Food Safety of Fish & Shellfish in Ōtautahi/Christchurch – 2019 SURVEY

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Cover photos:
Top = Pipis
Middle = Yellowbelly flounder
Bottom = Cockles

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SCIENCE + ENGAGEMENT

EOS ECOLOGY

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Shortfin eel

1 What Contaminants May be in Our Wild Food?

Heavy metals such as cadmium, lead, copper and zinc, and metalloids like arsenic, are found naturally in the environment. We absorb trace amounts of some heavy metals from our food, drinking water, and the air. Small (trace) amounts of some heavy metals in our body can actually be beneficial—trace amounts of selenium, zinc, and copper are essential to maintain our metabolism. However, having too much can be harmful for our health. Small children and infants are especially susceptible to heavy metals as they consume more food per kilogram of body weight than adults, and the toxic effects of certain heavy metals can be particularly detrimental to children's developing organs, especially the brain.

Polychlorinated biphenyls (PCBs) are man-made chemicals (typically oily solids or liquids that are clear to yellow in colour) that are persistent organic pollutants with a high environmental toxicity. Tests have shown that large amounts of PCBs given to animals over a short time can cause cancer, and the US Environmental Protection Agency has stated that PCBs are a probable human carcinogen. Birth defects have been linked to mothers exposed to PCBs.

Escherichia coli (*E. coli*) is used as an indicator organism in freshwater and in the flesh of shellfish, signalling the presence of pathogens from faecal material. The higher the number of *E. coli* the greater the likelihood that pathogens from faecal matter are also present, Whilst most strains of *E. coli* are harmless to humans and are beneficial bacteria that form part of a healthy intestinal tract, some strains of *E. coli* are harmful. Harmful *E. coli* and other pathogens can cause diarrhea, abdominal pain, fever and sometimes vomiting with some pathogens having serious effects on human health. Most people recover within about a week but can be more serious in infants and people with a weakened immune system.

Food that we buy is governed by food standards that help to ensure that such contaminants do not exceed safety levels. However, what about the food that we may gather from our local environments, such as our estuaries and rivers? This report looks at the levels of some heavy metals (cadmium, lead, arsenic, copper, zinc), polychlorinated biphenyls (PCBs), and bacteria (*E. coli*) that are in our wild food (such as fish and shellfish) found within the Avon-Heathcote Estuary/Ihutai and its two main rivers (Ōtākaro/Avon River, Ōpāwaho/Heathcote River).

Where Do Contaminants Come From?

Whilst heavy metals are found naturally in our environment, human activities are responsible for increasing levels above those that occur naturally. Heavy metals are found in building construction materials, power generation and transmission, electronic product manufacturing, and the production of machinery and vehicles, they are in many consumer products, and in timber treatment and agricultural fertilisers. PCBs are man-made chemicals that were used widely in electrical equipment like capacitors and transformers, as well as in hydraulic fluids, heat transfer fluids, lubricants, flame retardants, some paints and printing inks, and plasticizers. PCBs were manufactured between 1930–late 1970s and used widely in industry across the globe. They were imported but not manufactured in New Zealand, and following bans in other countries, were banned in New Zealand in the mid 1980s, but could be present still in some pre-1980 products.

Contaminants can enter rivers in run-off from roads and buildings via our stormwater network and overland runoff, or from agricultural land through overland runoff. What we wash into our wastewater network (i.e., down house drains and toilets) could also potentially enter our receiving environment through leakage from aging or damaged infrastructure and pumping station overflows. Both heavy metals and PCBs bind to soil and sediment, and so once in our waterway environments they accumulate in the sediment. Eventually they may get transported to the estuary, where the sediment with the bound metal contaminants accumulates. This means that the sediment in rivers and estuaries can have high contamination loads of heavy metals. The concentrations are likely to vary by site depending on the location of the contaminant sources and where the contaminated sediment is accumulating.

Bacteria such as *E. coli* can come from human and animal waste. Common *E. coli* sources are faecal material from pets, livestock and wildlife, as well as from wastewater discharges, untreated wastewater overflows, and leaky septic tanks. In New Zealand our human waste is taken to septic tanks or to centralised wastewater treatment systems that are designed to kill pathogens. However, when this infrastructure is overloaded (such as in large storm events) there can be an overflow of raw sewage to our rivers. Animal waste from farming may also enter our waterways and be a source for *E. coli*, as can large numbers of waterfowl and other birds. In urban areas dog poo that is not picked up off the footpath can enter our rivers when it rains and be a source of pathogens. Typically, *E. coli* cannot survive long outside of a host, but *E. coli* has greater survival in sediment, or in water with sediment in it. Whilst salt water will usually kill off bacteria such as *E. coli*, *E. coli* can also survive for longer when there is sediment in the saltwater. River or estuary sediments can therefore sometimes have higher levels of bacteria than what is found in the water that lies over that sediment.

In general, marine and freshwater organisms accumulate contaminants from their environment. Fish absorb contaminants from water and sediment they live in, and from the food they eat. Bottom-dwelling fish, such as flounder, are expected to have greater levels of contamination as they live on/in the sediment where contaminants accumulate. Fish higher up the food chain can also have higher levels of some contaminants that bio-accumulate, as they absorb the contaminants in the flesh of the fish that they themselves eat. Shellfish feed by filtering particles out of the water, which can include fine sediment particles with heavy metals attached or that has live pathogens such as *E. coli*. The gut of shellfish is a perfect environment for any live pathogens filtered by the shellfish to start to multiply. As with other animals, lead, cadmium, copper and zinc are essential to fish and shellfish at very tiny (trace) levels, but higher levels are a direct result of pollution. PCBs are a human-made compound and so their presence in animals at any level is a direct result of pollution. PCBs are absorbed by the body and stored in fatty tissue, where they will accumulate. As PCBs bio-accumulate, animals further up the food-chain accumulate the PCBs from the smaller animals that they eat. This can have important implications for the type of fish we eat.

