A Race to the North – How Size, Age and Growth Influence a Gradient in Sockeye Body Size

Cameron Freshwater, Marc Trudel, Strahan Tucker, Terry Beacham, and Francis Juanes

Marine Ecology, Fisheries and Conservation Lab - University of Victoria

Pacific Biological Station - Fisheries and Oceans Canada

University of Victoria

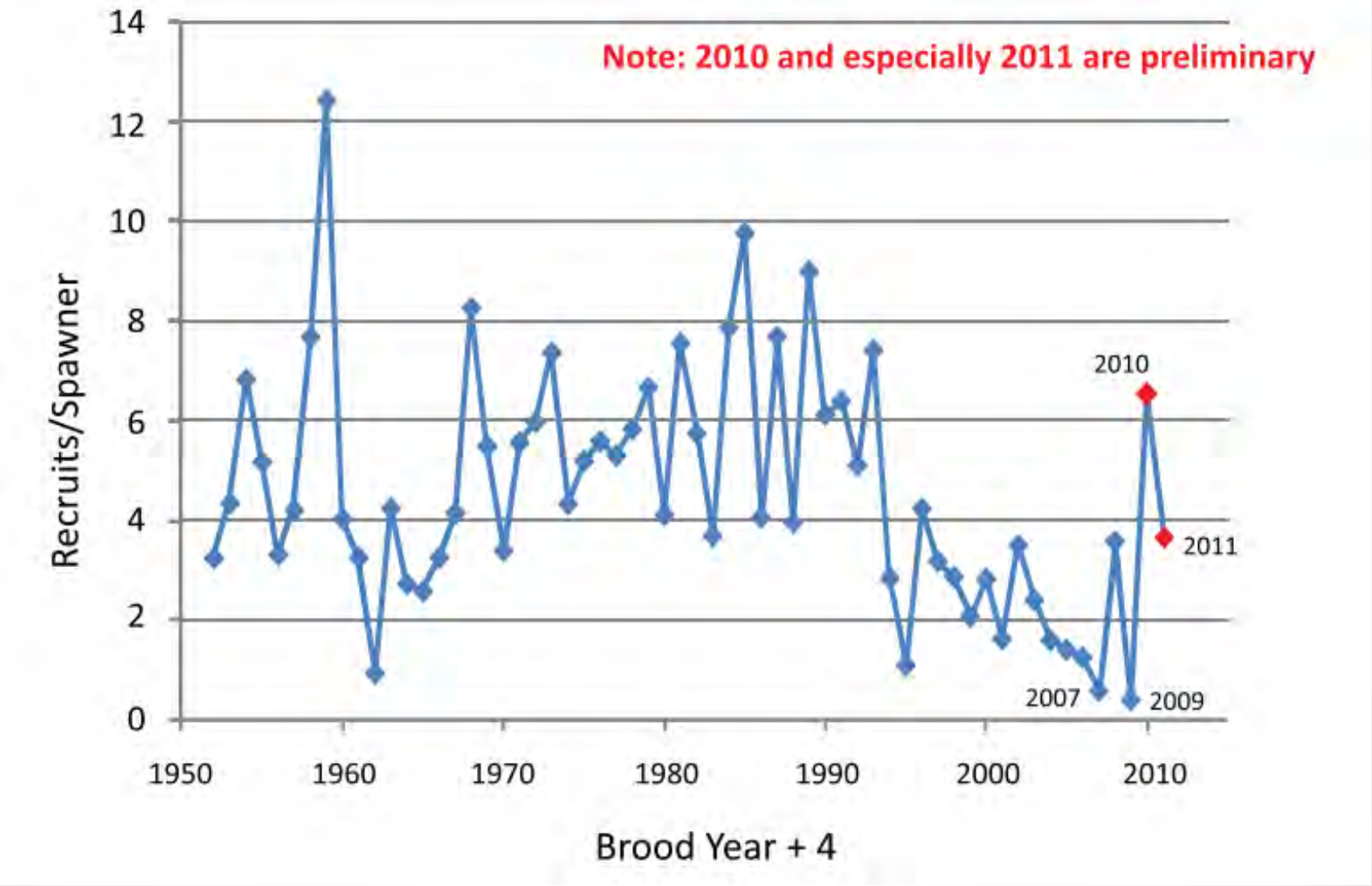
Pêches et Océans Canada

Fisheries and Oceans Canada

LIBERO

Pacific Salmon

Sockeye Fishery



Variation in Fraser River sockeye salmon production 1950s-2011 (Cohen Commission 2012)

Life Cycle of Sockeye Salmon

Mature adults (spawning grounds)
8

7

Mature adults (directed migration towards natal river)

1

Eggs (redds, usually in streams)

Sockeye Salmon Life Cycle Phases

2 Alevin (gravel)

6

Immature adults (open ocean), multiple years

3

Fry (usually in lakes, 1 year)

4

Smolts (downstream migration to sea)

5

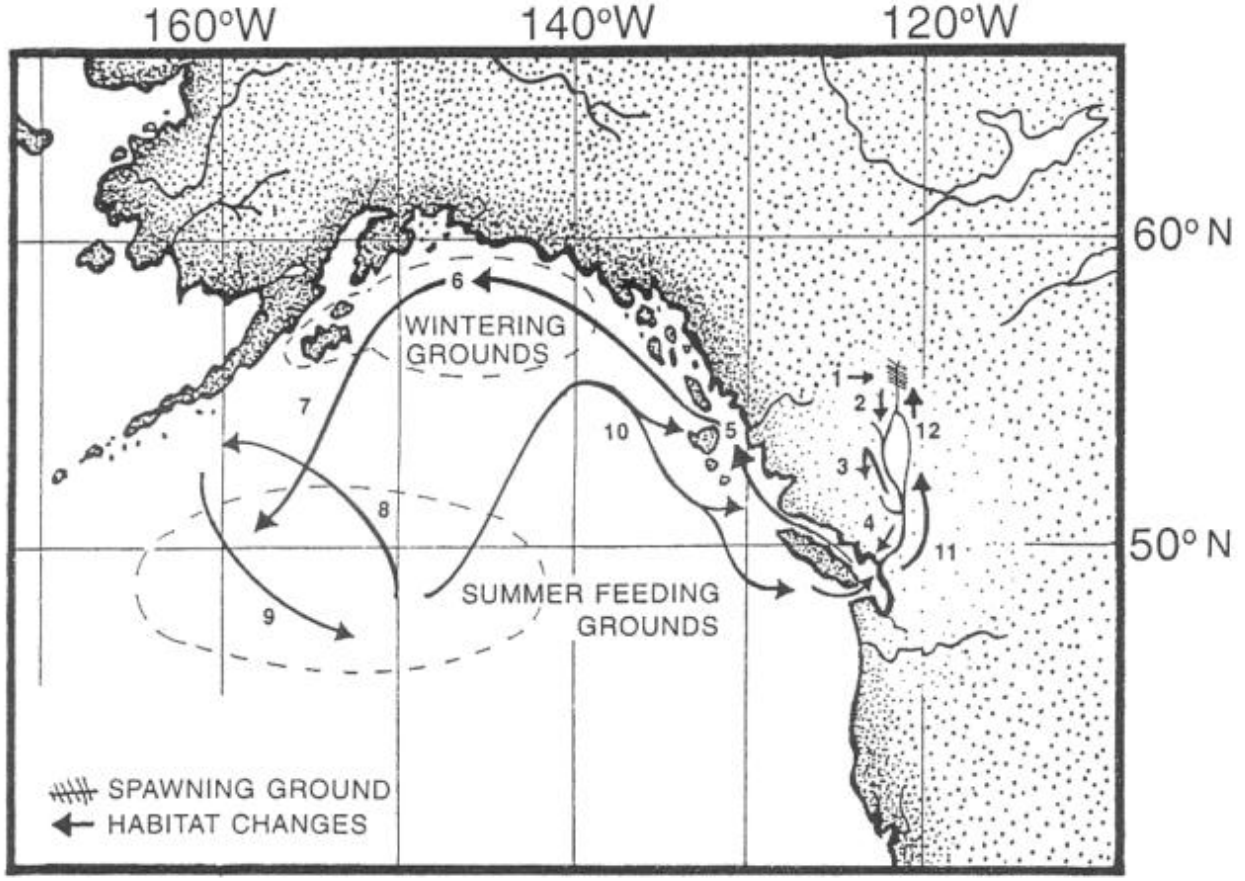
Post smolts (coastal)

