# Otolith microstructure reveals the importance of tidal wetlands as nursery habitat for Chinook salmon in the Skagit River, Washington state


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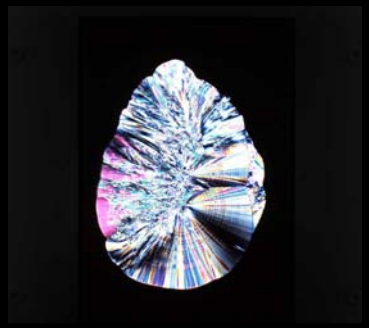
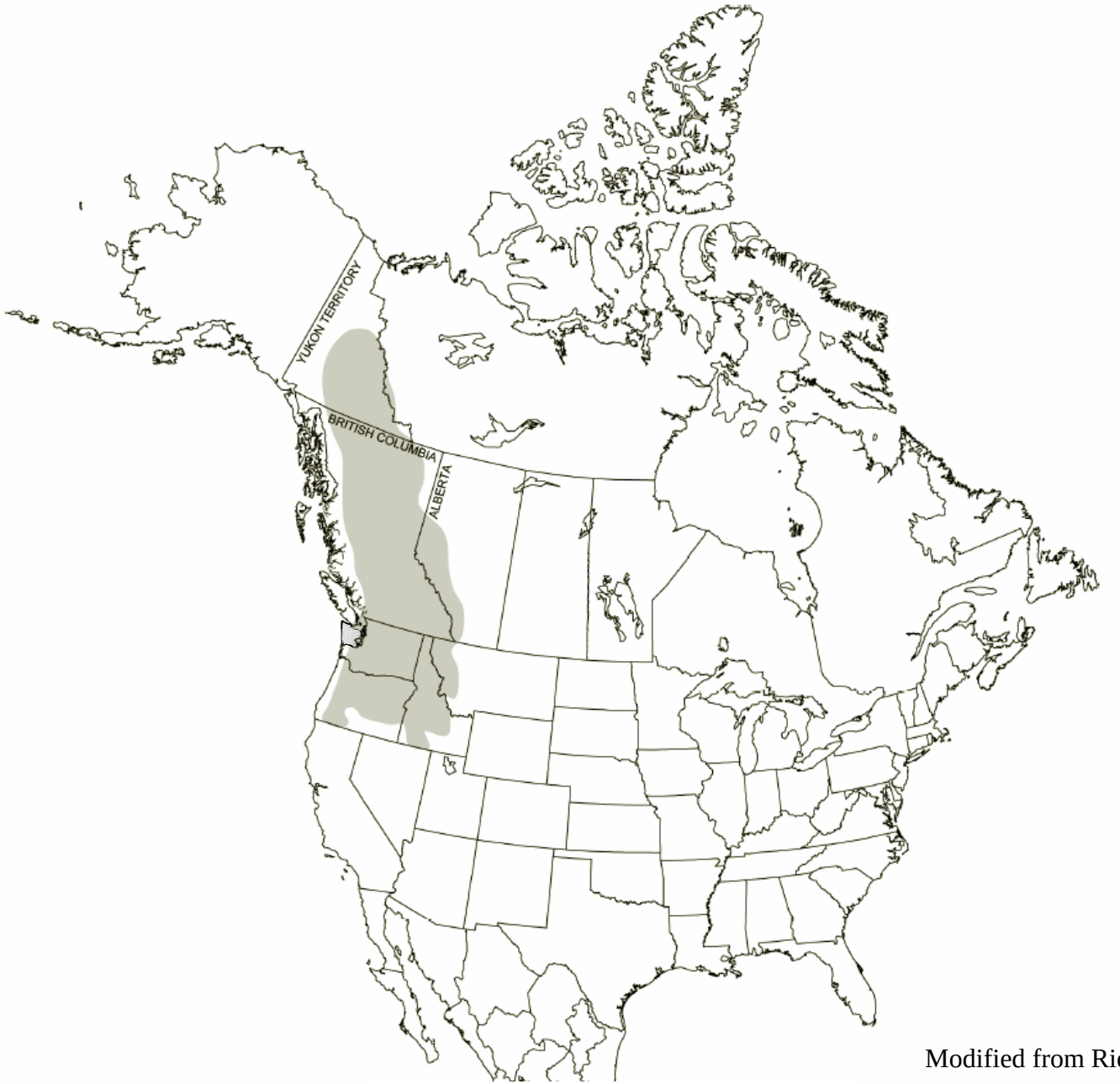
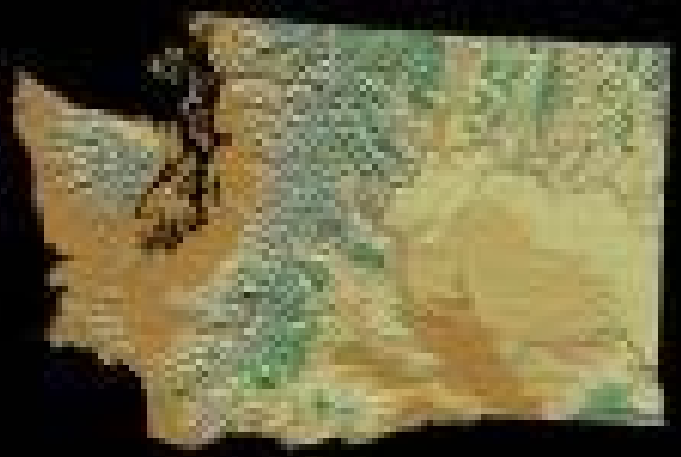
**Skagit River System Cooperative**




Modified from Rieman et al. 1997.



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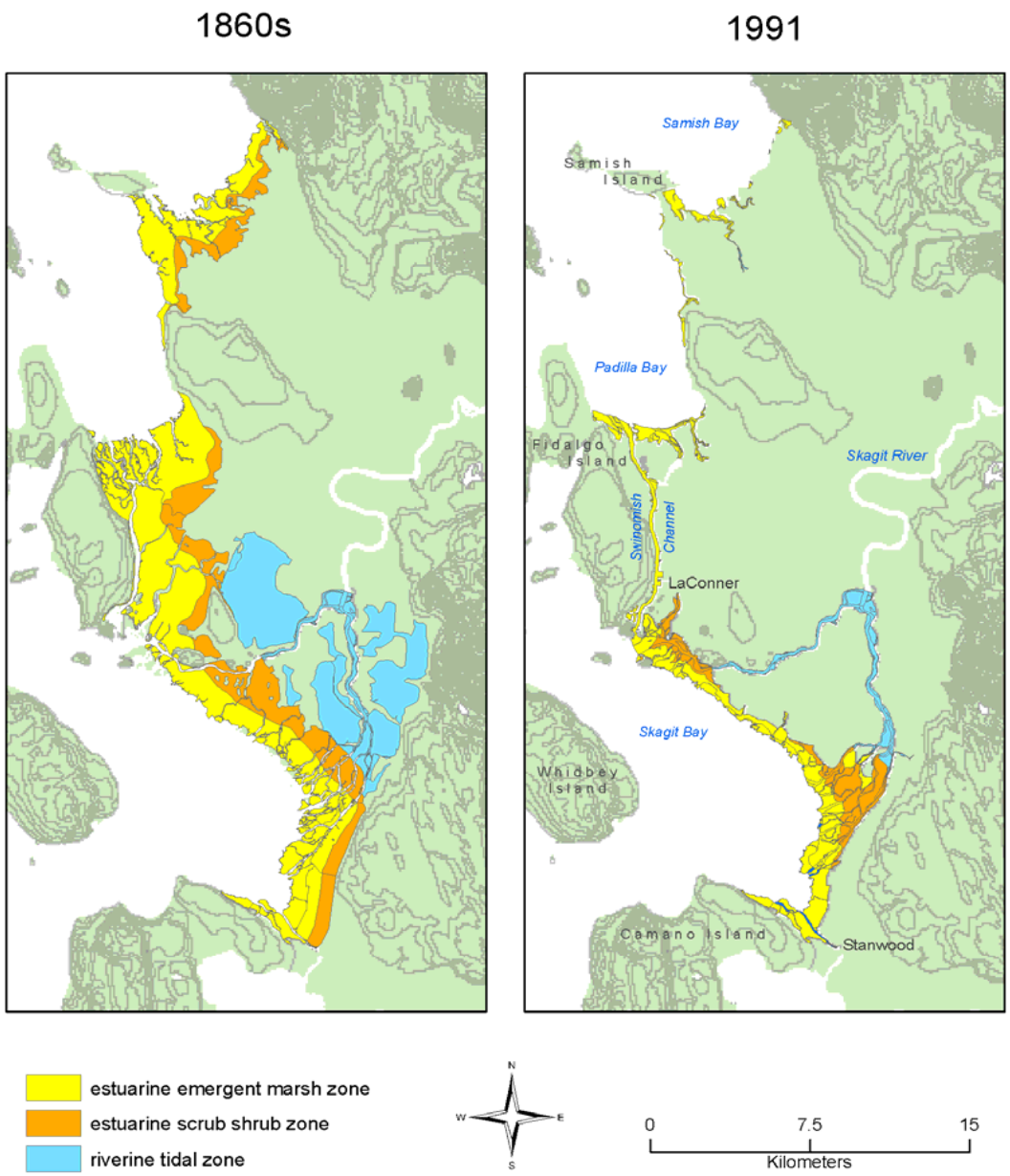
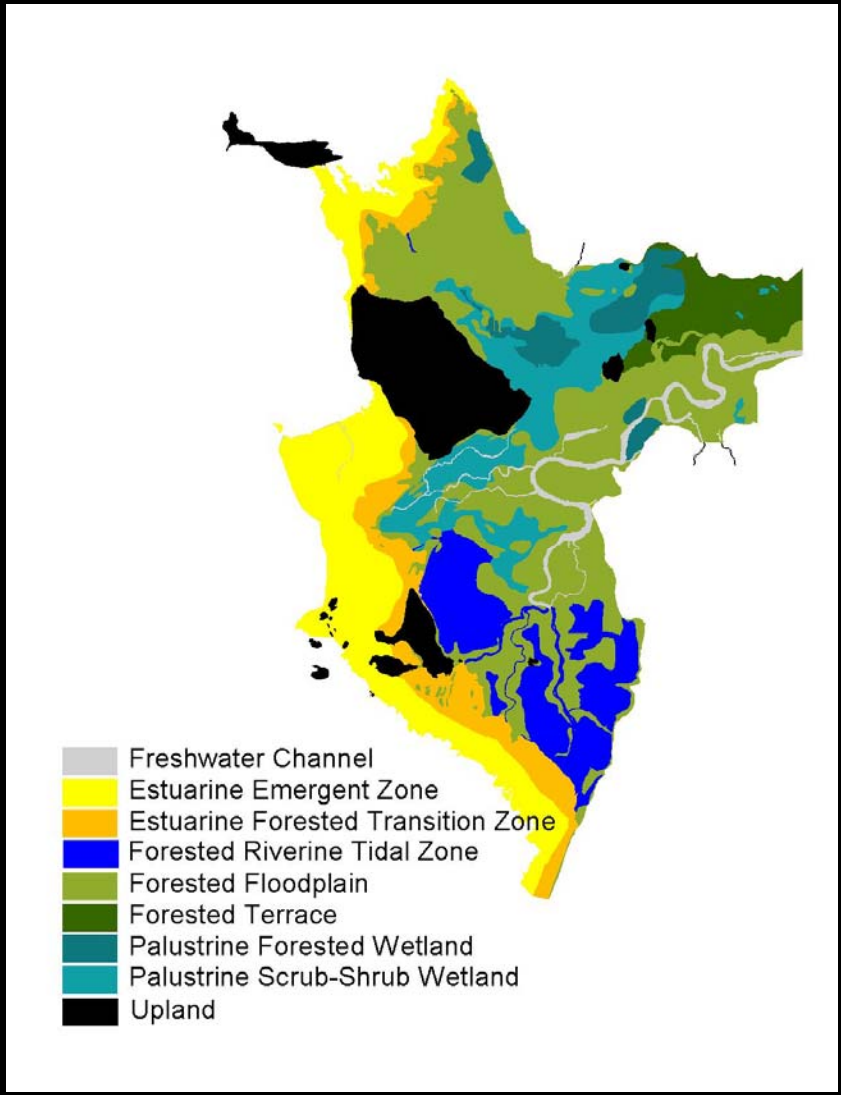
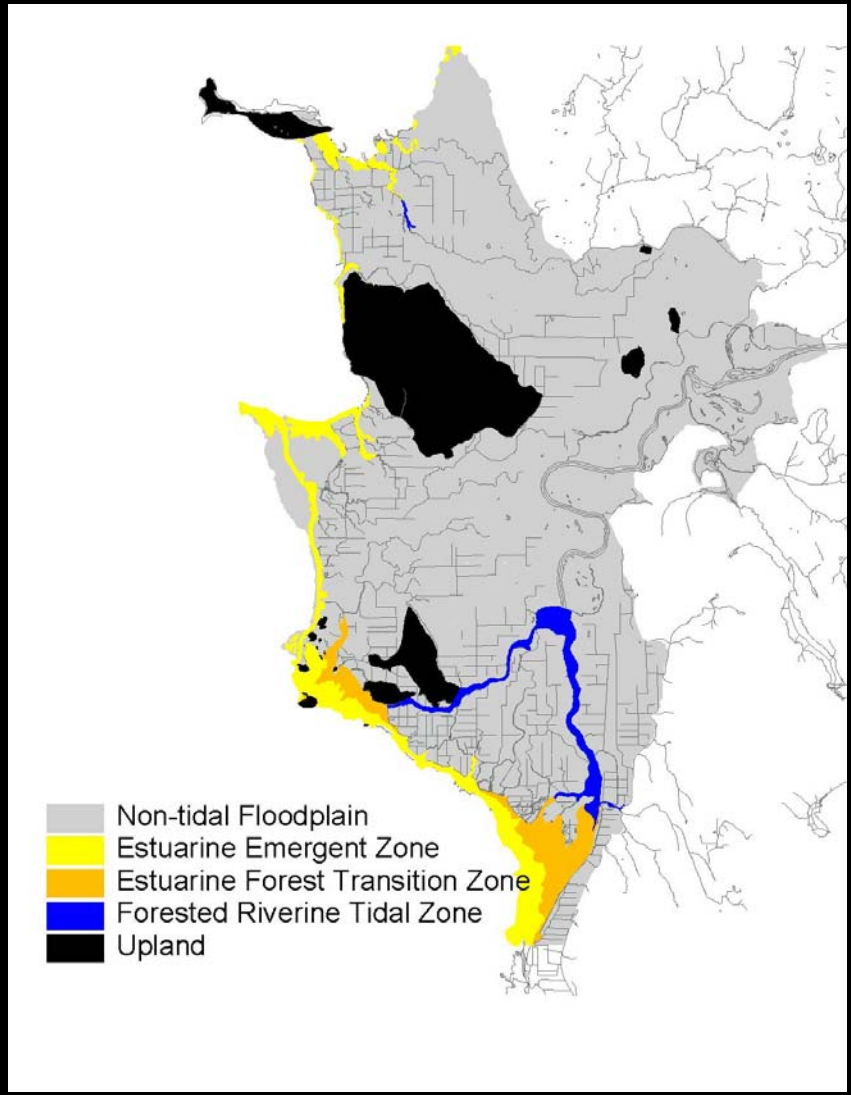
# How has Skagit Delta Habitat Changed?

