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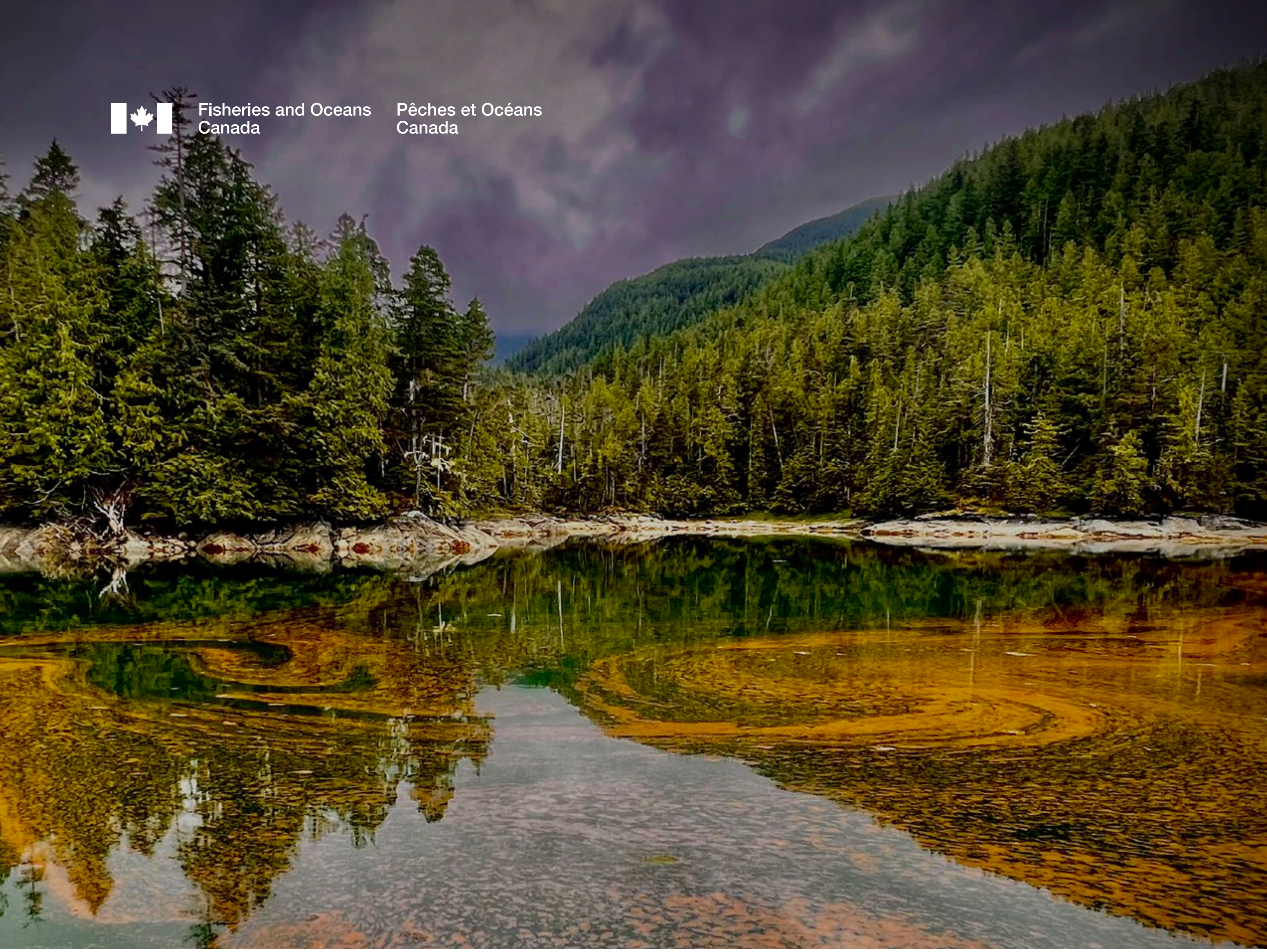

Follow the Fish

The WCVI Follow the Fish Program

One of British Columbia's most important natural resources:
Chinook salmon from the West Coast of Vancouver Island (WCVI)

Monitoring Biotoxins and Contaminants and their Impacts on WCVI Chinook Salmon

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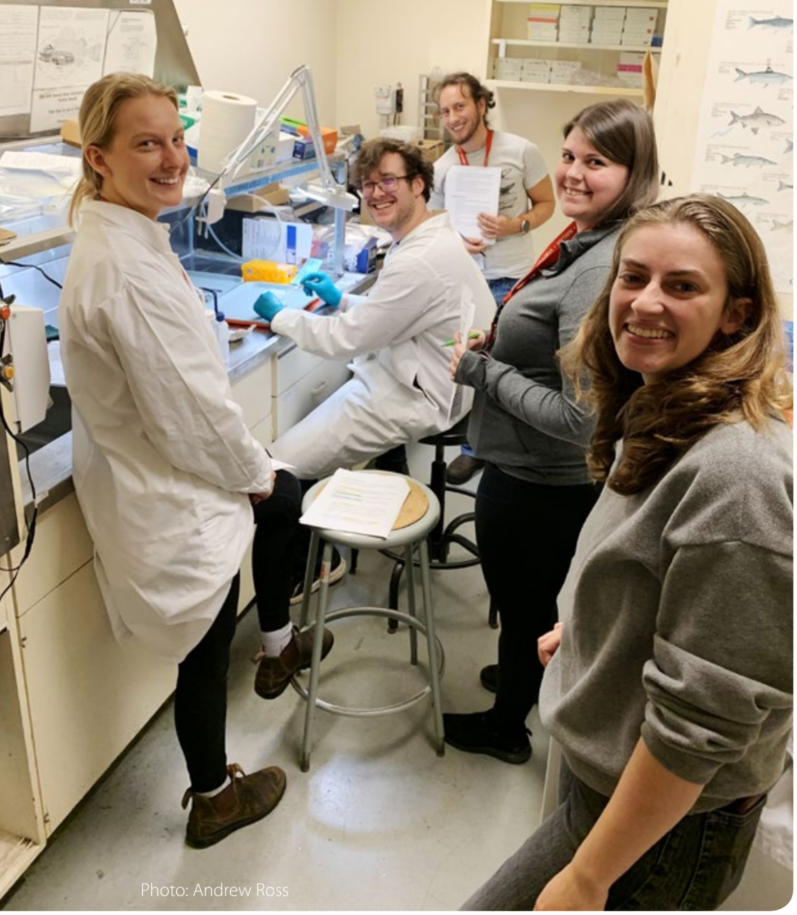
Canada



Juvenile Chinook salmon are dissected to obtain gill, liver and other tissues for biotoxin analysis.

