sediment-bound nutrients such as nitrogen or phosphorus, on the environment. If there are no obvious signs of nutrient enrichment at a site it may be difficult to assess a particular site for the effects of nutrient enrichment. Therefore concentrations of these nutrients are compared against New Zealand estuarine reference sites.

Trace metal results however, 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 order to prevent differences in sediment composition from affecting assessment of differences between sites, and reference estuary sites, sediment trace metal values and total volatile solids (TVS) data were normalised to the proportion of 'fines' (mud), i.e. the clay/silt fraction (particles < 62.5µm) 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.

2.3 Results

2.3.1 Visual Assessment of Sediment Cores

All cores displayed distinct, measurable RPD layers, which allowed a reasonably accurate measure of the depth to which sediments were at least partially oxygenated (Fig. 3). Replicate sediment cores from each site were fairly consistent in RPD layer depth but varied significantly between sites (Table 2). A greater RPD layer allows greater numbers of interstitial organisms (organisms living in the spaces between sediment grains) to occur, potentially increasing total abundance and biodiversity. It also suggests a higher proportion of sediment is composed of larger grain sizes (sand).

Table 2: Mean redox potential discontinuity layer depth for sites A, B and C in the Wairoa River estuary (± 1 SE)

Site	RPD layer depth (cm)
A	2.8 ± 0.2
B	7.4 ± 0.4
C	3.6 ± 0.29

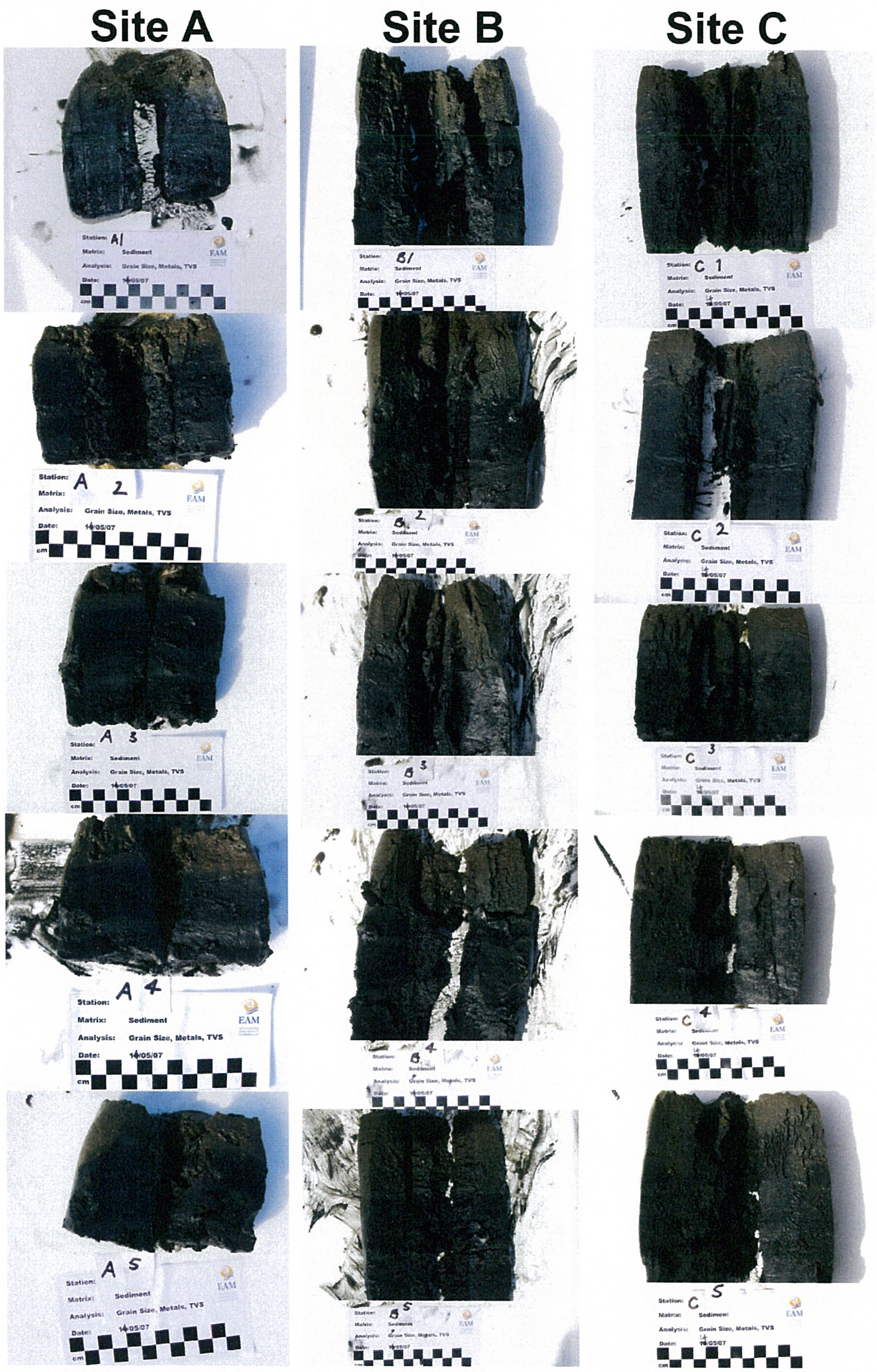

Figure 3: Sediment core profiles showing RPD and anoxic layers. Scale bar divisions = 1cm

2.3.2 Sediment Composition

The composition of sediments at the three sites sampled consisted exclusively of sands, silts and clay, and compared against Larcombes (1996) study of the same sites this predominance of sand, silt and clay has remained (Fig. 4, Table 3). In the present study site B consisted mainly of fine and very fine sand, while site C comprised a fairly even amount of both sand and silt/clay. In contrast site A was comprised predominantly of silt and clay.

Comparing the amounts of fines, sands and gravels between this study and the 1996 study it is evident that there has been an increase in fines at sites A and B, with a corresponding decrease in the sand fraction (Fig. 4, Table 3). Between 1996 and the present there has been an increase of approximately 28% and 6% in the amount of fines at sites A and B respectively, with a corresponding decrease in the sand fraction by a similar amount. Meanwhile, there has been almost no change in the proportions of the various sediment fractions at the reference site C.