HEAVY METALS

Naturally occurring and also used in man-made products and processes.

As ARSENIC
Released during mining, geothermal production & erosion caused by intensive land use, present in treated timber.

Cd CADMIUM
In batteries, pigments, metal coatings,fertilisers.

Cu COPPER
In brake pads, water pipes, hot water cylinders, building cladding (roofing and architectural additions), released during mining.

Pb LEAD
In batteries, solder, ammunition, in the past in leaded petrol & paints.

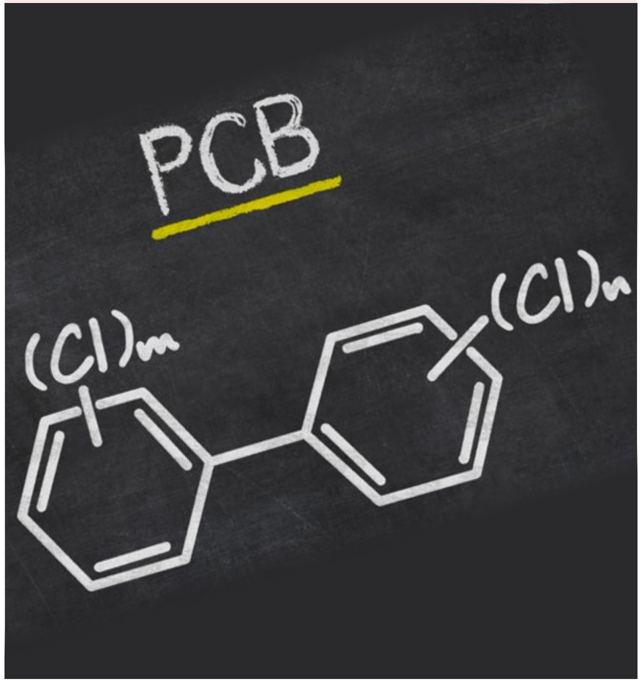
Zn ZINC
In many metal alloys, galvanizing (including zinc galvanized roofs), batteries, plastics, tyres, paints, florescent lights.

ESCHERICHIA COLI (PATHOGENS)

E. coli – rom faecal matter from humans, mammals & birds. Elevated levels can come from wastewater discharge, untreated wastewater overflows, leaky septic tanks, farm animal/ waterfowl/birds/dog poo.

POLYCHLORINATED BIPHENYLS

A man-made product that has been banned due to its toxicity. Used in electrical equipment (e.g., capacitors, transformers), hydraulic fluids, heat transfer fluids, lubricants, flame retardants, some paints/printing inks, plasticizers.



Food Standard Safety Levels

The Australia and New Zealand Food Standards Code (ANZFSC, accessed at www.legislation.gov.au/Details/F2017C00333) has set maximum levels for PCBs, heavy metals such as lead, cadmium and arsenic, and *E. coli* in different types of food (Table 1). These standards do not cover copper and zinc. *E. coli* is also covered by MPI (2018) in their document entitled *Regulated Control Scheme – Bivalve Molluscan Shellfish for Human Consumption*, which specifies the food safety requirements for commercial growing, harvesting, sorting and transporting of shellfish human consumption (Table 1). Whilst the shellfish sites monitored in our report are not commercial growing areas, these standards are nevertheless worth comparing to.

TABLE 1: **Food standard safety levels for the animals & contaminants** covered in this report.

	FISH (maximum level in mg/kg)	SHELLFISH (maximum level in mg/kg)	SOURCE
HEAVY METALS			
Cadmium	*no limit specified*	2	ANZFSC (Schedule 19, Standard 1.4.1)
Lead	0.5	2	ANZFSC (Schedule 19, Standard 1.4.1)
Arsenic (inorganic)*	2	1	ANZFSC (Schedule 19, Standard 1.4.1)
Copper	n/a	n/a	ANZFSC (Schedule 19, Standard 1.4.1)
Zinc	n/a	n/a	ANZFSC (Schedule 19, Standard 1.4.1)
POLYCHLORINATED BIPHENYLS			
PCBs total	0.5	*no limit specified*	ANZFSC (Schedule 19, Standard 1.4.1)

	SHELLFISH (allowable levels of *E. coli* MPN/100 g)	SOURCE
PATHOGENS		
E. coli	Only 1 sample (of 5) can exceed 230 MPN/100 g NO samples can exceed 700 MPN/100 g	ANZFSC (Schedule 27, Standard 1.6.1)
	Adverse Pollution Conditions (APC) strategy for 'approved'[+] commercial growing areas: median < 230 MPN/100 g AND not more than 10% of samples exceed 700 MPN/100 g	MPI (2018)
	APC strategy for 'restricted'[+] commercial growing areas: median < 4,600 MPN/100 g AND not more than 10% exceed 14,100 MPN/100 g	MPI (2018)

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

+ 'Approved' and 'restricted' areas refers to two of six possible classifications that MPI applies to commercial shellfish growing areas, and cover the upper and lower range for areas where there are humans living in the catchment. Growing areas are defined into these classifications based on a number of descriptive criteria and whether or not they meet the water and shellfish *E. coli* standards prescribed for those classifications; the *E. coli* standards for shellfish are as indicated in the table above.

Yelloweyed mullet

2 Where We Sampled (Figure 1)

Estuary fish were collected within the deeper water channels of the estuary, including out from the McCormacks Bay causeway at the western end and out from Penguin Street.

