TE ARAWA LAKES TRUST

NIWA Taihoro Nukurangi

# Contaminants in kai – Te Arawa rohe Part 2: Risk Assessment

**NIWA Client Report: HAM2011-023**
**March 2011**

**NIWA Project: HRC08201**

# Contaminants in Kai – Te Arawa rohe Part 2: Risk Assessment

**Ngaire Phillips**
**Michael Stewart**
**Chris Hickey**
**Greg Olsen**

*NIWA contact/Corresponding author*

**Ngaire Phillips**

*Prepared for*

**Te Arawa Lakes Trust &**
**Health Research Council of New Zealand**

NIWA Client Report: HAM2011-023
March 2011

NIWA Project: HRC08201

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

# Contents



*Reviewed by:*

Dr Craig Depree

*Approved for release by:*

Dr David Roper

*Formatting checked*

A. Bartley

# Executive Summary

Gathering of wild kai (food) has always been of importance to Māori society. With kai increasingly susceptible to accumulation of anthropogenic contaminants, and in the case of the Te Arawa region, natural geothermally-derived contaminants, the potential impact on the resident wild kai and, in turn, on Māori consuming them, is also likely to increase. However, despite the potential for adverse health effects associated with eating 'contaminated' kai, to date, this issue has received only limited attention.

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, which are often important kai species. 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 and cadmium associated with geothermal activity, as well as lead, copper and zinc from anthropogenic sources such as urban stormwater runoff.

The aim of this project was to quantify the risk to local Māori of consuming wild kai gathered from the rohe (territory of iwi or hapū) of Te Arawa, New Zealand. A companion report (Phillips et al. 2011) presented data assessing the concentrations of selected heavy metal and organic contaminants in the aquatic environment and how these contaminant levels related to tissue concentrations in resident kai. This report describes the assessment process that was undertaken to quantify the potential risk to local Māori from the consumption of wild kai gathered from the Te Arawa rohe.

Data on local consumption rates were derived using a questionnaire on kai consumption rates and portion sizes. Local average consumption rates (g /day) were calculated as follows: watercress (15.8), mussels (16.9), koura (2.5), whitebait (5.7), eel (9.6), trout (10.9), kakahi (0.33) (Phillips et al 2011). 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 fish represents a relatively small proportion of the main source of fish for the local community participants. The watercress consumption rate of 15.8 g/day was again much lower than the proposed average consumption rate of 33 g/day for consumers of watercress (Golder Associates and NIWA 2009). Meal sizes were calculated at 224 g/meal for trout and eel, 112 g/meal for smelt and whitebait, 152 g/meal for koura, 144 g/meal for shellfish (mussels, pipi, kakahi) and 155 g/meal for watercress.

A risk assessment was carried out on the kai contaminant data using established US EPA formulae. The risk assessment calculated *consumption limits (meals per month)* for the whole catchment using median (50$^{th}$ percentile) and 95$^{th}$ percentile contaminant concentration data to approximate harvesting of kai with random contamination concentrations that might be expected from harvesting randomly

across all sites (median) or predominantly from the most contaminated kai ($95^{th}$ percentile), that might be expected from harvesting predominantly at the most contaminated sites. In addition, a risk assessment was performed for each species harvested from each site to gain an understanding of potential “hotspots” in the catchment.

The results of the risk assessment were clear. In terms of the whole catchment, if harvesting was carried out randomly across all sites *and* consumption rates were as calculated from the questionnaire data, then there is *a significant risk* to local Te Arawa iwi members associated with consumption of trout, pipi, mussel and watercress. In the second scenario, that is, if harvesting were undertaken predominantly at the most contaminated sites *and* consumption rates were as calculated from the questionnaire data, then a *significant risk* is associated with the consumption of trout, eel and pipi. A lack of replicate samples across the catchment precluded calculation of this risk scenario for whitebait, kakahi, mussel and watercress. However, given that mussel and watercress present a risk at median contaminant concentrations, the risk can only increase if these species were harvested from the most contaminated sites. Based on consumption rates calculated from iwi participants in our study, the risks associated with consumption of all other kai species investigated (koura, eel, smelt, whitebait and kakahi) are low. Clearly, increased consumption of these species could see the risks increase, if consumption rates exceeded the risk-based consumption limits calculated from our study. The risk of eating trout in the Te Arawa rohe was greater than other species, with contaminant levels in 9 out of the 13 trout sampled corresponding to a consumption limit of less than 4 meals per month.

A number of potential “hotspots” (areas of increased risk of consumption of many species) were evident from the results. The Maketu site was identified as being of concern, with significant risk of consumption of both pipi and mussels. Waiowhiro watercress samples were also a concern. Recommended safe consumption rates of all four species sampled in the lower Kaituna River ranged from <1 to ca. 3 meals/month. In addition, at the Ohau Channel site, kai contaminant concentrations were such that safe consumption rates for three of the four species were limited to between 0.7 – 1.4 meals/month. For sites where both trout and koura were collected, the risk associated with consumption of these species was Rotorua = Upper Kaituna = Rotoiti = Ohau Channel > Okareka = Tarawera > Rotokakahi = Rotoma > Tikitapu.

Limitations of this study were the small number of iwi participants who completed the kai consumption questionnaire (which therefore limits the reliability of the consumption rate estimates) and the low number of specimens collected of each species – typically only a single specimen per site for larger species such as trout and eel. Because of the inherent assumptions and associated error involved with any risk assessment process, it would have been beneficial to collect multiple specimens at each site. This would have enabled a more robust assessment of the risk, associated with consuming kai gathered from the Te Arawa rohe. However, notwithstanding these limitations, this study has provided a valuable screen of potential risks associated with kai consumption in the Te Arawa rohe.

The major recommendations that can be made from this study include:

- communicating the risks identified within the Te Arawa rohe to iwi members and the wider community
- obtaining larger sample sizes of some kai species to provide a more representative spatial assessment of kai contamination in the region
- obtaining more robust datasets of contaminants – including arsenic and mercury speciation
- obtaining more robust consumption data and meal size portions through participation of larger numbers of consumers of wild kai in completing the questionnaire, and
- conducting a risk assessment for total fish diet, which incorporates both wild caught kai and commercial (i.e., store brought) dietary consumption.

# 1. Introduction

## 1.1 Background

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 addition to increasing pressures from anthropogenic contaminants, a unique aspect of the rohe of Te Arawa (Rotorua) is that natural geothermal activity is an important source of heavy metals into receiving environments from which kai is harvested. Heavy metal contaminants of particular concern from geothermal activity are arsenic, mercury and cadmium. However, despite the potential for adverse health effects, the impact of environmental contamination (both anthropogenic and geothermal) on the resident wild kai and, in turn, on Māori consuming them, to date, has not been investigated, although recent work has started to address this deficiency (Stewart et al. 2010, Stewart et al. in press, Whyte et al. 2009). As part of a larger research programme, we investigated contaminant concentrations in kai, and undertook a risk assessment based on local consumption rates for Maori from the Arowhenua rohe (Stewart et al. 2010, Stewart et al. in press). An important point of difference in the Te Arawa rohe is that a major source of environmental contaminants entering 'kai harvesting' environments is via natural geothermal sources – and hence unlike growing pressures from catchment development (i.e., urbanisation, farming etc.), these geothermal inputs have been present ever since Māori have been harvesting kai from the rohe.

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, where consumption of marine fish and mammals is a significant component of subsistence diets (Hoekstra et al. 2005). While large mammals are unlikely to be a major source of contaminants in traditional Māori diets, eel is a popular food for 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

## 1.2 Synopsis of Te Arawa contaminant data report

This report is the second of two reports on contaminants in kai from the rohe of Te Arawa. The first is a data report (Phillips et al. 2011), with key findings summarised below.

A survey of past and present kai consumption patterns was undertaken by questionnaire to establish historic and contemporary consumption rates of key species by local iwi members. The levels of bioaccumulative contaminants were characterised in a number of commonly gathered fish/shellfish (rainbow trout, koura, pipi, longfin eel) and plant species (watercress), as well as in associated aquatic sediments from 23 sites throughout the rohe of Te Arawa.

Local average consumption rates of wild kai ranged from 0.33 g/day for kakahi to 10.88 g/day for trout. Watercress consumption was calculated at 15.8 g/day. The average total fish consumption rate from the survey (97 g/day) was much higher than the average New Zealand (NZ) consumption rate of 32 g/day, with wild caught kai comprising only 12% of the total consumption. This result indicates that wild caught kai is only a small proportion of the main source of aquatic food for the local community surveyed.

The following general conclusions can be made about the contaminant concentrations in the Te Arawa rohe from the first report:

1) sediment contaminant concentrations were generally below the Australian and New Zealand Environment Conservation Council (ANZECC) Interim Sediment Quality Guideline (ISQG) (ANZECC 2000) guidelines, with a few exceptions:

    a) ANZECC ISQG low values were exceeded for arsenic and mercury at 55% of sites sampled and for cadmium at 10% sites.

   b) The ANZECC ISQG high guideline value was exceeded at 15% of sites for arsenic and at 25% sites for mercury.

   c) These results reflect, to some extent, the input of geothermally-sourced metals at our study sites.

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

3) Mercury concentrations were generally highest in trout tissue.

4) The Upper Puarenga Stream, Ohau Channel and Rotoiti sites, consistently reported elevated sediment and biota concentrations for a number of contaminants, relative to other study sites.

5) 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)

## 1.3 Aim of this study

The overall aim of this study was to determine the risk to Māori and non-Māori of consuming key kai species harvested from sites around the rohe of Te Arawa. The contaminant data from a companion report (Phillips et al. 2011, Phillips et al. in prep) forms the basis for a cumulative risk assessment, of which the implications to human health are presented in this report. An important aspect of this study was looking at the potential impacts of naturally occurring (hence technically background levels) contaminants associated with the geothermal activity in the area. At many of the geothermally impacted kai gathering locations, the assumption was that natural inputs of contaminants would be more significant than those from urbanisation (i.e., stormwater runoff etc.).

# 2. Methods

## 2.1 Sampling

The focus of this study was the Rotorua district (Te Arawa Lakes district), New Zealand, which includes the large town of Rotorua, which has a population of 68,600, of which Māori make up 35% of the population (Statistics New Zealand 2006). The coastal area around the small town of Maketu (pop. 1240), was also sampled, as it was identified as an important kai gathering area for Te Arawa.

The district is characterised by a large number of lakes, varying in depth, area and trophic status (McColl 1972). The Kaituna River is a major waterway linking Lake Rotoiti with Maketu on the coast (via the Okere Falls).

Sixteen sites were surveyed for biota (Figure 1). A total of two long fin eels (*Anguilla dieffenbachii*), 14 rainbow trout (*Oncorhynchus mykiss*), one composite whitebait sample (60 individuals), 10 composite koura samples (*Parenephrops planifrons*), six composite samples (between 30 and 60 individuals) of smelt (*Retropinna retriopinna*), one composite watercress sample (*Nasturtium officinale*) one composite mussel (*Perna canaliculus*), two composite pipi samples (55 individuals) (*Paphies australis*) and one composite kakahi sample (*Echyridella menziesi*) were collected. Collections were undertaken in September 2009 or January 2010 (for repeat samples of pipis at Maketu). Composite sediment samples were collected from all sites, at the time of biota collection. Additional sediment samples were collected from some locations (e.g., Sulphur Point).

## 2.2 Analysis of contaminants in kai and sediment

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). Trout and eel samples were analysed for a range of organochlorine pesticides (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 ($\gamma$-hexachlorocyclohexane or $\gamma$-HCH) and dieldrin. Eel and trout tissues were also analysed for selected PCBs (32 congeners ranging from PCB 8 - PCB 209). Watercress was analysed for the eight heavy metals only.

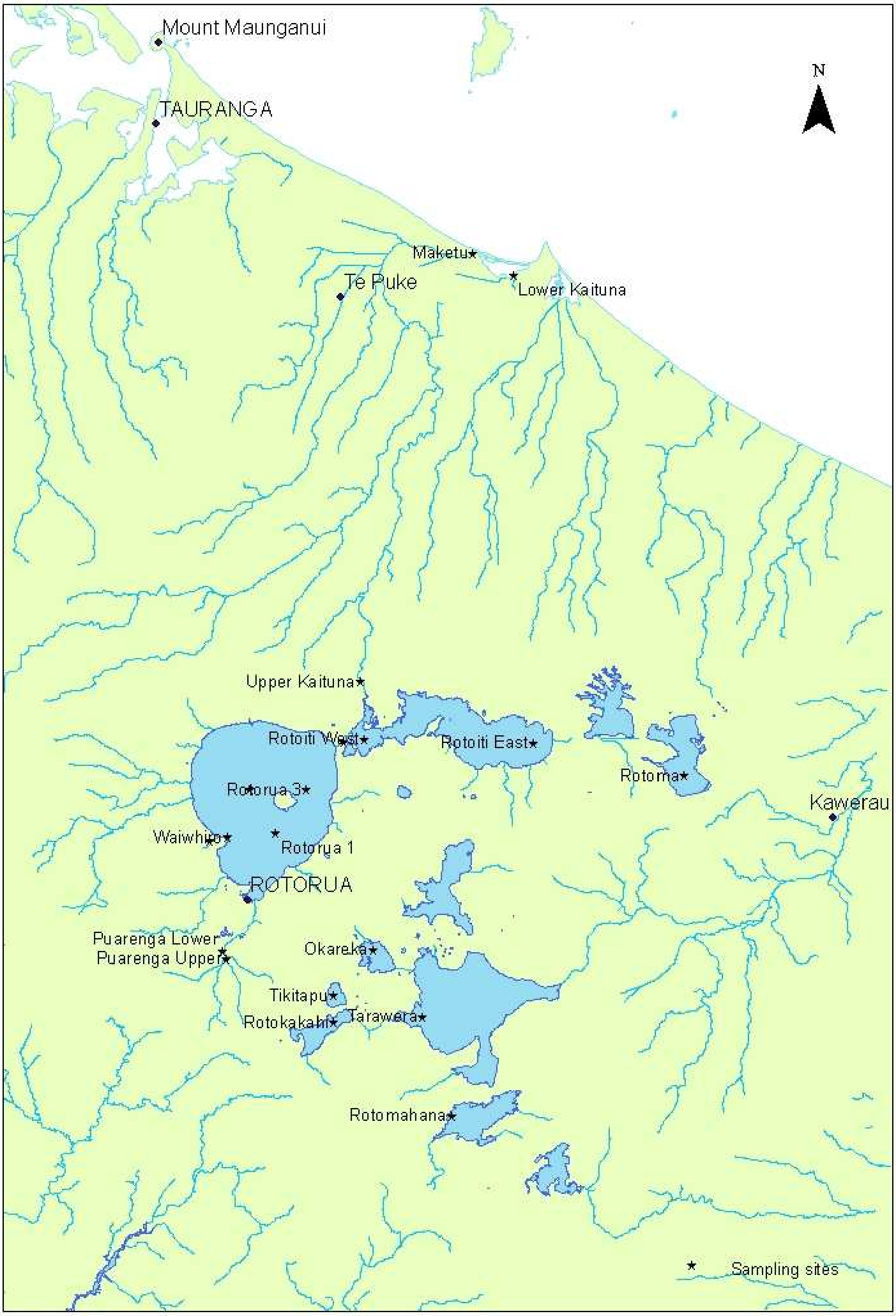



**Figure 1:** Kai collection sites in the Te Arawa rohe.

## 2.3 Risk Assessment

For the risk assessment, kai contaminant concentrations were converted from dry weight to wet weight concentrations using water content values measured for each of the various species. Accordingly, unless otherwise specified, all concentrations and kai consumption rates in this report are calculated on a wet weight basis.

Human health risk assessment is defined by the US EPA as a four step process:

1. *Hazard identification.* This assesses the likelihood that exposure to specific chemicals under defined exposure conditions will pose a threat to human health.

2. *Dose-response assessment.* Results in the derivation of toxicity values such as cancer potencies and non-cancer reference doses by evaluating the results of human and animal studies with controlled and quantified exposures.

3. *Exposure assessment.* This covers a range of assessments including chemical occurrences in fish, geographic distribution of contaminated fish, individual or population exposure assessment, multiple species exposure and multiple chemical exposure.

4. *Risk characterization.* In general, the risk characterization step of the risk assessment process combines the information for hazard identification, dose-response assessment, and exposure assessment in a comprehensive way that allows the evaluation of the nature and extent of risk.

Points 1 and 2 above are continually being modified as further information is incorporated and this is carried out by the US EPA and other environmental agencies.

Exposure assessment (point 3) in this study was limited, due to the small sample size and, in the case of larger species, only a single specimen collected per site.

Risk characterisation (point 4) was performed by following established US EPA procedures, calculating risk for both cancer and non-cancer health endpoints. Cancer oral slope factor (CSF) and reference doses (RfD) for chronic non-cancer oral exposure were obtained from US EPA Integrated Risk Information System (IRIS) (US EPA 2010), with the exception of CSF and RfD for PCBs and RfD for mercury which were based on US EPA guidelines (US EPA 2000). As no information for the heavy metal lead could be obtained and lindane was not detected in any sample these two contaminants were removed from the risk assessment calculations.

For carcinogenic effects we calculated both *individual* contaminant consumption limits (see Appendix 1 for values) and *additive* consumption limits for each species. An additive risk consumption limit is possible for carcinogenic chemicals as the effects (i.e., the development of cancer) is the same. *Individual* contaminant consumption limits were calculated using equation 2.3.1, based on US EPA equation 3-1, while *additive* consumption limits were calculated using equation 2.3.2, based on US EPA equation 3-14 (US EPA 2000):

$$\textbf{(2.3.1)} \qquad \mathbf{CR_{lim}}\ \text{(individual)} = \frac{\mathbf{ARL \bullet BW}}{\mathbf{Cm \bullet CSF}}$$

$$\textbf{(2.3.2)} \qquad \mathbf{CR_{lim}}\ \text{(additive)} = \frac{\mathbf{ARL \bullet BW}}{\sum_{\mathbf{m-1}}^{\mathbf{x}} \mathbf{Cm \bullet CSF}}$$

where
$CR_{lim}$ = maximum allowable fish consumption rate (kg/day)
ARL = maximum acceptable lifetime risk level (unitless)
BW = consumer body weight (kg)
Cm = concentration of chemical contaminant *m* in species (mg/kg)
CSF = cancer slope factor ($[\text{mg/kg-day}]^{-1}$).

