Tab C, No. 5(a)

SEDAR 28 Gulf of Mexico Cobia Update Assessment Report

Gulf and Caribbean Branch
Sustainable Fisheries Division
NOAA Fisheries - Southeast Fisheries Science Center

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1. INTRODUCTION

This document summarizes the update to the SEDAR 28 assessment of cobia (*Rachycentron canadum*) in the U.S. Gulf of Mexico (GOM) using data inputs through 2018 as implemented in the Stock Synthesis 3 modeling framework (Methot and Wetzel 2013). Except as otherwise noted, the specifications of the updated model and data streams follow those of the base model identified in the SEDAR 28 final report (SEDAR 2013). The major changes between the SEDAR 28 and SEDAR 28 Update base models include incorporating the Fishing Effort Survey (FES) adjustments to the recreational catch estimates, no longer estimating growth in the assessment, and no longer using the SEAMAP groundfish survey to inform shrimp bycatch fleet selectivity. Overfishing limits (OFL) and acceptable biological catch advice are included in this report; however, the ABC and sustainable yield recommendations provided within are tentative pending approval and adoption by the Gulf of Mexico Fisheries Management Council (GMFMC) and their Science and Statistical Committee (SSC).

2. TERMS OF REFERENCE

i. Update the approved SEDAR 28 Gulf of Mexico cobia base model with data through 2018.

A strict update to the approved SEDAR 28 Gulf of Mexico cobia model was not feasible for SEDAR 28, because the recreational data underwent a complete overhaul in methodology and updated data through 2018 was not available using the same methodology as used during SEDAR 28. After updating all data through 2018, internal model estimates of key growth parameters were no longer consistent with the values used in the approved SEDAR 28 model, and growth parameters were fixed using values recommended by the SEDAR 28 Data Workshop panel.

ii. Document any changes or corrections made to model and input data sets and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

Except as otherwise noted in this report, the specifications of the updated model and data streams follow those of the base model identified in the SEDAR 28 final report (SEDAR 2013). The major changes between the SEDAR 28 and SEDAR 28 Update base models include incorporating the Fishing Effort Survey (FES) adjustments to the recreational catch estimates, no longer estimating growth in the assessment, and no longer using the SEAMAP groundfish survey to inform shrimp bycatch fleet selectivity. Commercial and recreational landings and discards in pounds and numbers are provided in Table 16 and Table 17.

iii. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels.

Section 4.2 of this report reviews the updated parameter estimates and model uncertainties. Section 5 documents the estimates of stock status and management benchmarks, and provides the probability of overfishing occurring at specified future harvest and exploitation levels.

iv. Develop a stock assessment update report to address these TORS and fully document the input data and results of the stock assessment update.

This report fully documents the input and results of the stock assessment update.

3. DATA REVIEW AND UPDATE

A variety of data sources were used in the SEDAR 28 assessment update. Where practicable, the SEDAR 28 update base model used the same data sets as the SEDAR 28 base model with an updated time series. However, five alternately constructed data sets were provided for the SEDAR 28 update analysis and were included in the final SEDAR 28 update model.

1) The recreational landing statistics now incorporate the NOAA fishing effort survey (FES) (2019-S28Update-WP-02).
2) The commercial length data are now weighted to more accurately reflect the size composition of landings (2019-S28Update-WP-04).
3) The Headboat CPUE index now incorporates core vessel identification and zero-inflated models to conduct the CPUE standardization (2019-S28Update-WP-05).
4) The shrimp fishery bycatch estimation now incorporates the use of bycatch reduction devices into the analysis (2019-S28Update-WP-07).
5) The commercial discards now use estimation methods that have been recently developed and approved in recent assessments for GOM red grouper, gray triggerfish, and vermilion snapper (2019-S28Update-WP-06).

