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REGIONAL COUNCIL

Contaminants in shellfish flesh

An investigation into microbiological and trace metal contaminants in shellfish from selected locations in the Wellington region

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Executive summary

The Wellington region's varied and extensive coastline is utilised for both traditional and recreational harvesting of a number of shellfish species. Greater Wellington Regional Council periodically monitors the safety of these shellfish for human consumption. This report presents the results of the 2006 investigation, focusing on microbiological and trace metal contaminants in tuatua, cockles and blue mussels from selected sites in the western Wellington region.

Faecal coliform indicator bacteria were detected in eight out of a total of 58 shellfish samples. Four of the eight results above detection were recorded in cockle samples collected from Porirua Harbour. No samples had bacteria present at a concentration that exceeded the recommended microbiological guidelines for edible tissue.

Cadmium, chromium, copper, lead, mercury, nickel and zinc were all present in the three species of shellfish examined. However, none of the metal concentrations exceeded the national food standards for edible tissue, where standards exist.

The tuatua and cockle sample results showed little spatial variation in mean metal concentrations, with similar concentrations recorded between most sampling sites. However, there was some spatial variation in metal concentrations in the mussel samples from Wellington Harbour. Samples collected adjacent to Frank Kitts Park and the Thorndon Container Wharf in the inner harbour generally recorded the highest concentrations, while samples collected from Mahanga Bay, Shark Bay and Sunshine Bay consistently recorded the lowest concentrations. Higher (on average) metal concentrations in the inner harbour basin may reflect the influence of urban runoff, although mussels from Inconstant Point on the south eastern side of the harbour also recorded high concentrations of some metals relative to other sites, namely cadmium, copper, mercury and zinc. Differences in mussel size between sampling sites may be a confounding factor in inter-site comparisons, particularly for mercury and nickel. Concentrations of these metals tended to decrease with increasing mussel size.

Direct comparisons with the results of the 2001-2002 shellfish investigation are difficult but, generally speaking, the metal concentrations in shellfish flesh observed at many sites in 2006 were higher than those reported in the earlier investigation. The key exceptions are mercury and lead; average concentrations of these metals were lower at most sites in 2006.

Recommendations

1. Continue to monitor key contaminants in shellfish flesh from selected sites across the Wellington region.

2. Standardise the sampling and analytical methodology for future investigations of contaminants in shellfish flesh.

Contents

1. Introduction

The Wellington region's varied and extensive coastline is utilised for both traditional and recreational harvesting of a number of shellfish species. The Greater Wellington Regional Council (Greater Wellington) periodically monitors the safety of these shellfish for human consumption. Historically this monitoring centred on measuring the concentration of faecal coliform bacteria in the water column, rather than in the shellfish. More recent investigations have involved monitoring faecal coliforms, trace metals and organic contaminants within shellfish flesh. This report presents the results of the 2006 investigation, focusing on microbiological and trace metal contaminants in filter-feeding shellfish from selected sites in the western Wellington region.

Filter-feeding shellfish process large amounts of water from a fixed location, and have the tendency to accumulate a wide range of contaminants in their tissues. As such, tissue contaminant levels provide an indication of ambient water quality conditions, with the added advantage that the accumulated contaminants are representative of only those forms which are *biologically available* to other organisms. Periodic monitoring of contaminants in shellfish flesh can therefore assist in determining whether Objective 1 for the coastal environment in the Regional Policy Statement (1995) is being met; *that coastal water quality of a high standard.*

1.1 Background

During 2001-2002 Greater Wellington assessed contaminant concentrations in four species of shellfish collected from the following locations:

- Kapiti Coast (3 sites) – tuatua (*Paphies subtriangulata*)
- Porirua Harbour (3 sites) – cockle (*Austrovenus stutchburyi*)
- Wellington Harbour (9 sites) – blue mussel (*Mytilus galloprovincialis*)
- Wellington West & South Coast (3 sites) – black-foot päua (*Haliotis iris*)
- Wairarapa South & East Coast (3 sites) – black-foot päua.

The purpose of the monitoring was to:

- assess the use of shellfish monitoring for measuring marine and estuarine water quality with respect to low-level contaminants that are not practical to measure routinely as part of an ambient water quality programme[1];
- provide a baseline for identifying spatial patterns of contamination, and measuring trends over time in contaminant levels, should a sentinel shellfish monitoring programme be established in the region;
- contribute to regional information on the movement of chemical contaminants into marine food chains; and
- assess the risks to human health resulting from the collection and consumption of feral shellfish from the region.

[1] Obtaining a reliable measure of contaminant concentrations in coastal waters through direct measurements in water samples is difficult and expensive because concentrations are often very low in the water column. In addition, temporal variability is a problem, so multiple sampling is required to eliminate variations in concentrations with time, season, freshwater run-off, currents and tides (Phillips 1977).

The 21 study sites (Appendix 1a) were selected to represent the major biogeographic and ecological divisions of the region's coastline, as well as areas of the region where traditional and recreational collection of shellfish for human consumption occurs regularly (Stephenson 2003). Pollution sources were not specifically targeted, nor was a minimum distance from a known pollution source specified.

Contaminants examined included trace metals (cadmium, chromium, copper, lead, mercury, and zinc), organochlorines, chlorophenols, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls (Appendix 1b). The investigation was linked to Greater Wellington's stormwater investigations programme, in which the same suite of chemical contaminants was analysed in stormwater discharges from a variety of urban catchments.

The key findings of the 2001-2002 investigation were summarised in Sherriff (2005)[2], but otherwise have not been formally reported. Therefore the trace metal analytical results are reproduced in full in Appendix 1c of this report. The analytical results of a joint investigation with the Institute of Geological and Nuclear Sciences (IGNS) into trace metal contaminants in sediment and shellfish undertaken at 17 sites in Porirua Harbour in early 2004 are also provided in this report (Appendix 2).

The 2006 investigation was smaller in scope than the 2001-2002 investigation, focusing on sites in the western Wellington region and the contaminants considered to pose the greatest risk to public health; microbiological contaminants and trace metals.

1.2 Monitoring objectives

The primary aims of the 2006 shellfish investigation were:

1. To investigate the concentration of faecal coliform indicator bacteria and trace metals in shellfish flesh samples collected from selected locations around the coastline of the western Wellington region; and

2. Where possible, to compare the contaminant concentrations against relevant guidelines for human consumption.

1.3 Outline of report

This report comprises five sections. Section 1 provides an overview of the aims and scope of recent shellfish monitoring undertaken by Greater Wellington. Section 2 outlines the sampling sites and methods for the 2006 investigation. The results are summarised and discussed in Section 3 and include a comparison with data from previous monitoring and international shellfish monitoring programmes. Overall conclusions and recommendations are presented in Section 4.

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[2] The findings in the report are taken from Stephenson (2003), *Progress Report on the Investigation of Chemical Contaminants in Shellfish.*

2. Sampling sites and methods

2.1 Sampling sites and species

The 2006 investigation revisited many of the sites sampled in the 2001-2002 investigation, with the exception of sites on the west and south coast of Wellington City, and sites around the Wairarapa coast. The 2001-2002 investigation did not identify any significant metal contamination in samples from these sites and the 2006 investigation was more focused on shellfish areas likely to be influenced by urban stormwater discharges. For this reason, additional sites were added in Porirua Harbour (e.g., Browns Bay) and Wellington Harbour (e.g., Frank Kitts Park).

A total of 20 sites were sampled in the western Wellington region (Figure 2.1, Appendix 3a) as follows:

- Kapiti Coast (3 sites)
- Porirua Harbour (5 sites)
- Wellington Harbour (12 sites)[3]

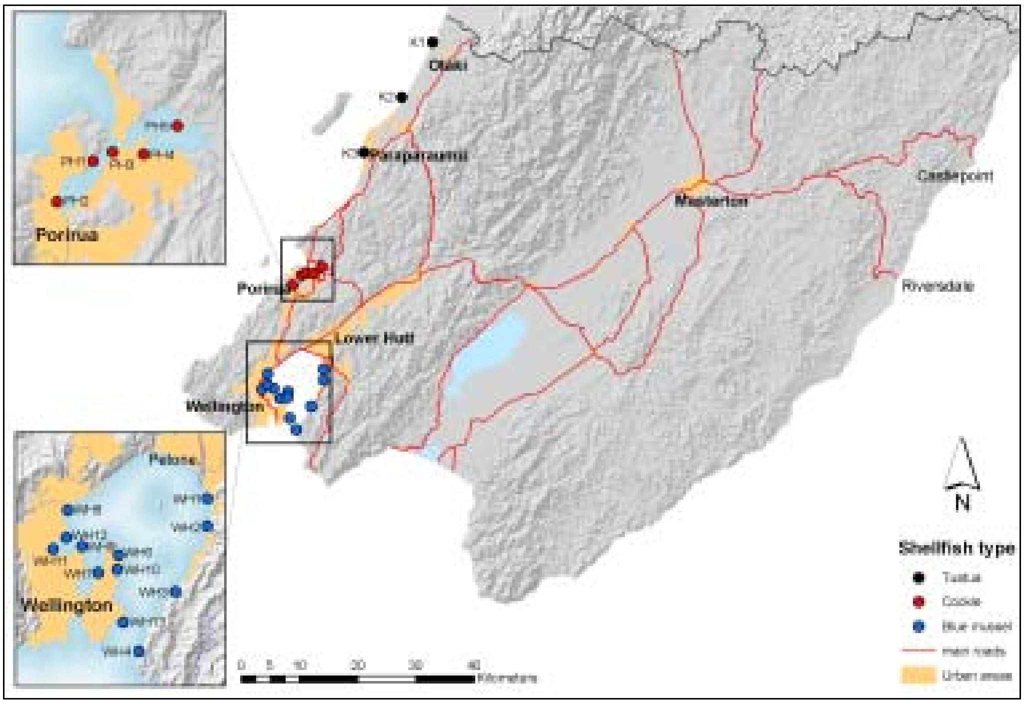

Figure 2.1: Location of shellfish sampling sites.

The species of shellfish examined were all filter-feeding bivalves:

- Tuatua (*Paphies subtriangulata*) – abundant in the lower inter-tidal and shallow sub-tidal areas along the exposed sandy beaches of the Kapiti Coast, with small populations also present on some other exposed beaches in the south and east of the region.

[3] A further site (WH5) at Hue-te-taka Peninsula on Wellington's south coast was also included in the original sampling programme but no mussels were found at this site.

- Cockle (*Austrovenus stutchburyi*) – abundant and widely distributed in Porirua Harbour on inter-tidal and shallow sub-tidal flats, and on channel margins, also in Wellington Harbour at Lowry Bay and Petone Beach.

