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Life History Data for SEDAR 75 Gulf of Mexico Gray Snapper

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The SEDAR 75 Life History Group reviewed updated age and reproductive data collected through the terminal year of 2019. Here we describe the data processing, age data, growth models, and maturity ogives for Gulf of Mexico gray snapper, *Lutjanus griseus*.

METHODS

Sample collection and processing

Gray snapper were sampled from the Gulf of Mexico (GOM) from South Texas to Monroe county, Florida from 1980 to 1983 and 1990 to 2019. Following the stock delineation described in SEDAR 51 (2018), gray snapper collected from national marine fisheries grid zones 1-21, 748, 744.1, 744.6, 744.7, headboat zones 12-27, or landed in a FL county north of Monroe county (along the west coast of FL) were assigned to the Gulf of Mexico stock. All fish collected from any other zone, headboat area, or county north of Miami-Dade (along the east coast of FL) were assigned to the South Atlantic stock and were excluded. This resulted in 46,486 age samples with an assigned calendar age and corresponding length measurement.

Fish collected throughout the time series were measured to the nearest mm fork length and/or total length and weighed to the nearest g, and sex was determined macroscopically if landed whole. Sagittal otoliths were removed, cleaned with distilled water, dried and a subset weighed to the nearest 0.0001 g prior to sectioning. All otoliths were processed and aged with the exception of those from the commercial handline fishery, which were subsampled due to large sample sizes. Subsample numbers were based on proportional landings by NMFS fishing grid. Otoliths were processed with either a Hillquist high-speed thin sectioning machine utilizing the methods of Cowan et al. (1995) or on an Isomet low-speed saw. Two transverse cuts were made through the otolith core to a thickness of 0.5 mm. Ages were assigned based on the count of annuli and the degree of marginal edge completion. Annuli were identified as opaque zones observed on the dorsal side of the sulcus acousticus in the transverse plane with reflected and/or transmitted light at 40x, including any partially completed opaque zones on the otolith margin. Biological (i.e., fractional) ages were estimated for fitting growth curves. Biological age accounts for the difference in time between peak spawning (defined as 1 July for gray snapper) and capture date (i.e., the difference in days divided by 365.25). This fraction was added to the annual age estimate when the capture data was after July 1st and subtracted when the capture data was before July 1st (Vanderkooy et al., 2020).

Growth models

Growth models were fit with size-modified von Bertalanffy growth functions following the methods of Diaz et al. (2004) used in SEDAR 51 (2018). Size-modified growth functions account for size-selective bias and truncation of size-at-age data above minimum length limits and have the flexibility to compare different variance structures among candidate models (Diaz et al. 2004). Differences in federal and state minimum length limits complicate the assignment of size limits in growth models for gray snapper. In 1990, federal management regulations were enacted that imposed a 12” minimum length limit (TL) on gray snapper caught by recreational or commercial fishers that continues to the current day. Additionally, the state of Florida imposed a

10” TL minimum size regulation beginning in 1990 that applied to all gray snapper landed in state territorial waters. It is difficult to confidently assign the correct size limit to many age samples because they lack sufficient capture location information to differentiate between state and federal waters. Therefore, two scenarios were explored to assess growth model fits based on different minimum length limits imposed by state and federal management agencies. In scenario 1, all fishery-dependent records captured after January 1, 1990 were assigned the 28.82 cm FL (12” TL) size limit. In Scenario 2, all fish landed by recreational fishers in FL territorial waters after Jan 1, 1990 were assigned the 24.02 cm FL (10” TL) size limit while all other fishery-dependent records collected after Jan 1, 1990 were assigned the 28.82 cm FL size limit. A third scenario was explored in SEDAR 51 (2018) where all fish landed in a FL county after January 1, 1990 were assigned the state minimum size limit and all other fishery-dependent records collected after January 1, 1990 were assigned the federal minimum length limit, but this scenario was not evaluated in SEDAR 75.

Von Bertalanffy growth functions were fit to gray snapper size-at-age data in AD Model Builder (Fournier et al. 2012) using inverse weighting where the (fractional) age-specific weight was the inverse of the (calendar) age-specific sample size. For example, if there were 100 age-0 gray snapper in the dataset, the weighting value applied to age-0 fish would be 0.01. We evaluated candidate models with variance parameters estimated as constant standard deviation (SD), constant coefficient of variation (CV), a linear function of age, or a linear function of size-at-age. Each of the four candidate models were fit to the size-at-age data for each of the two minimum size limit scenarios. Candidate models were compared based on Akaike’s information criterion corrected for small sample size (ΔAICc; Akaike 1981).

<u>Reproduction</u>

Reproductive data was obtained during standard biological sampling described above, and was evaluated for the years 1991 to 2021. All reproductive analysis was conducted in R, including binomial generalized linear models using logit link functions for the maturity ogives (Venables and Ripley 2002; R Core Team 2021). Reproductive phase assignment followed Brown-Peterson et al. (2011), and all historic records were updated as needed based on the most advanced gamete stage (MAGS), age of the post-ovulatory follicles (POFs), indicators of prior spawning, and the presence of short-term atresia. The gonadosomatic index (GSI) was calculated as the percentage of ovary weight to ovary-free body weight.

For SEDAR 51 (2018), individuals were considered mature for all secondary growth oocyte stages, including cortical alveolar (CA), which was defined as physiological maturity. It was determined by the Life History Workgroup that females with a MAGS of CA during the spawning season should be excluded from the maturity model in order to reduce uncertainty in estimates of size and age at maturity. It is difficult to determine whether females with MAGS of CA are developing for the spawning season for the first time or are repeat spawners. For SEDAR 75, all individuals in the Immature reproductive phase were assigned a value of “0” in the binary functional maturity model. Those in the Early Developing reproductive subphase with CA as the

MAGS were removed from the analysis. Individuals in the Early Developing subphase with either early vitellogenic stage or any subsequent reproductive phase (e.g. Spawning Capable, Actively Spawning, Regressing, Regenerating) were assigned a “1” for mature.

