Length frequencies for South Atlantic Red Snapper from the FISHstory project

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SEDAR 90 DW16: Length frequencies for South Atlantic Red Snapper from the FISHstory project

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Introduction

SAFMC Citizen Science Program

The South Atlantic Fishery Management Council (SAFMC) developed its Citizen Science Program based on guidance from a wide array of stakeholders and partners. The aim was to build a program that would engage fishermen, scientists, and managers in co-creating citizen science projects that would align with the Council's research needs. The Program's overall approach is to support and/or pursue projects that fill data gaps and address South Atlantic research priorities; complement existing programs and partnerships; use intentional project design that considers application to management and assessments during project development; and encourage fishermen and scientist collaboration. Projects developed under the SAFMC Citizen Science Program use a design team of diverse stakeholders (fishermen, scientists, managers, outreach specialists, etc.) with varying expertise who provide guidance throughout the design and development of a project. More information on the Program is available on the SAFMC's Citizen Science Program webpage.

FISHstory Project

In the South Atlantic, few fishery-dependent surveys were in existence prior to the 1970s; those that existed were limited in scope and lacked comprehensiveness and continuity. Monitoring of the recreational headboat fishery began in the 1970s, and monitoring of private and charter boat fishing began in the early 1980s. However, there is indication that recreational fisheries were already operating in the region (Clark 1962; U.S. Department of the Interior et al. 1991). Lack of historical data may impact the ability to measure and understand long-term changes, to set meaningful targets for management and formulate stock rebuilding plans, and to better understand nonstationarity or regime shifts in stock productivity (Rosenberg et al. 2005, McClenachan et al. 2012). Historic photos have the potential to provide quantifiable species and length composition data at a point in time when fishery dependent surveys of the for-hire fleet did not exist (McClenachan 2009).

FISHstory, a citizen science project developed under the SAFMC's Citizen Science Program, has developed a standardized protocol for archiving and analyzing historic fishing photos from the for-hire fleet. These historic photos document the beginning of the South Atlantic for-hire fishery and can help recreate information on catch and length composition prior to when dedicated fishery dependent surveys began.

The FISHstory project has three primary components: digitizing and archiving historic fishing photos; analyzing historic photos to estimate catch and effort using the crowdsourcing platform Zooniverse; and estimating historic length compositions for key species. FISHstory initially started as a pilot project (2020-2022). Methodologies for the three project components developed during the pilot showed great promise and demonstrated that volunteers are able to make valuable contributions in multiple ways (e.g., sharing historic photos, classifying photos in Zooniverse, helping with data validation). Additional funding was obtained in 2023 to support expansion of the FISHstory project – helping to grow the FISHstory photo archive, simplifying data collection and increasing the photos classified by volunteers in Zooniverse, and developing historic length compositions for an additional species.

This working paper will summarize Red Snapper length composition estimates produced through the FISHstory project.

Methods

Details on the development of the FISHstory length methodology are available in Byrd et al. 2022.

Photos for Length Analyses

To be included in FISHstory length analyses, archived photos need to be taken at the end of fishing trips where fishermen are displaying their harvested catch; must have fish hanging from a lumber leaderboard; have a known year or range of years; and a known state where the fishing trip occurred. Examples of the type of photos included in the FISHstory length analyses are in Figures 1a and 1b.

Length Analyst Training

All FISHstory length analysts have fish identification expertise. Prior to measuring, all analysts complete a virtual training session to learn the measuring and reporting process. Additionally, a standard comparison set of selected photographs for the species of interest (e.g., Red Snapper) are completed by each analyst prior to reviewing the dataset for practice and to determine if different readers had biases. Additional virtual training sessions are held with length analysts during the measuring process, as needed.

Data description

Historic photos were arranged randomly into batches of 100 photos. Analysts were randomly assigned two photo batches at a time until all batches were completed. Each photo batch was analyzed by two analysts; care was taken to minimize the number of times two users analyzed the same photo batches for quality control purposes.

Using the ImageJ software (Schindelin et al. 2012), analysts initially take three measurements of the lumber in the leaderboard where the fish are hanging to provide scalar measurements of known length using the line measurement tool. Analysts were instructed to take scalar measurements on the left, middle, and right of the leaderboard respectively, trying to bracket the fish species being measured. Most of the leaderboards were arranged with a top, middle, and bottom board. If the fish of interest was hanging on multiple boards, analysts were encouraged to take scalar measurements on each board the fish appeared. Next, all measurable species of the fish of interest (e.g. Red Snapper) were measured using the line tool in Image J (Figure 2). To be considered measurable, a few criteria needed to be met: individuals had to be whole (no major mutilations, especially to the head or the tail), both the tip of the snout and the fork of the tail had to be unobstructed, and individuals had to be hanging on the leaderboards used for scalar measurement. After completing measurements, analysts paste the measurement data from ImageJ into excel spreadsheets for further processing. Based on the number of pixels per inch estimated in the scalar, estimates of fish length are developed for each analyst.

