



OTOLITH CHEMICAL ANALYSIS
LAKE MICHIGAN STEELHEAD:
WHERE WERE YOU HATCHED?

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A FEW NOTES BEFORE WE BEGIN

- Collaboration between CMU and DNR
- Scientific collection permit for MI and WI
- Minimal catch for analysis
 - No impact to overall population
- Humane euthanasia of all target fish
- Immediate release of non-target species upon recovery
- Why sacrifice some fish?
 - Research will benefit conservation of total population

OUTLINE

- Introduction to Great Lakes steelhead
- What are otoliths?
- Steelhead research
 - Otolith Chemistry
 - Diet Analysis & Bioenergetics



GREAT LAKES STEELHEAD

- Introduced in the late 1800's
- Few self-sustaining populations established by the early 1900's
- Native range is the Pacific Coast
- Steelhead have been introduced to all continents except Antarctica

STEELHEAD OR RAINBOW TROUT?

- Steelhead are the migratory form of rainbow trout
- Great Lakes steelhead are considered potamodromous (migrating entirely in fresh water)
- Pacific coast steelhead are considered anadromous (migrating from fresh water to ocean)



GREAT LAKES STEELHEAD

- Many strains:
 - Skamania, Michigan, Ganaraska, Chambers, Arlee, Kamloops
- Historical stocking of parr in rivers supporting wild populations provide little contribution to the adult population
- Nearly 15% of all Great Lakes anglers target steelhead, not including stream fishing

GREAT LAKES STEELHEAD

- Juveniles live 1-3 years in stream habitat
- “Smolt” and migrate out to lake to fully mature
 - Smolting: morphological, physiological, and behavioral changes
- Return to natal stream to spawn 1-3 times



A COMPLEX POPULATION

- MIXED STOCK

- ▶ Hatchery-released & wild fish
- ▶ Lake population from many different tributaries



EQUAL OR NOT EQUAL?

- COMPLICATIONS TO CONSERVATION & MANAGEMENT
 - ▶ Unequal contribution of steelhead stocks to total population



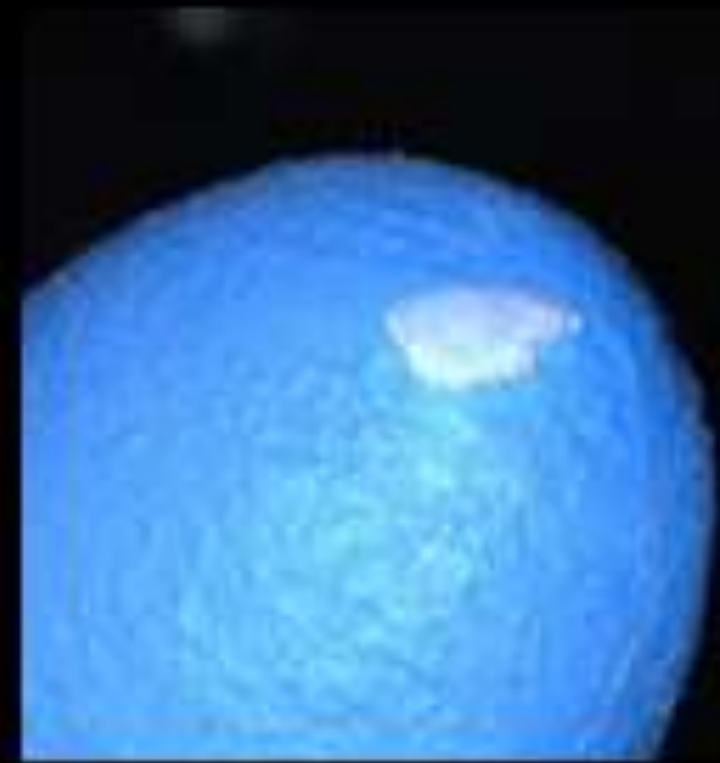
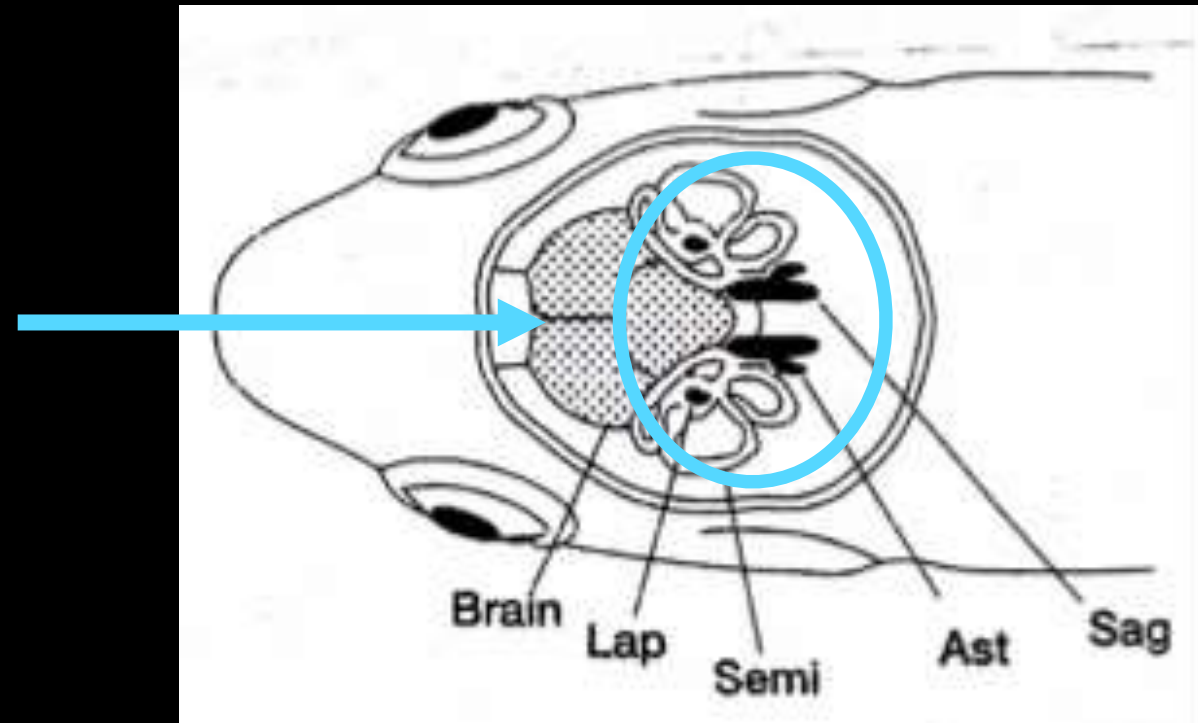
WHO CAME FROM WHERE? HOW?

- Knowledge of natal origin important
 - Juveniles depend on cold water habitat
- Target conservation and management to the areas that are the major contributors to the total population

OTOLITH CHEMISTRY HOLDS THE KEY!

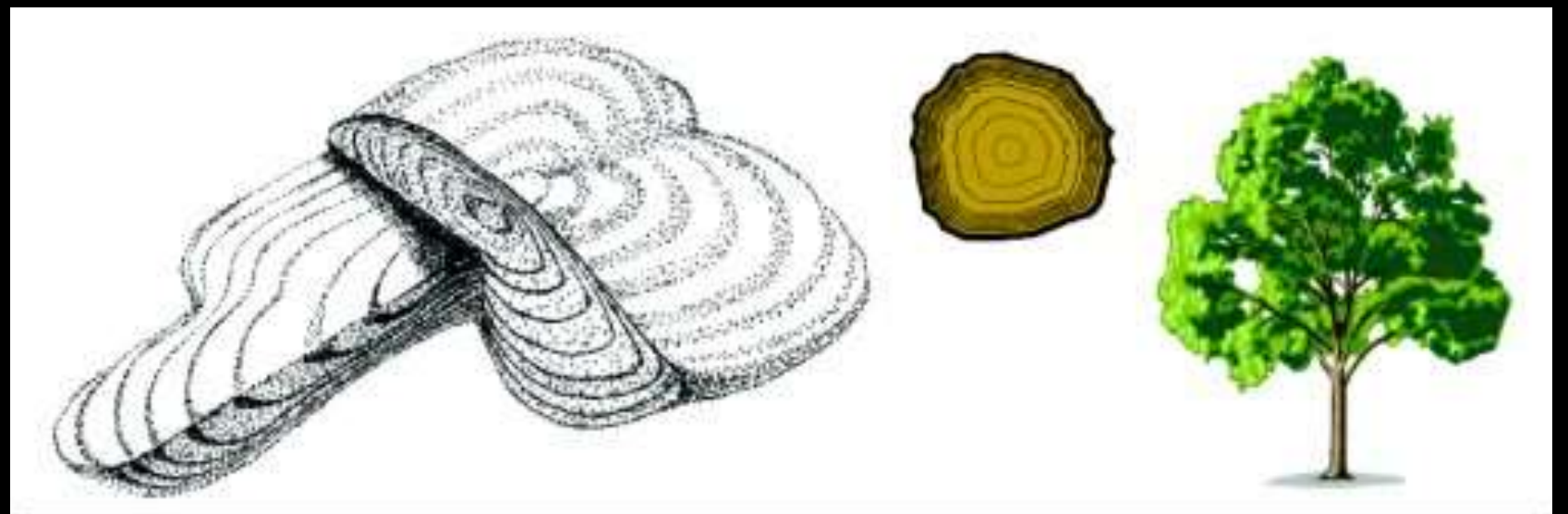
WHAT ARE OTOLITHS?

