Manukau Harbour Shellfish Quality Survey 1993

Auckland Regional Council
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SITE ABBREVIATIONS

Cornwallis	Cor
Granny's Bay	Gra
Pahurehure Inlet	Pah
Hingaia Bridge	Hin

1.0 INTRODUCTION

The Manukau Harbour Action Plan (MHAP) was completed in December 1990. One of the objectives of the MHAP was to map and characterise pollutants in the Manukau Harbour environment for the purpose of identifying and remedying pollution sources, and incidentally being able to comment on the suitability of tested shellfish for human consumption.

Shellfish quality surveys have been undertaken at selected sites annually each November since 1987. The complete objectives are stated in Manukau Harbour Action Plan - Shellfish Quality Survey ARWB Technical Publication No 53 (1988). In brief, the survey was designed to measure chronic ambient water quality as indicated by contaminant levels in a sentinel organism at representative sites in the Manukau Harbour .

The programme was reviewed after five years and the sampling programme scaled down from eleven sites to four sites which were considered to be representative of different catchment types within the Manukau Harbour. Additional information on contaminant levels in oysters from the South West Manukau is available in ARC Environment Technical Publication No. 16, which reports the NZ Steel Environmental Monitoring Programme.

This report presents the data for November 1993 survey; the 1992 survey was reported in ARC Environment Technical Publication No 34, the 1991 survey was reported in ARC Environment Technical Publication No 26, the 1990 survey was reported in Environment and Planning Technical Publication No. 1, the 1988 and 1989 surveys were been reported in ARWB Technical Publication No.86, and the 1987 survey was reported in ARWB Technical Publication No.53. Comparisons between years have been made for each of the three groups of pollutants measured .

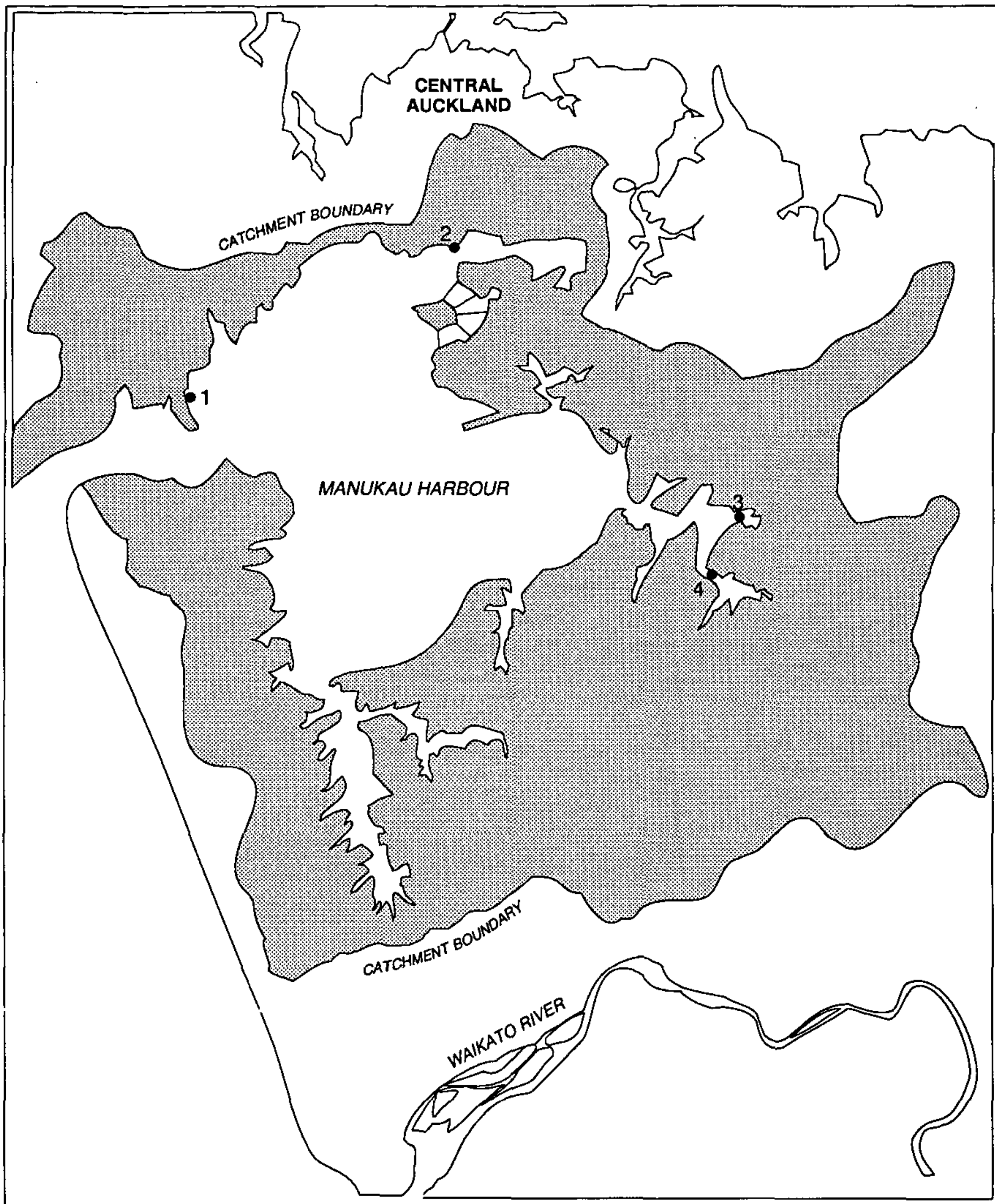
2.0 STUDY DESIGN AND METHODS

The study is restricted to sampling Pacific oyster (*Crassostrea gigas*) collected annually on one day during late November (ie prior to spawning) from four sites representing a wide variety of catchment uses including impacted sites and relatively uncontaminated areas.

2.1 SITES

Site selection was based upon obtaining a representative coverage of the Harbour and include a site adjacent to the main sources of known contamination and a reference site in the outer harbour, see figure 2.1

Cornwallis An outer harbour reference site that is used for recreation purposes.



Manukau Oyster Survey Sites 1993

1 Cornwallis Beach
2 Granny's Bay
3 Pahurehure Creek
4 Hingaia Bridge

Granny's Bay	This site is flushed by water from the Mangere Inlet and is subject to both point and non point source contamination. Historically this site has also been identified as having chronic bacteriological contamination.
Pahurehure Inlet	This site receives stormwater runoff from the urban/industrial areas of Papakura.
Hingaia Bridge	Extensive rural land with identified trace element contamination considered to derive from the Drury Industrial area.

2.2 FIELD SAMPLING

Sampling was conducted on the same day, following five days of little or no rainfall. Five replicates were collected randomly, at the same relative tidal height, at each site. Each replicate consisted of thirty-six individuals. For analysis these replicates were split into three subsamples of twelve oysters and dispatched to the three laboratories involved.

2.3 ANALYTICAL PROCEDURES

All analyses* were conducted on homogenised composite samples, consisting of twelve individual oysters per sample.

