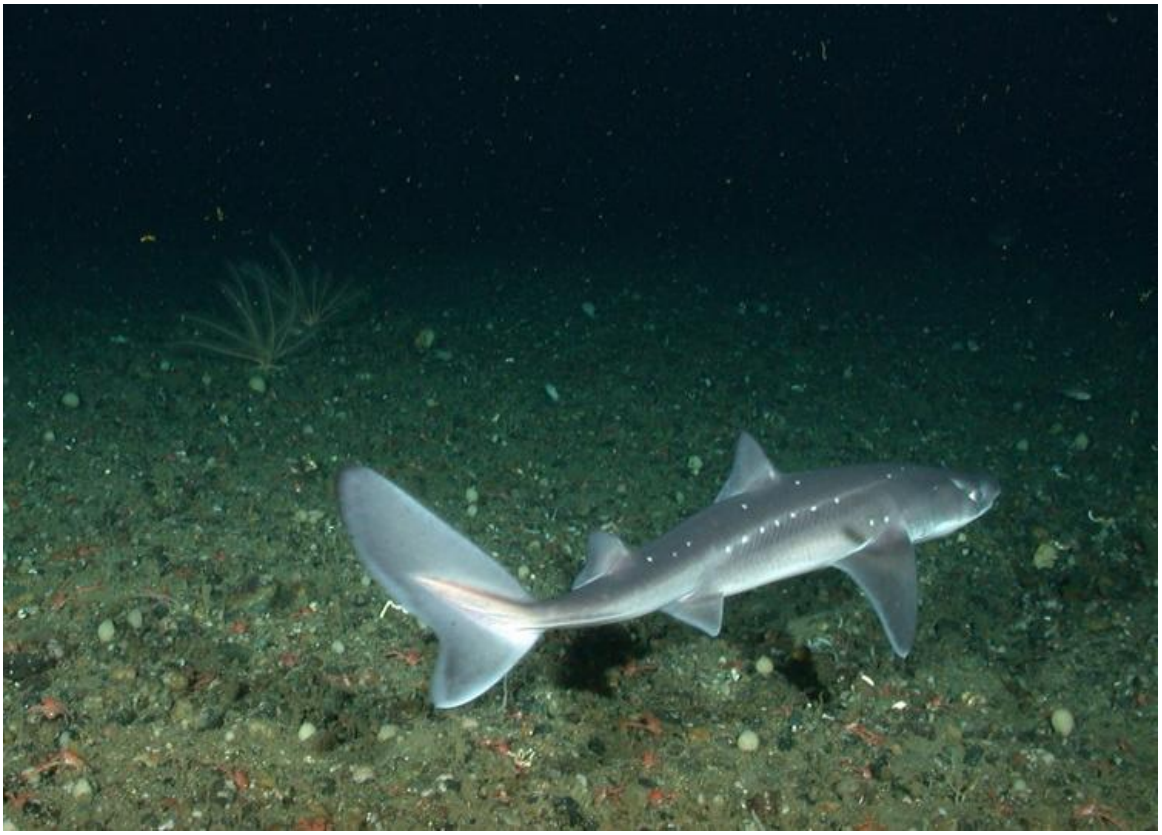
Northeast Fisheries Science Center Technical Memorandum 339

Proceedings of the 2024 Ageing Workshop for Atlantic Spiny Dogfish, *Squalus acanthias*

August 2025



Northeast Fisheries Science Center Technical Memorandum 339

Proceedings of the 2024 Ageing Workshop for Atlantic Spiny Dogfish, *Squalus acanthias*

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US DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

August 2025

Editorial Notes

Information Quality Act Compliance: In accordance with section 515 of Public Law 106-554, the Northeast Fisheries Science Center (NEFSC) completed both technical and policy reviews for this report. These pre-dissemination reviews are on file at the NEFSC Editorial Office.

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The views expressed herein are the authors' and do not necessarily reflect the views of NOAA or any of its sub-agencies.

EXECUTIVE SUMMARY

Spiny dogfish in the western north Atlantic (WNA) have a long and storied history within the scope of fisheries management. Once abundant, the WNA stock has more recently been overexploited. While not currently assessed as overfished, uncertainties surrounding biology, growth, and age estimation have prevented confident projections for biomass and thus effective management decisions. The 2024 Spiny Dogfish Ageing Workshop was convened 22 to 23 January 2024 in Raleigh, North Carolina, bringing together experts from around the world to share knowledge and best practices for age estimation in this hard-to-age species towards a goal of consistent age determination for the WNA stock in the future. The workshop agenda can be found in Appendix 1.

The workshop was attended by 21 scientists from government and state agencies, universities, and other organizations who gathered in a hybrid in-person/virtual setup to discuss biology, data collection, sample archiving, and data analysis towards developing standard practices for ageing programs in the United States (Appendix 2). Presentations covered a range of topics including program histories, scientific advances, workflows, and processing techniques (Appendix 3), and were followed by panel discussions to summarize dos and don'ts from the collective experience.

