Age validation of Black Rockfish, Copper Rockfish, and Cabezon using secondary ion mass spectrometry (SIMS) to elucidate seasonal patterns in otolith stable oxygen isotopes

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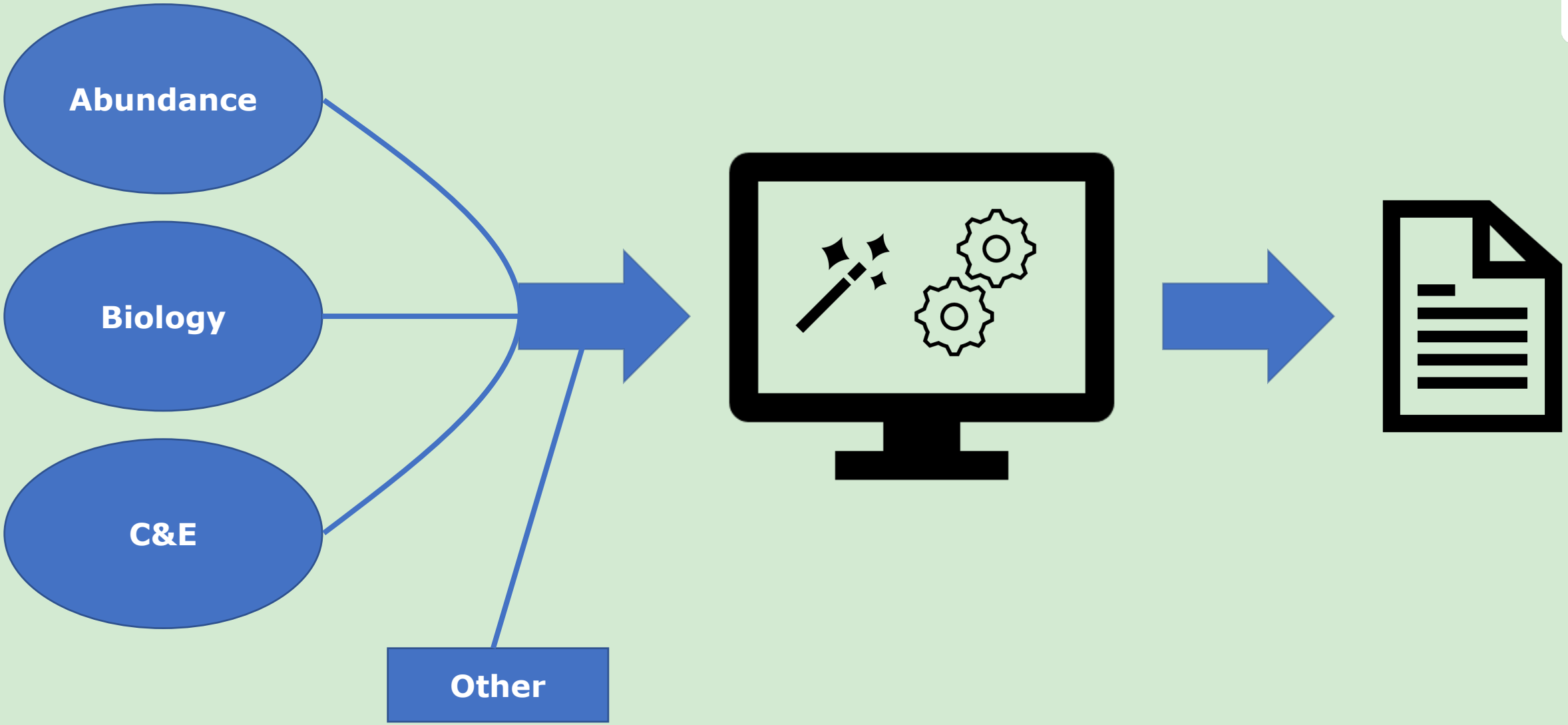
How are fisheries managed?



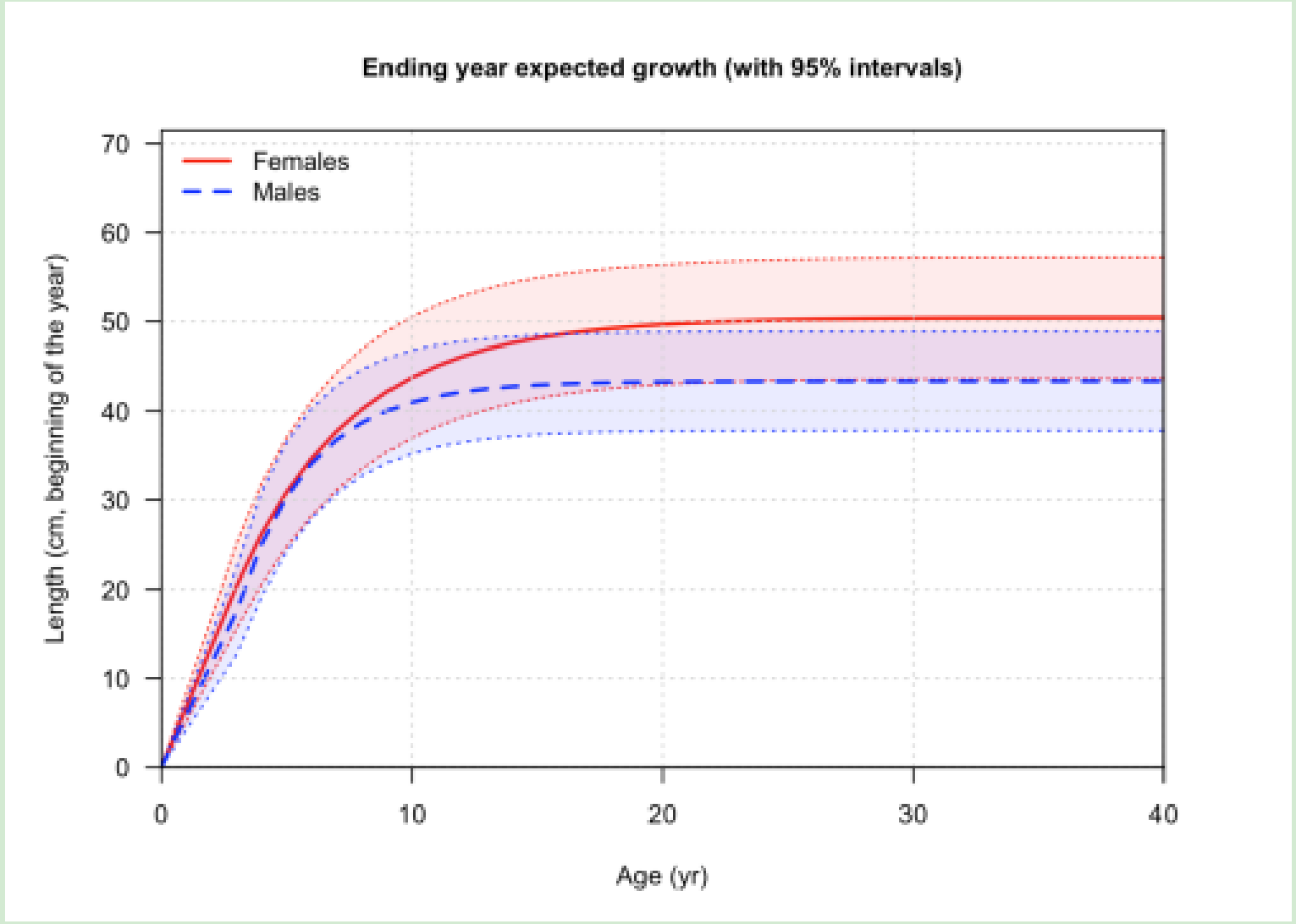
Fish Ages

Catch/stock weights-at-age

Length/maturity-at-age

Growth rates

Age-structured CPUE



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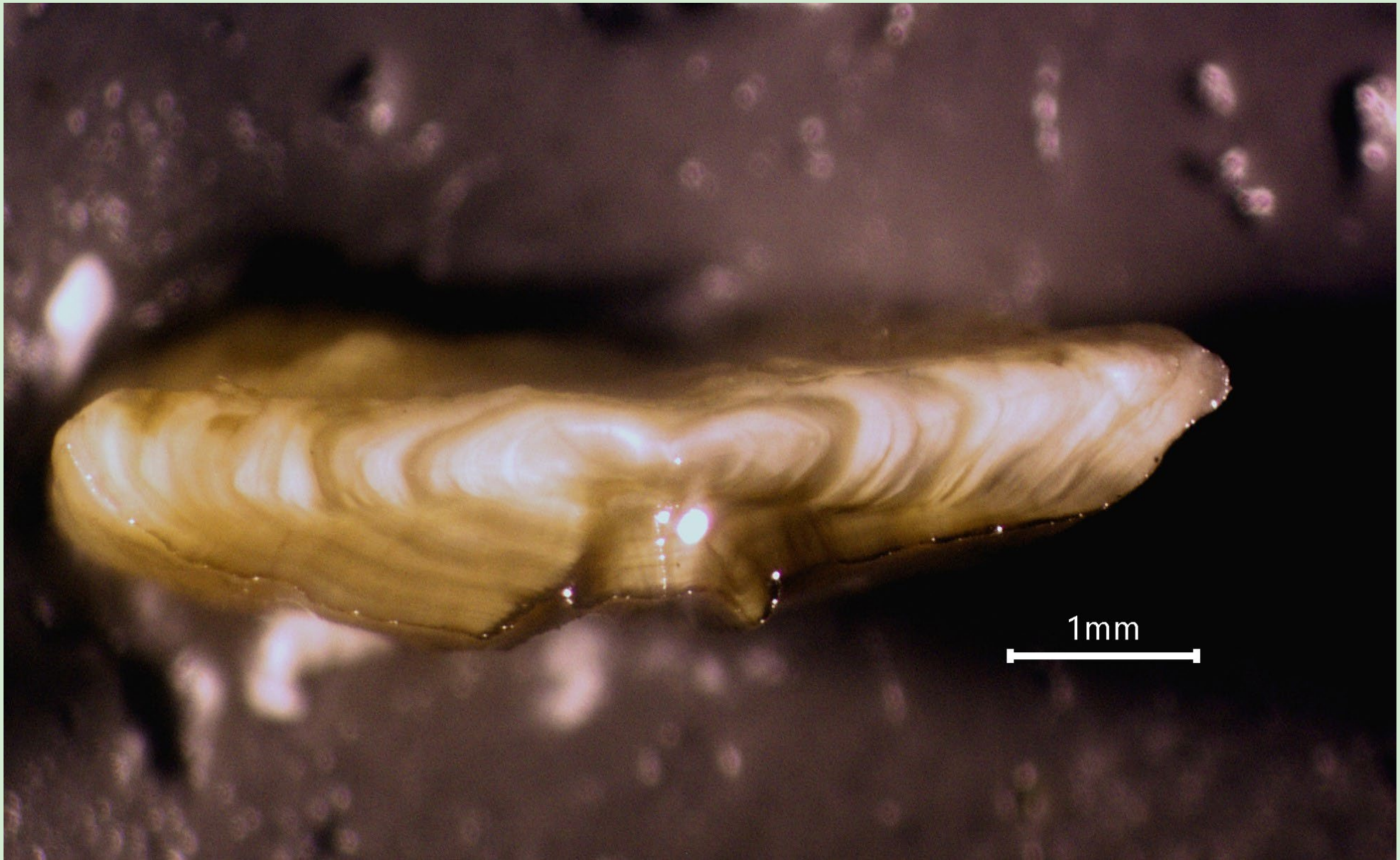
Precision=Verification



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Accuracy=Validation

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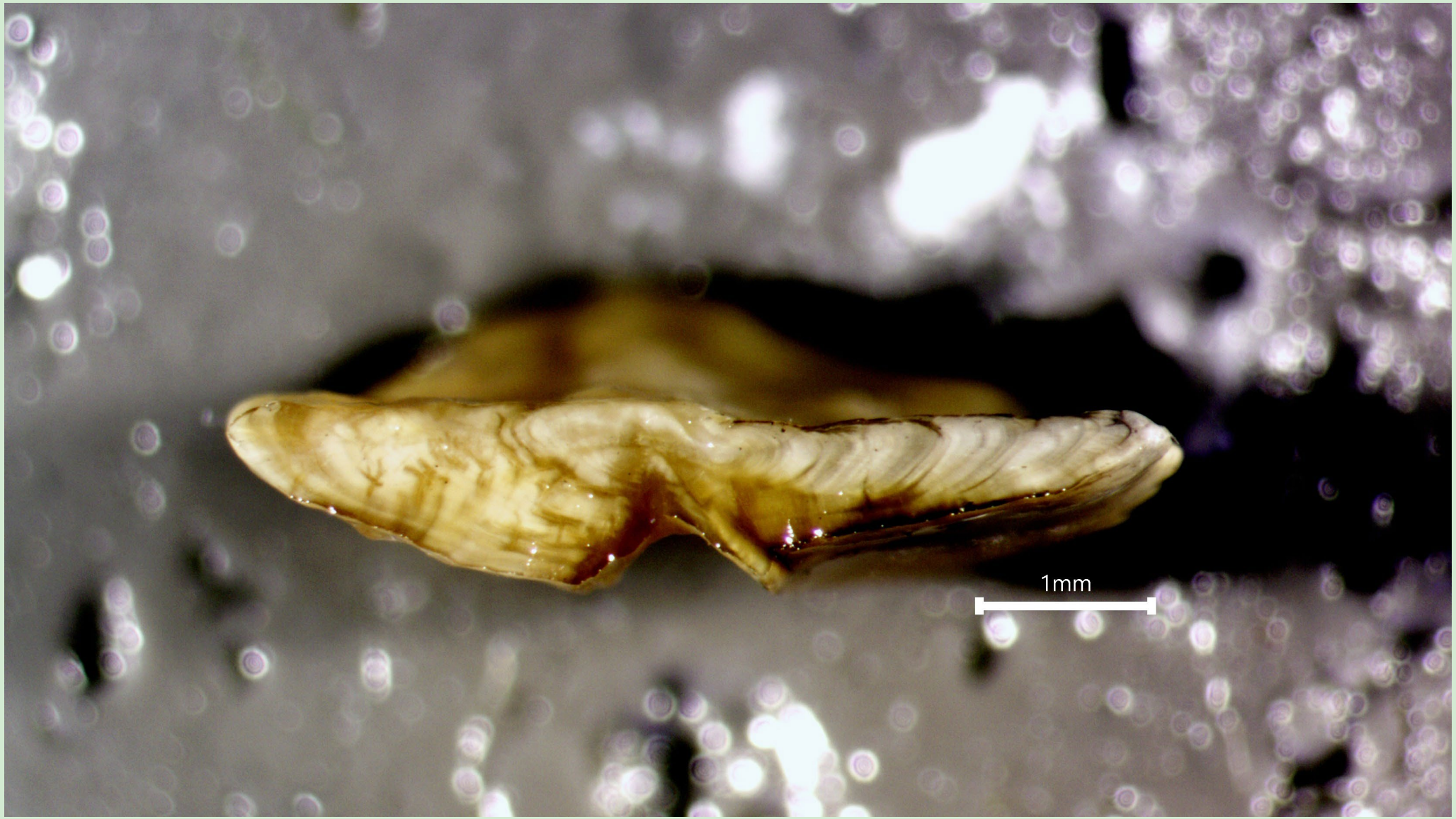

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Otolith Fun Facts

- **Otoliths are acellular, metabolically inert, and grow throughout a fish's life.**
- **Formed by precipitation of $CaCO_3$ over a protein matrix.**
- **Otoliths accrete by deposition of these materials around a core.**
- **Any elements accreted onto the otolith surface are permanently retained.**
- **∴ Otoliths contain a complete record of the temperature and chemical composition of ambient water the fish experienced over its lifespan.**

