Age and growth of Antarctic toothfish (*Dissostichus mawsoni*) in the Amundsen and Bellingshausen Seas

Ivory Carpenter[1,2], Hayley Kwasniewski[1,2], Rose Leeger[1,2], Ashley McKenzie[1,2], Illia Slypko[3], Cassandra Brooks[1,2]

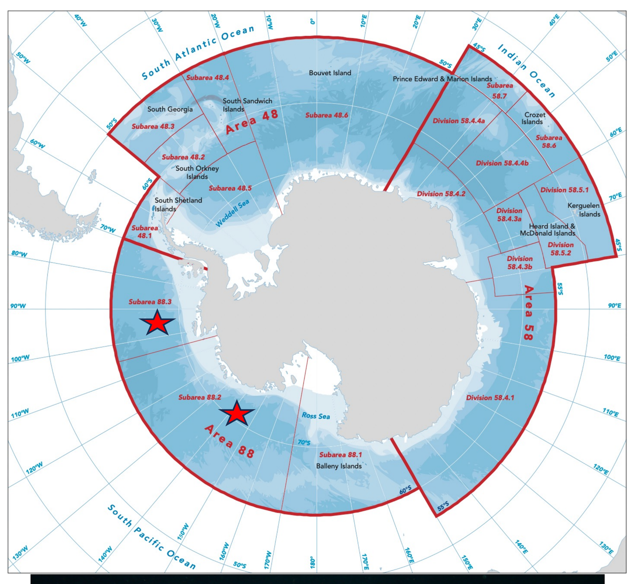
[1]Department of Environmental Studies, University of Colorado Boulder, Boulder, USA; [2]Institute of Arctic and Alpine Research, Boulder, USA; [3]Division of Antarctic Marine Living Resources, Institute of Fisheries and Marine Ecology of the State Agency of Melioration and Fisheries of Ukraine, Kyiv, Ukraine

Introduction

Antarctic toothfish (*Dissostichus mawsoni*) have a circumpolar distribution around the Antarctic continent.[1] These fish are long-lived (aged up to 39 years) and are essential to Antarctic ecosystems as apex predators.[2,3] Antarctic toothfish are highly sought after in commercial fisheries and sold as "Chilean seabass".[4] The Ross Sea fishery began in 1997,[1] and fishing for toothfish has continued to expand, including into the Amundsen and Bellingshausen Seas (CCAMLR subareas 88.2 and 88.3; see Figure 1).[5,6] Fisheries are managed under a precautionary approach by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Life history characteristics of toothfish such as their late maturity, slow growth, low fecundity, and moderately high longevity cause these fish to be vulnerable to overfishing.[3,7] Accurate life history information of Antarctic toothfish, such as age and growth parameters, is pivotal to sustainable fisheries management, and inaccuracy in toothfish aging can lead to failure in understanding population dynamics.[1]

Research suggests that the Amundsen Sea may be an important region for toothfish life history as there is evidence of ontogenetic movements between the Amundsen Sea and Ross Sea.[8] However, very little is known about life history of toothfish in the Amundsen and Bellingshausen Sea regions.[5,6] As commercial fisheries expand into these regions, it becomes increasingly critical to research age and growth parameters of Antarctic toothfish in the Amundsen and Bellingshausen Sea regions to ensure successful fisheries management and conservation efforts.



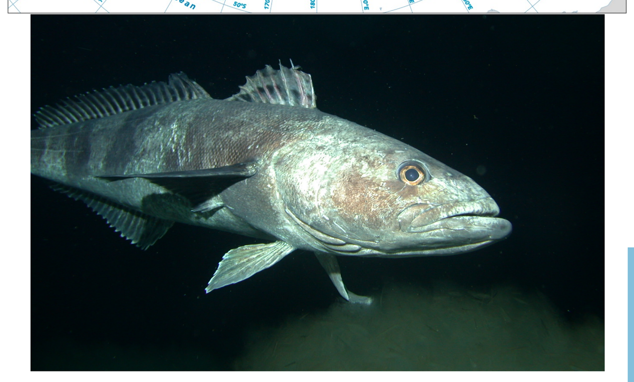


Figure 1 (top): Map of the CCAMLR subareas. Image by CCAMLR. Figure 2 (bottom): An Antarctic toothfish. Image by Paul A. Cziko.

