Gulf of Mexico Greater Amberjack (*Seriola dumerili*) Growth Model for SEDAR 70 Operational Assessment

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SEDAR70-WP-10

29 June 2020
Updated: 21 September 2020

Please cite this document as:

Murie, D. J., D.C. Parkyn, G.H. Smith Jr., R. Allman, A. Pacicco, J. Carroll, and N. Smith. 2020. Gulf of Mexico Greater Amberjack (*Seriola dumerili*) Growth Model for SEDAR 70 Operational Assessment. SEDAR70-WP-10. SEDAR, North Charleston, SC. 18 pp.

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September 2020

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INTRODUCTION

This SEDAR70 Data Workshop working document provides details of the overall growth model for the 2020 SEDAR 70 Operational Assessment (OA) for Gulf of Mexico Greater Amberjack. For comparison, growth models from the SEDAR 33 Benchmark Assessment based on the Life History Working Group (SEDAR 2014), the SEDAR 33 Update Assessment (SEDAR 2016; Lombardi unpub. data[1]), and the SEDAR 33 Update FINAL (Lombardi 2016 unpubl. data[2]) are provided, as are all other known growth models for Greater Amberjack from the Gulf of Mexico and South Atlantic.

METHODS

Otolith Processing, Aging, and Precision

Otoliths were processed and aged based on methods outlined in Murie and Parkyn (2008, 2013) and VanderKooy (2009). Greater Amberjack were assigned to an age class based on the count of opaque annuli (zones) and the appearance and quantity of opaque and translucent material at the edge of the otolith. Fish deposit the opaque zone in their otoliths during the spring to early summer months and therefore annual ages were advanced by 1 year if a large translucent zone was on the margin and the capture date was 1 January to 30 June. Fish were not advanced from 1 January to 30 June if the opaque zone was on the edge or there was a narrow translucent zone after the opaque zone, as this was interpreted as the fish having already deposited its opaque zone of its annulus for the year. After 30 June, the age was equal to the number of opaque zones. Biological ages of fish were also estimated as decimal-years (fractional) by accounting for the difference between its birth and its capture date. For Greater Amberjack in the Gulf of Mexico, peak spawning occurs in March-April, with the birthdate for calculation of biological ages set as 1 April. Differences between the two dates (in days) were divided by 365 and this value was subtracted from the annual age if the fish was captured between 1 January and 31 March, and it was added to the annual age if the capture date was 1 April or later (VanderKooy 2009).

Greater Amberjack is considered to be a difficult species to age (Murie and Parkyn 2008; VanderKooy 2009; Otolith Working Group pers. comm.). Average percent error (APE) (Beamish and Fournier 1981) is used to measure aging precision and is assessed annually by the GSMFC Otolith Working Group for all entities that contribute ages to the stock assessment. Campana (2001) indicated that a coefficient of variation (CV) of 5% is considered a reference level for many fishes aged using otoliths that are of moderate reading complexity, which corresponds to an APE of 3.6% (CV=-0.15+1.41APE; Campana 2001). With improvements in aging criteria and a training module for Greater Amberjack, APEs for all entities reading Greater Amberjack ages are now < 3.6% (SEDAR 2014; GSMFC Otolith Working Group unpub. data).

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[1] Lombardi (unpub. data) refers to tables and excel files provided by Linda Lombardi-Carlson (NMFS, Panama City, FL) to Nancie Cummings (NMFS SE Fisheries Center, Miami, FL) for the SEDAR 33 Update.

[2] Lombardi (2016, unpub. data) refers to an excel file provided by Linda Lombardi-Carlson (NMFS, Panama City, FL) to Nancie Cummings (NMFS SE Fisheries Center, Miami, FL) for an Oct 2016 revised SEDAR 33 Update, referred to as SEDAR 33 Update FINAL.

Length and Age Frequencies for Aged Greater Amberjack

General sampling summaries were produced for Greater Amberjack measured and aged throughout the time series of 1991-2018, with 2018 being the terminal year for the SEDAR 70 OA. These included the number of samples by each state over the time series, and the length and age frequencies by commercial, recreational and fishery-independent sampling. Length and age frequencies were also compared between data used in the growth analysis in SEDAR 33 Update FINAL and SEDAR 70 (this study).

Greater Amberjack samples collected from 1980-1990 were not included in the growth analyses, as per the decision made for the SEDAR 33 stock assessment based on the fishing mode not being reported for these samples (Lombardi 2016 unpub.data[2]).

Growth Models

For continuity with SEDAR 33 and the SEDAR 33 Update FINAL, a von Bertalanffy growth curve was modeled for all males, females and fish of unknown sex combined for the SEDAR 70 OA. The von Bertalanffy growth curve was modeled as:

$$L_t = L_\infty [1 - e^{-k(t-t_0)}]$$

where L_t = the predicted average fork length (FL, in mm), L_∞ = the average maximum FL, k = the growth coefficient (the rate of approach to L_∞), and t_0 = the theoretical age when FL = 0. A generalized von Bertalanffy growth curve was modeled in R using the FSA (Fishery Stock Analyses) package.