RESULTS

Age data

A total of 241 samples were dropped because they were deemed outliers (either as length or length-at-age outliers) and 3,574 records did not have a calendar age estimate. Final fork length was equal to observed fork length if recorded in the field or converted from maximum total, natural total, or standard length using conversion equations from SEDAR 51 (2018). There were 13 records that did not have a final length estimate of any kind that could be converted to final fork length (cm) and were excluded from the analyses. One record not marked as an outlier in the database was deemed an outlier due to suspicion of misidentification (i.e., Cubera snapper) based on excessive length (>90 cm) relative to all other lengths (<80 cm) in the dataset. This resulted in a final dataset of 46,486 records for gray snapper from the nGOM stock, collected during or before the terminal year (2019), with both an age and length estimate. Sample sizes by fishery and state are shown in Figures 1 and 2, respectively. Summary plots of age by year are shown in Figure 3. Frequency histograms of calendar age by year or length-at-age by year are shown in Figures 4 and 5, respectively.

Growth models

Fit statistics from von Bertalanffy growth models applied to gray snapper size-at-age data indicated that all eight candidate models fit the data relatively well in that they differed by less than 7 AICc units (Table 1). The model with variance estimated as a constant SD parameter had the lowest overall AICc value under scenario 1 and the lowest AICc score of the four candidate models in scenario 2 (third lowest overall). The model with variance estimated as a linear function of size-at-age had the second lowest overall AICc score. However, these three models differed by less than 2 AICc units and are therefore not significantly different (Burnham and Anderson 2004). Parameter values for the average asymptotic maximum length (L_∞) differed by less than 1.5 cm in both scenarios for the growth model with variance estimated as having a constant SD, as a linear function of age, or as a linear function of size-at-age. The growth coefficient parameter (k) also was similar among the three best-fit candidate models and ranged from 0.104 to 0.115. A growth model with variance modeled as a linear function of size-at-age was selected as the best-fit model to describe gray snapper growth in SEDAR 51 (2018) and was again among the best-fit models in this set. However, we decided that scenario 2 (i.e., assigning size limits to fish from either state or federal waters rather than assigning only federal size limits) was the most accurate approach in assigning minimum length limits to the age data for modeling growth. Thus, the Life History Working Group selected the VBGF parameters from the model with variance estimated as constant SD under scenario 2 as the best model to describe growth of gray snapper for SEDAR 75. In both scenarios, the growth model with variance estimated as having constant CV had the lowest L_∞ parameter but the highest ΔAICc value. Other VBGF parameters were similar among the three best-fit candidate models and effectively overlap when plotted against the size-at-age data (Figure 6).

Reproduction

Macroscopic sex observations were available for 28,165 gray snapper samples, most of which were collected from Florida waters (76.3%, n = 21,492). The overall sex ratio of the data was 0.48 proportion females, the same as was reported in SEDAR 51 (2018), despite the dramatic increase in sample size ($n_{SEDAR\ 51}$ = 6,789; Fitzhugh et al. 2017).

A total of 1,165 females were assessed histologically for reproductive phase and maturity status. Based on reproductive phase and GSI (Figures 7 and 8), spawning seasonality was observed to be similar to what was reported in SEDAR 51 (2018), with early development starting in March, spawning beginning in May (one spawning capable fish was observed in April), peaking from June through August, and lasting through September (Fitzhugh et al. 2017). It was reported in SEDAR 51 (2018) that that females contributed little to reproduction until about 300 mm FL based on GSI. However, the number of fish <300 mm FL was low. The number of records increased for SEDAR 75 and the same trend remained (Figure 9). One GSI outlier value of 27% was excluded in the analysis, following Fitzhugh et al. (2017).

For the maturity models, 1,057 females without CAs during the spawning season had length information, and 897 had ages. Using functional maturity for modeling size- and age-at-maturity, the L_{50} for Gulf of Mexico gray snapper was estimated at 269.8 mm FL, with an A_{50} of 2.5 years, with 90% of the population reaching functional maturity at 358.7 mm FL and 5.0 years (Figure 10).

REFERENCES

Akaike, H. 1981. Likelihood of a model and information criteria. Journal of Econometrics. 16:3-14.

Brown-Peterson, N.J., D. Wyanski, F. Saborido-Rey, B. Macewicz,, and SK.. Lowerre-Barbieri. (2011). A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries: Dynamics. Management, and Ecosystem Science 3:52-70.

Burnham, K.P. and D.R. Anderson. 2004. Multimodel inference: understanding AIC and BIC in model selection. Sociological Methods & Research. 33:261-304.

Cowan, J.H. Jr., R.L. Shipp, H.K. Bailey IV, and D.W. Haywick 1995. Procedure for rapid processing of large otoliths. Transactions of the American Fisheries Society 124:280-282.

Diaz, G.A., C.E. Porch, and M. Ortiz. 2004. Growth models for red snapper in the U.S. Gulf of Mexico waters estimated from landings with minimum size limit restrictions. NMFS/SEFSC/SFD 2004-038, 13 p.

Fitzhugh, G.R., V.C. Beech, H.M. Lyon, and P. Colson. 2017. Reproductive parameters for the Gulf of Mexico gray snapper, Lutjanus griseus, 1991-2015. SEDAR51-DW-06. SEDAR, North Charleston, SC. 9 p.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software. 27: 233-249.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

SEDAR (Southeast Data Assessment and Review) 51. 2018. Gulf of Mexico gray snapper. SEDAR 51 Stock Assessment Report. North Charleston, SC 29405.

Vanderkooy, S., J. Carroll, S. Elzey, J. Gilmore and J. Kipp, editors. 2020. A practical handbook for determining the ages of Gulf of Mexico fishes. Gulf States Marine Fisheries Commission, Publication No. 300.

Venables, W. N. & Ripley, B. D. (2002) Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0

Table 1. Growth model output for size-modified von Bertalanffy growth models fit to inverse-weighted size-at-age data for Gray snapper under size limit scenario A or B.

