Healthy Estuary and Rivers of the City

Water quality and ecosystem health monitoring programme of Ihutai

Heavy metals in fish and shellfish from Christchurch rivers and Estuary: 2010 Survey

Summary report on data collected in 2009

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Report prepared for Environment Canterbury by
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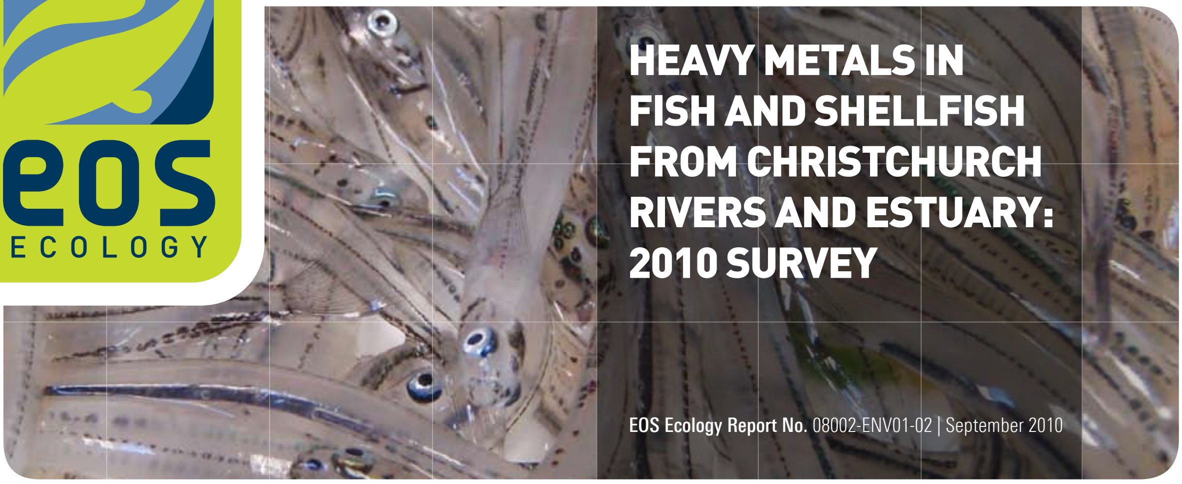
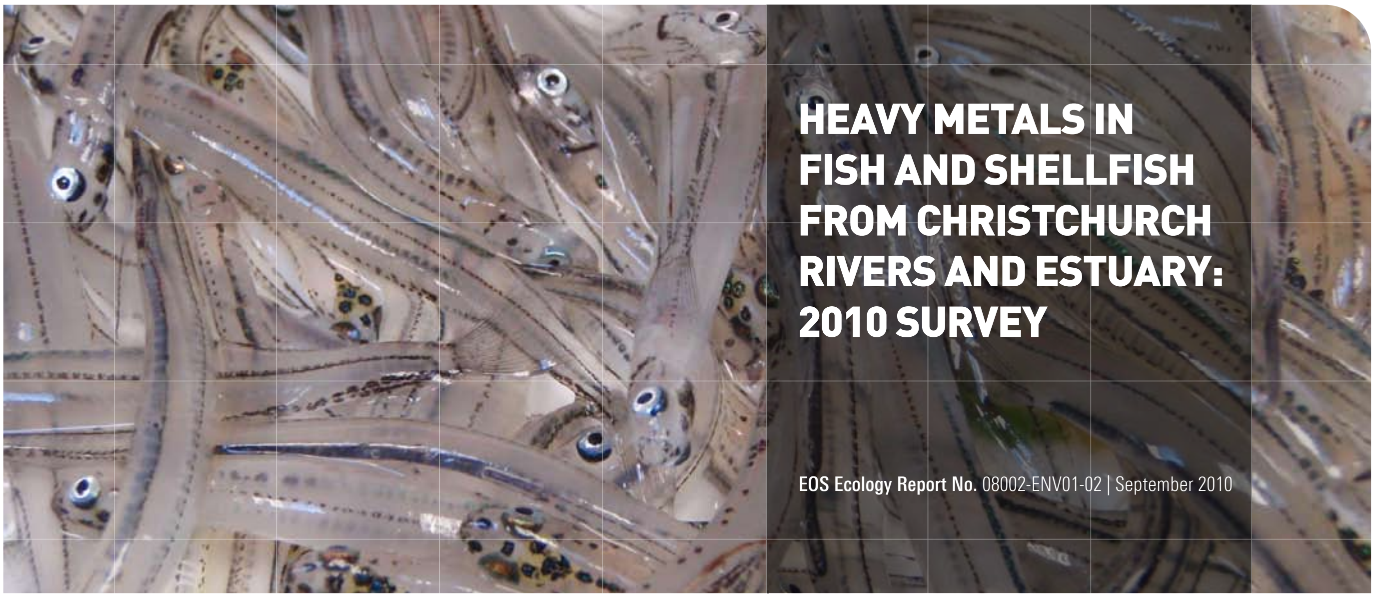