Research question:

What are the age and growth parameters of Antarctic toothfish in the Amundsen and Bellingshausen Sea regions (CCAMLR subareas 88.2 and 88.3)?

Methods

One tool commonly used to decipher the life history of fish species are otoliths, a calcium carbonate "ear stone" that, like tree trunk rings, have deposited annual layers. The ages of toothfish can be estimated using the transverse cross-sections of toothfish otolith samples.[9] Brooks et al. validated this method using lead-radium dating.[4]

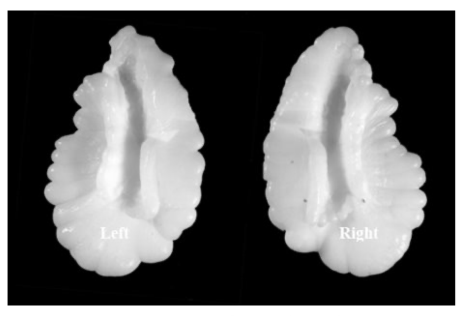


Figure 3: Left and Right otoliths.

1. Toothfish otoliths were collected by fisheries observers.
2. Otoliths were randomly assigned "left" or "right" (see Figure 3).
3. Otoliths were weighed and baked for approximately 4 minutes.
4. Otoliths were grinded down and polished to mount onto microscope slides and reveal aging plane (see Figure 5).
5. Mounted otoliths were placed under black light for one hour or more (see Figure 7).
6. Mounted otoliths were grinded down and polished to reveal the primordium (see Figure 4) and translucent and opaque zones.
7. The polished sections of otoliths were sealed using Flo-Texx.
8. Otoliths were imaged with a desktop imaging software.
9. The images were randomized.
10. Otoliths were aged on a 4K desktop monitor.
11. The reader identified the correct count path and the alternating opaque and translucent growth zones (see Figure 8). The opaque zones were counted to estimate age.
12. Age data was used for analysis; von Bertalanffy growth function was applied, and growth parameters estimated.

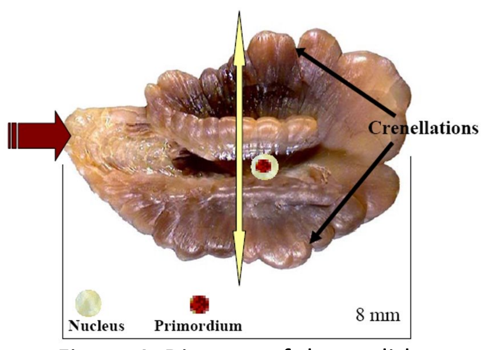


Figure 4: Diagram of the otolith primordium and nucleus.

Figure 5: Diagram of mounted otolith post-grinding.

Figure 6: Ivory posing with otolith image.

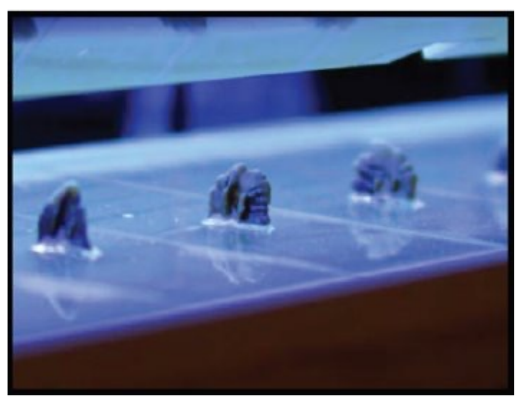


Figure 7: Mounted otoliths beneath black light.