- Hard calcium carbonate structures located behind the brain
- Used for hearing, balance, & orientation
- 3 pairs of otoliths:
 - Lapilli, Astericii, **Sagittae**



GROWTH & OTOLITHS

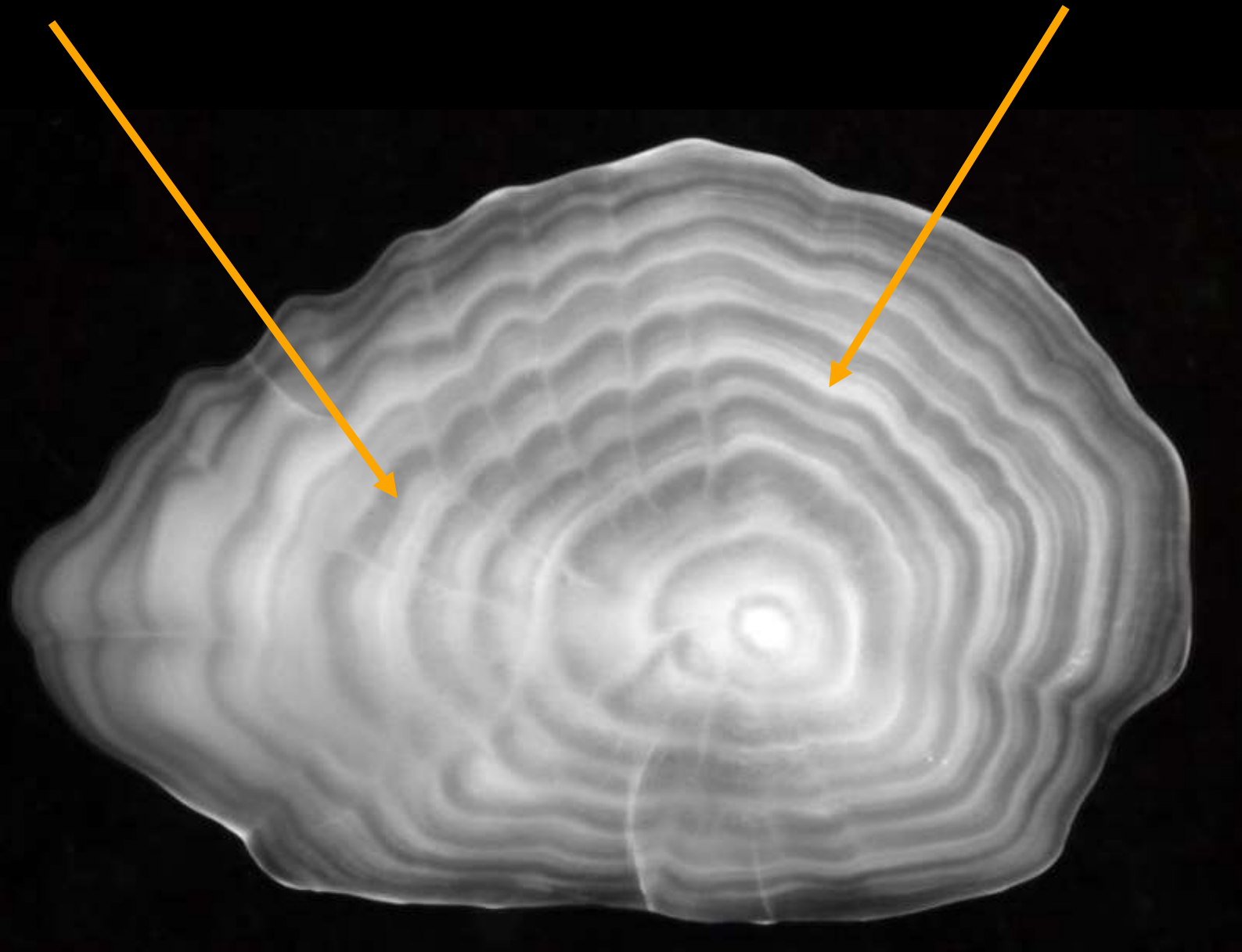
- Close resemblance to tree rings & layers of an onion
- Daily growth increments



GROWTH & OTOLITHS

Dark (opaque): slow growth

Light (translucent): fast growth

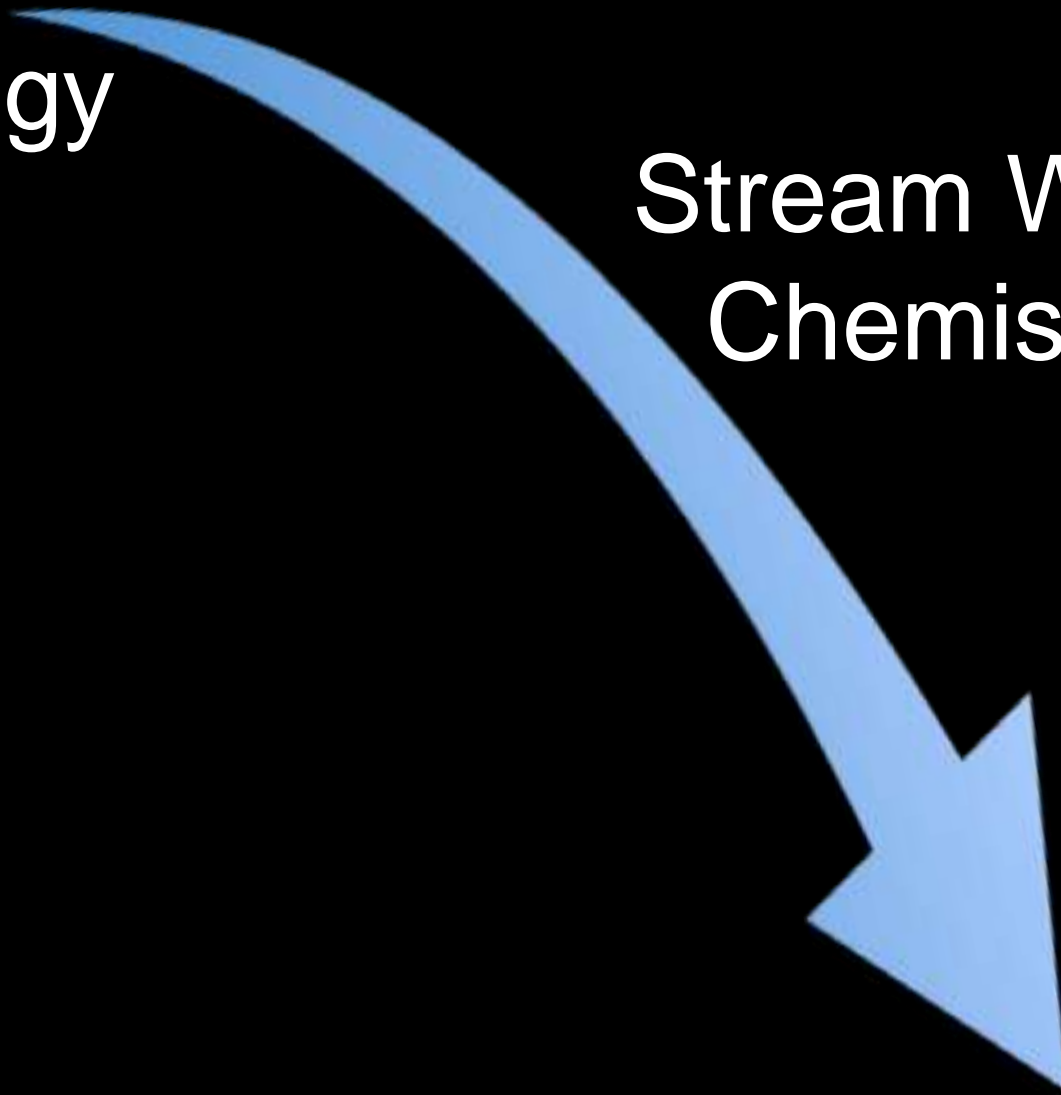


INFLUENCES OF OTOLITH CHEMISTRY

Bedrock &
Surficial Geology

Stream Water
Chemistry

Otolith
Chemistry



CHEMISTRY

- Columns (groups) of the periodic table have the same number of valence electrons
- Valence electrons are involved in bonding

Periodic Table of the Elements

1 IA 1A												13 IIIA 3A		14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A				
1 H Hydrogen 1.008												5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180					
3 Li Lithium 6.941	4 Be Beryllium 9.012											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948					
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B											
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.796					
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.908	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29					
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine 209	86 Rn Radon 222					
87 Fr Francium 223	88 Ra Radium 226	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [268]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown					