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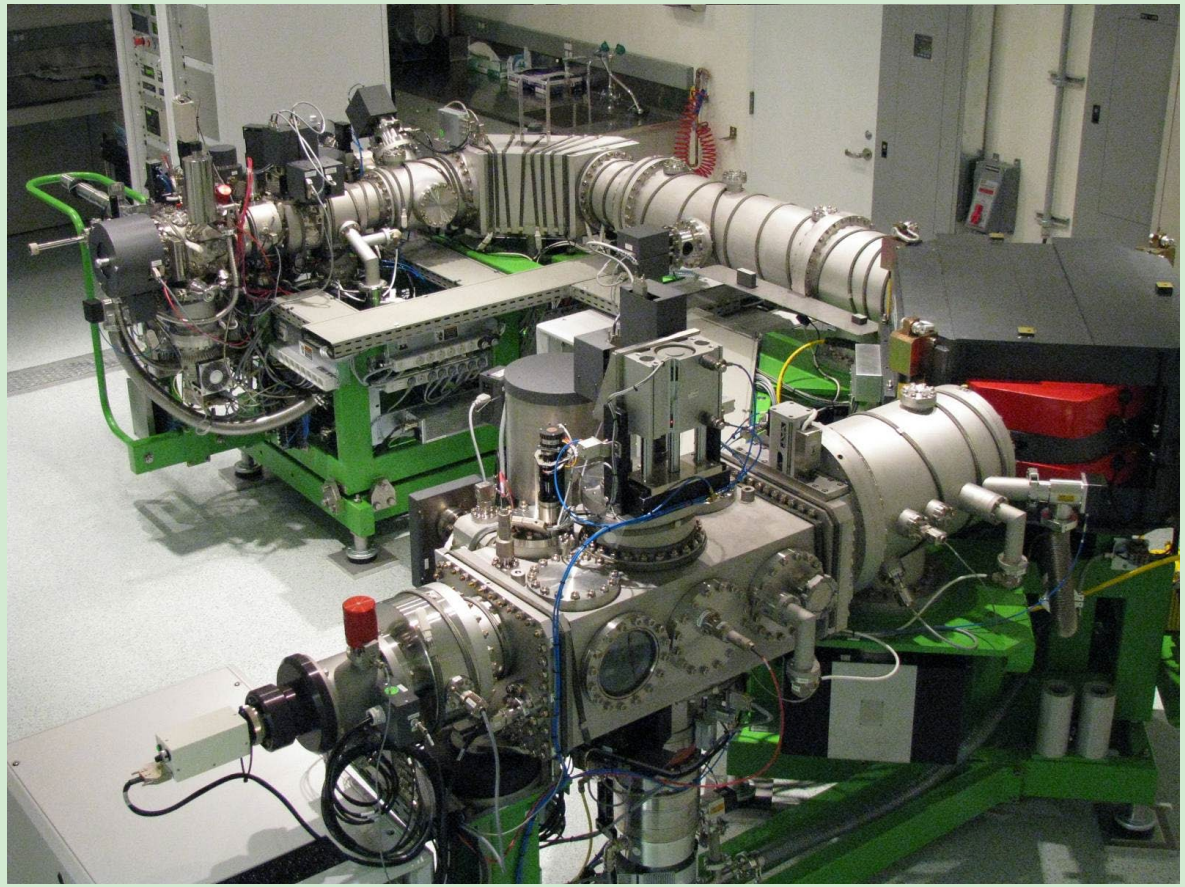
How do we validate ages using SIMS?

- **Otolith oxygen isotopes are in equilibrium with ambient seawater.**
- **Otolith $^{18}O/^{16}O$ ($\delta^{18}O$) is inversely related to water temperature and is a function of salinity.**
- **Probe the otolith from core to edge (the entire lifespan) and examine $\delta^{18}O$.**
- **$\therefore$ Sequential $\delta^{18}O$ across the otolith are a proxy for seasonal temperature cycles experienced by the fish.**
- **Count peaks (cold) and subsequent valleys (warm) for fish age, measure location of peaks on otolith and associate with visible growth marks.**



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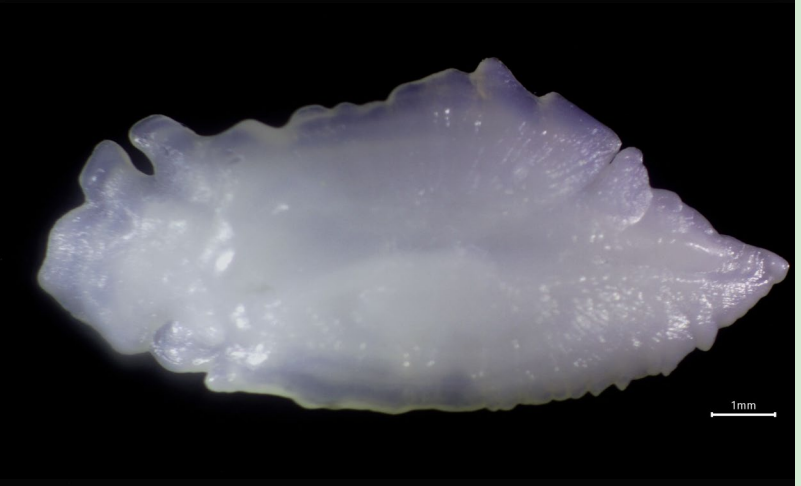
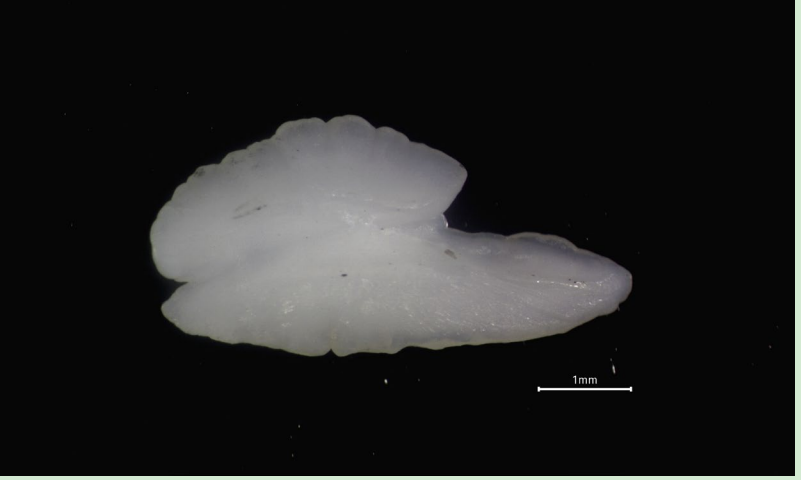




Methods

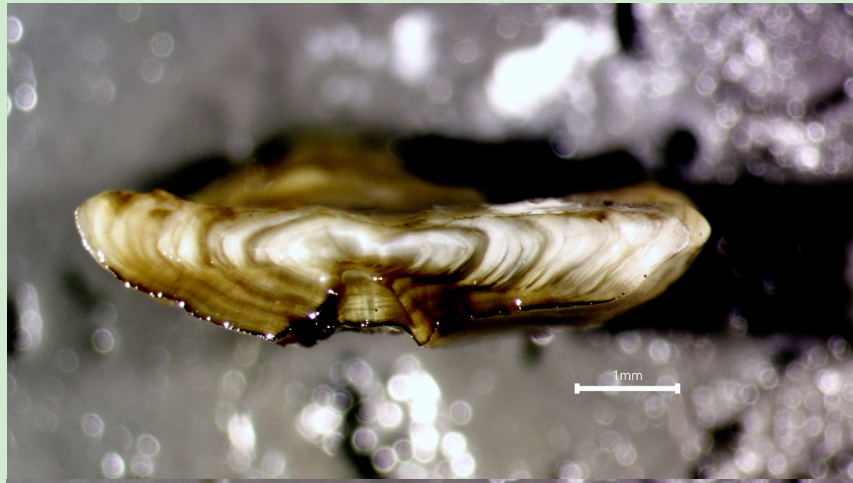
N=25 per species from commercial and recreational fleets

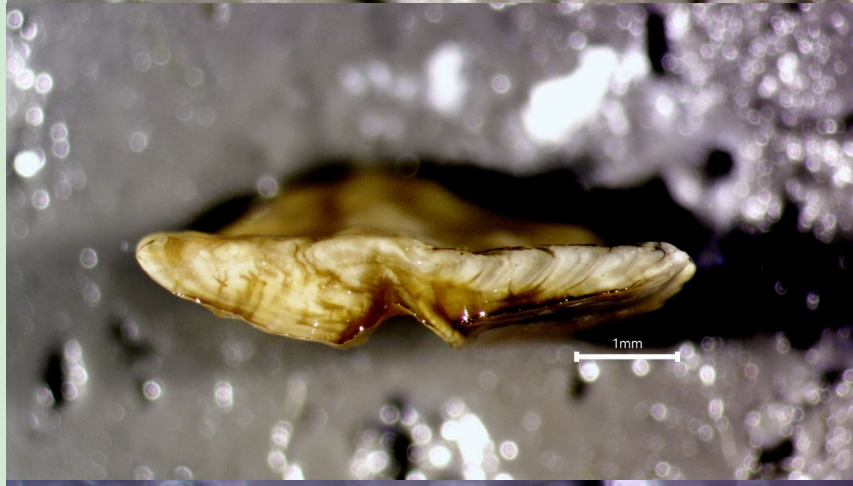
Left otoliths sent to CCIM

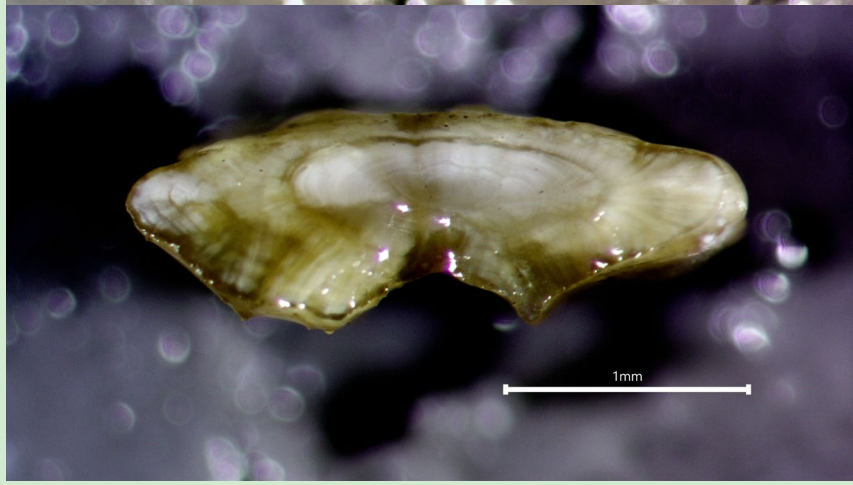
Right otoliths aged by ODFW (B&B)

Quick results

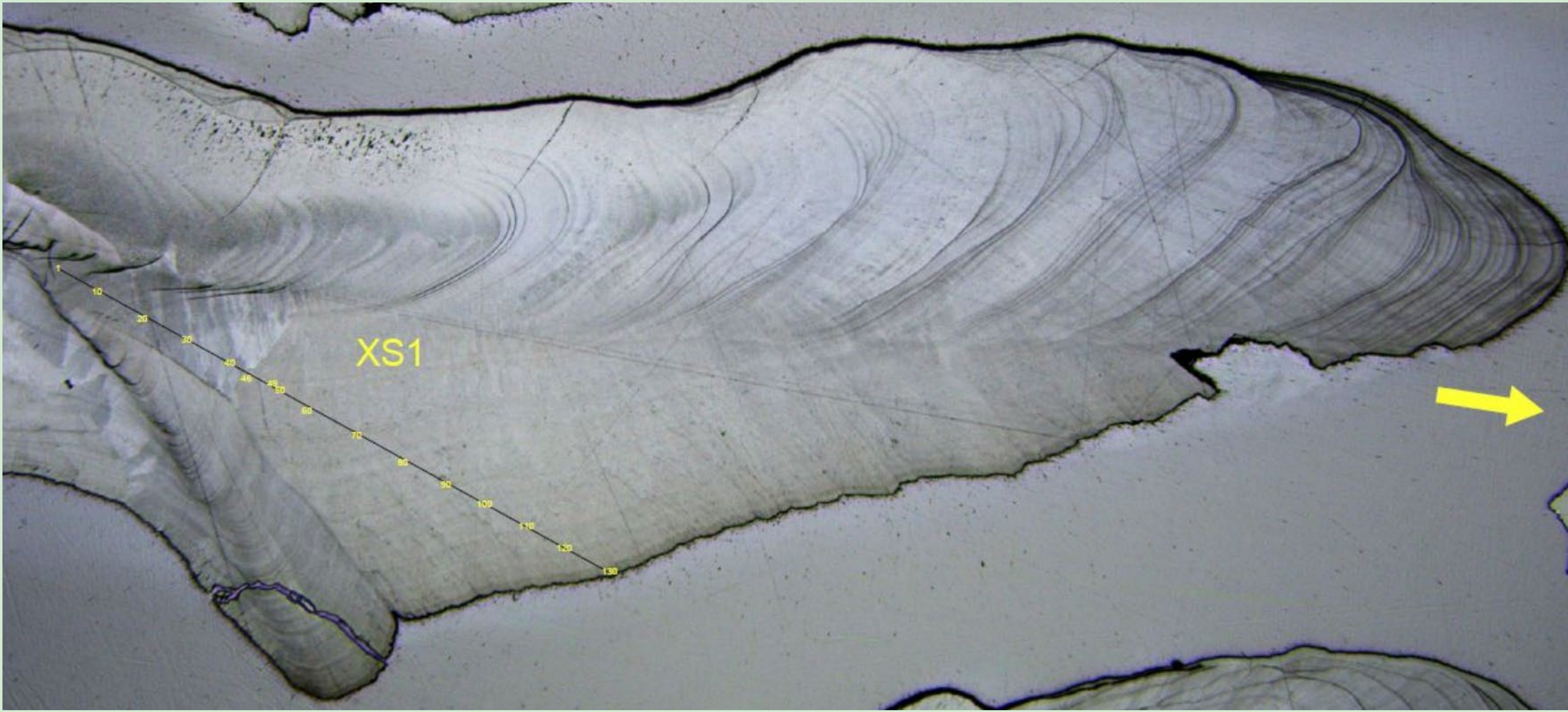
APE: BRF = 1.08%
CRF = 1.65%
CAB = 2.23%