HEAVY METALS IN FISH AND SHELLFISH FROM CHRISTCHURCH RIVERS AND ESTUARY: 2010 SURVEY

EOS Ecology Report No. 08002-ENV01-02 | September 2010

AQUATIC RESEARCH CONSULTANTS



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REPORT

Prepared for
Christchurch City Council

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WHAT ARE HEAVY METALS? HOW DO THEY GET INTO OUR RIVERS AND ESTUARIES?

Heavy metals such as cadmium and lead, and metaloids like arsenic, are found naturally in the environment. They are stable and cannot be degraded or destroyed, so they tend to accumulate in soils, water, and the atmosphere. We absorb trace amounts of some heavy metals from our food, drinking water, and the air. These very low levels generally so have no adverse affect, and in some cases can be beneficial—for example trace amounts of selenium, zinc, and copper are essential to maintain the metabolism of the human body. However, human activities from industry (such as mining, smelting) and run-off from urban and agricultural land-use increase the concentrations of these metals in the environment, potentially to levels which could have adverse effects on humans and animals. Small children and infants are more susceptible to ingesting high levels of heavy metals as they consume more food per kilogram of body weight than adults. In addition, the toxic effects of certain heavy metals can be particularly detrimental to children's developing organs, especially the brain.

Many heavy metals enter rivers in run-off from roads, factories, or agricultural land. They are washed through the stormwater system into the rivers where they can accumulate in the sediment. Eventually they may make their way down-river to an estuary, which traps the river sediment and thus accumulates metal contaminants. This means that the sediment in rivers and estuaries can have high contamination loads of heavy metals. The metal concentrations are likely to vary by site depending on where contaminated sediment is accumulating.

In general marine and freshwater organisms accumulate contaminants from their environment and have been used extensively to monitor heavy metal pollution. Shellfish feed by filtering particles out of the water and often accumulate contaminants, which can have a direct impact on our health if we eat shellfish that have high heavy metals concentrations (e.g., above the safe limits set in the Australia New Zealand Food Standards Code (FSANZ, 2008). Many signs have been erected around the Avon-Heathcote Estuary warning the public about eating shellfish due to the potential for contamination from the discharge of treated sewage (which ceased in March 2010) and stormwater inputs. Estuary and freshwater fish may also accumulate heavy metals, potentially making them unsafe to eat. Lead, mercury, and cadmium can be present in fish naturally at low levels, or at higher levels as a result of pollution. Mercury also bio-accumulates, meaning that animals further up the food-chain also accumulate the mercury in the smaller animals that they eat. This can have important implications for the type of fish we eat.

One of the signs around the estuary warning of the danger of eating shellfish collected there. Since March 2010 the treated sewage has not been discharged into the estuary.

HEAVY METALS TESTED

MERCURY

Mercury occurs naturally in the environment but can also be released into the atmosphere through industrial pollution. It can be transported over large distances and as it has a long life can accumulate in the environment when deposited into surface waters and soils. It is present in fish and seafood products mostly as methylmercury (ENHIS, 2007). Methylmercury accumulates as smaller animals are eaten by bigger animals, so predatory animals tend to have the highest levels. High amounts of mercury can damage our kidneys and central nervous system which can cause memory loss, slurred speech, hearing loss, lack of coordination, loss of sensation in fingers and toes, reproductive problems, coma, and possibly death (Vannoort & Thompson, 2006). The developing brain of a foetus is especially sensitive.

Hg

LEAD

Pb

Lead is used in batteries, solder, ammunition, and devices to shield x-rays. Most exposure to humans is due to pollution, particularly from lead-based paint and from leaded fuel, both of which are no-longer used in New Zealand.

Lead can build up in the body and targets the nervous system, reproductive system, and kidneys. Lead can be stored in bones without harm but if calcium intake increases, the lead will be released from the bone. Children and babies are particularly at risk from damage to their central nervous system, which can cause learning difficulties and behavioural changes. In New Zealand the estimated dietary exposure to lead has been decreasing over time and in general our weekly exposure to lead via our diet is under the guidelines developed by the World Health Organisation (WHO, 2000).