Scenario	Variance model	L_∞	k	t_0	Obj. func. value	AICc	ΔAICc
A	Constant σ	60.81	0.112	-1.499	107.04	222.09	0
	Constant CV	56.34	0.166	-0.863	109.32	226.64	4.55
	Linear function of age	62.07	0.104	-1.537	107.26	224.52	2.43
	Linear function of size-at-age	60.6	0.115	-1.252	106.78	223.56	1.47
B	Constant σ	60.76	0.113	-1.473	107.93	223.86	1.77
	Constant CV	56.26	0.168	-0.856	110.19	228.37	6.28
	Linear function of age	62.01	0.105	-1.537	108.13	226.25	4.16
	Linear function of size-at-age	60.54	0.116	-1.245	107.64	225.28	3.19

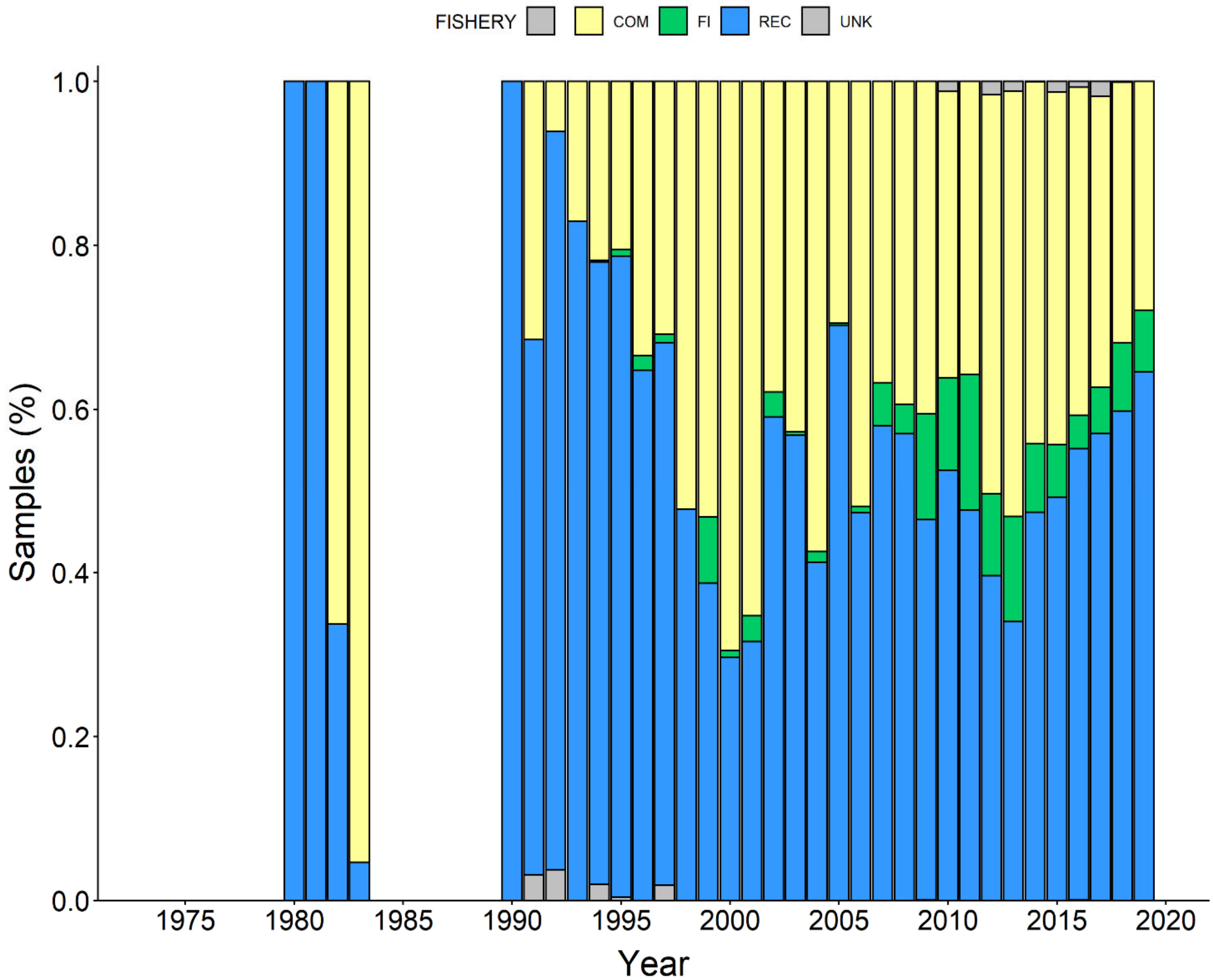

Figure 1. Proportion of age samples by fishery (commercial, recreational, fishery independent, or unknown) from 1980 to 2019.