For continuity with SEDAR 33 and the SEDAR 33 Update FINAL, a size-modified von Bertalanffy was also modeled, which took into account the effect of the minimum size limits at the time of capture of each fish (Diaz et al. 2004). Table 1 gives the size limits in effect for the commercial and recreational fisheries in the Gulf of Mexico; the size limit was set at 0 mm FL for all fishery-independent samples. These von Bertalanffy models are referred to as “Size-Modified” models in the report and were determined using solver in Excel.

RESULTS and DISCUSSION

Age Samples

A total of 7,649 records were submitted for age and growth analysis for the SEDAR 70 OA. Fish that had an age estimate but only either maximum total length (MTL) or natural total length (NTL) recorded had their lengths converted to FL using length conversions given in Table 3 of the SEDAR 33 Data Workshop Report (SEDAR 2014). For continuity with SEDAR 33/33 Update FINAL, 138 records were not used because they had been collected prior to 1991. A further 8 records and 700 records were not used as they had no accompanying length or age information, respectively. In addition, two records were outliers in initial QA/QC plots of age as a function of length. In total, therefore, 6801 fish were used in the growth analysis for SEDAR

70. These ages included 1835 ages that have been previously used in a growth analysis by Murie and Parkyn (2008) for Greater Amberjack captured between 1989-2008.

The majority of age samples were from the recreational fisheries in Florida and Louisiana (56%) and secondarily from the commercial fishery in Louisiana (23%) (Table 2). Most age samples from the recreational fisheries were from 2002-2018, with sampling increased in 2009, and from the commercial fisheries from 2009-2017 (Figure 1).

Length and Age Frequencies for Aged Greater Amberjack

Lengths ranged from 141-1829 mm FL, with the majority of fish between 750 and 1100 mm FL (Figure 2A). Fishery-independent sampling covered the entire range of sizes with an emphasis on smaller fish below the size limits for the recreational and commercial fisheries. Fish length distributions from recreational and commercial fisheries were progressively skewed towards larger fish as expected based on the greater minimum size limit in the commercial fishery.

Length frequency distributions for Greater Amberjack used in the SEDAR 70 growth analysis was similar to the length frequency distribution of data used in the SEDAR 33 Update FINAL (Figure 2B).

Ages ranged from 0 to 19 years, with the majority in the 3-5 year range (Figure 3A). As expected based on no minimum-size limit for fishery-independent samples and increasing size limits on recreational and commercial fisheries, samples from fishery-independent sources were in general from younger fish compared to recreational fishery samples, which in turn were generally from younger fish than the commercial samples (Figure 3A).

As with length frequency distributions, age frequency distributions for Greater Amberjack used in the SEDAR 70 growth analysis were similar to the age frequency distributions of data used in the SEDAR 33 Update FINAL (Figure 3B).

Growth Models

Both the size-modified and the non-size-modified growth models for Greater Amberjack using biological age and length data from 1991-2018 (Figure 4) converged, with the size-modified model showing the expected lower k and concomitant increase in L_∞ (Table 3). All parameter estimates for the models are provided in Table 3.

Observed mean lengths at age for Greater Amberjack were slightly above the SEDAR 70 size-modified von Bertalanffy for fish $\leq$ 5 years of age, in part demonstrating the capture of the fastest growing fish in age cohorts regulated by minimum size limits (Figure 5).

In comparison to the size-modified von Bertalanffy growth curves from SEDAR 33 and SEDAR 33 Update FINAL, the size-modified growth curve estimated for SEDAR 70 had a lower L_∞ and a concomitant higher k (Figure 6; Table 3).

SEDAR 70 growth curves for Gulf of Mexico Greater Amberjack fell within the range of previously reported growth curves (Figure 7; Table 4).

ACKNOWLEDGEMENTS

We especially thank the dozens of state, federal, and university fisheries biologists and technicians that have been involved with the field collections, port sampling, otolith processing, and aging of otoliths of Greater Amberjack through the decades represented by the samples used in this SEDAR 70 growth analysis. In particular, we are grateful to Eddie Leonard, Alicia Breton, and Amanda Croteau (University of Florida), and Isis Longo, Kisha Johnson, Kym Walsh, and Jenny Lang (Louisiana Department of Wildlife and Fisheries) for their expertise in amberjack otolith processing and aging.

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Table 1. Size limit restrictions on the harvest of Greater Amberjack from the Gulf of Mexico.

FISHERY	**EFFECTIVE DATE**	**END DATE**	**SIZE LIMIT INCHES**	**SIZE LIMIT MM**
COM	2/21/1990	Ongoing	36	914
REC	2/21/1990	8/3/2008	28	711
REC	8/4/2008	1/3/2016	30	762
REC	1/4/2016	Ongoing	34	864

Table 2. Number of Gulf of Mexico Greater Amberjack ages by state and sector (1991-2018).