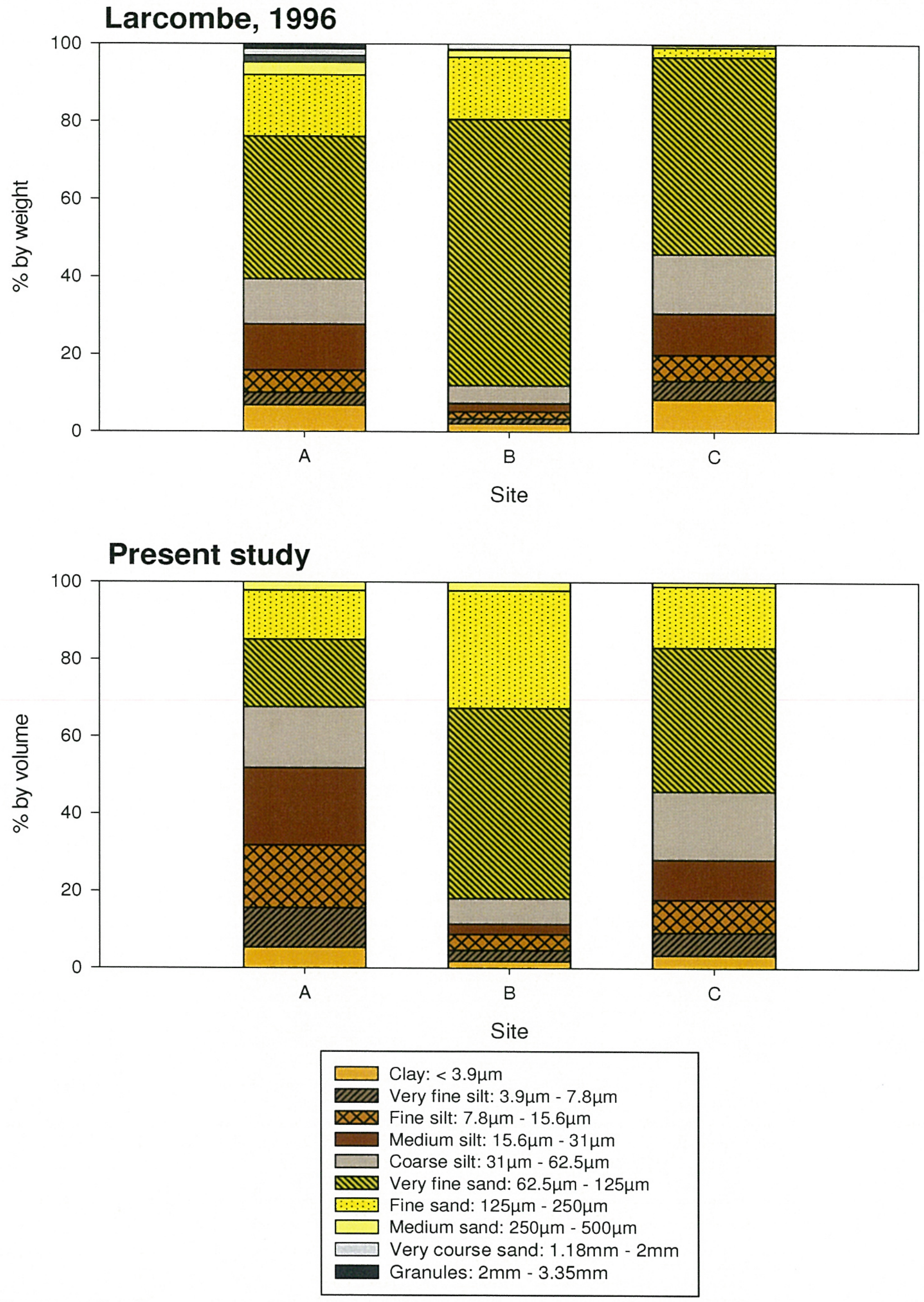

Figure 4: Sediment grain size distributions at sites A, B and C in the Wairoa River estuary in 1996 (top) and at present (bottom).

Table 3: Summary of sediment grain size analyses at sites A, B and C in the Wairoa River estuary in 1996 and at present.

	A		B		C	
	1996	**Present**	**1996**	**Present**	**1996**	**Present**
% Fines (< 62.5µm)	39.41	67.63	11.89	18.13	45.86	45.84
% Sand (62.5µm – 2mm)	59.24	32.37	88.11	81.87	54.14	54.16
% Gravel (> 2mm)	1.35	0	0	0	0	0

2.3.3 Sediment Quality – Nutrients

Site A had the highest concentration of both total nitrogen (TN) and total phosphorus (TP) followed by site C then site B (Fig. 5). TP was also able to be compared against levels reported by Larcombe, 1996 for the same sites. The only significant difference is an increase in TP at site A. 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, lie in the mid range of values (Table 4), and considering there was no obvious signs of nuisance algal growth, it is considered that the area surrounding the outfall was not enriched.

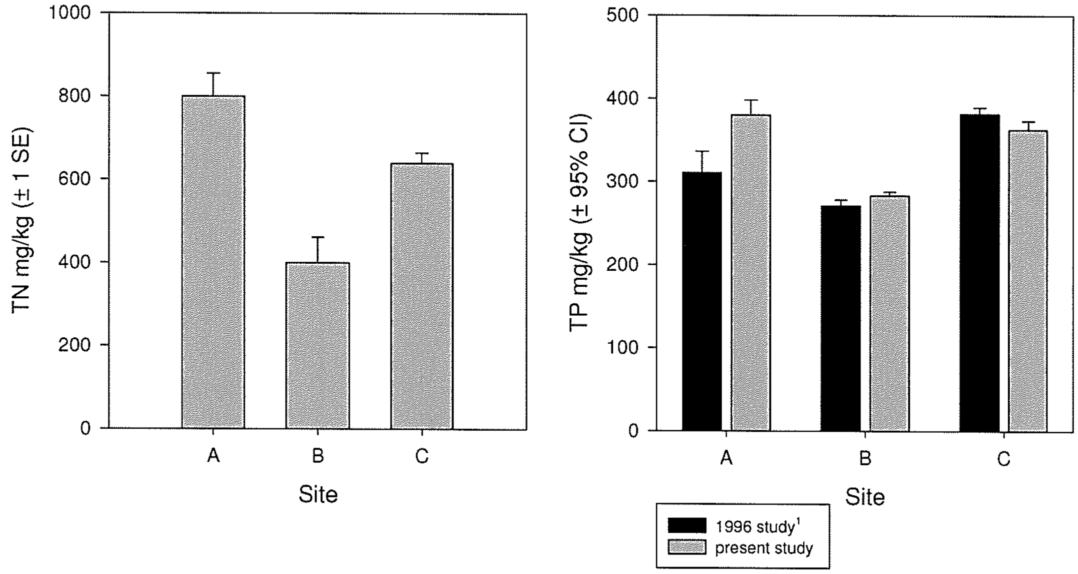

Figure 5: Mean total nitrogen and mean total recoverable phosphorus at sites A, B and C in the Wairoa River estuary.
1. (Larcombe, 1996a)

Table 4: Total Nitrogen (TN) and Total Phosphorus (TP) recorded at sites A, B and C, Wairoa River estuary with the range of values for New Zealand estuary reference sites.

Site	TN (mg/kg)	TP (mg/kg)
A	**600-900**	**355-404**
B	**250-500**	**275-290**
C	**600-700**	**347-378**
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 -Georges tide gate[2]	380-840	384-553

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

2.3.4 Sediment Quality – Trace Metals

Trace metals were present in the sediments at levels not exceeding ANZECC sediment quality guidelines (Fig. 6, Fig. 7). 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 previous 1996 study to compare against. These results indicate that accumulation of trace metals is not occurring in the sediments surrounding the WWTP outfall.

