Contaminants in kai – Arowhenua rohe
Part 1: Data Report

NIWA Client Report: HAM2010-105
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Contaminants in Kai – Arowhenua rohe Part 1: Data Report

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Executive Summary

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. 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=12), to establish historic and contemporary consumption rates of key species. The levels of bioaccumulative contaminants were characterised in a number of commonly gathered kai; shortfin eel (*Anguilla australis)*, longfin eel (*Anguilla dieffenbachii*), brown trout (*Salmo trutta*), black flounder (*Rhombosolea retiaria*) and watercress (*Nasturtium officinale*), from 12 sites throughout the Arowhenua rohe (Waihi River, Winchester, Temuka River, Te Nga Wai, Opihi River (below Pleasant Point), Ohapi Creek, Orari Ohapi (river mouth), Opihi River (upstream), Doncaster, Washdyke Creek, Opihi River (lagoon) and Washdyke (lagoon), as well as in associated aquatic sediments. In addition, hair samples were collected from 12 participants and 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 kai were calculated as 6.1, 4.0 and 4.7 g/day for eels, trout and flounder, respectively. Watercress consumption was calculated at 6.0 g/day. The consumption rates of wild caught fish were a lot lower than the average New Zealand (NZ) consumption rate of 32 g/day. In contrast, the average total fish consumption rate from the survey was 43 g/day, putting these rates into the NZ high consumption category and highlighting that wild caught kai is only a small proportion of the main source of aquatic food for the local community.

All contaminant data is reported on a dry weight basis.

The average concentration of mercury in hair samples of 0.86 µg/g was similar to that found for both the study reference group and to New Zealander's who consume 1-4 meals of fish per month. By comparison, it was much lower than previous studies in the geothermally-influenced Rotorua region, where concentrations as high as 39 µg/g were recorded. Selenium concentrations were similar between Arowhenua participants and the reference group.

Three sites had markedly higher total DDT (ΣDDT) concentrations present in eel fillet, namely Winchester (538 µg/kg), Ohapi Creek (917 µg/kg) and Doncaster (914 µg/kg). The concentrations of ΣDDT in trout and flounder were generally much lower than for eels. The highest concentrations of ΣDDT found in trout was from Temuka (81 µg/kg) and in flounder from Washdyke Lagoon (141 µg/kg). Other organochlorine pesticides were either below the limits of detection, or measured in much lower concentrations than any of the DDT congeners.

Polychlorinated biphenyls (PCBs) were analysed in eels only. Total concentrations ranged from 1.4 - 161 µg/kg, with the most elevated levels found at Doncaster and Winchester (161 and 67 µg/kg respectively). PCBs were never manufactured in New Zealand, but were imported and used extensively in the electricity industry as insulating fluids or resins in transformers and capacitors.

The concentrations of mercury were generally highest in eel fillet, with a median value of 1.05 mg/kg. The mercury concentrations were lower in trout fillet, with a median of 0.47 mg/kg. Concentrations were lower again in flounder fillet (median 0.18 mg/kg) and virtually undetectable in watercress. The source of mercury in the Arowhenua study area is unclear. Unlike parts of the North Island of New Zealand, South Canterbury does not have any identifiable geothermal inputs, which are considered to be natural sources of mercury and arsenic to lake and river systems.

Interestingly, tissue concentrations of arsenic were below detection limits for eels, but present for both flounder and trout, with median concentrations of 0.59 and 1.55 mg/kg, respectively. Watercress contained relatively low concentrations of arsenic (median 0.33 mg/kg). The arsenic found in biota could be caused by the multitude of contaminated sheep dip sites in the area, particularly given the absence of any identifiable geothermal activity. Prior to the 1950's sheep dips were arsenic-based and there are now thought to be over 50,000 contaminated sheep-dip sites in New Zealand.

Watercress recorded a median lead concentration of 1.0 mg/kg, which was consistently higher than observed in fish. The highest lead result in fish of 0.17 mg/kg was recorded in a flounder from Opihi River mouth.

Watercress had much higher cadmium concentrations than fish with most fish concentrations below detection limits (0.002 mg/kg). Zinc and copper concentrations were reasonably consistent among each species, with watercress recording the highest levels. Nickel was present in low concentrations in all fish species, usually below detection limits (0.1 mg/kg), but was detected in all watercress samples, with a median level of 1.2 mg/kg. Chromium was virtually undetectable in all fish species but recorded in watercress at a median level of 0.67 mg/kg.

Only one site contained sediment heavy metal concentrations that exceeded the Australian and New Zealand Environment Conservation Council (ANZECC) Interim Sediment Quality Guidelines (ISQG). Doncaster recorded a zinc concentration of 220 mg/kg, just above the low-ISQG value of 200 mg/kg. Four sites, Washdyke Lagoon (8.3 µg/kg), Washdyke Creek (3.8 µg/kg), Doncaster (3.3 µg/kg) and

Winchester (1.6 μg/kg) had total organic carbon normalised sediment concentrations of ΣDDT that reached or exceeded the ANZECC low-ISQG guideline of 1.6 μg/kg.

It would appear that high sediment ΣDDT concentrations translates to high ΣDDT concentrations in eel and flounder, but not trout. A similar inference for metals in watercress could not be made based on the available data.

The overall aim of this project is to determine the relative risk of consumption of kai species from sites where they are or 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 (Stewart et al. 2010).

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 throughout time, due to less 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, as a consequence of urban expansion or land use changes in agricultural catchments. 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 them, has not been investigated. 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 traditional 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 shortfin eels are often lipid rich, where levels can exceed 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). Canterbury is a region with a large agriculture and horticulture industry, where the application of organochlorine pesticides was widespread. Although a nationwide survey on organochlorines, including PCBs, was carried out in 1995 (Buckland, S. J. et al. 1998a), the region of South Canterbury was excluded from this study. In addition, sheep dips were arsenic-based until the 1950s, with organochlorine (e.g., dieldrin, lindane and DDT) and organophosphate (e.g., diazinon) insecticides used after this time (ECan 2010b). There are thought to be over 50,000 contaminated sheep-dip sites in New Zealand (MfE 2006). Metals, such as mercury and arsenic, can enter the food-chain from a combination of natural (e.g., geothermal) and anthropogenic inputs (e.g., landfills and other contaminated industrial sites). Cadmium, lead, copper and zinc are associated with urban contamination, usually as diffuse sources e.g., stormwater run-off.

This report describes the results of a survey of sites traditionally associated with the gathering of kai by local Māori. The concentrations of potentially bioaccumulative contaminants were characterised in a number of commonly gathered animal and plant species, as well as in associated sediments. A companion report (Stewart et al. 2010) then uses a risk assessment, 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 an indigenous Māori population (Arowhenua) located in South Canterbury. Analysis of this information allowed for the design of a sampling regime that aimed to characterise contaminant concentrations in kai and the associated environment (sediment) of direct relevance to members of Arowhenua iwi. In addition, a survey of past and present consumption patterns was undertaken by questionnaire (kai consumption survey, n=12) 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 (n=12) 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, see Appendix 1 for category descriptions).

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

Food Group	Less than A	A	Between A & B	B	Between B & C	C	More than C
Vegetables[a]	<50 (25)[b]	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)

[a] Also used to quantify watercress consumption.
[b] Values in brackets indicate numbers used in calculations for larger and smaller than size portions.

2.3 Sampling Design

2.3.1 Site and kai information

Kai harvest information from the individual questionnaires was compiled to determine what were the most popular kai gathering sites and which species were harvested most often. This information is presented in Table 2. Many historically harvested kai species included in the survey were not currently harvested by the interview participants. These are included in the footnote of Table 2.

All harvesting sites identified in the region are shown in Figure 1.

Figure 1: Map of all harvesting sites in Arowhenua region identified during focus group, interviews and questionnaires.

Table 2: Kai harvest frequency information at individual sites in Arowhenua region compiled from questionnaire.

Kai[a]	Opihi River upstream of SH bridge	Opihi River below SH bridge	Opihi River Mouth	Orari River Upstream of SH bridge	Orari River Mouth	Ohapi Creek	Temuka River	Waihi River	Te Hae Hae Te Moana	Jacks Point	Washdyke	Otaio River	TOTAL
Watercress	6	7	3	3	4	2	5	3	2				35
Eel	7	4	3	2	2	2	5	3	3	1	1	1	34
Trout	5	3	2	1	2	1	5	2	1	1	1	1	25
Whitebait	1	4	6		3		3				2		19
Flounder	1	2	5	1	2		2			1	3		17
Herrings		2	3	1	1					1	1		9
Lampreys	1	1	1		1		2	1			1		8
Mussels										5	1		6
Kahawai			2		1					1			4
Mullet		1	1							1	1		4
Oysters										1	2	1	4
Shark			2							1			3
Puha							3						3
Paua										3			3
Seaweed										1	1		2
Crayfish										1			1
Kina										1			1
TOTAL	**21**	**24**	**28**	**8**	**16**	**5**	**25**	**9**	**6**	**19**	**14**	**3**	**178**

[a]Common names only used in questionnaire. Kai species for which sampling frequency from interviews was zero included muttonbirds, cockles, freshwater mussels, tuatua, freshwater crayfish, greenbone, toheroa, pupu, hapuka, kingfish, snapper, moki, tarakihi, trevally.

2.3.2 Contaminants of concern

Information was available from the Environment Canterbury (ECan) website on identifying contaminated sites (ECan 2010a), where they stated:

In order to identify sites that may be contaminated, ECan uses the Ministry for the Environment's Hazardous Activities and Industries List (HAIL) which lists 53 specific land uses that have the potential to cause contamination of sites.

Some common examples of local land uses which may cause contamination are:

- *sheep dips (contaminated with arsenic and other insecticides);*
- *timber treatment sites;*
- *former gasworks;*
- *closed landfills;*
- *fuel service stations;*
- *horticultural sites.*

ECan were contacted in order to gather additional information about contaminated sites in the Arowhenua region via the Listed Land Use Register (LLUR). However, further discussions with ECan (Mongilo 2009) about known present and historic contaminated sites, only supplemented the information already obtained from the ECan website. ECan does not hold any information for sites east and north-east of Temuka (circled, see Figure 2), suggesting these should not be highly contaminated areas. An old sheep scour at Winchester was identified. Two sites below Temuka warranted analysis for pentachlorophenol (PCP) due to a historic timber treatment facility that was located near the banks of the Temuka River. As the Temuka River feeds into the Opihi River below site 19 (Table 3), this site would make a useful reference site for comparisons of PCP contamination. The Washdyke area has 25 sites under scrutiny by ECan, mostly due to possible contamination from fuel stations and fuel storage facilities. In addition, this area was thought to have once contained a wool scour and an historic timber treatment facility, suggesting kai and sediments may also be contaminated by PCP. The two coastal sites south of Timaru could be contaminated by tetraethyl lead (petrol additive and bioaccumulator) and lead acetate. There was no information for the rural sites northwest of Timaru (Te Nga Wai & Opuha; Figure 2), suggesting these may have lower contamination than other sites and hence be suitable as reference sites for comparative purposes.

[a] Green squares designate sites identified from focus group and interviews.

Figure 2: ECan Contaminated Sites information for the Arowhenua Region[a].

2.3.3 Proposed sites of collection and types of kai

Due to budgetary constraints, the number of sites, species collected from each site and contaminants analysed from each species were restricted. Popular harvesting sites and/or those sites close to known areas of contamination were preferentially selected. A total of 15 sites in the region were identified based upon the survey information (as described earlier in Table 2) and the information supplied by ECan on contamination in the Arowhenua Region (Section 2.3.2). The list of sites and analyses (Table 3) was prepared in consultation with Te Runanga o Arowhenua. In addition, a rural site and coastal site in areas far removed from urban influence were included as reference sites with anticipated low levels of contaminants for direct comparison.