Freshwater
Marine
Estuaries

Scott Hinch, UBC

The Race to the North

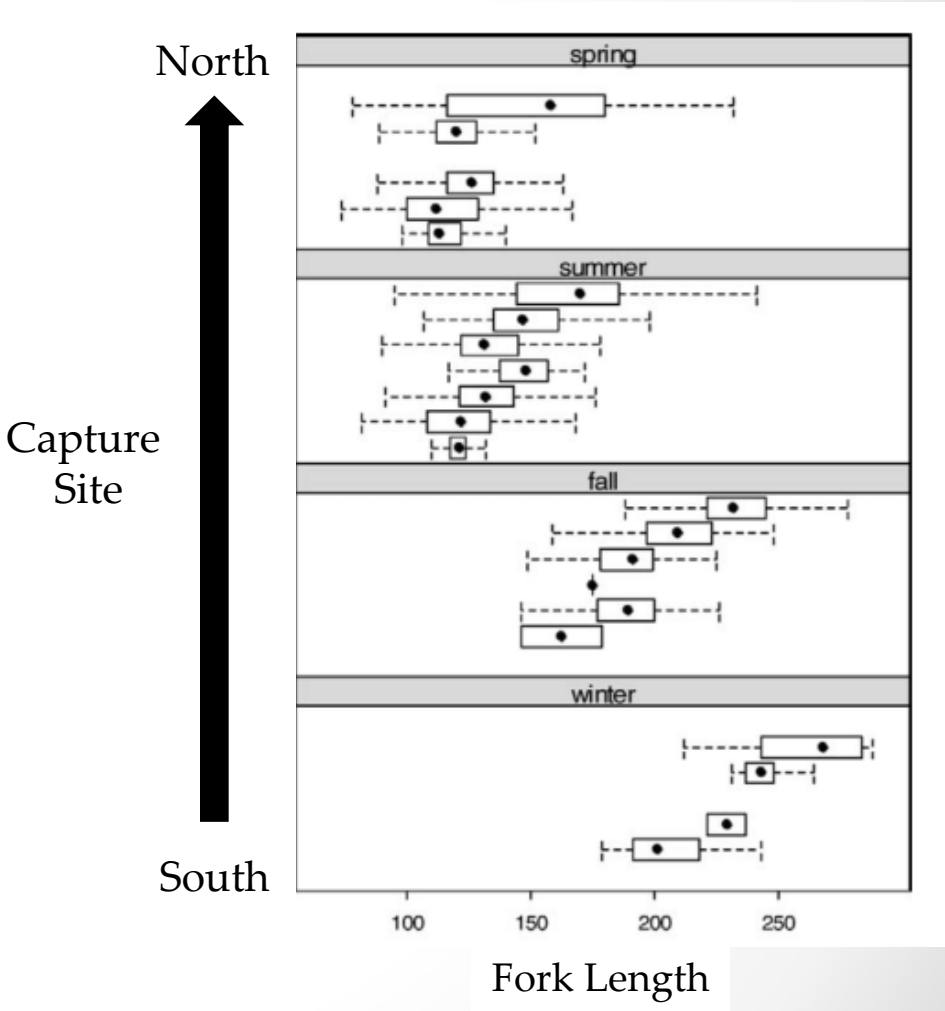
- Foraging conditions thought to improve with latitude and offshore movement



Habitats utilized by a successful Fraser River spawner (McKinnell et al. 2011)

The Race to the North

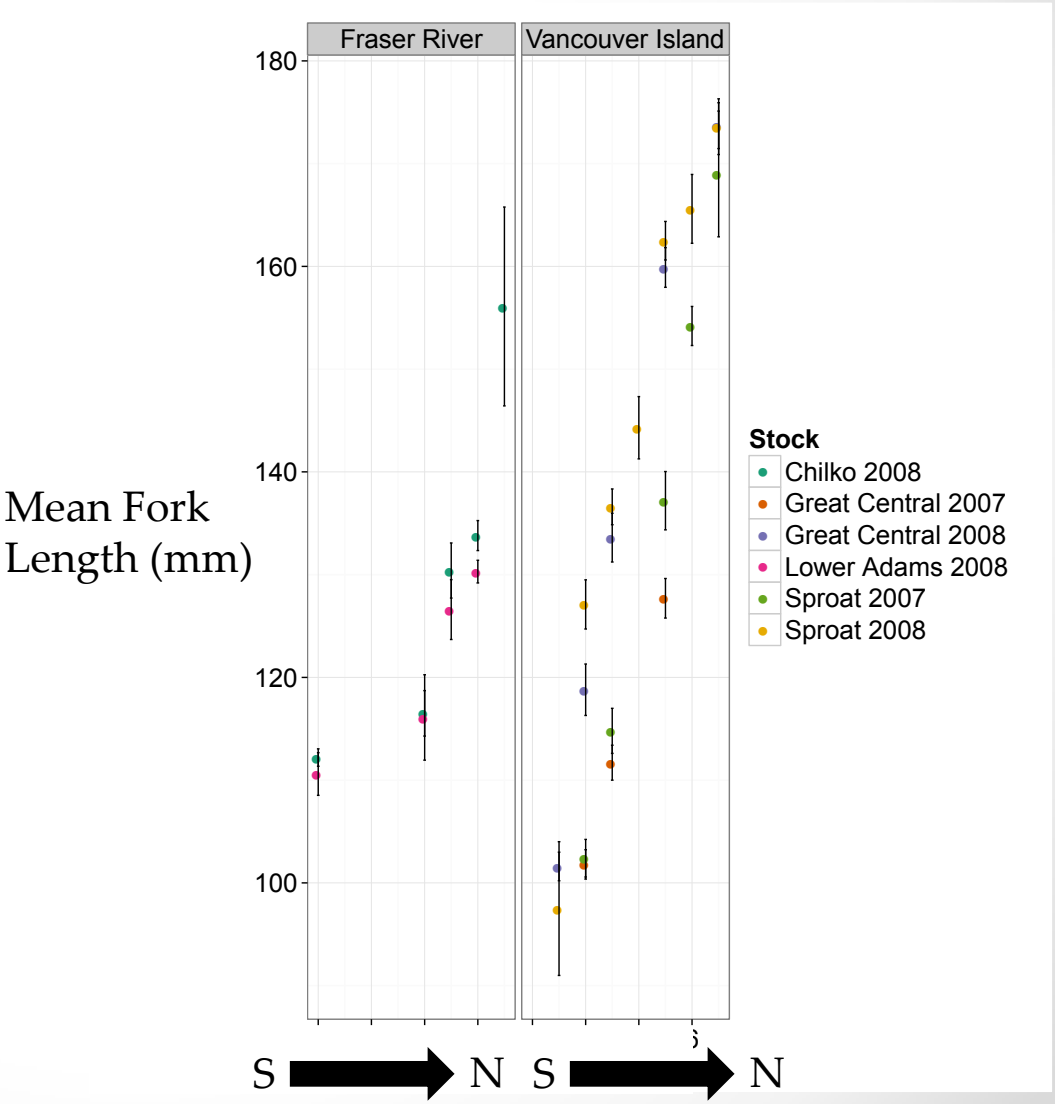
- Foraging conditions thought to improve with latitude and offshore movement
- Body length and energy content are higher at northern latitudes



Median fork length of sockeye salmon postsmolts (Tucker et al. 2009)

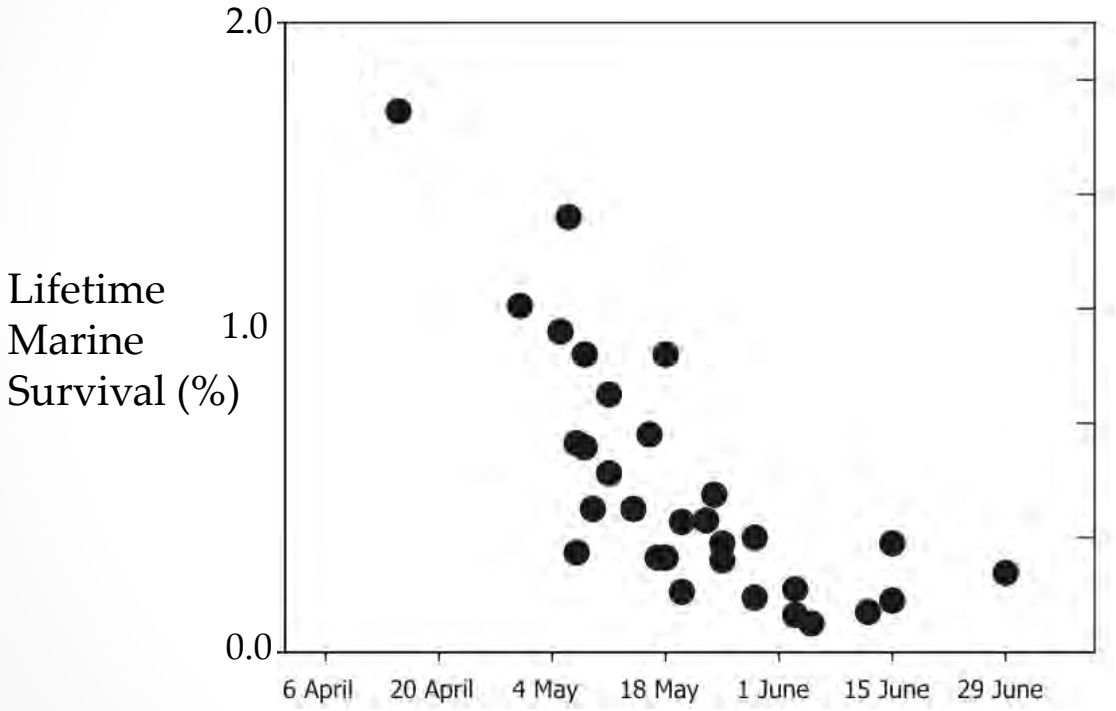
The Race to the North

- Foraging conditions thought to improve with latitude and offshore movement
- Body length and energy content are higher at northern latitudes
- Pattern also consistent among individuals **within** a stock



