DETERMINING AGE-READER PRECISION AND BIAS WHEN AGING *ARCTICA ISLANDICA*, THE OLDEST-LIVING BIVALVE ON EARTH

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BACKGROUND

- *Arctica islandica* are long-lived, boreal bivalves
- Lifespans in northern latitudes can exceed 500 years of age and Mid-Atlantic populations can exceed 200 years of age
- *A. islandica* are difficult to age due to a scarcity in validated age samples for training and low-precision between age readers due to the large number of annuli to count
- Determination of age frequencies used in fisheries management require the ages of many animals, but how do you age a 200-year-old animal accurately and precisely?

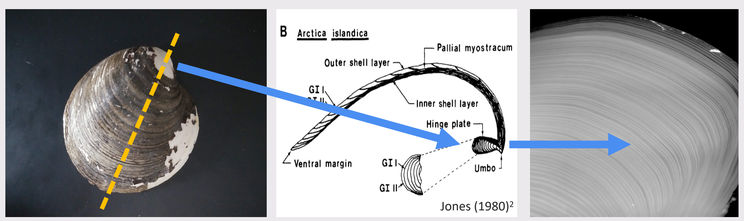
OBJECTIVES

To determine error inherent in *A. islandica* age estimates using a first and second age reader by:

- Identifying acceptable precision and bias thresholds
- Evaluating the application of these thresholds to a real, and extensive, dataset from Georges Bank, USA

DATA COLLECTION

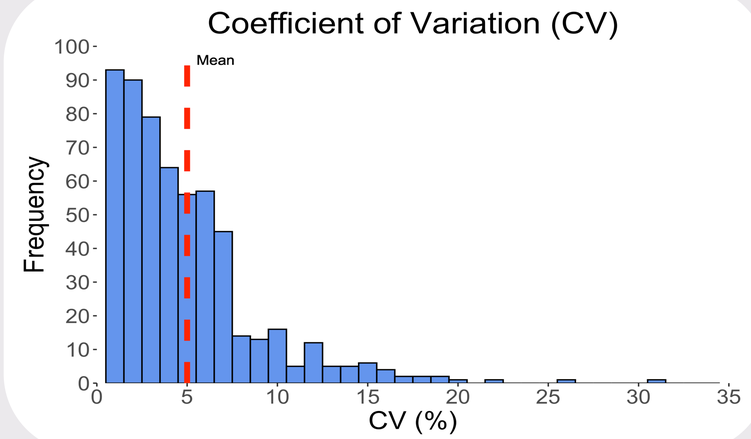
- 608 *A. islandica* clams were harvested from Georges Bank in 2017 and processed for age estimates and error analysis
- Animals were sexed and length measurements taken
- Shells were cut from the shell origin to the ventral margin
- The cut surface was polished to a mirror finish
- High-resolution images of the polished hinge were taken and stitched together using Olympus cellSens software[1]
- Aging methods were determined by carbon dating 15 of the oldest animals in our Mid-Atlantic dataset and age techniques were accepted if ages fit within the error of the C-14 results



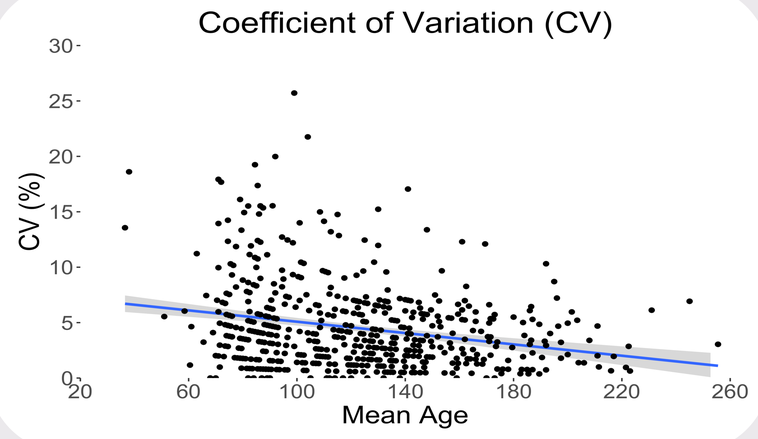
PRECISION

$$CV\% = \left(\frac{sd}{\bar{x}}\right) * 100 = \left(\frac{\sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}}{\bar{x}}\right) * 100$$

