Contaminants in kai – Te Arawa rohe
Part 1: Data Report

NIWA Client Report: HAM2011-021
March 2011

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Executive Summary

Traditionally, indigenous New Zealand Māori had their own knowledge systems conveying how the environment contributed to health and well-being. Wild kai (food), gathered from the sea, rivers, and lakes, has always been of significant cultural, recreational and economic importance in both traditional and contemporary Māori society. Today, such resources are increasingly susceptible to contamination, as a consequence of urban expansion or land use changes in agricultural catchments. In the Te Arawa lakes region, naturally elevated levels of heavy metals occur as a consequence of geothermal activity and are also a significant source of contamination in kai. The impact of environmental contamination on the resident wild kai and, in turn, on Māori consuming them, however, has not been investigated to date.

Many toxic contaminants are stored in the lipids of biota and can biomagnify up through the food-chain increasing the risk of consuming higher predatory animals, such as eel and trout. Bioaccumulative contaminants that are of potential concern include organochlorine pesticides (DDTs, dieldrin and lindane), polychlorinated biphenyls (PCBs), pentachlorophenol, dioxins, polycyclic aromatic hydrocarbons (PAHs), and selected heavy metals such as mercury, arsenic, cadmium, lead, copper and zinc.

A survey of past and present kai consumption patterns was undertaken by questionnaire (kai consumption survey; n=19), to establish historic and contemporary consumption rates of key species. The levels of bioaccumulative contaminants were characterised in a number of commonly gathered kai species, as well as in associated aquatic sediments, from up to 23 sites throughout the Te Arawa rohe. In addition, hair samples were collected from questionnaire participants, as well as from a reference group (non Te Arawa, limited or no wild kai consumption, representative of the "average" New Zealand population) (n=29). These samples were analysed for mercury and selenium to provide a measure of human exposure to mercury; which was used as a "model" bioaccumulative contaminant.

Local average consumption rates of wild fish and invertebrate species ranged from 0.33 g/day for kakahi to 10.9 g/day for trout, whereas for watercress the calculated consumption rate was 15.8 g/day. The total average wild fish consumption rate was 12.4 g/day. The consumption rates of wild caught fish were a lot lower than the average New Zealand consumption rate for total fish (gathered and bought) of 32 g/day. In contrast, the average total fish consumption rate from our survey was much higher, at 97 g/day. This indicates that wild caught kai represents a relatively small proportion of the main source of aquatic food for the local community.

The average concentration of mercury in hair samples was 2.73 mg/kg and was higher than the study reference group and New Zealander's who consume 1-4 meals of fish per month. In comparison, it was much lower than previous studies in the geothermally-influenced Rotorua region, where concentrations as high as 39 mg/kg were recorded. Selenium concentrations were also higher compared with the reference group.

Highest total DDT (ΣDDT) concentrations (dry weight) were detected in trout from the Upper Puarenga Stream site (141 µg/kg), with high levels also in lakes Rotokakahi and Rotomahana. The concentrations of ΣDDT were generally much lower in eels. The highest concentrations of ΣDDT found in eels were from the Lower Kaituna River site (14 µg/kg). Other organochlorine pesticides were either below the limits of detection, or measured in much lower concentrations than any of the DDT congeners.

Mercury concentrations were generally highest in trout tissue, with the highest concentrations observed at the Upper Puarenga Stream site (19 mg/kg). The highest concentrations of mercury in koura were recorded from the Rotoiti East site (6.5 mg/kg). Arsenic, cadmium and nickel concentrations were highest in pipis and mussels collected from the Maketu site. Concentrations of arsenic and cadmium were higher in koura than in other freshwater kai species, while pipi and mussels recorded highest levels of all species sampled. Chromium was not detected in trout, koura or eels but was found in pipis and mussels at concentrations ranging from 3.2 to 11.0 mg/kg. Copper concentrations were higher in koura than any other species, with the highest concentrations ranging from 16 mg/kg in Lake Rotokakahi to 54 mg/kg in Lake Okareka. Highest concentrations of lead were recorded in smelt from the Lower Kaituna River. Zinc concentrations were highest in smelt collected from Lake Rotomahana (290 mg/kg), with high concentrations in kakahi (Lake Rotokakahi), whitebait (Lower Kaituna River) and watercress (Waiowhiro Stream, Rotorua) also.

Exceedance of ANZECC ISQG (interim sediment quality guidelines) low values was observed for arsenic and mercury at 55% of sites sampled and for cadmium at 10% of the sites. The ANZECC ISQG high guideline value for arsenic was exceeded at 15% of sites and at 25% of sites for mercury. Based on the ratio of sediment to tissue metal concentrations, bioaccumulation “hotspots” were identified at Maketu (for shellfish), the Lower Kaituna site (for whitebait) and the Ohau Channel (for smelt). The relative risk of consumption of kai collected from these sites, based on levels recorded and how much is normally consumed by iwi participants, is presented in a separate report.

1. Introduction

Traditionally, indigenous New Zealand Māori had their own knowledge systems conveying how the environment contributed to health and well-being. Wild kai (food), gathered from the sea, rivers, and lakes, has always been of significant cultural, recreational and economic importance in both traditional and contemporary Māori society. Levels of wild caught kai have declined steadily through time, due to lower abundance, concerns over contamination and easier access to store-bought fish etc. (Tipa et al. 2010a, Tipa et al. 2010b). Today such resources are increasingly susceptible to contamination, partly as a consequence of urban expansion or land use changes in agricultural catchments. In the Te Arawa lakes region, naturally elevated levels of heavy metals occur as a consequence of geothermal activity and are also a significant source of contamination in kai. While it could be argued that contamination of wild kai has the potential to have a direct impact on the physical health of Māori, the effect of contamination of an important cultural activity on wellbeing is also likely. Māori associate their well-being as individuals, and as members of family and tribal groups, with maintaining the health of the natural environment (Durie 1994, Durie 1998, Panelli & Tipa 2007, Panelli & Tipa 2008).

A recent review of wild food in New Zealand (Turner et al. 2005) identified gaps in the knowledge of contaminants in non-commercial wild-caught foods, especially in terms of consumption levels (and hence exposure). A resulting draft position paper (NZFSA 2005) identified the need for information and education on contaminants in kai. Prior to this study, the impact of environmental contamination on the resident wild kai and, in turn, on Māori consuming it, has not been investigated, although recent work has started to address this deficiency (Stewart, M. et al. 2010, Stewart, M et al. in press, Whyte et al. 2009). Furthermore, while existing consumptive advice is available for some kai species of relevance to Māori, this advice is based on average national consumptive patterns and doesn’t account for potentially higher consumption rates of specific types of kai traditionally harvested by Māori.

The majority of the international research in the area of contaminants in the traditional diets of indigenous peoples has primarily focused on the levels and health effects of exposure to heavy metals and organochlorine contaminants through the consumption of marine fish and mammals in the subsistence diets of indigenous people from the northern hemisphere, for example, the Northern Contaminants Programme (NCP) and the Effects on Aboriginals from the Great Lakes Environment (EAGLE) project. Research to date has shown that certain indigenous communities have elevated contaminant concentrations due to exposure through their traditional diet (Hoekstra et al. 2005, Johansen et al. 2004, Odland et al. 2003, Van Oostdam et al. 2003, Van Oostdam et al. 1999).

As many toxic contaminants are stored in the lipids of biota they can be biomagnified up the food-chain. It is unknown whether contemporary Māori communities have been exposed, through their diet of wild kai, to levels of bioaccumulative contaminants as high as those observed in indigenous populations residing in the northern hemisphere. While large mammals are unlikely to be a major source of contaminants in traditional Māori diets, eel is a popular food of Māori and large eels are often lipid rich with levels greater than 20% (Sumner & Hopkirk 1976).

Bioaccumulative contaminants that are of potential concern are organochlorine pesticides (DDTs, dieldrin and lindane), polychlorinated biphenyls (PCBs), pentachlorophenol and dioxins, polycyclic aromatic hydrocarbons (PAHs), as well as certain heavy metals such as mercury, arsenic, cadmium, lead, copper and zinc. New Zealand used a considerable amount of organochlorine pesticides from the 1940s to the 1970s. DDT, in particular, was used largely to control grass grubs and porina caterpillars, with its use restricted in 1970 and finally banned in 1989 (Taylor et al. 1997). Lakes encompassing a wide range of sizes and catchment areas are found in the Rotorua area. In many of these lakes the effects of volcanism is still felt, with locally hot bottom waters and modified water chemistry and associated biota (McColl 1975). Metals such as mercury and arsenic can also enter into the foodchain from elevated environmental levels from geothermal inputs associated with volcanism, when compared with non-geothermal lakes. Therefore levels in kai species are likely to be naturally higher from such lakes. Urban contamination can also result in increased levels of metals, especially through diffuse sources such as stormwater

The boundaries of the Te Arawa region covers a land area of approximately 905,000 hectares and which extend from Ngakuru (south of Rotorua) in the south, through the Rotorua lakes area, and down the Kaituna River to the sea at Maketu. Te Arawa arrived at Maketu around 1350 (Stafford 1967). Te Arawa is a confederation of iwi which are descended from the crew of the Arawa canoe. From Maketu the voyagers and their succeeding generations moved inland occupying the central part of the North Island. This means Te Arawa have resided in the Rotorua area for centuries and the lakes of the region were and remain taonga (treasures) for Te Arawa. They are the foundation of their identity, cultural integrity, wairua, tikanga and kawa. The lakes of the Rotorua district remain the centre of Te Arawa settlement. For centuries the lakes have also been the mainstay of their economy as the lakes and their margins were an important source of freshwater fish, invertebrates, waterfowl, and plants. The coastal areas around Maketu are also an important source of marine kai (kaimoana).

This report describes the results of a survey of sites traditionally associated with the gathering of kai by local Maori. The rohe of Te Arawa was selected because of potential contaminant issues associated with geothermal activity and increased urbanisation of many lake catchments. In addition, there has been an increase in interest in harvesting of traditional species associated, in part, with the Te Arawa settlement (and associated customary fisheries) (Parlimentary Commissioner for the Environment 2006), as well as renewed interest in traditional harvesting methods (Kusabs, I.A. & Quinn 2009). The levels of bioaccumulative contaminants were characterised in a number of commonly gathered animal and plant species, as well as in associated aquatic sediment samples. A similar study has also been conducted with the Arowhenua hapu in Temuka as part of our overall research project (Stewart, M. et al. 2010, Stewart, M et al. in press).

A companion report then uses a risk assessment approach, based on established US EPA formulae (US EPA 2000), to calculate consumption limits for the whole region by species and for each species at each site. The implications of these results for Māori and non-Māori communities are also discussed.

2. Methods

2.1 Survey design

Information on kai harvesting information (i.e., site and species) was collated from the results of focus groups and individual interviews with members of the indigenous Māori population (Te Arawa) (n=19) located in the Rotorua region. Analysis of this information allowed for the design of a sampling regime that characterised contaminant concentrations in kai of direct relevance to iwi participants and the associated environment (i.e., sediment). In addition, a survey of past and present consumption patterns was undertaken by questionnaire with this same group, to establish historic and contemporary consumption rates of key species. This questionnaire was adapted from a range of other studies (including diet surveys, fish consumption surveys, traditional use surveys, surveys of the health of indigenous communities and perception/preference surveys).