Drivers of a Latitudinal Body Size Gradient

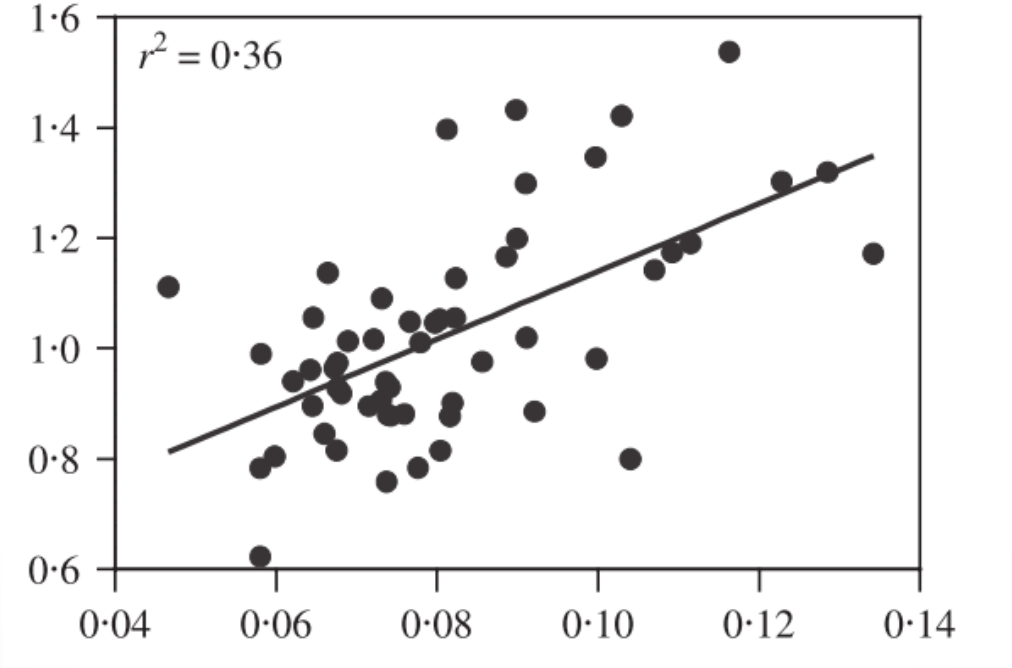
1. Early marine entry timing



Survival of Chinook originating from hatcheries significantly higher among early emigrants (Duffy and Beauchamp 2011)

Drivers of a Latitudinal Gradient

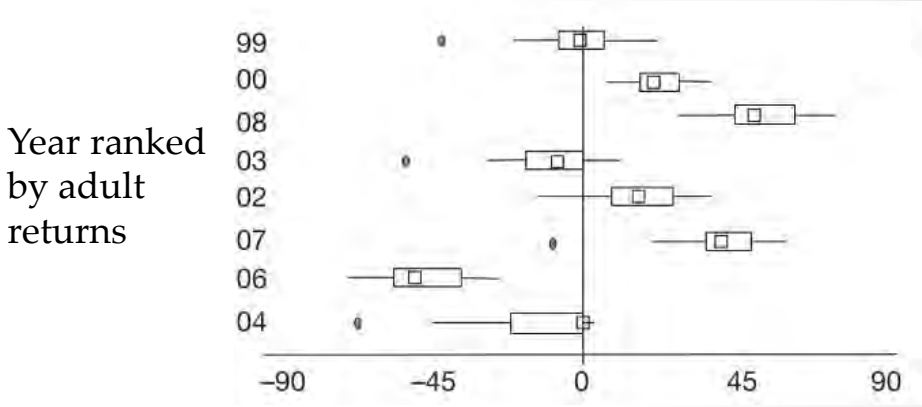
1. Early marine entry timing
2. Large initial emigration size



Chinook salmon first year marine growth relative to growth in freshwater (Ruggerone et al. 2009)

Drivers of a Latitudinal Gradient

1. Early marine entry timing
2. Large initial emigration size
3. Optimal marine entry timing and rapid growth

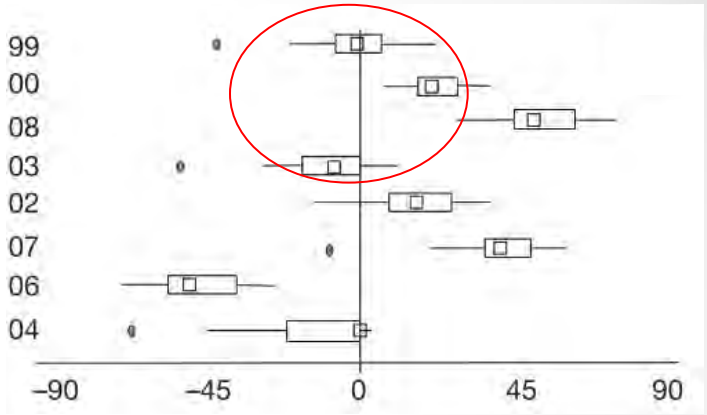


Positive correlation between adult Chinook return rates and juvenile emigration during biological spring (Tomaro et al. 2012)

Drivers of a Latitudinal Body Size Gradient

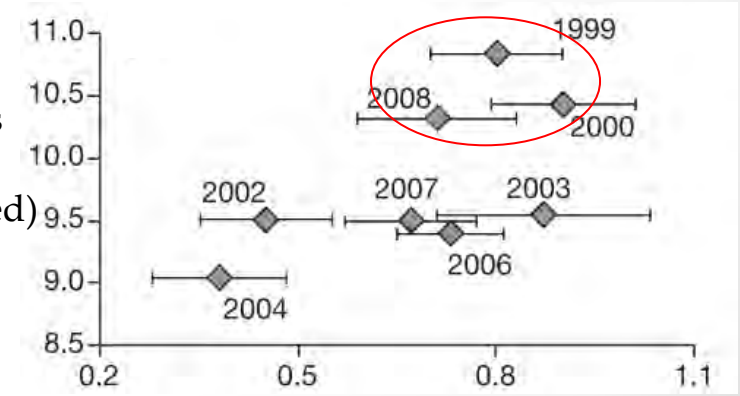
1. Early marine entry timing
2. Large initial emigration size
3. Optimal marine entry timing and rapid growth

Year ranked by adult returns



Entry date relative to biological spring

Adult returns (2 yr lag, ln-transformed)

