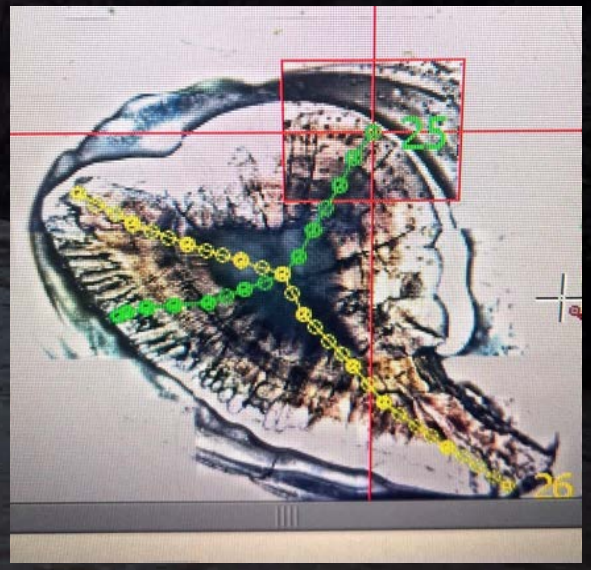
Tracking Natal Origins of Brown Trout In Grand Canyon Through Otolith Microchemistry



Michael Akland

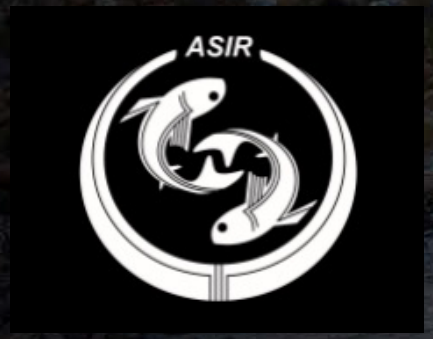
Karin Limburg

Brian Healy

William Pine III

ESF State University of New York College of Environmental Science and Forestry

Many collaborators!



Brown Trout In Grand Canyon

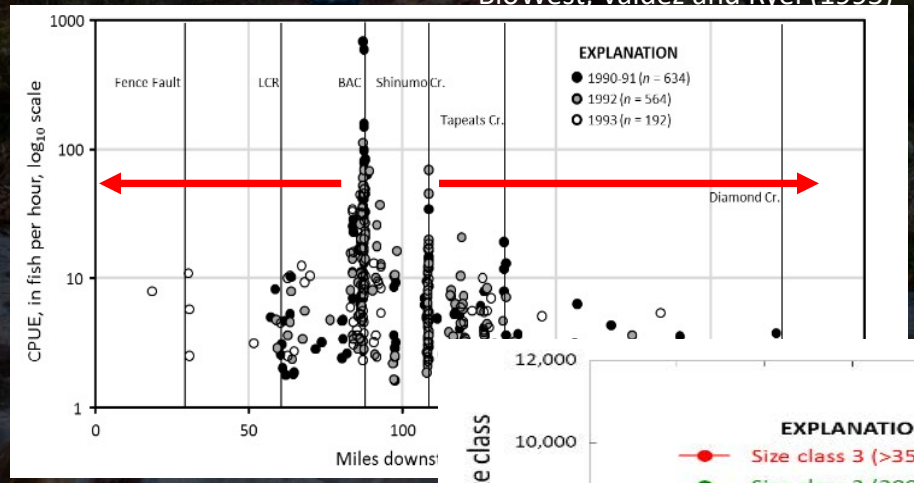
- High rate of piscivory could have potential impact on native fish
- Prior to 2013 - found in mainstem, but primary source was thought to be **Bright Angel Creek**
- Conservation efforts have aimed to suppress them to benefit natives
- **Bright Angel Creek**[1] source suppression (2012-Present)

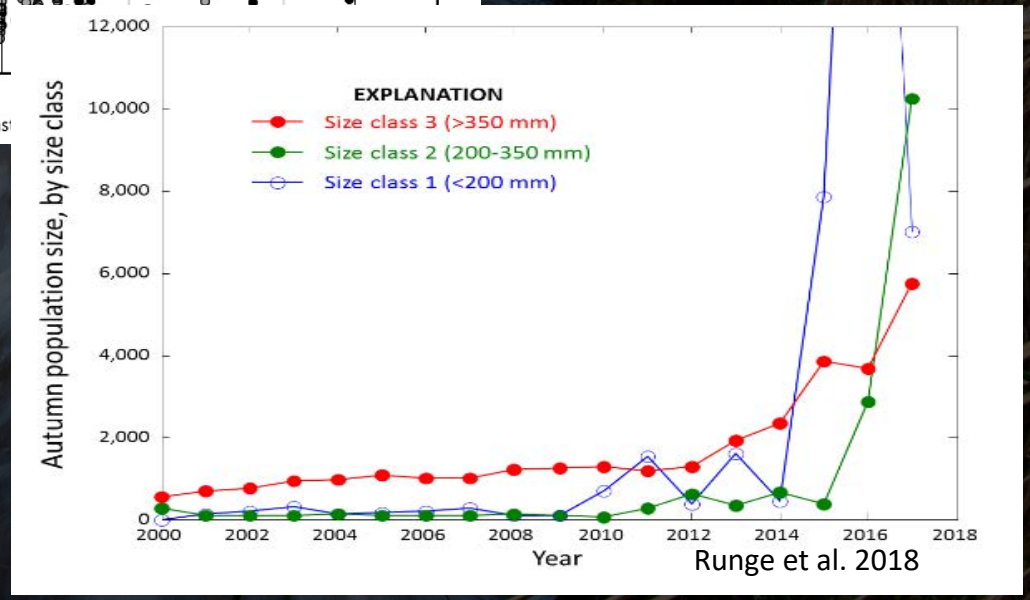
Things changed…

- Range expansion[2] 2013-17
- Pop. In Glen C. increasing since 2014[3]
- Today – 20-year lows, very rare canyon-wide – wider recruitment

1 Schelly et al., 2017; 2 Healy et al., 2022; Runge et al., 2018

BioWest, Valdez and Ryel (1995)