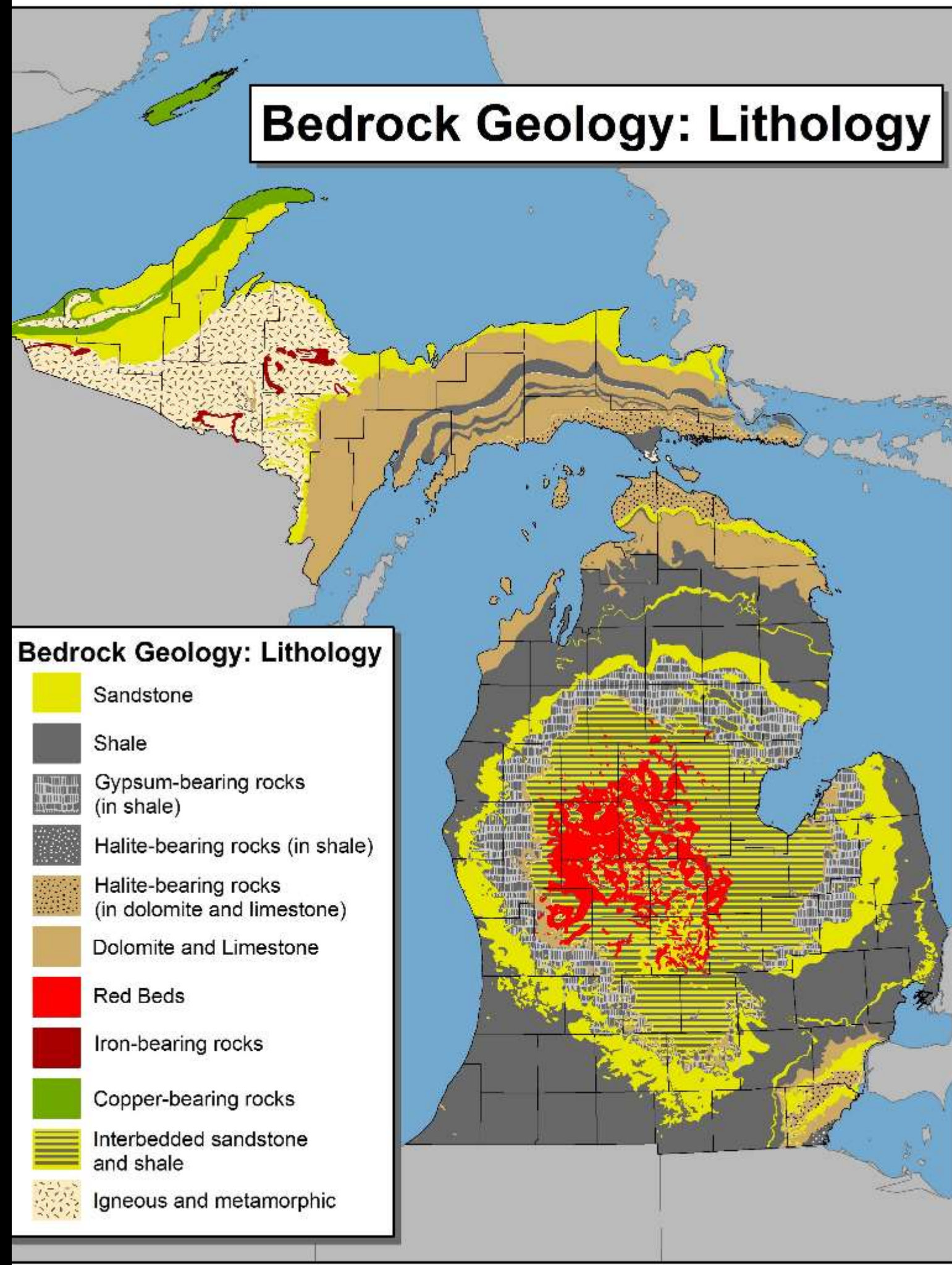
A BIT MORE CHEMISTRY

- Calcium (Ca), Strontium (Sr), Barium (Ba) are all in the the second group of the periodic table
- Ca, Sr, and Ba all have two valence electrons
- This allows Sr and Ba to easily substitute with Ca in the crystalline matrix of the otolith
- Elements of highest concern are Sr and Ba, others are important as well (Mg, Mn, Fe, Rb)

2	IIA	2A
4	Be	Beryllium 9.012
12	Mg	Magnesium 24.305
20	Ca	Calcium 40.078
38	Sr	Strontium 87.62
56	Ba	Barium 137.328
88	Ra	Radium 226.025

UNIQUE FINGERPRINT

- Unique geology gives way to unique otolith chemical fingerprint
- Different geologic layers have different Sr & Ba concentrations
- Each color on the map represents a different bedrock composition



STEELHEAD RESEARCH



HYPOTHESIS & CONSIDERATIONS

- Individual stocks can be determined through otolith chemical analysis when the chemical composition of the otolith is unique
 - Considerations:
 - Various spatial scales
 - Inter-annual variations
 - Age class & classification accuracy

GOALS

DETERMINE NATAL ORIGIN OF
JUVENILE STEELHEAD USING OTOLITH
CHEMISTRY



LONG-TERM:

- Determine natal origin of adult steelhead captured from Lake Michigan

HOLD ON...

We already know where juvenile steelhead come from



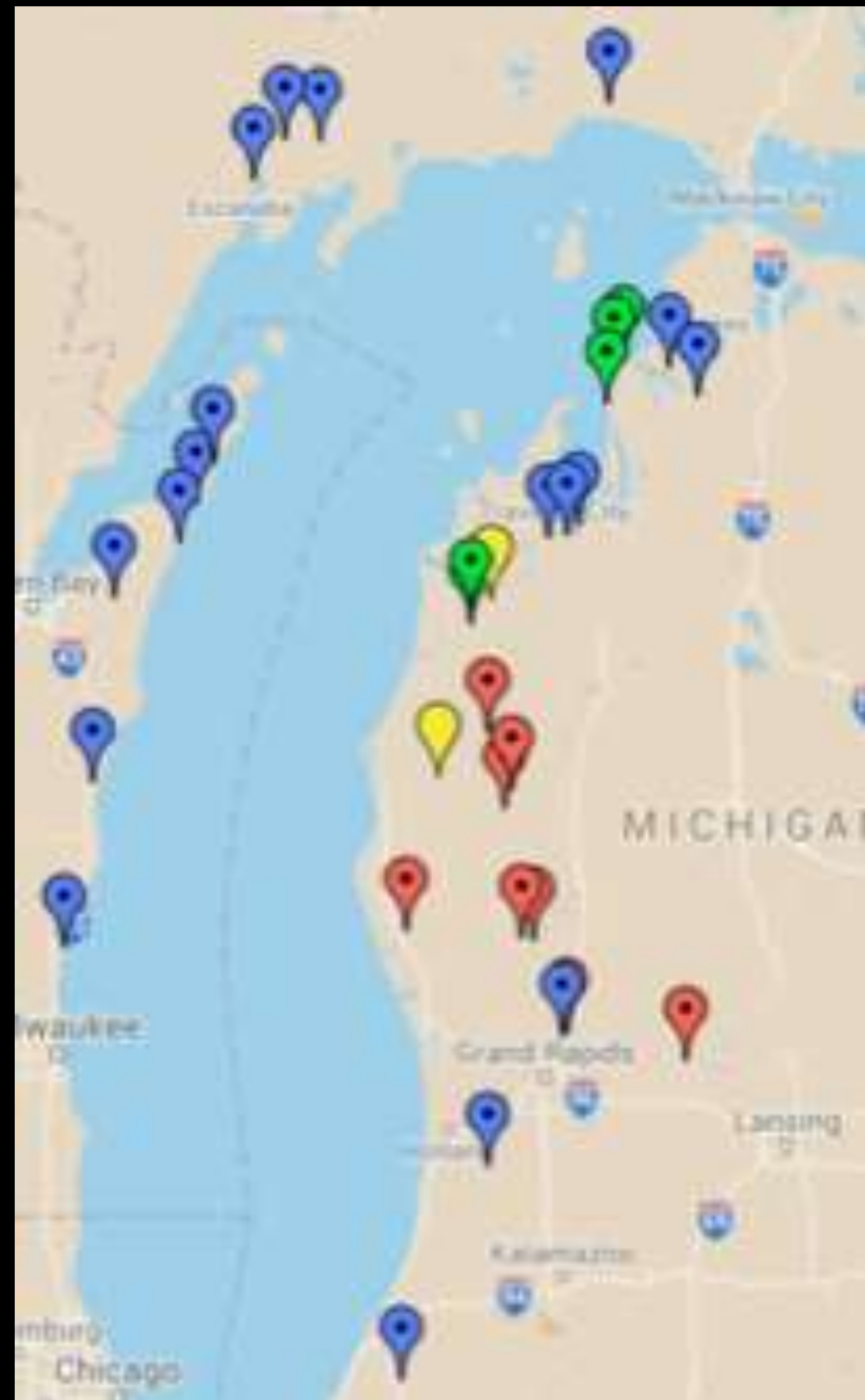
- The computer doesn't know this. That is needed for the long-term goal
- Wouldn't it be nice to know which streams contribute the most to the adult population?

WHY IS THIS IMPORTANT?

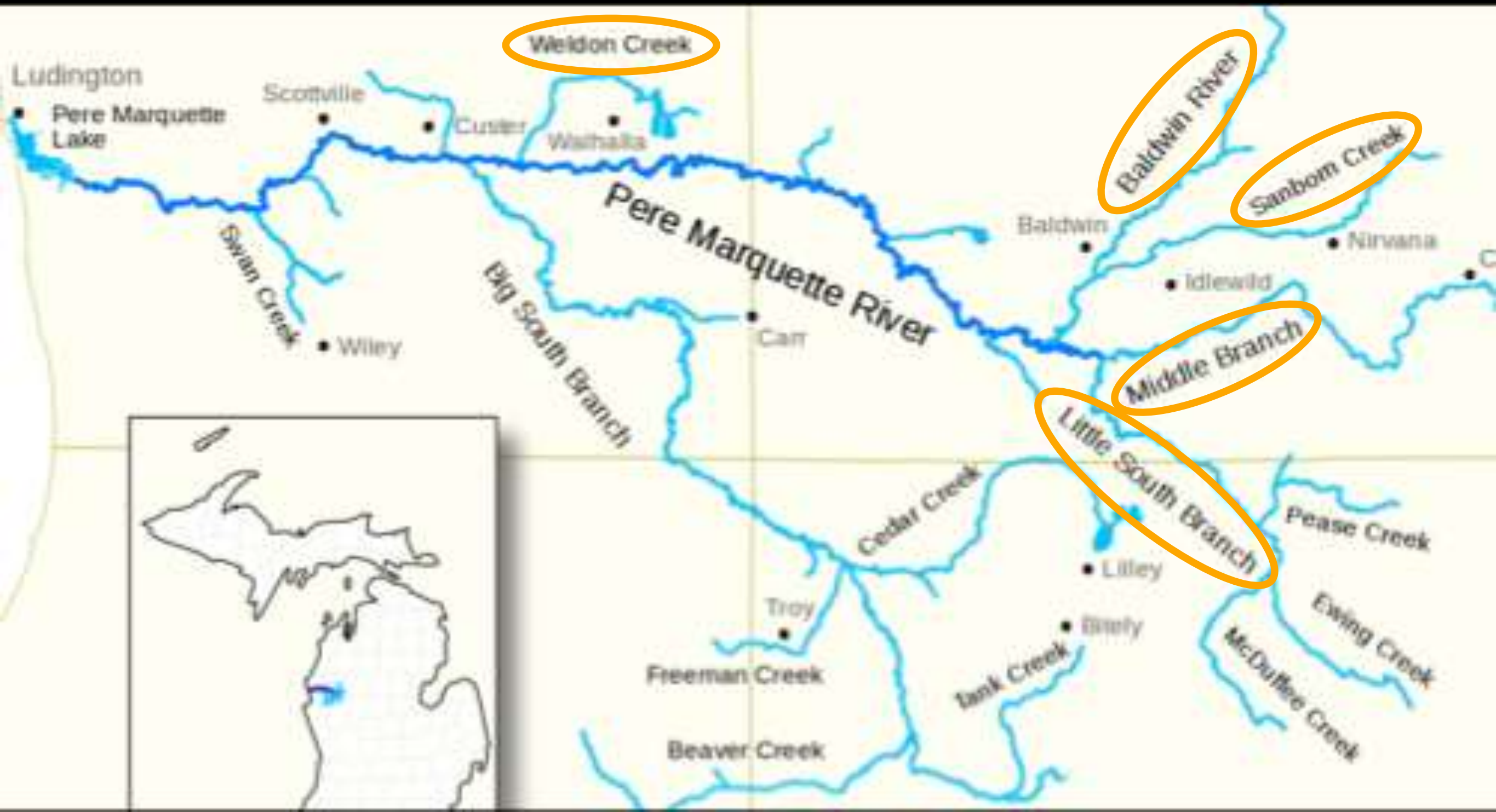
- This research provides a new tool for fisheries research
- The results of this study will pave the way for future research that attempts to determine the natal origins of adult steelhead collected from Lake Michigan
- This will allow for more effective conservation and management of both steelhead themselves and their natal habitats