Maximum allowable levels of metal contaminants in food (FSANZ, 2008)

Metals (mg/kg)	Crustacea	Fish	Shellfish
Mercury	0.5	0.5	0.5
Cadmium	n/a	n/a	2
Lead	n/a	0.5	2
Arsenic (inorganic)*	2	2	1

*Inorganic arsenic is estimated to be 10% of total arsenic (USFDA 1993).

CADMIUM

Cadmium occurs naturally in low levels in the environment and is also used in batteries, pigments, and metal coatings. Volcanic activity, industrial processes such as smelting or electroplating, and the addition of fertilisers can increase the concentration of cadmium in the environment. Shellfish can also be high in cadmium (Gray *et al.*, 2005; WHO, 1992). Long-term or high dose exposure to cadmium can cause kidney failure and softening of bones (Vannoort & Thomson, 2006), and high levels of cadmium have been linked to prostate cancer (Gray *et al.*, 2005).

Cd

ARSENIC

As

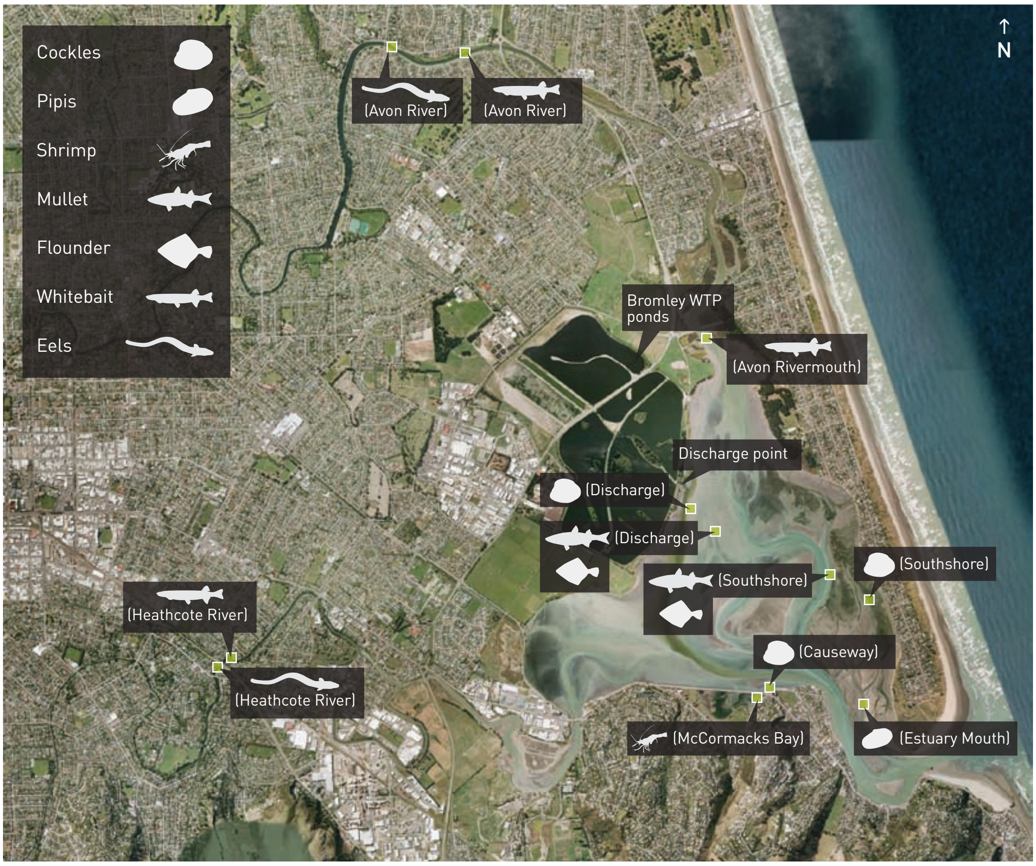
Arsenic is a naturally occurring element that is common in soils, water, and living organisms. In New Zealand arsenic levels in the environment can increase as a result of mining, geothermal production, treated timber, and erosion caused by intensive land use.