2.2 Kai consumption survey

The kai consumption survey aimed to characterise individual food consumption patterns (Appendix 1). Participants were asked to score the frequency of consumption of a range of foods purchased, along with those harvested from the wild. In addition, they were asked to identify the portion size of specific food types eaten per meal. Consumption frequency categories ranged from less than once per month to one or more times per day. Meal sizes were assessed using pictorial assessment of pre-weighed portion sizes of selected food groups (Table 1, refer to Appendix 1 for category descriptions).

Table 1: Meal sizes (g) for selected food groups.

Food group/Category	Less than A	A	Between A & B	B	Between B & C	C	More than C
Vegetables[1]	<50 (25)[2]	50	75	100	150	200	>200 (300)
Fish (any species)	50	100	150	200	300	400	>400 (450)
Mussels (fresh or marine)	<75 (50)	75	110	150	185	225	>225 (250)
Scallops	50	100	150	200	250	300	>300 (350)
Whitebait	<150 (75)	150	225	300	400	500	>500 (550)

[1] Also used to quantify water cress consumption.
[2] Values in parentheses indicate numbers used in calculations for larger and smaller than size portions.

2.3 Te Arawa consumption data

The kai consumption survey provided details of frequency of consumption and size of meals consumed. Using these data, consumption rates were calculated for individual participants and individual food groups. For the purposes of this study, we focused on total fish (all sources e.g., supermarket, takeaways and fishing), traditionally harvested fish (total of all species), as well as individual calculations for trout, koura, eel and watercress. Meal size was calculated using the pre-weighed portion allocations (Table 1). Frequency of consumption was calculated as number of times consumed per day, which was recorded as: special occasions (6 times/year) = 0.02; less than 1/month (9 times/year) = 0.03; 1-3 times/month = 0.07; 1/week = 0.13; 2/week = 0.27; 3-4 times/week = 0.47; 1/day = 1.0; 2/day = 2.0; 3/day = 3.0. Consumption rate (g/day) was then calculated as the amount consumed (g/meal) multiplied by frequency of consumption (number of times/day).

2.4 Sampling Design

2.4.1 Site and kai information

Kai harvest information from the individual interviews was compiled to determine the most popular kai gathering sites and species harvested most often, both historically and currently. This information is presented in Table 2. A number of kai species identified by the survey participants are no longer harvested. These are included in the footnote of Table 2.

Table 2: Kai harvest frequency information at individual sites in the Te Arawa rohe compiled from individual interviews.

Kai[a]	Rotorua	Rotoiti	Rotoma	Tarawera	Rotokakahi	Coast (incl Maketu)	Streams (incl Kaituna)	Ohau Channel	TOTAL
Trout	3	3		4	2	1	1	1	15
Koura	4	5	1	3				1	14
Pipi						9			9
Inanga (Whitebait)	1	4	1	1		1	1		9
Eel	1	3			1	2	1		8
Cockles						6			6
Tuatua						6			6
Kahawai						6			6
Kina						6			6
Paua						6			6
Mussels						6			6
Crayfish						6			6
Watercress	2	4							6
Snapper						6			6
Kakahi	1	3						1	5
Morihana (goldfish)	1	1	1	1	1				5
Puha	3	2							5

Kai[a]	Rotorua	Rotoiti	Rotoma	Tarawera	Rotokakahi	Coast (incl Maketu)	Streams (incl Kaituna)	Ohau Channel	TOTAL
Flounder						5			5
Tarakihi						5			5
Kingfish						4			4
Moki						4			4
Pupu (mudsnail)						2	1		3
Shark						3			3
Oysters						3			3
Hapuka						3			3
Gurnard						3			3
Trevally						3			3
Seaweed						2			2
Mullet						2			2
Lampreys						1			1
TOTAL	**16**	**25**	**3**	**9**	**4**	**101**	**4**	**3**	**162**

[a] Kai species for which sampling frequency from interviews was zero included butterfish, muttonbirds, greenbone, toheroa.

2.4.2 Contaminants of concern

A survey of the literature revealed a number of different types of contaminants that have previously been identified in the Te Arawa rohe. The contaminants and their potential sources are listed in Table 2.

Table 3: Potential sources of contamination in the Te Arawa rohe.

Contaminant	Potential source	Reference
Mercury, arsenic, boron, chloride	Geothermal activity (natural)	(Blomkvist & Lundstedt 1995, Brooks et al. 1976, Kim, J. & Burggraaf 1999a, Kim, J.P. 1995b, Robinson, B.H. et al. 1995, Weissberg & Zobel 1973)
PCPs, dioxin	Legacy of timber mill activities	(Gifford, J. S. et al. 1996, Gifford, J.S. et al. 1993, Gifford, J.S. et al. 1995)
zinc, copper, lead, cadmium	Stormwater	(Macaskill et al. 2003)
DDT	Insecticide use	(Solly & Shanks 1969)

2.4.3 Sampling sites and kai species

In part, because of the high costs of chemical analyses, the number of sites, the species collected from each site and the range of contaminants analysed had to be carefully planned and controlled to meet objectives of the project and budgets. Popular harvesting sites and/or those sites close to known areas of contamination were preferentially selected. Fig. 1 shows the location of these sites, while Table 4 presents further details of each site. The final selection was complied and finalised in consultation with the Te Arawa Lakes Trust. Sample collections were undertaken between September to November 2009, with repeat sampling at Maketu carried out in January 2010. Composite sediment samples were collected from all sites, at the time of biota collection.

Figure 1: Map of sampling sites in the Te Arawa region. Site locations are indicated by site name. See Table 4 for site details.

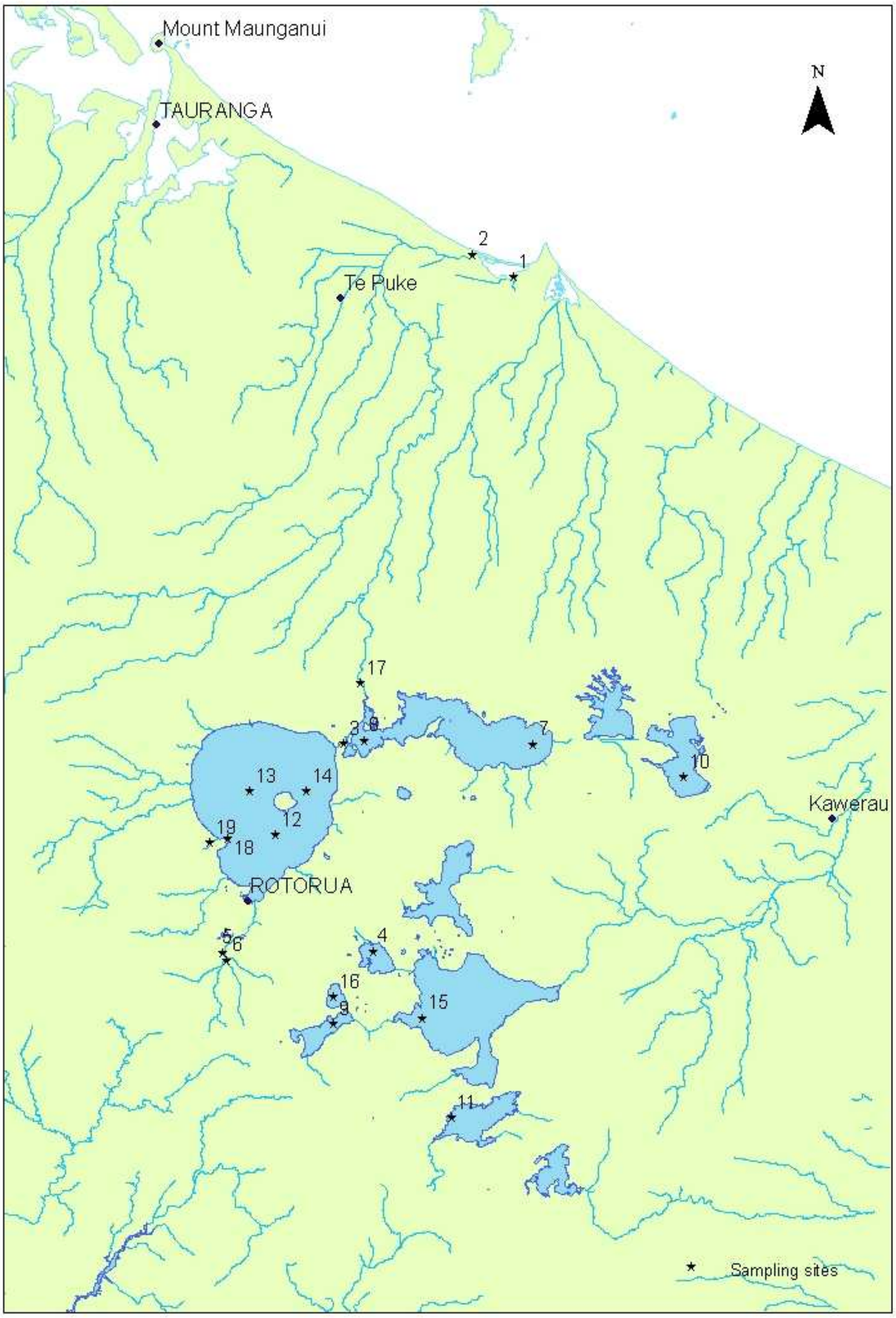


Table 4: Kai sampling sites and species from the Te Arawa rohe (n=1 unless otherwise stated).

Site ID (number on Figure 1)	Site location	Site name	GPS Coordinates	Samples obtained
2	Maketu Estuary	Maketu	E 2813700 N 6376450	Pipi[1] Sediment[2] Mussel[1]
1	Kaituna River Lower	Lower Kaituna	E 2811000 N 6377950	Whitebait[1] Sediment Smelt[1] Eel Trout
17	Kaituna River Upper	Upper Kaituna	E 2803600 N 6349550	Sediment Koura[1] Trout
3	Ohau Channel	Ohau Channel	E 2802500 N 6345550	Trout Sediment Koura[1] Smelt[1] Eel
10	Lake Rotoma	Rotoma	E 2824950 N 6343360	Trout Sediment Koura[1]
7	Lake Rotoiti 1	Rotoiti East	E 2811200 N 6345500	Trout Sediment Koura[1]
8	Lake Rotoiti 2	Rotoiti West	E 2809240 N 6347630	Sediment Koura[1] Smelt[1]
12	Lake Rotorua 2		E 2798000 N 6339500	Trout Sediment
13	Lake Rotorua 5		E 2796300 N 6342400	Sediment
14	Lake Rotorua 8		E 2800000 N 6342400	Koura[1] Sediment
18	Waiowhiro 1		E 2793250 N 6338540	Sediment Watercress
19	Waiowhiro 2		E 2794030 N 6339220	Sediment Watercress
1	Lake Okareka		E 2804400 N 6331800	Trout Koura[1] Sediment

Site ID (number on Figure 1)	Site location	Site name	GPS Coordinates	Samples obtained
5	Puarenga 1		E 2794515	Trout
			N 6331730	Sediment
6	Puarenga 2		E 2794750	Trout
			N 6331215	Sediment
16	Lake Tikitapu		E 2801800	Trout
			N 6328800	Koura[1]
				Sediment
15	Lake Tarawera		E 2807700	Trout
			N 6327400	Koura[1]
				Sediment
9	Lake Rotokakahi		E 2801800	Trout
			N 6327000	Koura[1]
				Smelt[1]
				Kakahi
				Sediment
11	Lake Rotomahana		E 2809600	Trout
			N 6320800	Smelt[1]
				Sediment

[1] Composite samples. See text for details.
[2] Composite sediment samples collected at each site.

