2021 Final Report
Virginia ~ Chesapeake Bay Finfish Ageing and Population Analysis

Hongsheng Liao, Jessica L. Gilmore, Alicia Nelson, Adam Kenyon, & Patrick Geer

September 23, 2022

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Contents

EXECUTIVE SUMMARY

This executive summary briefly summarizes what the Age and Growth Lab achieved in 2021 in terms of the objectives listed in the 2021 - 2022 proposal.

Objective 1: We propose to continue support of VMRC Age and Growth Laboratory, which is dedicated to providing Virginia fisheries management with reliable age estimates of marine fishes as an ongoing long-term activity. This includes yearly reports of catch-at-age of Virginia's important finfishes that are mandated by law, along with proper protocols to insure accuracy of the age estimates.

This objective is the major task the Age and Growth Lab is funded for, therefore, 14 chapters in the report are about the objective and each chapter is for one of 14 species the lab aged in 2021. We present the ageing results of 14 finfish species collected from commercial and recreational catches made in the Chesapeake Bay and Virginia waters of the Atlantic Ocean, U.S.A. in 2021. All fish were collected by the Virginia Marine Resources Commission's (VMRC) Biological Sampling Program in 2021 and aged in 2022 at the Age and Growth Laboratory of VMRC. We present measures of ageing precision, graphs of year-class distributions, and age-length keys for each species.

Three calcified structures (hard-parts) are used in age determination. Specifically, two calcified structures were used for determining fish ages of the following three species: Striped Bass, *Morone saxatilis*, (n = 716); Summer Flounder, *Paralichthys dentatus*, (n = 863); and Tautog, *Tautoga onitis*, (n = 119). Scales and otoliths were used to age Striped Bass and Summer Flounder, opercula and otoliths were used to age Tautog. Comparing alternative hard-parts allowed us to assess their usefulness in determining fish age as well as the relative precision of each structure. Ages were determined from otoliths only for the following species: Atlantic Croaker, *Micropogonias undulatus*, (n = 245); Black Drum, *Pogonias cromis*, (n = 26); Bluefish, *Pomatomus saltatrix*, (n = 185); Cobia, *Rachycentron canadum*, (n = 300); Red Drum, *Sciaenops ocellatus*, (n = 115); Sheepshead, *Archosargus probatocephalus*, (n = 144); Atlantic Spadefish, *Chaetodipterus faber*, (n = 209); Spanish Mackerel, *Scomberomorous maculates*, (n = 175); Spot, *Leiostomus xanthurus*, (n = 202); Spotted Seatrout, *Cynoscion nebulosus*, (n = 309); and Weakfish, *Cynoscion regalis*, (n = 155). In total, we made 9,048 age readings from scales, otoliths and opercula collected during 2021. A summary of the age ranges for all species aged is presented in Table 1.

Objective 2: VMRC will continue to develop sampling methods that are cost effective and representative of landings in the fisheries. This will produce accurate estimates of catch and effort. We have been using two-stage sampling to decide sample sizes for ageing 10 of our 14 species, which have helped to minimize costs on ageing while maximizing precision on estimates of catch-at-age.

In this report, we present sample sizes and coefficient of variation (CV) for estimates of age composition for the following species: Atlantic Croaker, Bluefish, Spadefish, Spanish Mackerel, Spot, Spotted Seatrout, Striped Bass, Summer Flounder, Tautog, and Weakfish. The sample sizes and the CVs enabled us to determine how many fish we needed to age in each length interval and to measure the precision for estimates of major age classes in each species, respectively, enhancing our efficiency and effectiveness on ageing those species. In addition to estimating the sample sizes for above species, we also estimated the sample size of Black Drum for 2022 ASMFC Black Drum benchmark stock assessment. The assessment used the sample size as a reference to evaluate whether the stock assessment had sufficient age data to switch from the current catch-based assessment methods to an age-structured model.

Table 1: The minimum and maximum ages, number of fish and their hard-parts collected, number of fish aged, and age readings for the 14 finfish species in 2021. The hard-parts and age readings include both scales and otoliths for Striped Bass and Summer Flounder, and both opercula and otoliths for Tautog. The scale-ages are reported for Striped Bass and Summer Flounder whereas the operculum-ages are reported for Tautog when they are available, however, the otolith-ages are reported when the scale- and operculum-ages are unavailable. The otolith-ages are for other species.

Species	Number of fish collected	Number of hard-parts	Numnber of fish aged	Number of readings	Minimum age	Maximum age
Atlantic Croaker	309	309	245	490	0	11
Black Drum	26	26	26	52	3	60
Bluefish	252	252	185	370	0	3
Cobia	302	301	300	600	3	11
Red Drum	115	115	115	230	0	2
Sheepshead	144	144	144	288	2	30
Spadefish	211	211	209	418	0	9
Spanish Mackerel	196	196	175	350	0	7
Spot	288	288	202	404	0	2
Spotted Seatrout	428	428	309	618	0	5
Striped Bass	884	1,179	716	2,022	2	24
Summer Flounder	971	1,319	863	2,426	1	13
Tautog	120	346	119	470	2	16
Weakfish	155	155	155	310	1	4
Totals	4,401	5,269	3,763	9,048		

Objective 3: VMRC will develop routine stock assessments based on age-structured models (such as SVPA, ADAPT, Stock Synthesis, and AD Model Builder, among others where appropriate). Following several years of accumulation of aged-catch data, age-structured stock assessment models will be developed and periodically updated.

The purpose of this objective is to prepare VMRC to make contributions to stock assessment of any species along Atlantic coast when requested by Atlantic States Marine Fisheries Commission (ASMFC) and Southeast Data, Assessment and Review (SEDAR). In 2021, ASMFC started to conduct the benchmark stock assessment for Black Drum and the update stock assessment for Striped Bass. The Lab Manager, Dr. Hongsheng Liao, is a member of both Atlantic Striped Bass and Black Drum Stock Assessment Subcommittee, and participated the stock assessment workshops for both species. In the Black Drum Benchmark Stock Assessment, Dr. Liao explored if there were sufficient age data to support any age-structured stock assessment model for Black Drum. Even though he found that there were not sufficient age data for any age-structured stock assessment model for Black Drum, he did find that the current age data could be used to track strong cohort progression through years and to monitor the stock abundance trend identified by the abundance indices used in the stock assessment. In 2021, Dr. Liao continued to update %MSP%fSPR%SPR Estimator by adding more functions in the estimator. One of the new functions allows users to compare %MSP, %Female SPR, and %SPR at the maximum YPR to an expected %MSP, %Female SPR, and %SPR with their corresponding fishing mortality.

Objective 4: Develop VMRC Age and Growth Laboratory web pages at VMRC web site to publish protocols, other aids such as pictures of aged otoliths for all species, and other information to assist *other states and laboratories in the methods of ageing marine fishes.*

Throughout the years we have continued to work on the design and content of a web page that promotes VMRC's efforts to properly manage Virginia's marine resources through our age and growth research. In addition to educating the public on the importance of ageing fishes, the web page has been of interest to fishermen for it provides fundamental information of the life history of Virginia's fishes. We posted VMRC 2020 Ageing Lab Final Report. We also posted Striped Bass Scale Preparation Protocol, Summer Flounder Scale Preparation Protocol, and Tautog Operculum Preparation Protocol. These documents provide the detailed information on what the ageing lab is about, what we do in the lab, and what contributions the ageing lab makes to the coast-wide marine fisheries management.

Objective 5: We will continue developing website-based applications (apps) to enhance sharing Virginia fish and their age data with anglers and fisheries biologists in other agencies.

In 2021, we updated age-length data in VMRC four web applications (Fish Age Estimator, Fish Growth Predictor, VMRC/CQFE Database App, and %MSP/%Female_SPR/%SPR Estimator). These apps help fishermen to understand the importance of knowledge on fish ages and growth, and allow fish and fisheries scientists to easily access and download the age and biological databases of 14 marine finfish species collected by VMRC at Chesapeake Bay and Virginia waters of Atlantic ocean from as early as 1998 to 2021 and aged by the lab. For example, in 2021 we shared VMRC Striped Bass otolith thin-section slides and their age data with Massachusetts Division of Marine Fisheries for its marginal increment analysis of Striped bass in Chesapeake Bay. We provided the age data of Summer Flounder collected by VMRC to New Jersey Fish and Wildlife Department for its gender composition study of Summer Flounder in various systems.

Objective 6: We will continue the publication of our results on accuracy and precision of ageing important marine finfish species, and their effects on stock assessments and fisheries management in scientific literature.

We continued to update the Ageing Lab Operation Protocol in 2021. Anytime when we revised an old processing method and added a new method, we added those new information in the protocol. In 2021, Jessica Gilmore, Chief Technician, participated ASMFC Tautog Spine Ageing Workshop, and we started to learn how to process and age Tautog spines, preparing a protocol for ageing Tautog spines. Therefore, we will be able to post the new protocol at VMRC website and share our expertise on ageing Tautog spines with other agencies along the east coast.

Besides above work the Age and Growth Lab did in 2021, to support environmental and wildlife agencies, and charities, we donated more than 1,336 pounds of dissected fish to the Salvation Army to feed the homeless, and Alton's Keep WildBird Rescue and Rehabilitation Center Inc., a local wildlife rescue agency which is responsible for saving injured animals found by the public.

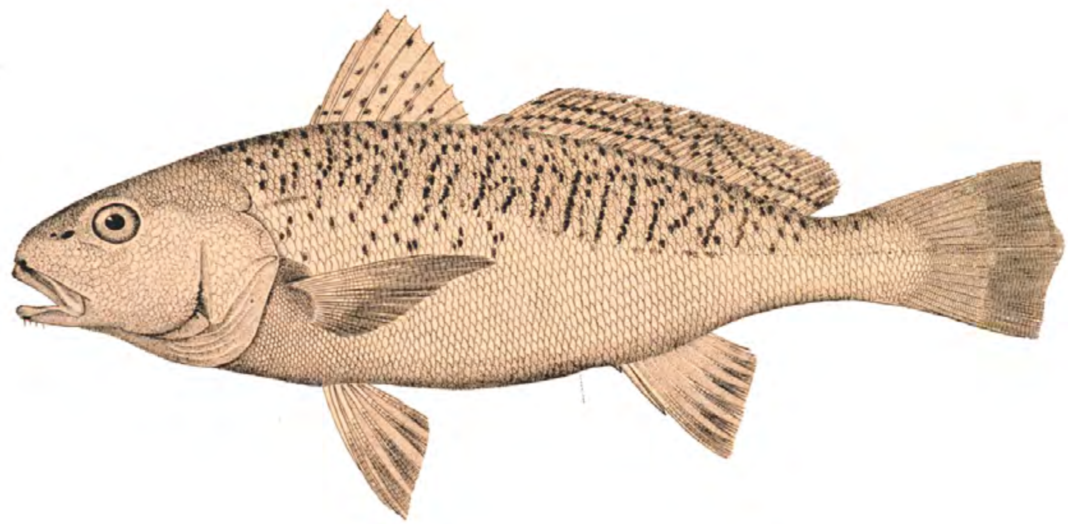
ACKNOWLEDGMENTS

We thank Emily Davis, Marben Abutin, Kate Draa, Kirsten Travis, Savannah Davidson, and Anna-Mai Christmas-Svajdlenka for their technical expertise in preparing otoliths, scales, and opercula for age determination. They all put in long hours processing "tons" of fish in our lab. We would like also to thank the VMRC field technicians, Richard Hancock, Myra Thompson, and Chris Williams, for their many efforts in this cooperative project. A special note of appreciation is extended to Ethan Thompson, VMRC Biological Sampling Program Supervisor, for his help in processing fish,

collecting hardparts, and many other lab activities whenever we were short of hands in the lab.

Chapter 1

ATLANTIC CROAKER *Micropogonias undulatus*



1.1 INTRODUCTION

We aged a total of 245 Atlantic Croaker, *Micropogonias undulatus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Croaker ages ranged from 0 to 11 years old with an average age of 2.6, a standard deviation of 1.9, and a standard error of 0.12. Ten age classes (0 to 8, and 11) were represented, comprising fish of the 2010, and 2013 to 2021 year-classes. The sample was dominated by fish from the year-classes of 2019 and 2020 with 26.5% and 36.7%, respectively.

1.2 METHODS

1.2.1 Sample size for ageing

We estimated sample size for ageing Croaker in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{1.1}$$

where A is the sample size for ageing Croaker in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Croaker used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Croaker collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

1.2.2 Handling of collections

Otoliths were received by the Age and Growth Laboratory in labeled coin envelopes, were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

1.2.3 Preparation

Sagittal otoliths, hereafter, referred to as "otoliths", were processed for age determination following the methods described in Barbieri et al. (1993) with a few modifications. The left or right otolith was randomly selected and attached, distal side down, to a glass slide with clear Crystalbond^{TM} 509 adhesive or imbedded in epoxy. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). Thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Atlantic Croaker.

1.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Atlantic Croaker. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is "2" and as its annulus number plus one when its margin code is "3" or "4" (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Atlantic Croaker otolith annulus formation occurs between April and June (Barbieri et al. 1993, 1994, and modified by CQFE/ODU). A Croaker with three visible annuli could be assigned an age of 3 or 4 depending on its capture month and margin code. When its margin code is "1", it is Age 3 no matter when it is captured. When it is captured after June and before January, it is Age 3 no matter what its margin code is. When it is captured after December and before April and its margin code is not "1", it is Age 4 ($3 + 1 = 4$). When it is captured between April and June, it is Age 3 when its margin code is "2" but Age 4 ($3 + 1 = 4$) when its margin code is "3" or "4".

Due to discrepancy on identification of the first annulus of Atlantic Croaker among Atlantic states, ASMFC has decided not to count the smallest annulus at the center of the thin-section as the first annulus. Following ASMFC's instruction, we didn't count the smallest annulus at the center as the first annulus in 2021 (Figure 1.1).

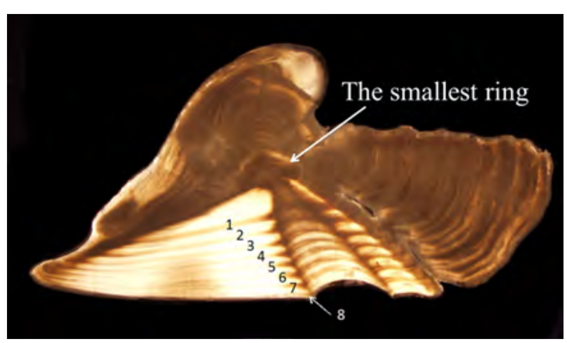


Figure 1.1: Otolith thin-sections of a 8 year-old Croaker without counting the smallest ring and with the last annulus on the edge of the thin-section

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 1.1).

1.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

1.3 RESULTS

1.3.1 Sample size

We estimated a sample size of 457 Atlantic Croaker in 2021, ranging in length interval from 4 to 16 inches (Table 1.1). This sample size provided a range in (CV) for age composition approximately from the smallest (CV) of 8% for Age 4 to the largest (CV) of 24% for Age 7. In 2021, we aged 245 of 309 Croaker (The rest of fish were either without otoliths or over-collected for certain length interval(s)) collected by VMRC. We fell short in our overall collections for this optimal length-class sampling estimate by 224 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

1.3.2 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 94% and a CV of 1.04% (test of symmetry: $\chi^2 = 3$, $df = 3$, $P = 0.3916$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 98% and a CV of 0.31% (test of symmetry: $\chi^2 = 1$, $df = 1$, $P = 0.3173$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 92.65% and a CV of 1.61% (test of symmetry: $\chi^2 = 6.14$, $df = 7$, $P = 0.5232$) (Figure 1.2).

There was no time-series bias for either reader. Reader 1 had an agreement of 100% with ages of fish aged in 2003. Reader 2 also had an agreement of 100% .

1.3.3 Year class

Of the 245 fish aged with otoliths, 10 age classes (0 to 8, and 11) were represented (Table 1.2). The average age was 2.6 years, and the standard deviation and standard error were 1.9 and 0.12, respectively. Year-class data show that the fishery was comprised of 10 year-classes: fish from the 2010, and 2013 to 2021 year-classes, with fish primarily from the year classes of 2019 and 2020 with 26.5% and 36.7%,

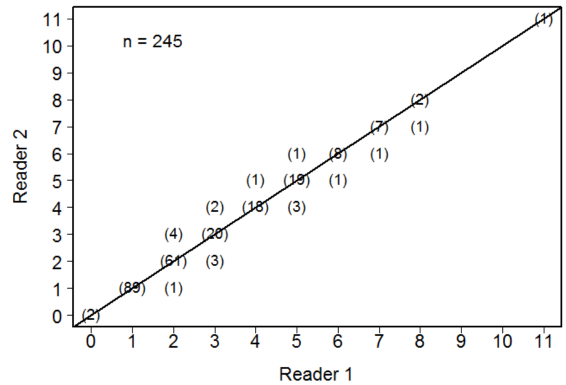


Figure 1.2: Between-reader comparison of otolith age estimates for Atlantic Croaker collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

respectively. The ratio of males to females was 1:5.94 in the sample collected (Figure 1.3).

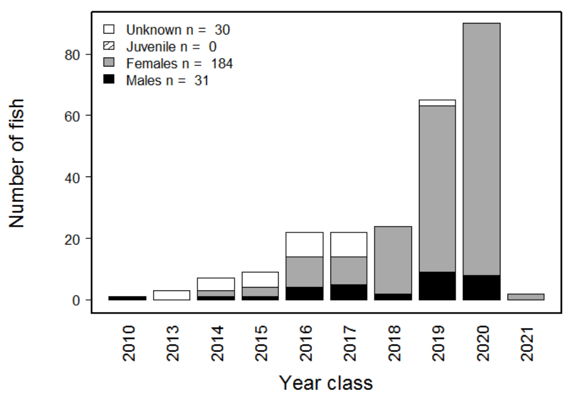


Figure 1.3: Year-class frequency distribution for Atlantic Croaker collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' is for gonads that were not available for examination or were not examined for sex during sampling.

1.3.4 Age-length key (ALK)

We developed an age-length-key (Table 1.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 1.1: Number of Atlantic Croaker collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
4 - 4.99	5	0	0	5
5 - 5.99	5	0	0	5
6 - 6.99	7	0	0	7
7 - 7.99	13	14	14	0
8 - 8.99	11	21	12	0
9 - 9.99	30	76	30	0
10 - 10.99	54	73	64	0
11 - 11.99	90	81	81	9
12 - 12.99	125	35	35	90
13 - 13.99	72	8	8	64
14 - 14.99	30	1	1	29
15 - 15.99	10	0	0	10
16 - 16.99	5	0	0	5
Totals	457	309	245	224

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Table 1.2: The number of Atlantic Croaker assigned to each total length-at-age category for 245 fish sampled for otolith age determination in Virginia during 2021.

	Age										
Interval	0	1	2	3	4	5	6	7	8	11	Totals
7 - 7.99	0	12	2	0	0	0	0	0	0	0	14
8 - 8.99	0	5	1	2	1	3	0	0	0	0	12
9 - 9.99	0	3	8	3	7	4	3	0	2	0	30
10 - 10.99	2	15	14	7	7	9	3	5	1	1	64
11 - 11.99	0	28	26	12	6	6	2	1	0	0	81
12 - 12.99	0	23	9	0	1	0	1	1	0	0	35
13 - 13.99	0	4	4	0	0	0	0	0	0	0	8
14 - 14.99	0	0	1	0	0	0	0	0	0	0	1
Totals	2	90	65	24	22	22	9	7	3	1	245

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Table 1.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Atlantic Croaker sampled for age determination in Virginia during 2021.

	Age									
Interval	0	1	2	3	4	5	6	7	8	11
7 - 7.99	0	0.86	0.14	0	0	0	0	0	0	0
8 - 8.99	0	0.42	0.08	0.17	0.08	0.25	0	0	0	0
9 - 9.99	0	0.1	0.27	0.1	0.23	0.13	0.1	0	0.07	0
10 - 10.99	0.03	0.23	0.22	0.11	0.11	0.14	0.05	0.08	0.02	0.02
11 - 11.99	0	0.35	0.32	0.15	0.07	0.07	0.02	0.01	0	0
12 - 12.99	0	0.66	0.26	0	0.03	0	0.03	0.03	0	0
13 - 13.99	0	0.5	0.5	0	0	0	0	0	0	0
14 - 14.99	0	0	1	0	0	0	0	0	0	0

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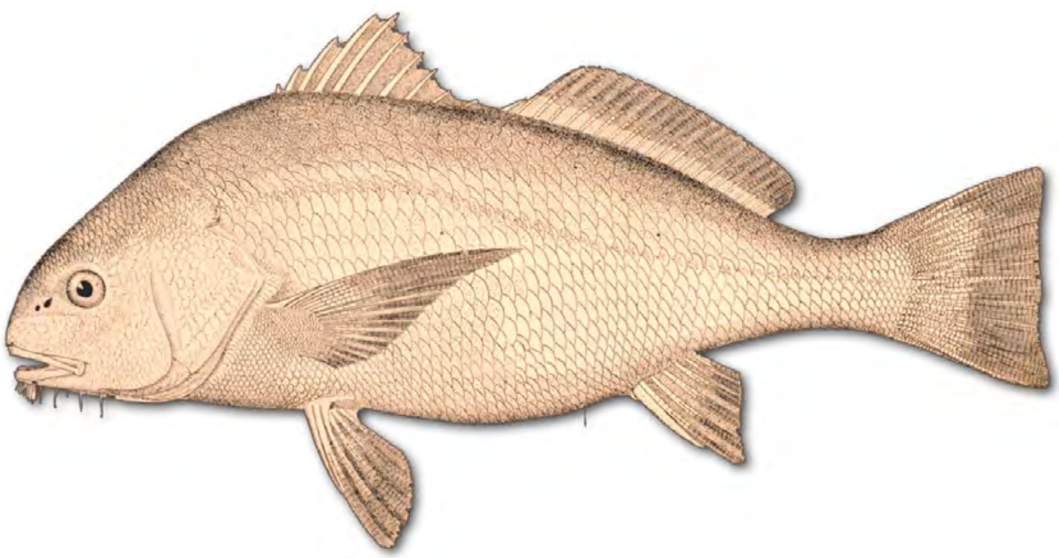
Chapter 2

BLACK DRUM *Pogonias cromis*



2.1 INTRODUCTION

We aged a total of 26 Black Drum, *Pogonias cromis*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Black drum ages ranged from 3 to 60 years old with an average age of 12.8, a standard deviation of 13.2, and a standard error of 2.59. Sixteen age classes (3 to 7, 9, 12 to 16, 18 to 19, 31, 41, and 60) were represented, comprising fish of the 1961, 1980, 1990, 2002 to 2003, 2005 to 2009, 2012, and 2014 to 2018 year-classes. The sample was dominated by fish from the year-classes of 2007, 2009, 2015, 2016, 2017, and 2018 with 7.7%, 7.7%, 7.7%, 11.5%, 15.4%, and 11.5%, respectively.

2.2 METHODS

2.2.1 Handling of collections

Sagittal otoliths, hereafter, referred to as "otoliths", were received by the Age and Growth Laboratory in labeled coin envelopes. In the lab they were sorted by date of capture, their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

2.2.2 Preparation

Otoliths were processed for age determination following the methods described in Bobko (1991) and Jones and Wells (1998). The left or right sagittal otolith was randomly selected and attached, distal side down, to a glass slide with Crystalbond™ 509 adhesive or embedded in epoxy. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet™ low-speed saw equipped with two, three inch diameter, Norton Diamond Grinding Wheels, separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The position of the marked core fell within the 0.5 mm space between the blades, such that the core was included in the removed thin-section. Otolith thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Black Drum.

2.2.3 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Black Drum. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Black Drum otolith annulus formation occurs between May and June (Beckman et al. 1990; Bobko 1991; Jones and Wells 1998). A Black Drum with ten visible annuli could be assigned an age of 10 or 11 depending on its capture month and margin code. When its margin code is "1", it is Age 10 no matter when it is captured. When it is captured after June and before January, it is Age 10 no matter what its margin code is. When it is captured after December and before May and its margin code is not "1", it is Age 11 (10 + 1 = 11). When it is captured between May and June, it is Age 10 when its margin code is "2" but Age 11 (10 + 1 = 11) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 2.1).

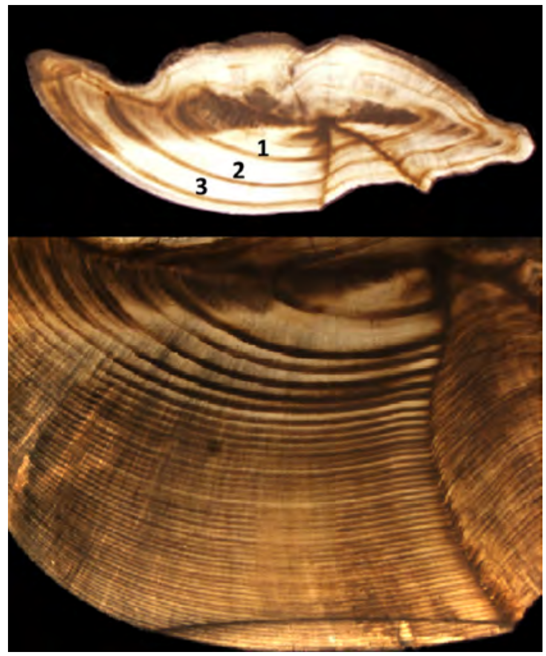


Figure 2.1: Otolith thin-sections of a 3 (Upper panel) and 47 year-old (Lower panel) Black Drum.

2.2.4 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. When the sample size for the current year was smaller than 50, the entire sample was read by each reader for the second time to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

2.3 RESULTS

2.3.1 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 96% and a *CV* of 0.19% (test of symmetry: χ^2 = 1, *df* = 1, *P* = 0.3173), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 100% . There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 100% (Figure 2.2).

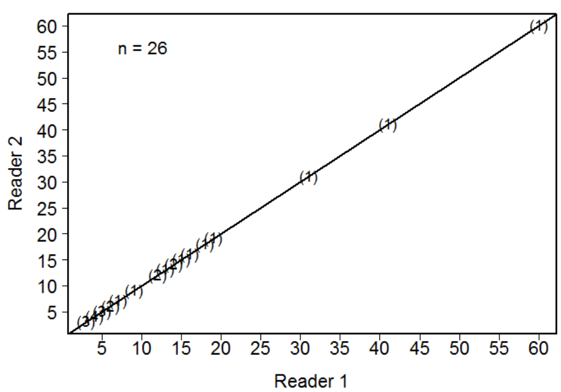


Figure 2.2: Between-reader comparison of otolith age estimates for Black Drum collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 80% with ages of fish aged in 2000 with a *CV* of 0.51% (test of symmetry: χ^2 = 10, *df* = 10, *P* = 0.4405). Reader 2 had an agreement of 84%with a *CV* of 0.84% (test of symmetry: χ^2 = 6, *df* = 7, *P* = 0.5397).

2.3.2 Year class

Of the 26 fish aged with otoliths, 16 age classes (3 to 7, 9, 12 to 16, 18 to 19, 31, 41, and 60) were represented (Table 2.1). The average age was 12.8 years, and the standard deviation and standard error were 13.2 and 2.59, respectively. Year-class data show that the fishery was comprised of 16 year-classes: fish from the 1961, 1980, 1990, 2002 to 2003, 2005 to 2009, 2012, and 2014 to 2018 year-classes, with fish primarily from the year classes of 2007, 2009, 2015, 2016, 2017, and 2018 with 7.7%, 7.7%, 7.7%, 11.5%, 15.4%, and 11.5%, respectively. The ratio of males to females was 1:2.25 in the sample collected (Figure 2.3).