Fish and seafood can accumulate considerable amounts of organic arsenic from their environment, but most foods contain trace levels of organic arsenic and occasional consumption is not a health concern. An acute high level exposure to arsenic can lead to vomiting, diarrhoea, anaemia, liver damage, and death. Long term (chronic) exposure is thought to be linked to skin disease, hypertension, some forms of diabetes, and cancer (Centeno *et al.* 2005). Arsenic is present in our food in different chemical forms, but inorganic arsenic is more toxic than organic arsenic. Most arsenic in our diet is present in the less toxic organic form (for example fish and shellfish mainly accumulate organic arsenic from their environment; WHO, 1981), and most of this leaves the human body within several days. There is no regulatory limit for total arsenic in fish or shellfish. However, it is difficult to reliably measure the forms of arsenic that are present, so many surveys of arsenic content measure total arsenic levels.

For more information see http://www.nzfsa.govt.nz/consumers/chemicals-nutrients-additives-and-toxins/arsenic/

WHERE WE SAMPLED

Estuary fish (sand founder and yelloweye mullet) were collected within the estuary from near the discharge point of the Bromley Wastewater Treatment Plant (WTP) and from the western side of the Southshore spit. Cockles were collected in these two areas as well as at the southern end of the causeway by Beachville Road, which is a popular shellfish gathering site. Pipis were collected near the end of the Brighton Spit and close to the estuary mouth, while estuary shrimp were collected from the southeastern end of McCormacks Bay. Shortfin eels were collected in the Avon River downstream of Anzac Drive, and in the Heathcote River just upstream of Opawa Road. Whitebait were collected at popular whitebaiting locations. For the Avon River this was at the rivermouth and upstream opposite Brooker Avenue, while in the Heathcote River this was in Opawa, downstream of Brougham Street.



COLLECTION METHODS

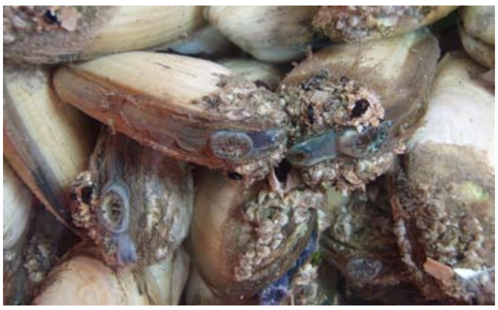
Collecting cockles at the Causeway site

SHELLFISH

Cockles and pipis were collected at low tide by hand; pipis on the 18 March and cockles on the 30–31 March 2010. The shellfish were kept cool with ice packs, their length measured, and then delivered live to Hill Laboratories for heavy metal testing. Ten replicate samples per site were collected. For cockles each sample was made up of three specimens, while for the smaller pipis seven specimens were needed per sample. Each sample was tested by the laboratory for mercury, and five samples per site for arsenic, lead, and cadmium.

Collecting pipis from the Estuary Mouth site, near the Brighton spit

A sample of the cockles *(Austrovenus stutchburyi)* collected



Live pipis *(Paphies australis)*

ESTUARY FISH AND SHRIMP

Sand flounder and yelloweye mullet were collected from the two estuary fish sites over several days in March and May 2010. Sand flounder were caught using a weighted drag net (mesh size 25 mm) and fish traps that were set and dragged along behind the boat. Half a dozen drags per site were needed to capture the required number of fish. A fine mesh (38 mm) gill net was used to catch yelloweye mullet. Set netting is not longer allowed in the estuary and so the gill net was instead deployed and dragged for less than ten minutes at a time, with the boat and burley used to drive or attract fish into the net. This was supplemented by baited pots and fishing rods with six hook herring jigs to capture mullet.

At each site ten fish of each type were placed on ice, anaesthetised and measured in the lab, and delivered to Hill Laboratories for testing. Ten fish of each type were analysed for mercury and five for arsenic and lead. The small size of the flounder meant that 2–3 fish had to be combined to make a single sample with sufficient flesh for testing in two samples from the Discharge site and one from the Southshore site

Shrimp were caught on the 23 March, 2010 using a fine mesh hand net and ten samples weighing approximately 5 g each (wet weight) were delivered to Hill Laboratories for testing. All of these samples were tested for mercury and five samples were tested for arsenic and lead.


