Proceedings of the Technical Expertise in Stock Assessment (TESA) national workshop on 'Best practices in age estimation', 31 January to 02 February 2023 in Moncton, New Brunswick

Daniel Ricard, Peter Comeau, Aaron Adamack, Jacob Burbank, Abby Daigle, Allan Debertin, Kim Emond, Tracey Loewen, Andrea Perreault, Gregory Puncher, Karen Robertson, Nicolas Rolland, Meredith Schofield, Andrew Smith, François-Étienne Sylvain and Stephen Wischniowski

Science Branch
Gulf Region
Fisheries and Oceans Canada
Moncton, New Brunswick, E1C 5K4, Canada

2024

Canadian Technical Report of Fisheries and Aquatic Sciences

Fisheries and Oceans Canada　Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences nnn

2024

PROCEEDINGS OF THE TECHNICAL EXPERTISE IN STOCK ASSESSMENT (TESA) NATIONAL WORKSHOP ON BEST PRATICES IN AGE ESTIMATION, 31 JANUARY TO 02 FEBRUARY 2023 IN MONCTON, NEW BRUNSWICK

by

Daniel Ricard[1], Peter Comeau[2], Aaron Adamack[3], Jacob Burbank[1], Abby Daigle[1], Allan Debertin[4], Kim Emond[5], Tracey Loewen[6], Andrea Perreault[3], Gregory Puncher[2], Karen Robertson[1], Nicolas Rolland[1], Meredith Schofield[3], Andrew Smith[5], Francois-Étienne Sylvain[1] and Stephen Wischniowski[7]

[1]Gulf Fisheries Centre, Fisheries and Oceans Canada, 343 Université Avenue, Moncton, New Brunswick, E1C 9B6
[2]Bedford Institute of Oceanography, Fisheries and Oceans Canada, 1 Challenger Dr., Dartmouth, Nova Scotia, B2Y 4A2
[3]Nortwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, 80 E White Hills Rd, St. John's, Newfoundland and Labrador, A1A 5J7
[4]Saint Andrews Biological Station, Fisheries and Oceans Canada, 125 Marine Science Dr., St. Andrews, New Brunswick, E5B 0E4
[5]Maurice Lamontagne Institute, Fisheries and Oceans Canada, 850 route de la Mer, Mont-Joli, Québec, QC G5H 3Z4
[6]Freshwater Institute, Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6
[7]Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, British Columbia, V9T 6N7

Cat. No. Fs97-6/nnnE-PDF ISBN ISBN GOES HERE ISSN 1488-5379

Correct citation for this publication:

Ricard, D., Comeau, P., Adamack, A., Burbank, J., Daigle, A., Debertin, A., Emond, K., Loewen, T., Perreault, A., Puncher, G., Robertson, K., Rolland, N., Schofield, M., Smith, A., Sylvain, F.-É. and Wischniowski, S. 2024. Proceedings of the Technical Expertise in Stock Assessment (TESA) national workshop on best pratices in age estimation, 31 January to 02 February 2023 in Moncton, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 27 p.

CONTENTS

ABSTRACT iv

RÉSUMÉ v

1 Introduction 1

1.1 Motivations . . . 1

1.2 Objectives . . . 2

1.3 Format . . . 2

2 Workshop activities and presentations 2

2.1 Day 1 - Basics of age estimation . . . 3

2.2 Day 2 - Digital imaging of ageing structures . . . 5

2.3 Day 3 - Analysis of age estimates . . . 6

3 Remarks from external experts 8

4 Discussion 9

5 Recommended best practices 9

6 Acknowledgements 12

7 Tables 13

8 Figures 17

9 References 20

APPENDICES 20

A List of DFO age structure collections 21

ABSTRACT

Ricard, D., Comeau, P., Adamack, A., Burbank, J., Daigle, A., Debertin, A., Emond, K., Loewen, T., Perreault, A., Puncher, G., Robertson, K., Rolland, N., Schofield, M., Smith, A., Sylvain, F.-É. and Wischniowski, S. 2024. Proceedings of the Technical Expertise in Stock Assessment (TESA) national workshop on best pratices in age estimation, 31 January to 02 February 2023 in Moncton, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 27 p.

A three-day workshop was held in Moncton, New Brunswick, from January 31 to February 02 2023. The aim of the workshop was to examine and discuss best practices in the use of structures for age estimation. A summary of the different presentations is given along with a brief overview of discussions that took place during the workshop. A total of 41 recommended best practices are formulated to provide guidance for practitioners involved in the collection of otoliths and other hard parts, and in analyses of age estimates.

RÉSUMÉ

Ricard, D., Comeau, P., Adamack, A., Burbank, J., Daigle, A., Debertin, A., Emond, K., Loewen, T., Perreault, A., Puncher, G., Robertson, K., Rolland, N., Schofield, M., Smith, A., Sylvain, F.-É. and Wischniowski, S. 2024. Proceedings of the Technical Expertise in Stock Assessment (TESA) national workshop on best pratices in age estimation, 31 January to 02 February 2023 in Moncton, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 27 p.

Un atelier de trois jours s'est tenu à Moncton, au Nouveau-Brunswick, du 31 janvier au 2 février 2023. Le but de l'atelier était d'examiner et de discuter des meilleures pratiques en matière d'utilisation de structures pour l'estimation de l'âge. Un résumé des différentes présentations est donné ainsi qu'un bref aperçu des discussions qui ont eu lieu au cours de l'atelier. Un total de 41 recommandations des meilleures pratiques sont formulées pour guider les praticiens impliqués dans la collecte d'otolithes et d'autres parties dures, et dans l'analyse des estimations d'âge.

1 Introduction

The purpose of the Technical Expertise in Stock Assessment (TESA) program is to promote stock assessment excellence through organising national activities that contribute to the development of expertise in stock assessment across Fisheries and Oceans Canada (DFO).

TESA was created in 2009, in response to a loss of stock assessment expertise in DFO owing to retirements. Each year, TESA organises three or four training courses and one or two topical workshops on stock assessment issues. TESA is a national program with one or two representatives in each region – for more details see the GCpedia website (only accessible from the DFO network).

This report provides a written record of the TESA workshop on "Best practices in age estimation" that was held in Moncton, NB, from January 31 to February 02 2023 (Figure 1). The list of participants can be found in Table 1 and all resources related to the workshop were stored in a git repository maintained by TESA.

1.1 Motivations

The use of an age-based population model is often lauded as the "gold standard" in stock assessment. Age-based models are favored over simpler population models because of their ability to convey biological realism and to provide a more nuanced understanding of population dynamics, including the effects of fishing on harvested populations. As the name implies, an age-based model requires information about the age of individuals in the population, which provides scientists with a foundation for analysing the demographics of a population as it evolves over time. Age estimates, in conjunction with other observations, can inform us on the growth of individuals, the age-at-maturation of individuals, the age structure of a population and on other vital factors necessary to understand variations in numbers and biomass.

All DFO regions (Figure 2) collect structures from marine and freshwater organisms that are used in estimating their age. The procedures associated with collecting, cataloguing, storing, and obtaining age estimates of samples vary from lab to lab. It is important to follow best practices when estimating age from hard structures and not all personnel are necessarily aware of these practices.

In any given year, DFO collects otoliths for a number of stocks, and processes these structures to obtain age estimates. It is estimated that tens of thousands of otoliths and scales are collected yearly in scientific activities at DFO. For example, thousands of otoliths are collected during annual mutli-species scientific surveys conducted by different DFO regions. Additional otoliths are collected in commercial port sampling activities and others come from fisheries observers. The logistical, financial and human resources associated with these otolith sampling programs are significant.