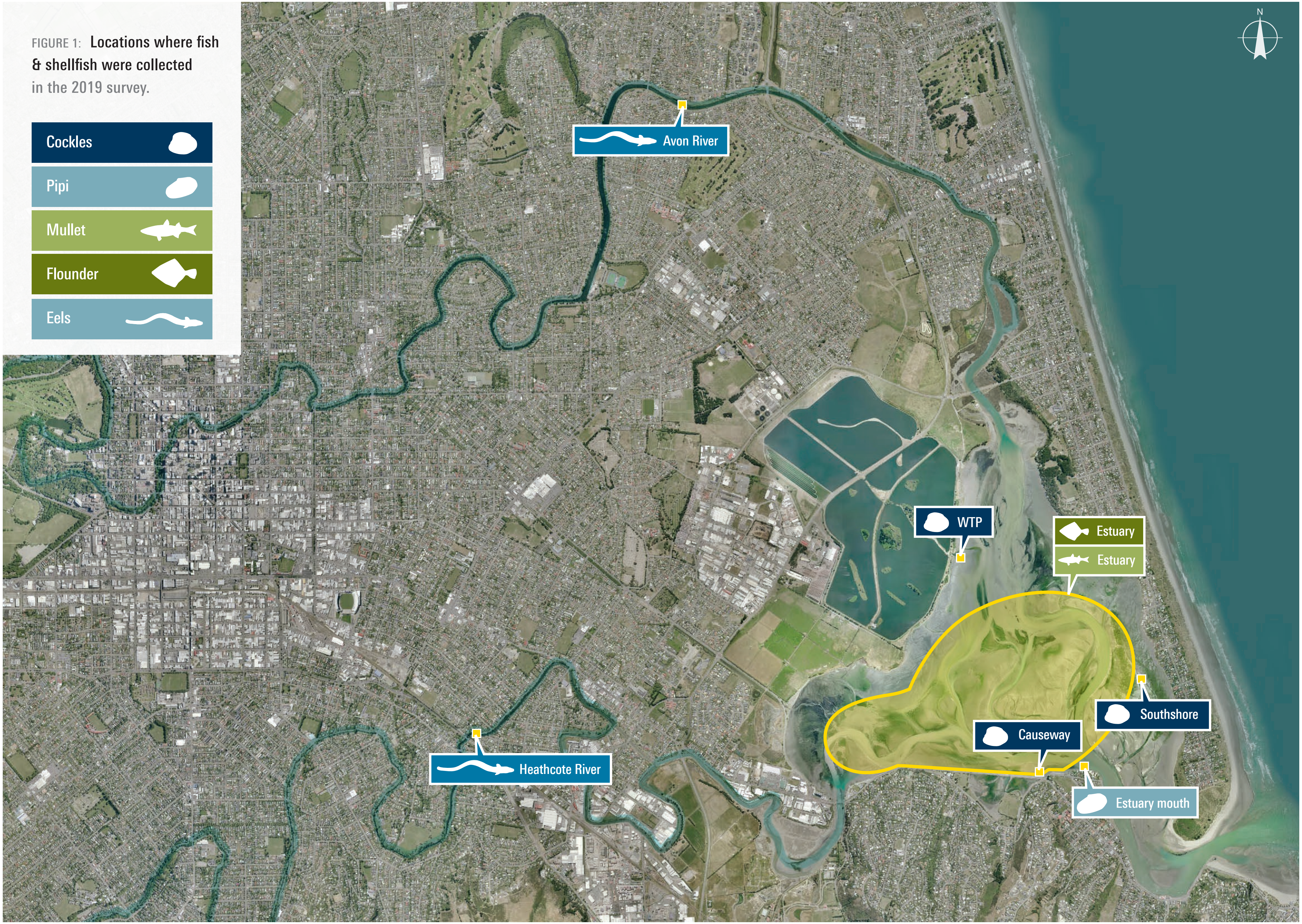
Cockles were collected near the old discharge point of the Christchurch Wastewater Treatment Plant (WTP), from the western side of the Southshore spit (Southshore), and at the eastern end of the causeway by the Estuary mouth (Causeway), which is a popular shellfish gathering site. *Note that the discharge from the Wastewater Treatment Plant stopped discharging into the Estuary in March 2010, when it was instead discharged 3 km offshore from New Brighton via an ocean outfall pipeline.*

Pipis were collected from alongside the shoreline east of the Beachville Road boat ramp (Estuary mouth).

Shortfin eels were collected in the Ōtākaro/Avon River downstream of Anzac Drive opposite Ogilvie Place, and in the Ōpāwaho/Heathcote River just downstream of Opawa Road.

All fish and shellfish were collected under EOS Ecology's Ministry for Primary Industries Special Permit (625) that allows for the collection of fish and other aquatic life for such purposes.

FIGURE 1: Locations where fish & shellfish were collected in the 2019 survey.



3 How We Sampled

Shellfish

Cockles (*Austrovenus stutchburyi*) and pipi (*Paphies australis*) were collected from four sites (three sites for cockles, one site for pipi) at low tide by hand on 6–7 March 2019 for heavy metal (cadmium, lead, arsenic, copper, zinc) testing, consisting of five replicate samples of 4–5 cockles and five replicate samples of six pipis. Shellfish lengths were measured at our lab before being frozen and delivered to Hill Laboratories, where they were shucked and blended before being tested for heavy metals.

Cockles were also collected for *E. coli* testing on five separate occasions (6–7 March, 20 March, 3 April, 17 April, 2 May 2019) at each of these sites, with 51–108 cockles collected per sample (i.e., per site, per occasion). The cockles were kept cool in a chilly bin with ice packs, their length measured at our lab, and then delivered (on the same day as their collection) live and chilled to Hill Laboratories, where they were shucked and blended before being tested for *E. coli*.


Collecting cockles


Collecting pipi


Measuring cockles in the laboratory


Pipi

Freshwater Fish

Five Shortfin eels (*Anguilla australis*) were collected from the Ōpāwaho/Heathcote River and Ōtākaro/Avon River using fyke nets that were baited and set overnight on the 3 April 2019. On retrieval of the nets the eels were put into aerated containers for transport to our lab where they were euthanised, measured and weighed, prior to delivery to Hill Laboratories where the fish were filleted and blended for testing.