2.5 Analysis of contaminants in kai and sediment

Organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs), were analysed using a procedure based on accelerated solvent extraction (ASE), gel permeation chromatography, silica/alumina column chromatography and gas chromatography-mass spectrometry (GC-MS), closely following the published methods of United States Environmental Protection Agency (US EPA 1977, US EPA 1986) and National Oceanic and Atmospheric Administration (NOAA 1993).

Quantitative analysis of PCBs and OCPs was carried out by capillary gas chromatography using a mass selective detector in selected ion mode (GC–MS–SIM), on an Agilent 6890 GC with 5975B MSD in splitless injection mode using a 30 m x 0.25 mm i.d. DB-5ms GC column with helium carrier gas. Final concentrations have been corrected for surrogate recoveries, with detection limits for individual OCPs ranging between 0.05-0.2 µg/kg dry weight and detection limits for PCBs ranging between 0.1-0.3 µg/kg dry weight. Detection limits of total congeners (e.g., ΣDDTs) were set at the highest detection limit of an individual congener from that series. Method performance was assessed by incorporating the analysis of in-house reference standards, standard reference material and GC check standards.

The analysis of metals in fish, watercress and sediment samples was carried out by a commercial laboratory (Hill Laboratories 2010), using IANZ accredited procedures involving acid digestion and analyses by ICP-MS. The analysis of pentachlorophenol (PCP) was carried out on sediments only.

All kai samples were analysed for eight selected heavy metals; arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn). In addition, trout and eel samples were analysed for a range of OCPs including DDT and DDT metabolites (p,p'-DDT, p,p'-DDE, p,p'-DDD and o,p isomers), chlordanes (cis/ & trans nonachlor, cis/ & trans chlordane) and chlordane metabolites (heptachlor, cis/ & trans heptachlor epoxide), hexachlorobenzene (HCB), lindane (γ-hexachlorocyclohexane or γ-HCH) and dieldrin. Eel and trout tissues were also analysed for selected PCBs (32 congeners ranging from PCB8 - PCB209). Watercress was analysed for the eight heavy metal contaminants only.

The full dataset of contaminant concentrations (based upon dry weights) is provided in Appendices 3a-3f. Moisture content, calculated from original dry weight/wet weight data, was used for subsequent wet weight corrections of analytical data.

2.6 Analysis of mercury in hair

We collected hair samples from participants of the kai consumption survey, as well as from a reference group (non-Te Arawa, limited or no wild kai consumption, representative of the "average" New Zealand population). These samples were analysed for mercury and selenium to provide a measure of human exposure to a "model" bioaccumulative contaminant (mercury). Selenium is known to be protective of the effects of mercury toxicity. Hair samples were collected using a standard protocol modified from Hill Laboratories (2000), Hamilton, New Zealand. Hair was cut from the nape of the neck at the back of the head so that the total hair sample corresponded to the thickness of a match (about 0.5 g). The strands were cut close to the scalp and aimed to be at least 6 cm long (if possible). To identify the direction that the hair had been growing, a cotton string was tied around the proximal end of the hair sample. Gloves were worn and a new pair used for each hair sample collection. The hair sample was collected into a pre-labelled sealed envelope or plastic bag after attachment of cotton. Hair treatments, such as bleaches and dyes, can extract elements from the hair, resulting in low concentrations. Information on what, if any, hair treatment had been applied, and how long ago was also gathered, along with gender, age, residential location and occupation.

Samples were subsequently sent to the University of Canberra, Australia, for analysis of mercury and selenium. Selenium was analysed, as high concentrations can offer protection from the effects of mercury (Berry & Ralston 2008). The analysis protocol involved initial weighing of the samples, freeze-drying and weighing again to assess moisture content. Samples were then weighed into a 7 mL Teflon (FEP) digestion bomb. Re-distilled analytical grade nitric acid (1 mL) HNO_3 was added to the samples. The bombs were then pressure capped, placed in a CEM Microwave oven and digested at approximately 150ºC for 45 minutes. After digestion, samples were diluted and analyzed by reaction cell-inductively coupled plasma mass spectrometry (DRC-ICPMS) for all relevant isotopes of Se and Hg. Any potential interference elements were also measured.

3. Results and discussion

3.1 Sampling

Twenty-four sites were surveyed and the following numbers of biota samples were collected: two long fin eel (*Anguilla dieffenbachii*); 14 rainbow trout (*Oncorhynchus mykiss*); one composite whitebait (*Galaxias* sp) (60 individuals); 10 composite koura (*Paranephrops planifrons*); six composite smelt (*Retropinna retriopinna*); two watercress (*Nasturtium officinale*); one composite mussel (*Perna canaliculus*); two composite pipi (*Paphies australis*); and one composite kakahi (*Echyridella menziesi*). Biometric data for each kai species is shown in Appendices 2a-2e, while sediment size proportion data are shown in Appendix 3f.

3.2 Te Arawa consumption data

Local average consumption rates of individual wild kai ranged from 0.33 g/day for kakahi (freshwater mussels) to 10.9 g/day for trout (Table 5). The total average consumption of traditionally harvested fish (eel and trout combined) of 12.41 g/day is much lower than the average New Zealand fish consumption rate of 32 g/day for total fish (traditional and non-traditional species) (Kim, N. & Smith 2006). It is higher than a comparable study recently undertaken in the Arowhenua rohe, where consumption rates for traditionally harvested species were 5.8 g/day (Stewart, M. et al. 2010). On the other hand, total fish consumption by Te Arawa (traditional and non-traditional) is 97.0 g/day, which was much higher than the New Zealand value (Table 5). This result suggests that wild caught fish represents only a small proportion of the total fish consumption by the local community that we surveyed. Watercress consumption was calculated at 15.8 g/day and was again much lower than the proposed average consumption rate of 33 g/day for consumers of watercress (Golder Associates and NIWA 2009). The maximum local consumption rates of eel (93.3 g/day) and trout (40 g/day) (Table 5) are above the average New Zealand fish consumption rate for total fish (32 g/day). Comparable rates for the Arowhenua iwi were 20 g/day and 13.3 g/day for eel and trout respectively.

Table 5: Consumption rates (g/day) for different food categories.

Measure	Food category					Traditionally harvested fish species			
	Watercress	Mussels[1]	Koura	Whitebait	All fish[2]	Total[3]	Eel	Trout	Kakahi
Mean	15.77	16.96	2.53	5.65	97.04	12.41	9.61	10.88	0.33
Median	7.33	5.00	3.13	2.50	80.00	5.00	5.00	5.00	0.00
Minimum	1.25	0.74	0.00	0.00	2.50	1.67	0.00	0.00	0.00
Maximum	90.00	86.33	12.50	70.00	303.33	95.00	93.33	40.00	2.50

[1] Marine and freshwater (kakahi) species.
[2] Includes all sources (e.g., supermarket, takeaways, restaurant).
[3] Traditionally harvested species only.

3.3 Mercury in hair

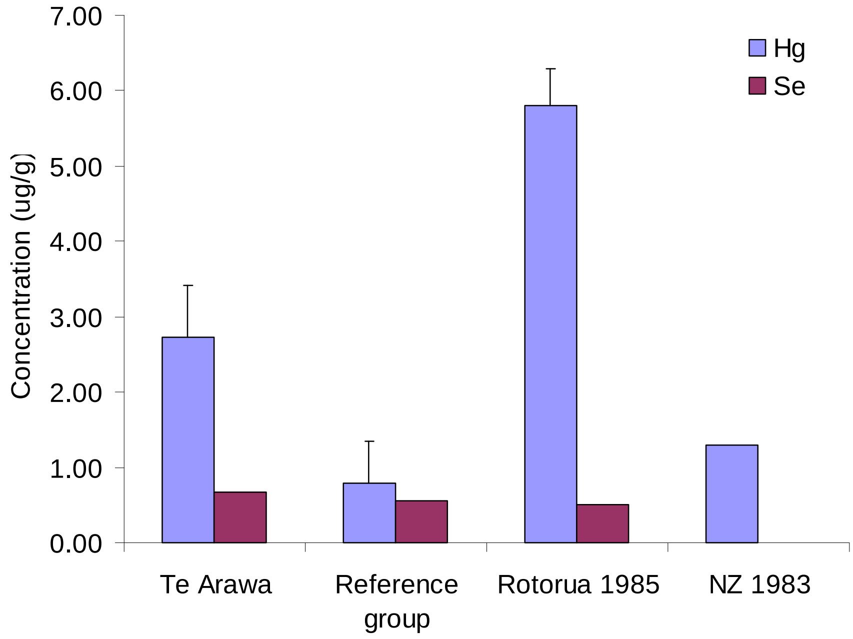
The concentrations of selenium and mercury (on a dry weight basis) for 12 of the 18 participants are presented in Table 6. Insufficient sample was obtained from 6 participants. The average concentration of mercury (2.7 mg/kg) was higher and more variable than that found for the study reference group (0.80 mg/kg) (Figure 2, n=29) or for New Zealanders who consume 1-4 fish meals per month (Airey 1983). However, it was much lower than a previous study in the geothermally-influenced Rotorua region (Siegel & Siegel 1985), where concentrations as high as 39 mg/kg were recorded. Selenium levels were similar (mean = 0.68 mg/kg) to those measured in the reference group (mean = 0.56 mg/kg) (Figure 4).

Table 6: Concentrations (µg/g, dry weight) of mercury (Hg) and selenium (Se) in hair samples from Te Arawa participants.

Participant #	Age	Se (mg/kg)	Hg (mg/kg)
1	52	0.01	0.25
4	25	0.64	0.64
5	73	0.60	0.60
6	56	0.69	0.85
7	33	1.40	0.87
8	41	0.47	1.15
9	54	0.47	1.32
10	60	0.68	0.79
11	63	0.81	0.01[1]
12	36	0.55	2.64
13	40	0.59	6.07
17	70	0.33	2.53
Mean	48.92	0.68	2.73
Median	44.00	0.55	2.73
Minimum	33.00	0.33	0.01
Maximum	70.00	1.45	8.66

[1] low level may be indicative of small sample size.

Figure 2: Mercury and selenium concentrations in hair of Te Arawa participants and the study reference group.



3.4 Te Arawa Contamination Data

All kai contaminant data (biota and sediment samples) are reported on a dry weight basis.

3.4.1 Organochlorine Pesticides

Muscle tissue concentrations of total polychlorinated biphenyls (PCBs) (29 congeners), ΣDDT (which comprises p,p'-DDT + o,p'-DDT + p,p'-DDE + o,p'-DDE + p,p'-DDD + o,p'-DDD), total chlordanes (sum of 6 congeners), hexachlorobenzene (HCB), lindane and dieldrin are shown for trout and eels (Table 7).