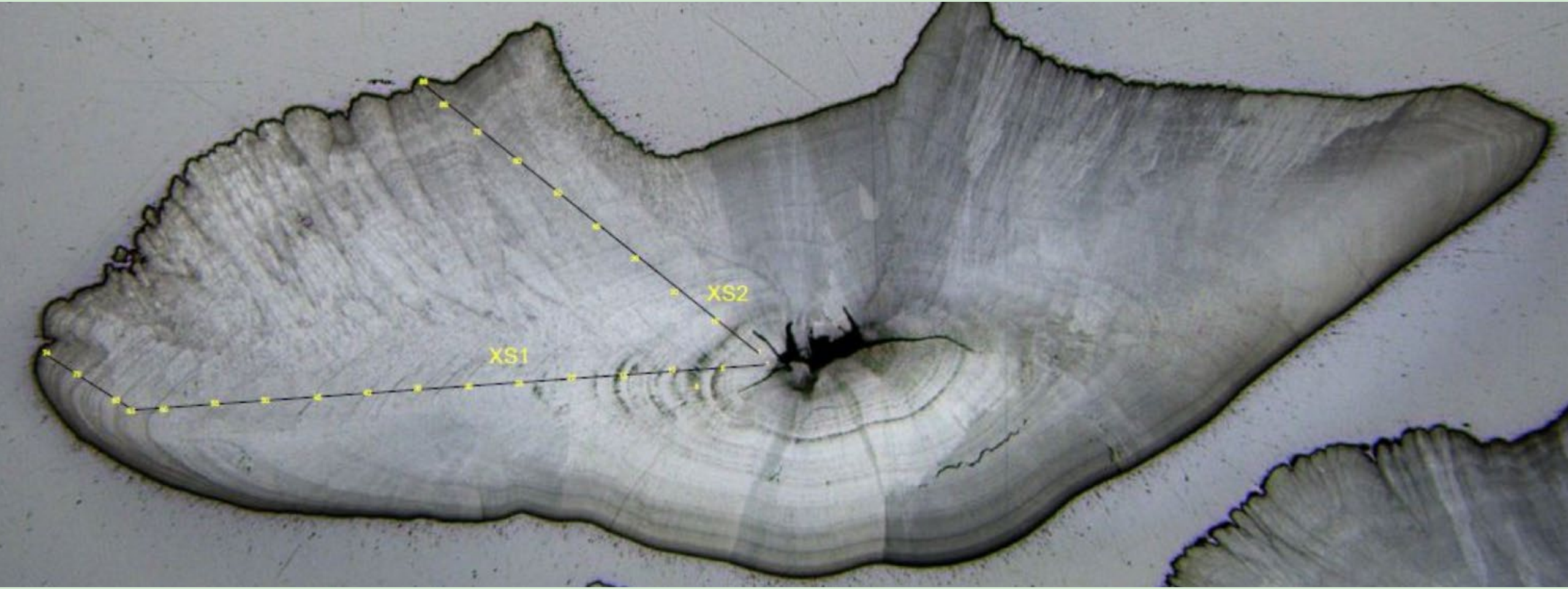


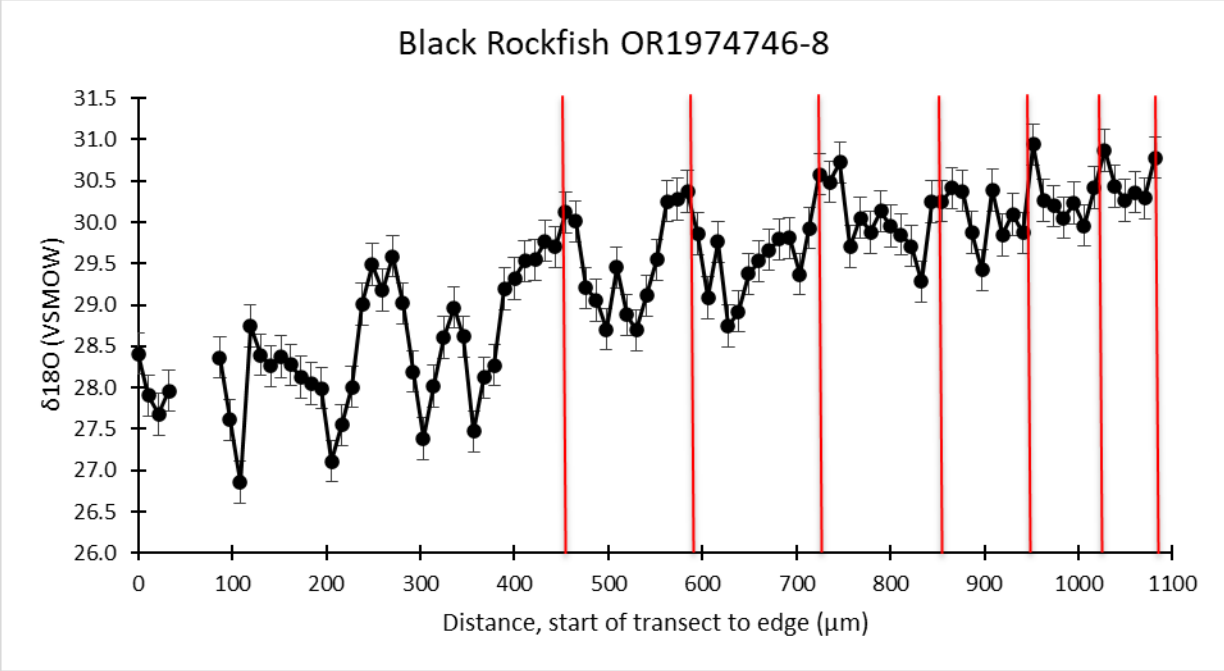


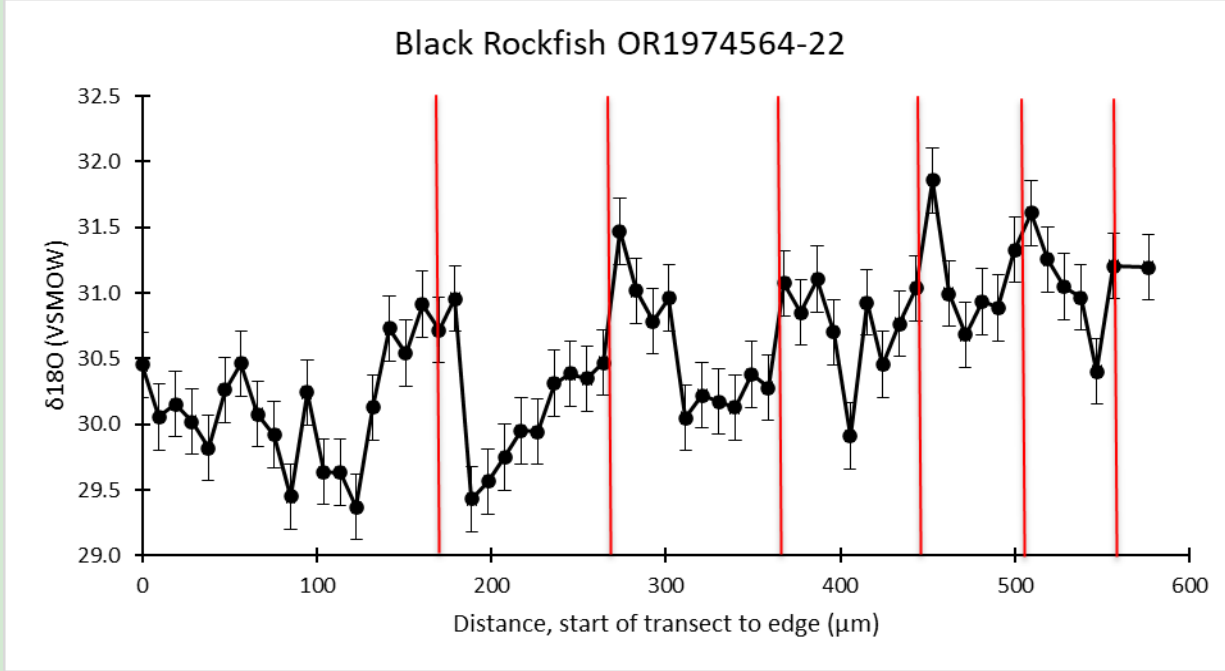
Black Rockfish (N=11); Copper Rockfish (N=12)

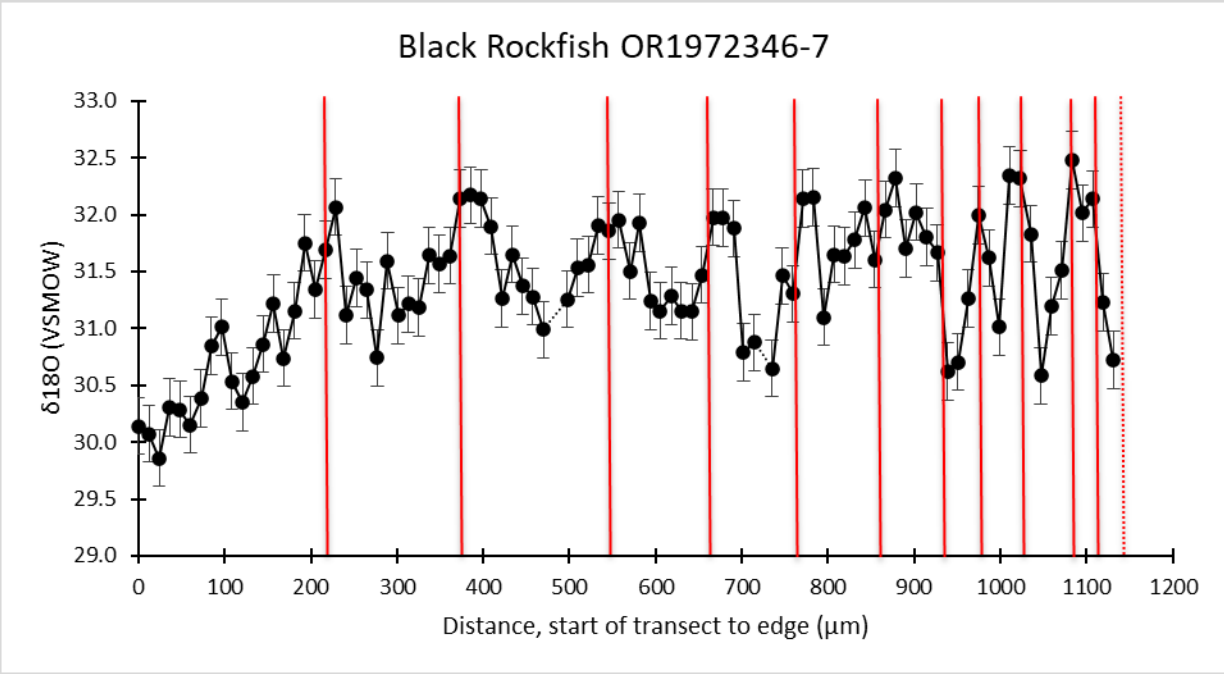


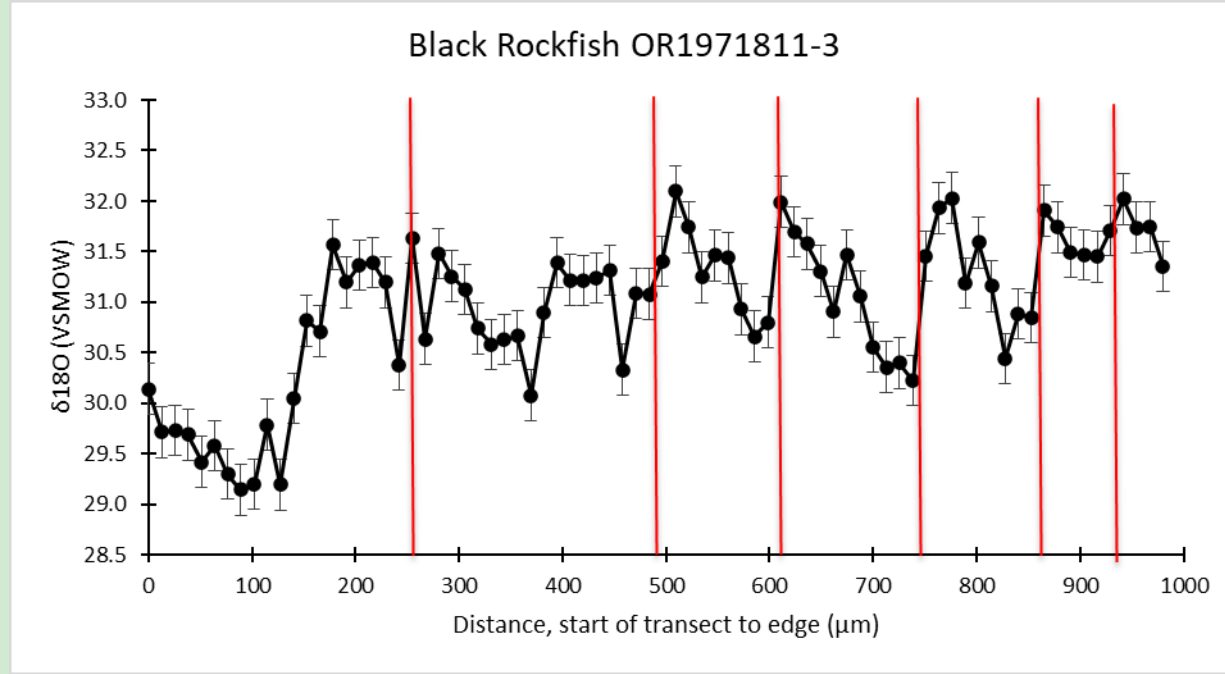
Cabezon (N=8)

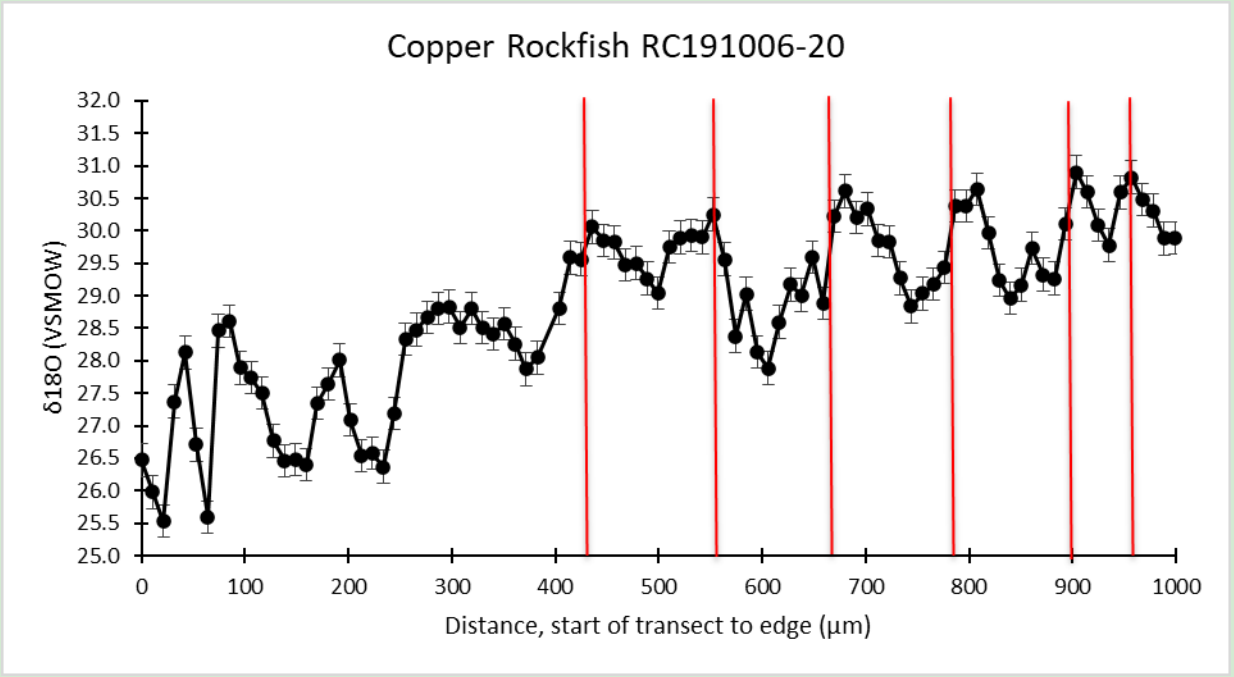


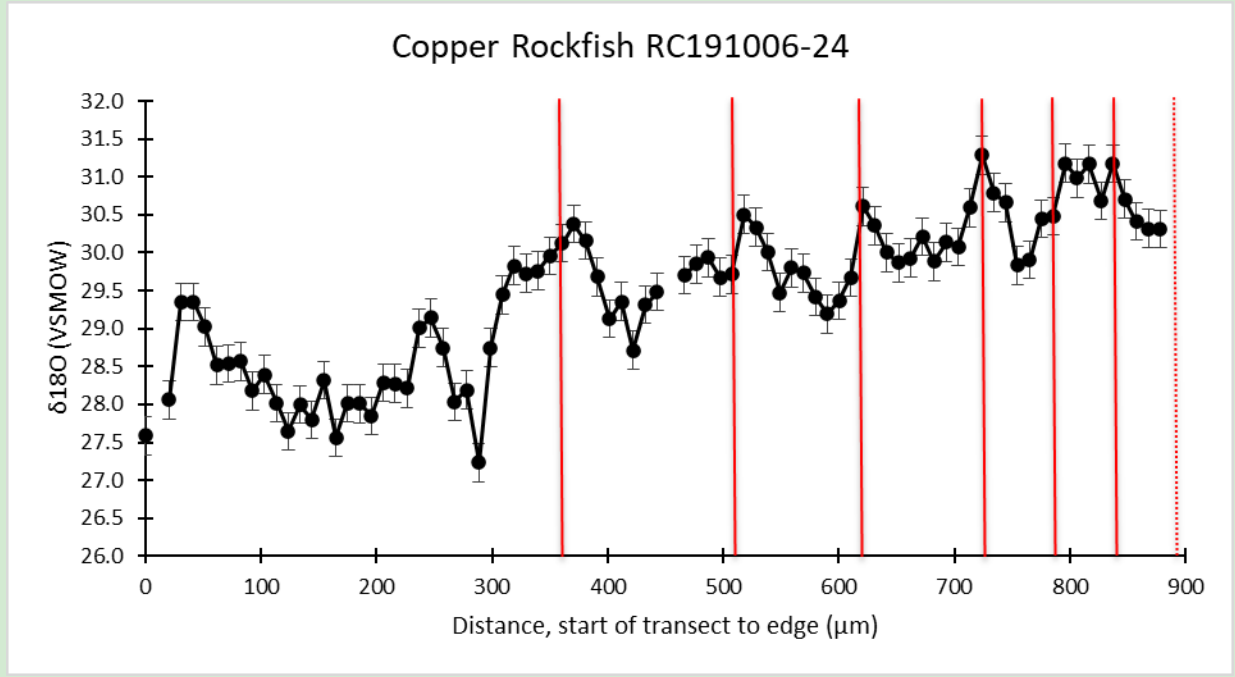

Black Rockfish OR1974746-8
δ18O (VSMOW)
31.5
31.0
30.5
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
0
100
200
300
400
500
600
700
800
900
1000
1100
Distance, start of transect to edge (µm)