The alternately constructed data sets listed above all incorporate best practices that have been developed and approved in recent SEDAR assessments. The updated inputs are documented in this report and further detailed in their respective working papers. The data utilized in the SEDAR 28 update base model are summarized below:

- Life History
  - Length-Weight Conversions
  - Growth
  - Reproduction
  - Natural Mortality
  - Release Mortality
- Fishery-Dependent Data
  - Commercial Landings
  - Recreational Landings
  - Commercial Discards
  - Recreational Discards
  - Shrimp Bycatch
  - Commercial Length Compositions
  - Recreational Length Compositions
  - Recreational Age Compositions
  - Recreational CPUE (MRIP and Headboat)
  - Shrimp Effort

3.1.Stock Identification and Management Unit

Following the decisions that were made during the SEDAR 28 data workshop plenary sessions, the stock boundary dividing the GOM stock from the South Atlantic stock for cobia remains defined as the state border between Florida and Georgia. The South Atlantic and Gulf stocks were separated at the FL/GA line because genetic data suggested that the split is north of the Brevard/Indian River County line. The FL/GA line was selected as the stock boundary based on recommendations from the SEDAR 28 data workshop commercial and recreational workgroups and comments that, for ease of management, the FL/GA line would be the preferable stock boundary and did not conflict with available life history information.

3.2.Life History

Life history data used in the assessment included natural mortality, growth, maturity, and fecundity. Some of the life history data were input in the Stock Synthesis model as fixed values, while others were treated as estimable parameters. The life history parameters for the GOM cobia were not updated for the SEDAR 28 update assessment and all values represent those provided during SEDAR 28. However, unlike the SEDAR 28 base model which estimated growth within the SS model, the von Bertalanffy parameters L_∞ and K were fixed model inputs using the recommended values from the SEDAR 28 DW.

3.2.1. Morphometric and Conversion Factors

The relationship between weight and length ($W = aFL^b$) for sexes combined was developed at the SEDAR 28 DW and used as a fixed model input (Table 1).

3.2.2. Reproduction

The parameters of cobia sex ratio, maturity, and fecundity remained identical to the parameters described for the SEDAR 28 base model. The same age-specific maturity vector was used as a fixed model input. The current assessment model also used age-2 for age at 50% maturity and assumed that all age-3+ fish were fully mature. The relationship between female weight and batch fecundity was developed at the SEDAR 28 DW. Fecundity was assumed to be directly proportional to female weight in the SS model. Following the recommendation from the SEDAR 28 DW to incorporate a skewed sex ratio, the current assessment follows the SEDAR 28 base model by using a 60% female sex ratio for all ages.

3.2.3. Natural Mortality Rate

The same scaled Lorenzen age-specific natural mortality vector that was developed and used in the SEDAR 28 base model was used in the SEDAR 28 update model. The cumulative survival of ages 3-11 based on a point estimate of natural mortality (M=0.38 y-1) was used to scale the age-based estimates of natural mortality (Table 2).

3.2.4. Release Mortality

The same discard mortality that was recommended by the SEDAR 28 DW and used in the SEDAR 28 base model was used in the SEDAR 28 update model. The discard mortality rate of 5% was used for both the commercial and recreational fisheries.

3.2.5. Growth

Cobia, like many pelagic fishes, have very fast growth in the first few years of life. Cobia also exhibit sexually-dimorphic growth, with females attaining a larger size-at-age and maximum size than males. Growth was modeled using the von Bertalanffy growth model (SEDAR 2013). The growth parameters estimated for SEDAR 28 and used in the SEDAR 28 update are summarized in Table 3.

A single von Bertalanffy equation was used in both the SEDAR 28 and in the SEDAR 28 update to model the growth of cobia for both sexes. In the SEDAR 28 update base model, the von Bertalanffy parameters L_∞ and K were fixed model inputs using the recommended values from the SEDAR 28 DW. Stock synthesis does not use t_0 as an input parameter; rather SS includes a parameter for the reference age for first size-at-age (A_{min}) and a parameter for the length at Amin (L_{min}) to describe the growth of fish from age 0.0 to A_{min} for both sexes.

3.3.Fishery Dependent Data

3.3.1. Landings

<u>Commercial Landings</u>

Commercial landings data (1927-2018) used in the assessment update are presented in Table 4 and Figure 1. Commercial landings were originally stratified by gear and included handline, longline, and miscellaneous (other) gears. For the assessment, commercial landings were aggregated across gears. Handline landings represented approximately 66% of total commercial landings since 1981. Commercial landings were reported in 1000s lb whole weight and converted to metric tons for input into the assessment model.