Arsenic concentrations in kai samples were weighted according to the US EPA assumption that 10% of total arsenic ($As_{tot}$) is present as toxic inorganic arsenic ($As_i$) in resident freshwater fish, with this modifier providing a protective estimate of health risk (US EPA 2003). This was supported by a more recent study, which concluded that for freshwater fish, toxic $As_i$ accounted for 10% of total arsenic ($As_{tot}$) at the 75$^{th}$ percentile (Schoof & Yager 2007). For marine and estuarine fish, the toxic $As_i$ proportion is only 2-3% (Schoof & Yager 2007), and therefore significantly lower than the 10% approximation used in this risk assessment. Consequently, this would reduce the risk for marine or estuarine fish by a factor of 3-5 where arsenic is the predominant contaminant. Schoof & Yager (2007) stated that there was "little correlation between $As_{tot}$ concentrations and $As_i$ concentrations, however, when only $As_{tot}$ data are available to assess health risks from arsenic in seafood, these data could support conservative, upper end estimates of the percent of $As_{tot}$ likely to be $As_i$". However, without arsenic speciation studies to determine accurate $As_i$ concentrations, a conservative approach is usually more prudent and has been used for this Te Arawa kai risk assessment. That is, a 10% approximation of $As_{tot}$ that is present as $As_i$ for freshwater kai species and 3% for marine species. As a protective measure, watercress arsenic concentrations were not adjusted for the risk assessment, as arsenic was assumed to be predominantly inorganic as observed in some plants (Daus et al. 2005, Zhang et al. 2002).

Body weight (BW) was set at 80 kg based on a previous study (Kim & Smith 2006). An “acceptable” lifetime cancer risk (ARL) level of $10^{-6}$ (1 in 1,000,000) is considered by some countries or institutions as negligible (World Health Organization 2009) and a level of $10^{-5}$ (1 in 100,000) is set by US EPA in their “Guidance for assessing chemical contaminant data for use in fish advisories” (US EPA 2000). As such, we set the ARL at $10^{-5}$ for Te Arawa risk calculations.

For assessment of non-carcinogenic risks an additive approach is only possible if effects are the same for all contaminants. Organochlorines such as DDT, lindane and dieldrin cause liver lesions, whereas the heavy metal mercury causes hand tremors and/or memory problems, while arsenic causes hyper-pigmentation (US EPA 2010). As these effects are notably different, non-carcinogenic risk assessment was calculated on a single contaminant class basis only, using equation 2.3.3, based on US EPA equation 3-3 (US EPA 2000):

$$\textbf{(2.3.3)} \qquad \mathbf{CR_{lim}} = \frac{\mathbf{RfD \bullet BW}}{\mathbf{Cm}}$$

where
$CR_{lim}$ = maximum allowable fish consumption rate (kg/day)
RfD = reference dose (mg/kg-day)
BW = consumer body weight (kg)
Cm = measured concentration of chemical contaminant *m* in a given species of fish (mg/kg).

The maximum allowable consumption rate $CR_{lim}$ (kg/day) was converted into a more useful measure of meals/month using equation 2.3.4:

$$\textbf{(2.3.4)} \qquad \mathbf{CR_{lim}\ (meals/month)} = \frac{\mathbf{CR_{lim}\ (kg/day)}}{\mathbf{MS \bullet days/month}}$$

where
MS = meal size (kg)
days/month = 30

# 3. Discussion on contaminants in risk assessment

This report is concerned with contaminants that are a long term risk to human health. As such, the contaminants selected are environmentally persistent, have a tendency to bioaccumulate in biota and are known (or suspected) to be toxic to humans.

Bioaccumulative contaminants that are covered in this report are the organochlorine pesticides (DDTs, dieldrin, lindane and chlordane), polychlorinated biphenyls (PCBs) and the heavy metals mercury, arsenic, cadmium, zinc, nickel, chromium and lead.

The Agency for Toxic Substances & Disease Registry (ATSDR) is a federal public health agency of the U.S. Department of Health and Human Services. The ATSDR has a toxic substances portal for useful information about toxic substances and how they affect human health (ATSDR 2010). All contaminants that are covered in this risk assessment are included in this portal and a brief summary of each is supplied below, supported, where available, with locally relevant information (e.g., use and potential sources).

## 3.1 Organochlorine pesticides

The organochlorine pesticides and PCBs listed above are all listed under the Stockholm Convention on Persistent Organic Pollutants (POPs), a global treaty (which New Zealand ratified in 2004) to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have adverse effects on human health and/or the environment. Exposure to POPs can lead to serious health effects including certain cancers, birth defects, dysfunctional immune and reproductive systems, greater susceptibility to disease and diminished intelligence (Stockholm Convention 2010).

### 3.1.1 DDT (dichlorodiphenyltrichloroethane)

DDT is a pesticide that was used extensively throughout the world to control insects that affect agriculture and horticulture. It is still used in some countries as a control measure for insects, such as mosquitoes, that carry malaria. DDT was used largely as an insecticide to control grass grubs and porina caterpillars in NZ, with its use restricted in 1970 and finally banned in 1989 (Taylor et al. 1997). DDT breaks down in the environment to DDE (dichlorodiphenyldichloroethylene) and DDD (dichlorodiphenyldichloroethane), all of which persist for years.

Exposure to DDT, DDE, and DDD occurs mostly from eating foods containing low concentrations of these compounds, particularly meat, fish and poultry. High levels of DDT can affect the nervous system causing excitability, tremors and seizures. In women, DDE can cause a reduction in the duration of lactation and an increased chance of having a premature baby (ATSDR 2010). DDT is classified by US EPA as a probable human carcinogen (US EPA 2010).

### 3.1.2 Aldrin/dieldrin

Aldrin and dieldrin are insecticides with similar chemical structures. Aldrin rapidly breaks down to dieldrin in the body and in the environment. Exposure to aldrin and dieldrin occurs mostly through eating contaminated foods, such as root crops, fish, or seafood. Aldrin and dieldrin accumulate in the body after years of exposure and can affect the nervous system (ATSDR 2010). The US EPA has classified dieldrin as a probable human carcinogen (US EPA 2010).

In NZ, aldrin and dieldrin were introduced in 1954 for use as stock remedies in sheep sprays or dips for controlling sheep ectoparasites. Aldrin was used to control horticultural pests such as wireworm, soldier fly and blackvine weevil, and in limited quantities, to control household spiders. Dieldrin was used for controlling carrot rust fly, crickets and armyworm and was also used for timber preservation (mostly in plywood glues) and to mothproof carpets (Buckland et al. 1998).

### 3.1.3 Lindane (γ-hexachlorocyclohexane; γ -HCH)

Lindane (γ-HCH) is one of eight isomers formed during the manufacture of technical grade (crude) hexachlorocyclohexane (HCH). Technical grade HCH typically contained about 10–15% of lindane. It is used as an insecticide on fruit, vegetables, and forest crops (ATSDR 2010).

In NZ, lindane was used as an insecticide in agriculture for the control of lice on cattle, ectoparasites (lice, keds and blowflies) in sheep and grass grub in pasture. Lindane was also used for insect control on vegetable and fruit crops, and as an active component of fly sprays, flea control and carpet moth products for household use. Technical grade HCH was not officially used in New Zealand, although many dip sites show evidence of its use (Buckland et al. 1998).

Exposure to lindane happens mostly from eating contaminated food or by breathing contaminated air in the workplace. Exposure to high levels of lindane can cause blood disorders, dizziness, headaches, seizures, and changes in the levels of sex hormones.

The US EPA has determined there is not enough evidence to determine whether lindane is a human carcinogen (US EPA 2010).

### 3.1.4 Chlordane

Technical chlordane is a mixture of chlordane and many related chemicals, of which the composition varies. Exposure to chlordane occurs mostly from eating contaminated foods, such as root crops, meats, fish, and shellfish, or from touching contaminated soil. High levels of chlordane can cause damage to the nervous system or liver (ATSDR 2010). The US EPA classes technical chlordane as a probable human carcinogen (US EPA 2010).

In NZ, chlordane was used as a broad spectrum agricultural insecticide, in the timber industry as a treatment against termites and borer, and as an insecticide in glues used for the manufacture of plywood, finger jointed and laminated timber (Buckland et al. 1998).

### 3.1.5 Hexachlorobenzene (HCB)

HCB was widely used as a pesticide to protect the seeds of onions, sorghum, wheat and other grains against fungus. It was also used to make fireworks, ammunition, and synthetic rubber (ATSDR 2010). In NZ, HCB was used experimentally between 1970 and 1972 as a seed dressing fungicide for cereal grain (Buckland et al. 1998). Exposure to HCB occurs primarily from eating contaminated food. Much lower exposures can occur from drinking water and breathing air contaminated with HCB (ATSDR 2010).

The main health effect from eating food contaminated with HCB is a liver disease called porphyria cutanea tarda. The USEPA has classified HCB as a probable human carcinogen (US EPA 2010).

## 3.2 PCBs

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds, referred to as congeners. PCBs have been used as coolants and lubricants in transformers, capacitors, and other electrical equipment because they have low flammability and are good electrical insulators (ATSDR 2010).

Exposure to PCBs can be via multiple pathways. Skin exposure can occur via old electrical devices (>30 years old) that leak small amounts of PCBs and in the workplace where contact may be made with equipment or devices containing PCBs.

Ingestion of PCBs is largely via contaminated food (fish, meat and dairy) and drinking contaminated well water, while inhalation exposure can occur by breathing air near hazardous waste sites (ATSDR 2010).

Health effects that have been associated with exposure to PCBs include acne-like skin conditions in adults and neurobehavioral and immunological changes in children (ATSDR 2010). The US EPA classifies PCBs as probable human carcinogens (US EPA 2010).

## 3.3 Heavy metals

### 3.3.1 Cadmium

Cadmium is a natural element in the Earth’s crust. It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). All soils and rocks, including coal and mineral fertilizers, contain some cadmium. Most cadmium used in the United States is extracted during the production of other metals like zinc, lead, and copper. Cadmium does not corrode easily and has many uses, including batteries, pigments, metal coatings, and plastics (ATSDR 2010).

Exposure to cadmium happens mostly in the workplace where cadmium products are made. The general population is exposed from breathing cigarette smoke, eating cadmium contaminated foods or drinking cadmium contaminated water (ATSDR 2010).

Long-term exposure to lower levels of cadmium in air, food, or water leads to accumulation of cadmium in the kidneys and possible kidney disease. Other long-term effects are lung damage and fragile bones (ATSDR 2010). The US EPA classifies cadmium as a probable human carcinogen (US EPA 2010).

### 3.3.2 Mercury

Mercury is a naturally occurring metal which has several forms. Mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or “salts”. Mercury also forms organic mercury compounds of which methylmercury is the most common. Naturally elevated mercury levels are associated with geothermal regions, such as those of the Te Arawa rohe (Blomkvist & Lundstedt 1995). Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings and batteries. Mercury salts are sometimes used in skin lightening creams, antiseptic creams and ointments (ATSDR 2010).

Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing foetus. The detrimental effects on normal brain function include irritability, shyness, tremors, changes in vision or hearing, and memory problems (ATSDR 2010). The US EPA does not classify metallic mercury as a human carcinogen, but classes methylmercury and mercuric chloride as possible human carcinogens (US EPA 2010).

### 3.3.3 Arsenic

Arsenic is a naturally occurring element widely distributed in the Earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic also forms organic arsenic compounds. Inorganic arsenic compounds are mainly used to preserve wood, with copper chromium arsenic (CCA) used to make "pressure-treated" timber. Organic arsenic compounds are used as pesticides, primarily on cotton fields and orchards (ATSDR 2010). Geothermal activity in the Taupo Volcanic Zone (TVZ), New Zealand, has resulted in elevated (0.01–0.1 mg $L^{-1}$) levels of arsenic and mercury in many of the region's soils, lakes and rivers (Robinson et al. 2006b)

Exposure to higher than average levels of arsenic occur mostly in the workplace, near hazardous waste sites, or in areas with high natural levels (e.g., geothermal areas). When exposed to high concentrations, inorganic arsenic can cause death. Exposure to lower levels for a long time (i.e., chronic exposure) can cause discoloration of the skin and the appearance of small corns or warts (ATSDR 2010). Inorganic arsenic is classified by the US EPA as a carcinogen (US EPA 2010).

### 3.3.4 Lead

Lead is a naturally occurring bluish-gray metal found in small amounts in the Earth's crust. Lead can be found in all parts of our environment. Much of it comes from human activities including burning fossil fuels (particularly petrol containing tetraethyl lead additives), mining and manufacturing. Lead has many different uses. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Because of health concerns, lead from paints and ceramic products, caulking, and pipe solder has been dramatically reduced in recent years. New Zealand has used lead free petrol since 1996 (Ministry of Economic Development, 2010).

Exposure to lead can be via breathing workplace air or dust, eating contaminated foods, or drinking contaminated water. Children can be exposed from eating lead-based paint chips or playing in contaminated soil. Lead can damage the nervous system, kidneys, and reproductive system (ATSDR 2010). The US EPA has classified lead as a probable human carcinogen (US EPA 2010).

### 3.3.5 Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases. Chromium is present in the environment in several different forms. The most common forms are chromium(0), chromium(III), and chromium(VI). No taste or odour is associated with chromium compounds. Chromium(III) occurs naturally in the environment and is an essential nutrient. Chromium(VI) and chromium(0) are generally produced by industrial processes. The metal chromium, which is the chromium(0) form, is used for making steel. Chromium(VI) and chromium(III) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving. Chromium(III) is an essential element in humans involved in glucose, fat and protein metabolism. Food, followed by drinking water and air, is the main source of exposure of the general population.

Hepatic, gastrointestinal and renal effects are the most common effects following ingestion and have been reported in individuals who ingested from 4-29 mg/kg Chromium(IV) (ATSDR, 2000a). Chromium(II) is significantly less toxic than Chromium(IV) because it is less readily crosses cell membranes. It is extremely unlikely that low level exposure would cause acute health effects. Chromium is a common skin sensitiser. Chromium(IV) is classified as a human carcinogen based on excess lung cancer found in heavily exposed workers through inhalation in chromium plating and chromate and chromate pigment production (US EPA 2010).

### 3.3.6 Zinc

Zinc is one of the most common elements in the earth's crust. It is found in air, soil, and water, and is present in all foods. Pure zinc is a bluish-white shiny metal. Zinc has many commercial uses as coatings to prevent rust, in dry cell batteries, and mixed with other metals to make alloys like brass, and bronze. Zinc combines with other elements to form zinc compounds. Common zinc compounds found at hazardous waste sites include zinc chloride, zinc oxide, zinc sulfate, and zinc sulfide. Zinc compounds are widely used in industry to make paint, rubber, dyes, wood preservatives, and ointments. Consumption of excess zinc can cause ataxia, lethargy and copper deficiency. There is inadequate information to assess carcinogenic potential of zinc (US EPA 2010).

### 3.3.7 Nickel

Nickel combined with other elements occurs naturally in the earth's crust. In the environment, it is primarily found combined with oxygen or sulfur as oxides or sulfides. Nickel is released into the atmosphere during nickel mining and by industries that make or use nickel, nickel alloys, or nickel compounds. These industries also might discharge nickel in waste water. Nickel is also released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators. Food is the major source of exposure to nickel. You may also be exposed to nickel by breathing air, drinking water, or smoking tobacco containing nickel. Skin contact with soil, bath or shower water, or metals containing nickel, as well as, metals plated with nickel can also result in exposure. Exposure to nickel can result in skin allergies. The most serious harmful health effects from exposure to nickel, such as chronic bronchitis, reduced lung function, and cancer of the lung and nasal sinus, have occurred in people who have breathed dust containing certain nickel compounds while working in nickel refineries or nickel processing plants. The US EPA has classified lead as a probable human carcinogen (US EPA 2010).

# 4. Risk Assessment

## 4.1 Te Arawa contaminant data

For the purposes of the risk assessments, wet weight corrections were made on all dry weight contaminant data. Median and 95$^{th}$ percentile values were calculated for each contaminant for each species of fish, for koura, for all shellfish and for watercress across all sites (Table 1). The median value was chosen over an arithmetic mean to remove the potentially large influence of contaminant outliers in a relatively small sample size and is used to determine what likely contaminant loads would be expected from harvesting randomly across all sites. The 95$^{th}$ percentile data is a worse case scenario in which harvesting involved the most contaminated kai, which might be expected from harvesting occurring only at the most contaminated sites.

## 4.2 Te Arawa consumption data

Local average consumption rates (g/day) were calculated as follows: watercress (15.8), mussels (16.9), koura (2.5), whitebait (5.7), eel (9.6), trout (10.9), kakahi (0.33) (Phillips et al. 2011). These values are based on meal sizes of 224g for trout and eel, 112g for smelt and whitebait, 152g for koura, 144g for kakahi, pipi and mussels and 155g for watercress.