Data fields included in these spreadsheets are pasted from Image J (as mentioned above), manually input by the analysts, or automatically generated from the ImageJ and manually entered fields. Additional data fields collected by analysts and recorded in the spreadsheet include: the total number of fish hanging (of the species being measured), percent of fish not measured, if there was bias between the fish measured vs those not measured and if so, the direction of the bias; lumber size (2x4 or 2x6); whether the photo was angled; and whether the measurement was taken on a curved fish. For a complete list of the data fields collected by analysts and where they originate see Table 1.

Each individual batch was visually examined for errors in any auto-filled fields, then input into an R script that compared measurements between all users to check for clear errors in measurement resulting in unreasonably large or small measurements. Once all noticeable and verifiable errors were corrected or removed, the data were further filtered and prepared for analysis.

Data filtering

1. **Exclude all photographs lacking timestamp metadata (i.e., those without a year designation; photos with year ranges were not used in estimating annual length compositions).**
2. **Remove data entries from years failing to meet both of the following criteria:**
    - **Minimum annual photo count: <10 images**
    - **Minimum annual fish measurements: <30 individuals**

    (i.e., exclude years where n.photos < 10 & n.fish < 30).

Binning

Length compositions for FISHstory data were developed following SEDAR 73, i.e., 30-mm bins over the range 210-990 mm (mid-points). All lengths below and above the minimum and maximum bins were pooled.

Annual Length Frequency Calculation

To estimate the length frequency distribution for a single year, a designed-based approach was used. Let the predicted number of fish ($\widehat{N}_p^l$) in a photo (*p*) for a given size class (*l*) be denoted

$$\widehat{N}_p^l = \frac{\sum_p^{p=P} \sum_s^{s=2} \frac{n_s^l}{n_s^m} N_{p,s}^l / 2}{P} \qquad (1)$$

where n_s^i is the total number of red snappers identified in a photo by analyst *s* and n_s^m is the number of red snappers measured in a photo by analyst *s*. $N_{p,s}^l$ is the total number of red snappers measured for a given size class *l* by analyst *s*. P is the total number of photos for a given year.

Uncertainty Estimation:
To quantify the uncertainty associated with the size frequency, a bootstrap method was used with the following procedure:

1. For a given year, randomly draw (with replacement) photos from the set of photos contributing to the length frequency calculation for that year (sample size is set to the number of photos included in the calculation of length frequency).

2. For a given photo, randomly draw (with replacement) samples of lengths from individual measured lengths (sample size is the maximum number of red snappers identified in that photo by analysts).

3. Calculate the average number of red snappers for each size bin across photos.

4. Repeat steps 1-3 over 25,000 bootstrap iterations.

5. Calculate the standard deviation of predicted number of red snappers for each size bin across bootstrap replicates.

This bootstrap procedure can be interpreted as a simulation of new length measurements from the same underlying photo analyzing effort.

Effective Sample Size:
For composition data, where a multinomial likelihood is often applied, input effective sample size is required for determining the weights. We followed Steward and Hamel (2014) to calculate the realized sample size using a bootstrap method. For each bootstrap replicate, the realized sample size (SS) is calculated

$$SS = {\sum_l R_l(1 - R_l)}\Big/{\sum_l (R_l - B_l)^2} \qquad (2)$$

where R_l is the calculated length proportion for size class *l* from the data and B_l is the bootstrapped proportion for size class *l*. The calculated SS is consistent only with the use of a multinomial error assumption.

Results

Annual Length Composition
The number of photos and measurements included in developing FISHstory annual length frequencies are in Table 2. Estimated length frequency by year from FISHstory data is in Figure 3a and Figure 3b. Annual length compositions show evidence of year class strength (Figure 3b). Estimated

length frequency and uncertainty by year from FISHstory data using the bootstrap method is in Figure 4. Estimated distribution of realized sample size by year using the bootstrap method is in Figure 5.

Length Frequency by Time Block – Pre Data Workshop

Length frequency by time block was also developed by using all available photos. Four distinct time blocks were identified (see details in Table 3). Estimated length frequency from the data is in Figure 6. Estimated length frequency and uncertainty by time block from FISHstory data using the bootstrap method is in Figure 7.