STATE	**COMMERCIAL**	**RECREATIONAL**	**FISHERY-INDEPENDENT**	**UNKNOWN**	**TOTAL**
Alabama	46	293	8		347
Florida	209	2433	579	1	3222
Louisiana	1542	1363	83		2988
Mississippi	48	5	2		55
Texas	4	170	15		189
TOTAL	**1849**	**4264**	**687**	1	**6801**

Table 3. The von Bertalanffy growth curve parameters for Gulf of Mexico Greater Amberjack based on biological ages and observed FL at capture for SEDAR 70 (this report, Size- and Non-size- modified) and previous size-modified growth curves, including SEDAR33, SEDAR 33 Update (Aug 2016), and SEDAR 33 Update FINAL (revised SEDAR 33 Update in Oct 2016) . The SEDAR 33 and SEDAR 33 (Update and Revised Update) size-modified von Bertalanffy parameters were estimated by L. Lombardi-Carlson (NMFS, Panama City, FL). In addition, von Bertalanffy parameters were either fixed (Linf) or estimated (k) within the Stock Synthesis model by N. Cummings (NMFS SE Science Center, Miami, FL) for SEDAR 33 and SEDAR 33 Update Stock Assessment Workshops (SAWs). Model parameters are defined in the text, with sigma = standard deviation for model and nLL = negative log-likelihood.

Model	n	Years	L_∞ (mm FL)	k	t_0	Sigma	nLL
SEDAR70 (Size-modified)	6801	1991-2018	1307	0.2298	-0.7570	116.14	3.6 x 10^4
SEDAR70 (Non-size-modified)	6801	1991-2018	1179 ± 8	0.3426 ± 0.009	-0.4899 ± 0.045		
SEDAR33-Update SAW		1991-2015	1436 fixed	0.2108			
SEDAR33 Update FINAL* REVISED OCT 2016 (Size-modified)	5284	1991-2015	1389 ± 24	0.2025 ± 0.009	-0.5915 ± 0.065	115.7 ± 1.544	2.99 x 10^4
SEDAR33 Update* AUG 2016 (Size-modified)	4700	1991-2015	1453 ± 33	0.1802 ± 0.009	-0.7366 ± 0.075	117.6 ± 1.682	2.66 x 10^4
SEDAR33-SAW		1991-2012	1436 fixed	0.1448			
SEDAR33 (Size-modified)	3993	1991-2012	1436 ± 38	0.1752 ± 0.001	-0.9535 ± 0.084	114.3 ± 1.736	2.25 x 10^4

* The SEDAR 33 Update (Aug 2016) data and analysis was revised in Oct 2016 (Lombardi-Carlson, file “S33update_GAM_growth_all_revised_data.xlsx”) and is reported here as SEDAR 33 Update FINAL.

Table 4. Summary table for estimated von Bertalanffy growth parameters for Greater Amberjack from previous studies and this study (SEDAR 70).

Stock	Model	Location	L_∞ (mm)	k	t_0
South Atlantic					
	Burch (1979)	South FL	1643	0.174	-0.653
	Manooch and Potts (1997a)	SE Atlantic	1514	0.119	-1.23
	Harris et al. (2007)	SE Atlantic	1242	0.28	-1.56
Gulf of Mexico					
	Manooch and Potts (1997b)	Gulf of Mexico	1109	0.227	-0.791
	Thompson et al. (1999)	Louisiana	1389	0.25	-0.79
	Murie and Parkyn (2008): All	Gulf of Mexico	1240	0.28	-1.01
	Murie and Parkyn (2008): Females	Gulf of Mexico	1280	0.26	-1.12
	Murie and Parkyn (2008): Males	Gulf of Mexico	1197	0.29	-0.92
	SEDAR 70 Size-modified: All*	Gulf of Mexico	1307	0.2298	-0.7570
	SEDAR 70 Non-Size-modified: All*	Gulf of Mexico	1179	0.3426	-0.4899
	SEDAR 33 Update FINAL Size-modified : All*	Gulf of Mexico	1389	0.2025	-0.5915
	SEDAR 33 Size-modified: All*	Gulf of Mexico	1436	0.1752	-0.9535

*Includes ages reported in Murie and Parkyn (2008)