After panel discussions, in-person attendees participated in a hands-on refresher in ageing techniques for dorsal fin spines. Following the refresher, each participant independently aged a calibration set of spines for comparison among the group. Participants provided feedback and critique of results in an open forum after the exercise, and summarized the collective feedback into a draft list of recommendations for standard operating procedures in current ageing programs.

These insights will inform a renewed effort to age spiny dogfish at the NEFSC and provide a sound basis for ensuring standardized protocols across programs into the future. Working with other ageing programs at Virginia Institute of Marine Science and the Norway Institute of Marine Research toward common protocols will ensure open, comparable research to inform management of spiny dogfish throughout the Atlantic.

INTRODUCTION and BACKGROUND

Spiny dogfish (*Squalus acanthias*) are a widely distributed temperate, coastal shark species with distinct geographic populations (Compagno 1984, McCauley *et al.* 2004). The western north Atlantic (WNA) population ranges from Canada to Florida, USA, and exhibits both north-south and inshore-offshore migration, overwintering offshore of the southernmost region of their range, and migrating up to cooler northern waters close to shore in the summer months (Schafer 1970, Templeman 1976, Colvocoresses and Musick 1980, McBride 2014). Spiny dogfish, like most

sharks, have slow growth rates, late sexual maturity, and a long gestational period up to 24 months, one of the longest of all shark species (Nammack *et al.* 1985, Stehlik 2007).

Since the 1980s, the NOAA Fisheries Northeast Fisheries Science Center (NEFSC) has sampled spiny dogfish caught aboard the NEFSC Multispecies Bottom Trawl Survey for routine monitoring of age, reproduction, and food habits data to support assessment of the WNA stock. This survey operates in waters of the US continental shelf from North Carolina to the US/Canadian border and provides relative abundance estimates and biological samples to support monitoring of dozens of species important to management. Spiny dogfish comprise a significant portion of survey catch, resulting in hundreds of samples collected each year toward life history studies, including ageing. These samples have provided the basis for much of the life history work conducted on this species in the WNA over the last 50 years.

Management background

The US spiny dogfish stock in the WNA is managed jointly by the Mid-Atlantic Fishery Management Council (MAFMC) and New England Fishery Management Council (NEFMC) in cooperation with NOAA Fisheries, which provides scientific advice via stock assessments for management in federal waters. While various commercial fisheries have existed for the spiny dogfish since the early 1900s, the first fishery management plan was not implemented until 2000. The US stock was first targeted heavily by foreign fleets in the 1970s and then by the domestic fleet in the 1980s and 1990s to supply the export market. By the mid-1990s, the WNA stock had been severely depleted. With the implementation of the first fishery management plan in 2000, the stock began to recover, and has most recently been assessed as not overfished although uncertainty in biomass projections remains (NEFSC 2023). Over the last 20 years, the US has become the largest distributor of spiny dogfish, accounting for approximately 90% of the global supply (Weirsma and Carroll 2018).

Concurrently, spiny dogfish management has been hindered by the lack of accurate and reliable age and growth estimates that are essential for age-based assessments of stock status. Spiny dogfish are particularly vulnerable to overfishing due to their life history characteristics and sexual size dimorphism, with females being larger than males and hence the target of most fisheries. This also makes them highly susceptible to fisheries-induced evolution (Rutter 1902, Cortés 2000). In this situation, overfishing and/or changes to key life history parameters such as size and age at maturity can often occur in a short time frame and are difficult to reverse, making routine and accurate age and growth assessments vital. However, routine ageing of spiny dogfish has not been done by state or federal agencies at a large scale since the mid-2000s due to questions surrounding the suitability of ageing structures and accuracy of resulting age data (see below). The lack of available age data has been highlighted as a key concern by scientists, reviewers, and fishery management councils since at least 1990, with repeated recommendations to develop best practices and implement routine ageing to support accurate assessments (NEFSC 1990, NEFSC 2006, ASMFC 2013, ASMFC 2019). Obtaining accurate age data was also the highest priority research recommendation set forth by the most recent research-track stock assessment in 2022 (Jiao et al. 2022, NEFSC 2023).

Age estimation background

Routine collection of dorsal fin spines (the most widely used ageing structure for spiny dogfish) and some ageing was carried out at the NEFSC from the 1980s to the early 2010s. The first comprehensive age and growth study for spiny dogfish in the WNA was conducted in the early 1980s (Nammack et al. 1985) and used counts of annuli on the surface of dorsal fin spines to estimate ages according to methods established for other populations (Ketchen 1975). A NOAA Fisheries Stock Assessment Review Committee report in 1986, however, cited variability in growth rates produced across different age studies as an area of concern, highlighting issues of subjectivity and lack of standardization in methods. Pursuit of a widely-accepted ageing method continued, and annual growth band deposition in fin spines was later validated with bomb radiocarbon methods (Campana et al. 2006); however, subsequent research suggested that difficulty in interpreting counts from spines rendered them less suitable than vertebrae for age estimation (Bubley et al. 2012). These results and the associated ambiguity in accepted methodology led to cessation of routine spine sampling on NEFSC surveys after 2011. Recently however, age validation using oxytetracycline was carried out for both vertebrae and fin spines as part of a tag-recapture study, and demonstrated that spines reliably record annual growth whereas vertebrae do not (James et al. 2020). Owing to this new evidence, spine sampling at the NEFSC was resumed in 2021, but the ageing program has not resumed due to lack of personnel with expertise in ageing this species.