Trace metals were analysed by AgResearch, Grasslands Research Centre, Palmerston North.

Microorganisms were analysed by the Department of Cellular and Molecular Biology, University of Auckland.

Organic contaminants were analysed by NIWAR Ecosystems, Hamilton

* full details of all analytical procedures are available on request

2.4 STATISTICAL ANALYSIS

Analysis of variance was undertaken to test if the population means were equal. Where the difference between means was significant ($p<0.05$) a Tukey's pairwise comparison was used to determine which samples were significantly different.

3.0 TRACE METALS

3.1 SUMMARY OF THE TRACE METAL RESULTS

Results are presented graphically as box and whisker plots in figures 3.1 to 3.5.

Raw data is presented in the Appendix to this report.

All trace metal concentrations are reported as μg/g dry weight unless otherwise stated.

Arsenic

The highest concentration of arsenic was found in oysters from Pahurehure Inlet. The mean concentration in oysters from this site was 12.6 μg/g, there was no significant difference between the sites.

Cadmium

Cadmium concentrations were low at all sites, the highest concentration of 2.0μg/g occurred in oysters from Hingaia. The lowest concentration occurred in oysters from Cornwallis and was significantly lower than all other sites.

Chromium

Chromium concentrations ranged from a mean of 6.8 μg/g at Hingaia Bridge to a mean of 4.2 μg/g at Cornwallis, there was a significant difference between concentrations at these two sites.

Copper

The highest concentration of copper was found in oysters from Hingaia Bridge where the mean was 711 μg/g, this was significantly higher than all other sites. There was no significant difference between mean concentrations at Granny's Bay and Pahurehure which were 553 μg/g and 410 μg/g respectively. The mean concentration at Cornwallis (101 μg/g) was significantly lower than the other sites.

Lead

At all sites lead levels were below the detection limit (3.8 μg/g).

Figure 3.1: Arsenic

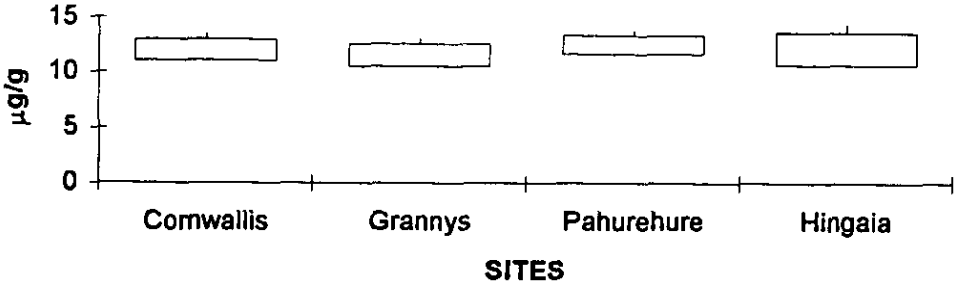


Figure 3.2: Cadmium

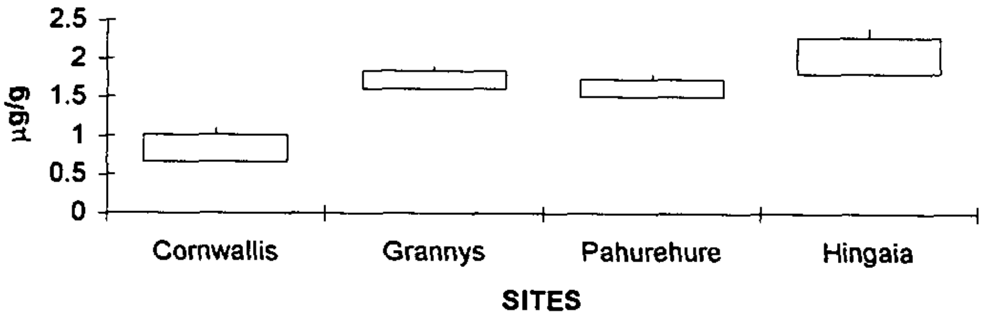
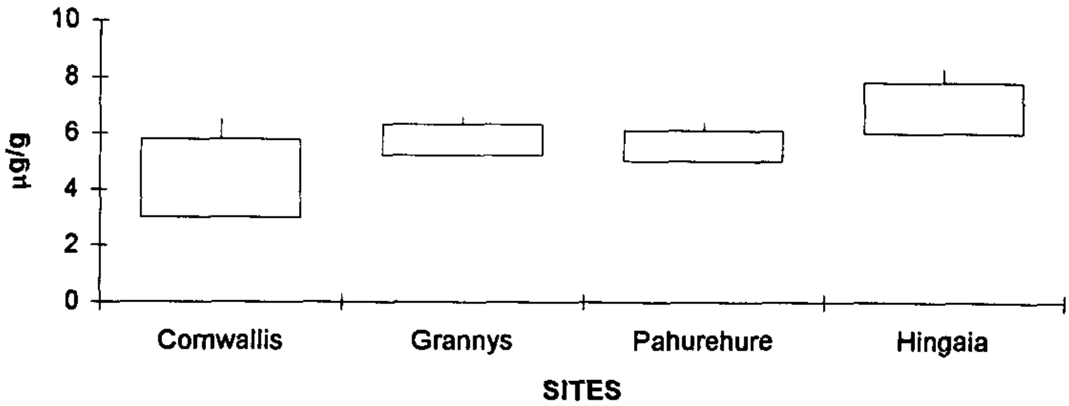


Figure 3.3: Chromium



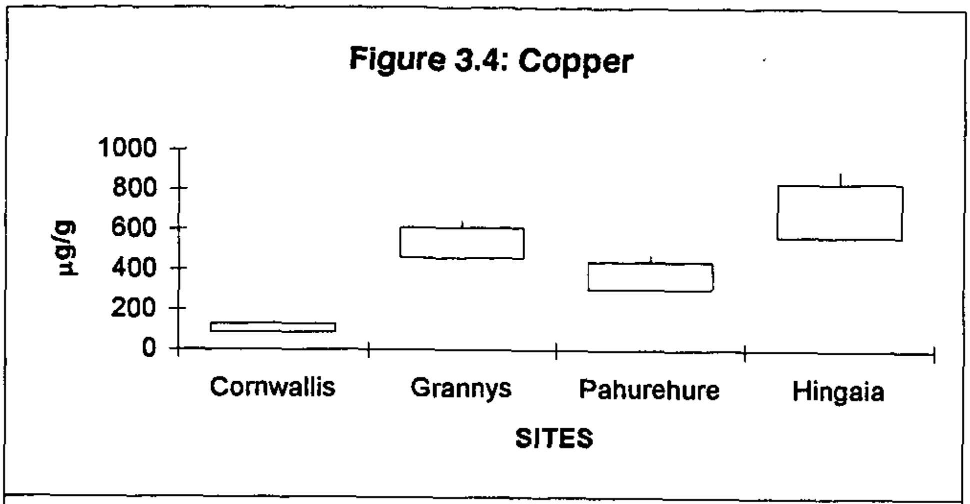


Figure 3.4: Copper
1000
800
600
400
200
0
µg/g
Cornwallis
Grannys
Pahurehure
Hingaia
SITES