The highest concentrations of ΣDDT (generally >85% of which is pp'-DDE) for trout was recorded for Upper Puarenga Stream (141 ug/kg), with high levels also recorded from Lake Rotokakahi (78 µg/kg) and Lake Rotomahana (32 µg/kg). Concentrations of pDDE in trout ranging from 1.82-73.9 ug/kg (wet weight) have been recorded from New Zealand streams (Buckland et al. 1998). The concentrations of ΣDDT in eel (Table 7) were lower than for trout at comparable sites (n=2), with the highest concentration in eels being from the lower Kaituna River (14 µg/kg). Levels ranging from 0.67-155 µg/kg have been reported from a study of eels throughout New Zealand (Buckland et al. 1998), while levels ranging from 0.15–153.34 µg/kg wet weight have been recorded elsewhere (Ferrante et al. 2010), suggesting that the levels recorded from our study are low. Other organochlorine pesticides were either undetected or detected in much lower levels than any of the DDT congeners (Table 7). Chlordane concentrations ranged from <0.2 – 2.1 µg/kg, with the highest concentration recorded in trout from the Ohau Channel (2.1 µg/kg) (Table 7). Dieldrin concentrations ranged from <0.2 – 0.6 µg/kg, with highest levels again recorded from the Ohau Channel in both trout and eels (0.6 µg/kg for both species). Dieldrin concentrations of 0.021-1.12 µg/kg and 0.24-11.4 µg/kg have been recorded for trout and eels from throughout New Zealand, respectively (Buckland et al. 1998).

HCB concentrations ranged from <0.1 – 0.65 µg/kg in trout and <0.1 – 0.14 µg/kg in eels (Table 7). Highest levels were recorded in trout from the Ohau Channel, lakes Rotorua, Rotoiti and Tikitapu. Concentrations ranging from <0.01-0.17 µg/kg have been recorded for New Zealand trout (Buckland et al. 1998). Lindane was not detected in any biota sample (limit of detection 0.2 µg/kg). Concentrations of 2.50–25.48 µg/kg have been recorded from European eels (Ferrante et al. 2010), while concentrations ranging from <0.01-0.083 µg/kg have been recorded for New Zealand eels (Buckland et al. 1998).

PCBs were analysed in trout and eel. Total concentrations ranged from 0.41 – 41.63 µg/kg (Table 6) in trout, with the highest level at the Upper Puarenga Stream site (41.63 µg/kg). Concentrations ranging between 0.2-0.5 µg/kg have been recorded fro New Zealand trout (Buckland et al. 1998). Levels in eels were lower, ranging from 1.09 – 2.07 µg/kg. These values are within the range of 1.29-18.5 µg/kg (wet weight) recorded for New Zealand eels (Buckland et al. 1998) and much lower than values from international studies (e.g., 980 – 6300 µg/kg for Canadian eels (Castonguay & Dutil 1989) or 37.12–518.32 µg/kg for European eels (Ferrante et al. 2010)).

Table 7: Organochlorine concentrations in trout and eel tissue (µg/kg dry weight) collected from each individual site (n=1).

Site	Total DDT	Total Chlordane	HCB	Lindane	Dieldrin	Total PCB
Trout						
Lower Kaituna	23	0.1	0.14	< 0.2	< 0.2	3.23
Ohau Channel	21	2.1	0.53	< 0.2	0.6	6.60
Okareka	6.6	<0.1	0.13	< 0.2	< 0.2	0.86
Puarenga Stream Lower	4	<0.1	0.34	< 0.2	< 0.2	0.84
Puarenga Stream Upper	141	<0.1	0.17	< 0.2	0.4	41.63
Rotokakahi	78	<0.1	0.14	< 0.2	0.3	1.39
Rotoiti	6	<0.1	0.47	< 0.2	0.2	1.33
Rotoma	3.7	<0.1	0.19	< 0.2	< 0.2	1.16
Rotomahana	32	<0.1	0.17	< 0.2	< 0.2	0.75
Rotorua	14	1.1	0.55	< 0.2	0.5	6.42
Tarawera	4.6	<0.1	0.32	< 0.2	< 0.2	0.41
Tikitapu	23	<0.1	0.65	< 0.2	0.4	4.84
Upper Kaituna	20	0.4	< 0.1	< 0.2	< 0.2	4.59
Eels						
Lower Kaituna	14	<0.1	< 0.1	< 0.2	< 0.2	1.09
Ohau Channel	7.9	0.3	0.14	< 0.2	0.6	2.07

3.4.2 Heavy Metals

Biota

Total concentrations of eight heavy metals; arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn), were measured in all fish, invertebrate, watercress, and sediment samples collected.

Mercury concentrations were generally highest in trout, with a median value of 4.10 mg/kg and a range of 0.19 – 19 mg/kg (Table 8), with Puarenga Stream Upper recording the highest value. The Puarenga Stream is heavily influenced by natural geothermal inputs at Whakarewarewa thermal area (and at Ngapuna) and the water is warm, acidic and enriched with heavy metals (Kusabs & Shaw 2008). (Kim, 1995a) reported methyl mercury levels in trout ranging from 0.07 to 4.13 mg/kg from various Rotorua lakes (most of the mercury is likely to be present as methyl mercury (Redmayne et al. 2000). Median mercury concentrations in koura were 0.194 mg/kg (with a range of 0.77 – 6.5 mg/kg) (Table 9), 0.104 mg/kg in smelt (range of 0.096 – 1.6 mg/kg) and 0.615 mg/kg in eel (range of 0.71 – 3.8 mg/kg) (Table 10) and undetectable in watercress (<0.010 mg/kg). Few studies directly report mercury concentrations in these species, although (Redmayne et al. 2000) reported methyl mercury concentrations of between 0.8 and 5.0 mg/kg for eels from South Island rivers. Levels in koura ranged between 0.024 and 0.156 mg/kg in geothermally influenced lakes in the Rotorua district (Kim & Burggraaf 1999b). Levels up to 0.4 mg/kg in smelt have also been reported (Kim & Burggraaf 1999b). A single whitebait sample from the Lower Kaituna in our study recorded a value of 0.073 mg/kg (Table 10). Fenaughty et al. (1988) recorded values of 0.1 – 0.3 mg/kg from the West Coast of the South Island. Pipis and mussels in our study recorded mercury at median values of 0.086 mg/kg and a value of 0.030 mg/kg for a single mussel sample, respectively (Table 10). Comparable results for mussels have been reported from the Bay of Islands (0.01 – 0.06 mg/kg) (Whyte et al. 2009). Background levels have been estimated as 0.02 mg/kg in pipi and 0.02 mg/kg in green-lipped mussels (Hoggins & Brooks 1973).

Arsenic levels were highest in pipis and mussels collected from Maketu (median of 11 mg/kg, range of 9.7 – 13.0 mg/kg) (Table 11). Pipis from Maketu analysed as part of Bay of Plenty Council's shellfish surveillance programme recorded lower levels (0.88 mg/kg) (Scholes 2010). Levels in mussels from the Bay of Islands range between 1.56 and 2.97 mg/kg wet weight) (Whyte et al. 2009). High arsenic levels were also recorded for koura from Lake Tarawera (7.8 mg/kg) (Table 9) and for whitebait from the Lower Kaituna (4.4 mg/kg) (Table 10). In comparison, the watercress sample had relatively low levels of arsenic (1.1 mg/kg) from the one site it was collected (Waiowhiro), with eels and trout tissue having even lower levels (Tables 10 and 8). Arsenic levels in watercress are well below those reported in other studies of geothermal waters (Robinson et al. 2006), where levels up to 138 mg/kg wet weight have been reported.

Cadmium concentrations were again highest in pipis (median of 0.44, range of 0.42 - 0.46 mg/kg) and mussels (0.49 mg/kg) (Table 11), with koura from lakes Tikitapu and Rotoma also recording high levels (median of 0.011, range of 0.003 - 0.12 mg/kg). Mussels from elsewhere in New Zealand have recorded concentrations between 0.09 and 0.75 mg/kg (Whyte et al. 2009). Levels in watercress, smelt and eels were similar. Levels in trout (<0.002 – 0.0056) were much lower than for other fish species. Levels in eels from Lake Ellesmere (South Island) have been reported between 0.01 – 0.07 mg/kg (Fenaughty et al. 1988).

Chromium was not detected in trout, koura or eel, but was recorded in pipis (median of 10 mg/kg, range of 3.2 – 11 mg/kg) and mussels (11 mg/kg) and in watercress (0.59 mg/kg), whitebait (0.25 mg/kg) and smelt (median of 0.55, range of 0.12 – 1.0 mg/kg). Pipis from Maketu analysed as part of Bay of Plenty Council's shellfish surveillance programme recorded lower levels (0.05 mg/kg wet weight) (Scholes 2010). Levels between 25 and 28 mg/kg have been reported for watercress (Edmonds & Hawke 2004)

Copper levels were much higher in koura than in any other species, with a median of 29 mg/kg and a range of 16 – 54 mg/kg, with highest levels recorded in Lake Okareka (Table 9). In comparison, highest levels of other species were: trout (2.1 mg/kg from Upper Puarenga Stream), smelt (3.2 mg/kg from Lake Rotomahana), watercress (5.3 mg/kg) and eel (1.4 mg/kg from Ohau Channel). Levels in pipis and mussels ranged between 3.9 and 5.4 mg/kg and were much higher than those reported as part of Bay of Plenty Council's shellfish surveillance programme (0.5 mg/kg wet weight) (Scholes 2010). Watercress from streams in Wellington reported levels between 0.32 and 1.01 mg/kg wet weight (Edmonds & Hawke 2004)

Highest lead concentrations were recorded from whitebait (0.55 mg/kg) and smelt (median of 0.10 mg/kg, range of 0.059 – 0.83 mg/kg). Lead levels in watercress were also high (0.38 mg/kg). In comparison, highest levels in koura were 0.063 mg/kg (Lake Rotoma), 0.013 mg/kg in eel (Ohau Channel) and were near detection limits (0.01 mg/kg) in trout. Levels between 0.01 and 0.52 mg/kg wet weight have been reported in watercress from Wellington streams (Edmonds & Hawke 2004). Comparative values for eels from lake Ellesmere are between 0.06 and 0.20 mg/ kg (Fenaughty et al. 1988). Levels ranging from 0.08 – 0.18 mg/kg (pipis) and 0.46 mg/kg (mussels) were recorded in our study. Pipis from Maketu analysed as part of Bay of Plenty Council's shellfish surveillance programme were lower (0.022 mg/kg wet weight) (Scholes 2010).

Nickel was below the level of detection in trout, koura or eel samples. Highest levels were recorded in mussel (8.1 mg/kg) and pipi samples collected from Maketu (range of 3.0 - 7.2 mg/kg). Lower levels (0.18 mg/kg wet weight) of nickel were reported in pipis from Maketu analysed as part of the Bay of Plenty Council's shellfish surveillance programme recorded (Scholes 2010). Smelt and whitebait also recorded higher levels (maximum of 0.77 and 0.54 mg/kg, respectively), as did watercress (0.24 mg/kg). Levels between 0.05 and 0.24 mg/kg wet weight have been reported in watercress from Wellington streams (Edmonds & Hawke 2004).

Zinc concentrations were highest in smelt collected from Lake Rotomahana (290 mg/kg), with high levels also in kakahi (170 mg/kg), whitebait (130 mg/kg and watercress (120 mg/kg). This is a remotely located lake and the source of zinc is therefore not anticipated to be from stormwater runoff, which might be expected in a more urbanised catchment. Koura from Lake Okareka recorded concentrations up to 110 mg/kg. Eel, trout, mussel and pipi samples were relatively low in zinc (Tables 8-11). Zinc levels in pipis from Maketu recorded lower levels (4.3 mg/kg wet weight) in a recent shellfish surveillance survey (Scholes 2010). Levels between 2.26 and 24.00 mg/kg wet weight have been reported in watercress from Wellington streams (Edmonds & Hawke 2004).