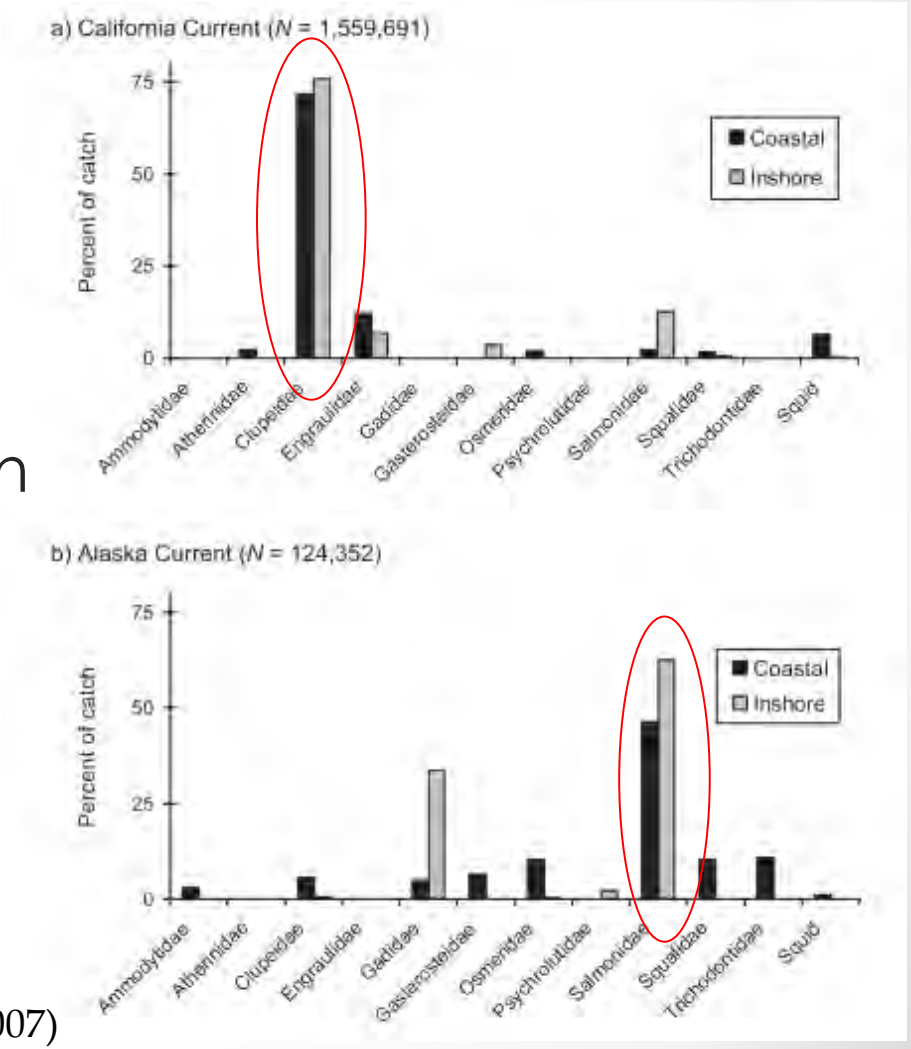


Mean growth rate (%bl/day)

High adult returns correlated with juvenile growth rate (Tomaro et al. 2012)

Drivers of a Latitudinal Body Size Gradient

1. Early marine entry timing
2. Large initial emigration size
3. Optimal marine entry timing and rapid growth
4. Accelerating growth during migration



Proportion of catch of most common marine groups in the California and Alaska Current systems (Orsi et al. 2007)

Drivers of a Latitudinal Body Size Gradient

1. Early marine entry timing
2. Large initial emigration size
3. Optimal marine entry timing and rapid growth
4. Accelerating growth during migration
5. Combination of the above

Study Area

Dixon Entrance

Haida Gwaii West

Hecate Strait

Triangle Island

WCVI North

Georgia Strait

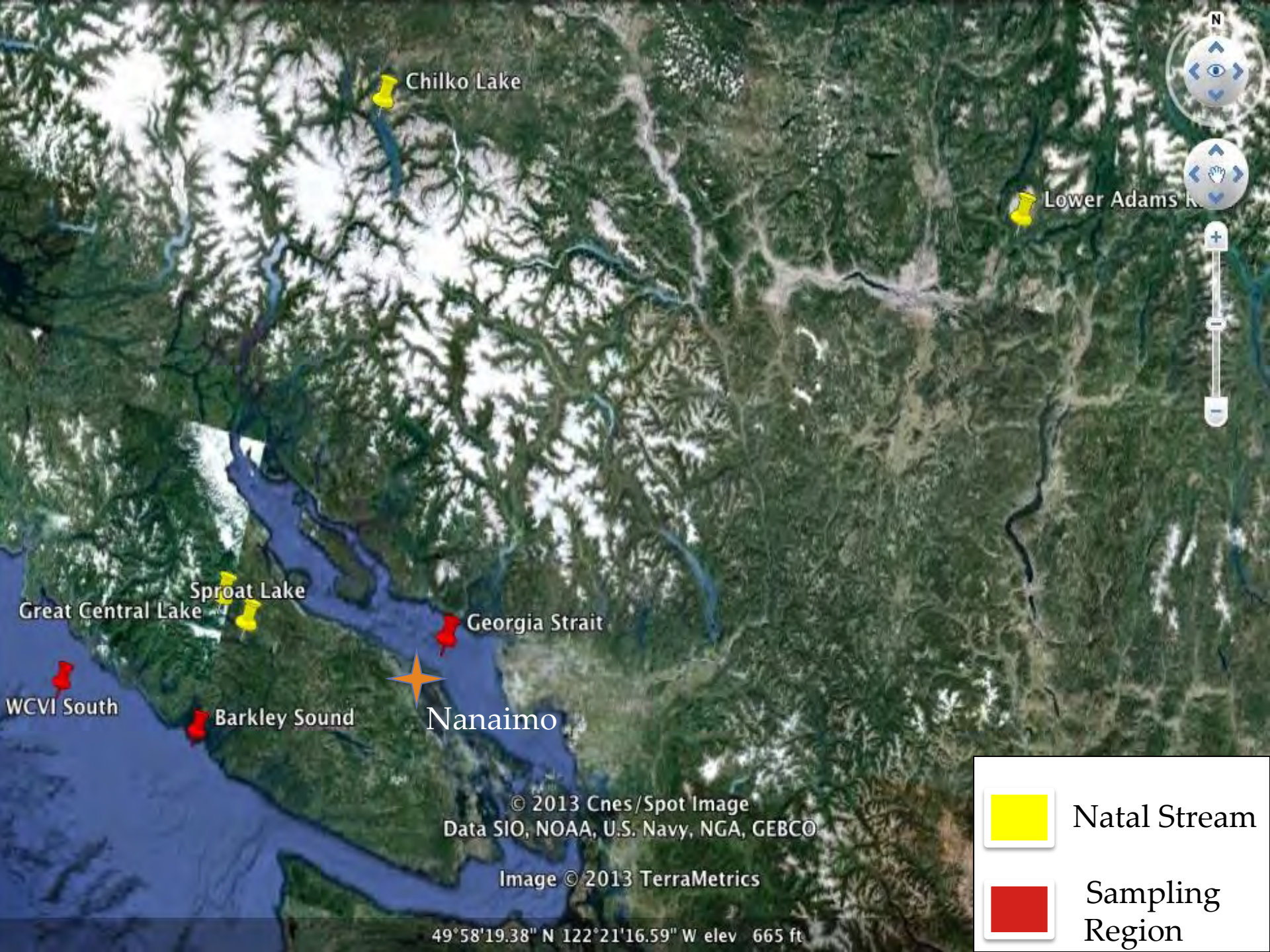
Barkley Sound

WCVI South

W.E. Ricker

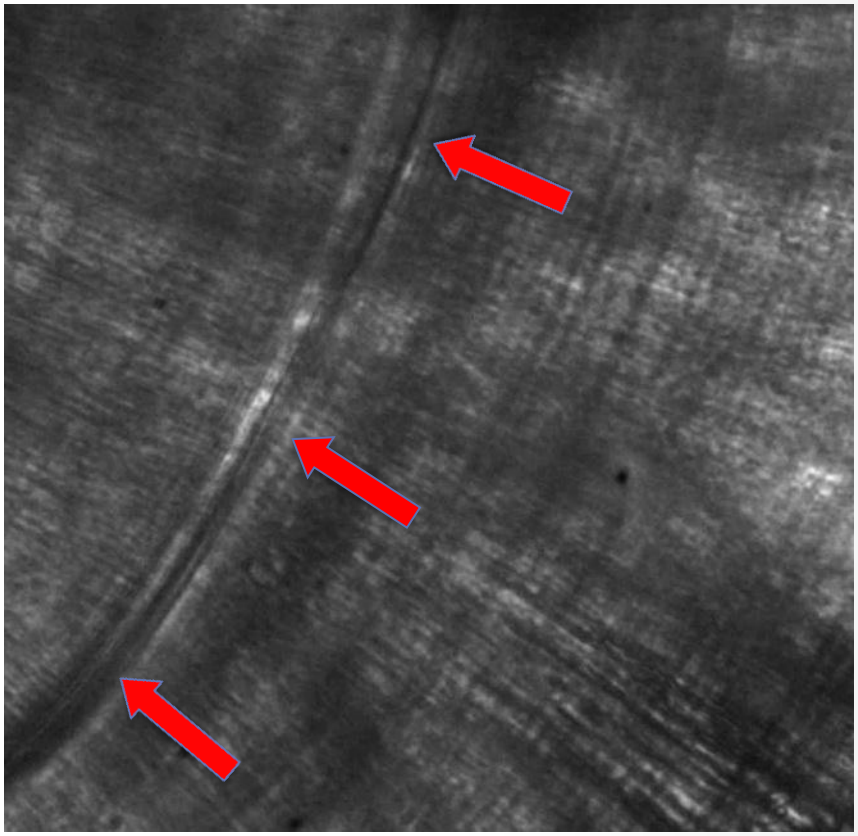
51°08'28.71" N 125°50'52.96" W elev 1415 ft