Salmon are exposed to various types of stress throughout their lives, some of which can impact their growth and survival. As part of DFO's Pacific Salmon Strategy Initiative (PSSI) Follow the Fish Program, DFO scientists and partners are investigating the risks posed by algal biotoxins and environmental contaminants to juvenile West Coast Vancouver Island Chinook salmon. Their research will help us to better understand and predict the effects of these chemical stressors on the health and productivity of WCVI Chinook and other Pacific salmon populations.

What are biotoxins and contaminants?

Biotoxins

Biotoxins are poisonous chemicals produced naturally by certain types of marine phytoplankton known as harmful algae. These include species of diatoms and dinoflagellates found in British Columbia coastal waters (Table 1).

Table 1. Biotoxins found regularly in B.C. coastal waters and the harmful algae that produce them.

Biotoxin(s)	Harmful Algae	Impact on Human Health	Impact on Marine Life
Domoic Acid	*Pseudo-nitzschia* species (diatoms)	Amnesic Shellfish Poisoning (ASP)	Toxic to marine mammals
Saxitoxins	*Alexandrium* species (dinoflagellates)	Paralytic Shellfish Poisoning (PSP)	Toxic to juvenile fish
Dinophysistoxin 1 Pectenotoxin 2	*Dinophysis* species (dinoflagellates)	Diarrhetic Shellfish Poisoning (DSP)	Unknown
Yessotoxin	*Protoceratium reticulatum* and *Gonyaulax spinifera* (dinoflagellates)	Unknown	Toxic to shellfish

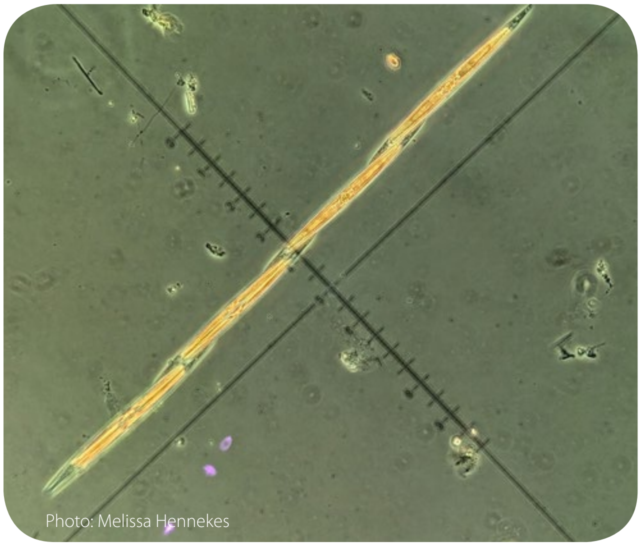
What are Harmful Algal Blooms?

Phytoplankton or microalgae are microscopic plants that form the basis of the marine food web. They also remove carbon dioxide (a 'greenhouse gas') from the atmosphere and supply half the oxygen that we breathe. Harmful algal blooms (HABs) are caused by the rapid growth of phytoplankton that produce poisonous substances, called biotoxins, or otherwise cause harm (for example, by physically damaging fish gills or using up oxygen in the water when they decompose). Like all plants, phytoplankton need sunlight and nutrients to grow. Marine algal blooms occur naturally in the spring and, sometimes, in the fall when conditions are good for phytoplankton growth (e.g. clear skies and coastal upwelling, which brings nutrients to the surface). Surplus nutrients introduced by agricultural or urban run-off can result in excessive growth of algae, including those that cause harm to other marine life. Warming ocean temperatures associated with climate change may also promote HABs. This was seen in 2015 when algae that produce the biotoxin domoic acid (which has been severely harming Californian marine mammals) grew rapidly during a marine heatwave in the northeast Pacific. Nutrient stress following the rapid consumption of nutrients during algal blooms may also be linked to the production of biotoxins by harmful algae.

A bloom of *Noctiluca scintillans*, which may harm other marine organisms by releasing ammonia.

Some *Alexandrium* cells produce saxitoxins, which can cause paralytic shellfish poisoning and harm juvenile fish.

Some *Dinophysis* cells produce biotoxins responsible for diarrhetic shellfish poisoning in humans.



Some *Pseudo-nitzschia* cells produce domoic acid, which causes amnesic shellfish poisoning and can harm marine mammals.

Water samples collected from small vessels are filtered on board using a filter holder and vacuum pump.

Domoic acid, a neurotoxin that causes amnesic shellfish poisoning (ASP) in humans, can severely affect the health of marine mammals with symptoms ranging from heart disease and reproductive problems to aggression, disorientation and mortality. Saxitoxins, which cause paralytic shellfish poisoning (PSP), are known to harm juvenile fish and are of particular concern for young salmon. Larger biotoxin molecules like dinophysistoxins, pectenotoxins and yessotoxin are less soluble in water than domoic acid or saxitoxins and may, therefore, accumulate The aim of the research carried out by the biotoxin team at DFO is to determine when and where juvenile salmon are exposed to algal biotoxins, whether or not they accumulate in salmon tissues, and how they may affect the health and survival of WCVI Chinook salmon and their predators, including southern resident killer whales.

Contaminants

Marine organisms face a wide array of contaminants including plastics, chemical pollutants, oil spills, and some would also include both light and noise pollution in this category. Chemical pollutants include:

- Heavy metals such as mercury, cadmium and lead, are natural occurring elements that at high levels pose health risks to organisms. While they are not man-made, anthropogenic activities have increased levels in the atmosphere and marine and aquatic systems;
- Persistent Organic Pollutants (POPs) are man-made chemicals that are persistent (do not readily break down in the environment or metabolize in organisms) and therefore remain in ecosystems long after their use. Examples of POPs include PCBs, PBDEs and pesticides, many of which are regulated or have been phased out; despite this they remain prevalent in our environment and in marine food webs. Due to their common lipid-loving chemical structures they typically accumulate in fatty tissues, putting marine mammals (which have high lipid reserves (i.e. blubber)) at risk of the associated endocrine and immune disrupting impacts;
- Nutrient pollution caused by the release of excess nutrients like nitrogen and phosphorus from agricultural runoff and sewage results in eutrophication, causing harmful algal blooms and oxygen depletion, and potentially creating nearshore 'dead zones';
- Pharmaceuticals and Personal Care Products (PPCPs), microplastics and associated chemicals, and fluorinated chemicals fall within a new class of chemicals referred to as CECs; or Chemicals of Emerging Concern. PPCPs include a diverse group of chemicals such as pharmaceuticals (e.g. ibuprofen), food additives (e.g. sucralose) and toiletries, which can enter waterways and affect marine life, potentially disrupting key physiological endpoint points; and
- Petroleum-associated chemicals resulting from oil spills from accidents or leaks are difficult to contain when released into aquatic and marine ecosystems and can impact marine life by coating marine organisms, damaging habitats, and have long-lasting ecological effects.