- Blue mussel (*Mytilus galloprovincialis*) – abundant and widely distributed in Wellington Harbour on natural hard substrates and wharf pilings, and on the outer coast from around the Porirua Harbour entrance to just south of Paekakariki.

2.2 Sample collection

Shellfish sampling was undertaken during February-March 2006 in accordance with a Special Permit from the Ministry of Fisheries. All samples were collected by hand at low tide from inter-tidal (cockles) or immediate sub-tidal (blue mussels and tuatua) areas (Figure 2.2).

Figure 2.2: Collecting blue mussels at Point Jerningham.

Three replicate samples were collected from each sampling site[4], with the number of shellfish per composite sample varying depending on the size and availability of shellfish at each site:

- Tuatua – 40 individuals per sample
- Cockles – 80-100 individuals per sample
- Blue mussels – 50-80 individuals per sample

Measurements of shellfish size (length) were made in the field using plastic callipers, and composite samples placed into labelled zip-lock plastic bags. The samples were transported to the laboratory in cool conditions.

[4] The exception was Raumati Beach at Kainui Road; only one replicate sample was obtained from this site.

2.3 Sample analysis

Samples were analysed for faecal coliform indicator bacteria and seven trace metals (cadmium, chromium, copper, lead, mercury, nickel and zinc) by Environmental Laboratory Services in Lower Hutt. Analyses were conducted on homogenised composite samples. Whole shucked shellfish were used for analysis in all cases, and samples were not depurated[5] prior to analysis.

Faecal coliform analysis was performed on a representative portion of the fresh sample, with the remainder of the sample frozen until required for metal analysis. Metal analysis was undertaken using acid digestion and inductively coupled plasma mass spectrometry (ICP-MS).

A sub-sample of each homogenate was dried at 80ºC for approximately 12 hours to determine the moisture content, enabling expression of metal contaminant concentrations on a dry as well as a wet weight basis.

Quality assurance comprised duplicate analyses on approximately 10% of the composite samples.

[5] Depuration is the term applied to the purification of shellfish, under controlled conditions. The process generally involves holding the shellfish in tanks of clean seawater for periods of 24-72 hours, enabling defaecation of sediment and any undigested food material in the gut (Phillips & Rainbow 1993). Depuration is generally considered more important for sediment dwelling shellfish (e.g., mud snail), although the need for depuration is debated in the literature. If metal bioavailability is the key monitoring objective, shellfish should be depurated to enable an accurate estimate of tissue metal content (Langston & Spence 1993). However, if, as was the case here, metal contamination is being assessed for human health purposes and the gut contents of the shellfish species are not usually removed or depurated before consumption, then depuration is not justified (Kennedy 1986).

3. Results and discussion

The results are summarised in Table 3.1 and Figures 3.1-3.3 and discussed in turn below for tuatua, cockles and blue mussels. Raw data are provided in Appendix 3b. All concentrations are reported on a *wet weight* basis unless otherwise stated.

3.1 Standards and guidelines

3.1.1 Faecal coliform indicator bacteria

The New Zealand Food Safety Authority (NZFSA) lists four documents as well as specific food product legislation that need to be considered when interpreting microbiological results. The documents (other than the specific food product legislation) are:

- Ministry of Health (1995) Microbiological Reference Criteria for Food
- Food Standards Australia New Zealand (2001), Standard 1.6.1 – Microbiological Limits for Food
- Food Standards Australia New Zealand (2001), Standard 1.6.1 – Microbiological Limits for Food with additional guidelines criteria.
- Food Standards Australia New Zealand (2001) 'Guidelines for the microbiological examination of ready-to-eat foods'.

The MoH (1995) criteria are used here as they include faecal coliform bacteria for shellfish. These criteria state that faecal coliform concentrations up to 230 MPN/100 g are acceptable, with up to two samples from the same batch (site) allowed to exceed this level. However, if a single sample result exceeds 330 MPN/100 g then the entire batch is deemed to be non-compliant with the standard.

Note that both the MoH (1995) and the FSANZ (2001) recommend a minimum of five samples for bivalve shellfish, comprising a minimum of 12 individuals per sample. Only three replicate samples were collected in this investigation.

3.1.2 Metals

The New Zealand (Australia New Zealand Food Standards Code) Food Standards 2002 stipulate the following guidelines for concentrations of trace metals in shellfish tissue:

- Cadmium: 2 mg/kg (wet weight)
- Lead: 2 mg/kg (wet weight)
- Mercury: 0.5 mg/kg (wet weight) – as an average of 5 samples

There are no published guidelines for acceptable concentrations of chromium, copper, nickel or zinc in shellfish tissue, although the previous food standards (New Zealand Food Regulations 1984, revoked in December 2002) prescribed a copper guideline of 30 mg/kg (wet weight) in any food except animal offal and tea.

Table 3.1: Summary of faecal coliform and mean (+/- 1 std dev) trace metal concentrations recorded in tuatua, cockle and blue mussel samples collected from 20 sites in the western Wellington region, February-March 2006.

Site No. and Location	No. of samples	Mean size (mm)	Std dev	Faecal coliforms (MPN/100g)	Metal concentration (mg/kg, wet weight)													
					Cadmium		Chromium		Copper		Mercury		Nickel		Lead		Zinc	
Tuatua (Kapiti Coast)					mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
K1 Otaki Beach	3	50.6	6.6	<3 - 7	0.077	0.005	1.017	0.317	1.37	0.26	0.010	0.0006	0.385	0.085	0.248	0.088	10.5	1.5
K2 Peka Peka Beach	3	49.6	6.8	all <3	0.074	0.013	0.853	0.136	1.47	0.21	0.010	0.0017	0.344	0.059	0.144	0.021	9.8	0.9
K3 Raumati Beach	1	50.9	4.5	<3	0.083	-	0.691	-	1.17	-	0.010	-	0.289	-	0.125	-	8.8	-
Cockles (Porirua Harbour)																		
PH1 - Te Onepoto Bay	3	28.0	3.4	all <3	0.016	0.002	0.613	0.044	1.35	0.10	0.008	0.0009	0.930	0.157	0.144	0.041	11.3	1.2
PH2 - Te Hiko St	3	28.5	2.9	<3 - 4	0.014	0.003	0.561	0.068	1.08	0.16	0.006	0.0010	0.984	0.216	0.119	0.013	10.2	0.8
PH3 - Paremata R. Stn	3	36.3	3.7	<3 - 4	0.034	0.005	0.747	0.045	1.11	0.15	0.007	0.0005	1.176	0.060	0.090	0.065	11.6	1.8
PH4 - Browns Bay	3	32.0	3.7	<3 - 9	0.014	0.003	0.599	0.073	0.86	0.13	0.007	0.0014	1.177	0.084	0.060	0.005	9.5	1.0
PH5 - Motukaraka Pt	3	28.5	4.8	all <3	0.015	0.002	0.475	0.057	0.92	0.38	0.006	0.0005	0.988	0.125	0.142	0.069	9.0	0.8
Blue Mussels (Wellington Harbour)																		
WH13 - Pt Dorset	3	48.9	6.3	all <3	0.127	0.014	0.438	0.040	0.63	0.07	0.011	0.0008	0.296	0.039	0.223	0.035	32.9	5.7
WH10 - Scorching Bay	3	65.8	5.8	all <3	0.127	0.018	0.383	0.047	0.59	0.10	0.008	0.0010	0.160	0.029	0.308	0.055	29.3	4.8
WH6 - Mahanga Bay	3	66.4	5.6	all <3	0.109	0.007	0.371	0.010	0.60	0.01	0.006	0.0004	0.136	0.005	0.257	0.051	33.8	3.2
WH7 - Shark Bay	3	64.2	6.2	all <3	0.106	0.021	0.385	0.042	0.66	0.05	0.006	0.0000	0.122	0.021	0.432	0.104	28.0	3.5
WH9 - Pt Jerningham	3	60.4	7.1	all <3	0.110	0.011	0.392	0.024	0.73	0.07	0.006	0.0001	0.137	0.006	0.552	0.063	31.3	4.5
WH11 - Frank Kitts Pk	3	58.3	6.2	<3 - 9	0.184	0.039	0.596	0.157	1.34	0.20	0.009	0.0011	0.162	0.028	1.476	0.333	61.2	8.5
WH12 - Thorndon C.T.	3	69.1	8.0	all <3	0.202	0.017	0.485	0.010	1.07	0.03	0.008	0.0004	0.135	0.016	1.077	0.155	49.8	3.1
WH8 - Ferry Terminal	3	60.8	7.0	<3 - 4	0.142	0.044	0.446	0.085	0.96	0.18	0.008	0.0014	0.150	0.020	0.569	0.113	44.7	7.7
WH1 - Pt Howard	3	65.2	6.2	all <3	0.155	0.045	0.403	0.040	0.71	0.09	0.008	0.0017	0.159	0.032	0.319	0.037	40.9	10.1
WH2 - Sunshine Bay	3	65.0	5.3	all <3	0.099	0.010	0.329	0.043	0.55	0.12	0.006	0.0005	0.136	0.023	0.226	0.054	28.4	1.9
WH3 - Burdans Gate	3	50.5	5.0	all <3	0.118	0.017	0.467	0.054	0.72	0.14	0.012	0.0023	0.283	0.040	0.264	0.037	37.4	6.2
WH4 - Inconstant Pt	3	48.1	5.3	all <3	0.167	0.019	0.470	0.031	0.98	0.07	0.012	0.0012	0.266	0.029	0.215	0.030	46.7	5.2