While the use of age-based models is common and the software available to implement such assessments is available and evolving, the manipulation of the input data that feeds into those models is often done in an ad-hoc fashion particular to the lab or agency in charge of the assessment. While these ad-hoc methods are most likely defensible and appropriate, the details that go into the computation of catch-at-age matrices are often poorly documented, making results hard to reproduce by someone outside a given lab or agency.

This workshop was formulated to provided an opportunity for DFO scientists involved in age estimation, in analyses of age and length information, and in developing age-based assessments, to share ideas and develop better methods to obtain and use age estimates data in stock assessments.

1.2 Objectives

The objectives of this workshop were to create a forum for discussion and for exchanging ideas among DFO scientists who use age-based models and who are involved in age estimation activities. In particular, the workshop provided:

- guidance on hard structures collection and on the sampling design for collecting hard structures;
- guidance on age determination using hard structures, best practices for annuli validation, reference collections, age estimation technician calibration, archival of hard structures and data warehousing;
- guidance on digital imaging of hard structures;
- guidance on going from length frequency samples and age-length keys to catch-at-age matrices that feed into age-based population models.

1.3 Format

A hybrid meeting was held from January 31 2023 to February 02 2023. The list of participants and the attendance can be found in Table 1. A total of 76 participants attended the event (30 in person and 46 virtually), including two external experts who joined the meeting virtually. The workshop was attended by a wide variety of DFO personnel ranging from research scientists, to biologists, to fisheries technicians and also included two students and a professor from a local university.

2 Workshop activities and presentations

The workshop was facilitated by its two co-chairs and included a number of presentations from DFO personel and external experts (Table 2, which contains links to the different presentations). Plenary presentations were followed by discussions between workshop participants on the topics at hand, with the main goal of exchanges being to openly share knowledge and to reach agreement on what constitutes “best practices” for age estimation using hard parts.

As part of the workshop planning, participants were asked to provide a summary of physical collections of hard structures and to identify the programs that were involved in the collection and analysis of ages using these structures. Given the large number of taxa for which age estimation materials are collected by different regions of Fisheries and Oceans Canada (Figure 3), the recommended best practices from this workshop involve programs spanning the whole country, and concern marine stocks in the Atlantic, Arctic and Pacific oceans, as well as a number of diadromous and freshwater species. The recommended best practices also apply to a number of different structures, including otoliths, scales, vertebrae and mollusc shells (Table A.1).

2.1 Day 1 - Basics of age estimation

The first day covered the basics of age estimation. The literature on research associated with otoliths is vast and varied. Peter Comeau gave a presentation on the history and realities of age estimation of marine organisms (link to presentation appears in Table 2). His presentation highlighted the importance of age estimation in stock assessments. He also pointed out that there once was a stigma associated with jobs that involved age estimation, they were perceived as an entry-level position with a low retention rate, whereas the reality is that they require a unique skill set, considerable experience and are essential to scientific inquiries related to fish population dynamics.

Julie Coad Davies gave an overview of the age estimation activities that she is involved in, in her role as lab manager for DTU Aqua and also through her chairing the International Council for the Exploration of the Sea (ICES) Working Group on SmartDots Governance (WGSMART) and the ICES Working Group on Biological Parameters (WGBIOP) (link to presentation appears in Table 2). Julie highlighted the importance of clear communication between laboratories and the paramount role of exchanges of both physical otoliths and digital images to identify potential age estimation biases that may exist between laboratories. Similarly, the ICES working groups have in their mandate the formulation of shared methodologies and protocols and provide guidelines for how to best captures information on biological parameters and how to conduct otolith exchanges between laboratories (ICES).

Stephen Wischniowski shared his experience of running an age estimation laboratory (the Sclerochronology Lab at the Pacific Biological Station) and being involved in the Committee of Age Reading Experts (CARE) (link to presentation appears in Table 2). The demands for age estimation services from the lab far exceed its ability to process samples and a “quota” is imposed on the number of otoliths that the lab can process. The lab technicians are taught the intricacies associated with age estimation from all types of species and structures. Stephen estimates that it takes five years to train a technician to the point where they can reliably estimate ages for a range of species and can teach others.

Sylvie Robichaud and Karen Robertson presented the procedures associated with age estimation of Atlantic Herring in the Gulf Region (link to presentation appears in Table 2). There are two spawning components that must first be distinguished from each other before age estimates can be made. The morphology of otoliths is used to distinguish between spawning components and the number of annuli and the date of capture are then integrated into an age estimate. The otoliths come from a variety of sources, ranging from research surveys to experimental fishing and from commercial fisheries. The laboratory protocols used to process samples require the extraction of otoliths, which are subsequently mounted in epoxy resin, photographed, and are then used for age estimation.

Kim Emond and Hélène Dionne presented the procedures associated with age estimation of Atlantic Herring in the Québec Region.The otolith based techniques to decipher between spring spawning and fall spawning herring stocks of Atlantic Herring used by the Québec region were explained and shown (link to presentation appears in Table 2). Similarities were seen between approaches used by the technicians in the Gulf region and those in the Québec region both for estimating Herring ages and spawning component assignment. The stock assessment for this stock relies on a variety of data sources and on a comprehensive sampling of otoliths. Ages determined from otoliths are essential to the stock assessment as they are a precursor for many important population model inputs such as the catch-at-age.

Tania Davignon-Burton gave a talk of reconciling expectations and realities in a age estimation production environment (link to presentation appears in Table 2). There are often high expectations for estimating ages using otoliths, but the laboratory activities required to obtain age estimates mean that some prioritisation must take place. In essence, it is not always quick and easy to age otoliths, it takes time and often demand outweighs technician time.

During the question period there were discussions pertaining to the importance of cleaning and storing hard structures appropriately. It was highlighted that clean otoliths are required for taking high quality pictures that are optimal for age estimation. Previously some labs had stored otoliths in glycerin solutions, however there was a consensus that it is better to store otoliths dry, as this is better for otolith preservation, reading of older otoliths, otolith microchemistry and isotopes. Several participants agreed it is best to clean otoliths immediately upon extraction, dry appropriately, and store dry, as this is best for age estimation, microchemistry and isotopic analyses. If otoliths are soaked in a solution such as glycerin to improve contrast and the readability of annuli, the otoliths should be cleaned, dried and stored dry after reading to avoid deterioration.

Tracey Loewen and Rick Wastle presented their work on estimating ages of difficult-to-age species and otolith microchemistry techniques used for age estimation (link to presentation appears in Table 2). They explained that their Otolith Ageing Lab at the Freshwater Institute in Winnipeg is responsible for age estimation of 32 species found in the Arctic, including but not limited to Arctic Char (*Salvelinus alpinus*), Dolly Varden (*Salvelinus malma*), Lake Trout (*Salvelinus namaycush*), Greenland Halibut (*Reinhardtius hippoglossoides*), Redfish (*Sebastes*) and Arctic Cod (*Boreogadus saida*). Otolith microchemistry techniques are used to support and validate age estimation technique, such as annual Zinc markers that align with growth rings on otoliths. Rick Wastle went in depth on approaches used to age Greenland Halibut in the Arctic as this species is difficult to age because of its slow growth. Despite the difficulty with estimating ages for the species, the lab persisted, testing a wide range of approaches before settling on what is perceived as the best and appropriate age estimation methods. The methods that they developed improve the understanding of growth patterns for the species. They elaborated that Strontium Calcium (SrCl) marking was used to try and validate growth rings with moderate success, and concluded sectioning the left otolith bulge as well as longitudinal sectioning have advantages for estimating ages in this slow growing species.

Daniel Ricard presented the Standard Operating Procedures (SOP) document used in the Gulf Region. This document is meant as a central point for any person seeking information about age estimation in the Gulf Region. The SOP document contains detailed information concerning the collection, preparation, age estimation and storage of age structures for fish species that are used for age estimation in the Gulf region. The summary of otolith collections held by the Gulf Region and available as OpenData records was also presented and suggested as a starting point for documenting physical collections, including reference collections.