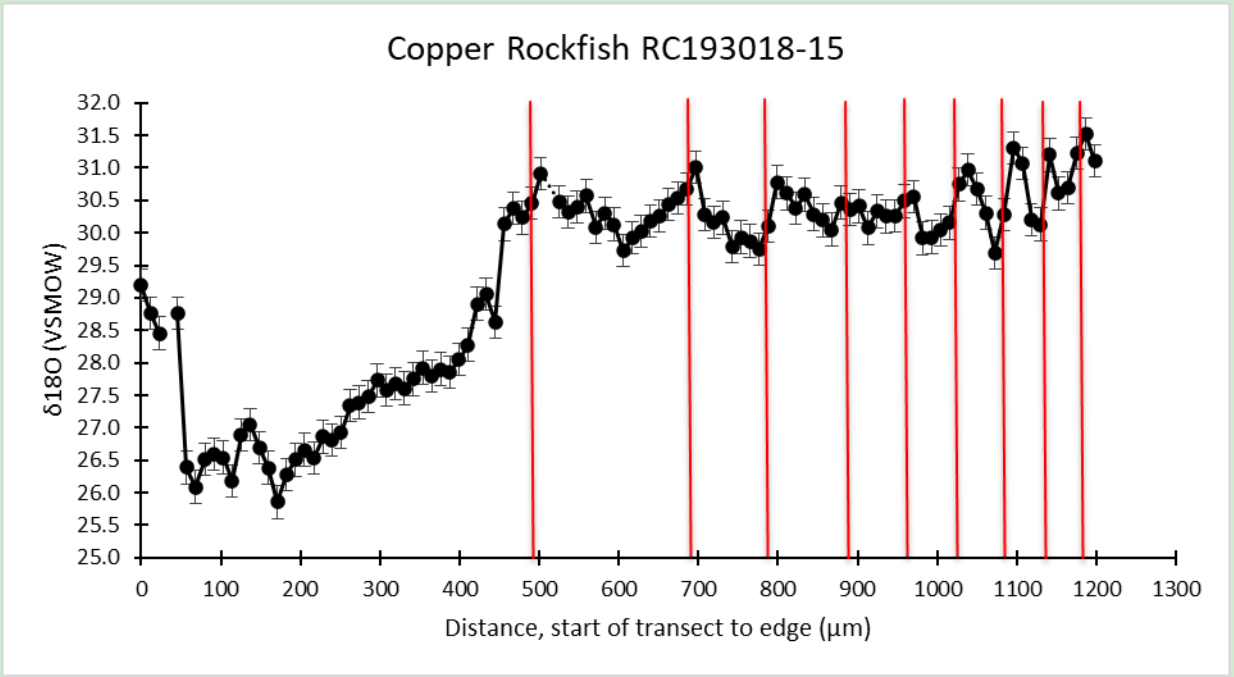

Black Rockfish OR1974564-22
δ18O (VSMOW)
32.5
32.0
31.5
31.0
30.5
30.0
29.5
29.0
0
100
200
300
400
500
600
Distance, start of transect to edge (µm)

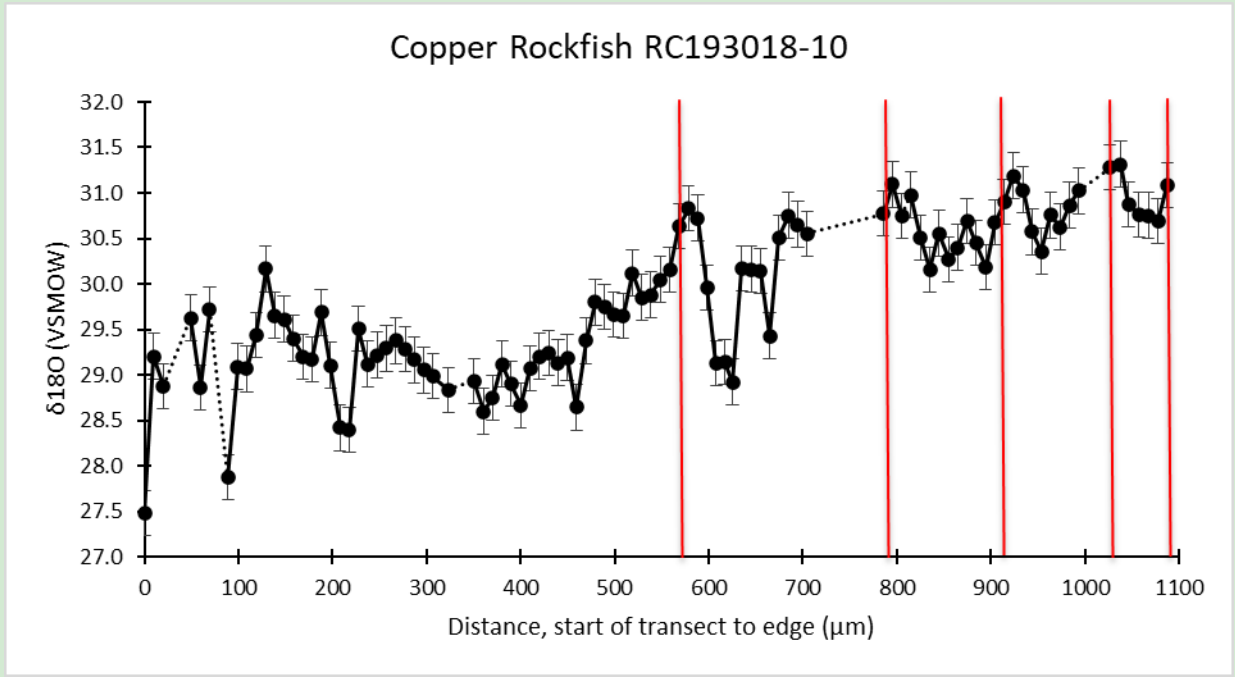

Black Rockfish OR1972346-7
δ18O (VSMOW)
33.0
32.5
32.0
31.5
31.0
30.5
30.0
29.5
29.0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Distance, start of transect to edge (µm)

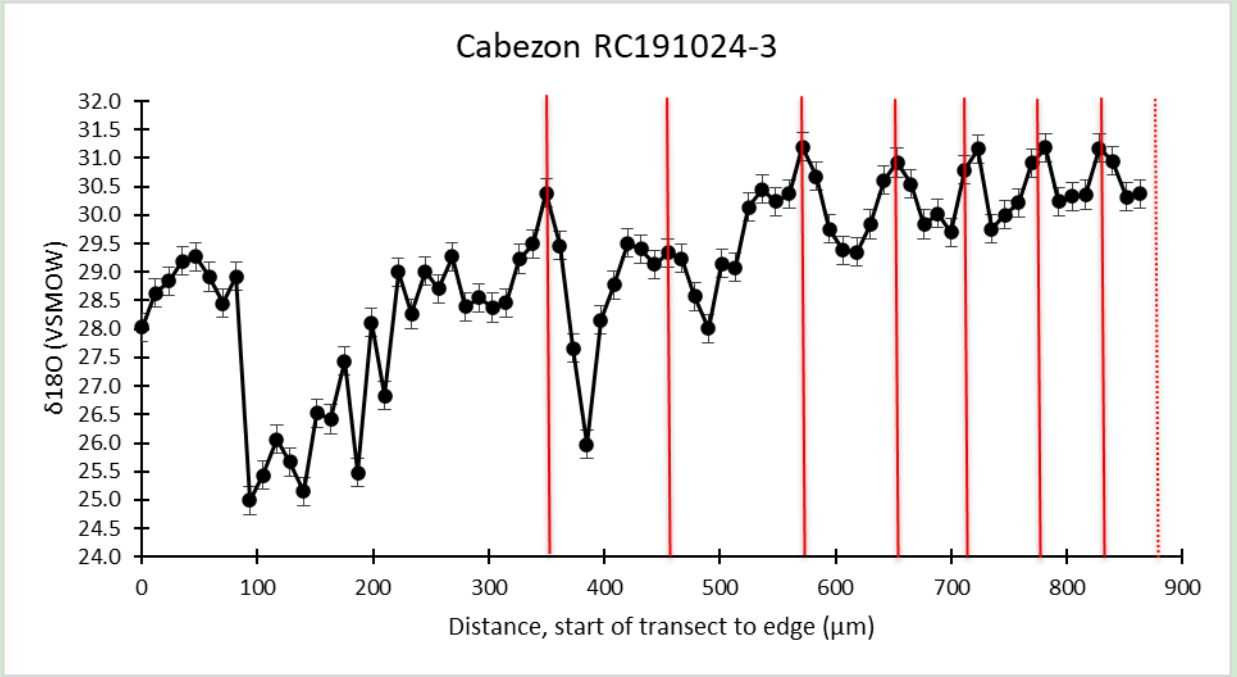

Black Rockfish OR1971811-3
δ18O (VSMOW)
33.0
32.5
32.0
31.5
31.0
30.5
30.0
29.5
29.0
28.5
0
100
200
300
400
500
600
700
800
900
1000
Distance, start of transect to edge (µm)

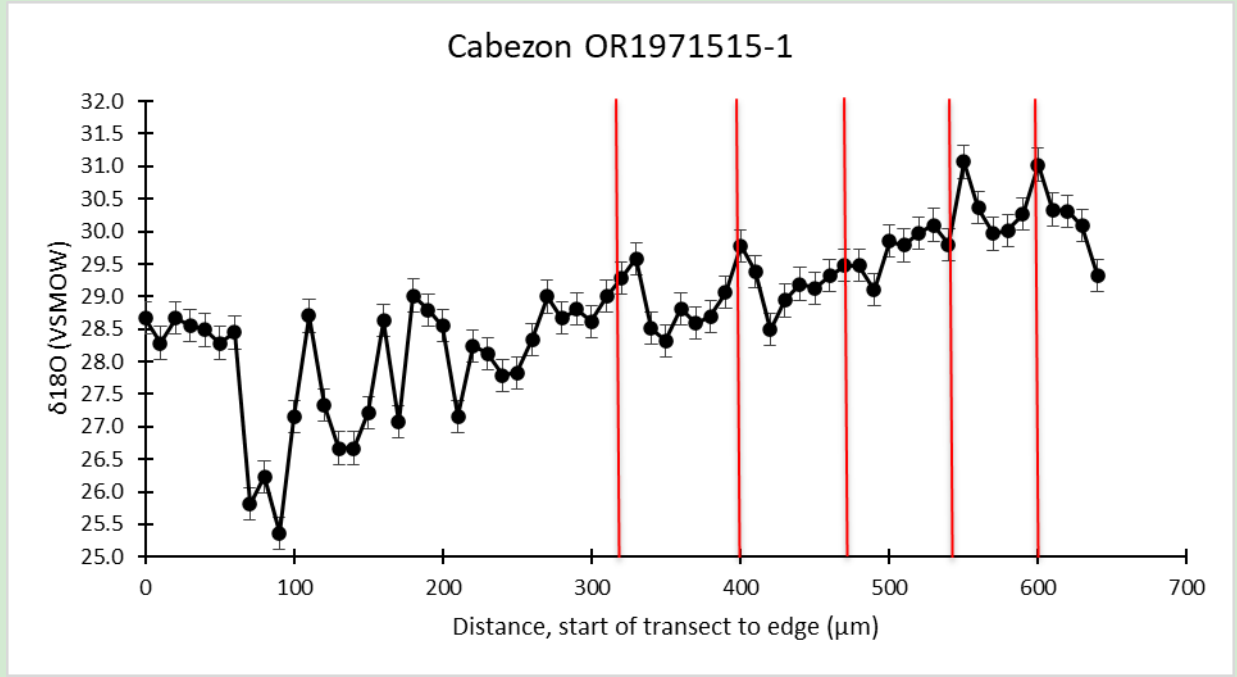

Copper Rockfish RC191006-20
δ18O (VSMOW)
Distance, start of transect to edge (µm)

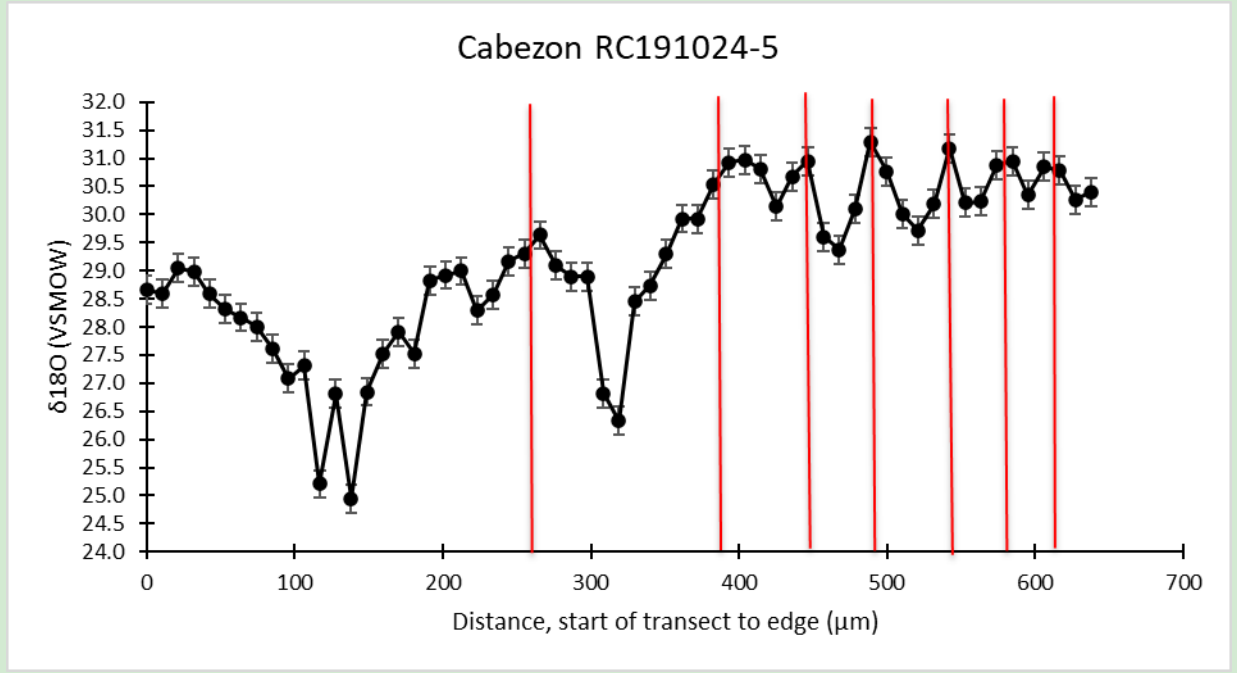

Copper Rockfish RC191006-24
δ18O (VSMOW)
Distance, start of transect to edge (µm)

