Characterizing tooth dentine trace element signatures over the lifespans of Northeast Pacific killer whales using Microchemistry

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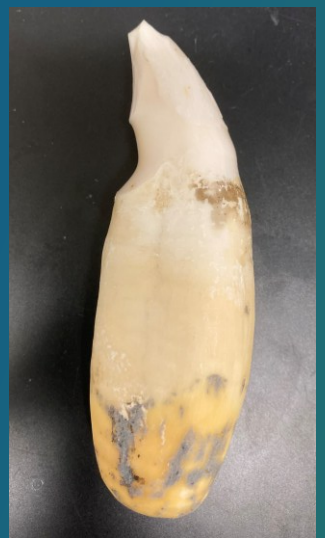
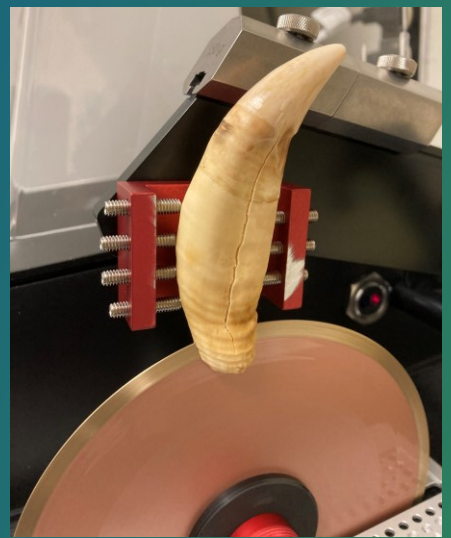
Fisheries and Oceans Canada | Pêches et Océans Canada









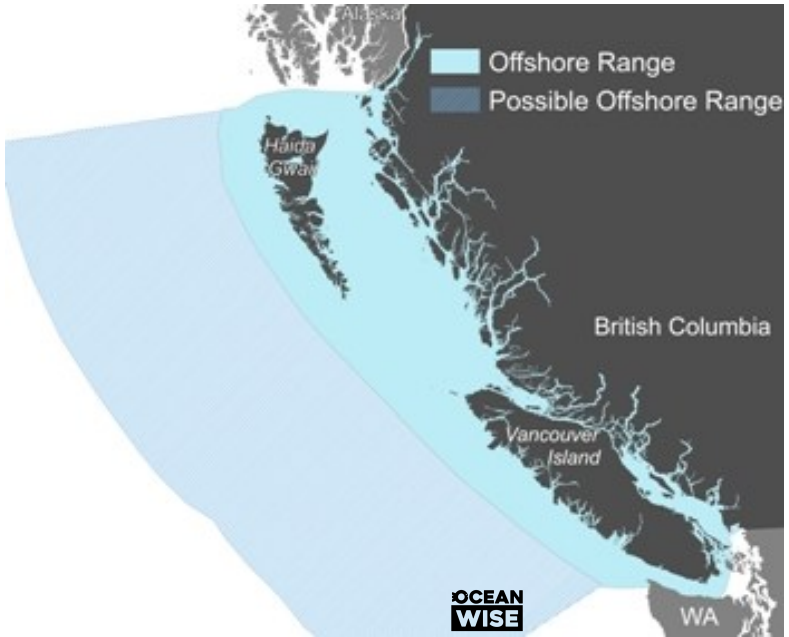




KW Ecotypes: recent subspecies status

- **Impetus:** All populations of killer whales (*Orcinus orca*) in the Northeast Pacific have population status designations of concern (COSEWIC 2024), therefore urgent need to be able to study the risks they face non-invasively:
  - Southern Residents: Endangered
  - Northern Residents: Threatened
  - Bigg's (Transients): Threatened
  - Offshores: Species of Special Concern





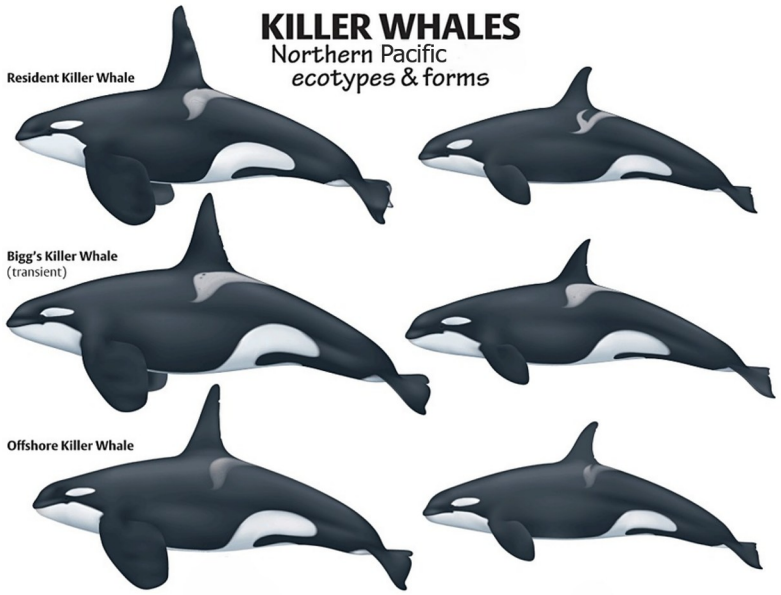


Figure modified from "Cultural traditions and the evolution of reproductive isolation: ecological speciation in killer whales?" Reisch et al. 2012.