Setting a fyke net in the Heathcote River/Ōpāwaho


Eels caught in a fyke net

Estuary Fish

Estuary fish (yellowbelly flounder and yelloweyed mullet) were collected for heavy metal (lead, arsenic, copper, zinc) and PCB testing.

- Ten yelloweyed mullet (*Aldrichetta forsteri*) were collected from the estuary on the 15 March 2019, consisting of five replicate samples of two fish per sample. Yelloweyed mullet were caught using rods with six baited hook herring jigs (Sabiki's) from an anchored boat while releasing a burley trail.
- Five yellowbelly flounder (*Rhombosolea leporina*) were collected from the estuary on the 29 March and 3 May 2019, consisting of five replicate samples of one fish per sample. As only one large flounder was caught in March using a drag net towed behind a boat for two tows we changed to using a hand held flounder net in deeper channels at low tide on the 3 May 2019. This method resulted in larger specimens being caught than in other years, and in a size range more likely to be caught and eaten.

The fish were put into aerated containers for transport to our lab where they were euthanised, measured and weighed, prior to delivery to Hill Laboratories where the fish were filleted and blended for testing.


Yellowbelly flounder


Netting yellowbelly flounder


Yelloweyed mullet


Fishing for yelloweyed mullet

4 Our Findings

SHELLFISH
Heavy metals

Where possible, we collected shellfish of a size most likely to be collected and eaten. Cockle size was similar across all sites, although slightly larger at the Causeway site (Table 2).

Pipi at the Estuary mouth had the highest recorded value for cadmium (0.04 mg/kg) and lead (0.18 mg/kg), whilst the highest recorded value for copper and arsenic were from cockles at Southshore (Table 3). Cockles from the Causeway site had the highest recorded value for zinc (9.9 mg/kg) (Table 3).

Given the large standard error bars there is unlikely to be any significant difference in heavy metal levels in shellfish between sites (Figure 2). In general however, as in the last two surveys (McMurtrie 2012, 2015) cockles from the WTP site had lower levels of cadmium and higher levels of lead and arsenic (Figure 2). Lead was more elevated in pipis in this year compared to the previous two surveys (McMurtrie 2012, 2015). Conversely arsenic was not as high as those recorded in the 2012 survey where total arsenic reached an average of 4.9 mg/kg at this site (McMurtrie, 2012). Copper and zinc have not been tested for in earlier surveys. Average values for copper and zinc in cockles in the Avon-Heathcote Estuary/Ihutai are slightly lower than those recorded by Milne (2006) for copper (0.92–1.35 mg/kg) and zinc (9–11.6 mg/kg) from five sites in the urbanized Porirua Harbour in the Wellington region.

Both pipi and cockles at all sites had levels of cadmium and lead below the ANZFSC maximum allowable level set for safe consumption of shellfish (Figure 2). In fact, the average level of these metals at each site was at least a tenth that of the ANZFSC maximum allowable metal contaminant levels. Copper and zinc have no standards set under the AZFSC.

The AZFSC provides guidelines for levels of inorganic arsenic in shellfish. However, as this is difficult and expensive to measure accurately, most studies measure total arsenic levels instead. In the USA the Food and Drug Administration (USFDA) had set maximum allowable levels for total arsenic in shellfish at 86 mg/kg (USFDA, 1993). The levels of total arsenic we found in the estuary shellfish were much lower than this (Figure 2). The highest concentration of total arsenic was at least a tenth that of the safe consumption levels set by the USFDA. The USFDA had also conservatively set the inorganic arsenic component at 10% of total arsenic (USFDA, 1993). Therefore the highest estimated inorganic arsenic levels in the collected samples (which was in cockles from the Causeway site) would be 0.198 mg/kg, which is well below the ANZFSC guidelines of 1 mg/kg inorganic arsenic.