**Table 1:** Median and 95th percentile contaminant data (mg/kg; wet weight) for kai from the Te Arawa rohe and input data assumptions used in risk assessment calculations.

| Species | Compound | Contaminant concentration (μg/kg wet weight) | | Risk Values[b] | | |
|---|---|---|---|---|---|---|
| | | Median[c] | 95th percentile[c] | CSF (mg/kg-day)$^{-1}$ | BW (kg) | RfD (mg/kg-day) |
| Trout | p,p-DDT | 0.20 | 1.31 | 0.34 | 80 | 5.0E-04 |
| n=13 | p,p-DDD | 0.30 | 1.72 | 0.24 | 80 | NA |
| | p,p-DDE | 4.0 | 21.7 | 0.34 | 80 | NA |
| | Dieldrin | 0.04 | 0.16 | 16.0 | 80 | 5.0E-05 |
| | ΣChlordanes | 0.04 | 0.44 | 0.35 | 80 | 5.0E-04 |
| | HCB | 0.05 | 0.18 | 1.6 | 80 | 8.0E-04 |
| | ΣPCBs | 1.4 | 20.6 | 2.0 | 80 | 2.0E-05 |
| | Cadmium | 0.00 | 0.89 | NA | 80 | 1.0E-03 |
| | Mercury | 1220 | 2340 | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 5.0 | 15.2 | 1.5 | 80 | 3.0E-04 |
| | Zinc | 4080 | 6010 | NA | 80 | 3.0E-01 |
| | Nickel | 0.00 | 0.00 | NA | 80 | 2.0E-02 |
| | Chromium | 0.00 | 0.00 | NA | 80 | 3.0E-03 |
| Eel | p,p-DDT | 0.18 | 0.24 | 0.34 | 80 | 5.0E-04 |
| n=2 | p,p-DDD | 0.18 | 0.18 | 0.24 | 80 | NA |
| | p,p-DDE | 2.23 | 2.71 | 0.34 | 80 | NA |
| | Dieldrin | 0.09 | 0.14 | 16.0 | 80 | 5.0E-05 |
| | ΣChlordanes | 0.06 | 0.09 | 0.35 | 80 | 5.0E-04 |
| | HCB | 0.03 | 0.03 | 1.6 | 80 | 8.0E-04 |
| | ΣPCBs | 1.6 | 2.0 | 2.0 | 80 | 2.0E-05 |
| | Cadmium | 4.1 | 4.1 | NA | 80 | 1.0E-03 |
| | Mercury | 564 | 564 | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 14.6 | 19.7 | 1.5 | 80 | 3.0E-04 |
| | Zinc | 12700 | 13600 | NA | 80 | 3.0E-01 |

| Species | Compound | Contaminant concentration (µg/kg wet weight) | | Risk Values[b] | | |
|---|---|---|---|---|---|---|
| | | Median[c] | 95th percentile[c] | CSF (mg/kg-day)$^{-1}$ | BW (kg) | RfD (mg/kg-day) |
| | Nickel | 0.00 | 0.00 | NA | 80 | 2.0E-02 |
| | Chromium | 0.00 | 0.00 | NA | 80 | 3.0E-03 |
| Koura | Cadmium | 1.8 | 21.2 | NA | 80 | 1.0E-03 |
| n=10 | Mercury | 194 | 810 | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 74.0 | 1133 | 1.5 | 80 | 3.0E-04 |
| | Zinc | 13200 | 16365 | NA | 80 | 3.0E-01 |
| | Nickel | 0.00 | 0.00 | NA | 80 | 2.0E-02 |
| | Chromium | 0.00 | 0.00 | NA | 80 | 3.0E-03 |
| Smelt | Cadmium | 4.8 | 8.3 | NA | 80 | 1.0E-03 |
| n=6 | Mercury | 130 | 277 | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 29.3 | 62.9 | NA | 80 | 3.0E-04 |
| | Zinc | 37000 | 50900 | 1.5 | 80 | 3.0E-01 |
| | Nickel | 87.7 | 142 | NA | 80 | 2.0E-02 |
| | Chromium | 121 | 181 | NA | 80 | 3.0E-03 |
| Pipi | Cadmium | 56.7 | 57.7 | NA | 80 | 1.0E-03 |
| n=3 | Mercury | 11.1 | 13.9 | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 42.5 | 49.5 | 1.5 | 80 | 3.0E-04 |
| | Zinc | 8115 | 8347 | NA | 80 | 3.0E-01 |
| | Nickel | 850 | 920 | NA | 80 | 2.0E-02 |
| | Chromium | 1288 | 1404 | NA | 80 | 3.0E-03 |
| Kakahi | Cadmium | 13.8 | NA | NA | 80 | 1.0E-03 |
| n=1 | Mercury | 8.0 | NA | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 87.4 | NA | 1.5 | 80 | 3.0E-04 |
| | Zinc | 12382 | NA | NA | 80 | 3.0E-01 |
| | Nickel | 26.2 | NA | NA | 80 | 2.0E-02 |
| | Chromium | 47.3 | NA | NA | 80 | 3.0E-03 |

| Species | Compound | Contaminant concentration (µg/kg wet weight) | | Risk Values[b] | | |
|---|---|---|---|---|---|---|
| | | Median[c] | 95th percentile[c] | CSF (mg/kg-day)$^{-1}$ | BW (kg) | RfD (mg/kg-day) |
| Mussel | Cadmium | 90.5 | NA | NA | 80 | 1.0E-03 |
| n=1 | Mercury | 30 | NA | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 129 | NA | 1.5 | 80 | 3.0E-04 |
| | Zinc | 12373 | NA | NA | 80 | 3.0E-01 |
| | Nickel | 1496 | NA | NA | 80 | 2.0E-02 |
| | Chromium | 2031 | NA | NA | 80 | 3.0E-03 |
| Watercress | Cadmium | 5.9 | NA | NA | 80 | 1.0E-03 |
| n=1 | Mercury | 0.00 | NA | NA | 80 | 1.0E-04 |
| | Arsenic | 107 | NA | 1.5 | 80 | 3.0E-04 |
| | Zinc | 11667 | NA | NA | 80 | 3.0E-01 |
| | Nickel | 23.0 | NA | NA | 80 | 2.0E-02 |
| | Chromium | 57.0 | NA | NA | 80 | 3.0E-03 |
| Whitebait | Cadmium | 15.3 | NA | NA | 80 | 1.0E-03 |
| n=1 | Mercury | 13.5 | NA | NA | 80 | 1.0E-04 |
| | Arsenic[d] | 81.2 | NA | 1.5 | 80 | 3.0E-04 |
| | Zinc | 22137 | NA | NA | 80 | 3.0E-01 |
| | Nickel | 66.4 | NA | NA | 80 | 2.0E-02 |
| | Chromium | 46.1 | NA | NA | 80 | 3.0E-03 |

[a] Local consumption rates are species specific with median consumption of 6.1, 4.0, 4.7 and 6.0 g/day for eels, trout, flounder and watercress respectively.
[b] CSF = cancer slope factor; BW = body weight, RfD = reference dose, NA = not applicable.
[c] Median concentration for samples where n=1 are equal to the concentration of that sample
[d] Arsenic risk calculation subsequently reduced by a factor of 10 for freshwater species and by 3% for estuarine/marine species (pipi and mussel) for risk assessment to reflect an approximate inorganic portion of total arsenic of 10% and 3% respectively and provide a protective estimate of health risk (US EPA, 2003).

### 4.3 Te Arawa catchment risk assessments

Median and 95$^{th}$ percentile contamination data (Table 1) were used to create risk assessments for lifetime cancer risk and chronic non-cancer risk. Monthly consumption limits for each kai species sampled in the Te Arawa catchment were calculated using equations 2.3.2, 2.3.3 and 2.3.4 in the methods section (2.3).

Median contamination risk data are shown in Table 2. These data approximate the risk associated with harvesting at all sites surveyed randomly. As presented in Table 2, calculated consumption limits are relatively low for all species. The lower the value the greater the risk. Lifetime non-cancer risk is the determining risk factor for consumption of trout and eel, whereas lifetime cancer risk dominates for consumption of all other species, although the estimates for whitebait, pipi, kakahi, mussel and watercress are based on single samples.

**Table 2:** Risk assessments for the **median** contamination profile for each kai species from Te Arawa rohe (scenario of randomly harvesting kai across all sites).

| | Risk Based Consumption Limit[a] (meals/month) | |
|---|---|---|
| **Species** | **Cancer Health Endpoint[b]** | **Non-cancer Health Endpoint[c]** |
| Trout | 8.7 | 0.9 |
| Koura | 4.7 | 8.1 |
| Eel | 3.9 | 1.9 |
| Smelt | 2.6 | 16.5 |
| Whitebait | 1.8 | 79.3 |
| Pipi | 2.6 | 38.8 |
| Kakahi | 1.3 | 57.2 |
| Mussel | 2.9 | 3.9 |
| Watercress | 1.0 | 43.4 |

[a] The assumed meal size is 224 g for trout and eel, 112 for smelt and whitebait, 152g for koura, 144 g for pipi, kakahi and mussel, and 155g for watercress.
[b] refers to lifetime cancer risk (based on 1 in 100,000 risk level).
[c] chronic systemic effects.

Risk assessment calculations using the 95th percentile contamination data represents a worse case scenario that approximates the risk associated with harvesting from the most contaminated sites only. Risk assessment data for this “worse case scenario” are presented in Table 3. For consumption of trout, eel and koura the dominant risk factor is associated with a lifetime non-cancer risk, with consumption limits of 0.4, 1.2 and 1.6 meals/month respectively. Cancer health endpoints are the greatest risk factor for consumption of smelt (1.1 meals per month) and pipi (2.2 meals per month).

**Table 3:** Risk assessments for the **95th percentile** contamination profile for each kai species from Te Arawa catchment (worst case scenario of harvesting from the most contaminated sites).

| | Risk Based Consumption Limit[a] (meals/month) | |
|---|---|---|
| **Species[d]** | **Cancer Health Endpoint[b]** | **Non-cancer Health Endpoint[c]** |
| Trout | 3.1 | 0.4 |
| Koura | 2.9 | 1.6 |
| Eel | 3.0 | 1.1 |
| Smelt | 2.0 | 7.4 |
| Pipi | 2.2 | 35.6 |

[a] The assumed meal size is 224 g for trout and eel, 112g for smelt and 152g for koura
[b] refers to lifetime cancer risk (based on 1 in 100,000 risk level).
[c] chronic systemic effects.
[d] 95th percentile values could not be calculated for whitebait, watercress, kakahi or watercress as only a single sampled was analysed.

Clearly the greatest risk overall is if consumption of kai was only from the most contaminated sites (95th percentile scenario, Table 3). It is of interest to note that for koura, based on median contaminant levels (Table 2), the cancer risk is greatest, whereas when considering only the most contaminated sites, the non-cancer risk is greater. This suggests that different contaminants may be dominant at the most contaminated sites.

## 4.4 Individual site risk assessments

To ascertain which sites and which kai species are affording the highest risk, risk assessments were undertaken for each individual sampling site (Section 4.4). Risk is defined as having a greater than 1 in 100,000 chance of developing a cancer or non-cancer disease. For each site cancer and non-cancer risk-based consumption limits were calculated for each species. In addition, pie graphs showing the proportion that each contaminant contributes to the overall risk for both cancer and non-cancer endpoints are presented.

**Table 4:** Summary of individual consumption limits for each species at each site for kai collected from the Te Arawa rohe.

| Site | Species | Monthly Consumption Limits (meals/month) Carcinogenic Endpoint | Non-Carcinogenic Endpoint |
|---|---|---|---|
| Ohau Channel | Trout | 3.9 | 0.7 |
| | Eel | 5.2 | 1.1 |
| | Koura | 1.4 | 2.7 |
| | Smelt | 12.4 | 9.3 |
| Okareka | Trout | 8.6 | 2.0 |
| | Koura | 1.5 | 22.5 |
| Puarenga Lower | Trout | 5.3 | 26.4 |
| Puarenga Upper | Trout | 1.2 | 0.4 |
| Rotokakahi | Trout | 2.5 | 3.5 |
| | Koura | 4.5 | 11.3 |
| | Smelt | 7.9 | 94.9 |
| | Kakahi | 1.3 | 208.0 |
| Rotoiti | Trout | 8.8 | 0.6 |
| | Koura (East) | 1.5 | 1.6 |
| | Koura (West) | 1.1 | 3.0 |
| | Smelt | 4.5 | 10.9 |
| Rotoma | Trout | 12.6 | 5.2 |
| | Koura | 1.0 | 22.9 |
| Rotomahana | Trout | 7.1 | 0.5 |
| | Smelt | 4.1 | 7.4 |
| Rotorua | Trout | 6.3 | 0.9 |
| | Koura | 1.3 | 6.3 |
| Tarawera | Trout | 5.9 | 12.2 |
| | Koura | 0.9 | 23.7 |

| | | Monthly Consumption Limits (meals/month) | |
|---|---|---|---|
| **Site** | **Species** | **Carcinogenic Endpoint** | **Non-Carcinogenic Endpoint** |
| Tikitapu | Trout | 7.5 | 6.0 |
| | Koura | 2.1 | 35.1 |
| Upper Kaituna | Trout | 7.5 | 0.7 |
| | Koura | 2.1 | 3.1 |
| Lower Kaituna | Trout | 7.2 | 0.5 |
| | Eel | 3.1 | 6.5 |
| | Smelt1 | 5.3 | 34.2 |
| | Smelt2 | 2.0 | 128.9 |
| | Whitebait | 1.8 | 159.3 |
| Maketu | Pipi | 2.2 | 35.3 |
| | Pipi (repeat) | 2.6 | 38.8 |
| | Pipi (2nd collection) | 3.0 | 124.3 |
| | Mussel | 2.9 | 24.6 |
| Waiowhiro | Watercress | 1.0 | 398.2 |

[a] The assumed meal size is 224 g for trout and eel, 112 for smelt and whitebait, 152g for koura, 144 g for pipi, mussels and kakahi, and 155g for watercress.
[b] refers to lifetime cancer risk (based on 1 in 100,000 risk level).
[c] chronic systemic effects.

### Ohau Channel

The greatest risk in consuming trout, eel and koura was associated with a non-cancer endpoint, with associated consumption limits of less than 1 meal/month for trout, less than 2 meals/month for eel, and three meals/month for smelt. This risk was dominated by mercury contamination. For koura, arsenic was the major contaminant of concern, resulting in an excess cancer risk and a consumption limit of 1.4 meals per month.

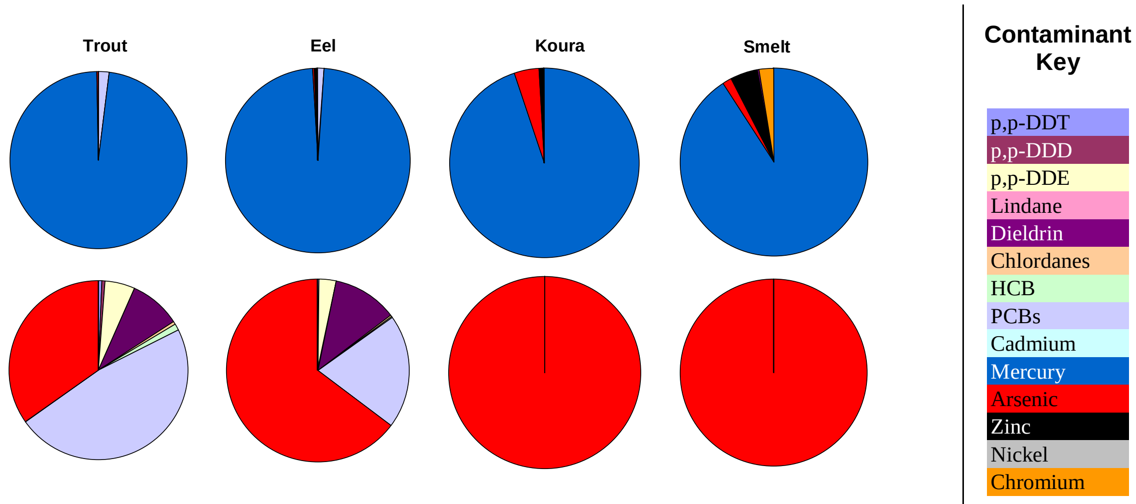
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 3.9 | 0.7 |
| Eel | 5.2 | 1.1 |
| Koura | 1.4 | 2.7 |
| Smelt | 12.4 | 9.3 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limits**




[a] The assumed meal size is 224 g for trout and eel, 112g for smelt and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

**Lake Okareka**

The risk based consumption limits for trout (non-cancer risk) and koura (cancer risk) were two and 1.5 meals/month respectively. Mercury and arsenic were the major individual determinands for each of these risks.

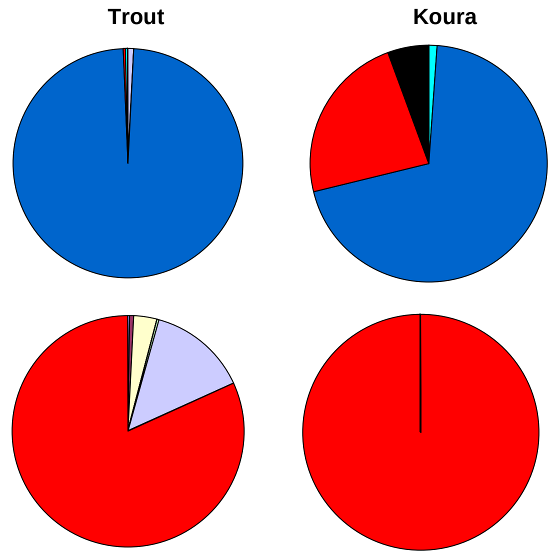
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c] |
|---|---|---|
| Trout | 8.6 | 2.0 |
| Koura | 1.5 | 22.5 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limits**




**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 224 g for trout and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

**Lower Kaituna River**

Trout, smelt, eel and whitebait were sampled from the Lower Kaituna River site. A non-cancer risk based consumption limit of 0.5 meals/month was calculated for trout, based on mercury levels. For all other species, the cancer risk was greater than the non-cancer risk, with the main determinand being arsenic.