- Skagit tidal delta habitats are much smaller and more fragmented than historically.
- Rearing opportunity of tidal delta rearing Chinook salmon has been greatly reduced (88% direct loss in habitat for salmon).
- Restoration opportunities exist at historic delta sites.



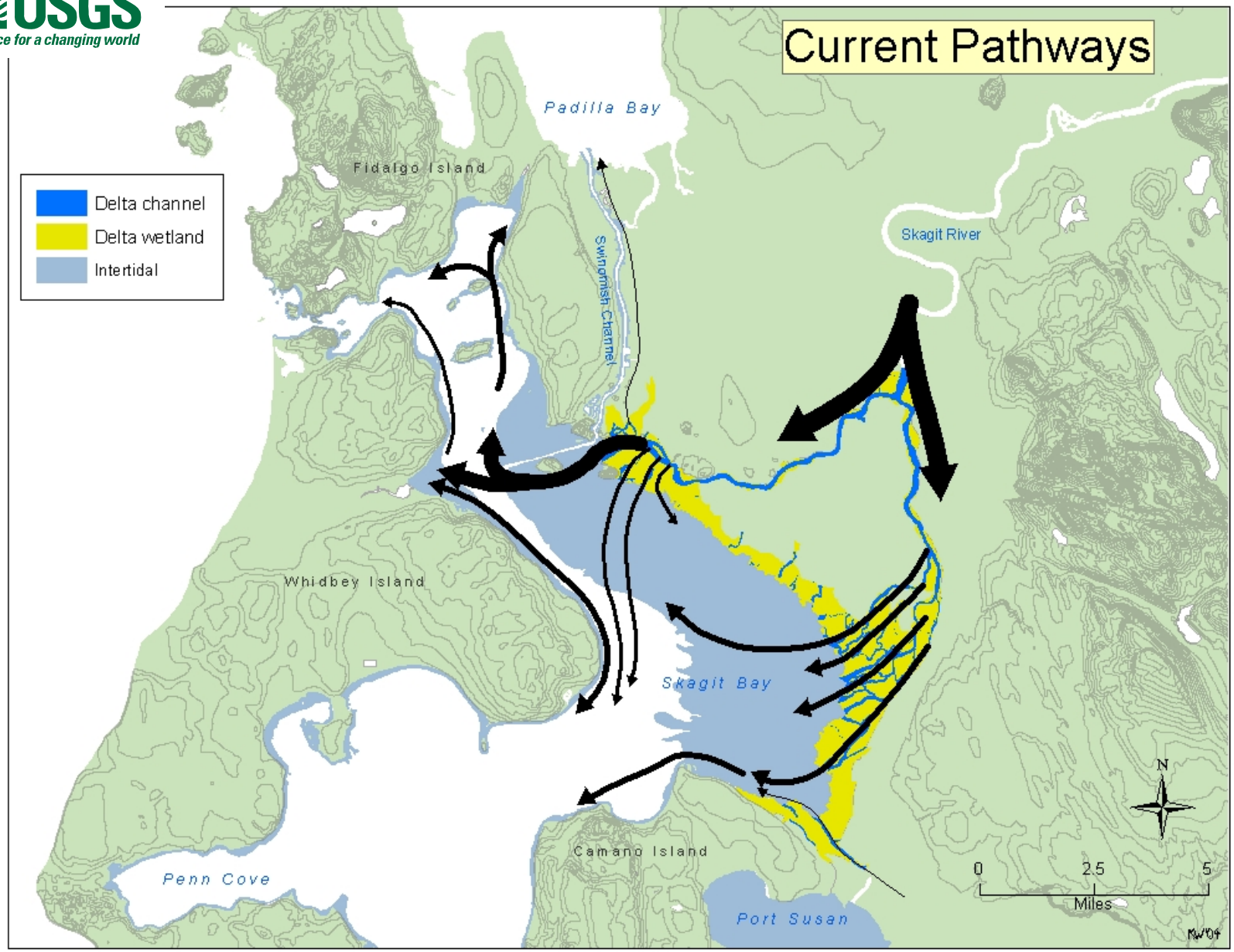
# Skagit Estuary - Historic and Current




**From B. Collins 2000 (University of Washington)**

**E. Beamer unpublished, (Skagit System Cooperative)**


Current Pathways
Delta channel
Delta wetland
Intertidal
Padilla Bay
Fidalgo Island
Swinomish Channel
Skagit River
Whidbey Island
Skagit Bay
Camano Island
Penn Cove
Port Susan
N
0
2.5
5
Miles
MW04

CHINOOK SALMON—SALT WATER PHASE

How important is the Skagit delta as
nursery habitat for Chinook Salmon?

# Objectives

**Evaluate:**

1. Length of residence and growth in various habitat types (freshwater,delta, and nearshore)
2. Age and size when entering or leaving different habitats (freshwater, delta and nearshore)
3. Interannual variation in (1) & (2)
4. Proportional contribution of different life histories to the adult population

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# What are otoliths?

- Calcium carbonate deposits located beneath the brain within the semicircular canals
- Used in orienting or maintaining balance
- Research is focused on the largest of three pairs (sagittae)

