Antarctic toothfish otolith reference set age data from the Ross Sea, Antarctica

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Project
» CAREER: Using Otolith Chemistry to Reveal the Life History of Antarctic Toothfish in the Ross Sea, Antarctica: Testing Fisheries and Climate Change Impacts on a Top Fish Predator (Antarctic toothfish connectivity)

Contributors	Affiliation	Role
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Abstract
Estimated ages for Antarctic toothfish using otoliths prepared via the bake, grind and polish method were validated and reported on by Brooks et al. 2011. The otoliths validated in the study by Brooks et al. 2011 serve as a reference set for all aging activities in the Brooks Lab and are permanently housed at the University of Colorado Boulder. Estimated ages for the reference set collection for both viewing methods investigated (Monitor versus Direct) for the three readers in this study are defined in the dataset as HK, CG and RL. The estimated ages established in the study by Brooks et al. 2011 by Reader 1 for the 185 otoliths selected for this study were compared with the consensus image view age estimates to serve as a between-method “proxy” comparison since both studies used the same otoliths. Reference set ages by Reader 1 in the Brooks et al. 2011 study are defined in the dataset as CB Direct R12. Note digits associated with each reader/method combination in each column header, for example HK Direct R14, represents the 14th time the reference set was aged by that ager. Individual readers may have required additional reads relative to other agers, however only the last two final reads of the reference set for each ager are reported on here as they served as the basis for comparison analyses.

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Coverage

Location: Ross Sea, Antarctica

Methods & Sampling

Three trained readers aged each otolith ($n = 185$) two times for each method in random order and blinded to previous estimates. Otoliths were aged according to criteria established by Underkoffler et al. (2010): beginning at the nucleus, readers first counted annuli along the dorsal-distal axis of the transverse section until the axis growth zones became compressed, then readers moved their count path to the proximal side of the otolith section where zones were more visible (SC-CAMLR 2001; Brooks et al. 2011). For the direct view method, readers independently estimated age using a Lecia MZ95 stereomicroscope with transmitted light at 10x—60 × magnifications. For the image view, three images of each otolith (whole, dorsal and ventral views)

were captured using a Lecia S9i microscope camera with transmitted light at 20x – 55 × magnifications using LAS X Life Science Microscope Software and saved as TIFF files (2160 × 1080-pixel resolution). Readers independently estimated ages using the images on 4 k-resolution monitors.

Data Processing Description

This study compared the precision and bias between the two viewing methods across the following dimensions. (1) Between methods, which was calculated for the consensus age estimates from the two methods. Consensus ages were derived from rounding the mean of all six estimated ages of each method. (2) Within readers. (3) Between readers. Additionally, the validated age estimates of Reader 1 from Brooks et al. (2011) were compared with our study's consensus image view age estimates as a between-method 'proxy' comparison since both studies used the same otoliths. We performed the standard fish age determination analyses for estimating precision and bias across the dimensions: (1) precision indices – average coefficient of variation, CV (Chang 1982), average percent error, APE (Beamish and Fournier 1981), and percent agreement, (2) age bias plots for visual identification of systematic differences between the two methods' age estimates (Campana et al.1995), and (3) Evans-Hoenig's symmetry testing to indicate systematic bias (Evans and Hoenig 1998; McBride 2015). For the between-reader comparison, paired t-tests compared the CVs for each method among the two most precise readers and all three readers. Analyses were performed using the Fisheries Stock Assessment (FSA) package (Ogle 2018) in R Statistical Software version 4.3.3 (R Core Team 2024) with α set at 0.05 for statistical significance in all analyses.

BCO-DMO Processing Description

- Loaded CSV file "GallagherCC_etal_age_data_2025.csv" into table "gallaghercc_etal_age_data_2025"; treated empty strings and "nd" as missing values
- Renamed all 15 columns to use underscores in place of spaces: Project ID -> Project_ID, Otolith ID -> Otolith_ID, and all reader age estimate columns (e.g., HK Direct R14 -> HK_Direct_R14, CG Monitor R1 -> CG_Monitor_R1, CB Direct R12 -> CB_Direct_R12, etc.)
- Output final table to "1000914_v1_otolith_age_data.csv"