<u>Recreational Landings</u>

Recreational landings data (1950-2018) used in the assessment update are presented in Table 5 and Figure 1. Final recreational landings were computed using fully calibrated estimates from the Marine Recreational Information Program (MRIP), the Southeast Region Headboat Survey (SRHS), the Texas Parks and Wildlife Department (TPWD), and the LA Creel Survey for all Gulf states and the East coast of Florida (2019-S28Update-WP-02). Recreational landings are reported by mode and include charterboat, headboat, private/rental boat, and shore modes. For the assessment, recreational landings were aggregated across modes and regions. Private/rental boat landings represented more than 75% of the total recreational landings by numbers since

1981. Recreational landings were reported in numbers of fish and input into the assessment model as 1000s of fish.

3.3.2. Discards

Commercial Discards

Commercial discards (1993-2018) used in the assessment are presented in Table 6. The commercial discards for cobia were estimated with newer discard estimation methods that have been recently used for other recent assessments including for GOM red grouper, gray triggerfish, and vermilion snapper. A full description of the commercial cobia discards, and how they were calculated, is given in 2019-S28Update-WP-06.

In SEDAR 28, commercial discards were reported as numbers of fish and converted to metric tons. The process of converting discard numbers to weights using the weight associated with the mean length of a discarded cobia from the reef fish observer program was not necessary. For the SEDAR 28 update, the discard estimates reported in numbers were input into the assessment as 1000s of fish. A discard mortality rate of 5%, as recommended by the SEDAR 28 DW, was used for the commercial fishery.

Recreational Discards

Recreational discards (1981-2019) used in the assessment update are presented in Table 7. Final recreational discards were computed using fully calibrated estimates from the MRIP (2019-SEDAR28-WP-02). Discards from the other recreational data sources (SRHS and TPWD) were computed using methods described in the SEDAR 28 Data Workshop report. The LA Creel does not estimate discards for cobia. Recreational discards were reported as numbers of fish and input into the assessment as 1000s of fish. A discard mortality rate of 5%, as recommended by the SEDAR28 DW, was used for the recreational fishery.

Shrimp Bycatch

Shrimp bycatch estimates for GOM cobia were generated using a Bayesian GLM approach (implemented in WinBUGS) developed by Scott Nichols during the SEDAR 7 GOM red snapper assessment (Nichols, 2004a) and updated during SEDAR 9 to evaluate the impact of bycatch reduction devices (BRDs) for data-rich species (Nichols 2006). Now that there are more shrimp observer data and more overlapping years in the use/non-use of BRDs for GOM cobia than were available for SEDAR 28, shrimp bycatch estimates were generated using the same WinBUGS Bayesian approach developed and modified for red snapper by Nichols (2004a, 2004b, 2006). A detailed description of the data and methods used to produce the shrimp bycatch estimates can be found in 2019-S28Update-WP-07.

Shrimp bycatch in numbers of fish and metric tons, respectively, are summarized in Table 8 and Figure 2. Annual estimates of shrimp fishery-associated bycatch of cobia over the years of 1972-2017 range from 2.4 thousand fish to 1.087 million fish. The shrimp bycatch estimates are characterized by strong interannual variation but have declined from generally high levels during the 1990s. Bycatch estimates have been at time series lows for the last decade and have shown little variation. The median of the shrimp fishery bycatch of cobia for the years of 1972-2017 was 254 thousand fish.

3.3.3. Fishery-dependent Size and Age Composition

Commercial Landings Length Composition

Commercial length composition data of landed fish used in the assessment are presented in Figure 3. The annual length compositions were combined into 3-cm bins. These compositions were estimated using the same two data sources approved in SEDAR 28 but were processed using recent best practices. For example, length samples from the commercial trip intercept program (TIP) are now weighted by the commercial landings (Table 4, Figure 1). In the SEDAR 28 base model, the length samples from the reef fish observer program (RFOP) previously included all fish captured. However, following methods used in the more recent SEDAR 61 GOM Red Grouper assessment, only the length composition data of discarded fish from the RFOP were included in the SEDAR 28 update model. Because of the low annual sample sizes (ranging from 4 to 22), the RFOP data were aggregated across years (2006-2018), while still allowing the model to take into account relative differences in sample size across years (Figure 4). This was implemented in SS using the super-period approach (Methot 2011). A full description of the methods used to develop the length composition data for the current assessment is provided in 2019-S28Update-WP-04.