WORKSHOP PURPOSE and GOALS

The Spiny Dogfish Ageing Workshop was held at the Sheraton Raleigh Hotel in Raleigh, NC, on 22 and 23 January 2024. Participants comprised personnel from NOAA Fisheries science centers, the Virginia Institute of Marine Science, the Washington Department of Fish and Wildlife, the Norway Institute of Marine Research, the Bedford Institute (Canada), and the South Carolina Department of Natural Resources. The primary goal of this workshop was to gather experts in dogfish ageing to review past and current age estimation research and techniques, identify knowledge gaps, and develop evidence-based best practice guidelines for ageing spiny dogfish at the NEFSC and other institutions.

The first day of the workshop consisted of presentations highlighting the status of the WNA spiny dogfish stock, history of data collection at the NEFSC, current ageing techniques, shortcomings of these techniques, and knowledge gaps. These presentations were followed by discussions and hands-on ageing of the NEFSC dorsal spine reference collection. The outcomes of the day helped to identify key gaps and biases, as well as key areas of future research.

On the second day, following the remaining presentations, participants drafted a set of best practice guidelines and SOPs for the collection, preparation, and ageing of spiny dogfish dorsal spines, which can be found in the Outcomes section of this report.

Workshop activities

Presentations

On day one, Michelle Passerotti and Jonathan Auguste presented a history of sampling and ageing effort for spiny dogfish at the NEFSC, and summarized the most recent stock assessment and the issues with life history estimates that were raised there. Marta Nammack and Walter Bubley next presented summaries of their respective dissertation projects focusing on ageing dogfish using different age structures (spines and vertebrae, respectively), which were completed almost 30 years apart (Nammack et al. 1985, Bubley et al. 2012). Jameson Gregg then gave an overview of sampling and ageing efforts at Virginia Institute of Marine Science, including some results from several small-scale ageing trials whose conclusions differed from those of the Nammack and Bubley studies. This was a good primer for discussion regarding standardization of methods and the inherently high variability of dogfish age data. Finally, Cindy Tribuzio presented an overview of her in-depth work on sample preparation and ageing methods for both Atlantic (*S. acanthias*) and Pacific spiny dogfish *Squalus suckleyi*, which form the modern foundation of techniques for processing and ageing dogfish spines.

On day two, Rosario Lavezza presented a synopsis of dogfish ageing procedures at the Institute of Marine Research (Norway), which notably utilizes spawning dates to classify small spines into year classes as part of the ageing protocol. This presentation and following discourse also included an in-depth discussion of identifying birth rings. The final presentation was from Lisa Hillier and Fabio Caltabellotta from the Washington Department of Fish and Wildlife, who discussed progress in improving ageing methods for Pacific spiny dogfish *Squalus suckleyi*. Their work proposes to use vertebrae following methods successful for goblin sharks, and provided a strong departure from the fin spine-based methods discussed for the majority of the workshop. Potential new methods for modeling growth from fin spine increment measurements were also presented. All presentation abstracts can be found in Appendix 1.

Panel discussion

Day one highlights of the panel discussion included the following:

- Discussion of evidence of fishery-induced changes to spiny dogfish life history and how future ageing studies can help confirm or contextualize this evidence from survey data.
- Need to document embryo data, including sex ratios, size at birth, timing of pupping.
- Also need to find ways to ensure putative changes in life history aren't a result of spatial changes in distribution, especially those linked to sex- and life stage-specific patterns, as suggested by some industry participants in the recent research track assessment. This can be done by ensuring the sampling universe encompasses all available sizes and life stages. For instance, NEFSC has initiated sample requests for port samplers to focus on larger spiny dogfish >90 cm stretched total length (STL).
- One key discussion point was the continued need for collaboration to improve the accuracy of ageing and standardization of methods. The creation of shared resources through online shared drives, annotated reference spine images, and metadata files were suggested. These shared files should include read codes, pictures, reader notes, and sample sources to ensure

consistency and provide key insight into age interpretation. Lastly, participants identified a need for increased international collaboration.

- Subjectivity of spine reading was a key concern identified. The need for standardization criteria were discussed and identified. Suggestions included the use of consistent features such as the base and the birth ring/first growth band as landmarks for measurement, the use of regular calibration between labs to maintain practices, and creating a consensus-built reference collection. To reduce subjectivity and mediate bias, multiple reads and having multiple readers was discussed. The consensus was that all spines should have at least two reads by different readers; however, it was acknowledged by all that this is not always possible. A standardization of time between reads performed by the same person was discussed as an alternative, as well as an acceptable percentage of second reads as a subsample.
- Quality control for samples was also discussed. The need for standard sample cleaning and storage procedures was identified to help ensure proper sample handing and prevent mishaps.
- Catch date was identified as a crucial factor for interpreting early growth.
- The Ketchen method (Ketchen 1975) was identified as the standard approach for estimating lost annuli due to wear.
- The benefits of using Bayesian growth modeling were also discussed.