When all metals were considered, high concentrations were most commonly recorded for trout in Lake Rotoma, Puarenga Lower, Lake Rotoiti and the Upper Kaituna site. For koura, both sites in Lake Rotoiti, the Upper Kaituna site, the Ohau Channel and Lake Okareka most commonly recorded high levels of metals.

Sediments

Sediment heavy metal concentrations for the sites where kai was harvested in this study were compared with the Australian and New Zealand Environment Conservation Council (ANZECC) Interim Sediment Quality Guidelines (ISQG) (ANZECC 2000) (Table 11). Low and high ISQG have been set by ANZECC, corresponding to the effects range-low and effects range-median adapted from Long et al (1995). The low ISQG value of 20 mg/kg for arsenic was exceeded at a number of sites and the high ISQG value of 70 mg/kg was exceeded at lakes Rotomahana, Rotorua (site 5) and Tarawera (Table 12). The low ISQG value for mercury was also exceeded at a number of sites, and the high ISQG value was exceeded in lakes Rotoiti (both sites) and Rotomahana (Table 12). The ISQG value for cadmium was also exceeded in Lake Rotomahana.

Table 8: Metal concentrations in trout (mg/kg dry weight) by individual site.

Site/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Lower Kaituna	0.22	< 0.0020	< 0.10	1	< 0.010	11	< 0.10	18
Ohau Channel	0.23	< 0.0020	< 0.10	2	< 0.010	5.7	< 0.10	18
Okareka	0.28	< 0.0020	< 0.10	1.2	< 0.010	2.2	< 0.10	16
Puarenga Lower	0.57	0.0033	< 0.10	0.76	< 0.010	0.19	< 0.10	22
Puarenga Upper	0.12	0.0045	< 0.10	2.1	0.01	19	< 0.10	55
Rotoiti	0.15	< 0.0020	< 0.10	0.94	< 0.010	5.1	< 0.10	13
Rotokakahi	0.53	< 0.0020	< 0.10	0.61	< 0.010	0.83	< 0.10	9.3
Rotoma	0.19	0.0056	< 0.10	0.68	< 0.010	1	< 0.10	16
Rotomahana	0.28	< 0.0020	< 0.10	1	< 0.010	8.4	< 0.10	17
Rotorua	< 0.10	< 0.0020	< 0.10	0.83	< 0.010	4.1	< 0.10	13
Tarawera	0.33	< 0.0020	< 0.10	0.64	< 0.010	0.27	< 0.10	13
Tikitapu	< 0.10	< 0.0020	< 0.10	1.2	< 0.010	0.56	< 0.10	12
Upper Kaituna	0.11	< 0.0020	< 0.10	1	< 0.010	7.1	< 0.10	19

Table 9: Metal concentrations in koura (mg/kg dry weight) by individual site.

Site/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Okareka	4.5	0.073	< 0.10	54	0.022	0.45	< 0.10	110
Rotoiti East	4.7	0.012	< 0.10	39	0.02	6.5	< 0.10	100
Tarawera	7.8	0.040	< 0.10	28	< 0.010	0.43	< 0.10	90
Ohau Channel	4.6	0.0087	< 0.10	20	0.028	3.5	< 0.10	86
Rotoma	6.2	0.110	< 0.10	28	0.063	0.41	< 0.10	71
Rotokakahi	1.3	0.0027	< 0.10	16	< 0.010	0.77	< 0.10	71
Tikitapu	1.3	0.120	< 0.10	35	0.033	0.23	< 0.10	69
Upper Kaituna	2.9	0.009	< 0.10	38	< 0.010	2.9	< 0.10	68
Rotoiti West	5	0.009	< 0.10	30	0.012	2.7	< 0.10	59
Rotorua East	4.4	0.0062	< 0.10	26	< 0.010	1.3	< 0.10	58

Table 10: Metal concentrations in smelt, whitebait, eel, kakahi and watercress (mg/kg dry weight) by individual site.

Site/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Whitebait								
Lower Kaituna	4.4	0.083	0.25	2.7	0.55	0.073	0.36	120
Smelt								
Lower Kaituna	1.3	0.032	0.12	2.5	0.83	0.3	0.26	170
Ohau Channel	0.6	0.0089	1	1.7	0.069	1.2	0.77	190
Rotomahana	1.9	0.044	0.8	3.2	0.22	1.6	0.69	290
Rotoiti West	1.6	0.015	0.25	2	0.059	1	0.12	190
Rotokakahi	0.77	0.0077	0.55	1.6	0.1	0.096	0.33	190
Eel								
Lower Kaituna	0.88	0.033	< 0.10	1	0.012	0.71	< 0.10	51
Ohau Channel	0.35	0.0023	< 0.10	1.4	0.013	3.8	< 0.10	54
Kakahi								
Rotokakahi	12	0.19	0.65	4.9	0.3	0.11	0.36	170
Watercress								
Waiowhiro	1.1	0.061	0.59	5.3	0.38	< 0.010	0.24	120

Table 11: Metal concentrations in pipis and mussels from Maketu (mg/kg dry weight). Replicate sampling is indicated in brackets.

Site/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Pipi (1)	13.0	0.44	11	5.4	0.11	0.11	6.6	63
Pipi (2)	11	0.42	10	5.3	0.18	0.086	7.2	65
Pipi (3)	9.7	0.46	3.2	4.7	0.084	0.057	3.0	54
Mussel (2)	7	0.49	11	3.9	0.46	0.16	8.1	67

Table 12: Metal concentrations in sediment (mg/kg dry weight) from individual sites in the Te Arawa Region with the ANZECC-ISQG guidelines as reference (ANZECC 2000). Levels exceeding the ISQG-low are underlined, those exceeding ISQG- high are in **bold**.

Site/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Lower Kaituna	14	0.023	0.82	1.3	2.4	0.052	0.32	17
Maketu	3.7	< 0.010	1.9	0.67	1.5	0.026	1.2	9.7
Ohau Channel	<u>25</u>	0.041	1.7	2	2.4	<u>0.51</u>	0.82	26
Okareka	<u>63</u>	0.14	2.8	8.6	18	0.11	1.5	53
Puarenga Downstream	13	0.053	2.8	2.9	5.4	0.025	0.67	31
Puarenga Upstream	15	0.067	2.1	3.2	5.2	0.033	0.82	32
Rotoiti Site1	<u>59</u>	0.066	1.6	4.8	3.4	**1.7**	0.87	32
Rotoiti Site2	<u>54</u>	0.046	1.2	4.3	3	**1.9**	0.8	26
Rotokakahi	19	0.081	3.2	4.5	9.6	0.07	1.6	32
Rotoma	<u>68</u>	0.51	2.7	8.4	18	<u>0.19</u>	1.9	55
Rotomahana	**260**	0.19	18	12	5.7	**1.8**	2	35
Rotorua Site 2	<u>64</u>	0.11	7	9	11	<u>0.85</u>	1.6	51
Rotorua Site 5	**95**	0.095	5.2	8.6	7.1	<u>0.78</u>	1.4	51
Rotorua Site 8	<u>52</u>	0.098	5.5	8.2	7.6	<u>0.81</u>	1.4	49
Sulphur Point 1	1.9	0.012	1.3	5.7	8.4	**1.2**	0.34	12
Sulphur Point 2&3	<u>55</u>	0.08	3.3	8.5	6.4	**5.3**	0.59	20
Tarawera	**880**	<u>2.5</u>	1.4	4.3	5.5	<u>0.15</u>	1.6	58
Tikitapu	14	0.09	2.7	7.3	26	0.12	1.7	52
Upper Kaituna River	8	0.016	0.82	1	1.8	0.039	0.36	17
Waiowhiro	16	0.21	6.4	14	29	0.083	1.6	130
ANZECC ISQG-Low	<u>20</u>	<u>1.5</u>	<u>80</u>	<u>65</u>	<u>50</u>	<u>0.15</u>	<u>21</u>	<u>200</u>
ANZECC ISQG-High	**70**	**10**	**370**	**270**	**220**	**1**	**52**	**410**

3.4.3 Evidence for bioaccumulation

The ratio of sediment to biota tissue contaminant levels can provide insight into whether or not bioaccumulation is occurring, thereby potentially representing a significant risk to consumers. Species are exposed to contaminants via a number of pathways, including through food consumption (directly through prey consumption, filtering particles from the water column or direct ingestion of sediment). If contaminant levels in biota are greater than that recorded in sediment, this suggests bioaccumulation is occurring, although without examining levels in water and food sources at the same time, it's not possible to determine what the major contaminant source is. However, such a comparison is useful for identifying "hotspots" of contamination for further investigation.

Table 13 presents the results of this analysis. All sites recorded accumulation of at least some metals (tissue/sediment ratios of greater than 1). It is evident that the Maketu site is a contaminant hotspot, with ratios greater than 1 for almost all (87%) metals in both pipis and mussels. Lead was the only metal not found to be bioaccumulated. Cadmium was the most highly accumulated. The Lower Kaituna site is also suggested as a hotspot, in particular for whitebait, with accumulated cadmium, copper, mercury, nickel and zinc. Smelt from the Ohau Channel also appears to be a hotspot.

Table 13: Ratios of biota to sediment metal concentrations for species collected from each site in the Te Arawa rohe. Numbers in bold indicate ratios greater than 1.

Site and species/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Proportion of biota: sediment ratios>1
Waiowhiro									
Watercress	0.069	0.290	0.092	0.379	0.013	0.060	0.150	0.923	0
Maketu									
Pipi (1)	**3.51**	**88.00**	**5.79**	**8.06**	0.07	**4.23**	**5.50**	**6.49**	87.5
Pipi (2)	**2.97**	**84.00**	**5.26**	**7.91**	0.12	**3.31**	**6.00**	**6.70**	87.5
Pipi (3)	**2.62**	**92.00**	**1.68**	**7.01**	0.06	**2.19**	**2.50**	**5.57**	87.5
Mussel	**1.89**	**98.00**	**5.79**	**5.82**	0.31	**6.15**	**6.75**	**6.91**	87.5
Lower Kaituna									
Whitebait (1)	0.31	**3.61**	0.30	**2.08**	0.23	**1.40**	**1.13**	**7.06**	62.5
Whitebait (2)	**1.08**	**9.20**	0.33	**4.48**	0.49	**3.54**	0.45	**13.40**	62.5
Smelt	0.09	**1.39**	0.15	**1.92**	0.35	**5.77**	0.81	**10.00**	50
Trout	0.02	0.04	0.06	0.77	0.00	**211.54**	0.16	**1.06**	25
Eel	0.06	**1.43**	0.06	0.77	0.01	**13.65**	0.16	**3.00**	37.5
Ohau Channel									
Koura	0.18	0.21	0.03	**10.00**	0.01	**6.86**	0.06	**3.31**	37.5
Smelt	**25.00**	0.04	**1.70**	**2.00**	**2.40**	0.51	0.82	**26.00**	62.5
Trout	0.01	0.02	0.03	**1.00**	0.00	**11.18**	0.06	0.69	12.5
Eel	0.01	0.06	0.03	0.70	0.01	**7.45**	0.06	2.08	25
Rotomahana									
Trout	0.00	0.01	0.00	0.08	0.00	**4.67**	0.03	0.49	12.5
Smelt	0.01	0.23	0.04	0.27	0.04	0.89	0.35	**8.29**	12.5
Rotoiti									
Koura (east)	0.09	0.26	0.04	**9.07**	0.01	**3.42**	0.06	**3.85**	37.5
Koura (west)	0.08	0.14	0.03	**6.25**	0.00	**1.59**	0.06	**1.84**	37.5
Smelt	0.03	0.23	0.16	0.42	0.02	0.59	0.14	**5.94**	12.5
Trout	0.00	0.02	0.03	0.20	0.00	**3.00**	0.06	0.41	12.5

