Bioaccumulation of toxic heavy metals in koura of the Te Arawa lakes: brief summary of findings (June 2006 – June 2008)

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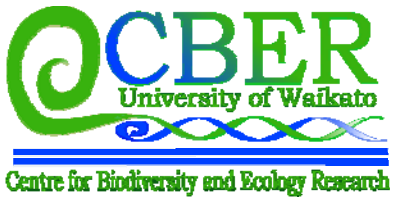

Executive Summary

Since June 2006 we have undertaken a number of analyses of elemental composition of the flesh of koura from the Te Arawa Lakes. The reasons for these studies have been four-fold. Firstly, to examine the possibility of bioaccumulation of key elements (lanthanum and aluminium) following whole-lake mineral treatments for nutrient control in lakes Okareka and Okaro, respectively; secondly, to examine patterns of elemental bioaccumulation in relation to differing lake geochemistry and trophic status; thirdly, to examine the possibility of seasonal bioaccumulation of some elements; and finally, to examine concentrations of toxic heavy metals in relation to possible health concerns associated with consuming Te Arawa Lakes koura. This short report deals exclusively with the last of these studies. Elemental analyses were undertaken of both the tail flesh and hepatopancreas (HP) of adult koura. These tissues were chosen because the tail flesh is typically the main portion of the koura that is consumed, whereas it was likely that most heavy metals would be concentrated in the hepatopancreas because this tissue effectively performs the same functional role (sequestering and excreting toxins) as the liver of vertebrates. However, it should be noted that the hepatopancreas may also be consumed depending on personal taste.

With respect to naturally toxic elements for which maximum acceptable concentrations are recommended for seafood consumption (arsenic, cadmium, lead and mercury) only mercury consistently equalled or exceeded these concentrations for some of the lakes. However, there is evidence to suggest that mercury may vary significantly between seasons and this requires further investigation.

Methods

Collection of tissues

Adult koura (*Paranephrops planifrons*) were collected by SCUBA divers from all of the Te Arawa lakes that are known to support significant populations: Rotorua, Rotoiti, Rotoehu, Rotoma, Okataina, Tarawera, Tikitapu, Okareka, Rerewhakaaitu. Collections of koura from Lakes Okareka, Tikitapu and Rerewhakaaitu were undertaken as part of fish health monitoring associated with whole lake mineral treatments in 2006 and 2007. Other lakes were sampled in the winter of 2007 and late summer of 2008, with the exception of Lake Rotorua which was only sampled in late summer 2008. Koura were collected from under logs and boulders near the lake shore in lakes Rotorua, Rotoehu, Tikitapu and Rerewhakaaitu due to the relative scarcity of animals in open water. In the other lakes, which support more abundant populations, koura were collected from the lake bed at depths from 15 to 25 m. Where possible, five adult males and five females were obtained for metals analysis on each sampling occasion. Elemental analyses were performed on both the tail flesh and the hepatopancreas (digestive gland).

Koura were either anaesthetised in an ice/water slurry for 10 min or killed by freezing prior to dissection. Measurements were taken of total length (± 1 mm), ocular carapace length (± 1 mm) and total weight (± 0.01 g). Animals were dissected by cutting along the midline of the ventral cephalothorax (Fig. 1) and along both sides of the tail. The entire hepatopancreas (Fig. 2) and approximately 1 – 2.5 g of tail flesh were removed and stored in cryovials at -20°C for later analysis of metals by inductively-coupled plasma mass spectrometry (ICPMS).