SPATIAL VARIATION

- How specific can we get?
- Watershed A, B, C?
 - Manistee
 - K-zoo
 - St. Joe

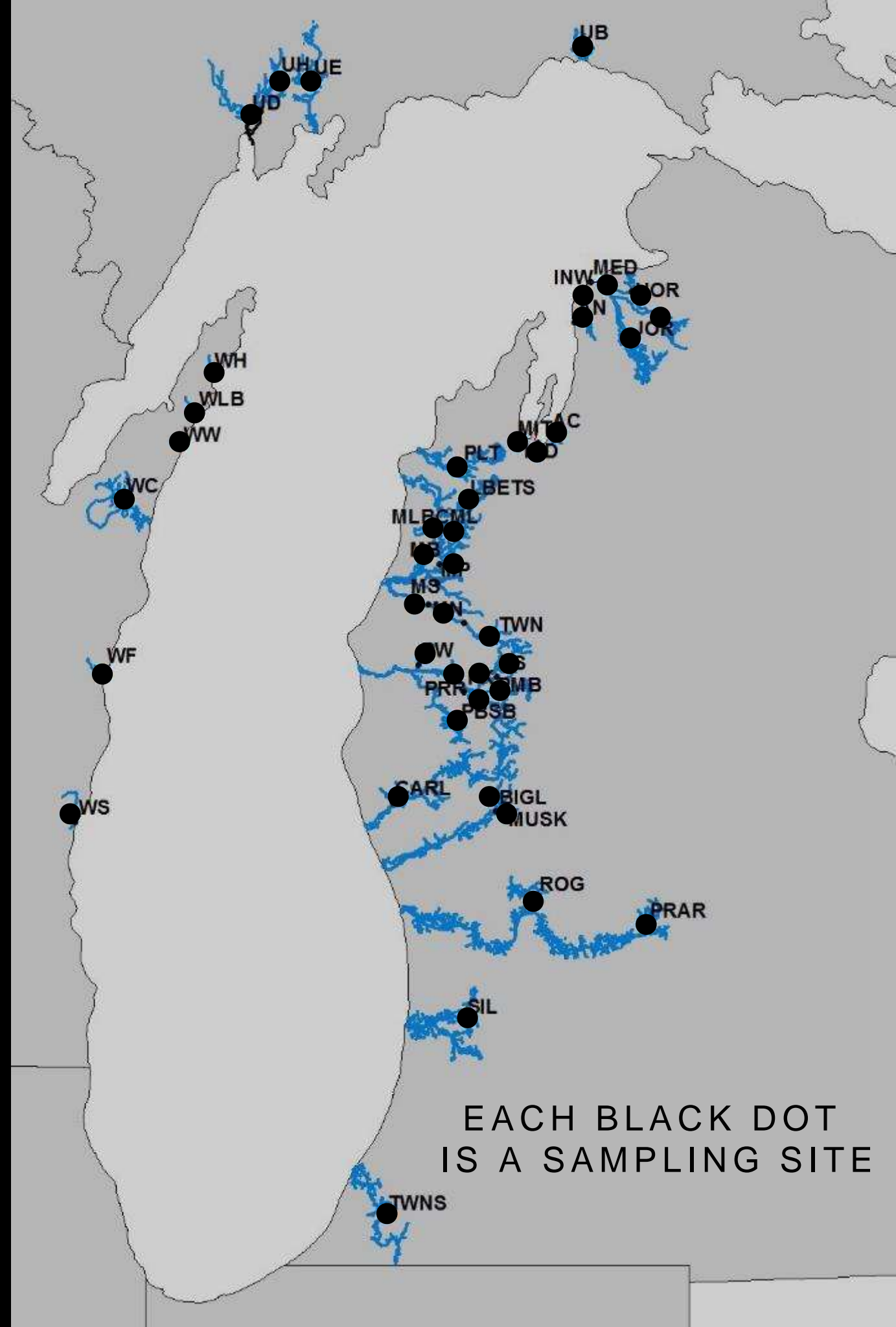


CAN WE GET MORE SPECIFIC?



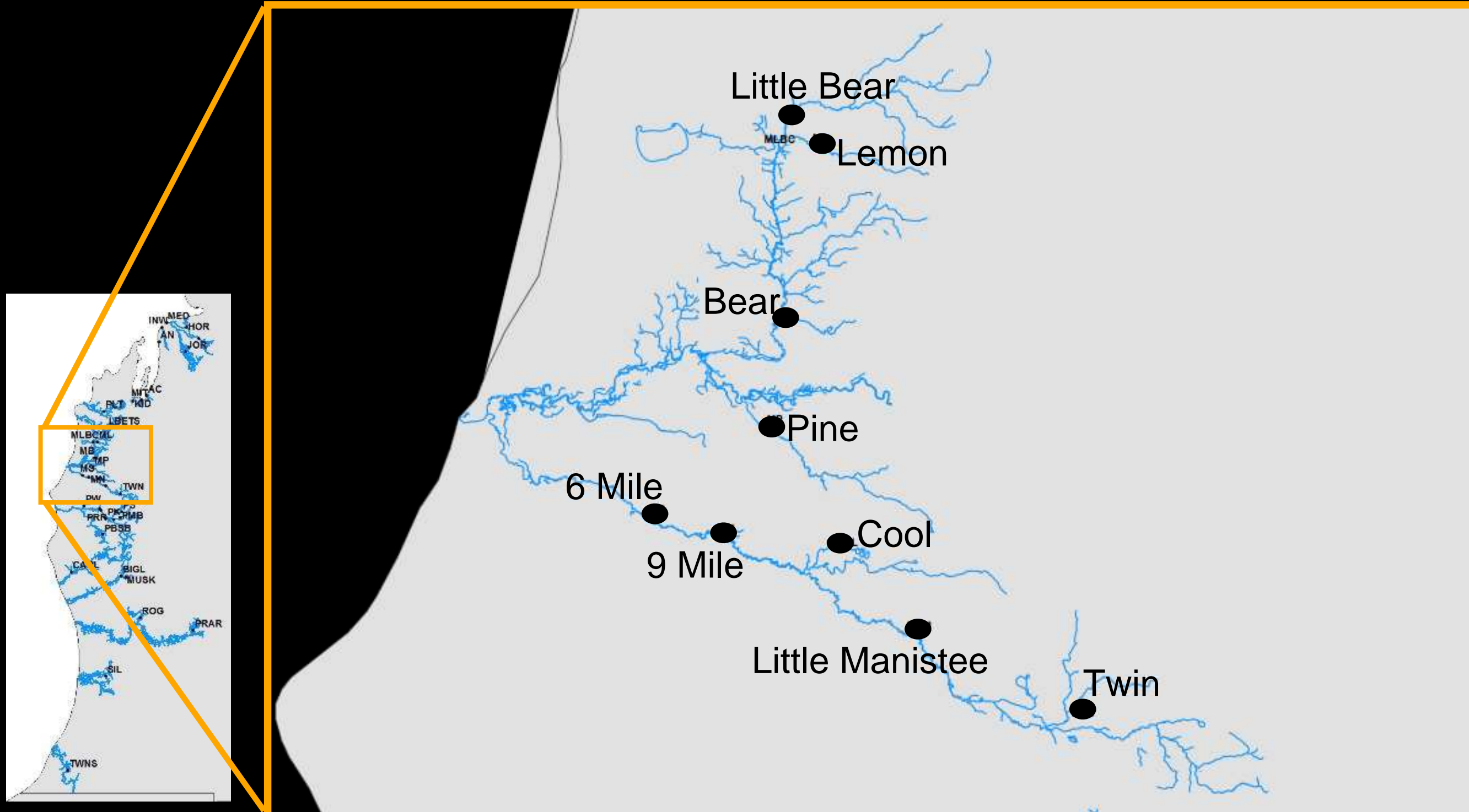
2014 FIELD SAMPLING

- Spring: June-July
- Fall: August-November
- Total sites:
 - 36 Lower Peninsula
 - 4 Upper Peninsula
 - 6 Wisconsin
- All sites will be revisited in spring and fall 2015