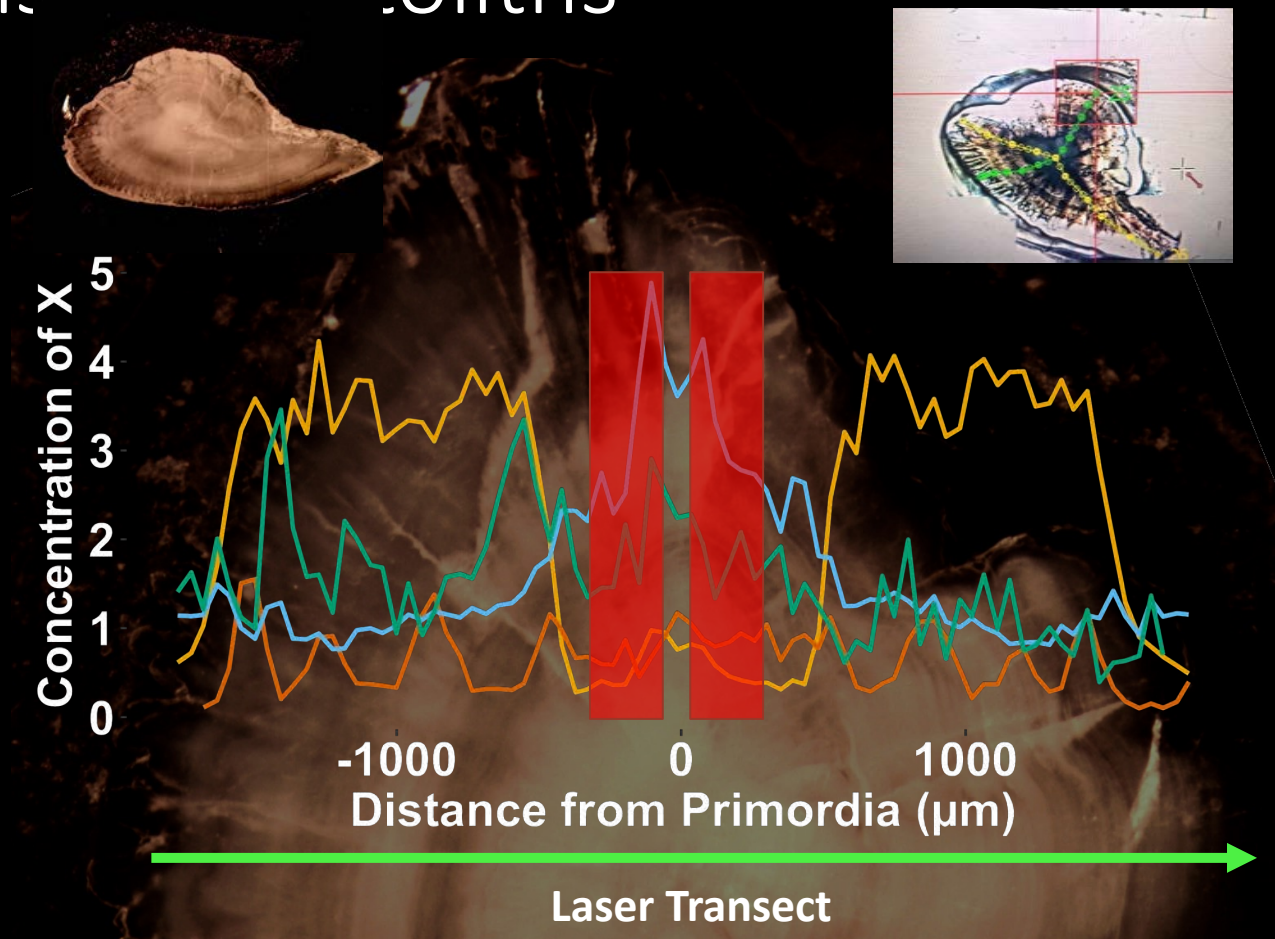
Runge et al. 2018

All that change…
Goals of Research – Retrace the Past

- Address previous hypotheses regarding expansion/invasion:
  - *Observed fish in Glen Canyon either evaded detection while being reared or moved into Glen Canyon from elsewhere* (1996-2012) – Runge et al. 2018
  - *Inhibiting access to primary spawning areas (weir) + fall HFE's contributed to upstream straying to Glen Canyon* – Healy et al. 2022
- Elucidate if invasion of Glen Canyon came from Bright Angel Creek
- Compare natal origins of fish captured during years of invasion (2013-2017) to post-invasion (2018-2022)
- Inform/improve suppression effectiveness

Understanding Natal Origins With Otoliths

- Calcium carbonate “ear-stones”
- Grow throughout life
- Incorporate elements into structure
  - Physiological (growth rate, ontogeny, etc.)
  - Environmental (ambient concs/movement)
- **Brown trout** remain in natal stream during 1st year of life[1]
- Otolith core = natal period = origin[2]
- We can use YOY otolith core chemistry to predict/categorize where adults were born
- ^{55}Mn, ^{63}Cu, ^{88}Sr, and ^{138}Ba

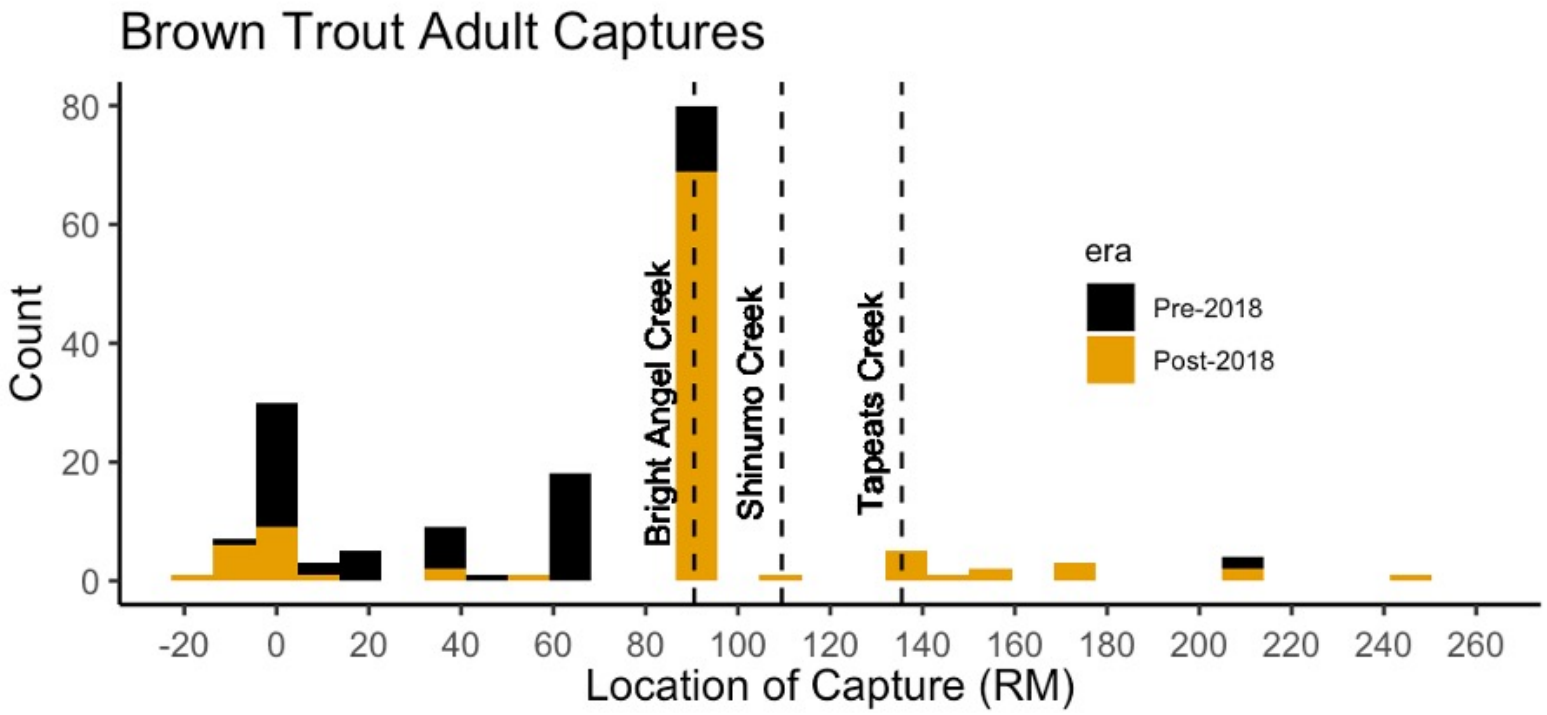


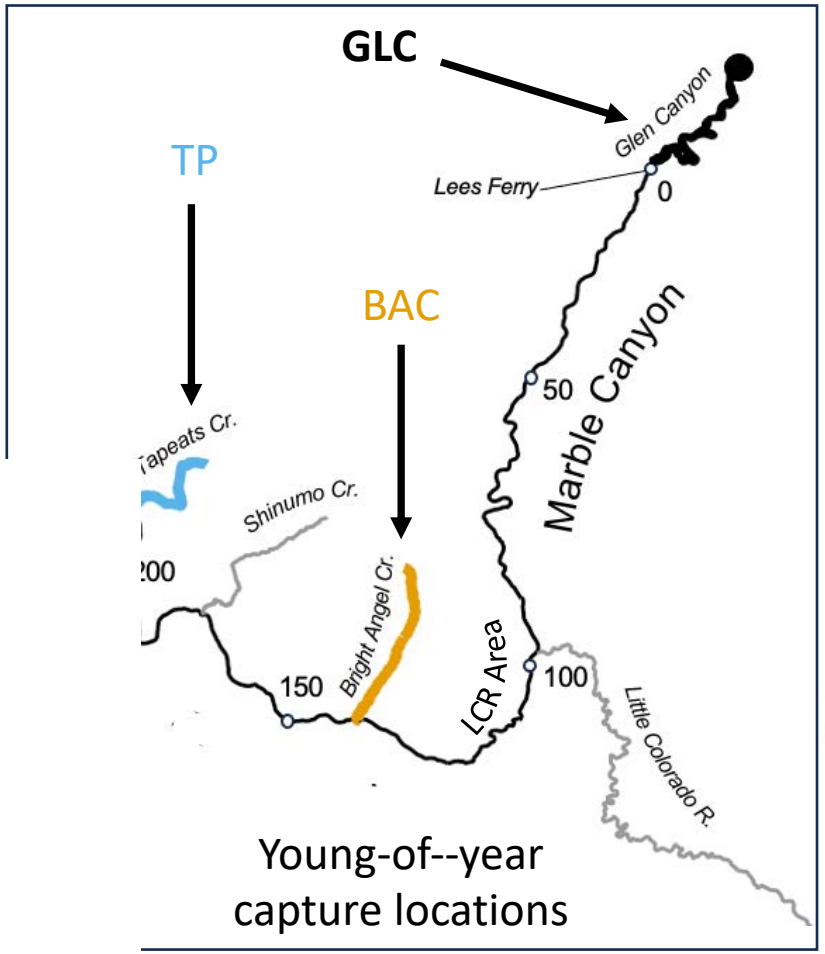
1 Jonsson & Jonsson 2002;2 Mikheev et al, 2020