Previously, if more than 100 fish were measured in a given year, the sample size was fixed at 100 to avoid over-weighting the length composition data. Instead of capping the annual sample size at 100, the SEDAR 28 update base model used the total annual sample sizes (Table 9). The annual sample sizes were later adjusted using the Francis weighting method where the sample sizes are adjusted based on variability in the observed mean length by year (Francis 2011).

Recreational Landings Length Composition

Recreational length composition data of landed fish used in the assessment are presented in Figure 5. The annual length compositions were combined into 3-cm bins. These compositions were estimated using the same data sources approved in SEDAR 28 but were processed using recent best practices. A full description of the methods used to develop the length composition data for the current assessment is provided in 2019-S28Update-WP-04.

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Shrimp Bycatch Length Composition

No direct length data are available for cobia from the shrimp observer data. The SEDAR 28 base model used the annual length composition obtained from the SEAMAP groundfish survey to inform shrimp bycatch fleet selectivity. The groundfish survey typically overlaps with the shrimp fleet and uses similar net configurations. However, using these data to infer the shrimp bycatch fleet selectivity is no longer a common practice in recent SEDAR assessments. For example, the SEDAR 67 vermilion snapper stock assessment report notes that the groundfish data had an overabundance of anomalously larger/old fish, which was likely due to the SEAMAP groundfish trawls not using bycatch reduction or turtle excluder devices that are mandated for use on commercial boats (SEDAR 2020a).

Recreational Landings Age Composition

Recreational age composition data used in the assessment are presented in Figure 6. Following the methods used in SEDAR 28, the age compositions were made conditional on length. In other words, a separate age composition was specified for each 3 cm length bin containing fish whose ages had been estimated. Using these conditional age compositions has the advantage of linking age data directly to length data (essentially creating an age-length key).

3.3.4. Fishery-Dependent Indices

Shrimp Effort

In order to scale interannual variation in shrimp bycatch fishing mortality within the assessment, an index of shrimp effort was used. The index was estimated using the same data source and method used in SEDAR 28. Annual effort was reported as the number of vessel-days associated with depth 1 (<=10 fathoms) (2019-S28Update-WP-07). To relativize the index to have a mean of 1, annual effort estimates were divided by the mean of the entire time series. Shrimp effort declined sharply from 2002 to 2008, and has remained at relatively low levels from 2008 to 2017 (Table 10, Figure 7).

Recreational Catch-per-Unit Effort (CPUE)

Two recreational indices were used in the SEDAR 28 assessment: The Marine Recreational Information Program (MRIP) and the Southeast Region Headboat Survey (SRHS). Both indices are fishery-dependent and both provide indices of abundance for the recreational fishery for cobia in the GOM. The MRIP survey tracks total catches of cobia (landed plus discards), whereas the Headboat survey tracks only landed fish.

The MRIP index was constructed for the years 1981 to 2018 (Table 11, Figure 8), and developed using the same delta-lognormal modeling approach used to develop the MRIP index in SEDAR 28 (SEDAR 2013).

The SRHS index was constructed for the years 1986 to 2019 (Table 11, Figure 9). A new method for the SRHS index is now available following the SEDAR 58 Atlantic cobia stock assessment

(SEDAR 2020b, SEDAR58-DW09). The method from SEDAR 58 incorporates core vessel identification and uses a zero-inflated negative binomial model to provide an index. The standardized headboat CPUE index is described in more detail in 2019-S28Update-WP-05.

The coefficients of variation (CV) associated with each of the standardized fishery dependent indices were converted to log-scale standard errors using:

$$\log(SE) = \sqrt{log_e(1 + CV^2)}$$

The time series of CVs for each index were then relativized to have a mean of 0.2 by dividing the annual CVs by the mean of the CVs for each respective time series and multiplying by 0.2.

4. STOCK ASSESSMENT MODEL AND UPDATE

4.1.Stock Synthesis Model Configuration

For the purposes of the SEDAR 28 cobia assessment, the Stock Synthesis 3 (SS3) software package was utilized (v3.24; Methot 2011). Stock Synthesis is an integrated statistical catch-at-age (SCAA) model, which projects forward from initial conditions using age-structured population dynamics equations. SCAA models consist of three modules: the population dynamics module, an observation module, and a likelihood function. Each of the modules is closely linked. Stock synthesis uses input biological parameters (e.g., growth, fecundity, and natural mortality) to propagate abundance and biomass forward from initial conditions (population dynamics model) and develops predicted data sets based on estimates of fishing mortality, selectivity, and catchability (the observation model). Finally, the observed and predicted data are compared (the likelihood module) to determine best-fit parameter estimates using a statistical maximum likelihood framework (see Methot and Wetzel, 2013 for a description of equations and complete modeling framework). The integrated approach to natural resource modeling aims to utilize available data in the least processed form possible in order to maintain consistency in error structure across data analysis and modeling assumptions, while more reliably propagating uncertainty estimates, especially in critical population parameters such as stock status and projected yield (Maunder and Punt, 2013).