AVERAGE COEFFICIENT OF VARIATION (ACV) < 7%



ACCEPTABLE PRECISION ERROR RATE = 10%



1 Age studies in marine fisheries often employ age estimates with an ACV less than 7% [3]. This threshold was also chosen for *A. islandica* to mirror methods used by federal and state resource managers. Georges Bank had an ACV of 5% (red dashed line), therefore **Georges Bank precision was high and met ACV precision thresholds**. If the error rate threshold is exceeded (see right), samples with the highest CV are aged by consensus until error rate is less than 10%.

2 Error is defined here as samples with a dual-reader CV greater than 10%. Age estimates are accepted by the primary age reader if the error rate (i.e., occurrence of error) is less than 10% (probability = 0.1) using a binomial test. **Georges Bank (n=609) met the conditions of a 10% error rate** where only 53 samples had CVs greater than 10% (p=0.14). The blue regression line (95% confidence shading) depicts a declining CV with mean age.

BIAS

- If precision is low, tests of symmetry can help identify if/where mis-aging is occurring between two age readers
- There are two well-supported tests of symmetry [4]:

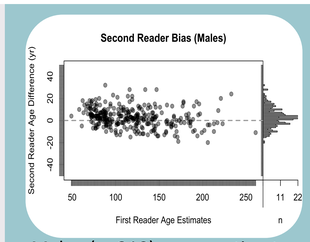
1. Bowker Test

$$\chi^2 = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{\left(n_{ij} - n_{ji}\right)^2}{n_{ij} + n_{ji}}$$

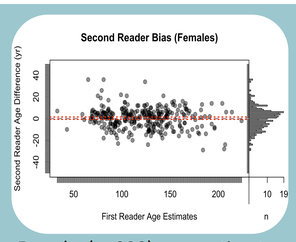
2. Evans-Hoenig Test

$$\chi^2 = \sum_{p=1}^{m-1} \frac{\left(\sum_{j=1}^{m-p}\left(n_{p+j,j} - n_{j,p+j}\right)\right)^2}{\sum_{j=1}^{m-p}\left(n_{p+j,j} + n_{j,p+j}\right)}$$

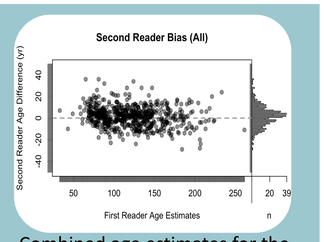
where p = j - i



Male (n=310) age estimates exhibit a bias only for the Evans-Hoenig's test (p=0.02). The Bowker's test was non-significant.



Female (n=298) age estimates have no significant bias when evaluated by the two tests for symmetry. Red-dashed lines indicate 95% agreement.



Combined age estimates for the entire error sample (n=608) exhibit a bias only for the Evans-Hoenig's test (p=0.02). The Bowker's test was non-significant.

More analyses need to be conducted to identify the ideal test of symmetry for extremely long-lived species (with many samples) where little to no validated age datasets exist.

References

[1] Pace SM, Powell EN, Mann R, Long MC, Klinck JM. 2017. Development of an Age—Frequency Distribution for Ocean Quahogs (Arctica islandica) on Georges Bank. J. Shellfish Res. 36:41–53.

[2] Jones D. 1980. Annual Cycle of Shell Growth Increment Formation in Two Continental Shelf Bivalves and its Paleoecologic Significance. Palaios, 6(3), 331–340.

[3] Campana S. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. 59:197–242.

[4] McBride RS. 2015. Diagnosis of paired age agreement: a simulation of accuracy and precision effects. ICES J. Mar. Sci. 72:2149–2167.

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