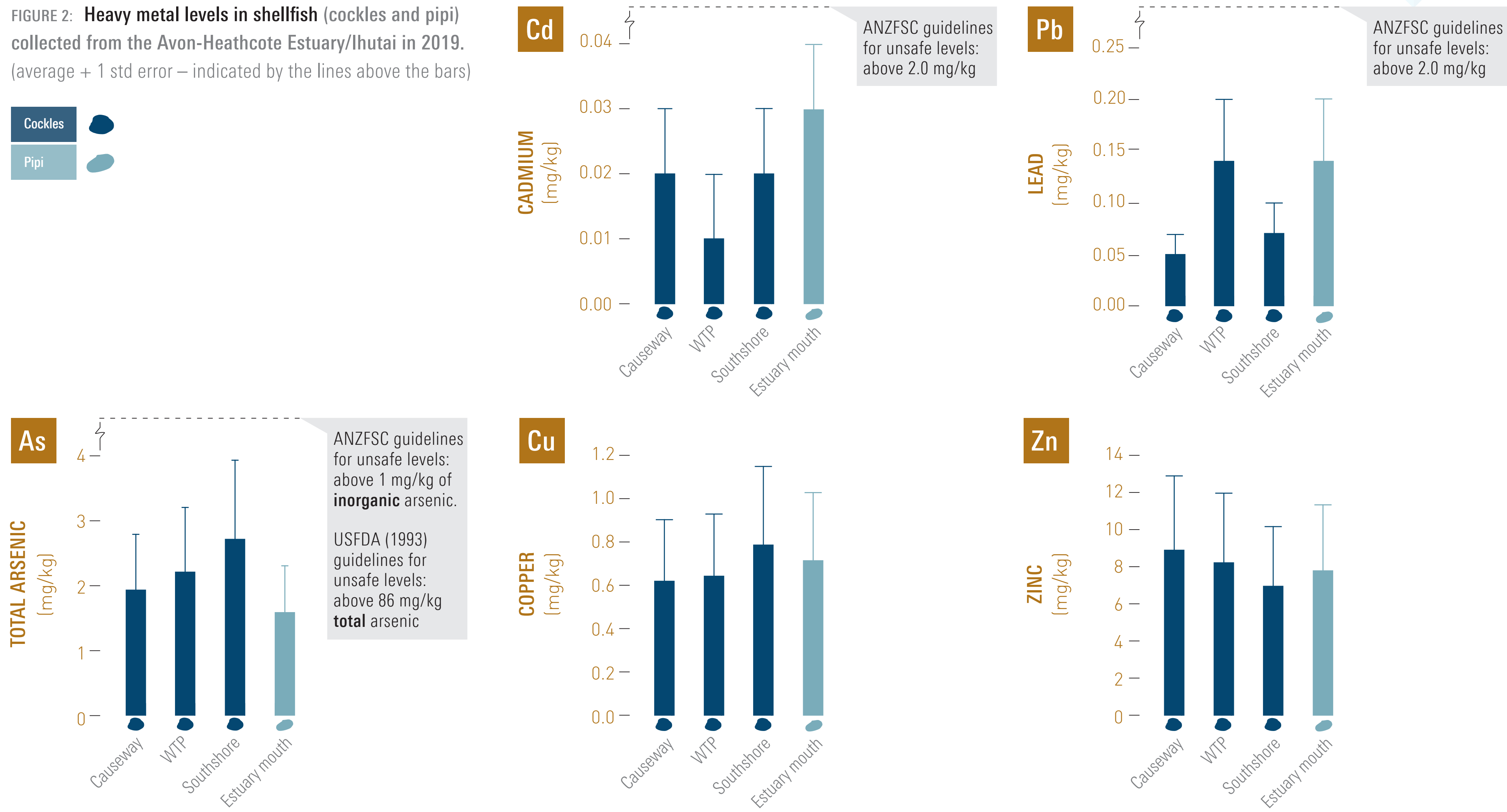
TABLE 2: **Average shell length** (mm ± 1 std error) of shellfish collected in March 2019 for heavy metal testing. (n = number collected)

Cockles	Causeway	38 ± 1 (n=20)
	WTP	30 ± 1 (n=22)
	Southshore	30 ± 1 (n=22)
Pipi	Estuary mouth	56 ± 1 (n=30)

TABLE 3: **Average, minimum and maximum levels of heavy metals in shellfish** collected from Avon-Heathcote Estuary/Ihutai in March 2019. (Maximum value for each metal has been highlighted)

		Cadmium			Lead			Arsenic			Copper			Zinc		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Cockles	Causeway	0.02	0.01	0.03	0.05	0.03	0.07	1.93	1.72	2.20	0.62	0.53	0.70	8.92	8.10	**9.90**
	WTP	0.01	0.01	0.02	0.14	0.08	**0.20**	2.22	1.60	2.60	0.64	0.55	0.71	8.26	6.50	9.50
	Southshore	0.02	0.01	0.03	0.07	0.05	0.09	2.72	2.20	**4.00**	0.79	0.65	**0.88**	6.98	5.40	7.70
Pipi	Estuary mouth	0.03	0.02	**0.04**	0.14	0.11	0.18	1.60	1.48	1.68	0.71	0.64	0.78	7.82	7.30	8.50

FIGURE 2: **Heavy metal levels in shellfish** (cockles and pipi) **collected from the Avon-Heathcote Estuary/Ihutai in 2019.** (average + 1 std error – indicated by the lines above the bars)



SHELLFISH
E. coli

As for the heavy metal testing, where possible we collected shellfish of the size most likely to be collected and eaten. Cockle size was similar across all sites, although slightly larger at the causeway site (Table 4), which is a popular shellfish gathering site.

E. coli levels were relatively low at both the Causeway and Southshore sites, with two of the five samples below the detection limit of 18 MPN/100 g at each of these sites (Table 5). The Causeway and Southshore sites did not exceed the ANZFSC standards that require that only one sample out of five can exceed 230 MPN/100 g, and that no one sample can exceed 700 MPN/100 g. These sites also met the food safety standards set out by MPI (2018) for Adverse Pollution Conditions (APC) for both 'approved' and 'restricted' commercial growing areas (Table 1, Figure 3).

E. coli levels at the WTP site were highly variable, with two samples under the detection limit but three samples with very elevated *E. coli* levels (Table 5). Two of these samples were especially high (1300 and 1700 MPN/100 g), exceeding the ANZFSC standards that require that only one sample out of five can exceed 230 MPN/100 g, and that no one sample can exceed 700 MPN/100 g (Table 5). In addition, the median value of 490 MPN/100 g also exceeded the MPI (2018) regulations for Adverse Pollution Conditions (APC) in 'approved' commercial growing areas, which requires that the median value from five samples does not exceed 230 MPN/100 g (Figure 3).

TABLE 4: **Average shell length of cockles** (mm ± 1 std error) collected on five occasions over nine weeks in March–May 2019 for *E. coli* testing. (n = number collected)

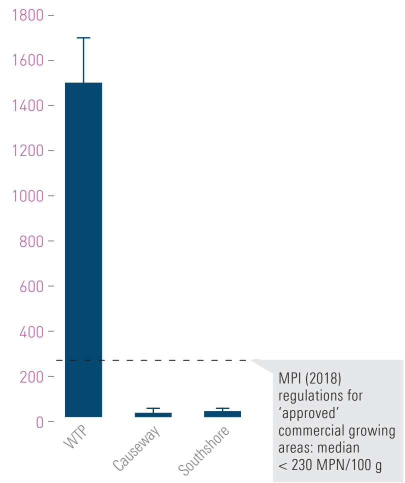
Cockles	Causeway	31 ± 0.3 (n=293)
	WTP	27 ± 0.1 (n=443)
	Southshore	28 ± 0.2 (n=370)