Because of its extreme flexibility, there is not a single prototypical Stock Synthesis model. Depending on the life history and data availability of the modeled species, SS3 models can range from highly complex and data rich individual-based models to relatively simpler age-structured production models. The flexibility allows the user to input all data sources that are available, but can also lead to overparameterization if careful attention is not paid to model configuration and diagnostics. Although SS3 makes it relatively easy to implement highly complex models, models of moderate complexity are often best given the data limitations in most fisheries. Many of the modeling assumptions in Stock Synthesis have been thoroughly simulation tested. The framework is used for fisheries management of a wide variety of marine species worldwide, most notably for United States federally managed fish stocks in the northwest Pacific and the GOM.

For cobia, a model of moderate complexity was implemented. The model produces predicted fits for catch and discards for two modeled fleets (commercial and recreational) along with associated recreational and commercial length compositions and recreational age compositions, as well as predicted fits for dead discards for one bycatch fleet (shrimp) and two CPUE indices corresponding to the recreational fleet (MRIP and SRHS; note that both recreational CPUE indices assume a single selectivity that mirrors the aggregated recreational fleet), and one effort time series (shrimp effort) (Figure 10 summarizes the input data used and corresponding temporal length). Estimated parameters include fishing mortality by fleet for each year it was operating, selectivity and retention parameters for each directed fleet, the parameters describing the stock-recruit function, stock-recruit deviation parameters, and a scaling parameter for the shrimp effort series. A variety of derived quantities are produced including full time series of recruitment, abundance, biomass, spawning stock biomass, and harvest rate. Projections are implemented within SS3 starting from the year succeeding the terminal year of the assessment model utilizing the same population dynamics equations and modeling assumptions (with some minor alterations in assumptions to account for forecasting recruitment).

4.1.1. Initial Conditions

The model begins in 1927, when the stock is assumed to be at near virgin conditions, and has a terminal year of 2018. Commercial landings of cobia were first reported in 1927. Recreational landings were hindcast to 1950 and estimates of shrimp effort were available back to 1945. Substantial removals of cobia did not occur until after WWII for any of the fisheries and so it was assumed that total removals were negligible before 1950 and an initial equilibrium fishing mortality rate of zero was assumed for all fleets.

4.1.2. Temporal Structure

Fish are modeled from age-0 through age-10 (the last age is a plus group). No seasonality was included in the model and fishing and spawning seasons were assumed to be continuous and homogeneously distributed throughout the year.

4.1.3. Spatial Structure

The GOM cobia population was modeled as a single stock that occurred from the Georgia-Florida border in the South Atlantic through the Northern GOM to the Mexico-Texas border. A single area model was implemented where recruits are assumed to homogeneously settle across the entire range of the stock.

4.1.4. Life History

Almost all life history parameters (e.g., growth, length-weight conversions, maturity, fecundity, and natural mortality) were estimated external to the model and input as fixed values.

Stock Synthesis 3 uses these parameters to move fish among age classes and length bins on January 1st of each modeled year starting from birth at age-0. Because the 'true' birth date often does not occur until later in the year, some slight alterations in growth and natural mortality parameters are required to account for the approximate difference between true age and modeled age when parameters are input instead of estimated (e.g., age-0 natural mortality and t_0, age at zero size, must be prorated to account for 'birth' occurring six months later than modeled in SS3). In addition, the length-weight relationship is used to convert from size to biomass, and the maturity and fecundity parameters are used to assign a spawning output to each modeled fish.