Length Frequency by Time Block – Updated at Data Workshop

During the SEDAR 90 Data Workshop the length frequency by time block analysis was revised. The years included in each time block were updated based on technological changes during the historic time period which could impact selectivity. Time blocks are described in the bullets below and were determined based on information from SEDAR41-DW23: Atlantic Red Snapper Fishing History Timeline, the SEDAR 74 Gulf Red Snapper Stock Assessment, and conversations with Florida fishermen during the SEDAR 90 Data Workshop. Photos with associated year ranges (as opposed to a specific year) were included in these length composition estimates, when the year range fell within a time block.

- Pre 1964: limited availability of Loran A
- 1965-1974: Loran A is more available; mostly used by for-hire and commercial vessels; very limited for private anglers; advent of Loran C but limited use
- 1975 – early 1980s: transition to Loran C; Loran C more feasible to use on private vessels; Loran A discontinued in early 1980s

Length compositions by time block, including sample sizes, are provided in Figure 8.

The following information describes initial management actions established for Red Snapper in the South Atlantic to help provide context for the FISHstory data. The initial SAMC Snapper Grouper Fishery Management Plan implemented in 1983 established a minimum size limit of 12-inch total length for Red Snapper due to concerns of growth overfishing. The minimum size limit was implemented to try and prevent harvest on some of the smallest fish to increase the yield per recruit (SAFMC 1983). The state of Florida established a 12-inch minimum size limit in 1985 (SEDAR 2021).

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Table 1. Data fields collected by FISHstory length analysts.

Field	Filled by	Description
Unique ID	Autofill	Unique identifier for each measurement
Measurement Number	Paste from ImageJ	Measurement number for each photo
Photo Name	Paste from ImageJ	
X	Paste from ImageJ	Starting X coordinate for measurement line
Y	Paste from ImageJ	Starting Y coordinate for measurement line
Angle	Paste from ImageJ	Angle of measurement line relative to photo
Length	Paste from ImageJ	Length in pixels of measurement line
Curved Fish Y/N	Manual entry	Y/N whether the fish is noticeably curved
Analyst	Manual entry	Name of analyst
Species	Manual entry	Species of measured fish
Batch	Manual entry	Photo batch number
Total Fish Hanging	Manual entry	Total number of measured and unmeasured individuals of the target species
Percent Unmeasurable	Manual entry	Proportion of unmeasured fish by the total number of the target species
Bias Y/N	Manual entry	Y/N whether the photo is biased by size
Bias L/S	Manual entry	If the photo is biased, is it biased in favor of large (L) or small (S) individuals?
Lumber Size	Manual entry	Denotes if scalar boards are 2x4 or 2x6
Angled Photo Y/N	Manual entry	Y/N whether the photo was taken at an angle
Label Number	Autofill	Measurement number for each photo
Measurement Type	Autofill	Denotes if the measurement is a scalar (S) or a fish measurement (CL)
Closest Scalar	Autofill/Manual entry	If photo is not angled, denotes that the mean of the scalar measurements should be used. If angled, analyst must enter whether the closest scalar is the left (L) middle (M) or right (R)
Scalar ID	Autofill	If photo is not angled, denotes that the mean of the scalar measurements should be used. If angled, autofills the specific scalar's Unique ID to be used for a given fish measurement
Scalar Length (Pixels)	Autofill	Number of pixels for either the mean of the

		scalar measurements (not angled) or the individual scalar (angled)
Actual Lumber Size	Autofill	Actual width measurement in inches of a 2x4 or 2x6, depending on lumber size entry
Scale Ratio	Autofill	Ratio of scalar length pixels field to actual lumber size field
Length (Inches)	Autofill	Length in inches of a given fish, calculated by multiplying the length (pixels) field by the scale ratio field.
Fish-Level Comments	Manual entry	Any specific comments about the given individual fish measured
Photo-Level Comments	Manual entry	Any specific comments about the given photo

Table 2. Number of photos and measurements included in developing annual length frequencies.

Year	# of photos	# of measurements	# of boats	State
1954	33	532	1	FL
1956	38	1128	3	FL
1959	39	1393	2	FL
1960	65	3031	4	FL
1961	105	3891	3	FL
1962	180	9573	3	FL
1963	125	5609	3	FL
1964	128	5186	4	FL
1965	25	755	2	FL
1966	16	518	2	FL
1967	11	575	3	FL
1968	55	2509	4	FL
1969	22	585	2	FL
1970	36	585	3	FL
1971	62	1746	3	FL
1972	23	454	4	FL
1973	22	745	5	FL

Table 3. Number of photos and measurements by year or range of years. Color is used to represent the time blocks defined for developing length frequency by time block.