Sampling Region


Chilko Lake
Lower Adams R.
Sproat Lake
Great Central Lake
Georgia Strait
WCVI South
Barkley Sound
Nanaimo
© 2013 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2013 TerraMetrics
49°58'19.38" N 122°21'16.59" W elev 665 ft
Natal Stream
Sampling Region

Otolith Microstructure

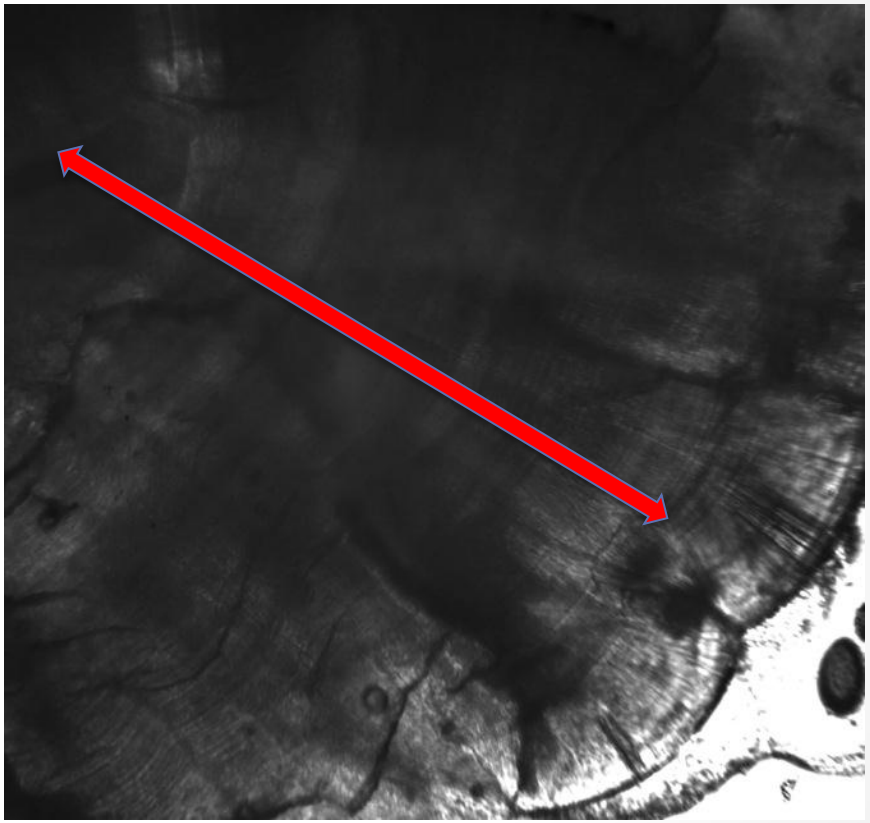
1. Early marine entry = large number of rings between entry and capture



Marine entry check at 400x magnification

Otolith Microstructure

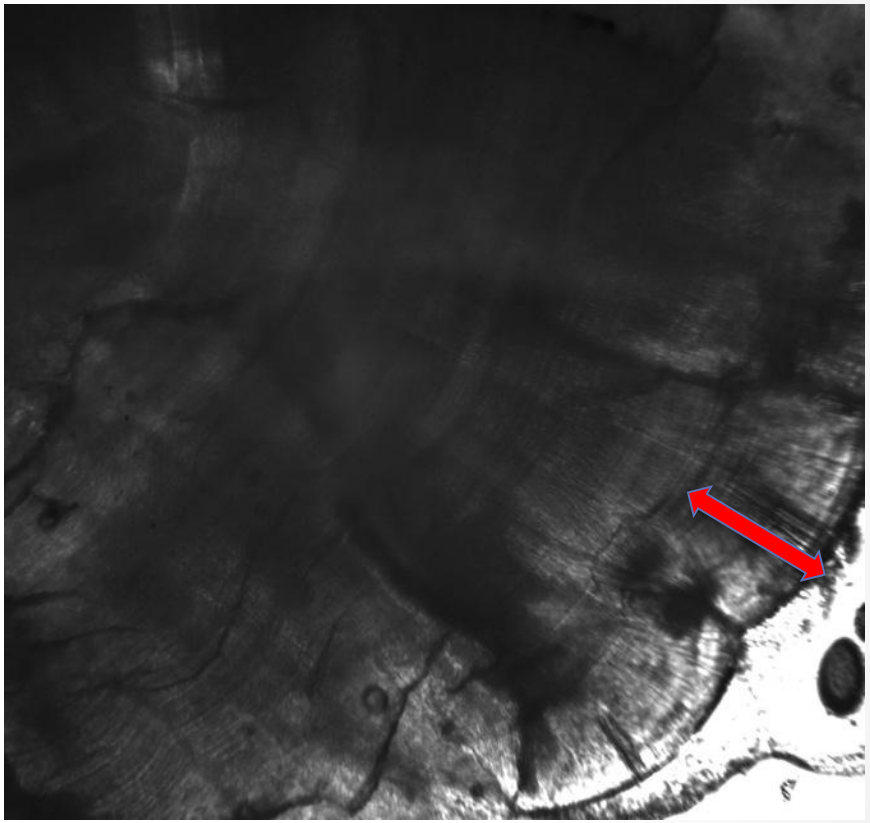
1. Early marine entry
2. Large size at marine entry = radius at marine entry check large



Total otolith radius (A) and radius at marine entry (B) measured from primordia; 100x magnification

Otolith Microstructure

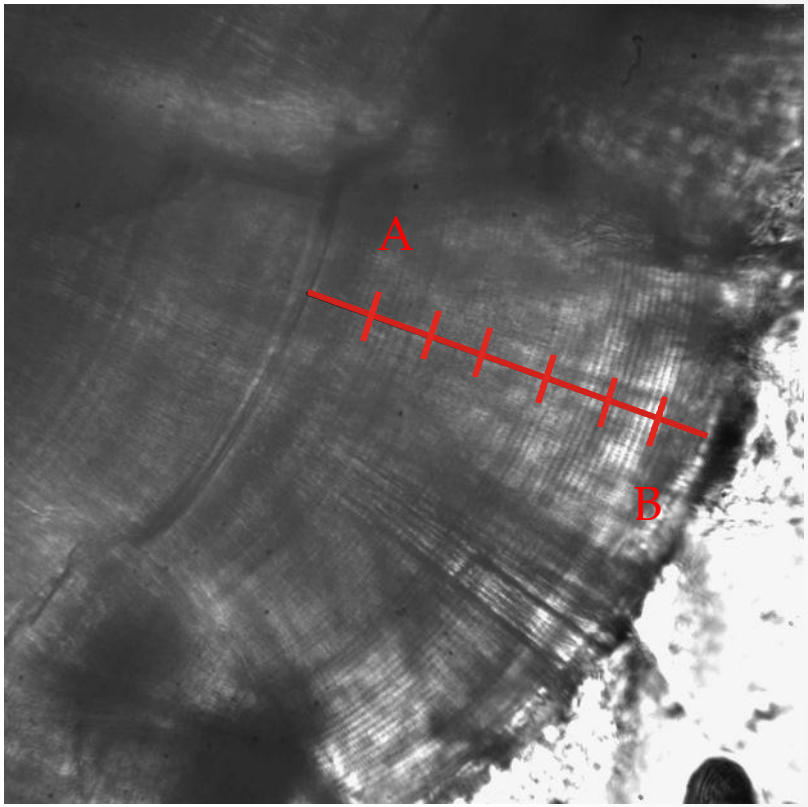
1. Early marine entry
2. Large size at marine entry
3. Sustained marine growth = large mean daily growth rate



Total otolith radius (A) and radius at marine entry (B) measured from primordia; 100x magnification

Otolith Microstructure

1. Early marine entry
2. Large size at marine
3. Sustained marine
4. Rapid early or late marine growth = first or last week of daily increments is large