Contaminants are one of the key stressors



Stressors:

- Decline in prey quantity/quality
- Increased shipping activity and associated impacts (i.e. noise)
- Anthropogenic contaminants

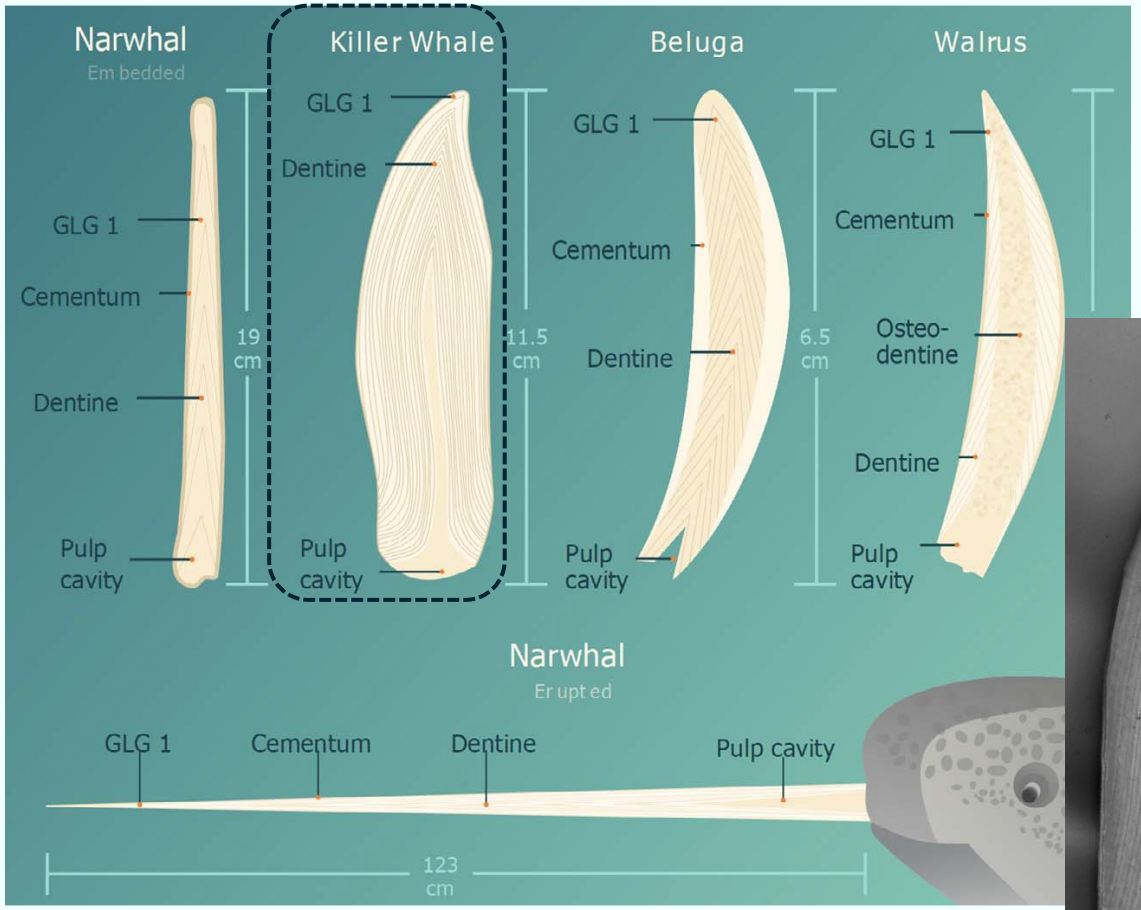
Contaminants:

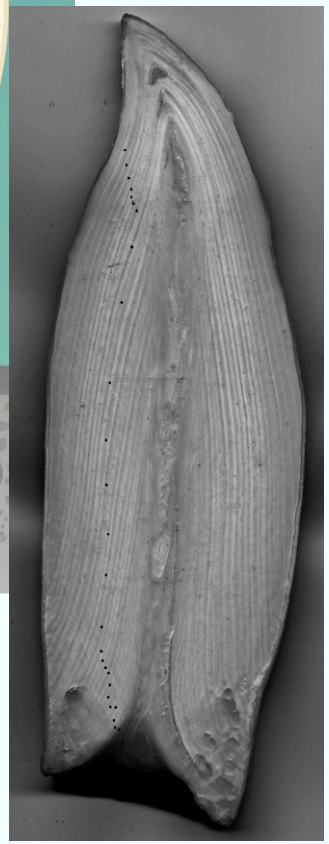
- Many classes of contaminants including metals and man-made organic chemicals used everyday.
- Contaminants of concern include those that do not readily break down (**p**ersistent), those that are **t**oxic and those that **b**ioaccumulate in food webs.
- *As part of the Whales Initiative program the contaminant team needs to characterize the exposure and effects associated with contaminants to inform regulatory processes*

Project Goal:

- Pilot project evaluating life history exposure and effects of environmental contaminants, through the use killer whale teeth from archival specimens.

KW Dentine Growth Layer Groups





Hudson et al., 2021

Toothed Whales:

- the only mammals that have a single set of teeth, thus preserving signals for the animal's entire life
- Growth layer groups (GLGs) of dentine are formed sequentially and preserve time resolved chemical signals enabling the measure of many compounds.