Year	# of photos	# of measurements	Year	# of photos	# of measurements
1948	1	4	1970	36	585
1949	1	1	1970s	1	5
1951	3	21	1971	62	1746
1952	8	108	1972	23	454
1953	1	4	1973	22	745
1954	33	532	1974	6	280
1955	1	42	1975	4	130
1956	38	1128	1977	1	4
1957	7	251	1978	1	7
1958	1	7	1980s	1	3
1959	39	1393	1985-1986	10	67
1960	65	3031	1985-2002	21	369
1961	105	3891	1986-2002	7	98
1962	180	9573	1986-2015	3	44
1963	125	5609	1987	1	4
1964	128	5186	1990	4	77
1965	25	755	1992	2	6
1966	16	518	2001	5	148
1967	11	575	2002	3	18
1968	55	2509	2002-2015	5	80
1969	22	585			

Figure 1a. An example photo from the FISHstory photo set used for length analyses from a completed fishing trip on the Marianne from Sept 4, 1962. Fish are hanging on a 2x6 lumber leaderboard. Photo credit: Rusty Hudson and Hudson, Stone, and Timmons families.

Figure 1b. An example photo from the FISHstory photo set used for length analyses from a completed fishing trip on the Snow White from August 14, 1968. Fish are hanging on a 2x4 lumber leaderboard. Photo credit: Paul Nelson.

Figure 2. An illustrated example of completed length measurements in a FISHstory photo. Red lines indicate scalar measurements. Blue lines indicate fish (Red Snapper) measurements. The individual fish between lines 4 and 5 was not measured because its tail was obstructed. Photo credit: Rusty Hudson and the Hudson, Stone, and Timmons families.

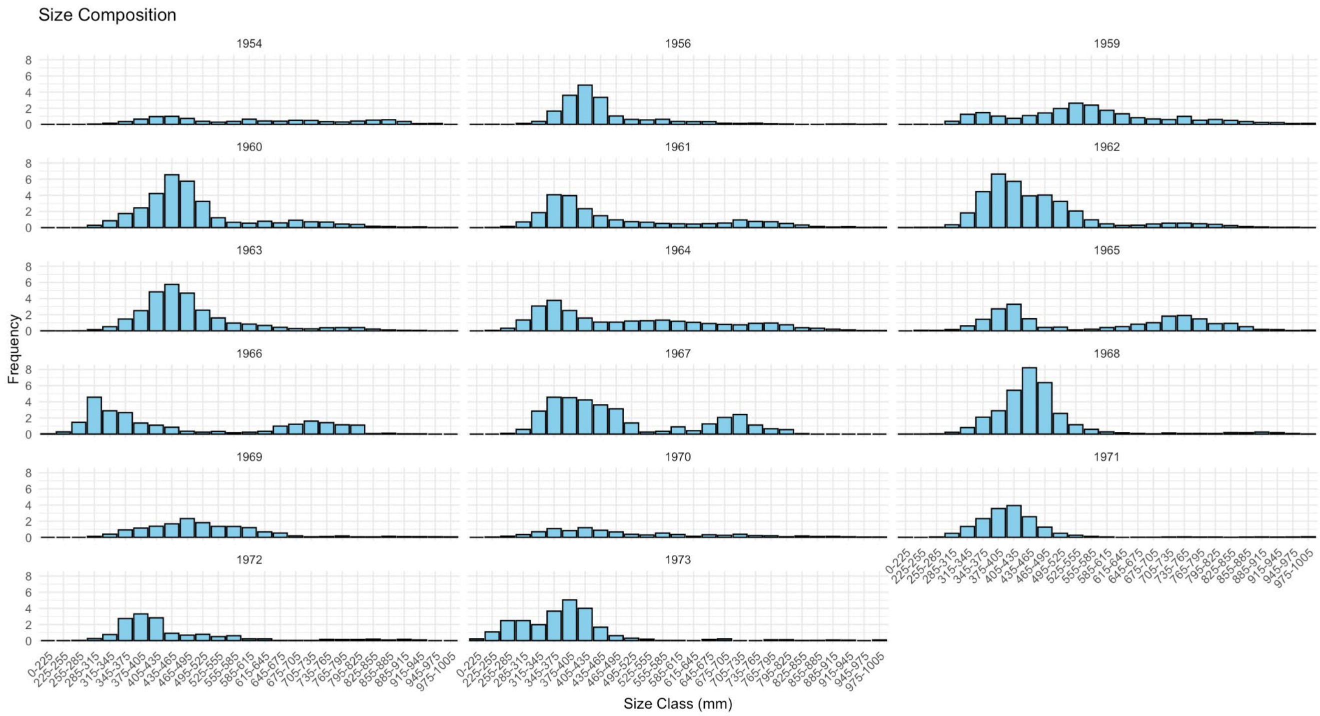

Figure 3a. Estimated length frequency by year from FISHstory data.