Specimen Collection – Multiagency effort (thanks to NPS, USGS, AZGFD)

Otoliths – from 217 fish

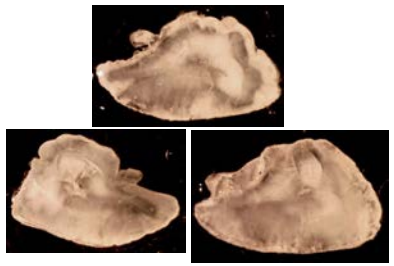
- Young-of-year – known origins: **recruitment** loci (N = 49)
- Adults—unknown origins (N=168)
  - Glen Canyon to Pearce Ferry, and tributaries





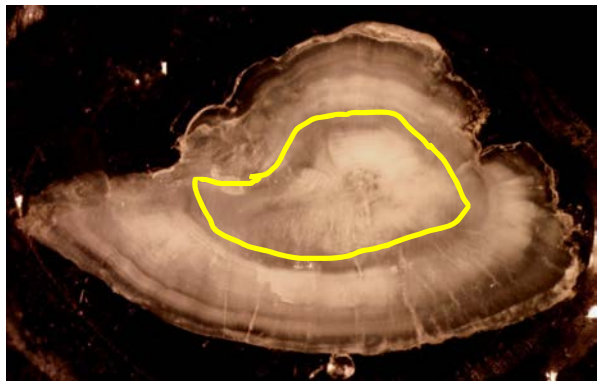
Methods: Determining Natal Origins

Create Baselines from YOY otoliths



Create natal origin chemistry categories from YOY – assumed to be captured at their origin
(**Linear Discriminant Analysis**)

Input adult otolith core chemistry



ID adult core chemistry: Determine likelihood that each adult originated in each natal origin
(**LDA probability**)

Predicted Origin

Mainstem Colorado %

Bright Angel Creek %

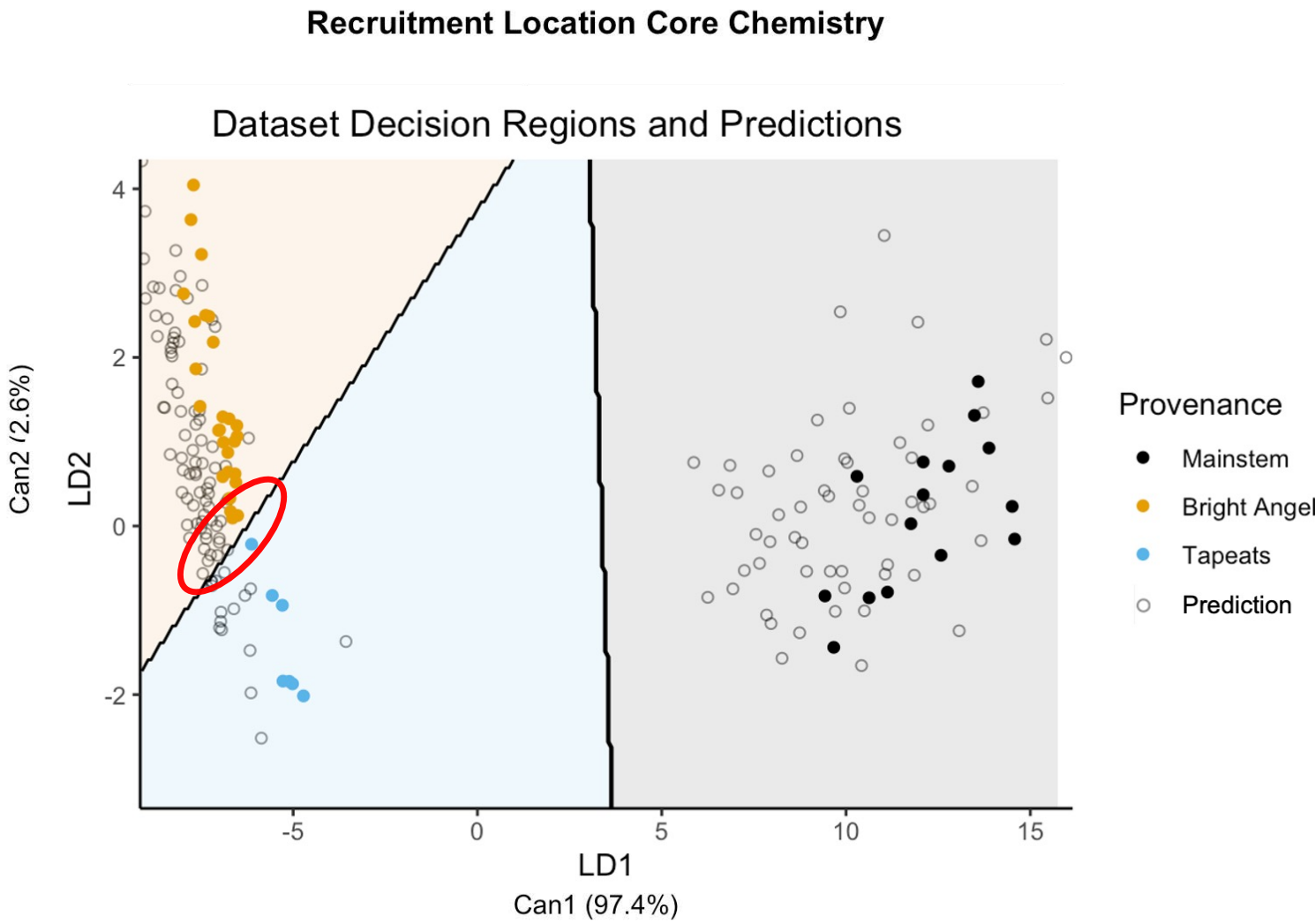
Tapeats Creek %

1. Sort/Predict Natal Origins
Reject any below 70% probability
2. Break up by capture location and era
(during or after invasion**)**