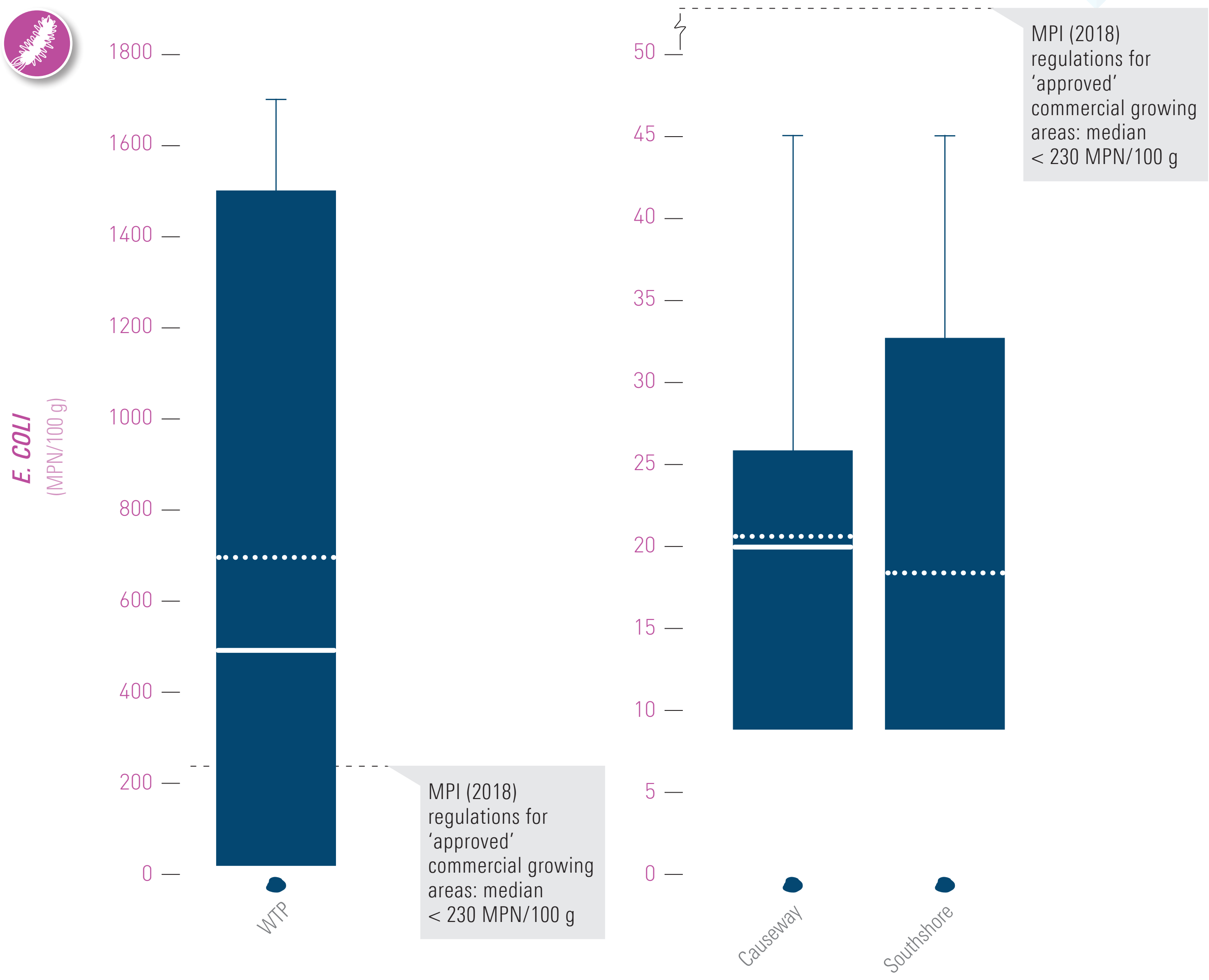
TABLE 5: ***E. coli* levels in cockles** collected from the Avon-Heathcote Estuary/Ihutai on five occasions over nine weeks in March–May 2019.

	E. coli levels (MPN/100 g)		
Date	Causeway	WTP	Southshore
6/03/19	<18	1700 (exceeds ANZFSC standards)	20
20/03/19	20	1300 (exceeds ANZFSC standards – no sample can exceed 700 MPN/100 g)	45
3/04/19	20	490	<18
17/04/19	<18	<18	<18
2/05/19	45	<18	<18

FIGURE 3: **Box plots showing median (solid white line) and average (dotted white line) levels of *E. coli* in cockles** collected from the Avon-Heathcote Estuary/Ihutai on five occasions over nine weeks in March – May 2019. For graphing purposes, results that were below the laboratory detection limit were included at half the detection limit level – the samples that this applies to are shown in Table 5.
(lines above the bars indicate the 'maximum' value)

(Please note the huge difference in y-axis (vertical) scale numbers between WTP site & the other two sites. We've split them apart to show more detail at the Causeway and Southshore sites. Below is how the data looks next to each other on the same scale.)





FISH
Heavy Metals & PCBs

There is no size limit for yelloweye mullet for recreational fishing. The minimum size for yellowbelly flounder (under flatfish in the regulations) for recreational fishing is 250 mm and so the fish we caught were within the legal size limit – and thus representative of the size that would be caught for eating. The shortfin eels caught were of similar size between the two rivers (Table 6). There are no size limits on shortfin eels for recreational fishing, although the Ministry of Fisheries (MoF) recommends that recreational fishers return shortfin eels longer than 600 mm (Ministry of Fisheries, 2008).