Growth was modeled with a three parameter von Bertalanffy equation (L_{min}, L_{max}, and K) (Table 3, Figure 11). In SS, when fish recruit at the real age of 0.0 they have a body size equal to the lower edge of the first population bin (Lbin; fixed at 6 cm Fork Length (FL)). Fish then grow linearly until they reach a real age equal to the input value of A_{min} (growth age for L_{min}) and have a size equal to the L_{min}. As they age further, they grow according to the von Bertalanffy growth equation. The value of A_{min} was fixed at 0.75 which is representative of a fractional age of 0.42 (lifespan: May 1 – October 1). This value of A_{min} was documented in SEDAR 28 and was based on 10 observations of length-at-age data for age-0 fish collected in the months of October and November. L_{max} and K were fixed within the model to the recommended values from the SEDAR 28 DW. The L_{max} was set equivalent to L_{∞} (128.1 cm) and K was set to 0.42. The L_{min} associated with the fixed A_{min} and the variation in the size-at-age for ages 0.5 and 10 were estimated in the model. For intermediate ages a linear interpolation of the CV on mean size-at-age is used.

A fixed power function length-weight relationship was used to convert body length (cm) to body weight (kg) (Table 1, Figure 11). Fecundity was assumed to be proportional to female biomass, and maturity was input as a fixed function of age, with age-2 fish being 50% mature and age-3+ fish being fully mature.

The SEDAR 28 update base model assumes that the natural mortality rate decreases as a function of age based on the Lorenzen (1996) function (Table 2, Figure 11). To account for the difference in true and SS3 modeled birth date, age-0 natural mortality was reduced so that age-0 fish underwent 7 months of instantaneous natural mortality.

4.1.5. Stock-Recruit

The spawning stock was assumed to be the total mature female biomass and a single Beverton-Holt stock-recruit function was used to parameterize the relationship between spawning output and resulting age-0 fish. The stock-recruit function (representing the arithmetic mean spawner-recruit levels) requires three parameters: steepness (h) characterizes the initial slope of the ascending limb; the virgin recruitment (R0; estimated in log space) represents the asymptote or unfished recruitment levels; and the variance term (‘sigma_R’, σR) is the standard deviation of the log of recruitment (it both penalizes deviations from the spawner-recruit curve and defines the offset between the arithmetic mean spawner-recruit curve and the expected geometric mean from which the deviations are calculated). Although these parameters are often highly correlated, they can be simultaneously estimated in SS3. Steepness and R0 were directly estimated and the recruitment variance was fixed at 0.6. As noted in the SEDAR 28 GOM cobia stock assessment report, rarely is sigma R directly estimable from the given data and hence it is often necessary to input as a fixed parameter (SEDAR 2013).

Annual deviations from the stock-recruit function were estimated in SS3 as a vector of deviations forced to sum to zero and assuming a lognormal error structure. A lognormal bias adjustment factor is applied to recruitment estimates as recommended by Methot et al. (2020), but only to the data-rich years in the assessment. This allows SS to apply the full bias-correction only to those recruitment deviations that have enough data to inform the model about the full range of recruitment variability (Methot et al., 2020). The bias adjustment was phased in until the full adjustment was implemented in 1982. The full bias adjustment was then phased out again starting in 2017, because the age composition data contains little information on younger year classes for the most recent years. Prior to 1962, recruitment is estimated as a function of spawning stock biomass based on the stock-recruit parameters (i.e., there is no deviation in recruitment estimates from the stock-recruit curve).

4.1.6. Fleet Structure and Surveys

The assessment was constructed to include three fishing fleets and two indices of abundance. The three fishing fleets were commercial, recreational, and the shrimp bycatch fishery. The two indices of abundance used in the assessment were the marine recreational fishing statistical survey (MRIP) and southeast region headboat survey (SRHS). Commercial landings and length compositions were summed across modes and regions and a single selectivity curve and time series of fishing mortality were estimated. Similarly, recreational landings and length and age compositions were summed across modes and regions and a single selectivity curve and time series of fishing mortality were estimated. All fishing was assumed to be continuous and homogenous across the entire year. In addition, a gulf-wide shrimp bycatch fleet was included in the model. Shrimp bycatch was assumed to be 100% dead discards with no landings. The shrimp fishery was assumed to operate continuously across the entire year with no seasonality.