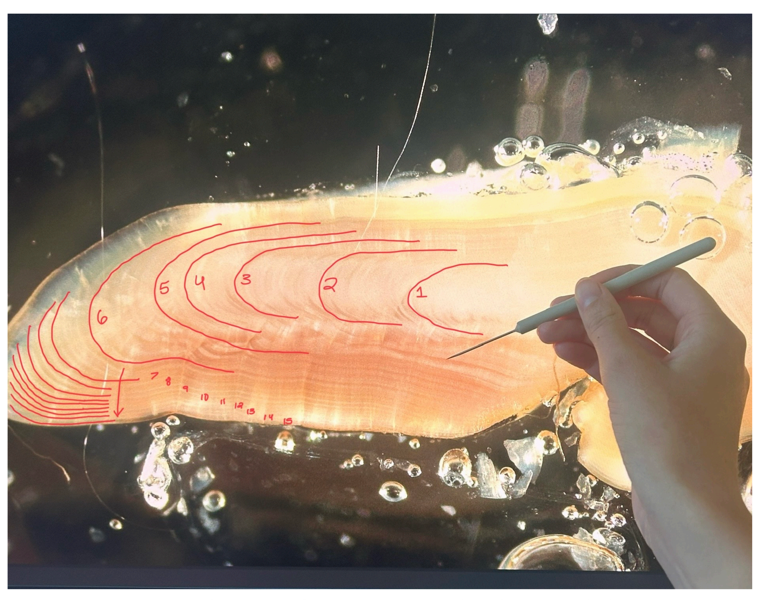


Figure 8: Ivory's identified count path of an otolith image on a 4K desktop monitor. Otolith is estimated to be aged about 15 years.

Reader Age Verification and Training

Before ageing can begin, a reader must first undergo an otolith ageing training method on an age-validated reference set of 200 otoliths. The reader aged the reference set approximately 12 times until the CV and APE were meeting aging precision criteria (CV = <7.5% and APE = <5%). The CV after 12 reads on the reference set was 6.57%, and the APE was 4.65%.