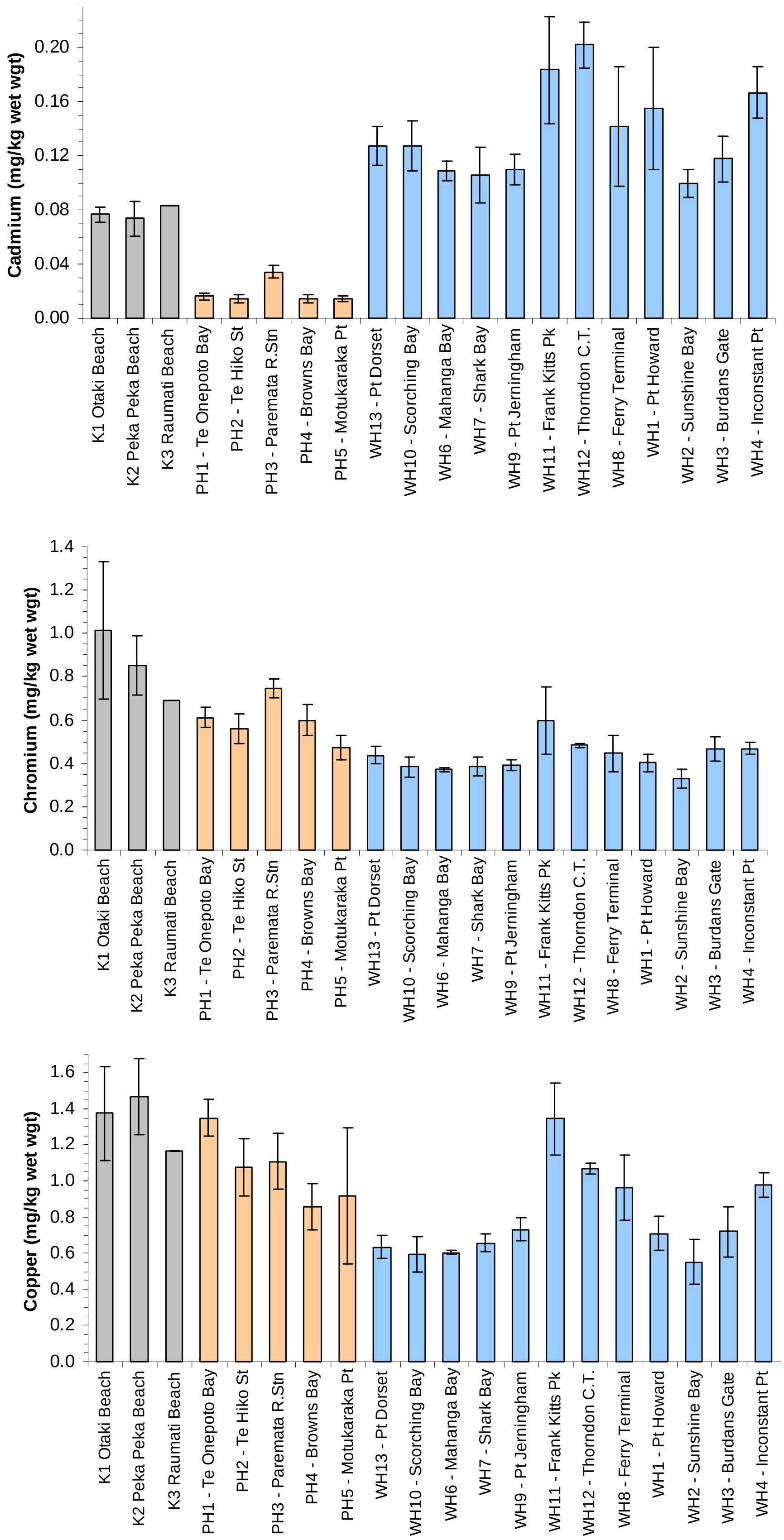

Figure 3.1: Mean cadmium, chromium and copper concentrations (+/- 1 std dev) in tuatua (Kapiti Coast), cockles (Porirua Harbour), and blue mussels (Wellington Harbour) in February-March 2006.

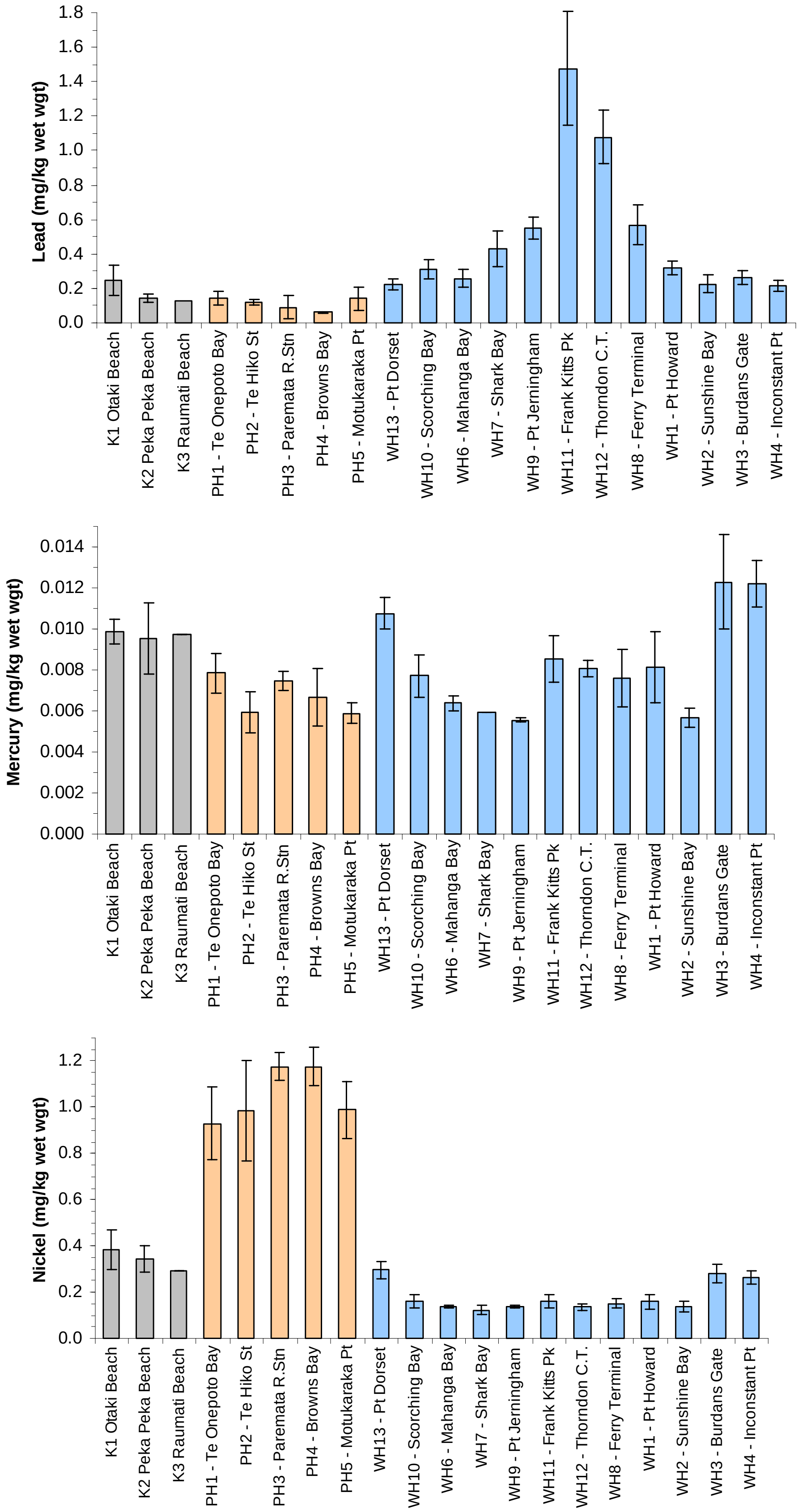

Figure 3.2: Mean lead, mercury and nickel concentrations (+/- 1 std dev) in tuatua (Kapiti Coast), cockles (Porirua Harbour), and blue mussels (Wellington Harbour) in February-March 2006.

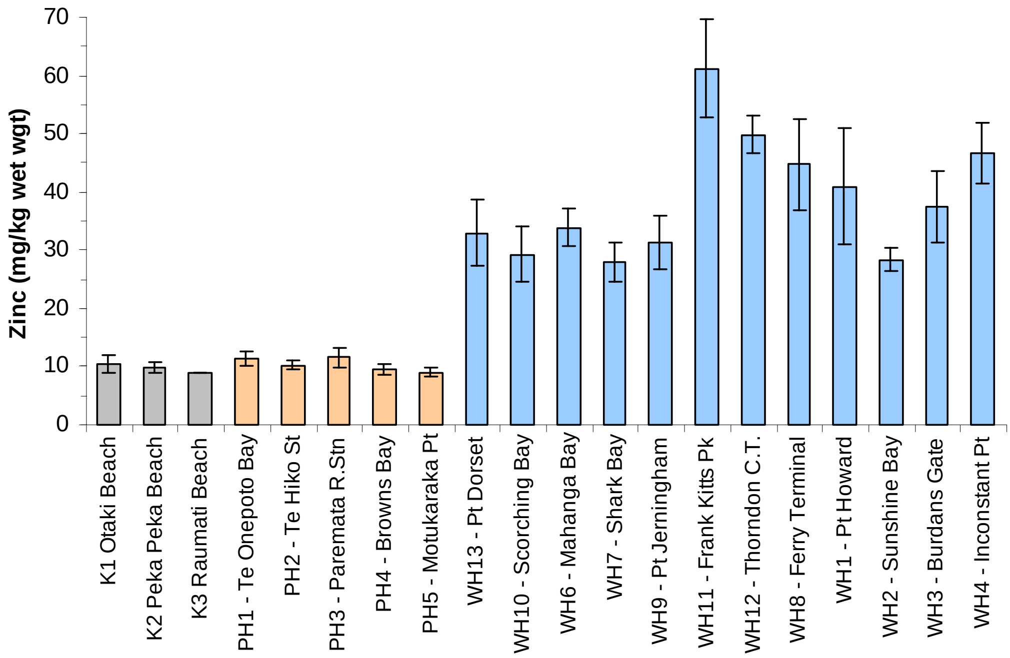

Figure 3.3: Mean zinc concentrations (+/- 1 std dev) in tuatua (Kapiti Coast), cockles (Porirua Harbour), and blue mussels (Wellington Harbour) in February-March 2006.

3.2 Tuatua

3.2.1 Microbiological contaminants

Faecal coliform indicator bacteria were detected in one of the seven tuatua samples collected from the three sampling sites on the Kapiti Coast. The single result above detection was from Otaki Beach (7 MPN/100g) and was well below recommended guidelines for edible tissue.

3.2.2 Trace metals

Cadmium, chromium, copper, lead, mercury, nickel and zinc were present in all tuatua samples (Table 3.1). However none of these metals were present at concentrations that exceeded the national food standards for edible tissue.

The sample results showed little spatial variation, with similar concentrations recorded between the three sampling sites (Figures 3.1-3.3). There was also little difference in the individual sizes of tuatua collected from each sampling site (Figure 3.4), with the mean length across all seven samples determined at 50.2 mm. Less variation in shellfish size was recorded at Raumati Beach as only one replicate sample was collected from this site.