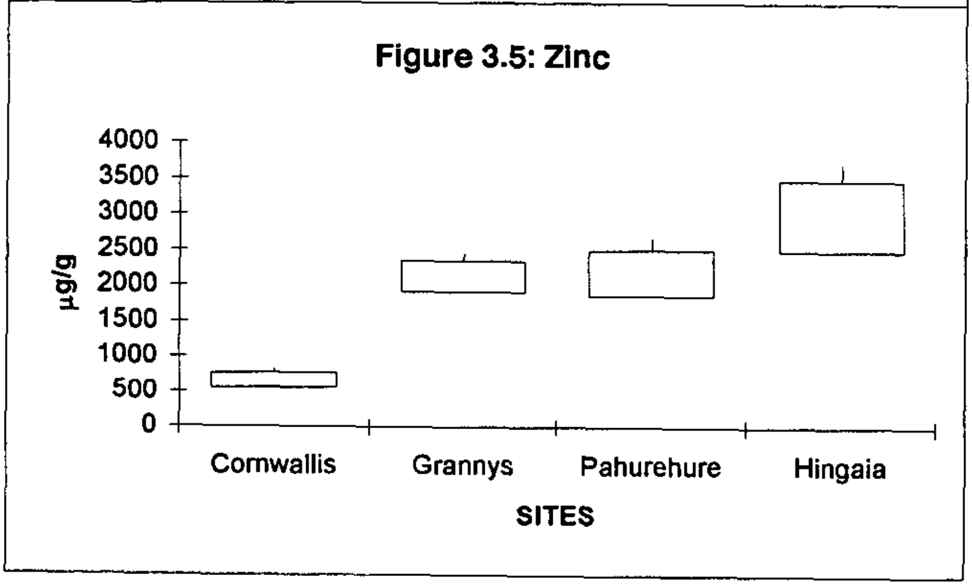


Figure 3.5: Zinc
4000
3500
3000
2500
2000
1500
1000
500
0
µg/g
Cornwallis
Grannys
Pahurehure
Hingaia
SITES

Nickel

Nickel levels were near or below the detection limit (0.75 μg/g) for all samples. the highest mean concentration was found in oysters from Granny's Bay (mean 1.3 μg/g)

Zinc

The highest concentration of zinc was found in oysters from Hingaia Bridge where the mean concentration was 2894μg/g, this was not significantly different from the mean concentration at Pahurehure Inlet (2370μg/g), but was significantly higher than concentrations at Grannys Bay (2210μg/g) and Cornwallis (653 μg/g). Concentrations at Cornwallis were significantly lower than all other sites.

Table 3.1 Trace Metals: Tukey's comparisons of means between sites

Sites are arranged from left to right in decreasing order of contaminant concentration. Sites joined by lines are not significantly different from each other.

Arsenic	PAH	COR	HIN	GRA
Cadmium	HIN	GRA	PAH	COR
Chromium	HIN	GRA	PAH	COR
Copper	GRA	HIN	PAH	COR
Zinc	HIN	PAH	GRA	COR

3.2 A COMPARISON OF THE 1993 RESULTS WITH THE 1987-1992 RESULTS

Over the seven year period none of the seven trace metals reported showed any obvious temporal trend.

Arsenic

In 1989 arsenic concentrations were below the detection level, hence only 5 years data is used in the analysis. The 1993 concentration for arsenic was the second to highest concentration recorded, however it was not statistically different from concentrations in 1988, 1990 and 1991. A Tukey's comparison of means show that concentrations in 1987 and 1992 were significantly lower than concentrations in other years (table 3.2).

Cadmium

The 1993 concentration was the second to lowest, but was not significantly different from the 1988, 1990, 1991 and 1992 concentrations. The highest concentration occurred in 1989, this concentration was significantly higher than all other years. The lowest concentration occurred in 1987 and was significantly lower than all other years (table 3.2).

Chromium

The 1993 concentration was the highest concentration, this was significantly higher than all other years. The lowest concentration occurred in 1987 (table 3.2).

Copper

The concentration from the 1993 survey was the second to lowest concentration recorded. However the only statistically significant difference that the lowest concentration 1988 was significantly lower than all other years (table 3.2).

Zinc

The concentration from the 1993 survey was the second to lowest concentration recorded, the lowest concentration occurred in 1988. Concentrations in 1988, 1993 and 189 were significantly lower than all other years (table 3.2).

Table 3.2 Trace Metals: Tukey's comparison of means between 1987 - 1992

Years are arranged from left to right in decreasing order of contaminant concentration. Years joined by lines are not significantly different from each other. (* below detection)

Arsenic	90	93	88	91	92	87	89*
Cadmium	89	91	88	90	92	93	87
Chromium	93	92	90	91	89	88	87
Copper	89	90	92	91	87	93	88
Zinc	89	91	90	92	87	93	88

3.3 DISCUSSION

The input of trace metals into the Manukau Harbour is largely a function of the types of land use in the adjacent catchments. The availability and uptake of trace metals is also influenced by tidal exchange and current movement. Concentrations in this report are dry weight whereas maximum permissible concentrations are often reported as wet weight. To calculate a dry weight equivalent the wet weight value can be multiplied by between five to ten times but would require a value to be specifically developed for any given sample/site combination (NH & MRC 1980). Oysters from the Hingaia Bridge showed the highest level of contamination for four of the seven trace metals reported, lead was below detection at all sites.

Arsenic

Arsenic is not and essential element and is toxic to humans and aquatic organisms. It can be accumulated by shellfish to relatively high levels and is also a known carcinogen in humans (Hart, 1982: Bryan, 1976). The predominant commercial use of arsenic, in the Auckland region is by timber treatment companies who use it in wood preservation processes. Historically arsenic was used in some weed killers and insecticides, registration for these applications was withdrawn in 1972. Arsenic continued to be used for rabbit control and was finally withdrawn in 1987. There was no evidence of any gradient in arsenic levels in 1993.

Cadmium

Cadmium is not an essential or beneficial element to humans and is infact very toxic. The permissible level of cadmium in oysters is 2 µg/g wet weight (10-20 µg/g dry weight). The highest concentration in the 1993 study occurred in samples from the Hingaia site where the mean cadmium concentration was 2.0 µg/g dry weight, which is well within the maximum permissible level.

Chromium

Chromium is measured as total metal, but is commonly found in two oxidation states, chromium III and chromium VI. The hexavalent form (Cr VI) is more harmful, probably because it is more mobile and a stronger oxidiser, as a result it diffuses into tissues, binds biological molecules and inactivates enzymes responsible for the production of energy from food. Cr VI tends to be associated with human activities. Chromium is carcinogenic in humans, it is bioaccumulated by marine and freshwater organisms, but at present there is no evidence that it is concentrated through the food chain and there is no recommended standard for shellfish.