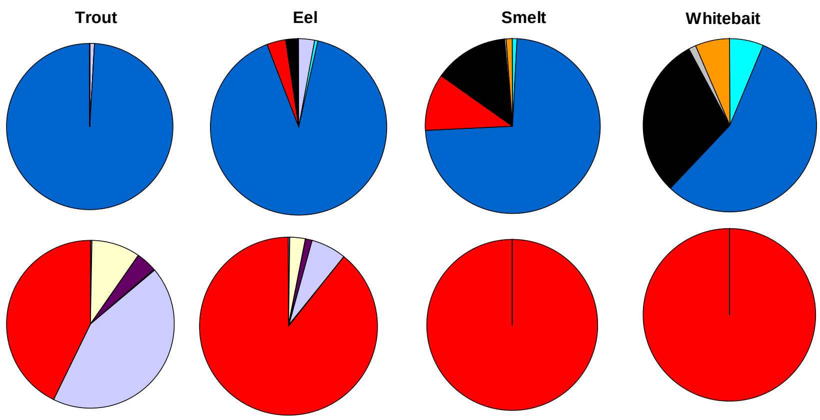
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c] |
|---|---|---|
| Trout | 7.2 | 0.5 |
| Eel | 3.1 | 6.5 |
| Smelt | 2.0 | 128.9 |
| Whitebait | 1.8 | 159.3 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limits**




**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 224 g for trout and eel, and 112g for smelt and whitebait; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

**Puarenga Lower**

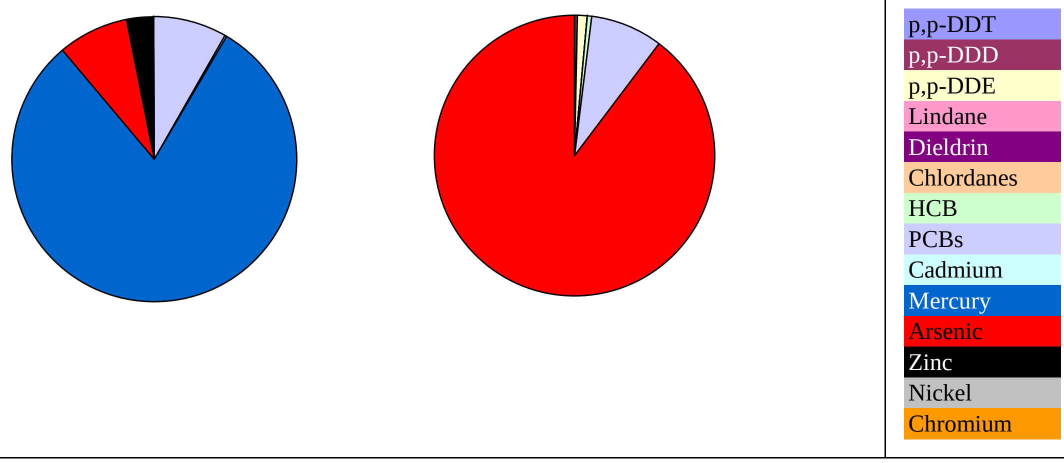
The greatest risk associated with consumption of trout from the Lower Puarenga River was due to tissue concentrations of arsenic, resulting in cancer risk consumption limit of less than six meals per month.

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 5.3 | 26.4 |

**Contaminant contribution to non-cancer (left) and cancer (right) based consumption limits**




[a] The assumed meal size is 224 g for trout; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

### Puarenga Upper

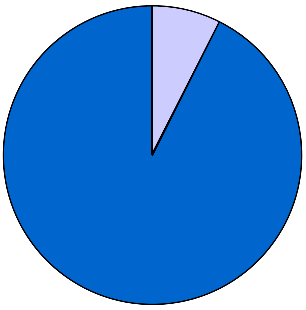
The greatest risk associated with consumption of trout from the Upper Puarenga River was due to PCBs, resulting in non-cancer risk consumption limit of less than 1 meal per month. The cancer risk due to mercury is also significant, with a consumption limit of 1.2 meals per month.

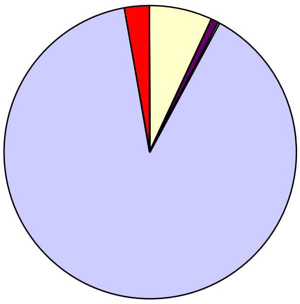
| Site Picture | Kai Harvested |
|---|---|
|  |  |

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,d] |
|---|---|---|
| Trout | 1.2 | 0.4 |

**Contaminant contribution to non-cancer (left) and cancer (right) based consumption limits**





**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 224 g for trout; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Lake Rotokakahi

For all kai species collected from this site, the greatest risk associated with consumption was due to the concentrations of arsenic in biota tissue, resulting in cancer endpoint consumption limits ranging from 1.3 meals/month for kakahi to 7.9 meals/month for smelt.

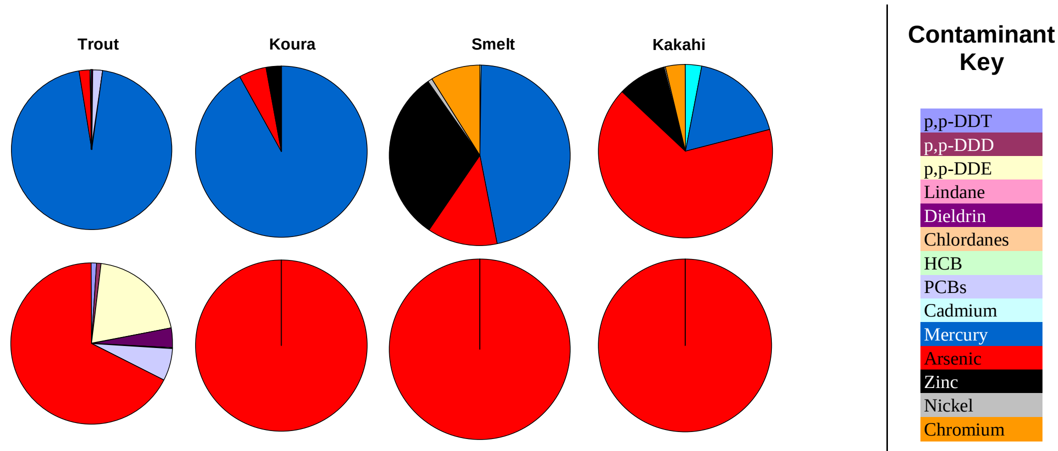
**Site picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,d] |
|---|---|---|
| Trout | 2.5 | 3.5 |
| Koura | 4.5 | 11.3 |
| Smelt | 7.9 | 94.9 |
| Kakahi | 1.3 | 208.0 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limits**




[a] The assumed meal size is 224 g for trout, 112g for smelt, 152g for koura and 144 g for kakahi; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Lake Rotoiti

An increased cancer risk was associated with consumption of more than 4.5 meals/month of smelt and approximately one meal/month of koura. This risk was predominantly due to arsenic. For trout, a greater non-cancer risk was identified with a calculated consumption limit of less than one meal/month. The main determinand for this non-cancer risk in trout was mercury.

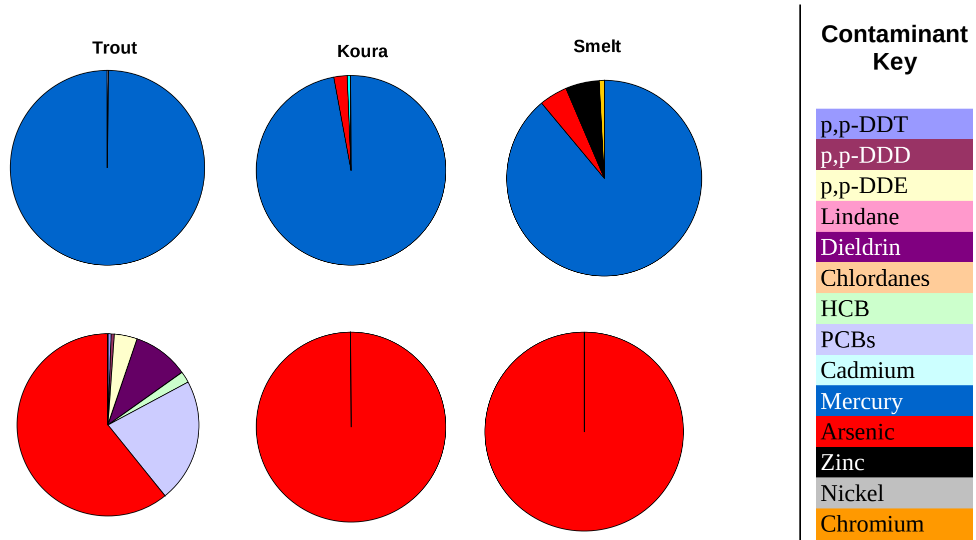
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,d] |
|---|---|---|
| Trout | 8.8 | 0.6 |
| Koura (West) | 1.1 | 3.0 |
| Smelt | 4.5 | 10.9 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




[a] The assumed meal size is 224 g for trout and eel, 114g for smelt and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Lake Rotoma

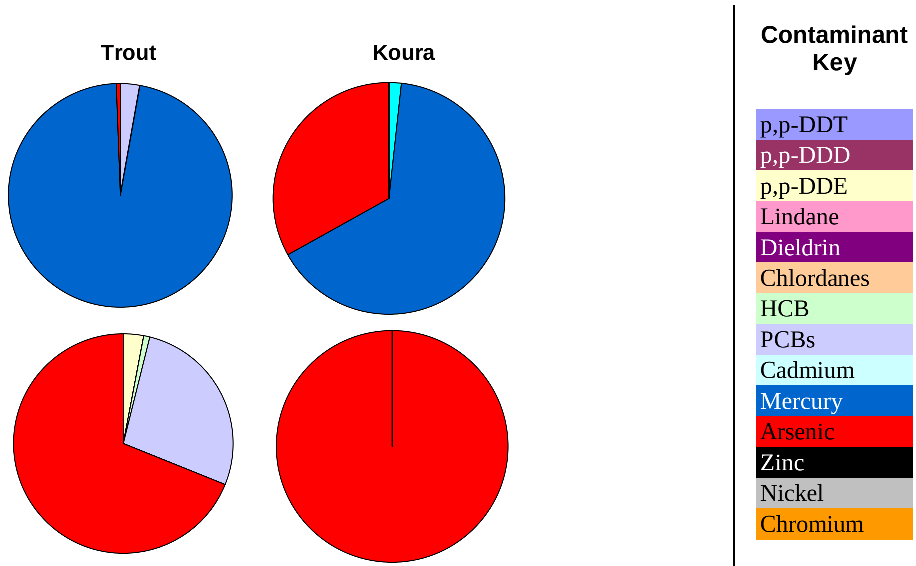
An increased cancer risk was associated with consuming no more than one meal per month of koura. This risk was attributable primarily to the tissue concentrations of arsenic. In contrast, for trout, a greater non-cancer risk was identified, with mercury being the major determinand. The calculated consumption limit for trout (based on this non-cancer risk) was less than six meals/month.

| Site Picture | Kai Harvested |
|---|---|
|  |   |

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,d] |
|---|---|---|
| Trout | 12.6 | 5.2 |
| Koura | 1.0 | 22.9 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




[a] The assumed meal size is 224 g for trout and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

**Lake Rotomahana**

A non-cancer endpoint was identified as the greater risk for trout, with a consumption limit of less than one meal/month (equate to one meal every two months), due to elevated mercury concentrations. An increased cancer risk was identified if consumption of smelt was greater than four meals/month. This increased risk was attributed to arsenic contamination of smelt.

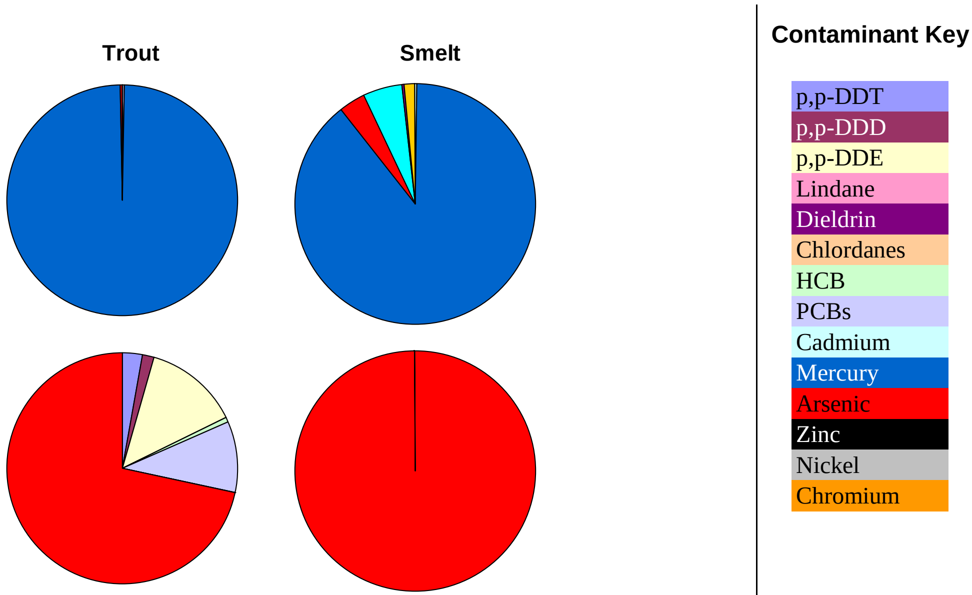
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,d] |
|---|---|---|
| Trout | 7.1 | 0.5 |
| Smelt | 4.1 | 7.4 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




[a] The assumed meal size is 224 g for trout and 112g for smelt; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

**Lake Rotorua**

An increased cancer risk was associated with consumption of more than 1.3 meals/month of koura from this site, due exclusively to tissue concentrations of arsenic. For trout, a greater non-cancer risk was calculated, due to mercury, resulting in a consumption limit of approximately one meal/month.

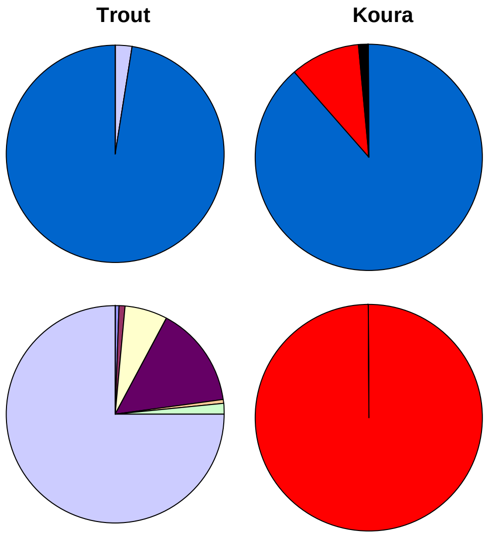
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 6.3 | 0.9 |
| Koura | 1.3 | 6.3 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




**Contaminant Key**

p,p-DDT
p,p-DDD
p,p-DDE
Lindane
Dieldrin
Chlordanes
HCB
PCBs
Cadmium
Mercury
Arsenic
Zinc
Nickel
Chromium

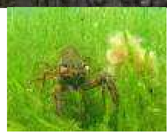
[a] The assumed meal size is 224 g for trout and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Lake Tarawera

Cancer endpoints were determined as the greater risk for both trout and koura, with risk-based consumption limits of 5.9 meal/month and less than one meals/month for trout and koura, respectively. Arsenic was the contaminant primarily responsible for these risks. Consumption limits were much less restrictive based on non-cancer endpoints, with respective limits of 12 and 24 meal per month for trout and koura. This non-carcinogenic risk was largely attributable to mercury.

**Site Picture**

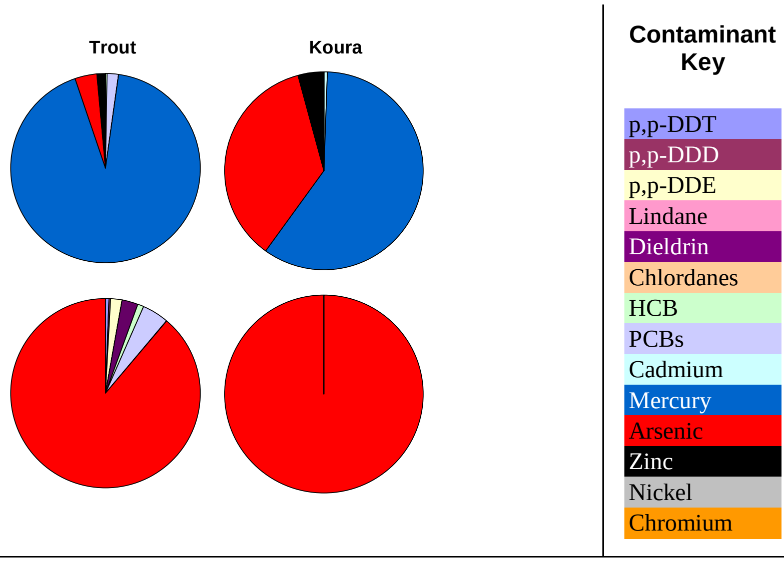
**Kai Harvested**



**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 5.9 | 12.2 |
| Koura | 0.9 | 23.7 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




[a] The assumed meal size is 224 g for trout and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

### Lake Tikitapu

A consumption limit of approximately 4 meals/month of koura was calculated in association with an increased cancer risk. This was primarily due to elevated arsenic levels. For trout, a greater non-cancer risk was determined, due predominantly to the tissue concentration of mercury, resulting in a consumption limit of 6.0 meals/month.

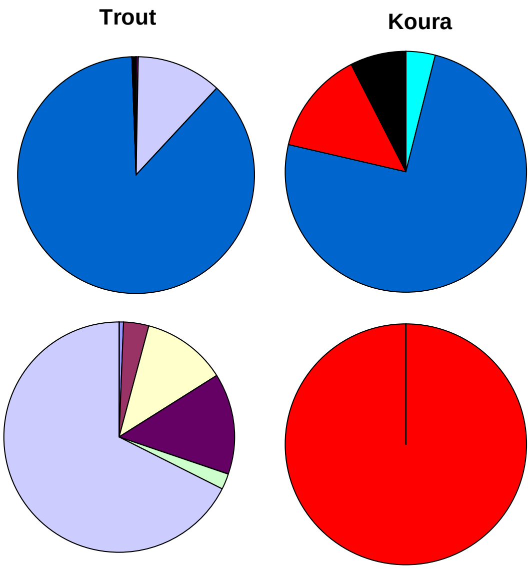
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 7.5 | 6.0 |
| Koura | 4.1 | 35.1 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 224 g for trout and 152g for koura;[b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

### Upper Kaituna

An increased cancer risk was associated with consumption of more than two meals/month of koura from this site, due to arsenic contamination. For trout, a greater non-cancer risk was identified (attributable primarily to mercury), resulting in a consumption limit of less than one meal/month.

