Ontogenetic migration of a Bering Sea yellowfin sole revealed by otolith $\delta^{18}O$ analysis via ion microprobe

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Introduction

Yellowfin sole (*Limanda aspera*):

- Common species of eastern Bering Sea (EBS) flatfish
- Undertakes gradual ontogenetic depth migration until maturity (Fig. 1)
- Post-maturity, moves seasonally over continental shelf to spawn and feed (Fig. 2)
- Passes through discrete oceanic domains in EBS during migration

Otolith stable oxygen isotopes ratios ($\delta^{18}O$):

- Provide a biological record of a fish's environmental history
- Are a function of temperature and salinity
- Can be used to estimate temperature based on $\delta^{18}O$ of ambient seawater

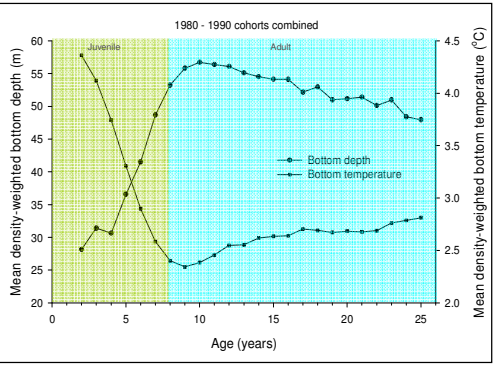


Fig 1. Ontogenetic change in occupied water temperature and depth, from summer NMFS trawl survey data.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					Spawning						
Shelf break 100-270 m depth 32-33 psu salinity				Inner shelf < 50 m 31-32 psu salinity				Shelf break 100-270 m depth 32-33 salinity			

Fig 2. Schematic showing seasonal movements of adult yellowfin sole.

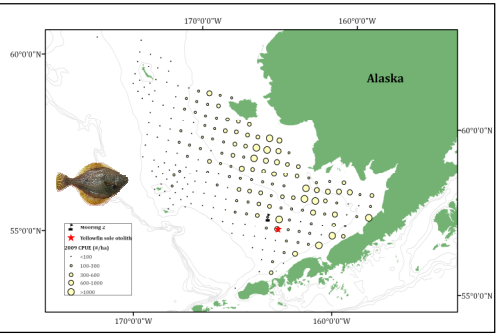


Fig 3. Summer 2009 distribution of yellowfin sole, with capture location of $\delta^{18}O$ specimen and location of M2 mooring buoy, source of surface (~10 m) and bottom (~65 m) temperature records.

Study objective: **Investigate the environmental history of an EBS yellowfin sole by conducting otolith stable oxygen isotope ($\delta^{18}O$) analysis using a high-resolution ion microprobe.**

Methods

- Otolith collected from an adult male yellowfin sole during NMFS trawl survey in June 2009 (Fig. 3)
- Values of $\delta^{18}O$ measured from 10-micron spot samples taken from otolith core to edge using an ion microprobe (Fig. 4) and reported relative to Vienna Mean Standard Ocean Water (VSMOW) standard in ‰
- Water temperatures estimated from $\delta^{18}O$ values using proxy $\delta^{18}O$-seawater values of -0.6 and -1.2‰ (based on salinity)
- Due to known ontogenetic shift in distribution (Fig. 1), juvenile phase (1981-1986) estimated temperatures compared to M2 (Fig. 3) surface temperatures. Adult phase (1987-2007) estimated temperatures compared to M2 bottom temperatures

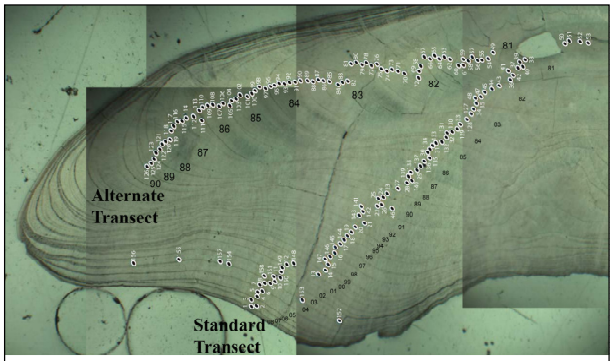


Fig 4. Yellowfin sole otolith labeled with $\delta^{18}O$ spot sample locations (white numbering) and calendar year assignments (black numbering) for standard and alternate transects.

Results

- Measured values of $\delta^{18}O$ = 28.95 to 34.11‰
- Average spot-to-spot precision of $\delta^{18}O$ analyses = ±0.3‰
- Recurring pattern of $\delta^{18}O$ values evident, presumably related to seasonal changes in water temperature (Fig. 5)
- Ontogenetic migration from shallow to deeper waters revealed by increasingly higher $\delta^{18}O$ values from age-0 until approximately age-6 (the year 1987), roughly corresponding to onset of maturity (Fig. 5)
- Temperatures predicted from otolith $\delta^{18}O$ values (based on both proxy $\delta^{18}O$-seawater values) fall within the range of observed M2 temperatures during the juvenile phase. During the adult phase, predicted temperatures are reasonable using proxy -0.6‰ and are lower than observed temperatures using proxy -1.2‰ (Fig. 6)

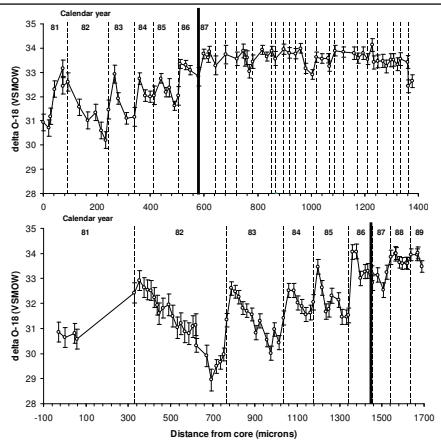
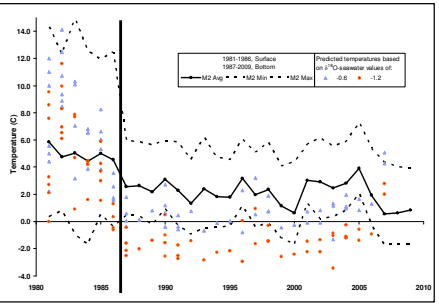


Fig 5. Measurements of $\delta^{18}O$ (in ‰ relative to VSMOW, ± 2 s.d.) from the otolith core to the edge of the standard transect and the alternate transect. Solid black line indicates assumed transition between juvenile and adult phases.

Fig 6. Annual average, minimum, and maximum instrumental (M2) temperatures, and water temperatures estimated from otolith $\delta^{18}O$ values (standard transect) based on proxy $\delta^{18}O$-seawater values of -0.6 and -1.2‰. Solid black line indicates assumed transition between juvenile and adult phases.



Preliminary conclusions

1. **Values of $\delta^{18}O$ increased from the otolith core until approximately age-6 (maturity), demonstrating ontogenetic migration.**
2. **A recurring seasonal pattern of $\delta^{18}O$ values was evident.**
3. **Water temperatures estimated from juvenile-phase otolith $\delta^{18}O$ values were reasonable based on instrumental temperatures. Adult-phase estimated temperatures were only reasonable using a more positive seawater $\delta^{18}O$ value, suggesting that adults could be in relatively saline waters (~33 psu, possibly during the winter migration) while the otolith is accreting material.**

Further investigation regarding otolith growth, $\delta^{18}O$(water), and seawater-aragonite fractionation is required before making inferences regarding absolute temperatures experienced by this yellowfin sole.

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