Table 3: Proposed subset of sites and species to be sampled for contaminants from Arowhenua March/April 2009.

Area	Site location	GPS Coordinates	Species
Opihi River	upstream of SH1 bridge	Confirmed on site	eel, watercress
Opihi River	downstream SH1 bridge, below Pleasant point	E2372225 N5659139	eel, watercress, whitebait
Opihi River	river mouth, Horseshoe bend	E2377978 N5657081	eel, watercress, flounder, yellow eye mullet[a], & whitebait
Orari River	river mouth, Orari Ohapi	E2382708 N5661494	eel, watercress, trout, flounder, & whitebait
Temuka River	Temuka River	E2371649 N5661078	eel, watercress, trout, & whitebait
Jacks Point	Jacks Point	E2371316 N5640379	mussels & paua
	Caledonia ground	E2371805 N5642410	mussels & paua
Washdyke	Washdyke lagoon	E2370242 N5647982	flounder, eel, & whitebait
	bridge near Doncaster	E2369627 N5648533	flounder & eel
	Washdyke Creek	E2370373 N5647189	flounder & eel
Waihi River	Waihi River	E2372095 N5668310	eel, watercress, trout
	Winchester	E2371802 N5667852	eel, watercress, trout
Ohapi Creek	Ohapi Creek	E2378046 N5662521	eel, watercress
Rural Inland Sites	Te Nga Wai (Opawa Crossing)	E2340502 N5662460	eel, watercress
	Opuha	E2348140 N5678827	eel, watercress

[a] referred to as mullet in Table 2.

2.4 Sample preparation

Eels, trout and flounder were partially thawed, weighed and measured. Clean fillets of fish or eel muscle tissue were carefully removed from each individual, avoiding the gut. Otoliths were removed from 9 eels for accurate age determination. Watercress was cut, while frozen, into small pieces. All samples were weighed, frozen and freeze dried with a shelf temperature of -20°C. Biometric data for eel, trout/flounder and watercress are shown in Appendix 2.

Each sediment composite was allowed to thaw and placed in a shallow plastic tray. All large stones and plant material were removed and the sediment thoroughly homogenized before freeze drying. Freeze dried sediment was sieved dry through a 2 mm stainless steel sieve and all material greater than 2 mm discarded. A sub-sample of the freeze dried (<2 mm) sieved sediment was re-suspended in Nanopure water, sonicated for 1 hour and wet sieved through a 63 µm nylon mesh. The <63 µm fraction was oven dried and a gravimetric analysis performed. Sediment size analysis data and total organic carbon (TOC) are shown in Appendix 2.

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), following established procedures involving acid digestion and analyses by ICP-MS. The analysis of pentachlorophenol (PCP) was carried out on sediment only using established procedures (Hill Laboratories 2010).

Fish and sediment 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; γ-HCH) and dieldrin. The 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). Eel tissue was also analysed for selected PCBs (32 congeners ranging from PCB 8 - PCB 209). Watercress was analysed for the eight heavy metals only.

The full dataset (based upon dry weight) is shown in Appendices 3a-3f.

2.6 Analysis of mercury in hair

Hair samples were collected using a standard protocol modified from Hill Laboratories (2000). 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 60 mm 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-labeled 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 when, 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 digestion bomb. Re-distilled Merck Supapure nitric acid (1 mL) was added to the samples. The bombs were then pressure capped, placed in a microwave oven and digested at approximately 150ºC for 45 minutes. After digestion, samples were diluted and all relevant isotopes of Hg and Se analyzed by Dynamic Reaction Cell-Inductively Coupled Plasma Mass

Spectrometry (DRC-ICPMS). Any potential interference elements were also measured.

2.7 Arowhenua 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, eel, flounder 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).

3. Results and discussion

3.1 Sampling

As an initial screening exercise, fish were collected as single animals and where possible specimens were chosen that would reflect what would realistically be consumed. All fish were caught by electric fishing techniques, with the exception of Opihi river mouth and Orari Ohapi, where nets were used to catch trout. Watercress was harvested by hand, avoiding roots. Twelve sites (Figure 3) were surveyed and a total of 9 shortfin eels (*Anguilla australis)*, 1 longfin eel (*Anguilla dieffenbachii*), 5 brown trout (*Salmo trutta*) and 4 black flounder (*Rhombosolea retiaria*) were collected (Table 4). Collections were undertaken in 2009 either between 12th and 14th May, or on the 3rd June. Composite watercress samples (*Nasturtium officinale*) were collected from 8 sites between 12th and 14th May. Composite sediment samples were collected from all sites, at the time of biota collection. Biometric data for each kai species are shown in Appendices 2a-2c, while the particle size distribution data for sediments are shown in Appendix 2d.

No coastal sites were sampled due to high swells on the shore at both survey times. Whitebait was out of season.

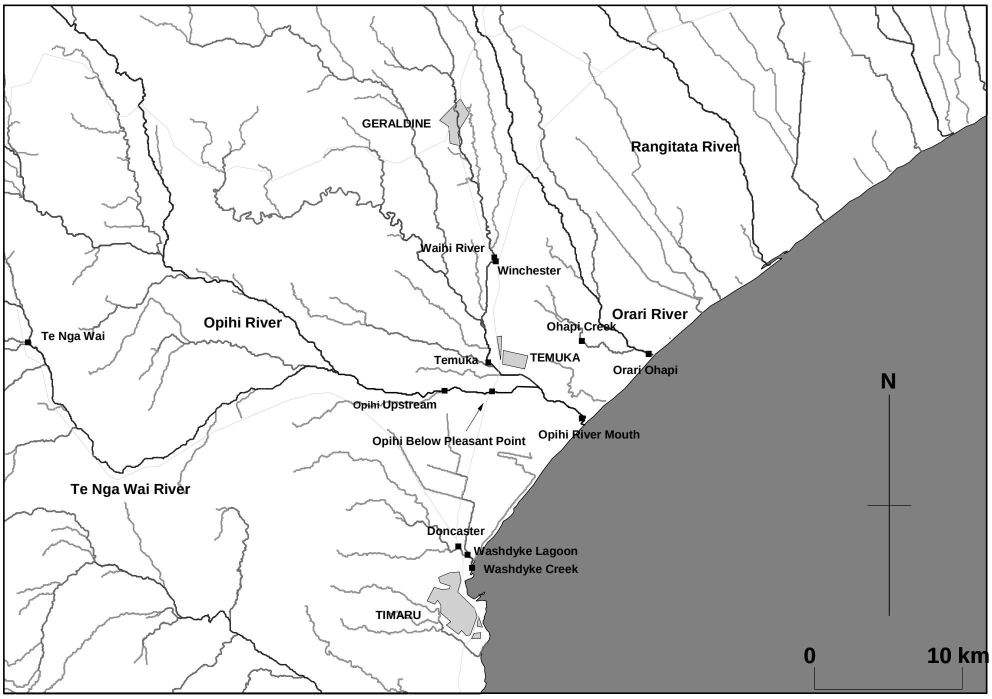


Figure 1: Twelve collection sites in this study.

Table 4: Sampling sites and species[a] harvested from Arowhenua Region in May/June 2009.

Site location	GPS Coordinates	Samples obtained	Comments
Waihi River	E2372095 N5668229	watercress	Upstream of wool scour
		sediment	
		eel	
		trout	
Winchester	E2372170 N5667920	watercress	Exact location obtained from Arowhenua
		sediment	
		eel	
		trout	
Temuka River	E2371649 N5661079	watercress	
		sediment	
		eel	
		trout	
Te Nga Wai	E2340457 N5662437	watercress	Chose Te Nga Wai over Opuha as rural reference site for logistical reasons
		sediment	
		eel	
Opihi River (below Pleasant Point)	E2371924 N5659077	watercress	
		sediment	
		eel	
Ohapi Creek	E2378025 N5662540	watercress	
		sediment	
		eel	
Orari Ohapi (River mouth)	E2382582 N5661627	watercress	No watercress sampled due to flooding and scouring of River banks
		sediment	
		eel	
		trout	

Site location	GPS Coordinates	Samples obtained	Comments
Opihi River (upstream)	E2368692 N5659135	watercress sediment eel	Site location obtained from Arowhenua
Doncaster	E2369612 N5648525	sediment eel flounder	Drain discharging light brown unknown material into creek.
Washdyke Creek	E2370545 N5647090	sediment	No eels and only juvenile flounder
Opihi River (lagoon)	E2378010 N5657250	sediment trout flounder watercress	No eels found Trout substituted for mullet as mullet is a marine fish
Washdyke lagoon	E2370242 N5647982	sediment, eel, flounder	

[a] whitebait was excluded from study because it was out of season at time of collection.

3.2 Arowhenua consumption data

Local average consumption rates of harvested kai were calculated as 6.1, 4.0 and 4.7 g/day for eels, trout and flounder respectively (Table 5). Watercress consumption was calculated at 6.0 g/day. These consumption rates are markedly lower than average New Zealand consumption rate of 32 g/day for total fish (Kim & Smith 2006) and the proposed average consumption rate of 33 g/day for consumers of watercress (Golder Associates and NIWA 2009). Even the maximum local consumption rates of 20.0, 13.3 and 13.3 g/day for eels, trout and flounder respectively, were still well below the average New Zealand fish consumption rate. In contrast, the average total fish consumption from the survey was 43 g/day, putting local consumption rates into the New Zealand high category of 43 g/day (Kim & Smith 2006) and highlighting that wild caught kai is only a small proportion of the main source of fish for the local community.

Table 5: Consumption rates (g/day) of wild kai from Arowhenua Region for different food categories (n=13).

Measure/ Food category	Watercress	Mussels	All fish	Traditionally harvested fish species Total[a]	Eel	Trout	Flounder
mean	6.0	11.1	43	5.8	6.1	4.0	4.7
median	4.7	3.8	27	4.5	3.8	3.3	3.3
minimum	0.0	0.0	5.0	3.3	0.0	0.0	0.0
maximum	15.0	60.0	187	12.8	20.0	13.3	13.3

[a] Sum of all traditional fish harvested.

Meal sizes were calculated at 213 g/meal for all fish species and 175 g/meal for watercress.

3.3 Mercury in hair

The concentrations of mercury and selenium for all 12 participants (on a dry weight basis) are presented in Table 6. The average concentration of mercury was similar to that found for the study reference group (Figure 4, n=29) and for New Zealanders who consume 1-4 fish meals per month (Airey 1983). In contrast, mercury and selenium concentrations for the Arowhenua region were much lower than previous studies in the geothermally-influenced Rotorua region (Siegel & Siegel 1985), where concentrations as high as 39 µg/g were recorded. Selenium concentrations were similar between Arowhenua participants and the reference group (Figure 4).