Day two highlights of the panel discussion included the following:

- Continuing the conversation from day one, the need for standardization was a key topic of discussion. Day two expanded on the idea of establishing criteria for interpreting growth bands and creating clear rejection criteria for determining what are considered usable spines for ageing. This discussion highlighted the need for quality control, suggesting that age readers should perform initial quality checks by plotting data to identify and revisit outliers.
- Determining a fully formed annulus at the base and interpreting early growth was also discussed. One suggestion was to use seasonality of collection as an indication of whether the band at the base is fully formed or not. It was determined that more research is needed to understand the timing of annulus formation throughout the year, particularly between populations.
- In day one's panel discussion the group came to a consensus that the ideal protocol for ageing included having second reads (100% most ideal) and two separate readers for each set. Day two's discussion expanded on this idea and identified that having a process for resolving discrepancies is integral. One suggestion was for the two agers to review the spines together and come to a consensus when possible. When not, it was recommended to choose one or the other's ages, instead of an average.
- Other topics of discussion that were revisited were having standard cleaning and collection procedures, the need for collaborative training sets and calibration exercises for new and existing readers to maintain consistency, Bayesian growth modeling, and the Ketchen worn spine correction factor. These discussions reinforced the importance of these topics, but no new insights were gained.

Recordings of the presentations and panel discussions from the workshop can be found at: https://www.youtube.com/playlist?list=PLyDI7nMDflD0_IHgLxTYGDCSbKw_G1_lv

Ageing practice and calibration trial

To prepare for breakout sessions, ageing stations were set up around the room and workshop participants were instructed to organize themselves into groups of two or three individuals per station, ideally with at least one experienced ager into each group. Each station had a digital dissecting microscope with gooseneck lights available to view spines under reflected light. For the first portion of the practical, participants viewed spines as a group and discussed interpretations openly. After a short break, participants returned to stations and viewed the same spines individually and recorded their band counts for comparison among the group. Box and whisker plots of independent spine counts and base diameter measurements from panel participants are provided in Figures 1 and 2. Variance in band counts among readers was high, especially for older fish, as is typical for this species. Variance in base measurements, however, was fairly consistent across samples regardless of age.

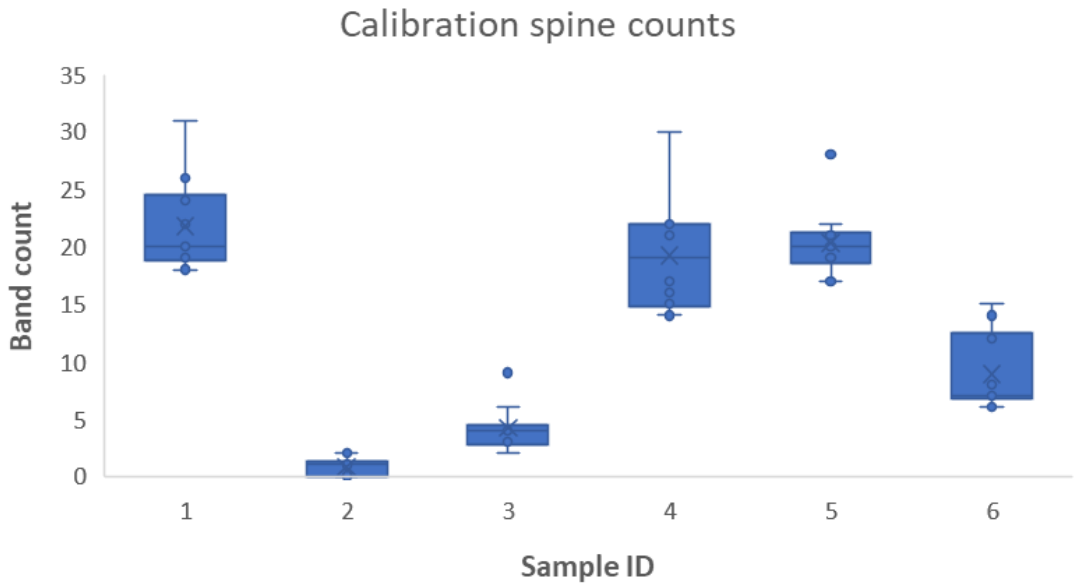

Figure 1. *Box and whisker plot of band counts from age readers (n=9) for six spiny dogfish spines.*