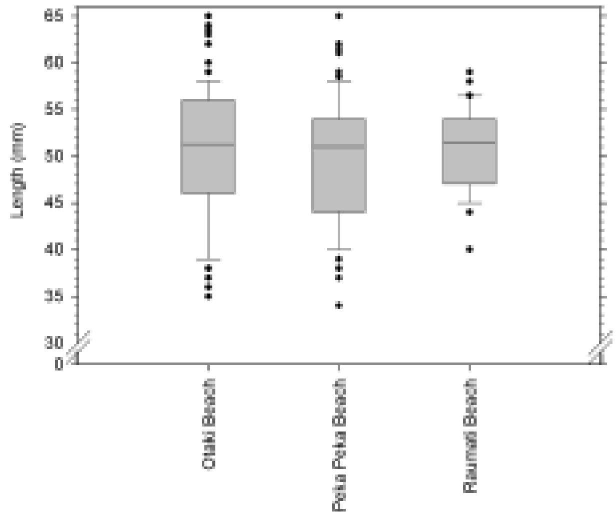

Figure 3.4: Box-plot summarising the distribution of tuatua sizes (shell lengths) collected from each of the three sampling sites on the Kapiti Coast. Note the break on the y-axis.

(Explanation: the horizontal black line inside the box represents the median value, the bottom and top edges of the box represent the 25th and 75th percentile values respectively, the "whiskers" extending below and above the box represent the 5th and 95th percentile vales respectively, and points outside the whiskers represent outliers).

3.3 Cockles

3.3.1 Microbiological contaminants

Faecal coliform indicator bacteria were detected in four of the fifteen cockle samples collected from the five sampling sites in Porirua Harbour; Te Hiko Street (one sample), Paremata Railway Station (one sample), and Browns Bay (two samples). In three instances the results were just above detection (4 MPN/100g), with the other result 9 MPN/100g. All results were well below recommended guidelines for edible tissue.

In an earlier investigation of microbial and metal contaminants in cockles from Porirua Harbour[6] (five sites), Berry et al. (1997) reported faecal coliform concentrations up to 2.4 times guideline values and recommended that shellfish should not be consumed from the harbour. The results on which this recommendation was based related to single composite samples collected near Paremata Station, Ivey Bay and the Horokiri Stream mouth. The other two sites sampled by Berry et al. (1997) were Mungavin Point and Browns Bay.

3.3.2 Trace metals

Cadmium, chromium, copper, lead, mercury, nickel and zinc were present in measurable amounts in all cockle samples. However none of these metals were present at concentrations that exceeded the national food standards for edible tissue (Table 3.1).

[6] This investigation also examined metal, polycyclic aromatic hydrocarbon (PAH) and organochlorine pesticide contamination in inter-tidal sediments (12 sites).

As with the tuatua samples, there was little spatial variation in metal concentrations, with similar mean concentrations recorded across the five sampling sites (Figures 3.1-3.3). The exceptions were cadmium and chromium; mean concentrations of these metals were higher in cockles collected adjacent to the Paremata Railway Station. The reason for this is unclear, although cockles were much larger at this site compared with the other sites (Figure 3.5).

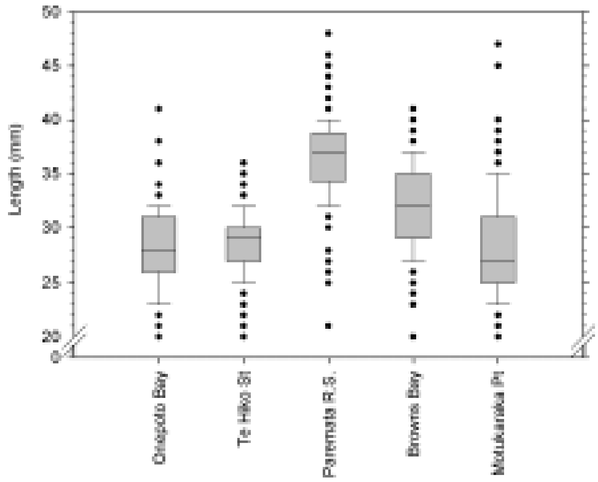

Figure 3.5: Box-plot summarising the distribution of cockle sizes (shell lengths) collected from each of the five sampling sites in the Porirua Harbour. Note the break on the y-axis.

(Explanation: the horizontal black line inside the box represents the median value, the bottom and top edges of the box represent the 25th and 75th percentile values respectively, the "whiskers" extending below and above the box represent the 5th and 95th percentile vales respectively, and points outside the whiskers represent outliers).

The 2004 cockle and sediment quality investigation undertaken in conjunction with IGNS focused on 17 sites within Porirua Harbour, including the five sites sampled in 2006. Accurate comparison of the two data-sets is difficult as only single replicate samples were collected in 2004 and most of the samples comprised a small number of shellfish. However, the 2006 metal concentrations are generally similar to those recorded in 2004 (Appendix 2), the key exceptions being lead (0.03-0.08 mg/kg higher at four of the five sites in 2006) and nickel (0.6-0.9 mg/kg lower at all five sites in 2006). The highest overall metal concentrations recorded across both data-sets were found in cockles collected at the mouth of Porirua Stream in 2004. This site had a zinc tissue concentration almost 10 mg/kg higher than the site with the second highest concentration (Figure 3.6).

The metal concentrations in cockles from Porirua Harbour are quite low compared with those observed in cockles from Waitemata Harbour in Auckland (Ahrens[7], pers. comm., 2006).

[7] Dr Michael Ahrens, Ecotoxicologist, National Institute of Water & Atmospheric Research (NIWA).

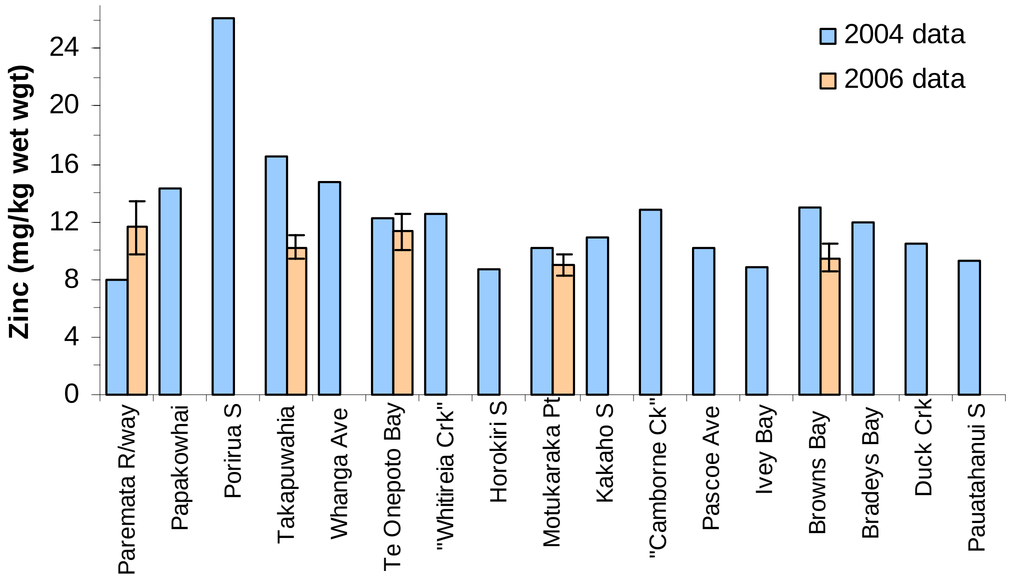

Figure 3.6: Zinc concentrations in cockles collected from Porirua Harbour in 2004 (based on a single sample from each of 17 sites) and 2006 (based on mean (+/- 1 std dev) of three replicate samples from 5 sites).

3.4 Blue mussels

3.4.1 Microbiological contaminants

Faecal coliform indicator bacteria were detected in three of the thirty-six mussel samples collected from twelve sites in Wellington Harbour. Two of these samples were collected adjacent to Frank Kitts Park, with the other sample adjacent to the Ferry Terminal. In all three cases, the results were low (<10 MPN/100g) and well below recommended guidelines for edible tissue. The detection of faecal coliforms at Frank Kitts Park is not surprising given its close proximity to urban stormwater outfalls.

3.4.2 Trace metals

Cadmium, chromium, copper, lead, mercury, nickel and zinc were present in measurable amounts in all blue mussel samples. However none of these metals were present at concentrations that exceeded the national food standards for edible tissue (Table 3.1).

There was some spatial variation in metal concentrations across the twelve sampling sites (Figures 3.1-3.3). This variation was exhibited very clearly in mean lead and copper concentrations, with mussel samples collected adjacent to Frank Kitts Park in the inner harbour containing the highest concentrations. Frank Kitts Park also recorded the highest mean zinc and chromium concentrations, with the mean cadmium concentration for this site second only to samples collected from the nearby Thorndon Container Wharf. Mussel samples from Inconstant Point on the south eastern side of the harbour also recorded high concentrations of some metals relative to other sites, namely cadmium, copper, mercury and zinc. Samples from Mahanga Bay, Shark Bay and Sunshine Bay consistently recorded the lowest metal concentrations.

Higher (on average) metal concentrations in the inner harbour basin adjacent to Frank Kitts Park and the Thorndon Container Wharf may be due to the influence of urban runoff. However, differences in mussel size (often a function of the *age* of the shellfish) between sampling sites may be a confounding factor. It is widely reported that metal concentrations can vary with shellfish size (e.g., Phillips 1980, Langston & Spence 1993), and Figure 3.7 clearly shows that mussels collected from several sites were well outside the overall mean size (length) of 60.2 mm.

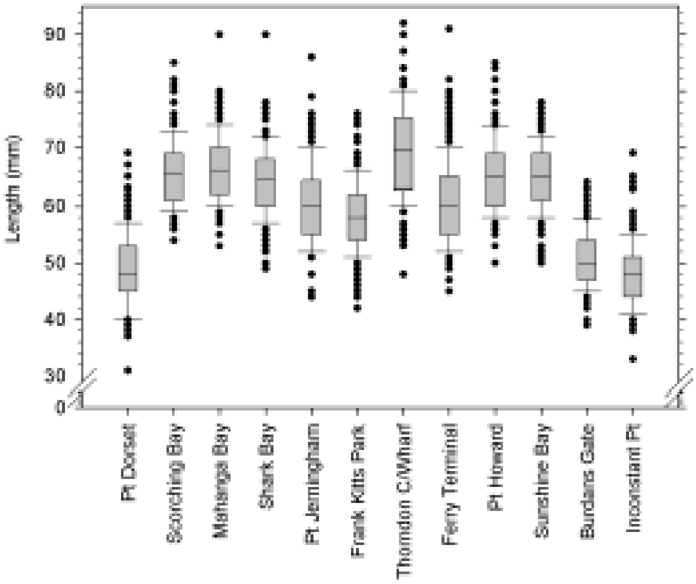

Figure 3.7: Box-plot summarising the distribution of blue mussel sizes (shell lengths) collected from each of the twelve sampling sites in Wellington Harbour. Note the break on the y-axis.

(Explanation: the horizontal black line inside the box represents the median value, the bottom and top edges of the box represent the 25th and 75th percentile values respectively, the "whiskers" extending below and above the box represent the 5th and 95th percentile vales respectively, and points outside the whiskers represent outliers).