Figure 1: Koura – ventral dissection

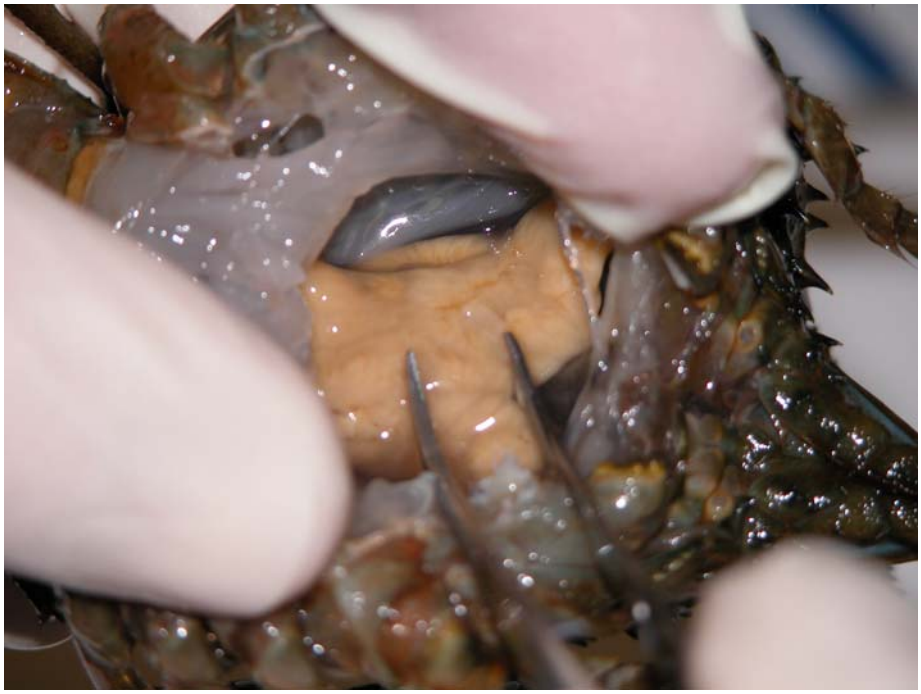

Figure 2: Removal of the hepatopancreas

ICPMS elemental analysis

A suite of 28 elements, including physiologically regulated and non-regulated metals, were measured in koura tissue samples based on established methods (USEPA, 1987). In brief, tissue samples were accurately weighed and digested using tetramethylammonium hydroxide, heat and mixing. The digested colloidal suspension was then partially oxidized by the addition of hydrogen peroxide and metals were solubilised by acidification with nitric acid and heating. Samples were diluted and filtered prior to analysis by inductively-coupled plasma mass spectrometry (Department of Chemistry, Waikato University, Hamilton, NZ). All tissue element concentrations were determined on a wet weight basis.

The measured elements were: lithium (Li), boron (B), sodium (Na), magnesium (Mg), phosphorus (P), potassium (K), calcium (Ca), vanadium (V), chromium (Cr), iron (Fe), manganese (Mn), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic* (As), selenium (Se), strontium (Sr), silver (Ag), cadmium* (Cd), indium (In), barium (Ba), lanthanum (La), mercury* (Hg), thalium (Tl), lead* (Pb), bismuth (Bi), uranium (U).

* denotes elements for which the New Zealand Food Safety Authority prescribes maximum acceptable concentrations in seafoods as follows:

arsenic - 2.0 mg/kg

cadmium – 2.0 mg/kg

lead – 0.5 mg/kg

mercury – 0.5 mg/kg

Results

Koura collected from lake shorelines were typically smaller than those collected at depth (Table 1) which may affect maximum elemental concentrations for those elements, such as mercury, that accumulate with age.

Table 1: Summary of koura collections from the Te Arawa Lakes (June 2006 – June 2008). Measurements are average values from all individuals.

Lake	# of collections	Total sample size	Total length (mm)	Ocular/carapace length (mm)	Total weight (g)
Okareka	6	66	129	45	59.7
Okataina	2	20	130	45	58.6
Rerewhakaaitu	3	32	108	29	33.6
Rotoehu	2	20	71	17	9.1
Rotoiti	3	25	104	33	30.6
Rotoma	2	20	135	47	59.1
Rotorua	1	10	76	25	12.9
Tarawera	3	33	124	42	47.4
Tikitapu	6	62	95	32	25.9

The elements were not uniformly distributed between the two tissues. Most of the heavier elements were preferentially concentrated in the hepatopancreas. Some elements (Mn, Co, Ni, Zn, Ag, Cd, Ba, La, Tl, U) were very strongly (more than 10-fold) concentrated in the hepatopancreas compared to the tail flesh, while others (Li, B, Al, As, Se, Sr) were less preferentially distributed (approximately 2 to 5-fold higher in the HP). Surprisingly, mercury concentrations were typically approximately 2 to 3-fold higher in the tail flesh compared to the hepatopancreas. This contrasts strongly with the distribution of this element in finfish, such as trout, where it is always more concentrated in the liver.