Yelloweyed mullet had the highest average levels and the highest maximum recorded value for all tested heavy metals (lead, total arsenic, copper and zinc) (Figure 4, Table 7). In fact lead was under the detection limit of 0.010 mg/kg for all flounder and eel samples, whilst lead averaged 0.3 mg/kg and reached as high as 0.42 mg/kg in yelloweyed mullet. The average levels of lead in yelloweyed mullet are also the highest recorded in all food safety surveys (Greenwood, 2008; McMurtrie, 2010, 2012, 2015). Arsenic was below the laboratory detection limit of 0.1 mg/kg for all shortfin eel samples. PCBs were under the detectable limit of 0.04 mg/kg in all samples for all fish.

The levels of lead in all fish tested were well below the AZFSC maximum allowable level of 0.5 mg/kg set for safe consumption, although the levels in mullet are approaching this limit. Copper and zinc have no standards set under the AZFSC.

The AZFSC provides guidelines for levels of inorganic arsenic in fish. However, as this is difficult and expensive to measure accurately, most studies measure total arsenic levels instead. The USFDA has conservatively set the inorganic arsenic component at 10% of total arsenic (USFDA, 1993). Therefore the highest estimated inorganic arsenic levels in the collected samples (which was from a yelloweyed mullet sample) would be 0.075 mg/kg, which is well below the ANZFSC guidelines of 1 mg/kg inorganic arsenic.

TABLE 6: **Average length of fish** (mm ± 1 std error) caught for testing and taken for analysis in 2019. (n = number of fish collected)

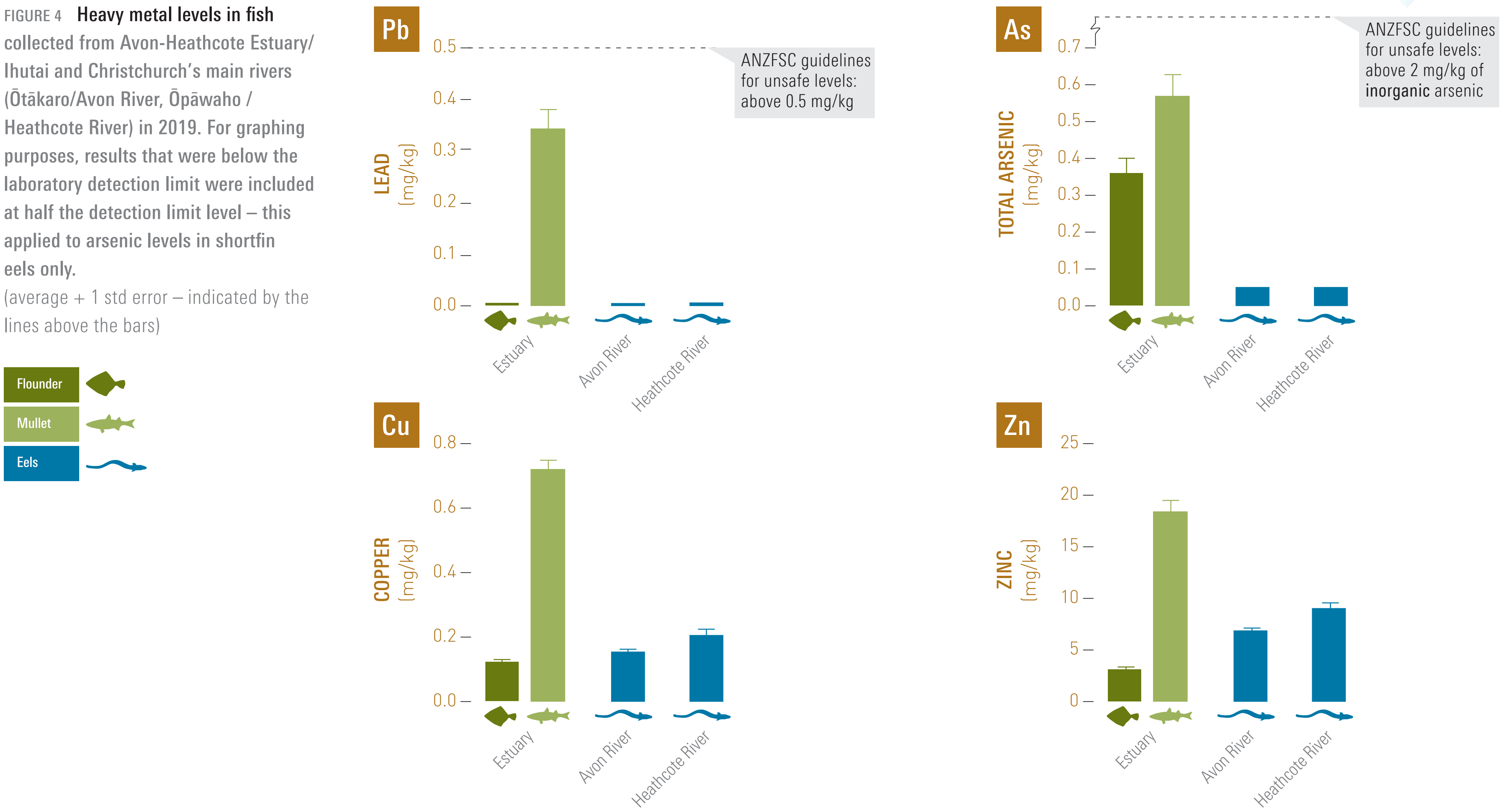
Yellowbelly flounder	Estuary	369 ± 165 (n=5)
Yelloweyed mullet	Estuary	172 ± 54 (n=10)
Shortfin eel	Ōtākaro/Avon River	527 ± 236 (n=5)
	Ōpāwaho/Heathcote River	520 ± 233 (n=5)

TABLE 7: **Average, minimum and maximum levels of heavy metals in fish** collected from Ihutai /Avon-Heathcote Estuary and Christchurch's main rivers (Ōtākaro/Avon River, Ōpāwaho/Heathcote River) in 2019. (Maximum value for each metal is highlighted) (BDL = below detection limits)