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

Participant #	Age	Se	Hg
1	52	0.01	0.25
2	25	0.64	0.64
3	73	0.60	0.60
4	56	0.69	0.85
5	49	0.42	1.02
6	60	0.01	1.34
7	80	0.01	0.51
8	46	0.01	0.79
9	44	0.60	2.16
10	57	2.97	0.04
11	58	0.32	1.26
12	49	0.44	0.90
mean	54	0.56	0.86
median	54	0.43	0.86
minimum	25	0.01	0.04
maximum	80	2.97	2.16

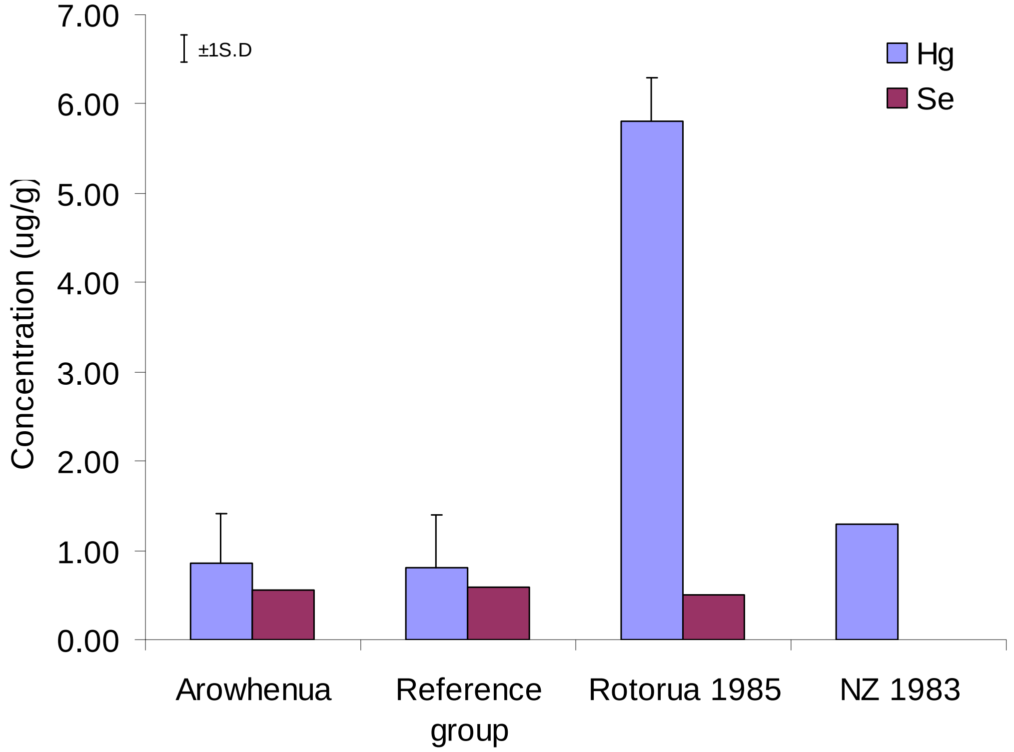


Figure 4: Comparisons of mean mercury (Hg) and selenium (Se) concentrations in hair samples of Arowhenua participants with selected reference groups.

3.4 Arowhenua contamination data

All kai contaminant data was measured and is reported on a dry weight basis.

3.4.1 Organochlorine pesticides

Concentrations of total DDT (ΣDDT = p,p'-DDT + o,p'-DDT + p,p'-DDE + o,p'-DDE + p,p'-DDD + o,p'-DDD), total chlordanes (sum of 6 congeners), HCB, lindane and dieldrin are shown for eels (Table 7), trout (Table 8), flounder (Table 9) and sediment (Table 10). PCBs were analysed in eels only and are shown in Table 2.

Three sites had markedly higher ΣDDT concentrations in eel tissue (Table 7), namely Winchester (538 µg/kg), Ohapi Creek (917 µg/kg) and Doncaster (914 µg/kg). Winchester and Ohapi Creek are predominantly rural areas, while Doncaster is part of the Washdyke industrial area, adjacent to the major town in the region, Timaru. The tissue concentrations of ΣDDT for trout (Table 8) and flounder (Table 9) were generally much lower than for eels. The highest tissue concentrations of ΣDDT for trout was from Temuka (81 µg/kg) and in flounder from Washdyke Lagoon (141 µg/kg).

Other organochlorine pesticides were either undetected, or detected at much lower concentrations than any of the DDT congeners (Tables 7-10). Dieldrin concentrations ranged from <0.2 to 40 µg/kg in eel tissue, with the highest concentration recorded at Doncaster. Other sites, with elevated eel dieldrin concentrations relative to the other sites, were Ohapi Creek (14.8 µg/kg) and Winchester (5.6 µg/kg) (Table 7). Dieldrin tissue concentrations ranged from 0.3 to 2.5 µg/kg for trout (Table 8) and 0.5 to 2.7 µg/kg for flounder (Table 9).

Total chlordane (sum of six congeners) concentrations ranged from <0.1 - 25.6 µg/kg in eels (Table 7), <0.1 - 0.2 µg/kg in trout (Table 8) and <0.1 - 1.7 µg/kg in flounder (Table 9). Doncaster (25.6 µg/kg, eel) and Winchester (3.7 µg/kg, eel) were the two most contaminated sites.

Hexachlorobenzene (HCB) concentrations ranged from <0.1 - 1.06 µg/kg in eels (Table 7), below detection limits (<0.1 µg/kg) in trout (Table 8) and <0.1 - 0.12 µg/kg in flounder (Table 9). The most contaminated sites were Doncaster (1.06 µg/kg, eel), Winchester (0.60 µg/kg, eel) and Waihi River (0.58 µg/kg, eel) (Table 7). Lindane (γ-hexachlorocyclohexane, (γ-HCH)) was not detected in any biota sample (limit of detection 0.2 µg/kg).

Doncaster, Washdyke Lagoon and Ohapi Creek, had the highest sediment concentrations of ΣDDT, with 26.5, 25.7 and 7.0 µg/kg respectively (Table 10). The relationship of sediment contamination to fish contamination is discussed in section 3.5.

Sediment organochlorine concentrations normalised to 1% Total Organic Carbon (TOC) of ΣDDT 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). Four sites had TOC normalised sediment ΣDDT concentrations that reached or exceed the ANZECC ISQ-Low guideline (1.6 µg/kg); Washdyke Lagoon (8.3 µg/kg), Washdyke Creek (3.8 µg/kg), Doncaster (3.3 µg/kg) and Winchester (1.6 µg/kg).

3.4.2 PCBs

Polychlorinated biphenyls (PCBs) were analysed in eel tissue only, with a total of 32 congeners included in the PCB suite. Total concentrations ranged from 1.4 - 161 µg/kg (Table 7), with the most elevated levels found at Doncaster and Winchester (161 and 67 µg/kg, respectively). PCBs were never manufactured in New Zealand, but were imported and used extensively in the electricity industry as insulating fluids and resins in transformers and capacitors (Buckland, Simon J et al. 1998b). As Doncaster is an industrial site, high relative levels of PCBs are not a surprising result, however, Winchester is a small rural town, so elevated levels at this location (relative to other rural sites in the area) was an unexpected result and could reflect an unknown or unrecorded source of PCBs in this area.

Table 7: Organochlorine concentrations in eels (µg/kg dry weight) at individual sites in the Arowhenua Region.

Eel	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek	Orari Ohapi	Opihi River upstream	Doncaster	Washdyke Lagoon
ΣDDT	160	538	148	52	37	917	55	57	914	100
ΣChlordanes	1.2	3.7	0.7	0.1	<0.1	0.7	<0.1	0.1	25.6	2.9
HCB	0.58	0.60	0.21	0.23	< 0.1	0.41	< 0.1	0.31	1.06	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	1.6	5.6	0.6	0.6	< 0.2	14.8	1.5	1.1	40	1.3
ΣPCBs	9.1	67	8.6	2.4	5.6	19.5	3.6	1.4	161	17.6

Table 8: Organochlorine concentrations (µg/kg dry weight) in trout from individual sites in the Arowhenua Region.

Trout	Waihi River	Winchester	Temuka	Orari Ohapi	Opihi River Mouth
ΣDDT	64	64	81	9.6	14
ΣChlordanes	<0.1	0.2	<0.1	<0.1	<0.1
HCB	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	0.3	2.5	0.7	0.7	0.4

Table 9: Organochlorine concentrations (µg/kg dry weight) in flounder from individual sites in the Arowhenua Region.

Flounder	Orari Ohapi	Doncaster	Opihi River Mouth	Washdyke Lagoon
ΣDDT	33	67	51	141
ΣChlordanes	<0.1	1.7	<0.1	1.5
HCB	< 0.1	0.12	< 0.1	0.10
lindane	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	0.5	2.7	0.7	2.1

Table 10: Organochlorine concentrations (µg/kg dry weight) in sediment from individual sites in the Arowhenua Region[a].

	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek
Σ DDT	0.3	1.9	0.8	0.6	<0.2	7.0
Σ Chlordane	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
HCB	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Orari Ohapi	**Opihi River upstream**	**Doncaster**	**Washdyke Creek**	**Opihi River Mouth**	**Washdyke Lagoon**
Σ DDT	<0.2	<0.2	26.5	2.5	1.2	25.7
Σ Chlordane	<0.1	<0.1	0.1	<0.1	<0.1	0.1
HCB	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

[a] pentachlorophenol and 2,3,4,6-tetrachlorophenol were not detected in any sediment (LOD 50 µg/kg).

Table 11: Total Organic Carbon normalised sediment ΣDDT concentrations with ANZECC ISQG-Low and ISQG-High Guidelines (ANZECC 2000).

Site	ΣDDT (1% TOC)[a,b]
Waihi River	0.5
Winchester	**1.6**
Temuka	0.8
Te Nga Wai	1.0
Opihi River below PP	<0.2
Ohapi Creek	1.3
Orari Ohapi	<0.2
Opihi River upstream	<0.2
Doncaster	**3.3**
Washdyke Creek	**3.8**
Opihi River Mouth	1.2
Washdyke Lagoon	**8.3**
ANZECC-Low	1.6
ANZECC-High	46.0

[a] Concentrations below detection limits not TOC normalised.
[b] Values in bold exceed ANZECC ISQG-Low guideline.

3.4.3 Heavy metals

The analysis of 8 heavy metals; arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn), was carried out on all fish tissue, watercress, and sediments.

Mercury contamination was generally highest in eel tissue, with a median value of 1.05 mg/kg and a range of 0.12 - 1.9 mg/kg (Table 12). The mercury concentrations were lower in the flesh from trout, with a median of 0.47 mg/kg and a range of 0.21 - 2.1 mg/kg (Table 13) and lower still in flounder tissue (median 0.18 mg/kg; range 0.11 - 0.48 mg/kg; Table 14). Mercury was generally below the limits of detection in watercress, with a range of <0.010 - 0.014 mg/kg (Table 15). The source of mercury in these kai is unclear. Unlike parts of the North Island of New Zealand, South

Canterbury does not have any identifiable geothermal inputs, which are considered to be natural sources of some heavy metals to lake and river systems.

The concentration trend in fish tissue was different for arsenic, indicating differential uptake between the three fish species. In contrast to mercury, arsenic was undetectable in eel tissue (Table 12), with highest concentrations in trout (median 1.55 mg/kg; range < 0.1 - 3.7 mg/kg; Table 13), and lower concentrations in flounder (median 0.59 mg/kg; range 0.28 - 2.2 mg/kg; Table 14). The concentration of arsenic in watercress ranged from <0.1 - 0.63 mg/kg, with a median concentration of 0.33 mg/kg (Table 15).

The arsenic found in biota could be caused by the multitude of historic sheep dip sites in the area, particularly given the absence of any identifiable geothermal activity. Prior to the 1950's sheep dips were arsenic-based (ECan 2010b) and there are now thought to be over 50,000 contaminated sheep-dip sites in New Zealand (MfE 2007).