Comparison of mean mussel size for each of the 12 sampling sites against mean metal concentrations suggests that size may influence mercury and nickel concentrations. Mean concentrations of these metals tend to decrease with mussel size (Figure 3.8).

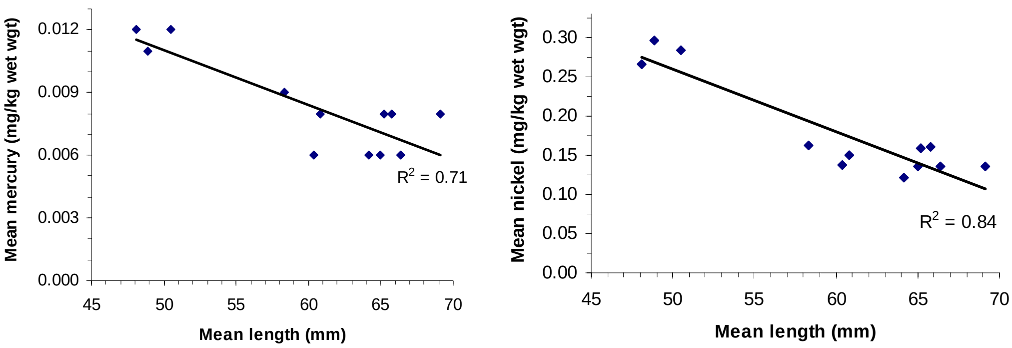

Figure 3.8: Mean mercury (left) and nickel concentrations versus mean size (length) of blue mussels collected from 12 locations in Wellington Harbour. Note start point on the x-axis.

3.5 Comparison with the results of the 2001-2002 investigation

Although many of the same sites were sampled in 2006 and at the same time of year[8], direct comparisons with the 2001-2002 results are difficult for several reasons:

- only a single composite sample was collected from each site in 2001-2002, so the variability in metal concentrations at each site is not known;
- shell lengths were not recorded for many shellfish collected in 2001-2002, so it is not known whether there was a significant difference in the size of shellfish collected in the two investigations; and
- moisture content was not determined for the 2001-2002 samples, preventing a more accurate comparison of the two sets of results based on a dry-weight basis.

It is also not known whether there were any differences in the analytical process with respect to the acid digestion of the shellfish samples.

While the above limitations require caution to be exercised when comparing the 2001-2002 and 2006 sample results, generally speaking, the metal concentrations in shellfish flesh observed at many sites in 2006 were higher than the concentrations reported in 2001-2002 (Figure 3.9). The key exceptions are mercury and lead; average concentrations of these metals were lower at most sites in 2006 (Figure 3.10).

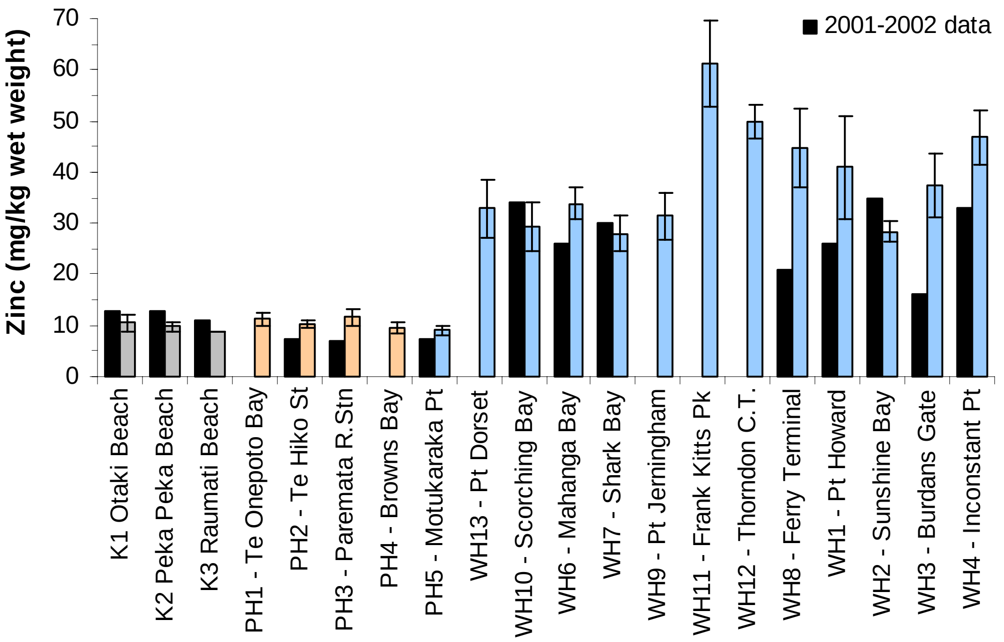

Figure 3.9: Mean zinc concentrations (+/- 1 std dev) in tuatua (Kapiti Coast), cockles (Porirua Harbour), and blue mussels (Wellington Harbour) collected in 2001-2002 and 2006.

[8] This is important as trace metal concentrations in shellfish tissue, particularly bivalves, can vary with season (Phillips 1980).

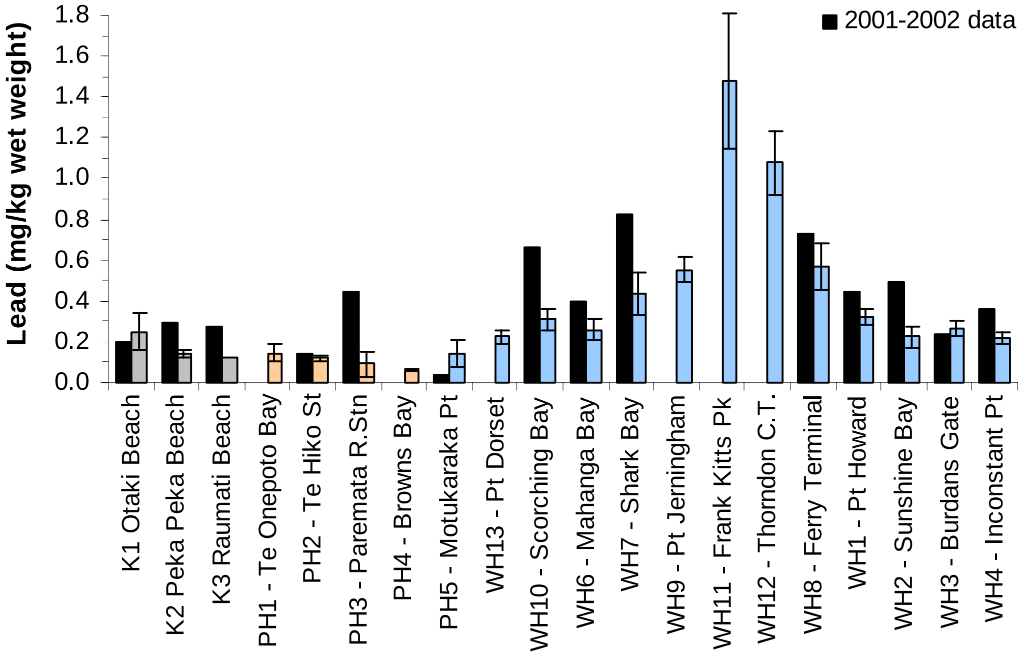

Figure 3.10: Mean lead concentrations (+/- 1 std dev) in tuatua (Kapiti Coast), cockles (Porirua Harbour), and blue mussels (Wellington Harbour) collected in 2001-2002 and 2006.

The significance of the differences between the 2001-2002 and 2006 trace metal concentrations are difficult to ascertain. This is not only because of the limitations outlined above, but also because inter-annual (i.e., between year) variation in shellfish tissue metal burdens can be quite high. This inter-annual variability has been demonstrated in annual monitoring of metals in oysters from Manukau Harbour, and is attributed to natural variability due to factors such as climate, hydrodynamic and biological processes, as well as changes in contaminant loads coming off the land (Auckland Regional Council 2004).

3.6 Comparison with international shellfish investigations

In the absence of shellfish tissue guidelines for a number of the trace metals examined, it is useful to compare the concentrations recorded with those published in the international literature. Most of the data relate to oysters and mussels as these are the shellfish most commonly monitored. Only the mussel data are considered here where they are compared (on a dry weight basis) with the mussel data from Wellington Harbour. It is not appropriate to compare data between taxonomic groups (e.g., oysters and mussels, mussels and cockles) as shellfish differ in their ability to concentrate some metals (Phillips 1980, O'Conner 1992).

Mussel metal data reported from international databases by Cantillo (1998) are summarised in Table 3.2, alongside the metal concentrations in blue mussels from Wellington Harbour. The international data is published from the United States National Status and Trends (NS&T), French Réseau National d'Observation de la Qualité du Mulieu Marin (RNO) and National Oceanic and Atmospheric Administration world-wide bivalve databases (WMW). The NS&T and RNO databases reflect samples collected from representative sites, whereas the WMW database includes data from investigations specifically designed to sample “hot spots” of contamination. Consequently, the median and 85th percentile values of the WMW database are generally higher, with exceedance of the 85th percentile vales considered to denote contamination. In contrast, the 85th percentile values of the NS&T and RNO data sets are more indicative of the typical range of trace element concentrations (Cantillo 1998).

Table 3.2: Comparison of trace metal concentrations recorded in blue mussels from Wellington Harbour with NS&T, RNO and WMW median and 85th percentile concentrations (µg/g dry weight)† reported by Cantillo (1998).

Site/Programme	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Wellington Harbour (2006)							
- Range	1.1-3.7	3.6-11.8	5.5-23.3	2.3-28.6	0.06-0.23	1.4-5.0	295-1,081
- Median	1.7	5.7	9.6	4.4	0.12	2.3	481
- Mean	2.0	6.3	11.8	7.4	0.12	2.6	572
- 85th %ile	3.0	7.9	17.2	14.1	0.15	3.8	831
US NS&T median	2.2	1.8	9.1	1.8	0.12	1.9	130
US NS&T 85th %ile	4.8	3.1	12	5.1	0.26	3.5	190
RNO (France) median	0.95	-	7.1	2.3	0.12	-	110
RNO (France) 85th %ile	1.9	-	9.1	4.5	0.22	-	180
WMW (World) median	2.0	1.6	7.9	5.0	0.32	2.2	130
WMW (World) 85th %ile	7.5	6.5	21	20	0.99	5.0	260

†NS&T data cover 1986-1995 (n>1830), RNO data cover 1979-1994 (n>3150), WMW data (n>340)

Median cadmium concentrations in blue mussel samples collected from Wellington Harbour were lower than the medians reported from two of the three international databases. Median mercury and nickel concentrations were similar (indicating that concentrations of these metals are within the “normal” range), although the 85th percentile mercury concentrations were significantly lower in the Wellington Harbour mussels. Median chromium, copper, lead and zinc concentrations were generally higher than the equivalent values in the international databases, with the median zinc concentration three to four times higher. In addition, the 85th percentile zinc concentration was more than three times the 85th percentile value in the WMW database (i.e., denotes contamination). The 85th percentile chromium concentration from the Wellington Harbour mussels also exceeded the 85th percentile WMW database concentration. The 85th percentile copper and lead concentrations did not exceed the equivalent WMW database concentrations.