2.2 Day 2 - Digital imaging of ageing structures

The second day of the workshop focused on topics related to the capture of digital images of ageing structures, how to annotate, and common software to store and manipulate images.

The day started with a tour of the laboratory facilities used in age estimations at the Gulf Fisheries Centre. The laboratories used for age estimation of Atlantic Cod (*Gadus morhua*), White Hake (*Urophycis tenuis*), American Plaice (*Hippoglossoides platessoides*), Witch Flounder (*Glyptocephalus cynoglossus*), Winter Flounder (*Pseudopleuronectes americanus*), Yellowtail Flounder (*Limanda ferruginea*) and Atlantic Herring (*Clupea harengus*). The facilities used for imaging whole otoliths mounted in epoxy and imaging of whole otoliths were visited and participants had the opportunity to ask questions and try the tools and software used by their Gulf Region colleagues. Participants also visited the Atlantic Cod, American Plaice, Winter Flounder, Yellowtail Flounder and Atlantic Herring otolith collections, had the opportunity to see the vast amounts of otoliths stored at the Gulf Fisheries Centre and see how the ageing structures are stored and archived.

A presentation about *SmartDots* from external expert Julie Coad Davies showed how this tool is being used for otolith exchanges between laboratories in Europe (link to presentation appears in Table 2). The development of the *SmartDots* application is managed by ICES Working Group on SmartDots Governance (WGSMART) in close collaboration with the ICES Secretariat as well as national fisheries laboratories. *SmartDots* and its associated website provide a set of software tools to support users in managing all data of ICES biological reading (like age, maturity, larvae identification) workshops and exchanges (ICES 2024). There was tangible interest among DFO employees to use *SmartDots*. Several people noted the value of being able to exchange digital otoliths and provide several annotations/reader interpretations on an otolith image, to compare and contrast the patterns identified by technicians and help in recording authoritative interpretations of otolith images. This would also allow cross-region comparisons where technicians from other regions estimate the age of an individual using otolith images, hence providing cross-region comparisons of age interpretation. This approach would help house ageing structure interpretations in one common place.

Karen Robertson gave a presentation on taking good images of otoliths, which could be transferable to other ageing structures (link to presentation appears in Table 2). She showed how it is important to have a reliable workspace with appropriate lighting and a microscope equipped with a digital camera. The image capture can be done in a number of softwares, including the one provided by the microscope manufacturer, the Leica *LAS X* software suite. Karen also pointed out the importance of having a well-defined naming convention for images and a strict protocol for file storage. Image processing is an important step to improve the readability of otolith images and a number of filtering options are available. There were brief discussions on what the appropriate naming convention should be and consensus among the group that this should be standardised when possible.

David Fishman presented options for developing a storage solution for otolith/ageing structure images in the form of *DFO Dots*, an application which can be integrated with *SmartDots*. A discussion about *DFO Dots* followed. Participants felt that having access to a tool that helps in managing otolith collections, curating reference collections and supporting age estimation tasks would be beneficial to their work. There was enthusiastic support for further development of *DFO Dots* among the workshop participants. Of particular relevance to the earlier presentation by Julie Coad Davies is the seamless integration of *SmartDots* in the the *DFO Dots* application through the use of the Application Programming Interface (API) required by *SmartDots*.

A group discussion on the reporting features of *SmartDots* and how the tool can be used for obtaining growth increments followed. Participants noted the value of having annotated imaged otoliths and being able to readily generate quick reports in *SmartDots* to rapidly assess results of age reading runs.

Others, particularly those in production ageing labs noted capturing digital images of ageing structures adds time to the laboratory process used to obtain age estimates. It is unclear whether the benefits of obtaining digital images of ageing structures outweighs the costs associated with the additional time required. To address this it was suggested that as a starting point, a reference collection should be imaged. Having a reference collection of imaged otoliths/ageing structures allows researchers to document examples of what otoliths/ageing structures of a particular age-class look like and to explain why classification of being a different age would be incorrect. Reference collections are also useful for training new readers and for providing continuity in ageing methodologies when there are discontinuities in an age estimation program (e.g. times when there is no overlap between new and former readers).

Once digital images of ageing structures are available, an additional step is to annotate them. It was noted that it is probably impractical to annotate images in production ageing situations, but as a starting point the reference collection should be annotated in *SmartDots* or *DFO Dots*. This provides an authoritative record that can be used to better document the reference collection. If steps are done to facilitate more rapid imaging of otoliths and potentially automated annotations, such approaches could eventually be integrated into the workflow of production ageing labs. However, such advances are far off and the automation of image annotation can have major drawbacks, as annotation and reading of age structures takes significant expertise and can include some subjective decisions on unclear growth increments.

2.3 Day 3 - Analysis of age estimates

The third day of the workshop focused on what is done with age estimates, namely the use of such data in fitting growth models and in computing catch-at-age matrices. Such applications of ageing data are often the backbone of stock assessment models, making their computation imperative for well informed estimates of population abundance and projections.

Daniel Ricard and Andrea Perreault gave presentations on growth models (link to presentation appears in Table 2). Daniel Ricard showed how growth models are typically fit and gave examples of developing growth models for American Plaice. Daniel also showed how to effectively fit growth models for males and females and highlighted the importance of weighting observations to ensure that the model fitting accounted for the sampling design. Andrea Perrault gave a talk on the importance of accounting for length-stratified sampling when fitting growth models from survey data as length-stratified sampling can lead to biased estimates of growth model parameters (Perreault et al. 2020). Andrea went over several potential methods that can be used to account for length-stratified length sampling when fitting growth models and with simulations showed the method that leads to the least amount of bias. During the question period Andrea pointed out the risks of overestimating the asymptotic length in a von Bertalanffy growth model (often called $L_{infinity}$), which include overestimation of biomass and the potential perception that fish are bigger than they actually are, and this bias propagates through to the biomass estimates.

Lisa Ailloud from NOAA NMFS gave a presentation about age-length keys (link to presentation appears in Table 2). She discussed the distinction between forward and reverse age-length keys, and provided an alternative hybrid methodology that was previously applied to bluefin tuna (Ailloud et al. 2019; Ailloud and Hoenig 2019). She also described how to fill gaps in age-length keys when not enough information is available.

Catch-at-age calculations presentation by Andrew Smith from the Québec Region described his experience with trying to replicate catch-at-age calculations that were previously done in a bespoke software called *catch.exe*. An R package called *catchR* that was developed to compute catch-at-age matrices was also presented (Ouellette-Plante et al. 2022). Use of the package and cautions of trying to reproduce exact catch-at-age matrices from previous work that made several subjective decisions was shared. The *catchR* package was presented and it was shown how the package can reduce subjectivity in the computation of catch-at-age.

Kim Emond from the Québec Region presented the methodologies used in the herring stock assessment to compute catch-at-age matrices from commercial landings and from hydroacoustic surveys(link to presentation appears in Table 2). Once again, Kim highlighted the need to reduce subjectivity in computations of catch-at-age, to document decisions and be consitent with decision making across years.

Christopher Corriveau and Ellie Weise from Dalhousie University presented their work on using DNA methylation to estimate ages (link to presentation appears in Table 2). The presentation provided an overview of this new methodology and highlighted a novel way forward for age estimation that could provide less reader subjectivity if refined and calibrated appropriately.

Finally, a group discussion took place to draft the recommended best practices that appear in section 5. The list covers a variety of subjects, ranging from practical suggestions for age estimation to broader considerations that could foster the development of a community of age readers within DFO.