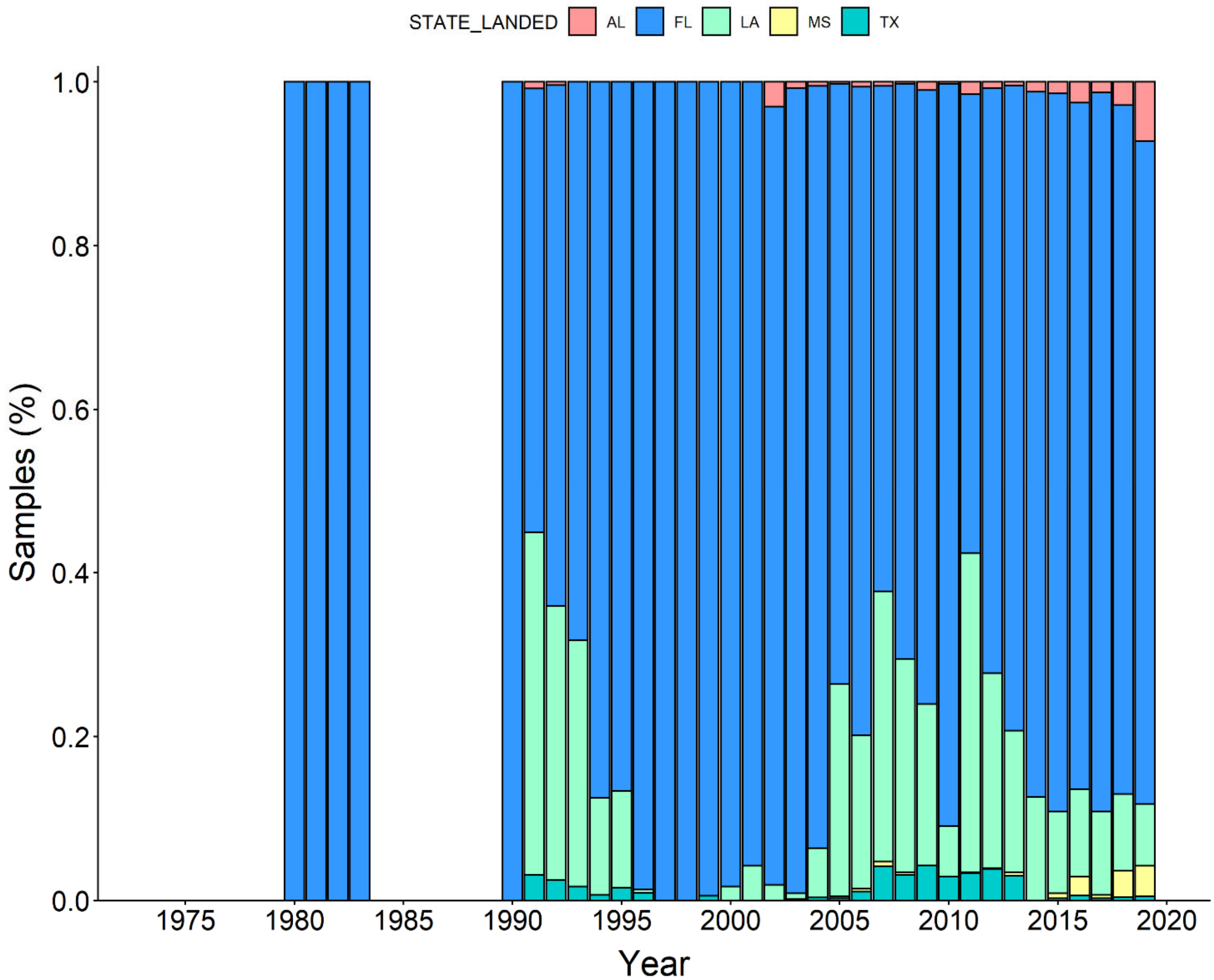

Figure 2. Proportion of age samples by state (Alabama, Florida, Louisiana, Mississippi, or Texas) from 1980 to 2019.

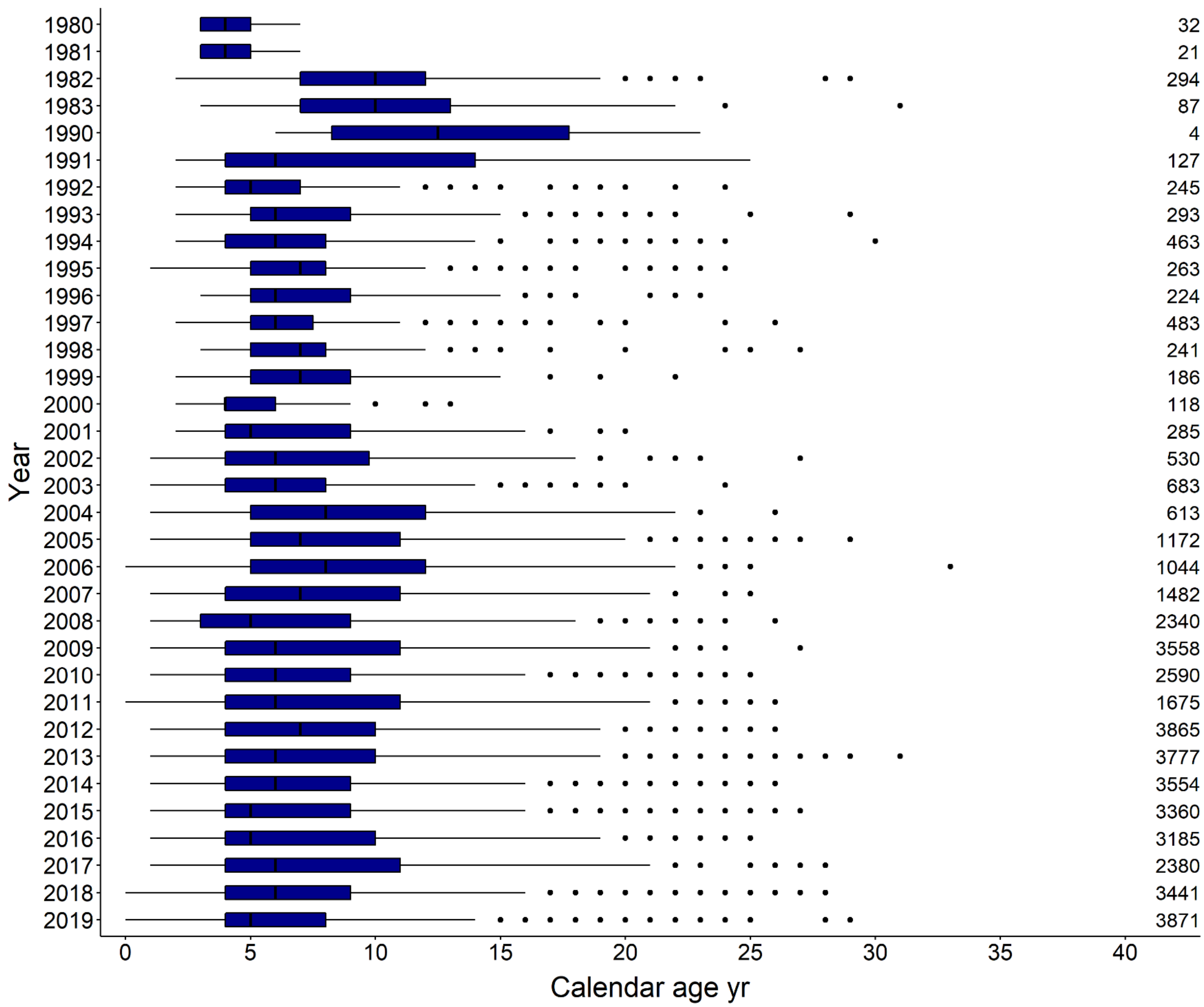

Figure 3. Boxplots of gray snapper age samples collected from 1980 to 2019. Year-specific sample sizes are shown along the right side of the panel. Boxes indicate the inner quartiles, whiskers indicate 1.5*the inner quartile range, and points indicate outliers.