Lead concentrations in eel tissue ranged between 0.014 and 0.2 mg/kg, with a median value of 0.026 mg/kg (Table 12). The maximum concentration was from Doncaster. Lead concentrations in trout were generally lower than those for eels, with many results below detection limits (0.01 mg/kg). The maximum lead concentration of 0.038 mg/kg was observed in a trout from the Winchester site (Table 13). For flounder, half the samples had lead concentrations below detection limits (0.01 mg/kg) with the highest level (0.17 mg/kg) recorded in a flounder from Opihi River mouth (Table 14). Concentrations of lead in watercress ranged from 0.35 to 1.6 mg/kg, with a median of 1.0 mg/kg (Table 15). The watercress lead levels were typically much higher than those observed in the fish, with median concentrations between 10 to 40-fold higher than those in edible fish tissue (Tables 11-14).

Cadmium was virtually undetectable in all fish analysed (Tables 11-13). The maximum fish tissue concentration of 0.041 mg/kg was for an eel collected from Opihi River upstream. Watercress had much higher cadmium concentrations than fish, with a median of 0.145 mg/g and a range of 0.078 - 0.22 mg/kg (Table 15).

Zinc concentrations were reasonably consistent among each species. Zinc concentrations in eels ranged from 22 - 46 mg/kg with a median value of 34 mg/kg (Table 12) and in trout zinc ranged from 14 - 20 mg/kg, with a median of 16 mg/kg (Table 13). Zinc in flounder ranged from 25 - 34 mg/kg with a median value of 31 mg/kg (Table 14). Watercress had the highest levels of zinc, ranging from 35-71 mg/kg with a median of 43 mg/kg (Table 15).

Copper concentrations were again reasonably consistent among each species. In eel, copper concentrations ranged from 0.56-1.10 mg/kg, with a median of 0.87 mg/kg (Table 12) and in trout the concentrations were in the range 0.9-1.7 mg/kg, with a median value of 1.2 mg/kg (Table 13). Flounder had copper concentrations of 0.7-1.2 mg/kg, with a median of 1.2 mg/kg (Table 14). As observed for zinc, watercress had the highest levels of copper, ranging from 5.0-12.0 mg/kg and a median of 8.3 mg/kg (Table 15).

Nickel was present in low concentrations in all fish species, often below detection limits (0.1 mg/kg) (Tables 11-13). However, a concentration of 0.45 mg/kg for nickel in flounder from Opihi River Mouth (Table 14) was recorded. Nickel was detected in all watercress samples, ranging from 0.2-2.9 mg/kg with a median of 1.2 mg/kg (Table 15).

Chromium was virtually undetectable in all fish species at the detection limit (0.1 mg/kg) (Tables 11-13). The one exception was eel from Washdyke, with chromium at a level of 0.3 mg/kg (Table 12). Chromium concentrations in watercress ranged between 0.22-1.40 mg/kg, with a median level of 0.67 mg/kg (Table 15).

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 16). 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). These sediment guidelines were only exceeded on one occasion. The low ISQG value of 200 mg/kg for zinc was exceeded at Doncaster, with a value of 220 mg/kg (Table 16).

Table 12: Metal concentrations in eels (mg/kg dry weight) from individual sites in the Arowhenua Region.

Metal	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek	Orari Ohapi	Opihi River upstream	Doncaster	Washdyke Lagoon	median
arsenic	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.11	< 0.10	< 0.10	< 0.17	-
cadmium	0.0029	0.0065	0.0026	0.0045	0.011	0.0029	0.0065	0.041	0.0033	< 0.0033	0.0045
chromium	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.11	< 0.10	< 0.10	0.3	0.3
copper	1.10	0.89	0.60	1.10	0.83	1.10	0.84	0.59	0.56	0.92	0.87
lead	0.014	0.054	0.028	0.019	0.029	0.017	0.024	0.014	0.2	0.062	0.026
mercury	0.87	1.4	1.4	1.2	1.9	0.9	0.78	1.3	0.37	0.12	1.05
nickel	< 0.10	< 0.10	< 0.10	0.12	< 0.10	< 0.10	0.15	< 0.10	< 0.10	0.17	0.15
zinc	22	35	32	40	32	40	40	24	33	46	34

Table 13: Metal concentrations in trout (mg/kg dry weight) from individual sites in the Arowhenua Region.

Metal	Waihi River	Winchester	Temuka	Orari Ohapi	Opihi River mouth	median
arsenic	< 0.1	0.27	2	1.1	3.7	1.55
cadmium	0.002	< 0.0020	< 0.0020	< 0.0020	< 0.0020	0.002
chromium	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	-
copper	1.7	1.5	0.9	1.0	1.2	1.2
lead	0.02	0.038	< 0.010	< 0.010	< 0.010	0.029
mercury	0.48	0.3	2.1	0.21	0.47	0.47
nickel	0.13	< 0.10	< 0.10	< 0.10	< 0.10	0.13
zinc	14	16	15	20	19	16

Table 14: Metal concentrations in flounder (mg/kg dry weight) from individual sites in the Arowhenua Region.

Metal	Orari Ohapi	Doncaster	Washdyke Lagoon	Opihi River mouth	median
arsenic	0.28	0.74	2.2	0.44	0.59
cadmium	< 0.0020	< 0.0020	< 0.0020	< 0.0020	-
chromium	< 0.10	< 0.10	< 0.10	< 0.10	-
copper	1.2	1.2	0.7	1.2	1.2
lead	< 0.010	< 0.010	0.01	0.17	0.09
mercury	0.48	0.15	0.21	0.11	0.18
nickel	< 0.10	< 0.10	< 0.10	0.45	0.45
zinc	34	32	29	25	31

Table 15: Metal concentrations in watercress (mg/kg dry weight) from individual sites in the Arowhenua Region.

Metal	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi below PP	Ohapi Creek	Opihi upstream	Opihi River mouth	median
arsenic	0.15	< 0.10	0.38	< 0.10	0.63	0.37	0.17	0.33	0.35
cadmium	0.13	0.11	0.15	0.14	0.15	0.078	0.22	0.2	0.145
chromium	0.71	0.40	1.10	0.17	0.84	1.40	0.22	0.62	0.67
copper	6.1	6.5	8.4	12.0	8.4	8.2	10.0	5.0	8.3
lead	0.81	0.67	1.1	0.35	1.3	1.6	0.9	1.1	1.0
mercury	< 0.010	< 0.010	0.012	< 0.010	0.014	< 0.010	< 0.010	< 0.010	0.013
nickel	0.6	0.2	1.3	1.2	1.8	0.9	2.9	1.2	1.2
zinc	39	59	44	70	38	71	35	42	43

Table 16: Metal concentrations in sediment (mg/kg dry weight) from individual sites in the Arowhenua Region with the ANZECC-ISQG guidelines as reference (ANZECC 2000).

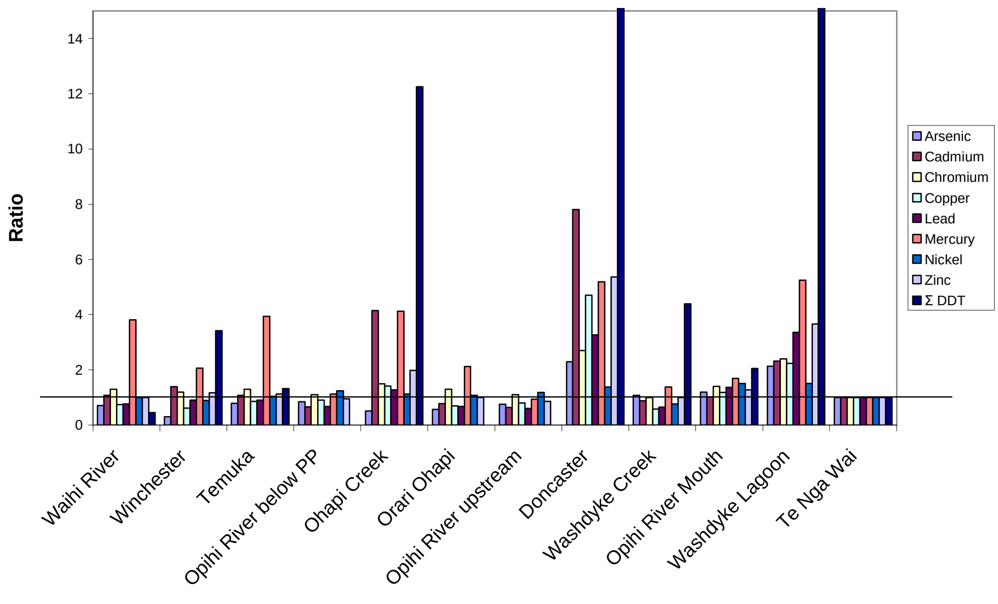
Metal	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek	ANZECC ISQG-Low
arsenic	2.6	1.1	2.9	3.7	3.1	1.9	20
cadmium	0.044	0.057	0.044	0.041	0.027	0.170	1.5
chromium	13	12	13	10	11	15	80
copper	6.3	5.2	7.3	8.5	7.7	12.0	65
lead	8.4	10	10	11	7.4	14	50
mercury	0.061	0.033	0.063	0.016	0.018	0.066	0.15
nickel	7.3	6.5	7.6	7.3	9.0	8.2	21
zinc	41	48	46	41	39	81	200
Metal	**Orari Ohapi**	**Opihi River upstream**	**Doncaster**	**Washdyke Creek**	**Opihi River Mouth**	**Washdyke Lagoon**	**ANZECC ISQG-High**
arsenic	2.1	2.8	8.5	4	4.4	7.9	70
cadmium	0.032	0.026	0.320	0.036	0.042	0.095	10.0
chromium	13	11	27	10	14	24	370
copper	5.9	6.8	40.0	4.9	10.0	19.0	270
lead	7.4	6.6	36	7.1	15	37	220
mercury	0.034	0.015	0.083	0.022	0.027	0.084	1
nickel	7.9	8.6	10.0	5.6	11.0	11.0	52
zinc	41	35	220	41	52	150	410

3.5 Site contamination comparisons

An assessment was made as to whether the analysis of contaminant concentrations in sediments was sufficient in determining potential hotspots of contamination and whether that could then be applied in predicting whether biota from that site would also show elevated concentrations relative to a reference site.

Sediment concentration ratios, relative to the reference site, Te Nga Wai, were calculated for all heavy metals plus ΣDDT, with the data presented in Figure 5. Sites which had consistently high ratios for most contaminants were Doncaster, Washdyke Lagoon and Ohapi Creek (Figure 5). Individual contaminants that stood out were ΣDDT, cadmium and mercury. ΣDDT ratios were 46.5, 45.1, 12.3, 4.4 and 3.4 for Doncaster, Washdyke Lagoon, Ohapi Creek, Washdyke Creek and Winchester respectively. Seven of the twelve sites had mercury ratios greater than 2, while cadmium was elevated in Doncaster, Washdyke Lagoon and Ohapi Creek (Figure 5).

Figure 5: Sediment concentration ratios [a,b,c] for individual sites in Arowhenua Region.