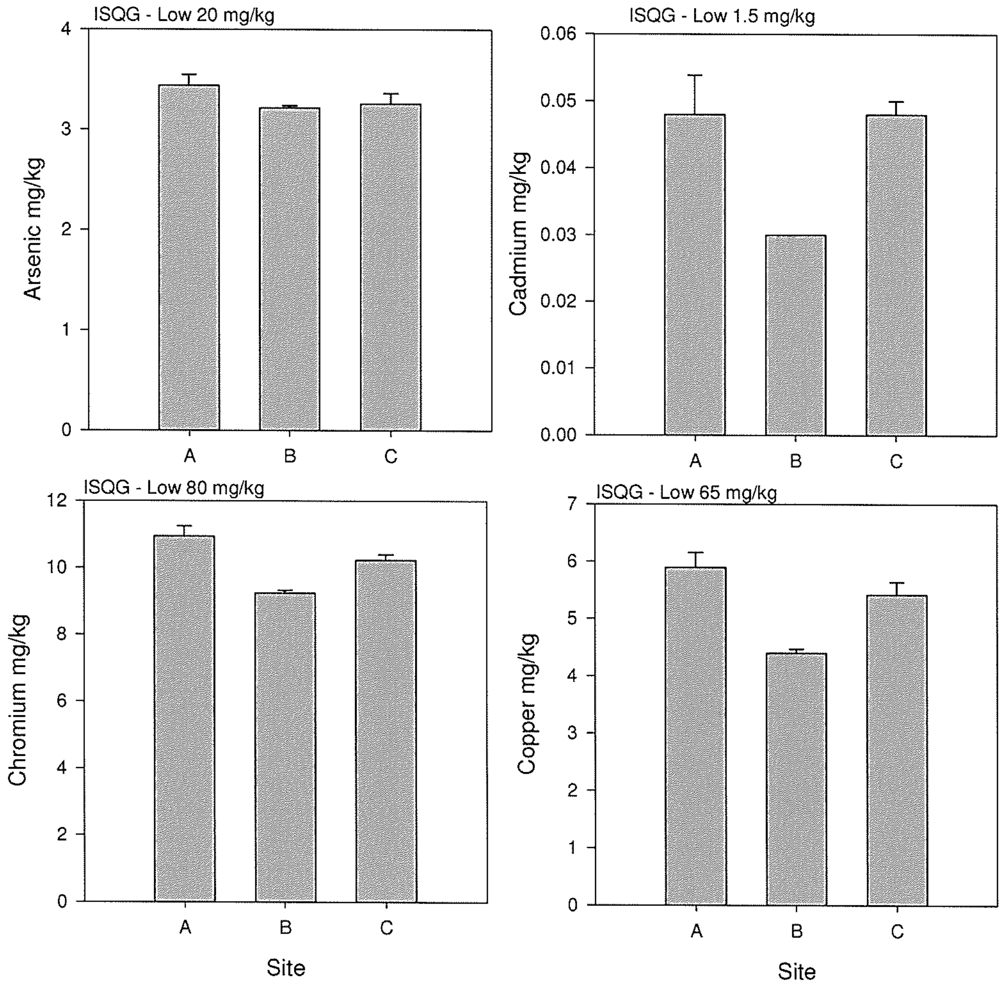

Figure 6: Mean Arsenic, Cadmium, Chromium and Copper trace metal concentration at sites A, B and C in the Wairoa River estuary. Error bars ± 1 SE, results expressed on a dry weight basis.

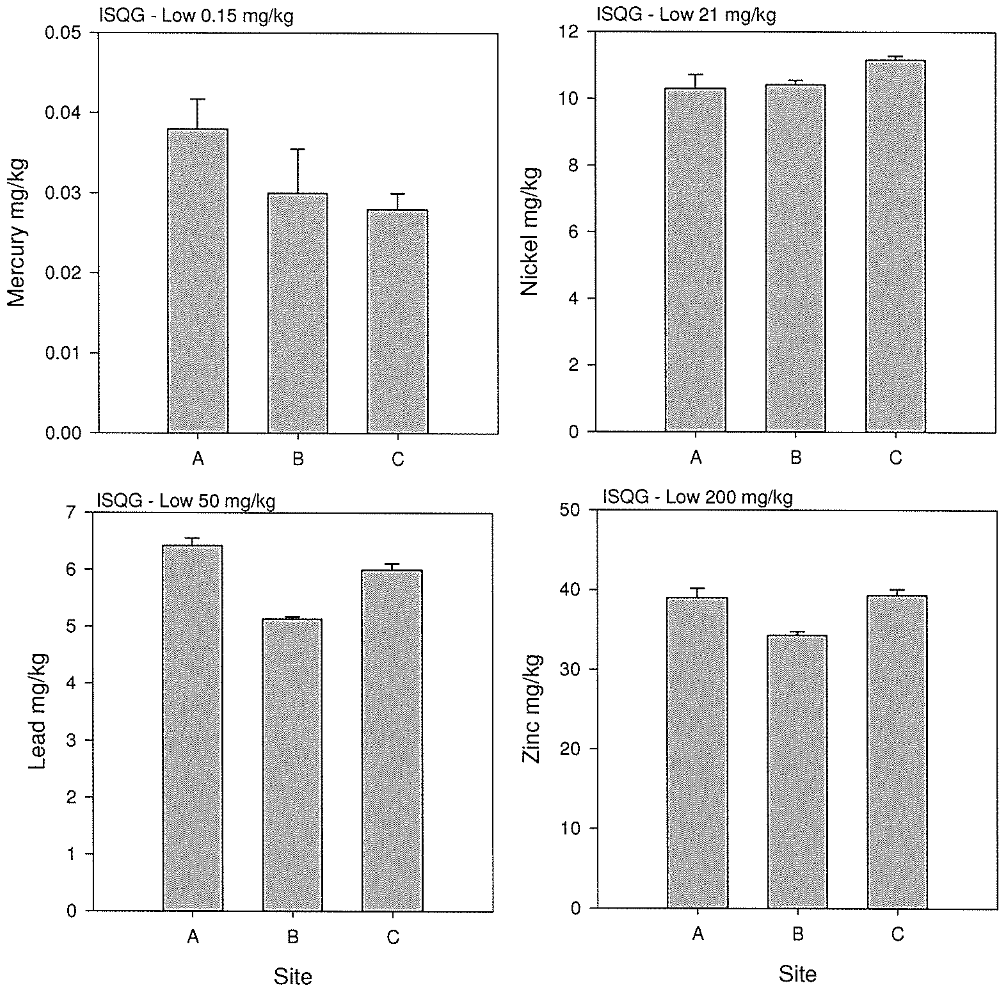

Figure 7: Mean Mercury, Nickel, Lead and Zinc trace metal concentration at sites A, B and C in the Wairoa River estuary. Error bars ± 1 SE, results expressed on a dry weight basis.

Normalisation[2] of data allows an accurate assessment of between site data, and also allows comparison against other Hawke's Bay and New Zealand reference estuary sites (Table 5). Between sites, B was significantly higher than site C and A in all 8 trace metals analysed. Similarly site C was significantly higher than site A in all trace metals except mercury, where there was no difference between sites A and C. Compared to other estuaries around New Zealand levels of trace metals at site B are in the mid range, while sites A and C are at the lower end of the range, and for some trace metals levels are very low e.g. cadmium.