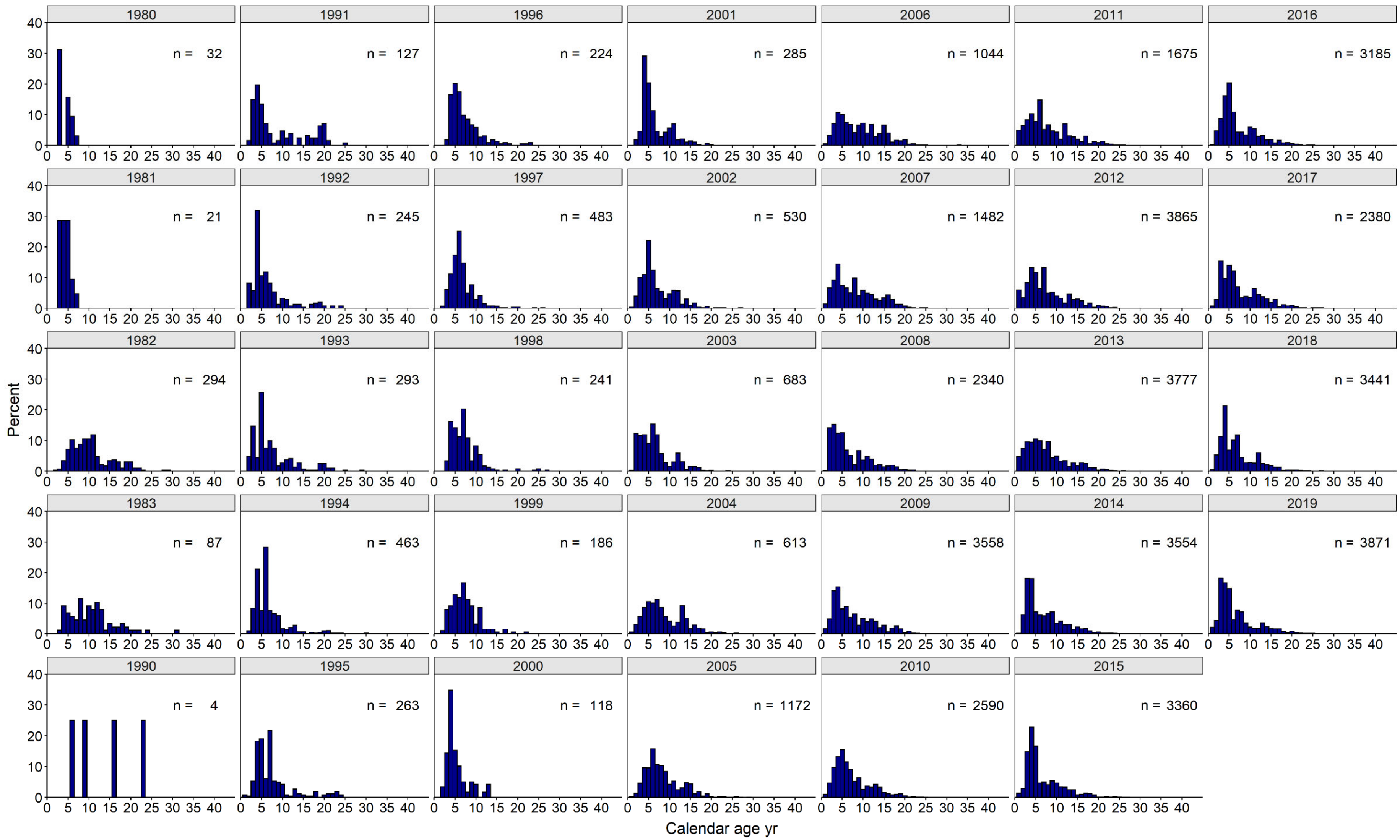

Figure 4. Frequency histograms of calendar age by year for gray snapper age samples collected from 1980 to 2019. No samples were collected from 1984 to 1989. Year-specific sample sizes are shown at the top right of each panel.

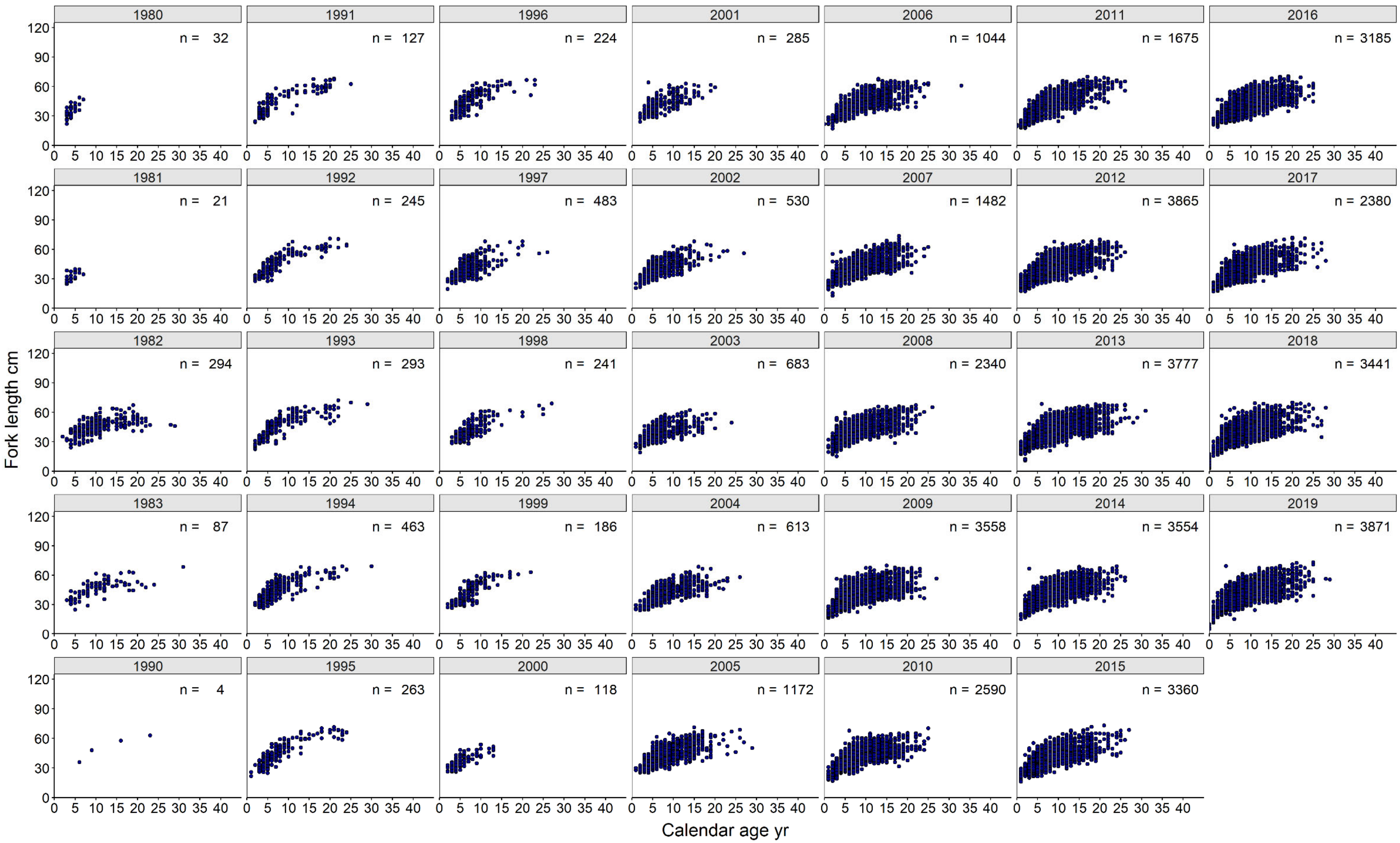

Figure 5. Scatterplots of calendar age (yr) vs fork length (cm) for gray snapper age samples collected from 1980 to 2019. No samples were collected from 1984 to 1989. Year-specific sample sizes are shown at the top right of each panel.