Results from the 1993 study showed chromium at increased levels when compared with previous surveys. The highest concentration measured at Hingaia Bridge where the mean concentration was 6.8µg/g dry weight.

Copper

Copper is a ubiquitous metal in urban areas and is an essential element in metabolic processes. It also occurs as a trace element additive to some stock foods and supplements. However, in humans, ingesting large quantities of copper can cause vomiting and low concentrations of copper are toxic to aquatic life. There was no obvious gradient of copper contamination although the concentration in oysters from the outer Harbour site, Cornwallis, was significantly lower than all other sites.

In oyster the maximum permissible concentration of copper to avoid receiving an emetic does at average consumption levels is 70.0 µg/g wet weight (350-700 µg/g dry weight, NH & MRC 1980). Concentrations at Hingaia (mean 711 µg/g), Granny's Bay (mean 550 µg/g) and Pahurehure (mean 409 µg/g) all exceeded this level. However it is significant to note that the mean concentration of copper at Grannys Bay in 1993 was almost half that of the 1992 mean concentration (1015µg/g).

Zinc

Zinc is an ubiquitous metal in urban areas, principal inputs to the harbour are from urban runoff. It is not particularly toxic to humans, but is accumulated by oysters. As with copper, there was no obvious gradient of zinc contamination although the concentration in oysters from the outer Harbour site, Cornwallis, was significantly lower than all other sites.

The maximum permissible zinc concentration in oysters, for human consumption is 1000µg/g wet weight (5000 to 10000µg/g dry weight NH & MRC, 1980), no sites exceeded this level.

4.0 <u>ORGANICS</u>

4.1 SUMMARY OF THE ORGANIC RESULTS

Results are presented graphically as box and whisker plots in figures 4.1 to 4.5

Raw data is presented in the Appendix to this report.

All concentrations are reported as ng/g dry weight unless otherwise stated.

Total Chlorophenols

Chlorophenols were detected at low levels in some replicates from three sites, Grannies Bay, Pahurehure Inlet and Hingaia Bridge.

Table 4.1: Organic contaminants: Tukey's comparison of means between sites

Sites are arranged from left to right in decreasing order of contaminant concentration. Sites joined by lines are not significantly different from each other.

Chlordane	GRA	COR	PAH	HIN
Total DDT	GRA	PAH	HIN	COR
Dieldrin	GRA	PAH	HIN	COR
Total PCB	GRA	PAH	HIN	COR
Total PAH	GRA	PAH	HIN	COR