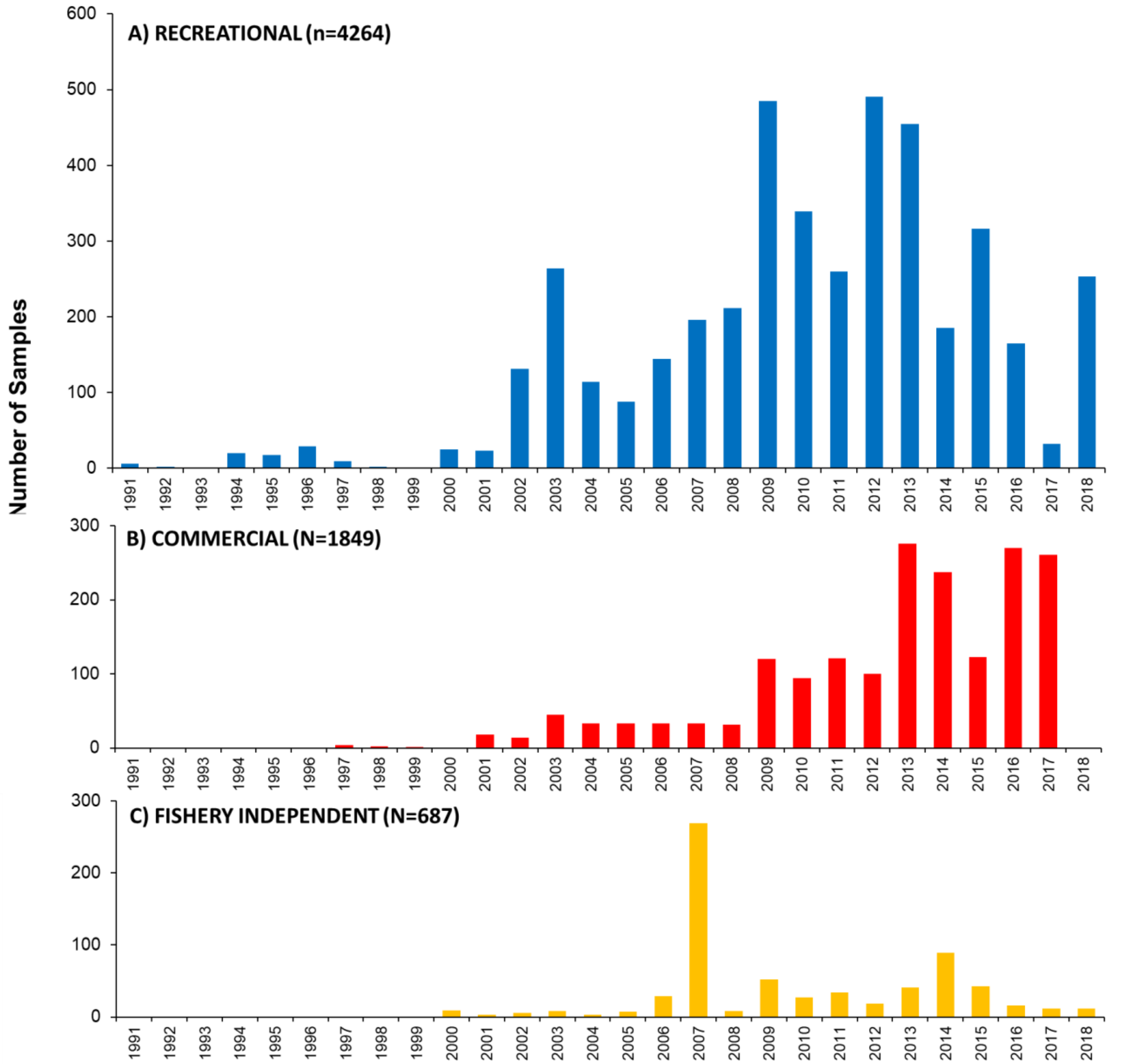

Figure 1. Number of age samples for Greater Amberjack in the Gulf of Mexico by fishery and year of collection used in this SEDAR 70 growth analysis.