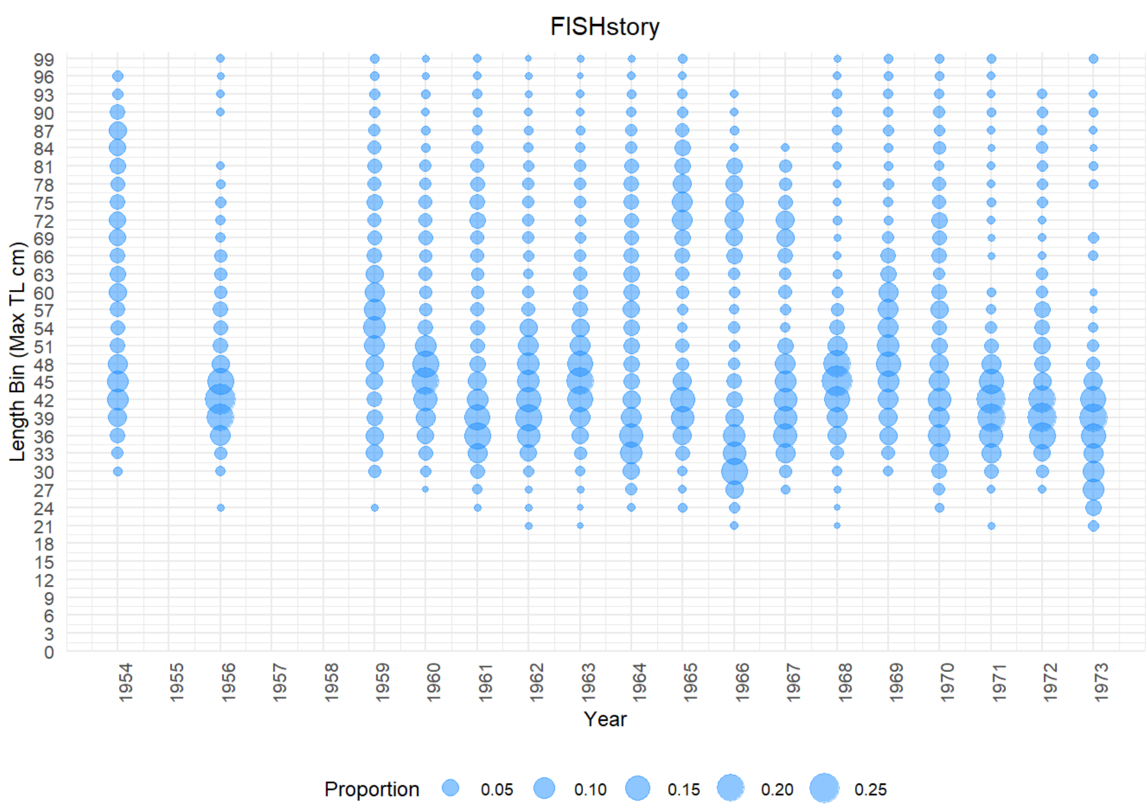

Figure 3b. Estimated length frequency by year from FISHstory data. Plot provided by S. Bionion-Rock, NOAA Fisheries.