Figure 4.1: Technical Chlordane Equivalent

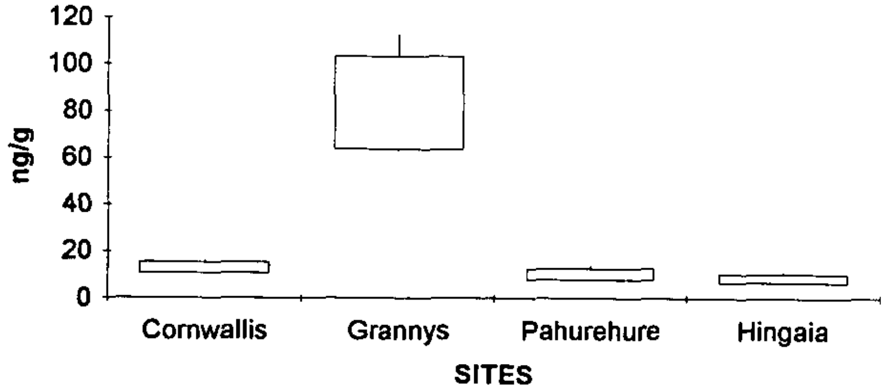


Figure 4.2: Total DDT

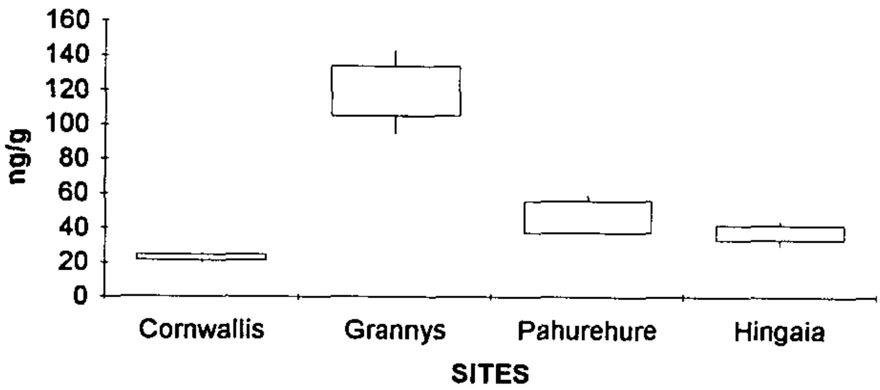


Figure 4.3: Dieldrin

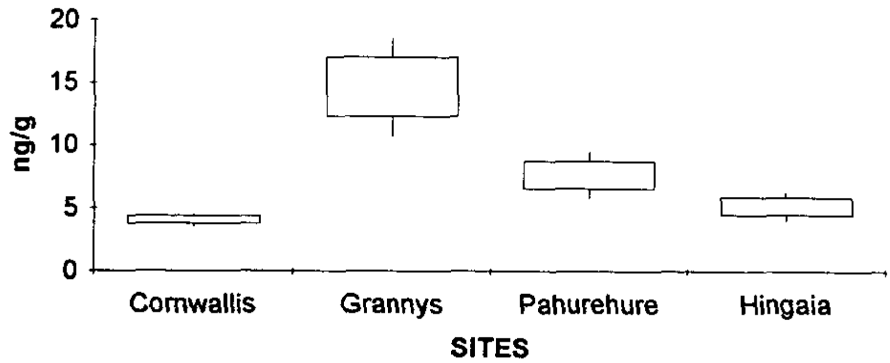


Figure 4.4: Total Polychlorinated Biphenyls

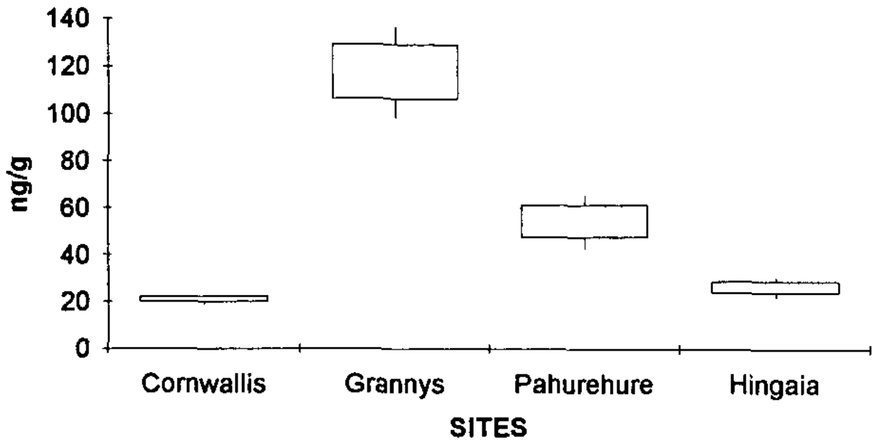
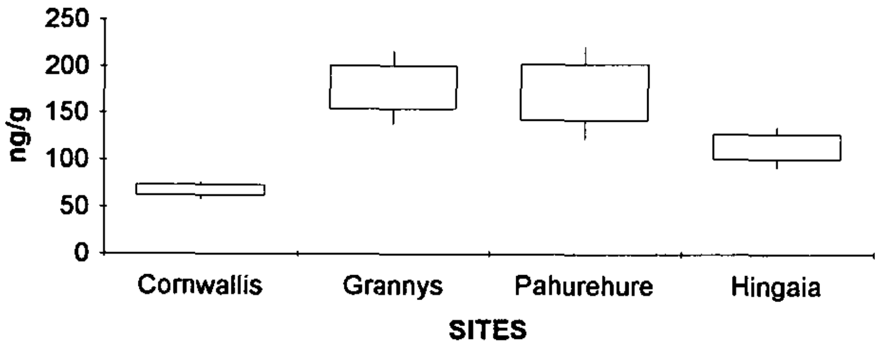


Figure 4.5: Polynuclear Aromatic Hydrocarbons



Technical Chlordane Equivalent

Analysis was undertaken for the cis- and trans-chlordane isomers. These two compounds comprise 43% of pure technical chlordane, thus the equivalent technical chlordane was calculated by multiplying the sum of cis- and trans-chlordane compounds by 2.33.

The highest concentration of chlordane's occurred in oysters from Granny's Bay (mean 92.86 ng/g). There was no significant difference between any of the other sites which had means ranging from 14.41 ng/g at Cornwallis to 9.27 ng/g at Hingaia.

Total DDT

DDT is a combination of two isomers o,p' and p,p' and has several metabolites, those most frequently found are DDD and DDE. Tissue analysis was carried out for all three metabolites, the results of which were combined to give a total DDT concentration.

The highest concentration of DDT occurred in oysters sampled from Granny's Bay (mean 125.34 ng/g), this site was significantly higher than all other sites. Concentrations at Hingaia and Pahurehure were not significantly different from each other whilst concentrations at Cornwallis (mean 27.63 ng/g) were significantly lower than Pahurehure.

Dieldrin

The highest concentration of dieldrin occurred in oysters sampled from Granny's Bay (mean 15.2 ng/g). The mean concentration at Pahurehure was 7.58 ng/g, at Hingaia 5.16 ng/g and the lowest concentration of 4.11 ng/g was found in oysters from Cornwallis.

Total PCB's

A subset of 20 individual congeners were tested for, this included all the predominant persistent congeners. The sum of the concentration of these congeners was then taken as the 'total' PCB's. As we do not test for all congeners this 'total' is an underestimate, but provided the same subset is used in subsequent analysis, does give sound basis for comparison.

The highest concentration of PCB's occurred in oysters sampled from Granny's Bay (mean 120.47 ng/g), this was significantly higher than all other sites. Concentrations at Pahurehure (mean 54.73 ng/g) were significantly higher than Hingaia (mean 27.53 ng/g) and Cornwallis (mean 21.32 ng/g).

Total Polynuclear Aromatic Hydrocarbons (PAH)

PAH analysed for were anthracene, fluoranthene, pyrene, chysene, benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[g,h,i]perylene. The most toxic PAH is benzo[a]pyrene, a known carcinogen, it was a minor component of PAH determined with levels of the order of less than 0.1 to 1.72 ng/g. The most abundant PAH at all sites were pyrene and fluoranthene.

Highest concentration of total PAH's were found in oysters from Granny's Bay (mean 186.06 ng/g), this was not significantly different from the concentration at Pahurehure (mean 165.59 ng/n). Concentrations at Hingaia (mean 109.63 ng/n) and Cornwallis were not significantly from each other.

4.2 COMPARISON OF THE 1993 RESULTS WITH THE 1987-1992 RESULTS

This programme has been running now for seven years over which time analytical techniques and recoveries have been modified and improved. The organic contaminants are lipophilic and are therefore largely partitioned into the lipid portion of the oyster. *Different analytical procedures can result in* varying amounts of lipid being recovered from a given weight of dry tissue, thereby giving rise to contaminant concentrations which are variable when expressed in dry weight terms, but are more consistent when normalised in terms of lipid content. To enable a comparison between years the results have been lipid normalised and corrected for the varying contaminant recovery rates. Raw data from the earlier surveys is presented in the appendices ARWB Technical Publication No's 53 and 86 and in ARC Environment Technical Publication No's. 1, 26 and 34.

Overall there was no clear temporal pattern, all compounds, concentrations fluctuated from year to year, but did not show any trends in either direction.

Table 4.2: Tukey's comparison of means between 1987 - 1992

Years are arranged from left to right in decreasing order of contaminant concentration.
Years joined by lines are not significantly different from each other.

Chlordane	87	88	89	90	91	93	92
Total DDT	88	90	87	89	92	91	93
Dieldrin	88	87	90	91	89	92	93
Total PCB's	93	92	87	90	88	91	89
Total PAH	87	93	90	92	91	88	89

4.3 DISCUSSION

Historically the input of organic contaminants into the Manukau harbour was largely a function of the types of land use in the adjacent catchments. A number of the compounds reported are no longer registered for use and their occurrence most likely reflects historical inputs and mobilisation of historically contaminated soils. The availability and uptake of organic contaminants is also influenced by tidal exchange and current movement. Concentrations in this report are on a dry weight basis, whereas maximum permissible concentrations are often reported as wet weight. To calculate a dry weight equivalent the wet weight value can be multiplied by between five to ten times but would require a value to be specifically developed for any given sample/site combination (NH & MRC 1980). It is difficult to obtain recommended standards for organics in that for most organics their toxicity is cumulative and is related to consumption rate over time as to oppose to an emetic dose.

Total Chlorophenols

Chlorophenols are used in New Zealand in a variety of industrial and agricultural applications including biocides, preservatives, dyes and pesticides.

In the 1992 survey chlorophenols levels were very low and in most samples only penta-chlorophenol was detected.

Technical Chlordane Equivalent

In New Zealand chlordane was historically used for timber treatment and pest control. Concentrations at all sites were within the recommended standard for human consumption as specified in the Australian Water Quality Criteria (1984). Chlordanes levels from the 1993 survey were similar to previous years.

Total DDT

DDT is a chlorinated hydrocarbon that historically was manufactured as an insecticide. It is highly toxic, persists in the environment and is a possible human carcinogen. Registration of all DDT products was withdrawn in 1989, but there may still be some application of old stocks of DDT products by rural and domestic users.