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Parameters

Parameter	Description	Units
Project_ID	Reference Set Collection ID	unitless
Otolith_ID	Unique identifier for individual otoliths	unitless
HK_Direct_R14	Age estimate (years) assigned by reader HK using the direct microscope viewing method during read 14	Years
HK_Direct_R15	Age estimate (years) assigned by reader HK using the direct microscope viewing method during read 15	Years
HK_Monitor_R1	Age estimate (years) assigned by reader HK using the monitor/image viewing method during read 1	Years

HK_Monitor_R2	Age estimate (years) assigned by reader HK using the monitor/image viewing method during read 2	Years
RL_Direct_R10	Age estimate (years) assigned by reader RL using the direct microscope viewing method during read 10	Years
RL_Direct_R11	Age estimate (years) assigned by reader RL using the direct microscope viewing method during read 11	Years
RL_Monitor_R1	Age estimate (years) assigned by reader RL using the monitor/image viewing method during read 1	Years
RL_Monitor_R2	Age estimate (years) assigned by reader RL using the monitor/image viewing method during read 2	Years
CG_Direct_R9	Age estimate (years) assigned by reader CG using the direct microscope viewing method during read 9	Years
CG_Direct_R10	Age estimate (years) assigned by reader CG using the direct microscope viewing method during read 10	Years
CG_Monitor_R1	Age estimate (years) assigned by reader CG using the monitor/image viewing method during read 1	Years
CG_Monitor_R2	Age estimate (years) assigned by reader CG using the monitor/image viewing method during read 2	Years
CB_Direct_R12	Validated age estimate (years) assigned by Reader 1 in Brooks et al. (2011) using the direct microscope viewing method during read 12; used as a reference comparison dataset	Years

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Project Information

CAREER: Using Otolith Chemistry to Reveal the Life History of Antarctic Toothfish in the Ross Sea, Antarctica: Testing Fisheries and Climate Change Impacts on a Top Fish Predator (Antarctic toothfish connectivity)

Coverage: Southern Ocean

NSF Award Abstract:

The Ross Sea, Antarctica, is one of the last large intact marine ecosystems left in the world, yet is facing increasing pressure from commercial fisheries and environmental change. It is the most productive stretch of the Southern Ocean, supporting an array of marine life, including Antarctic toothfish – the region's top fish predator. While a commercial fishery for toothfish continues to grow in the Ross Sea, fundamental knowledge

gaps remain regarding toothfish ecology and the impacts of toothfish fishing on the broader Ross Sea ecosystem. Recognizing the global value of the Ross Sea, a large (>2 million km2) marine protected area was adopted by the multi-national Commission for the Conservation of Antarctic Marine Living Resources in 2016. This research will fill a critical gap in the knowledge of Antarctic toothfish and deepen understanding of biological-physical interactions for fish ecology, while contributing to knowledge of impacts of fishing and environmental change on the Ross Sea system. This work will further provide innovative tools for studying connectivity among geographically distinct fish populations and for synthesizing and assessing the efficacy of a large-scale marine protected area. In developing an integrated research and education program in engaged scholarship, this project seeks to train the next generation of scholars to engage across the science-policy-public interface, engage with Southern Ocean stakeholders throughout the research process, and to deepen the public's appreciation of the Antarctic.

A major research priority among Ross Sea scientists is to better understand the life history of the Antarctic toothfish and test the efficacy of the Ross Sea Marine Protected Area (MPA) in protecting against the impacts of overfishing and climate change. Like growth rings of a tree, fish ear bones, called otoliths, develop annual layers of calcium carbonate that incorporates elements from their environment. Otoliths offer information on the fish's growth and the surrounding ocean conditions. Hypothesizing that much of the Antarctic toothfish life cycle is structured by ocean circulation, this research employs a multi-disciplinary approach combining age and growth work with otolith chemistry testing, while also utilizing GIS mapping. The project will measure life history parameters as well as trace elements and stable isotopes in otoliths in three distinct sets collected over the last four decades in the Ross Sea. The information will be used to quantify the transport pathways Antarctic toothfish use across their life history, and across time, in the Ross Sea. The project will assess if toothfish populations from the Ross Sea are connected more widely across the Antarctic. By comparing life history and otolith chemistry data across time, the researchers will assess change in life history parameters and spatial dynamics and seek to infer if these changes are driven by fishing or climate change. Spatially mapping of these data will allow an assessment of the efficacy of the Ross Sea MPA in protecting toothfish and where further protections might be needed.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
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