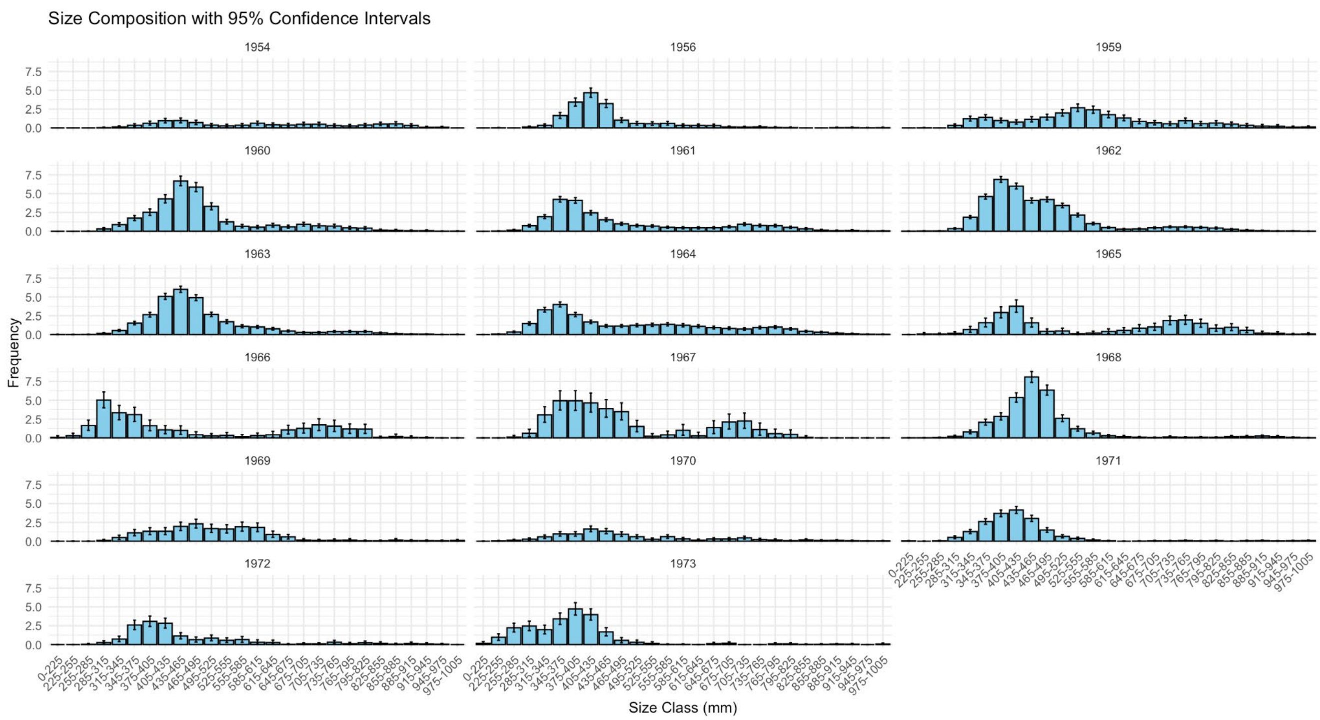

Figure 4. Estimated length frequency and uncertainty by year from FISHstory data using the bootstrap method.

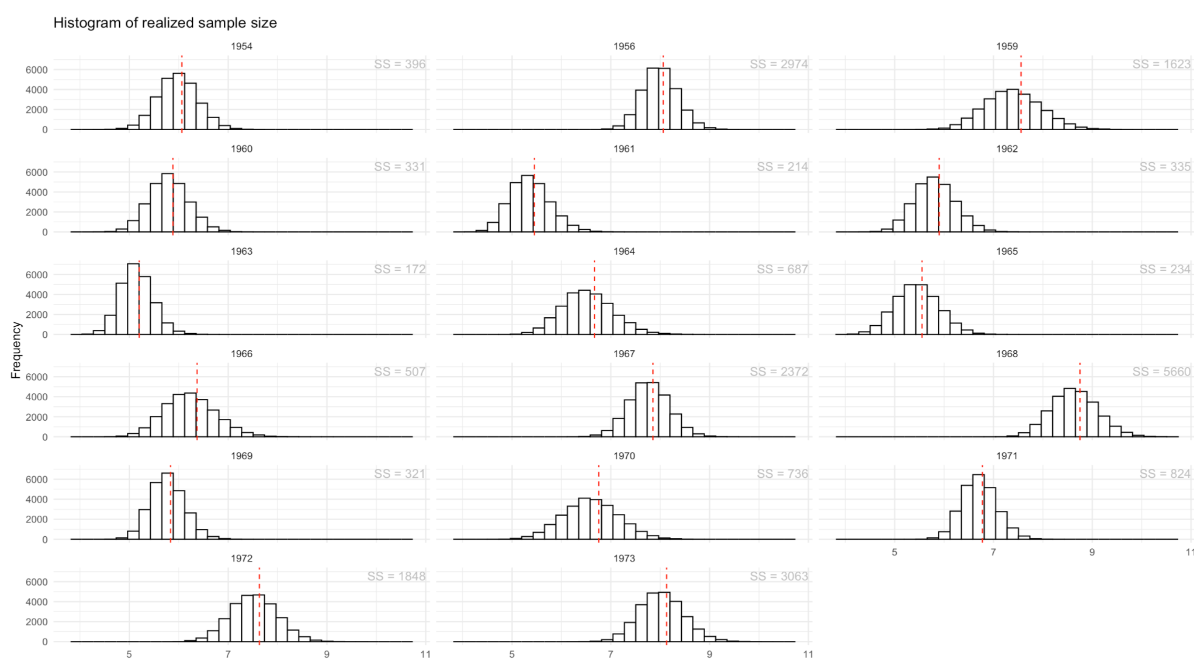

Figure 5. Estimated distribution of realized sample size by year using the bootstrap method.

