Proposal for Methodology Review of Suitability of Fish Age Estimates Developed Using Fourier Transformed Near-Infrared Spectroscopy for Inclusion in Groundfish Stock Assessments

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Background and Purpose

Modern age-structured stock assessments rely on data from biological sampling to characterize fishery and survey catch. Individual fish-length data represent the most commonly and easily collected biological information. However, the informational content of length data is limited, for many groundfish, as growth typically slows dramatically while fish are relatively young. Age data provide vital information for model estimates of recruitment strength and variability, which are critical for understanding population dynamics and accurately identifying abundance trends and forecasting near-term harvest guidance. Additionally, age data play a vital role in enabling research to discern environmental drivers of recruitment success and growth.

Despite their importance, the resources available to support age reading have not kept pace with the collection of ageing structures (primarily otoliths) for species that have been assessed using age data. Since the mid-2000s, the number of species with age-based assessments has increased from ~20 to 35, and the number of modeled areas in these assessments has increased from 25 to 46. In contrast, the Pacific States Marine Fisheries Commission's ageing lab in Newport, that is funded by the NW Fisheries Science Center, was staffed with 1-2 fewer age readers from 2015 to 2022 than during 2012-14. The consequence is that, with over 1 million structures age structures collected as part of fishery or NMFS survey sampling since 2001 for species with age-based assessments, more than half of those (in both categories) were unaged as of 2022.

In response to the need to identify faster ways of ageing fish, staff from the NW Fisheries Science Center and the Ageing Lab we support via Pacific States Marine Fisheries Commission in Newport, have been actively engaged in the Agency's Strategic Initiative (SI) to evaluate the use of Fourier Transformed Near-Infrared Spectroscopy (FT-NIRS) as a means of estimating fish ages more rapidly than can be done by manually reading the number of otolith rings (annuli). This exploration involves spectral scanning of otoliths and estimating non-linear relationships between the spectral data and traditionally-determined fish ages, and potentially other biometric data. This technology may be able to dramatically reduce production age-reading times. For most species, traditional otolith reading can produce 45-65 ages per day, depending on the species' difficulty and the reader. That many otoliths can be scanned in an hour with FT-NIRS, however considerable testing is still required to assess the approach's ability to replicate reference ages and evaluate the stability of estimated relationships across such factors as sample year, otolith age, storage medium, fish sex, and geographic area. FT-NIRS will not replace all traditional age reading, but could eventually greatly reduce the reliance on that approach for assessment ageing.

Research in other Science Centers has already identified useful estimated relationships for some species that are robust to many of these potential axes of variability, although our own work on west coast groundfish has been slowed by pandemic-era restrictions and by a recent equipment failure. However, a new spectrometer will arrive in September and we think there is a reasonable chance of being able to identify a limited number of groundfish species that are high priorities for assessment in 2025-27, for which we will be able to document acceptable FT-NIRS performance (and summarize positive FT-NIRS results of interest from other regions) for SSC review in the May-July timeframe in 2024.

Methods

For FT-NIRS to provide a reliable alternative to traditional ageing, transformation of otolith spectral data must be capable of replicating, within acceptable error bounds, ages developed via traditional ageing. There must either be a consistent relationship between changes in the microchemistry of ageing structures and traditional age reads, or the dimensions of variability must be well understood, so that separate equations for transforming spectral data into age estimates can be developed for each metadata stratum where that transformational relationship is different. For instance, the relationship between age and otolith microchemistry might differ by area or over time, or between males and females. Testing for stability in the transformational equations across possible dimensions of variability is essential for establishing how production ageing would be conducted. Accordingly, we will explore and document the variability in estimated relationships between traditional age reads and spectral data across major categorical dimensions.

Modeling and evaluation will rely on selecting subsamples of available otoliths within strata, and fitting conventionally-determined ages to spectral data, using non-linear methods. The resulting equations will then be used to estimate ages for out-of-sample fish within each stratum, with calculation of standard metrics of estimation error. Evaluation of rounding vs truncation of fractional estimated ages will also be conducted. In addition to documenting the degree to which traditional age data can be reliably replicated using this alternative approach, we will evaluate the effect that replacing large blocks of traditional ages in assessments with FT-NIRS ages has on important assessment metrics.

This general approach to expediting age estimates need not be restricted to using the spectral data as the universe of the independent variables. Addition of other metadata, such as otolith weight, catch date, fish length, and fish weight to the estimating equation could allow age to be estimated with greater accuracy and precision. Evaluation of the benefits of including additional variables and the costs/implications for use of the age data in estimating other relationships, such as growth, will be explored, as time permits.

References

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