Preliminary Results & Discussion

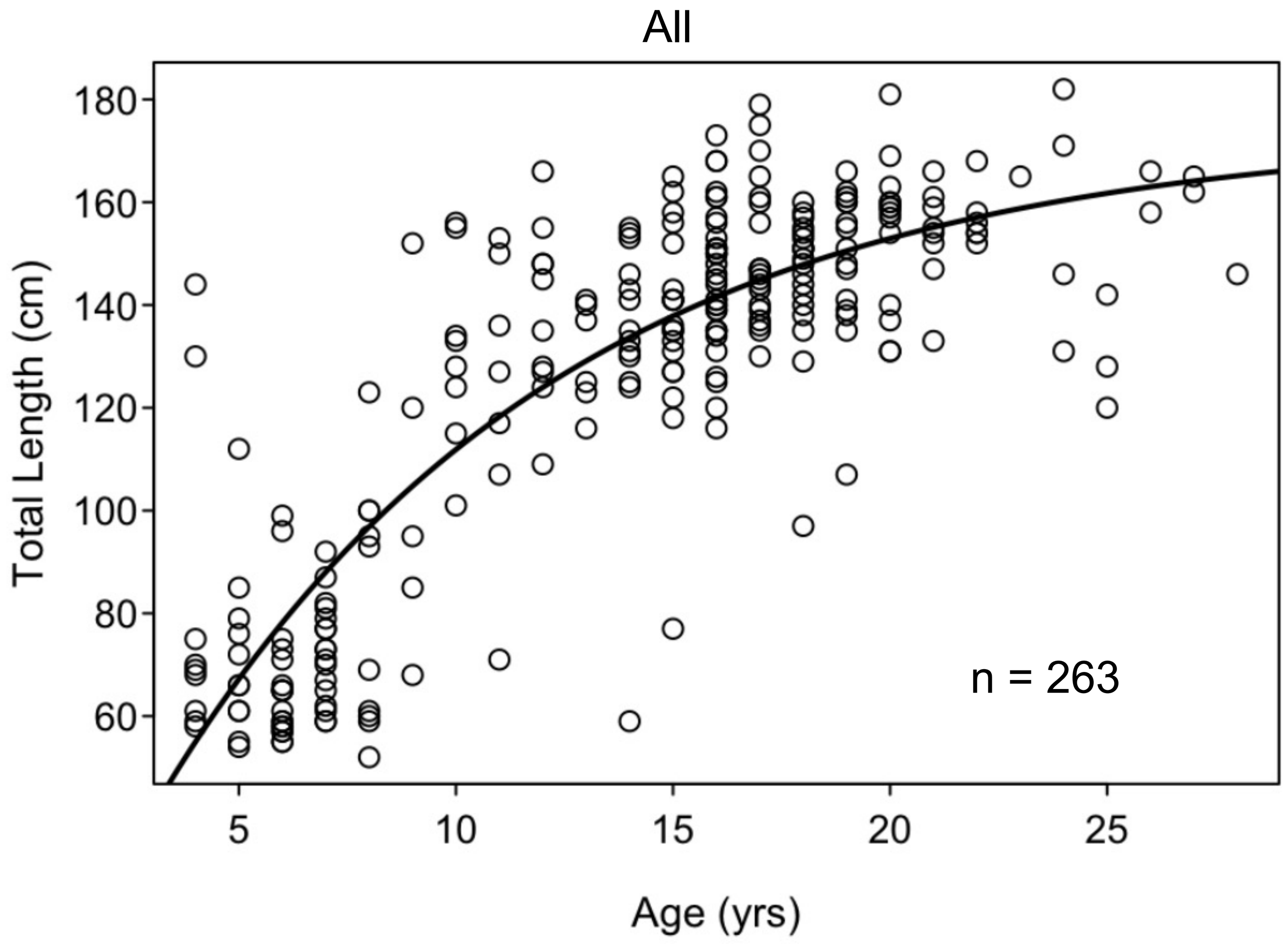


Figure 9: von Bertalanffy growth curve based on age-length data for the entire subarea 88.3 population.

	n	L∞ (cm)	k	t_0
This Study				
All	263	173.9 (162.5-192.2)	0.108 (0.079-0.140)	0.492 (-0.877-1.482)
Male	110	173.3 (152.4-234.3)	0.096 (0.044-0.155)	-0.865 (-4.726-1.126)
Female	149	170.3 (159.6-187.3)	0.129 (0.092-0.170)	1.593 (0.251-2.524)
Brooks et al. 2011				
All	1,508	158.9 (151.5–166.3)	0.111 (0.091–0.130)	-0.605 (-1.511-0.301)
Male	670	149.7 (141.0–158.5)	0.124 (0.094–0.154)	-0.605 (-1.830-0.620)
Female	841	162.3 (151.9–172.7)	0.111 (0.085–0.134)	-0.278 (-1.491-0.935)

Table 1: A comparison of the von Bertalanffy growth function parameters from this study (Antarctic toothfish in subarea 88.3, Bellingshausen Sea Region) vs. the parameters from the Brooks et al. 2011 study (Antarctic toothfish in the Ross Sea) with 95% confidence intervals

Here we provide preliminary results for the Bellingshausen Sea (88.3) with Amundsen Sea (88.2) results forthcoming. These results show growth rates (k) similar to Brooks et al., however fish from 88.3 appear to be overall much larger (L-inf) (see Table 1). Longline fishing targets the biggest (and oldest) individuals in a population and over time can lead to age truncation (where individuals become smaller and younger over time). Thus, the larger fish in 88.3 likely represent a newly exploited population, whereas the population in the Ross Sea has been fished for many years. These observed differences could also potentially be a result of distinctions in environmental factors or physical characteristics, variation in population feeding ecology, temporal or spatial aspects, or other unknown factors.[2,3,8]

The results of this study and future work can help to fill critical knowledge gaps that currently exist for life history of Antarctic toothfish in the Bellingshausen and Amundsen Sea regions and can further inform future sustainable fisheries management strategies for these areas. These results may also provide insight into areas important for toothfish life history for consideration for future Marine Protected Area planning by CCAMLR. There is currently an MPA proposal that encompasses part of the Bellingshausen Sea but not the Amundsen Sea.