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[2] Heavy metals have been shown to preferentially adhere to fine sediments in the silt/clay fraction that have reactive surface properties. Therefore, differences in heavy 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.

Table 5: Chemical sediment characteristics (normalised to 100% fines) for sites A, B and C in the Wairoa River estuary and other New Zealand reference estuaries.

. Site	TVS (% dry wt)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Site A	**4.82**	**5.09**	**0.07**	**16.17**	**8.72**	**15.23**	**9.49**	**57.69**
Site B	**9.15**	**17.76**	**0.17**	**50.97**	**24.27**	**57.47**	**28.32**	**189.30**
Site C	**4.88**	**7.11**	**0.11**	**22.30**	**11.82**	**24.35**	**13.1**	**85.82**
Otamatea[1]	10.14		0.71	36.48	24.56	16.73	20.28	69.98
Ohiwa[1]	148.76		0.49	36.82	20.02	19.4	16.92	137.81
Ruataniwha[1]	13.04		1.09	260.87	77.17	148.91	51.09	407.61
Waimea[1]	5.31		1.22	275.97	39.18	295.92	30.2	170.61
Havelock[1]	7.85		1.57	255.49	56.02	138.74	29.32	225.13
Avon-Heathcote[1]	18.52		1.85	288.89	59.26	122.22	116.67	709.26
Kaikorai[1]	18.75		0.37	177.94	61.76	57.35	166.54	677.21
New River[1]	41.18		5.88	652.94	223.53	294.12	41.18	1005.88
Ahuriri - Georges tide gate[2]	12.60	33.51	0.67	80.43	58.18	46.92	77.08	601.88
Ahuriri - Pirimu[2]	19.39	51.02	1.02	95.51	40.2	65.31	55.92	369.39
Ahuriri - Rail Bridge[2]	26.27	98.87	1.41	157.63	55.08	104.52	109.04	649.72

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

2.3.5 Sediment Quality – Total Volatile Solids

Total volatile solids (TVS), also referred to as Ash Free Dry Weight (AFDW) represents the amount of organic matter present in the sediments. As in trace metals, levels of organic matter in sediments will tend to be higher in sites with a higher fines fraction, therefore TVS data were also normalised to 100% of the fines fraction for each site in order to compare between sites and reference estuarine sites. Compared to New Zealand reference estuaries, levels of organic matter in the sites surrounding the outfall are at the low end of the range (Table 5). Between sites in the Wairoa River estuary, site B was significantly higher than sites A and C, with no significant difference between sites A and C. Compared to 1996 organic matter was significantly higher at all three sites (Table 6).

Table 6: Comparison of TVS (± 95%CI, normalised to 100% fines) in sediments at sites A, B and C in 1996 and at present in the Wairoa River estuary.

Site	1996[1] (% dry weight)	Present (% dry weight)
A	2.13 ± 0.40	4.82 ± 0.72
B	3.04 ± 0.61	9.15 ± 1.05
C	2.62 ± 0.40	4.88 ± 0.51

1. (Larcombe, 1996a)

2.4 Overview

Site A - 100m downstream (SW) of outfall

- Shallowest RPD layer (oxygenated layer)
- Highest silt/clay ('fines') fraction and approximately 28% higher in fines than in 1996
- No apparent nutrient enrichment, although significantly higher in total P than in 1996 and lies in the mid range for nutrients (total N, total P) compared to other New Zealand estuaries.
- Trace metals well below ANZECC ISQG-low guidelines and low compared to other New Zealand estuaries)
- TVS (organic content) significantly higher than 1996 but low compared to other New Zealand estuaries.

Site B - 100m upstream (NE) of outfall

- Deepest RPD layer
- Highest sand content, but significantly higher in fines than 1996 (6%)
- No apparent nutrient enrichment, and no difference in total P compared to 1996. Lies in the low range compared to other New Zealand estuaries.
- Trace metals well below ANZECC ISQG-low guidelines but highest levels among sites sampled.

- TVS significantly higher than 1996 and highest of sites sampled but low compared to other New Zealand estuaries.

Site C - 500m upstream (NE) of outfall

- No difference in sediment composition compared to 1996
- No significant difference in total P compared to 1996, no apparent enrichment
- Low levels of trace metals, and well below ANZECC ISQG-low guidelines
- Low levels of TVS, but slightly higher than in 1996.

Overall, sediments at the 'impact' site A compared to the 'reference' site C were the most similar at the time of the last sediment study (1996), however, now site A is higher in the proportion of fine sediments, organic matter, nutrients and some trace metals. Although sediment characteristics of the 'impact' sites A and B have changed over time the changes do not represent any enrichment or contamination issues, although it is likely that these differences have occurred as a result of the discharge of fine organic matter from the outfall.

3. Benthic Ecology

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 prey for fish and other organisms. Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion and nutrient loading, or other forms of environmental degradation. 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 (Pearson and Rosenberg, 1978, Warwick, 1993). 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 invertebrate communities in marine sediments. Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have documentation of background or reference conditions for an area. There is no such information available for the WWTP discharge area, however data from Larcombes, (1996) study, although a single snapshot in time, provides a contrast with which to examine the present findings. This section presents analyses and interpretations of the macrofaunal data collected at sites surrounding the WWTP during May 2007. Included are descriptions and comparisons of soft-bottom macrofaunal assemblages in the area, and analysis of benthic community structure.

3.2 Sampling Sites and Methodology

3.2.1 Sample sites

Sample sites were the same as those described in section 2, Sediment Characteristics, and the same as those sampled by Larcombe, (1996) (Fig. 1)

3.2.2 Methodology

Sampling was carried out at the same time as sediment samples were collected (14th May 2007). Although it was low tide, sampling sites were submerged, with a depth of approximately 70cm. At each site, five replicate infaunal cores were collected using a circular PVC 130mm (internal Φ) x 100m long core (total area $0.013m^2$). Samples were collected by pushing the core into the sediment to a depth of 150mm (Robertson et al., 2002) and digging down the outside of the core and placing a hand over the bottom and extracting the core and intact sample. Samples were ejected from the core into a 0.5mm mesh sieve and sediment gently washed through, leaving infauna on the screen. Samples were then washed into sample jars with 95% 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 samples 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 all biology enumerated and identified to the lowest possible taxonomic grouping.

3.2.3 Data analysis

Benthic infaunal data were compared between sites, as well as to the previous 1996 study. Abundance, diversity indices, richness and evenness were evaluated by ANOVA (STATISTICA v5).

Data were also analysed using a permutational multivariate analysis of variance (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’. Data were square root 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). Multivariate analyses were based on the Bray-Curtis distance matrix. Spatial variations in species composition of the full dataset were visually assessed using principle coordinate analysis (PCO) (Anderson, 2003) a type of metric multidimensional scaling.