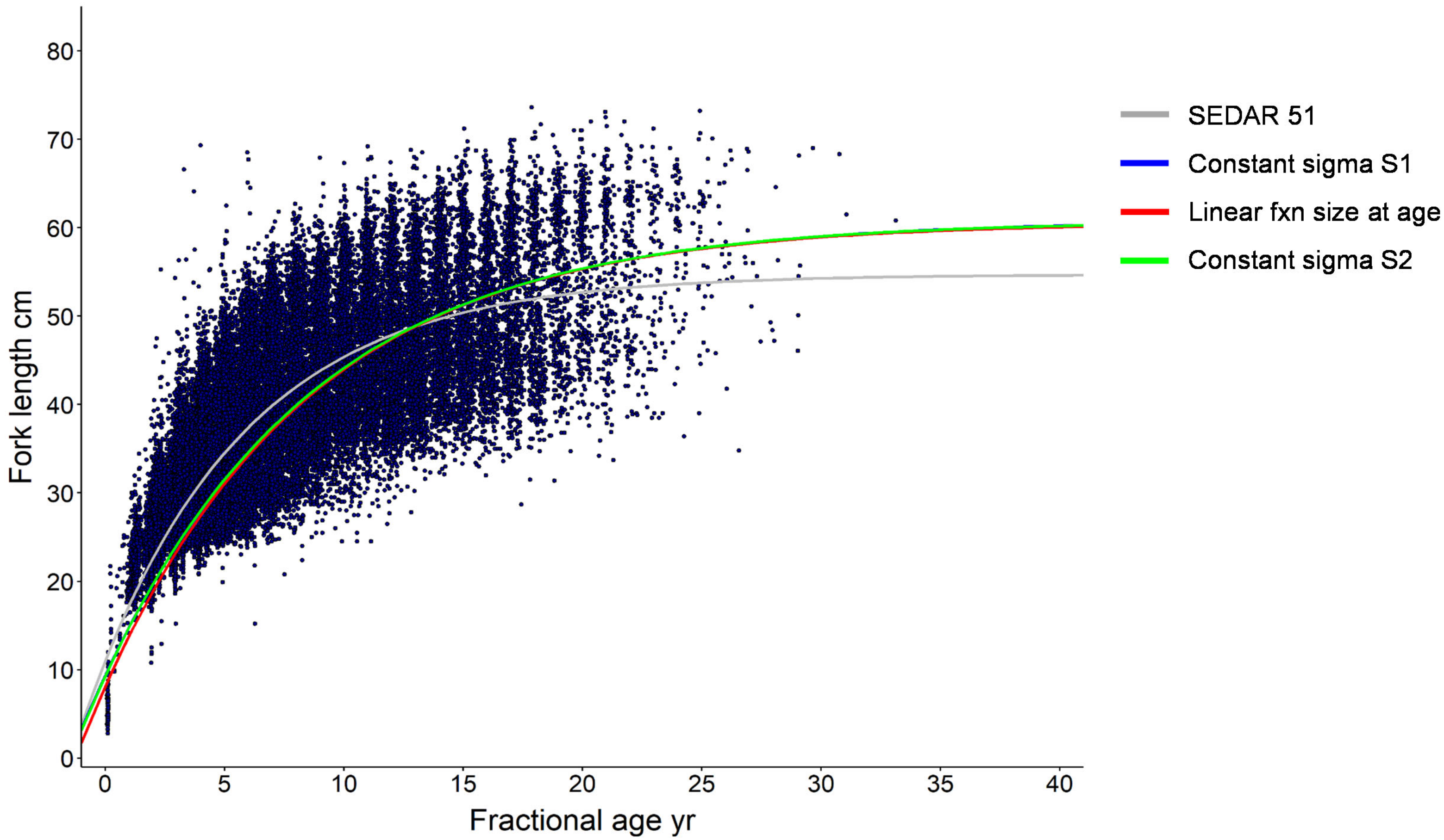

Figure 6. Scatterplot of fractional age (yr) versus fork length (cm) for gray snapper age samples collected from the Gulf of Mexico from 1980 to 2019. Lines indicate the final von Bertalanffy growth parameters estimated in SEDAR 51 (gray) versus three candidate models estimated in SEDAR 75 under scenario 1 (federal size limits) or scenario 2 (state and federal size limits). Candidate models estimated in SEDAR 75 used inverse weighted data, which were not used in SEDAR 51. The three candidate models estimated in SEDAR 75 have different parameter estimates but highly overlap.