Site and species/Metal	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	Proportion of biota: sediment ratios>1
Rotokakahi									
Kakahi	0.63	**2.35**	0.20	**1.09**	0.03	**1.57**	0.23	**5.31**	50
Smelt	0.04	0.10	0.17	0.36	0.01	**1.37**	0.21	**5.94**	25
Koura	0.07	0.03	0.02	**3.56**	0.00	**11.00**	0.03	**2.22**	37.5
Trout	0.03	0.01	0.02	0.14	0.00	**11.86**	0.03	**0.29**	12.5
Okareka									
Koura	0.07	0.52	0.02	**6.28**	0.00	**4.09**	0.03	**2.08**	37.5
Trout	0.00	0.01	0.02	0.14	0.00	**20.00**	0.03	0.30	12.5
Rotoma									
Koura	0.09	0.22	0.02	**3.33**	0.00	**2.16**	0.03	**1.29**	37.5
Trout	0.00	0.01	0.02	0.08	0.00	**5.26**	0.03	**0.29**	12.5
Rotorua									
Koura (east)	0.07	0.06	0.01	**2.89**	0.00	**1.53**	0.03	**1.14**	37.5
Trout	0.00	0.00	0.01	0.10	0.00	**5.97**	0.03	0.32	12.5
Tarawera									
Koura	0.01	0.02	0.04	**6.51**	0.00	**2.87**	0.03	**1.55**	37.5
Trout	0.00	0.00	0.04	0.15	0.00	**1.80**	0.03	0.22	12.5
Tikitapu									
Koura	0.09	**1.33**	0.02	**4.79**	0.00	**1.92**	0.03	**1.33**	50
Trout	0.00	0.01	0.02	0.16	0.00	**4.67**	0.03	0.23	12.5
Upper Kaituna									
Koura	0.36	0.56	0.06	**38.00**	0.00	**74.36**	0.14	**4.00**	37.5
Trout	0.01	0.06	0.06	1.00	0.00	**182.05**	0.14	**1.12**	25
Puarenga Lower									
Trout	0.04	0.06	0.02	0.26	0.00	**7.60**	0.07	0.71	12.5
Puarenga Upper									
Trout	0.01	0.07	0.02	0.66	0.00	**575.76**	0.06	**1.72**	25

4. Conclusions

This report is the first part of two reports collectively used to determine the human health risk to local Māori of eating wild harvested kai (food) in the rohe of Te Arawa. Part one (this report) describes the results of a survey of contaminants in kai species from important kai gathering locations, identified directly by participants from the Te Arawa iwi. This project is part of a larger research programme aimed at determining the potential risks to iwi associated with consumption of wild kai. Key findings from this report are:

- overall fish consumption by participants was similar to the average New Zealand high consumption rate

- traditionally harvested fish formed only a small component of overall fish consumption

- mercury and selenium levels measured in hair samples from 12 participants were slightly higher than the study reference group (representative of a group for whom wild kai is a negligible component of their diets and who live outside the study area), but lower than previous studies in the Rotorua District

- contaminant analysis indicated differential uptake of specific contaminants by different species. For example, pipis and mussels recorded much higher levels of arsenic, cadmium, nickel, chromium and lead than other species. Trout recorded higher levels of DDT, PCBs and mercury than other species

- the Upper Puarenga Stream site, as well as Ohau Channel and Rotoiti sites, consistently reported high levels of a number of contaminants; in sediment and biota

- pipis and mussels from Maketu also recorded high levels of some metals

- hotspots for bioaccumulation of metals included Maketu (for shellfish),the Lower Kaituna site (for whitebait) and the Ohau Channel site (for smelt).

The overall aim of this project was to determine the relative risk of consumption of kai species from sites where they have been harvested. The contaminant data and consumption rates presented in this report form the basis for a risk assessment, which is presented in a separate report (Phillips et al. 2011). That report also includes a discussion of the implications of these results for Māori and non-Māori consumers of wild kai.

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7. Abbreviations

ANZECC	Australian and New Zealand Environmental Conservation Council.
ASE	accelerated solvent extraction.
DDD	dichlorodiphenyldichloroethane.
DDE	dichlorodiphenyldichloroethylene.
DDT	dichlorodiphenyltrichloroethane.
DRC-ICPMS	dynamic reaction cell-inductively coupled plasma mass spectrometry.
EAGLE	Effects on Aboriginals from the Great Lakes Environment.
γ-HCH	gamma-hexachlorocyclohexane or lindane.
GC-MS	gas chromatography - mass spectrometry.
SIM	selected ion mode.
HCB	hexachlorobenzene.
ICP-MS	inductively coupled plasma mass spectrometry.
ISQG	interim sediment quality guidelines.
kg	kilograms
mg	milligrams
mm	millimetres
NCP	Northern contaminants programme.
PCB	polychlorinated biphenyl.

PCP	pentachlorophenol
ppb	parts per billion = μg/kg.
ppm	parts per million = mg/kg.
TOC	total organic carbon.
μg	microgram (i.e., 10^{-6} g).
US EPA	United States Environmental Protection Agency.

8. Glossary

Anthropogenic	Effects, processes, or materials that are derived from human activities.
Aquatic	Dwelling in water.
Bioaccumulation	Accumulation of a chemical by an aquatic organism.
Biomagnification	The increase in concentration of a substance up the food chain.
Catchment	An area of land from which water from rainfall drains toward a common watercourse, stream, river, lake, or estuary.
Chronic toxicity	Long-term effect on an organism, usually caused by toxic substances.
Concentration	The measure of how much of a given substance there is mixed with another substance.
Congener	In chemistry, congeners are related chemicals, e.g., There are 209 congeners of polychlorinated biphenyls (see PCB).
Contaminant	Any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise), or heat, that results in an undesirable change to the physical, chemical, or biological environment. Also called pollutant.
Detection limit	A value below which the laboratory analyst is not confident that any apparent concentration is real.
Dioxins	The by-products of various industrial processes (such as bleaching paper pulp, and chemical and pesticide manufacture) and combustion activities (such as burning rubbish, forest fires, and waste incineration).

Geothermal	Relating to the internal heat of the Earth. The water of hot springs and geysers is heated by geothermal sources.
Guideline	Numerical limit for a chemical, or a narrative statement, recommended to support and maintain a designated water use.
Hazardous	Having the capacity to adversely affect either health or the environment.
Indigenous	Native, or belonging naturally to a given region or ecosystem, as opposed to exotic or introduced (can be used for people, animal, or plant species or even mineral resources).
Iwi	A Maori tribal group.
Kai	Traditional Māori food.
Median	In statistics, the middle score in a range of samples or measurements (that is, half the scores will be higher than the median and half will be lower).
Organochlorine	A chemical that contains carbon and chlorine atoms joined together. Some organochlorines are persistent (remain chemically stable) and present a risk to the environment and human health, such as dioxin, DDT and PCBs.
ppb	1 part per billion = 1 mg m^{-3} = 1 µg L^{-1}.
ppm	1 part per million = 1 g m^{-3} = 1 mg L^{-1}.
Risk Assessment	The determination of a quantitative or qualitative value of risk related to a concrete situation and a recognised threat.
Rohe	The geographical territory of an iwi or a hapu.
Runanga	The governing council or administrative group of a Māori hapu or Iwi.

Screen	A low-cost monitoring method used to make an initial assessment.
Sediment	Particles or clumps of particles of sand, clay, silt, or plant or animal matter carried in water.
Soluble	Fraction of material that passes though a filter (international convention uses a 0.45 μm membrane filter).
Species	One of the basic units of biological classification. A species comprises individual organisms that are very similar in appearance, anatomy, physiology, and genetics, due to having relatively recent common ancestors; and can interbreed.
Stormwater	Flow of water from urban surface areas after rainfall.
Total metal	The concentration of a metal in an unfiltered sample that is digested in strong acid.
Toxic substance	A material able to cause adverse effects in living organisms.
Toxicity	Is the inherent potential or capacity of a material to cause adverse effects on living organisms.
Vascular	Containing vessels which conduct fluid.

9. Appendices

Appendix 1: Kai consumption survey Consumption Survey questionnaire (extract).

Appendix 2: Biometric data.

Appendix 3: Contaminant data.

Appendix 1: Extract of Kai Consumption Survey questionnaire for Te Arawa.

D. DIET AND LIFESTYLE

28. How would you describe your eating pattern? (***Please mark one box only***):

- ☐ Eat all foods, including fish and animal products
- ☐ Eat eggs, dairy products, fish and chicken but avoid all other meats
- ☐ Eat eggs, dairy products and fish but avoid all meats
- ☐ Eat eggs and dairy products but avoid all meats and fish
- ☐ Eat eggs but avoid dairy products, all meats and fish
- ☐ Eat dairy products but avoid eggs, all meats and fish
- ☐ Eat no animal products
- ☐ Other *(please specify)*____

29 For the foods that you have purchased over the last year, on average, how often have you eaten these foods**.** ***Please answer by ticking the appropriate boxes.***

FOODS YOU PURCHASED AND EAT	**NEVER**	**Less than once**	**1 – 3 times**	**1 time**	**2 times**	**3 to 4 times**	**5-6 times**	**1 times**	**2 times**	**3 or more times**
		Per month		**Per week**				**Per day**		
CEREALS, SNACKS										
Sultana Bran, All Bran, Bran Flakes										
Weetbix, Weeties										
Cornflakes, Nutrigrain, Special K										
Ricies,										
Porridge										
Muesli										
Rice										
Pasta or noodles										
Crackers, crispbread,										
Biscuits										
Cakes, pastries, fruit pies & tarts										
Meat pies, pasties, quiche, savouries										
Pizza										
Hamburgers										
Chocolate										
Flavoured milk drinks (Milo etc.)										
Nuts										
Peanut butter										
Potato crisps, Twisties etc.										
Jam, marmalade, honey etc.										
Vegemite, marmite										

DAIRY PRODUCTS									
Cheese									
Ice-cream									
Yogurt									
Beef									
Veal									
Chicken									
Lamb									
Pork									
Bacon									
Ham									
Corned beef, luncheon, salami									
Sausages, saveloys									
Fish (steamed, grilled, baked)									
Fish, fried (including take- aways)									
Fish tinned									

FRUIT										
Tinned or frozen fruit										
Fruit juice										
Oranges or other citrus										
Apples										
Pears										
Bananas										
Watermelon, rock melon, honey dew										
Pineapple										
Strawberries										
Apricots										
Nectarines, peaches										
Avocado										
VEGETABLES										
Potatoes – roasted, fried (incl. chips)										
Potatoes cooked without fat										
Tomato sauce, tomato paste, dried tomatoes										
Fresh or tinned tomatoes										
Peppers										
Lettuce, rocket, other salad greens										
Cucumber										
Celery										
Beetroot										
Carrots										
Cabbage or brussel sprouts										
Broccoli										
Silverbeet or spinach										

VEGETABLES (cont.)										
Peas										
Green beans										
Bean sprouts										
Baked beans										
Soy beans, tofu										
Other beans (chick peas, lentils)										
Pumpkin										
Onion or leeks										
Garlic (not garlic tablets)										
Mushrooms										
Courgettes										
Puha										
Kamokamo										
Watercress										

30. Over the last year, on average, how often did you drink beer, wine and / or spirits. ***Please answer by ticking the appropriate boxes.***

ALCOHOL YOU PURCHASED & DRANK	**NEVER**	**Less than once**	**1 – 3 times**	**1 time**	**2 times**	**3 to 4 times**	**5-6 times**	**1 times**	**2 times**	**3 or more times**
		Per month		**Per week**				**Per day**		
Beer (low alcohol)										
Beer (full strength)										
Red wine										
White wine										
Port, sherry etc.										
Spirits, liqueurs etc.										