3.3 Results

3.3.1 Species Abundance, Richness, Diversity and Evenness

A complete list of all benthic infaunal data is included in appendix 2. Total number of individuals (N) ranged between 127 and 266 individuals per core (Fig. 7a), with sites A and B having significantly more individuals than site C (no difference between A and B). Comparing the 1996 data to the present for total number of individuals, the only significant difference was that site C (1996) was higher than all other sites (A, B, C – 2007 and A, B – 1996, no difference). The amphipod *Paracorphium excavatum* accounted for 85% and 53% of all individuals in 2007 and 1996 respectively.

Species richness (S), or number of taxa present in each core ranged from 4 – 7 (Fig. 7b), and did not differ significantly between sites or years.

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. In the present study, diversity, assessed by the Shannon-Weiner index was found to be significantly lower at site A than sites B and C (no difference) (Fig. 7c). Moreover the results for H' at site A in the present study were also significantly lower compared to all sites in 1996.

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 study evenness at site A was significantly lower than sites B and C (Fig 7d). However, compared to the 1996 study there were no significant differences between any of the sites.

Although the size of the infaunal samples collected in Larcombe's 1996 study were $0.05m^2$, compared to $0.013m^2$ used in this study, data were nonetheless compared as the number of species detected in a sample usually changes much more in relation to sample size or sampling intensity than does the distribution of relative abundances. (Huston, 1997)

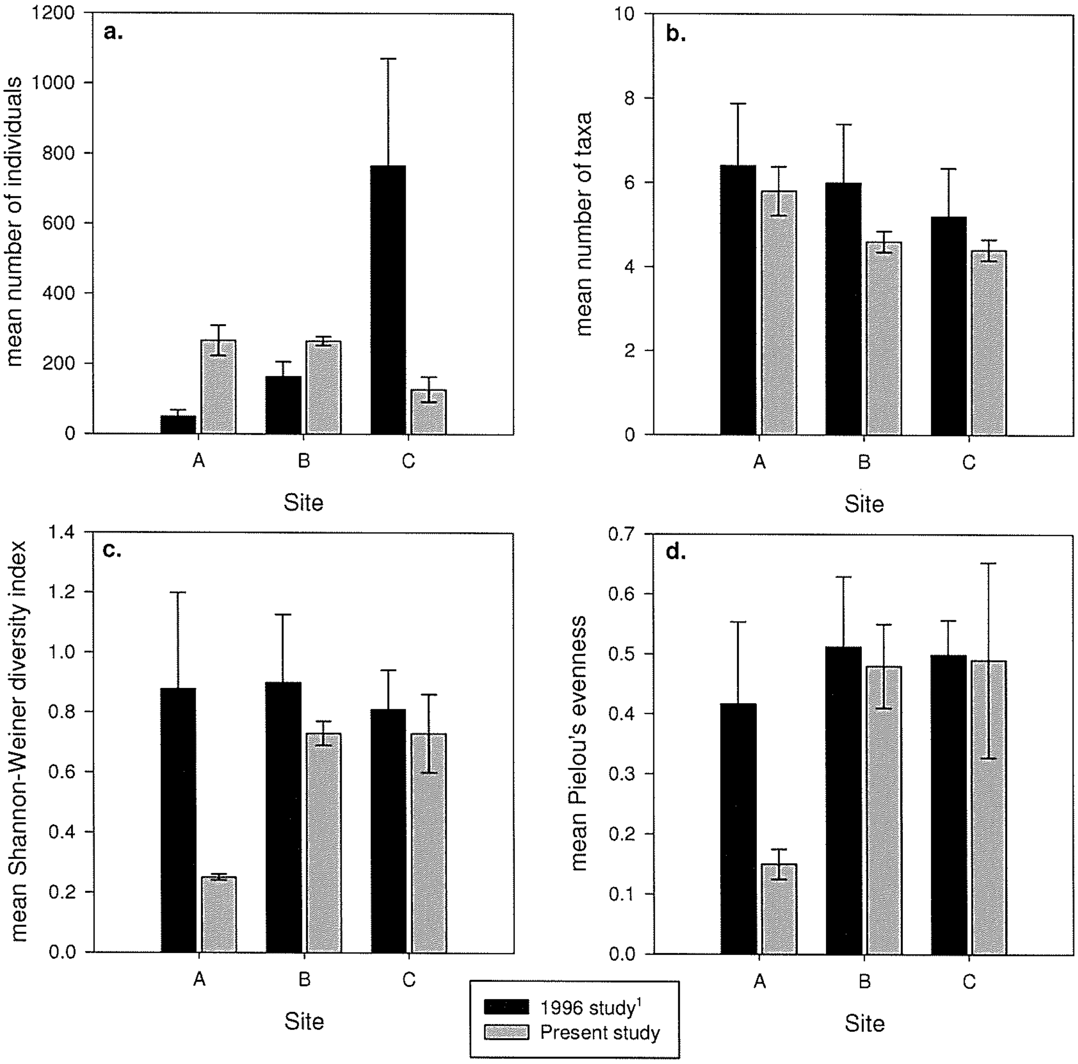

Figure 8: Plots comparing means of a) individual abundance, b) number of taxa, c) Shannon-Weiner diversity index and d) Pielou's evennness of benthic macroinfauna from the 1996 and present studies at sites A, B and C in the Wairoa River estuary. Error bars ± 95%CI

1. (Larcombe, 1996a)

3.3.2 Community Structure

Multivariate analysis of the infaunal data allows a comparison to be made between sites and years in multidimensional space. Similarities in species abundance between sites and years are expressed on a two dimensional plane called a principle coordinates ordination (PCO) plot, or multi-dimensioinal scaling (MDS) plot (Fig. 9 and Fig. 10). Comparing infauna spatially and temporally it is evident that 5 groups are separated out (Fig. 9). These groups are site A1996, site B1996, site C1996, site B2007 and a group comprised of sites A2007 and C2007 combined (Fig. 9). This suggests that the proportions of infaunal species found at each site are quite unique and predictable. Figure 10 graphically presents correlations between species. Groupings can be broadly represented by sites and years as separated out in the PCO analysis (Fig. 9).

The PERMANOVA results indicate that sites (for each year) are significantly different from each other (df=5, $p<0.01$) while pairwise comparisons between sites (for each year) showed all sites were significantly different from each other. Thus community composition has over time become more similar among sites, but still remains significantly different. This is evident by the close grouping between the 2007 sites compared to the 1996 groupings (Fig. 9), and driven primarily by the increased evenness of the nereid polychaete *Nicon aestuariensis*, the gastropod *Potamopyrgus antipodum* and the amphipod, *Paracorphium excavatum* among sites. This increased level of similarity among communities is likely a result of changes in sediment composition at sites A and B, with a higher proportion of fines favouring deposit feeding organisms e.g. *Scolelepis* sp and surface scavenging organisms, e.g. *Helice crassa, Paracorphium excavatum* and *Potamopyrgus antipodum.* The occurrence of the pipi, *Paphies australis* at site A, although a species susceptible to the effects associated with increasing fines, is likely taking advantage of the higher suspended organic matter discharged from the outfall.