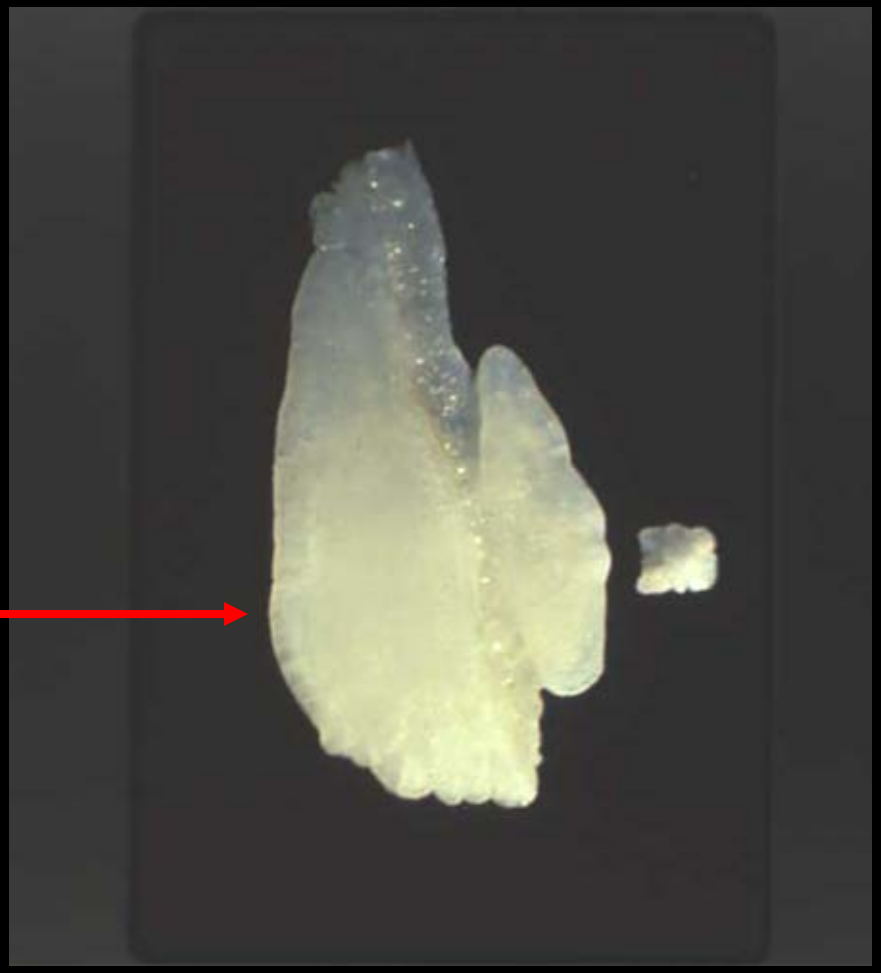
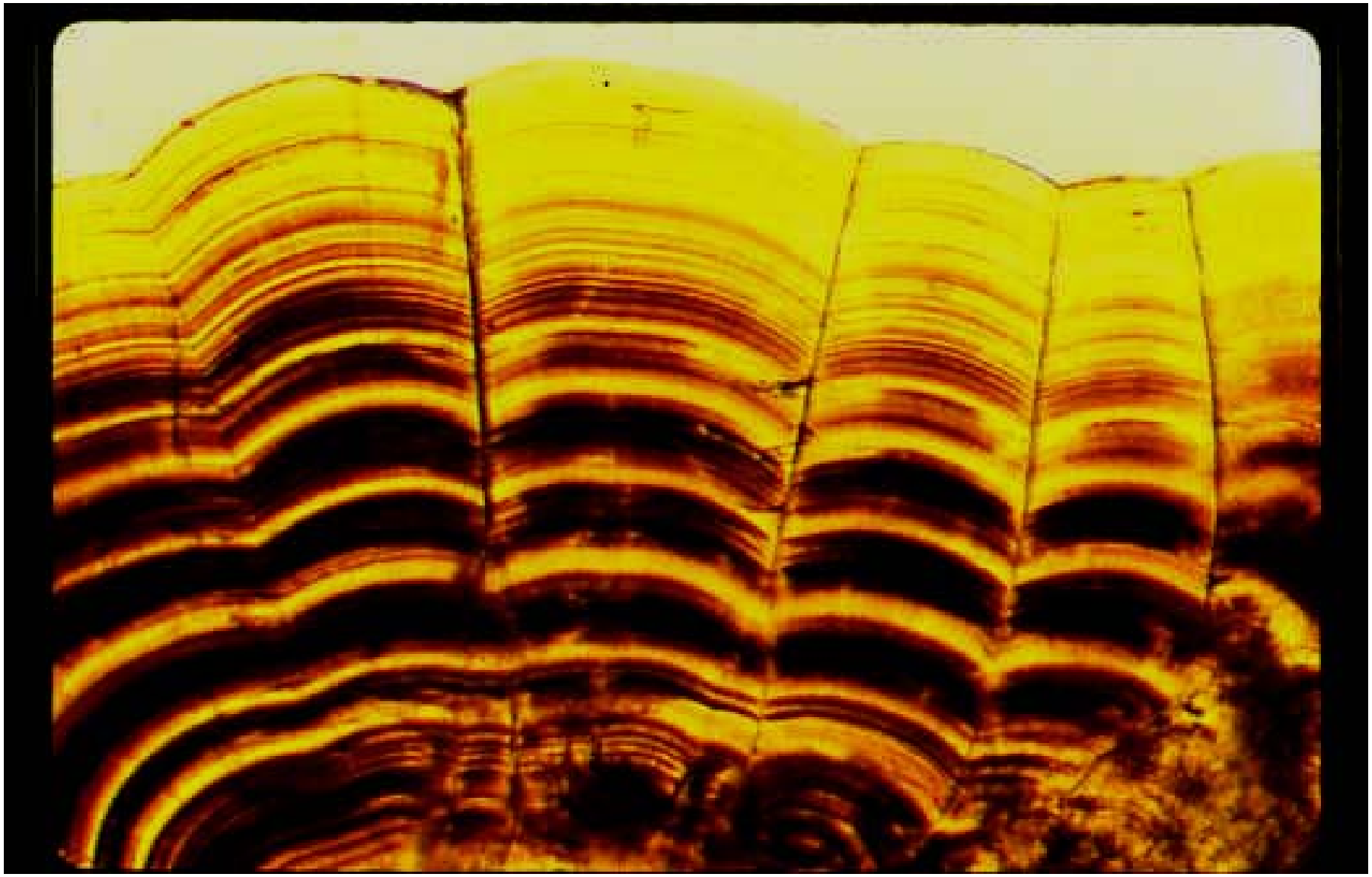


Photo courtesy of Eric Volk

# Whole-otolith annual rings



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# Daily Growth Pattern

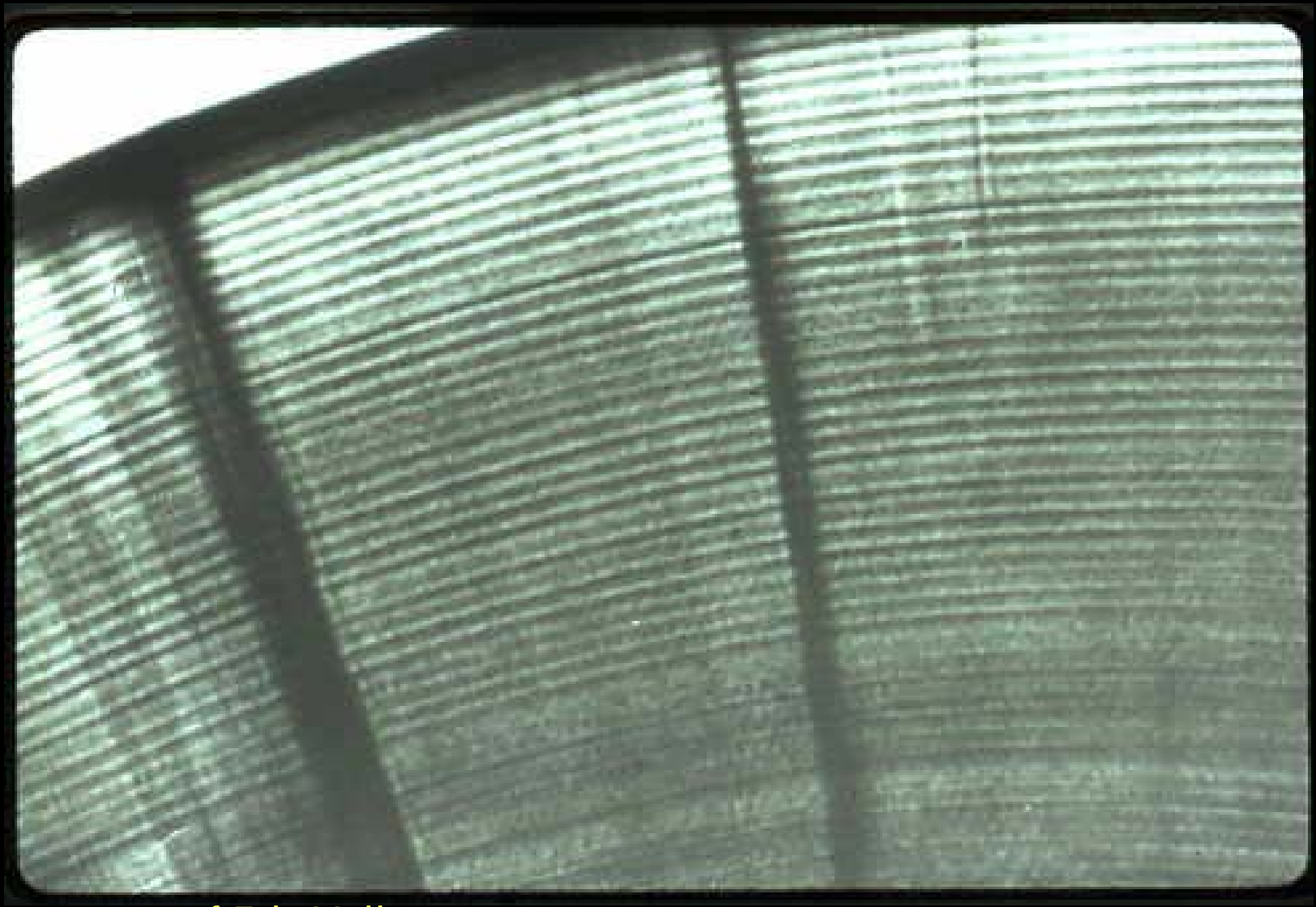


Photo courtesy of Eric Volk

# Otoliths as a tool for identifying life history types

- Presence or absence of “checks”
  - Identify checks associated with different life history events—e.g., migration between habitats
- Changes in increment patterns and width
  - Estimate residence (# of increments) and growth (mean incremental width) within habitat type
  - Estimate fork length at entrance to or exit from habitat type
- Changes in Sr/Ca ratio across otolith radius
  - Analyze chemical components using an Inductively Coupled Mass Spectrometer (ICPMS)