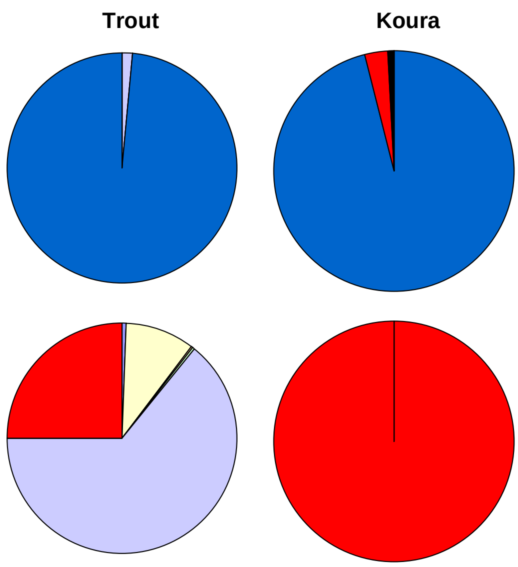
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Trout | 7.5 | 0.7 |
| Koura | 2.1 | 3.1 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 224 g for all trout and 152g for koura; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Maketu

For both pipis and mussels, cancer endpoint risks were attributable exclusively to the tissue concentrations of arsenic, resulting in consumption limits of approximately two and three meals/month for pipis and mussels, respectively. The non-cancer risk was attributable to chromium, although the risk was very low for both species.

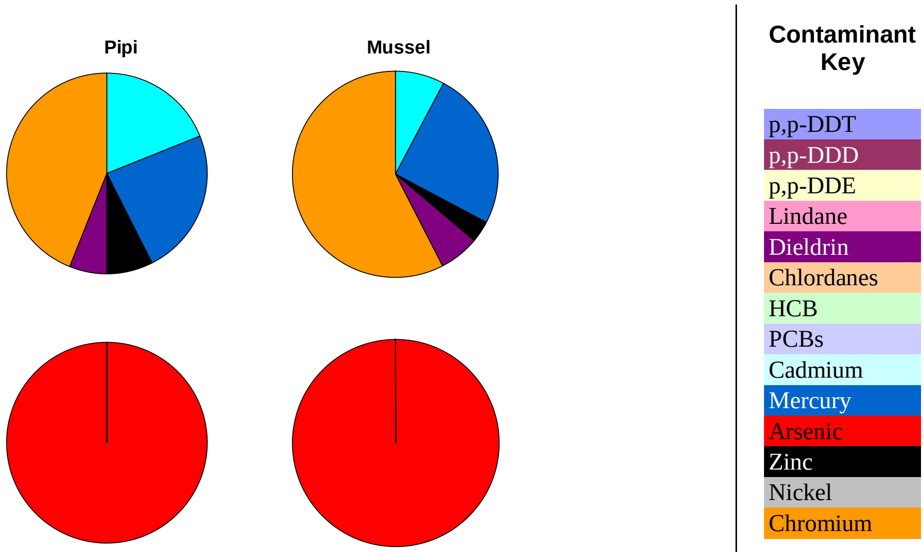
**Site Picture**

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Pipi | 2.2 | 35.3 |
| Mussel | 2.9 | 24.6 |

**Contaminant contribution to non-cancer (upper) and cancer (lower) based consumption limit**




[a] The assumed meal size is 144 g for pipi and mussels; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

## Waiowhiro Stream

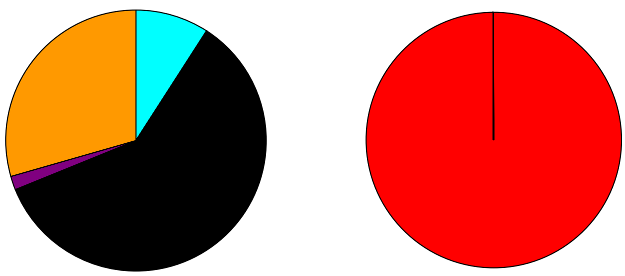
For watercress collected from this site, based on a cancer endpoint, a consumption limit of one meal/month was determined, which was attributable to arsenic. In contrast, the non-cancer risk was very low, with a consumption limit of approximately 400 meals per month.

**Kai Harvested**

**Risk Based Consumption Limit[a] (meals/month)**

| Species | Cancer Health Endpoint[b] | Non-cancer Health Endpoint[c,e] |
|---|---|---|
| Watercress | 1.0 | 398.2 |

**Contaminant contribution to cancer based consumption limit**



**Contaminant Key**

- p,p-DDT
- p,p-DDD
- p,p-DDE
- Lindane
- Dieldrin
- Chlordanes
- HCB
- PCBs
- Cadmium
- Mercury
- Arsenic
- Zinc
- Nickel
- Chromium

[a] The assumed meal size is 155 g for watercress; [b] refers to lifetime cancer risk (based on 1 in 100,000 risk level); [c] chronic systemic effects.

### 4.5 Predominant contaminants associated with risk

For most kai species analysed a potential cancer endpoint, due primarily to arsenic, was identified (Table 6). However, for trout a greater non-cancer risk was identified at three sites (Upper Puarenga Stream, Lake Rotokakahi, Lake Tarawera), where determinands to this risk were a combination of arsenic, PCBs and a range of organochlorine pesticides. For smelt, the non-cancer risk was greater in the Ohau Channel, with mercury the main determinand. For all other sites where smelt was sampled a cancer risk was predominant, with arsenic the main determinand. Finally, at the two sites where eels were collected, both cancer and non-cancer risks was associated with consumption

**Table 6:** Percentage of sites where cancer and non-cancer risk identified for each species, as well as predominant contaminant associated with risk.

| Species | Cancer | | Non-cancer | |
|---|---|---|---|---|
| | % of sites | Determinand contaminant(s) | % of sites | Determinand contaminant(s) |
| Trout | 23 | arsenic, PCBs, p,p,-DDE, p,p-DDD, dieldrin | 77 | mercury |
| Eel | 50 | arsenic | 50 | mercury |
| Smelt | 75 | arsenic | 25 | mercury |
| Whitebait | 100 | arsenic | - | - |
| Koura | 100 | arsenic | - | - |
| Kakahi | 100 | arsenic | - | - |
| Pipi | 100 | arsenic | - | - |
| Mussel | 100 | arsenic | - | - |
| Watercress | 100 | arsenic | - | - |

### 4.6 Potential risks versus current consumption rates

Local consumption rates and meal sizes were calculated from the interview data, with results presented in Table 7. The average total fish consumption rate (97 g/day) for people who contributed to the questionnaire is much higher than the New Zealand ‘average’ consumption rate of 32 g/day (Kim & Smith 2006). In contrast, the total average wild fish consumption rate was 12.4 g/day, indicating that wild caught kai represents a relatively small proportion of the main source of aquatic food for the local community.

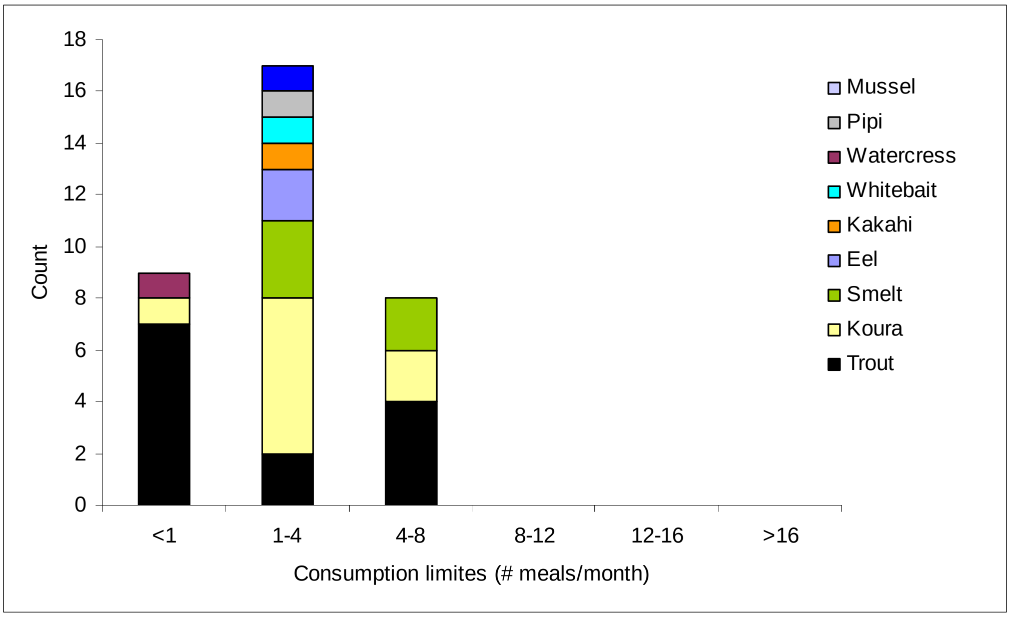
**Table 7:** Kai consumption rates and meal sizes of Te Arawa participants.

| Kai species | average meal size per sitting (g) | Consumption rate g/month | meals/month |
|---|---|---|---|
| total fish[a] | 224.0 | 2910 | 13.0 |
| watercress | 154.7 | 473.1 | 3.1 |
| mussels | 144.4 | 508.8 | 3.5 |
| eel | 223.7 | 288.3 | 1.3 |
| trout | 223.9 | 326.3 | 1.5 |
| pipi | 144.5 | 508.8 | 3.5 |
| koura | 152.0 | 76.0 | 0.5 |
| kakahi | 144.5 | 9.9 | 0.1 |
| whitebait | 111.8 | 62.2 | 0.6 |
| smelt | 111.8 | 62.2 | 0.5 |

[a] includes fish from all sources.

The distribution of each species for all sites across the risk-based consumption limit (i.e., meals/month) categories is shown in Figure 20. These data clearly show that trout represents the highest potential risk to consumers, with most trout caught having a consumption limit of less than four meals per month. Most other kai species analysed were in the category of 1-4 allowable meals per month. Koura, smelt and trout from some sites were in the 4-8 meals per month category.

**Figure 20:** Distribution of allowable number of meals/month for each kai species.




We considered two possible harvesting and consumption scenarios in determining the potential risk of contaminants to members of the Te Arawa iwi. The first is where consumption of kai occurs from sites randomly throughout the rohe of Te Arawa, and the second is where the risk of consumption is only through consumption of kai from the most contaminated sites. The first scenario was approximated by a risk assessment of the median ($50^{th}$ percentile) concentrations of contaminant in biota. Comparisons of the consumption limits based on the endpoint exhibiting the highest risk (i.e., either cancer or non-cancer risk), using the median contaminant concentration data, with actual consumption rates enabled assessment of the first scenario (Table 8). This shows that if harvesting was carried out randomly across all sites and consumption rates were as calculated from the kai consumption data, then there is a significant risk to members of Te Arawa iwi associated with consumption of trout, pipi, mussel and watercress. The current and calculated risk based consumption rates for eel are also reasonably close (1.3 meals/month actual versus a risked-based limit of approximately 2 meals/month).

**Table 8:** Comparison of risk-based consumption limits for *median* contaminant concentration data and actual consumption rates for survey participants. Bold indicates exceedance of consumption limit.

| kai species | risk-based consumption limit (meals/month) | actual consumption rate for Te Arawa (meals/month) |
|---|---|---|
| Trout | **0.9** | **1.5** |
| Koura | 4.7 | 0.5 |
| Eel | 1.9 | 1.3 |
| Smelt | 2.6 | 0.6 |
| Whitebait | 1.8 | 0.6 |
| Pipi | **2.6** | **3.5** |
| Kakahi | 1.3 | 0.1 |
| Mussel | **2.9** | **3.5** |
| Watercress | **1.0** | **3.1** |

The second scenario, where harvesting consists primarily of the most contaminated sites, is defined by the 95$^{th}$ percentile contaminant concentrations (Table 9). If this was to occur, then a significant health risk is apparent for the consumption of trout, eel and pipi. A lack of replicate samples precluded calculation of this risk for whitebait, kakahi, mussel and watercress.

**Table 9:** Comparison of allowable consumption limits for *95$^{th}$ percentile* contaminant concentration data and actual consumption rates for survey participants. Bold indicates exceedance of consumption limit.

| kai species | risk-based consumption limit (meals/month) | actual consumption rate for Te Arawa (meals/month) |
|---|---|---|
| Trout | **0.4** | **1.5** |
| Koura | 1.6 | 0.5 |
| Eel | **1.1** | **1.3** |
| Smelt | 2.0 | 0.6 |
| Pipi | **2.2** | **3.5** |

To assess which sites are of concern across the Te Arawa rohe, a summary of risk-based consumption limits (meals/month for each of the most widely sampled species (trout, eel, koura, smelt) in this study is shown in Figures 21 to 24. Each figure gives a pictorial account, binned into categories of consumption limits, for ease of interpretation.

A number of potential "hotspots" i.e., area of increased risk for many species, were evident from the results. The Maketu site is of concern, with significant risk from consumption of both pipi and mussels (less than 4 meals/month). Waiowhiro watercress samples are also a concern. Consumption of all 4 species sampled in the lower Kaituna River ranged from <1 meal/month to 3.1 meals/month. Similarly, 3 of the 4 species sampled from the Ohau Channel were also limited to between 0.7 – 1.4 meals/month. For sites where both trout and koura were collected, the risk associated with consumption of these species was Rotorua = Upper Kaituna = Rotoiti = Ohau Channel > Okareka = Tarawera > Rotokakahi = Rotoma > Tikitapu.

The geothermal waters in the Taupo Volcanic Zone (TVZ) are high in mercury compared to other natural waters in New Zealand (Weissberg & Zobel 1973). Previous studies have analysed concentrations of total mercury in rainbow trout (Brooks et al. 1976) or it's more bioavailable form, methyl mercury (Kim,1995, Kim & Burggraaf 1999). Concentrations of mercury in trout flesh from our study were similar to these literature values. The authors also calculated consumption limits, although some differences in methods for calculating these limits makes direct comparison difficult. The current average consumption rate of Te Arawa study participants across all lakes is 1.5 meals of trout per month. On the basis of the risk assessment undertaken in this report, consumption of trout should be limited to less than one meal per month when harvested from sites in proximity to the upper and lower Kaituna River, the Ohau Channel, upper Puarenga Stream and lakes Rotoiti, Rotomahana and Rotorua. A precautionary approach should be taken to other sites in these waterbodies. Kim (1995) recommended a consumption frequency of one meal every three weeks from Lake Rotomahana (based on a 150 g meal size) for a 70 kg male or one meal per month for a 50 kg female. Consumption should be limited to between 1 and 4 meals per month of trout caught in lakes Rotokakahi and Okareka.

Few studies of metal concentrations in koura appear to have been published (Turner et al. 2005). From our risk assessment data it can also be concluded that koura from Lake Tarawera (at least in the vicinity of our study site) should be consumed less than once a month in order to avoid increased risk of cancer. At sites in the upper Kaituna River, Ohau Channel and in lakes Rotorua, Rotoma, Rotoiti and Okareka, koura should be consumed no more than four times per month, or once per week. Current consumption rates on average are 0.5 meals per month.

Eels harvested from the Lower Kaituna and the Ohau Channel should not be harvested more than four times per month, although this conclusion is based on a limited sample size. Bioaccumulation of mercury in eels is related to age of the fish, with progressively higher tissue concentrations with increasing age (Kim, 1995). Therefore, our results may to some extent reflect age-related differences. In a study of South Island rivers, Redmayne et al (2000) found that mercury concentrations (measured as methyl mercury) in long-finned eels linearly vary with both length and age for a given river, but also exhibited differences between catchments.

Previous reports of arsenic accumulation in watercress in the TVZ identified the hyper-accumulation properties of watercress and other aquatic plants, with concentrations in the plants of 100-50,000 times that in the ambient water (Robinson et al. 2006a, Robinson et al. 2003). The concentrations reported in these are considerably higher than that reported in our study (0.11 mg/kg). It should be noted that any arsenic toxicity from consuming watercress will depend on the amount and frequency eaten, how the watercress is prepared, what it is consumed with and the chemical form of arsenic in the plant (Robinson et al. 2006a). Risk-based consumption limits for watercress are currently being exceeded by questionnaire participants from the Te Arawa rohe, although this is based on a single composite sample from Waiowhiro Stream.