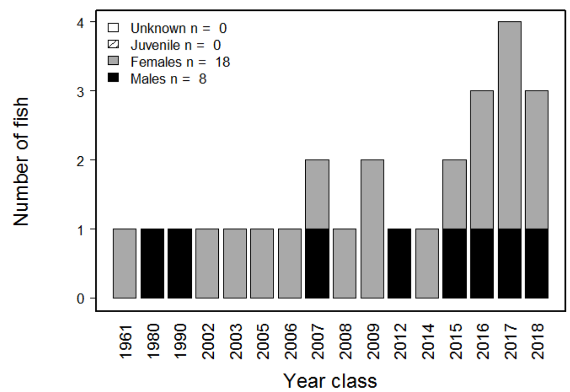


Figure 2.3: Year-class frequency distribution for Black Drum collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

2.3.3 Age-length key (ALK)

We developed an age-length-key (Table 2.2) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 2.1: The number of Black Drum assigned to each total length (inch)-at-age category for 26 fish sampled for otolith age determination in Virginia during 2021.

	Age																
Interval	3	4	5	6	7	9	12	13	14	15	16	18	19	31	41	60	Totals
20 - 20.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
22 - 22.99	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
25 - 25.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27 - 27.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28 - 28.99	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
30 - 30.99	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31 - 31.99	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	3
32 - 32.99	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
34 - 34.99	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
36 - 36.99	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
37 - 37.99	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	3
38 - 38.99	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
39 - 39.99	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
42 - 42.99	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	3
46 - 46.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
Totals	3	4	3	2	1	1	2	1	2	1	1	1	1	1	1	1	26

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Table 2.2: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Black Drum sampled for age determination in Virginia during 2021.

	Age															
Interval	3	4	5	6	7	9	12	13	14	15	16	18	19	31	41	60
20 - 20.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 - 22.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 - 25.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 - 27.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28 - 28.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 30.99	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
31 - 31.99	0	0	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0	0
32 - 32.99	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
34 - 34.99	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
36 - 36.99	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
37 - 37.99	0	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	0	0
38 - 38.99	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
39 - 39.99	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
42 - 42.99	0	0	0	0	0	0	0	0	0.33	0	0.33	0.33	0	0	0	0
46 - 46.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33

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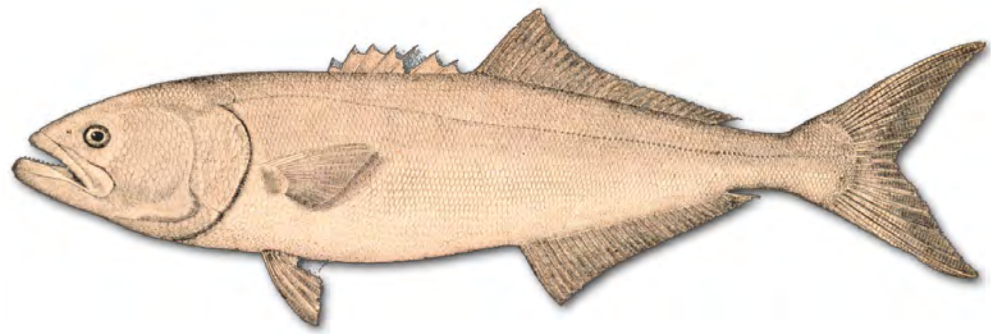
Chapter 3

BLUEFISH *Pomatomus saltatrix*



3.1 INTRODUCTION

We aged a total of 185 Bluefish, *Pomatomus saltatrix*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Bluefish ages ranged from 0 to 3 years old with an average age of 1.4, a standard deviation of 0.8, and a standard error of 0.06. Four age classes (0 to 3) were represented, comprising fish of the 2018 to 2021 year-classes. The sample was dominated by fish from the year-class of 2020 with 61.6%.

3.2 METHODS

3.2.1 Sample size for ageing

We estimated sample size for ageing Bluefish in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \quad (3.1)$$

where A is the sample size for ageing Bluefish in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Bluefish used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Bluefish collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021. Based on VMRC's request in 2010, we used 1-cm length interval for Bluefish, which differed from other species (1-inch).

3.2.2 Handling of collections

Otoliths were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

3.2.3 Preparation

We used our thin-section and bake technique to process Bluefish sagittal otoliths (hereafter, referred to as "otoliths") for age determination (Robillard et al. 2009). Otolith preparation began by randomly selecting either the right or left otolith. Each whole otolith was placed in a ceramic "Coors" spot plate well and baked in a Thermolyne 1400 furnace at 400 °C. Baking time was dependent on the otolith's size and gauged by color, with a light caramel color desired. Once a suitable color was achieved the baked otolith was embedded in epoxy resin with its distal surface orientated downwards. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core. Then, the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet™ low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The otolith was positioned so the blades straddled each side of the otolith focus. It was crucial that this cut be perpendicular to the long axis of the otolith. Failure to do so resulted in broad and distorted winter growth zones. A proper cut resulted in annuli that were clearly defined and delineated. Once cut, thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Bluefish.

3.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Bluefish. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code “1”, “2”, “3”, and “4” stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Bluefish otolith annulus formation occurs between March and June (Robillard et al. 2009). A Bluefish with three visible annuli could be assigned an age of 3 or 4 depending on its capture month and margin code. When its margin code is "1", it is Age 3 no matter when it is captured. When it is captured after June and before January, it is Age 3 no matter what its margin code is. When it is captured after December and before March and its margin code is not "1", it is Age 4 (3 + 1 = 4). When it is captured between March and June, it is Age 3 when its margin code is "2" but Age 4 (3 + 1 = 4) when its margin code is "3" or "4".

All thin-sections were aged by two different readers using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 3.1). Each reader aged all of the otolith samples.

If an otolith was properly sectioned, the sulcal groove came to a sharp point within the middle of the focus. Typically the first year's annulus

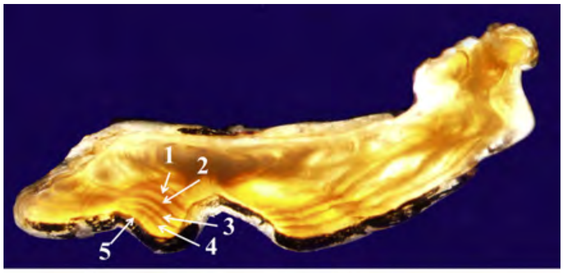


Figure 3.1: Otolith thin-section of a 5 year-old Bluefish with the last annulus on the edge of the thin-section

was found by locating the focus of the otolith, which was characterized as a visually distinct dark, oblong region found in the center of the otolith. The first year's annulus had the highest visibility proximal to the focus along the edge of the sulcal groove. Once located, the first year's annulus was followed outward from the sulcal groove towards the dorsal perimeter of the otolith. Often, but not always, the first year was associated with a very distinct crenellation on the dorsal surface and a prominent protrusion on the ventral surface. Both of these landmarks had a tendency to become less prominent in older fish.

Even with the bake and thin-section technique, interpretation of the growth zones from the otoliths of young Bluefish was difficult. Rapid growth within the first year of life prevents a sharp delineation between opaque and translucent zones. When the exact location of the first year was not clearly evident, and the otolith had been sectioned accurately, a combination of surface landscape (1st year crenellation) and the position of the second annuli were used to help determine the position of the first annulus.

What appeared to be "double annuli" were occasionally observed in Bluefish 4-7 years of age and older. This double-annulus formation was typically characterized by distinct and separate annuli in extremely close proximity to each other. We do not know if the formation of these double annuli were two separate annuli, or in fact only one, but they seemed to occur during times of reduced growth after maturation. "Double annuli" were considered to be one annulus when both marks joined to form a central origin (the origin being the sulcal groove and the outer peripheral edge of the otolith). If these annuli did not meet to form a central origin they were considered two distinct annuli, and were counted as such.

All samples were aged in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, both readers sat down together and re-aged the fish, again without any knowledge of previously estimated ages or lengths, and assigned a final age to the fish. When the readers were unable to agree on a final age, the fish was excluded from further analysis.

3.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

3.3 RESULTS

3.3.1 Sample size

We estimated a sample size of 421 Bluefish in 2021, ranging in length interval from 14 to 121 centimeters (Table 3.1). This sample size provided a range in (CV) for age composition approximately from the smallest (CV) of 6% for Age 1 to the largest (CV) of 23% for Age 8. In 2021, we aged 185 of 252 Bluefish (The rest of fish were either without otoliths or over-collected for certain length interval(s)) collected by VMRC. We fell short in our over-all collections for this optimal length-class sampling estimate by 262 fish, as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

3.3.2 Reading precision

Both readers had high self-precision.Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 96% and a CV of 1.35% (test of symmetry: χ^2 = 2, df = 2, P = 0.3679), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 100% . There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 97.3% and a CV of 1.99% (test of symmetry: χ^2 = 5, df = 2, P = 0.0821) (Figure 3.2).

There was no time-series bias for either reader. Reader 1 had an agreement of 92% with ages of fish aged in 2000 with a CV of 6.73% (test of symmetry: χ^2 = 4, df = 3, P = 0.2615). Reader 2 had an agreement of 96% with a CV of 3.77% (test of symmetry: χ^2 = 2, df = 2, P = 0.3679).

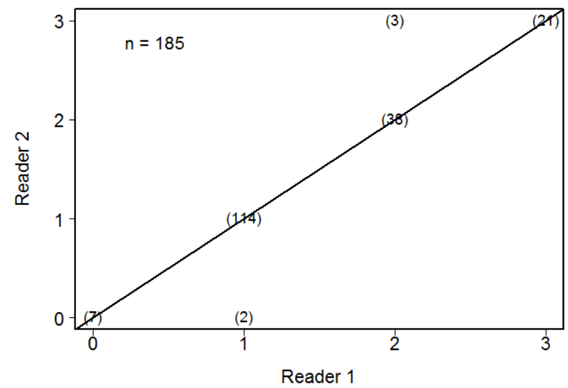


Figure 3.2: Between-reader comparison of otolith age estimates for Bluefish collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

3.3.3 Year class

Of the 185 fish aged with otoliths, 4 age classes (0 to 3) were represented (Table 3.2). The average age was 1.4 years, and the standard deviation and standard error were 0.8 and 0.06, respectively. Year-class data show that the fishery was comprised of 4 year-classes: fish from the 2018 to 2021 year-classes, with fish primarily from the year class of 2020 with 61.6%. The ratio of males to females was 1:1.84 in the sample collected (Figure 3.3).

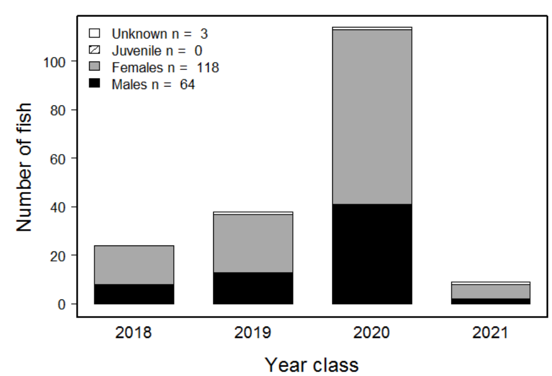


Figure 3.3: Year-class frequency distribution for Bluefish collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

3.3.4 Age-length key (ALK)

We developed an age-length-key (Table 3.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length cm intervals.

Table 3.1: Number of Bluefish collected and aged in each 1-cm length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

(Go back to text)

Interval	Target	Collected	Aged	Need
14 - 14.99	5	0	0	5
17 - 17.99	5	0	0	5
18 - 18.99	5	0	0	5
19 - 19.99	5	1	1	4
20 - 20.99	5	0	0	5
21 - 21.99	5	0	0	5
22 - 22.99	5	0	0	5
23 - 23.99	5	3	3	2
24 - 24.99	5	0	0	5
25 - 25.99	5	3	3	2
26 - 26.99	5	6	6	0
27 - 27.99	5	6	6	0
28 - 28.99	5	9	6	0
29 - 29.99	5	14	6	0
30 - 30.99	5	11	7	0
31 - 31.99	5	10	6	0
32 - 32.99	5	9	6	0
33 - 33.99	5	10	6	0
34 - 34.99	5	14	6	0
35 - 35.99	5	14	6	0
36 - 36.99	5	12	6	0
37 - 37.99	5	7	6	0
38 - 38.99	5	10	7	0
39 - 39.99	5	5	5	0
40 - 40.99	5	6	6	0
41 - 41.99	5	16	6	0
42 - 42.99	5	6	6	0
43 - 43.99	5	9	6	0
44 - 44.99	5	8	6	0
45 - 45.99	6	8	8	0
46 - 46.99	5	8	8	0
47 - 47.99	5	6	6	0
48 - 48.99	5	3	3	2
49 - 49.99	5	1	1	4
50 - 50.99	5	1	1	4
51 - 51.99	5	2	2	3
52 - 52.99	5	1	1	4
53 - 53.99	5	3	3	2
54 - 54.99	5	3	3	2
55 - 55.99	5	3	3	2
56 - 56.99	5	1	1	4

(To continue)

Table 3.1 (Continued)

Interval	Target	Collected	Aged	Need
57 - 57.99	5	2	2	3
58 - 58.99	5	2	2	3
59 - 59.99	5	0	0	5
60 - 60.99	5	3	3	2
61 - 61.99	5	2	2	3
62 - 62.99	5	4	4	1
63 - 63.99	5	2	2	3
64 - 64.99	5	2	2	3
65 - 65.99	5	2	2	3
66 - 66.99	5	0	0	5
67 - 67.99	5	2	2	3
68 - 68.99	5	0	0	5
69 - 69.99	5	0	0	5
70 - 70.99	5	0	0	5
71 - 71.99	5	0	0	5
72 - 72.99	5	0	0	5
73 - 73.99	5	0	0	5
74 - 74.99	5	1	1	4
75 - 75.99	5	1	1	4
76 - 76.99	5	0	0	5
77 - 77.99	5	0	0	5
78 - 78.99	5	0	0	5
79 - 79.99	5	0	0	5
80 - 80.99	5	0	0	5
81 - 81.99	5	0	0	5
82 - 82.99	5	0	0	5
83 - 83.99	5	0	0	5
84 - 84.99	5	0	0	5
85 - 85.99	5	0	0	5
86 - 86.99	5	0	0	5
87 - 87.99	5	0	0	5
88 - 88.99	5	0	0	5
89 - 89.99	5	0	0	5
90 - 90.99	5	0	0	5
91 - 91.99	5	0	0	5
92 - 92.99	5	0	0	5
93 - 93.99	5	0	0	5
94 - 94.99	5	0	0	5
95 - 95.99	5	0	0	5
96 - 96.99	5	0	0	5
97 - 97.99	5	0	0	5
98 - 98.99	5	0	0	5
121 - 121.99	5	0	0	5
Totals	421	252	185	262

(Go back to text)

Table 3.2: The number of Bluefish assigned to each total length (cm)-at-age category for 185 fish sampled for otolith age determination in Virginia during 2021.

	Age				
Interval	0	1	2	3	Totals
19 - 19.99	1	0	0	0	1
23 - 23.99	1	2	0	0	3
25 - 25.99	0	3	0	0	3
26 - 26.99	1	5	0	0	6
27 - 27.99	2	4	0	0	6
28 - 28.99	1	5	0	0	6
29 - 29.99	0	6	0	0	6
30 - 30.99	0	7	0	0	7
31 - 31.99	1	5	0	0	6
32 - 32.99	2	4	0	0	6
33 - 33.99	0	6	0	0	6
34 - 34.99	0	6	0	0	6
35 - 35.99	0	6	0	0	6
36 - 36.99	0	6	0	0	6
37 - 37.99	0	4	2	0	6
38 - 38.99	0	7	0	0	7
39 - 39.99	0	2	2	1	5
40 - 40.99	0	3	3	0	6
41 - 41.99	0	4	2	0	6
42 - 42.99	0	5	1	0	6
43 - 43.99	0	4	2	0	6
44 - 44.99	0	5	1	0	6
45 - 45.99	0	4	4	0	8
46 - 46.99	0	4	4	0	8
47 - 47.99	0	4	2	0	6
48 - 48.99	0	1	2	0	3
49 - 49.99	0	0	1	0	1
50 - 50.99	0	1	0	0	1
51 - 51.99	0	0	2	0	2
52 - 52.99	0	0	0	1	1
53 - 53.99	0	1	0	2	3
54 - 54.99	0	0	3	0	3
55 - 55.99	0	0	2	1	3
56 - 56.99	0	0	0	1	1
57 - 57.99	0	0	1	1	2
58 - 58.99	0	0	1	1	2
60 - 60.99	0	0	1	2	3
61 - 61.99	0	0	0	2	2
62 - 62.99	0	0	2	2	4
63 - 63.99	0	0	0	2	2
64 - 64.99	0	0	0	2	2

(To continue)

Table 3.2 (Continued)

					Age
Interval	0	1	2	3	Totals
65 - 65.99	0	0	0	2	2
67 - 67.99	0	0	0	2	2
74 - 74.99	0	0	0	1	1
75 - 75.99	0	0	0	1	1
Totals	9	114	38	24	185

(Go back to text)

Table 3.3: Age-Length key, as proportion-at-age in each 1-cm length interval, based on otolith ages for Bluefish sampled for age determination in Virginia during 2021.

	Age			
Interval	0	1	2	3
19 - 19.99	1	0	0	0
23 - 23.99	0.33	0.67	0	0
25 - 25.99	0	1	0	0
26 - 26.99	0.17	0.83	0	0
27 - 27.99	0.33	0.67	0	0
28 - 28.99	0.17	0.83	0	0
29 - 29.99	0	1	0	0
30 - 30.99	0	1	0	0
31 - 31.99	0.17	0.83	0	0
32 - 32.99	0.33	0.67	0	0
33 - 33.99	0	1	0	0
34 - 34.99	0	1	0	0
35 - 35.99	0	1	0	0
36 - 36.99	0	1	0	0
37 - 37.99	0	0.67	0.33	0
38 - 38.99	0	1	0	0
39 - 39.99	0	0.4	0.4	0.2
40 - 40.99	0	0.5	0.5	0
41 - 41.99	0	0.67	0.33	0
42 - 42.99	0	0.83	0.17	0
43 - 43.99	0	0.67	0.33	0
44 - 44.99	0	0.83	0.17	0
45 - 45.99	0	0.5	0.5	0
46 - 46.99	0	0.5	0.5	0
47 - 47.99	0	0.67	0.33	0
48 - 48.99	0	0.33	0.67	0
49 - 49.99	0	0	1	0
50 - 50.99	0	1	0	0
51 - 51.99	0	0	1	0
52 - 52.99	0	0	0	1
53 - 53.99	0	0.33	0	0.67
54 - 54.99	0	0	1	0
55 - 55.99	0	0	0.67	0.33
56 - 56.99	0	0	0	1
57 - 57.99	0	0	0.5	0.5
58 - 58.99	0	0	0.5	0.5
60 - 60.99	0	0	0.33	0.67
61 - 61.99	0	0	0	1
62 - 62.99	0	0	0.5	0.5
63 - 63.99	0	0	0	1
64 - 64.99	0	0	0	1

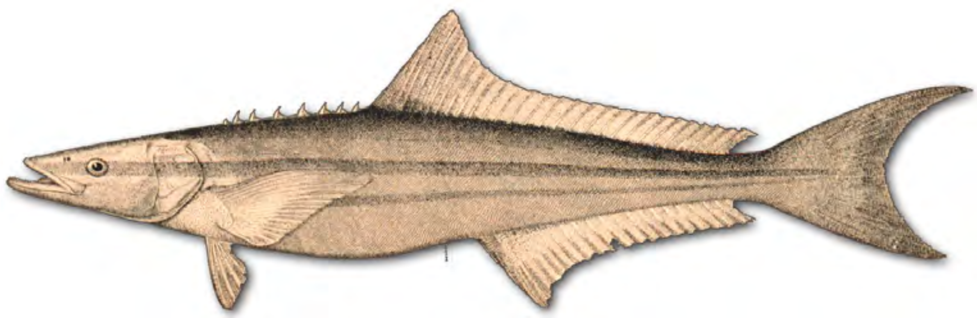
(To continue)

Table 3.3 (Continued)

				Age
Interval	0	1	2	3
65 - 65.99	0	0	0	1
67 - 67.99	0	0	0	1
74 - 74.99	0	0	0	1
75 - 75.99	0	0	0	1

Chapter 4

COBIA *Rachycentron canadum*



4.1 INTRODUCTION

We aged a total of 300 Cobia, *Rachycentron canadum*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Cobia ages ranged from 3 to 11 years old with an average age of 4.8, a standard deviation of 1.5, and a standard error of 0.09. Nine age classes (3 to 11) were represented, comprising fish of the 2010 to 2018 year-classes. The sample was dominated by fish from the year-classes of 2015, 2016, 2017, and 2018 with 19.7%, 31.7%, 12.7%, and 26.3%, respectively.

4.2 METHODS

4.2.1 Handling of collections

Sagittal otoliths, hereafter, referred to as "otoliths", were received by the Age and Growth Laboratory in labeled coin envelopes and were sorted by date of capture, their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored inside of protective Axygen 2 ml micro-tubes within their original labeled coin envelopes.

4.2.2 Preparation

Otoliths were processed for age determination. The left or right otolith was randomly selected and embedded, distal side down, in epoxy resin and allowed to harden overnight. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, three inch diameter, Norton Diamond Grinding Wheels, separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The position of the marked core fell within the 0.5 mm space between the blades, such that the core was included in the removed thin section. Otolith thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Cobia.

4.2.3 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Cobia. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Cobia otolith annulus formation occurs between June and July (Richards 1967 and modified by CQFE/ODU). A Cobia with five visible annuli could be assigned an age of 5 or 6 depending on its capture month and margin code. When its margin code is "1", it is Age 5 no matter when it is captured. When it is captured after July and before January, it is Age 5 no matter what its margin code is. When it is captured after December and before June and its margin code is not "1", it is Age 6 (5 + 1 = 6). When it is captured between June and July, it is Age 5 when its margin code is "2" but Age 6 (5 + 1 = 6) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 4.1).

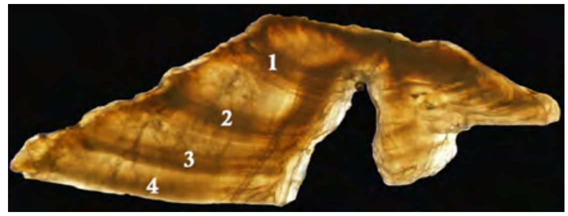


Figure 4.1: Otolith thin-section of a 4 year-old Cobia.

4.2.4 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (*CV*) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

4.3 RESULTS

4.3.1 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 94% and a *CV* of 0.69% (test of symmetry: $\chi^2 = 1$, $df = 2$, $P = 0.6065$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 96%

and a *CV* of 0.51% (test of symmetry: $\chi^2 = 2$, $df = 1$, $P = 0.1573$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 95.33% and a *CV* of 0.67% (test of symmetry: $\chi^2 = 6$, $df = 7$, $P = 0.5397$) (Figure 4.2).

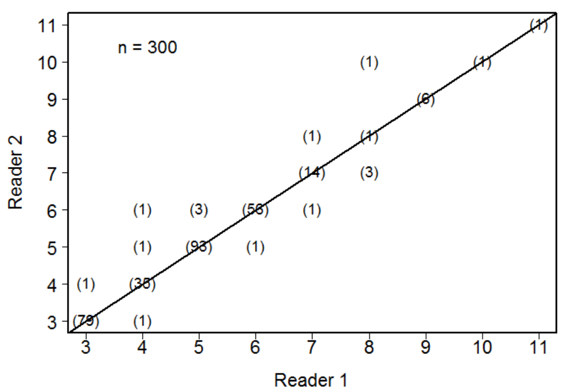


Figure 4.2: Between-reader comparison of otolith age estimates for Cobia collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 78% with ages of fish aged in 2000 with a *CV* of 2.5% (test of symmetry: $\chi^2 = 9$, $df = 9$, $P = 0.4373$). Reader 2 had an agreement of 80% with a *CV* of 1.86% (test of symmetry: $\chi^2 = 6$, $df = 7$, $P = 0.5397$).

4.3.2 Year class

Of the 300 fish aged with otoliths, 9 age classes (3 to 11) were represented (Table 4.1). The average age was 4.8 years, and the standard deviation and standard error were 1.5 and 0.09, respectively. Year-class data show that the fishery was comprised of 9 year-classes: fish from the 2010 to 2018 year-classes, with fish primarily from the year classes of 2015, 2016, 2017, and 2018 with 19.7%, 31.7%, 12.7%, and 26.3%, respectively. The ratio of males to females was 1:2.66 in the sample collected (Figure 4.3).

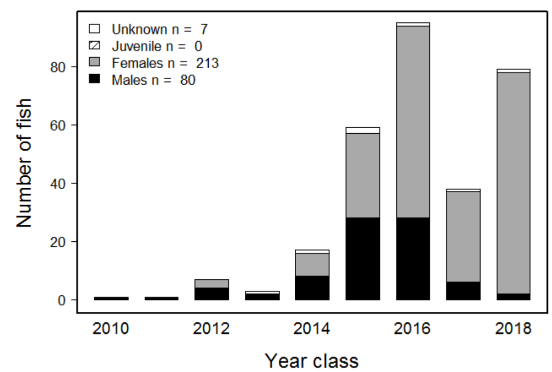


Figure 4.3: Year-class frequency distribution for Cobia collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

4.3.3 Age-length key (ALK)

We developed an age-length-key (Table 4.2) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 4.1: The number of Cobia assigned to each total length (inch)-at-age category for 300 fish sampled for otolith age determination in Virginia during 2021.

	Age									
Interval	3	4	5	6	7	8	9	10	11	Totals
36 - 36.99	4	0	0	0	0	0	0	0	0	4
37 - 37.99	4	1	1	0	0	0	0	0	0	6
38 - 38.99	10	1	2	0	0	0	0	0	0	13
39 - 39.99	14	3	6	2	1	0	0	0	0	26
40 - 40.99	13	3	9	3	0	0	1	0	0	29
41 - 41.99	16	5	6	6	0	0	0	0	0	33
42 - 42.99	7	9	9	11	2	0	0	0	0	38
43 - 43.99	6	5	9	2	1	1	2	0	0	26
44 - 44.99	3	6	11	4	2	2	1	0	0	29
45 - 45.99	2	2	16	3	2	0	0	0	0	25
46 - 46.99	0	3	10	2	0	0	0	1	0	16
47 - 47.99	0	0	9	6	2	0	1	0	1	19
48 - 48.99	0	0	2	2	1	0	0	0	0	5
49 - 49.99	0	0	2	5	1	0	0	0	0	8
50 - 50.99	0	0	3	2	2	0	0	0	0	7
51 - 51.99	0	0	0	5	2	0	1	0	0	8
52 - 52.99	0	0	0	2	1	0	0	0	0	3
53 - 53.99	0	0	0	1	0	0	0	0	0	1
54 - 54.99	0	0	0	2	0	0	1	0	0	3
57 - 57.99	0	0	0	1	0	0	0	0	0	1
Totals	79	38	95	59	17	3	7	1	1	300

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Table 4.2: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Cobia sampled for age determination in Virginia during 2021.