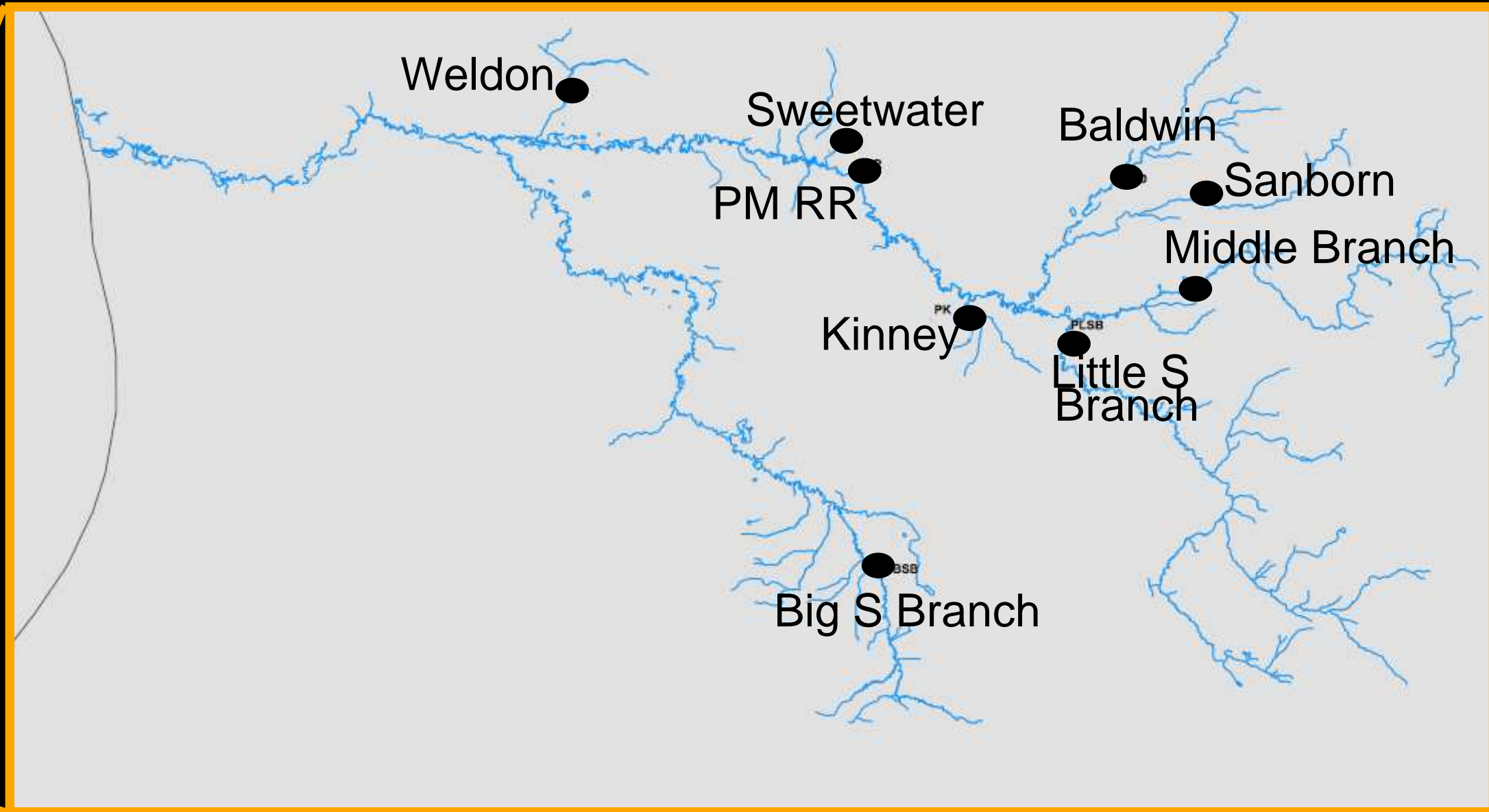
MANISTEE & LITTLE MANISTEE

INTENSIVE SAMPLING



PERE MARQUETTE

INTENSIVE SAMPLING



FIELD COLLECTIONS

- Electro-fishing
- Electrical current induced by closing circuit
- Temporarily stuns fish
- Non-target species released
- Target species collected



NEW FOR
2015

“Unnamed Creek”

Tributary of the
Dowagiac

Sampled 14-May-15



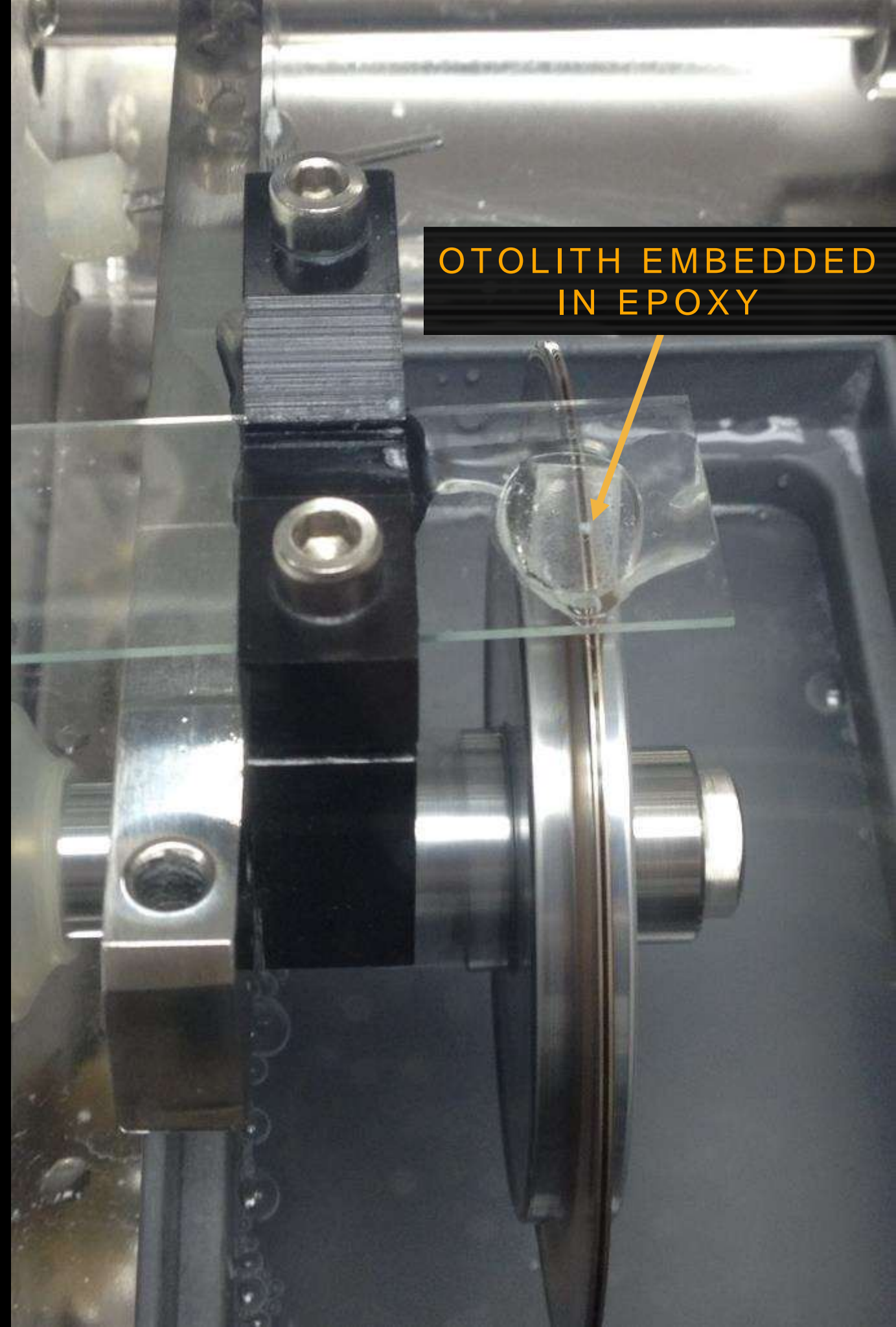
LABORATORY WORK

- Over 700 fish excised:
 - Length & weight
 - Otoliths removed
 - Scale sample
 - Stomach removed