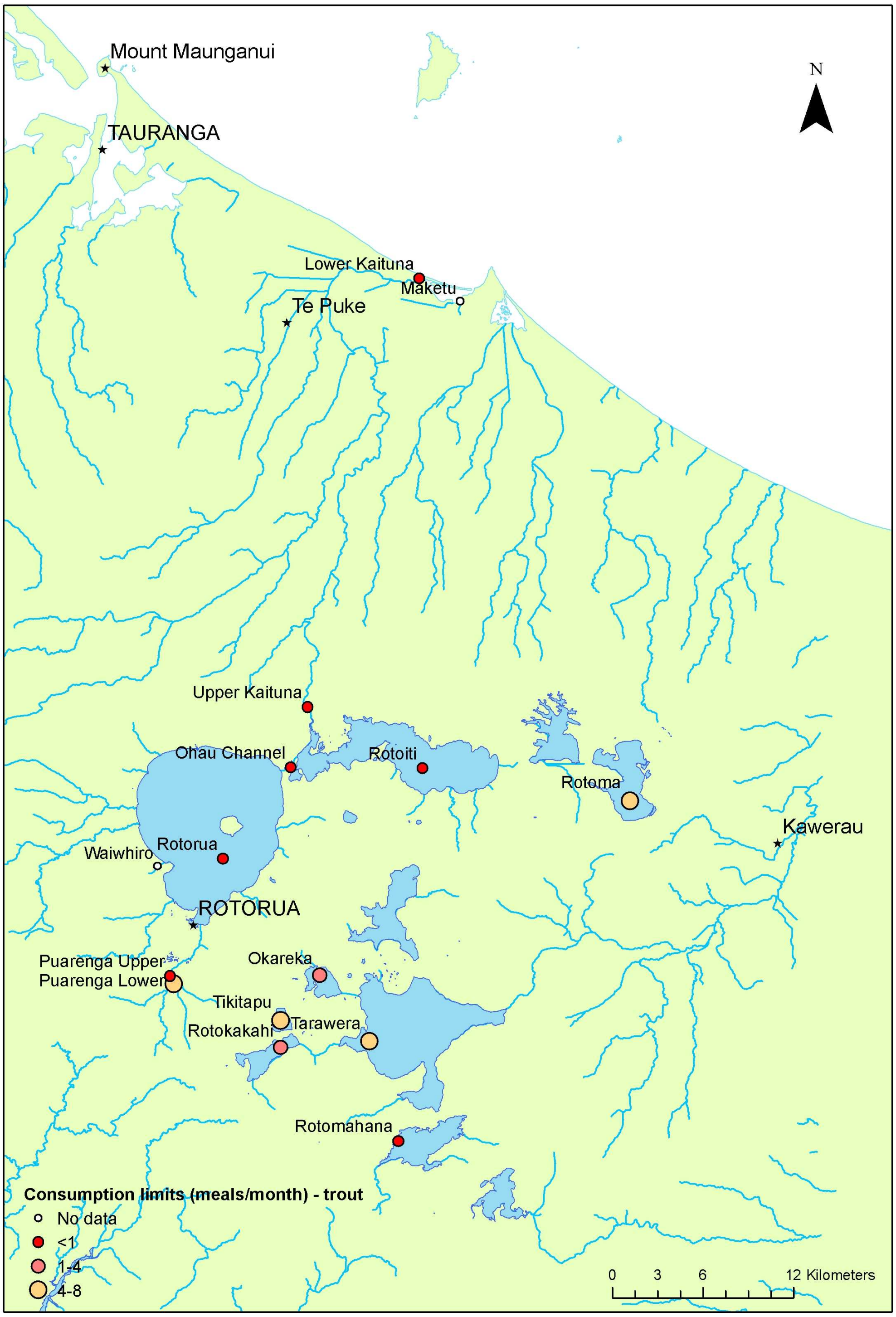



**Figure 21:** Trout consumption limits (meals per month) based on highest risk factor endpoint.


**Figure 22:** Koura consumption limits (meals per month) based on highest risk factor endpoint.

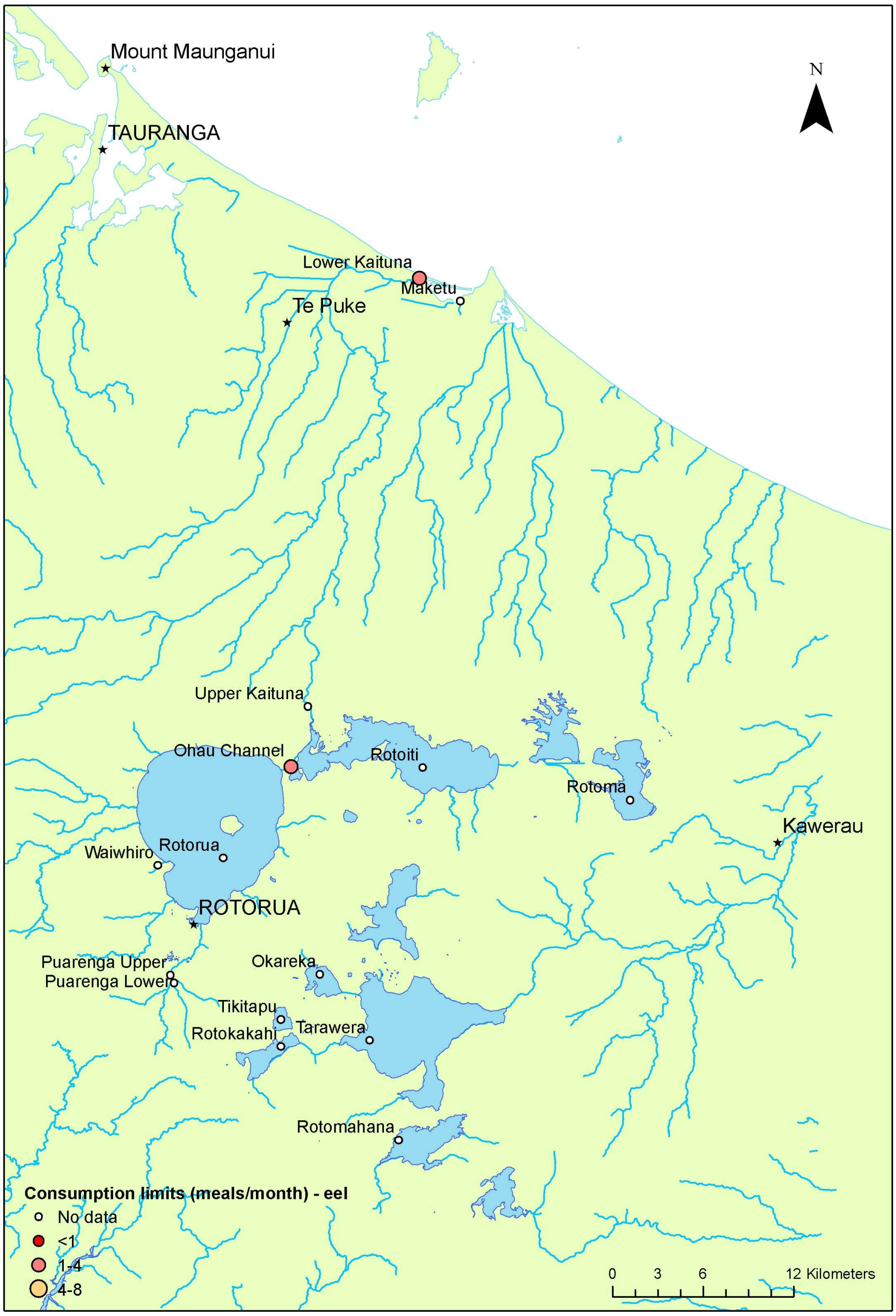



**Figure 23:** Eel consumption limits (meals per month) based on highest risk factor endpoint.

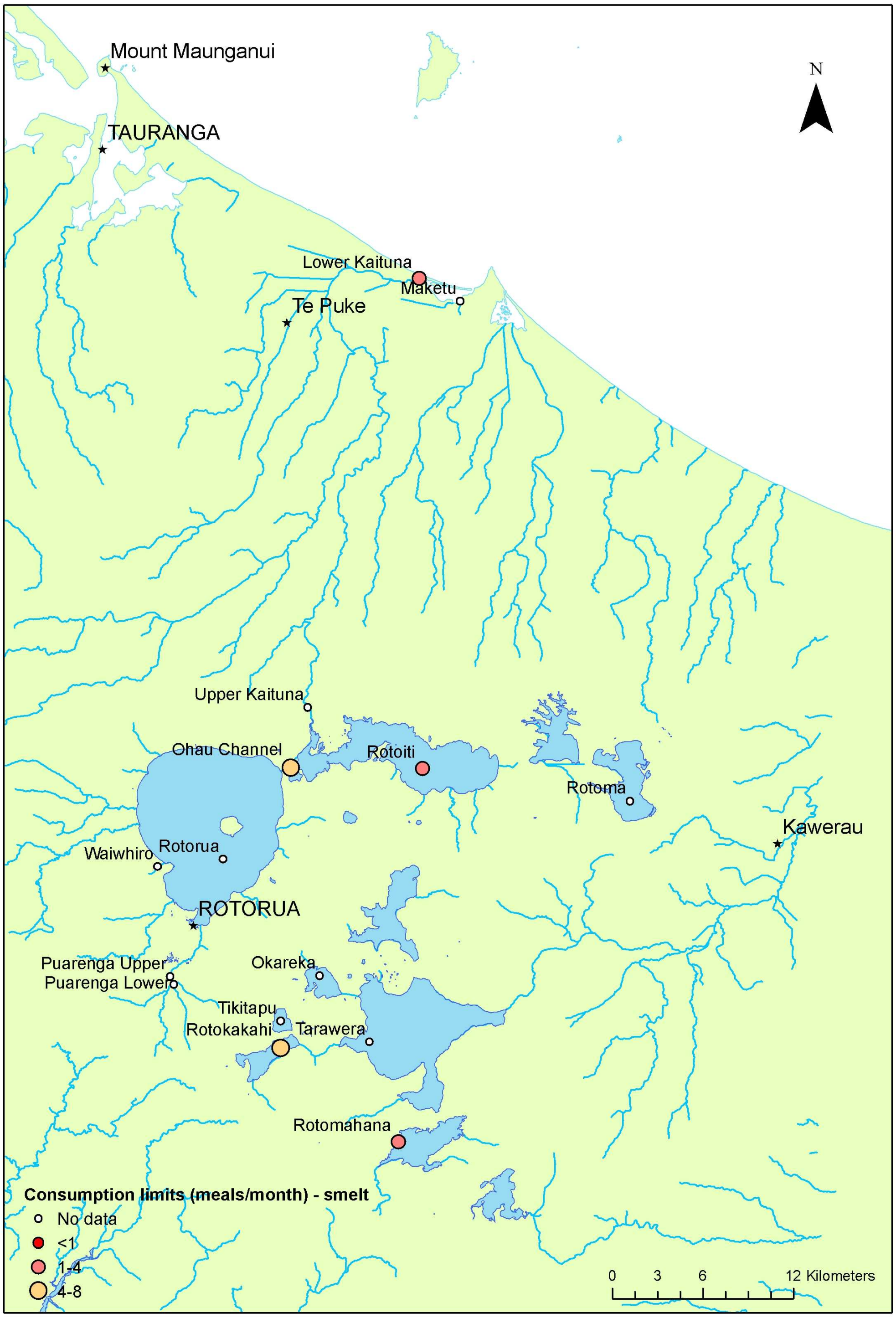



**Figure 24:** Smelt consumption limits (meals per month) based on highest risk factor endpoint.

# 5. Summary and Conclusions

The following summarises the basis to and results of our assessment of risk of contaminants in kai in the Te Arawa rohe:

- Local average consumption rates (g/day) were calculated as follows: watercress (15.8), mussels (16.9), koura (2.5), whitebait (5.7), eel (9.6), trout (10.9), kakahi (0.33) Total fish consumption (97 g/day) was much higher than the NZ 'average' consumption category of 32 g/day (Kim & Smith 2006). Of this amount 13% comprised traditionally harvested fish, indicating that wild caught kai represents only a small proportion of the total "food basket" for the local community. 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).

- Meal sizes were calculated at 224 g/meal for trout and eel, 112 g/meal for smelt and whitebait, 152 g/meal for koura, 144 g/meal for shellfish (mussels, pipi, kakahi) and 155 g/meal for watercress.

A risk assessment was carried out on the contaminant data, using established US EPA formulae. The risk assessment calculated consumption limits (as meals per month) for each species for the whole catchment, using contaminant concentration data to approximate harvesting of kai with random contamination concentrations that might be expected from harvesting randomly across all sites (based on the median or 50$^{th}$ percentile) or predominantly harvesting from the most contaminated sites (95$^{th}$ percentile).

Based on calculated consumption rates from our study group, the results of the risk assessment were clear:

- If harvesting was carried out randomly across all sites where kai species were collected, then there is a significant risk to members of Te Arawa iwi associated with consumption of trout, pipi, mussel and watercress.

- However, if harvesting were undertaken predominantly at the most contaminated sites, then a significant risk is apparent for the consumption of trout, eel and pipi. A lack of replicate samples precluded calculation of this risk for whitebait, kakahi, mussel and watercress; however given that mussels and watercress were identified as being at risk at median contaminant levels, this risk will be greater if only harvested from the most contaminated sites.

- The risk of eating trout in the Te Arawa rohe was greater than other species, with contaminant concentrations in 9 of the 13 trout sampled resulting in a consumption limit of less than 4 meals per month (or <1 meal per week).

- A number of potential “hotspots” i.e., areas of increased risk for many species, were evident from the results. The Maketu site is of concern, with significant risk of consumption of both pipi and mussels. Waiowhiro watercress samples are also a concern. Consumption of all four species sampled in the lower Kaituna River ranged from <1 meal/month to three meals/month. Similarly, three of the four species sampled from the Ohau Channel were also limited to between 0.7 – 1.4 meals/month. For sites where both trout and koura were collected, the relative risk associated with consumption of these species was in the order: Rotorua = Upper Kaituna = Rotoiti = Ohau Channel > Okareka = Tarawera > Rotokakahi = Rotoma > Tikitapu.

Any conclusions made from this study need to bear in mind certain limitations, specifically:

- a small sample size of people completed the kai consumption questionnaire (n=19) and so calculation of consumption rates would be improved by including more participants

- for large biota (i.e., eel and trout) the sample often consisted of a single specimen, so caution must be taken when applying consumption limits on a site by site basis

- not all contaminants were analysed in all kai species, e.g., PCBs were only analysed in trout and eels (since these represented the highest bioaccumulation risk based on their high lipid levels).

The results from this study clearly illustrate the need to more accurately assess the risk of consuming wild kai in the rohe of Te Arawa by:

- collecting samples from more sites, species and with multiple specimens at each site, so a more statistically robust spatial assessment can be made of risk

- expanding the contaminant dataset to include:

    - PCB analyses in all large freshwater fish

  - metal speciation studies on arsenic and mercury - for at least a subset of each kai species at representative locations, i.e., estuarine, river, marine - to more accurately gauge risk

- obtaining a more robust dataset of kai consumption in the region, by including more consumers of wild kai, in the questionnaire process

- calculation of site-specific consumption rates, which would increase reliability of risk estimates (for sites that are subject to regular harvesting), and

- conducting a risk assessment for total fish diet which incorporates both wild and commercial dietary consumption.

Notwithstanding these limitations, this study has provided a valuable screen of potential risks associated with kai consumption in the Te Arawa rohe.

# 6. Acknowledgements

We are grateful to all Te Arawa participants for their contributions to this study. We thank the Te Arawa Lakes Trust, especially Hera Smith, Willy Emery and Roku Mihinui for their efforts in garnering enthusiasm and participation, disseminating knowledge about the project and for their general support. We also thank Eddie Bowman, Joe Butterworth and Ian Kusabs for sample collection. This research was funded by the Health Research Council of New Zealand, Contract HRC/207. Kai consumption data were collected under Ethics Approval MEC/07/07/088.

# 7. References

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.

ATSDR. Toxic Substances Portal 2010. Retrieved 27th October, 2010, from http://www.atsdr.cdc.gov/substances/index.asp

Blomkvist, D.; Lundstedt, L. (1995). Sediment investigation of the Rotorua lakes. Environment BOP, Environment Report 95/23 *No.* 38 p.

Brooks, R.R.; Lewis, J.R.; Reeves, R.D. (1976). Mercury and other heavy metals in trout of central North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 10(2)*: 233–244.

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

Daus, B.; Wennrich, R.; Morgenstern, P.; Weiß, H.; Leonhardt Palmieri, H.E.; Nalini, H.A.; Leonel, L.V.; Guedes Monteiro, R.P.; Moreira, R.M. (2005). Arsenic Speciation in Plant Samples from the Iron Quadrangle, Minas Gerais, Brazil. *Microchimica Acta 151(3)*: 175–180.

Golder Associates and NIWA (2009). Trace elements in watercress in the Tarawera River. NORST-KWR-001 16 p.

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.

Kim, J.P. (1995). Methylmercury in rainbow trout (*Oncorhynchus mykiss*) from Lakes Okareka, Okaro, Rotomahana, Rotorua and Tarawera, North Island, New Zealand. *The Science of the Total Environment 164*: 209–219.

Kim, J.P.; Burggraaf, S. (1999). Mercury bioaccumulation in rainbow trout (*Oncorhynchus mykiss*) and the trout food web in lakes Okareka, Okaro, Tarawera, Rotomahana and Rotorua, New Zealand. *Water, Air, and Soil Pollution 115*: 535–546.

Kim, N.; Smith, J. (2006). Review of science relating to discharges from the Kinleith Pulp and Paper mill. Environment Waikato Technical Report 2005/58 ,83 p.

McColl, R. (1975). Chemical and biological conditions in lakes of the Volcanic Plateau. *In*: Jolly, V.; Brown, J. (eds). New Zealand lakes, pp. 121–139. Auckland University Press, Auckland.

McColl, R.H.S. (1972). Chemistry and trophic status of seven New Zealand lakes. *New Zealand journal of marine and freshwater research 6(4)*: 399–447.

Ministry of Economic Development. Retrieved 27th October, 2010, from http://www.med.govt.nz/templates/MultipageDocumentPage____10256.aspx#P243_26629

Phillips, N.; Stewart, M.; Olsen, G.; Hickey, C. (2011). Contaminants in kai – Te Arawa rohe. Part 1: Data report. NIWA Hamilton. HAM2010-021. p. 64.

Redmayne, A.; Kim, J.P.; Closs, G.; Hunter, K. (2000). Methyl Mercury bioaccumulation in long-finned eels, *Anguilla dieffenbachii*, from three rivers in Otago, New Zealand. *The Science of the Total Environment 262*: 37–47.

Robinson, B.; Kim, N.; Marchetti, M.; Moni, C.; Schroeter, L.; van den Dijssel, C.; Milne, G.; Clothier, B. (2006a). Arsenic hyperaccumulation by aquatic macrophytes in the Taupo Volcanic Zone, New Zealand. *Environmental and Experimental Botany 58(1-3)*: 206–215.

Robinson, B.; Marchetti, M.; Moni, C.; Schroeter, L.; van den Dijssel, C.; Milne, G.; Bolan, N.; Mahimairaja, S. (2006b). Arsenic accumulation by aquatic and terrestrial plants: Taupo Volcanic Zone, New Zealand. *In*: Naidu, R.; Smith, E.; Owens , G.; Bhattacharya , R.; Nadebaum, P. (eds). Managing Arsenic in the Environment : From Soil to Human Health, pp. 235–247. CSIRO publishing, Adelaide, Australia.

Robinson, B.H.; Duwig, C.; Bolan, N.; Kannathasan, M.; Saravanan, A. (2003). Uptake of arsenic by New Zealand watercress (*Lepidium sativum*). *The Science of the Total Environment 301*: 67–73.