	Age								
Interval	3	4	5	6	7	8	9	10	11
36 - 36.99	1	0	0	0	0	0	0	0	0
37 - 37.99	0.67	0.17	0.17	0	0	0	0	0	0
38 - 38.99	0.77	0.08	0.15	0	0	0	0	0	0
39 - 39.99	0.54	0.12	0.23	0.08	0.04	0	0	0	0
40 - 40.99	0.45	0.1	0.31	0.1	0	0	0.03	0	0
41 - 41.99	0.48	0.15	0.18	0.18	0	0	0	0	0
42 - 42.99	0.18	0.24	0.24	0.29	0.05	0	0	0	0
43 - 43.99	0.23	0.19	0.35	0.08	0.04	0.04	0.08	0	0
44 - 44.99	0.1	0.21	0.38	0.14	0.07	0.07	0.03	0	0
45 - 45.99	0.08	0.08	0.64	0.12	0.08	0	0	0	0
46 - 46.99	0	0.19	0.62	0.12	0	0	0	0.06	0
47 - 47.99	0	0	0.47	0.32	0.11	0	0.05	0	0.05
48 - 48.99	0	0	0.4	0.4	0.2	0	0	0	0
49 - 49.99	0	0	0.25	0.62	0.12	0	0	0	0
50 - 50.99	0	0	0.43	0.29	0.29	0	0	0	0
51 - 51.99	0	0	0	0.62	0.25	0	0.12	0	0
52 - 52.99	0	0	0	0.67	0.33	0	0	0	0
53 - 53.99	0	0	0	1	0	0	0	0	0
54 - 54.99	0	0	0	0.67	0	0	0.33	0	0
57 - 57.99	0	0	0	1	0	0	0	0	0

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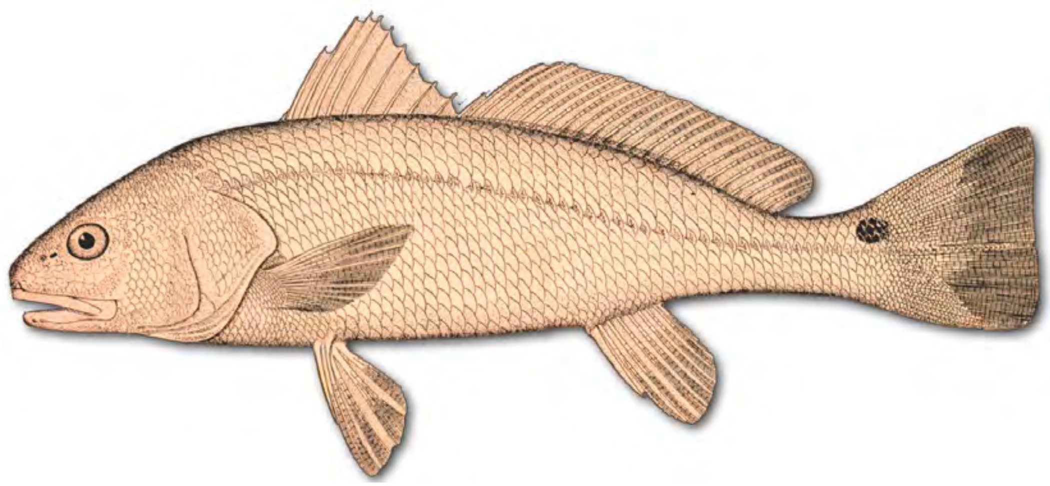
Chapter 5

RED DRUM *Sciaenops ocellatus*



5.1 INTRODUCTION

We aged a total of 115 Red Drum, *Sciaenops ocellatus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Red drum ages ranged from 0 to 2 years old with an average age of 1.2, a standard deviation of 0.4, and a standard error of 0.04. Three age classes (0 to 2) were represented, comprising fish of the 2019 to 2021 year-classes. The sample was dominated by fish from the year-class of 2020 with 76.5%.

5.2 METHODS

5.2.1 Handling of collections

Sagittal otoliths, hereafter, referred to as "otoliths", were received by the Age and Growth Laboratory in labeled coin envelopes, and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

5.2.2 Preparation

Otoliths were processed for age determination following the methods described in Ross et al. (1995) and Jones and Wells (1998) for Red Drum. The left or right sagittal otolith was randomly selected and attached, distal side down, to a glass slide with Crystalbond^{TM} 509 adhesive. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, three inch diameter, Norton Diamond Grinding Wheels, separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The position of the marked core fell within the 0.5 mm space between the blades, such that the core was included in the removed thin-section. Otolith thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Red Drum.

5.2.3 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Red Drum. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code “1”, “2”, “3”, and “4” stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is "2" and as its annulus number plus one when its margin code is "3" or "4" (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Red Drum otolith annulus formation occurs between March and July (Ross et al. 1995 and modified by CQFE/ODU). A Red Drum with two visible annuli could be assigned an age of 2 or 3 depending on its capture month and margin code. When its margin code is "1", it is Age 2 no matter when it is captured. When it is captured after July and before January, it is Age 2 no matter what its margin code is. When it is captured after December and before March and its margin code is not "1", it is Age 3 (2 + 1 = 3). When it is captured between March and July, it is Age 2 when its margin code is "2" but Age 3 (2 + 1 = 3) when its margin code is "3" or "4".

Due to discrepancy on identification of the first annulus of Red Drum among Atlantic states, ASMFC has decided not to count the smallest annulus at the center of the thin-section as the first annulus. Following ASMFC's instruction, we didn't count the smallest annulus at the center as the first annulus in 2021 (Figure 5.1).

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader

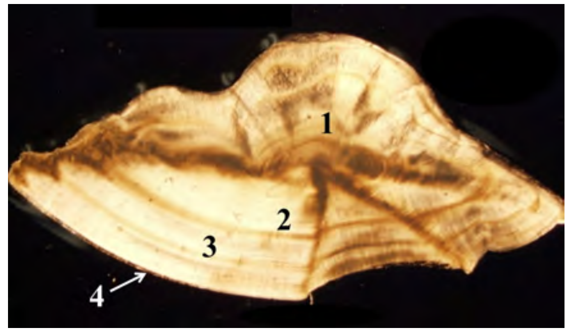


Figure 5.1: Otolith thin-section of a 3 year-old Red Drum with the last annulus on the edge of the thin-section

1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 4.1).

5.2.4 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

5.3 RESULTS

5.3.1 Reading precision

Reader 1 had moderate self-precision and Read 2 had high self-precision. Specifically, there was a difference between the first and second readings for Reader 1 with an agreement of 88% and a *CV* of 5.28% (test of symmetry: $\chi^2 = 6$, $df = 2$, $P = 0.0498$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 96%and a *CV* of 1.89% (test of symmetry: $\chi^2 = 2$, $df = 1$, $P = 0.1573$). There was an evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 93.04% and a *CV* of 3.28% (test of symmetry: $\chi^2 = 8$, $df = 1$, $P = 0.0047$) (Figure 5.2).

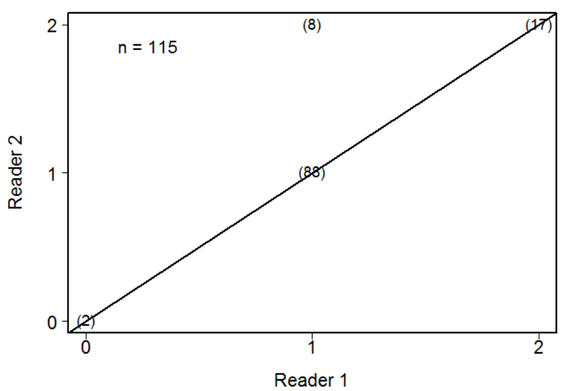


Figure 5.2: Between-reader comparison of otolith age estimates for Red Drum collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 96% with ages of fish aged in 2000 with a *CV* of 1.11% (test of symmetry: $\chi^2 = 2$, $df = 2$, $P = 0.3679$). Reader 2 also had an agreement of 100% .

5.3.2 Year class

Of the 115 fish aged with otoliths, 3 age classes (0 to 2) were represented (Table 5.1). The average age was 1.2 years, and the standard deviation and standard error were 0.4 and 0.04, respectively. Year-class data show that the fishery was comprised of 3 year-classes: fish from the 2019 to 2021 year-classes, with fish primarily from the year class of 2020 with 76.5%. The ratio of males to females was 1:0.74 in the sample collected (Figure 5.3).

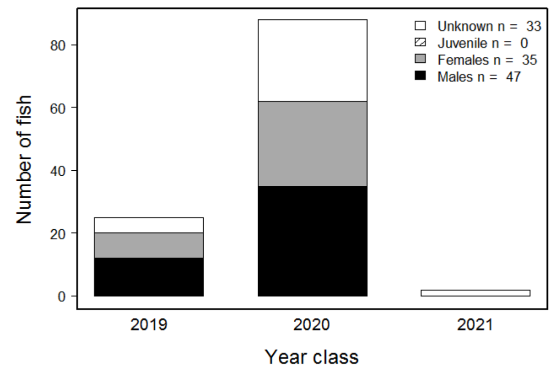


Figure 5.3: Year-class frequency distribution for Red Drum collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

5.3.3 Age-length key (ALK)

We developed an age-length-key (Table 5.2) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 5.1: The number of Red Drum assigned to each total length (inch)-at-age category for 115 fish sampled for otolith age determination in Virginia during 2021.

	Age			
Interval	0	1	2	Totals
16 - 16.99	1	0	0	1
17 - 17.99	1	8	0	9
18 - 18.99	0	6	3	9
19 - 19.99	0	10	5	15
20 - 20.99	0	8	0	8
21 - 21.99	0	15	1	16
22 - 22.99	0	14	0	14
23 - 23.99	0	11	4	15
24 - 24.99	0	11	3	14
25 - 25.99	0	4	4	8
26 - 26.99	0	0	5	5
27 - 27.99	0	1	0	1
Totals	2	88	25	115

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Table 5.2: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Red Drum sampled for age determination in Virginia during 2021.

	Age		
Interval	0	1	2
16 - 16.99	1	0	0
17 - 17.99	0.11	0.89	0
18 - 18.99	0	0.67	0.33
19 - 19.99	0	0.67	0.33
20 - 20.99	0	1	0
21 - 21.99	0	0.94	0.06
22 - 22.99	0	1	0
23 - 23.99	0	0.73	0.27
24 - 24.99	0	0.79	0.21
25 - 25.99	0	0.5	0.5
26 - 26.99	0	0	1
27 - 27.99	0	1	0

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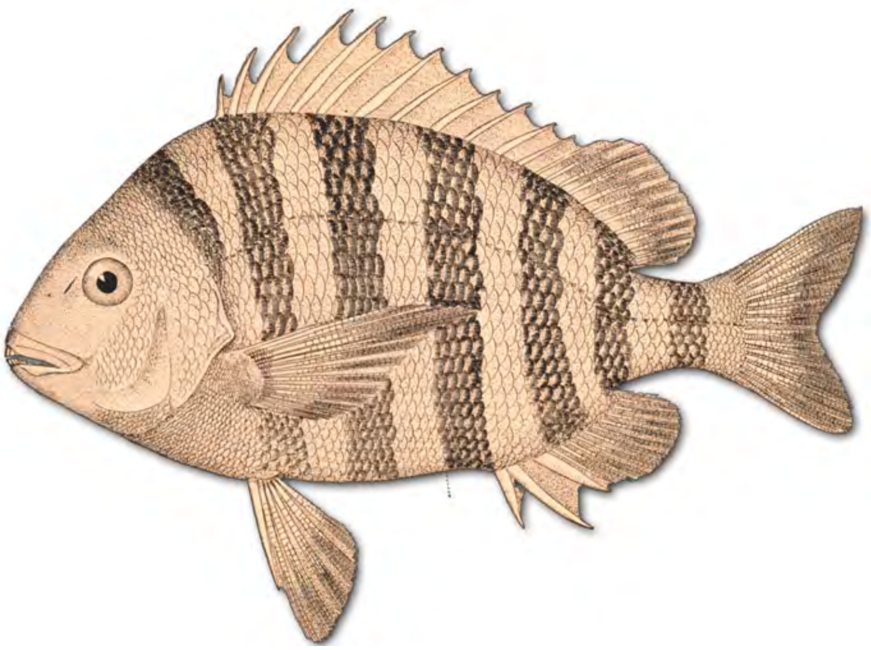
Chapter 6

SHEEPSHEAD *Archosargus probatocephalus*



6.1 INTRODUCTION

We aged a total of 144 Sheepshead, *Archosargus probatocephalus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Sheepshead ages ranged from 2 to 30 years old with an average age of 9.1, a standard deviation of 7.3, and a standard error of 0.61. Twenty-two age classes (2 to 18, 20, 23 to 24, and 29 to 30) were represented, comprising fish of the 1991 to 1992, 1997 to 1998, 2001, and 2003 to 2019 year-classes. The sample was dominated by fish from the year-classes of 2016 and 2019 with 17.4% and 23.6%, respectively.

6.2 METHODS

6.2.1 Handling of collections

Sagittal otoliths, hereafter, referred to as "otoliths", were received by the Age and Growth Laboratory in labeled coin envelopes,and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

6.2.2 Preparation

Otoliths were processed for age determination following the methods described in Ballenger (2011). The left or right otolith was randomly selected and embedded, distal side down, in epoxy resin and allowed to harden overnight. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, three inch diameter, Norton Diamond Grinding Wheels, separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The position of the marked core fell within the 0.5 mm space between the blades, such that the core was included in the removed thin section. Otolith thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Sheepshead.

6.2.3 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Sheepshead. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January

1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is "2" and as its annulus number plus one when its margin code is "3" or "4" (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Sheepshead otolith annulus formation occurs between May and July (Ballenger 2011 and modified by CQFE/ODU). A Sheepshead with nine visible annuli could be assigned an age of 9 or 10 depending on its capture month and margin code. When its margin code is "1", it is Age 9 no matter when it is captured. When it is captured after July and before January, it is Age 9 no matter what its margin code is. When it is captured after December and before May and its margin code is not "1", it is Age 10 (9 + 1 = 10). When it is captured between May and July, it is Age 9 when its margin code is "2" but Age 10 (9 + 1 = 10) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 6.1).

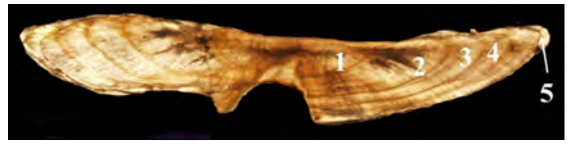


Figure 6.1: Otolith thin-section of a 5 year-old Sheepshead

6.2.4 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (*CV*) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

6.3 RESULTS

6.3.1 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 90% and a *CV* of 0.74% (test of symmetry: χ^2 = 5, *df* = 5, P = 0.4159), and there was no significant difference between the first and second readings for Reader 2 with an agreement of

100% . There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 94.44% and a *CV* of 0.39% (test of symmetry: $\chi^2 = 6$, $df = 7$, $P = 0.5397$) (Figure 6.2).

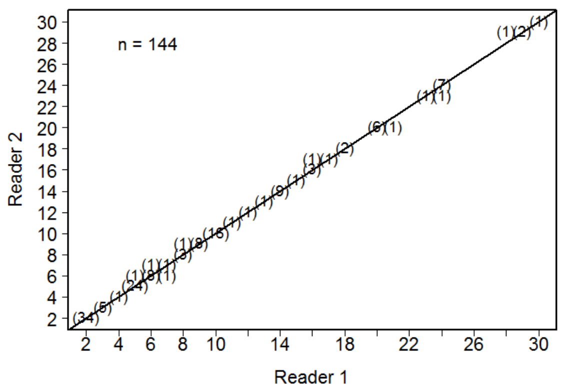


Figure 6.2: Between-reader comparison of otolith age estimates for Sheepshead collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 84% with ages of fish aged in 2008 with a *CV* of 1.28% (test of symmetry: $\chi^2 = 8$, $df = 7$, $P = 0.3326$). Reader 2 had an agreement of 94% with a *CV* of 0.64% (test of symmetry: $\chi^2 = 3$, $df = 3$, $P = 0.3916$).

6.3.2 Year class

Of the 144 fish aged with otoliths, 22 age classes (2 to 18, 20, 23 to 24, and 29 to 30) were represented (Table 6.1). The average age was 9.1 years, and the standard deviation and standard error were 7.3 and 0.61, respectively. Year-class data show that the fishery was comprised of 22 year-classes: fish from the 1991 to 1992, 1997 to 1998, 2001, and 2003 to 2019 year-classes, with fish primarily from the year classes of 2016 and 2019 with 17.4% and 23.6%, respectively. The ratio of males to females was 1:1.23 in the sample collected (Figure 6.3).

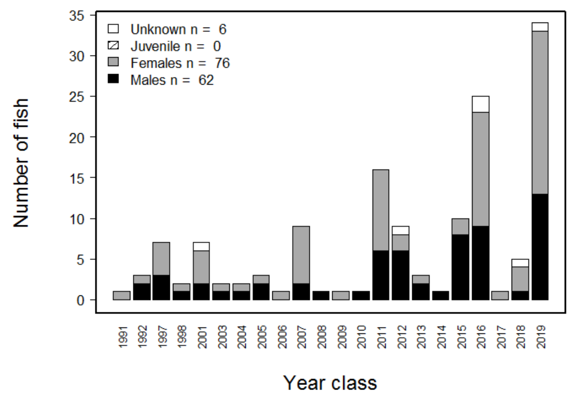


Figure 6.3: Year-class frequency distribution for Sheepshead collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

6.3.3 Age-length key (ALK)

We developed an age-length-key (Table 6.2) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 6.1: The number of sheepshead assigned to each total length (inch)-at-age category for 144 fish sampled for otolith age determination in Virginia during 2021.

	Age																					
Interval	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	23	24	29	30	Totals
10 - 10.99	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
11 - 11.99	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
12 - 12.99	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
13 - 13.99	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
14 - 14.99	12	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
15 - 15.99	10	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
16 - 16.99	1	3	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
17 - 17.99	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
18 - 18.99	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
19 - 19.99	0	0	0	9	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	11
20 - 20.99	0	0	0	1	4	1	2	3	2	0	0	0	0	1	0	0	0	0	0	0	0	0	14
21 - 21.99	0	0	0	0	1	0	1	4	4	0	1	0	1	0	1	1	1	0	0	0	0	0	15
22 - 22.99	0	0	0	0	1	0	0	1	4	1	0	0	2	0	0	0	0	3	1	2	0	0	15
23 - 23.99	0	0	0	0	0	0	0	1	2	0	0	1	1	0	2	0	0	1	1	1	1	0	11
24 - 24.99	0	1	0	0	0	0	0	0	2	0	0	0	5	0	0	1	1	1	0	3	2	1	17
25 - 25.99	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	3
Totals	34	5	1	25	10	1	3	9	16	1	1	1	9	1	3	2	2	7	2	7	3	1	144

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Table 6.2: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Sheepshead sampled for age determination in Virginia during 2021.

	Age																				
Interval	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	23	24	29	30
10 - 10.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 - 11.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 - 12.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 - 13.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 - 14.99	0.75	0	0.06	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 - 15.99	0.83	0.08	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 - 16.99	0.14	0.43	0	0.29	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 - 17.99	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 - 18.99	0	0	0	0.4	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0
19 - 19.99	0	0	0	0.82	0.09	0	0	0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0
20 - 20.99	0	0	0	0.07	0.29	0.07	0.14	0.21	0.14	0	0	0	0	0.07	0	0	0	0	0	0	0	0
21 - 21.99	0	0	0	0	0.07	0	0.07	0.27	0.27	0	0.07	0	0.07	0	0.07	0.07	0.07	0	0	0	0	0
22 - 22.99	0	0	0	0	0.07	0	0	0.07	0.27	0.07	0	0	0.13	0	0	0	0	0.2	0.07	0.13	0	0
23 - 23.99	0	0	0	0	0	0	0	0.09	0.18	0	0	0.09	0.09	0	0.18	0	0	0.09	0.09	0.09	0.09	0
24 - 24.99	0	0.06	0	0	0	0	0	0	0.12	0	0	0	0.29	0	0	0.06	0.06	0.06	0	0.18	0.12	0.06
25 - 25.99	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0.33	0	0.33	0	0

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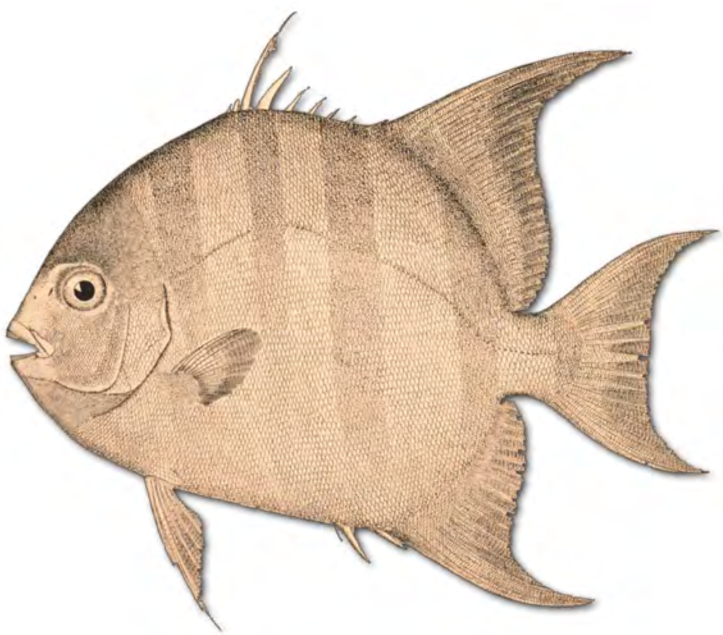
Chapter 7

ATLANTIC SPADEFISH
Chaetodipterus faber



7.1 INTRODUCTION

We aged a total of 209 Spadefish, *Chaetodipterus faber*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Spadefish ages ranged from 0 to 9 years old with an average age of 3, a standard deviation of 2.1, and a standard error of 0.15. Nine age classes (0 to 6, and 8 to 9) were represented, comprising fish of the 2012 to 2013, and 2015 to 2021 year-classes. The sample was dominated by fish from the year-classes of 2015, 2016, 2018, 2019, and 2021 with 12.9%, 17.7%, 17.2%, 23.9%, and 16.8%, respectively.

7.2 METHODS

7.2.1 Sample size for ageing

We estimated sample size for ageing Spadefish in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{7.1}$$

where A is the sample size for ageing Spadefish in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Spadefish used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Spadefish collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

7.2.2 Handling of collections

Otoliths were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

7.2.3 Preparation

We used our thin-section and bake technique to process Spadefish sagittal otoliths (hereafter, referred to as "otoliths") for age determination. Otolith preparation began by randomly selecting either the right or left otolith. Each whole otolith was placed in a ceramic "Coors" spot plate well and baked in a Thermolyne 1400 furnace at 400 °C. Baking time was dependent on the otolith's size and gauged by color, with a light caramel color desired. Once a suitable color was achieved the baked otolith was embedded in epoxy resin with its distal surface orientated downwards and allowed to harden overnight. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet™ low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The otolith was positioned so the blades straddled each side of the otolith focus. It was crucial that this cut be perpendicular to the long axis of the otolith. Failure to do so resulted in broadening and distored winter growth zones. A proper cut resulted in annuli that were clearly defined and delineated. Once cut, thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Atlantic Spadefish.

7.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Spadefish. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code “1”, “2”, “3”, and “4” stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Spadefish otolith annulus formation occurs between January and July (Hayse 1987 and modified by CQFE/ODU). A Spadefish with three visible annuli could be assigned an age of 3 or 4 depending on its capture month and margin code. When its margin code is "1", it is Age 3 no matter when it is captured. When it is captured after July and before January, it is Age 3 no matter what its margin code is. When it is captured between January and July, it is Age 3 when its margin code is "2" but Age 4 ($3 + 1 = 4$) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers’ ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020

-2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 7.1).

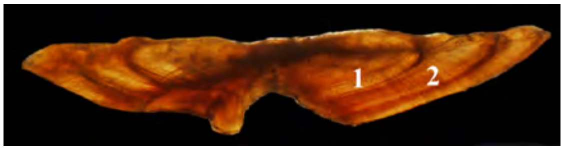


Figure 7.1: Otolith thin-section of a 2 year-old Spadefish

7.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (*CV*) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

7.3 RESULTS

7.3.1 Sample size

We estimated a sample size of 401 Spadefish in 2021, ranging in length interval from 3 to 21 inches (Table 7.1). This sample size provided a range in (*CV*) for age composition approximately from the smallest (*CV*) of 7% for Age 2 to the largest (*CV*) of 19% for Age 6. In 2021, we aged 209 of 211 Spadefish (The rest of fish were either without otoliths or over-collected for certain length interval(s)) collected by VMRC. We fell short in our overall collections for this optimal length-class sampling estimate by 208 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

7.3.2 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 88% and a *CV* of 2.7% (test of symmetry: $\chi^2 = 4$, $df = 5$, $P = 0.5494$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 94% and a *CV* of 1.1% (test of symmetry: $\chi^2 = 3$, $df = 3$, $P = 0.3916$). There was an evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 85.65% and a *CV* of 3.49% (test of symmetry: $\chi^2 = 21$, $df = 11$, $P = 0.0334$) (Figure 7.2).

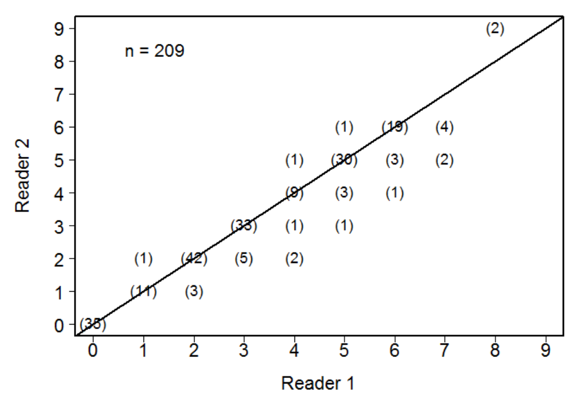


Figure 7.2: Between-reader comparison of otolith age estimates for Spadefish collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 78% with ages of fish aged in 2003 with a CV of 3.05% (test of symmetry: χ^2 = 6.33, df = 7, P = 0.5014). Reader 2 had an agreement of 92% with a CV of 1.32% (test of symmetry: χ^2 = 4, df = 4, P = 0.406).

7.3.3 Year class

Of the 209 fish aged with otoliths, 9 age classes (0 to 6, and 8 to 9) were represented (Table 7.2). The average age was 3 years, and the standard deviation and standard error were 2.1 and 0.15, respectively. Year-class data show that the fishery was comprised of 9 year-classes: fish from the 2012 to 2013, and 2015 to 2021 year-classes, with fish primarily from the year classes of 2015, 2016, 2018, 2019, and 2021 with 12.9%, 17.7%, 17.2%, 23.9%, and 16.8%, respectively. The ratio of males to females was 1:0.77 in the sample collected (Figure 7.3).

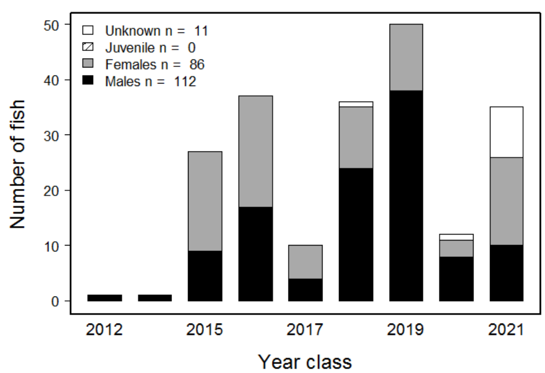


Figure 7.3: Year-class frequency distribution for Spadefish collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

7.3.4 Age-length key (ALK)

We developed an age-length-key (Table 7.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 7.1: Number of Atlantic Spadefish collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
3 - 3.99	5	1	1	4
4 - 4.99	7	14	12	0
5 - 5.99	14	24	24	0
6 - 6.99	50	30	30	20
7 - 7.99	54	24	24	30
8 - 8.99	41	11	11	30
9 - 9.99	28	10	10	18
10 - 10.99	21	12	12	9
11 - 11.99	21	5	5	16
12 - 12.99	27	8	8	19
13 - 13.99	21	8	8	13
14 - 14.99	21	3	3	18
15 - 15.99	18	9	9	9
16 - 16.99	17	3	3	14
17 - 17.99	22	19	19	3
18 - 18.99	15	16	16	0
19 - 19.99	9	8	8	1
20 - 20.99	5	5	5	0
21 - 21.99	5	1	1	4
Totals	401	211	209	208

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Table 7.2: The number of Atlantic Spadefish assigned to each total length-at-age category for 209 fish sampled for otolith age determination in Virginia during 2021.