It is likely that most metal concentrations contained in the international databases were derived from depurated mussel samples. This may partly explain why some of the metal concentrations reported for the Wellington Harbour mussel samples are higher than those contained in the international databases. In terms of the significant difference in zinc concentrations, it is possible that some species-specific response is at play. For example, *Mytilus galloprovincialis* may possibly be able to concentrate zinc to higher levels than other *Mytilus* species which feature more prominently in the international databases (e.g., *M. edulis*).

3.7 Future monitoring

Where possible, the sampling and analytical methodology outlined in this report should be adopted for future investigations of contaminants in shellfish flesh. However, some further refinements of the methodology are recommended:

- Ideally, sample collection should target shellfish of a similar size across all sites to reduce the influence of size on tissue contaminant concentrations.
- Quality assurance procedures should incorporate analysis of trace metals in standard reference materials to provide a check on analytical accuracy (analysis of samples in duplicate only provides a check on analytical precision).
- Consideration should be given to including arsenic in future investigations. Although not strictly a metal, arsenic is a non-essential element and a known carcinogen that is toxic to both humans and aquatic organisms.
- If microbiological contaminants are investigated in the future, samples should be analysed for *Escherichia coli* (*E. coli*) in addition/or in place of, faecal coliform bacteria. *E. coli* are specified in Standard 1.6.1 (Microbiological Limits for Food) of the Australia New Zealand Food Standards Code for bivalve molluscs.

4. Conclusions and recommendations

Faecal coliform indicator bacteria were detected in eight (13.7%) of the fifty-eight samples of shellfish examined. Four of the eight results above detection were recorded in cockle samples collected from Porirua Harbour. In all cases results were only slightly above detection and no samples had bacteria present at a concentration that exceeded the recommended microbiological guidelines for edible tissue.

Cadmium, chromium, copper, lead, mercury, nickel and zinc were all present in the three species of shellfish examined. However, none of the metal concentrations exceeded the national food standards for edible tissue, where standards exist.

The tuatua and cockle sample results showed little spatial variation in mean metal concentrations, with similar concentrations recorded between most sampling sites. However, there was some variation in metal concentrations in the mussel samples from Wellington Harbour. Samples collected adjacent to Frank Kitts Park and the Thorndon Container Wharf in the inner harbour generally recorded the highest concentrations, while samples collected from Mahanga Bay, Shark Bay and Sunshine Bay consistently recorded the lowest concentrations. Higher (on average) metal concentrations in the inner harbour basin may reflect the influence of urban runoff, although mussels from Inconstant Point on the south eastern side of the harbour also recorded high concentrations of some metals relative to other sites, namely cadmium, copper, mercury and zinc. Differences in mussel size between sampling sites may be a confounding factor in inter-site comparisons, particularly for mercury and nickel. Concentrations of these metals tended to decrease with increasing mussel size.

Direct comparisons with the results of the 2001-2002 shellfish investigation are difficult but, generally speaking, the metal concentrations in shellfish flesh observed at many sites in 2006 were higher than the concentrations reported in the earlier investigation. The key exceptions are mercury and lead; average concentrations of these metals were lower at most sites in 2006.

4.1 Recommendations

1. Continue to monitor key contaminants in shellfish flesh from selected sites across the Wellington region.

2. Standardise the sampling and analytical methodology for future investigations of contaminants in shellfish flesh.

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Laura Watts and Ted Taylor reviewed a draft version of this report.

Marianne Miller assisted with the formatting of this report.

Appendix 1: 2001-2002 shellfish investigation

(a) Sampling sites

Locality	Date collected	Grid reference		Species
		Easting	Northing	
Porirua Harbour at Te Hiko Street	20/03/2001	2664306	6007564	cockle
Porirua Harbour at Paremata Railway Station	20/03/2001	2666645	6009635	cockle
Porirua Harbour at Motukaraka Point	20/03/2001	2669325	6010746	cockle
Wellington Harbour at Point Howard	22/03/2001	2669600	5993020	blue mussel
Wellington Harbour at Sunshine Bay	22/03/2001	2669646	5991109	blue mussel
Wellington Harbour at Burdans Gate	22/03/2001	2667482	5986637	blue mussel
Wellington Harbour at Inconstant Point	22/03/2001	2664932	5982542	blue mussel
Wellington south coast at Hue-te-taka Peninsula	26/03/2001	2661470	5983320	blue mussel
Wellington Harbour at Mahanga Bay	26/03/2001	2663547	5989182	blue mussel
Wellington Harbour at Shark Bay	26/03/2001	2662176	5987920	blue mussel
Wellington Harbour at Ferry Terminal	26/03/2001	2660007	5992268	blue mussel
Wellington Harbour at Scorching Bay	6/04/2001	2663480	5988121	blue mussel
Wellington west coast at Green Point	19/02/2002	2661474	6008975	black-foot paua
Wellington west coast at Ohariu Bay	19/02/2002	2653909	5998020	black-foot paua
Wellington south coast at Island Bay	19/02/2002	2658929	5983010	black-foot paua
Wairarapa south coast at Cape Palliser	4/03/2002	2696850	5953303	black-foot paua
Wairarapa east coast at Flat Point	8/03/2002	2758655	5991411	black-foot paua
Wairarapa east coast at Mataikona	8/03/2002	2784826	6037721	black-foot paua
Raumati Beach at Kainui Road	20/03/2001	2676176	6027855	tuatua
Peka Peka Beach at Road End	13/03/2002	2683215	6039608	tuatua
Otaki Beach at Surf Club	13/03/2002	2688601	6050007	tuatua

(b) Analytes

All analyses were conducted by Agriquality New Zealand Limited on homogenised composite samples, consisting of a minimum of 140 individual shellfish per sample for cockles, 40 for mussels, 24 for paua, and 40 for tuatua. Whole shucked shellfish were used for analysis in all cases.

(i) Lipids

The sample was extracted in organic solvent, the solvent removed by evaporation, and the amount of lipid in the sample determined gravimetrically.

(ii) Metals

The sample was digested with acid and metals analysed using inductively coupled plasma mass spectrometry. For mercury, reduction followed by analysis using flame-less atomic absorption spectrophotometry was used. The analytes were:

- Cadmium (Cd)
- Chromium (Cr)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Zinc (Zn)

(iii) Chlorophenols (CPs)

The sample was acidified, spiked with an isotopically labelled surrogate standard and extracted with organic solvent. The sample extract was partitioned with aqueous carbonate and derivatised using phase transfer acetylation. Measurement was performed using high-resolution gas chromatography with high-resolution electron impact mass spectrometry. The analytes were:

- 2-MCP (2-monochlorophenol)
- 3-MCP (3-monochlorophenol)
- 4-MCP (4-monochlorophenol)

- 2,6-DCP (2,6-dichlorophenol)
- 2,4 / 2,5-DCP (2,4 / 2,5-dichlorophenol)
- 3,5-DCP (3,5-dichlorophenol)
- 2,3-DCP (2,3-dichlorophenol)
- 3,4-DCP (3,4-dichlorophenol)

- 2,4,6-TCP (2,4,6-trichlorophenol)
- 2,3,6-TCP (2,3,6-trichlorophenol)
- 2,3,5-TCP (2,3,5-trichlorophenol)
- 2,4,5-TCP (2,4,5-trichlorophenol)
- 2,3,4-TCP (2,3,4-trichlorophenol)
- 3,4,5-TCP (3,4,5-trichlorophenol)

- 2,3,5,6-TeCP (2,3,5,6-tetrachlorophenol)
- 2,3,4,6-TeCP (2,3,4,6-tetrachlorophenol)
- 2,3,4,5-TeCP (2,3,4,5-tetrachlorophenol)

- PCP (pentachlorophenol)

(iv) Organochlorine pesticides (OCs)

The sample was spiked with an isotopically labelled surrogate standard, extracted with organic solvent and the extract purified by column chromatographic techniques. Measurement was performed using high-resolution gas chromatography with high-resolution electron impact mass spectrometry. The analytes were:

- α-HCH (alpha-hexachlorocyclohexane)
- β-HCH (beta-hexachlorocyclohexane)
- γ-HCH (gamma-hexachlorocyclohexane)
- HCB (hexachlorobenzene)
- Aldrin
- Dieldrin
- Heptachlor
- Heptachlor epoxide
- α-chlordane (alpha-chlordane)
- γ-chlordane (gamma-chlordane)
- p,p'-DDE
- p,p'-TDE
- o,p'-DDT (dichlorodiphenyltrichloroethane)
- p,p'-DDT (dichlorodiphenyltrichloroethane)

(v) Polycyclic Aromatic Hydrocarbons (PAHs)

The sample was spiked with a range of isotopically labelled PAHs and extracted with organic solvent. The extract was purified by chemical treatment and column chromatographic techniques and analysed by high-resolution gas chromatography with low resolution mass spectrometry. The analytes were 16 USEPA Priority Pollutant PAHs as follows:

- Naphthalene
- Acenaphthylene
- Acenaphthene
- Fluorene
- Phenanthrene
- Anthracene
- Fluoranthene
- Pyrene
- Benz(a)anthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-c,d)pyrene
- Dibenz(a,h)anthracene
- Benzo(g,h,i)perylene

(vi) Polychlorinated Biphenyls (PCBs)

The sample was spiked with isotopically labelled surrogate standards and extracted with organic solvent. The extract was purified by liquid partitioning and column chromatographic techniques. Measurement was performed using high-resolution gas chromatography with high-resolution electron impact mass spectrometry. The analytes were (PCB numbering by Ballschmiter and Zell 1980):