DDT is broken down under chemical and biological action to form DDD and DDE both of which are toxic and persist in the environment. The ratio of these products to the parent compound gives an insight into the degree of weathering and therefore the age of the DDT detected. The ratio of DDT/DDE varied between sites but was always less than one which indicates no major fresh inputs of DDT into the harbour. Total DDT levels at all sites were below the recommended safe level for human consumption, as specified by USEPA Criteria.

Other Organochlorines

Determinations were undertaken for dieldrin, lindane, heptachlor, heptachor epoxide and endrin, but only dieldrin was detected. Dieldrin is a pesticide, which was deregistered in 1989 and permits for its use in horticulture and agriculture were revoked. Use of dieldrin for commercial pest control in buildings did not require a permit and it is possible that old stocks are still used for this application.

Dieldrin was found at all sites with decreasing gradient from the inner sites to the outer site of Cornwallis. All concentrations were within the recommended standard for human consumption as specified in the Australian Water Quality Criteria (1984).

Total PCB

PCB are complex mixtures of congeners manufactured by the reaction of biphenyl with chlorine. They have high insulating properties and a general inertness which makes them suitable for a number of applications. One of the main uses is as a dielectric fluid in electrical capacitors and transformers.

PCBs persist in the environment and accumulate in the lipids of exposed organisms resulting in bioconcentration along the food chain. The toxicity of PCB varies between congeners however current guide-lines refer to total PCB. PCB concentrations at all sites were below the recommended safe level for human consumption, as specified by USEPA Criteria.

Total Polynuclear Aromatic Hydrocarbons (PAH)

PAH are formed by the incomplete combustion of organic material. There is a natural background level of PAH in the environment resulting from events such as forest fires and volcanic activities. A significant anthropogenic source of PAH's is found in motor vehicle emissions and wood and coal burning fires. The total PAH levels were of a similar magnitude to previous years. Levels tend to fluctuate more than organochlorines. This is probably due to their lower persistence and the greater variations in pollutant loadings. As with other organic contaminants the highest levels occurred at the inner harbour sites. There is no specified safe level for PAH in food.

5.0 MICROORGANISMS

The oyster samples were analysed for the presence and abundance of three commonly occurring sewage-associated microorganisms, faecal coliforms, enterococci and *Vibrio parahaemolyticus.*

5.1 SUMMARY OF THE RESULTS

Raw data is presented in the Appendix to this report. Due to the number of samples in which no microorganisms were detected, it is not possible to undertake statistical analysis of the results.

Faecal Coliforms

Pahurehure Inlet and Granny's Bay showed elevated faecal coliform levels and the median levels exceeded the recommended standard of 230 MPN/100gm as specified in the National Health Institute's Microbiological Criteria for Food. Faecal coliforms were detected in all samples from Hingaia, but none exceeded the recommended standard. At Cornwallis, low levels were detected in two samples and in the other three samples no faecal coliforms were detected.

Enterococci

Elevated enterococci levels were found in all samples of oysters from Pahurehure Inlet. Low levels were found in all samples from Hingaia and in some samples from Cornwallis and Granny's Bay.

Vibrio parahaemolyticus

Vibrio parahaemolyticus was confirmed in all samples from Pahurehure Inlet and Hingaia Bridge and in one sample each from Cornwallis and Granny's Bay.

5.2 DISCUSSION

Faecal coliforms and enterococci are not themselves pathogenic , but are used to rpovide an indication of likely levels of other, potentially pathogenic sewage-derived microorganisms.

whereas *Vibrio parahaemolyticus* is an opportunistic pathogen which may cause an intestinal disorder characterised by vomiting and diarrhoea.

There was evidence of microbiological contamination at three (Granny's Bay, Pahurehure Inlet, Hingaia Bridge) of the four sites sampled, with faecal coliform levels exceeding recommended guidelines at two of the sites. There are no criteria relating to maximum acceptable levels of enterococci in shellfish. However Pahurehure Inlet which showed elevated levels of faecal coliforms also had elevated entereococci numbers, indicating faecal contamination. The samples in which *Vibro* was confirmed did not exceeded the maximum allowable level in food of 1000 organisms/g, as specified by the International Commission on Microbiological Specifications for Food, 1982.

6.0 CONCLUSIONS

Oysters from sites adjacent to high density urban/residential development can be expected to be chronically or at least intermittently unsuitable for human consumption. Consistent with previous surveys there was a general gradient of decreasing concentration for most trace metals and organic contaminants, from the most northern inner harbour site of Granny's Bay to the outer harbour site of Cornwallis. There was no obvious temporal pattern for any trace metal or organic contaminant.

Oysters from Granny's Bay showed significant contamination by a range of trace metals and synthetic organic pollutants. Levels of copper at Granny's Bay, Hingaia and Pahurehure all exceeded the maximum permissible concentrations set by the NH & MRC (Australia) 1980. None of the synthetic organics analysed for exceeded recommended permissible concentrations, but some of these compounds tend to persist in the environment and their toxicity can be cumulative.

Elevated levels of faecal coliforms and enterococci were detected in all samples from Pahurehure and Granny's Bay, indicating faecal contamination, but of unknown origin. Median values of faecal coliforms at both of these sites exceeded the standard of 230 MPN/ 100gm, as specified in the National Health Institutes' Microbiological Criteria for Food. *Vibrio parahaemolyticus* was confirmed in all samples from Pahurehure and Hingaia, but levels were within the recommended standard, as specified by the International Commission on Microbiological Specifications for Food, 1982.

With respect to the long-term trends of contamination that can be expected in shellfish adjacent to urban areas this will depend on, among other influences, the efficacy of the stormwater quality control, sewage upgrading and pollution abatement programmes. The shellfish quality programme provides baseline information on contaminant sources, levels and distribution. Valuable data for monitoring the effectiveness of management initiatives is also obtained.

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Table 1 Cornwallis

TRACE METALS	Replicate / Concentration (μg/g dry weight) 1	2	3	4	5
Arsenic	11.0	13.5	11.2	11.7	12.6
Cadmium	0.74	0.80	0.66	1.1	0.86
Chromium	6.5	3.6	3.0	4.8	3.1
Copper	139	90	84	106	85
Lead	nd	nd	nd	nd	nd
Zinc	824	639	540	639	625

Table 2 Granny's Bay

TRACE METALS	Replicate / Concentration (μg/g dry weight) 1	2	3	4	5
Arsenic	10.5	12.8	13.1	11.5	11.0
Cadmium	1.7	1.9	1.6	1.9	1.8
Chromium	5.2	5.8	6.3	6.6	5.8
Copper	477	554	649	628	455
Lead	nd	nd	nd	nd	nd
Zinc	1904	2284	2447	2319	2094

Table 3 Pahurehure Inlet

TRACE METALS	Replicate / Concentration (μg/g dry weight) 1	2	3	4	5
Arsenic	12.3	11.6	12.2	13.0	13.8
Cadmium	1.7	1.5	1.5	1.5	1.8
Chromium	6.0	5.1	4.7	5.0	6.4
Copper	434	379	302	458	475
Lead	nd	nd	nd	nd	nd
Zinc	2669	2269	1860	2520	2533