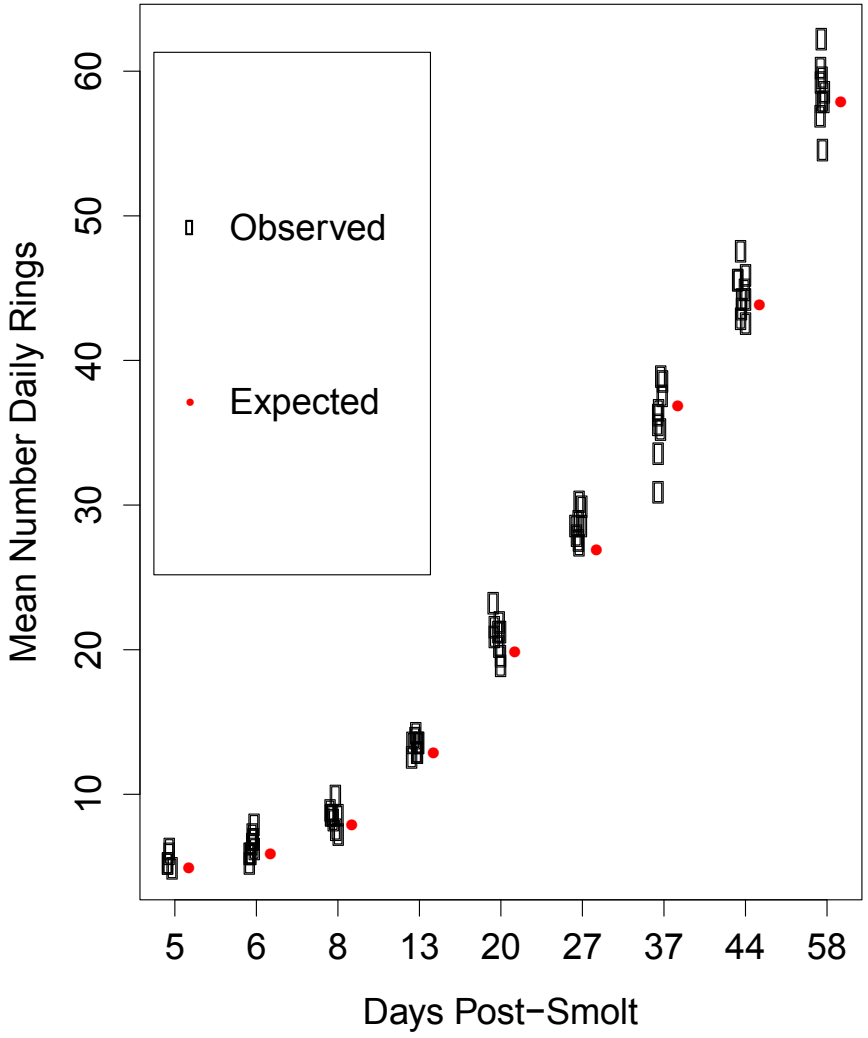
Weekly marine growth measurements at 400x magnification

Validation

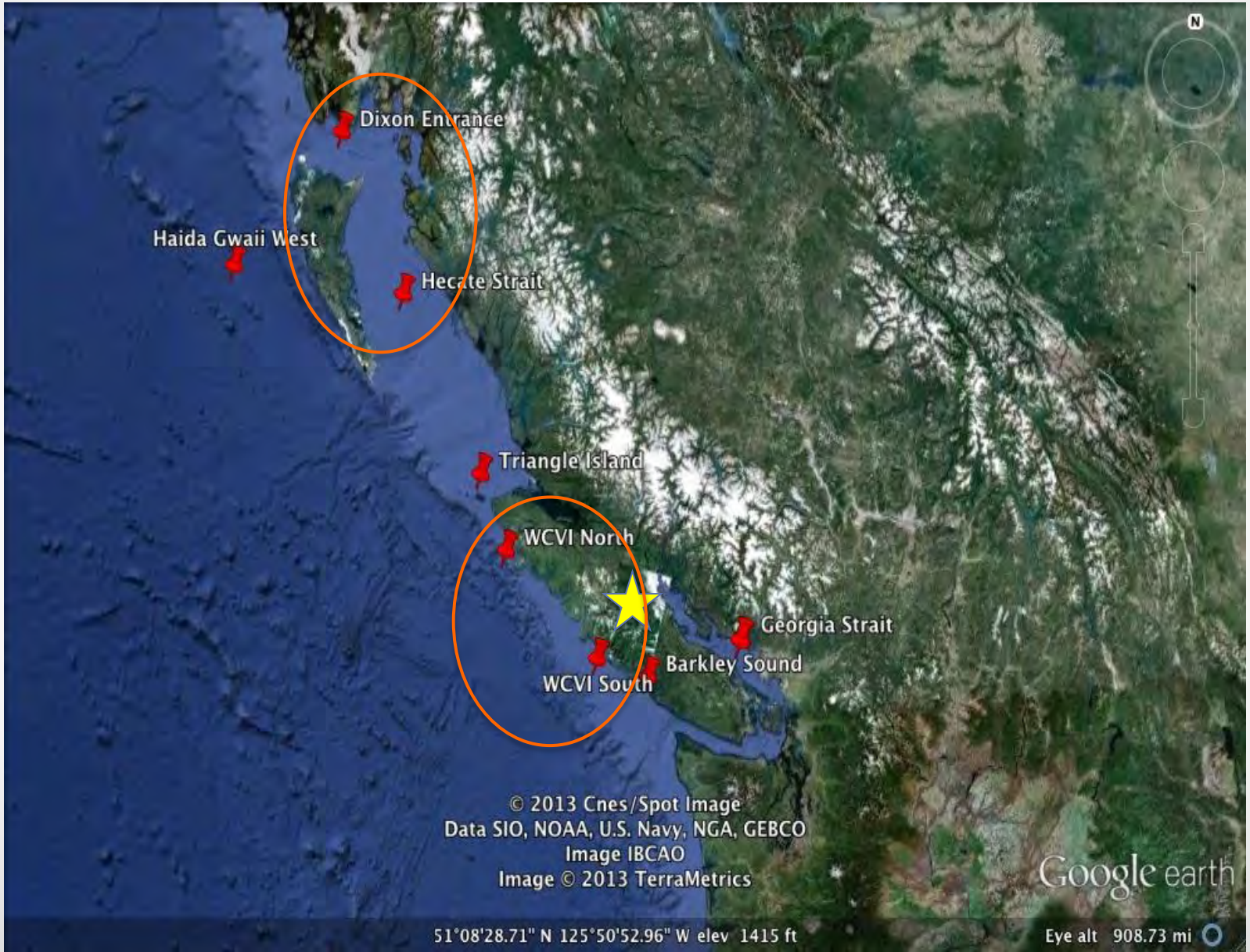
- Confirm:
  - Deposition rate
  - Relationship between somatic and otolith growth
  - Marine entry check
- Visually by experimental rearing

Validation

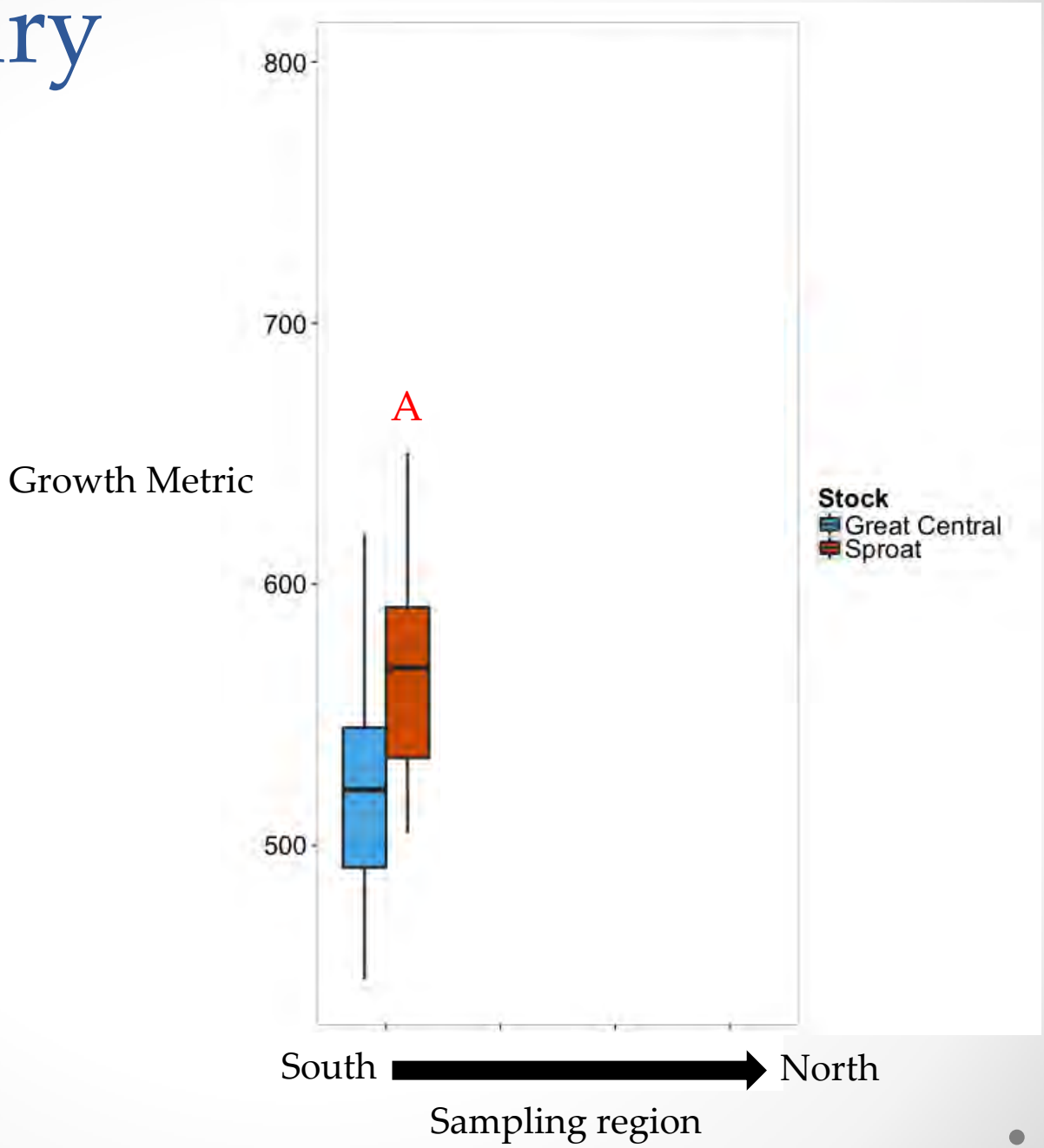
- Confirm:
  - Deposition rate
  - Relationship between somatic and otolith growth
  - Marine entry check
- Visually by experimental rearing