Results: Natal Origins with otoliths

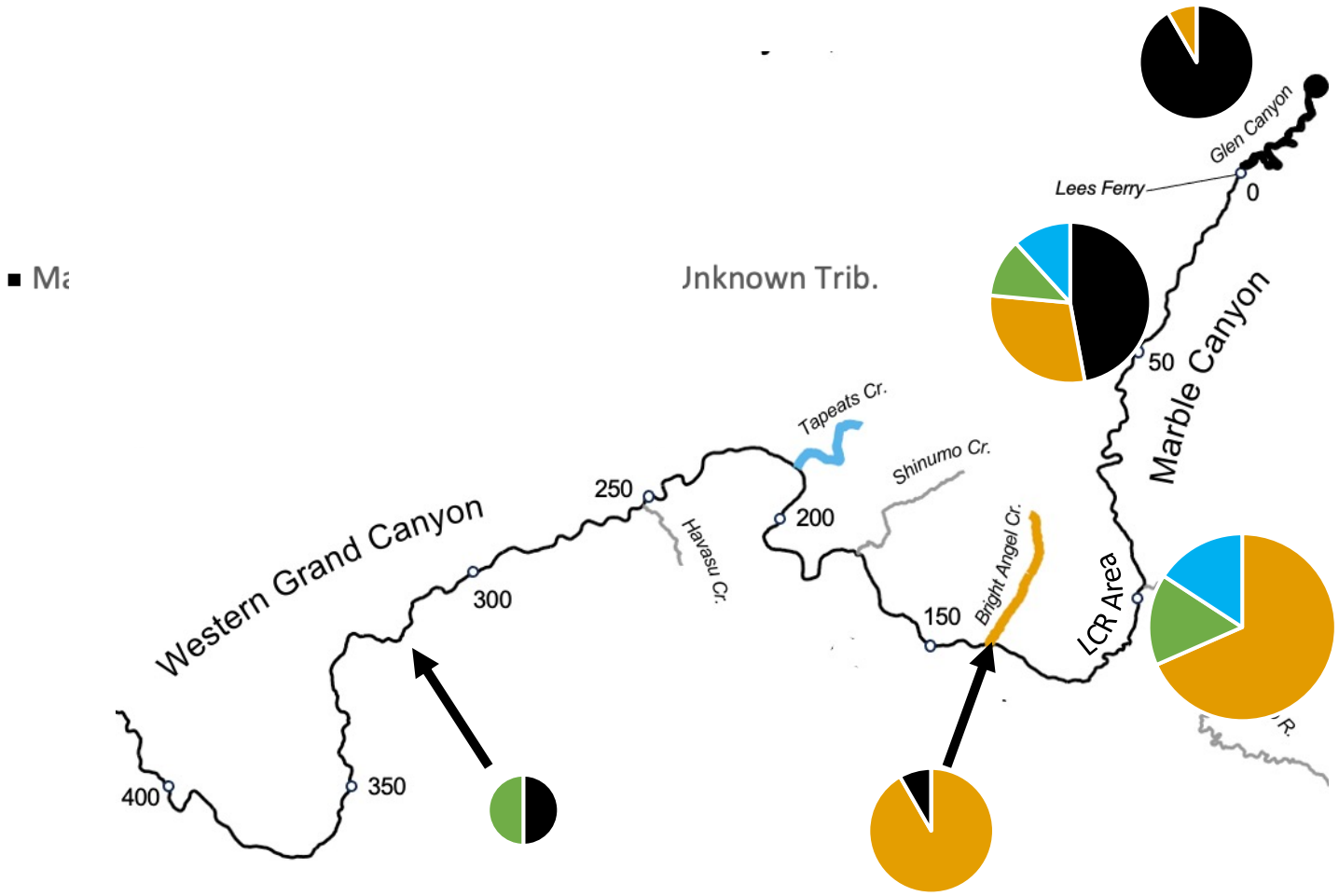
- Each rearing loci was distinct
- 152 origins successfully predicted –to one of the three YOY sources
- 16 “unsuccessful” – ambiguous chem
  - No relation to mainstem origins
  - Originated in **unknown tributary**

  - **Mainstem** vs Glen Canyon = **Natal origin** vs capture location



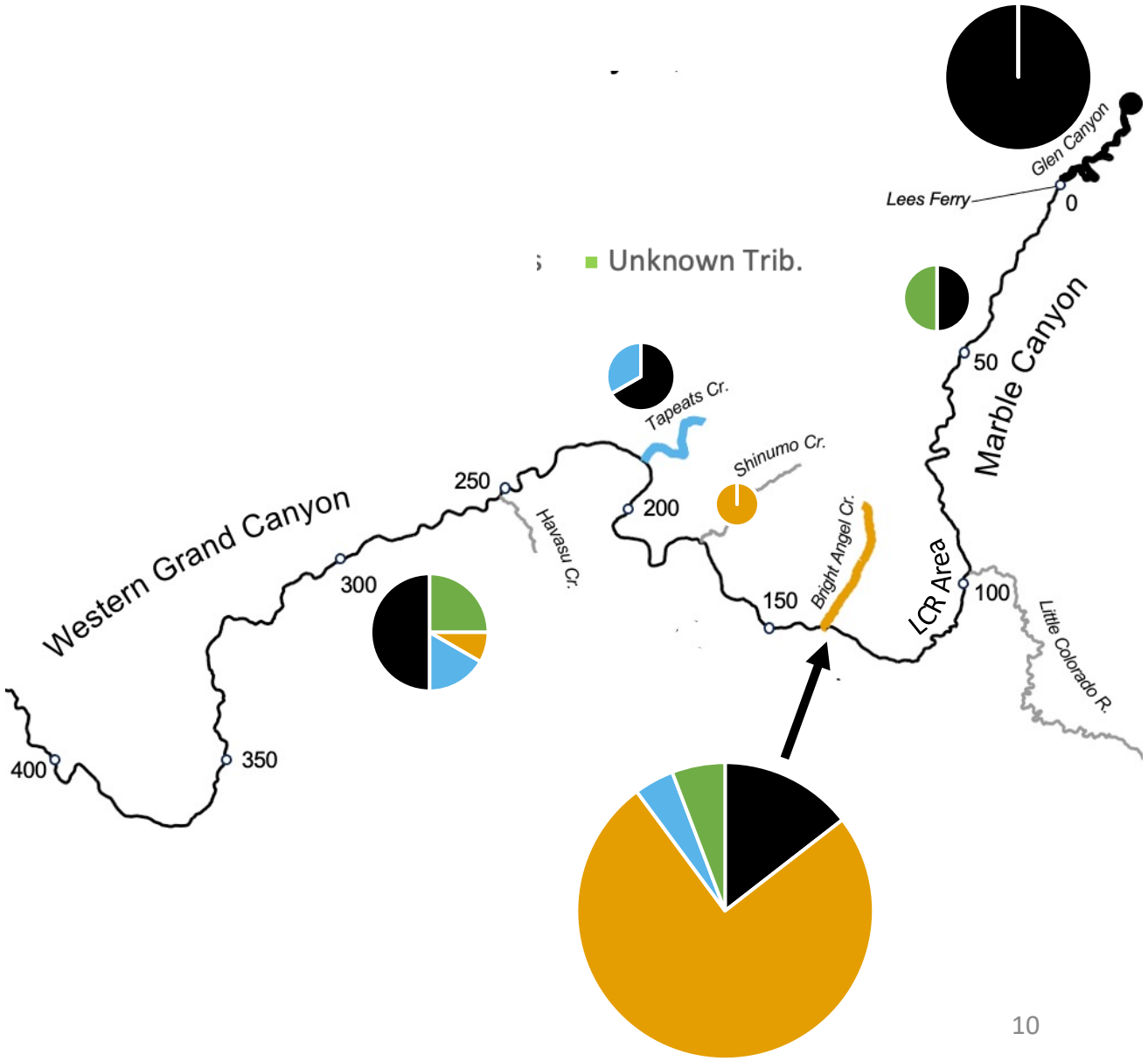
Results:
Natal Origins

- Invasion (2013-2017)
  - Glen Canyon:
    - 90% **mainstem** origin
    - 10% from **Bright Angel**
  - Marble Canyon: mixing
    - 47% **mainstem** origin
    - 30% Bright Angel
  - LCR Confluence area: no **mainstem**
  - Bright Angel:
    - Mostly Bright Angel origins
    - One **mainstem** fish
  - Western GC – low catch, mixed