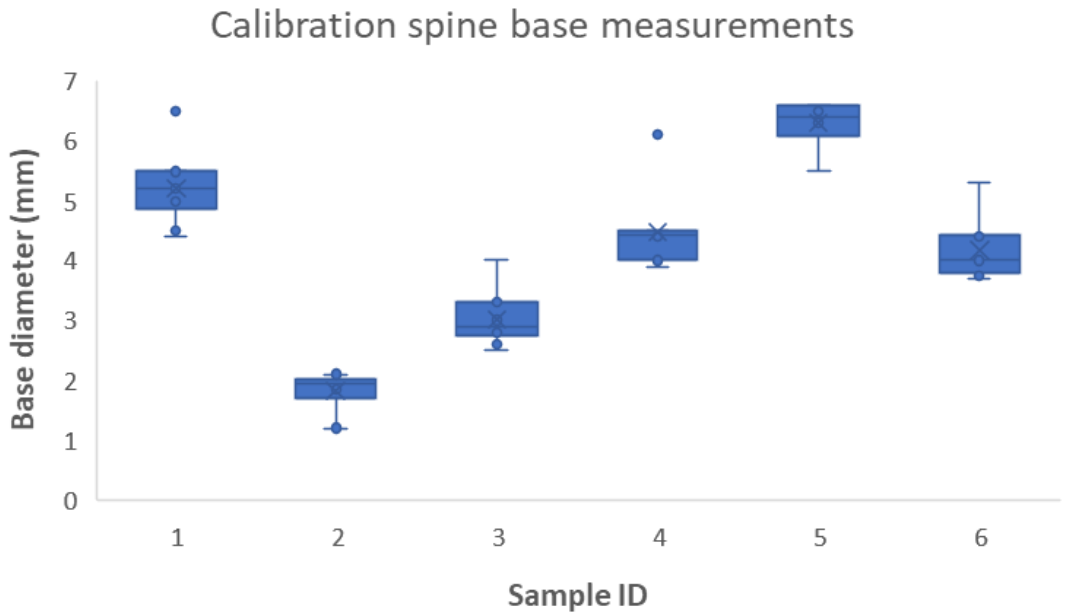

Figure 2. *Box and whisker plot of base diameter measurements from age readers (n=9) for six spiny dogfish spines.*

OUTCOMES

The best practice guidelines listed below were developed over the course of the workshop.

Sample collection

- The second dorsal spine is to be collected for use in ageing
- To remove, cut around the second dorsal spine down to the vertebrae and then horizontally under the spine base to remove a small chunk of flesh that encompasses the entirety of the dorsal spine
- Increase sampling universe to include full geographical range of the species (i.e. Canada) and target full size range of the species using observer and port samples

Cleaning

- Boiling the spines is the easiest way to remove tissue without damaging the enamel
- Carefully remove all soft tissue, and consistently check to ensure all tissue is removed before drying
- Remove the inner tissue plug using delicate tools to avoid damage

Storage

- Depending on the purpose, either clean and dry spines thoroughly before storing in paper coin envelopes, or keep spines frozen
- Periodically check archived samples for any degradation

- Do not mark spines with markers or pencil, and remove any marks previously made on archived spines to avoid biasing other readers

Ageing

- Use a reference or training set to train new readers in all aspects, and have all readers periodically review the set to ensure precision over time.
- When possible, have two or more readers age a given set with minimum 20% replication. If bias or low precision is present, increase replication.
- When only a single reader is available, set a standard amount of time between first and second reads. VIMS sets theirs at 2 weeks.
- When double reads don't match, review each spine individually instead of always defaulting to one ager over the other. The ideal protocol would include both readers coming to a consensus on mismatched ages.
- For spines that are unworn, or the base diameter at the point of wear is smaller than the putative base diameter at birth (roughly 1.5-1.8 mm), include caliper measurements at the first, second, and third growth bands for reference. This can help ensure standardized identification of the first few growth bands across readers.
- The presence of gestational bands as laid out in Ketchen (1975) is questionable. Moving forward, it is suggested to not subtract 2 bands from the total annuli count.
- When possible, capture images of the spines and annotate the images for use in training and inter-reader calibrations.
- Gently applying mineral oil helps to increase visibility of the bands and protects the spine enamel from flaking off.
- Consider catch date/seasonality of sample to inform age classification, particularly when it comes to young spines.
- Establish a good criterion for what is considered unusable condition for broken and worn spines.

Data management

- Include notes and read codes in data both for future readers and other groups.
- Reader should perform initial quality checks after first reads by plotting data to identify outliers and revisit those spines.
- Create detailed metadata files to go along with ageing data collected.

SUMMARY, RECOMMENDATIONS, and NEXT STEPS

To our knowledge, this workshop was the first of its kind to be held focused on age estimation in Atlantic spiny dogfish. Feedback from participants was overwhelmingly positive, with many conveying relief that this workshop was offered, as they were all experiencing similar difficulties and uncertainties in their respective programs' ageing studies. On the US Atlantic coast, NEFSC and VIMS both have substantial spine archives available for both retrospective and ongoing routine ageing studies to track growth in the WNA stock (roughly 10,000 and 4,100 spines, respectively, collected between 1980-2023). Participants across the board, including those studying Pacific spiny dogfish and other species, echoed the sentiment that ageing dogfish is challenging, and even with guidelines provided from other studies can be difficult to produce unbiased, high-precision results that can be confidently used in assessments. To address these issues, participants identified three crucial next steps. The first is to develop a comprehensive set of standard operating procedures (SOPs) that would cover the entirety of the ageing procedure, from spine collection and cleaning to interpretation of the data. Secondly, labs should exchange reference collections for regular calibration exercises. This would help to train new agers, as well as maintain consistency across labs. Lastly, the group determined that follow up workshops are essential. These workshops would not only serve as a platform to review and refine SOPs, but also to provide advanced training, discuss new research, identify new areas of concern, ensure continued collaboration, and help maintain the highest standards of data collection.