3 Remarks from external experts

Remarks from Julie Coad Davies from DTU Aqua:

> The workshop has been an excellent forum for those working with age reading and the age data resulting from their work. With such a variety of expertise across labs and regions under the DFO it is important that a community is formed to facilitate knowledge sharing on best practices. There are opportunities for age reading calibration across labs who are age reading the same stocks, cooperation on updating reference collections and knowledge sharing on image acquisition and method testing.
>
> Future plans to have a DFO version of SmartDots will facilitate this and will support an overall improvement in the quality of the age data coming from the age reading labs and how the data is subsequently used in the stock assessment process. Forming a working group who meet annually will foster the communication required to sustain the community.

Remarks from Lisa Ailloud from NOAA NMFS:

> The 2023 TESA best practices in ageing workshop was a very successful meeting. It provided a forum for experts from different labs and regions to share experiences, pain points and new developments in fish age determination and modeling. Age and growth play an important role in stock assessment and any biases in these input quantities can ultimately affect the correct evaluation of stock status and management advice. It is therefore essential to identify the potential sources of bias and take the necessary steps to mitigate them. Discussions carried out during the workshop helped advance this goal. Having a wide range of expertise present helped broaden the discussions and bridge the gap between the various stages of data and model development.
>
> As participants shared their individual experiences, advances and setbacks, it became clear that many of the issues raised were common across labs and relevant to the group as a whole. This type of forum where solutions can be worked out and shared among experts is an important step towards homogenizing protocols and increasing overall efficiency. Participants clearly showed an interest in understanding past practices and improving upon them. Discussions around making use of automation and open science principles to increase transparency in the process were very encouraging. New technological developments were also shared with the group. Preliminary results for their application appear very promising.

4 Discussion

Over and over during the workshop, it was emphasised that while otoliths are the most common structure used for estimating ages, other ageing structures are also used, and the best practices used for otoliths are applicable to other structures.

It was discussed how age estimation using ageing structures is more than just “counting the rings” and requires a wealth of experience in order to interpret the patterns observed on ageing structures.

The workshop attendees identified the need to develop and foster a community of DFO scientists whose tasks involve age estimation. As such, the workshop provided a starting point in establishing this community.

5 Recommended best practices

The working group formulated the following recommended best practices for how to deal with physical collections of structures used for age estimation.

1. General
   (a) Foster a community of DFO scientists whose mandated tasks include sampling of ageing structures, age estimation using ageing structures or analysis of age estimates data.
   (b) Creation of a DFO working group that meets regularly to ensure that age estimations practices in different labs follow shared best practices. One of the tasks of this working group would be to emulate the Pacific Ocean’s Committee of Age Reading Experts (CARE), which provides an international forum to develop and support age estimation expertise, for the Atlantic and Arctic Oceans.
   (c) Provide support for inter-regional ageing structure exchanges and secondary reader testing.
   (d) Recognise the fact that the skills required to obtain unbiased age estimates from ageing structures are unique and take time and dedication to acquire. As such, positions involving age estimation should be valued, and achieving a higher retention of personel in these functions should be sought.
2. Ageing structure cataloguing, storage and inventory
   (a) Ensure that physical collections of ageing structures follow the DFO "Policy on Collection, Storage, Management and Use of Physical Samples for Science Research".
   (b) Ageing structures should be stored in an environment that minimises degradation and that maintains readability.
   (c) Ageing structures removed from an individual animal should be uniquely identified.

(d) Clearly label ageing structures so they can be traced back to their collection, implement good bookkeeping of your ageing structures.
(e) An electronic inventory of the physical ageing structures available should be documented and updated regularly.
(f) A subset of ageing structures should be preserved in their unaltered state for future unforeseen usage (i.e. not in resin or glycerin).

3. Reference collections
    (a) Actively curate reference collections so that old ageing structures that have lost their readability are replaced by new ageing structures, this includes renewing ageing structures.
    (b) Ensure that the age structures in the reference collection are representative of what will be available to age estimation technicians (the structures should cover wide spatial and temporal ranges, both annual and inter annual, all ages used in the stock assessment and both easy and difficult to read ageing structures,...).
    (c) Ensure reference collections are updated with samples from recent years.
    (d) In addition to a physical reference collection, develop its digital equivalent by taking images of the ageing structures.
    (e) Ideally, also annotate your digital reference collection using SmartDots.
    (f) Strive to have a validation study to ascertain the periodicity of ageing patterns.
4. Laboratory operations
    (a) Strive to obtain unbiased age estimates by regularly performing age reader calibrations and by carrying out regular quality-checks for each species/stock (both within and across laboratories).
    (b) Develop and publish Standard Operating Procedures (SOP) for each lab.
    (c) Develop standardised protocols to validate age estimates (add to your regional SOP).
    (d) Favour age estimation in a “blind” setting, where no prior knowledge (except date of capture) is used when interpreting patterns in ageing structures, don’t let outside information influence your age estimates.
    (e) Establish a quality-control process to identify mistakes made during data entry (e.g. typos).
    (f) Document the uncertainty associated with age estimates by means of a standardised quality assurance scale.
    (g) Generate an age-error matrix as part of your standard procedures.
    (h) Have at least two trained age readers for any given stock, for redundancy.
5. Training
    (a) Develop a document that details the training steps for new technicians involved in age estimation, and/or add it to your regional SOP.
    (b) Establish procedures that integrate current practices (e.g. labels that have been used for many years) into improved practices.

6. Digital imaging of ageing structures

    (a) Ensure that a correctly calibrated scale bar is present in the image so that the image scale in pixels per mm can be determined.
    (b) The file naming convention to use when taking images of ageing structures should uniquely identify each ageing structure, should contain the image number (in cases where more than one picture is taken for each ageing structure) and also contain the resolution of the image (in pixels per mm).
    (c) When practical, promote the capture of digital images of ageing structures.
    (d) Digital images (JPEG format) of ageing structures should be stored in enterprise-level infrastructure where proper backups are in place.
    (e) Continue the development of an application to store and retrieve digital images of ageing structures to facilitate the management of these images and to provide integration with the *SmartDots* software.

7. Analysis of age estimates

    (a) When computing catch-at-age matrices, the sampling design used in the collection of data should be accounted for.
    (b) Analyses that compute catch-at-age matrices from length samples and age estimates should strive to be fully documented and reproducible.
    (c) Contemporary procedures that reduce bias in age structure estimates should be used.
    (d) Assessment methods would ideally incorporate ageing errors into the assessment framework.

8. Preparing for changes associated with a warming climate

    (a) Rates of growth are likely to change, and so are the patterns associated with age estimation, so regularly revisit the patterns used for estimating ages. Additionally, the patterns used to identify periods of weaker or stronger growth and/or changes in the timing of annuli formation should be regularly revisited.
    (b) To ensure that potential changes are identified and communicated within the age estimation community, continue to foster inter-regional communication and organise events that promote collaborations.
    (c) As northward migration of species will shift stock boundaries and change the species that will require science advice, the expertise associated with age estimation of new species must be acquired accordingly.
    (d) Establish a process so that “cheat sheets” and guides used for training technicians involved in age estimation, and the associated laboratory processes for age estimation are updated regularly.

9. Research and development

    (a) Pursue further studies in sclerochronology that will support the identification of changes in patterns used in estimating ages.

(b) Investigate the trade-offs involved between taking images and annotating them versus just estimating a single age-length pair.

These best recommended practices were formulated at the workshop and further revised by all authors. They represent procedures that should be followed by all DFO personnel involved in age estimations and also contain suggestions for fostering a community of age readers within DFO.

6 Acknowledgements

The authors would like to acknowledge all the workshop participants for their attendance and their active participation in discussions. Joeleen Savoie helped with workshop organisation and logistics. Lisa Leblanc from the ASEC was extremely generous with her time and hospitality during the workshop. Dr. Robyn Forrest and Stephanie Sardelis provided constructive reviews of an earlier version of this report, which greatly improved the final product. We thank the Gulf Region publication coordinator Jeffery Clements for his help in handling this report submission.