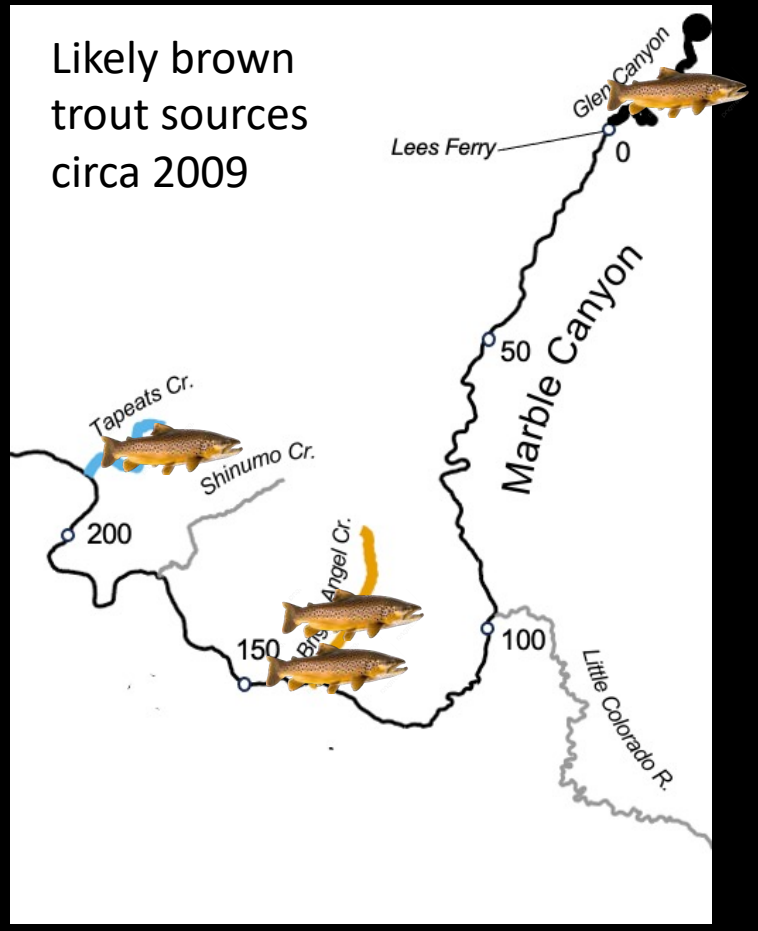
Results:
Natal Origins

- Post-Invasion (2018-2022)
  - Glen Canyon: 100% **mainstem** origins
  - Marble Canyon: low numbers - mix
  - LCR Confluence area: no data
  - Bright Angel:
    - 77% Bright Angel origins
    - Lower reaches – lots of mixing
  - Western Grand Canyon: mixing
    - Every natal origin is found here!



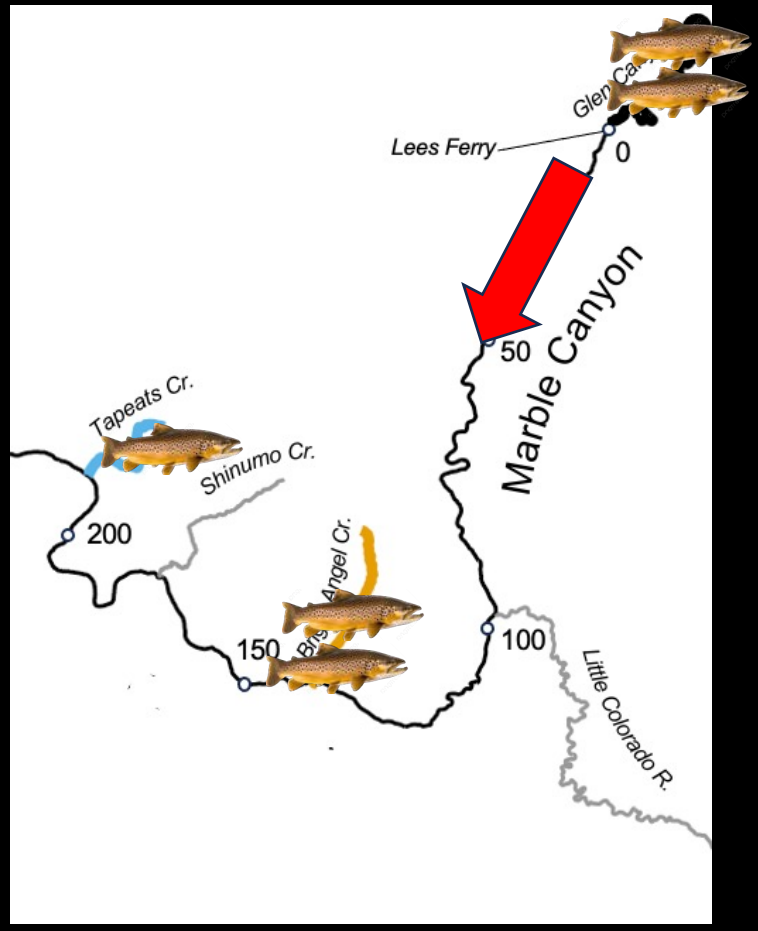
What does this tell us about the invasion?

- Recruitment within mainstem isn't new
  - Large 10+ y/o fish captured in BAC and GLC with mainstem origins born 2003-2008
  - Specific area within mainstem? Can't say.
- Invasion of Glen C. + Marble C. was from multiple sources – mostly fish from within the mainstem
- Fish found near LCR 2013-2016 mostly from Bright Angel Creek



What does this tell us about the present?

- Mainstem-origin fish are prevalent (relatively)
  - Found in most river reaches
  - Stray to BAC and Tapeats to spawn
- Fish found in WGC are from all loci – mixing area
- No eveidence of straying from BAC and Tapeats <u>to</u> Glen Canyon
  - One tributary fish found in Marble C. in April 2022



1 Jonsson et al., 2001; 2 Limburg et al., 2003; 3 Yard et al. 2011

Some conclusions…

- *Observed fish (pre-invasion) in Glen Canyon evaded detection while being reared AND additional fish moved into Glen Canyon from elsewhere*
  - Initial increases in GLC were potentially due to exceeding an Allee affect threshold through immigration (supporting Healy et al. 2022)
- *Inhibiting access to primary spawning areas + fall HFE's contributed to upstream straying* – Healy et al. 2022

Some conclusions…

- Expansion within mainstem was likely already underway by 2013
  - Mainstem origin fish were not a minority in Marble and Glen canyons
- As far back as this analysis goes, BNT have exhibited mixed natal origins
  - Contributions of each loci to overall population are unclear
- Brown trout are highly adaptive, and mixed natal origins makes them likely to persist in GC

Many thanks

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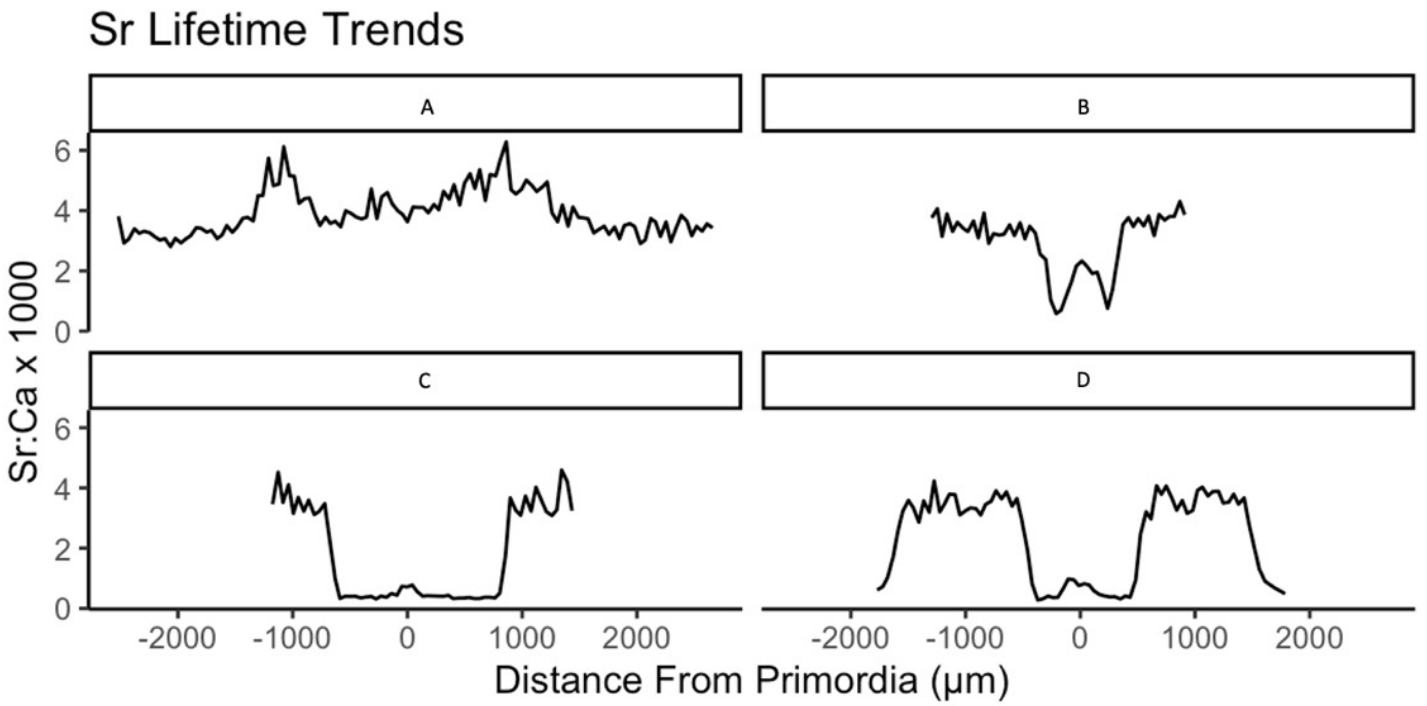
Questions?