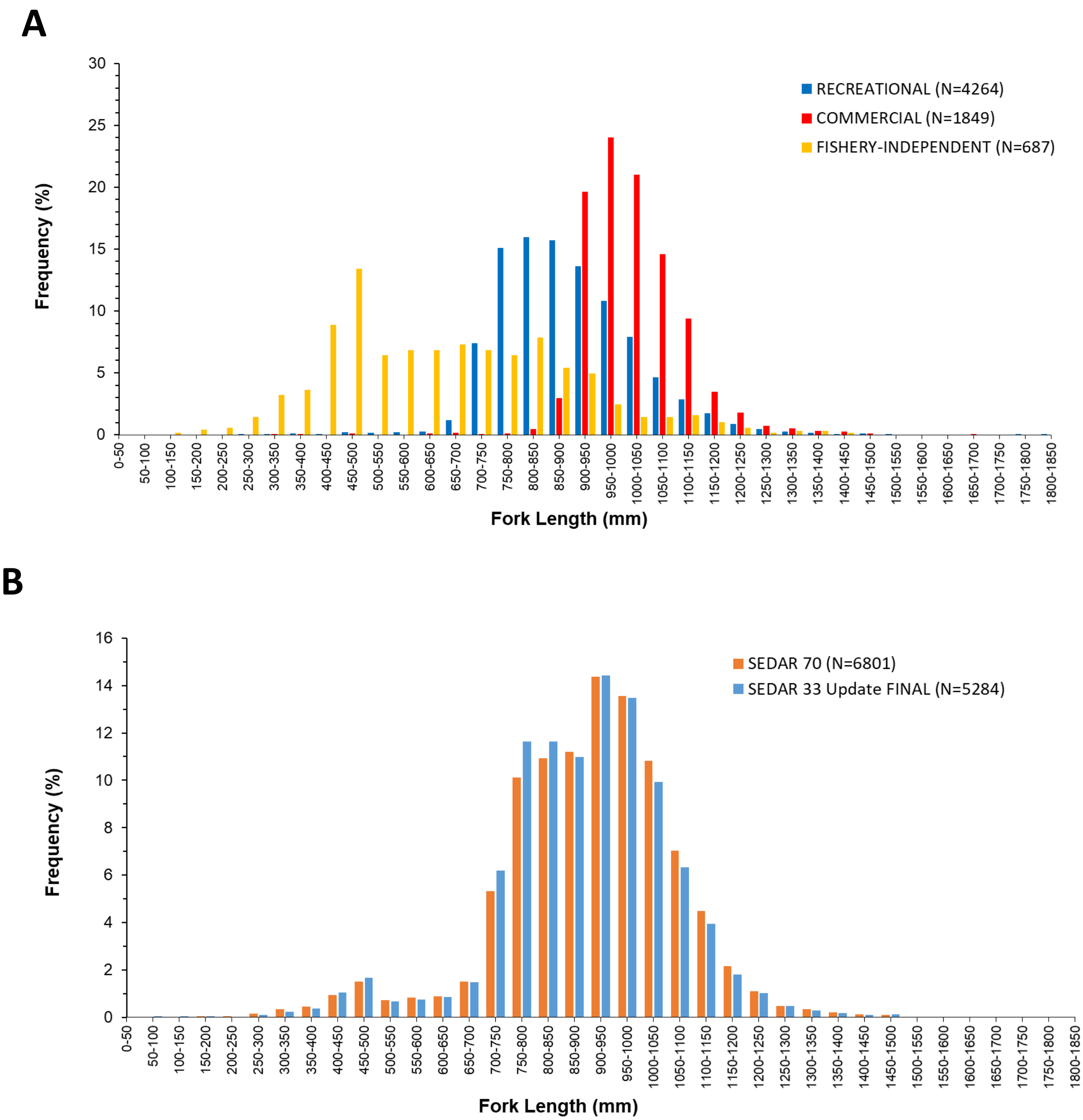

Figure 2. Length frequency distributions for Greater Amberjack: A) used in SEDAR 70 age and growth analysis by fishery; and B) comparisons between fish used in the growth analysis in SEDAR 33 Update FINAL and the current analysis for SEDAR 70.