Chemical contaminants can impact survival of Pacific salmon by impairing their reproductive, immune, respiratory, neurological and endocrine systems. Those known to impact Pacific salmon and the specific effects are shown in Table 2 (next page).

Chemical contaminants are typically produced by human activities such as resource extraction, industrial processes and manufacturing, transportation, and improper waste treatment. Once they have entered aquatic ecosystems (either via air or water) they can enter the food web (**Figure 1**). Many of these contaminants are known to be persistent in the environment, remaining long after their use, and many can travel long distances; additionally they are not readily metabolized or broken down in organisms, resulting in their bioaccumulation over the life time of an individual Chinook as well as the biomagnification of these compounds to their predators including the Southern Resident Killer Whales (next page).

Figure 1. Chemical contaminants are released into the environment via human-related activities, entering the marine food web through air and by direct deposit into water, and accumulating in all trophic levels of the food web.

Table 2. Known impacts on fish and salmonids for PCBs, PBDEs, DDT and mercury as reported in the literature.[1]

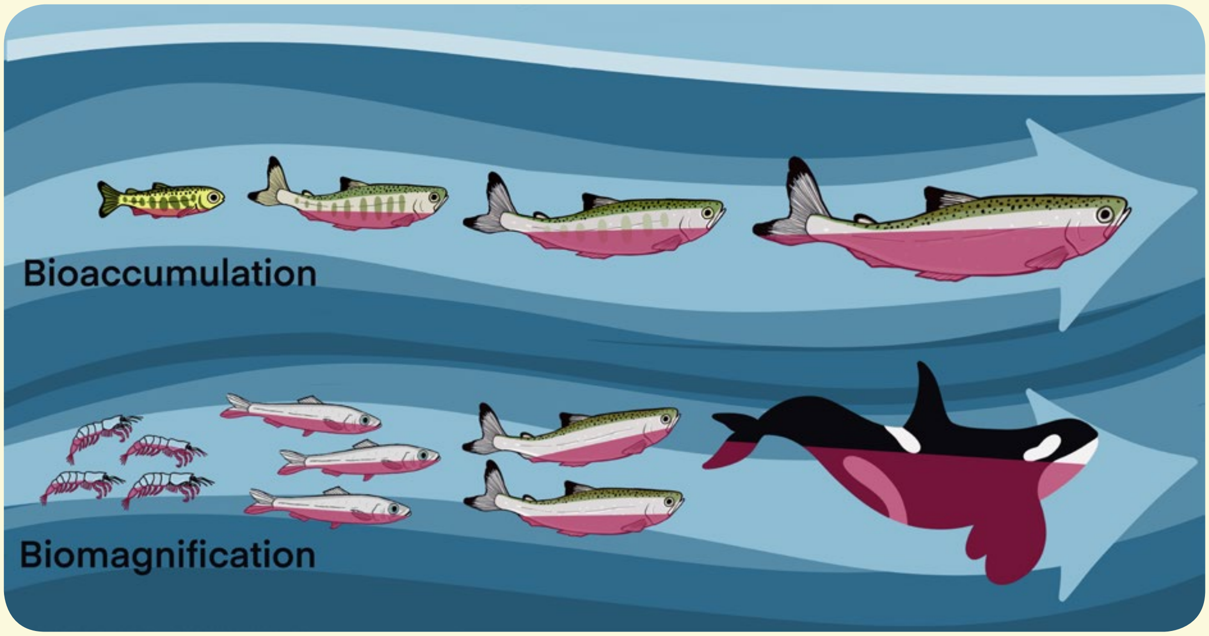
Contaminants	Species	Impact
PCBs	Various juvenile salmonids	Biochemical and immune system effects
	Fish	Growth, reproduction, mortality
PBDEs	Juvenile Chinook salmon	Increased disease susceptibility
	Juvenile Chinook salmon	Altered thyroid
Sum DDT	Juvenile and adult fish	Effects on behaviour and growth, mortality
Mercury	Juvenile and adult fish	Sublethal effects (growth, reproduction, behaviour)

1. Noël, M., Loseto, L.L., Colbourne, K., Bartlett, M., Bokvist, J., and Brown, T.M. 2025 Contaminant concentrations in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) collected from the West Coast of Vancouver Island, British Columbia, in 2022. Can. Tech. Rep. Fish. Aquat. Sci. 3655: vii + 20 p.

What are Bioaccumulation and Biomagnification?

Bioaccumulation: is the increase of contaminants in an organism over time due to their inability to metabolize and eliminate them, as they bind to fats or proteins and increase in an organism over its life time. Thus, older animals will have higher contaminant burdens or tissue concentrations.

Biomagnification: at each trophic level the contaminant will amplify, often an order of magnitude, putting top predators of long food webs at risk.



Comparing Biotoxins and Contaminants

Biotoxins are produced by harmful algae in sea water, possibly in response to stressful conditions (like higher temperatures and nutrient limitation) related to climate change, whereas contaminants can be introduced into the marine environment as a result of their usage, emission, or disposal. Though both are toxic, the biotoxins are natural or biological toxins, while chemical contaminants are anthropogenic (or human-caused). Certain biotoxins (e.g. PSP toxins) are known to cause respiratory distress and paralysis in young fish while exposure to contaminants can result in death, illness, or reproductive failure.