4.1.7. Selectivity and Retention

Selectivity represents the probability of capture by age or length for a given fishery and subsumes a number of interrelated dynamics (e.g., gear type, targeting, and availability of fish due to spatial structure). In the SEDAR 28 update base model, size based selectivity patterns were specified for the commercial and recreational fisheries, and age based selectivity was specified for the shrimp trawl fishery. Four selectivity patterns were defined in SS: 1) commercial fishery, 2) recreational fishery, 3) shrimp trawl fishery, and 4) MRIP index. The size-based selectivity patterns for the commercial and recreational fisheries were asymptotic, and their selectivities were modeled with a two parameter logistic function. The shrimp bycatch age-based selectivity was fixed at 100% for age-0, and 0% for age-1+. The length based selectivity pattern of the MRIP index was assumed to mirror the selectivity pattern of the recreational fishery. Selectivity patterns were assumed to be constant over time for each fishery and survey.

Each of the directed fisheries was also assumed to have regulatory discards based on selection (catch) of fish below the minimum size limit (i.e., all fish below this size were discarded). A knife-edge (vertical) retention function with fixed input parameters was included to account for changing minimum sizes across years and fleets. A minimum size limit of 33 inches (83.8 cm FL) was enacted in 1983 in both federal and state waters for all fisheries (48 FR 5270). A time block was specified to create separate retention curves for the time periods of 1927-1984 and 1985-2018. Prior to the minimum size limit, it was assumed that some discarding occurred in both the commercial and recreational fishery. The MRIP data set estimated low levels of discards prior to the size limit; no information was available on commercial discards prior to 1993. To account for discarding prior to the size limit, a retention curve with an inflection point of 40 cm FL and slope of 2 (almost knife-edge) was used for both fisheries. The retention curves were fixed because there were no length composition data of discarded fish available to inform the model on their shape. Retention parameters for the time period 1985-2011 were estimated by the model for both the commercial and recreational fisheries.

4.1.8. Landings and Age Composition

Landings by fleet and associated length compositions were calculated based on estimated fleet specific continuous fishing mortality rates and age-specific selectivity curves using Baranov's catch equation. Because of low annual samples sizes of discarded lengths from the RFOP (Table 9), the data were aggregated across years (2006-2018), while still allowing the model to take into account relative differences in sample size across years. This was implemented in SS using the super-period approach (Methot 2011).

SS provides the option to model the age composition as a set of conditional ages at length. This modeling framework operates similarly to an age-length key where a distribution of ages is input for a given length bin. This modeling approach is recommended (Methot 2011) and avoids double use of fish for both age and size information because the age information is considered conditional on the length information, contains more detailed information on the variance of size-at-age, provides better ability to estimate growth parameters, and the age composition need not be selected completely at random. Thus, data collected in a length-stratified program can be incorporated, provided there is no bias for a particular age within a length bin. The age composition data was input in this manner with ages assigned to 3 cm length bins with the length bins ranging from 6 to 189 cm and ages from 0-10 where 10 represents a plus group.

4.1.9. Discards and Bycatch

Discards from the directed fleets were modeled using size-based retention functions where selected fish below the time-varying minimum retention were discarded. The discard mortality rate of 0.05 was then applied to the discarded fish to determine the level of dead discards from each fleet.

For shrimp bycatch, the 'super-period' approach was utilized to avoid fitting to the extremely noisy and uncertain yearly estimates of shrimp bycatch. The premise of a super-period is that, instead of fitting each observation directly, a measure of central tendency for the entire time series is fit. In the case of shrimp bycatch, the median has typically been utilized (i.e., the observed median is fit to the predicted median) in recent assessments (e.g. GOM Vermilion Snapper; SEDAR 2020a) and was implemented for the SEDAR 28 cobia update assessment. The model still predicts annual bycatch values, but does not attempt to fit these to the annual observations. The super-period covers years 1972-2017 (i.e., the median values correspond to observed and predicted bycatch values for these years), which are the years that estimates of shrimp bycatch were available. The model estimates shrimp bycatch in years outside the super period with help from the shrimp effort series, but the predicted median covers only the period for which observations of shrimp bycatch are available.