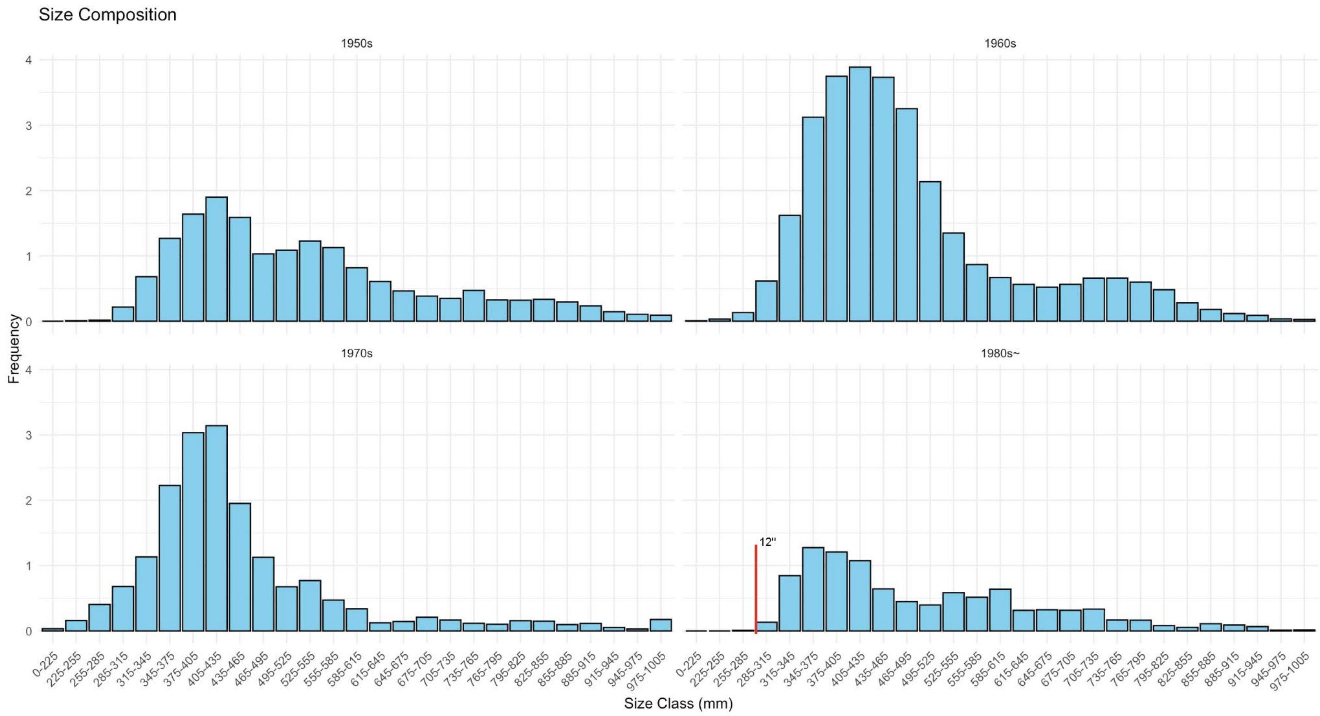

Figure 6. Estimated length frequency by time block (i.e., 1950s, 1960s, 1970s, and 1980s ~ 2010s) from FISHstory data. Red vertical line represents the 12’’ TL minimal size limit implemented in the 1980s.