# Variation in Daily Growth Pattern

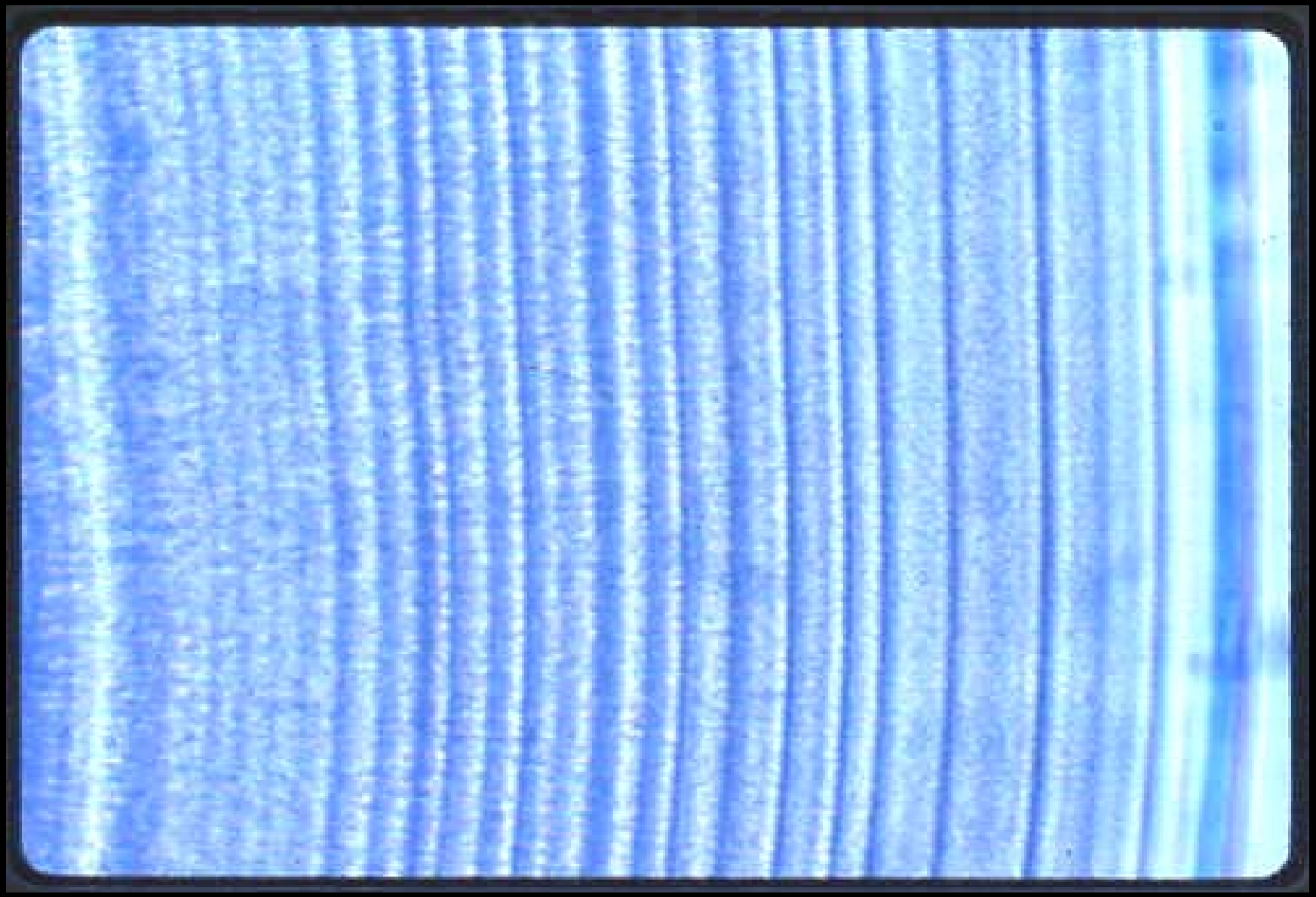
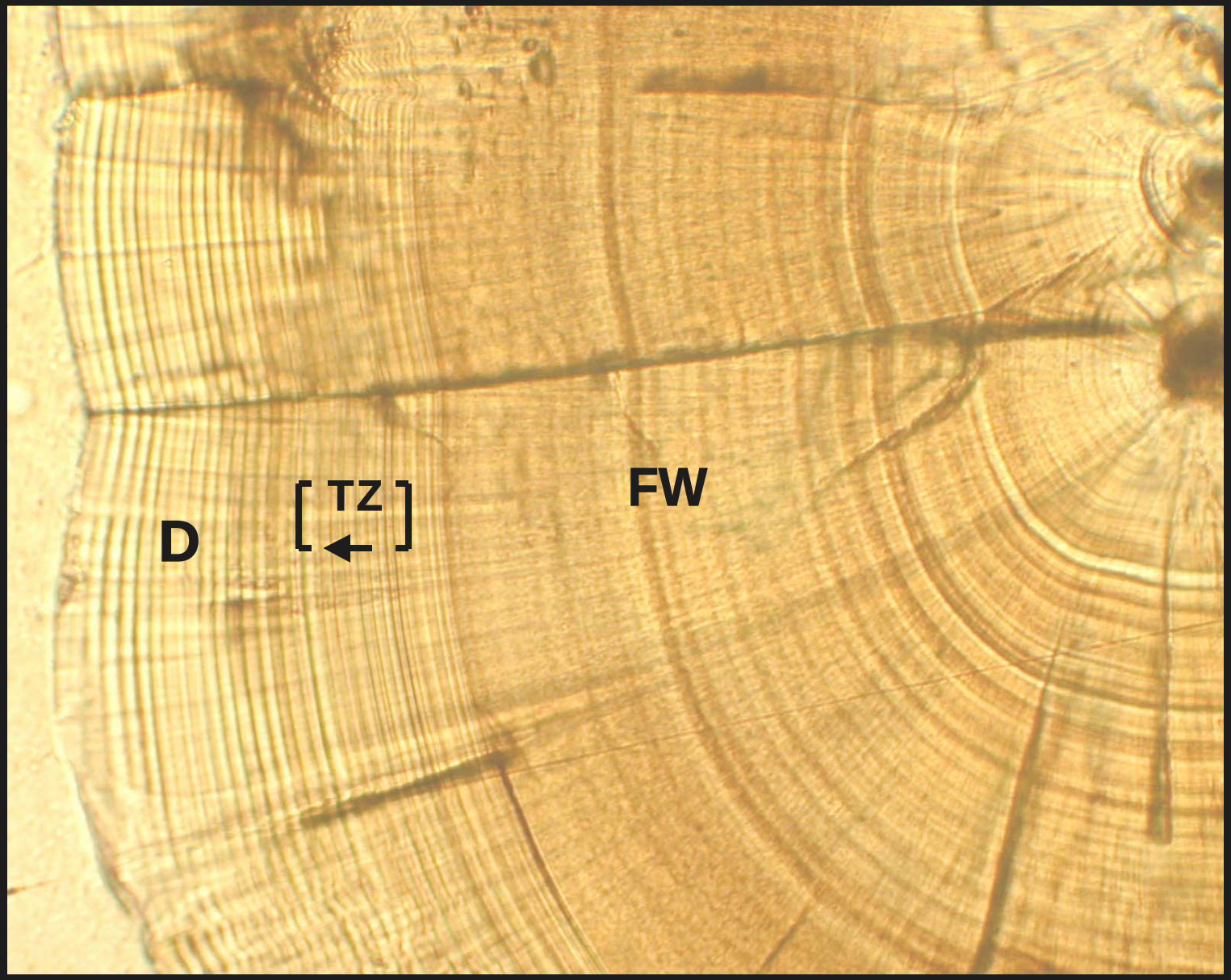


Photo courtesy of Eric Volk

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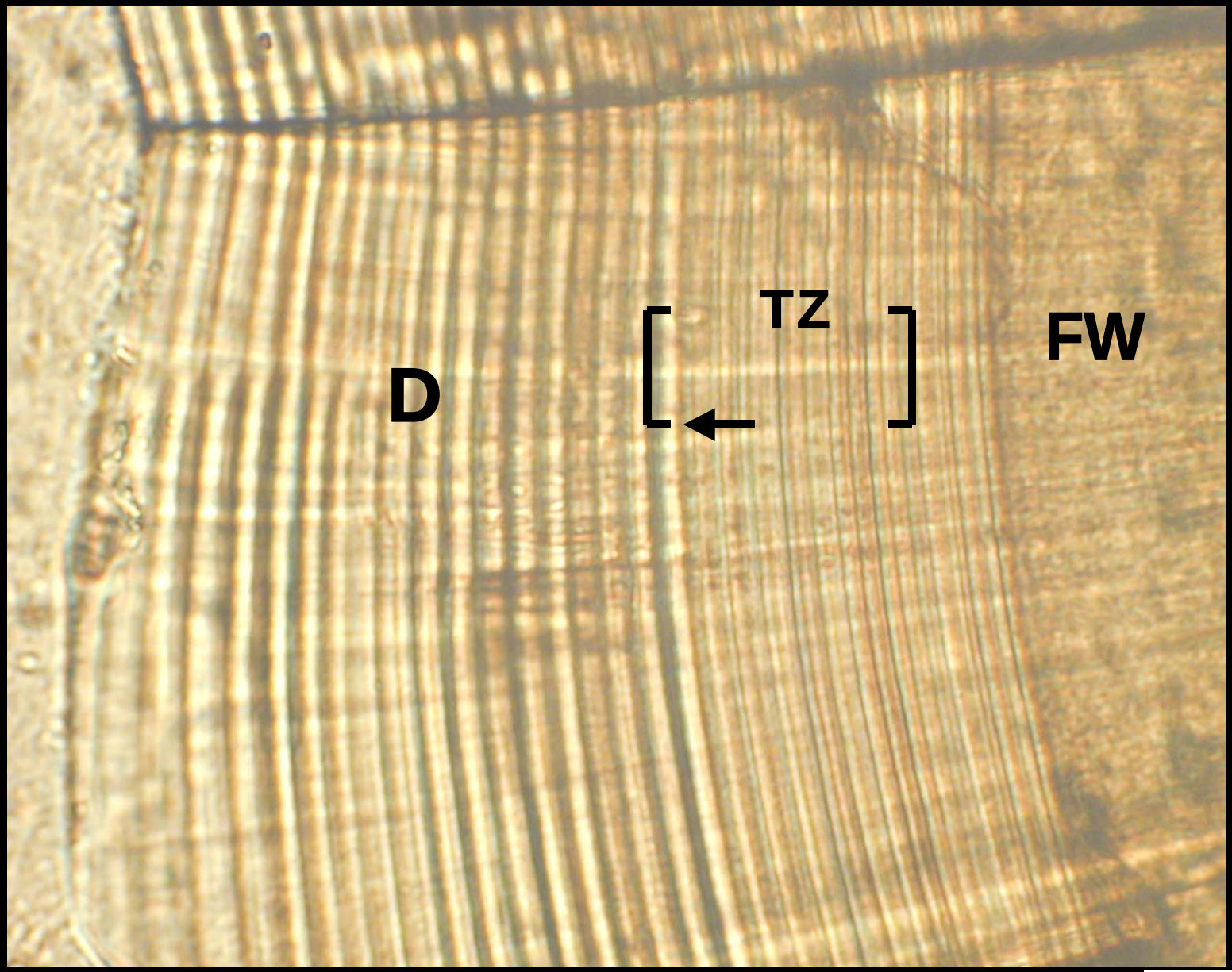