A

B

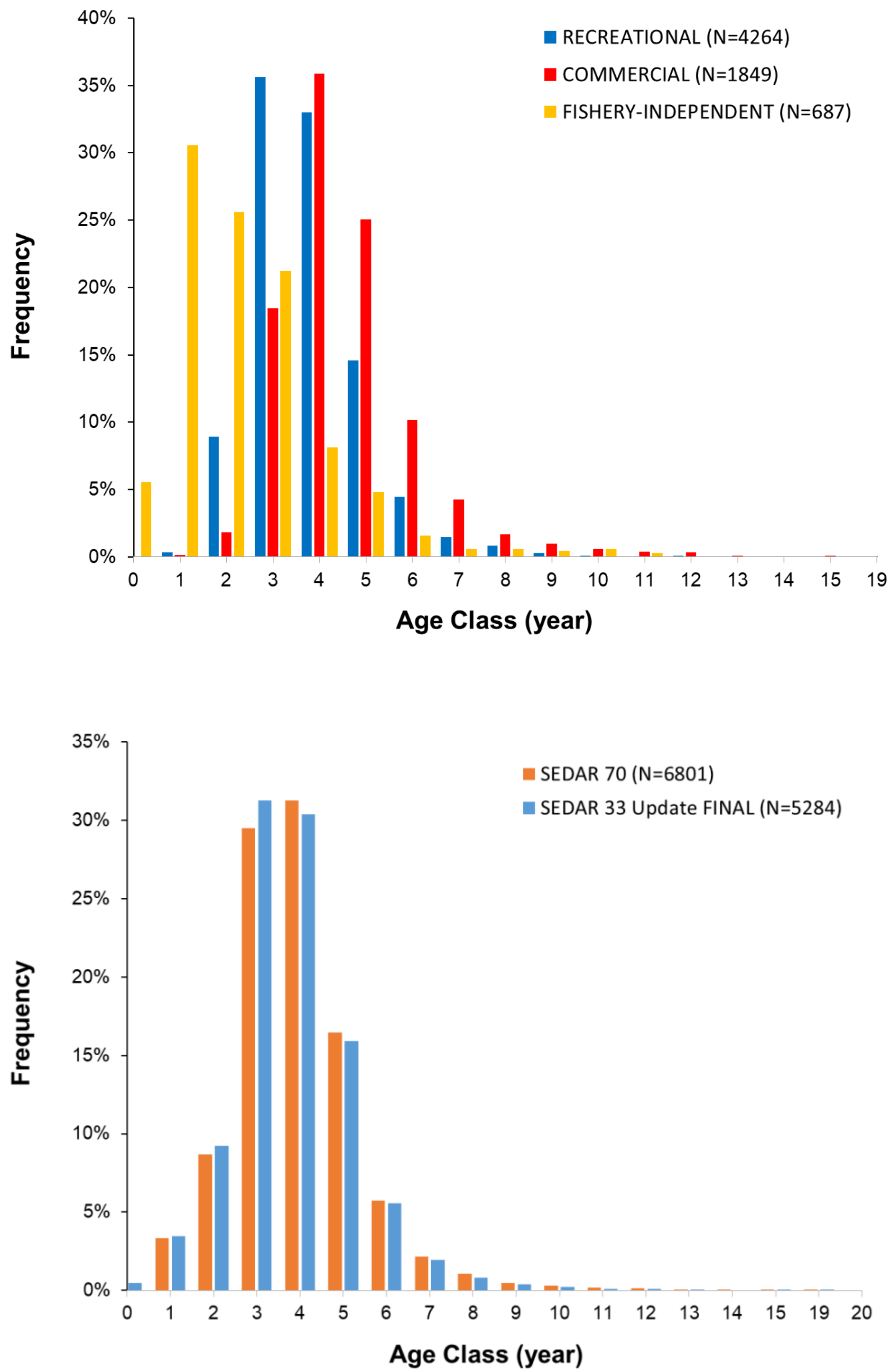

Figure 3. Age frequency distributions for Greater Amberjack: A) used in SEDAR 70 age and growth analysis by fishery; and B) comparison between fish used in the growth analysis in SEDAR 33 Update FINAL and the current analysis for SEDAR 70.

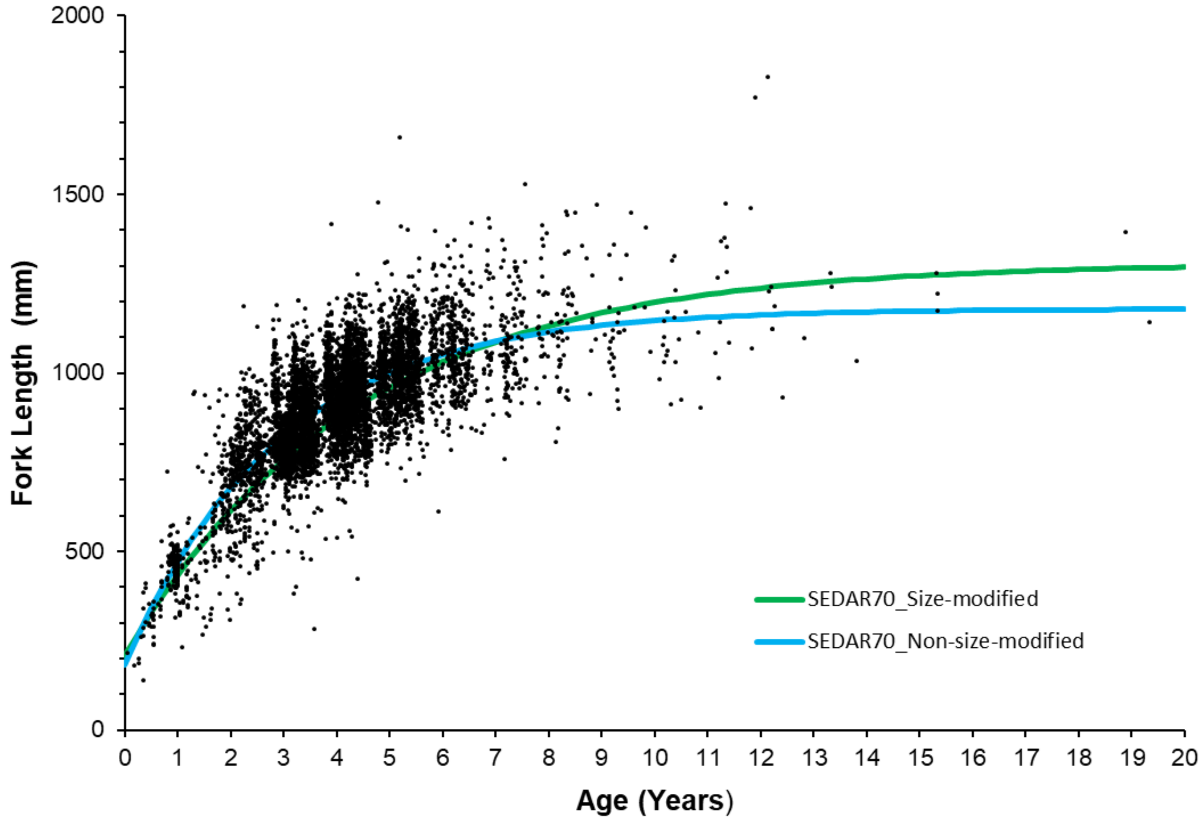

Figure 4. von Bertalanffy growth curves for Greater Amberjack from the Gulf of Mexico collected from recreational, commercial, and fishery-independent fisheries in 1991-2018 based on biological ages. The non-size-modified model is the usual von Bertalanffy without any correction for minimum size limits whereas the size-modified von Bertalanffy takes into account the minimum size limit in effect at the time of the fish capture (see text for minimum size limits). Parameter estimates for both models are given in Table 2.