This photo and the cover photo are images of a Noctiluca bloom in BC, taken by Ginny Sherrow

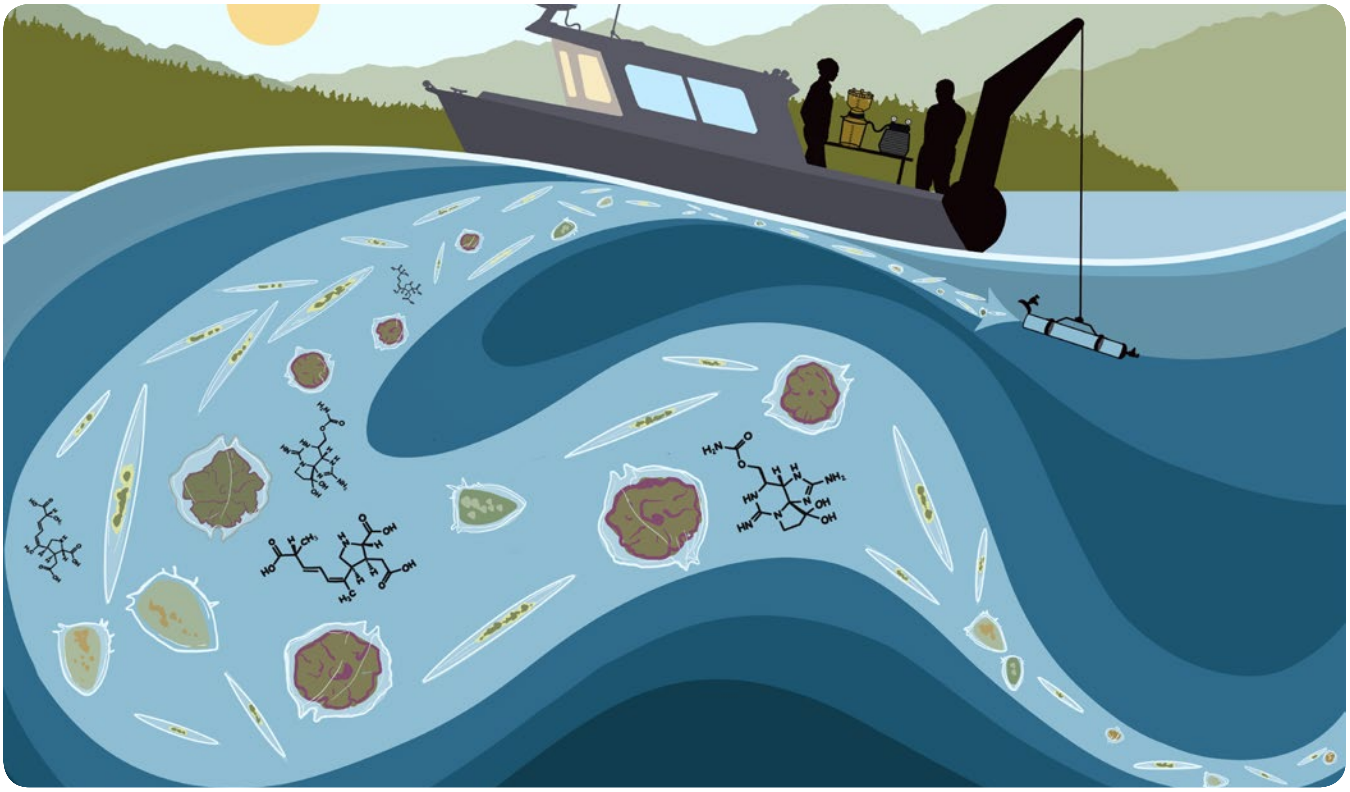


Figure 2. Boat-based collection of seawater for biotoxin analysis.

The Follow the Fish Biotoxin Monitoring Program

The DFO biotoxin team has been measuring biotoxins in Clayoquot Sound on the West Coast of Vancouver Island since fall 2020 using a method developed as part of their Marine Biotoxin Monitoring Program.[2] Surface seawater is collected monthly at each study location using a sampling bottle (**Figure 2**), then filtered to separate biotoxins present in algal cells from those dissolved in the water. The filter and filtered seawater are both analyzed for biotoxins using a technique called liquid chromatography-tandem mass spectrometry (**Figure 4**) and the results combined to obtain the total concentration of each biotoxin in the original sample.[3]

In fall 2023 the team started monitoring biotoxins in Barkley Sound at locations close to where juvenile salmon were being caught and studied as part of the Follow the Fish program (**Figure 3**). Their results show that, just as in Clayoquot Sound, PSP toxins known to harm juvenile fish tend to peak during August and September while other biotoxins follow similar seasonal patterns (**Figure 5**). By analyzing the same biotoxins in the gills and livers of fish caught in Barkley Sound they have also shown that biotoxin levels in these tissues reflect those in the surrounding sea water (**Figure 6**). Their findings confirm that ***young Chinook salmon are being exposed to biotoxins in their critical habitat.*** and that exposure and impacts are likely to reflect any future changes in the production of biotoxins by harmful algae due to climate change, pollution, or other factors.

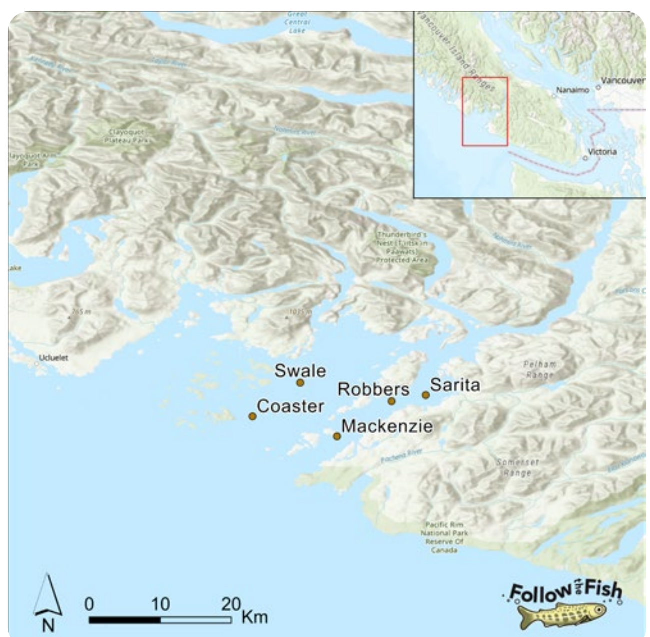


Figure 3. Map of Barkley Sound showing where sea water is collected for biotoxin analysis.

2. Ross, A.R.S., Mueller, M. 2024. Monitoring Harmful Algal Biotoxins in British Columbia Coastal Waters. *PICES Press*, 32(2), 37-39.