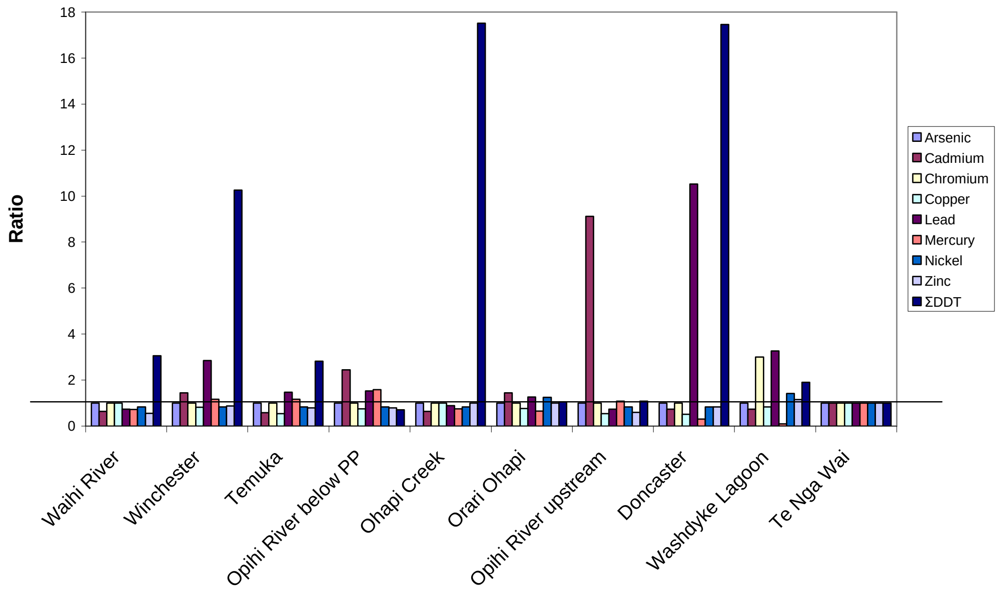
[a] Ratios are calculated by dividing contaminant concentrations by those measured at the reference site (Te Nga Wai).
[b] Any value > 1 (indicated by horizontal grey line) has an elevated concentration compared to the reference site.
[c] Values for Doncaster and Washdyke Lagoon exceed the scale shown. Values are 46.5 and 45.1 respectively.

Doncaster and Washdyke Lagoon are either within, or adjacent to, the Washdyke industrial area, so elevated sediment contamination is expected. Ohapi Creek is a rural area, so elevated ΣDDT can be explained by historic agricultural use, however elevated ratios of mercury (4.1) and cadmium (4.1) were unexpected.

Further contaminant comparisons were made using eel and watercress as model species to assess whether high sediment ratios translate through to high kai concentrations.

Eel contaminant ratios, relative to the reference site, Te Nga Wai, were calculated for each site where eels were harvested and the results presented in Figure 6.

Figure 6: Eel concentration ratios [a,b,c] for individual sites in Arowhenua Region.

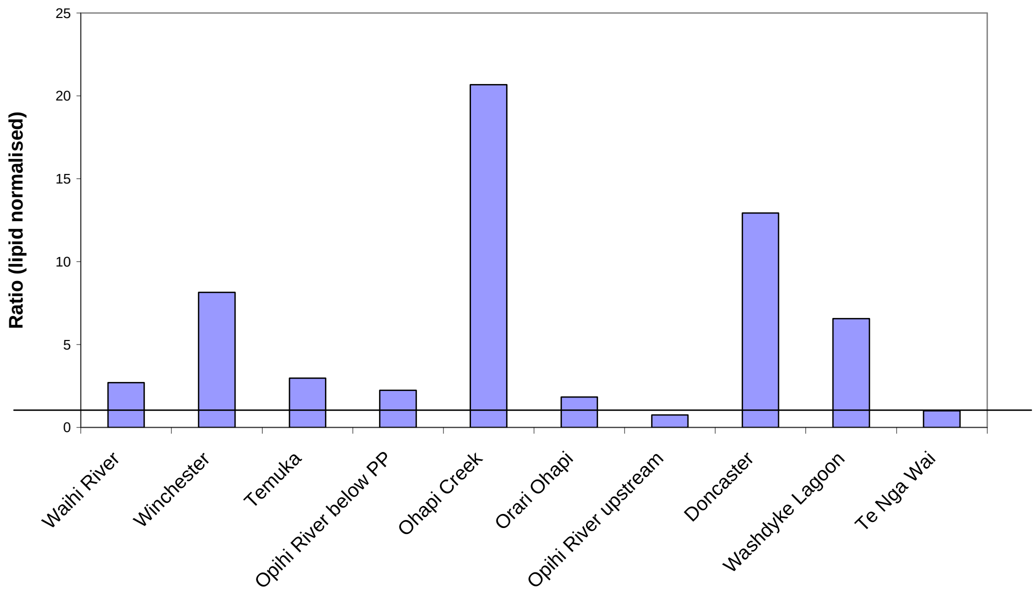


[a] Ratios are calculated by dividing contaminant concentrations by those measured at the reference site (Te Nga Wai).
[b] Any value over 1 (indicated by horizontal line) has an elevated concentration compared to the reference site.
[c] All concentrations below detection limit were set to detection limit for purposes of calculations.

A different contamination profile was observed in the eels than in the sediment. Whereas the sediment analyses were effective in showing consistently elevated contamination in Doncaster, Washdyke Lagoon and Ohapi Creek for multiple contaminants (Figure 5), this was not apparent with the eel data. The contamination was usually only elevated for one contaminant (Figure 6). The most consistently elevated contaminant in eels, relative to the reference site, was ΣDDT, with ratios exceeding 2 for half of the sites; Waihi River (3.1), Winchester (10.3), Temuka (2.8), Ohapi Creek (17.5) and Doncaster (17.5) (Figure 6). Washdyke Lagoon showed a high ΣDDT sediment ratio (45.1) that was not reflected in the eel ΣDDT ratio of 1.9. The eel collected from Washdyke Lagoon was relatively small with a length of 385 mm, weight of 123 g and lipid content of 3.7%. These parameters were very low compared with the regional averages of 576 mm, 469 g and 20.6% respectively (see Appendix 2a). Concentrations of ΣDDT and other lipophilic contaminants in tissue are lipid dependant, i.e., the higher the % lipid the higher the concentration of ΣDDT. This is a likely explanation for the lower than expected ratio for ΣDDT in the eel from Washdyke Lagoon.

Calculation of lipid normalised ΣDDT ratios, was achieved by dividing the ΣDDT concentration by % lipid. The ratio, relative to Te Nga Wai (Figure 7), more accurately reflects the sediment ΣDDT ratios, highlighting Doncaster, Washdyke Lagoon, Ohapi Creek, Washdyke Creek and Winchester as potential hotspots.

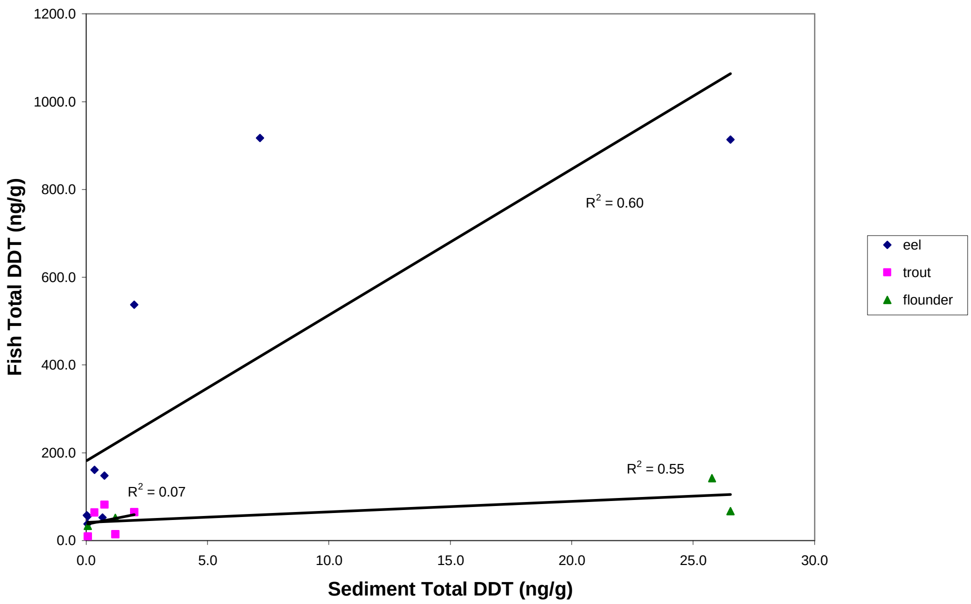
Figure 7: Eel ΣDDT ratios [a,b] (lipid normalised) for individual sites in Arowhenua Region.



[a] Ratios are calculated by dividing contaminant concentrations by those measured at the reference site (Te Nga Wai).
[b] Any value over 1 (indicated by horizontal line) has an elevated concentration compared to the reference site.

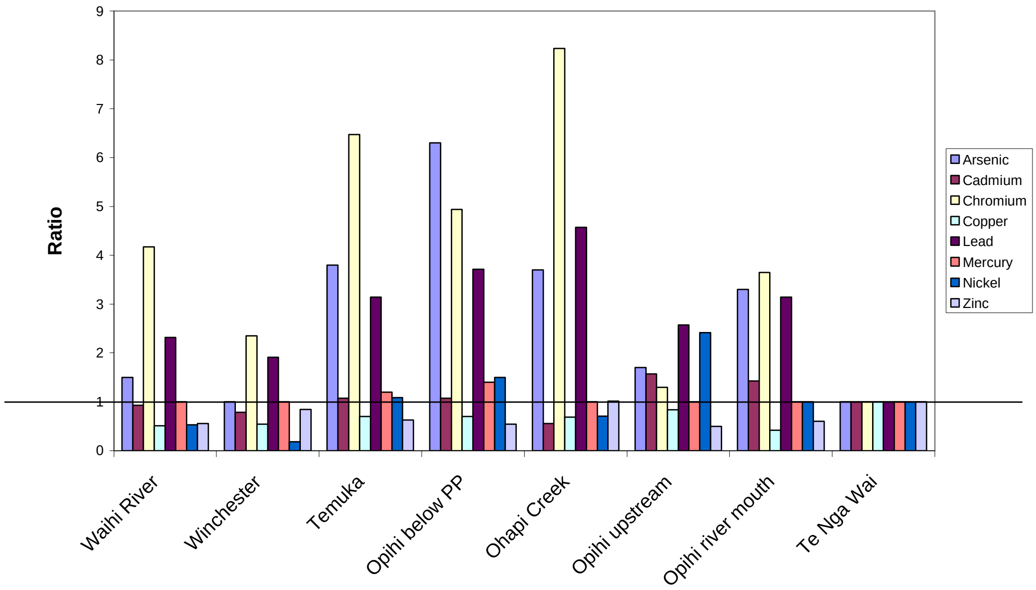
This approach shows that, for DDT at least, analysis of sediment ΣDDT ratios, relative to a reference site, could be used to rapidly screen sites. Elevated ΣDDT levels in sediment will most likely correspond to elevated eel ΣDDT concentrations. This method could be equally effective for assessing the contaminant levels in a range of aquatic species, although this would be restricted to those organisms which are sedentary (shellfish), dwell in or on sediment (flounder) or are territorial (eel) in nature. For fish that are highly mobile (e.g., trout), this relationship is unreliable. This is highlighted in Figure 8, where a reasonable correlation exists between sediment ΣDDT concentrations and fish ΣDDT concentrations for flounder and eel, with R^2 values of 0.60 and 0.55 respectively, but no such relationship for trout exists, with an R^2 value of 0.07 (Figure 8). This also highlights that eels are very susceptible to small changes in environmental concentrations.

Figure 8: Relationship between sediment ΣDDT concentration and fish ΣDDT concentration for individual species from sites in Arowhenua Region.