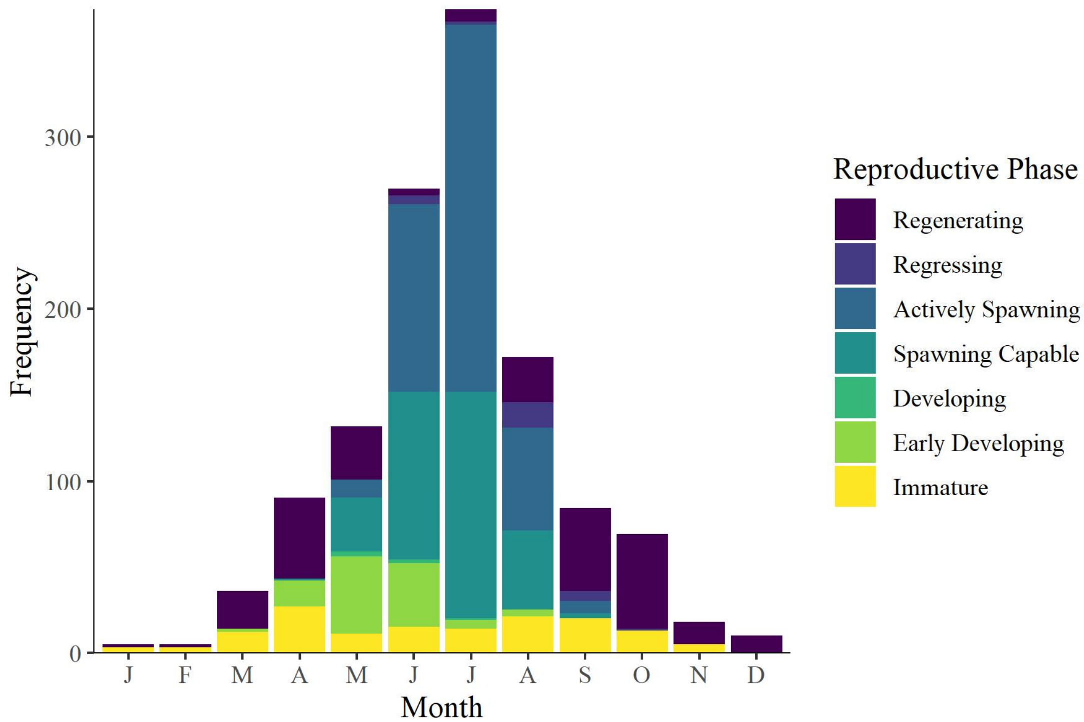

Figure 7. Reproductive stage by month for female Gray Snapper (n = 1,165). Reproductive phases follow those established in Brown-Peterson et al. (2011).

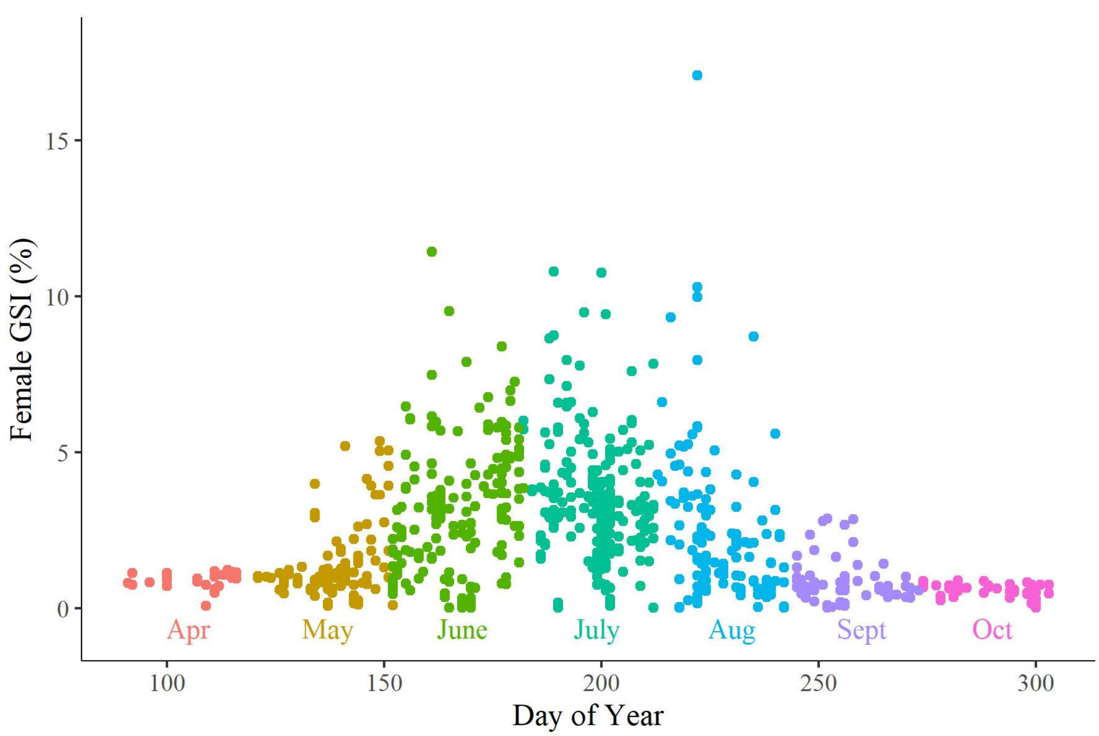

Figure 8. Gonadosomatic index (GSI) by day of the year observed for female Gray Snapper through primary spawning season (n = 821). One outlier not shown (GSI = 27%).