Schoof, R.A.; Yager, J.W. (2007). Variation of Total and Speciated Arsenic in Commonly Consumed Fish and Seafood. *Human and Ecological Risk Assessment: An International Journal 13(5)*: 946–965.

Statistics New Zealand. 2006 Census (2006). Retrieved 1st November, 2010, from http://www.stats.govt.nz/Census/2006CensusHomePage/

Stewart, M.; Hickey, C.; Phillips, N.; Olsen, G. (2010). Contaminants in Kai – Arowhenua rohe. Part 2: Risk Assessment. *No. HAM2010-116*. 57 p.

Stewart, M.; Phillips, N.; Olsen, G.; Hickey, C.; Tipa, G. (2011). Organochlorines and other Bioaccumulative Contaminants in Wild Caught Food as a Human Health Risk to the Indigenous Maori Population of South Canterbury, New Zealand. *Science of the Total Environment* 409(11): 2029-2039

Stockholm Convention (2010). Retrieved 11th October, 2010, from http://chm.pops.int/Home/tabid/36/language/en-US/Default.aspx

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. (1997a). The State of New Zealand's Environment 1997. *No. ME612*. p.

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

US EPA (2000). Guidance for Assessing Chemical Contaminant Data for Use In Fish Advisories. Volume 2: Risk Assessment and Fish Consumption Limits - Third Edition. *No. EPA 823-B-00-008*. 383 p.

US EPA (2003). Columbia River Basin Fish Contaminant Survey. *No. EPA 910-R-02-006*. 284 p.

US EPA. Integrated Risk Information System (2010). Retrieved 5th July, 2010, from http://www.epa.gov/ncea/iris/index.html

Weissberg, B.G.; Zobel, M.G.R. (1973). Geothermal mercury pollution in New Zealand. *Bulletin of Environmental Contamination and Toxicology 9(3)*: 148–155.

Whyte, A.L.H.; Raumati Hook, G.; Greening, G.E.; Gibbs-Smith, E.; Gardner, J.P.A. (2009). Human dietary exposure to heavy metals via the consumption of greenshell mussels (Perna canaliculus Gmelin 1791) from the Bay of Islands, northern New Zealand. *Science of the Total Environment 407(14)*: 4348–4355.

World Health Organization (2009). Environmental Health Criteria 239. Principles for Modelling Dose-Response for the Risk Assessment of Chemicals. World Health Organisation (WHO) International Programme on Chemical Safety (IPCS), Geneva. *No.* 163 p.

Zhang, W.; Cai, Y.; Tu, C.; Ma, L.Q. (2002). Arsenic speciation and distribution in an arsenic hyperaccumulating plant. *The Science of The Total Environment 300(1-3)*: 167–177.

# 8. Abbreviations

| | |
|---|---|
| **ANZECC** | Australian and New Zealand Environmental Conservation Council. |
| **DDD** | Dichlorodiphenyldichloroethane. |
| **DDE** | Dichlorodiphenyldichloroethylene. |
| **DDT** | Dichlorodiphenyltrichloroethane. |
| **$\gamma$-HCH** | Gamma-hexachlorocyclohexane = lindane. |
| **HCB** | Hexachlorobenzene. |
| **ISQG** | Interim sediment quality guidelines. |
| **kg** | kilogram(s). |
| **mg** | milligram |
| **mm** | millimetre(s). |
| **PCB** | Polychlorinated biphenyl. |
| **$\mu$g** | microgram. |
| **US EPA** | United States Environmental Protection Association. |

# 9. 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. |
| **Bioavailable** | That fraction of a chemical which is available for uptake for an organism. Only a small fraction of the metals found in soils and in natural waters is bioavailable. |
| **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 or toxicant. |
| **Determinand** | A variable associated with either increased or decreased risk. |

| | |
|---|---|
| **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. |
| **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. |

| | |
|---|---|
| **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. |
| **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. |
| **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. |

# 10. Appendices

## **Appendix 1a:** Lower Kaituna consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 3.05E-05 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 77071.5 | 1310215.6 | | 175710.6 |
| | p,p-DDD | 1.69E-04 | 0.24 | 80 | NA | 1.00E-05 | 19688.1 | | | |
| | p,p-DDE | 4.14E-03 | 0.34 | 80 | NA | 1.00E-05 | 568.6 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 3.50E-05 | 16 | 80 | 5.00E-05 | 1.00E-05 | 1430.1 | 114407.4 | | 15343.0 |
| | Chlordanes (total) | 5.71E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 40055.4 | 700969.8 | | 94005.8 |
| | HCB | 2.68E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 18626.0 | 2384129.0 | | 319731.2 |
| | PCBs (total) | 3.23E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 123.9 | 495.6 | | 66.5 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 2.12E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 3.8 | | 0.5 |
| | Arsenic* (10%) | 4.23E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 126.0 | | | |
| | Zinc | 3.46E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 6932.7 | | 929.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 1.92E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 53.8 | | 7.2 | |
| Eel | p,p-DDT | 2.50E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 9428.2 | 160279.2 | | 21494.8 |
| | p,p-DDD | 1.80E-04 | 0.24 | 80 | NA | 1.00E-05 | 18527.5 | NA | | |
| | p,p-DDE | 2.76E-03 | 0.34 | 80 | NA | 1.00E-05 | 852.6 | NA | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 2.81E-05 | 16 | 80 | 5.00E-05 | 1.00E-05 | 1777.3 | 142181.3 | | 19067.7 |
| | Chlordanes (total) | 2.51E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 90939.5 | 1591442.1 | | 213425.4 |
| | HCB | 2.13E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 23451.4 | 3001774.5 | | 402562.5 |
| | PCBs (total) | 1.09E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 365.8 | 1463.1 | | 196.2 |
| | Cadmium | 7.62E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 10505.1 | | 1408.8 |
| | Mercury | 1.64E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 48.8 | | 6.5 |
| | Arsenic* (10%) | 2.03E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 26.3 | | | |
| | Zinc | 1.18E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2039.2 | | 273.5 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.31E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 23.4 | | 3.1 | |
| Smelt1 | Cadmium | 6.69E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 11956.5 | | 3207.2 |
| | Mercury | 6.27E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 127.5 | | 34.2 |
| | Arsenic* (10%) | 2.72E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 19.6 | | | |
| | Zinc | 3.55E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 675.2 | | 181.1 |
| | Nickel | 5.44E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 29431.4 | | 7894.7 |
| | Chromium | 2.51E-02 | NA | 80 | 3.00E-03 | 1.00E-05 | | 9565.2 | | 2565.8 |
| | Copper | 5.23E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 19.6 | | 5.3 | |
| Smelt2 | Cadmium | 8.32E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 9612.0 | | 2578.3 |
| | Mercury | 1.66E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 480.6 | | 128.9 |
| | Arsenic* (10%) | 7.24E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 7.4 | | | |
| | Zinc | 2.35E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1020.3 | | 273.7 |
| | Nickel | 9.77E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 16375.9 | | 4392.7 |
| | Chromium | 1.12E-01 | NA | 80 | 3.00E-03 | 1.00E-05 | | 2139.4 | | 573.9 |
| | Copper | 5.43E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 7.4 | | 2.0 | |
| Whitebait | Cadmium | 1.53E-02 | NA | 80 | 1.00E-03 | 1.00E-05 | | 5224.8 | | 1401.5 |
| | Mercury | 1.35E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 594.0 | | 159.3 |
| | Arsenic* (10%) | 8.12E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 6.6 | | | |
| | Zinc | 2.21E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1084.1 | | 290.8 |
| | Nickel | 6.64E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 24092.0 | | 6462.4 |
| | Chromium | 4.61E-02 | NA | 80 | 3.00E-03 | 1.00E-05 | | 5203.9 | | 1395.9 |
| | Copper | 4.98E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 6.6 | | 1.8 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

**Appendix 1b:** Ohau Channel consumption limit calculations[a]**.**

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 4.18E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 5634.9 | 95793.1 | | 12846.6 |
| | p,p-DDD | 6.13E-04 | 0.24 | 80 | NA | 1.00E-05 | 5440.8 | | | |
| | p,p-DDE | 4.60E-03 | 0.34 | 80 | NA | 1.00E-05 | 511.5 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 1.55E-04 | 16 | 80 | 5.00E-05 | 1.00E-05 | 321.9 | 25750.6 | | 3453.4 |
| | Chlordanes (total) | 5.83E-04 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 3920.6 | 68610.1 | | 9201.2 |
| | HCB | 1.47E-04 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 3397.6 | 434892.0 | | 58322.6 |
| | PCBs (total) | 6.60E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 60.6 | 242.5 | | 32.5 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 1.58E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 5.1 | | 0.7 |
| | Arsenic* (10%) | 6.36E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 83.9 | | | |
| | Zinc | 4.98E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 4823.2 | | 646.8 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 5.53E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 29.1 | | 3.9 | |
| Eel | p,p-DDT | 1.14E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 20589.1 | 350014.7 | | 46939.8 |
| | p,p-DDD | 1.81E-04 | 0.24 | 80 | NA | 1.00E-05 | 18392.2 | | | |
| | p,p-DDE | 1.71E-03 | 0.34 | 80 | NA | 1.00E-05 | 1378.9 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 1.50E-04 | 16 | 80 | 5.00E-05 | 1.00E-05 | 334.3 | 26746.6 | | 3586.9 |
| | Chlordanes (total) | 9.77E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 23404.9 | 409586.6 | | 54928.9 |
| | HCB | 3.44E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 14553.2 | 1862809.8 | | 249818.0 |
| | PCBs (total) | 2.07E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 193.3 | 773.0 | | 103.7 |
| | Cadmium | 5.83E-04 | NA | 80 | 1.00E-03 | 1.00E-05 | | 137199.5 | | 18399.6 |
| | Mercury | 9.63E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 8.3 | | 1.1 |
| | Arsenic* (10%) | 8.87E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 60.1 | | | |
| | Zinc | 1.37E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1753.1 | | 235.1 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 3.55E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 38.8 | | 5.2 | |
| Koura | Cadmium | 1.43E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 55841.2 | | 11021.3 |
| | Mercury | 5.76E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 13.9 | | 2.7 |
| | Arsenic* (10%) | 7.57E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 7.0 | | | |
| | Zinc | 1.42E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1694.7 | | 334.5 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 3.29E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | | 7.0 | | 1.4 | |
| Smelt | Cadmium | 1.71E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 46755.6 | | 12541.7 |
| | Mercury | 2.31E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 34.7 | | 9.3 |
| | Arsenic* (10%) | 1.15E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 46.2 | | | |
| | Zinc | 3.65E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 657.0 | | 176.2 |
| | Nickel | 1.48E-01 | NA | 80 | 2.00E-02 | 1.00E-05 | | 10808.4 | | 2899.3 |
| | Chromium | 0.19225 | NA | 80 | 0.003 | 1.00E-05 | | 1248.4 | | 334.9 |
| | Copper | 0.326825 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 46.2 | | 12.4 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1c:** Okareka consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 7.96E-05 | 0.34 | 80 | 5.00E-04 | 0.00001 | 29555.1 | 502437.3 | | 67381.0 |
| | p,p-DDD | 3.01E-04 | 0.24 | 80 | NA | 0.00001 | 11074.1 | | | |
| | p,p-DDE | 1.21E-03 | 0.34 | 80 | NA | 0.00001 | 1938.4 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 0.00001 | | | | |
| | Dieldrin | 0.00E+00 | 16 | 80 | 5.00E-05 | 0.00001 | | | | |
| | Chlordanes (total) | 5.33E-06 | 0.35 | 80 | 5.00E-04 | 0.00001 | 428443.8 | 7497766.3 | | 1005511.8 |
| | HCB | 3.13E-05 | 1.6 | 80 | 8.00E-04 | 0.00001 | 15972.7 | 2044505.9 | | 274185.0 |
| | PCBs (total) | 8.59E-04 | 2 | 80 | 2.00E-05 | 0.00001 | 465.6 | 1862.2 | | 249.7 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 0.00001 | | | | |
| | Mercury | 5.30E-01 | NA | 80 | 1.00E-04 | 0.00001 | | 15.1 | | 2.0 |
| | Arsenic* (10%) | 6.75E-03 | 1.5 | 80 | 3.00E-04 | 0.00001 | 79.0 | | | |
| | Zinc | 3.86E+00 | NA | 80 | 3.00E-01 | 0.00001 | | 6221.4 | | 834.3 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 0.00001 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 0.00001 | | | | |
| | Copper | 2.89E-01 | NA | 80 | NA | 0.00001 | | | | |
| | | | | | | TOTAL | 64.5 | | 8.6 | |
| Koura | p,p-DDT | 3.40E-01 | 80 | 0.0005 | 1.00E-05 | 0.032 | | | | |
| | p,p-DDD | | | | | | | | | |
| | p,p-DDE | | | | | | | | | |
| | Lindane | | | | | | | | | |
| | Dieldrin | | | | | | | | | |
| | Chlordanes (total) | | | | | | | | | |
| | HCB | | | | | | | | | |
| | Cadmium | 1.14E-02 | NA | 80 | 1.00E-03 | 0.00001 | NA | 7024.3 | | 1386.4 |
| | Mercury | 7.02E-02 | NA | 80 | 1.00E-04 | 0.00001 | NA | 113.9 | | 22.5 |
| | Arsenic* (3%) | 7.02E-02 | 1.5 | 80 | 3.00E-04 | 0.00001 | 7.6 | | | |
| | Zinc | 1.72E+01 | NA | 80 | 3.00E-01 | 0.00001 | | 1398.5 | | 276.0 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 0.00001 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 0.00001 | | | | |
| | Copper | 8.42E+00 | NA | 80 | NA | 0.00001 | | | | |
| | | | | | | TOTAL | 7.6 | | 1.5 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1d:** Puarenga Lower consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 6.83E-05 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 34428.0 | 585276.3 | | 78490.3 |
| | p,p-DDD | 1.23E-04 | 0.24 | 80 | NA | 1.00E-05 | 27097.4 | | | |
| | p,p-DDE | 6.35E-04 | 0.34 | 80 | NA | 1.00E-05 | 3705.5 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 0.00E+00 | 16 | 80 | 5.00E-05 | 1.00E-05 | | | | |
| | Chlordanes (total) | 4.64E-06 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 492864.2 | 8625124.0 | | 1156699.7 |
| | HCB | 7.20E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 6939.7 | 888275.9 | | 119125.1 |
| | PCBs (total) | 8.44E-04 | 2 | 80 | 2.00E-05 | 1.00E-05 | 473.7 | 1894.7 | | 254.1 |
| | Cadmium | 7.07E-04 | NA | 80 | 1.00E-03 | 1.00E-05 | | 113131.3 | | 15171.8 |
| | Mercury | 4.07E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 196.5 | | 26.4 |
| | Arsenic* (10%) | 1.22E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 43.7 | | | |
| | Zinc | 4.71E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 5090.9 | | 682.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 1.63E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 39.2 | | 5.3 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1e:** Puarenga Upper consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 5.26E-05 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 44707.2 | 760021.7 | | 101925.1 |
| | p,p-DDD | 2.25E-04 | 0.24 | 80 | NA | 1.00E-05 | 14834.7 | | | |
| | p,p-DDE | 1.91E-02 | 0.34 | 80 | NA | 1.00E-05 | 122.9 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 4.93E-05 | 16 | 80 | 5.00E-05 | 1.00E-05 | 1014.6 | 81171.0 | | 10885.7 |
| | Chlordanes (total) | 6.04E-06 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 378391.1 | 6621844.5 | | 888043.5 |
| | HCB | 2.32E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 21583.2 | 2762652.7 | | 370494.3 |
| | PCBs (total) | 4.16E-02 | 2 | 80 | 2.00E-05 | 1.00E-05 | 9.6 | 38.4 | | 5.2 |
| | Cadmium | 6.19E-04 | NA | 80 | 1.00E-03 | 1.00E-05 | | 129149.7 | | 17320.0 |
| | Mercury | 2.62E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 3.1 | | 0.4 |
| | Arsenic* (10%) | 1.65E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 322.9 | | | |
| | Zinc | 7.57E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 3170.0 | | 425.1 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.89E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 8.6 | | 1.2 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1f:** Lake Rotokakahi consumption limit calculations[a].