7 Tables

Table 1. Alphabetical list of participants (by last name) to the TESA worskhop on best practices in age estimation. Particpants from Fisheries and Oceans Canada (DFO) are identified by their region (GLF is the Gulf Region, MAR is the Maritimes Region, NL is the Newfoundland and Labrador Region, OP is Ontario and Prairie Region, ARC is the Arctic Region, PAC is the Pacific Region and QUE is the Québec Region.).

Name	Affiliation	Attendance	Day 1	Day 2	Day 3
Aaron Adamack	DFO - NL	Virtual	✓	✓	✓
Lisa Ailloud (external expert)	NOAA NMFS	Virtual			✓
Laura Alsip	DFO - ARC	Virtual	✓	✓	✓
Kelly Antaya	DFO - NL	Virtual	✓	✓	✓
Mark Billard	DFO - MAR	Virtual	✓	✓	✓
Jacob Burbank	DFO - GLF	In person	✓	✓	✓
Lauren Burke	DFO - OP	Virtual	✓	✓	✓
Barbara Campbell	DFO - PAC	Virtual	✓	✓	✓
Karalea Cantera	DFO - PAC	Virtual	✓	✓	✓
Lynn Collier	DFO - MAR	Virtual	✓	✓	✓
Peter Comeau (co-chair)	DFO - MAR	In person	✓	✓	✓
Chelsea Cooke	DFO - PAC	Virtual	✓	✓	✓
Christopher Corriveau	Dalhousie University	In person	✓	✓	✓
Abby Daigle	DFO - GLF	In person	✓	✓	✓
Andrew Darcy	DFO - GLF	In person	✓	✓	
Guillaume Dauphin	DFO - GLF	In person	✓	✓	✓
Julie Davies (external expert)	DTU Aqua	Virtual	✓	✓	✓
Tania Davignon-Burton	DFO - MAR	Virtual	✓	✓	✓
Allan Debertin	DFO - MAR	Virtual	✓	✓	✓
Nell den Heyer	DFO - MAR	Virtual	✓	✓	✓
Mathieu Desgagnés	DFO - QUE	Virtual	✓	✓	✓
Hélène Dionne	DFO - QUE	In person	✓	✓	✓
Dwight Drover	DFO - NL	Virtual	✓	✓	✓
Kim Emond	DFO - QUE	In person	✓	✓	✓
Gillian Forbes	DFO - NL	In person	✓	✓	✓
Isabelle Forest	DFO - GLF	In person	✓	✓	✓
Danni Harper	DFO - MAR	Virtual	✓	✓	✓
Sarah Hawkshaw	DFO - PAC	Virtual	✓	✓	✓
Victoria Healey	DFO - NL	Virtual	✓	✓	✓
Erin Herder	DFO - PAC	Virtual	✓	✓	✓
Kendra Holt	DFO - PAC	Virtual	✓	✓	✓
Matthew Horsman	DFO - GLF	In person	✓	✓	✓
Mary-Jane Hudson	DFO - PAC	Virtual	✓	✓	✓
Samantha Hudson	DFO - GLF	Virtual	✓	✓	✓
Yeongha Jung	DFO - PAC	Virtual	✓	✓	✓

Continued on next page ...

... *Continued from previous page*

Name	Affiliation	Attendance	Day 1	Day 2	Day 3
Kelly Kraska	DFO - MAR	In person	✓	✓	✓
Madeline Lavery	DFO - PAC	Virtual	✓	✓	✓
Michael Legge	DFO - OP	In person	✓	✓	✓
Marc Legresley	DFO - NL	Virtual	✓	✓	✓
Lingbo Li	DFO - MAR	Virtual	✓	✓	✓
Tracey Loewen	DFO - OP	In person	✓	✓	✓
Ellen MacEachern	DFO - MAR	In person	✓	✓	✓
Colin MacFarlane	DFO - GLF	In person	✓	✓	✓
Brendan K Malley	DFO - ARC	Virtual	✓	✓	✓
Kiana Matwichuk	DFO - PAC	Virtual	✓	✓	✓
Mackenzie Mazur	DFO - PAC	Virtual	✓	✓	✓
Judy McArthur	DFO - PAC	Virtual	✓	✓	✓
Kelsey McGee	DFO - GLF	In person	✓	✓	✓
Jessie Mcintyre	DFO - MAR	Virtual	✓	✓	✓
Liz Miller	DFO - MAR	Virtual	✓	✓	✓
Maya Miller	DFO - PAC	Virtual	✓	✓	✓
Kirby Morrill	DFO - GLF	In person	✓	✓	✓
George Nau	DFO - MAR	Virtual	✓	✓	✓
Andrea Perreault	DFO - NL	Virtual	✓	✓	✓
Hannah Polaczek	DFO - NL	Virtual	✓	✓	✓
Gregory Puncher	DFO - MAR	In person	✓	✓	✓
Catriona Regnier-McKellar	DFO - MAR	Virtual	✓	✓	✓
Daniel Ricard (co-chair)	DFO - GLF	In person	✓	✓	✓
Kierstyn Rideout	DFO - NL	In person	✓	✓	✓
Karen Robertson	DFO - GLF	In person	✓	✓	✓
Sylvie Robichaud	DFO - GLF	In person	✓	✓	✓
Nicolas Rolland	DFO - GLF	In person	✓	✓	✓
Chelsea Rothkop	DFO - PAC	Virtual	✓	✓	✓
Daniel Ruzzante	Dalhousie University	Virtual			✓
Meredith Schofield	DFO - NL	In person	✓	✓	✓
Andrew Smith	DFO - QUE	Virtual	✓	✓	✓
Jolene Sutton	DFO - GLF	In person	✓	✓	✓
François-Étienne Sylvain	DFO - GLF	In person	✓	✓	✓
Jaime Thomson	DFO - NL	In person	✓	✓	✓
François Turcotte	DFO - GLF	Virtual			✓
Audrey Ty	DFO - PAC	Virtual	✓	✓	✓
Kari Underhill	DFO - GLF	In person	✓	✓	✓
Lenore J Vandenbyllaardt	DFO - ARC	Virtual	✓	✓	✓
Rick J Wastle	DFO - ARC	Virtual	✓	✓	✓
Emily Way-Nee	DFO - MAR	Virtual	✓	✓	✓
Ellie Weise	Dalhousie University	In person	✓	✓	✓

Continued on next page ...

... Continued from previous page

Name	Affiliation	Attendance	Day 1	Day 2	Day 3
Gabrielle Wilson	DFO - MAR	Virtual	✓	✓	✓
Stephen Wischniowski	DFO - PAC	Virtual	✓	✓	✓
Emily Yungwirth	DFO - PAC	Virtual	✓	✓	✓

Table 2. List of presentations given at the TESA workshop on best practices in age estimation.

Presenter(s)	Presentation title	Link to slides
Day 1		
Peter Comeau	Fish age determination - Some of the basics	Power Point file
Julie Davies	How do we coordinate QA of age reading practices across laboratories, when the common goal is to provide age data for stock assessment purposes?	PDF file
Stephen Wischniowski	Sclerochronology Laboratory	PDF file
Kim Emond and Hélène Dionne	Age determination of Atlantic Herring in the Québec region	PDF file
Sylvie Robichaud and Karen Robertson	Age determination of Atlantic Herring in the Gulf region	Power Point file
Tania Davignon-Burton	Reconciling dreams, expectations and reality in a production ageing environment	Power Point file
Tracey Loewen and Rick Wastle	Otolith microchemistry, difficult-to-age marine species, element marking in otoliths	PDF file
Day 2		
Julie Davies	SmartDots – a tool created by the users for the users	PDF file
Karen Robertson, Isabelle Forest and Sylvie Robichaud	Taking good pictures of otoliths, and annotating them in SmartDots	Power Point file
Day 3		
Andrea Perreault	Impacts of ignoring length-stratified sampling design	Power Point file
Lisa Ailloud	Analyses of ageing data / A general theory of age-length keys	Power Point file
Kim Emond and Hélène Dionne	Catch-at-age of commercial herring landings and numbers-at-age from acoustics surveys	PDF file
Chris Corriveau and Ellie Weise	Developing aging clocks for fish using DNA methylation	Power Point file

8 Figures

Figure 1. Day 1 of the TESA workshop “best practices in age estimation” held at the Atlantic Science Enterprise Center in Moncton, NB on 31 January, 01-02 February 2023.