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Appendix 1: Workshop Agenda

January 22-23rd, 2024

Sheraton Raleigh Hotel, 421 S. Salisbury St, Raleigh, NC

Day 1/Jan. 22nd

08:30: Welcome and Introductions – Michelle Passerotti

08:45: Ageing Atlantic spiny dogfish at the NEFSC: Past, present, and future – Michelle Passerotti/J. Auguste

09:30: Perspectives on *S. acanthias* aging in the northeastern US – Marta Nammack/Wally Bubley

10:15: Break

10:30: VIMS aging perspectives – Jameson Gregg

11:00: Discussion

11:30: Lunch

1:00: Perspectives from spiny dogfish ageing on two coasts– Cindy Tribuzio (remote)

1:45: Ageing protocol overview – Cindy Tribuzio + group

2:45: Break

3:00: Hands-on aging using reference collection/age trial

5:00: End Day 1

Day 2/Jan. 23rd

08:00: Recap Day 1 – Michelle Passerotti

08:15: Ageing spiny dogfish in Norway – Rosario Lavezza, Norway Institute of Marine Research (remote)

09:00: Bayesian techniques for spiny dogfish age and growth studies – Fabio Caltabellotta/Lisa Hillier

09:45: Break

10:00: Practical discussion
- Developing best practices and SOPs
- Cleaning
- Counting
- Workflows
- Precision tools
- Data analysis

11:45: Final thoughts/discussion

12:30: Meeting adjourned

Appendix 2: Workshop Participants and Affiliations

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Fabio Caltabellotta, Washington Department of Fish and Wildlife, Marine Fish Science Unit, Olympia, WA

Melanie Chattin, Multispecies Research Group, Virginia Institute of Marine Sciences, Gloucester Point, VA

Jason Didden, Mid-Atlantic Fisheries Management Council, Dover, DE

Jameson Gregg, Multispecies Research Group, Virginia Institute of Marine Sciences, Gloucester Point, VA

Lisa Hillier, Washington Department of Fish and Wildlife, Marine Fish Science Unit, Olympia, WA

Tyler Johnson, Pacific States Marine Fisheries Commission, Newport, OR

Warren Joyce, Department of Fisheries and Oceans, New Bedford, CA

Torfinn Larsen, Institute of Marine Research, Tromsø, Norway

Rosario Lavezza, Deep Sea Fish Sharks and Shellfish, Institute of Marine Research, Tromsø, Norway

Mary Elizabeth Matta, Resource Ecology and Fisheries Management, NOAA Fisheries Alaska Fisheries Science Center, Seattle, WA

Marta Nammack, NOAA Fisheries, Retired

Nikki Paige, Pacific States Marine Fisheries Commission, Newport, OR

Cyrena Riley, Demersal and Benthic Sciences, Fisheries and Oceans Canada, Mont-Joli, Quebec, Canada

Merrie Schultz, Washington Department of Fish and Wildlife, Olympia, WA

Mark Terwilliger, Marine Resources Program, Oregon Dept of Fish and Wildlife, Newport, OR
Ole Thomas Albert, Institute of Marine Research, Tromsø, Norway

Jennifer Topping, Washington Department of Fish and Wildlife, Olympia, WA

Cindy Tribuzio, Auke Bay Laboratories, NOAA Fisheries Alaska Fisheries Science Center, Juneau, AK

Appendix 3: Presentation Abstracts

Ageing Atlantic spiny dogfish at the NEFSC: Past, present, and future

Michelle S. Passerotti,[1] Jonathan Auguste[2]

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[2]*A.I.S. in support of NOAA/NMFS*

Age determination for Atlantic spiny dogfish *Squalus acanthias* has been a topic of both interest and frustration for fisheries scientists for more than 50 years. While the first comprehensive age and growth study for the western North Atlantic Ocean was published in 1985, routine production ageing associated with fisheries management was not begun in earnest until the late 1990s, at which point the stock was experiencing steep population declines and assessments were hampered by uncertainty in life history and catch data. Since then, the science underlying age determination has been called into question on several fronts, ranging from putative ageing methods for dorsal fin spines (e.g. age correction for worn spines and growth band interpretation) to questions about the suitability of dorsal fin spines for ageing at all. The uncertainty surrounding ageing over the years has led to inconsistent sample collection and processing according to the prevailing assessment priorities and favored methods at the time. This, in turn, has hindered retention of ageing expertise as well as stock management overall by reducing the capacity of fisheries scientists to produce accurate growth parameters for age-based assessment models. This presentation summarizes the history of these challenges and outlines a renewed approach to production ageing for spiny dogfish at the NOAA Fisheries Northeast Fisheries Science Center, including synthesizing best practices, investigating the remaining areas of uncertainty in ageing methods, and ensuring ageing expertise and processing capacity is retained for future management.