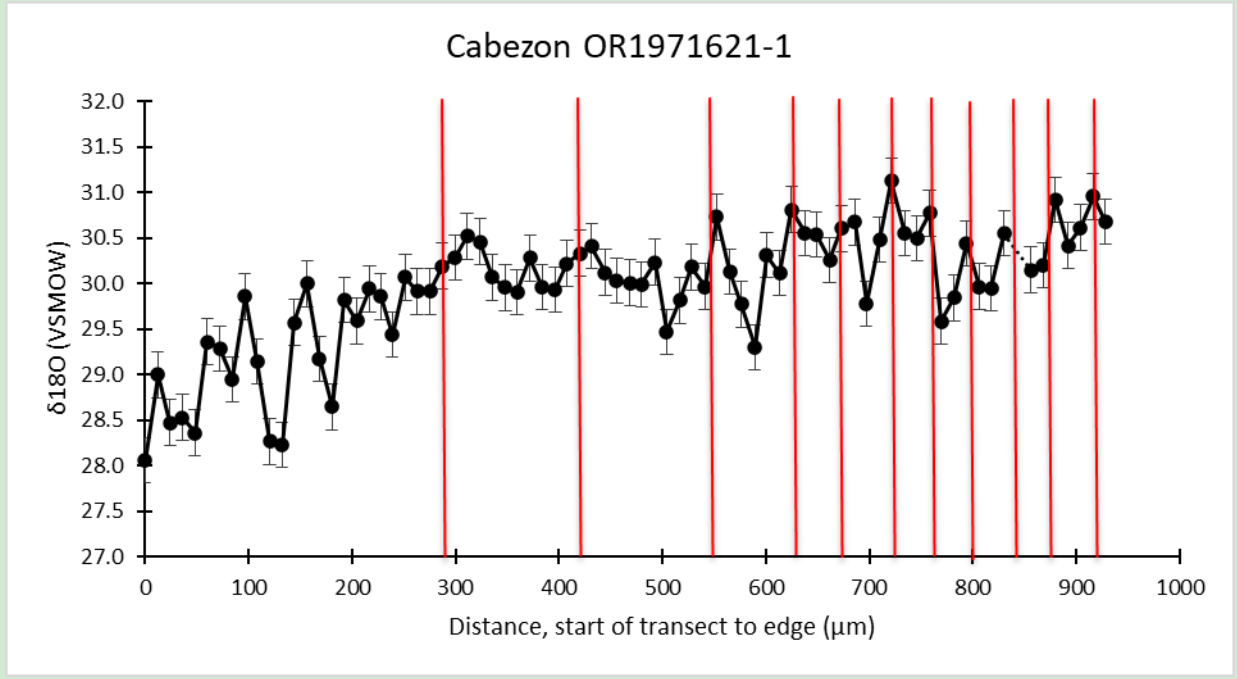

Copper Rockfish RC193018-15
δ18O (VSMOW)
Distance, start of transect to edge (µm)


Copper Rockfish RC193018-10
δ18O (VSMOW)
Distance, start of transect to edge (µm)


Cabezon RC191024-3
δ18O (VSMOW)
Distance, start of transect to edge (µm)


Cabezon OR1971515-1
δ18O (VSMOW)
Distance, start of transect to edge (µm)

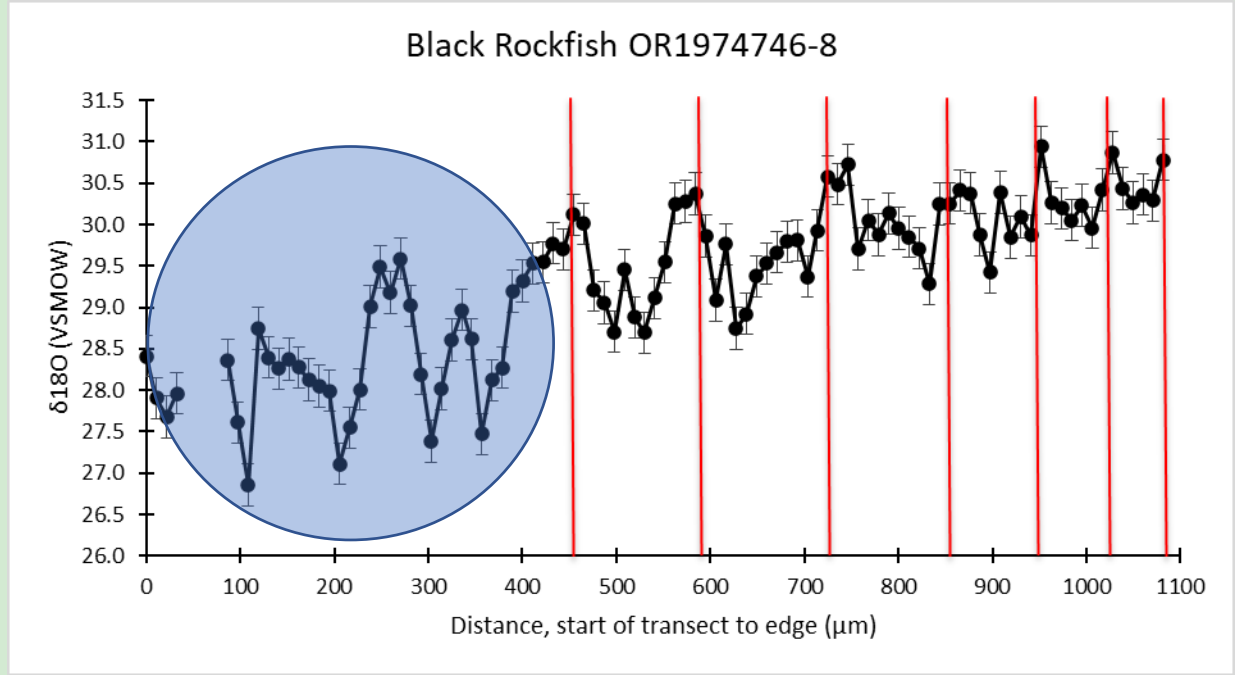

Cabezon RC191024-5
δ18O (VSMOW)
Distance, start of transect to edge (µm)

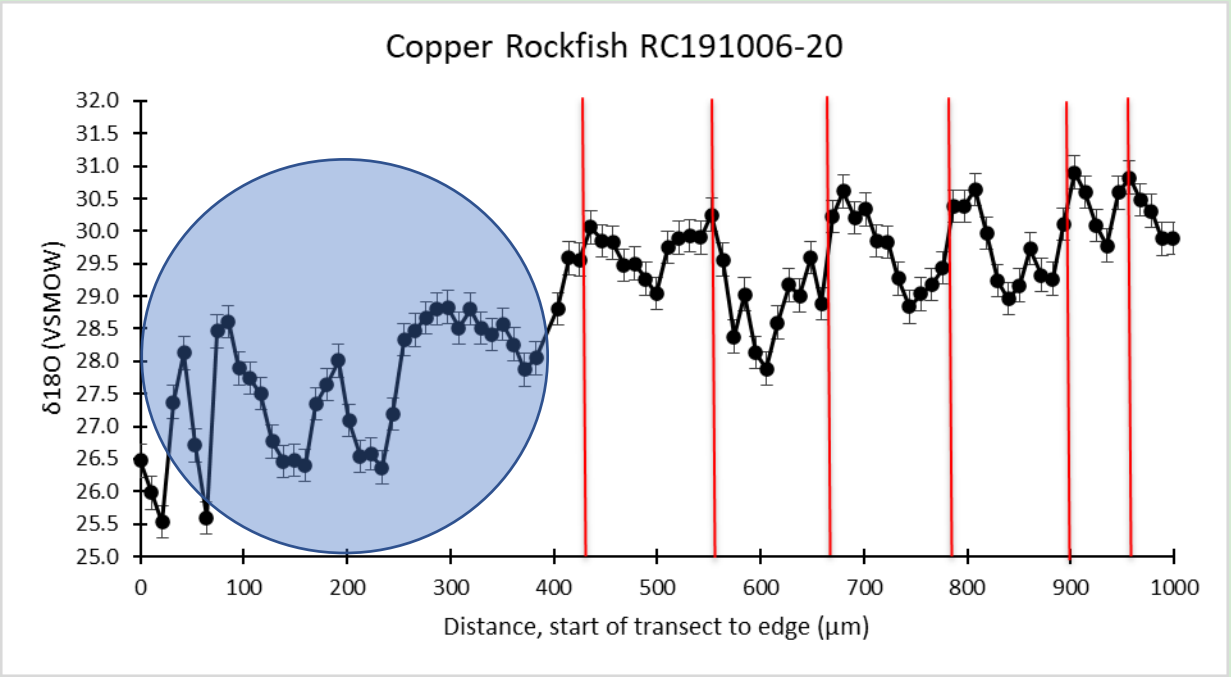

Cabezon OR1971621-1
δ18O (VSMOW)
Distance, start of transect to edge (µm)

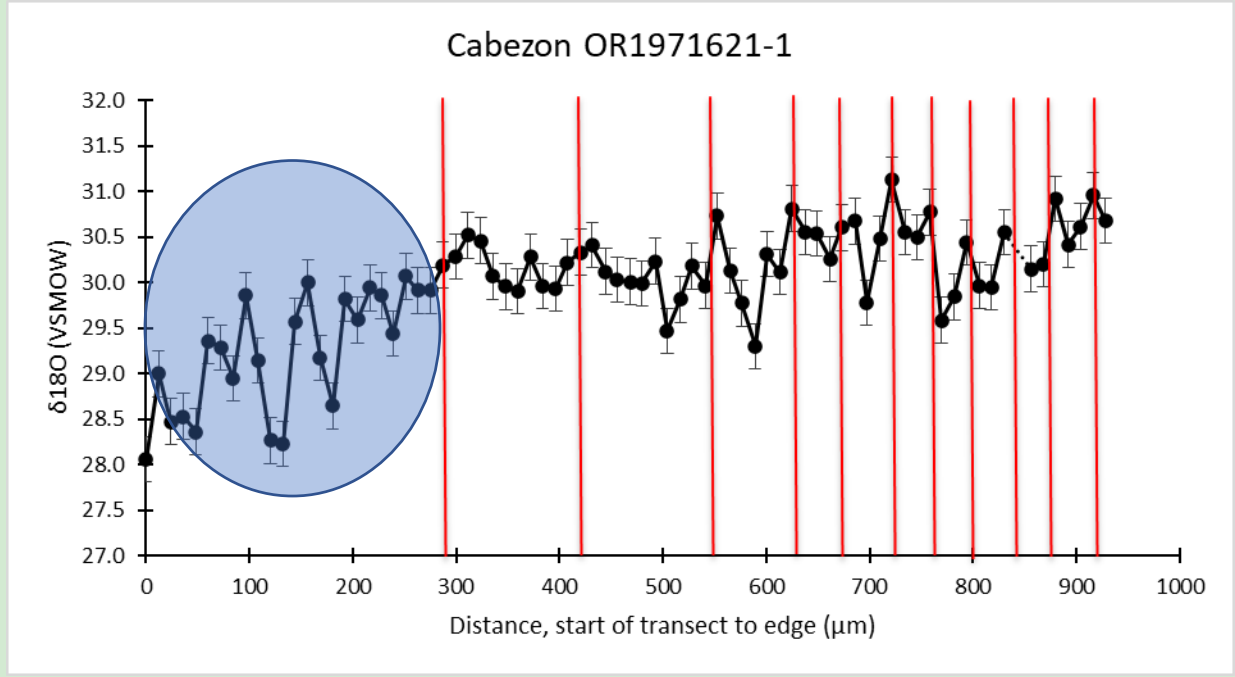
Validation: Periodicity (SIMS)

Age at 1st increment

BRF: newly settled otolith radii
CRF: no data
Cab: newly settled otolith radii



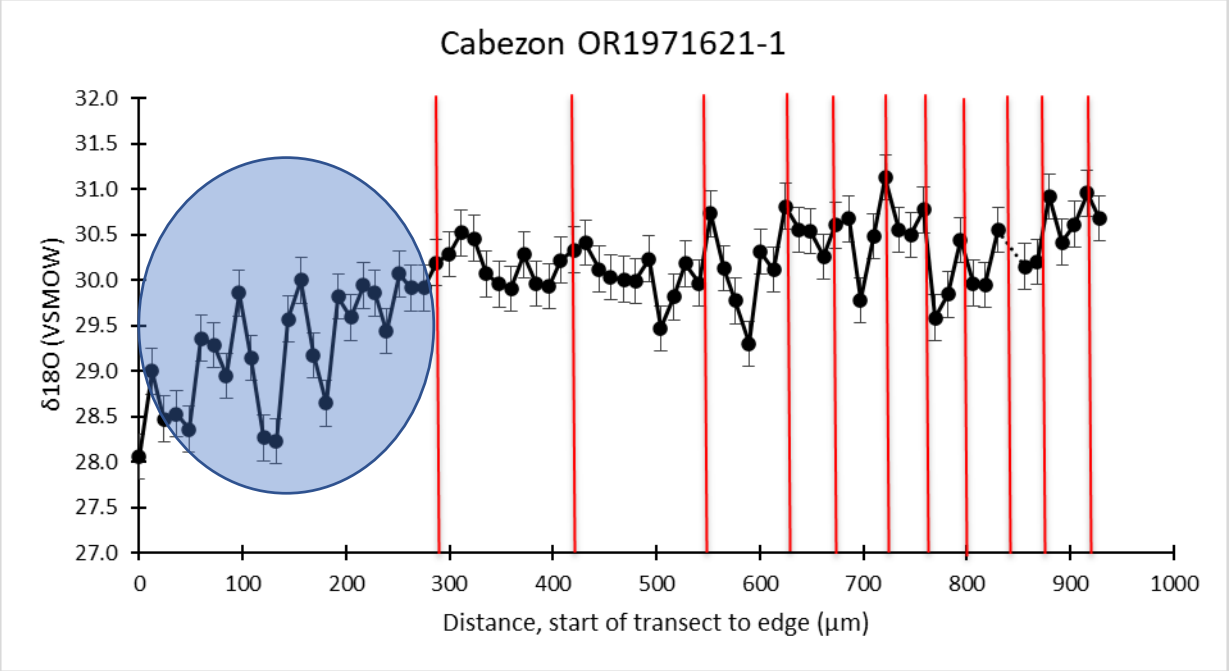




So, what's influencing the seasonal (and intra-seasonal) variation in otolith $\delta^{18}O$?