Table 4 Hingaia Bridge

TRACE METALS	Replicate / Concentration (μg/g dry weight) 1	2	3	4	5
Arsenic	11.9	14.4	11.4	10.8	10.6
Cadmium	1.9	2.4	1.9	2.0	1.8
Chromium	6.0	8.3	6.0	6.9	7.0
Copper	669	755	563	903	665
Lead	nd	nd	nd	nd	nd
Zinc	2743	2918	2487	3723	2599

Table 5: Cornwallis

ORGANIC CONTAMINANTS	Replicate/concentration (ng/g dry weight) 1	2	3	4	5
2,4,6 trichlorophenol	n.d	n.d	n.d	n.d	n.d
2,4,5 trichlorophenol	n.d	n.d	n.d	n.d	n.d
2,3,4,6 tetrachlorophenol	n.d	n.d	n.d	n.d	n.d
pentachlorophenol (PCP)	n.d	n.d	n.d	n.d	n.d
p,p DDT	0.87	1.43	1.29	1.22	1.32
o,p DDT	0.13	0.29	0.19	0.18	0.15
p,p, DDD	2.73	4.01	3.19	2.79	3.39
o,p DDD	0.76	0.9	0.77	0.76	0.85
p,p, DDE	12.94	16.43	16.77	15.18	15.49
o,p DDE	2.27	2.84	3.4	2.35	3.95
PCB 15	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 18	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 49	0.36	0.59	0.68	0.55	0.64
PCB 44	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 121	0.79	1.13	1.2	1.09	1.16
PCB 101	2.35	2.9	3.14	2.82	3.1
PCB 77	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 151	0.66	0.73	0.71	0.64	0.76
PCB 118	2.32	2.74	2.6	2.45	2.85
PCB 153	7.75	8.71	8.13	8.23	8.95
PCB 105	0.66	0.83	0.78	0.7	0.8
PCB 141	0.18	0.23	0.17	0.16	0.21
PCB 138	2.83	3.41	3.24	3.14	3.44
PCB 156	0.19	0.23	0.19	0.16	0.2
PCB 180	0.64	0.79	0.66	0.58	0.74
PCB 170	0.15	0.16	0.17	0.09	0.12
PCB 195	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 194	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 206	<0.1	<0.1	<0.1	<0.1	<0.1
PCB209	<0.1	<0.1	<0.1	<0.1	<0.1
lindane	0.4	0.51	0.67	0.57	0.56
heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1
heptachlor epoxide	<0.5	<0.5	<0.5	<0.5	<0.5
dieldrin	3.8	4.34	4.62	3.55	4.24
endrin	<0.1	<0.1	<0.1	<0.1	<0.1
trans chlordane	2.49	3.83	3.91	3.33	4.16
cis chlordane	2.02	2.78	2.83	2.62	2.95
anthracene	0.34	0.49	0.52	0.47	0.4
fluoroanthene	16.56	22.49	25.72	20.25	20.67
pyrene	36.04	45.48	41.15	35.33	27.62
chrysene	2.39	3.58	3.44	3.38	3.59
benz[a]anthracene	1.59	1.73	1.41	1.24	1.22
benzo[b]fluoranthene	1.73	1.81	2.4	2.33	2.08
benzo[k]fluoranthene	0.55	0.68	0.74	0.89	0.75
benzo[a]pyrene	0.34	0.21	0.1	<0.1	0.16
dibenz[a,h]anthracene	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[g,h,i]perylene	0.41	0.32	0.54	0.54	0.38

Table 6: Grannys Bay

ORGANIC CONTAMINANTS	Replicate/concentration (ng/g dry weight) 1	2	3	4	5
2,4,6 trichlorophenol	0.22	n.d.	0.28	0.35	n.d.
2,4,5 trichlorophenol	<0.2	n.d.	<0.2	<0.2	n.d.
2,3,4,6 tetrachlorophenol	0.76	n.d.	0.74	1.24	n.d.
pentachlorophenol (PCP)	1.87	n.d.	5	5.68	n.d.
p,p DDT	5.74	6.88	6	5.17	5.22
o,p DDT	0.45	0.47	0.38	0.33	0.3
p,p, DDD	30.47	32.68	29.66	20.97	25.08
o,p DDD	8.83	9.22	7.79	5.25	6.37
p,p, DDE	93.02	90.17	89.16	60.46	67.96
o,p DDE	4.36	4.04	4.42	2.69	3.15
PCB 15	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 18	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 49	3.11	2.85	2.48	1.77	2.25
PCB 44	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 121	6.94	6.54	6.29	4.24	5.33
PCB 101	21.63	20.96	19.46	14	16.49
PCB 77	0.92	0.66	0.78	0.56	0.77
PCB 151	4.21	4.08	4.1	3.16	3.38
PCB 118	20.89	20.96	19.27	14.92	16.55
PCB 153	49.92	49.64	43.64	35.81	36.97
PCB 105	6.02	6.38	6.25	4.8	5.25
PCB 141	1.26	0.97	0.79	0.52	0.64
PCB 138	17.43	19.49	18.35	15.8	16.44
PCB 156	1	0.88	0.86	0.74	0.81
PCB 180	3.06	2.43	1.88	1.5	1.69
PCB 170	0.36	0.41	0.24	0.31	0.25
PCB 195	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 194	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 206	<0.1	<0.1	<0.1	<0.1	<0.1
PCB209	<0.1	<0.1	<0.1	<0.1	<0.1
lindane	0.88	1.09	1.03	0.79	0.74
heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1
heptachlor epoxide	<0.5	<0.5	<0.5	<0.5	<0.5
dieldrin	16.25	18.65	15.51	10.71	14.38
endrin	<0.1	<0.1	<0.1	<0.1	<0.1
trans chlordane	26.58	28.24	25.19	16.5	20.87
cis chlordane	18.93	20.37	16.98	10.82	14.79
anthracene	1.58	2.44	1.98	1.6	2.09
fluoroanthene	56.34	57.96	46.95	32.63	49.17
pyrene	109.89	106.7	87.96	69.6	94.17
chrysene	14.39	15.14	13.39	9.46	12.75
benz[a]anthracene	8.51	9.77	8.71	6.24	7.59
benzo[b]fluoranthene	13	16.32	12.64	10.76	13.24
benzo[k]fluoranthene	3.74	4.57	4.3	3.45	4.18
benzo[a]pyrene	0.4	0.57	0.83	1.2	0.58
dibenz[a,h]anthracene	0.24	0.34	0.38	0.35	0.18
benzo[g,h,i]perylene	1.9	2.7	2.45	2.42	2.46