	Age									
Interval	0	1	2	3	4	5	6	8	9	Totals
3 - 3.99	1	0	0	0	0	0	0	0	0	1
4 - 4.99	11	1	0	0	0	0	0	0	0	12
5 - 5.99	23	1	0	0	0	0	0	0	0	24
6 - 6.99	0	8	22	0	0	0	0	0	0	30
7 - 7.99	0	1	15	8	0	0	0	0	0	24
8 - 8.99	0	1	7	3	0	0	0	0	0	11
9 - 9.99	0	0	4	6	0	0	0	0	0	10
10 - 10.99	0	0	1	8	2	1	0	0	0	12
11 - 11.99	0	0	0	4	1	0	0	0	0	5
12 - 12.99	0	0	1	4	0	3	0	0	0	8
13 - 13.99	0	0	0	1	4	3	0	0	0	8
14 - 14.99	0	0	0	2	0	1	0	0	0	3
15 - 15.99	0	0	0	0	0	7	2	0	0	9
16 - 16.99	0	0	0	0	0	2	1	0	0	3
17 - 17.99	0	0	0	0	2	12	5	0	0	19
18 - 18.99	0	0	0	0	1	4	9	1	1	16
19 - 19.99	0	0	0	0	0	2	6	0	0	8
20 - 20.99	0	0	0	0	0	2	3	0	0	5
21 - 21.99	0	0	0	0	0	0	1	0	0	1
Totals	35	12	50	36	10	37	27	1	1	209

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Table 7.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Atlantic Spadefish sampled for age determination in Virginia during 2021.

	Age								
Interval	0	1	2	3	4	5	6	8	9
3 - 3.99	1	0	0	0	0	0	0	0	0
4 - 4.99	0.92	0.08	0	0	0	0	0	0	0
5 - 5.99	0.96	0.04	0	0	0	0	0	0	0
6 - 6.99	0	0.27	0.73	0	0	0	0	0	0
7 - 7.99	0	0.04	0.62	0.33	0	0	0	0	0
8 - 8.99	0	0.09	0.64	0.27	0	0	0	0	0
9 - 9.99	0	0	0.4	0.6	0	0	0	0	0
10 - 10.99	0	0	0.08	0.67	0.17	0.08	0	0	0
11 - 11.99	0	0	0	0.8	0.2	0	0	0	0
12 - 12.99	0	0	0.12	0.5	0	0.38	0	0	0
13 - 13.99	0	0	0	0.12	0.5	0.38	0	0	0
14 - 14.99	0	0	0	0.67	0	0.33	0	0	0
15 - 15.99	0	0	0	0	0	0.78	0.22	0	0
16 - 16.99	0	0	0	0	0	0.67	0.33	0	0
17 - 17.99	0	0	0	0	0.11	0.63	0.26	0	0
18 - 18.99	0	0	0	0	0.06	0.25	0.56	0.06	0.06
19 - 19.99	0	0	0	0	0	0.25	0.75	0	0
20 - 20.99	0	0	0	0	0	0.4	0.6	0	0
21 - 21.99	0	0	0	0	0	0	1	0	0

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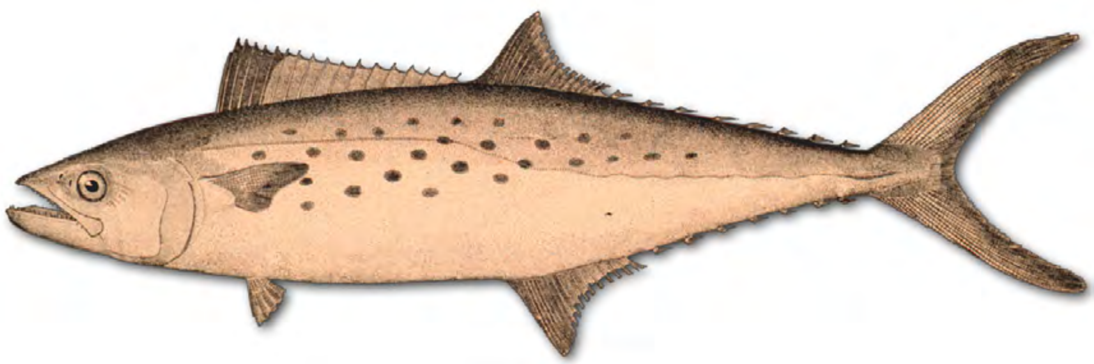
Chapter 8

SPANISH MACKEREL
Scomberomorous maculatus



8.1 INTRODUCTION

We aged a total of 175 Spanish Mackerel, *Scomberomorous maculatus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Spanish Mackerel ages ranged from 0 to 7 years old with an average age of 2.3, a standard deviation of 1.4, and a standard error of 0.11. Eight age classes (0 to 7) were represented, comprising fish of the 2014 to 2021 year-classes. The sample was dominated by fish from the year-classes of 2018, 2019, and 2020 with 30.3%, 20%, and 30.3%, respectively.

8.2 METHODS

8.2.1 Sample size for ageing

We estimated sample size for ageing Spanish Mackerel in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{8.1}$$

where A is the sample size for ageing Spanish Mackerel in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Spanish Mackerel used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Spanish Mackerel collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

8.2.2 Handling of collections

Otoliths were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

8.2.3 Preparation

Sagittal otoliths, hereafter, referred to as "otolith", were processed for age determination. The left or right otolith was randomly selected and embedded, distal side down, in epoxy resin and allowed to harden overnight. The otoliths were viewed by eye, and when necessary, under a stereo microscope to identify the location of the core, and the position of the core marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, three inch diameter, Norton Diamond Grinding Wheels, separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The position of the marked core fell within the 0.5 mm space between the blades, such that the core was included in the removed thin section. Otolith thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Spanish Mackerel.

8.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Spanish Mackerel. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code “1”, “2”, “3”, and “4” stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Spanish Mackerel otolith annulus formation occurs between May and June (Schmidt et al. 1993). A Spanish Mackerel with two visible annuli could be assigned an age of 2 or 3 depending on its capture month and margin code. When its margin code is "1", it is Age 2 no matter when it is captured. When it is captured after June and before January, it is Age 2 no matter what its margin code is. When it is captured after December and before May and its margin code is not "1", it is Age 3 ($2 + 1 = 3$). When it is captured between May and June, it is Age 2 when its margin code is "2" but Age 3 ($2 + 1 = 3$) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification(Figure 8.1).

8.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two read-

Figure 8.1: Otolith thin-section of a 3 year-old Spanish Mackerel with the last annulus on the edge of the thin-section

ers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

8.3 RESULTS

8.3.1 Sample size

We estimated a sample size of 260 Spanish Mackerel in 2021, ranging in length interval from 12 to 32 inches (Table 8.1). This sample size provided a range in (*CV*) for age composition approximately from the smallest (*CV*) of 4% for Age 1 to the largest (*CV*) of 16% for Age 3. In 2021, we aged 175 of 196 Spanish Mackerel (The rest of fish were either without otoliths or over-collected for certain length interval(s)) collected by VMRC. We fell short in our over-all collections for this optimal length-class sampling estimate by 94 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

8.3.2 Reading precision

Both readers had high self-precision.Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 88% and a *CV* of 3.5% (test of symmetry: $\chi^2 = 4$, $df = 2$, $P = 0.1353$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 98% and a *CV* of 0.4% (test of symmetry: $\chi^2 = 1$, $df = 1$, $P = 0.3173$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 88.57% and a *CV* of 3.68% (test of symmetry: $\chi^2 = 11.62$, $df = 8$, $P = 0.169$) (Figure 8.2).

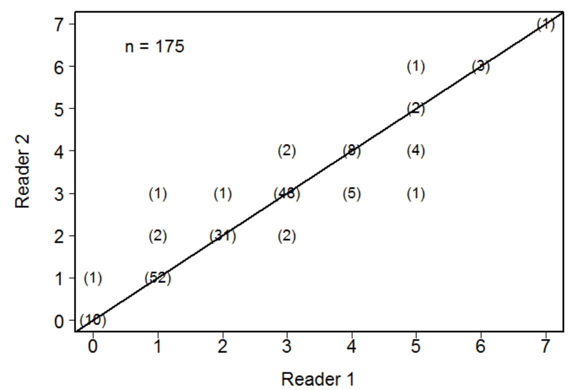


Figure 8.2: Between-reader comparison of otolith age estimates for Spanish Mackerel collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 96% with fish aged in 2003 with a *CV* of 1.35% (test of symmetry: $\chi^2 = 2$, $df = 2$, $P = 0.3679$). Reader 2 had an agreement of 98% with a *CV* of 0.22% (test of symmetry: $\chi^2 = 1$, $df = 1$, $P = 0.3173$).

8.3.3 Year class

Of the 175 fish aged with otoliths, 8 age classes (0 to 7) were represented (Table 8.2). The average age was 2.3 years, and the standard deviation and standard error were 1.4 and 0.11, respectively. Year-class data show that the fishery was comprised of 8 year-classes: fish from the 2014 to 2021 year-classes, with fish primarily from the year classes of 2018, 2019, and 2020 with 30.3%, 20%, and 30.3%, respectively. The ratio of males to females was 1:2.23 in the sample collected (Figure 8.3).

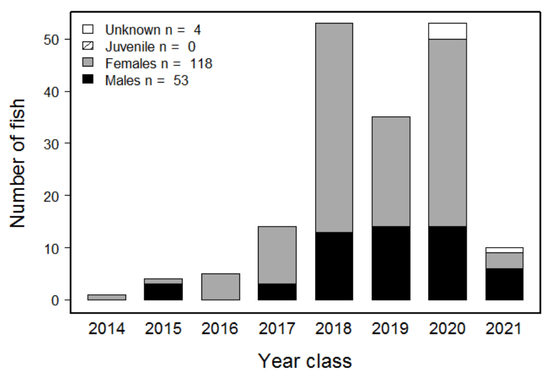


Figure 8.3: Year-class frequency distribution for Spanish Mackerel collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

8.3.4 Age-length key (ALK)

We developed an age-length-key (Table 8.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 8.1: Number of Spanish Mackerel collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
12 - 12.99	5	1	1	4
13 - 13.99	5	4	4	1
14 - 14.99	21	11	11	10
15 - 15.99	35	3	3	32
16 - 16.99	39	20	20	19
17 - 17.99	34	32	32	2
18 - 18.99	20	22	22	0
19 - 19.99	17	27	18	0
20 - 20.99	12	14	14	0
21 - 21.99	13	9	9	4
22 - 22.99	7	12	8	0
23 - 23.99	6	8	6	0
24 - 24.99	6	12	6	0
25 - 25.99	5	7	7	0
26 - 26.99	5	3	3	2
27 - 27.99	5	6	6	0
28 - 28.99	5	3	3	2
29 - 29.99	5	2	2	3
30 - 30.99	5	0	0	5
31 - 31.99	5	0	0	5
32 - 32.99	5	0	0	5
Totals	260	196	175	94

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Table 8.2: The number of Spanish Mackerel assigned to each total length-at-age category for 175 fish sampled for otolith age determination in Virginia during 2021.

	Age								
Interval	0	1	2	3	4	5	6	7	Totals
12 - 12.99	1	0	0	0	0	0	0	0	1
13 - 13.99	2	2	0	0	0	0	0	0	4
14 - 14.99	6	5	0	0	0	0	0	0	11
15 - 15.99	0	3	0	0	0	0	0	0	3
16 - 16.99	1	17	2	0	0	0	0	0	20
17 - 17.99	0	16	13	3	0	0	0	0	32
18 - 18.99	0	6	9	6	1	0	0	0	22
19 - 19.99	0	3	2	12	1	0	0	0	18
20 - 20.99	0	1	4	8	0	0	1	0	14
21 - 21.99	0	0	2	4	3	0	0	0	9
22 - 22.99	0	0	2	5	1	0	0	0	8
23 - 23.99	0	0	1	3	1	1	0	0	6
24 - 24.99	0	0	0	3	1	0	2	0	6
25 - 25.99	0	0	0	7	0	0	0	0	7
26 - 26.99	0	0	0	0	3	0	0	0	3
27 - 27.99	0	0	0	1	1	3	1	0	6
28 - 28.99	0	0	0	1	1	0	0	1	3
29 - 29.99	0	0	0	0	1	1	0	0	2
Totals	10	53	35	53	14	5	4	1	175

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Table 8.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Spanish Mackerel sampled for age determination in Virginia during 2021.

	Age							
Interval	0	1	2	3	4	5	6	7
12 - 12.99	1	0	0	0	0	0	0	0
13 - 13.99	0.5	0.5	0	0	0	0	0	0
14 - 14.99	0.55	0.45	0	0	0	0	0	0
15 - 15.99	0	1	0	0	0	0	0	0
16 - 16.99	0.05	0.85	0.1	0	0	0	0	0
17 - 17.99	0	0.5	0.41	0.09	0	0	0	0
18 - 18.99	0	0.27	0.41	0.27	0.05	0	0	0
19 - 19.99	0	0.17	0.11	0.67	0.06	0	0	0
20 - 20.99	0	0.07	0.29	0.57	0	0	0.07	0
21 - 21.99	0	0	0.22	0.44	0.33	0	0	0
22 - 22.99	0	0	0.25	0.62	0.12	0	0	0
23 - 23.99	0	0	0.17	0.5	0.17	0.17	0	0
24 - 24.99	0	0	0	0.5	0.17	0	0.33	0
25 - 25.99	0	0	0	1	0	0	0	0
26 - 26.99	0	0	0	0	1	0	0	0
27 - 27.99	0	0	0	0.17	0.17	0.5	0.17	0
28 - 28.99	0	0	0	0.33	0.33	0	0	0.33
29 - 29.99	0	0	0	0	0.5	0.5	0	0

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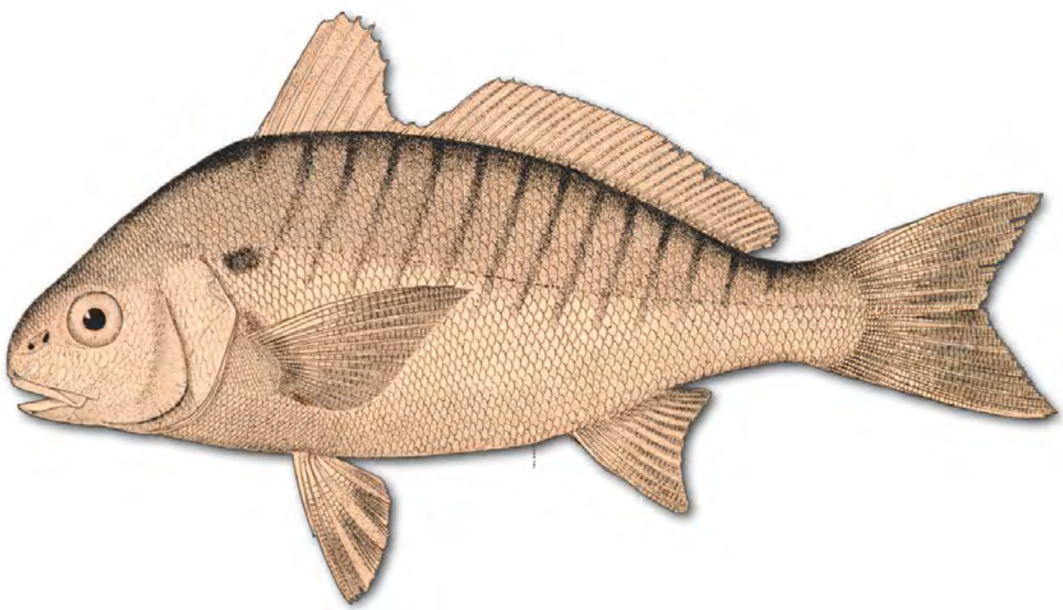
Chapter 9

SPOT *Leiostomus xanthurus*



9.1 INTRODUCTION

We aged a total of 202 Spot, *Leiostomus xanthurus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Spot ages ranged from 0 to 2 years old with an average age of 1.1, a standard deviation of 0.4, and a standard error of 0.03. Three age classes (0 to 2) were represented, comprising fish of the 2019 to 2021 year-classes. The sample was dominated by fish from the year-class of 2020 with 86.1%.

9.2 METHODS

9.2.1 Sample size for ageing

We estimated sample size for ageing Spot in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{9.1}$$

where A is the sample size for ageing Spot in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Spot used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Spot collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

9.2.2 Handling of collections

Otoliths were received by the Age & and Growth Laboratory in labeled coin envelopes, were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

9.2.3 Preparation

Sagittal otoliths, hereafter, referred to as "otoliths", were processed for age determination following the methods described in Barbieri et al. (1994) with a few modifications. The left or right otolith was randomly selected and embedded (distal side down) in epoxy resin and allowed to harden overnight. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet™ low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). Thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Spot.

9.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Spot. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is "2" and as its annulus number plus one when its margin code is "3" or "4" (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Spot otolith annulus formation occurs between May and July (Piner and Jones 2004). A Spot with one visible annuli could be assigned an age of 1 or 2 depending on its capture month and margin code. When its margin code is "1", it is Age 1 no matter when it is captured. When it is captured after July and before January, it is Age 1 no matter what its margin code is. When it is captured after December and before May and its margin code is not "1", it is Age 2 (1 + 1 = 2). When it is captured between May and July, it is Age 1 when its margin code is "2" but Age 2 (1 + 1 = 2) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 9.1).

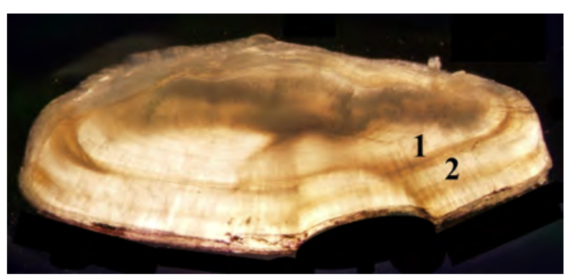


Figure 9.1: Otolith thin-section of a 2 year-old Spot

9.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (*CV*) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

9.3 RESULTS

9.3.1 Sample size

We estimated a sample size of 211 Spot in 2021, ranging in length interval from 4 to 12 inches (Table 9.1). This sample size provided a range in (*CV*) for age composition approximately from the smallest (*CV*) of 4% for Age 1 to the largest (*CV*) of 19% for Age 0. In 2021, we randomly selected and aged 202 fish from 288 Spot collected by VMRC. We fell short in our over-all collections for this optimal length-class sampling estimate by 19 fish. We were short only a few fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would not be influenced significantly.

9.3.2 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 94% and a *CV* of 2.45% (test of symmetry: χ^2 = 3, *df* = 2, *P* = 0.2231), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 100% . There was an evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 80.2% and a *CV* of 14.47% (test of symmetry: χ^2 = 40, *df* = 2, *P* = 0) (Figure 9.2).

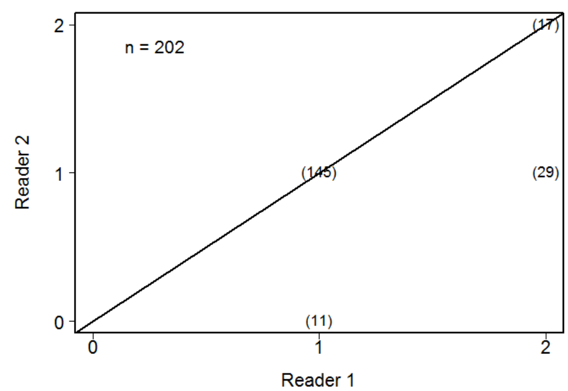


Figure 9.2: Between-reader comparison of otolith age estimates for Spot collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 96% with ages of fish aged in 2003 with a *CV* of 1.89% (test of symmetry: χ^2 = 2, *df* = 1, *P* = 0.1573). Reader 2 also had an agreement of 100% .

9.3.3 Year class

Of the 202 fish aged with otoliths, 3 age classes (0 to 2) were represented (Table 9.2). The average age was 1.1 years, and the standard deviation and standard error were 0.4 and 0.03, respectively. Year-class data show that the fishery was comprised of 3 year-classes: fish from the 2019 to 2021 year-classes, with fish primarily from the year class of 2020 with 86.1%. The ratio of males to females was 1:6.62 in the sample collected (Figure 9.3).

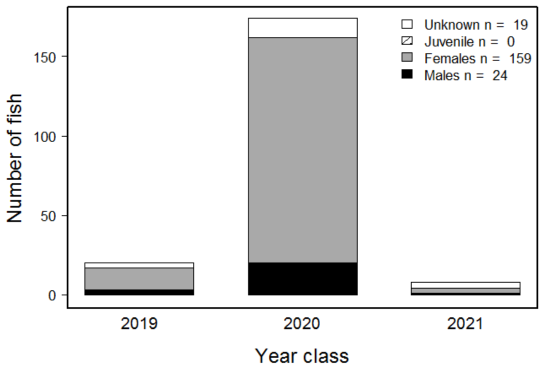


Figure 9.3: Year-class frequency distribution for Spot collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' is for gonads that were not available for examination or were not examined for sex during sampling.

9.3.4 Age-length key (ALK)

We developed an age-length-key (Table 9.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 9.1: Number of Spot collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
4 - 4.99	5	0	0	5
5 - 5.99	6	6	6	0
6 - 6.99	6	9	6	0
7 - 7.99	24	29	24	0
8 - 8.99	46	98	46	0
9 - 9.99	64	100	74	0
10 - 10.99	50	45	45	5
11 - 11.99	5	0	0	5
12 - 12.99	5	1	1	4
Totals	211	288	202	19

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Table 9.2: The number of Spot assigned to each total length-at-age category for 202 fish sampled for otolith age determination in Virginia during 2021.

	Age			
Interval	0	1	2	Totals
5 - 5.99	3	3	0	6
6 - 6.99	5	1	0	6
7 - 7.99	0	21	3	24
8 - 8.99	0	43	3	46
9 - 9.99	0	65	9	74
10 - 10.99	0	40	5	45
12 - 12.99	0	1	0	1
Totals	8	174	20	202

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Table 9.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Spot sampled for age determination in Virginia during 2021.

	Age		
Interval	0	1	2
5 - 5.99	0.5	0.5	0
6 - 6.99	0.83	0.17	0
7 - 7.99	0	0.88	0.12
8 - 8.99	0	0.93	0.07
9 - 9.99	0	0.88	0.12
10 - 10.99	0	0.89	0.11
12 - 12.99	0	1	0

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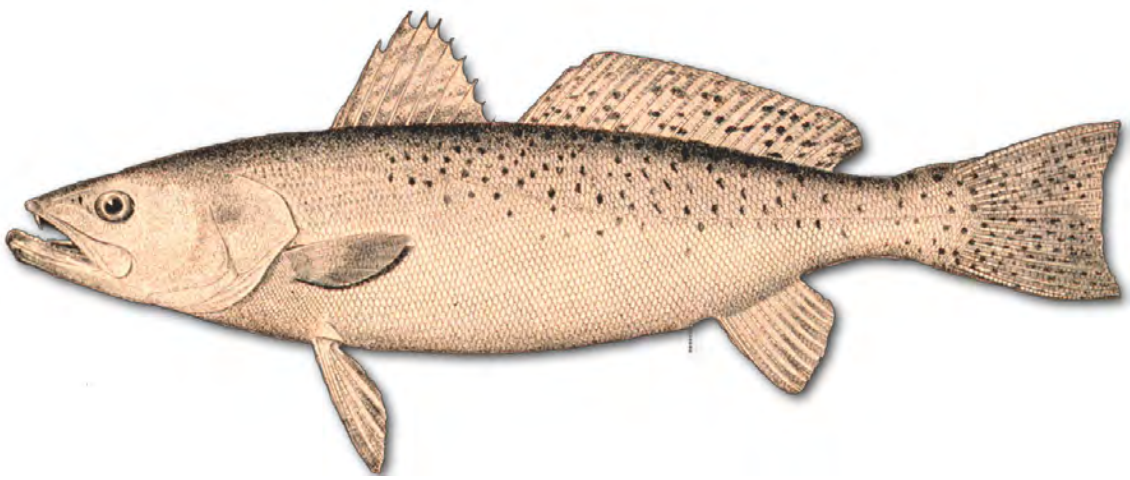
Chapter 10

SPOTTED SEATROUT *Cynoscion nebulosus*



10.1 INTRODUCTION

We aged a total of 309 Spotted Seatrout, *Cynoscion nebulosus*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. Spotted seatrout ages ranged from 0 to 5 years old with an average age of 1.4, a standard deviation of 1, and a standard error of 0.06. Six age classes (0 to 5) were represented, comprising fish of the 2016 to 2021 year-classes. The sample was dominated by fish from the year-class of 2020 with 46.3%.

10.2 METHODS

10.2.1 Sample size for ageing

We estimated sample size for ageing Spotted Seatrout in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{10.1}$$

where A is the sample size for ageing Spotted Seatrout in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Spotted Seatrout used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Spotted Seatrout collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

10.2.2 Handling of collections

Otoliths were received by the Age & Growth Laboratory in labeled coin envelopes. In the lab they were sorted by date of capture, their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

10.2.3 Preparation

Sagittal otoliths, hereafter, referred to as "otoliths", were processed for age determination. The left or right otolith was randomly selected and attached, distal side down, to a glass slide with clear Crystalbond$^{\text{TM}}$ 509 adhesive. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet$^{\text{TM}}$ low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). Thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Spotted Seatrout.

10.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Spotted Seatrout. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code “1”, “2”, “3”, and “4” stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is “2” and as its annulus number plus one when its margin code is “3” or “4” (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Spotted Seatrout otolith annulus formation occurs between March and May (Ihde and Chittenden 2003). A Spotted Seatrout with two visible annuli could be assigned an age of 2 or 3 depending on its capture month and margin code. When its margin code is "1", it is Age 2 no matter when it is captured. When it is captured after May and before January, it is Age 2 no matter what its margin code is. When it is captured after December and before March and its margin code is not "1", it is Age 3 ($2 + 1 = 3$). When it is captured between March and May, it is Age 2 when its margin code is "2" but Age 3 ($2 + 1 = 3$) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers’ ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 10.1).

10.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sam-

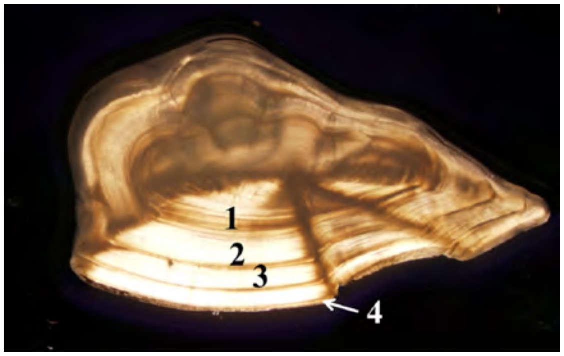


Figure 10.1: Otolith thin-section of a 4 year-old Spotted Seatrout with the last annulus on the edge of the thin-section

ple for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

10.3 RESULTS

10.3.1 Sample size

We estimated a sample size of 342 Spotted Seatrout in 2021, ranging in length interval from 7 to 34 inches (Table 10.1). This sample size provided a range in (CV) for age composition approximately from the smallest (CV) of 5% for Age 1 to the largest (CV) of 19% for Age 4. In 2021, we randomly selected and aged 309 fish from 428 Spotted Seatrout collected by VMRC. We fell short in our over-all collections for this optimal length-class sampling estimate by 54 fish. We were short only a few fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would not be influenced significantly.

10.3.2 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 100%, and there was no significant difference between the first and second readings for Reader 2 with an agreement of 100%. There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 100% (Figure 10.2).

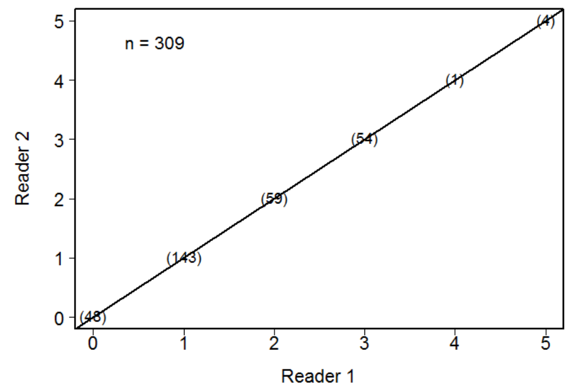


Figure 10.2: Between-reader comparison of otolith age estimates for Spotted Seatrout collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 100% with ages of fish aged in 2003. Reader 2 also had an agreement of 100%.