Variability in $\delta^{18}O$ prior to age-1

- Extended larval and juvenile duration
  - BRF larvae and small juveniles are pelagic for ~ 6 months
  - CRF have a 2-3 month pelagic duration
  - Cabezon remain in the plankton 3-4 months
- All settle in nearshore shallow areas



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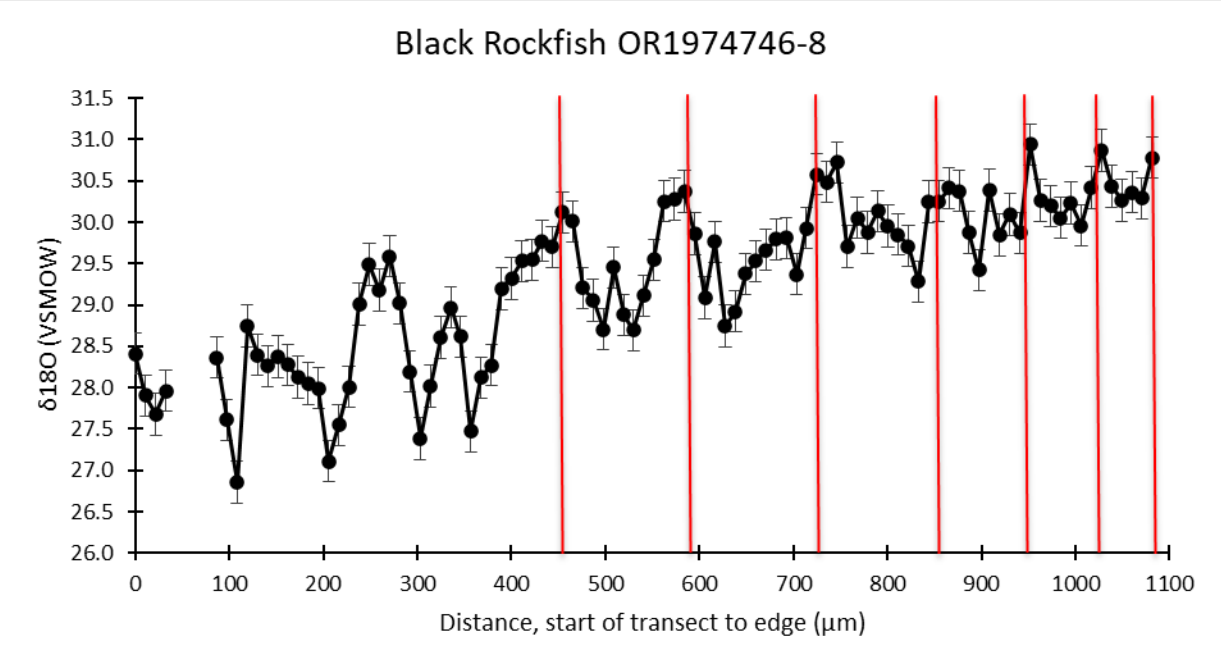
So, what's influencing the seasonal (and intra-seasonal) variation in otolith $\delta^{18}O$?

Peaks and valleys in the $\delta^{18}O$ chronologies (and noise)

- **Coastal circulation dynamics off Oregon**



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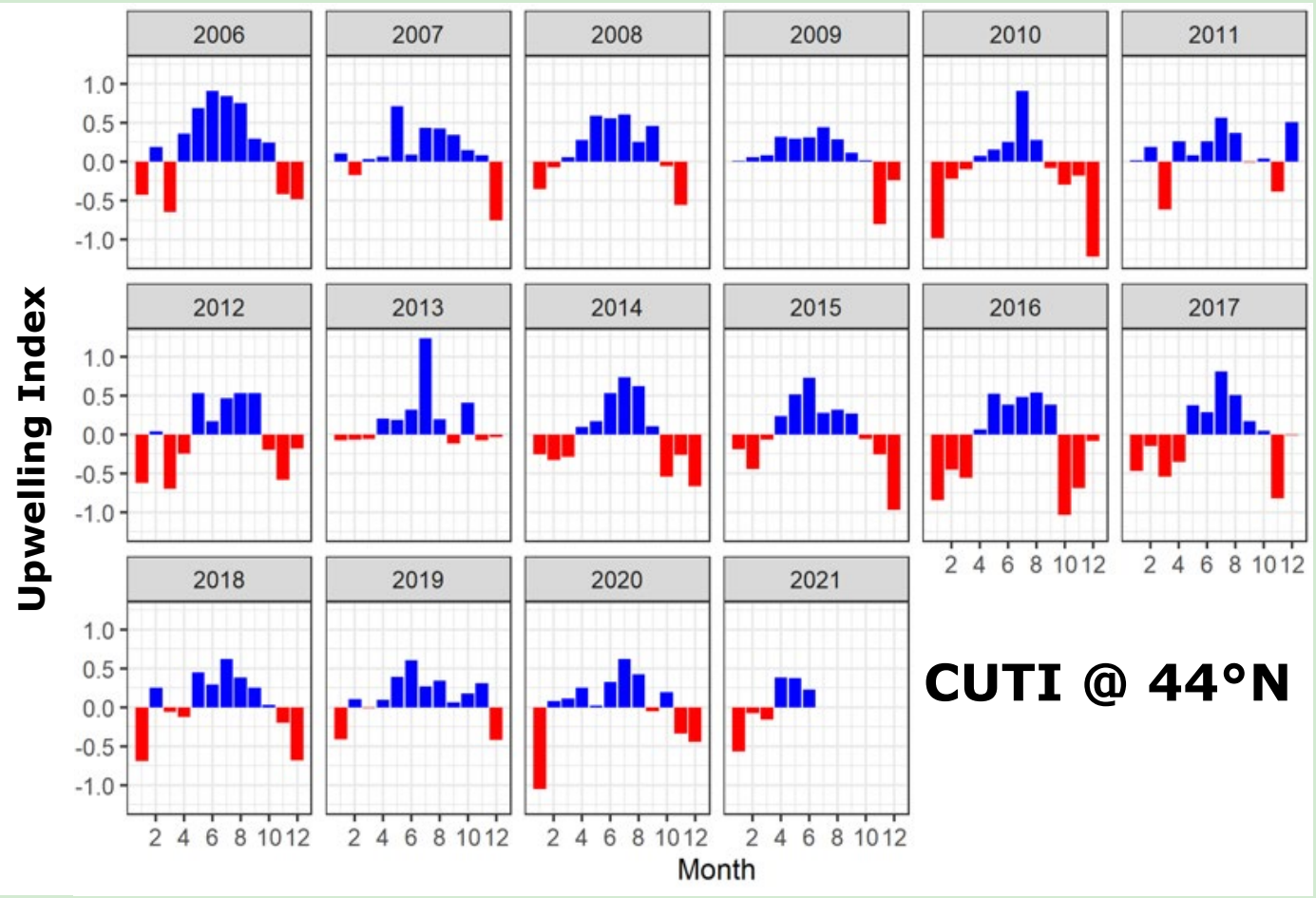
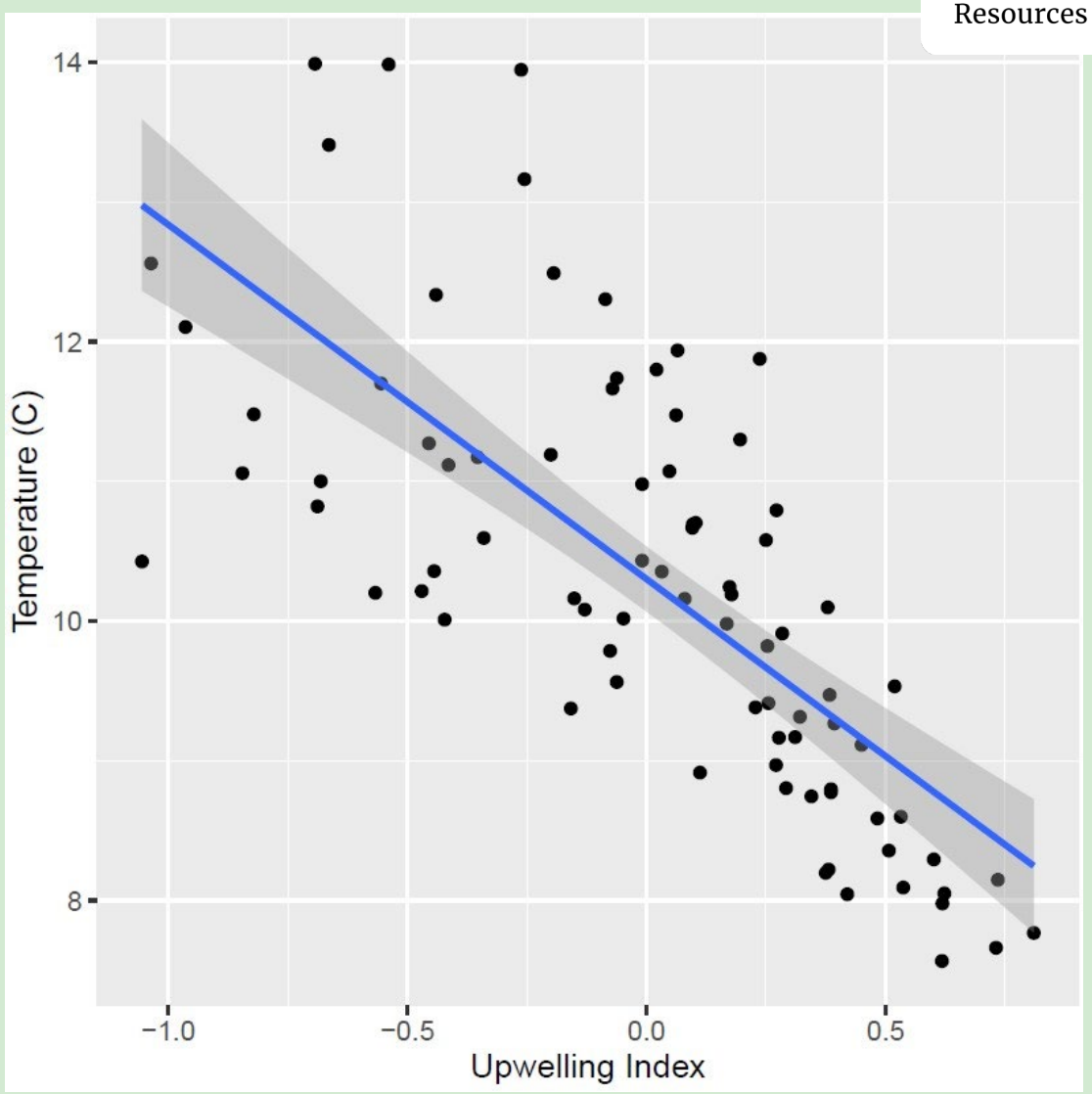
Coastal Upwelling Transport Index

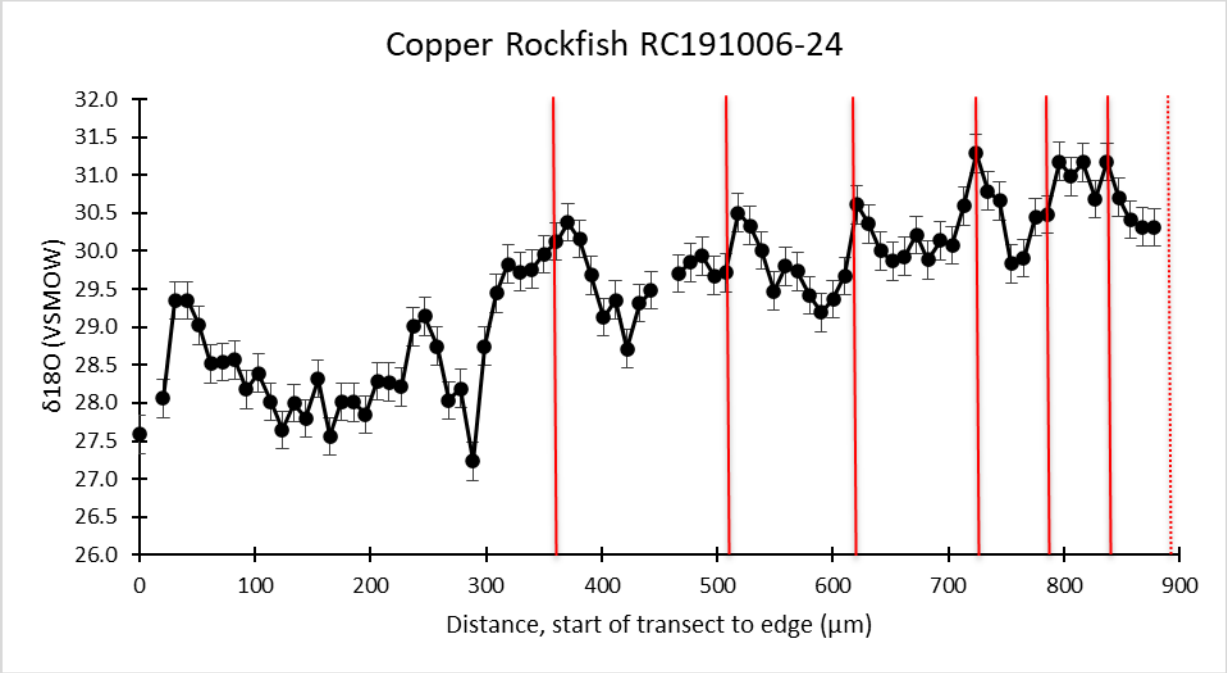




So, what's influencing the seasonal (and intra-seasonal) variation in otolith $\delta^{18}O$?

Increase in max $\delta^{18}O$ and decrease in $\delta^{18}O$ variability with age

- Infers possible ontogenetic movements from shallower to colder, deeper water with age



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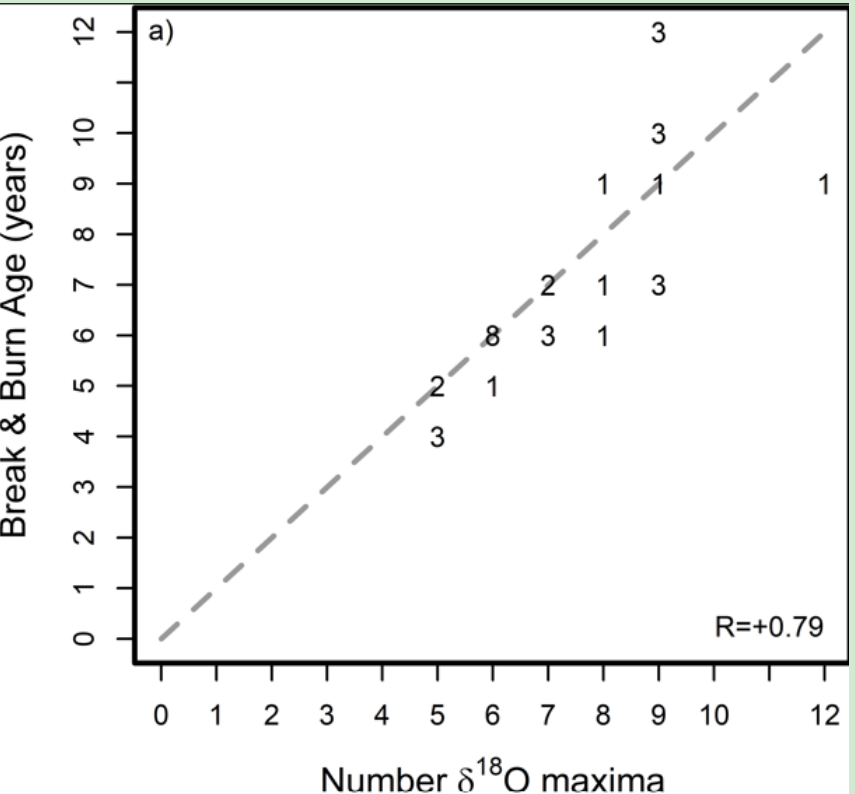
So, what's influencing the seasonal (and intra-seasonal) variation in otolith $\delta^{18}O$?