01


02


03


04


05

01 » Shrimp *(Palaemon affinis)*

02 » Yelloweye mullet *(Aldrichetta forsteri)*

03 » Coming in after a day of successful fishing

04 » Sand flounder *(Rhombosolea plebeia)*

05 » Netting for shrimp in McCormacks Bay

01 » Setting the fyke nets in the Heathcote River

02 » Measuring eels from the Heathcote River

03 » A shortfin eel *(Anguilla australis)*

04 » Whitebaiters in the Avon River

05 » Collecting eels from the Avon River

06 » Inanga whitebait *(Galaxias maculatus)*

FRESHWATER FISH

Shortfin eels were collected from the Heathcote River and Avon River using fyke nets that were baited and set overnight during March 2010. These nets are a series of hoops connected by mesh. Once the fish enter the inverted funnel entrance they can't find the narrow exit and are trapped. The next day the eels were anaesthetised, their length measured, and either taken to Hill Laboratories for analysis or returned to the river if too many were caught. Mercury levels were tested in ten eels and arsenic and lead in five eels from each site.

Whitebait were collected during the whitebaiting season, in October 2009, when the tiny fish are migrating upriver after having spent six months developing in the ocean. Instead of capturing the whitebait ourselves we collected them from kind whitebaiters who gave us a portion of their catch. Ten samples from each site, weighing approximately 4 g and made up of 10–11 fish, were delivered to Hill Laboratories for testing. All of these samples were tested for mercury and five samples per site were tested for arsenic and lead.

RESULTS

SHELLFISH

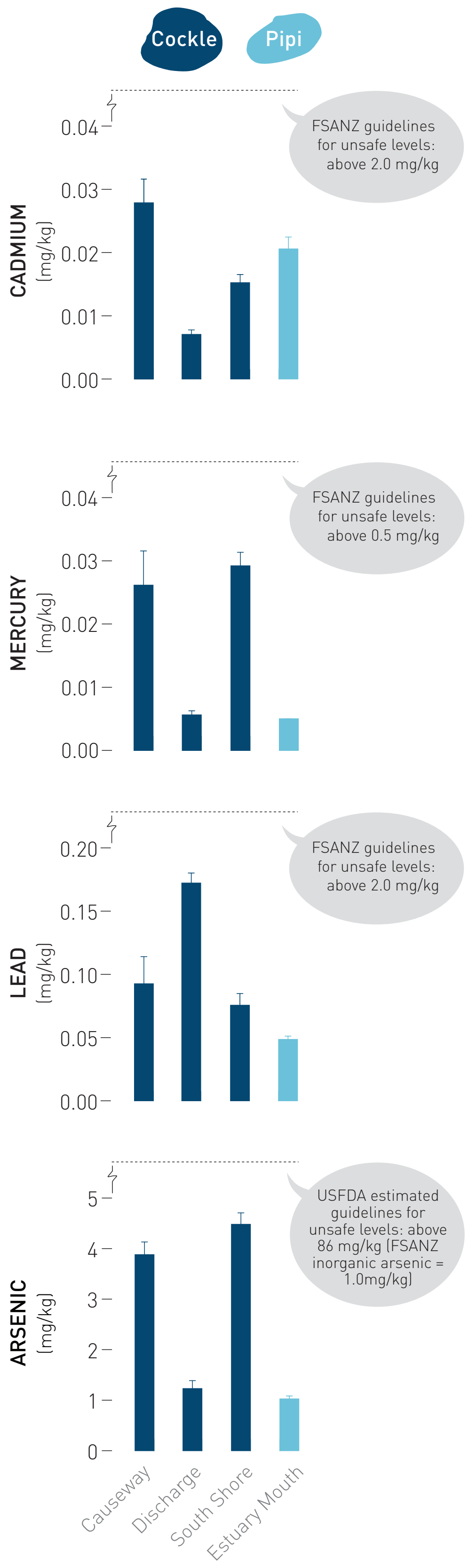
Where possible we collected larger shellfish; the size most likely to be collected and eaten. Cockles, however, were smallest at the Southshore site, and the pipis found after an hour of searching were not particularly large.

Both pipis and cockles at all sites had levels of cadmium, lead, and mercury below the Food Standards Australia New Zealand (FSANZ) (2008) maximum level set for safe consumption of shellfish. In fact, the average level of all three metals at each site was at least 1/10 that of the FSANZ maximum allowable metal contaminant levels. Cockles collected from the Discharge site had the lowest levels of arsenic, cadmium, and mercury, but had the highest levels of lead.