Archival Tooth KW Project:

- **Diet** – to inform foraging and exposure
  - $\delta^{15}N$, $\delta^{13}C$, others SI (IRMS, DFO-FWI)
- **Hormones** – toxicity endpoints (reproductive and stress)
  - Progesterone, testosterone, estradiol, cortisol etc. (LC-MS, DFO-IOS)
- **Trace metals** – informs on diet, physiology and exposure
  - Includes essential and non-essential

Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS)



Helium Gas

213 nm laser

sample chamber



detector

vacuum chamber

lenses

plasma

Produces data showing how element concentrations change over animal's lifetime

- **Archival Samples analysed:**
  - 14 adult and sub-adult teeth collected between 1945-2016
  - 4 fetal teeth (n=3 Resident, 1 unknown, all of unknown sex) collected between 1975-2014
  - Actively searching for more tooth samples to increase our sample size *(please email us if you can assist!)*

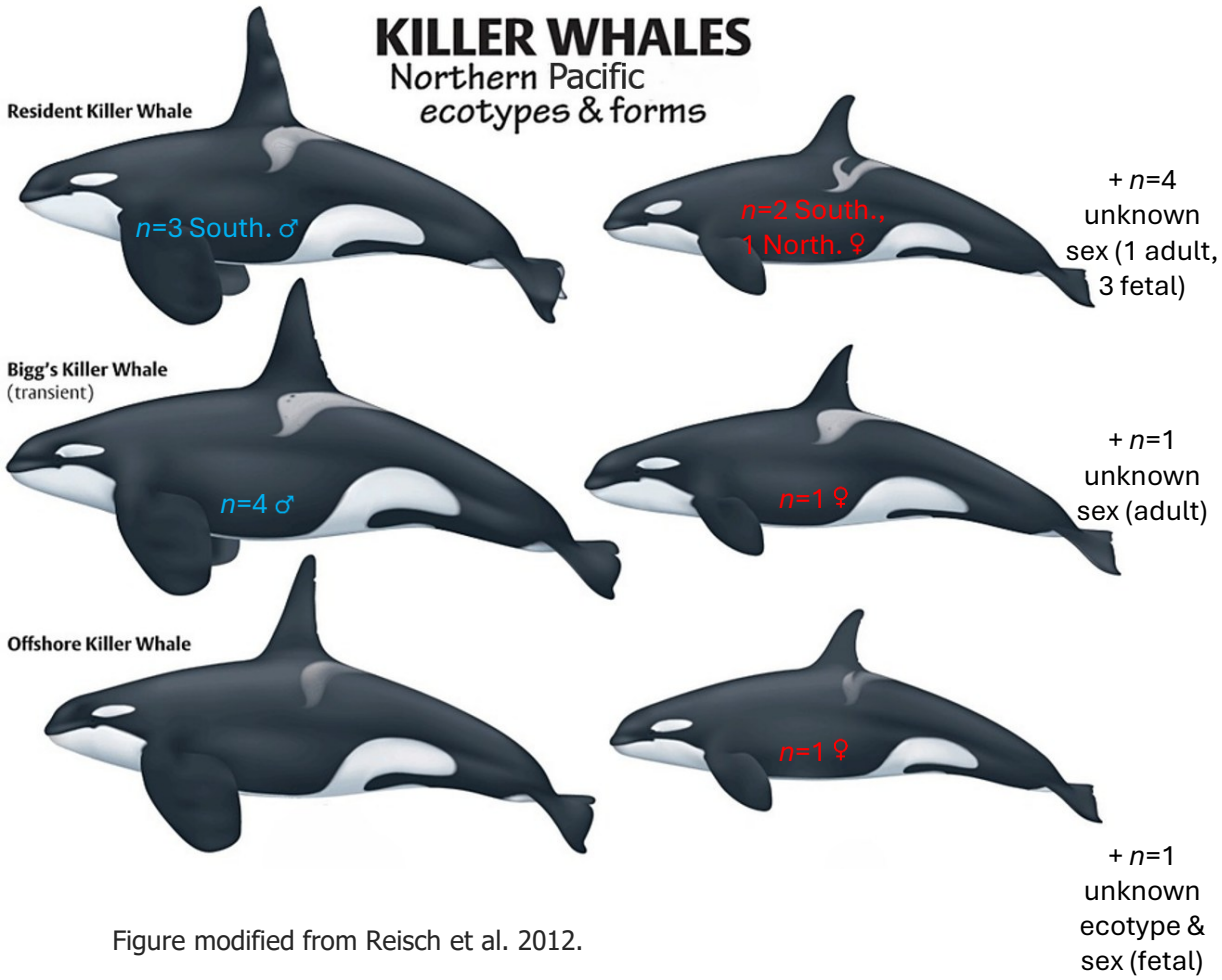


Figure modified from Reisch et al. 2012.

Preliminary Results

Trace metal analysis:

- magnesium, manganese, copper, zinc, strontium, barium & lead successful
- lithium, arsenic, rubidium, selenium and cesium were mostly below detection limits, but likely detectable with newer, more sensitive mass spectrometer *(coming soon!)*