Mainstem origin, captured in GLC

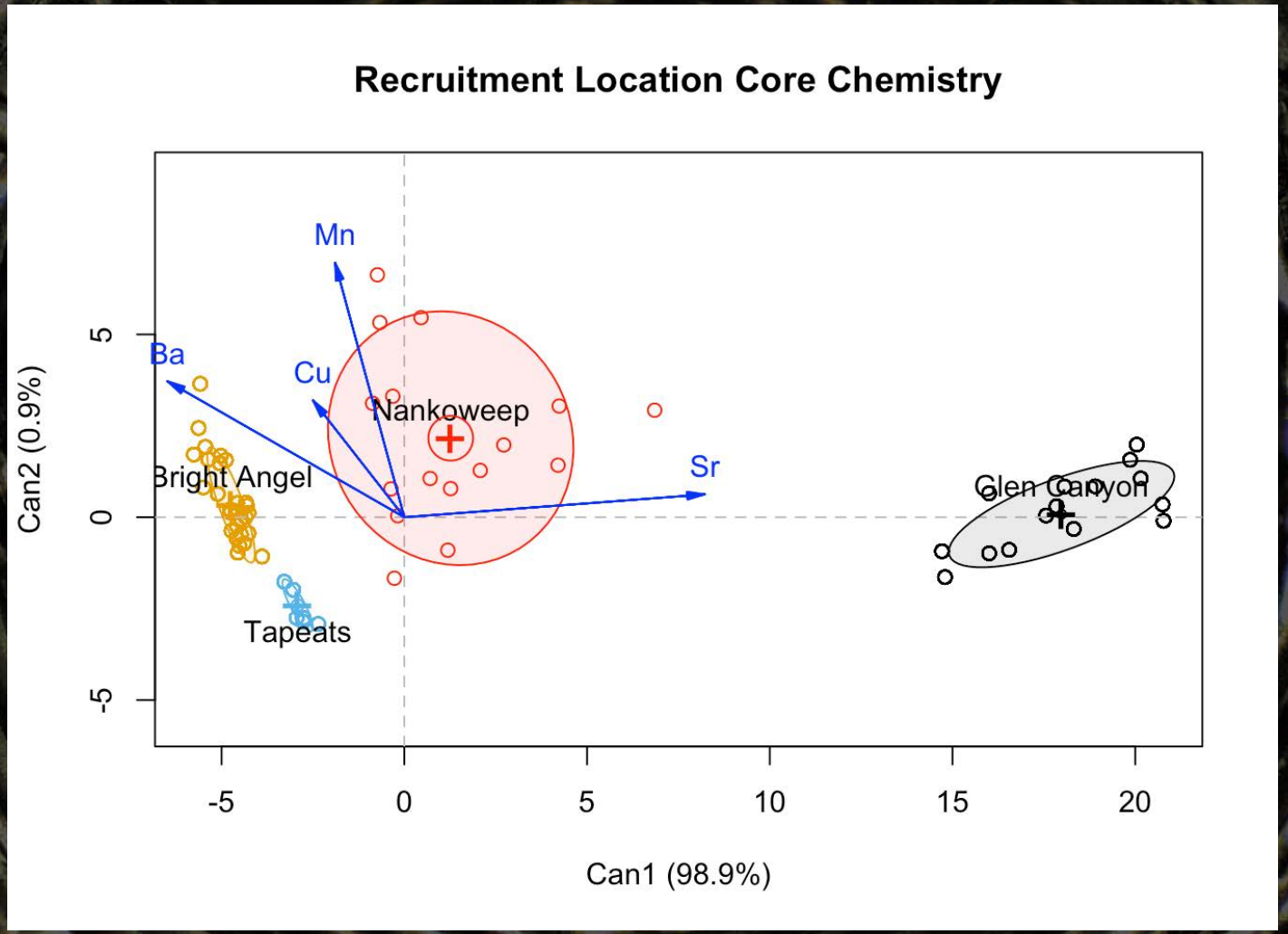
BAC emigrant captured in mainstem



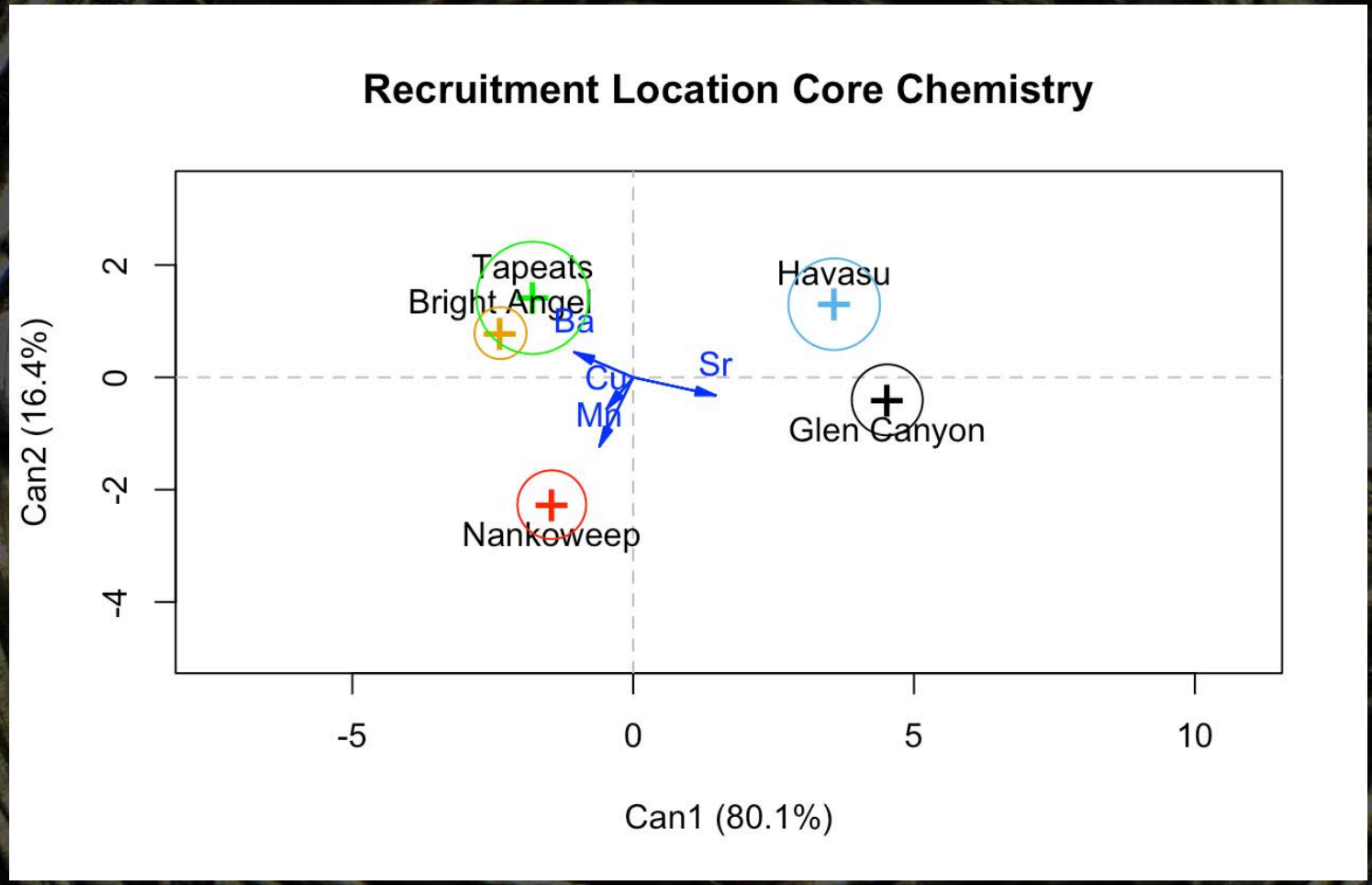
Early trib emigrant – left at age-0

Tributary emigrant + stayed in Tapeats after spawning season (captured in March)