3. Ross, A.R.S., Ip, B., Mueller, M., Surridge, B., Hartmann, H., Hundal, N., Matthews, N., Shannon, H., Hennekes, M., Sastri, A., Perry, R.I. 2025. Seasonal monitoring of dissolved and particulate algal biotoxins in the northern Salish Sea using high performance liquid chromatography and tandem mass spectrometry. *Harmful Algae* 145, 102854.

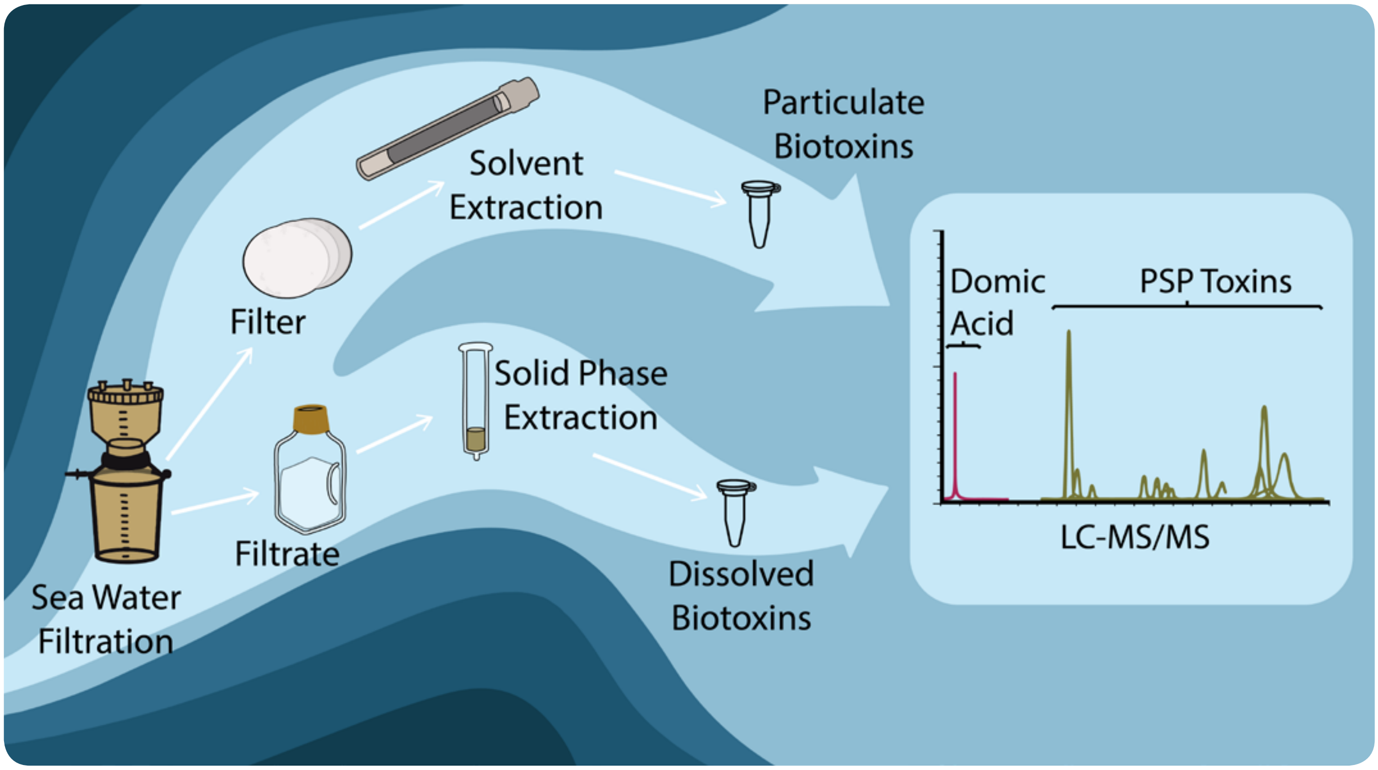


Figure 4. Analysis of biotoxins in sea water using liquid chromatography-tandem mass spectrometry (LC-MS/MS).

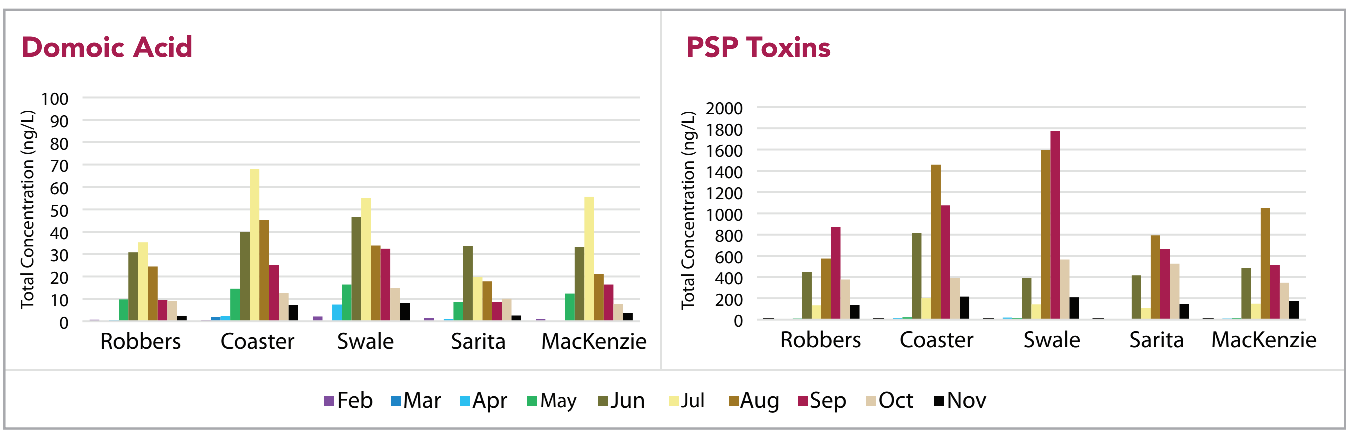


Figure 5. Seasonal distribution of biotoxins (left- domoic acid, right-PSP toxins) in Barkley Sound during 2024.