Distance 8.140 mm

Laser transect

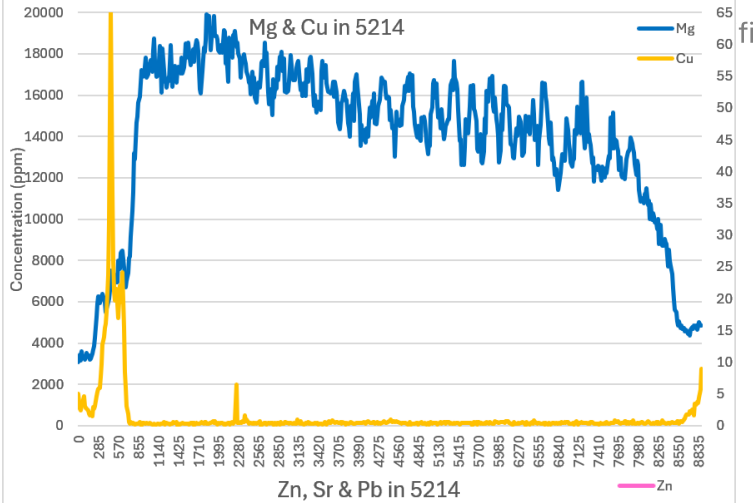
enamel

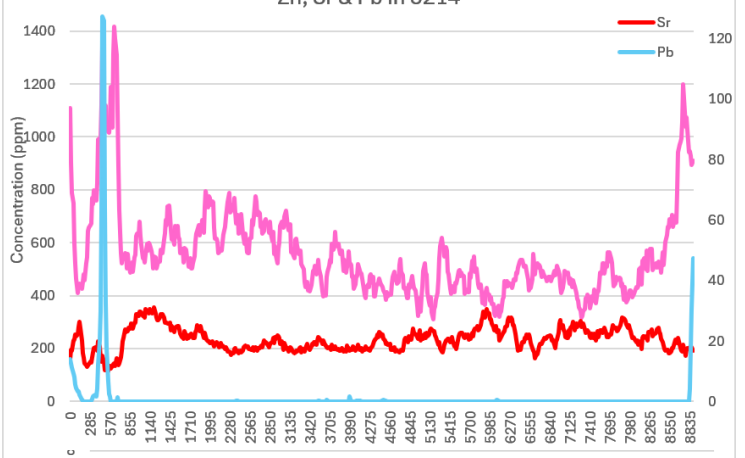
earliest layers

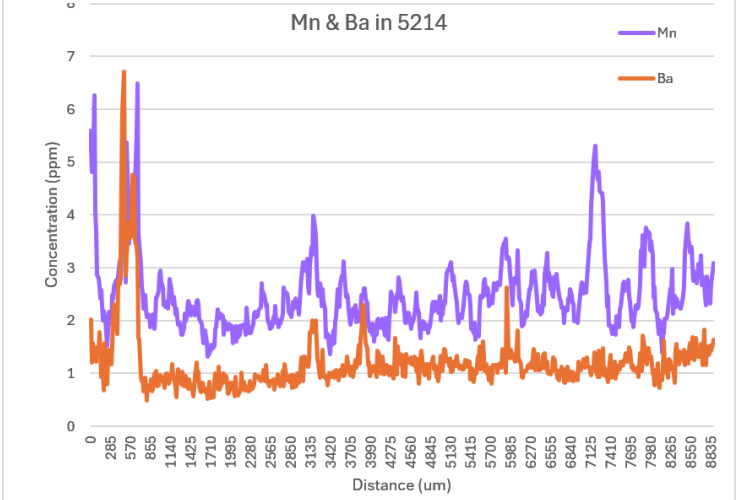
dentine growth layer groups (GLGs)