Arsenic

The average detection limit for arsenic in all tissues sampled was 0.46 mg/kg. Arsenic concentrations were highest in the hepatopancreas and around five-fold higher in this tissue compared to the tail flesh. Average concentrations in the hepatopancreas were approximately equal to or slightly

exceeded the recommended maximum acceptable concentration for seafood (2.0 mg/kg) in koura from lakes Okareka, Okataina, Rotoiti, Rotoma, Rotoehu and Rotorua. Highest concentrations were obtained from koura sampled at Hot Water Beach in Lake Tarawera (~5 mg/kg). Given that the hepatopancreas represents a small proportion of the total consumable tissue of the koura and that tail flesh concentrations were typically below 1.0 mg/kg, arsenic in koura tissue is unlikely to pose a significant health risk. The source of arsenic in the Te Arawa lakes is geothermal activity and koura from those lakes with significant active geothermal inputs typically contained more arsenic.

Cadmium

The average detection limit for cadmium in all tissues sampled was 0.02 mg/kg. Cadmium was strongly concentrated in the hepatopancreas and well below the recommended maximum acceptable level for seafood (2.0 mg/kg) in all lakes except for koura from Lake Rotoma which reached average levels of 7 mg/kg. However, the hepatopancreas represents a minor proportion of the total consumable tissue of the animal so this level of cadmium is unlikely to pose any significant health risk. The source of cadmium in Lake Rotoma is unknown. Although cadmium is a significant contaminant in some agricultural fertilisers, the catchment of Lake Rotoma is not primarily pastoral.

Lead

The average detection limit for lead in all tissues sampled was 0.09 mg/kg. Tikitapu was the only lake where koura contained detectable levels of lead and then only in the hepatopancreas. This is in accordance with relatively high concentrations of lead measured in sediments from this lake compared to other lakes of the Te Arawa group (D. Trolle, pers. comm.). However, the average concentration in all samples of this tissue was 0.29 mg/kg, below the maximum acceptable level for seafood (0.5 mg/kg). Given that the hepatopancreas represents a minor proportion of the total consumable tissue, the ingestible concentration of lead from Lake Tikitapu koura is well within safe food guidelines. The question of why Lake Tikitapu contains comparatively higher concentrations of lead than other Te Arawa lakes is

unresolved. It is possible that this derives from historical use of leaded petrol. The relatively small volume of the lake and the high traffic volumes (both vehicles and water craft) may be the cause. Lead contamination of the lake is likely to decline following the removal of lead additives from New Zealand petrol in 1996.

Mercury

The average detection limit for mercury in all tissues sampled was 0.09 mg/kg. Mercury concentrations in tail flesh varied between sampling periods and between lakes. There is some evidence that mercury may be more concentrated in koura tissues during winter months and decline in summer but this requires further verification. Those lakes where flesh concentrations equalled or exceeded recommended maximum acceptable values for seafood were Tikitapu, Okareka, Rotoehu, Rerewhakaaitu and Rotoiti, but flesh concentrations were typically lower in summer sampled animals compared to winter samples. Highest values were obtained from winter-sampled koura from Lake Rotoiti and averaged 13 mg/kg. This concentration of mercury gives some cause for concern and further research is required to evaluate seasonal changes in mercury bioaccumulation in this and the other lakes. The primary source of mercury in the Te Arawa lakes is presumably past and present volcanic/geothermal activity, however, the main mercury compound responsible for mercury bioaccumulation in aquatic organisms is methylmercury produced by anaerobic microorganisms. The seasonal stratification and hypolimnectic oxygen depletion in degraded lakes such as Rotoehu and Rotoiti may contribute to greater production of methylmercury. Therefore, mercury bioaccumulation in lake koura is probably dependent both on total sediment concentration of inorganic mercury and microbial production of organic mercury.

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