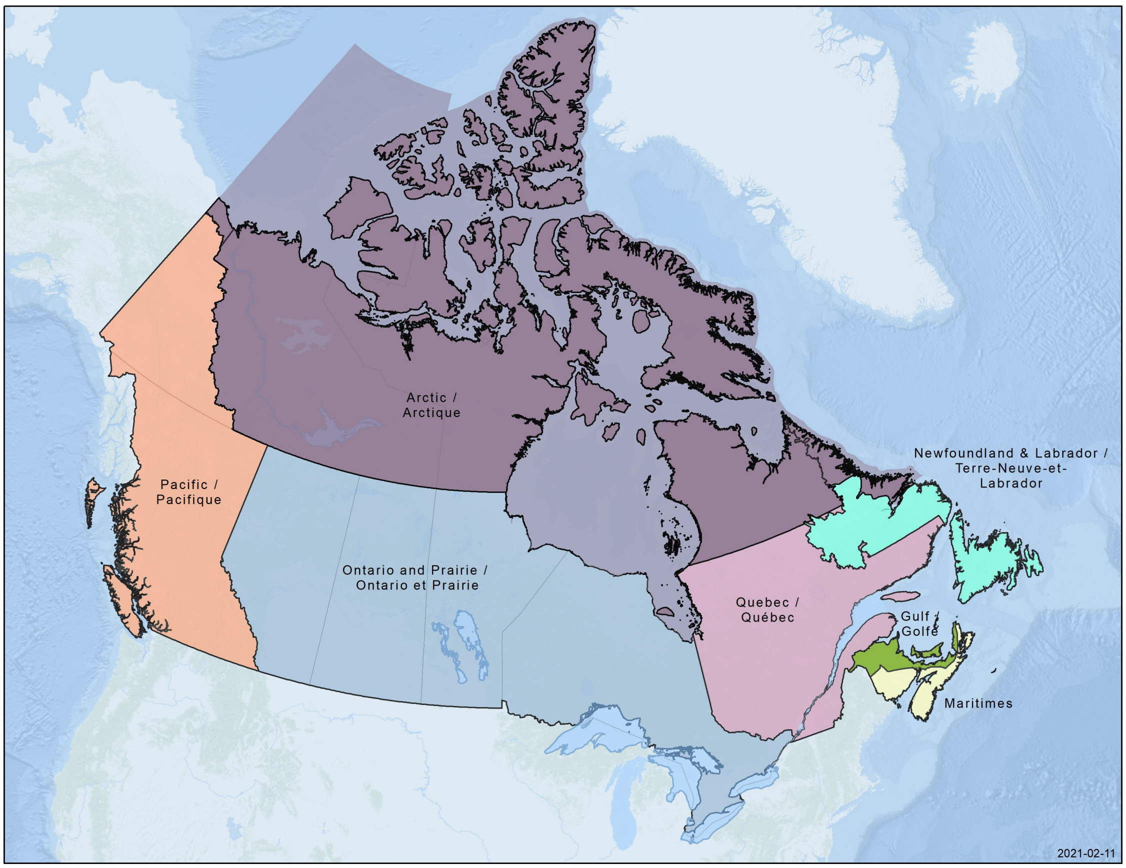

Figure 2. DFO regions map from https://www.dfo-mpo.gc.ca/about-notre-sujet/organisation-eng.htm.

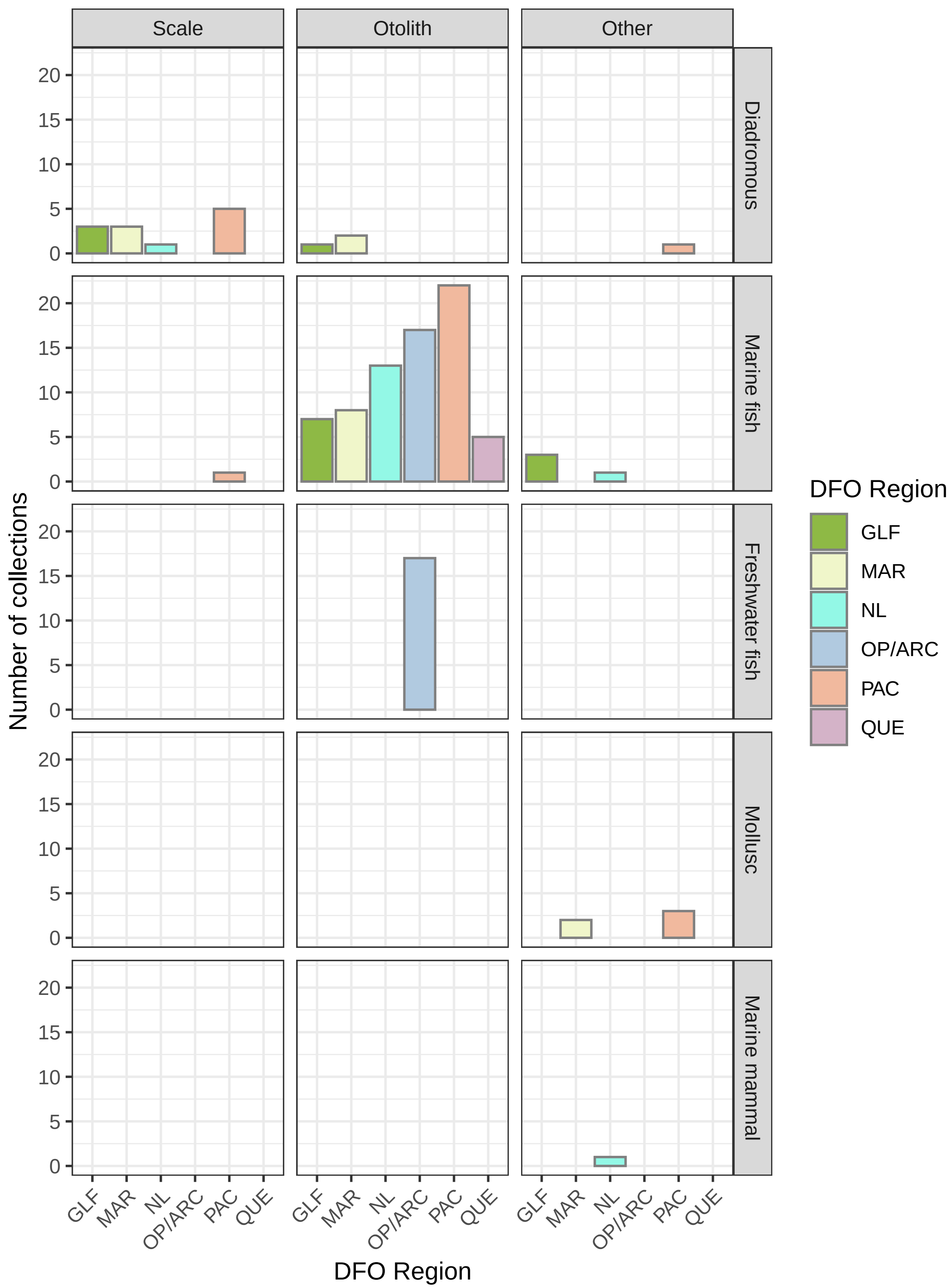

Figure 3. Number of stocks for which ageing materials are collected and analysed by the different regions of Fisheries and Oceans Canada (GLF is the Gulf Region, MAR is the Maritimes Region, NL is the Newfoundland and Labrador Region, OP is Ontario and Prairie Region, ARC is the Arctic Region, PAC is the Pacific Region and QUE is the Québec Region).). The list of collections used to generate this figure appear in Table A.1.