Atlantic spiny dogfish ageing workshop

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Male and female spiny dogfish, *Squalus acanthias,* were collected in the Western North Atlantic in the Gulf of Maine between July 2006 and June 2009. *Squalus acanthias* ranged from 25 cm to 102 cm stretch total length and were caught during all months of the year except January. Second dorsal fin spines were utilized for age estimates due to their larger size and less enamel wear in relation to the first dorsal fin spines. Vertebral central increments were visualized for age estimates using a modified histological staining technique. Birth increments for both second dorsal fin spines and vertebral centra were identified by using full-term embryos to provide an estimated size at birth. Age estimates derived from banding patterns visible in both the vertebral centra and second dorsal fin spines were compared. Magnification, water, and orienting the spine to reflect light were methods utilized to visualize the increments on second dorsal fin spines, depending on the size of the spine and the increment's location on the spine. The wear point was noted and measured if it occurred on a spine, with the majority of individuals having wear of the enamel to a point in which increments would be removed. Wear increased with size and missing increments were corrected using Ketchen's correction factor. Increments from stained vertebral centra were counted under a dissecting microscope at 30X magnification. Age estimates obtained from vertebral centra ranged from less than 1 year old to 24 years and from less than 1 to 28 years from second dorsal fin spines. Comparisons between the second dorsal fin spine and the stained vertebral centra were significantly different between worn spines corrected for wear and vertebral centra, but not unworn spines and vertebral centra.

Life history of spiny dogfish, *Squalus acanthias*, off the northeastern United States

Marta Nammack, NOAA Fisheries, Retired

A total of 1,685 spiny dogfish from the mid-Atlantic and southern New England areas collected from NMFS groundfish surveys, the Virginia Institute of Marine Science Sea Grant Shark Longlining Program, and commercial trawlers were aged using dorsal fin spines. Each distinct circulus was presumed to be an annual structure. Indistinct double rings in which circuli were close together were counted as a single annulus. The white ring (when visible) near the tip of the spine was counted as the birth ring because it occurred at the same spine diameter (~1.75mm) in young dogfish as the spine base diameter of full-term embryos. Spines were examined from the entire size range of the species: full term embryos, juveniles, mature males up to 90 cm in TL and 2.8 kg in weight, and mature females up to 110 cm at 6.5 kg. Each spine was read, then reread a year later, and age determinations that did not agree within acceptance criteria were not included. Many spines were worn at the tip so that the more distal circuli could not be discerned. Instead of throwing these out, an age-base diameter expression for estimating ages from worn spines was used to calculate corrected ages by measuring the diameter at the worn point and adding the appropriate number of years to those already counted up to the point of wear. This helped avoid underestimating age and overestimating growth rate. Growth ring analysis of dorsal fin spines yielded von Bertalanffy growth parameters for males ($K=0.1481$, $L\infty=82.49$ cm, $t_0=-2.67$) and for females ($K=0.1057$, $L\infty=100.5$ cm, and $t_0=-2.90$). Length and age at 50% maturity for females were 80.7 cm and 12.5 years, and for males 60.1 cm and 6 years.

Spiny Dogfish Ageing at the Virginia Institute of Marine Science

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Data and sample collection of spiny dogfish (*Squalus acanthus*) has occurred over several decades at the Virginia Institute of Marine Science (VIMS), including individualized projects to multispecies long-term monitoring programs. Early projects focused specifically on the life history of spiny dogfish (Nammack 1985). The Multispecies Research Group was established in the early 2000's to create a long-term trawl monitoring program in Chesapeake Bay. A few years later in 2007, a larger scale multispecies bottom trawl survey was developed to sample the nearshore waters of the northwest Atlantic Ocean (Northeast Area Monitoring and Assessment Program, NEAMAP). The NEAMAP survey conducts research cruises annually in the spring and fall from southern New England through the mid-Atlantic. Spiny dogfish are a priority species on the NEAMAP survey that receives additional biological sampling on a subsample of the total catch at each of the randomized sampling stations. Individual length, weight, sex, maturity, egg and pup stage, stomachs for diet analysis and dorsal spines are collected for ageing. While data on spiny dogfish has been requested and submitted for various assessments, the age data and the age samples were yet to be processed due to hesitations with specific regression calculations on worn spines.

Over 4,100 individual spines have been collected and archived from NEAMAP from 2007 to 2023. Small scale ageing trials occurred in 2009, 2019 and 2022 to duplicate published experiments by Nammack 1985, Bubley 2012, and Tribuzio 2016 respectively. Upon the successful results of these duplicated trials, it was determined that the large-scale feasibility of an efficient production method of ageing would be warranted to assign and calculate ages of the archived 4,100 + NEAMAP spiny dogfish samples.