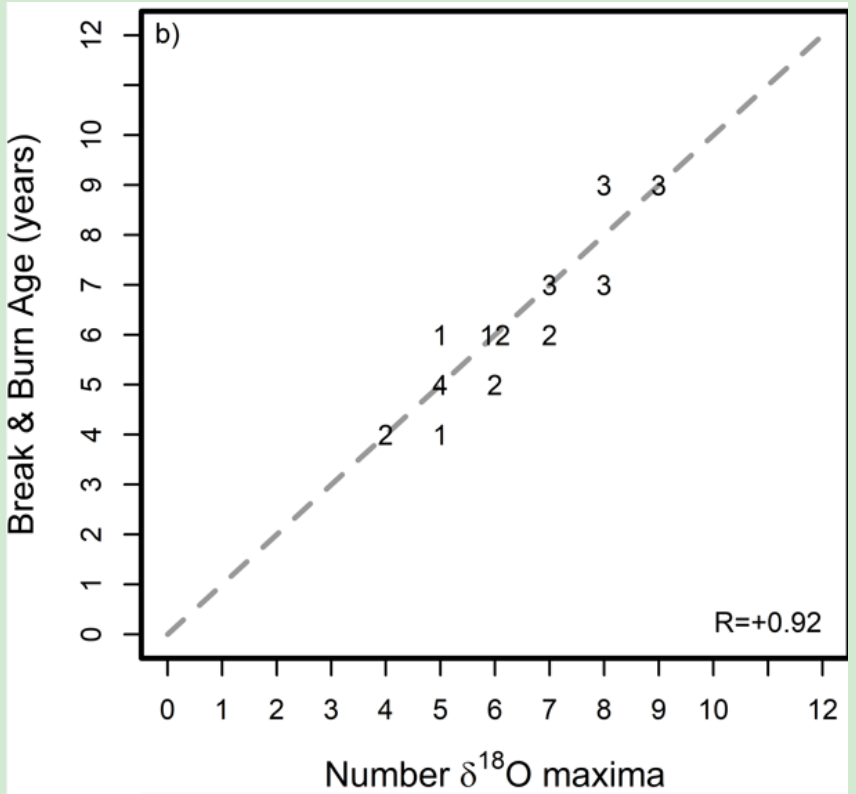
Why are Black RF "noisier" than the other species?

- Black RF are semi-pelagic and move more than the other species, both vertically and laterally

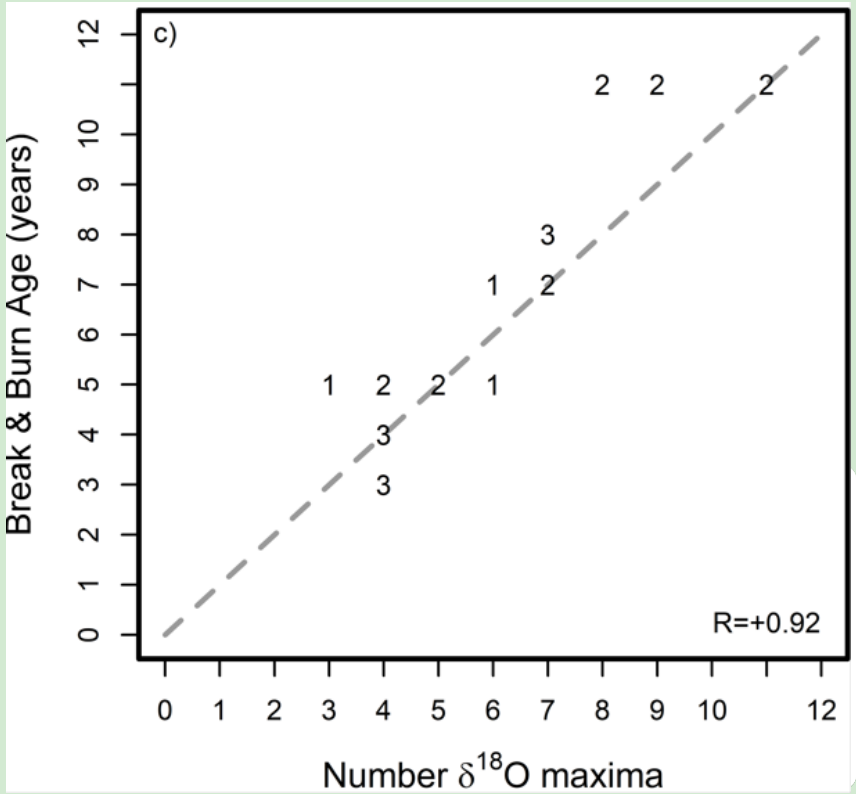
Black Rockfish



Copper Rockfish



Cabezon



Conclusions

- **SIMS was a valuable tool for validating our highly precise break-and-burn ages…up to 12 years for BRF, 9 years for CRF, and 11 years for Cabezon.**

- **Otolith $\delta^{18}O$ peaks were highly correlated with traditional break-and-burn ages.**

- **The utility of SIMS to validate annuli was complicated by intra-seasonal variation in the upwelling strength off Oregon, as well as by pre-settlement duration and ontogenetic movements offshore with age.**

- **Efforts should be made to validate ages for Oregon's important groundfish species.**

Acknowledgements

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Patrick McDonald
Betty Kamikawa

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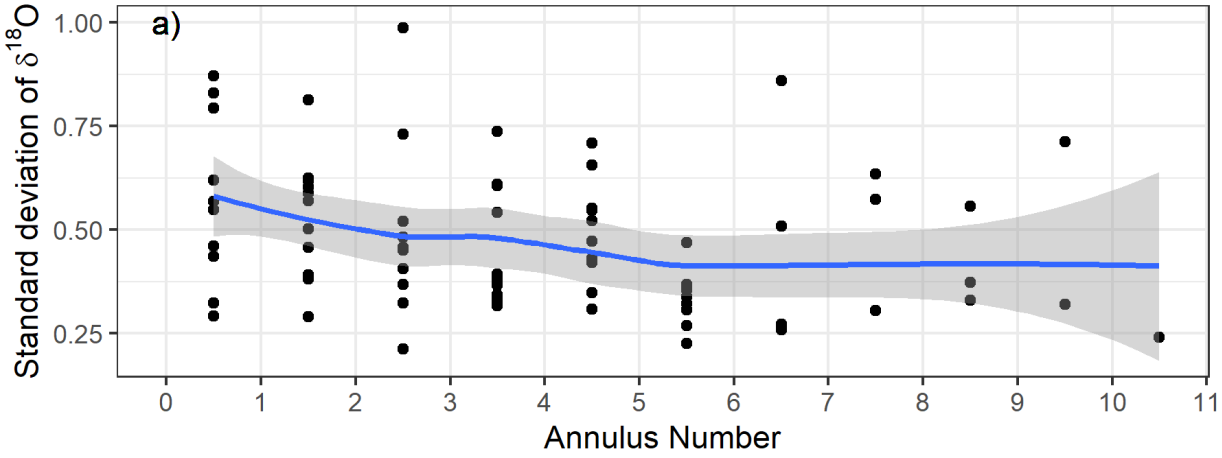

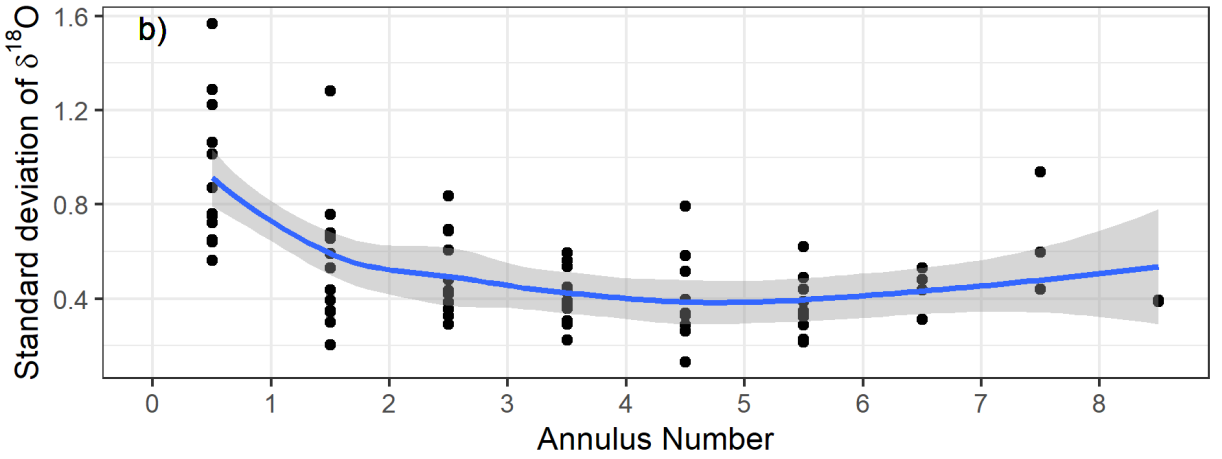

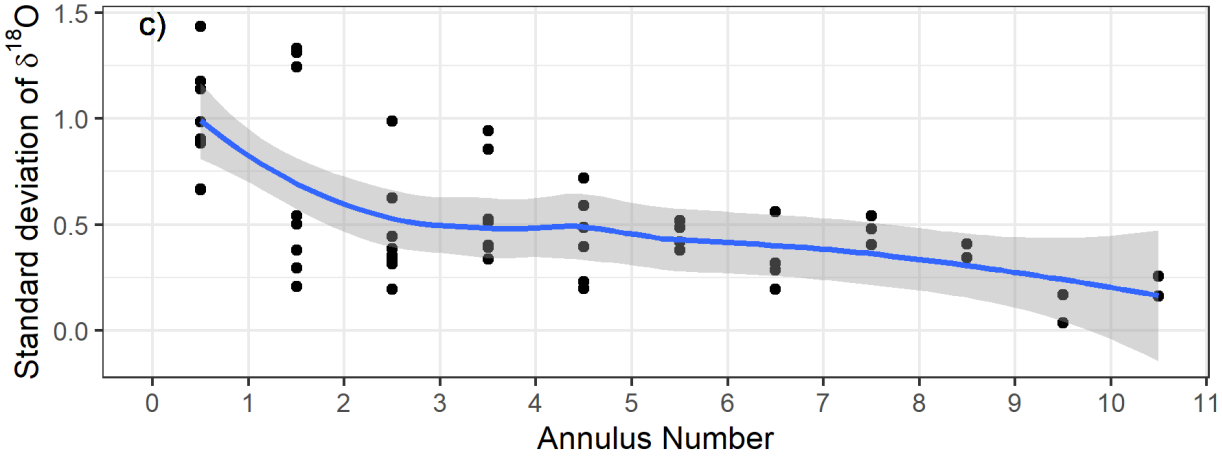

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Annual variation in otolith $\delta^{18}O$ was highest in the first year of life and decreased with age for all species

Validation: a two-step process

- **Determine increment periodicity across the age range of interest (SIMS)**

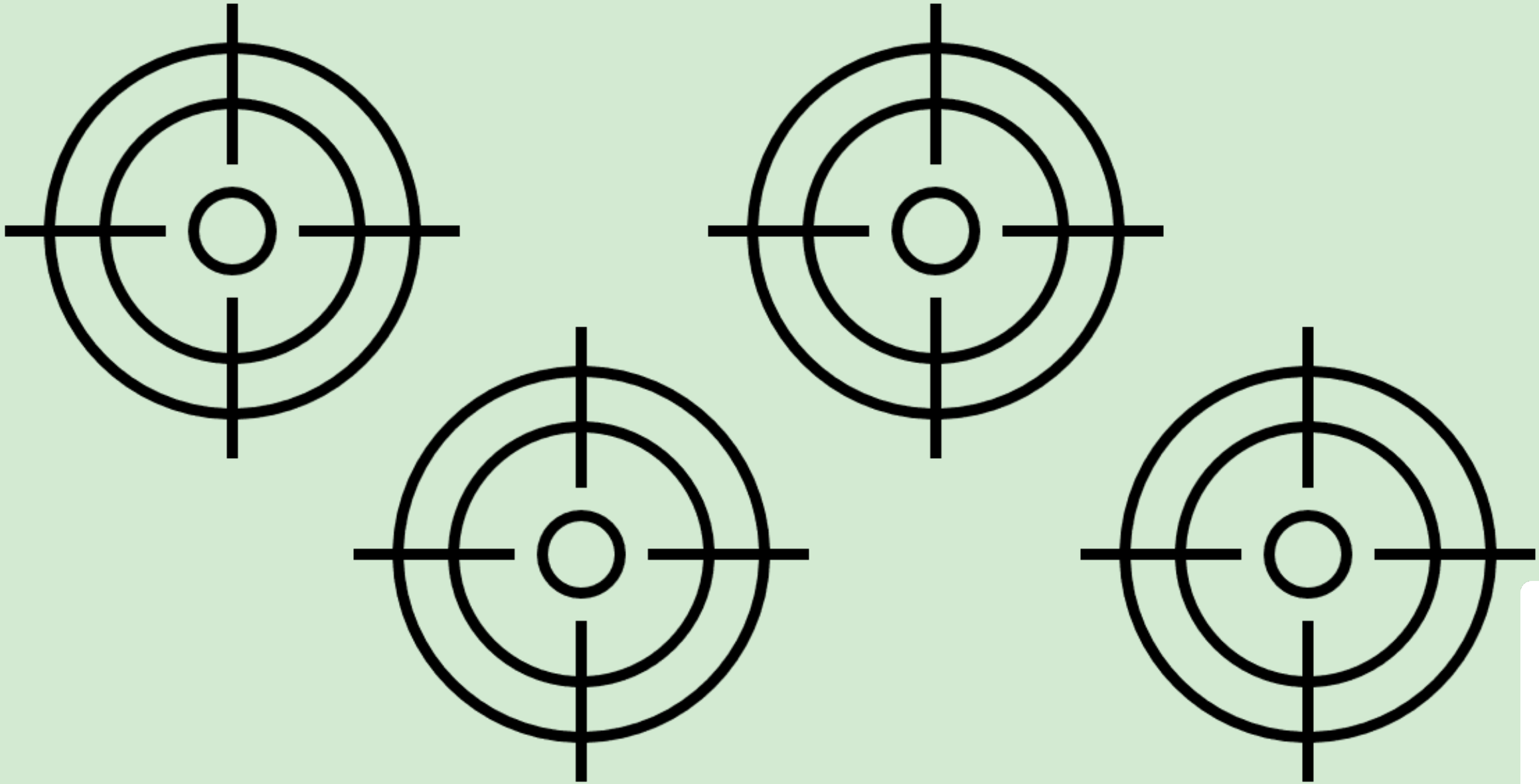
- **Determine age at first increment formation**

BRF: Otolith radius 24 YOY captured late October 2016
Otolith radius core to inner edge of first increment from 24 age-5 fish captured in 2020
⟶ No significant difference (t=-0.72, p=0.48)

CRF: 

Cab: Otolith radius from newly settled juveniles (99 days old, 350.7 µm)
Otolith diameters from previous study (1200-1500 µm)
⟶ 1st bold thick translucent zone past benchmark

Validation & Verification (Accuracy and Precision)