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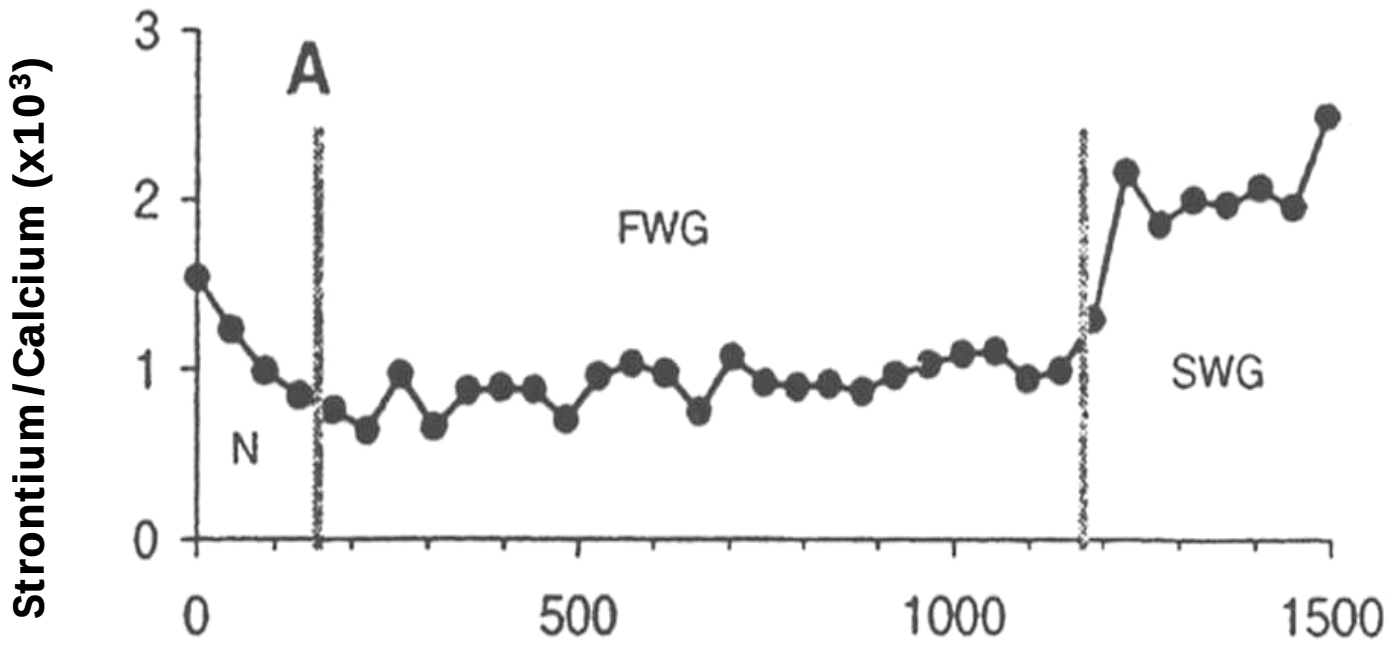
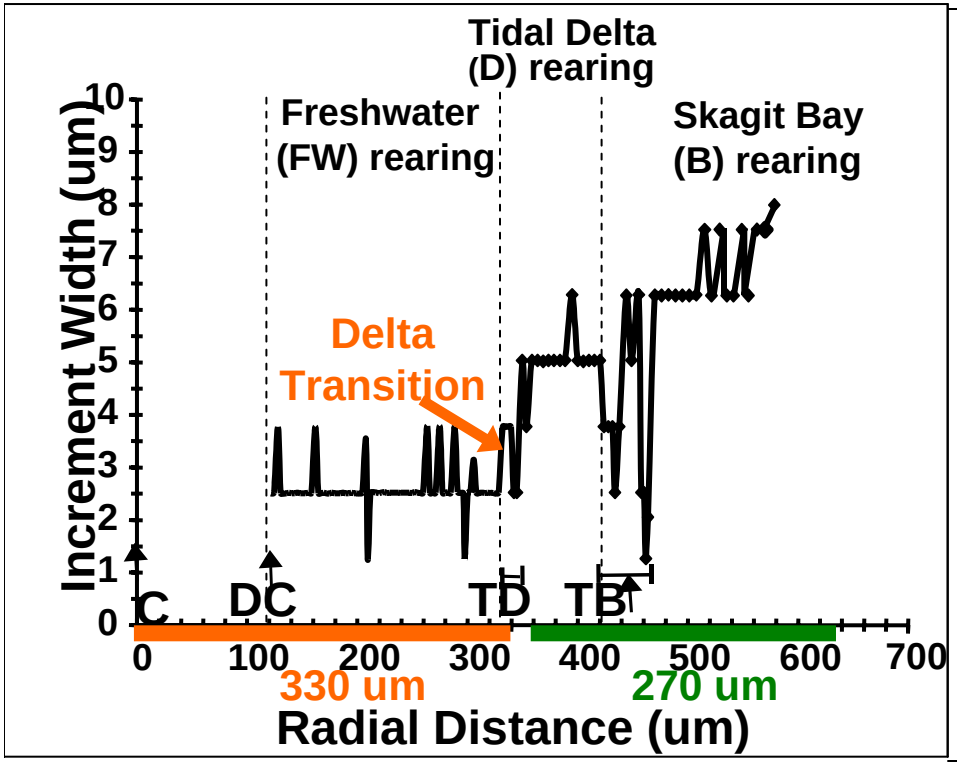
# Elemental Analysis

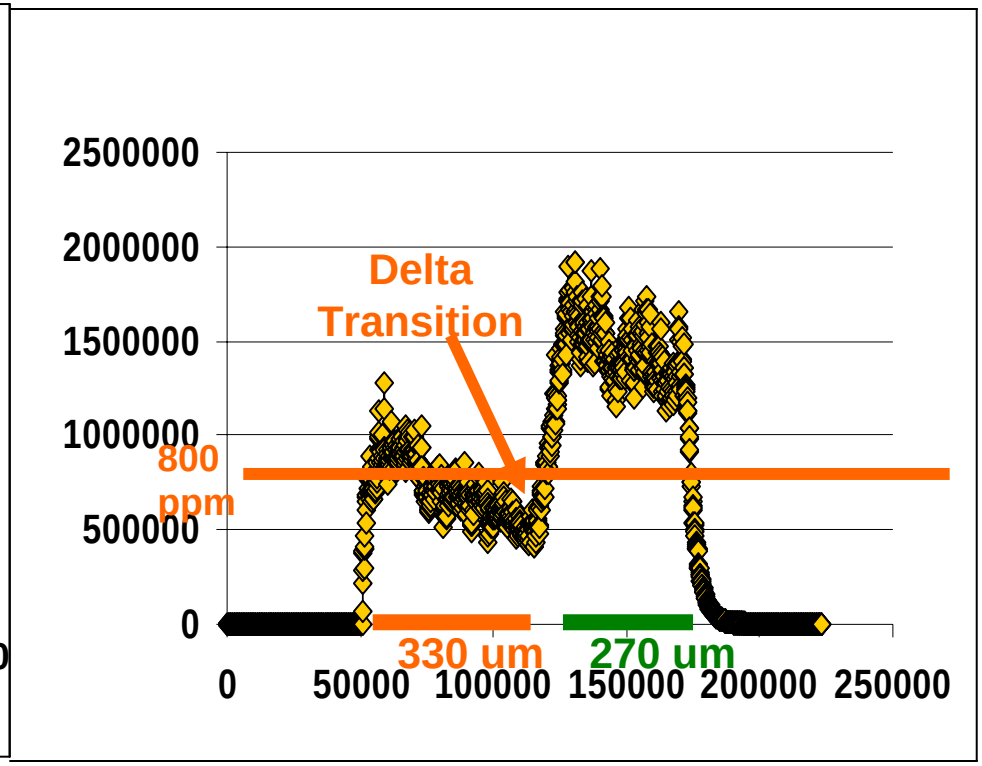



Otolith radial distance (microns)

Zimmerman (2000)

# OTOLITH CHEMISTRY vs. MICROSTRUCTURE




**Methods closely agree with FW to delta transition and the radial distance representing total delta and bay time**

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# Three life histories for Skagit River fall Chinook

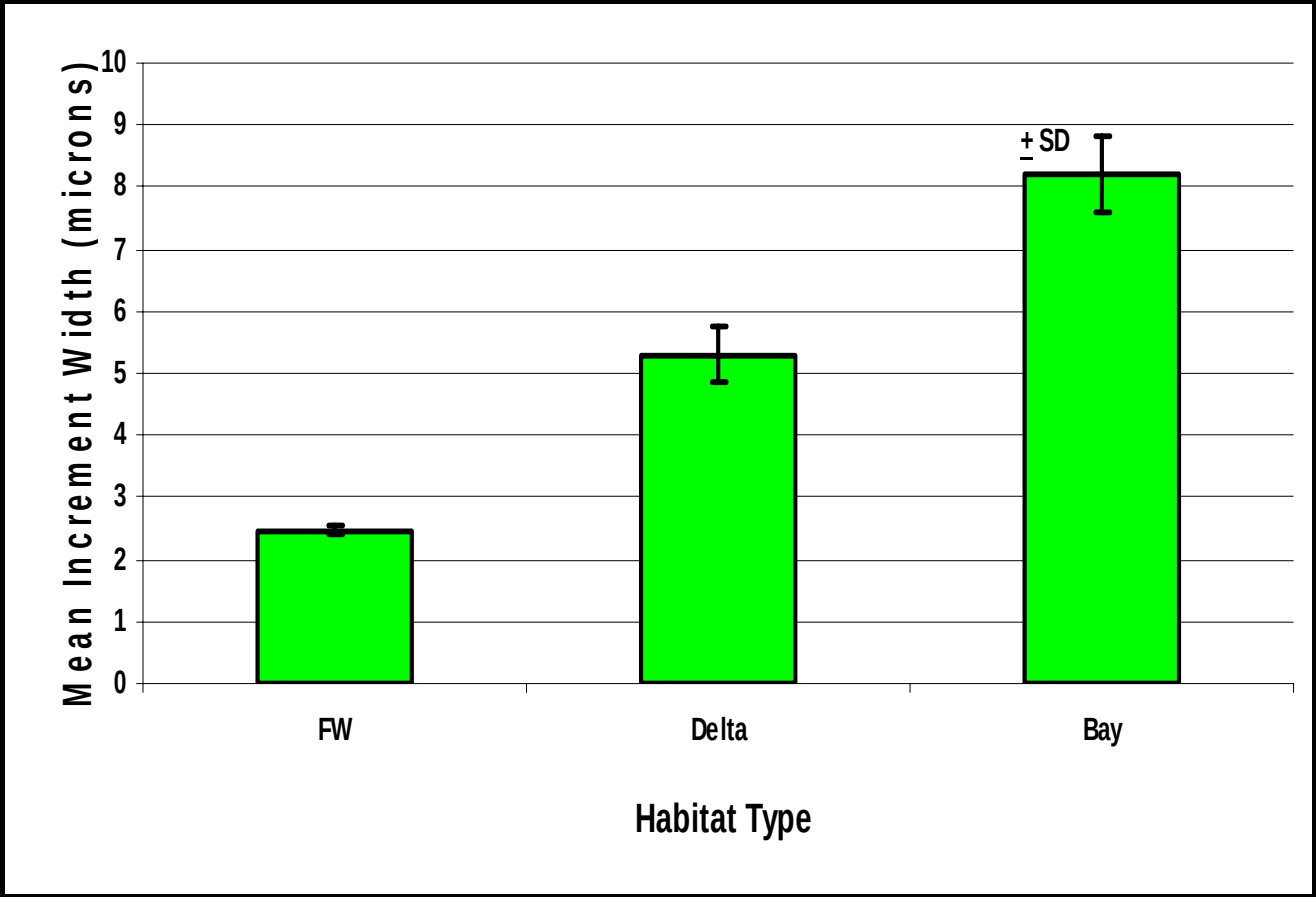
- **Type 1 (fry migrants)** - fry emerge and quickly migrate into Skagit Bay, similar to pink and chum salmon

- **Type 2 (delta users)** - fry emerge and quickly migrate into the delta where they rear to ~70 mm fork length, then migrate to Skagit Bay
  * (> 1 strategy within this category)

- **Type 3 (parr migrants)** - fry emerge and rear a couple of months in freshwater to get up to size (~70 mm fork length), then migrate to Skagit Bay