The data in Figures 6-8 show that a relationship exists between sediment ΣDDT and eel flesh ΣDDT, however this is not apparent for heavy metals and would not be expected for metals other than mercury. Watercress is an aquatic plant which makes it a suitable candidate for assessing metal bio-concentration relative to high sediment metal concentrations. Contamination ratios for watercress, relative to the reference site, Te Nga Wai, were calculated and are presented in Figure 9. The two most highly contaminated sites, Doncaster and Washdyke Lagoon, did not have any watercress, so no comparisons can be made for these sites, which severely limits our ability to interpret possible relationships. Nevertheless, elevated ratios of arsenic, chromium and lead were observed at almost all sites, relative to the reference site. This pattern was not observed when comparing the sediment ratios (Figure 5).

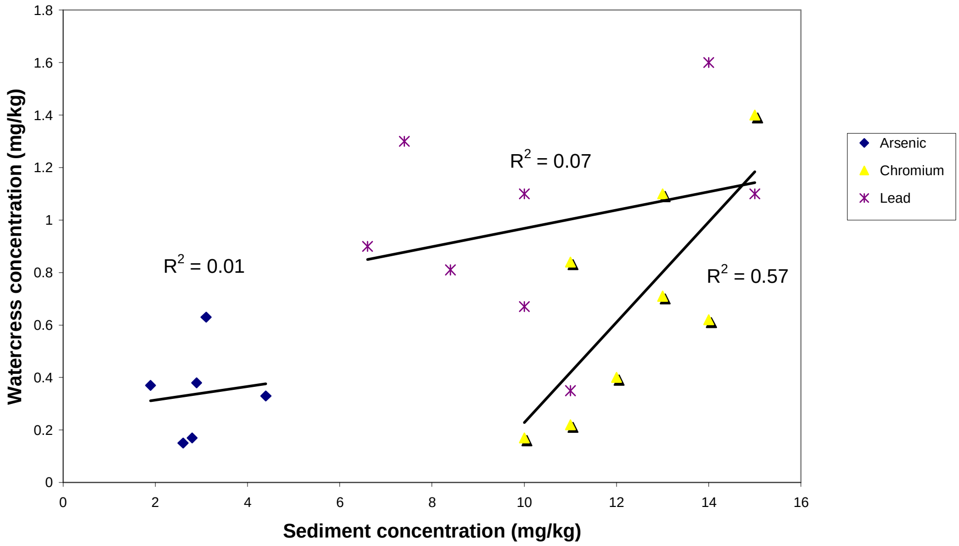
Figure 9: Watercress concentration ratios [a,b,c] for individual sites in Arowhenua Region.



[a] Ratios are calculated by dividing contaminant concentrations by those measured at the reference site (Te Nga Wai).
[b] Any value over 1 (indicated by horizontal line) has an elevated concentration compared to the reference site.
[c] All concentrations below detection limit were set to detection limit for purposes of calculations.

An assessment of bioaccumulation of arsenic, chromium and lead in watercress was made by comparing watercress concentrations of these metals with sediment concentrations (Figure 10). A reasonable correlation was observed for chromium (R^2 = 0.57) but no correlation was observed for arsenic or lead (R^2 = 0.01 and 0.07 respectively). The lack of correlation with sediment concentrations indicates that the bioaccumulation of arsenic and lead is primarily from the river water.

Figure 10: Relationship between watercress concentrations of arsenic, chromium and lead with sediment in Arowhenua.



4. Conclusions

This report is the first of two reports collectively used to determine the human health risk to local Māori of eating wild harvested kai (food) in the rohe of Arowhenua. Part one (this report) describes the information gained from a survey of members of Arowhenua iwi of important kai gathering locations. Key conclusions from this report are:

- overall fish consumption by participants was similar to the average New Zealand high consumption rate;
- however, traditionally harvested fish formed only a small component of overall fish consumption;
- mercury and selenium levels measured in hair samples from 12 participants were similar to the study reference group, as well as to published New Zealand average data;
- contaminant analysis indicated differential uptake of specific contaminants by different species. For example, watercress recorded much higher levels of cadmium, nickel, chromium, lead, zinc and copper than fish. Eel tissue had the highest concentrations of DDT, PCBs and mercury, whereas arsenic levels were highest in trout tissue;
- Winchester, Ohapi Creek, Doncaster and Washdyke Lagoon sites consistently reported elevated levels of a number of contaminants;
- PCBs, DDT and arsenic are likely to be legacy contaminants from past activities. The cause of elevated mercury concentrations is unclear;
- Sediment metal concentrations were below ANZECC guidelines, with one exception. Doncaster recorded a value of 220 mg/kg for zinc, just above the low ISQG low guideline value of 200 mg/kg;
- It appears that high sediment ΣDDT concentrations translate to high ΣDDT concentrations in eel and flounder, but not trout. A similar inference for metals in watercress could not be made based on the available data, indicating that contaminant bioaccumulation (particularly arsenic and lead) is primarily from the overlying river water.

The overall aim of this project was to determine the relative risk of consumption of kai species from sites where they are or 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 (Stewart et al. 2010). That report also includes a discussion of the implications of these results for Māori and non-Māori consumers of wild kai.

5. Acknowledgements

The authors thank Lindsay Hawke and Julian Sykes (NIWA Christchurch) and Te Runanga o Arowhenua members for their participation in the research and for help with field sampling. This research was funded by the Health Research Council of New Zealand, Contract HRC/207. Kai consumption data were collected under Ethics Approval # Ethics Approval MEC/07/07/088.

6. References

Airey, D. (1983). Total mercury concentrations in human hair from 13 countries in relation to fish consumption and location. *The Science of the Total Environment 31(2)*: 157-180. <http://dx.doi.org/Doi: 10.1016/0048-9697(83)90067-0>

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

Berry, M.; Ralston, N. (2008). Mercury Toxicity and the Mitigating Role of Selenium. *EcoHealth 5(4)*: 456-459. <http://dx.doi.org/10.1007/s10393-008-0204-y>

Buckland, S.J.; Jones, P.D.; Ellis, H.K.; Salter, R.T. (1998a). Organochlorines in New Zealand: Ambient concentrations of selected organochlorines in rivers. *No. ME317*. 191 p.

Buckland, S.J.; Scobie, S.; Heslop, V. (1998b). Concentrations of PCDDs, PCDFs and PCBs in retail foods and an assessment of dietary intake for New Zealanders. *No.* 115 p.

Durie, M. (1994). Whaiora: Māori Health Development. Oxford University Press, Auckland. p.

Durie, M. (1998). Te mana te kawanatanga. Oxford University Press, Auckland. p.

ECan. Identifying contaminated sites. 2010a. Retrieved 31st August, 2010, from http://ecan.govt.nz/advice/your-land/contaminated-land/Pages/contaminated-land-identification.aspx

ECan. Managing old sheep dip and footbath sites. 2010b. Retrieved 3rd August, 2010, from http://ecan.govt.nz/advice/your-business/farming/Pages/managing-old-sheepdip-footbath-sites.aspx

Golder Associates and NIWA (2009). Trace elements in watercress in the Tarawera River. *No.* 16 p.

Hill Laboratories (2000). Hair Analysis Technical Note CT.RJH.2223 Version 2, Issue Date 22 February 2000. *No.* p.

Hill Laboratories. 2010. Retrieved 3rd August, 2010, from http://www.hill-laboratories.com/

Hoekstra, P.F.; O'Hara, T.M.; Backus, S.M.; Hanns, C.; Muir, D.C.G. (2005). Concentrations of persistent organochlorine contaminants in bowhead whale tissues and other biota from northern Alaska: Implications for human exposure from a subsistence diet. *Environmental Research 98(3)*: 329-340. <http://dx.doi.org/DOI: 10.1016/j.envres.2004.09.012>

Johansen, P.; Muir, D.; Asmund, G.; Riget, F. (2004). Human exposure to contaminants in the traditional Greenland diet. *Science of The Total Environment 331(1-3)*: 189-206. <http://dx.doi.org/DOI: 10.1016/j.scitotenv.2004.03.029>

Kim, N.; Smith, J. (2006). Review of science relating to discharges from the Kinleith Pulp and Paper mill. Environment Waikato Technical Report. *No. 2005/58*. 83 p.

Long, E.; Macdonald, D.; Smith, S.; Calder, F. (1995). Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management 19(1)*: 81-97. <http://dx.doi.org/10.1007/bf02472006>

MfE (2006). Identifying, Investigating and Managing Risks Associated with Former Sheep-dip Sites: A guide for local authorities. *No.* 108 p.

MfE (2007). Environment New Zealand 2007 *No.* 458 p.

Mongilo, B. (2009).

NOAA. (1993). Technical Memorandum NOS ORCA 71. Sampling and analytical methods of the national status and trends program national benthic surveillance and mussel watch projects 1984-1992. Vols III & IV. p.

NZFSA (2005). Review of Non-Commercial Wild Food in New Zealand. *No.* 28 p.

Odland, J.O.; Deutch, B.; Hansen, J.C.; Burkow, I.C. (2003). The importance of diet on exposure to and effects of persistent organic pollutants on human health in the Arctic. *Acta paediatricia 92*: 1255-1266.

Panelli, R.; Tipa, G. (2007). Placing well-being: recognizing culture-environment specificity. *Ecohealth 4(4)*: 445–460.

Panelli, R.; Tipa, G. (2008). Beyond foodscapes: considering geographies of Indigenous well-being. *Health and Place 15(2)*: 455-465.

Siegel, B.Z.; Siegel, S.M. (1985). Mercury in human hair: Uncertainties in the meaning and significance of 'unexposed' and 'exposed' in sample populations. *Water, Air, & Soil Pollution 26(2)*: 191-199.

Stewart, M.; Hickey, C.; Phillips, N.; Olsen, G. (2010). Contaminants in Kai – Arowhenua rohe. Part 2: Risk Assessment. *No. HAM2010-116*. 83 p.

Sumner, J.L.; Hopkirk, G. (1976). Lipid composition of New Zealand eels. *Journal of the Science of Food and Agriculture 27*: 933-938.

Taylor, R.; Smith, I.; Cochrane, P.; Stephenson, B.; Gibbs, N. (1997). The State of New Zealand's Environment 1997. *No. ME612*. p.

Tipa, G.; Nelson, K.; Downs, S.; Home, M.; Phillips, N. (2010a). A survey of wild kai consumption in the Arowhenua rohe. *No. HAM2010-098*. 120 p.

Tipa, G.; Nelson, K.; Emery, W.; Smith, H.; Phillips, N. (2010b). A survey of wild kai consumption in the Te Arawa rohe. *No. HAM2010-096*. 171 p.

Turner, N.; Cressey, P.; Lake, R.; Whyte, R. (2005). Review of non-commercial wild food in New Zealand. *No.* 181 p.

US EPA (1977). Method 600/4-81-055. Interim methods for the sampling and analysis or priority pollutants in sediments and fish tissue. (Revised October 1980 (NERL). p.

US EPA (1986). Method 503/6-90-004. Analytical methods for US EPA priority pollutants and 301(h) pesticides in estuarine and marine sediments. *No.* p.

US EPA (2000). Guidance for Assessing Chemical Contaminant Data for Use In Fish Advisories. No. EPA 823-B-00-008. Volume 2: Risk Assessment and Fish Consumption Limits - Third Edition. *No.* p.