References

1. Hanchet, S., Dunn, A., Parker, S., Horn, P., Stevens, D., & Mormede, S. (2015). The Antarctic toothfish (*Dissostichus mawsoni*): biology, ecology, and life history in the Ross Sea region. *Hydrobiologia 761*, 397-414.
2. Ashford, J., Dinniman, M., Brooks, C., Andrews, A., Hofmann, E., Cailliet, G., Jones, C., & Ramanna, N. (2012). Does large-scale ocean circulation structure life history connectivity in Antarctic Toothfish (*Dissostichus mawsoni*)? *Canadian Journal of Fisheries and Aquatic Sciences 69*(12).
3. Seong, G., Chung, S., Kim, D., Kang, D., Jin, S., & Baeck, G. (2023). Feeding ecology of Antarctic toothfish, *Dissostichus mawsoni* in the subarea 88.3 (Bellingshausen Sea and eastern Amundsen Sea) of the Southern Ocean. *Frontiers in Marine Science 10.*
4. Brooks, C., Andrews, A., Ashford, J., Ramanna, N., Jones, C., Lundstrom, C., & Cailliet, G. (2011). Age estimation and lead-radium dating of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. *Polar Biology 34*.
5. CCAMLR. (2024). *Fishery report 2023: Dissostichus mawsoni in Subarea 88.3.* CCAMLR.
6. CCAMLR. (2024). *Fishery report 2023: Dissostichus mawsoni in Subarea 88.2.* CCAMLR.
7. CCAMLR. (2024). *Species description 2023: Dissostichus mawsoni.* CCAMLR.
8. Zhao, Z., Slypko, I., Demianenko, K., & Zhu, G. (2024). Otolith chemistry reveals movement of the Antarctic toothfish (Dissostichus mawsoni) in the Amundsen Sea polynya, Antarctica. *Fisheries Research 276*.
9. Underkoffler, K., Ramanna, N., & Ashford, J. (2010). *Estimating the age of Patagonian toothfish (Dissostichus eleginoides) using transverse cross-sections of otoliths.* Southern Ocean Living Resources Laboratory, Center for Quantitative Fisheries Ecology, Old Dominion University.

Acknowledgements

This research was funded by the NSF, the Undergraduate Research Opportunity Fund and the Patricia Sheffels & Department of Environmental Studies Undergraduate Research Fund from the University of Colorado Boulder. Research samples in this study were provided by Illia Slypko. Thanks to Dr. Cassandra Brooks for allowing me to conduct this research in her lab and to Ashley McKenzie for helping me calculate the age and growth parameters, and Hayley Kwasniewski and Rose Leeger for their support.

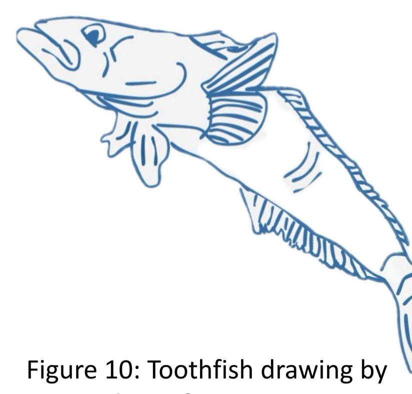


Figure 10: Toothfish drawing by Ivory Carpenter.

Contact Information: ivory.carpenter@colorado.edu Official Toothfish Instagram: @antarctic.toothfish