most recent layers

1 mm

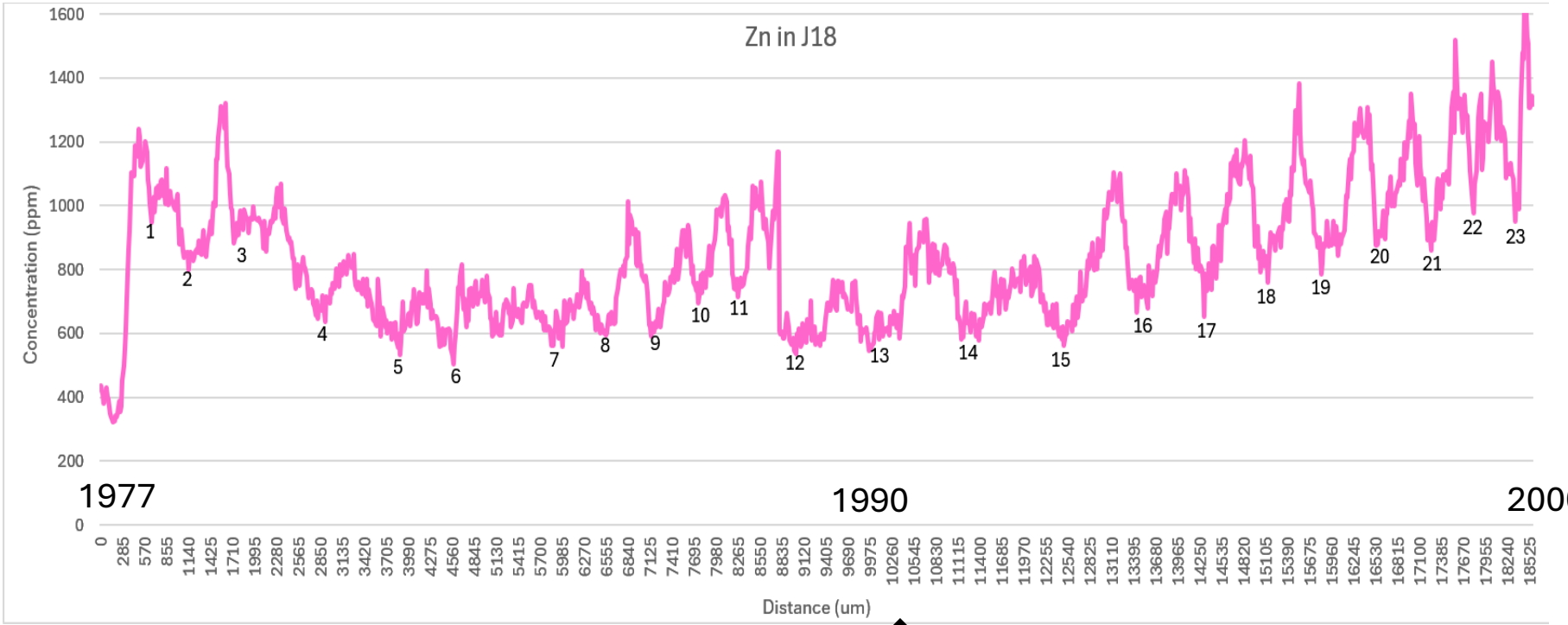


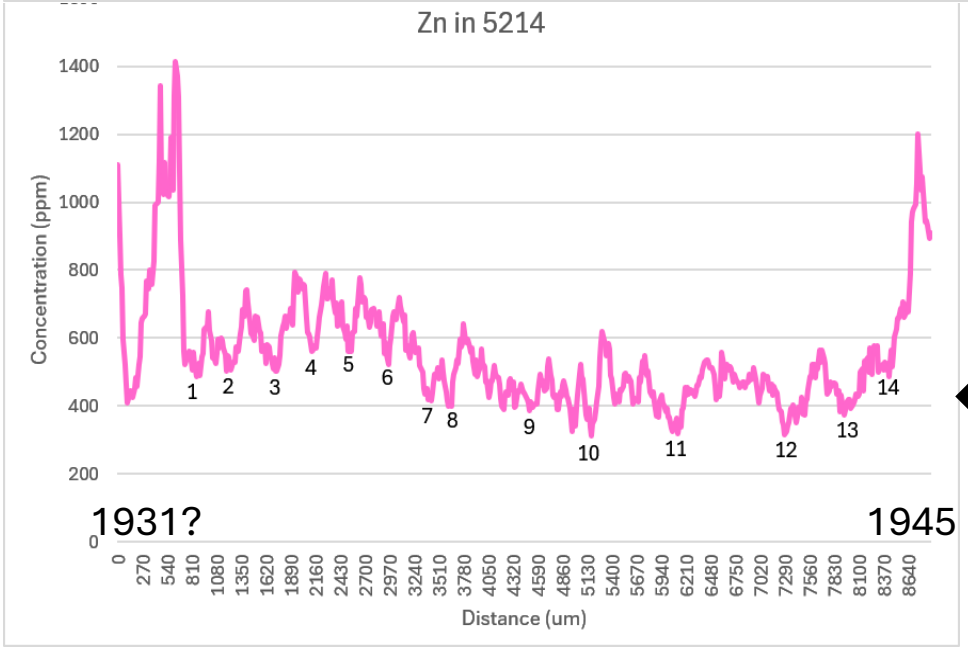




Unclassified - Non-Classifié

Whale Tooth Aging with Zinc





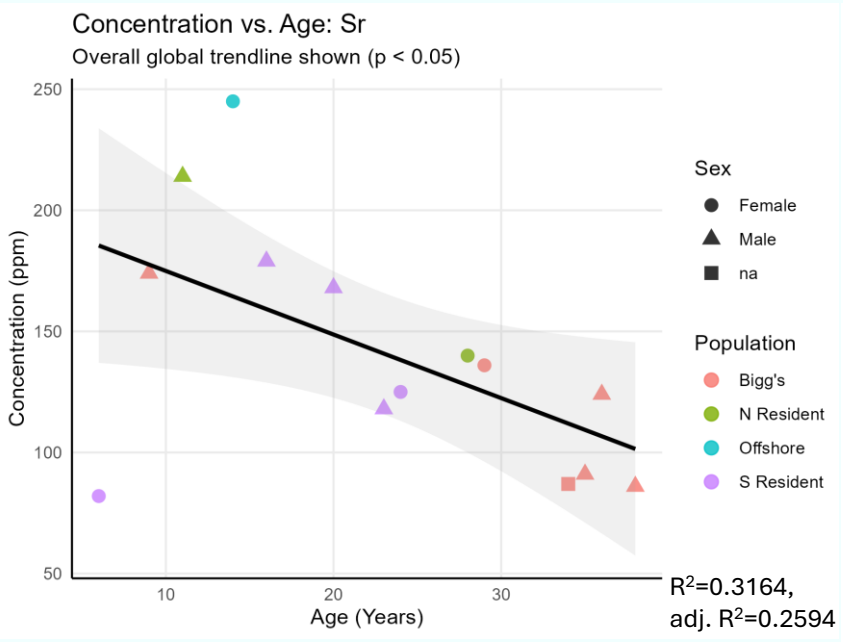
Zn microchemistry signals reveal annual dips that can be counted to determine age of killer whales

J18 has a known age of 23 years (1977-2000)

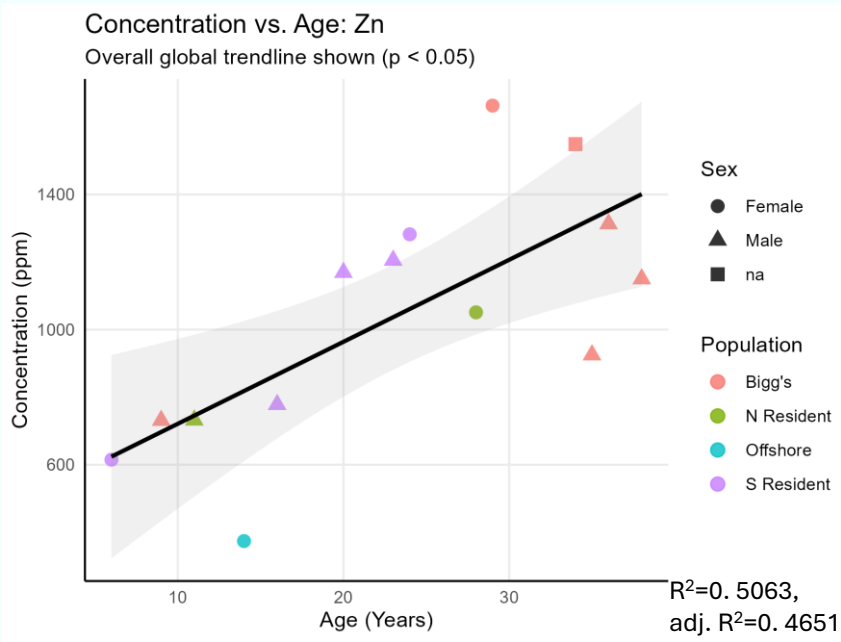
5214 was described as a sub-adult of unknown age: ***counting the Zn troughs indicates that she was about 14 years old***