- PCB#28 (2,4,4’-trichlorobiphenyl)
- PCB#31 (2,4’,5-trichlorobiphenyl)
- PCB#52 (2,2’,5,5’-tetrachlorobiphenyl)
- PCB#49 (2,2’,4,5’-tetrachlorobiphenyl)
- PCB#44 (2,2’,3,5’-tetrachlorobiphenyl)
- PCB#74 (2,4,4’,5-tetrachlorobiphenyl)
- PCB#70 (2,3’,4’,5-tetrachlorobiphenyl)
- PCB#81 (3,4,4’,5-tetrachlorobiphenyl)
- PCB#77 (3,3’,4,4’-tetrachlorobiphenyl)
- PCB#101 (2,2’,4,5,5’-pentachlorobiphenyl)
- PCB#99 (2,2’,4,4’,5-pentachlorobiphenyl)
- PCB#110 (2,3,3’,4’,6-pentachlorobiphenyl)
- PCB#123 (2’,3,4,4’,5-pentachlorobiphenyl)
- PCB#118 (2,3’,4,4’,5-pentachlorobiphenyl)
- PCB#114 (2,3,4,4’,5-pentachlorobiphenyl)
- PCB#105 (2,3,3’,4,4’-pentachlorobiphenyl)
- PCB#126 (3,3’,4,4’,5-pentachlorobiphenyl)
- PCB#153 (2,2’,4,4’,5,5’-hexachlorobiphenyl)
- PCB#138 (2,2’,3,4,4’,5’-hexachlorobiphenyl)
- PCB#167 (2,3’,4,4’,5,5’-hexachlorobiphenyl)
- PCB#156 (2,3,3’,4,4’,5-hexachlorobiphenyl)
- PCB#157 (2,3,3’,4,4’,5’-hexachlorobiphenyl)

- PCB#169 (3,3’,4,4’,5,5’-hexachlorobiphenyl)
- PCB#187 (2,2’,3,4’,5,5’,6-heptachlorobiphenyl)
- PCB#183 (2,2’,3,4,4’,5’,6-heptachlorobiphenyl)
- PCB#180 (2,2’,3,4,4’,5,5’-heptachlorobiphenyl)
- PCB#170 (2,2’,3,3’,4,4’,5-heptachlorobiphenyl)
- PCB#189 (2,3,3’,4,4’,5,5’-heptachlorobiphenyl)
- PCB#202 (2,2’,3,3’,5,5’,6,6’-octachlorobiphenyl)
- PCB#196 (2,2’,3,3’,4,4’,5,6’-octachlorobiphenyl)
- PCB#194 (2,2’,3,3’,4,4’,5,5’-octachlorobiphenyl)
- PCB#208 (2,2’,3,3’,4,5,5’,6,6’-nonachlorobiphenyl)
- PCB#206 (2,2’,3,3’,4,4’,5,5’,6-nonachlorobiphenyl)
- PCB#209 (2,2’,3,3’,4,4’,5,5’,6,6’-decachlorobiphenyl)

(c) Analytical results (trace metals only)

Locality	No. of individuals	Mean size & std dev (mm)	Lipid (g/g)	Metal concentration (mg/kg, wet weight)					
				Cd	Cr	Cu	Hg	Pb	Zn
Tuatua									
Raumati Beach at Kainui Road	N.D.	N.D.	0.0006	0.081	0.69	1.5	0.028	0.27	11
Peka Peka Beach at Road End	249	50.6 (4.3)	0.0080	0.080	<1	2.0	0.026	0.29	13
Otaki Beach at Surf Club	199	51.0 (3.3)	0.0110	0.120	<1	1.7	0.024	0.20	13
Cockles									
Porirua Harbour @ Te Hiko Street	N.D.	N.D.	0.0023	0.009	0.38	0.75	0.006	0.14	7.4
Porirua Harbour @ Paremata Railway	N.D.	N.D.	0.0044	0.021	0.63	0.71	0.015	0.45	7.0
Porirua Harbour @ Motukaraka Point	N.D.	N.D.	0.0036	0.009	0.39	0.70	0.016	0.04	7.2
Paua									
Wellington W coast at Green Point	25	133.5 (6.0)	0.021	0.90	<1	16.0	0.038	0.05	23
Wellington W coast at Ohariu Bay	25	122.1 (5.4)	0.013	0.40	<1	11.0	0.017	0.03	18
Wellington S coast at Island Bay	25	141.2 (13.2)	0.012	0.95	<1	5.9	0.014	0.08	22
Wairarapa S coast at Cape Palliser	24	154.1 (6.6)	0.007	1.60	<1	9.4	0.019	0.06	22
Wairarapa E coast at Flat Point	26	145.9 (9.1)	0.025	0.69	<1	10.0	0.015	0.04	17
Wairarapa E coast at Mataikona	25	128.9 (5.5)	0.018	0.55	<1	15.0	0.026	0.06	21
Blue Mussels									
Wellington S coast at Hue-te-taka Peninsula	N.D.	N.D.	0.0062	0.110	0.50	0.71	0.110	0.41	30
Wellington Harbour @ Scorching Bay	N.D.	N.D.	0.0048	0.110	0.54	0.65	0.024	0.66	34
Wellington Harbour @ Mahanga Bay	N.D.	N.D.	0.0038	0.110	0.28	0.54	0.022	0.40	26
Wellington Harbour @ Shark Bay	N.D.	N.D.	0.0058	0.095	0.30	0.67	0.017	0.82	30
Wellington Harbour @ Ferry Terminal	N.D.	N.D.	0.0060	0.072	0.36	0.79	0.018	0.73	21
Wellington Harbour @ Point Howard	N.D.	N.D.	0.0070	0.080	0.28	0.66	0.016	0.45	26
Wellington Harbour @ Mahina Bay	N.D.	N.D.	0.0056	0.110	0.29	0.50	0.017	0.49	35
Wellington Harbour @ Burdans Gate	N.D.	N.D.	0.0074	0.044	0.43	0.85	0.380	0.24	16
Wellington Harbour @ Inconstant Point	N.D.	N.D.	0.0058	0.110	0.58	0.76	0.026	0.36	33

N.D. not determined

Appendix 2: 2004 Porirua Harbour investigation – results

Analyses performed using ICPMS. All results reported in mg/kg on a wet weight basis.

Site Number	Locality	Date of Collection	Easting	Northing	Number of specimens	Mean shell length (mm)	Standard deviation (mm)	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Silver	Zinc
S1	Paremata Railway	27/01/2004	2666653	6009511	16	22.9	1.3	2.76	0.026	0.68	0.64	0.05	0.008	1.97	<0.05	8.0
S2	Papakowhai	03/02/2004	2666004	6008365	12	31.2	1.5	2.79	0.013	0.61	0.98	0.08	0.013	1.67	<0.05	14.3
S3	Aotea Lagoon	03/02/2004	2665913	6007962	0											
S4	Porirua Stream	27/01/2004	2664603	6006992	11	25.5	0.6	2.80	0.015	1.07	1.58	0.24	0.008	3.09	<0.05	26.1
S5	Takapuwahia	27/01/2004	2664275	6007600	14	23.6	0.9	2.86	0.018	0.62	1.05	0.09	0.008	1.89	<0.05	16.5
S6	Whanga Avenue	26/01/2004	2664470	6008132	9	26.2	1.2	2.08	0.016	0.41	1.04	0.08	0.008	1.55	<0.05	14.8
S7	Onepoto Park	26/01/2004	2664933	6008673	0											
S8	Te Onepoto Bay	29/01/2004	2665806	6009261	14	27.1	2.2	2.52	0.020	0.59	0.96	0.09	0.013	1.51	<0.05	12.2
S9	"Whitireia Creek"	29/01/2004	2666392	6010384	11	35.0	1.1	3.55	0.030	0.78	0.81	0.03	0.010	2.26	<0.05	12.5
P1	Horokiri Stream	14/01/2004	2669837	6010642	58	24.7	3.1	1.89	0.016	0.46	0.65	0.02	0.014	1.58	<0.05	8.7
P2	Motukaraka Point	14/01/2004	2669438	6010675	34	26.6	1.9	2.17	0.018	0.55	0.78	0.06	0.019	1.88	<0.05	10.2
P3	Kakaho Stream	14/01/2004	2669040	6011345	32	27.1	2.3	2.19	0.013	0.46	0.86	0.08	0.018	1.58	<0.05	10.9
P4	"Camborne Creek"	14/01/2004	2668097	6011302	22	26.0	1.3	2.39	0.022	0.47	0.89	0.05	0.020	1.72	<0.05	12.8
P5	Pascoe Avenue	16/01/2004	2667155	6010466	33	28.0	2.0	2.72	0.013	0.51	1.00	0.06	0.012	1.33	<0.05	10.2
P6	Ivey Bay	16/01/2004	2667370	6009705	58	23.0	1.8	2.29	0.015	0.36	1.30	0.10	0.011	1.07	<0.05	8.9
P7	Browns Bay	16/01/2004	2667986	6009597	61	21.1	1.7	2.86	0.013	0.42	0.93	0.07	0.010	1.91	<0.05	13.0
P8	Bradeys Bay	16/01/2004	2668961	6009506	18	33.3	1.9	2.34	0.010	0.44	0.87	0.06	0.014	1.59	<0.05	12.0
P9	Duck Creek	16/01/2004	2669597	6009501	33	28.3	1.7	2.84	0.013	0.68	0.70	0.05	0.020	1.65	<0.05	10.5
P10	Pauatahanui Stream	14/01/2004	2670387	6009757	49	21.5	3.2	1.94	0.014	0.35	0.91	0.03	0.016	1.43	<0.05	9.3

Appendix 3: 2006 shellfish investigation

(a) Sampling sites

Site Name	Site No.	Easting	Northing	Shellfish Type	Date of Collection
Otaki Beach - Surf Club	K1	2688300	6049500	Tuatua	28/02/2006
Peka Peka Beach - Road End	K2	2683000	6040000	Tuatua	28/02/2006
Raumati Beach - Kainui Rd	K3	2676500	6030500	Tuatua	28/02/2006
Porirua Harbour - Te Onepoto Bay	PH1	2665800	6009200	Cockle	27/02/2006
Porirua Harbour - Te Hiko St	PH2	2664300	6007500	Cockle	27/02/2006
Porirua Harbour - Paremata Railway Station	PH3	2666600	6009600	Cockle	27/02/2006
Porirua Harbour - Browns Bay	PH4	2667900	6009500	Cockle	27/02/2006
Porirua Harbour - Motukaraka Pt	PH5	2669300	6010700	Cockle	27/02/2006
Wgtn Harbour - Pt Howard	WH1	2669600	5993000	Blue mussel	14/03/2006
Wgtn Harbour - Sunshine Bay	WH2	2669600	5991100	Blue mussel	14/03/2006
Wgtn Harbour - Burdans Gate	WH3	2667400	5986600	Blue mussel	14/03/2006
Wgtn Harbour - Inconstant Pt	WH4	2664900	5982500	Blue mussel	14/03/2006
Wgtn South Coast - Hue-te-taka Peninsula	WH5	2661400	5983300	Blue mussel	NS - no mussels
Wgtn Harbour - Mahanga Bay	WH6	2663500	5989100	Blue mussel	13/03/2006
Wgtn Harbour - Shark Bay	WH7	2662100	5987900	Blue mussel	13/03/2006
Wgtn Harbour - Ferry Terminal	WH8	2660000	5992200	Blue mussel	15/03/2006
Wgtn Harbour - Pt Jerningham	WH9	2661000	5989700	Blue mussel	13/03/2006
Wgtn Harbour - Scorching Bay	WH10	2663400	5988100	Blue mussel	13/03/2006
Wgtn Harbour - Frank Kitts Park	WH11	2659000	5989500	Blue mussel	15/03/2006
Wgtn Harbour - Thorndon Container Terminal	WH12	2659900	5959900	Blue mussel	15/03/2006
Wgtn Harbour - Pt Dorset	WH13	2663800	5984500	Blue mussel	13/03/2006

(b) Analytical results

Faecal coliforms were below detection (3 MPN/100 g) in all but the following samples:

- K1-R1: 7 MPN/100g
- P2-R2: 4 MPN/100g
- PH3-R2: 4 MPN/100g
- PH4-R1: 4 MPN/100g
- PH4-R2: 9 MPN/100g
- WH8-R2: 4 MPN/100g
- WH8-R3 (duplicate sample): 4 MPN/100g
- WH11-R2: 7 MPN/100g
- WH11-R3: 9 MPN/100g

Metal concentrations expressed on a wet weight basis.