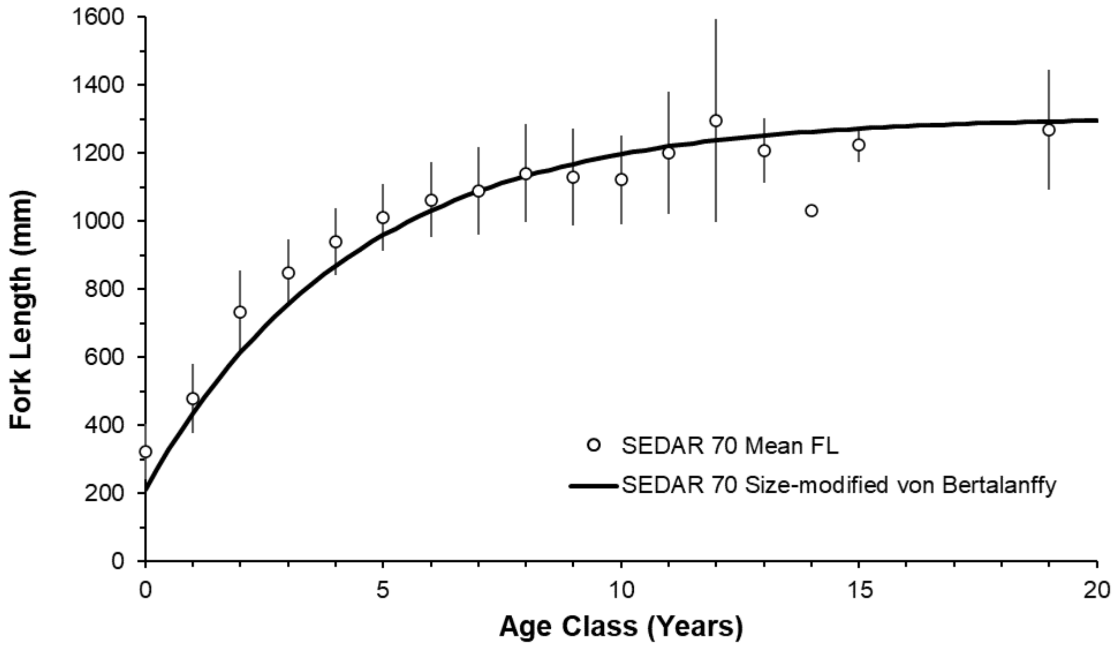

Figure 5. Mean (± 1SD) length at age for Greater Amberjack from the Gulf of Mexico collected from recreational, commercial, and fishery-independent fisheries in 1991-2018 for SEDAR 70 age and growth analysis. The solid black line is the predicted SEDAR 70 size-modified von Bertalanffy (parameter estimates are given in Table 2).