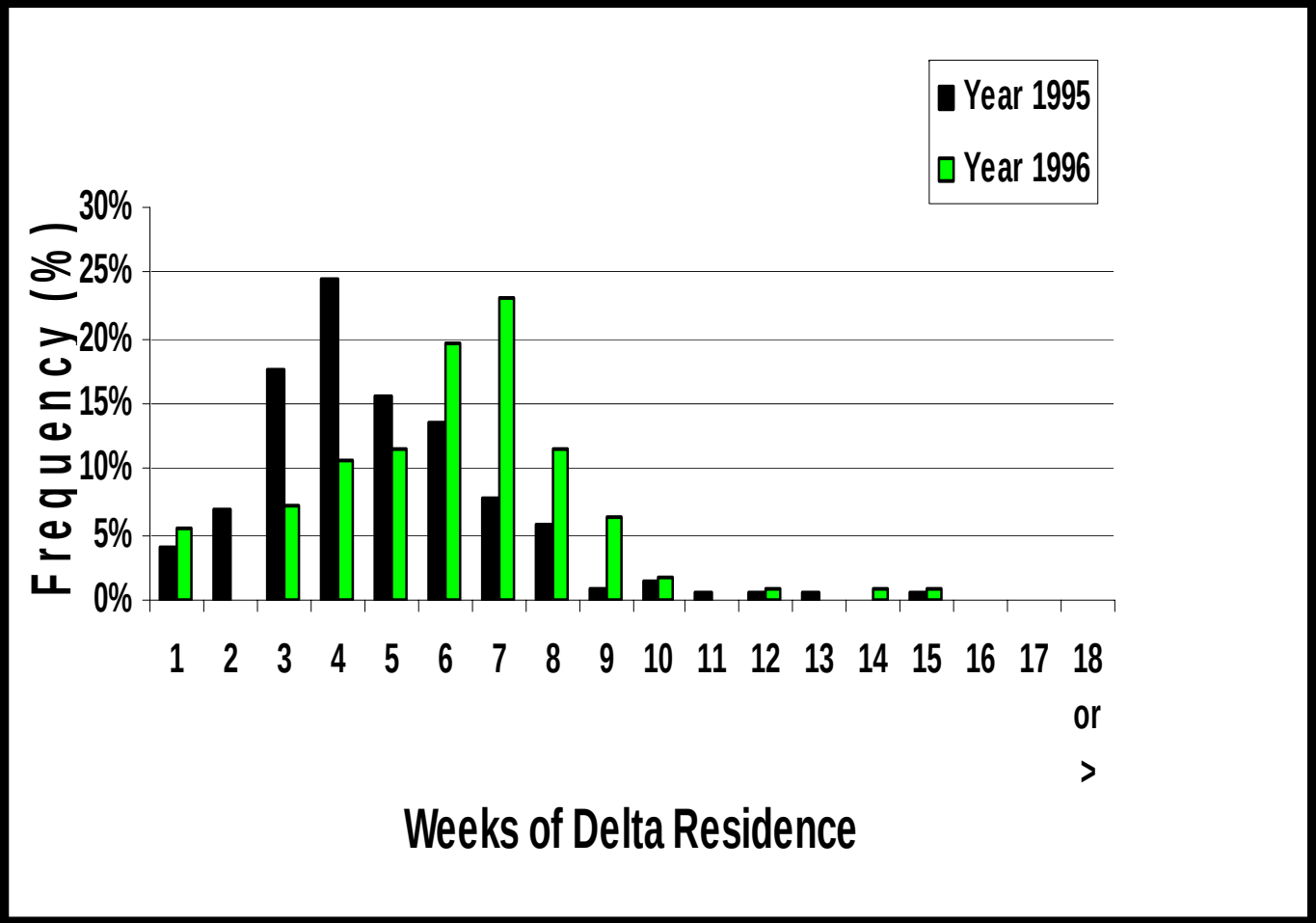
# Back-calculated growth for different habitats

- Mean increment width doubles during lower delta residence;
- and increases 1.5 times during near-shore residence



# Delta Residence

- Residence time varies from year to year
- In higher density year (1995) residence time was shortened
- At least 70% of all delta users used the delta for a month or longer

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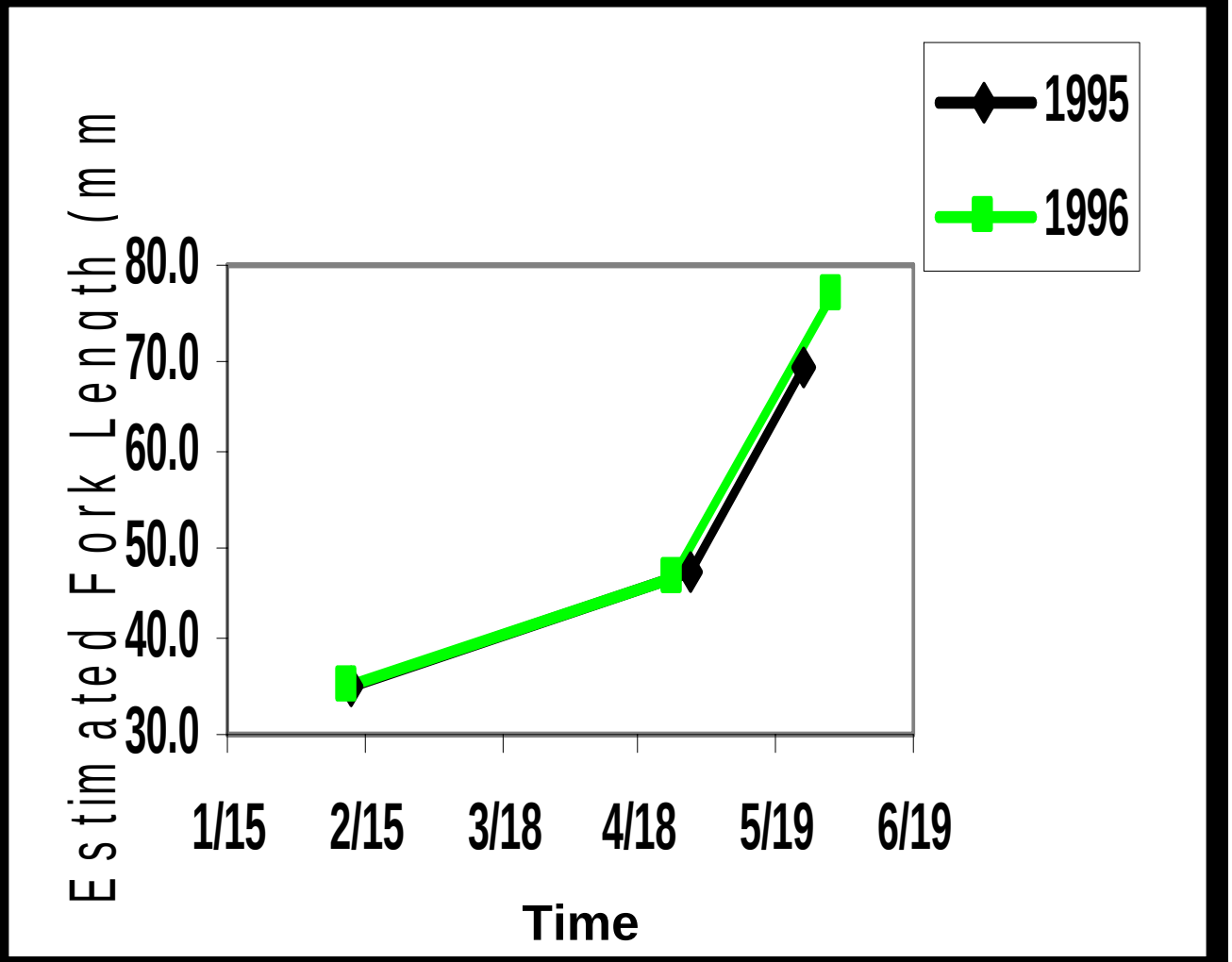
# Delta Residence varies among years

- **Dominant life history type in both 1995 and 1996**
- **Size at entrance to delta 47mm and size at exit 69-77mm, with a 4-5 fold increase in weight**
- **In 1996 arrived in the delta slightly earlier and stayed later, growing almost 10mm larger**

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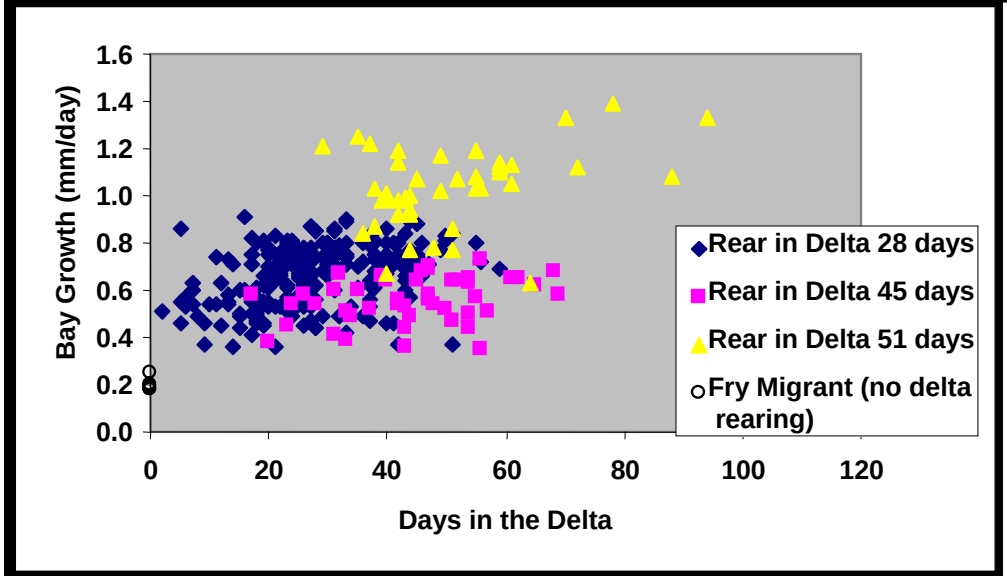
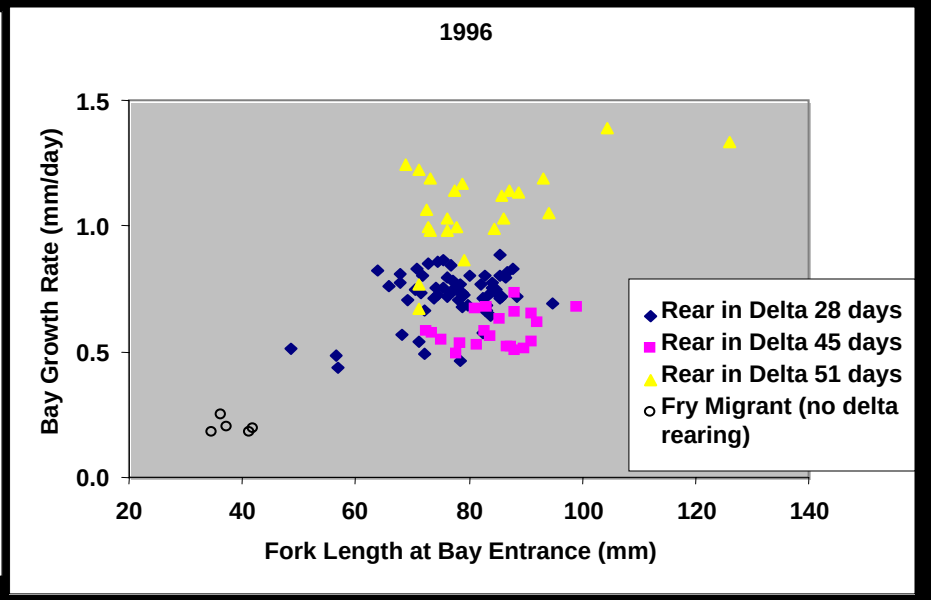
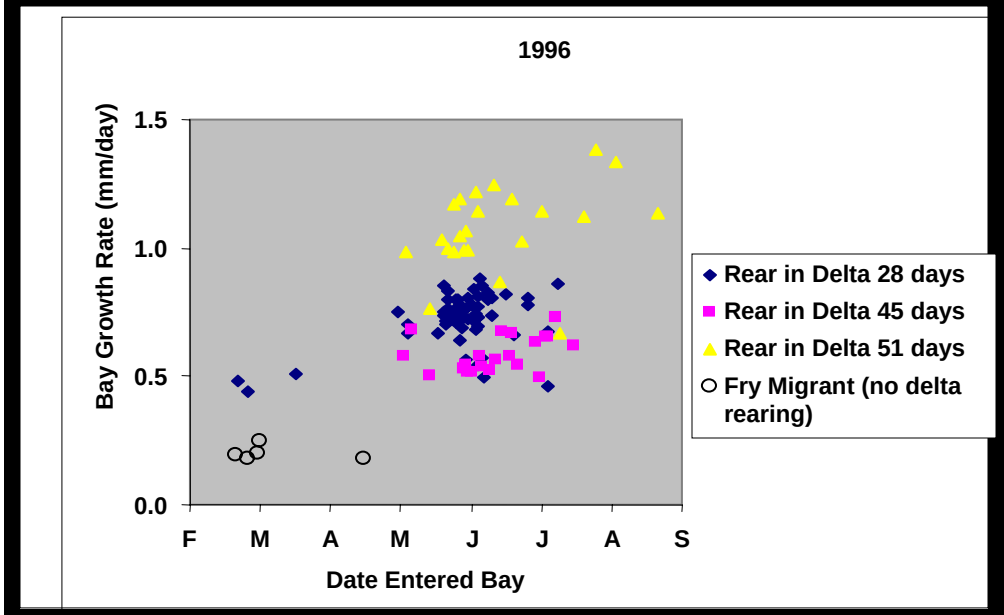
# Importance of Delta Habitat on Growth of Juvenile Chinook in Skagit Bay