10.3.3 Year class

Of the 309 fish aged with otoliths, 6 age classes (0 to 5) were represented (Table 10.2). The average age was 1.4 years, and the standard deviation and standard error were 1 and 0.06, respectively. Year-class data show that the fishery was comprised of 6 year-classes: fish from the 2016 to 2021 year-classes, with fish primarily from the year class of 2020 with 46.3%. The ratio of males to females was 1:1.42 in the sample collected (Figure 10.3).

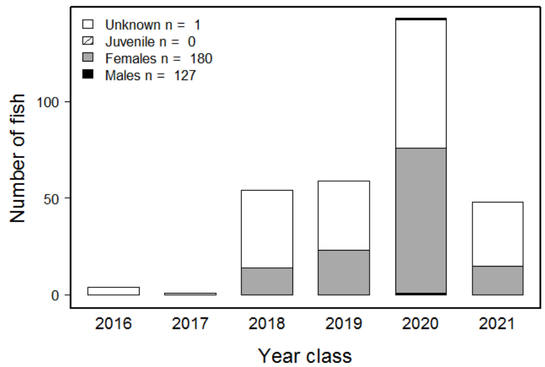


Figure 10.3: Year-class frequency distribution for Spotted Seatrout collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

10.3.4 Age-length key (ALK)

We developed an age-length-key (Table 10.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 10.1: Number of Spotted Seatrout collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
7 - 7.99	5	0	0	5
8 - 8.99	5	0	0	5
9 - 9.99	5	1	1	4
10 - 10.99	5	6	6	0
11 - 11.99	5	19	6	0
12 - 12.99	25	28	28	0
13 - 13.99	16	8	8	8
14 - 14.99	16	18	18	0
15 - 15.99	25	42	26	0
16 - 16.99	32	60	33	0
17 - 17.99	32	42	32	0
18 - 18.99	27	44	29	0
19 - 19.99	23	34	24	0
20 - 20.99	24	27	24	0
21 - 21.99	12	21	12	0
22 - 22.99	13	16	14	0
23 - 23.99	11	17	12	0
24 - 24.99	11	21	12	0
25 - 25.99	9	15	15	0
26 - 26.99	6	3	3	3
27 - 27.99	5	1	1	4
28 - 28.99	5	2	2	3
29 - 29.99	5	1	1	4
30 - 30.99	5	2	2	3
31 - 31.99	5	0	0	5
32 - 32.99	5	0	0	5
34 - 34.99	5	0	0	5
Totals	342	428	309	54

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Table 10.2: The number of Spotted Seatrout assigned to each total length-at-age category for 309 fish sampled for otolith age determination in Virginia during 2021.

	Age						
Interval	0	1	2	3	4	5	Totals
9 - 9.99	1	0	0	0	0	0	1
10 - 10.99	6	0	0	0	0	0	6
11 - 11.99	6	0	0	0	0	0	6
12 - 12.99	28	0	0	0	0	0	28
13 - 13.99	7	1	0	0	0	0	8
14 - 14.99	0	18	0	0	0	0	18
15 - 15.99	0	26	0	0	0	0	26
16 - 16.99	0	31	2	0	0	0	33
17 - 17.99	0	24	8	0	0	0	32
18 - 18.99	0	21	7	1	0	0	29
19 - 19.99	0	12	7	5	0	0	24
20 - 20.99	0	7	12	5	0	0	24
21 - 21.99	0	0	9	3	0	0	12
22 - 22.99	0	3	8	3	0	0	14
23 - 23.99	0	0	4	8	0	0	12
24 - 24.99	0	0	2	10	0	0	12
25 - 25.99	0	0	0	15	0	0	15
26 - 26.99	0	0	0	3	0	0	3
27 - 27.99	0	0	0	1	0	0	1
28 - 28.99	0	0	0	0	1	1	2
29 - 29.99	0	0	0	0	0	1	1
30 - 30.99	0	0	0	0	0	2	2
Totals	48	143	59	54	1	4	309

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Table 10.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Spotted Seatrout sampled for age determination in Virginia during 2021.

	Age					
Interval	0	1	2	3	4	5
9 - 9.99	1	0	0	0	0	0
10 - 10.99	1	0	0	0	0	0
11 - 11.99	1	0	0	0	0	0
12 - 12.99	1	0	0	0	0	0
13 - 13.99	0.88	0.12	0	0	0	0
14 - 14.99	0	1	0	0	0	0
15 - 15.99	0	1	0	0	0	0
16 - 16.99	0	0.94	0.06	0	0	0
17 - 17.99	0	0.75	0.25	0	0	0
18 - 18.99	0	0.72	0.24	0.03	0	0
19 - 19.99	0	0.5	0.29	0.21	0	0
20 - 20.99	0	0.29	0.5	0.21	0	0
21 - 21.99	0	0	0.75	0.25	0	0
22 - 22.99	0	0.21	0.57	0.21	0	0
23 - 23.99	0	0	0.33	0.67	0	0
24 - 24.99	0	0	0.17	0.83	0	0
25 - 25.99	0	0	0	1	0	0
26 - 26.99	0	0	0	1	0	0
27 - 27.99	0	0	0	1	0	0
28 - 28.99	0	0	0	0	0.5	0.5
29 - 29.99	0	0	0	0	0	1
30 - 30.99	0	0	0	0	0	1

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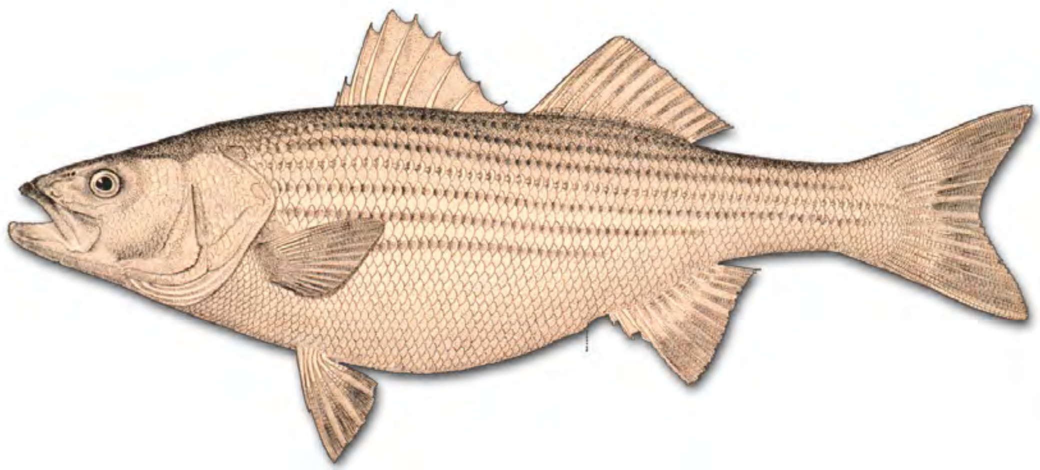
Chapter 11

STRIPED BASS *Morone saxatilis*



11.1 INTRODUCTION

We aged a total of 716 Striped Bass, *Morone saxatilis*, using their scales collected by the VMRC's Biological Sampling Program in 2021. Of 716 aged fish, 526 and 190 fish were collected in Chesapeake Bay (bay fish) and Virginia waters of the Atlantic Ocean (ocean fish), respectively. The average bay fish age was 6.6 years with a standard deviation of 3.9 and a standard error of 0.17. Twenty-two age classes (2 to 13, and 15 to 24) were represented in the bay fish, comprising fish from the 1997 to 2006, and 2008 to 2019 year classes. The bay fish sample in 2021 was dominated by the year classes of 2014, 2015, 2016, 2017, and 2018 with 8%, 32%, 12%, 13%, and 15%, respectively. The average ocean fish age was 10.6 years with a standard deviation of 2.2 and a standard error of 0.16. Sixteen age classes (5 to 19, and 22) were represented in the ocean fish, comprising fish from the 1999, and 2002 to 2016 year classes. The ocean fish sample in 2021 was dominated by the year classes of 2010, 2011, and 2012 with 12%, 52%, and 12%, respectively. We also aged 295 fish using their otoliths in addition to ageing their scales. The otolith ages were compared to the scale ages to examine how close both ages were to one another (see details in Results).

11.2 METHODS

11.2.1 Sample size for ageing

We estimated sample sizes for ageing Striped Bass collected in both Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021, respectively, using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{11.1}$$

where A is the sample size for ageing Striped Bass in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Striped Bass used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Striped Bass collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

11.2.2 Handling of collection

Sagittal otoliths (hereafter, referred to as "otoliths") and scales were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted based on date of capture. Their envelope labels were verified against VMRC's collection data, and each fish assigned a unique Age and Growth Laboratory identification number. All otoliths and scales were stored dry within their original labeled coin envelopes; otoliths were contained inside protective Axygen 2.0 ml microtubes.

11.2.3 Preparation

Scales

Striped bass scales were prepared for age and growth analysis by making acetate impressions of the scale microstructure. Due to extreme variation in the size and shape of scales from individual fish, we selected only those scales that had even margins and which were of uniform size. We selected a range of four to six preferred scales (based on overall scale size) from each fish, making sure that only non-regenerated scales were used. Scale impressions were made on extruded clear acetate sheets (25 mm x 75 mm) with a Carver Laboratory Heated Press (model "C"). The scales were pressed with the following settings:

Pressure: 15000 psi
Temperature: 77 °C (170 °F)
Time: 5 to 10 min

Striped bass scales that were the size of a quarter (coin) or larger, were pressed individually for up to twenty minutes. After pressing, the impressions were viewed with a Bell and Howell microfiche reader and checked again for regeneration and incomplete margins. Impressions that were too light, or when all scales were regenerated a new impression was made using different scales from the same fish.

Click here to obtain the protocol at the VMRC website on how to prepare scale impression for ageing Striped Bass.

Otoliths

We used our thin-section and bake technique to process Spadefish sagittal otoliths (hereafter, referred to as "otoliths") for age determination. Otolith preparation began by randomly selecting either the right or left otolith. Each whole otolith was placed in a ceramic "Coors" spot plate well and baked in a Thermolyne 1400 furnace at 400 °C. Baking time was dependent on the otolith's size and gauged by color, with a light caramel color desired. Once a suitable color was achieved the baked otolith was embedded in epoxy resin with its distal surface orientated downwards and allowed to harden overnight. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The otolith was positioned so the blades straddled each side of the otolith focus. It was crucial that this cut be perpendicular to the long axis of the otolith. Failure to do so resulted in broadening and distorted winter growth zones. A proper cut resulted in annuli that were clearly defined and delineated. Once cut, thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Striped Bass.

11.2.4 Readings

The CQFE system assigns an age class to a fish based on a combination of reading the information contained in its otolith, the date of its capture, and the species-specific period when it deposits its annulus. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called annuli. Technically, an otolith annulus is the combination of both the opaque and the translucent bands. In practice, only the opaque bands are counted as annuli. The number of these visible dark bands replaces "x" in our notation below, and is the initial "age" assignment of the fish.

Second, the otolith section is examined for translucent growth. If no translucent growth is visible beyond the last dark annulus, the otolith is called "even" and no modification of the assigned age is made. The initial assigned age, then, is the age class of the fish. Any growth beyond the last annulus can be interpreted as either being toward the next age class or within the same age class. If translucent growth is visible beyond the last dark annulus, a "+" is added to the notation.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the dark band of the annulus. If the fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class notation of "x+x", where "x" is the number of dark bands in the otolith. If the fish is captured between January 1 and the end of the species-specific annulus deposition period, it is assigned an age class notation of "x+(x+1)". Thus, any growth beyond the last annulus, after its "birthday", but before the dark band deposition period, is interpreted as being toward the next age class.

For example, Striped Bass otolith deposition occurs between April and June (Secor et al. 1995). A Striped Bass captured between January 1 and June 30, before the end of the species' annulus formation period, with three visible annuli and some translucent growth after the last annulus, would be assigned an age class of "x+(x+1)" or 3+(3+1), noted as 3+4. This is the same age-class assigned to a fish with four visible annuli captured after the end of June 30, the period of annulus formation, which would be noted as 4+4.

Striped bass scales are also considered to have a deposition between April and June (Secor et al. 1995), and age class assignment using these hard-parts is conducted in the same way as otoliths.

All Striped Bass samples (scale pressings and sectioned otoliths) were aged by two different readers in chronological order based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, both readers sat down together and re-aged the fish again without any knowledge of previously estimated ages or lengths, then assigned a final age to the fish. When the age readers were unable to agree on a final age, the fish was excluded from further analysis.

Scales

We determined fish age by viewing acetate impressions of scales (Figure 11.1) with a standard Bell and Howell R-735 microfiche reader equipped with 20 and 29 mm lenses. Annuli on

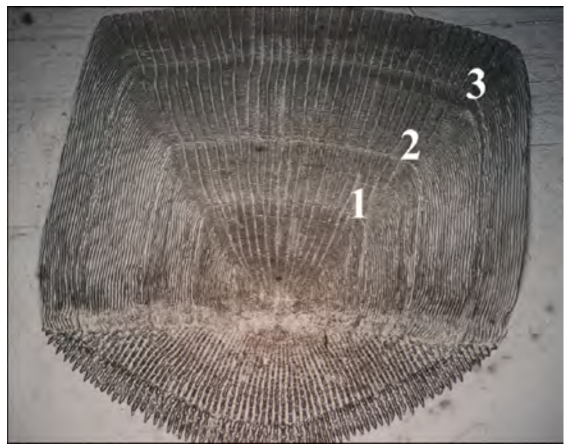


Figure 11.1: Scale impression of a 3 year-old Striped Bass.

Striped Bass scales are identified based on two scale microstructure features, "crossing over" and circuli disruption. Primarily, "crossing over" in the lateral margins near the posterior/anterior interface of the scale is used to determine the origin of the annulus. Here compressed circuli (annulus) "cross-over" the previously deposited circuli of the previous year's growth. Typically annuli of the first three years can be observed transversing this interface as dark bands. These bands remain consistent throughout the posterior field and rejoin the posterior/anterior interface on the opposite side of the focus. Annuli can also be observed in the anterior lateral field of the scale. Here the annuli typically reveal a pattern of discontinuous and suddenly breaking segmented circuli. This event can also be distinguished by the presence of concentric white lines, which are typically associated with the disruption of circuli.

Annuli can also be observed bisecting the perpendicular plain of the radial striations in the anterior field of the scale. Radii emanate out from the focus of the scale towards the outer corner margins of the anterior field. These radial striations consist mainly of segmented concave circuli. The point of intersection between radii and annuli results in a "straightening out" of the concave circuli. This straightening of the circuli should be consistent throughout the entire anterior field of the scale. This event is further amplified by the presence of concave circuli neighboring both directly above and below the annulus. The first year's annulus can be difficult to locate on some scales. It is typically best identified in the lateral field of the anterior portion of the scale. The distance from the focus to the first year's annulus is typically larger with respect to the following annuli. For the annuli two through six, summer growth generally decreases proportionally. For ages greater than six, a crowding effect of the annuli near the outer margins of the scale is observed. This crowding effect creates difficulties in edge interpretation. At this point it is best to focus on the straightening of the circuli at the anterior margins of the scale.

When ageing young Striped Bass, zero through age two, extreme caution must be taken as not to over age the structure. In young fish there is no point of reference to aid in the determination of the first year; this invariably results in over examination of the scale and such events as hatching or saltwater incursion marks (checks) may be interpreted as the first year.

Otoliths

All thin-sections were aged by two different readers using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 11.2). Each reader aged all of the otolith samples. By convention an annulus is identified as the narrow opaque zone, or winter growth. Typically the first year's annulus can be determined by first locating the focus of the otolith. The focus is generally located, depending on preparation, in the center of the otolith, and is visually well defined as a dark oblong region. The first year's annulus can be located directly below the focus, along the outer ridge of the sulcal groove on the ventral and dorsal sides of the otolith. This insertion point along the sulcal ridge resembles a check mark (not to be confused with a false annulus). Here the annulus can be followed outwards along the ventral and dorsal surfaces where it encircles the focus. Subsequent annuli also emanate from the sulcal ridge; however, they do not encircle the focus, but rather travel outwards to the distal surface of the otolith. To be considered a true annulus, each annulus must be rooted in the sulcus and travel without interruption to the distal surface of the otolith. The annuli in Striped Bass have a tendency to split as they advance towards the distal surface. As a result, it is critical that reading path proceed in a direction down the sulcal ridge and outwards to the distal surface.

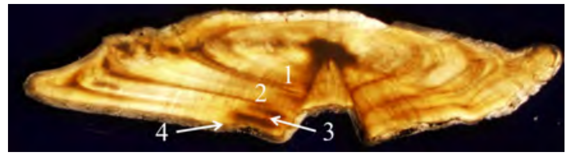


Figure 11.2: Otolith thin-section of a 4 year-old Striped Bass with the last annulus on the edge of the thin-section

Click here to obtain the protocol at the CQFE website on how to age Striped Bass using their otolith thin-sections.

11.2.5 Comparison Tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for following comparisons: 1) between the two readers in the current year; 2) within each reader in the current year; 3) time-series bias between the current and previous years within each reader;

and 4) between scale and otoliths ages. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2000 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

11.3 RESULTS

11.3.1 Sample size

We estimated a sample size of 554 bay Striped Bass in 2021, ranging in length interval from 10 to 55 inches (Table 11.1). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 10% for Age 4 and 5 to the largest *CV* of 24% for Age 14 of the bay fish. We randomly selected and aged 526 fish from 694 Striped Bass collected by VMRC in Chesapeake Bay in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 144 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

We estimated a sample size of 612 ocean Striped Bass in 2021, ranging in length interval from 20 to 53 inches (Table 11.2). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 10% for Age 10 and 11 to the largest *CV* of 20% for Age 16 and 17 of the ocean fish. We aged all 190 Striped Bass collected by VMRC in Virginia waters of the Atlantic Ocean in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 422 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

11.3.2 Scales

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 80% (1 year or less agreement of 96%) and a *CV* of 2.2% (test of symmetry: $\chi^2 = 6$, $df = 8$, $P = 0.6472$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 72% (1 year or less agreement of 96%) and a *CV* of 2.97% (test of symmetry: $\chi^2 = 11.33$, $df = 8$, $P = 0.1835$). There was an evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 72% (1 year or less agreement of 94%) and a *CV* of 3.09% (test of symmetry: $\chi^2 = 113.28$, $df = 43$, $P < 0.0001$) (Figure 11.3).

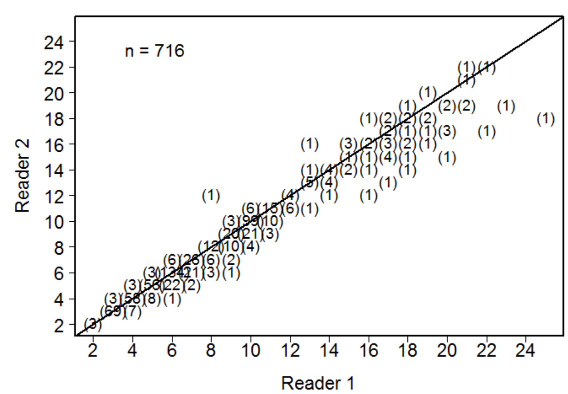


Figure 11.3: Between-reader comparison of scale age estimates for Striped Bass collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 48% (1 year or less agreement of 88%) with ages of fish aged in 2000 with a *CV* of 6.9% (test of symmetry: χ^2

= 21.13, *df* = 16, P = 0.1734). Reader 2 had an agreement of 65% (1 year or less agreement of 97%) with a *CV* of 3.81% (test of symmetry: χ^2 = 11.67, *df* = 13, P = 0.5551).

Of the 526 bay Striped Bass aged with scales, 22 age classes (2 to 13, and 15 to 24) were represented (Table 11.3). The average age for the sample was 6.6 years. The standard deviation and standard error were 3.9 and 0.17, respectively. Year-class data (Figure 11.4) indicates that recruitment into the fishery in Chesapeake Bay begins at age 2, which corresponds to the 2019 year-class for Striped Bass caught in 2021. Striped bass in the sample in 2021 was dominated by the year classes of 2014, 2015, 2016, 2017, and 2018 with 8%, 32%, 12%, 13%, and 15%, respectively. The sex ratio of male to female was 1:1.1 for the bay fish.

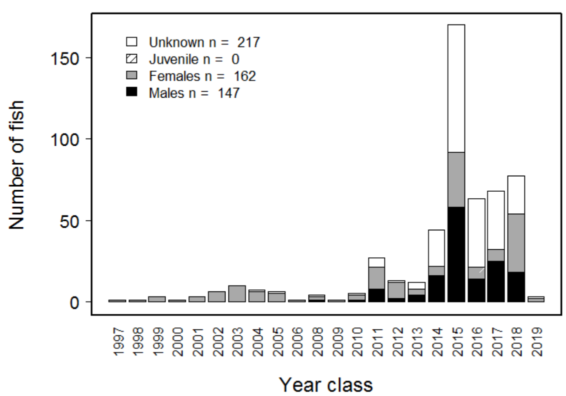


Figure 11.4: Year-class frequency distribution for Striped Bass collected in Chesapeake Bay, Virginia for ageing in 2021. Distribution is broken down by sex and estimated using scale ages. 'Unknown' represents the fish gonads that were not available for examination or were not examined for sex during sampling.

Of the 190 ocean Striped Bass aged with scales, 16 age classes (5 to 19, and 22) were represented (Table 11.4). The average age for the sample was 10.6 years. The standard deviation and standard error were 2.2 and 0.16, respectively. Year-class data (Figure 11.5) indicates that recruitment into the fishery in Virginia waters of Atlantic ocean begins at age 5, which corresponds to the 2016 year-class for Striped Bass caught in 2021. Striped bass in the sample in 2021 was dominated by the year classes of 2010, 2011, and 2012 with 12%, 52%, and 12%, respectively. The sex ratio of male to female was 1:3.79 for the ocean fish.

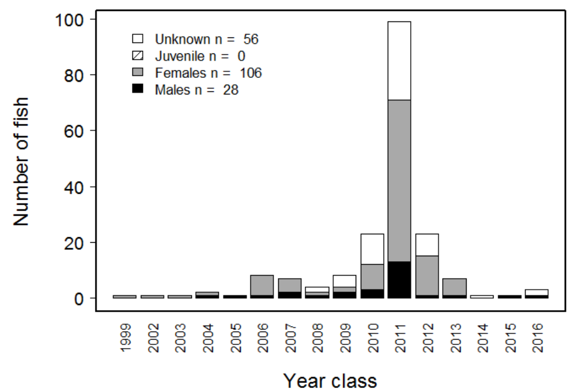


Figure 11.5: Year-class frequency distribution for Striped Bass collected in Virginia waters of the Atlantic Ocean for ageing in 2021. Distribution is broken down by sex and estimated using scale ages. 'Unknown' represents the fish gonads that were not available for examination or were not examined for sex during sampling.

11.3.3 Otoliths

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 86% and a *CV* of 0.53% (test of symmetry: χ^2 = 7, *df* = 7, P = 0.4289), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 90% and a *CV* of 0.53% (test of symmetry: χ^2 = 5, *df* = 5, P = 0.4159). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 93% (1 year or less agreement of 98%) and a *CV* of 0.49% (test of symmetry: χ^2 = 17.33, *df* = 16, P = 0.3644) (Figure 11.6).

There was no time-series bias for either reader. Reader 1 had an agreement of 80% with ages of fish aged in 2003 with a *CV* of 2.1% (test of symmetry: χ^2 = 12, *df* = 8, P = 0.1512). Reader 2 had an agreement of 85% with a *CV*

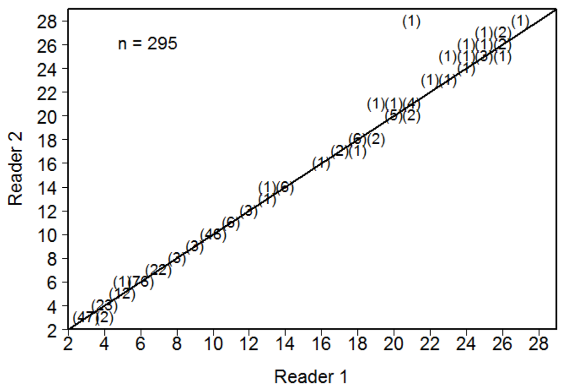


Figure 11.6: Between-reader comparison of otolith age estimates for Striped Bass collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

of 1.17% (test of symmetry: $\chi^2 = 9$, $df = 8$, $P = 0.3423$).

Of the 295 Striped Bass aged with otoliths, 22 age classes (3 to 14, 16 to 18, 20 to 21, and 23 to 27) were represented (Table 11.5). The average age for the sample was 8.7 years. The standard deviation and standard error were 6.1 and 0.36, respectively.

11.3.4 Comparison of scale and otolith ages

We aged 295 Striped Bass using scales and otoliths. There was an evidence of systematic disagreement between otolith and scale ages (test of symmetry: $\chi^2 = 75.98$, $df = 44$, $P = 0.002$) with an average *CV* of 4.04%. There was an agreement of 66% between scale and otoliths ages whereas scales were assigned a lower and higher age than otoliths for 26% and 7% of the fish, respectively (Figure 11.7). There was also an evidence of bias between otolith and scale ages using an age bias plot (Figure 11.8), with scale generally assigned higher ages for younger fish and lower ages for older fish than otolith age estimates.

Figure 11.7: Comparison of scale and otolith age estimates for Striped Bass collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

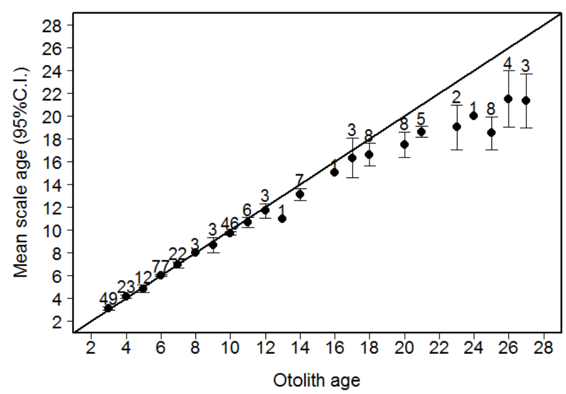


Figure 11.8: Age-bias plot for Striped Bass scale and otolith age estimates in 2021. The number above the upper CI bar is number of fish.

11.3.5 Age-Length-Key (ALK)

We developed an age-length-key for both bay (Table 11.6) and ocean fish (Table 11.7) using scale ages, separately. The ALK can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using scale ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

11.4 RECOMMENDATIONS

We recommend that VMRC and ASMFC use otoliths for ageing Striped Bass. Although preparation time is greater for otoliths compared to scales, nonetheless as the mean age of Striped Bass increases in the recovering fishery, otoliths should provide more reliable estimates of age (Secor et al. 1995; Liao et al. 2013). We will continue to compare the age estimates between otoliths and scales.