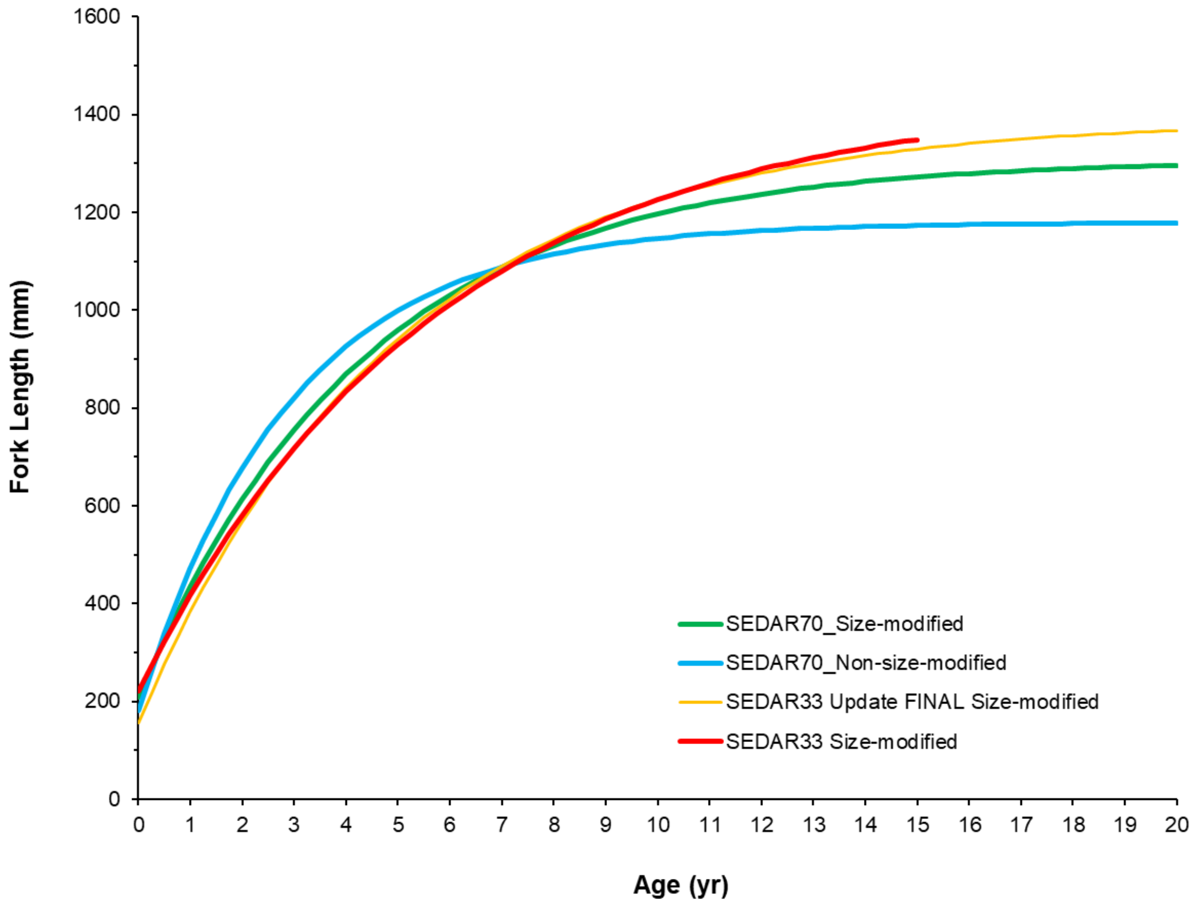

Figure 6. Comparison of pooled (recreational, commercial, and fishery-independent fisheries) size-modified von Bertalanffy growth curves for Greater Amberjack from the Gulf of Mexico from SEDAR 33, SEDAR 33 Update FINAL, and SEDAR 70 (this report, size- and non-size modified). Parameter estimates, sampling years, and sample sizes are given in Table 2.

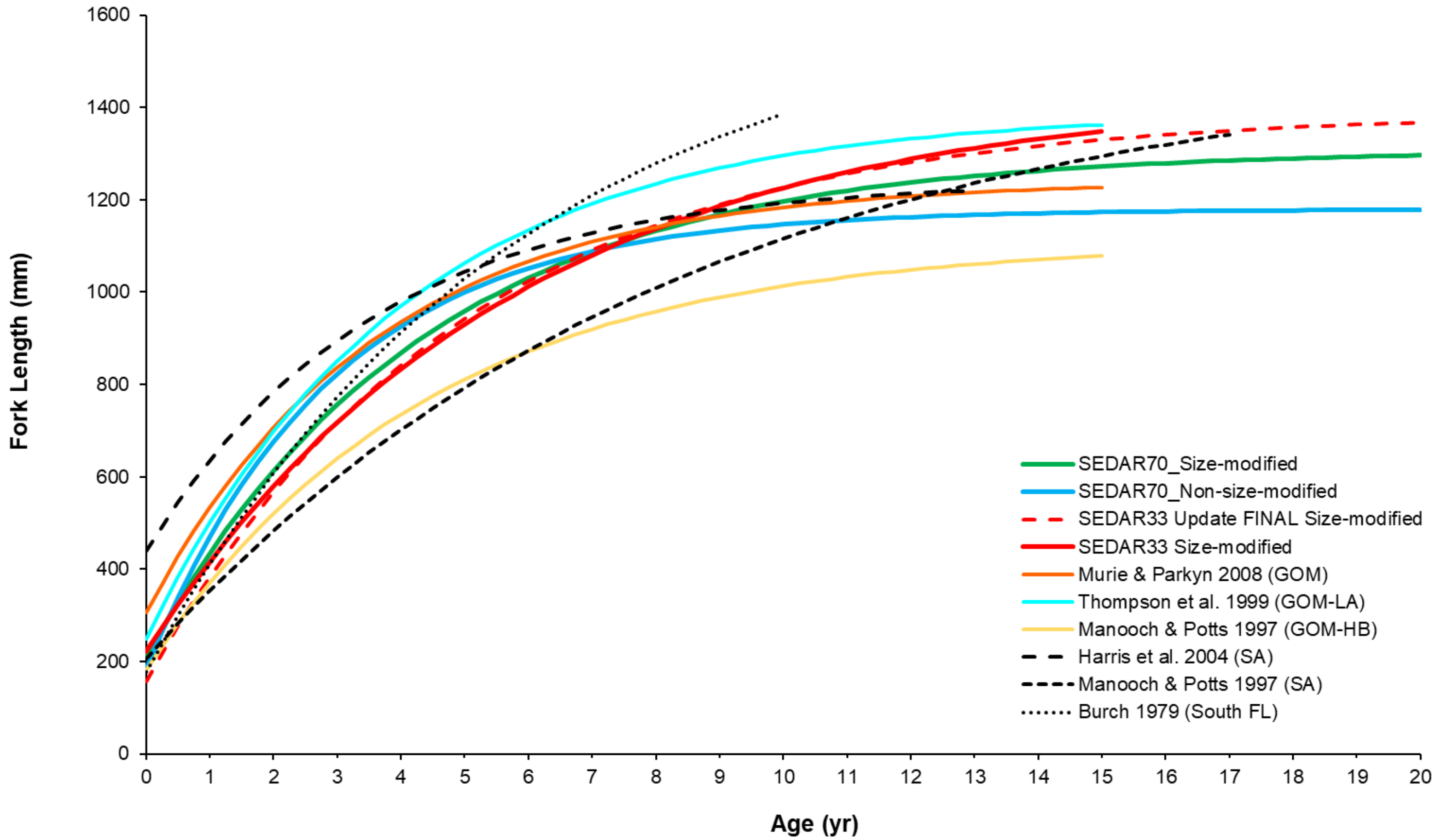

Figure 7. All known reported von Bertalanffy growth curves for Greater Amberjack from the Gulf of Mexico and the US South Atlantic. All lines represent the predicted FL at age for von Bertalanffy models up to the maximum age of the fish sampled. Parameter estimates for models are given in Table 3.