Microchemistry and Age Trends

- Several analytes showed a relationship with the age of the whale at death :
- Dentine strontium concentration decreased with age since it was highest when the whales were youngest and was associated with nursing in belugas (Clark et al., 2023. “Patterns of trace element deposition in beluga whale teeth reflect early life history”).
- Dentine lead (contaminant) and zinc (physiological) concentrations showed a tendency to increase with age

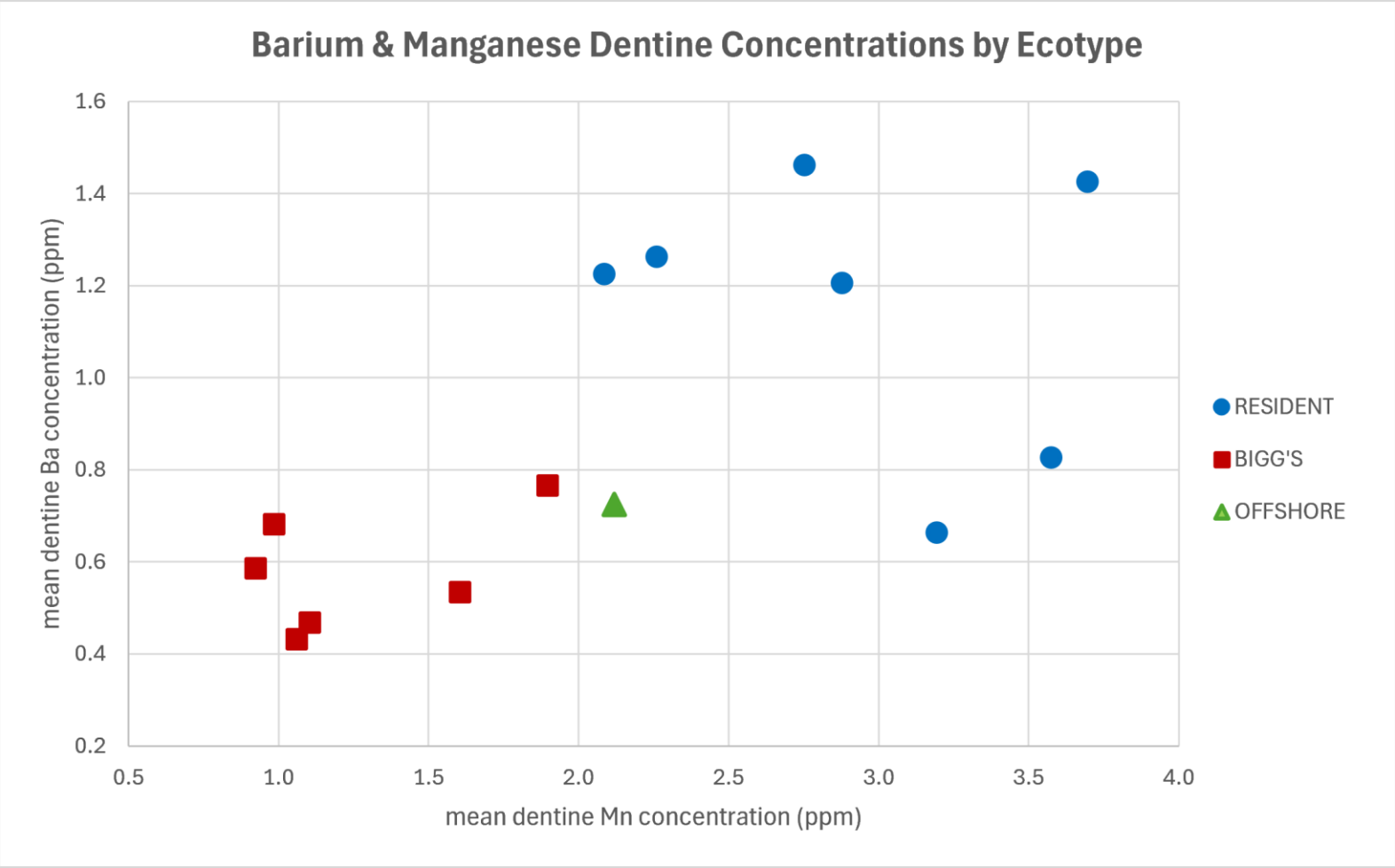






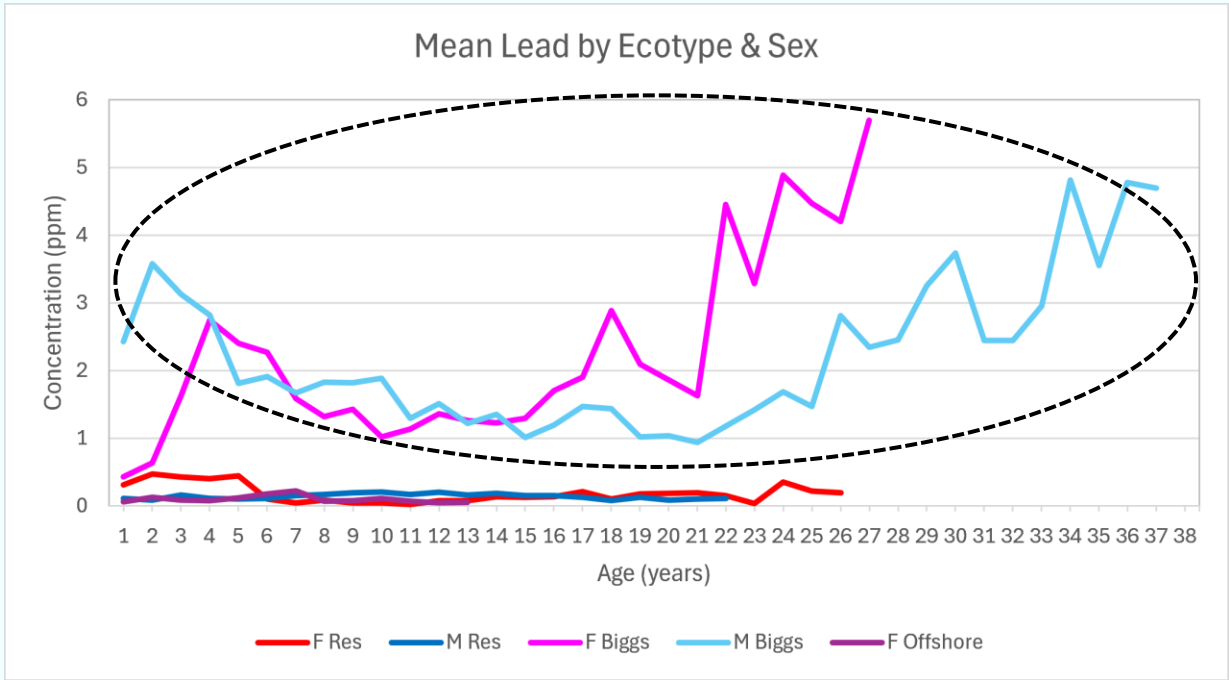
Microchemical Discrimination of Ecotypes

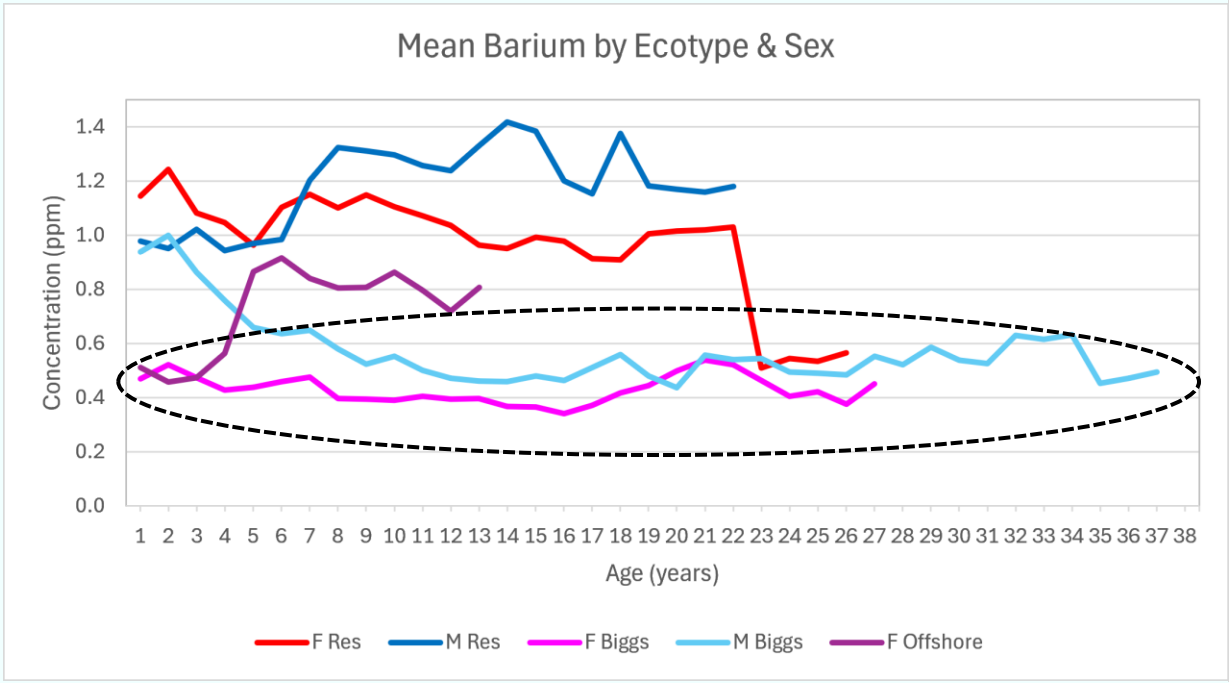
- Essential elements barium and manganese discriminated among the ecotypes, likely reflecting foraging and physiology