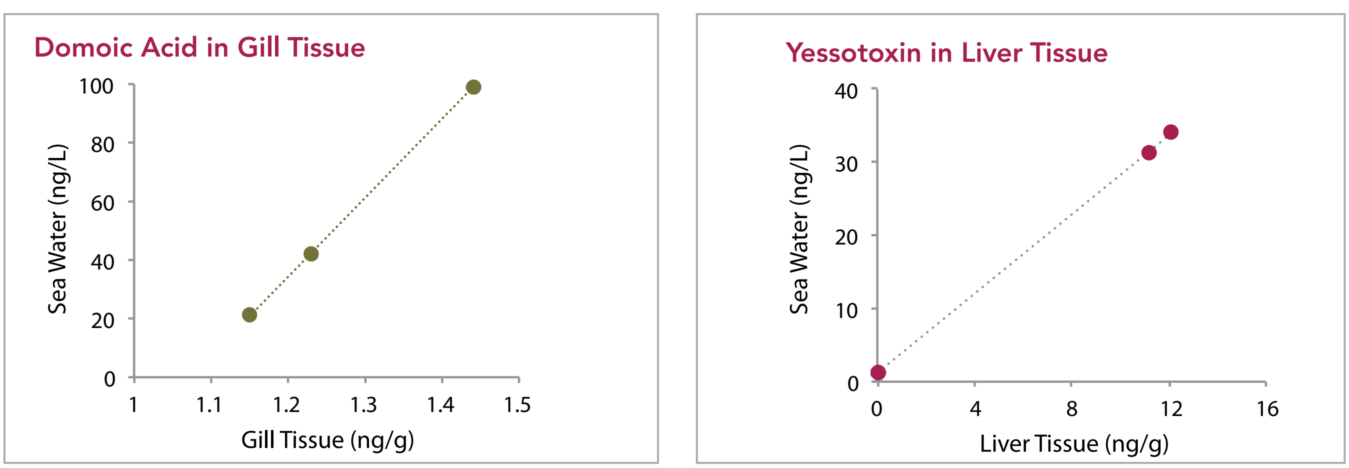


Figure 6. Biotoxin uptake in juvenile Chinook salmon tissues at the sampling location Coaster in Barkley Sound during fall 2023.

Dr. Andrew Ross Bio

Dr. Andrew Ross is a Research Scientist at the DFO Institute of Ocean Sciences in Sidney, B.C. Born and raised in England, Andrew first became fascinated by the ocean during summer holidays on the south coast and learned to SCUBA dive while studying for a B.Sc. in Chemistry at the University of Surrey. He earned his Ph.D. in Analytical and Marine Chemistry from the University of British Columbia, then led research in plant proteomics at NRC before joining DFO where he established the Marine Biotoxin Monitoring Program in 2020. Andrew is lead scientist on the PSSI project to investigate the levels and potential health impacts of exposure to biotoxins produced by harmful algae in Pacific salmon on the west coast of Vancouver Island.

Dr. Andrew Ross

The Follow the Fish Contaminants Monitoring Program

To start the program the DFO contaminants team first wanted to characterize the levels of contaminants present in WCVI juvenile Chinook salmon and this was achieved by measuring a total suite of 13 contaminant classes, with over 700 analytes. Analytes represent the group of individual constitutes of chemicals of similar structure within one contaminant class, for example there are 209 analytes or congeners of PCBs that reflect slight modifications of the chemical structure of PCBs (e.g. number of chlorine atoms), and they will also differ in their toxicity profiles. These contaminants are measurable by commercial laboratories and have been deemed a chemical of concern. The 13 classes examined included: legacy and current use pesticides, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), dioxins and furans, per- and polyfluoroalkyl substances (PFAS), polycyclic aromatic hydrocarbons (PAHs), pharmaceutical and personal care products (PPCPs), alkylphenols, hexabromocyclododecane (HBCDD), polychlorinated paraffins, brominated and chlorinated flame retardants and metals including mercury.

This first sweep of analyses were carried out on Robertson Creek juvenile Chinook collected from the nearshore of marine waters of Barkley Sound in July 2022. Due to the low individual fish weights, multiple individuals were used to create two composite samples to enable the large suite of contaminant analyses to be performed, in addition to the analyses of δ15N and δ13C stable isotopes. Nitrogen and stable isotope data provide information about the trophic status and habitat which provides additional context on foraging and exposure to chemical contaminants.

Results from this study are the first of its kind with limited data only available for urbanized areas such as Puget Sound, WA. Results revealed metals, PAHs and PCBs to be the top three contaminants measured at highest concentrations. Overall levels measured were generally lower than levels observed in juvenile Chinook in heavily urbanized habitats in and near Puget Sound (Figure 7). When comparing the concentrations of contaminants in Robertson Creek juvenile Chinook in the present study to established effects thresholds for fish, results suggest that ***Robertson Creek juvenile Chinook salmon from Barkley Sound are at low risk of contaminant associated health impacts***, specifically PCBs, PBDEs, DDT, PAHs and mercury. However, these findings are based on a low sample size and further analyses are warranted.

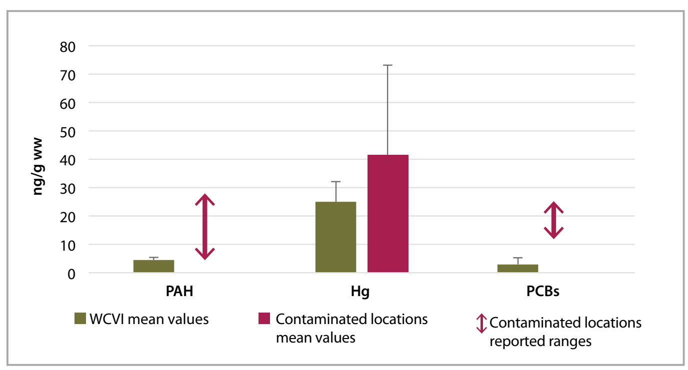


Figure 7. Average concentrations of PAH, mercury (Hg) and PCB contaminants in WCVI juvenile salmon through the Follow the Fish Program, compared with ranges (PAH and PCBs) and average values (Hg) recorded in the literature for more urbanized locations.[4]

4. Lundin, J.I., Chittaro, P.M., Ylitalo, G.M., Kern, J.W., Kuligowski, D.R., Sol, S.Y., Baugh, K.A., Boyd, D.T., Baker, M.C., Neely, R.M., King, K.G., Scholz, N.L. 2021. Decreased Growth Rate Associated with Tissue Contaminants in Juvenile Chinook Salmon Out-Migrating through an Industrial Waterway. *Environmental Science & Technology* 55 (14), 9968-9978