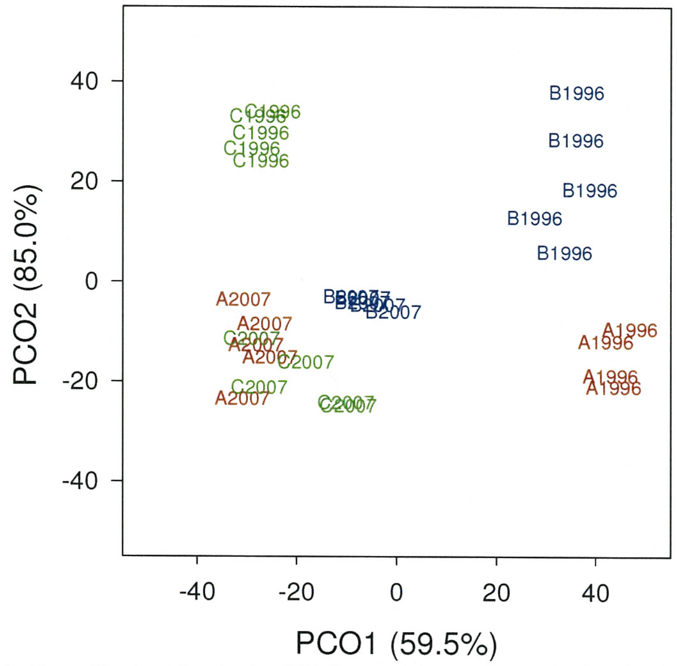

Figure 9: Principle Coordinates Analysis (PCO) plot (or metric MDS) of benthic infauna at sites A, B and C collected in 1996 and at present (2007), from the Wairoa River estuary. Data were square root transformed prior to analysis and groupings are based on Bray-Curtis dissimilarities. Percentage labels represent the total % variation among samples explained by each axis.

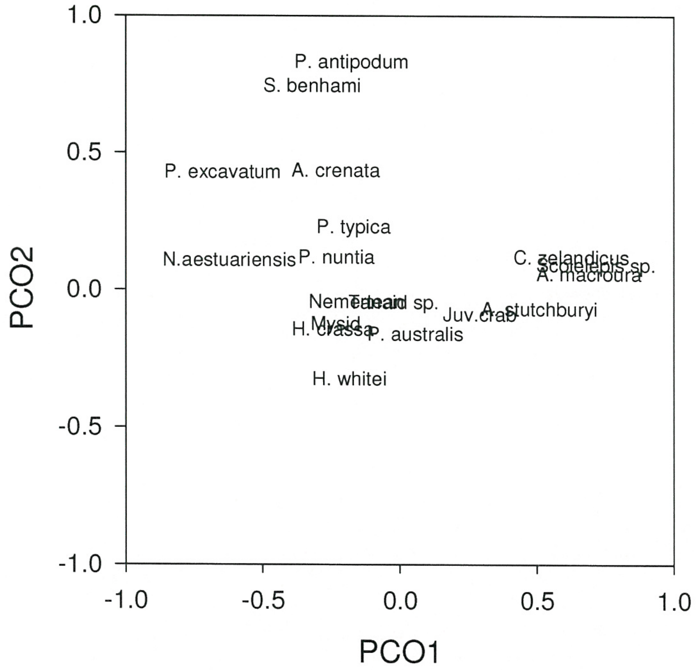

Figure 10: Correlations between benthic infauna abundance and PCO axes from the 1996 and present studies for all sites.

3.4 Overview

Site A – 100m downstream (SW) of outfall

- Significantly higher numbers of individuals than the control site C
- Significantly lower diversity than sites B and C, and compared to 1996 study also significantly lower in diversity.
- Significantly lower species evenness than sites B and C.
- Community composition significantly different from sites B and C (present study and all sites in 1996 study
- Certain species susceptible to the effects of increased fine sediments such as *Paphies australis* do occur here
- Macrobenthic fauna predominantly deposit feeders and surface scavengers

Site B – 100m upstream (NE) of outfall

- Significantly higher numbers of individuals than the control site C.
- No difference in Shannon-Weiner diversity index or Pielou's evenness compared to control site C, or to sites sampled in 1996 study.
- Community composition significantly different from sites A and C (present study) and all sites in 1996 study.
- Macrobenthic fauna predominantly deposit feeders and surface scavengers

Site C – 500m upstream (NE) of outfall

- Community composition significantly different from sites A and B (present study) and all sites in the1996 study.

In general the macrobenthic communities at sites surrounding the outfall are becoming more homogeneous in composition over time, and the species that are becoming more common are deposit feeders and surface scavenging organisms. Animals with these particular modes of feeding tend to proliferate in areas of high sediment bound organic matter.

4. Trace Metals in Flounder

4.1 Introduction

Yellow-bellied Flounder, *Rhombosolea leporina* were collected to assess the accumulation of contaminants in their tissues. The bioaccumulation of contaminants in fish occurs through biological uptake and retention of contaminants. Exposure pathways for demersal fishes include the adsorption or absorption of dissolved chemicals from the water and the ingestion and assimilation of pollutants from food sources. They also accumulate pollutants by ingesting pollutant containing suspended particulate matter or sediment particles. Demersal fish can be useful bioindicators because of their association with sediments. Hence, levels of contaminants in tissues of demersal fish are often related to those found in the environment. This part of the study involves the analysis of muscle tissues from Flounder collected by set net. Flounder collected by netting are considered representative of demersal fishes living within a specified area. Although the liver is where contaminants typically concentrate due to the physiological role of this organ and the high lipid levels found there, chemical analyses were performed on muscle tissue of net-caught Flounder as these represent a typical fisher's catch, and are therefore of recreational, customary and commercial importance. Muscle tissue was analysed from Flounder because it is the tissue most often consumed by humans, and results are therefore directly pertinent to human health. All muscle tissues were analysed for trace metal contaminants. This chapter presents the results of tissue analyses that were performed during this study.

4.2 Sampling Sites and Methodology

4.2.1 Sample sites

Two sites were sampled to assess possible bioaccumulation of contaminants in Flounder, an 'impact' site, was located directly in front of the outfall and a 'reference' site, was located in the Mangawhio estuary on the Mahia Peninsula, approximately 42km east of the outfall. Compared to the Wairoa River estuary the Mangawhio estuary does not have a major riverine input. It also lies adjacent to the old Mahia landfill, however the surrounding catchment uses are similar in their pastoral functions.

4.2.2 Methodology

A typical recreational set net, 60m in length, was used to capture Flounder at both sites. The net was set at low tide on the night of the 21st May 2007 in the Mangawhio and at low tide in the morning of the 22rd May 2007 in the Wairoa River estuary, and left for the duration of the flood tide. Caught Flounder were measured (total length) and weighed to the nearest gram and filleted. The following day fillets from each site were combined into a single sample and sent to Hills Laboratories, Hamilton for analysis. Samples were analysed for trace metal concentration by first, mincing samples into a homogenous matrix, followed by nitric and hydrochloric micro acid digestion at 85°C for 1 hour. Resultant concentrations of trace metals were measured by ICP-MS.