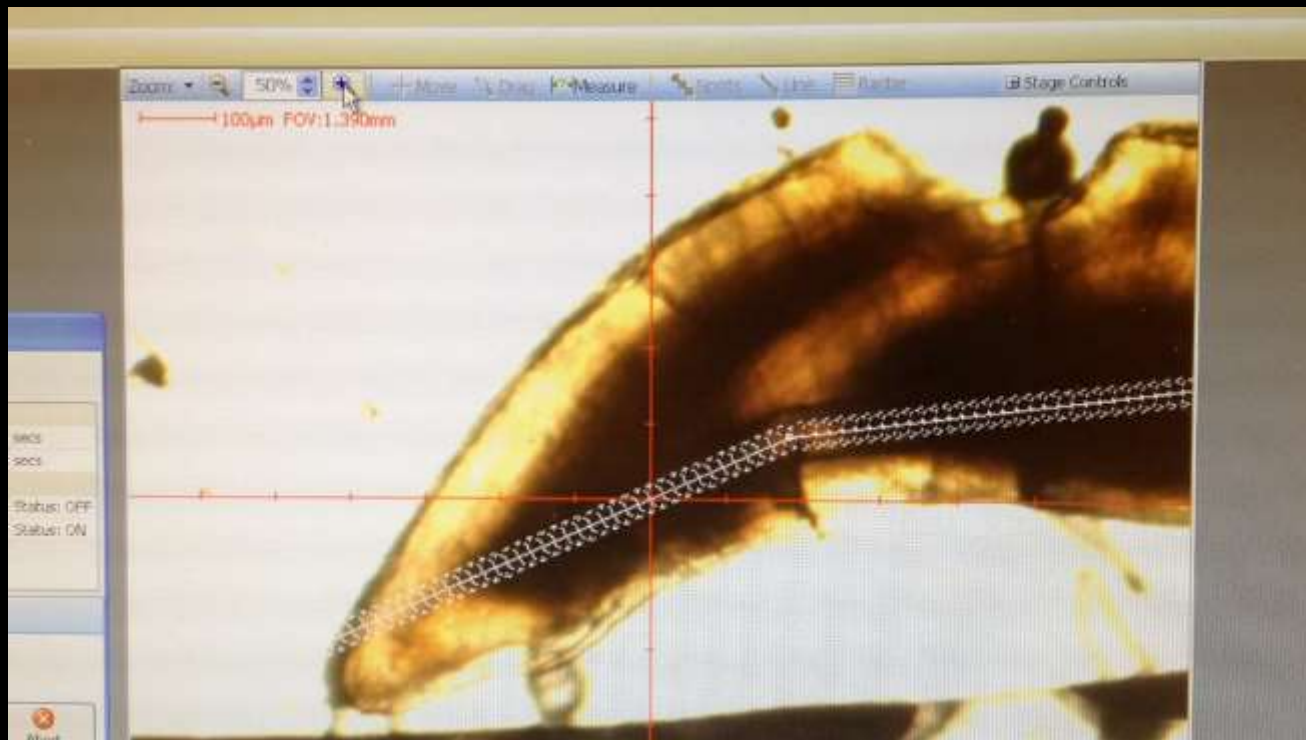
OTOLITH PREP

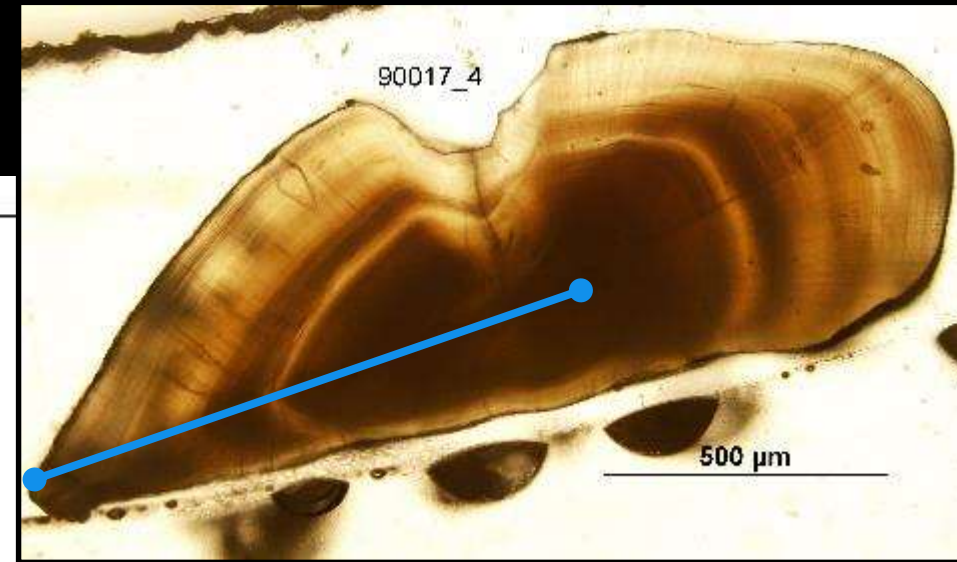
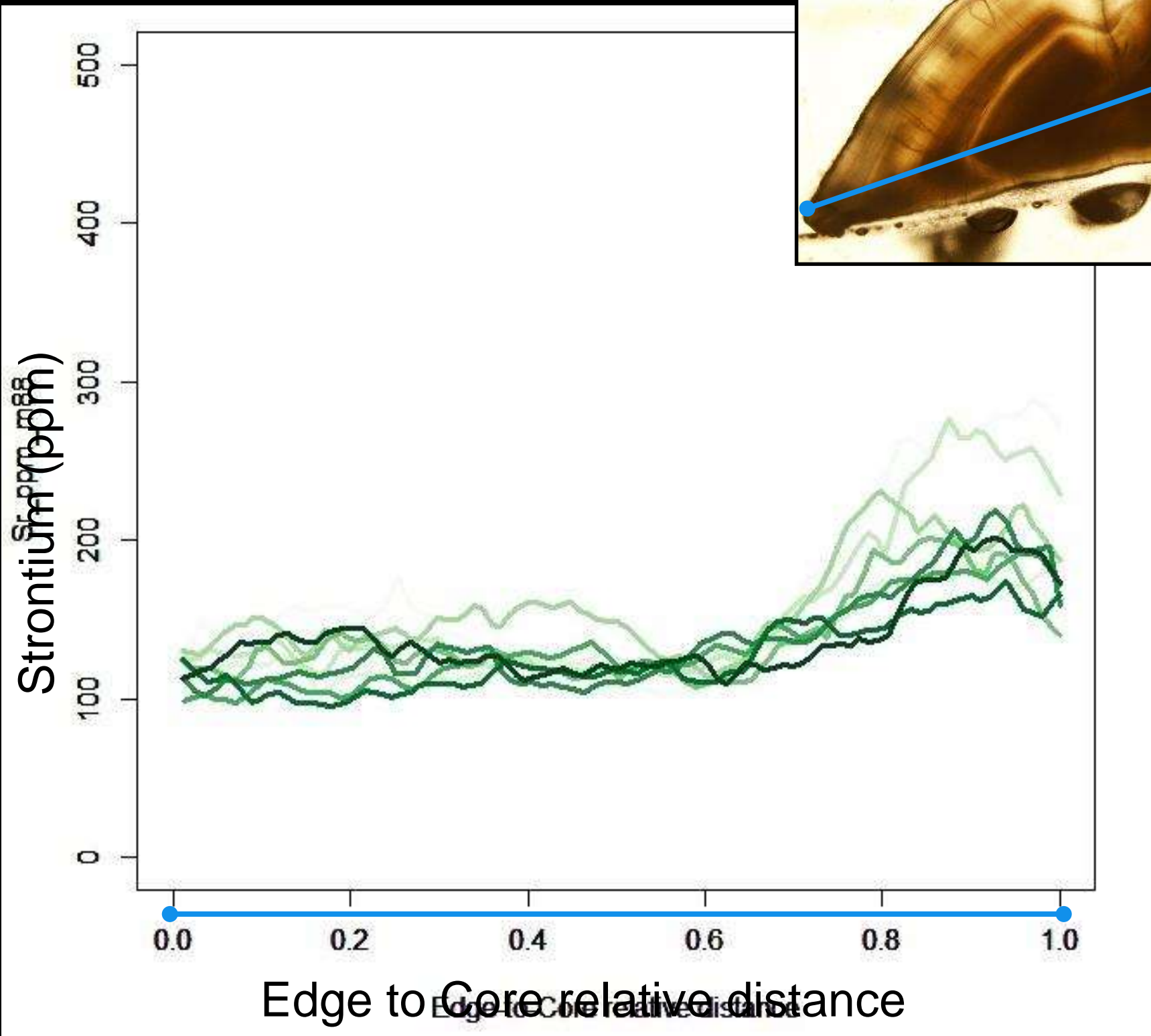
- Remove
- Dry
- Embed
- Section
- Polish, polish, polish, check under microscope, polish more
- Ablate

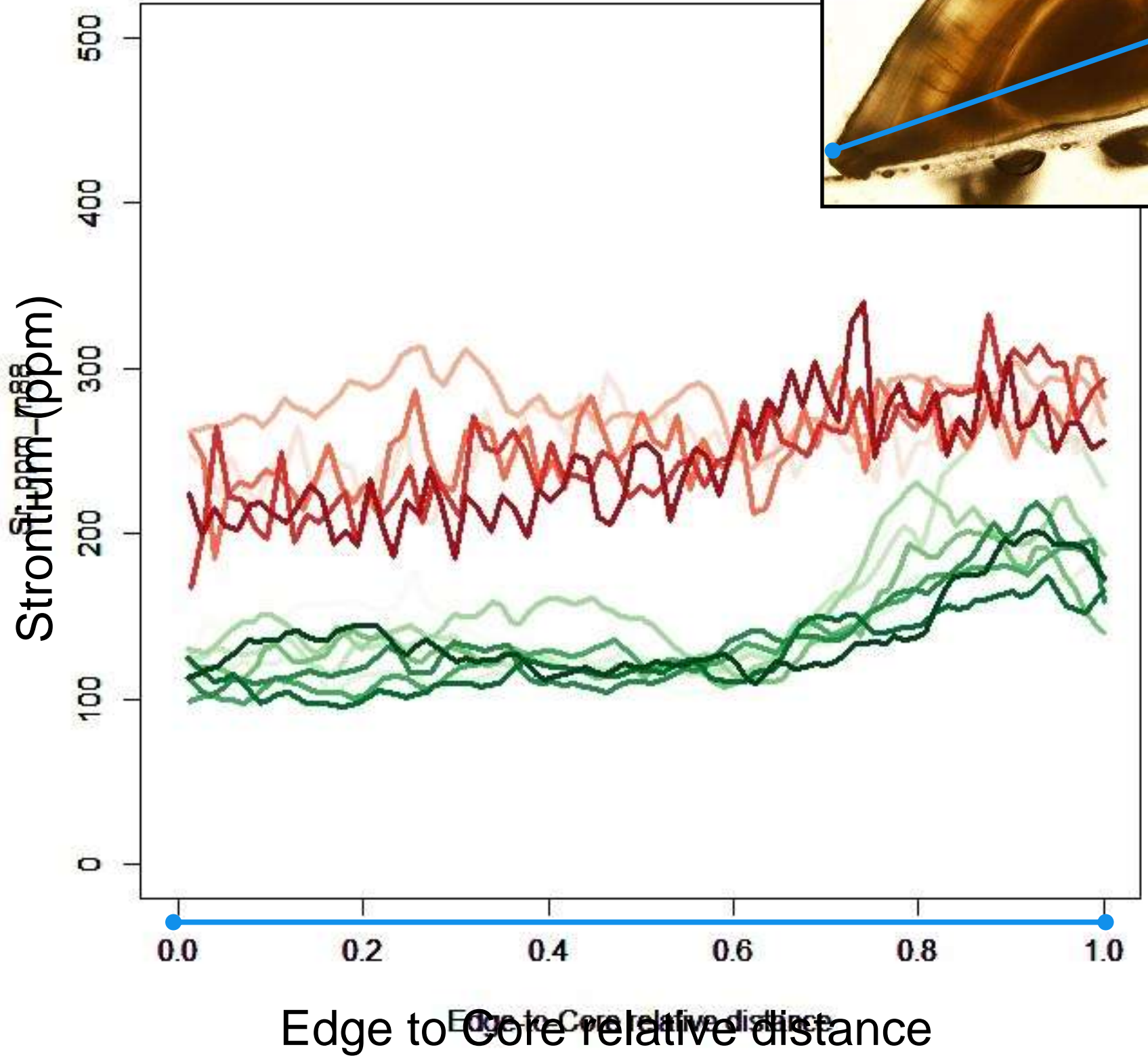
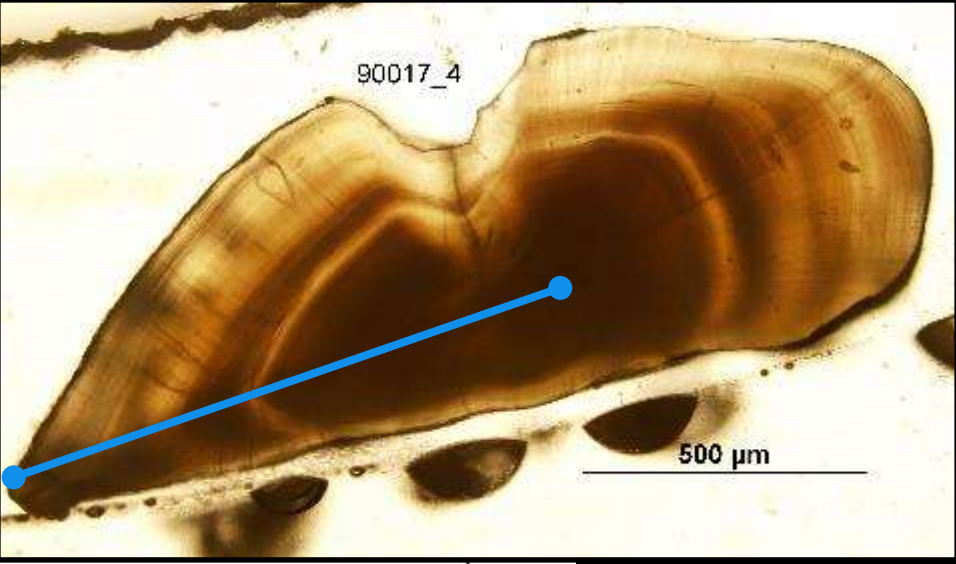