Table 11.1: Number of bay Striped Bass collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
10 - 10.99	5	0	0	5
11 - 11.99	5	0	0	5
12 - 12.99	5	0	0	5
13 - 13.99	5	6	6	0
14 - 14.99	5	9	9	0
15 - 15.99	5	15	12	0
16 - 16.99	5	9	9	0
17 - 17.99	5	6	6	0
18 - 18.99	10	35	17	0
19 - 19.99	21	44	32	0
20 - 20.99	26	68	51	0
21 - 21.99	26	55	36	0
22 - 22.99	25	68	34	0
23 - 23.99	27	49	34	0
24 - 24.99	26	40	31	0
25 - 25.99	23	42	31	0
26 - 26.99	23	40	27	0
27 - 27.99	20	33	22	0
28 - 28.99	17	25	19	0
29 - 29.99	16	17	17	0
30 - 30.99	13	13	13	0
31 - 31.99	14	9	9	5
32 - 32.99	20	14	14	6
33 - 33.99	17	9	9	8
34 - 34.99	15	7	7	8
35 - 35.99	17	13	13	4
36 - 36.99	18	6	6	12
37 - 37.99	18	9	9	9
38 - 38.99	16	6	6	10
39 - 39.99	10	1	1	9
40 - 40.99	10	1	1	9
41 - 41.99	8	1	1	7
42 - 42.99	8	3	3	5
43 - 43.99	8	1	1	7
44 - 44.99	10	7	7	3
45 - 45.99	8	5	5	3
46 - 46.99	9	7	7	2
47 - 47.99	5	13	13	0
48 - 48.99	5	1	1	4
49 - 49.99	5	5	5	0
50 - 50.99	5	1	1	4
51 - 51.99	5	1	1	4
52 - 52.99	5	0	0	5
55 - 55.99	5	0	0	5
Totals	554	694	526	144

(Go back to text)

Table 11.2: Number of ocean Striped Bass collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
20 - 20.99	5	2	2	3
21 - 21.99	5	0	0	5
22 - 22.99	5	1	1	4
23 - 23.99	5	0	0	5
24 - 24.99	5	0	0	5
25 - 25.99	5	0	0	5
26 - 26.99	5	0	0	5
27 - 27.99	5	0	0	5
28 - 28.99	5	0	0	5
29 - 29.99	5	1	1	4
30 - 30.99	5	2	2	3
31 - 31.99	7	0	0	7
32 - 32.99	13	1	1	12
33 - 33.99	21	1	1	20
34 - 34.99	29	6	6	23
35 - 35.99	49	7	7	42
36 - 36.99	64	18	18	46
37 - 37.99	74	35	35	39
38 - 38.99	63	41	41	22
39 - 39.99	45	33	33	12
40 - 40.99	41	17	17	24
41 - 41.99	36	5	5	31
42 - 42.99	23	9	9	14
43 - 43.99	17	9	9	8
44 - 44.99	16	1	1	15
45 - 45.99	10	1	1	9
46 - 46.99	11	0	0	11
47 - 47.99	11	0	0	11
48 - 48.99	7	0	0	7
49 - 49.99	5	0	0	5
50 - 50.99	5	0	0	5
51 - 51.99	5	0	0	5
53 - 53.99	5	0	0	5
Totals	612	190	190	422

(Go back to text)

Table 11.3: The number of Striped Bass assigned to each total length-at-age category for 526 fish sampled for scale age determination in Chesapeake Bay, Virginia during 2021.

	Age																					
Interval	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	Totals
13 - 13.99	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
14 - 14.99	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
15 - 15.99	0	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
16 - 16.99	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
17 - 17.99	0	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
18 - 18.99	0	6	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
19 - 19.99	1	10	12	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
20 - 20.99	0	8	21	14	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
21 - 21.99	0	3	7	8	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36
22 - 22.99	0	2	3	8	18	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
23 - 23.99	0	5	3	2	21	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
24 - 24.99	0	3	0	6	19	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31
25 - 25.99	0	0	6	4	14	3	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	31
26 - 26.99	0	1	3	1	14	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
27 - 27.99	0	1	2	1	14	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	22
28 - 28.99	0	0	1	2	7	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
29 - 29.99	0	0	0	4	10	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
30 - 30.99	0	0	0	0	7	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	13
31 - 31.99	0	0	0	2	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
32 - 32.99	0	0	0	0	6	4	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	14
33 - 33.99	0	0	0	0	5	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	9
34 - 34.99	0	0	0	0	2	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
35 - 35.99	0	0	0	0	2	3	0	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	13
36 - 36.99	0	0	0	0	1	1	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	6
37 - 37.99	0	0	0	0	0	0	0	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	9
38 - 38.99	0	0	0	0	0	0	0	1	4	0	0	1	0	0	0	0	0	0	0	0	0	0	6
39 - 39.99	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
40 - 40.99	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
41 - 41.99	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
42 - 42.99	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	3
43 - 43.99	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
44 - 44.99	0	0	0	0	0	0	0	0	0	0	1	1	0	2	2	0	0	0	0	0	0	1	7
45 - 45.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	1	0	0	0	0	5
46 - 46.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	1	0	0	0	0	0	7
47 - 47.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	4	3	2	1	1	0	0	13
48 - 48.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
49 - 49.99	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	2	0	0	5
50 - 50.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
51 - 51.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Totals	3	77	68	63	170	44	12	13	27	5	1	4	1	6	7	10	6	3	1	3	1	1	526

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Table 11.4: The number of Striped Bass assigned to each total length-at-age category for 190 fish sampled for scale age determination in Virginia waters of Atlantic ocean during 2021.

	Age																
Interval	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	22	Totals
20 - 20.99	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
22 - 22.99	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
29 - 29.99	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
30 - 30.99	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
32 - 32.99	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
33 - 33.99	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
34 - 34.99	0	0	0	1	1	2	2	0	0	0	0	0	0	0	0	0	6
35 - 35.99	0	0	0	0	1	3	2	1	0	0	0	0	0	0	0	0	7
36 - 36.99	0	0	0	1	4	8	3	2	0	0	0	0	0	0	0	0	18
37 - 37.99	0	0	0	2	10	18	3	0	1	0	1	0	0	0	0	0	35
38 - 38.99	0	0	0	1	3	29	5	1	0	2	0	0	0	0	0	0	41
39 - 39.99	0	0	0	1	3	19	7	1	0	2	0	0	0	0	0	0	33
40 - 40.99	0	0	0	0	1	12	0	1	0	1	1	1	0	0	0	0	17
41 - 41.99	0	0	0	0	0	3	0	1	0	1	0	0	0	0	0	0	5
42 - 42.99	0	0	0	0	0	2	1	0	2	1	2	0	1	0	0	0	9
43 - 43.99	0	0	0	0	0	1	0	1	1	0	3	0	1	1	1	0	9
44 - 44.99	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
45 - 45.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Totals	3	1	1	7	23	99	23	8	4	7	8	1	2	1	1	1	190

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Table 11.5: The number of Striped Bass assigned to each total length-at-age category for 295 fish sampled for otolith age determination in Chesapeake Bay and Virginia waters of Atlantic Ocean during 2021.

	Age																						
Interval	3	4	5	6	7	8	9	10	11	12	13	14	16	17	18	20	21	23	24	25	26	27	Totals
13 - 13.99	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
14 - 14.99	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
15 - 15.99	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
16 - 16.99	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
17 - 17.99	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
18 - 18.99	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
19 - 19.99	6	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
20 - 20.99	2	8	4	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
21 - 21.99	1	2	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
22 - 22.99	1	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
23 - 23.99	0	0	1	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
24 - 24.99	0	0	0	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
25 - 25.99	1	2	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
26 - 26.99	0	1	0	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
27 - 27.99	0	1	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
28 - 28.99	0	0	1	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
29 - 29.99	0	0	1	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
30 - 30.99	0	0	0	4	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
31 - 31.99	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
32 - 32.99	0	0	0	3	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
33 - 33.99	0	0	0	3	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
34 - 34.99	0	0	0	2	1	1	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12
35 - 35.99	0	0	0	2	3	0	0	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	13
36 - 36.99	0	0	0	1	1	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
37 - 37.99	0	0	0	0	0	0	0	9	0	0	1	0	0	1	0	0	0	0	0	0	0	0	11
38 - 38.99	0	0	0	0	0	0	0	5	1	0	0	1	0	0	0	0	0	0	0	0	0	0	7
39 - 39.99	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
40 - 40.99	0	0	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7
41 - 41.99	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	3
42 - 42.99	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
43 - 43.99	0	0	0	0	0	0	0	0	1	1	0	2	1	0	1	0	1	0	0	0	0	0	7
44 - 44.99	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	1	1	0	6
45 - 45.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	3	1	0	6
46 - 46.99	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	1	0	1	7
47 - 47.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2	2	1	1	1	1	13
48 - 48.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
49 - 49.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	0	5
50 - 50.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
51 - 51.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Totals	49	23	12	77	22	3	3	46	6	3	1	7	1	3	8	8	5	2	1	8	4	3	295

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Table 11.6: Age-Length key, as proportion-at-age in each 1-inch length interval, based on scale ages for Striped Bass sampled in Chesapeake Bay, Virginia during 2021.

	Age																				
Interval	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24
13 - 13.99	0.17	0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 - 14.99	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 - 15.99	0	0.92	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 - 16.99	0.11	0.89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 - 17.99	0	0.83	0	0	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 - 18.99	0	0.35	0.53	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 - 19.99	0.03	0.31	0.38	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 - 20.99	0	0.16	0.41	0.27	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 - 21.99	0	0.08	0.19	0.22	0.47	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 - 22.99	0	0.06	0.09	0.24	0.53	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 - 23.99	0	0.15	0.09	0.06	0.62	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 - 24.99	0	0.1	0	0.19	0.61	0.06	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 - 25.99	0	0	0.19	0.13	0.45	0.1	0.1	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0
26 - 26.99	0	0.04	0.11	0.04	0.52	0.22	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27 - 27.99	0	0.05	0.09	0.05	0.64	0.14	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
28 - 28.99	0	0	0.05	0.11	0.37	0.26	0.16	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29 - 29.99	0	0	0	0.24	0.59	0.12	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30 - 30.99	0	0	0	0	0.54	0.23	0	0	0.23	0	0	0	0	0	0	0	0	0	0	0	0	0
31 - 31.99	0	0	0	0.22	0.56	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32 - 32.99	0	0	0	0	0.43	0.29	0.07	0	0.14	0.07	0	0	0	0	0	0	0	0	0	0	0	0
33 - 33.99	0	0	0	0	0.56	0.11	0.11	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0
34 - 34.99	0	0	0	0	0.29	0.14	0	0.43	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0
35 - 35.99	0	0	0	0	0.15	0.23	0	0.23	0.38	0	0	0	0	0	0	0	0	0	0	0	0	0
36 - 36.99	0	0	0	0	0.17	0.17	0.17	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
37 - 37.99	0	0	0	0	0	0	0	0.44	0.33	0.22	0	0	0	0	0	0	0	0	0	0	0	0
38 - 38.99	0	0	0	0	0	0	0	0.17	0.67	0	0	0.17	0	0	0	0	0	0	0	0	0	0
39 - 39.99	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
40 - 40.99	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
41 - 41.99	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
42 - 42.99	0	0	0	0	0	0	0	0	0	0.33	0	0.33	0	0.33	0	0	0	0	0	0	0	0
43 - 43.99	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
44 - 44.99	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0	0.29	0.29	0	0	0	0	0	0	0.14
45 - 45.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0.2	0.4	0	0.2	0	0	0	0
46 - 46.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.43	0.29	0.14	0	0	0	0	0
47 - 47.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.08	0.31	0.23	0.15	0.08	0.08	0	0
48 - 48.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
49 - 49.99	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0.2	0	0	0.4	0	0
50 - 50.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
51 - 51.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

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Table 11.7: Age-Length key, as proportion-at-age in each 1-inch length interval, based on scale ages for Striped Bass sampled in Virginia waters of the Atlantic Ocean during 2021.

	Age															
Interval	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	22
20 - 20.99	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 - 22.99	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29 - 29.99	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
30 - 30.99	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32 - 32.99	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
33 - 33.99	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
34 - 34.99	0	0	0	0.17	0.17	0.33	0.33	0	0	0	0	0	0	0	0	0
35 - 35.99	0	0	0	0	0.14	0.43	0.29	0.14	0	0	0	0	0	0	0	0
36 - 36.99	0	0	0	0.06	0.22	0.44	0.17	0.11	0	0	0	0	0	0	0	0
37 - 37.99	0	0	0	0.06	0.29	0.51	0.09	0	0.03	0	0.03	0	0	0	0	0
38 - 38.99	0	0	0	0.02	0.07	0.71	0.12	0.02	0	0.05	0	0	0	0	0	0
39 - 39.99	0	0	0	0.03	0.09	0.58	0.21	0.03	0	0.06	0	0	0	0	0	0
40 - 40.99	0	0	0	0	0.06	0.71	0	0.06	0	0.06	0.06	0.06	0	0	0	0
41 - 41.99	0	0	0	0	0	0.6	0	0.2	0	0.2	0	0	0	0	0	0
42 - 42.99	0	0	0	0	0	0.22	0.11	0	0.22	0.11	0.22	0	0.11	0	0	0
43 - 43.99	0	0	0	0	0	0.11	0	0.11	0.11	0	0.33	0	0.11	0.11	0.11	0
44 - 44.99	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
45 - 45.99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

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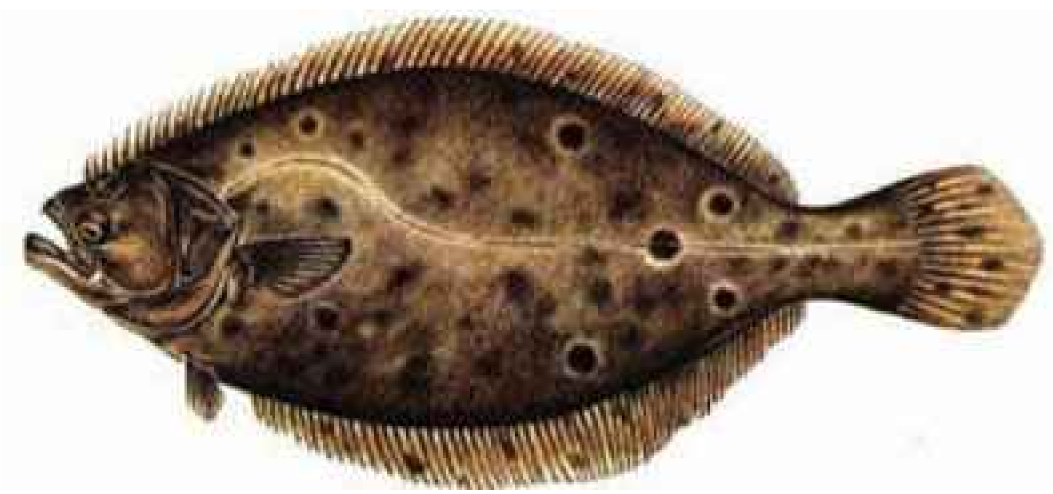
Chapter 12

SUMMER FLOUNDER *Paralichthys dentatus*



12.1 INTRODUCTION

We aged a total of 863 Summer Flounder,*Paralichthys dentatus*, using their scales (2 fish aged using otoliths only) collected by the VMRC's Biological Sampling Program in 2021. Of 863 aged fish, 341 and 522 fish were collected in Chesapeake Bay (bay fish) and Virginia waters of the Atlantic Ocean (ocean fish), respectively. The average bay fish age was 3 years with a standard deviation of 1.5 and a standard error of 0.08. Nine age classes (1 to 9) were represented in the bay fish, comprising fish from the 2012 to 2020 year classes. The bay fish sample in 2021 was dominated by the year classes of 2017, 2018, 2019, and 2020 with 17%, 21%, 29%, and 16%, respectively. The average ocean fish age was 4.9 years with a standard deviation of 2.2 and a standard error of 0.1. Thirteen age classes (1 to 13) were represented in the ocean fish, comprising fish from the 2008 to 2020 year classes. The ocean fish sample in 2021 was dominated by the year classes of 2014, 2015, 2016, 2017, 2018, and 2019 with 11%, 11%, 14%, 18%, 21%, and 10%, respectively. We also aged 348 fish using their otoliths in addition to ageing their scales. The otolith ages were compared to the scale ages to examine how close both ages were to one another (see details in Results).

12.2 METHODS

12.2.1 Sample size for ageing

We estimated sample sizes for ageing Summer Flounder collected in both Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021, respectively, using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \qquad (12.1)$$

where A is the sample size for ageing Summer Flounder in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Summer Flounder used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Summer Flounder collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

12.2.2 Handling of collection

Sagittal otoliths (hereafter, referred to as "otoliths") and scales were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted based on date of capture, their envelope labels were verified against VMRC's collection data, and each fish assigned a unique Age and Growth Laboratory identification number. All otoliths and scales were stored dry within their original labeled coin envelopes; otoliths were contained inside protective Axygen 2.0 ml microtubes.

12.2.3 Preparation

Scales

Summer flounder scales were prepared for age and growth analysis by making acetate impressions of the scale microstructure. Due to extreme variation in the size and shape of scales from individual fish, we selected only those scales that had even margins and which were of uniform size. We selected a range of four to six preferred scales (based on overall scale size) from each fish, making sure that only non-regenerated scales were used. Scale impressions were made on extruded clear acetate sheets (25 mm x 75 mm) with a Carver Laboratory Heated Press (model "C"). The scales were pressed with the following settings:

Pressure: 15000 psi
Temperature: 77 °C (170 °F)
Time: 5 to 10 min

Summer Flounder scales that were the size of a quarter (coin) or larger, were pressed individually for up to twenty minutes. After pressing, the impressions were viewed with a Bell and Howell microfiche reader and checked again for regeneration and incomplete margins. Impressions that were too light, or when all scales were regenerated a new impression was made using different scales from the same fish.

Click here to obtain the protocol at the VMRC website on how to prepare scale impression for ageing Summer Flounder.

Otoliths

We used our thin-section and bake technique to process Spadefish sagittal otoliths (hereafter, referred to as "otoliths") for age determination. Otolith preparation began by randomly selecting either the right or left otolith. Each whole otolith was placed in a ceramic "Coors" spot plate well and baked in a Thermolyne 1400 furnace at 400 °C. Baking time was dependent on the otolith's size and gauged by color, with a light caramel color desired. Once a suitable color was achieved the baked otolith was embedded in epoxy resin with its distal surface orientated downwards and allowed to harden overnight. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet™ low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The otolith was positioned so the blades straddled each side of the otolith focus. It was crucial that this cut be perpendicular to the long axis of the otolith. Failure to do so resulted in broadening and distorted winter growth zones. A proper cut resulted in annuli that were clearly defined and delineated. Once cut, thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Summer Flounder.

12.2.4 Readings

The CQFE system assigns an age class to a fish based on a combination of reading the information contained in its otolith, the date of its capture, and the species-specific period when it deposits its annulus. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called annuli. Technically, an otolith annulus is the combination of both the opaque and the translucent bands. In practice, only the opaque bands are counted as annuli. The number of these visible dark bands replaces "x" in our notation below, and is the initial "age" assignment of the fish.

Second, the otolith section is examined for translucent growth. If no translucent growth is visible beyond the last dark annulus, the otolith is called "even" and no modification of the assigned age is made. The initial assigned age, then, is the age class of the fish. Any growth beyond the last annulus can be interpreted as either being toward the next age class or within the same age class. If translucent growth is visible beyond the last dark annulus, a "+" is added to the notation.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the dark band of the annulus. If the fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class notation of "x+x", where "x" is the number of dark bands in the otolith. If the fish is captured between January 1 and the end of the species-specific annulus deposition period, it is assigned an age class notation of "x+(x+1)". Thus, any growth beyond the last annulus, after its "birthday", but before the dark band deposition period, is interpreted as being toward the next age class.

For example, Summer Flounder otolith deposition occurs between January and April (Bolz 1999). A Summer Flounder captured between January 1 and April 30, before the end of the species' annulus formation period, with three visible annuli and some translucent growth after the last annulus, would be assigned an age class of "x+(x+1)" or 3+(3+1), noted as 3+4. This is the same age-class assigned to a fish with four visible annuli captured after the end of June 30, the period of annulus formation, which would be noted as 4+4.

Summer flounder scales are also considered to have a deposition between January and June (Bolz 1999 and modified by CQFE), and age class assignment using these hard-parts is conducted in the same way as otoliths.

All Summer Flounder samples (scale pressings and sectioned otoliths) were aged by two different readers in chronological order based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, both readers sat down together and re-aged the fish again without any knowledge of previously estimated ages or lengths, then assigned a final age to the fish. When the age readers were unable to agree on a final age, the fish was excluded from further analysis.

Scales

We determined fish age by viewing acetate impressions of scales (Figure 12.1) with a standard Bell and Howell R-735 microfiche reader equipped with 20 and 29 mm lenses. Annuli

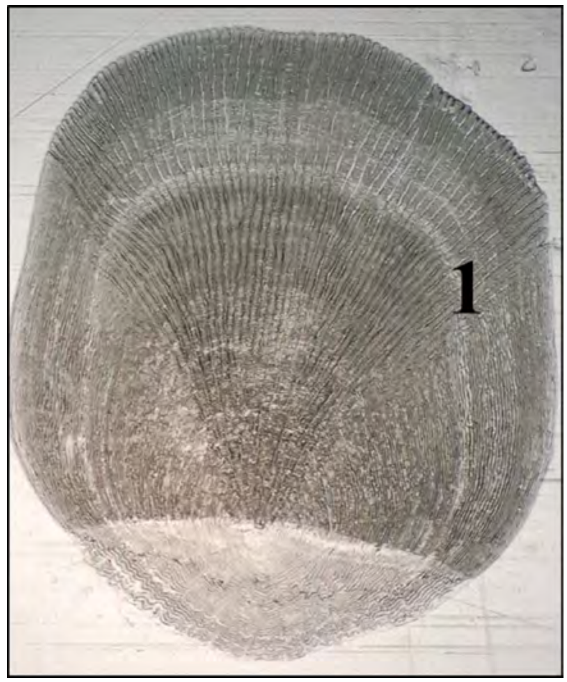


Figure 12.1: Scale impression of a 1 year-old Summer Flounder

on Summer Flounder scales are identified based on two scale microstructure features, "crossing over" and circuli disruption. Primarily, "crossing over" in the lateral margins near the posterior/anterior interface of the scale is used to determine the origin of the annulus. Here compressed circuli (annulus) "cross-over" the previously deposited circuli of the previous year's growth. Typically annuli of the first three years can be observed transversing this interface as dark bands. These bands remain consistent throughout the posterior field and rejoin the posterior/anterior interface on the opposite side of the focus. Annuli can also be observed in the anterior lateral field of the scale. Here the annuli typically reveal a pattern of discontinuous and suddenly breaking segmented circuli. This event can also be distinguished by the presence of concentric white lines, which are typically associated with the disruption of circuli.

Annuli can also be observed bisecting the perpendicular plain of the radial striations in the anterior field of the scale. Radii emanate out from the focus of the scale towards the outer corner margins of the anterior field. These radial striations consist mainly of segmented concave circuli. The point of intersection between radii and annuli results in a "straightening out" of the concave circuli. This straightening of the circuli should be consistent throughout the entire anterior field of the scale. This event is further amplified by the presence of concave circuli neighboring both directly above and below the annulus. The first year's annulus can be difficult to locate on some scales. It is typically best identified in the lateral field of the anterior portion of the scale. The distance from the focus to the first year's annulus is typically larger with respect to the following annuli. For the annuli two through six, summer growth generally decreases proportionally. For ages greater than six, a crowding effect of the annuli near the outer margins of the scale is observed. This crowding effect creates difficulties in edge interpretation. At this point it is best to focus on the straightening of the circuli at the anterior margins of the scale.

When ageing young Summer Flounder, zero through age two, extreme caution must be taken as not to over age the structure. In young fish there is no point of reference to aid in the determination of the first year; this invariably results in over examination of the scale and such events as hatching or saltwater incursion marks (checks) may be interpreted as the first year.

Otoliths

All thin-sections were aged by two different readers using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 12.2). Each reader aged all of the otolith samples. By convention an annulus is identified as the narrow opaque zone, or winter growth. Typically the first year's annulus can be determined by first locating the focus of the otolith. The focus is generally located, depending on preparation, in the center of the otolith, and is visually well defined as a dark oblong region. The first year's annulus can be located directly below the focus, along the outer ridge of the sulcal groove on the ventral and dorsal sides of the otolith. This insertion point along the sulcal ridge resembles a check mark (not to be confused with a false annulus). Here the annulus can be followed outwards along the ventral and dorsal surfaces where it encircles the focus. Subsequent annuli also emanate from the sulcal ridge; however, they do not encircle the focus, but rather travel outwards to the distal surface of the otolith. To be considered a true annulus, each annulus must be rooted in the sulcus and travel without interruption to the distal surface of the otolith. The annuli in Summer Flounder have a tendency to split as they advance towards the distal surface. As a result, it is critical that reading path proceed in a direction down the sulcal ridge and outwards to the distal surface.

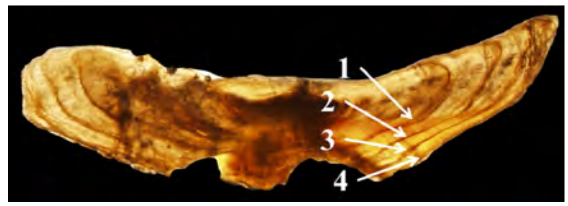


Figure 12.2: Otolith thin-section of a 4 year-old Summer Flounder with the last annulus on the edge of the thin-section

Click here to obtain the protocol at the CQFE website on how to age Summer Flounder using their otolith thin-sections.

12.2.5 Comparison Tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (*CV*) analysis were used to detect any systematic difference and precision on age readings, respectively, for following comparisons: 1) between the two readers in the current year; 2) within each reader in the current year; 3) time-series bias between the current and previous years within each reader; and 4) between scale and otoliths ages. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2000 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

12.3 RESULTS

12.3.1 Sample size

We estimated a sample size of 380 bay Summer Flounder in 2021, ranging in length interval from 8 to 28 inches (Table 12.1). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 7% for Age 2 to the largest *CV* of 21% for Age 6 of the bay fish. We aged 341 of 372 Summer Flounder (The rest of fish were either without scales or over-collected for certain length interval(s)) collected by VMRC in Chesapeake Bay in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 58 fish. We were short some fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would possibly be influenced significantly.

We estimated a sample size of 525 ocean Summer Flounder in 2021, ranging in length interval from 13 to 32 inches (Table 12.2). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 9% for Age 4 and 5 to the largest *CV* of 24% for Age 9 of the ocean fish. We randomly selected and aged 522 fish from 599 Summer Flounder collected by VMRC in Virginia waters of the Atlantic Ocean in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 33 fish. We were short only a few fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would not be influenced significantly.

12.3.2 Scales

Both readers had moderate self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 78% (1 year or less agreement of 98%) and a *CV* of 5.27% (test of symmetry: $\chi^2 = 3.67$, $df = 6$, $P = 0.7217$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 82% (1 year or less agreement of 92%) and a *CV* of 6.33% (test of symmetry: $\chi^2 = 7$, $df = 7$, $P = 0.4289$). There was an evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 72% (1 year or less agreement of 96%) and a *CV* of 6.26% (test of symmetry: $\chi^2 = 40.98$, $df = 23$, $P = 0.0119$) (Figure 12.3).

There was no time-series bias for either reader. Reader 1 had an agreement of 70% (1 year or less agreement of 100%) with ages of fish aged in 2000 with a *CV* of 5.92% (test of symmetry: $\chi^2 = 4.33$, $df = 4$, $P = 0.3628$). Reader 2 had an agreement of 82% (1 year or less agreement of 100%) with a *CV* of 3.49% (test of symmetry: $\chi^2 = 3.67$, $df = 4$, $P = 0.453$).

Of the 341 bay Summer Flounder aged with scales (but 2 of the 341 fish aged with otoliths only), 9 age classes (1 to 9) were represented (Table 12.3). The average age for the sample was 3 years. The standard deviation and standard error were 1.5 and 0.08, respectively.