4.3 Results

4.3.1 Length, weight and condition of Flounder

The length-weight relationship in Flounder is described by a 2 parameter power equation of the order $y = ax^b$ (Wairoa $R^2 = 0.981$, $p = 0.0015$, Mangawhio $R^2 = 0.977$, $p < 0.001$) (Fig. 11). Given the small sample size, and crossing of the two regression lines it is difficult to elucidate a clear difference in the length-weight relationship between the two sites. Nevertheless, for Wairoa Flounder weight can be confidently predicted by the equation: $\text{weight} = 0.0332(\text{total length})^{2.6832}$

Based on the length-weight data, a condition index was calculated for each fish using the equation: $\text{Condition} = (\text{weight}/\text{length}^3) \times 100$. Mean condition index values were 1.126 ± 0.02 (Wairoa) and 1.133 ± 0.04 (Mangawhio). Given the similar length-weight relationships and no difference between condition indices, results of tissue analyses of could be compared with confidence that physiologically the flounder from each site were similar

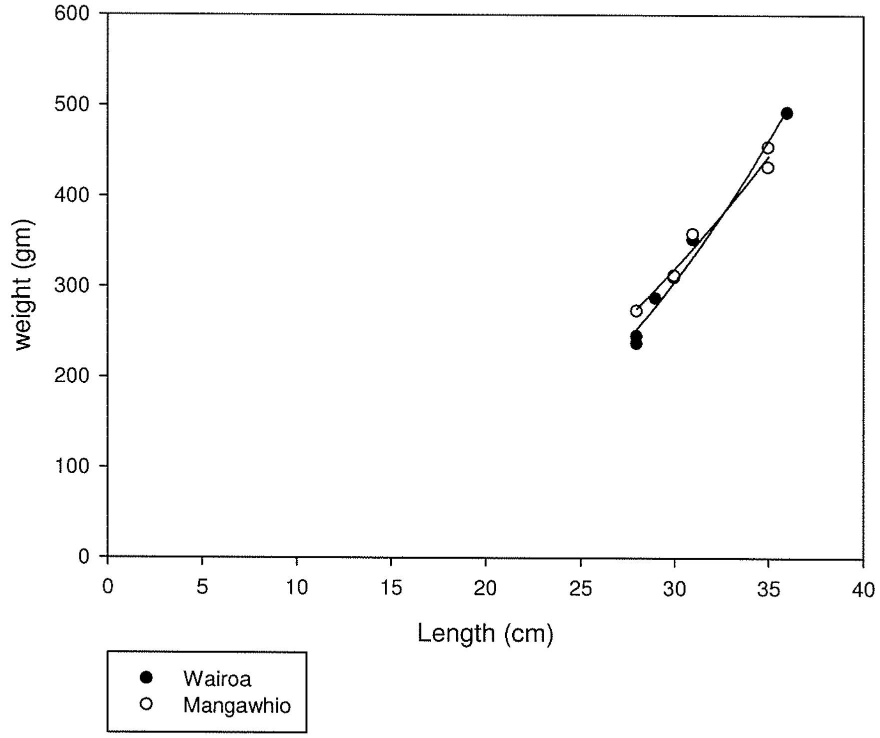

Figure 11: Length, weight relationships for Flounder caught at the outfall site (Wairoa) and reference site (Mangawhio).

4.3.2 Concentrations of Trace Metals in Wairoa Flounder

The results of the trace metal extraction showed that in general Flounder from Wairoa were lower in all trace metals than Managwhio Flounder except for copper (Table 7). Overall, trace metal concentrations in Wairoa Flounder are similar to other Hawke's Bay Flounder and fall well below food safety standards (Food Standards Australia and New Zealand (FSANZ) guidelines for fish (standard 1.4.1)).

Table 7: Trace metal concentrations in Flounder tissue sourced from the Wairoa River estuary and Mangawhio estuary compared to results from other New Zealand studies of trace metal bioaccumulation in flounder and food safety standards - FSANZ maximum permitted concentration (MPC) guidelines.

Trace metal	Wairoa (mg/kg)	Mangawhio (mg/kg)	Clive[1] (mg/kg)	Control[1] (mg/kg)	Manukau[2] (mg/kg)	MPC (mg/kg)
Arsenic	0.39	1.3	0.76	2.71	0.6	2.0 (inorganic)
Cadmium	< 0.0004	0.0006			< 0.2	2.0
Chromium	<0.02	0.061			0.5	
Copper	0.12	0.1	0.24	0.16	4	10.0
Lead	0.0053	0.0077	0.028	0.009	< 0.2	0.5
Mercury	0.094	0.098	0.036	0.077		1.0
Nickel	< 0.02	< 0.02			0.5	
Zinc	6.9	4.8	12.5	4.39	17	

1. (Kingett_Mitchell, 2003) 2. (Winchester, 1988)

4.4 Overview

- Flounder caught at a reference estuary (Mangawhio) were of comparable size, weight and physiology of Flounder caught at the outfall.
- Compared to concentrations of trace metals in Flounder caught in the reference estuary (Mangawhio), Wairoa Flounder were higher in Zn only.
- Concentrations of the trace metals As, Cu, Pb and Zn were lower in Wairoa flounder compared to other Flounder caught around wastewater outfalls in Hawke's Bay. Hg, however is higher in Wairoa Flounder.

The concentration of trace metals in Wairoa flounder is low and would not pose a health hazard unless large quantities were consumed daily over the course of a lifetime.

5. Summary

5.1 Introduction

The Wairoa District Council has recently begun an expanded programme of monitoring at the Wairoa Wastewater Treatment Plant. As part of that programme effluent plume studies of the outfall and a benthic survey of the area surrounding the outfall were conducted in May and June 2007. The objective of these studies was to assess the potential and actual effects of the effluent discharge on the biological communities of the Wairoa River estuary, and human health.

5.2 Sediment Characteristics

The sediment characteristics of the two sites (A and B) surrounding the outfall have changed markedly since the last survey in 1996. It is evident from Fig. 2 that these two sites will from time to time be exposed to the direct effects of the discharge. Therefore given the close proximity of these sites to the outfall, and the shallow depth of the discharge area it is to be expected that some effects will be seen at these sites. Proportions of fine silts and clays, total volatile solids and total phosphorus (site A only) are all greater than those found in 1996. These indicators suggest that over time the fine organic matter typically discharged from an effluent outfall is having a detrimental effect on sediment texture and sediment quality in the near vicinity of the outfall. It is unknown if trace metal contaminants are accumulating in the sediments around the outfall, as this has been the first trace metals assessment undertaken in the area.

Although sediments at sites around the outfall have declined in quality over time, the extent of these effects is highly localised, as evidenced by the stability of sediment texture and phosphorus levels at site C. In addition, compared to ANZECC guidelines for trace metal contaminants in sediments, concentrations found at sites around the outfall were below ISQG-low values and compared to New Zealand reference estuaries levels of total volatile solids, nutrients and trace metals are at the lower end of the range. At these levels adverse biological effects are seldom expected to occur. Therefore, discharge effects on sediments in the Wairoa River estuary are sustainable in their present capacity and do not appear to be causing an undue adverse effect.