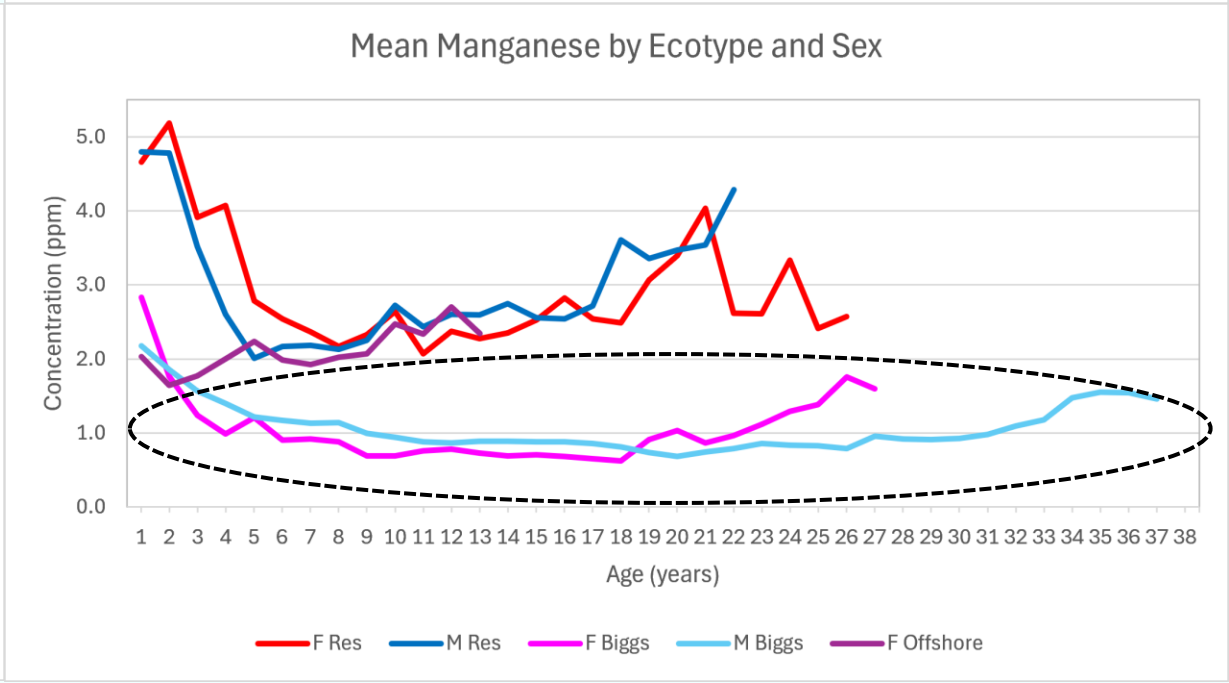


Sex Differences?

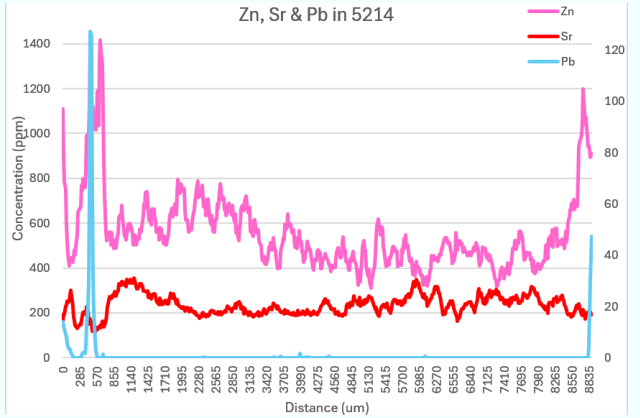
- Checked for sex differences but none observed
- Barium, manganese and lead cluster with ecotype not sex







Summary and Next steps

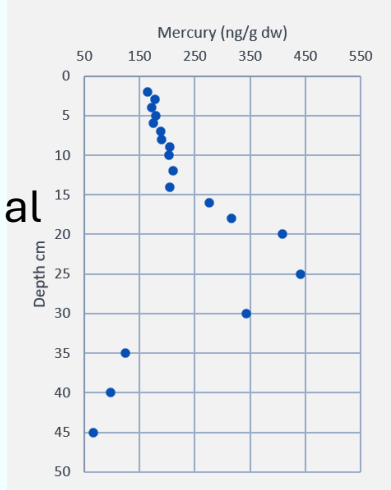


Trace Elements (LA-ICP-MS)

- LA-ICP-MS on KW GLGs is a success!
- Age & ecotypes identified and discriminated: *useful for determination of characteristics of unknown specimens*

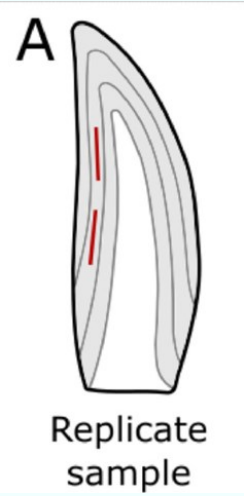
<u>Next steps:</u>

- Method development to run the toxic metal Mercury.
- Evaluation of the full temporal sequence (1947-2014) of non-essential elements.
  - Match to sediment cores in SoG.
- Mother – fetus pairs and fetal evaluations.



Destructive Sampling

- Diet (Stable isotopes) and Hormone analyses require destructive sampling to remove tissue matter for analyses.
- Stable Isotopes: method recently established to demonstrate consistency of signal across one GLG (Bowen and Kurle 2025)
- Hormones: past work on whole teeth, our lab is developing a method for low mass analyses of dentine to enable annual resolution of stress and reproductive hormones, stay tuned…



ank you!

Tooth Contributors:

Royal BC Museum

Royal Ontario Museum

Ocean Wise

Shaw Centre for the Salish Sea



Technical assistance:

- Dr. Jody Spence at the UVic Department of Earth and Ocean Sciences Biogeochemistry Laboratory
- Dr. Wei Wang at the University of Manitoba Department of Earth Sciences LA-ICP-MS Laboratory

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