Preliminary Results

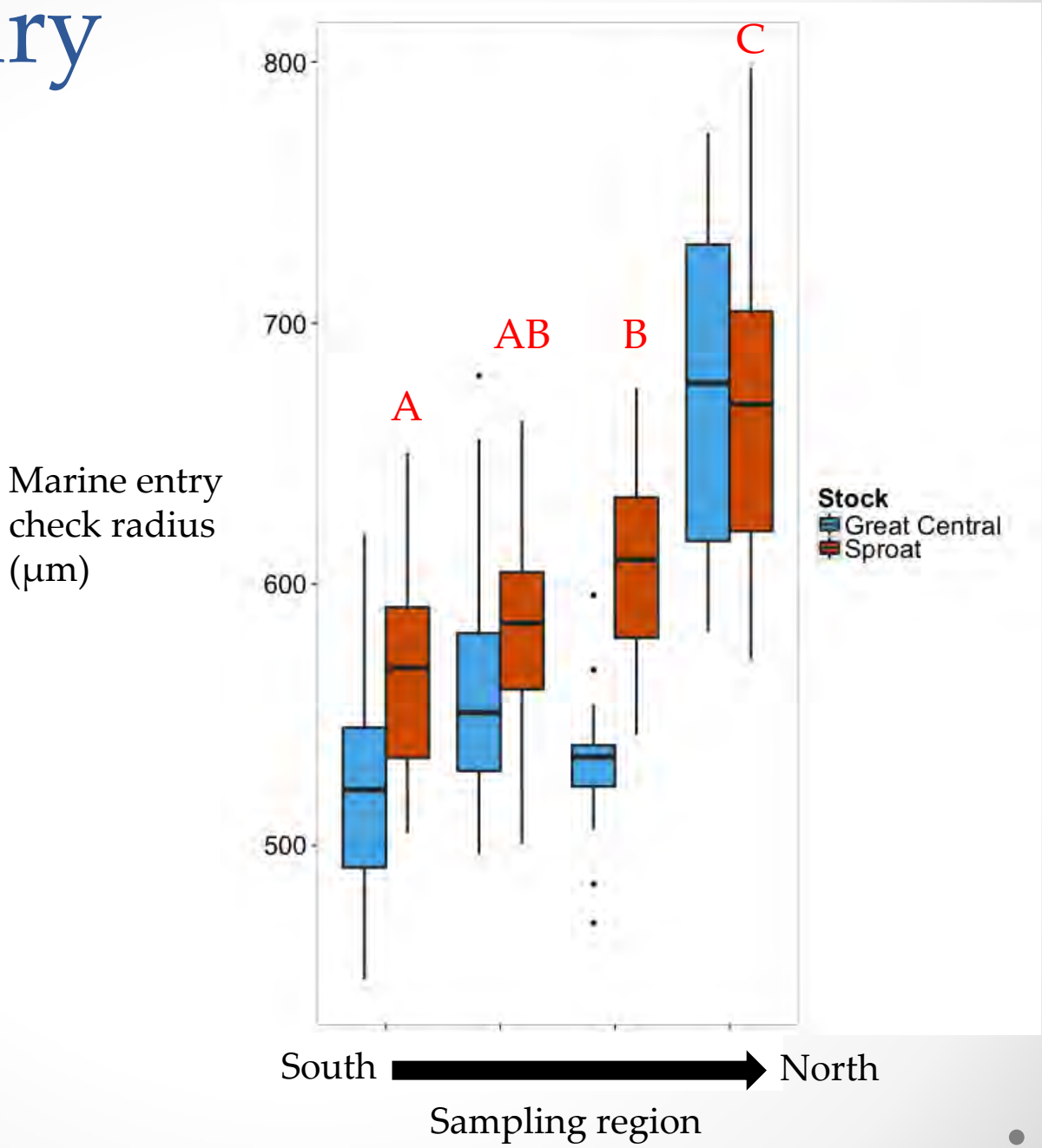


Preliminary Results



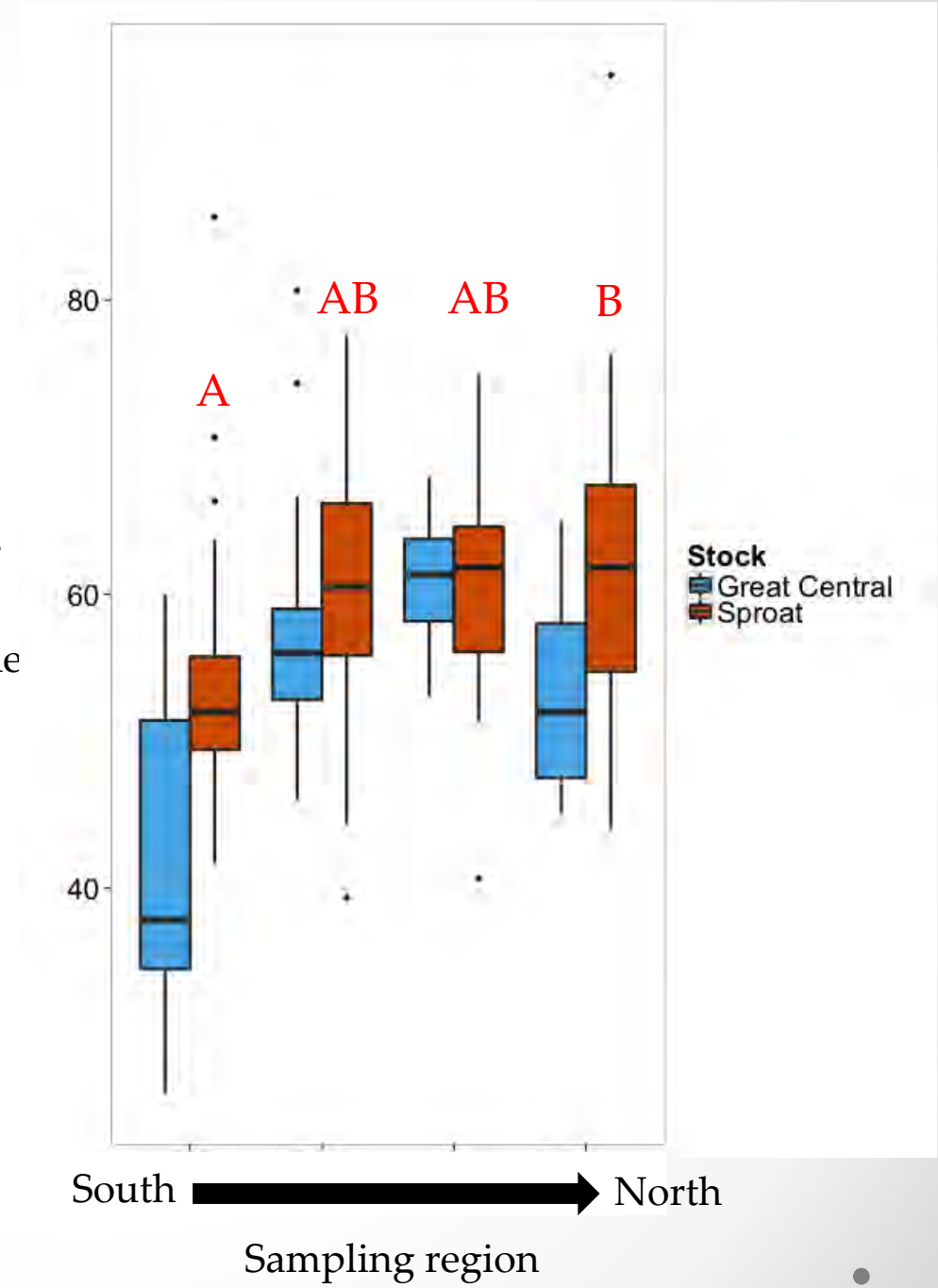
Preliminary Results

Smolt size at ocean entry



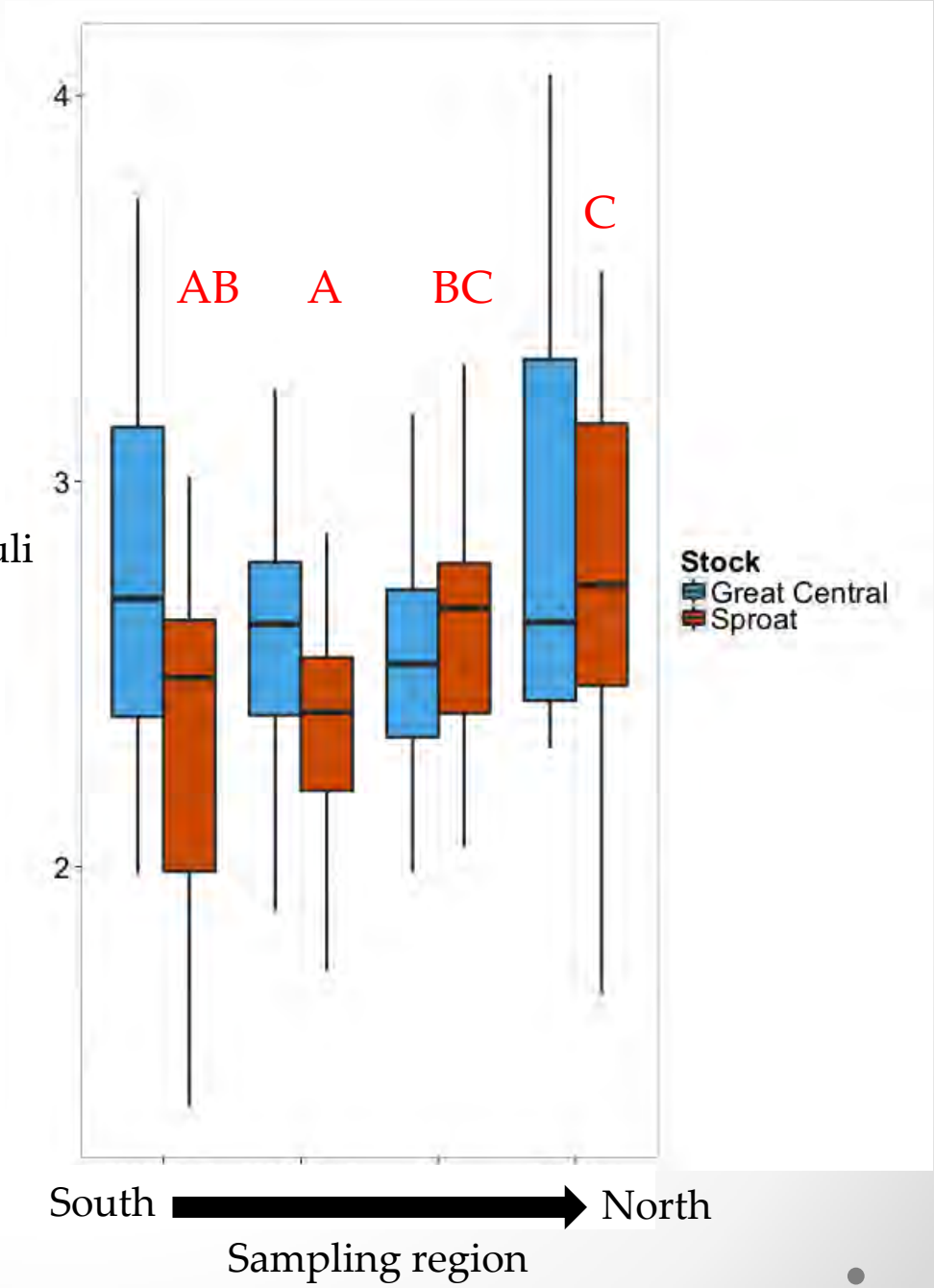
Preliminary Results

Days at sea before capture

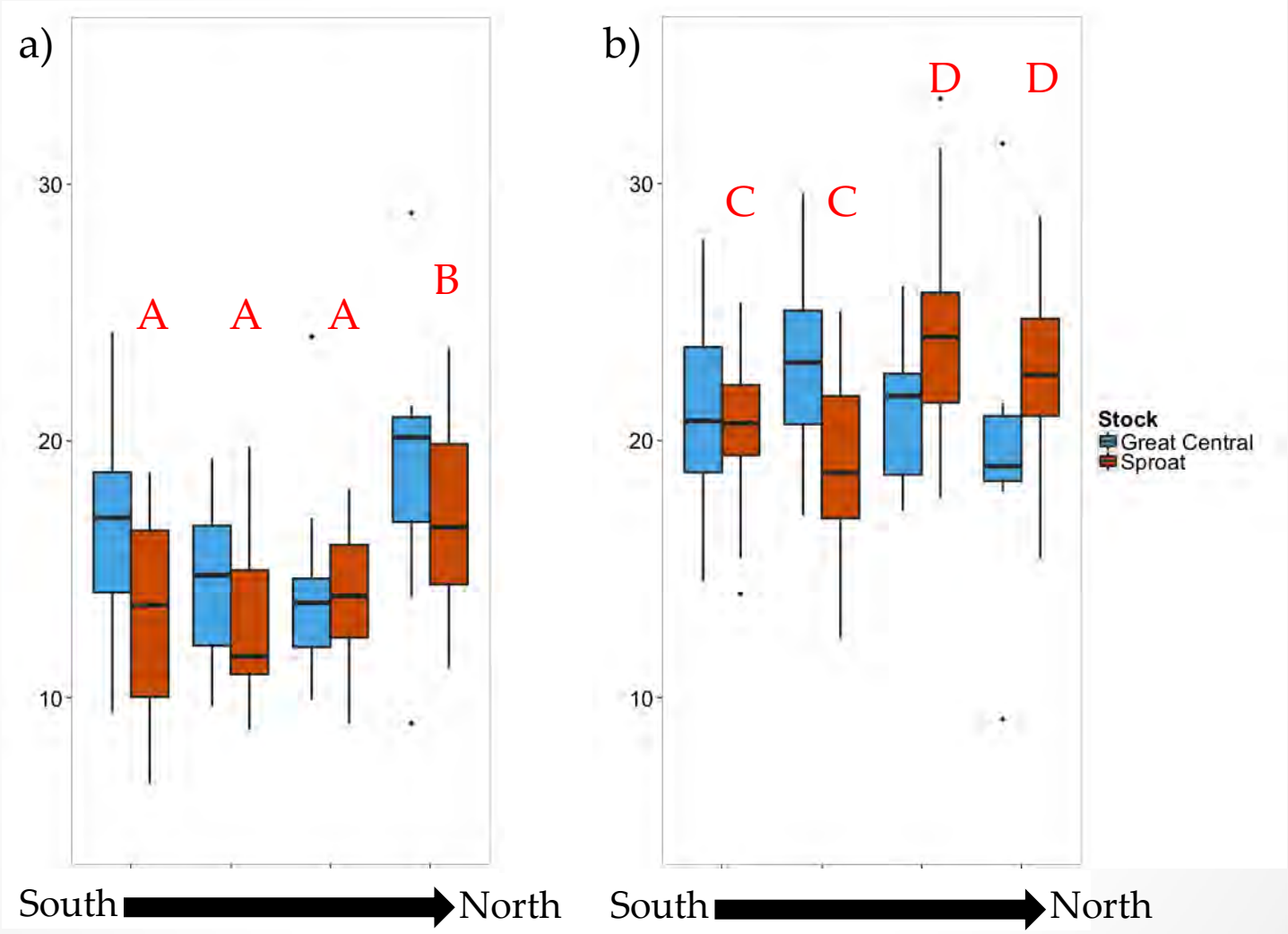


Preliminary Results

Mean daily growth rate



Preliminary Results



(a) First and (b) last week marine growth

Conclusions

- Larger juvenile size correlated with larger smolt size and early marine growth
- Potential threshold before migration
- Growth accelerates during ocean residency
- Stock specific differences in median values, similar trends