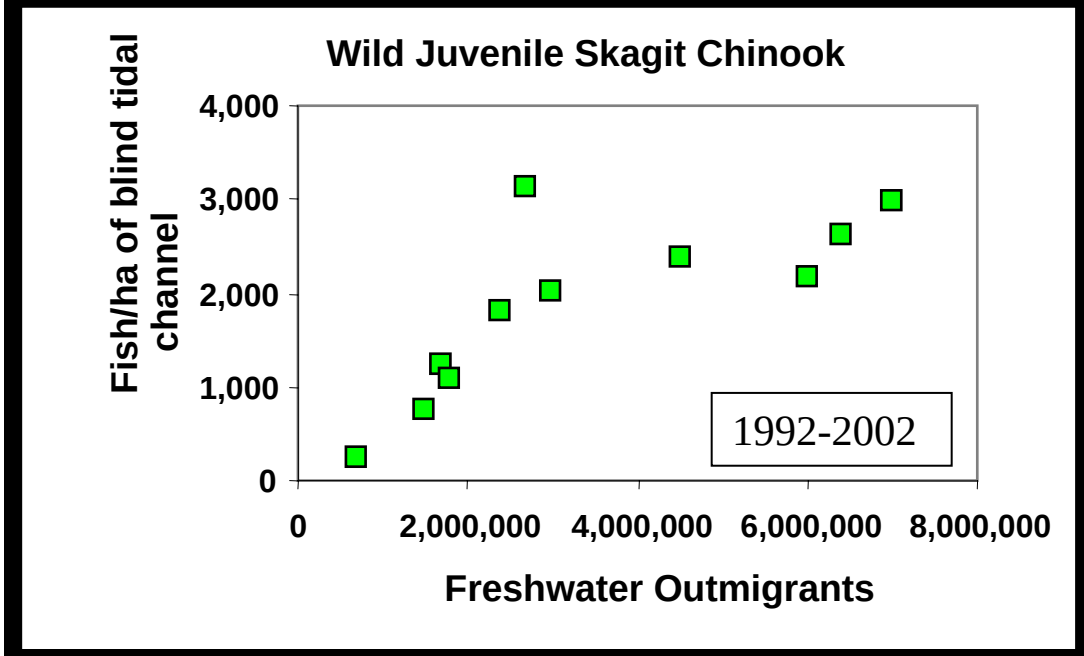


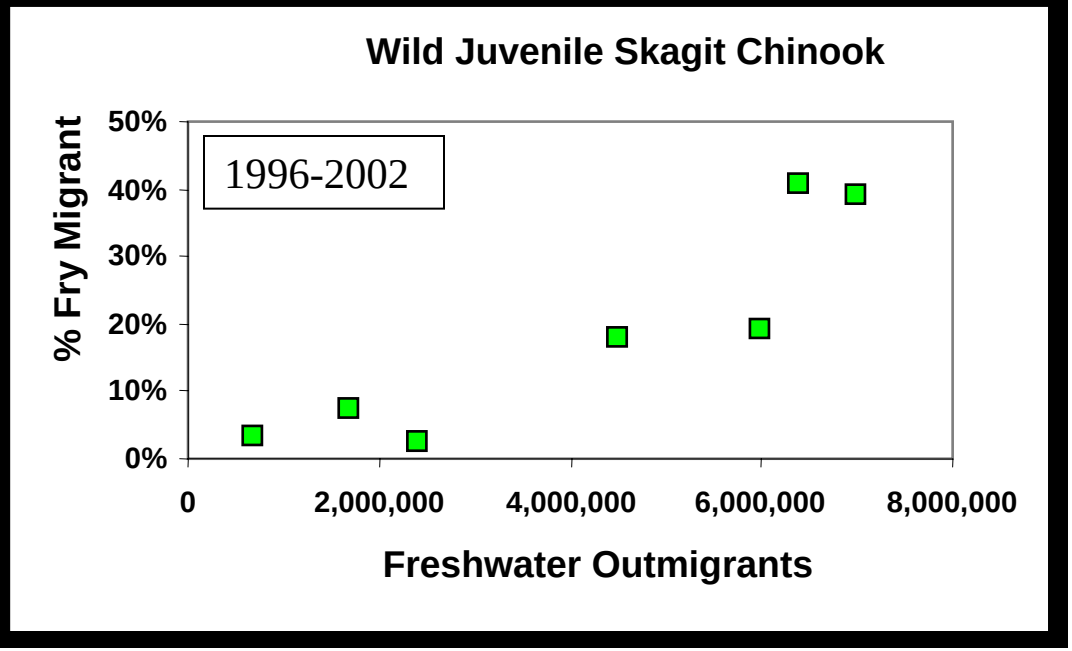

- The longer wild sub-yearling Chinook spend in the delta, the better they grow in nearshore habitat.
- Fish size at bay entrance positively influenced growth rate in the nearshore.
- The later in the season fish entered near-shore habitat, the better they grew in nearshore habitat.

# Indication of Density Dependence in the Delta




- **The number of Chinook per unit area within the delta levels-off as the total number of outmigrants increases.**
- **The size of Chinook in delta habitat (not shown) decreases as a function of outmigration up to populations of ~3,000,000.**

**The proportion of the total wild juvenile Chinook population in Skagit Bay bypassing delta habitat and migrating directly to the nearshore (defined as fry migrants) increases with outmigration levels above 2,500,000.**




Freshwater Chinook smolt population estimates from D. Seiler, WDFW, Olympia, WA

# Current and future results will provide guidance for recovery plans and actions

- Motivating and guiding habitat restoration within the delta
- Supporting decisions of whether to restore habitat in the delta or in upstream areas.

Beamer, E., A. McBride, C. Greene, R. Henderson, G. Hood, K. Wolf, K. Larsen, C. Rice, and K. Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. http://www.skagitcoop.org/documents.html

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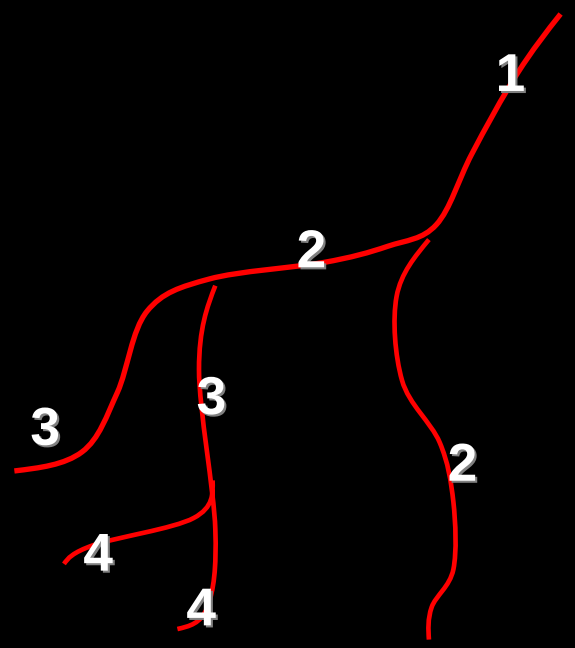
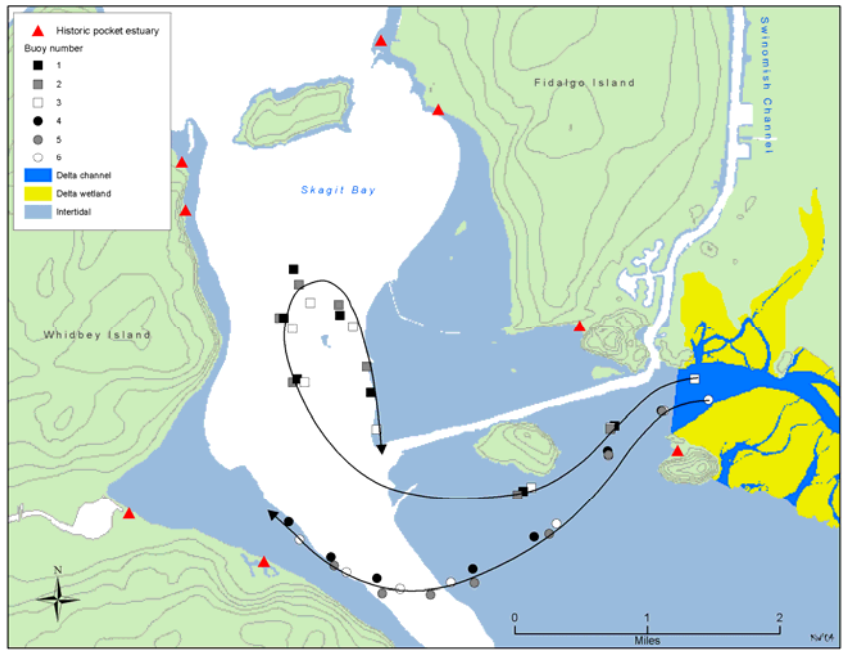
Padilla Bay
Fidalgo Island
Similk Beach
Turners Bay
Skagit River
Kiket Lagoon
Lone Tree Lagoon
SneeOosh Lagoon
Ala Lagoon
Dugualla Lagoon
Dugualla Bay Heights
Whidbey Island
Skagit Bay
Crescent Harbor
Mariners Cove
Arrowhead Lagoon
English Boom Lagoon
Camano Island
Penn Cove
Delta channel
Delta wetland
Intertidal
N
W
E
S
0
5
10
Kilometers