		Lead			Arsenic			Copper			Zinc			PCBs
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	
Yellowbelly flounder	Estuary	*BDL*	*BDL*	*BDL*	0.36	0.26	0.46	0.12	0.08	0.15	3.16	2.50	3.90	*BDL*
Yelloweyed mullet	Estuary	0.34	0.21	0.42	0.57	0.44	0.75	0.72	0.68	0.85	18.44	15.90	22.00	*BDL*
Shortfin eel	Ōtākaro/Avon River	*BDL*	*BDL*	*BDL*	*BDL*	*BDL*	*BDL*	0.15	0.14	0.18	6.92	6.20	7.60	*BDL*
	Ōpāwaho/Heathcote River	*BDL*	*BDL*	*BDL*	0.05	0.05	0.05	0.21	0.17	0.25	9.06	7.70	10.70	*BDL*

FIGURE 4 **Heavy metal levels in fish** collected from Avon-Heathcote Estuary/ Ihutai and Christchurch's main rivers (Ōtākaro/Avon River, Ōpāwaho / Heathcote River) in 2019. For graphing purposes, results that were below the laboratory detection limit were included at half the detection limit level – this applied to arsenic levels in shortfin eels only.

(average + 1 std error – indicated by the lines above the bars)




Yellowbelly flounder

5 Are Fish & Shellfish Safe to Eat?

Heavy Metals:

The shellfish (cockles, pipi) and fish (yelloweyed mullet, yellowbelly flounder, shortfin eel) all had metal concentrations (e.g., cadmium, lead, arsenic) below the FSANZ (2015) limits. There are no current ANZFSC limits for copper and zinc. Thus based on heavy metal levels with known food standards, these fish and shellfish are safe for consumption. However, levels of lead in yelloweye mullet were approaching the food safety limit in some samples.

PCBs:

All PCBs that were tested for in fish (yelloweyed mullet, yellowbelly flounder, shortfin eel) were below the laboratory detection limits of 0.04 mg/kg, meaning they are safe for consumption in relation to PCBs.

E. coli:

E. coli levels in shellfish collected from the Causeway and Southshore sites were at a safe level for food consumption based on the food standards set under the ANZFSC and the commercial standards in the 'Regulated Control Scheme – Bivalve Molluscan Shellfish for Human Consumption' (MPI, 2018). However, *E. coli* levels at the WTP site varied widely and exceeded a number of food safety limits under both the ANZFSC and MPI (2018) standards – they are not safe to consume. *E. coli* and other pathogen levels in shellfish can vary greatly over time, so caution must always be applied to collecting shellfish – even though the results have shown safe levels at two of the three monitored sites, these values could change following large rain events or at other times of the year.

E. coli are often used as a indicator organism, signalling the presence of pathogens from faecal material – meaning that high levels of *E. coli* could also indicate the presence of other pathogens that may be harmful for human consumption. Past monitoring by EOS Ecology has found elevated levels of both *E. coli* and norovirus in shellfish collected around the estuary, with elevated levels related to sewage overflow events (such as following the Christchurch earthquakes and during large rain events), but also during otherwise stable weather (McMurtrie & Hewitt, 2013). Enteric viruses such as norovirus are highly contagious and can survive freezing, meaning that care must be taken when preparing shellfish collected from the estuary. Guidance can be found at www.foodsmart.govt.nz/food-safety/foodborne-illnesses/norovirus, as well as following the warning signs maintained by the CCC around the estuary. Given the wide fluctuations in *E. coli* levels in cockles from some locations, it would be ideal to test for *E. coli* and enteric viruses in shellfish around the estuary on a more regular basis, and to try to determine what may be the cause of the fluctuations.

Are fish and shellfish safe to eat based on heavy metal and PCB levels according to the ANZFSC?

		Arsenic (inorganic)*	Cadmium	Lead	Copper	Zinc	PCBs
COCKLE	Causeway	✓ SAFE	✓ SAFE	✓ SAFE	*no limit*	*no limit*	*no limit*
	WTP	✓ SAFE	✓ SAFE	✓ SAFE	*no limit*	*no limit*	*no limit*
	Southshore	✓ SAFE	✓ SAFE	✓ SAFE	*no limit*	*no limit*	*no limit*
PIPI	Estuary mouth	✓ SAFE	✓ SAFE	✓ SAFE	*no limit*	*no limit*	*no limit*
EELS	Ōpāwaho/Heathcote River	✓ SAFE	*no limit*	✓ SAFE	*no limit*	*no limit*	✓ SAFE
	Ōtākaro/Avon River	✓ SAFE	*no limit*	✓ SAFE	*no limit*	*no limit*	✓ SAFE
YELLOWEYED MULLET	Estuary	✓ SAFE	*no limit*	✓ SAFE	*no limit*	*no limit*	✓ SAFE
YELLOWBELLY FLOUNDER	Estuary	✓ SAFE	*no limit*	✓ SAFE	*no limit*	*no limit*	✓ SAFE

* based on estimate that inorganic arsenic is 10% of total arsenic

Are cockles safe to eat based on *E. coli* levels according to the Australian New Zealand Food Standards Code (ANZFSC) and the MPI (2018) regulations?

Note that because *E. coli* levels can fluctuate widely at different times of year caution must always be applied to their consumption, especially from an estuary affected by urban and rural land use.

		E.coli	What food safety standards are exceeded
COCKLE	Causeway	✓ SAFE (but caution applied)	*no limits exceeded*
	WTP	✗ UNSAFE	Exceeds food safety standards under ANZFSC
			Exceeds food safety standards under MPI (2018)*
	Southshore	✓ SAFE (but caution applied)	*no limits exceeded*

* MPI (2018) covers the regulations for commercial shellfish growing areas, but are nevertheless interesting to compare to here.

Collecting cockles at
McCormacks Bay causeway

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Flounder caught in net
in the Estuary

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