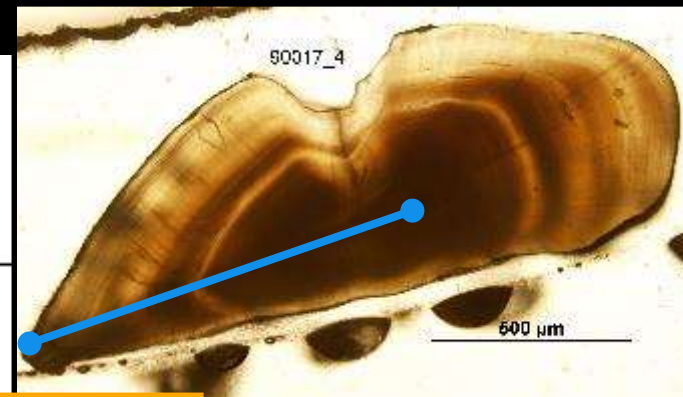
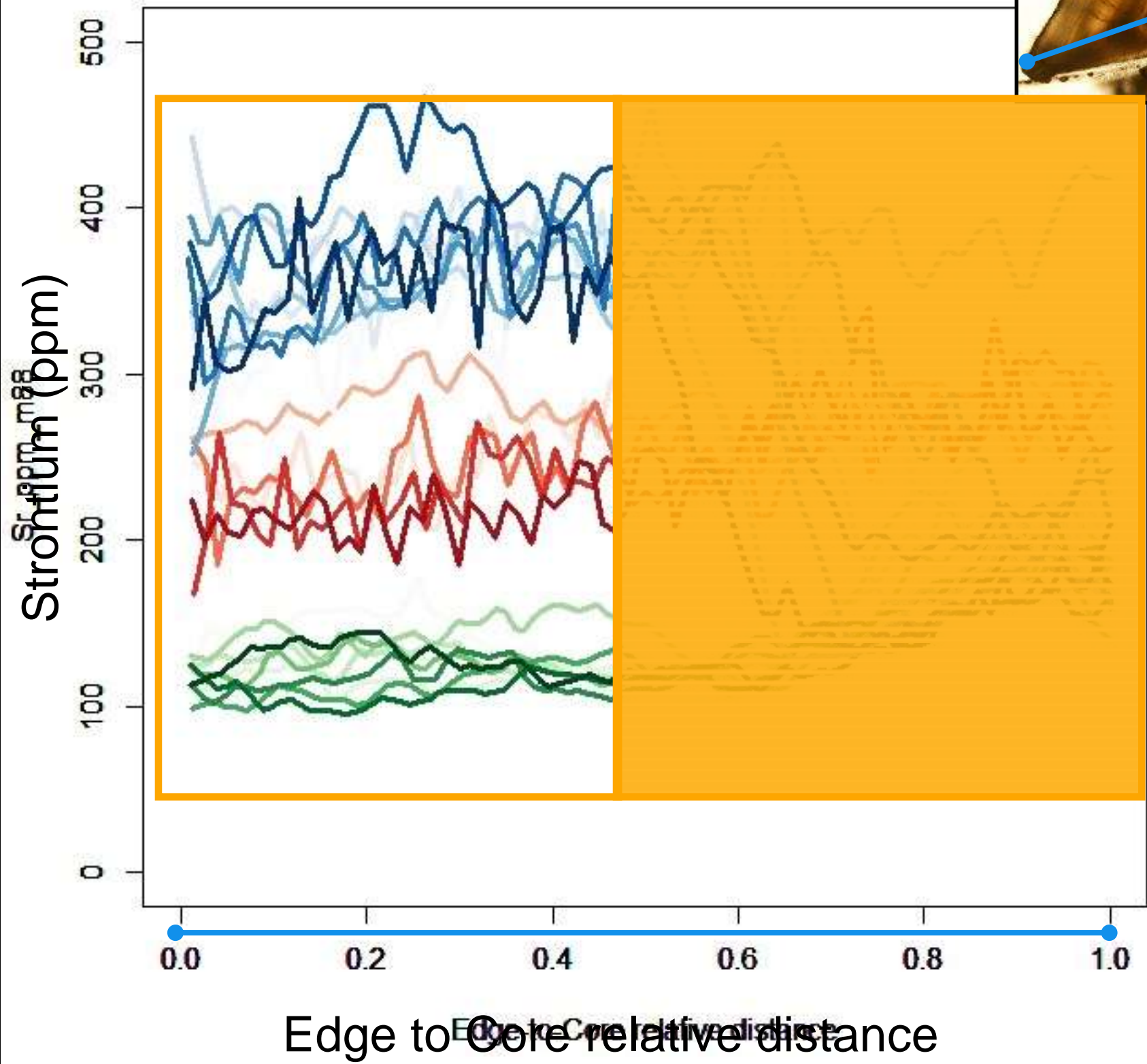
LASER ABLATION INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY

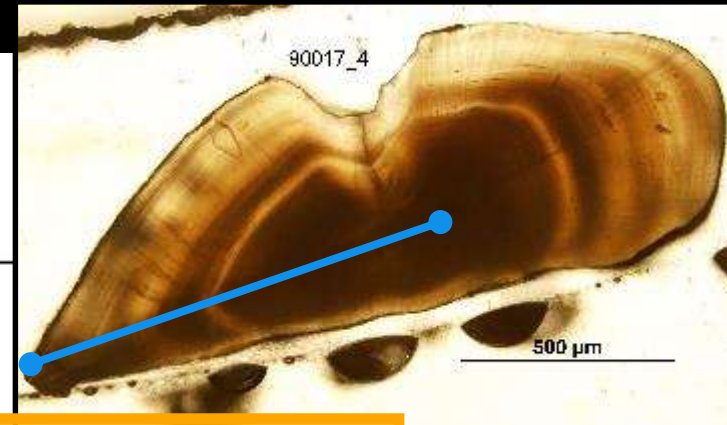
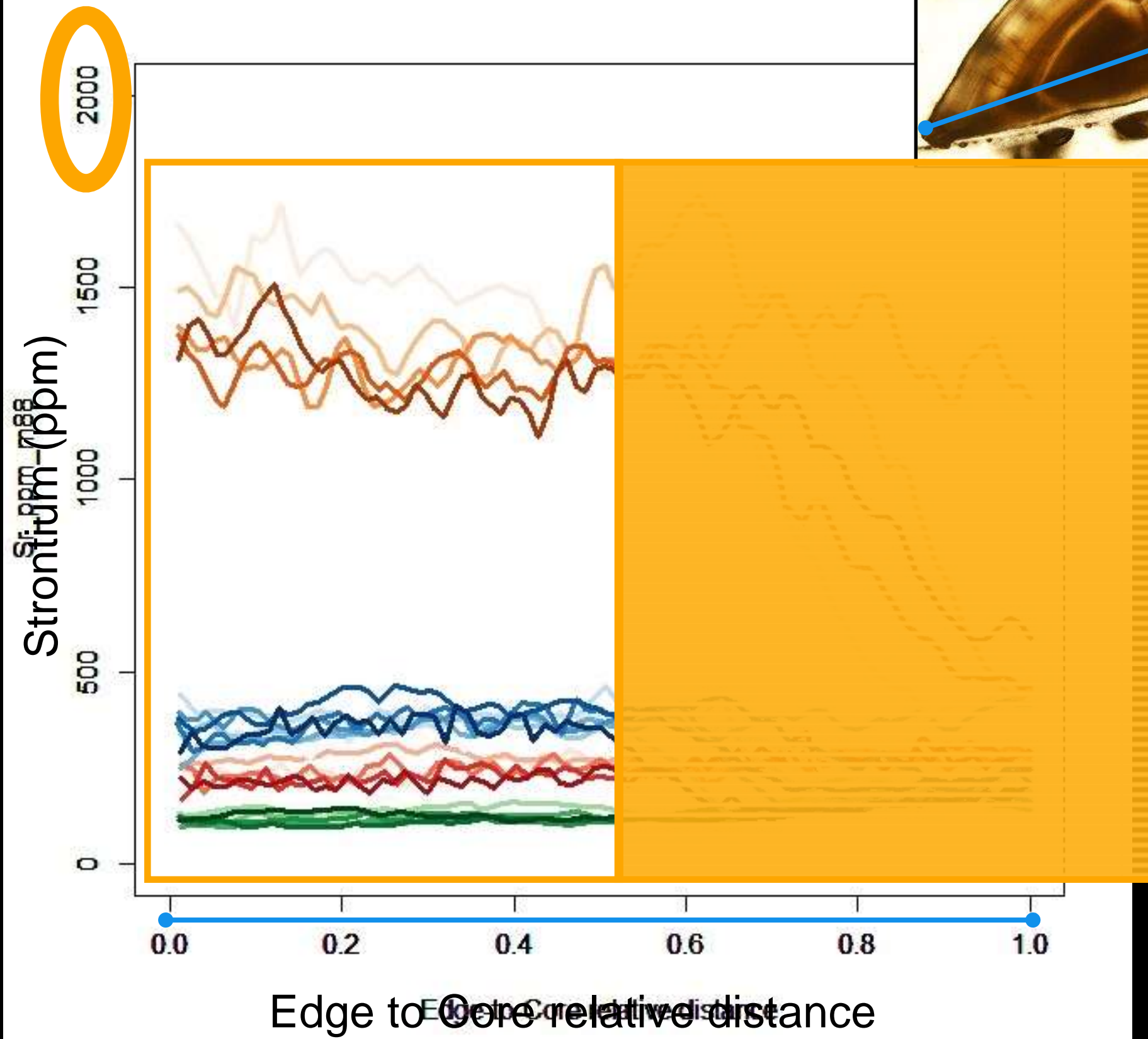
LA-ICP-MS: LASER ABLATIONS











WHY IS THIS IMPORTANT?

Knowing which streams contribute to the surviving and reproducing population of steelhead in Lake Michigan will allow for more effective conservation and management of both steelhead themselves and their natal habitats

OTOLITH CHEMISTRY HOLDS THE KEY!

DIET ANALYSIS

- Previous studies have only concentrated on very few streams
- Data from 46 streams in the Lake MI basin
- Land use impacts, spatial variation, TOD, season
- Funding recently awarded



BIOENERGETICS MODEL

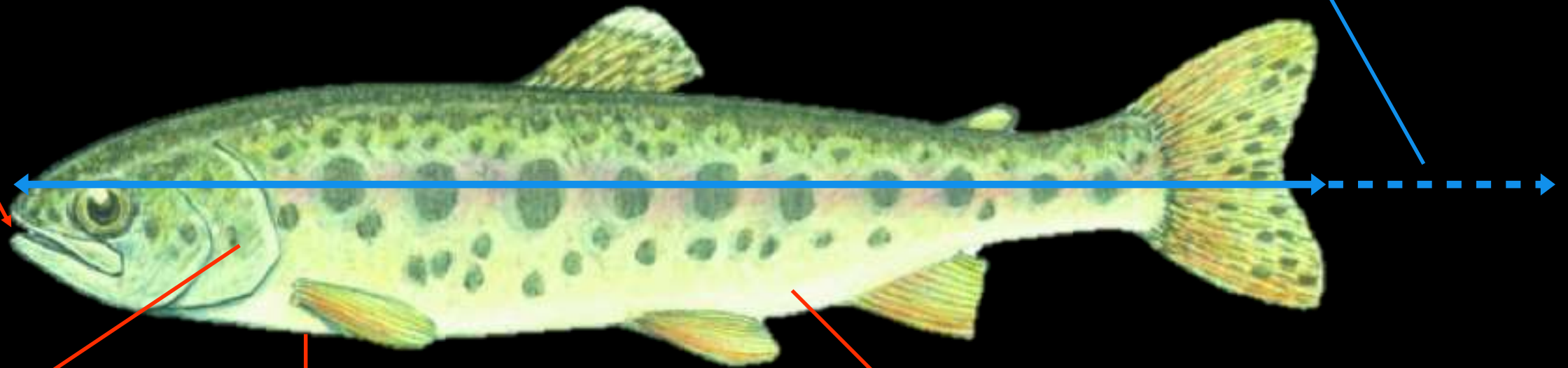
- Determine how diet composition influences growth of juvenile steelhead
- Fill the gap of a basin-wide diet analysis
- Compare actual growth & diet with model



$$G = C - R - S - F - U$$

C = Consumption

G = Growth



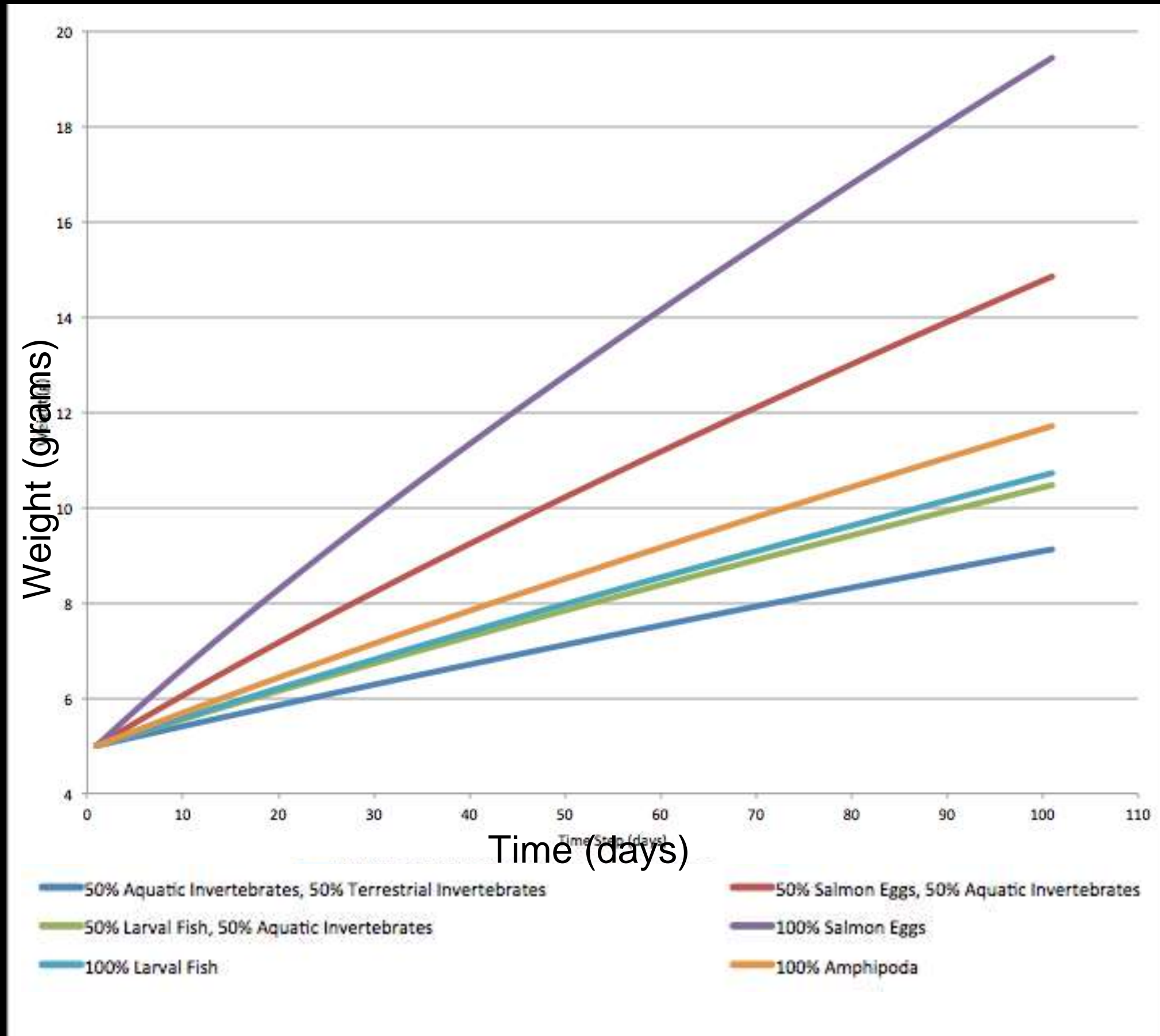
R = Respiration

S = Specific Dynamic Action
(cost of digestion)

U = Excretion

F = Egestion

Change in growth due to differences in diet composition



BIOENERGETICS FUTURE DIRECTIONS

- Model can be modified to simulate seasonal changes
 - Temperature
 - Diet composition
 - Stream velocity
- Potential to aid in stream restorations to provide adequate, high quality food for juvenile steelhead



WHAT NEXT?

- Spring field sampling has begun
- Fall sampling in August-October
- Otolith data will be presented at IAGLR & AFS in '15 & '16
- Continue to work on diet analysis & bioenergetics model



ACKNOWLEDGEMENTS & THANKS



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THE SMALL ARMY CMU UNDERGRADUATE STEELHEAD PROJECT VOLUNTEERS

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Halley Love

Dave Thumser

Joe Decaussin

Alan McTaggart

Jameson Farinosi

Carlie Money

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