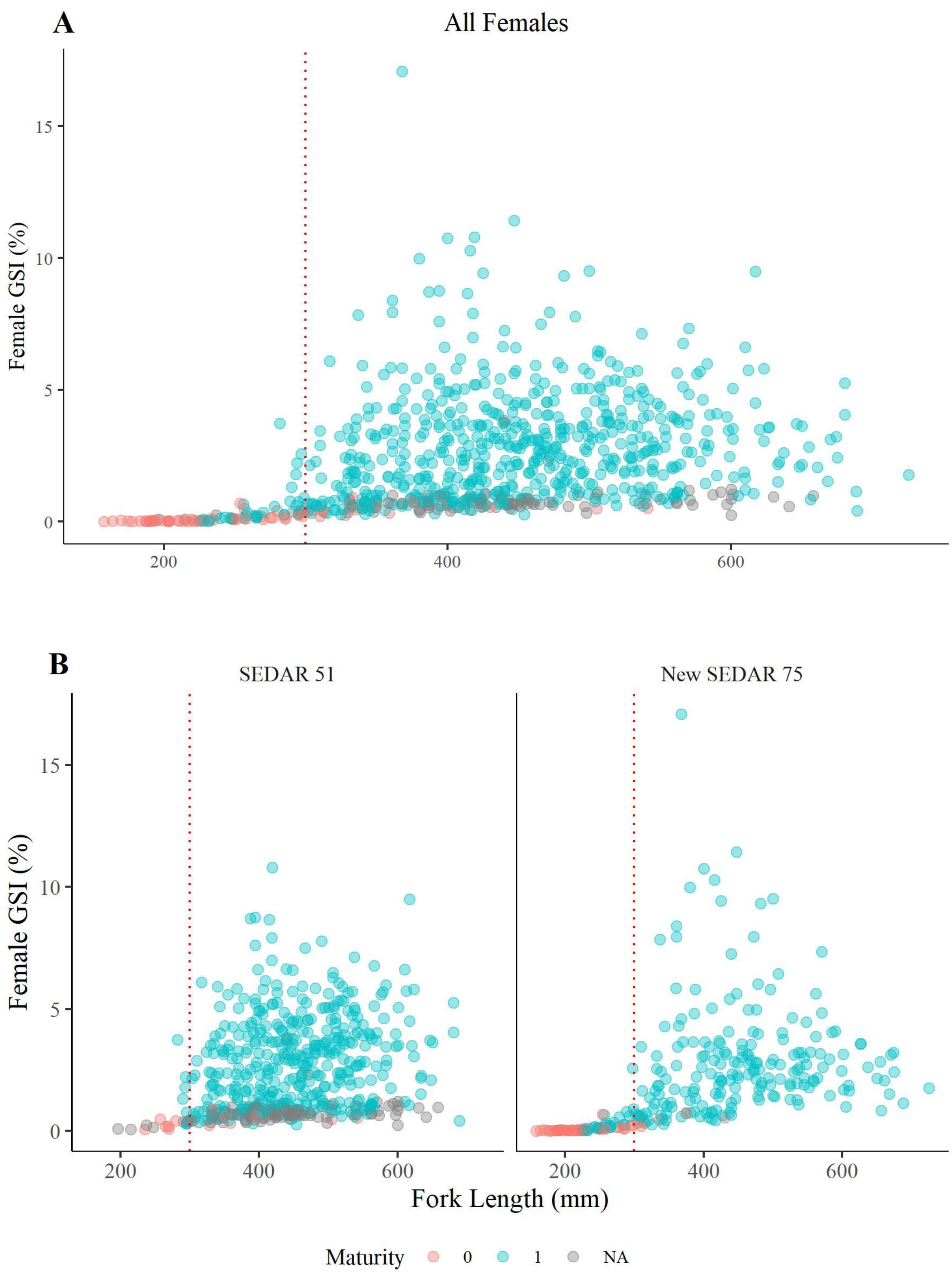

Figure 9. A) Gonadosomatic index (GSI) by fork length for all female Gray Snapper evaluated in SEDAR 75 during the primary spawning season (n = 821). B) Comparison of observed GSI values for SEDAR 51 and those added for SEDAR 75 (n = 547 and = 274, respectively). Dashed red line indicates 300 mm fork length. One outlier not shown (GSI = 27%).

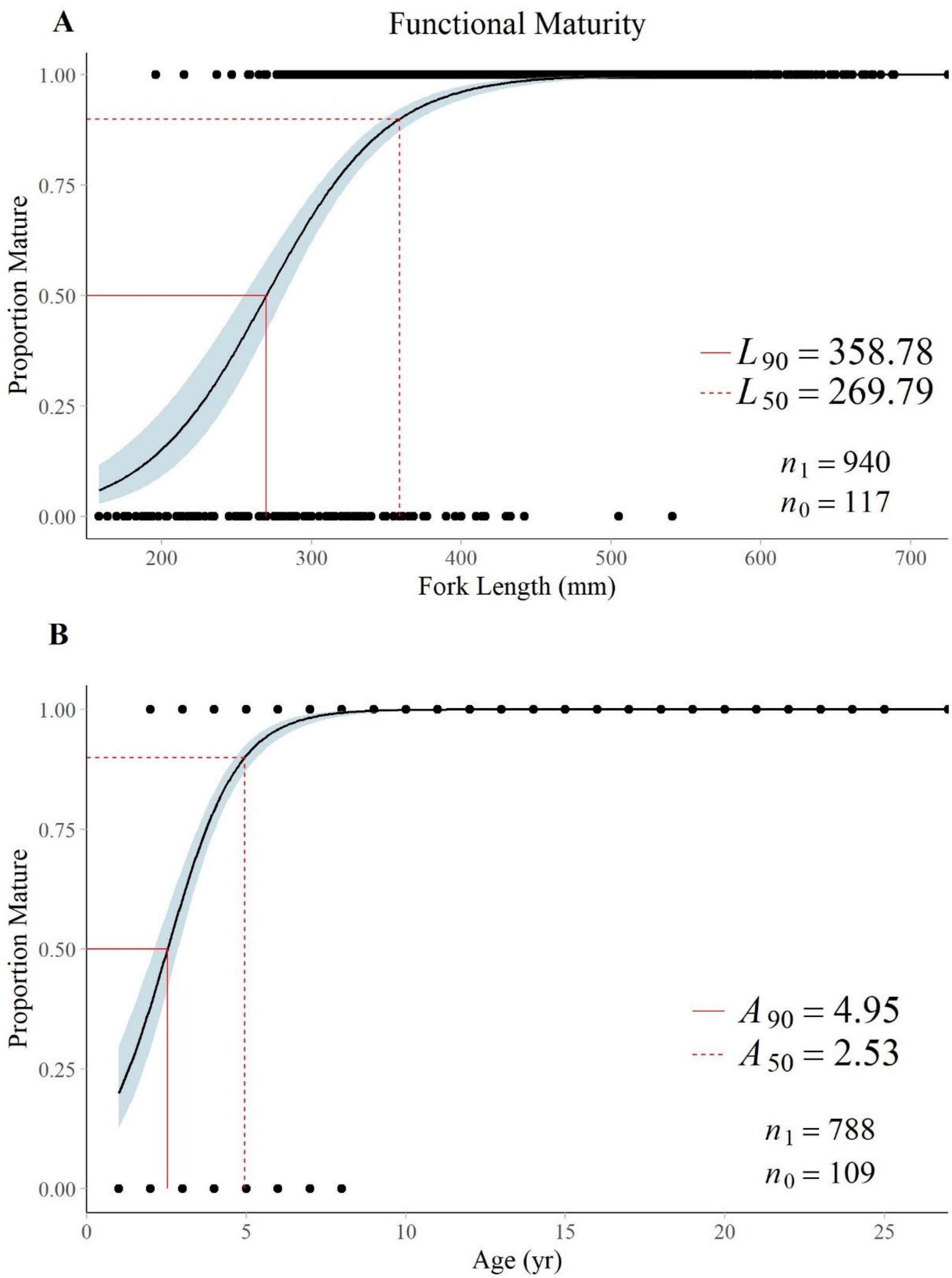

Figure 10. Functional maturity ogives for female gray snapper for A) fork length and B) age. Of the females captured April – October that did not have cortical alveolar (CA) oocytes as the most advance gamete stage (MAGS), 1,057 had fork length and 897 had age estimates. Solid black circles indicate binary values for immature (0) or mature (1) individuals, the black line indicates predicted maturity, and the light blue shading indicates 95% CIs.