9 References

Ailloud, L.E., and Hoenig, J.M. 2019. A general theory of age-length keys: Combining the forward and inverse keys to estimate age composition from incomplete data. ICES Journal of Marine Science 76: 1515–1523.

Ailloud, L.E., Lauretta, M.V., Walter III, J. F., and Hoenig, J.M. 2019. Estimating age composition for multiple years when there are gaps in the ageing data: The case of western Atlantic bluefin tuna. ICES Journal of Marine Science 76: 1690–1701.

ICES. WGBIOP guidelines for otolith exchanges and workshops.

ICES. 2024. ICES SmartDots. Copenhagen, Denmark (accessed January 22 2024).

Ouellette-Plante, J., Van Beveren, E., Benoît, H.P., and Brassard, C. 2022. Details of catchR, an R package to estimate the age and length composition of fishery catches, with an application to 3Pn4RS Atlantic cod. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/015. iv + 71 p.

Perreault, A.M.J., Zheng, N., and Cadigan, N.G. 2020. Estimation of growth parameters based on length-stratified age samples. Can. J. Fish. Aquat. Sci. 77(3): 439–450.

APPENDIX A List of DFO age structure collections

As part of the planning for the workshop, participants were asked to provide an overview of age structures that are collected as part of scientific activities in different regions of DFO. The list appearing in Table A.1 shows the different collections that exist at DFO.

Table A.1. Fisheries and Oceans Canada (DFO) regions (NL is the Newfoundland and Labrador Region, MAR is the Maritimes Region, GUL is the Gulf Region, QUE is the Québec Region, OP is Ontario and Prairie Region, ARC is the Arctic Region and PAC is the Pacific Region). SFA is Salmon Fishing Area, NAFO is the Northwest Atlantic Fisheries Organization and PMFC is the Pacific Marine Fisheries Commission

Region	Common name	Scientific name	Stock	Type of structure	Years collected
GLF	Atlantic Cod	*Gadus morhua*	NAFO 4T	otolith	1971 to 2022
GLF	White Hake	*Urophycis tenuis*	NAFO 4T	otolith	1971 to 2022
GLF	American Plaice	*Hippoglossoides platessoides*	NAFO 4T	otolith	1971 to 2022
GLF	Winter Flounder	*Pseudopleuronectes americanus*	NAFO 4T	otolith	1971 to 2022
GLF	Yellowtail Flounder	*Limande ferruginea*	NAFO 4T	otolith	1971 to 2022
GLF	Witch Flounder	*Glyptocephalus cynoglossus*	NAFO 4RST	otolith	1971 to 2022
GLF	Winter Skate	*Leucoraja ocellata*	NAFO 4T	vertebrae	2004 to 2007
GLF	Smooth Skate	*Malacoraja senta*	NAFO 4T	vertebrae	2004 to 2017
GLF	Thorny Skate	*Amblyraja radiata*	NAFO 4T	vertebrae	2004 to 2013
GLF	Atlantic Herring	*Clupea harengus*	NAFO 4T	otolith	1965 to 2022
GLF	Alewife	*Alosa pseudoharengus*	SFA 16, 18	scale	1983 to 2022
GLF	Atlantic Salmon	*Salmo salar*	SFA 15, 16, 18	scale	1973 to 2022
GLF	Blueback Herring	*Alosa aestivalis*	SFA 18	otolith	2021 and 2022
GLF	Striped Bass	*Morone saxatilis*	SFA 16, 18	scale	1995 to 2022
MAR	Atlantic Cod	*Gadus morhua*	NAFO 5Z	otolith	1970 to 2022
MAR	Atlantic Cod	*Gadus morhua*	NAFO 4X	otolith	1970 to 2022
MAR	Atlantic Herring	*Clupea harengus*	NAFO 4VWX	otolith	1954 to 2022
MAR	Haddock	*Melanogrammus aeglefinus*	NAFO 5Z	otolith	1970 to 2022
MAR	Haddock	*Melanogrammus aeglefinus*	NAFO 4X	otolith	1970 to 2022
MAR	Pollock	*Pollachius pollachius*	NAFO 4X	otolith	1970 to 2022
MAR	Silver Hake	*Brosme brosme*	NAFO 4VWX	otolith	1975 to 2022

Continued on next page ...

... *Continued from previous page*

Region	Common name	Scientific name	Stock	Type of structure	Years collected
MAR	Atlantic Halibut	*Hippoglossus hippoglosus*	NAFO 3NOPs4VWX5Zc	otolith	1995 to 2022
MAR	Arctic Surf Clam	*Mactromeris polynyma*		shell	??
MAR	Sea Scallop	*Placopecten magellanicus*		shell	??
MAR	Atlantic Salmon	*Salmo salar*		scale	1950s to 2022
MAR	Alewife	*Alosa pseudoharengus*		scale	1970s to 2022
MAR	Blueback Herring	*Alosa aestivalis*		scale	1970s to 2022
MAR	Striped Bass	*Morone saxatilis*		otolith / Scales	1980s to 2022
MAR	American Eel	*Anguilla rostrata*		otolith	1980 to 2022
QUE	Atlantic Herring	*Clupea harengus*	NAFO 4RS	otolith	4R: 1965 to 2022, 4S: 1985 to 2022
QUE	Capelin	*Mallotus sp.*	NAFO 4RST	otolith	1984 to 2022
QUE	Atlantic Mackerel	*Scomber scombrus*	NAFO 3-5	otolith	1973 to 2022
QUE	Atlantic Halibut	*Hippoglossus hippoglossus*	NAFO 4RST	otolith	1990 to 2022
QUE	Atlantic Cod	*Gadus morhua*	NAFO 3Pn4RS	otolith	1974 to 2022
PAC	Turbot/Arrowtooth flounder	*Atheresthes stomias*	PMFC 3CD, 5ABCDE	otolith	1980 to 2022
PAC	Petrale Sole	*Eopsetta jordani*	PMFC 3CD, 5ABCDE	otolith	1964 to 2022
PAC	Dover Sole	*Microstomus pacificus*	PMFC 3CD, 5ABCDE	otolith	1979 to 2022
PAC	Rougheye Rockfish	*Sebastes aleutianus*	PMFC 3CD, 5ABCDE	otolith	1978 to 2022
PAC	Pacific Ocean Perch	*Sebastes alutus*	PMFC 3CD, 5ABCDE	otolith	1973 to 2022
PAC	Redbanded Rockfish	*Sebastes babcocki*	PMFC 3CD, 5ABCDE	otolith	1986 to 2022
PAC	Shortraker Rockfish	*Sebastes borealis*	PMFC 3CD, 5ABCDE	otolith	1980 to 2022
PAC	Silvergray Rockfish	*Sebastes brevispinis*	PMFC 3CD, 4B, 5ABCDE	otolith	1973 to 2022
PAC	Copper Rockfish	*Sebastes caurinus*	PMFC 3CD, 4B, 5ABCDE	otolith	1984 to 2022

Continued on next page ...