Lab No.	Site No.	Shellfish Type	No. Shellfish per Sample	Mean Size* (mm)	Size* Range (mm)	Moisture (%)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)
12355	K1 - R1	Tuatua	40	53.2	43.5-65	84.4	0.083	0.728	1.39	0.277	0.010	0.326	9.8
12356	K1 - R2	Tuatua	40	49.0	35-63	81.7	0.072	1.356	1.63	0.319	0.011	0.482	12.3
12357	K1 - R3	Tuatua	40	49.5	36-65	83.1	0.075	0.967	1.10	0.149	0.009	0.347	9.4
12358	K2 - R1	Tuatua	40	52.1	34-62	82.6	0.088	0.697	1.28	0.121	0.011	0.275	9.4
12359	K2 - R2	Tuatua	40	47.7	34-74	81.3	0.069	0.947	1.70	0.162	0.010	0.373	10.8
12360	K2 - R3	Tuatua	40	49.0	38-65	82.2	0.064	0.915	1.43	0.149	0.008	0.382	9.1
D/12361	K2 - R3 Dup	Tuatua	-	-	-	82.5	0.064	0.828	1.37	0.138	0.008	0.349	8.8
12362	K3 - R1	Tuatua	40	50.9	40-59	82.5	0.083	0.691	1.17	0.125	0.010	0.289	8.8
12204	PH1 - R1	Cockle	100	27.3	19-38	85.8	0.015	0.579	1.37	0.145	0.007	0.755	9.8
12205	PH1 - R1	Cockle	100	28.7	22-41	84.6	0.015	0.597	1.24	0.185	0.008	1.058	12.0
12206	PH1 - R3	Cockle	100	27.9	19-34	83.9	0.019	0.663	1.44	0.103	0.009	0.976	12.0
12207	PH2 - R1	Cockle	100	28.1	20-33	87.6	0.013	0.517	0.94	0.119	<0.005	1.231	9.9
12208	PH2 - R2	Cockle	100	28.8	19-35	83.9	0.018	0.639	1.25	0.106	0.007	0.828	11.1
12209	PH2 - R3	Cockle	100	28.7	19-36	85	0.012	0.527	1.05	0.132	0.005	0.894	9.6
12210	PH3 - R1	Cockle	80	36.4	26-46	84.3	0.033	0.731	1.29	0.166	0.007	1.236	13.6
12211	PH3 - R2	Cockle	80	36.2	25-43	84.5	0.031	0.711	1.01	0.055	0.007	1.116	10.3
12212	PH3 - R3	Cockle	80	36.5	21-48	84.4	0.039	0.798	1.02	0.050	0.008	1.176	10.9
12213	PH4 - R1	Cockle	100	32.9	24-41	86.5	0.017	0.667	0.98	0.062	0.008	1.273	10.4
D/12214	PH4 - R1 Dup	Cockle	-	-	-	86.4	0.015	0.618	0.89	0.067	0.007	1.201	9.7
12215	PH4 - R2	Cockle	100	31.3	20-40	84.9	0.012	0.609	0.88	0.063	0.006	1.138	9.6
12216	PH4 - R3	Cockle	100	31.7	23-39	88.7	0.012	0.522	0.72	0.055	<0.005	1.119	8.4
12217	PH5 - R1	Cockle	100	28.0	20-45	87	0.016	0.428	0.70	0.093	0.006	0.883	8.6
12218	PH5 - R2	Cockle	100	28.2	20-40	88.1	0.013	0.538	1.35	0.221	0.005	0.955	9.9
12219	PH5 - R3	Cockle	100	29.2	19-47	88.1	0.014	0.459	0.70	0.111	0.006	1.126	8.5
14318	WH9 - R1	Blue mussel	50	60.8	51-86	86.8	0.110	0.390	0.80	0.563	0.006	0.144	27.2
14319	WH9 - R2	Blue mussel	50	59.9	45-76	87	0.099	0.370	0.67	0.485	0.005	0.134	30.8
14320	WH9 - R3	Blue mussel	50	60.4	44-79	86.1	0.121	0.418	0.73	0.608	0.006	0.134	36.1
14321	WH7 - R1	Blue mussel	50	64.2	49-77	85.9	0.088	0.359	0.62	0.429	<0.005	0.104	28.7
14322	WH7 - R2	Blue mussel	50	65.4	54-90	86.4	0.129	0.433	0.71	0.538	0.006	0.145	31.0
14323	WH7 - R3	Blue mussel	50	63.1	53-77	87.8	0.101	0.362	0.64	0.330	0.006	0.119	24.2
14324	WH6 - R1	Blue mussel	50	66.8	53-80	86.2	0.117	0.383	0.59	0.316	0.007	0.140	37.5
14325	WH6 - R2	Blue mussel	50	67.7	59-90	86.4	0.104	0.364	0.61	0.227	0.006	0.131	32.3
14326	WH6 - R3	Blue mussel	50	64.8	57-73	86.9	0.105	0.367	0.60	0.228	0.006	0.137	31.6
14327	WH10 - R1	Blue mussel	50	64.6	56-80	87.5	0.106	0.331	0.48	0.253	0.007	0.127	27.4
D/14328	WH10-R1 Dup	Blue mussel	-	-	-	87.9	0.107	0.360	0.53	0.269	0.006	0.136	23.0
14329	W10 - R2	Blue mussel	50	65.5	54-85	86.9	0.141	0.395	0.67	0.310	0.008	0.176	25.7
14330	WH10 - R3	Blue mussel	50	67.4	57-81	86.6	0.135	0.423	0.63	0.362	0.009	0.177	34.8
14331	WH13 - R1	Blue mussel	60	48.4	38-67	86.7	0.143	0.480	0.70	0.264	0.012	0.335	39.0
14332	WH13 - R2	Blue mussel	60	48.3	37-69	86.6	0.123	0.435	0.63	0.202	0.011	0.296	32.0
14333	WH13 - R3	Blue mussel	60	49.9	31-65	87.3	0.116	0.400	0.57	0.203	0.010	0.258	27.7
14393	WH3 - R1	Blue mussel	70	50.4	42-64	87.2	0.114	0.441	0.61	0.226	0.011	0.250	32.6
14394	WH3 - R2	Blue mussel	70	51.4	40-61	84.9	0.137	0.529	0.87	0.300	0.015	0.327	44.4
14395	WH3 - R3	Blue mussel	70	49.8	39-64	87.2	0.103	0.430	0.68	0.265	0.011	0.273	35.1
14396	WH4 - R1	Blue mussel	80	46.8	33-69	82.9	0.165	0.445	0.98	0.203	0.012	0.262	51.0
14397	WH4 - R2	Blue mussel	80	47.8	38-64	83.7	0.149	0.459	0.91	0.193	0.011	0.239	41.0
D/14398	WH4 - R2 Dup	Blue mussel	-	-	-	83.4	0.154	0.446	0.94	0.194	0.011	0.241	38.6
14399	WH4 - R3	Blue mussel	80	49.6	41-65	83.1	0.186	0.504	1.04	0.248	0.014	0.296	48.3
14400	WH2 - R1	Blue mussel	60	64.5	50-75	87.6	0.092	0.313	0.51	0.183	0.006	0.122	28.9
14401	WH2 - R2	Blue mussel	60	67.3	53-78	87.9	0.094	0.295	0.45	0.207	0.005	0.124	26.3
14402	WH2 - R3	Blue mussel	60	63.3	52-74	86.1	0.111	0.377	0.69	0.286	0.006	0.162	29.9
14403	WH1 - R1	Blue mussel	60	66.4	53-84	84.1	0.158	0.403	0.75	0.328	0.009	0.163	45.0
14404	WH1 - R2	Blue mussel	60	65.0	53-85	81.2	0.198	0.444	0.78	0.351	0.010	0.189	48.3
14405	WH1 - R3	Blue mussel	60	64.3	50-76	87.8	0.109	0.364	0.60	0.279	0.006	0.125	29.5
14719	WH8 - R1	Blue mussel	60	61.9	45-80	86.8	0.097	0.359	0.75	0.504	0.006	0.127	37.5
14720	WH8 - R2	Blue mussel	60	62.3	49-91	82.8	0.184	0.449	1.07	0.700	0.009	0.160	52.9
14721	WH8 - R3	Blue mussel	60	58.3	50-74	81.4	0.145	0.529	1.06	0.504	0.008	0.162	43.7
D/14722	WH8 - R3 Dup	Blue mussel	-	-	-	81.7	0.161	0.466	1.13	0.561	0.009	0.167	41.5
14723	WH11 - R1	Blue mussel	60	57.8	42-72	84.9	0.141	0.453	1.11	1.114	0.007	0.130	53.0
14724	WH11 - R2	Blue mussel	60	59.1	46-74	83.8	0.219	0.571	1.44	1.768	0.009	0.174	60.8
14725	WH11 - R3	Blue mussel	60	58.2	44-76	84.5	0.191	0.763	1.48	1.546	0.009	0.183	70.0
14726	WH12 - R1	Blue mussel	50	66.0	53-90	83.9	0.188	0.477	1.03	0.921	0.008	0.118	52.0
14727	WH12 - R2	Blue mussel	50	67.6	48-82	84.2	0.221	0.481	1.10	1.230	0.009	0.147	51.3
14728	WH12 - R3	Blue mussel	50	71.8	54-92	84.7	0.198	0.496	1.08	1.079	0.008	0.142	46.2

* Shellfish length