The FSANZ (2008) provides guidelines for levels of inorganic arsenic in shellfish (as well as in fish and shrimp). However, as this is difficult and expensive to measure accurately, most studies measure total arsenic levels instead. In America the US Food and Drug Administration (USFDA) has set maximum levels for total arsenic in shellfish at 86 mg/kg (USFDA,1993). The levels of total arsenic that we found in the estuary shellfish were much lower than this, with the highest total arsenic level being 5.0 mg/kg (at Southshore), with levels below 1.5 mg/kg at the Discharge site (for cockles) and Brighton Spit (for pipis). Thus even the highest concentration of total arsenic was at least 1/10 that of the safe consumption levels set by the USFDA. The USFDA has also conservatively set the inorganic arsenic component at 10% of total arsenic (USFDA, 1993). If we apply this rationale to our samples then the highest estimated inorganic arsenic levels would be 0.5 mg/kg; still below the FSANZ guidelines of less than 1 mg/kg inorganic arsenic.

Average shellfish shell length (mm ± 1 std error)

Cockles	Causeway	48 ± 0.4
	Discharge	38 ± 0.3
	Southshore	34 ± 0.4
Pipis	Estuary Mouth	54 ± 0.6




Yelloweye mullet

FISH AND SHRIMP

The levels of lead and mercury in shrimp from McCormacks Bay were well below the FSANZ maximum metal contamination levels for food. Levels of lead and mercury were also lower in shrimp compared to the fish species tested. Following the USFDA (1993) conservative estimate of inorganic arsenic being 10% of total arsenic, the estimated level of inorganic arsenic in shrimp (average of 0.17 mg/kg) was also well below the FSANZ 2 mg/kg guideline for fish. However, the total arsenic levels (average 1.69 mg/kg) was still more than two times that of the sampled fish (mullet, flounder, shortfin eel, whitebait), and was marginally higher than the levels found in pipis from Southshore and cockles from the Discharge site. However, total arsenic levels in cockles from the Causeway and Southshore sites (3.9 and 4.5 mg/kg) still remained higher even than shrimp.

The size of mullet caught in this survey were generally larger than those caught throughout the estuary in 2006 (James, 2007), but the larger size of fish we caught would be more desirable for consumption (although there is no size or catch limit). The size of flounder caught were generally of a similar size to those caught throughout the estuary in 2006 (James, 2007), but are smaller than what would be regarded an acceptable eating size.

Average shortfin eel length (± 1 std error)

	Avon River	Heathcote River
Length of shortfin eels taken for analysis (mm)	459 ± 13	457 ± 30
Length of all shortfin eels caught (mm)*	499 ± 14	No extras caught

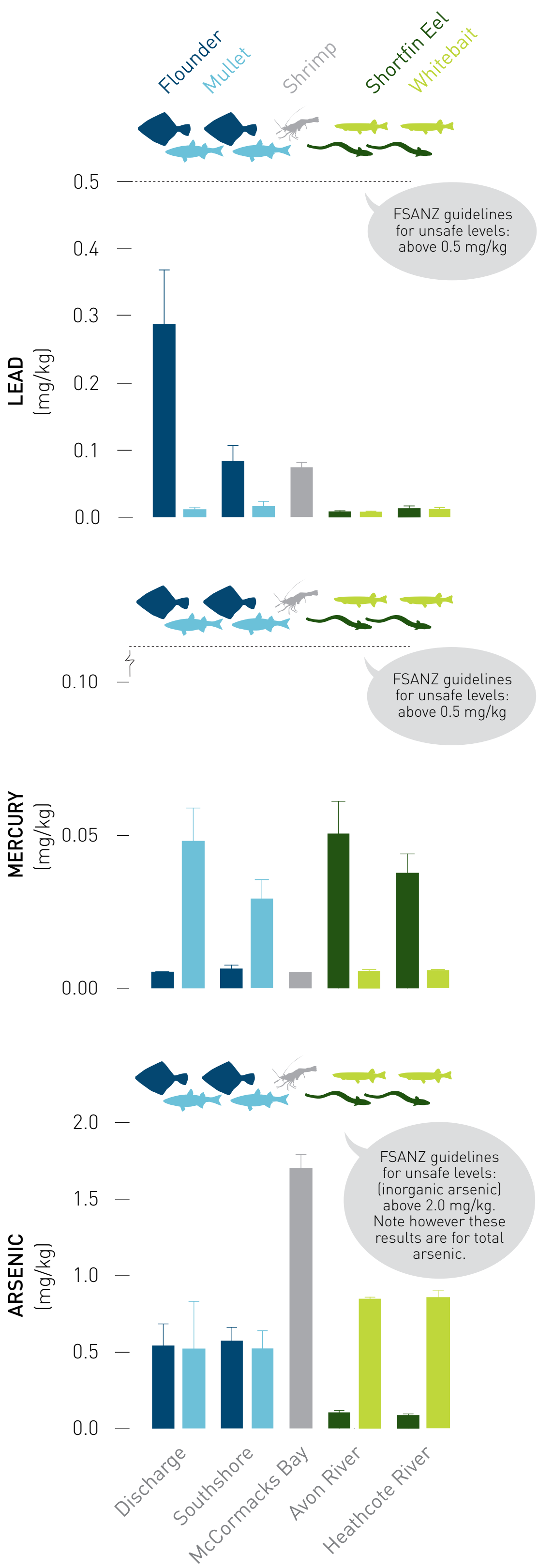
* 27 extra shortfin eels were caught in the Avon River