Table 7: Pahurehure

ORGANIC CONTAMINANTS	Replicate/concentration (ng/g dry weight) 1	2	3	4	5
2,4,6 trichlorophenol	n.d.	<0.2	n.d.	<0.2	<0.2
2,4,5 trichlorophenol	n.d.	<0.2	n.d.	<0.2	<0.2
2,3,4,6 tetrachlorophenol	n.d.	<0.2	n.d.	0.52	0.49
pentachlorophenol (PCP)	n.d.	0.64	n.d.	1.02	4.15
p,p DDT	4.28	3.19	2.64	4.22	2.68
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1
p,p, DDD	12.6	9.1	8.16	11.27	7.08
o,p DDD	1.98	1.32	1.81	1.8	1.25
p,p, DDE	39.4	28.07	30.84	38.39	28.96
o,p DDE	1.23	0.81	1.06	1.06	0.9
PCB 15	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 18	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 49	0.84	0.42	0.64	0.51	0.58
PCB 44	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 121	2.55	1.8	2	2.04	1.57
PCB 101	7.04	5.32	5.63	6.08	4.57
PCB 77	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 151	2.58	2.24	2.11	2.43	1.65
PCB 118	5.07	3.81	3.98	4.42	3.35
PCB 153	26	23.41	22.13	24.75	18.41
PCB 105	1.35	1	1.27	1.28	0.92
PCB 141	1.62	1.21	0.79	1	0.58
PCB 138	12.64	11.31	9.9	10.81	8.13
PCB 156	0.83	0.57	0.73	0.7	0.55
PCB 180	4.55	3.23	2.69	3.09	1.95
PCB 170	0.83	0.59	0.64	0.43	0.51
PCB 195	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 194	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 206	<0.1	<0.1	<0.1	<0.1	<0.1
PCB209	<0.1	<0.1	<0.1	<0.1	<0.1
lindane	0.8	0.55	0.68	0.48	0.65
heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1
heptachlor epoxide	<0.5	<0.5	<0.5	<0.5	<0.5
dieldrin	9.53	5.8	7.06	7.5	8.03
endrin	<0.1	<0.1	<0.1	<0.1	<0.1
trans chlordane	3.49	2.02	3.18	2.5	2.65
cis chlordane	2.46	1.29	2.15	1.7	1.97
anthracene	1.59	1.22	1.39	1.53	1.17
fluoroanthene	60.42	37.69	40.41	44.14	32.42
pyrene	106.8	80.34	74.22	90.42	57.38
chrysene	18.25	12.15	11.55	11.08	9.44
benz[a]anthracene	8.21	6.72	5.99	6.32	4.89
benzo[b]fluoranthene	17.26	13.47	11.34	10.35	9.53
benzo[k]fluoranthene	5.52	4.5	3.66	3.13	3.3
benzo[a]pyrene	0.81	1.72	0.85	0.9	1.17
dibenz[a,h]anthracene	0.39	0.45	0.21	0.37	0.26
benzo[g,h,i]perylene	3.29	2.86	2.42	2.13	2.3

Table 8: Hingaia Bridge

	Replicate/concentration (ng/g dry weight)				
ORGANIC CONTAMINANTS	1	2	3	4	5
2,4,6 trichlorophenol	0.23	<0.2	<0.2	n.d.	0.37
2,4,5 trichlorophenol	<0.2	<0.2	<0.2	<0.2	<0.2
2,3,4,6 tetrachlorophenol	1.33	0.59	0.83	n.d.	1.14
pentachlorophenol (PCP)	6.45	5.54	3.74	n.d.	7.01
p,p DDT	2.47	2.38	2.22	1.59	2.85
o,p DDT	<0.1	<0.1	<0.1	<0.1	<0.1
p,p, DDD	5.79	5.88	5.87	4.5	6.83
o,p DDD	1.01	0.91	0.85	0.83	0.99
p,p, DDE	29.46	31.22	30.88	22.59	33.12
o,p DDE	0.94	0.88	0.78	0.59	1.01
PCB 15	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 18	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 49	0.59	0.6	0.43	0.39	0.62
PCB 44	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 121	1.24	1.24	1.06	0.95	1.35
PCB 101	3.38	3.34	2.92	2.39	3.53
PCB 77	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 151	0.96	0.93	0.9	0.7	0.99
PCB 118	2.85	2.96	2.67	2.07	3.04
PCB 153	12.03	11.56	11.24	8.65	12.52
PCB 105	0.85	0.8	0.84	0.64	0.92
PCB 141	0.37	0.32	0.32	0.3	0.28
PCB 138	5.03	4.99	5.1	3.99	5.32
PCB 156	0.38	0.31	0.3	0.29	0.39
PCB 180	1.35	1.43	1.17	1.11	1.21
PCB 170	0.25	0.31	0.3	0.29	0.28
PCB 195	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 194	<0.1	<0.1	<0.1	<0.1	<0.1
PCB 206	<0.1	<0.1	<0.1	<0.1	<0.1
PCB209	<0.1	<0.1	<0.1	<0.1	<0.1
lindane	0.52	0.51	0.51	0.48	0.58
heptachlor	<0.1	<0.1	<0.1	<0.1	<0.1
heptachlor epoxide	<0.5	<0.5	<0.5	<0.5	<0.5
dieldrin	6.39	4.65	4.96	4.05	5.74
endrin	<0.1	<0.1	<0.1	<0.1	<0.1
trans chlordane	2.54	2.8	1.74	1.69	2.84
cis chlordane	1.85	2.11	1.19	1.2	1.93
anthracene	0.86	1.12	0.82	0.48	1.14
fluoroanthene	25.82	31.96	33.93	28	29.75
pyrene	48.62	55.81	82.99	65.87	54.39
chrysene	5.23	6.23	6.21	5.03	5.69
benz[a]anthracene	2.37	2.48	2.32	1.46	2.6
benzo[b]fluoranthene	5.18	6.07	6.34	4.7	5.63
benzo[k]fluoranthene	1.89	2.04	2.25	1.84	2.07
benzo[a]pyrene	0.5	0.4	0.48	0.36	0.62
dibenz[a,h]anthracene	<0.1	<0.1	<0.1	<0.1	<0.1
benzo[g,h,i]perylene	1.15	1.28	1.3	1.31	1.48

Table 9: Faecal Coliforms MPN/100gm

	Replicate				
SITE	1	2	3	4	5
Cornwallis	20	nd	20	nd	nd
Granny's Bay	230	230	300	230	230
Pahurehure Inlet	300	300	140	800	170
Hingaia Bridge	40	40	220	40	70

Table 10: Enterococci CFU/100gm

	Replicate				
SITE	1	2	3	4	5
Cornwallis	110	20	20	nd	20
Granny's Bay	nd	nd	20	220	nd
Pahurehure Inlet	270	110	220	170	90
Hingaia Bridge	40	20	60	20	20

Table 11: ***Vibro parahaemolyticus*** **CFU/100gm**

	Replicate				
SITE	1	2	3	4	5
Cornwallis	68	nd	nd	nd	nd
Granny's Bay	68	nd	nd	nd	nd
Pahurehure Inlet	1500	1500	1500	6800	3200
Hingaia Bridge	147	3200	147	1500	1500