Henery, R.E., Sommer, T.R., Goldman,C.R. 2010. Growth and Methylmercury Accumulation in Juvenile Chinook Salmon in the Sacramento River and Its Floodplain, the Yolo Bypass, *Transactions of the American Fisheries Society*, Volume 139, Issue 2, March 2010, Pages 550–563

O'Neill, S.M., Carey, A.J., Harding, L.B., West, J.E., Ylitalo, G.M., Chamberlin, J.W. 2020. Chemical tracers guide identification of the location and source of persistent organic pollutants in juvenile Chinook salmon (*Oncorhynchus tshawytscha*), migrating seaward through an estuary with multiple contaminant inputs. Science of the Total Environment, Volume 712: 135516

Dr. Lisa Loseto Bio

Dr. Lisa Loseto is a Research Scientist that joined the Institute of Ocean Sciences (IOS) in 2024, and prior she was based out of DFO's Freshwater Institute where her research focused on beluga health as means to understand ecosystem health, a program that partnered with the Inuvialuit. In her new position at IOS, she leads the Centre of Expertise for whale contaminant research and the Whales Initiative program targeting two of Canada's endangered and most contaminated marine mammal populations, the Southern Resident Killer Whale and the St. Lawrence Beluga. In understanding exposure of contaminants to endangered whales, Lisa is characterizing exposure in key prey such as Chinook salmon and sources to the region measured and monitored through sediment programs. Lisa obtained a B.Sc. Honours at York University in Toronto, a M.Sc. in toxicology at the University of Ottawa, and a PhD in zoology from the University of Manitoba.

Photo: Jasmine Brewster

Dr. Lisa Loseto

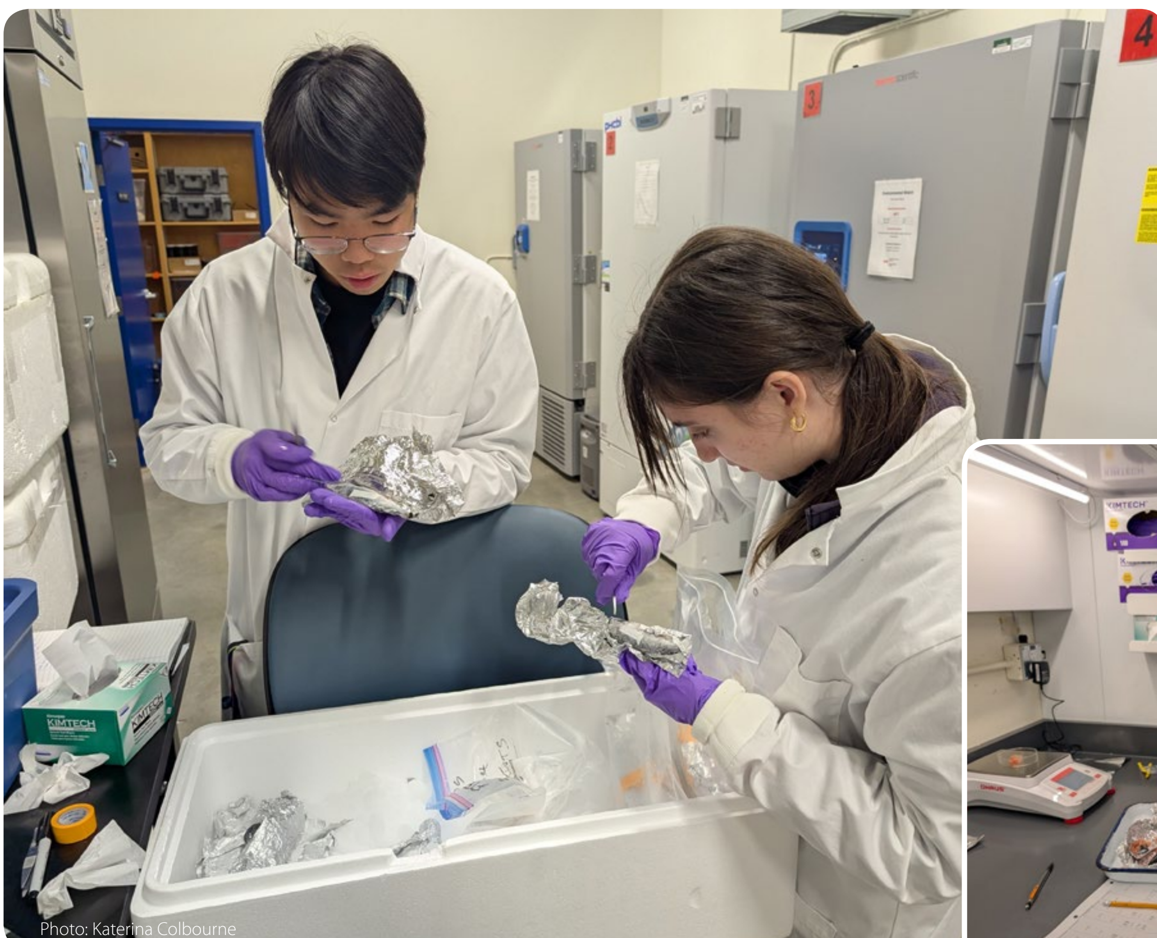


Photo: Katerina Colbourne

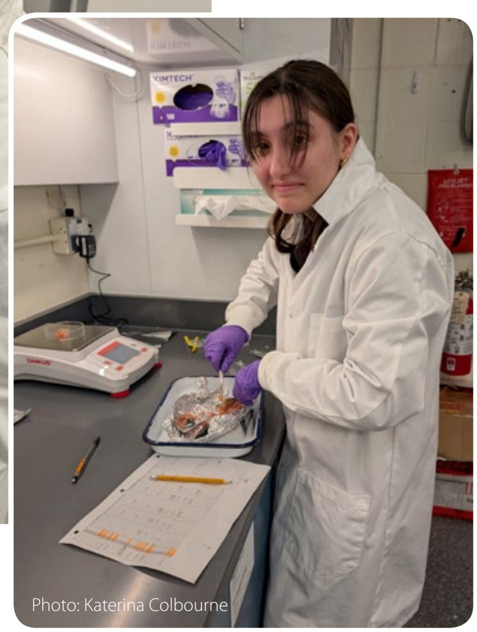


Photo: Katerina Colbourne

DFO biologists dissecting Pacific salmon tissues for contaminant analysis.