5.3 Benthic Ecology

The benthic infauna in the area around the outfall are characterised by large numbers of the amphipod *Paracorphium excavatum.* This small crustacean feeds not by filtering but on finely divided organic matter picked up or licked from the surface of sand grains. Also abundant are deposit feeding polychaete worms and the ubiquitous euryhaline snail *Potamopyrgus antipodum.* These species also feed by picking and sorting organic matter from among sediment grains. This type of assemblage is often found around outfalls and can proliferate to very high densities in highly enriched, fine grained sediments. As abundance was significantly higher at sites around the outfall, and the downstream site (A) was significantly lower in diversity and evenness indices compared to both the control and 1996 results it would appear that infaunal communities around the outfall are being affected over time by the discharge. With respect to community composition all sites in the present study were significantly different to each other and to those found in 1996. Furthermore the communities sampled in the present study are becoming more similar over time. This increased similarity in community composition is likely the result of a combination of factors, including the effects of the WWTP outfall discharge and other upstream discharges (e.g. AFFCO discharge). It may however be a result of the patchy nature of estuarine habitats in space and time. Thus, discharge effects on benthic infaunal communities around the outfall are evident, and may continue to alter composition over time. These effects are not considered adverse however, as a species that is highly sensitive to the effects of increased levels of fine particulate matter, the pipi, *Paphies australis* does occur at the most impacted site (A).

5.4 Trace Metals in Flounder

Yellow-bellied flounder, *Rhombosolea leporine*, caught adjacent to the outfall contained five out of eight trace metals in detectable concentrations. These trace metals are known to bioaccumulate in the flesh of bottom dwelling fishes such as flounder. As flounder are regularly caught by the general public in the Wairoa River estuary there is the possibility that the concentration of these contaminants occur at levels that may be harmful to human health. The concentrations of trace metals found in Wairoa flounder were however well below food safety guidelines, and compared to flounder caught at a reference site (Mangawhio estuary) and from around another Hawke's Bay outfall, levels were lower or within those reported.

The occurrence of these trace metals in Wairoa flounder tissue could be due to a range of factors, including having been discharged from the outfall, from other point and non point source discharges or from the environment itself. Confounding matters further is that true control sites, free of contaminants, are difficult to identify, for e.g. Mangawhio flounder were 3x higher in Arsenic than Wairoa flounder. One aspect that made flounder comparable between sites was the similarity in physiology, as assessed by the condition index and length-weight relationships. In general there was no evidence to show that the discharge of effluent from the outfall was having any effect on trace metal contaminants in Wairoa flounder tissue.

5. Conclusions

- Although the sites surrounding the outfall are higher in the proportion of fines, TVS (organic matter) and phosphorus than the control and 1996 results, contaminant levels were below ANZECC ISQG-low guidelines and low compared to New Zealand reference estuary sites.

- Benthic infaunal communities surrounding the outfall and the reference site are becoming more similar over time, dominated by surface scavenging and deposit feeding species that are frequently found around outfall sites. However, sensitive bivalve species were present in the downstream, impacted site.

- Trace metals were found in Wairoa flounder, but were well below FSANZ maximum permitted concentrations for fish, and were lower or within the range of reported values for flounder from around another Hawke's Bay outfall.

References

Anderson, M.J., 2003. PCO: a FORTRAN computer program for principal coordinate analysis. Department of Statistics, University of Auckland, New Zealand.

Anderson, M.J., 2005. PERMANOVA: a FORTRAN computer program for permutational multivariate analysis of variance. Department of Statistics, University of Auckland, New Zealand.

ANZECC, 2000. Australian and New Zealand guidelines for fresh and marine water quality 2000, Volume 1., National Water Quality Management Strategy Paper No. 4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Bennett, C., 2006. Ahuriri Stormwater Discharge Compliance Monitoring. Cawthron Report No. 1146, Cawthron, Napier.

Crawford, J., 2007. Wairoa Wastewater Treatment Plant Review (2006). Report No. 2-Y2514.00, Opus International Consultants Ltd, Hamilton.

Gray, J.S., 1981. The Ecology of Marine Sediments: An Introduction to the Structure and Function of Benthic Communities. Cambridge University Press, Cambridge, 185 pp pp.

Huston, M.A., 1997. Hidden treatments in ecological experiments: re-evaluating the ecosystem function of biodiversity. Oecologia, 110. no. 4: 449-460.

Kingett_Mitchell, 2003. Assessment of Hastings Outfall - Benthic survey 2002, Kingett Mitchell, Auckland.

Larcombe, M.F., 1996a. Wairoa Sewage Treatment Plant Discharge Effects on the Wairoa Estuary, Bioresearches, Auckland.

Larcombe, M.F., 1996b. AFFCO Wairoa Liquid Waste Discharge Effects on the Wairoa Estuary, Bioresearches, Auckland.

Metson, A.J., Saunders, W.M.H. and Nott, J.H., 1971. Some chemical properties of soils from areas of Barley grass (*Hordeum murinum* L) infestation. New Zealnd Journal of Agricultural Research, 14(2): 334-351.

Pearson, T.H. and Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology Annual Review, 16: 229–311.

Robertson, B.M. et al., 2002. Estuarine Environmental Assessment and Monitoring: A National Protocol. Cawthron.

Walters, K. and Coen, L.D., 2006. A comparison of statistical approaches to analysing community convergence between natural and constructed oyster reefs. Journal of Experimental and Marine Biology and Ecology, 330: 81-95.

Winchester, R.V., 1988. Trace metal levels in fish from the Manukau Harbour, Auckland, New Zealand, related to a water pollution incident (Note). New Zealand Journal of Marine and Freshwater Research, Vol. 22: 621-624.

Appendices

Appendix 1:

Wairoa District Council Wastewater Outfall Dye Dilution Study

Appendix 2:

Benthic macroinvertebrate infauna results

(Number $0.013m^{-2}$)

General Group	Taxa	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Nemertea	Nemertean															3
Bivalvia	*Paphies australis*		1	3	3	3										
Gastropoda	*Potamopyrgus antipodum*	2	4	6	3	12	14	22	18	20	19	4	4	2	7	6
Polychaeta: Nereididae	*Perinereis nuntia*			2	1		1									
Polychaeta: Nereididae	*Nicon aestuariensis*	3	3	2	2	1	1	3	1	3	1	10	16	22	10	12
Polychaeta: Spionidae	*Scolelepis* sp.		2	2	1		43	36	47	28	56	3	2	1	2	7
Mysidacea	Mysid		1			1		1								
Tanaidacea	*Tanaid* sp.								1							
Decapoda	*Helice crassa*			1	1											
Decapoda	*Halicarcinus whitei*	1											1			
Amphipoda	*Paracorphium excavatum*	105	232	338	281	316	239	202	187	233	150	37	27	110	226	126
	No. of individuals	**111**	**243**	**354**	**292**	**333**	**298**	**264**	**254**	**284**	**226**	**54**	**50**	**135**	**245**	**154**
	No. of taxa	**4**	**6**	**7**	**7**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**5**	**4**	**4**	**5**

Appendix 3:

Laboratory reports: sediment grain size

Appendix 4:
Laboratory reports: TVS, nutrients and trace metals

Appendix 5:

Laboratory report: Trace metals in flounder flesh