Average yelloweye mullet length (± 1 std error)

	Discharge Site	Southshore Site
Length of fish analysed in current study (mm)	277 ± 17	232 ± 9
Length of fish in estuary (James, 2007) (mm)	73 to 194	194

Average sand flounder length (± 1 std error)

	Discharge Site	Southshore Site
Length of fish analysed in current study (mm)	75 ± 4	87 ± 4
Length of fish in estuary (James, 2007) (mm)	39 to 110	



We analysed shortfin eels that were from the most common size range encountered during our sampling, although the largest eels were returned to the rivers as they are an important part of the breeding population of this slow growing species.

The levels of lead and mercury from flounder, mullet, eels, and whitebait were all well below the maximum acceptable levels for eating fish (FSANZ, 2008). However, in general flounder had higher levels of lead than any other fish, with levels also considerably higher from the Discharge site (average level of 0.29 mg/kg). Mercury was low in all fish species, although levels were much lower in the smaller fish species (flounder and whitebait).

The safe limit for inorganic arsenic in fish is 2 mg/kg, so the estimated level of inorganic arsenic (e.g., 10% of total arsenic) in flounder (est. 0.055 mg/kg), mullet (est. 0.052 mg/kg), eels (est. 0.009 mg/kg), and whitebait (est. 0.085 mg/kg) were all below this level. However, it is interesting to see the highest levels were recorded in the whitebait, which would have only recently entered the river system in their migration upstream. The whitebait collected at the mouth of the Avon River had on average, slightly higher levels of total arsenic than those caught further upstream (9.05 mg/kg downstream versus 7.95 mg/kg upstream). However, the highest total arsenic level (1.2 mg/kg total arsenic) was actually found in a whitebait sample collected from the upstream Avon River site.

DISCUSSION

Avon-Heathcote estuary from the air, looking south

THE INFLUENCE OF SITE LOCATION

There was no one site that consistently had higher heavy metal levels in fish or shellfish than the other sites. However, fish caught in the estuary had higher lead levels than the fish caught in the rivers (eels and whitebait), and the Discharge site had the highest lead levels of all sites sampled for both cockles and sand flounder. The collection of all fish and shellfish, excluding the whitebait (which were collected five months earlier), were collected only a few weeks after the Bromley Wastewater Treatment Plant (WTP) ceased discharging treated effluent into the estuary. Thus it could be too soon to discern any great change in heavy metal levels in the fish and shellfish as a consequence of this.

Sunrise at the Beachville Road jetty

Because shellfish are sessile (e.g., don't move around a lot) they probably provide the best opportunity to look at differences between sites. Our results showed that cockles from the Causeway and Southshore sites had higher levels than the Discharge site for most heavy metals. The exception was lead, which was instead significantly higher in cockles from the Discharge site. This pattern of higher lead levels in the western side of the estuary is the same as that found over 20 years ago by the Christchurch Drainage Board (CDB, 1988). Their study also found that smaller cockles had higher levels of heavy metals than larger ones, but we only found this to be true for arsenic and mercury. Our results imply that site location has a greater influence on heavy metal levels in cockles than size does.

For freshwater fish (whitebait and shortfin eels), the river that they were collected from made little difference to the levels of mercury or arsenic, with fish collected from both rivers having similar levels. However, lead levels were consistently higher in both whitebait and eels caught in the Avon River. Whitebait were also sampled from two sites in the Avon River to see if there was any difference in the fish found further upstream, which would have spent a longer period of time in the freshwater environment. Whitebait collected at the mouth of the Avon River had, on average, slightly higher levels of arsenic but lower levels of lead. However, the arsenic levels were quite variable between each sample, with the highest level of arsenic actually recorded from whitebait sample from the upstream site. The heavy metal levels in whitebait may be accumulated from their time in the marine and estuary environment as well as the river. However, without further analysis little can be deduced from the differences found in this sampling round.