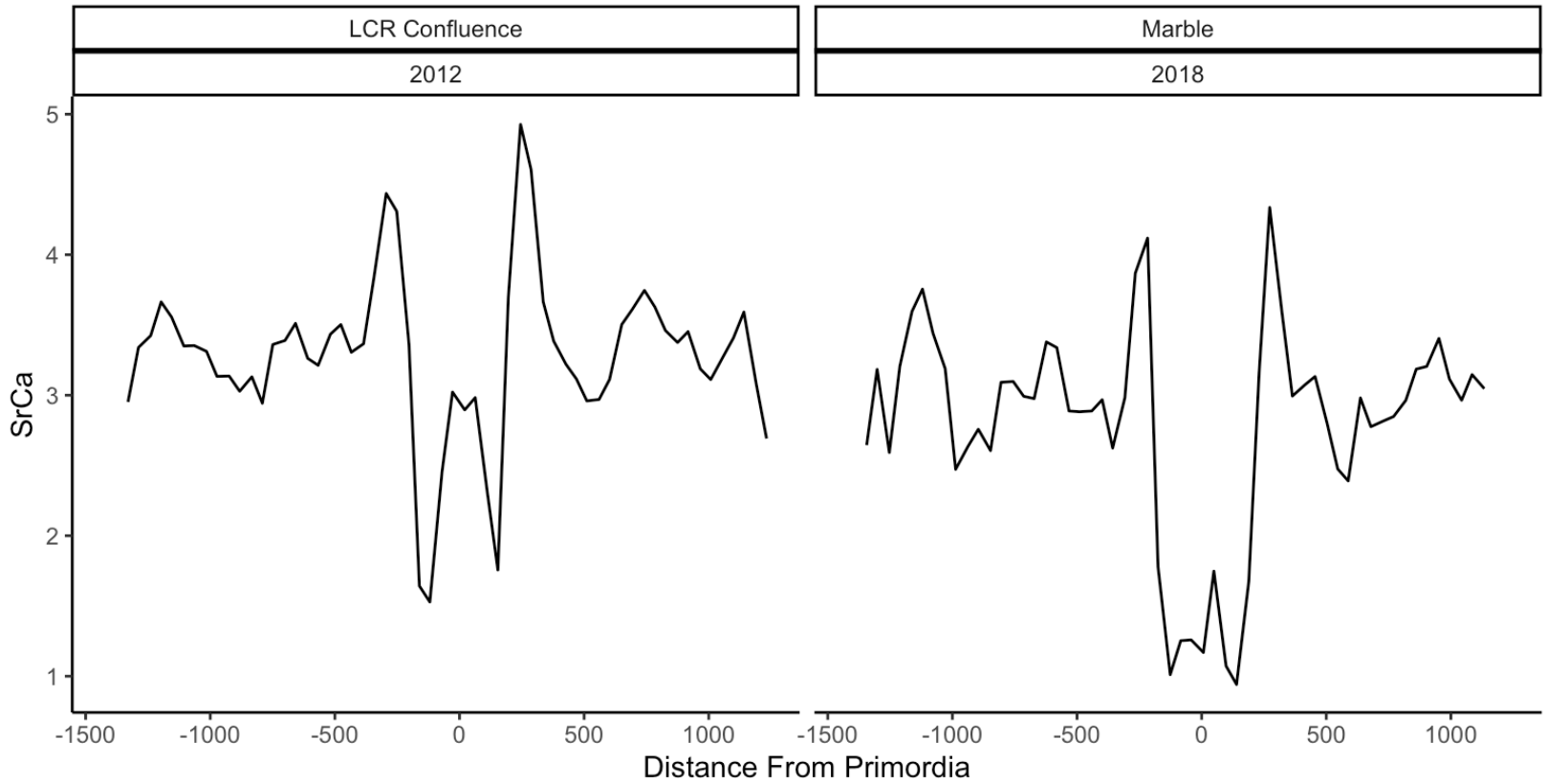
Including Nankoweep Creek Rainbow Trout



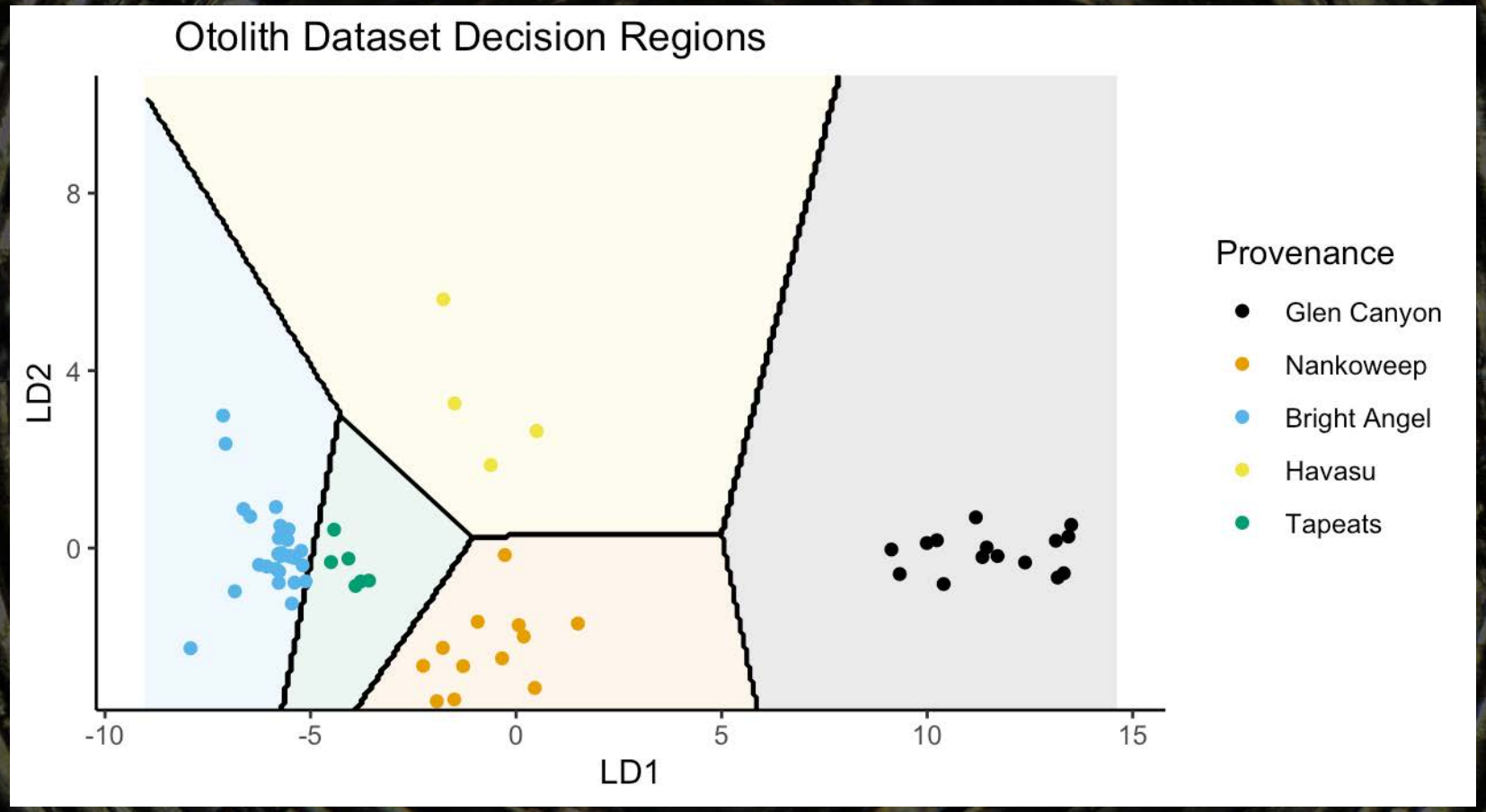
Nankoweep Creek Rainbow Trout + Havasu Bluehead Suckers