E. KAIMOANA / KAI AWA / KAI ROTO

This section will help us understand your eating patterns with respect to kaimoana, kai awa and kai roto

31. Do you eat kai moana, kai awa and or kai roto?

☐ Yes ↓ ☐ No Go to Question 43

32. How often do you eat different types of kaimoana? ***Please answer by ticking the appropriate boxes.***

Kai	NEVER	Less than once	1 – 3 times	1 time	2 times	3 to 4 times	5-6 times	1 times	2 times	3 or more times
Kakahi										
Morihana										
Koura										
Watercress										
Puha										
Pipi										
Cockles										
Snapper										
Toheroa										
Tuatua										
Inanga										
Lampreys										
Mutton birds										
Pupu										
Tuna (Eel)										
Flounder										
Hapuka										
Mullet										
Kahawai										
Kingfish										
Gurnard										
Moki										
Shark										
Tarakihi										
Trevally										
Kina										
Paua										
Mussels										
Crayfish										
Oysters										
Seaweed										
Freshwater crayfish Other (please specify type)										
Watercress										
Puha										

33. How do you normally get the majority of your kaimoana, kai awa or kai roto?

☐ Caught by me or someone else from my household
☐ Get given it from someone else (no money is paid)

☐ I know where the kai I was given was gathered from
Please name the place(s)_________________________
____

☐ I don't know where the kai I was given was gathered from.

Buy it: please name the place(s) ____
____

34. What quantities of kaimoana, kai roto or kai awa do you usually eat?

For each of the examples shown on this page, on average, how much would you usually eat at a main meal. When answering the question think of the amount of food that you ate, not how often you might have eaten it. *Please tick the box that is closest to the total amount that you ate.*

34.2 When you ate vegetables did you usually eat?

A	B	C
		

☐	☐	☐	☐	☐	☐	☐
Less than A	A	Between A & B	B	Between B & C	C	More than C

34.3 When you ate mussels did you usually eat?

A	B	C
		

☐	☐	☐	☐	☐	☐	☐
Less than A	A	Between A & B	B	Between B & C	C	More than C

34.4 When you ate fish, did you usually eat?

A B C

☐	☐	☐	☐	☐	☐	☐
Less than A	A	Between A & B	B	Between B & C	C	More than C

34.5 When you ate whitebait, did you usually eat?

A	B	C

☐	☐	☐	☐	☐	☐	☐
Less than A	A	Between A & B	B	Between B & C	C	More than C

34.6 **When you eat koura, how many would you (as an individual) usually eat at a meal?**

- ☐ one koura
- ☐ 2 – 3 koura
- ☐ 4 – 5 koura
- ☐ More than 5 koura

35. What parts of the different species of kaimoana, kai awa or kai roto do you usually eat? *Please tick the appropriate boxes.*

36.1 For fish (e.g., snapper, trout, moki, groper etc.) – tick all the parts you eat.

- ☐ 1: fish heads

- ☐ 2: fish eyes
- ☐ 3. fins
- ☐ 4. fish fillets
- ☐ 5. fish tails

35.2 For eels – tick all the parts you eat

- ☐ 1: heads
- ☐ 2. fillets

36.3 For koura – tick all the parts you eat

- ☐ 1: heads
- ☐ 2. tails
- ☐ 3. legs etc.

36 Did you give away or sell any kaimoana, kai roto, kai awa gathered from the sites listed above

- ☐ Yes
  Please also tick the locations from which you gathered kai and then gave it away.
  - ☐ Rivers and streams
  - ☐ River estuaries and mouths
  - ☐ Lakes
  - ☐ Coastline
  - ☐ Sea waters
  - ☐ Ohau Channel
  - ☐ Other – please list the sites______________
- ☐ No

Appendix 2a: Biometric data for trout collected from Te Arawa region in September and November 2009.

Site	length (mm)	weight (g)	% moisture
Lower Kaituna	510	1216	80.8
Ohau Channel	355	656	72.2
Ohau Channel	515	1592	72.5
Okareka	515	1339	76.0
Puarenga Stream lower	215	125	78.6[a]
Puarenga Stream lower	175	63	[a]
Puarenga Stream upper	565	1342	86.2
Rotokakahi	565	2845	63.1
Rotoiti	505	1822	67.0
Rotoma	530	1490	79.4
Rotomahana	485	1385	74.3
Rotorua	390	810	70.2
Tarawera	515	1775	67.3
Tikitapu	495	1612	68.2
Upper Kaituna	525	1370	78.5

[a] two small trout from Puarenga Stream lower pooled for analyses.

Appendix 2b: Biometric data for koura collected from Te Arawa region in September and November 2009.

	Size (mm)				Total		
Site	**<70**	**70-110**	**>110**	**#**	**flesh wet weight (g)**	**flesh dry weight (g)**	**% moisture**
Ohau Channel	1	10	7	18	100.2	16.5	83.5
Okareka	0	5	8	13	106.4	16.6	84.4
Rotoiti East	1	18	8	27	118.9	18.3	84.6
Rotoiti West	0	25	0	25	105.0	20.5	80.5
Rotoma	1	15	1	17	53.6	9.0	83.2
Rotorua East	2	28	1	31	134.3	25.7	80.9
Tarawera	0	19	3	22	86.5	13.4	84.5
Tikitapu	6	4	0	10	28.6	5.6	80.4
Upper Kaituna	2	5	0	7	24.9	4.3	82.7
Rotokakahi	2	18	3	23	63.9	11.6	81.8

Appendix 2c: Biometric data for eel collected from Te Arawa region in September 2009.

Site	**Lower Kaituna**		**Ohau Channel**
Species	Eel	Whitebait	Eel
Length (mm)	365	40-60	565
Weight (g)	127	60	458

Appendix 2d: Biometric data for smelt and whitebait collected from Te Arawa region in September and November 2009.

Site	species	wet weight (g)	dry weight (g)	% moisture	length (mm)	#
Lower Kiatuna	smelt	25.7	4.7	81.9	35-65	30
Lower Kiatuna	smelt	110.0	23.0	79.1	55-100	35-40
Ohau Channel	smelt	200.0	38.5	80.8	35-75	50-60
Rotomahana	smelt	139.0	25.4	81.8	40-60	60
Rotoiti West	smelt	196.0	38.6	80.3	ND[a]	ND
Rotokakahi	smelt	311.3	73.3	76.5	ND	ND
Lower Kiatuna	whitebait	39.3	7.25	81.6	40-60	60

[a] ND = not determined.

Appendix 2e: Biometric data for pipi, mussel and kakahi collected from Te Arawa region September and November 2009 and January 2010.

Site	Sample	flesh wet weight (g)	flesh dry weight (g)	% moisture	length (mm)	#
Maketu[a]	pipi	236.0	30.4	87.1	35-55	55
Rotokakahi[b]	kakahi	346.0	25.2	92.7	70	40
Maketu[c]	pipi	191.0	24.0	87.4	40-55	47
Maketu[c]	mussels	150.0	27.7	81.5	50-100	40

[a] collected 15th September 2009.
[b] collected 11th November 2009.
[c] collected 26th January 2010.

Appendix 2f: Sediment size proportion data from Te Arawa region.

Site	2000-63 µm (%)	<63 µm (%)	Total %	Total Organic Carbon[a]
Lower Kaituna	88.4	11.6	100.0	1.0
Maketu	98.0	2.0	100.0	0.32
Ohau Channel	93.0	7.0	100.0	1.8
Okareka	88.3	11.7	100.0	5.1
Puarenga Stream downstream of mill	90.6	9.4	100.0	0.84
Puarenga Stream upstream of mill	86.0	14.0	100.0	2.6
Rotoiti Site1	42.5	57.5	100.0	6.3
Rotoiti Site2	22.5	77.5	100.0	5.7
Rotoma	97.5	2.5	100.0	4.6
Rotomahana	47.5	52.5	100.0	2.8
Upper Kaituna River	98.2	1.8	100.0	0.31
Rotokakahi	45.6	54.4	100.0	4.1
Rotorua Site 2	42.1	57.9	100.0	5.0
Rotorua Site 5	58.4	41.6	100.0	6.5
Rotorua Site 8	57.1	42.9	100.0	5.2
Sulfur Point 2&4	72.5	27.5	100.0	4.9
Sulfur Point 1	93.6	6.4	100.0	1.8
Waiowhiro	83.0	17.0	100.0	3.7
Tarawera	33.3	66.7	100.0	3.8
Tikitapu	55.0	45.0	100.0	2.8

[a] g/100g (dry weight)

Appendix 3a: Organochlorine Pesticide concentrations (µg/kg dry weight) in trout and eels from Te Arawa region.

Site	Lower Kaituna Trout	Ohau Channel Trout	Okareka Trout	Puarenga Stm Lower Trout	Puarenga Stm Upper Trout	Rotokakahi Trout	Rotoiti Trout	Rotoma Trout	Rotomahana Trout	Rotorua Trout	Tarawera Trout	Tikitapu Trout	Upper Kaituna Trout	Lower Kaituna Eel	Ohau Channel Eel
o,p-DDE	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0
p,p'-DDE	22	17	5.0	3.0	139	69	4.3	3.6	23	11	3.0	15.9	18.7	12.0	6.7
o,p-DDD	0.1	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
p,p-DDD	0.9	2.2	1.2	0.6	1.6	3.9	1.1	0.1	4.3	1.6	0.7	6.7	0.4	0.8	0.7
o,p-DDT	0.1	0.2	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.1	0.0
p,p'-DDT	0.2	1.5	0.3	0.3	0.4	4.0	0.5	0.0	4.7	1.0	0.9	0.6	1.1	1.1	0.5
Total DDT	23	21	6.9	4.2	141	78	6.0	3.8	32	14	4.6	23	20	14	7.9
DDT/Σ DDT (%)	1.07	8.17	6.21	9.18	0.31	5.48	8.40	0.00	14.63	8.14	20.79	2.80	5.78	8.22	5.93
heptachlor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
heptachlor epox	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
trans-chlordane	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.1
cis-chlordane	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1
trans-nonachlor	0.1	0.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.3	0.1	0.2
cis-nonachlor	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0	0.1

Site	Lower Kaituna Trout	Ohau Channel Trout	Okareka Trout	Puarenga Stm Lower Trout	Puarenga Stm Upper Trout	Rotokakahi Trout	Rotoiti Trout	Rotoma Trout	Rotomahana Trout	Rotorua Trout	Tarawera Trout	Tikitapu Trout	Upper Kaituna Trout	Lower Kaituna Eel	Ohau Channel Eel
Total Chlordane	0.3	2.1	0.0	0.0	0.0	0.1	0.2	0.0	0.0	1.1	0.0	0.1	0.5	0.1	0.4
lindane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
hexachlorobenzene	0.14	0.53	0.13	0.34	0.17	0.14	0.47	0.19	0.17	0.55	0.32	0.65	0.08	0.09	0.14
dieldrin	0.2	0.6	0.0	0.0	0.4	0.3	0.2	0.0	0.0	0.5	0.1	0.4	0.0	0.1	0.6

Appendix 3c: PCB concentrations (µg/kg dry weight) in biota from Te Arawa region.