Collecting cockles from the Causeway site

For the estuarine fish, there was also no relationship between site and metal contamination, with heavy metals in both fish species similar between sites. The obvious exception was the particularly high levels of lead in flounder collected at the Discharge site. Given the transient nature of both types of fish (but in particular yelloweye mullet) it is unlikely that any differences would be associated with where they were caught, although the higher levels of lead in flounder near the Bromley WTP discharge point is of interest.

Because fish move around so much it is difficult to attribute any differences in heavy metal levels to the location where the fish were caught. Although typically regarded as marine species, flounder and mullet do not just live in the sea and estuary area, but move up into the lower reaches of rivers to feed. Flounder will move a short distance up-river, although they stay within the tidal zone. Mullet however, regularly move considerable distances up-river, into freshwater above the tidal zone, where they may remain and feed for several tide cycles before returning to the estuary. The whitebait caught would have spent around six months developing in the ocean before their spring migration into rivers and streams, where they will stay for 1–2 years before moving down into the tidal reaches of rivers to lay their eggs in grasses along the streambank during autumn high tides. When the young hatch they are washed out to sea to develop and will return in the next season's whitebait run. In contrast eels will typically spend most of their life in freshwater, only migrating to the sea to spawn later in their life.

View of the Avon-Heathcote estuary from above Monks Bay, looking North

THE INFLUENCE OF LIFE HISTORY

Some of the differences in heavy metal loadings between the animals collected may be due to differences in life history, habitat preferences, feeding behaviour, and even how metals behave and accumulate, rather than site-specific differences.

Feeding habitats and life history patterns could influence heavy metal levels in fish. Flounders live and feed from the estuary floor and so may be more exposed to contaminants in the sediment than other free-swimming fish such as mullet and whitebait. This could explain the higher levels of lead in flounder compared to other fish. The whitebait caught would be little more than six months old, with much of this time having been spent in the ocean where they feed on tiny zooplankton in the water. Thus heavy metal levels in whitebait could be a reflection of their time spent at sea and in the estuary as much as their time spent in the river.

The age of fish caught and their feeding habits could help explain the level of mercury in fish, as it accumulates over an animal's life time as well as up the food chain (e.g., predators also accumulate the mercury from the prey they eat). The higher level of mercury in eels than all other animals tested may be related to their age and predatory status. The eels caught in this study could be somewhere between 14 and 22 years (as they grow very slowly and are long-lived) and would feed on smaller fish as well as invertebrates. However age or predatory status does not account for the similarly high levels of mercury in yelloweye mullet, that were estimated to be only 1–2 years old and which mainly feed on algae.

Pipis and cockles are relatively stationary animals that live in the sediment and filter particles out of the water column. Compared to fish, they actively ingest heavy metals bound to particles (organic and inorganic), meaning that they would be more exposed to heavy metals while feeding. Shrimp also feed by stirring the sediment up and collecting very small particles of organic matter, and so they too would be exposed to the heavy metals bound to this food. Our study and other studies (FSA, 2005) have found that cockles accumulate more arsenic than fish do. This may be due to their feeding or habitat preferences, or other factors.

SO ARE FISH AND SHELLFISH SAFE TO EAT?

Cockles, pipis, shrimp, yelloweye mullet, sand flounder, shortfin eels, and whitebait all had metal concentrations (e.g., mercury, cadmium, lead, arsenic) below the FSANZ (2008) limits for safe food consumption. However, the high arsenic levels in shellfish could warrant further investigation, with testing of inorganic arsenic in shellfish and shrimp to properly ascertain the relationship between total arsenic and inorganic arsenic levels.

Despite this clean bill of health, the consumption of shellfish in particular should still be cautioned. Bacteria and enteric viruses—which can cause vomiting, diarrhoea, and abdominal pain—are still being found in shellfish collected from the estuary. EOS Ecology continues to collect shellfish (cockles and tuatuas) for testing of bacteria (*E. coli* and *Salmonella*) and enteric viruses on behalf of the Christchurch City Council. It is expected that the viral and bacterial levels should drop with the treated sewage from the Bromley WTP no longer being discharged into the estuary. However, until further monitoring can be completed we feel that shellfish from the estuary should still be considered unsafe to eat (especially raw) due to a potential for high bacterial or viral levels.

A bed of pipi shells at the Estuary Mouth pipi collection site

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