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Perspectives from spiny dogfish ageing on two coasts

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Age determination of spiny dogfish, either the Pacific spiny dogfish (*Squalus suckleyi*) or the more cosmopolitan spiny dogfish (*S. acanthias*), has existed for over 100 years. While age reading methods were originally developed for *S. suckleyi*, they have been applied universally across both species, which until recently were believed to be conspecific. The use of dorsal fin spines was initially proposed in the 1930s. However, early studies focused solely on intact, unworn spines, which resulted in biased estimates of age. In the 1970s, an approach was proposed that allowed for less-than-ideal spines and accounted for annuli that may have been worn away. The assumption that banding patterns were annual (and thus age estimates were accurate) was independently validated in the 1980s using chemical tagging methods and in the early 2000s using radiocarbon dating methods. However, the dorsal fin spine method, while accurate, is highly imprecise, with measurement error in the forms of low between-reader agreement and uncertainty in the estimation of lost annuli on worn spines. An alternative ageing approach was developed for *S. acanthias* using histological methods applied to vertebrae, which resulted in more precise age estimates. However, when tested on *S. suckleyi*, the vertebra method was biased low. Further, recent research has shown that the banding pattern in vertebrae may not be annual for a number of species, including *S. acanthias*. At present, the existing spine method for age estimation is preferred. The presentation was intended to foster discussion regarding challenges, criteria used to interpret spine banding patterns, and future research efforts in age determination. Participants walked through an age determination manual that was developed for *S. suckleyi*, considered a living document and intended to evolve as methods and criteria change, as well as examined numerous images of spines, ranging from high readability to low readability. Discussion centered on interpretation of various banding patterns, how to improve images, and potential areas for improvement to criteria.

Age reading of Spurdog at IMR

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Elasmobranch fin spines are made up of an inner layer of cartilage and pulp tissue, a *"stem layer"*, and the mantle, consisting of dentine, pigment, and an external mineralized layer of enamel. Mantle deposition *(continuous)* is not synchronous with the upward growth of the spine *(seasonal)*, resulting in a seasonal pigmentation pattern characterized by alternating annual dark and light zones on the surface of spines. The succession of a light and a dark zone identifies an annual growth cycle which can be defined as a *"growth band."*

Our aim is to identify and quantify these growth bands and despite this approach has been validated by studies with oxytetracycline *(OTC)* – tag – recapture and *bomb-pulse* dating *(McFarlane and Beamish,1987, Campana et al., 2006)* the intrinsic subjectivity of the analysis can affect the consistency of the results. As with age reading of otoliths and other calcified structures, it is therefore important to use some objective references to minimize the most common mistakes and harmonize the readings:

- The second dorsal spines are cooked and rinsed for soft tissue to prepare ageing structures that are easier to interpret. Age is given as age group, with 1 January as a fictive birth date. In the NE-Atlantic, the parturition period of spurdog is considered to be late summer/early winter. Individuals with actual birth dates e.g., 1 September and 1 February are thus considered as belonging to the same age group and year class.
- Age bands are counted from the tip towards the base. Identification of the first few ages is guided by the width of the spine compared to a reference collection of juveniles and near-term pups. Further counting of ages is guided by an assumed gradual decrease in band width and eventually a sudden change to more distinct narrow bands of similar size for older individuals.
- For worn spines, the method of Ketchen is used to estimate the number of worn age bands. Total age estimate is given by the sum of the read bands and the calculated number of worn bands. In applications, care should be taken if the calculated number of worn bands is more than a few.
- Further, age reading comparison among approved readers and the use of a reference collection are important measures to ensure consistency.

Pacific spiny dogfish

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Ageing was considered one of the major sources of uncertainty during the last stock assessment of the Pacific spiny dogfish (*Squalus suckleyi*) off the continental U.S. West Coast in 2021. The species has been aged using the second dorsal fin spines, and the wear on the spines in older dogfish drives ageing uncertainty. Although different approaches have been applied to account for missing ages or unreadable annuli due to wearing on the spines, it's unclear if there is an age overestimation in larger females. The main aim of the present study was to develop an ageing method for the Pacific spiny dogfish using the vertebral central, back-calculate dogfish growth based on the spines and apply a Bayesian von Bertalanffy growth model to estimate the growth parameters. We removed four sections of 10 vertebrae each, below the first and second dorsal fins, from two specimens. Each vertebral central was cleaned manually following the standard protocol described in the literature, and no decalcification process was applied. Unfortunately, attempts to see growth band patterns in the stained bowtie sections (~0.35-0.40 mm) using Alcian blue staining were unsuccessful during the trials. To back-calculate dogfish growth, we assumed that the dorsal fin spines grow proportionally to the total length of the dogfish. We removed the second dorsal fin spine from a near-term embryo and measured its size from the tip to the base of the spine. This measurement was used for the back-calculation as the birth-size band. Using a Bayesian von Bertalanffy growth model informed by back-calculated length at age, a literature search of maximum TL, the TL of the smallest free-swimming individuals, and informative priors, we estimated that females grow to 134 cm TL, Brody growth rate of 0.04 y^{-1}, mature at 20 years, and live up to 67 years. Our results provide more plausible life history information than reported in previous studies.

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