Site	Lower Kaituna Trout	Ohau Channel Trout	Okareka Trout	Puarenga Stm Lower Trout	Puarenga Stm Upper Trout	Puarenga Stm Upper Repeat	Rotokakahi Trout	Rotoiti Trout	Rotoma Trout	Rotomahana Trout	Rotorua Trout	Tarawera Trout	Tikitapu Trout	Upper Kaituna Trout	Lower Kaituna Eel	Ohau Chan-nel Eel
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.3	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.1
28	0.2	0.9	0.1	0.0	0.8	0.5	0.1	0.1	0.1	0.3	0.5	0.0	0.0	0.1	0.2	0.5
52	0.3	1.4	0.3	0.7	1.2	0.8	0.4	0.1	0.2	0.3	3.5	0.1	0.2	0.3	0.5	0.5
49	0.4	1.6	1.0	2.4	2.8	2.3	0.7	0.1	0.6	1.1	4.8	0.1	0.1	0.2	1.3	0.9
44	0.0	0.2	0.0	0.0	0.3	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	0.1	0.5	0.1	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.1	0.4
121	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
101	1.0	2.1	0.1	0.1	0.7	0.7	0.2	0.3	0.1	0.1	1.4	0.1	1.1	1.6	0.2	0.6
86	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.1
110	0.5	1.4	0.0	0.0	0.3	0.3	0.1	0.2	0.0	0.0	1.0	0.0	0.5	0.9	0.1	0.3
77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
151	0.3	0.5	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.3	0.0	0.3	0.4	0.0	0.1
118	1.0	1.8	0.1	0.1	16.7	16.8	0.2	0.2	0.2	0.1	1.1	0.1	0.9	1.8	0.4	0.6
153	4.3	4.5	0.6	0.2	94.4	92.9	0.7	0.9	1.4	0.3	2.9	0.2	4.1	5.4	0.6	1.5

Site	Lower Kaituna Trout	Ohau Channel Trout	Okareka Trout	Puarenga Stm Lower Trout	Puarenga Stm Upper Trout	Puarenga Stm Upper Repeat	Rotokakahi Trout	Rotoiti Trout	Rotoma Trout	Rotomahana Trout	Rotorua Trout	Tarawera Trout	Tikitapu Trout	Upper Kaituna Trout	Lower Kaituna Eel	Ohau Chan-nel Eel
105	0.2	0.6	0.0	0.0	3.3	3.5	0.0	0.1	0.0	0.0	0.3	0.0	0.2	0.6	0.1	0.2
141	0.5	0.5	0.1	0.1	1.1	1.1	0.1	0.3	0.1	0.1	0.4	0.1	0.5	0.6	0.1	0.2
138	2.8	3.5	0.3	0.1	56.2	56.7	0.4	0.6	0.8	0.2	2.2	0.1	2.7	3.9	0.5	1.0
126	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
187	0.9	0.9	0.2	0.0	8.1	8.0	0.2	0.2	0.3	0.1	0.6	0.1	0.7	1.1	0.1	0.3
128	0.3	0.5	0.0	0.0	6.8	6.6	0.0	0.1	0.1	0.0	0.3	0.0	0.4	0.6	0.1	0.1
156	0.3	0.2	0.0	0.0	6.5	6.2	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.3	0.1	0.1
180	2.0	1.4	0.3	0.1	63.5	61.1	0.3	0.4	0.9	0.1	0.9	0.1	1.9	2.0	0.2	0.5
169	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
170	1.0	0.8	0.1	0.1	30.3	28.5	0.1	0.2	0.4	0.1	0.5	0.1	0.9	1.0	0.1	0.3
195	0.1	0.1	0.0	0.0	1.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
194	0.2	0.1	0.0	0.0	6.0	5.8	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.2	0.0	0.1
206	0.0	0.0	0.0	0.0	1.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
209	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total PCB	16.8	23.9	3.6	3.9	302.4	295.5	3.8	4.0	5.6	2.9	21.6	1.2	15.2	21.4	4.7	8.2

Appendix 3d: Heavy metal concentrations (mg/kg dry weight) in biota from Te Arawa.

Site/Species	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Waiowhiro watercress	1.1	0.061	0.59	5.3	0.38	< 0.010	0.24	120
Maketu pipi	13	0.44	11	5.4	0.11	0.11	6.6	63
Lower Kaituna whitebait	4.4	0.083	0.25	2.7	0.55	0.073	0.36	120
Lower Kaituna whitebait(2)	4	0.046	0.62	3	0.73	0.092	0.54	130
Lower Kaituna smelt	1.3	0.032	0.12	2.5	0.83	0.3	0.26	170
Ohua Channel smelt	0.6	0.0089	1	1.7	0.069	1.2	0.77	190
Rotomahana smelt	1.9	0.044	0.8	3.2	0.22	1.6	0.69	290
Rotoiti West smelt	1.6	0.015	0.25	2	0.059	1	0.12	190
Rotokakahi smelt	0.77	0.0077	0.55	1.6	0.1	0.096	0.33	190
Rotokakahi kakahi	12	0.19	0.65	4.9	0.3	0.11	0.36	170
Ohau Channel koura	4.6	0.0087	< 0.10	20	0.028	3.5	< 0.10	86
Okareka koura	4.5	0.073	< 0.10	54	0.022	0.45	< 0.10	110
Rotoiti East koura	4.7	0.012	< 0.10	39	0.02	6.5	< 0.10	100
Rotoiti West koura	5	0.009	< 0.10	30	0.012	2.7	< 0.10	59
Rotoma koura	6.2	0.11	< 0.10	28	0.063	0.41	< 0.10	71
Rotorua East koura	4.4	0.0062	< 0.10	26	< 0.010	1.3	< 0.10	58

Site/Species	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Tarawera koura	7.8	0.04	< 0.10	28	< 0.010	0.43	< 0.10	90
Tikitapu koura	1.3	0.12	< 0.10	35	0.033	0.23	< 0.10	69
Upper Kaituna koura	2.9	0.009	< 0.10	38	< 0.010	2.9	< 0.10	68
Rotokakahi koura	1.3	0.0027	< 0.10	16	< 0.010	0.77	< 0.10	71
Lower Kaituna trout	0.22	< 0.0020	< 0.10	1	< 0.010	11	< 0.10	18
Ohau Channel trout	0.23	< 0.0020	< 0.10	2	< 0.010	5.7	< 0.10	18
Okareka trout	0.28	< 0.0020	< 0.10	1.2	< 0.010	2.2	< 0.10	16
Puarenga Lower trout	0.57	0.0033	< 0.10	0.76	< 0.010	0.19	< 0.10	22
Puarenga Upper trout	0.12	0.0045	< 0.10	2.1	0.01	19	< 0.10	55
Rotokakahi trout	0.53	< 0.0020	< 0.10	0.61	< 0.010	0.83	< 0.10	9.3
Rotoiti trout	0.15	< 0.0020	< 0.10	0.94	< 0.010	5.1	< 0.10	13
Rotoma trout	0.19	0.0056	< 0.10	0.68	< 0.010	1	< 0.10	16
Rotomahana trout	0.28	< 0.0020	< 0.10	1	< 0.010	8.4	< 0.10	17
Rotorua trout	< 0.10	< 0.0020	< 0.10	0.83	< 0.010	4.1	< 0.10	13
Tarawera trout	0.33	< 0.0020	< 0.10	0.64	< 0.010	0.27	< 0.10	13
Tikitapu trout	< 0.10	< 0.0020	< 0.10	1.2	< 0.010	0.56	< 0.10	12
Upper Kaituna trout	0.11	< 0.0020	< 0.10	1	< 0.010	7.1	< 0.10	19
Lower Kaituna eel	0.88	0.033	< 0.10	1	0.012	0.71	< 0.10	51

Site/Species	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Ohau Channel eel	0.35	0.0023	< 0.10	1.4	0.013	3.8	< 0.10	54
Maketu pipi repeat	11	0.42	10	5.3	0.18	0.086	7.2	65
Maketu pipi second collection	9.7	0.46	3.2	4.7	0.084	0.057	3	54
Maketu mussel second collection	7	0.49	11	3.9	0.46	0.16	8.1	67

Appendix 3f: Heavy metal concentrations (mg/kg dry weight) and total organic carbon (g/100g) in sediment from Te Arawa region.

Site/Metal	Manganese	Total Organic Carbon	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Maketu	170	0.32	3.7	< 0.010	1.9	0.67	1.5	0.026	1.2	9.7
Lower Kaituna	160	1	14	0.023	0.82	1.3	2.4	0.052	0.32	17
Upper Kaituna River	270	0.31	8	0.016	0.82	1	1.8	0.039	0.36	17
Rotoiti Site1	580	6.3	59	0.066	1.6	4.8	3.4	1.7	0.87	32
Rotoiti Site2	420	5.7	54	0.046	1.2	4.3	3	1.9	0.8	26
Ohau Channel	160	1.8	25	0.041	1.7	2	2.4	0.51	0.82	26
Rotorua Site 2	400	5	64	0.11	7	9	11	0.85	1.6	51
Rotorua Site 5	430	6.5	95	0.095	5.2	8.6	7.1	0.78	1.4	51
Rotorua Site 8	380	5.2	52	0.098	5.5	8.2	7.6	0.81	1.4	49
Sulphur Point 1	5.3	1.8	1.9	0.012	1.3	5.7	8.4	1.2	0.34	12
Sulphur Point 2&3	52	4.9	55	0.08	3.3	8.5	6.4	5.3	0.59	20
Waiowhiro	180	3.7	16	0.21	6.4	14	29	0.083	1.6	130
Puarenga Downstream	890	0.84	13	0.053	2.8	2.9	5.4	0.025	0.67	31

Site/Metal	Manganese	Total Organic Carbon	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Tarawera	15,000	3.8	880	2.5	1.4	4.3	5.5	0.15	1.6	58
Rotokakahi	560	4.1	19	0.081	3.2	4.5	9.6	0.07	1.6	32
Okareka	2,800	5.1	63	0.14	2.8	8.6	18	0.11	1.5	53
Rotomahana	310	2.8	260	0.19	18	12	5.7	1.8	2	35
Tikitapu	460	2.8	14	0.09	2.7	7.3	26	0.12	1.7	52
Rotoma	1,400	4.6	68	0.51	2.7	8.4	18	0.19	1.9	55