Early Emigrant Fish
Born in unknown tributary



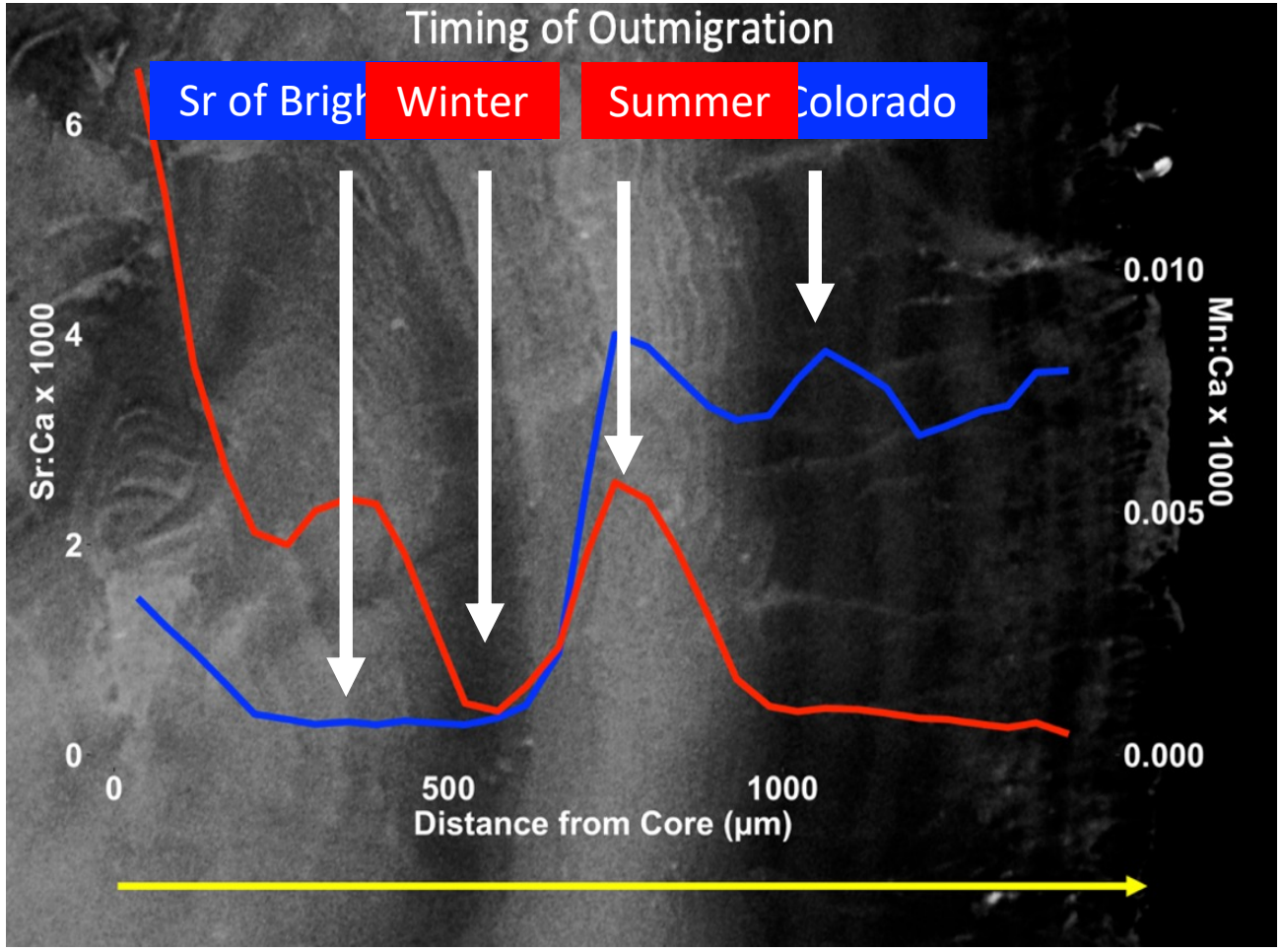
Nankoweep Creek Rainbow Trout + Havasu Bluehead Suckers



Methods: Timing Emigration from Tributaries (otoliths)

- Strontium proven proxy in GC[1]
- Manganese increases seasonally
- Overlay on photos, confirm age of emigration

Season of Emigration	Total Count	Proportion
Spring	44	63%
Summer	5	7%
Fall	18	26%
Winter	3	4%

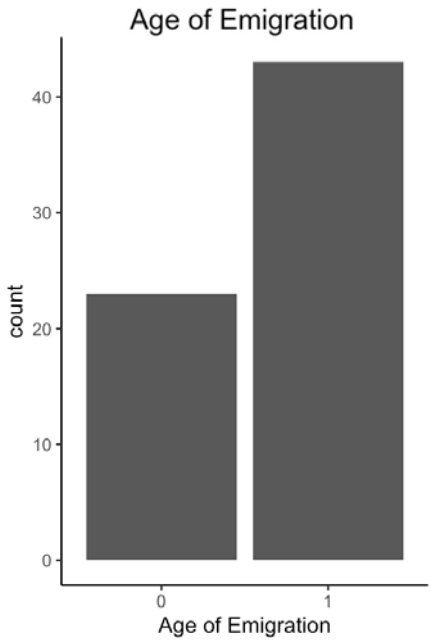


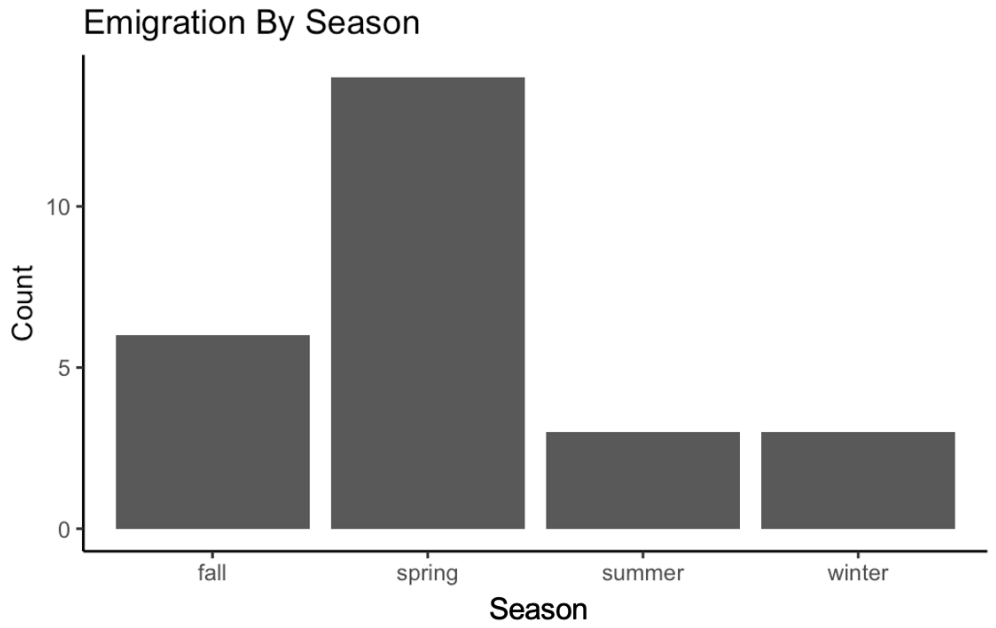
1 - Hayden et al. 2013; Limburg et al. 2013

Results:
When do fish emigrate from natal streams?

- 23% at age-0
- 77% of fish emigrate at age-1
- No evidence of emigration past age-1

- 64% emigrated in spring
- 27% emigrated in fall
- Small portion in summer and winter





35/66 : 31/66

By Length:
Outer laminae concentrations of mercury