| | | | Input Data/Assumptions | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 1.48E-03 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 1590.2 | 27032.6 | | 3625.3 |
| | p,p-DDD | 1.43E-03 | 0.24 | 80 | NA | 1.00E-05 | 2326.2 | | | |
| | p,p-DDE | 2.56E-02 | 0.34 | 80 | NA | 1.00E-05 | 91.8 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 1.00E-04 | 16 | 80 | 5.00E-05 | 1.00E-05 | 497.6 | 39804.1 | | 5338.1 |
| | Chlordanes (total) | 5.47E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 41776.9 | 731096.2 | | 98046.0 |
| | HCB | 5.09E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 9832.2 | 1258523.1 | | 168778.2 |
| | PCBs (total) | 1.39E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 287.3 | 1149.1 | | 154.1 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 3.06E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 26.1 | | 3.5 |
| | Arsenic* (10%) | 1.96E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 27.3 | | | |
| | Zinc | 3.43E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 6992.1 | | 937.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.25E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 18.4 | | 2.5 | |
| Koura | Cadmium | 4.90E-04 | NA | 80 | 1.00E-03 | 1.00E-05 | | 163218.4 | | 32214.2 |
| | Mercury | 1.40E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 57.2 | | 11.3 |
| | Arsenic* (10%) | 2.36E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 22.6 | | | |
| | Zinc | 1.29E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1862.1 | | 367.5 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.90E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 22.6 | | 4.5 | |
| Smelt | Cadmium | 1.81E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 44124.0 | | 11835.8 |
| | Mercury | 2.26E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 353.9 | | 94.9 |
| | Arsenic* (10%) | 1.81E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 29.4 | | | |
| | Zinc | 4.47E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 536.5 | | 143.9 |
| | Nickel | 7.77E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 20591.2 | | 5523.4 |
| | Chromium | 1.30E-01 | NA | 80 | 3.00E-03 | 1.00E-05 | | 1853.2 | | 497.1 |
| | Copper | 3.77E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 29.4 | | 7.9 | |
| Kakahi | Cadmium | 1.38E-02 | NA | 80 | 1.00E-03 | 1.00E-05 | | 5781.1 | | 1204.4 |
| | Mercury | 8.01E-03 | NA | 80 | 1.00E-04 | 1.00E-05 | | 998.6 | | 208.0 |
| | Arsenic* (3%) | 8.74E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 6.1 | | | |
| | Zinc | 1.24E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1938.4 | | 403.8 |
| | Nickel | 2.62E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 61022.9 | | 12713.1 |
| | Chromium | 4.73E-02 | NA | 80 | 3.00E-03 | 1.00E-05 | | 5069.6 | | 1056.2 |
| | Copper | 3.57E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 6.1 | | 1.3 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1g:** Lake Rotoiti consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 1.65E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 14232.2 | 241946.8 | | 32447.0 |
| | p,p-DDD | 3.68E-04 | 0.24 | 80 | NA | 1.00E-05 | 9064.9 | NA | | |
| | p,p-DDE | 1.43E-03 | 0.34 | 80 | NA | 1.00E-05 | 1640.5 | NA | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 7.61E-05 | 16 | 80 | 5.00E-05 | 1.00E-05 | 657.2 | 52573.3 | | 7050.5 |
| | Chlordanes (total) | 4.96E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 46107.2 | 806876.6 | | 108208.8 |
| | HCB | 1.55E-04 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 3234.3 | 413984.4 | | 55518.7 |
| | PCBs (total) | 1.33E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 300.9 | 1203.4 | | 161.4 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 1.68E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 4.8 | | 0.6 |
| | Arsenic* (10%) | 4.95E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 107.7 | | | |
| | Zinc | 4.29E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 5591.1 | | 749.8 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | | | | | | TOTAL | 65.6 | | 8.8 | |
| Koura (Rotoiti East) | Cadmium | 1.85E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 43315.1 | | 8549.0 |
| | Mercury | 1.00E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 8.0 | | 1.6 |
| | Arsenic* (3%) | 7.23E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 7.4 | | | |
| | Zinc | 1.54E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1559.3 | | 307.8 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 6.00E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 7.4 | | 1.5 | |
| Koura (Rotoiti West) | Cadmium | 1.76E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 45528.5 | | 8985.9 |
| | Mercury | 5.27E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 15.2 | | 3.0 |
| | Arsenic* (3%) | 9.76E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 5.5 | | | |
| | Zinc | 1.15E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2083.5 | | 411.2 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 5.86E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 5.5 | | 1.1 | |
| Smelt (Rotoiti West) | Cadmium | 2.95E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 27081.2 | | 7264.3 |
| | Mercury | 1.97E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 40.6 | | 10.9 |
| | Arsenic* (10%) | 3.15E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 16.9 | | | |
| | Zinc | 3.74E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 641.4 | | 172.0 |
| | Nickel | 2.36E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 67702.9 | | 18160.7 |
| | Chromium | 4.92E-02 | NA | 80 | 3.00E-03 | 1.00E-05 | | 4874.6 | | 1307.6 |
| | Copper | 3.94E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 16.9 | | 4.5 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

# Appendix 1h: Lake Rotoma consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 0.00E+00 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | | | | |
| | p,p-DDD | 2.18E-05 | 0.24 | 80 | NA | 1.00E-05 | 152898.1 | | | |
| | p,p-DDE | 7.49E-04 | 0.34 | 80 | NA | 1.00E-05 | 3142.8 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 0.00E+00 | 16 | 80 | 5.00E-05 | 1.00E-05 | | | | |
| | Chlordanes (total) | 0.00E+00 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | | | | |
| | HCB | 3.84E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 13011.3 | 1665443.6 | | 223349.6 |
| | PCBs (total) | 1.16E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 345.0 | 1380.0 | | 185.1 |
| | Cadmium | 1.15E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 69434.1 | | 9311.7 |
| | Mercury | 2.06E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 38.9 | | 5.2 |
| | Arsenic* (10%) | 3.91E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 136.4 | | | |
| | Zinc | 3.29E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 7290.6 | | 977.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 1.40E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 94.1 | | 12.6 | |
| | | | | | | | | | | |
| Koura | Cadmium | 1.85E-02 | NA | 80 | 1.00E-03 | 1.00E-05 | | 4331.3 | | 854.9 |
| | Mercury | 6.88E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 116.2 | | 22.9 |
| | Arsenic* (3%) | 1.04E-01 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Zinc | 1.19E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2013.1 | | 397.3 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 4.70E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 5.1 | | 1.0 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

**Appendix 1i:** Lake Rotomahana consumption limit calculations[a].

| | | | Input Data/Assumptions | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 1.20E-03 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 1961.2 | 33339.8 | | 4471.1 |
| | p,p-DDD | 1.10E-03 | 0.24 | 80 | NA | 1.00E-05 | 3025.4 | | | |
| | p,p-DDE | 5.95E-03 | 0.34 | 80 | NA | 1.00E-05 | 395.6 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 0.00E+00 | 16 | 80 | 5.00E-05 | 1.00E-05 | | | | |
| | Chlordanes (total) | 5.12E-06 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 446301.6 | 7810278.0 | | 1047422.2 |
| | HCB | 4.49E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 11125.5 | 1424059.9 | | 190978.1 |
| | PCBs (total) | 7.50E-04 | 2 | 80 | 2.00E-05 | 1.00E-05 | 533.0 | 2132.0 | | 285.9 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 2.16E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 3.7 | | 0.5 |
| | Arsenic* (10%) | 7.20E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 74.1 | | | |
| | Zinc | 4.37E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 5492.2 | | 736.5 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.57E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 53.1 | | 7.1 | |
| Smelt | Cadmium | 8.02E-03 | | 80 | 1.00E-03 | 1.00E-05 | | 9969.5 | | 2674.2 |
| | Mercury | 2.92E-01 | | 80 | 1.00E-04 | 1.00E-05 | | 27.4 | | 7.4 |
| | Arsenic* (10%) | 3.47E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 15.4 | | | |
| | Zinc | 5.29E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 453.8 | | 121.7 |
| | Nickel | 1.26E-01 | NA | 80 | 2.00E-02 | 1.00E-05 | | 12714.7 | | 3410.6 |
| | Chromium | 1.46E-01 | NA | 80 | 3.00E-03 | 1.00E-05 | | 1645.0 | | 441.2 |
| | Copper | 5.84E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 15.4 | | 4.1 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1j:** Lake Rotorua consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 2.94E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 7990.9 | 135845.9 | | 18218.1 |
| | p,p-DDD | 4.89E-04 | 0.24 | 80 | NA | 1.00E-05 | 6818.0 | | | |
| | p,p-DDE | 3.33E-03 | 0.34 | 80 | NA | 1.00E-05 | 706.9 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 1.59E-04 | 16 | 80 | 5.00E-05 | 1.00E-05 | 315.1 | 25211.3 | | 3381.0 |
| | Chlordanes (total) | 3.39E-04 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 6746.9 | 118071.3 | | 15834.3 |
| | HCB | 1.62E-04 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 3077.2 | 393884.8 | | 52823.2 |
| | PCBs (total) | 6.42E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 62.3 | 249.1 | | 33.4 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 1.22E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 6.6 | | 0.9 |
| | Arsenic* (10%) | 0.00E+00 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Zinc | 3.87E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 6201.9 | | 831.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.47E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 46.8 | | 6.3 | |
| Koura (Rotorua East) | Cadmium | 1.19E-03 | | 80 | 1.00E-03 | 1.00E-05 | | 67428.1 | | 13308.2 |
| | Mercury | 2.49E-01 | | 80 | 1.00E-04 | 1.00E-05 | | 32.2 | | 6.3 |
| | Arsenic* (3%) | 8.42E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 6.3 | | | |
| | Zinc | 1.11E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2162.4 | | 426.8 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 4.98E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 6.3 | | 1.3 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1k:** Lake Tarawera consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 2.96E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 7955.8 | 135248.8 | | 18138.0 |
| | p,p-DDD | 2.14E-04 | 0.24 | 80 | NA | 1.00E-05 | 15589.7 | | | |
| | p,p-DDE | 9.79E-04 | 0.34 | 80 | NA | 1.00E-05 | 2403.2 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 3.35E-05 | 16 | 80 | 5.00E-05 | 1.00E-05 | 1492.4 | 119390.0 | | 16011.2 |
| | Chlordanes (total) | 1.27E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 179533.8 | 3141840.9 | | 421346.6 |
| | HCB | 1.04E-04 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 4827.4 | 617910.8 | | 82866.9 |
| | PCBs (total) | 4.06E-04 | 2 | 80 | 2.00E-05 | 1.00E-05 | 985.7 | 3942.7 | | 528.8 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 8.82E-02 | NA | 80 | 1.00E-04 | 1.00E-05 | | 90.7 | | 12.2 |
| | Arsenic* (10%) | 1.08E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 49.5 | | | |
| | Zinc | 4.24E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 5654.0 | | 758.2 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.09E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 44.0 | | 5.9 | |
| Koura | Cadmium | 6.20E-03 | | 80 | 1.00E-03 | 1.00E-05 | | 12910.4 | | 2548.1 |
| | Mercury | 6.66E-02 | | 80 | 1.00E-04 | 1.00E-05 | | 120.1 | | 23.7 |
| | Arsenic* (3%) | 1.21E-01 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Zinc | 1.39E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1721.4 | | 339.7 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 4.34E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 4.4 | | 0.9 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1l:** Lake Tikitapu consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 2.01E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 11702.8 | 198946.8 | | 26680.4 |
| | p,p-DDD | 2.14E-03 | 0.24 | 80 | NA | 1.00E-05 | 1555.8 | | | |
| | p,p-DDE | 5.06E-03 | 0.34 | 80 | NA | 1.00E-05 | 464.9 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 1.27E-04 | 16 | 80 | 5.00E-05 | 1.00E-05 | 393.8 | 31500.4 | | 4224.5 |
| | Chlordanes (total) | 4.32E-05 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 52941.9 | 926482.4 | | 124248.9 |
| | HCB | 2.08E-04 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 2406.3 | 308003.7 | | 41305.8 |
| | PCBs (total) | 4.84E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 82.6 | 330.3 | | 44.3 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 1.78E-01 | NA | 80 | 1.00E-04 | 1.00E-05 | | 44.9 | | 6.0 |
| | Arsenic* (10%) | 0.00E+00 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Zinc | 3.82E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 6288.8 | | 843.4 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 3.82E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 55.7 | | 7.5 | |
| Koura | Cadmium | 2.35E-02 | | 80 | 1.00E-03 | 1.00E-05 | | 3404.8 | | 672.0 |
| | Mercury | 4.50E-02 | | 80 | 1.00E-04 | 1.00E-05 | | 177.6 | | 35.1 |
| | Arsenic* (3%) | 2.55E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Zinc | 1.35E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | 21.0 | 1776.4 | | 350.6 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 6.85E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 21.0 | | 4.1 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

## **Appendix 1m:** Upper Kaituna consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Trout | p,p-DDT | 2.29E-04 | 0.34 | 80 | 5.00E-04 | 1.00E-05 | 10263.3 | 174476.8 | | 23398.8 |
| | p,p-DDD | 8.12E-05 | 0.24 | 80 | NA | 1.00E-05 | 41067.9 | | | |
| | p,p-DDE | 4.01E-03 | 0.34 | 80 | NA | 1.00E-05 | 587.4 | | | |
| | Lindane | 0.00E+00 | 1.3 | 80 | 3.00E-04 | 1.00E-05 | | | | |
| | Dieldrin | 0.00E+00 | 16 | 80 | 5.00E-05 | 1.00E-05 | | | | |
| | Chlordanes (total) | 1.05E-04 | 0.35 | 80 | 5.00E-04 | 1.00E-05 | 21779.7 | 381143.9 | | 51114.5 |
| | HCB | 1.70E-05 | 1.6 | 80 | 8.00E-04 | 1.00E-05 | 29347.9 | 3756537.0 | | 503782.3 |
| | PCBs (total) | 4.59E-03 | 2 | 80 | 2.00E-05 | 1.00E-05 | 87.2 | 348.9 | | 46.8 |
| | Cadmium | 0.00E+00 | NA | 80 | 1.00E-03 | 1.00E-05 | | | | |
| | Mercury | 1.52E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | 5.3 | | 0.7 |
| | Arsenic* (10%) | 2.36E-03 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 225.9 | | | |
| | Zinc | 4.08E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 5885.6 | | 789.3 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 2.15E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 56.2 | | 7.5 | |
| Koura | Cadmium | 1.56E-03 | | 80 | 1.00E-03 | 1.00E-05 | | 51369.5 | | 10138.7 |
| | Mercury | 5.02E-01 | | 80 | 1.00E-04 | 1.00E-05 | | 15.9 | | 3.1 |
| | Arsenic* (3%) | 5.02E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 10.6 | | | |
| | Zinc | 1.18E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2039.7 | | 402.6 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | | | |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | | | |
| | Copper | 6.58E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 10.6 | | 2.1 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

# Appendix 1n: Maketu consumption limit calculations[a].

| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Daily Consumption Limits (g/day): Cancer Risk | Daily Consumption Limits (g/day): Non Cancer Risk | Monthly Fish Consumption Limits (meals/month): Cancer Risk | Monthly Fish Consumption Limits (meals/month): Non Cancer Risk |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Input Data/Assumptions | | | | | | | | |
| Pipi | Cadmium | 5.67E-02 | | 80 | 1.00E-03 | 1.00E-05 | | 1411.5 | | 294.1 |
| | Mercury | 1.42E-02 | | 80 | 1.00E-04 | 1.00E-05 | | 564.6 | | 117.6 |
| | Arsenic* (3%) | 5.02E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 10.6 | | 2.2 | |
| | Zinc | 0.00E+00 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2957.4 | | 616.1 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | 1882.0 | | 392.1 |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | 169.4 | | 35.3 |
| | Copper | 0.00E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 10.6 | | 2.2 | |
| | HCB | | | | | | | | | |
| Pipi (repeat) | Cadmium | 5.41E-02 | | 80 | 1.00E-03 | 1.00E-05 | | 1478.7 | | 308.1 |
| | Mercury | 1.11E-02 | | 80 | 1.00E-04 | 1.00E-05 | | 722.2 | | 150.4 |
| | Arsenic* (3%) | 4.25E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 12.5 | | 2.6 | |
| | Zinc | 0.00E+00 | | 80 | 3.00E-01 | 1.00E-05 | | 2866.4 | | 597.2 |
| | Nickel | 0.00E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | 1725.1 | | 359.4 |
| | Chromium | 0.00E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | 186.3 | | 38.8 |
| | Copper | 0.00E+00 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 12.5 | | 2.6 | |
| Pipi (2nd collection) | Cadmium | 5.78E-02 | | 80 | 1.00E-03 | 1.00E-05 | | 1384.1 | | 288.3 |
| | Mercury | 7.16E-03 | | 80 | 1.00E-04 | 1.00E-05 | | 1117.0 | | 232.7 |
| | Arsenic* (3%) | 3.66E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 14.6 | | 3.0 | |
| | Zinc | 6.79E+00 | | 80 | 3.00E-01 | 1.00E-05 | | 3537.0 | | 736.9 |
| | Nickel | 3.77E-01 | NA | 80 | 2.00E-02 | 1.00E-05 | | 4244.4 | | 884.3 |
| | Chromium | 4.02E-01 | NA | 80 | 3.00E-03 | 1.00E-05 | | 596.9 | | 124.3 |
| | Copper | 5.91E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 14.6 | | 3.0 | |
| Mussel | Cadmium | 9.05E-02 | | 80 | 1.00E-03 | 1.00E-05 | NA | 884.1 | | 184.2 |
| | Mercury | 2.95E-02 | | 80 | 1.00E-04 | 1.00E-05 | NA | 270.8 | | 56.4 |
| | Arsenic* (3%) | 3.88E-02 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 13.8 | | 2.9 | |
| | Zinc | 1.24E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 1939.8 | | 404.1 |
| | Nickel | 1.50E+00 | NA | 80 | 2.00E-02 | 1.00E-05 | | 1069.7 | | 222.8 |
| | Chromium | 2.03E+00 | NA | 80 | 3.00E-03 | 1.00E-05 | | 118.1 | | 24.6 |
| | Copper | 7.20E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 13.8 | | 2.9 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box

**Appendix 1n:** Waiowhiro Stream consumption limit calculations[a].

| | | Input Data/Assumptions | | | | | Daily Consumption Limits (g/day) | | Monthly Fish Consumption Limits (meals/month) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Compound | Contaminant Concentration (mg/kg wet weight) | CSF (mg/kg-day)-1 | BW (kg) | RfD (mg/kg/day) | ARL | Cancer Risk | Non Cancer Risk | Cancer Risk | Non Cancer Risk |
| Watercress | Cadmium | 5.93E-03 | NA | 80 | 1.00E-03 | 1.00E-05 | | 13489.5 | | 2610.9 |
| | Mercury | 0.00E+00 | NA | 80 | 1.00E-04 | 1.00E-05 | | | | |
| | Arsenic* (3%) | 1.07E-01 | 1.5 | 80 | 3.00E-04 | 1.00E-05 | 5.0 | | 1.0 | |
| | Zinc | 1.17E+01 | NA | 80 | 3.00E-01 | 1.00E-05 | | 2057.1 | | 398.2 |
| | Nickel | 2.33E-02 | NA | 80 | 2.00E-02 | 1.00E-05 | | 68571.4 | | 13271.9 |
| | Chromium | 5.74E-02 | NA | 80 | 3.00E-03 | 1.00E-05 | | 4184.0 | | 809.8 |
| | Copper | 5.15E-01 | NA | 80 | NA | 1.00E-05 | | | | |
| | | | | | | TOTAL | 5.0 | | 1.0 | |

[a] Additive cancer risk consumption limits and greatest non-cancer risk consumption limits indicated by black box