Van Oostdam, J.; Donaldson, S.; Feeley, M.; Tremblay, N. (2003). Canadian Arctic Contaminants Assessment Report II: Human Health. Northern Contaminants Program. 127 p. Retrieved, from

Van Oostdam, J.; Gilman, U.A.; Dewailly, E.; Usher, P.; Wheatley, B.; Kuhnlein, H.; Neve, S.; Walker, J.; Tracy, B.; Feeley, M.; Jerome, V.; Kwavnick, B. (1999). Human health implications of environmental contaminants in Arctic Canada: a review. *The Science of the Total Environment 230*: 1-82.

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.
ECan	Environment Canterbury.
γ-HCH	Gamma-hexachlorocyclohexane = lindane.
GC-MS	Gas Chromatography - Mass Spectrometry.
GC–MS–SIM	Gas Chromatography - Mass Spectrometry - Selected Ion Mode.
HCB	Hexachlorobenzene.
ICP-MS	Inductively Coupled Plasma Mass Spectrometry.
ISQG	Interim sediment quality guidelines.
kg	kilogram(s).
LLUR	Listed Land Use Register.
MfE	Ministry for the Environment.

mg	milligram
MoH	Ministry of Health.
mm	millimetre(s).
NCP	Northern Contaminants Programme.
NOAA	National Oceanic and Atmospheric Administration.
NZ	New Zealand.
NZFSA	New Zealand Food Safety Authority.
OCP	Organochlorine pesticide.
PAH	Polycyclicaromatic hydrocarbons.
PCB	Polychlorinated biphenyl.
PCP	Pentachlorophenol
ppb	1 part per billion = 1 μg/kg.
ppm	1 part per million = 1 mg/kg.
TOC	Total Organic Carbon.
μg	microgram.
US EPA	United States Environmental Protection Association.

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).
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 questionnaire.
Appendix 2	Biometric data.
Appendix 3	Contaminant data.

Appendix 1: Extract of Kai Consumption Survey questionnaire for Arowhenua participants.

D. DIET AND LIFESTYLE

29. 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)*____

30. 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										
Watercress										

31. 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

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

☐ Yes ☐ No Go to Question 43

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

KAI	NEVER	Special occasions	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		
Butterfish											
Freshwater mussels											
Morihana											
Herrings											
Pipi											
Cockles											
Toheroa											
Tuatua											
Greenbone											
Lampreys											
Mutton birds											
Pupu											
Eel											
Flounder											
Hapuka											
Mullet											
Kahawai											
Kingfish											
Gurnard											
Snapper											
Moki											
Shark											
Tarakihi											
Trevally											
Whitebait											
Trout											
Kina											
Paua											
Mussels											
Crayfish											
Oysters											
Seaweed											
Freshwater crayfish											
Watercress											
Puha											

34. 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) ____________________________
  ____

35. 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.*

35.2 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

35.3 When you ate mussels did you usually eat?

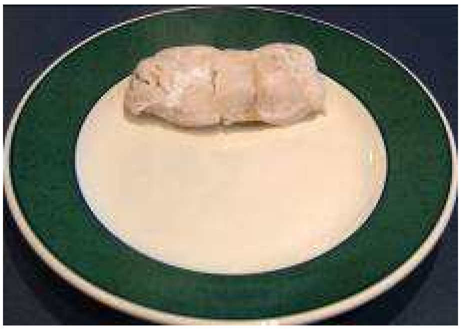
A B C



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

35.4 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

35.5 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

35.6 When you ate scallops did you usually eat?

A 

B 

C 

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

36. 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., blue cod, groper, trout etc.) – tick all the parts you eat

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

36.2 For eels – tick all the parts you eat

☐ 1: fish heads
☐ 2. fish fillets

36.3 For crayfish – tick all the parts you eat

☐ 1: heads
☐ 2. tails
☐ 3. legs etc.

36.4 For titi / muttonbirds

- ☐ 1: fresh and / or frozen
- ☐ 2. packed in a bucket
- ☐ 3. packed in a poha
- ☐ 4. preserved with stomachs intact

37 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
- ☐ River mouths
- ☐ From fishing reserves
- ☐ Coastline
- ☐ Sea waters
- ☐ Other – please list the sites______________

____

____.

☐ No

Appendix 2a: Biometric Data for Eel collected from Arowhenua Region in May and June 2009.

Site	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek	Orari Ohapi	Opihi River upstream	Doncaster	Washdyke Lagoon
Species	Shortfin	Shortfin	Shortfin	Shortfin	Shortfin	Longfin	Shortfin	Shortfin	Shortfin	Shortfin
Length (mm)	655	675	535	470	595	640	505	600	700	385
Weight (g)	577	630	280	240	406	769	271	530	862	123
Age (y)	19	32	16	15	13	28	14	11	23	ND
moisture (%)	63	60	73	70	76	74	73	58	59	81
Lipid (%)	27.7	32.8	17.0	19.8	5.0	14.3	10.3	39.5	36.4	3.7

ND = Not determined.

Appendix 2b: Biometric Data for Trout and Flounder collected from Arowhenua Region in May and June 2009.

Species	**Trout**					**Flounder**			
Site	**Waihi River**	**Winchester**	**Temuka**	**Orari Ohapi**	**Opihi River mouth**	**Orari Ohapi**[a]	**Doncaster**	**Opihi River mouth**	**Washdyke Lagoon**
Length (mm)	478	473		272	360	129-183	295	230	300
Weight (g)	1355	1173	1960	209	506	192	407	176	466
moisture (%)	72	74	76	76	76	80	79	81	75
Lipid (% dw)	4.4	5.4	4.3	3.3	3.6	5.3	4.5	3.6	7.9

[a] Composite of 3 small flounder.

Appendix 2c: Biometric Data for Watercress collected from Arowhenua Region in May 2009.

Site	Wet weight (g)	Dry Weight (g)	% moisture	dw/ww
Waihi River	167	10.55	94	0.063
Winchester	133	9.25	93	0.070
Temuka	203	10.00	95	0.049
Te Nga Wai	274	20.35	93	0.074
Opihi River below Pleasant Point	189	10.05	95	0.053
Ohapi Creek	450	13.30	97	0.030
Opihi River upstream	267	21.75	92	0.081
Opihi River Mouth	180	15.55	91	0.086

Appendix 2d: Particle size distribution data and total organic carbon (TOC) for sediment sites from Arowhenua Region collected from Arowhenua.

Site	>2mm (%)	2000-63 mm (%)	<63 mm (%)	Total %	TOC[a]
Waihi River	47.1	48.6	4.37	100.00	0.6
Winchester	3.0	89.2	7.74	100.00	1.2
Temuka	28.1	55.3	16.63	100.00	0.9
Te Nga Wai	10.4	81.0	8.61	100.00	0.6
Opihi River below PP	9.1	86.4	4.46	100.00	0.2
Ohapi Creek	4.9	52.5	42.54	100.00	5.4
Orari Ohapi	5.3	92.4	2.25	100.00	0.2
Opihi River upstream	6.0	91.5	2.53	100.00	0.2
Doncaster	19.5	39.5	40.98	100.00	8.0
Washdyke Creek	0.6	79.8	19.53	100.00	0.7
Opihi River Mouth	15.0	42.9	42.10	100.00	1.0
Washdyke Lagoon	2.4	33.3	64.37	100.00	3.1

[a] g/100g (dry weight).

Appendix 3a: Organochlorine pesticide concentrations (µg/kg dry weight) in biota from Arowhenua.

Site	Te Nga Wai	Opihi River below PP	Opihi River upstream	Opihi River Mouth		Temuka		Winchester	
Species	**Eel**	**Eel**	**Eel**	**Trout**	**Flounder**	**Eel**	**Trout**	**Eel**	**Trout**
o,p-DDE	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.2	< 0.1	0.2	< 0.1
p,p'-DDE	48.3	35.6	51.7	13.2	46.5	137.2	77.8	481.5	62.6
o,p-DDD	< 0.2	< 0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2
p,p-DDD	1.1	0.5	1.9	0.3	2.0	4.2	1.6	16.1	0.6
o,p-DDT	0.2	< 0.1	0.3	< 0.1	0.4	0.5	0.4	1.3	0.1
p,p'-DDT	2.7	1.2	3.1	0.6	2.1	5.6	1.5	38.4	1.1
Σ DDT	52.4	37.3	57.0	14.0	51.3	147.7	81.3	537.5	64.4
DDT/Σ DDT (%)	5.6	3.1	6.0	4.0	4.7	4.1	2.4	7.4	1.9
heptachlor	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
heptachlor epoxide	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-chlordane	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.4	< 0.1
cis-chlordane	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.3	< 0.1
trans-nonachlor	0.1	< 0.1	0.1	< 0.1	< 0.1	0.5	< 0.1	2.0	0.2
cis-nonachlor	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.9	< 0.1
Total Chlordane	0.1	0.0	0.1	0.0	0.0	0.7	0.0	3.7	0.2
HCB	0.2	< 0.1	0.3	< 0.1	< 0.1	0.2	< 0.1	0.6	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	0.6	< 0.2	1.1	0.4	0.7	0.6	0.7	5.6	2.5

Appendix 3a: (cont). Organochlorine pesticide concentrations (µg/kg dry weight) in biota from Arowhenua.

Site	Waihi River		Ohapi Creek	Orari Ohapi			Doncaster		Washdyke Lagoon	
Species	**Eel**	**Trout**	**Eel**	**Eel**	**Trout**	**Flounder**	**Eel**	**Flounder**	**Eel**	**Flounder**
o,p-DDE	< 0.1	< 0.1	0.1	0.1	< 0.1	< 0.1	0.2	0.2	0.4	0.6
p,p'-DDE	145.3	62.7	888.0	52.2	9.2	32.0	697.6	50.3	49.8	110.2
o,p-DDD	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	1.5	0.7	< 0.2	0.8
p,p-DDD	5.3	0.3	10.1	1.7	0.2	0.4	146.1	6.2	11.6	10.3
o,p-DDT	1.1	< 0.1	0.7	0.2	< 0.1	0.1	2.9	0.9	2.4	1.5
p,p'-DDT	8.7	0.7	18.4	0.8	0.3	0.9	65.5	8.3	35.8	18.0
Σ DDT	160.4	63.6	917.3	54.9	9.6	33.4	913.9	66.7	99.9	141.4
DDT/Σ DDT (%)	6.2	1.0	2.1	1.8	3.0	2.9	7.5	13.8	38.2	13.8
heptachlor	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
heptachlor epoxide	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-chlordane	0.2	< 0.1	0.1	< 0.1	< 0.1	< 0.1	2.9	0.5	0.6	0.5
cis-chlordane	0.2	< 0.1	0.1	< 0.1	< 0.1	< 0.1	4.1	0.4	0.6	0.4
trans-nonachlor	0.6	< 0.1	0.3	< 0.1	< 0.1	< 0.1	13.0	0.6	1.3	0.5
cis-nonachlor	0.2	< 0.1	0.2	< 0.1	< 0.1	< 0.1	5.5	0.2	0.5	0.1
Total Chlordane	1.2	0.0	0.7	0.0	0.0	0.0	25.6	1.7	2.9	1.5
HCB	0.6	< 0.1	0.4	< 0.1	< 0.1	< 0.1	1.1	0.1	< 0.1	0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	1.6	0.3	14.8	1.5	0.7	0.5	39.7	2.7	1.3	2.1

Appendix 3b: Organochlorine pesticide concentrations (µg/kg dry weight) in sediment from Arowhenua.