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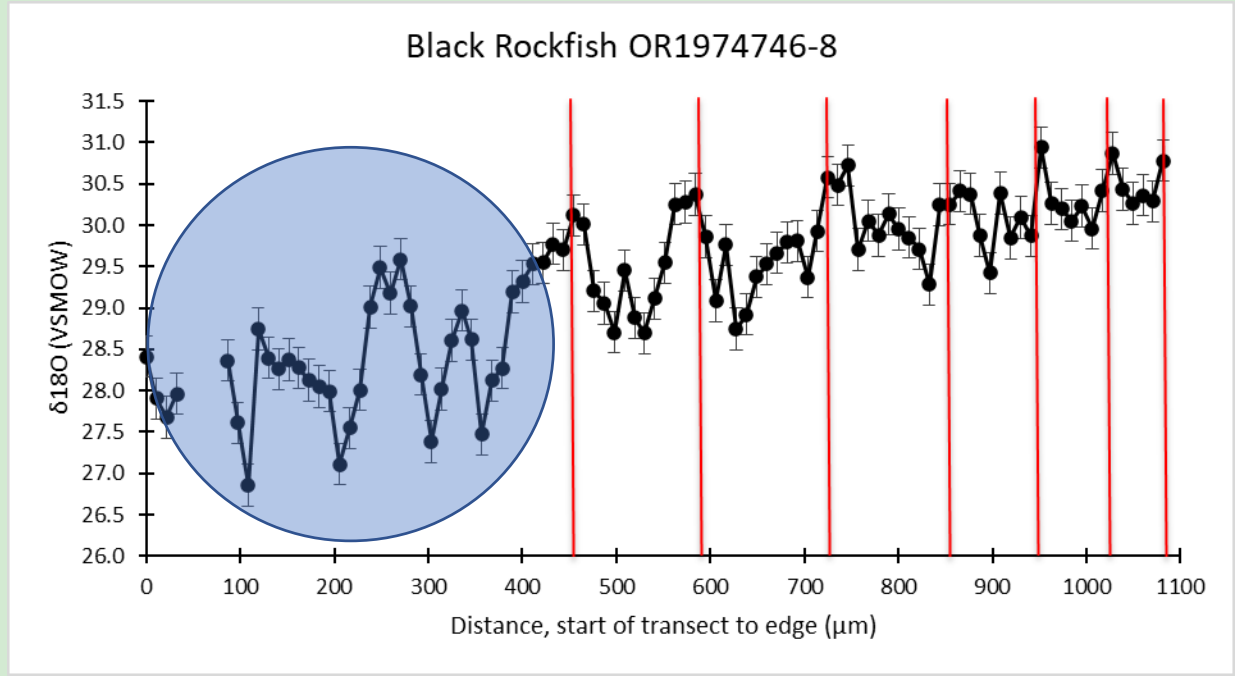
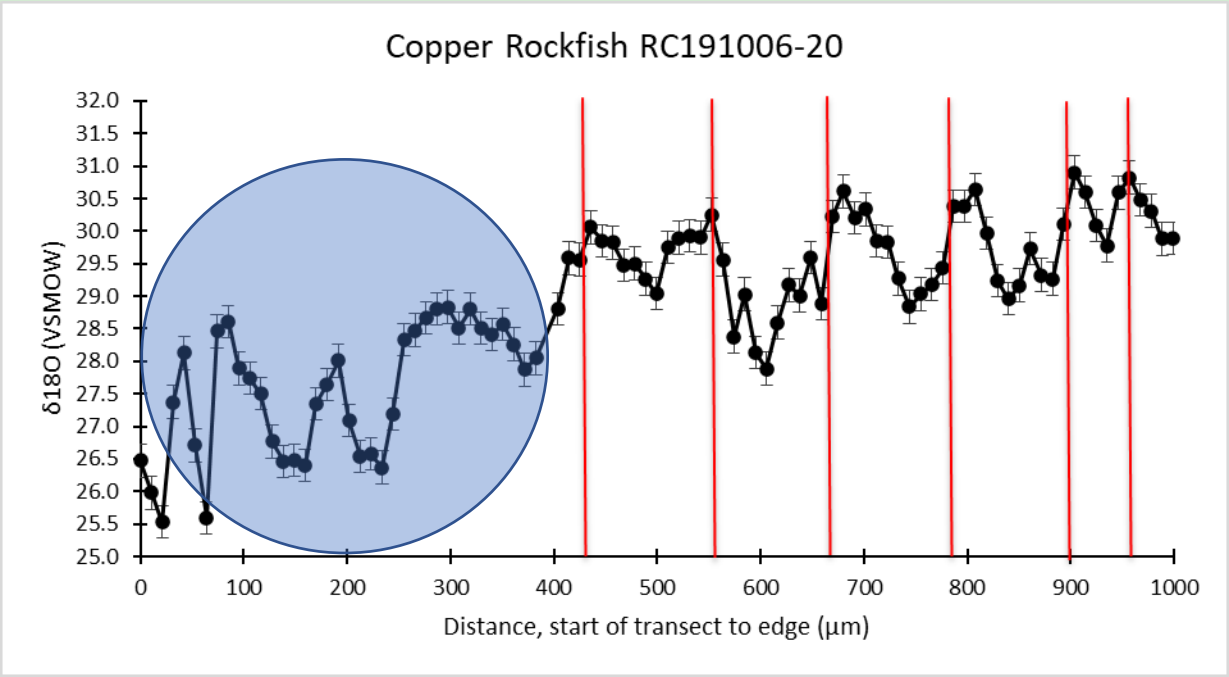
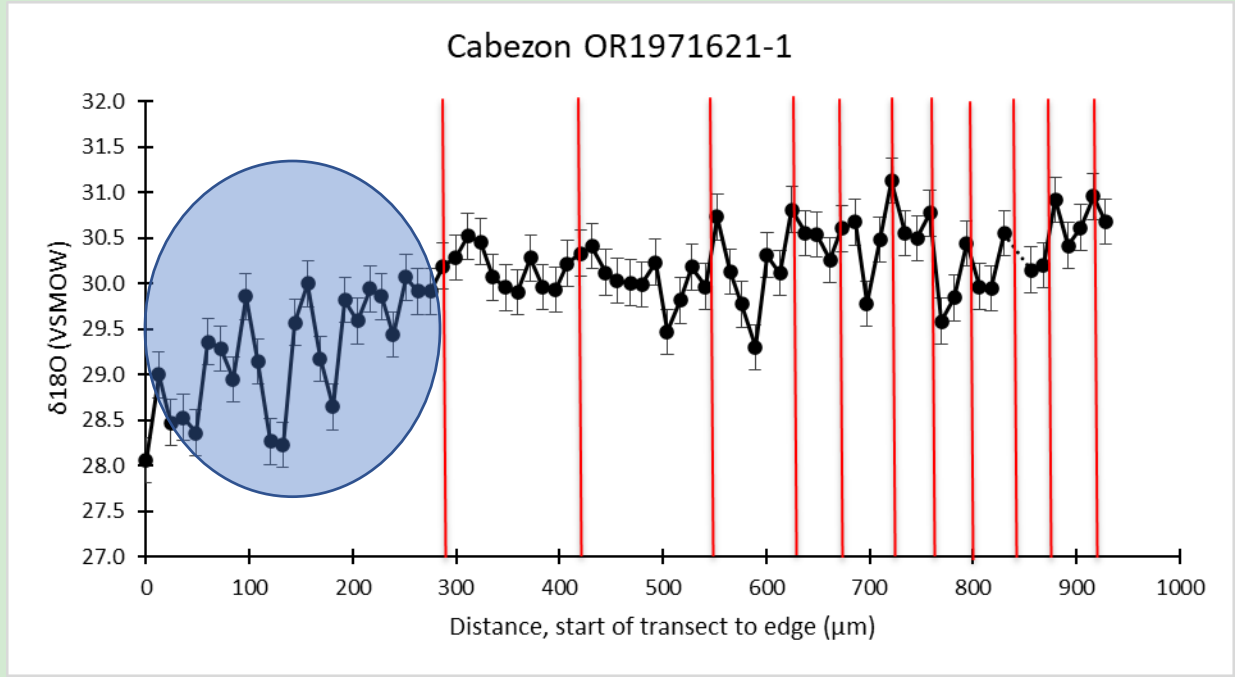
Validation: Periodicty (SIMS)
Age at 1st increment



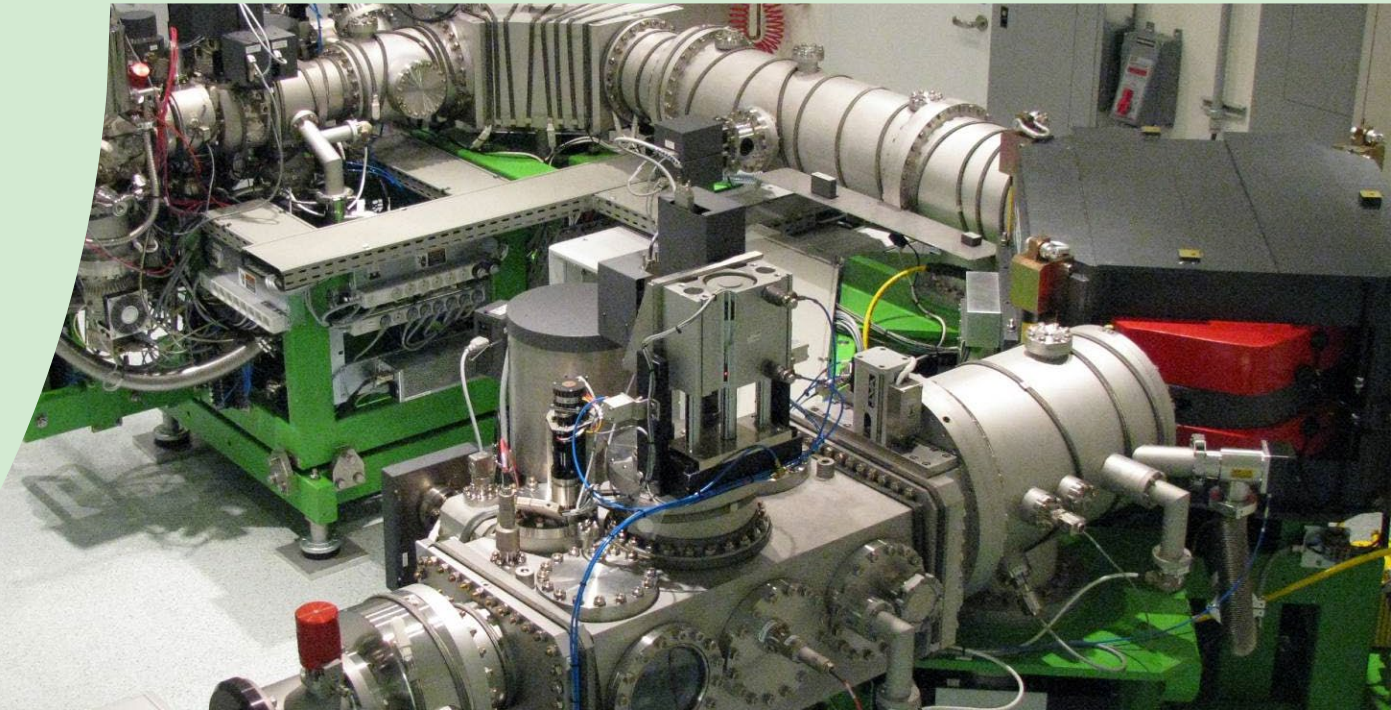




Secondary Ion Mass Spectrometry (SIMS)

- **The IMS-1280 is designed for microanalysis of light stable isotopes directly from minerals.**

- **The primary ion beam (Cs^+) excavates and ionizes atoms and molecules within the sample. These secondary ions are extracted into a mass analyzer to determine their mass/charge ratios and relative abundances.**



Age bias plots

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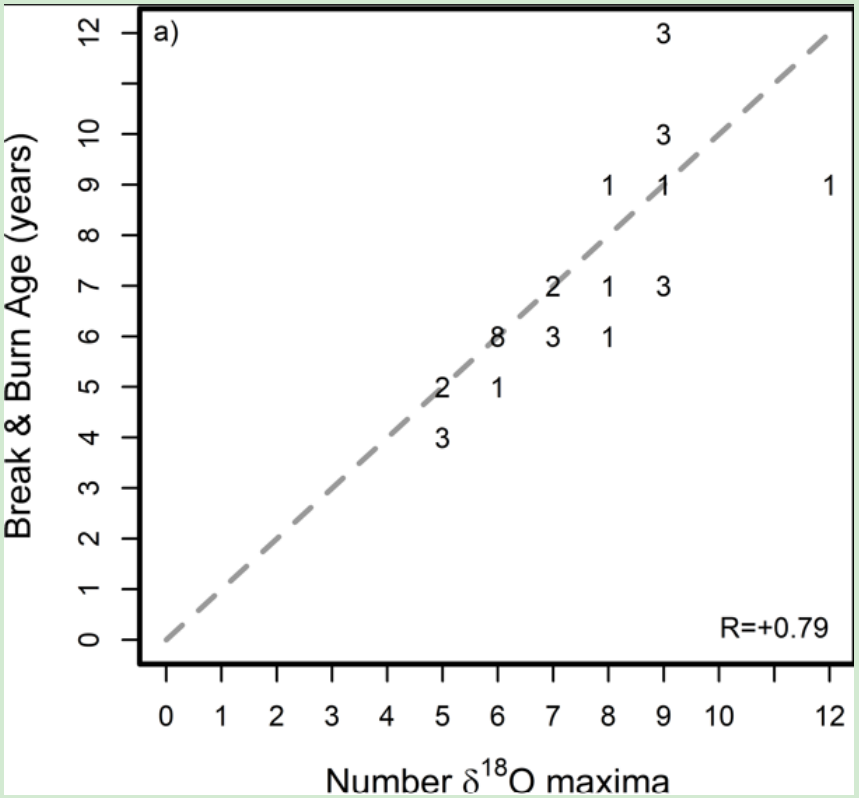
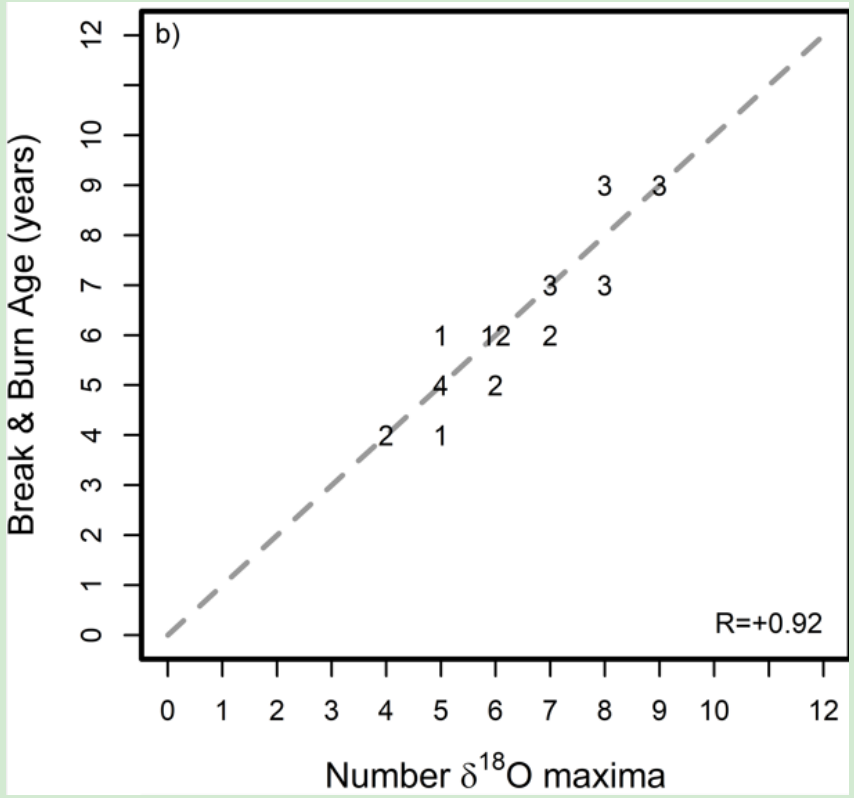
Black Rockfish



Copper Rockfish



Cabezon