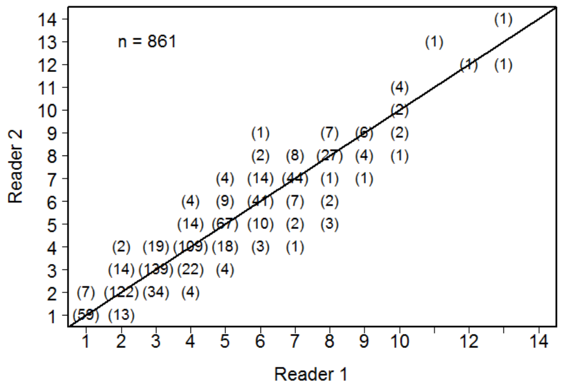


Figure 12.3: Between-reader comparison of scale age estimates for Summer Flounder collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

Year-class data (Figure 12.4) indicates that recruitment into the fishery in Chesapeake Bay begins at age 1, which corresponds to the 2020 year-class for Summer Flounder caught in 2021. Summer flounder in the sample in 2021 was dominated by the year classes of 2017, 2018, 2019, and 2020 with 17%, 21%, 29%, and 16%, respectively. The sex ratio of male to female was 1:Inf for the bay fish.

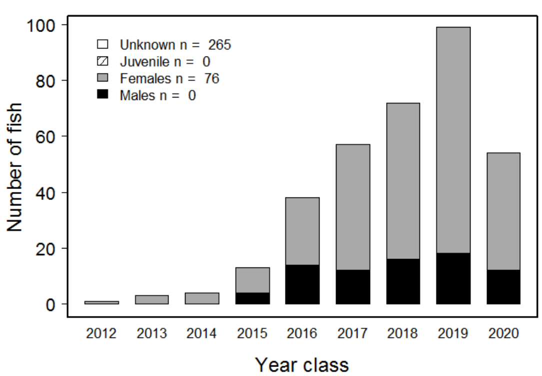


Figure 12.4: Year-class frequency distribution for Summer Flounder collected in Chesapeake Bay, Virginia for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

Of the 522 ocean Summer Flounder aged with scales, 13 age classes (1 to 13) were represented (Table 12.4). The average age for the sample was 4.9 years. The standard deviation and standard error were 2.2 and 0.1, respectively. Year-class data (Figure 12.5) indicates that recruitment into the fishery in Virginia waters of Atlantic ocean begins at age 1, which corresponds to the 2020 year-class for Summer Flounder caught in 2021. Summer flounder in the sample in 2021 was dominated by the year classes of 2014, 2015, 2016, 2017, 2018, and 2019 with 11%, 11%, 14%, 18%, 21%, and 10%, respectively. The sex ratio of male to female was 1:1.18 for the ocean fish.

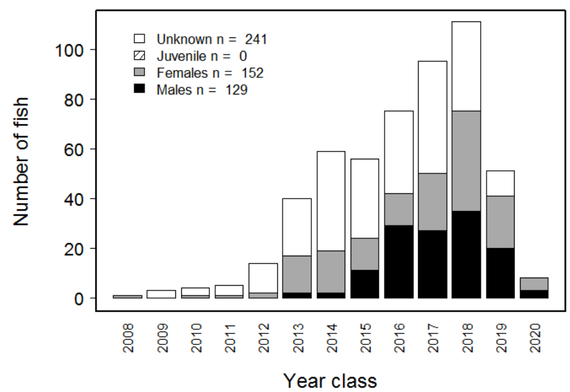


Figure 12.5: Year-class frequency distribution for Summer Flounder collected in Virginia waters of the Atlantic Ocean for ageing in 2021. Distribution is broken down by. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

12.3.3 Otoliths

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 86% and a *CV* of 2.79% (test of symmetry: $\chi^2 = 5$, $df = 4$, $P = 0.2873$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 90% and a *CV* of 1.4% (test of symmetry: $\chi^2 = 3$, $df = 4$, $P = 0.5578$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 86% (1 year or less agreement of 99%) and a *CV* of

2.42% (test of symmetry: $\chi^2 = 10.97$, $df = 14$, $P = 0.6887$) (Figure 12.6).

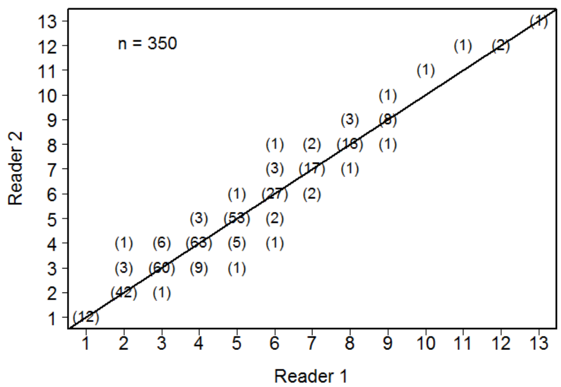


Figure 12.6: Between-reader comparison of otolith age estimates for Summer Flounder collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 82% with ages of fish aged in 2003 with a *CV* of 5.3% (test of symmetry: $\chi^2 = 9$, $df = 5$, $P = 0.1091$). Reader 2 had an agreement of 92% with a *CV* of 1.69% (test of symmetry: $\chi^2 = 2$, $df = 3$, $P = 0.5724$).

Of the 350 Summer Flounder aged with otoliths, 13 age classes (1 to 13) were represented (Table 12.5). The average age for the sample was 4.5 years. The standard deviation and standard error were 2.1 and 0.11, respectively.

12.3.4 Comparison of scale and otolith ages

We aged 348 Summer Flounder using scales and otoliths (Excluding 2 fish with otolith-ages only). There was an evidence of systematic disagreement between otolith and scale ages (test of symmetry: $\chi^2 = 77.07$, $df = 26$, $P < 0.0001$) with an average *CV* of 12.1%. There was an agreement of 53% between scale and otoliths ages whereas scales were assigned a lower and higher age than otoliths for 38% and 9% of the fish, respectively (Figure 12.7). There was also an evidence of bias between otolith and scale ages using an age bias plot(Figure 12.8), with scale generally assigned higher ages for younger fish and lower ages for older fish than otolith age estimates.

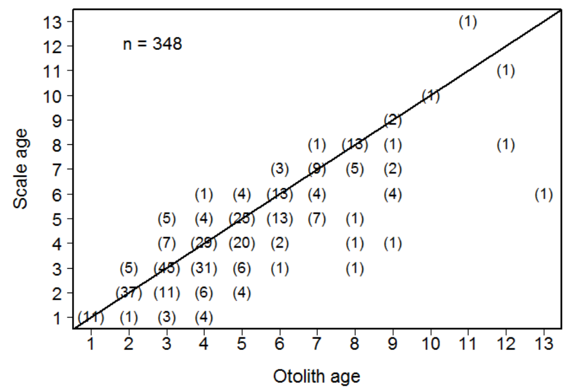


Figure 12.7: Comparison of scale and otolith age estimates for Summer Flounder collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish

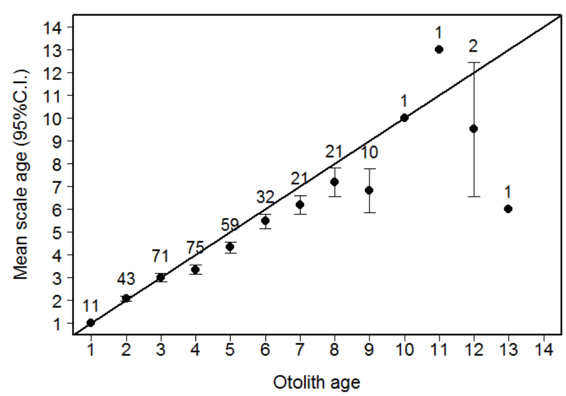


Figure 12.8: Age-bias plot for Summer Flounder scale and otolith age estimates in 2021. The number above the upper CI bar is number of fish.

12.3.5 Age-Length-Key (ALK)

We developed an age-length-key for both bay (Table 12.6) and ocean fish (Table 12.7) using scale ages, separately. The ALK can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using scale ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

12.4 RECOMMENDATIONS

Atlantic States Marine Fisheries Commission held a QAQC ageing workshop in St. Petersburg, Florida, in March of 2019 (ASMFC 2019). The workshop recommended that summer flounder should be aged using otoliths, not scales, when possible.

Table 12.1: Number of bay Summer Flounder collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
8 - 8.99	5	0	0	5
13 - 13.99	5	0	0	5
14 - 14.99	77	66	66	11
15 - 15.99	60	50	50	10
16 - 16.99	47	41	41	6
17 - 17.99	42	76	55	0
18 - 18.99	36	50	40	0
19 - 19.99	31	29	29	2
20 - 20.99	29	31	31	0
21 - 21.99	16	14	14	2
22 - 22.99	7	7	7	0
23 - 23.99	5	5	5	0
24 - 24.99	5	3	3	2
25 - 25.99	5	0	0	5
26 - 26.99	5	0	0	5
28 - 28.99	5	0	0	5
Totals	380	372	341	58

(Go back to text)

Table 12.2: Number of ocean Summer Flounder collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
13 - 13.99	5	3	3	2
14 - 14.99	41	46	43	0
15 - 15.99	65	90	66	0
16 - 16.99	65	96	74	0
17 - 17.99	59	78	60	0
18 - 18.99	45	56	46	0
19 - 19.99	31	34	34	0
20 - 20.99	28	22	22	6
21 - 21.99	22	27	27	0
22 - 22.99	27	22	22	5
23 - 23.99	27	25	25	2
24 - 24.99	24	27	27	0
25 - 25.99	20	22	22	0
26 - 26.99	18	20	20	0
27 - 27.99	15	16	16	0
28 - 28.99	11	11	11	0
29 - 29.99	7	2	2	5
30 - 30.99	5	1	1	4
31 - 31.99	5	1	1	4
32 - 32.99	5	0	0	5
Totals	525	599	522	33

(Go back to text)

Table 12.3: The number of Summer Flounder assigned to each total length-at-age category for 341 fish sampled for scale age determination in Chesapeake Bay, Virginia during 2021.

	Age									
Interval	1	2	3	4	5	6	7	8	9	Totals
14 - 14.99	34	29	2	1	0	0	0	0	0	66
15 - 15.99	16	27	7	0	0	0	0	0	0	50
16 - 16.99	1	18	17	5	0	0	0	0	0	41
17 - 17.99	3	16	17	13	5	1	0	0	0	55
18 - 18.99	0	7	7	15	8	2	0	1	0	40
19 - 19.99	0	0	12	7	6	1	2	0	1	29
20 - 20.99	0	2	8	7	8	4	1	1	0	31
21 - 21.99	0	0	2	5	4	1	1	1	0	14
22 - 22.99	0	0	0	3	2	2	0	0	0	7
23 - 23.99	0	0	0	1	3	1	0	0	0	5
24 - 24.99	0	0	0	0	2	1	0	0	0	3
Totals	54	99	72	57	38	13	4	3	1	341

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Table 12.4: The number of Summer Flounder assigned to each total length-at-age category for 522 fish sampled for scale age determination in Virginia waters of Atlantic ocean during 2021.

	Age													
Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	Totals
13 - 13.99	0	2	1	0	0	0	0	0	0	0	0	0	0	3
14 - 14.99	1	8	15	10	5	3	0	1	0	0	0	0	0	43
15 - 15.99	2	7	27	15	10	4	1	0	0	0	0	0	0	66
16 - 16.99	1	17	23	16	14	3	0	0	0	0	0	0	0	74
17 - 17.99	3	10	16	10	15	3	2	1	0	0	0	0	0	60
18 - 18.99	1	3	12	11	8	4	4	2	1	0	0	0	0	46
19 - 19.99	0	3	8	11	3	5	2	1	1	0	0	0	0	34
20 - 20.99	0	0	4	7	3	2	3	3	0	0	0	0	0	22
21 - 21.99	0	1	4	4	6	6	5	0	1	0	0	0	0	27
22 - 22.99	0	0	1	2	4	6	5	2	0	1	1	0	0	22
23 - 23.99	0	0	0	5	2	7	7	3	1	0	0	0	0	25
24 - 24.99	0	0	0	3	3	7	10	3	0	1	0	0	0	27
25 - 25.99	0	0	0	1	2	3	8	3	4	0	1	0	0	22
26 - 26.99	0	0	0	0	0	2	8	4	3	1	0	2	0	20
27 - 27.99	0	0	0	0	0	1	3	8	2	0	0	1	1	16
28 - 28.99	0	0	0	0	0	0	1	8	0	1	1	0	0	11
29 - 29.99	0	0	0	0	0	0	0	1	0	0	1	0	0	2
30 - 30.99	0	0	0	0	0	0	0	0	1	0	0	0	0	1
31 - 31.99	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Totals	8	51	111	95	75	56	59	40	14	5	4	3	1	522

(Go back to text)

Table 12.5: The number of Summer Flounder assigned to each total length-at-age category for 350 fish sampled for otolith age determination in Chesapeake Bay and Virginia waters of Atlantic Ocean during 2021.

	Age													
Interval	1	2	3	4	5	6	7	8	9	10	11	12	13	Totals
13 - 13.99	0	1	0	0	0	0	0	0	0	0	0	0	0	1
14 - 14.99	6	8	5	3	4	0	0	0	2	0	0	0	0	28
15 - 15.99	4	6	13	13	10	2	5	1	2	0	0	0	0	56
16 - 16.99	0	14	11	16	15	4	1	1	1	0	0	0	0	63
17 - 17.99	2	9	17	9	9	2	2	2	0	0	0	0	0	52
18 - 18.99	0	5	5	13	3	5	1	1	1	0	0	1	0	35
19 - 19.99	0	0	13	9	1	1	0	0	0	0	0	0	0	24
20 - 20.99	0	0	5	6	4	0	0	0	0	0	0	0	0	15
21 - 21.99	0	0	2	3	3	1	1	0	0	0	0	0	1	11
22 - 22.99	0	0	0	1	4	2	2	0	1	0	0	1	0	11
23 - 23.99	0	0	0	2	3	6	4	2	0	0	0	0	0	17
24 - 24.99	0	0	0	1	3	4	3	3	0	0	0	0	0	14
25 - 25.99	0	0	0	0	0	3	0	3	1	0	0	0	0	7
26 - 26.99	0	0	0	0	0	2	0	2	0	0	0	0	0	4
27 - 27.99	0	0	0	0	0	0	2	2	1	0	1	0	0	6
28 - 28.99	0	0	0	0	0	0	0	4	0	0	0	0	0	4
30 - 30.99	0	0	0	0	0	0	0	0	1	0	0	0	0	1
31 - 31.99	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Totals	12	43	71	76	59	32	21	21	10	1	1	2	1	350

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Table 12.6: Age-Length key, as proportion-at-age in each 1-inch length interval, based on scale ages for Summer Flounder sampled in Chesapeake Bay, Virginia during 2021.

	Age								
Interval	1	2	3	4	5	6	7	8	9
14 - 14.99	0.52	0.44	0.03	0.02	0	0	0	0	0
15 - 15.99	0.32	0.54	0.14	0	0	0	0	0	0
16 - 16.99	0.02	0.44	0.41	0.12	0	0	0	0	0
17 - 17.99	0.05	0.29	0.31	0.24	0.09	0.02	0	0	0
18 - 18.99	0	0.17	0.17	0.38	0.2	0.05	0	0.03	0
19 - 19.99	0	0	0.41	0.24	0.21	0.03	0.07	0	0.03
20 - 20.99	0	0.06	0.26	0.23	0.26	0.13	0.03	0.03	0
21 - 21.99	0	0	0.14	0.36	0.29	0.07	0.07	0.07	0
22 - 22.99	0	0	0	0.43	0.29	0.29	0	0	0
23 - 23.99	0	0	0	0.2	0.6	0.2	0	0	0
24 - 24.99	0	0	0	0	0.67	0.33	0	0	0

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Table 12.7: Age-Length key, as proportion-at-age in each 1-inch length interval, based on scale ages for Summer Flounder sampled in Virginia waters of the Atlantic Ocean during 2021.

	Age												
Interval	1	2	3	4	5	6	7	8	9	10	11	12	13
13 - 13.99	0	0.67	0.33	0	0	0	0	0	0	0	0	0	0
14 - 14.99	0.02	0.19	0.35	0.23	0.12	0.07	0	0.02	0	0	0	0	0
15 - 15.99	0.03	0.11	0.41	0.23	0.15	0.06	0.02	0	0	0	0	0	0
16 - 16.99	0.01	0.23	0.31	0.22	0.19	0.04	0	0	0	0	0	0	0
17 - 17.99	0.05	0.17	0.27	0.17	0.25	0.05	0.03	0.02	0	0	0	0	0
18 - 18.99	0.02	0.07	0.26	0.24	0.17	0.09	0.09	0.04	0.02	0	0	0	0
19 - 19.99	0	0.09	0.24	0.32	0.09	0.15	0.06	0.03	0.03	0	0	0	0
20 - 20.99	0	0	0.18	0.32	0.14	0.09	0.14	0.14	0	0	0	0	0
21 - 21.99	0	0.04	0.15	0.15	0.22	0.22	0.19	0	0.04	0	0	0	0
22 - 22.99	0	0	0.05	0.09	0.18	0.27	0.23	0.09	0	0.05	0.05	0	0
23 - 23.99	0	0	0	0.2	0.08	0.28	0.28	0.12	0.04	0	0	0	0
24 - 24.99	0	0	0	0.11	0.11	0.26	0.37	0.11	0	0.04	0	0	0
25 - 25.99	0	0	0	0.05	0.09	0.14	0.36	0.14	0.18	0	0.05	0	0
26 - 26.99	0	0	0	0	0	0.1	0.4	0.2	0.15	0.05	0	0.1	0
27 - 27.99	0	0	0	0	0	0.06	0.19	0.5	0.12	0	0	0.06	0.06
28 - 28.99	0	0	0	0	0	0	0.09	0.73	0	0.09	0.09	0	0
29 - 29.99	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0
30 - 30.99	0	0	0	0	0	0	0	0	1	0	0	0	0
31 - 31.99	0	0	0	0	0	0	0	0	0	1	0	0	0

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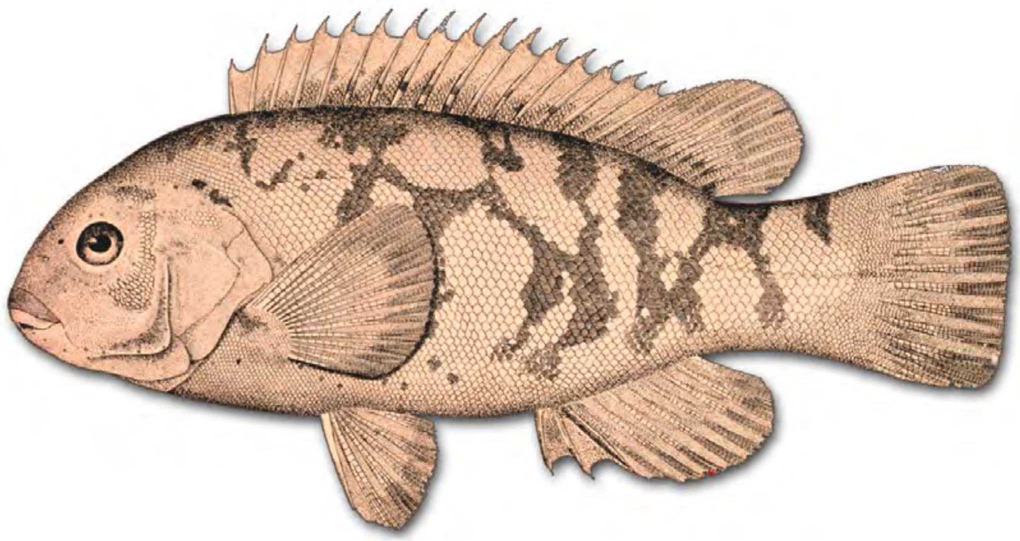
Chapter 13

TAUTOG *Tautoga onitis*



13.1 INTRODUCTION

We aged a total of 119 Tautog, *Tautoga onitis*, using their opercula collected by the VMRC's Biological Sampling Program in 2021. Of 119 aged fish, 118 and 1 fish were collected in Chesapeake Bay (bay fish) and Virginia waters of the Atlantic Ocean (ocean fish), respectively. The average age for the bay fish was 5.3 years with a standard deviation of 1.8 and a standard error of 0.17. Ten age classes (2 to 10, and 13) were represented in the bay fish, comprising fish from the 2008, and 2011 to 2019 year classes. The bay fish sample in 2021 was dominated by the year classes of 2015, 2016, 2017, and 2018 with 29%, 19%, 16%, and 15%, respectively. Only one ocean fish was collected, 16 years old, and in the year class of 2005. We also aged 116 fish using their otoliths in addition to ageing their opercula. The otolith ages were compared to the operculum ages to examine how close both ages were to one another (see details in Results).

13.2 METHODS

13.2.1 Sample size for ageing

We estimated sample sizes for ageing Tautog collected in both Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021, respectively, using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \qquad (13.1)$$

where A is the sample size for ageing Tautog in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Tautog used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Tautog collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

13.2.2 Handling of collection

Sagittal otoliths (hereafter, referred to as "otoliths") and opercula were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted based on date of capture. Their envelope labels were verified against VMRC's collection data, and each fish assigned a unique Age and Growth Laboratory identification number. All otoliths and opercula were stored dry within their original labeled coin envelopes; otoliths were contained inside protective Axygen 2.0 ml microtubes.

13.2.3 Preparation

Opercula

Tautog opercula were boiled for several minutes to remove any attached skin and connective tissue. After boiling, opercula were inspected for damage. If there were no obvious flaws, the opercula was dried and then stored in a new, labeled envelope.

Click here to obtain the protocol at the VMRC website on how to prepare opercula for ageing Tautog.

Otoliths

We used our thin-section and bake technique to process Spadefish sagittal otoliths (hereafter, referred to as "otoliths") for age determination. Otolith preparation began by randomly selecting either the right or left otolith. Each whole otolith was placed in a ceramic "Coors" spot plate well and baked in a Thermolyne 1400 furnace at 400 °C. Baking time was dependent on the otolith's size and gauged by color, with a light caramel color desired. Once a suitable color was achieved the baked otolith was embedded in epoxy resin with its distal surface orientated downwards and allowed to harden overnight. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a permanent marker across the epoxy resin surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). The otolith was positioned so the blades straddled each side of the otolith focus. It was crucial that this cut be perpendicular to the long axis of the otolith. Failure to do so resulted in broadening and distorted winter growth zones. A proper cut resulted in annuli that were clearly defined and delineated. Once cut, thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-section.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Tautog.

13.2.4 Readings

The CQFE system assigns an age class to a fish based on a combination of reading the information contained in its otolith, the date of its capture, and the species-specific period when it deposits its annulus. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called annuli. Technically, an otolith annulus is the combination of both the opaque and the translucent bands. In practice, only the opaque bands are counted as annuli. The number of these visible dark bands replaces "x" in our notation below, and is the initial "age" assignment of the fish.

Second, the otolith section is examined for translucent growth. If no translucent growth is visible beyond the last dark annulus, the otolith is called "even" and no modification of the assigned age is made. The initial assigned age, then, is the age class of the fish. Any growth beyond the last annulus can be interpreted as either being toward the next age class or within the same age class. If translucent growth is visible beyond the last dark annulus, a "+" is added to the notation.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the dark band of the annulus. If the fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class notation of "x+x", where "x" is the number of dark bands in the otolith. If the fish is captured between January 1 and the end of the species-specific annulus deposition period, it is assigned an age class notation of "x+(x+1)". Thus, any growth beyond the last annulus, after its "birthday", but before the dark band deposition period, is interpreted as being toward the next age class.

For example, Tautog otolith deposition occurs between May and July (Hostetter and Munroe 1993). A Tautog captured between January 1 and July 31, before the end of the species' annulus formation period, with three visible annuli and some translucent growth after the last annulus, would be assigned an age class of "x+(x+1)" or 3+(3+1), noted as 3+4. This is the same age-class assigned to a fish with four visible annuli captured after the end of June 30, the period of annulus formation, which would be noted as 4+4.

Tautog opercula are also considered to have a deposition period of May through July (Hostetter and Munroe 1993), and age class assignment using these hard-parts is conducted in the same way as otoliths.

All Tautog samples (opercula and sectioned otoliths) were aged by two different readers in chronological order based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, both readers sat down together and re-aged the fish again without any knowledge of previously estimated ages or lengths, then assigned a final age to the fish. When the age readers were unable to agree on a final age, the fish was excluded from further analysis.

Opercula

All prepared opercula were aged by two different readers in chronological order based on collection date, without knowledge of previously estimated ages or the specimen lengths. Opercula were aged on a light table with no magnification (Figure 13.1).

Otoliths

All otolith thin-sections were aged by two different readers using a Nikon SMZ1000 stereo microscope under transmitted light and darkfield polarization at between 8 and 20 times magnification (Figure 13.2). Each reader aged all of the otolith samples.

Click here to obtain the protocol at the CQFE website on how to age Tautog using their otolith thin-sections.

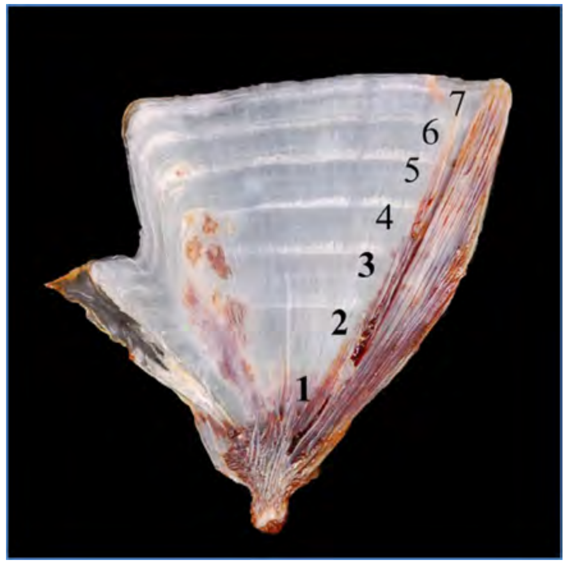


Figure 13.1: Operculum of a 7 year-old Tautog

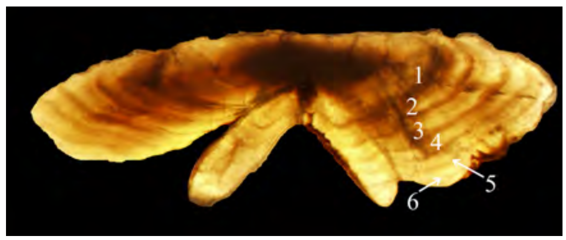


Figure 13.2: Otolith thin-section of 6 year-old Tautog

13.2.5 Comparison Tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for following comparisons: 1) between the two readers in the current year; 2) within each reader in the current year; 3) time-series bias between the current and previous years within each reader; and 4) between operculum and otoliths ages. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2000 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

13.3 RESULTS

13.3.1 Sample size

We estimated a sample size of 414 bay Tautog in 2021, ranging in length interval from 8 to 26 inches (Table 13.1). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 9% for Age 6 to the largest *CV* of 22% for Age 9 of the bay fish. We aged all 118 Tautog collected by VMRC in Chesapeake Bay in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 300 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

We estimated a sample size of 436 ocean Tautog in 2021, ranging in length interval from 15 to 30 inches (Table 13.2). This sample size provided a range in *CV* for age composition approximately from the smallest *CV* of 10% for Age 6 to the largest *CV* of 25% for Age 13 and 23 of the ocean fish. We aged only 1 tautog collected by VMRC in Virginia waters of the Atlantic Ocean in 2021. We fell short in our over-all collections for this optimal length-class sampling estimate by 435 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

13.3.2 Opercula

Reader 1 had moderate self-precision and Read 2 had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 72% (1 year or less agreement of 90%) and a *CV* of 5.31% (test of symmetry: $\chi^2 = 14$, $df = 10$, $P = 0.173$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 72% (1 year or less agreement of 100%) and a *CV* of 3.74% (test of symmetry: $\chi^2 = 6$, $df = 7$, $P = 0.5397$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 71% (1 year or less agreement of 94%) and a *CV* of 5.19% (test of symmetry: $\chi^2 = 12.52$, $df = 12$, $P = 0.4046$) (Figure 13.3).