Site	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek
o,p-DDE	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
p,p'-DDE	0.3	1.4	0.5	0.3	< 0.1	6.4
o,p-DDD	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
p,p-DDD	< 0.1	0.2	< 0.1	< 0.1	< 0.1	0.4
o,p-DDT	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
p,p'-DDT	< 0.1	0.3	0.2	0.3	< 0.1	0.2
Total DDT	0.3	1.9	0.8	0.6	0.0	7.0
heptachlor	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
heptachlor epox	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-chlordane	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
cis-chlordane	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-nonachlor	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
cis-nonachlor	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total Chlordane	0.0	0.0	0.0	0.0	0.0	0.0
hexachlorobenzene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

Appendix 3b: (cont). Organochlorine pesticide concentrations (µg/kg dry weight) in sediment from Arowhenua.

Site	Orari Ohapi	Opihi River upstream	Doncaster	Washdyke Creek	Opihi River Mouth	Washdyke Lagoon
o,p-DDE	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
p,p'-DDE	< 0.1	< 0.1	19	2.3	0.8	21.2
o,p-DDD	< 0.2	< 0.2	0.5	< 0.2	< 0.2	< 0.2
p,p-DDD	< 0.1	< 0.1	4.7	0.2	< 0.1	2.1
o,p-DDT	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2
p,p'-DDT	< 0.1	< 0.1	2.3	< 0.1	0.4	2.2
Total DDT	0.0	0.0	27	2.5	1.2	26
heptachlor	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
heptachlor epox	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-chlordane	< 0.1	< 0.1	0.1	< 0.1	< 0.1	0.1
cis-chlordane	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
trans-nonachlor	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
cis-nonachlor	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total Chlordane	0.0	0.0	0.1	0.0	0.0	0.1
hexachlorobenzene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
lindane	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
dieldrin	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

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

Site	Te Nga Wai	Opihi River below PP	Opihi River upstream	Temuka	Winchester	Waihi River	Ohapi Creek	Orari Ohapi	Doncaster	Washdyke Lagoon
PCB congener										
8	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1
14	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
18	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
28	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	0.7	< 0.1	2.9	< 0.1
52	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	10.6	< 0.1
49	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
65	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
44	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	3.1	< 0.1
66	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
121	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
101	0.2	0.2	0.2	0.6	1.4	0.5	1.3	0.2	19.6	1.4
86	< 0.1	< 0.1	< 0.1	0.1	0.3	< 0.1	0.2	< 0.1	5.1	0.4
110	< 0.1	< 0.1	0.2	0.3	0.7	0.3	0.5	0.1	14.5	0.8
77	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
151	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1	0.2	< 0.1	1.1	< 0.1
118	0.2	0.3	0.3	0.8	2.7	0.6	1.1	0.2	17.7	1.7
153	0.7	1.5	0.4	2.2	18.6	1.7	5.3	0.9	24.6	3.8
105	0.2	0.1	0.2	0.9	5.5	3.0	0.4	0.5	8.1	0.6
141	< 0.1	0.2	< 0.1	0.2	0.5	0.2	0.4	0.1	3.4	0.4
138	0.5	1.1	< 0.1	1.7	14.5	1.3	3.6	0.7	23.4	3.4
126	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
187	0.3	0.5	0.2	0.7	5.8	0.5	1.8	0.2	8.3	1.0
128	< 0.1	< 0.1	< 0.1	< 0.1	1.2	0.1	0.3	< 0.1	3.6	1.0

Appendix 3c: (cont.) PCB concentrations (µg/kg dry weight) in biota from Arowhenua.

Site	Te Nga Wai	Opihi River below PP	Opihi River upstream	Temuka	Winchester	Waihi River	Ohapi Creek	Orari Ohapi	Doncaster	Washdyke Lagoon
185	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.3	< 0.1
156	< 0.1	< 0.1	< 0.1	< 0.1	1.3	< 0.1	0.3	< 0.1	2.1	< 0.1
180	0.2	0.8	< 0.1	0.6	9.0	0.5	2.0	0.3	7.0	1.8
169	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
170	0.1	0.5	< 0.1	0.5	3.2	0.3	1.2	0.2	5.4	1.4
195	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
194	< 0.1	< 0.1	< 0.1	< 0.1	2.0	< 0.1	0.2	< 0.1	< 0.1	< 0.1
206	< 0.1	< 0.1	< 0.1	< 0.1	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
209	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total PCBs	2.4	5.6	1.4	8.6	67.3	9.1	19.5	3.6	160.6	17.6

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

Site	Te Nga Wai	Opihi River below PP	Opihi River upstream	Opihi River Mouth		Temuka		Winchester	
Species	**Eel**	**Eel**	**Eel**	**Trout**	**Flounder**	**Eel**	**Trout**	**Eel**	**Trout**
Arsenic1	< 0.49	< 0.48	< 0.47	3.00	< 0.50	< 0.48	1.70	< 0.49	< 0.50
Arsenic2	< 0.10	< 0.10	< 0.10	3.70	0.44	< 0.10	2.00	< 0.10	0.27
Cadmium1	< 0.0097	0.0160	0.0370	< 0.0097	< 0.0099	< 0.0096	< 0.010	< 0.0097	< 0.010
Cadmium2	0.0045	0.0110	0.0410	< 0.0020	< 0.0020	0.0026	< 0.0020	0.0065	< 0.0020
Chromium1	< 0.49	< 0.48	< 0.47	< 0.49	< 0.50	< 0.48	< 0.50	< 0.49	< 0.50
Chromium2	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Copper1	1.3	1.3	0.8	1.7	1.4	0.9	1.8	0.8	2.1
Copper2	1.1	0.8	0.6	1.2	1.2	0.6	0.9	0.9	1.5
Lead1	< 0.049	< 0.048	< 0.047	< 0.049	0.110	< 0.048	< 0.050	0.110	< 0.050
Lead2	0.019	0.029	0.014	< 0.010	0.170	0.028	< 0.010	0.054	0.038
Mercury1	1.20	1.80	1.20	0.45	0.10	1.30	2.00	1.20	0.27
Mercury2	1.20	1.90	1.30	0.47	0.11	1.40	2.10	1.40	0.30
Nickel1	< 0.49	< 0.48	< 0.47	< 0.49	< 0.50	< 0.48	< 0.50	< 0.49	< 0.50
Nickel2	0.12	< 0.10	< 0.10	< 0.10	0.45	< 0.10	< 0.10	< 0.10	< 0.10
Zinc1	38	31	24	18	25	29	17	35	17
Zinc2	40	32	24	19	25	32	15	35	16

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

Site	Waihi River		Ohapi Creek	Orari Ohapi			Doncaster		Washdyke Lagoon	
Species	**Eel**	**Trout**	**Eel**	**Eel**	**Trout**	**Flounder**	**Eel**	**Flounder**	**Eel**	**Flounder**
Arsenic1	< 0.47	< 0.48	< 0.49	< 0.21	1.30	< 0.49	< 0.49	0.71	< 0.33	1.80
Arsenic2	< 0.10	< 0.10	< 0.10	< 0.11	1.10	0.28	< 0.10	0.74	< 0.17	2.20
Cadmium1	< 0.0094	< 0.0096	< 0.0098	0.0096	< 0.0098	< 0.0098	< 0.0098	< 0.0098	< 0.0065	< 0.0099
Cadmium2	0.0029	0.0020	0.0029	0.0065	< 0.0020	< 0.0020	0.0033	< 0.0020	< 0.0033	< 0.0020
Chromium1	< 0.47	< 0.48	< 0.49	< 0.21	< 0.49	< 0.49	< 0.49	< 0.49	0.4	< 0.50
Chromium2	< 0.10	< 0.10	< 0.10	< 0.11	< 0.10	< 0.10	< 0.10	< 0.10	0.3	< 0.10
Copper1	0.8	1.3	1.2	1.0	1.8	1.5	0.8	1.8	0.8	1.4
Copper2	1.1	1.7	1.1	0.8	1.0	1.2	0.6	1.2	0.9	0.7
Lead1	< 0.047	< 0.048	< 0.049	0.032	< 0.049	< 0.049	0.220	< 0.049	0.066	< 0.050
Lead2	0.014	0.020	0.017	0.024	< 0.010	< 0.010	0.200	< 0.010	0.062	0.010
Mercury1	0.80	0.52	0.82	0.76	0.20	0.47	0.35	0.12	0.10	0.20
Mercury2	0.87	0.48	0.90	0.78	0.21	0.48	0.37	0.15	0.12	0.21
Nickel1	< 0.47	< 0.48	< 0.49	< 0.21	< 0.49	< 0.49	< 0.49	< 0.49	< 0.33	< 0.50
Nickel2	< 0.10	0.13	< 0.10	0.15	< 0.10	< 0.10	< 0.10	< 0.10	0.17	< 0.10
Zinc1	20	12	39	38	22	33	32	31	43	29
Zinc2	22	14	40	40	20	34	33	32	46	29

Appendix 3e: Heavy Metal concentrations (mg/kg dry weight) in watercress from Arowhenua.

Site	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi below PP	Ohapi Creek	Opihi upstream	Opihi River mouth
Arsenic	0.15	< 0.10	0.38	< 0.10	0.63	0.37	0.17	0.33
Cadmium	0.130	0.110	0.150	0.140	0.150	0.078	0.220	0.200
Chromium	0.71	0.40	1.10	0.17	0.84	1.40	0.22	0.62
Copper	6.1	6.5	8.4	12.0	8.4	8.2	10.0	5.0
Lead	0.81	0.67	1.10	0.35	1.30	1.60	0.90	1.10
Mercury	< 0.010	< 0.010	0.012	< 0.010	0.014	< 0.010	< 0.010	< 0.010
Nickel	0.63	0.22	1.30	1.20	1.80	0.85	2.90	1.20
Zinc	39	59	44	70	38	71	35	42

Appendix 3f: Heavy Metal concentrations (mg/kg dry weight) and total organic carbon (g/100g) in sediment from Arowhenua.

	Waihi River	Winchester	Temuka	Te Nga Wai	Opihi River below PP	Ohapi Creek
Total Organic Carbon	0.55	1.2	0.92	0.59	0.2	5.4
Arsenic	2.6	1.1	2.9	3.7	3.1	1.9
Cadmium	0.044	0.057	0.044	0.041	0.027	0.170
Chromium	13	12	13	10	11	15
Copper	6.3	5.2	7.3	8.5	7.7	12.0
Lead	8.4	10	10	11	7.4	14
Mercury	0.061	0.033	0.063	0.016	0.018	0.066
Nickel	7.3	6.5	7.6	7.3	9.0	8.2
Zinc	41	48	46	41	39	81

Appendix 3f: (cont). Heavy Metal concentrations (mg/kg dry weight) and total organic carbon (g/100g) in sediment from Arowhenua.

	Orari Ohapi	**Opihi River upstream**	**Doncaster**	**Washdyke Creek**	**Opihi River Mouth**	**Washdyke Lagoon**
Total Organic Carbon	0.16	0.18	8	0.66	0.99	3.1
Total Recoverable Arsenic	2.1	2.8	8.5	4	4.4	7.9
Total Recoverable Cadmium	0.032	0.026	0.320	0.036	0.042	0.095
Total Recoverable Chromium	13	11	27	10	14	24
Total Recoverable Copper	5.9	6.8	40.0	4.9	10.0	19.0
Total Recoverable Lead	7.4	6.6	36	7.1	15	37
Total Recoverable Mercury	0.034	0.015	0.083	0.022	0.027	0.084
Total Recoverable Nickel	7.9	8.6	10.0	5.6	11.0	11.0
Total Recoverable Zinc	41	35	220	41	52	150