# Habitat Connectivity

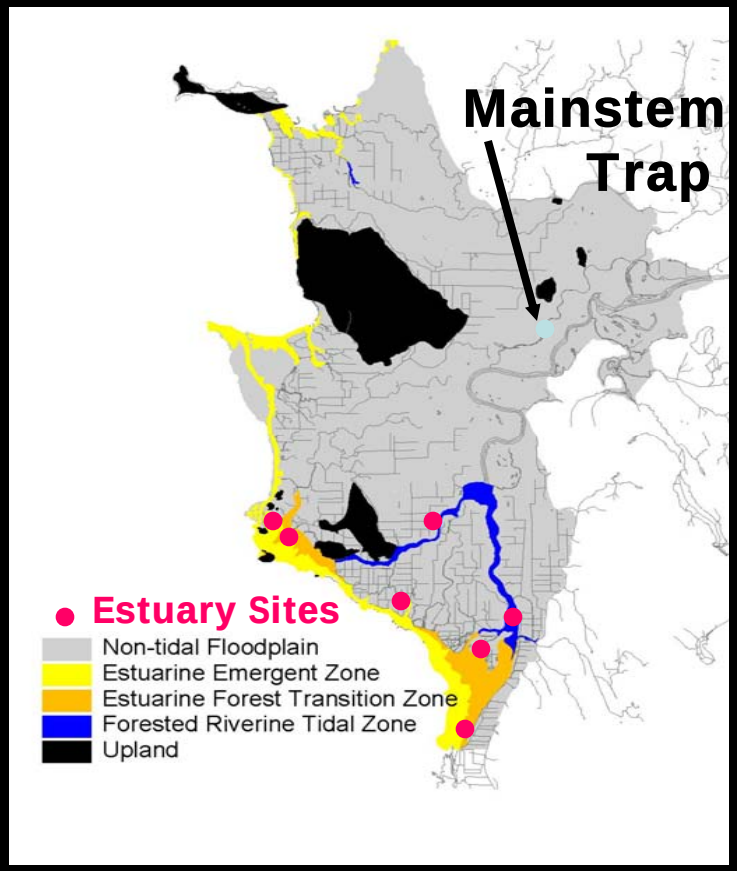
- Applies to delta and nearshore
- Function of distance traveled and branching
- Local and landscape scale
- Explains 60% of the variation in Chinook density (after freshwater smolt population)
- Some areas are more strategic for restoration or are bottlenecks to limits in rearing capacity



# Estuarine Check Summary

- The estuarine check appears to be formed in the lower estuary zone (yellow on map)
- Mean otolith increment width in lower Estuarine Region: 5.5 microns compared to 2.5 microns in the Freshwater Region
- No estuarine checks observed on any of the 200 samples collected at the mainstem trap

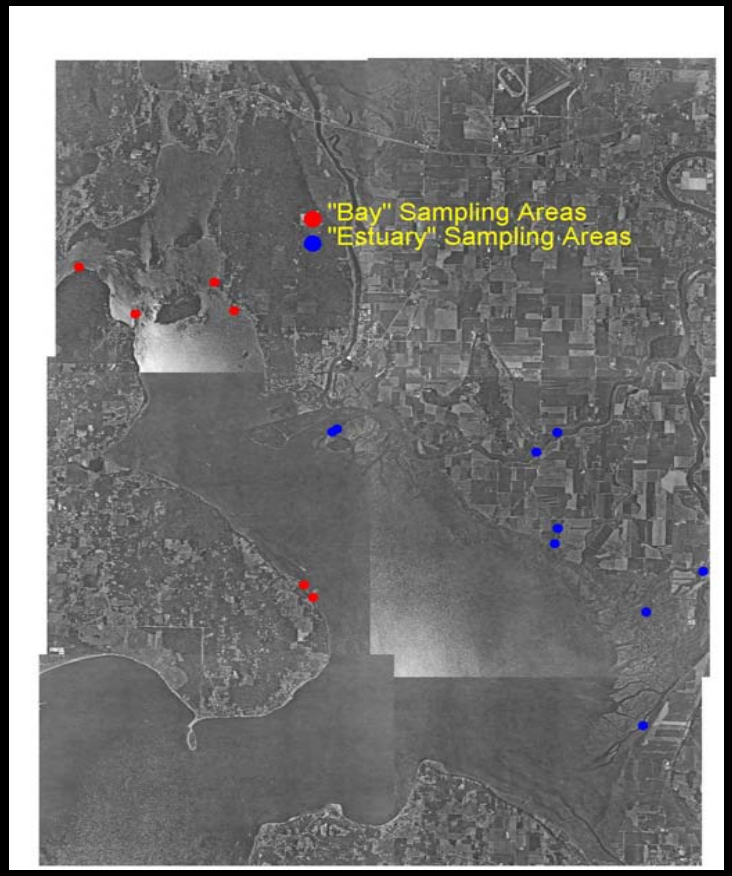


# Bay Check Summary

- Bay Checks appear to be formed when fish leave the vegetated estuarine delta and are associated with more saline habitat in Skagit Bay.

- Mean otolith increment width in Bay Region: 8 microns compared to 5.5 microns in the lower Estuarine Region

- A Bay Check has never been observed on samples collected at estuary or mainstem trap sites.



# Otolith uses

1. **Determine annual growth patterns -** aging, general life history info., individual based growth rates

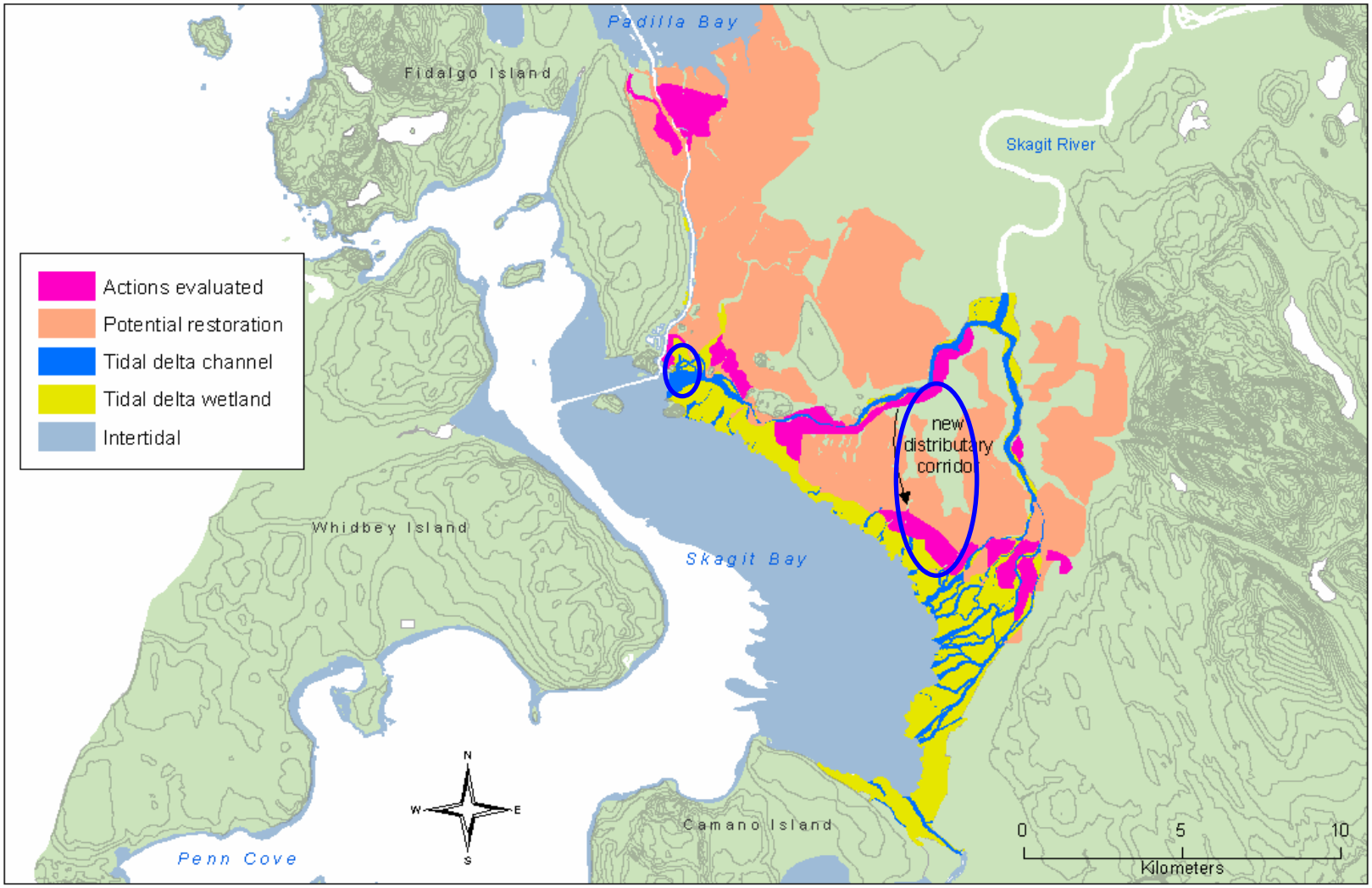
2. **Determine daily growth patterns -** aging (YOY), growth, residence time, life history trajectories, distinguishing wild fish from hatchery fish, ...

3. **Determine elemental composition -** stock ID, environmental conditions (temp., diet, water chemistry), river/lake of origin, population structure, ...

4. **Fish Identification -** induced chemical or thermal marking patterns for research or hatchery programs

# Importance of understanding different juvenile life history types

- Chinook vary their habitat use over time and space
- Understanding specific life history types is critical to understanding production bottlenecks
- Growth, reproductive success and survival can be limited by such bottlenecks


Padilla Bay
Fidalgo Island
Skagit River
Actions evaluated
Potential restoration
Tidal delta channel
Tidal delta wetland
Intertidal
new distributary corrido
Whidbey Island
Skagit Bay
N
W
E
S
Camano Island
Penn Cove
0
5
10
Kilometers

# Differential Growth in the Delta

| Lower Delta Sites | Ave. growth rate (mm/day) | Upper Delta Sites | Ave. growth rate (mm/day) |
|---|---|---|---|
| Brown Slough Barrow Channel<br>Brown Slough Dike Side<br>Ika Saltmarsh<br>Tom Moore Saltmarsh | 1.60<br>1.80<br>2.93<br>1.13 | Cattail Marsh<br>Deepwater Slough<br>Freshwater Pond<br>Grain of Sand | 0.40<br>0.57<br>0.54<br>0.64 |
| All sites combined | 1.68<br>S.D. = 0.88<br>n = 62 | All sites combined | 0.53<br>S.D. = .24<br>n = 74 |

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