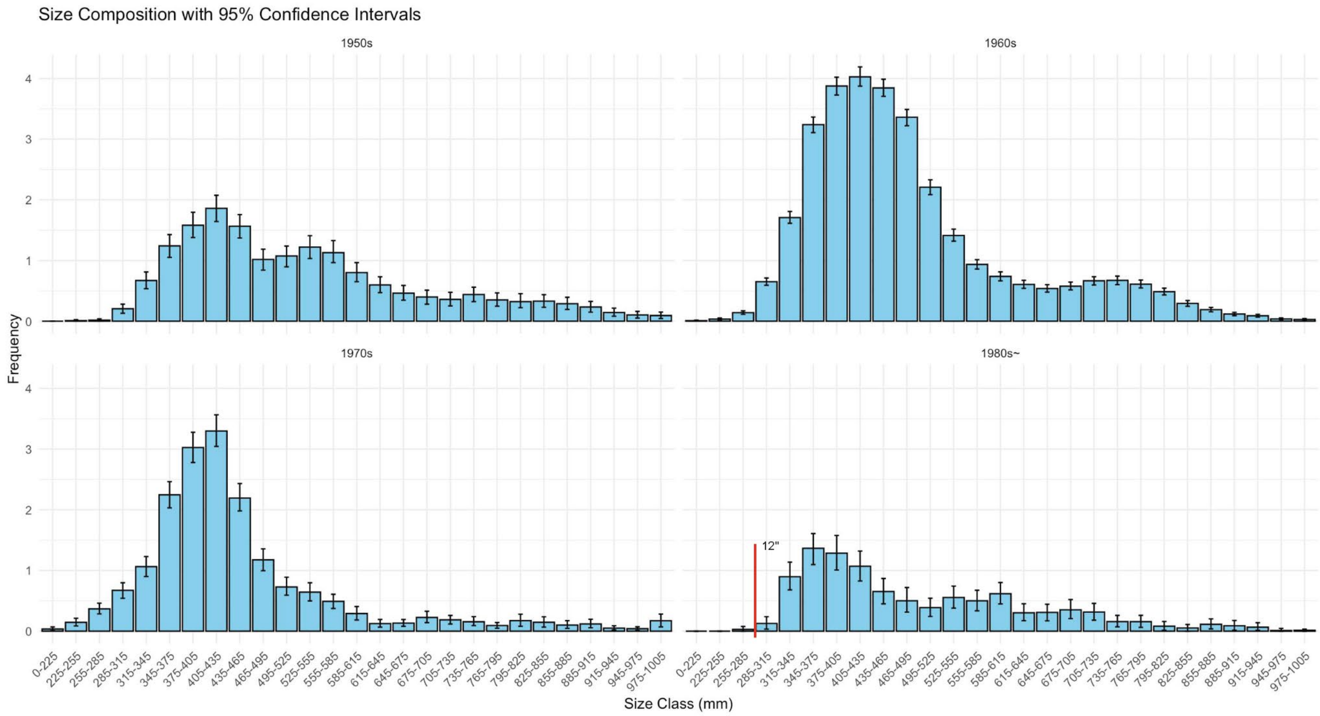

Figure 7. Estimated length frequency by time block (i.e., 1950s, 1960s, 1970s, and 1980s ~ 2010s) from FISHstory data using the bootstrap method. Red vertical line represents the 12’’ TL minimal size limit implemented in 1980s.

Table:

year_block	n.photo	n.fish
Block 1: Pre 1964	736	30781
Block 2: 1965-1974	279	8757
Block 3: 1975 - early 1980s	17	211

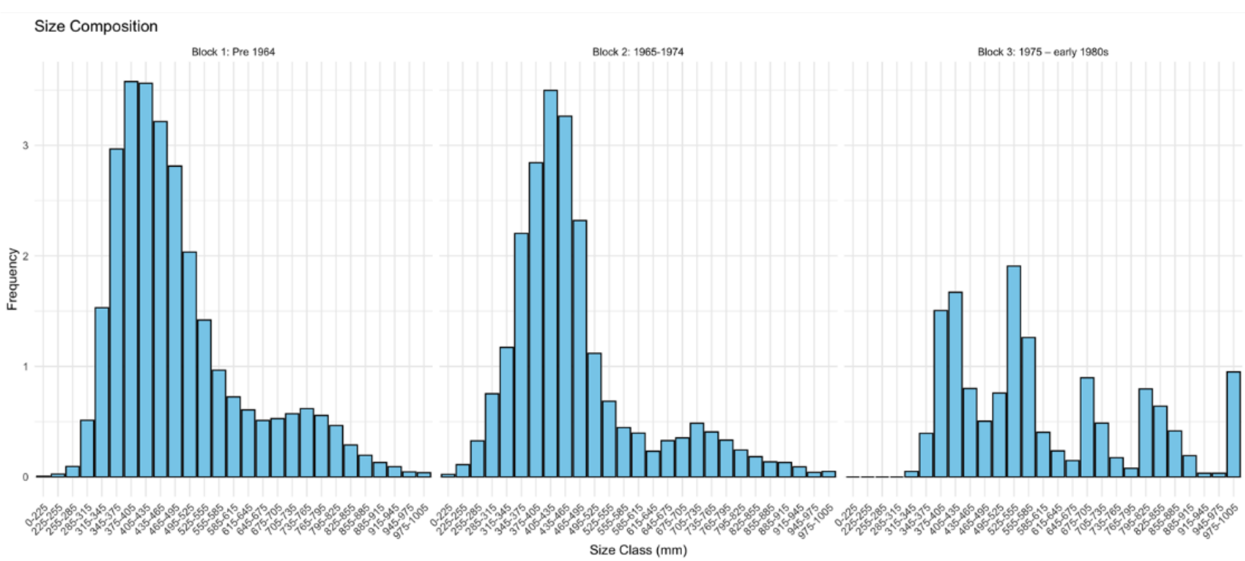

Figure 8. Estimated length frequency from FISHstory data by revised time blocks from SEDAR 90 Data Workshop.