Photo: Marie Noel (+ use of AI)

Next Steps

The DFO biotoxin team are continuing their investigation of the effects of biotoxin exposure on juvenile salmon, and the linkages between biotoxin production by harmful algae and environmental conditions like water temperature and nutrient levels. Their ultimate goal is to better understand and predict the future impact of biotoxins on the growth and survival of WCVI Chinook salmon in a changing climate. Meanwhile, their ***discovery of seasonal patterns in biotoxin production is being used to mitigate their impact on local salmon populations*** by timing the release of hatchery fish to coincide with lower biotoxin concentrations.

For the DFO contaminants team, the findings from the first year helped narrow their target analyses of contaminants allowing them to focus on the highest three most predominant contaminants: metals, PAHs and PCBs, using a larger sample size of juvenile Chinook. They are currently examining these compounds throughout the sample season, following WCVI juvenile Chinook from the summer to the spring of the following year to understand temporal changes in contaminant loads.

While there may not be clear local sources resulting in the measured contaminants levels in WCVI juvenile Chinook, these chemicals are able to persist and travel over long ranges away from the original source, and thus the low levels likely reflect the distance from major sources such as the urban centres of Vancouver. Some contaminants like PCBs were banned in 1977 to prohibit the use and import of these chemicals, however their persistence means they are still prevalent in the environment. Other contaminants such as metals, including mercury, are naturally occurring elements, however anthropogenic activities have increased their presence in the environment (e.g. fossil fuel emissions). The Minamata Convention on mercury (UNEP) is working to reduce the human driven emissions of mercury. PAHs originate both from natural and anthropogenic sources: they may be released in forest fires and from crude oil, and human activities such as burning fossil fuels can also produce PAHs. In BC there are water and sediment quality guidelines for PCBs, PAHs and mercury levels in place to reduce exposure and contamination.

Next, to better understand the impacts of contaminants on WCVI juvenile Chinook the team will use targeted genomics to measure potential impacts at the molecular level. This is done by examining genes known to be impacted by contaminants. For example, contaminants are known to impact the endocrine system, so the association between thyroid and estrogen gene receptors and levels of measured contaminants may be used to infer potential effects.

Thank you to our Contaminant and Biotoxin teams!

- Katerina Colbourne
- Marie Noel
- Mackenzie Mueller
- Nicole LaForge

Thank you to our collaborators!

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- Cermaq Canada — Brian Nesbitt
- Pacific Salmon Foundation — Nicole Frederickson
- Snuneymuxw First Nation — John White
- Parks Canada — Erich Kelch

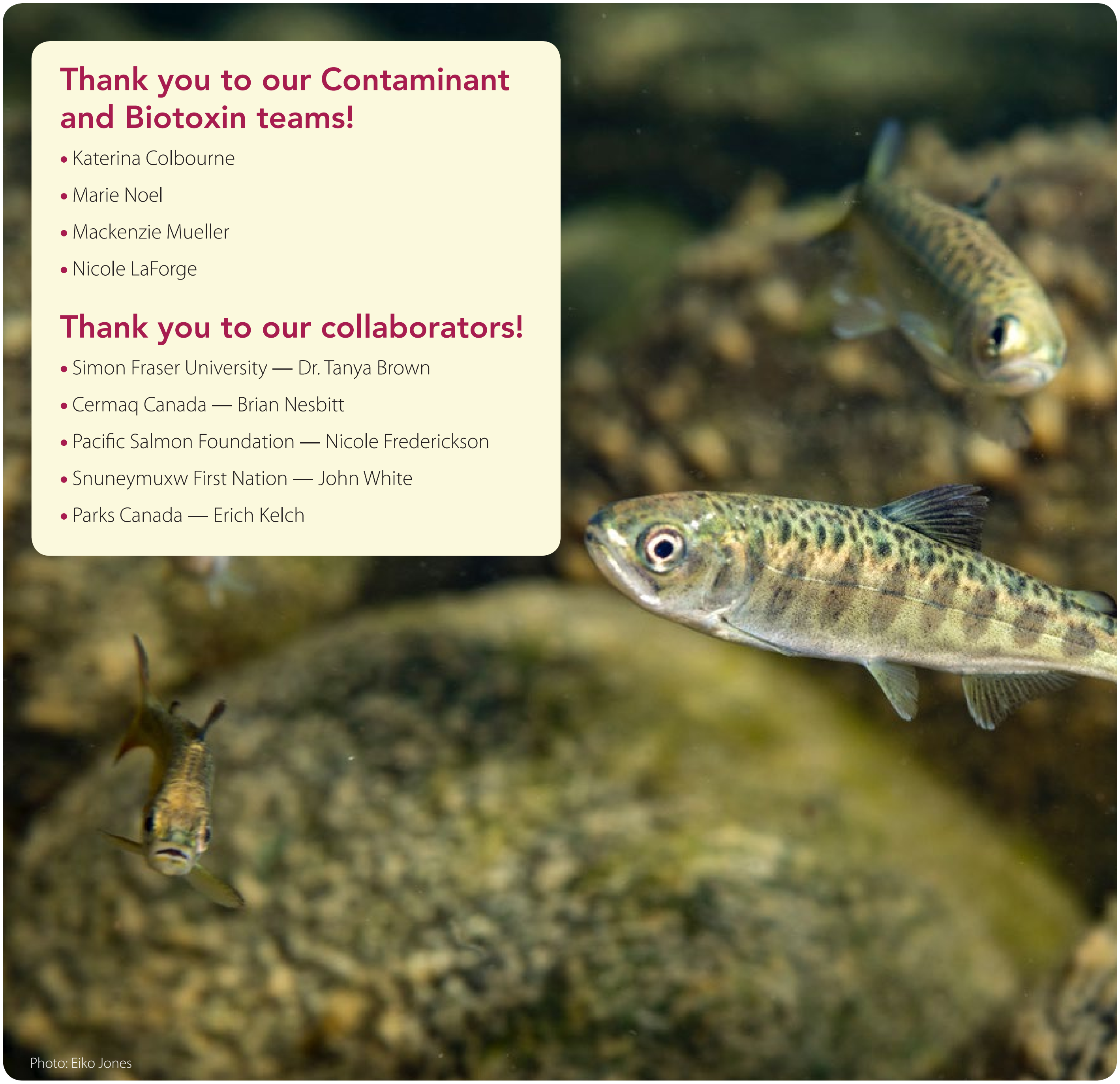

Photo: Eiko Jones

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New research and monitoring for Pacific salmon and their ecosystems. Follow the Fish Newsletter Vol. 3: 12 pp.

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