... Continued from previous page

Region	Common name	Scientific name	Stock	Type of structure	Years collected
PAC	Widow Rockfish	*Sebastes entomelas*	PMFC 3CD, 4B, 5ABCDE	otolith	1979 to 2022
PAC	Yellowtail Rockfish	*Sebastes flavidus*	PMFC 3CD, 4B, 5ABCDE	otolith	1977 to 2022
PAC	Bocaccio	*Sebastes paucispinis*	PMFC 3CD, 5ABCDE	otolith	1978 to 2022
PAC	Canary Rockfish	*Sebastes pinniger*	PMFC 3CD, 4B, 5ABCDE	otolith	1973 to 2022
PAC	Redstripe Rockfish	*Sebastes proriger*	PMFC 3CD, 5ABCDE	otolith	1977 to 2022
PAC	Yellowmouth Rockfish	*Sebastes reedi*	PMFC 3CD, 5ABCDE	otolith	1977 to 2022
PAC	Yelloweye Rockfish	*Sebastes ruberrimus*	PMFC 3CD, 4B, 5ABCDE	otolith	1979 to 2022
PAC	Quillback Eockfish	*Sebastes maliger*	PMFC 3CD, 4B, 5ABCDE	otolith	1979 to 2022
PAC	Black Spotted Rockfish	*Sebastes melanostictus*	PMFC 3CD, 5ABCDE	otolith	1966 to 2022
PAC	Sablefish	*Anoplopoma fimbria*	PMFC 3ACD,5ABCE	otolith	1965 to 2022
PAC	Lingcod	*Ophiodon elongatus*	PMFC 3CD,5ABCDE	finray/otolith	1965 to 2022
PAC	Hake	*Merluccius productus*	PMFC 3CD,4B,5ABCE	otolith	1985 to 2022
PAC	Eulachon	*Thaleichthys pacificus*	selective collections	otolith	2015 to 2022
PAC	Herring	*Clupea harengus pallasi*	2E,2W,3-8,10, 14,17,19,23-27 SA6	scale	1992 to 2022
PAC	Chum	*Oncorhynchus keta*	2-29, 110-130, WCVI, Yukon	scale	1900 to 2022
PAC	Coho	*Oncorhynchus kisutch*	2-20, 110-130	scale	1901 to 2022
PAC	Steelhead	*Oncorhynchus mykiss*	incidental	scale	1902 to 2022
PAC	Sockeye/Kokanee	*Oncorhynchus nerka*	1-29,120,130, WCVI	scale	1903 to 2022
PAC	Chinook	*Oncorhynchus tshawytscha*	2-29,110-130, WCVI, Yukon	scale	1904 to 2022
PAC	Abalone	*Holiotus kamtschatkana*	Research	shell	2000 to 2022

Continued on next page ...

... Continued from previous page

Region	Common name	Scientific name	Stock	Type of structure	Years collected
PAC	Geoduck	*Panopea abrupta*	NC, CC, HG, SOG, WCVI	shell	2003 to 2020
PAC	Manila clam	*Tapes philippinarum*	Research	shell	1995 to 2022
PAC	Rocky Mountain Riged Mussel	*Gonidea angulata*	Okanogan lake CAN	shell	2019 to 2022
NL	Capelin	*Mallotus villosus*	NAFO 2J3KL	otolith	1978 to 2022
NL	Atlantic Herring	*Clupea harengus*	NAFO 3KLPs	otolith	1965 to 2022
NL	Atlantic Cod	*Gadus morhua*	NAFO 2J3KL, 3NO, 3Ps	otolith	1950s to 2022
NL	American Plaice	*Hippoglossoides platessoides*	NAFO 2J3KL, 3NO, 3Ps	otolith	1978 to 2022
NL	Greenland Halibut	*Reinhardtius hippoglossoides*	NAFO 2+3KLMNO	otolith	1978 to 2022
NL	White Hake	*Urophycis tenuis*	NAFO 3PLNO	otolith	1984 to 2019
NL	Atlantic Salmon	*Salmo salar*	NAFO 2HJ, 3KLMNO, 3Ps, 4R	scale	1975 to 2023
NL	Harp seal	*Pagophilus groenlandicus*	Northwest Atlantic	canine tooth	1979 to 2022
NL	Wolffish (3 Species)	*Anarhichadidae spp.*	NAFO 2J3KLNOP	otolith	2001 to 2006
NL	Sand Lance	*Ammodytes spp.*		otolith	
NL	Redfish	*Sebastes spp.*	NAFO 2HJ3K, 3LN, 3O	otolith	1978 to 2022
NL	Yellowtail Flounder	*Limande ferruginea*	NAFO 3LNO	otolith	1978 to 2022
NL	Witch Flounder	*Glyptocephalus cynoglossus*	NAFO 2J3KL, 3NO, 3Ps	otolith	1978 to 2022
NL	Atlantic Halibut	*Hippoglossus hippoglossus*	NAFO 3NOPs4VWX5Zc	otolith	1978 to 2022
NL	Haddock	*Melanogrammus aeglefinus*	NAFO 2HJ3K, 3LNO, 3Ps	otolith	1978 to 2022
NL	Skates (Various)	*Rajidae spp.*	NAFO 2J3KLNOP	vertebrae	2004 to 2022

Continued on next page ...

... Continued from previous page

Region	Common name	Scientific name	Stock	Type of structure	Years collected
OP/ARC	Broad Whitefish	*Coregonus nasus*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Lake Cisco	*Coregonus artedi*	Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Arctic Cisco	*Coregonus autumnalis*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Least Cisco	*Coregonus sardinella*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Inconnu	*Stenodus leucichthys*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Arctic Grayling	*Thymallus arcticus*	Various Locations Arctic Canada	otoliths and fin clips	1970s to 2022
OP/ARC	Round Whitefish	*Prosopium cylindrecium*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Arctic Char	*Salvelinus alpinus*	Canada and international locations	otoliths and fin clips	1970s to 2022
OP/ARC	Lake Trout	*Salvelinus namaycush*	Canada	otoliths and fin clips	1970s to 2022
OP/ARC	Bull Trout	*Salvelinus confluentus*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Dolly Varden Char	*Salvelinus malma*	Western Canadian Arctic	otoliths and fin clips	1970s to 2022
OP/ARC	Burbot	*Lota lota*	Canada	otoliths	1970s to 2022
OP/ARC	Walleye	*Sander vitreum*	Southern Canada	otoliths, dorsal spines	1970s to 2022
OP/ARC	Greenland Halibut	*Reinhardtius hippoglossoides*	NAFO Div. 0	otoliths	1996 to 2022
OP/ARC	Northern Pike	*Esox lucius*	Canada	otoliths and cliethra	1970s to 2022
OP/ARC	Arctic Flounder	*Liopsetta glacialis*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Starry Flounder	*Platichthys stellatus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Slimy Sculpin	*Cottus cognatus*	Canadian Arctic	otoliths	2012 to 2022

Continued on next page ...

... *Continued from previous page*

Region	Common name	Scientific name	Stock	Type of structure	Years collected
OP/ARC	Fourhorn Sculpin	*Myoxocephalus quadricornis*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Arctic Staghorn Sculpin	*Gymnocanthus tricuspis*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Grubby Sculpin	*Myoxocephalus aenaeus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Longnose Sucker	*Catostomus catostomus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Pacific Herring	*Clupea pallasii*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Bering Wolffish	*Anarhichas orientalis*	Western Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Capelin	*Mallotus villosus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Pacific Sand Lance	*Ammodytes personatus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Banded Gunnel	*Ammodytes personatus*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Greenland Cod	*Gadus ogac*	Western Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Saffron Cod	*Eleginus gracilis*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Arctic Cod	*Boreogadus saida*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Polar Cod	*Arctogadus glacialis*	Canadian Arctic	otoliths	2012 to 2022
OP/ARC	Channel Catfish	*Ictalurus punctatus*	Manitoba	otoliths	2022
OP/ARC	Freshwater Drum	*Aplodinotus grunniens*	Unknown	otoliths	
OP/ARC	Deepwater Redfish	*Sebastes mentella*	NAFO 0B	otoliths	2019 to 2022