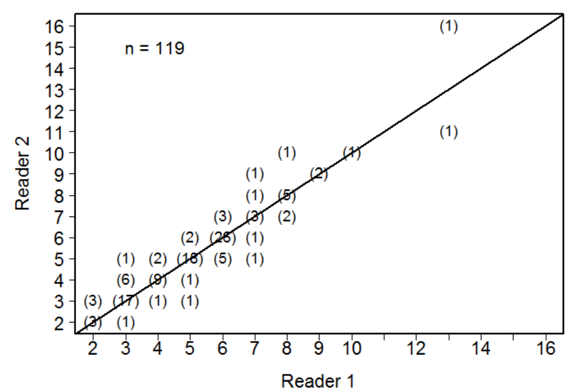


Figure 13.3: Between-reader comparison of operculum age estimates for Tautog collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 66% (1 year or less agreement of 96%) with ages of fish aged in 2000 with a *CV* of 5.06% (test of symmetry: $\chi^2 = 5.8$, $df = 9$, $P = 0.7598$). Reader 2 had an agreement of 70% (1 year or less agreement of 100%) with a *CV* of 4.13% (test of symmetry: $\chi^2 = 8.2$, $df = 6$, $P = 0.2238$).

Of the 118 bay Tautog aged with opercula, 10 age classes (2 to 10, and 13) were represented (Table 13.3). The average age for the sample was 5.3 years. The standard deviation and standard error were 1.8 and 0.17, respectively. Year-class data (Figure 13.4) indicates that recruitment into the fishery in Chesapeake Bay begins at age 2, which corresponds to the 2019 year-class for Tautog caught in 2021. Tautog in the sample in 2021 was dominated by the year classes of 2015, 2016, 2017, and 2018 with 29%, 19%, 16%, and 15%, respectively. The sex ratio of male to female was 1:1.84 for the bay fish.

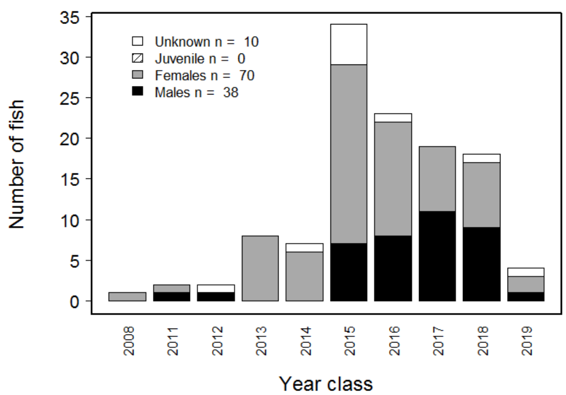


Figure 13.4: Year-class frequency distribution for Tautog collected in Chesapeake Bay, Virginia for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents the fish gonads that were not available for examination or were not examined for sex during sampling.

Only one ocean fish was collected, 16 years old, and in the year class of 2005.

13.3.3 Otoliths

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 90% and a *CV* of 1.42% (test of symmetry: $\chi^2 = 5$, *df* = 4, $P = 0.2873$), and there was no significant difference between the first and second readings for Reader 2 with an agreement of 96% and a *CV* of 0.97% (test of symmetry: $\chi^2 = 2$, *df* = 2, $P = 0.3679$). There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 95% (1 year or less agreement of 100%) and a *CV* of 0.54% (test of symmetry: $\chi^2 = 6$, *df* = 5, $P = 0.3062$) (Figure 13.5). There was no time-series bias for either reader. Reader 1 had an agreement of 90% with ages of fish aged in 2003 with a *CV* of 1.15% (test of symmetry: $\chi^2 = 5$, *df* = 2, $P = 0.0821$). Reader 2 had an agreement of 94% with a *CV* of 0.77% (test of symmetry: $\chi^2 = 3$, *df* = 1, $P = 0.0833$).

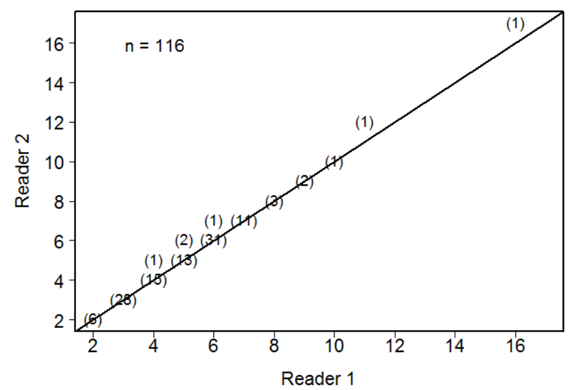


Figure 13.5: Between-reader comparison of otolith age estimates for Tautog collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

Of the 116 Tautog aged with otoliths, 11 age classes (2 to 10, 12, and 17) were represented (Table 13.4). The average age for the sample was 5.1 years. The standard deviation and standard error were 2.2 and 0.2, respectively.

13.3.4 Comparison of operculum and otolith ages

We aged 116 Tautog using opercula and otoliths. There was an evidence of systematic disagreement between otolith and operculum ages (test of symmetry: $\chi^2 = 25.31$, *df* = 13, $P = 0.021$) with an average *CV* of 6.83%. There was an agreement of 61% between operculum and otoliths ages whereas opercula were assigned a lower and higher age than otoliths for 9% and 30% of the fish, respectively (Figure 13.6). There was also an evidence of bias between otolith and operculum ages using an age bias plot (Figure 13.7), with operculum generally assigned higher ages for younger fish and lower ages for older fish than otolith age estimates.

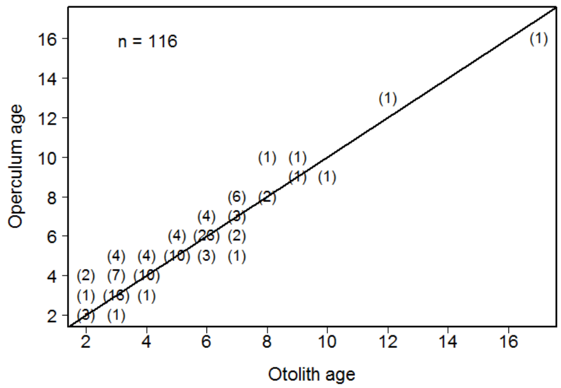


Figure 13.6: Comparison of operculum and otolith age estimates for Tautog collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

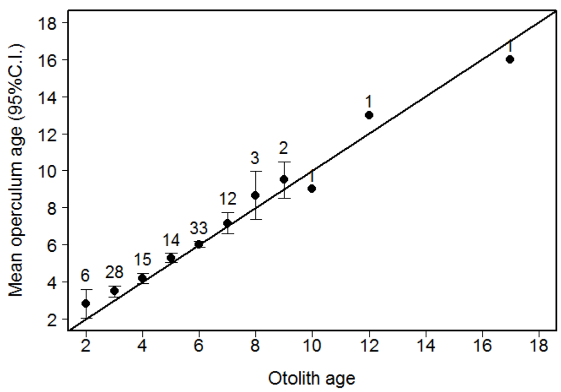


Figure 13.7: Age-bias plot for Tautog operculum and otolith age estimates in 2021. The number above the upper CI bar is number of fish.

13.3.5 Age-Length-Key (ALK)

We developed an age-length-key for bay fish (Table 13.5) using operculum ages, separately. No ALK was developed for the ocean tautog because there was only one ocean fish collected and aged in 2021. The ALK can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using operculum ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 13.1: Number of bay Tautog collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
8 - 8.99	5	0	0	5
9 - 9.99	5	1	1	4
10 - 10.99	5	5	5	0
11 - 11.99	5	3	3	2
12 - 12.99	6	10	10	0
13 - 13.99	8	7	7	1
14 - 14.99	39	19	19	20
15 - 15.99	109	33	33	76
16 - 16.99	98	21	21	77
17 - 17.99	64	15	15	49
18 - 18.99	27	3	3	24
19 - 19.99	17	0	0	17
20 - 20.99	6	1	1	5
21 - 21.99	5	0	0	5
22 - 22.99	5	0	0	5
24 - 24.99	5	0	0	5
26 - 26.99	5	0	0	5
Totals	414	118	118	300

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Table 13.2: Number of ocean Tautog collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
15 - 15.99	23	0	0	23
16 - 16.99	50	0	0	50
17 - 17.99	50	0	0	50
18 - 18.99	27	0	0	27
19 - 19.99	50	0	0	50
20 - 20.99	35	0	0	35
21 - 21.99	42	0	0	42
22 - 22.99	31	0	0	31
23 - 23.99	15	0	0	15
24 - 24.99	19	0	0	19
25 - 25.99	23	0	0	23
26 - 26.99	23	1	1	22
27 - 27.99	31	0	0	31
28 - 28.99	12	0	0	12
30 - 30.99	5	0	0	5
Totals	436	1	1	435

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Table 13.3: The number of Tautog assigned to each total length-at-age category for 118 fish sampled for operculum age determination in Chesapeake Bay, Virginia during 2021.

	Age										
Interval	2	3	4	5	6	7	8	9	10	13	Totals
9 - 9.99	1	0	0	0	0	0	0	0	0	0	1
10 - 10.99	2	2	1	0	0	0	0	0	0	0	5
11 - 11.99	0	1	2	0	0	0	0	0	0	0	3
12 - 12.99	1	5	2	2	0	0	0	0	0	0	10
13 - 13.99	0	2	2	1	2	0	0	0	0	0	7
14 - 14.99	0	5	5	6	2	0	1	0	0	0	19
15 - 15.99	0	3	5	8	11	4	1	1	0	0	33
16 - 16.99	0	0	2	5	11	1	1	0	1	0	21
17 - 17.99	0	0	0	1	8	1	4	0	0	1	15
18 - 18.99	0	0	0	0	0	0	1	1	1	0	3
20 - 20.99	0	0	0	0	0	1	0	0	0	0	1
Totals	4	18	19	23	34	7	8	2	2	1	118

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Table 13.4: The number of Tautog assigned to each total length-at-age category for 116 fish sampled for otolith age determination in Chesapeake Bay and Virginia waters of Atlantic Ocean during 2021.

	Age											
Interval	2	3	4	5	6	7	8	9	10	12	17	Totals
9 - 9.99	1	0	0	0	0	0	0	0	0	0	0	1
10 - 10.99	3	2	0	0	0	0	0	0	0	0	0	5
11 - 11.99	1	1	1	0	0	0	0	0	0	0	0	3
12 - 12.99	1	7	2	0	0	0	0	0	0	0	0	10
13 - 13.99	0	3	2	0	2	0	0	0	0	0	0	7
14 - 14.99	0	10	2	4	2	1	0	0	0	0	0	19
15 - 15.99	0	5	6	5	12	2	0	0	1	0	0	31
16 - 16.99	0	0	2	3	10	4	0	1	0	0	0	20
17 - 17.99	0	0	0	2	7	4	1	0	0	1	0	15
18 - 18.99	0	0	0	0	0	0	2	1	0	0	0	3
20 - 20.99	0	0	0	0	0	1	0	0	0	0	0	1
26 - 26.99	0	0	0	0	0	0	0	0	0	0	1	1
Totals	6	28	15	14	33	12	3	2	1	1	1	116

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Table 13.5: Age-Length key, as proportion-at-age in each 1-inch length interval, based on operculum ages for Tautog sampled in Chesapeake Bay, Virginia during 2021.

	Age									
Interval	2	3	4	5	6	7	8	9	10	13
9 - 9.99	1	0	0	0	0	0	0	0	0	0
10 - 10.99	0.4	0.4	0.2	0	0	0	0	0	0	0
11 - 11.99	0	0.33	0.67	0	0	0	0	0	0	0
12 - 12.99	0.1	0.5	0.2	0.2	0	0	0	0	0	0
13 - 13.99	0	0.29	0.29	0.14	0.29	0	0	0	0	0
14 - 14.99	0	0.26	0.26	0.32	0.11	0	0.05	0	0	0
15 - 15.99	0	0.09	0.15	0.24	0.33	0.12	0.03	0.03	0	0
16 - 16.99	0	0	0.1	0.24	0.52	0.05	0.05	0	0.05	0
17 - 17.99	0	0	0	0.07	0.53	0.07	0.27	0	0	0.07
18 - 18.99	0	0	0	0	0	0	0.33	0.33	0.33	0
20 - 20.99	0	0	0	0	0	1	0	0	0	0

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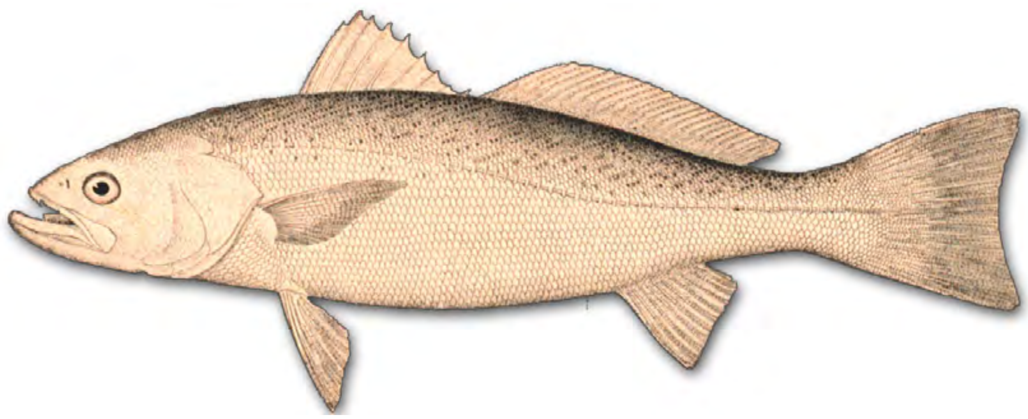
Chapter 14

WEAKFISH *Cynoscion regalis*



14.1 INTRODUCTION

We aged a total of 155 Weakfish, *Cynoscion regalis*, collected by the VMRC's Biological Sampling Program for age and growth analysis in 2021. The Weakfish ages ranged from 1 to 4 years old with an average age of 2.4, a standard deviation of 0.9, and a standard error of 0.07. Four age classes (1 to 4) were represented, comprising fish of the 2017 to 2020 year-classes. The sample was dominated by fish from the year-class of 2018 with 48.4%.

14.2 METHODS

14.2.1 Sample size for ageing

We estimated sample size for ageing Weakfish in 2021 using a two-stage random sampling method (Quinn and Deriso 1999) to increase precision in estimates of age composition from fish sampled efficiently and effectively. The basic equation is:

$$A = \frac{V_a}{\theta_a^2 CV_a^2 + B_a/L} \tag{14.1}$$

where A is the sample size for ageing Weakfish in 2021; θ_a stands for the proportion of Age a fish in a catch; V_a, B_a, and CV_a represent the variance components within and between length intervals, and the coefficient of variation for Age a, respectively; L is the total number of Weakfish used by VMRC to estimate length distribution of the catches from 2015 to 2019. θ_a, V_a, and B_a were calculated using pooled age-length data of Weakfish collected from 2015 to 2019 and using equations in Quinn and Deriso (1999). For simplicity, the equations are not listed here. The equation (1.1) indicates:1) The more fish that are aged, the smaller the CV_a (or higher precision) that will be obtained for Age a; 2) given a sample size A, the CV_a is different for each age due to different θ_a, V_a, and B_a among different ages. Therefore, the criterion to age A (number) of fish is that A should be a number above which there is only a 1% CV_a reduction for the most abundant age in catch by ageing an additional 100 or more fish. Finally, A_l is A multiplied by the proportion of length interval l from the length distribution of the 2015 to 2019 catch. A_l is number of fish to be aged for length interval l in 2021.

14.2.2 Handling of collections

Otoliths were received by the Age & Growth Laboratory in labeled coin envelopes, and were sorted by date of capture. Their envelope labels were verified against VMRC's collection data, and each fish was assigned a unique Age and Growth Laboratory identification number. All otoliths were stored dry in their original labeled coin envelopes.

14.2.3 Preparation

Sagittal otoliths, hereafter, referred to as "otoliths", were processed for age determination following the methods described in Lowerre-Barbieri et al. (1994) with a few modifications. The left or right otolith was randomly selected and attached, distal side down, to a glass slide with clear Crystalbond^{TM} 509 adhesive. The otoliths were viewed by eye and, when necessary, under a stereo microscope to identify the location of the core, and the position of the core was marked using a pencil across the otolith surface. At least one transverse cross-section (hereafter, referred to as "thin-section") was then removed from the marked core of each otolith using a Buehler IsoMet^{TM} low-speed saw equipped with two, 3-inch diameter, Norton diamond grinding wheels (hereafter, referred to as "blades"), separated by a stainless steel spacer of 0.5 mm (diameter 2.5"). Thin-sections were placed on labeled glass slides and covered with a thin layer of Flo-texx mounting medium that not only fixed the sections to the slide, but more importantly, provided enhanced contrast and greater readability by increasing light transmission through the thin-sections.

Click here to obtain the protocol at the CQFE website on how to prepare otolith thin-section for ageing Weakfish.

14.2.4 Readings

The VMRC system assigns an age class to a fish based on a combination of number of annuli in a thin-section, the date of capture, and the species-specific period when the annulus is deposited. Each year, as the fish grows, its otoliths grow and leave behind markers of their age, called an annulus. Technically, an otolith annulus is the combination of both the opaque and the translucent band. In practice, only the opaque bands are counted as annuli and recorded in our ageing notation.

In 2019 a new notation method recommended by Atlantic States Marine Fisheries Commission (ASMFC) was used to assign age on Weakfish. In addition to recording the number of annulus, the margin or the growth width after the last annulus is coded from 1 to 4. The margin code "1", "2", "3", and "4" stands for no growth, the growth width less than or equal to one third of, larger than one third but less than or equal to two thirds of, and larger than two thirds of the growth width formed in the previous year, respectively.

By convention all fish in the Northern Hemisphere are assigned a birth date of January 1. In addition, each species has a specific period during which it deposits the annulus. If a fish is captured after the end of the species-specific annulus deposition period and before January 1, it is assigned an age class as the same as its annulus number without referencing its margin code. If a fish has a margin code of "1", it is assigned an age class as the same as its annulus number no matter in which month it is captured. If a fish is captured after December 31 and before its annulus deposition period, it is assigned an age class as its annulus number plus one when its margin code is "2", "3", or "4". If a fish is captured during its annulus deposition period, it is assigned an age class as the same as its annulus number when its margin code is "2" and as its annulus number plus one when its margin code is "3" or "4" (**Note: Based on the growth of Virginia species we use two criteria for Margin Code 2 to assign a fish an age class depending on its capture month, which could be different from how other states and agencies use Margin Code 2**).

For example, Weakfish otolith annulus formation occurs between April and June (Lowerre-Barbieri et al. 1994 and modified by CQFE/ODU). A Weakfish with two visible annuli could be assigned an age of 2 or 3 depending on its capture month and margin code. When its margin code is "1", it is Age 2 no matter when it is captured. When it is captured after June and before January, it is Age 2 no matter what its margin code is. When it is captured after December and before April and its margin code is not "1", it is Age 3 ($2 + 1 = 3$). When it is captured between April and June, it is Age 2 when its margin code is "2" but Age 3 ($2 + 1 = 3$) when its margin code is "3" or "4".

All samples were aged by two readers in chronological order, based on collection date, without knowledge of previously estimated ages or the specimen lengths. When the readers' ages agreed, that age was assigned to the fish. When the two readers disagreed, Reader 1 re-aged the fish with disagreement and decided a final age for the fish. This method is different from what we used before the pandemic of COVID-19 during the period of 2020 -2021 because of 6-food social distance requirement. All thin-sections were aged using a Nikon SMZ1000 stereo microscope under transmitted light and dark-field polarization at between 8 and 20 times magnification (Figure 14.1).

14.2.5 Comparison tests

A symmetry test (Hoenig et al. 1995) and coefficient of variation (CV) analysis were used to detect any systematic difference and precision on age readings, respectively, for the following comparisons: 1) between the two readers in the current year, 2) within each reader

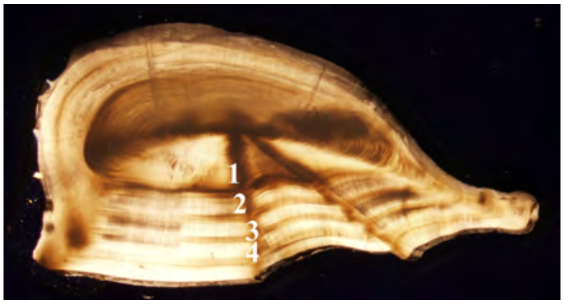


Figure 14.1: Otolith thin-section of 4 year-old Weakfish

in the current year, and 3) time-series bias between the current and previous years within each reader. The readings from the entire sample for the current year were used to examine the difference between two readers. A random sub-sample of 50 fish from the current year was selected for second readings to examine the difference within a reader. Fifty otoliths randomly selected from fish aged in 2003 were used to examine the time-series bias within each reader. A figure of 1:1 equivalence was used to illustrate those differences (Campana et al. 1995). All statistics analyses were performed in R 3.5.3 (R Core Team 2019).

14.3 RESULTS

14.3.1 Sample size

We estimated a sample size of 310 for ageing Weakfish in 2021, ranging in length interval from 4 to 34 inches (Table 14.1). This sample size provided a range in (*CV*) for age composition approximately from the smallest (*CV*) of 6% for Age 2 to the largest (*CV*) of 20% for Age 4. In 2021, we aged all 155 Weakfish collected by VMRC. We fell short in our over-all collections for this optimal length-class sampling estimate by 160 fish. We were short many fish from the major length intervals (The interval requires 10 or more fish), as a result, the precision for the estimates of major age groups would definitely be influenced significantly. Therefore, precaution should be used when developing ALK using these age data.

14.3.2 Reading precision

Both readers had high self-precision. Specifically, there was no significant difference between the first and second readings for Reader 1 with an agreement of 100%, and there was no significant difference between the first and second readings for Reader 2 with an agreement of 100%. There was no evidence of systematic disagreement between Reader 1 and Reader 2 with an agreement of 100% (Figure 14.2).

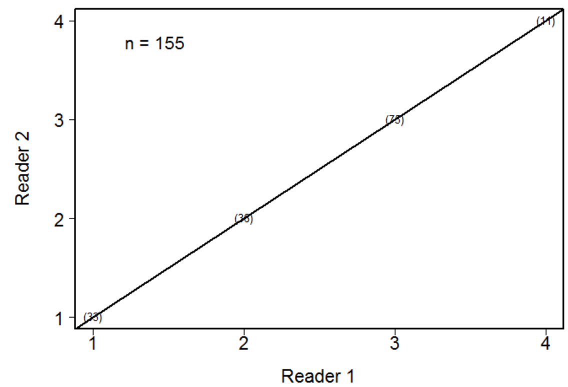


Figure 14.2: Between-reader comparison of otolith age estimates for Weakfish collected in Chesapeake Bay and Virginia waters of the Atlantic Ocean in 2021. The number in parentheses is number of fish.

There was no time-series bias for either reader. Reader 1 had an agreement of 100% with ages of fish aged in 2003. Reader 2 had an agreement of 94% with a *CV* of 0.85% (test of symmetry: $\chi^2 = 3$, $df = 3$, $P = 0.3916$).

14.3.3 Year class

Of the 155 fish aged with otoliths, 4 age classes (1 to 4) were represented (Table 14.2). The average age was 2.4 years, and the standard deviation and standard error were 0.9 and 0.07, respectively. Year-class data show that the fishery was comprised of 4 year-classes: fish from the 2017 to 2020 year-classes, with fish primarily from the year-class of 2018 with 48.4%. The ratio of males to females was 1:4.43 in the sample collected (Figure 14.3).

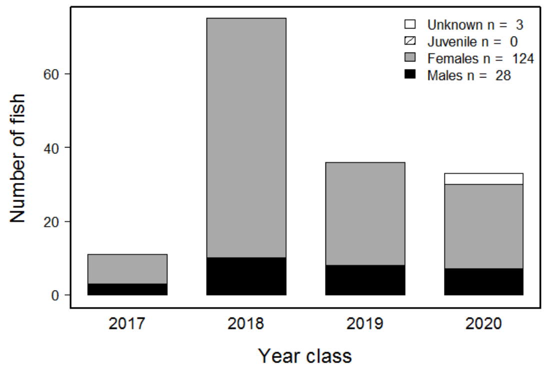


Figure 14.3: Year-class frequency distribution for Weakfish collected for ageing in 2021. Distribution is broken down by sex. 'Unknown' represents gonads that were not available for examination or were not examined for sex during sampling.

14.3.4 Age-length key (ALK)

We developed an age-length-key (Table 14.3) that can be used in the conversion of numbers-at-length in the estimated catch to numbers-at-age using otolith ages. The table is based on VMRC's stratified sampling of landings by total length inch intervals.

Table 14.1: Number of Weakfish collected and aged in each 1-inch length interval in 2021. 'Target' represents the sample size for ageing estimated for 2021, and 'Need' represents number of fish shorted in each length interval compared to the optimum sample size for ageing and number of fish aged.

Interval	Target	Collected	Aged	Need
4 - 4.99	5	0	0	5
6 - 6.99	5	0	0	5
7 - 7.99	5	3	3	2
8 - 8.99	7	6	6	1
9 - 9.99	27	8	8	19
10 - 10.99	51	20	20	31
11 - 11.99	38	25	25	13
12 - 12.99	28	18	18	10
13 - 13.99	19	15	15	4
14 - 14.99	13	11	11	2
15 - 15.99	16	14	14	2
16 - 16.99	13	5	5	8
17 - 17.99	8	8	8	0
18 - 18.99	5	8	8	0
19 - 19.99	5	7	7	0
20 - 20.99	5	1	1	4
21 - 21.99	5	5	5	0
22 - 22.99	5	0	0	5
23 - 23.99	5	1	1	4
24 - 24.99	5	0	0	5
25 - 25.99	5	0	0	5
26 - 26.99	5	0	0	5
27 - 27.99	5	0	0	5
28 - 28.99	5	0	0	5
30 - 30.99	5	0	0	5
31 - 31.99	5	0	0	5
33 - 33.99	5	0	0	5
34 - 34.99	5	0	0	5
Totals	310	155	155	160

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Table 14.2: The number of Weakfish assigned to each total length-at-age category for 155 fish sampled for otolith age determination in Virginia during 2021.

	Age				
Interval	1	2	3	4	Totals
7 - 7.99	3	0	0	0	3
8 - 8.99	6	0	0	0	6
9 - 9.99	4	4	0	0	8
10 - 10.99	11	6	3	0	20
11 - 11.99	9	8	8	0	25
12 - 12.99	0	10	7	1	18
13 - 13.99	0	3	12	0	15
14 - 14.99	0	0	9	2	11
15 - 15.99	0	1	12	1	14
16 - 16.99	0	0	3	2	5
17 - 17.99	0	0	8	0	8
18 - 18.99	0	3	3	2	8
19 - 19.99	0	1	5	1	7
20 - 20.99	0	0	1	0	1
21 - 21.99	0	0	3	2	5
23 - 23.99	0	0	1	0	1
Totals	33	36	75	11	155

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Table 14.3: Age-Length key, as proportion-at-age in each 1-inch length interval, based on otolith ages for Weakfish sampled for age determination in Virginia during 2021.

	Age			
Interval	1	2	3	4
7 - 7.99	1	0	0	0
8 - 8.99	1	0	0	0
9 - 9.99	0.5	0.5	0	0
10 - 10.99	0.55	0.3	0.15	0
11 - 11.99	0.36	0.32	0.32	0
12 - 12.99	0	0.56	0.39	0.06
13 - 13.99	0	0.2	0.8	0
14 - 14.99	0	0	0.82	0.18
15 - 15.99	0	0.07	0.86	0.07
16 - 16.99	0	0	0.6	0.4
17 - 17.99	0	0	1	0
18 - 18.99	0	0.38	0.38	0.25
19 - 19.99	0	0.14	0.71	0.14
20 - 20.99	0	0	1	0
21 - 21.99	0	0	0.6	0.4
23 - 23.99	0	0	1	0

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