4.1.10. Shrimp Effort

Shrimp effort was also incorporated into the model as an index of shrimp bycatch fishing mortality; the observed effort series helps inform annual estimates of shrimp fishing mortality and stabilizes annual estimates of shrimp bycatch. Essentially, a catchability parameter (q) is estimated to scale the effort series to the fishing mortality rates. Because annual estimates of shrimp bycatch are not fit directly, the super-period approach can create an unstable model if there is no information on annual variability (e.g., in fishing mortality or catch) for the fleet that contains the super-period. Essentially, there is an infinite combination of annual values that could lead to the given median, which can create a flat likelihood response surface and cause model instability. Using the super-period approach while fitting to a time series of effort allows the model the flexibility to fit the median without being constrained to fit uncertain annual bycatch estimates, but constrains the model enough to maintain the bycatch estimates within feasible fishing mortality bounds and avoids overly strong year-to-year deviations.

4.1.11. Catch-per-Unit Effort (CPUE) Indices

Two CPUE indices developed using data from the recreational fleet (MRIP 1981-2018, and SRHS 1986-2018) were included in the model. They were assumed to reflect annual variation in the population trajectory, and were fit in the SEDAR 28 assessment.

4.1.12. Goodness of Fit and Assumed Error Structure

A maximum likelihood approach was used to assess goodness of fit to each of the data sources. Each data set has an assumed error distribution and an associated likelihood component, the value of which was determined by the difference between observed and predicted values along with the assumed variance of the error distribution. The total likelihood was the sum of each individual component. A nonlinear iterative search algorithm was used to minimize the total negative log likelihood across the multidimensional parameter space to determine the parameter values that provide the best fit to the data. With this type of integrated modeling approach, data weighting (i.e., the variance associated with each data set) can impact model results, particularly if the various data sets indicate differing population trends. Ideally, the model would allow the data to ‘self-weight’ in order to determine the relative variance among data sets. However, it is seldom possible to freely estimate all the variance terms in addition to the set of model parameters, and variance terms must be input based on calculated variance from the observed data. The latter approach suffers from a lack of information regarding relative variance among different data sets. Ultimately, expert judgement usually must be used to input relative variance components, and this is the approach used in SS3.

The landings data, CPUE indices, and shrimp bycatch super-period all assume a lognormal error structure. The commercial landings are assumed to be the most representative and reliable data source in the model, especially over the most recent time period, because this information is collected in the form of a census, as opposed to being collected as part of a survey like most other input data. The recreational landings are assumed to be slightly less representative, because the charter/private component is collected using the Fishing Effort Survey (FES), albeit with a relatively large sample size. The CPUE indices are assumed to be slightly noisier, mainly due to lower sample sizes and uncertainty in the relationship between CPUE and abundance trends. Although the annual estimates of shrimp bycatch are assumed to be extremely noisy, the median is expected to be fairly representative of the scale of discards of the shrimp fleet. The discards and super-period median bycatch were assumed to be the least representative and reliable data source in the model. The landings and discards were assumed to have a constant variance, while interannual variation in the CPUE indices was estimated through the standardization techniques used to determine the final observed index values. The shrimp effort series was treated in a similar way to the other indices, except that a time-invariant error structure was assumed.

The input standard error for the landings was set to 0.01 for the commercial fisheries and 0.15 for the recreational fishery. The commercial and recreational discards, and super-period median bycatch were assumed to have a standard error of 0.5. Each of the indices was scaled to an average standard error of 0.2 across the entire time series, but the relative annual variation was maintained in the scaling. The shrimp effort series was also given an average standard error of 0.2.

The age and length composition data for the various fisheries and surveys were assumed to follow a multinomial error structure where the variance was determined by the input effective sample size (Neff). For the multinomial, a smaller sample size represents higher variance and vice versa, because the number is meant to represent the number of fish sampled each year to determine the composition. Observed sample sizes are often overestimated for fisheries data, because samples are rarely truly random or independent (Hulson et al., 2012). In addition, using higher effective sample sizes can lead to the composition data dominating the likelihood and reduce fit to other data sources. Iterative reweighting is often used to adjust the effective sample size to better represent the residual variance between observed and predicted values (Methot and Wetzel, 2013). For the SEDAR 28 cobia update base model, observed sample sizes were used to start. The Francis weighting method was used to adjust the sample sizes based on the variability in the observed mean length by year (Francis 2011). Francis reweighted sample sizes and the final effective sample sizes for each year are provided on the figures illustrating the age composition and length composition (given by N adj. and N eff. in each panel, respectively).

A penalty on deviations from the stock-recruit curve was also included (essentially a Bayesian prior) in order to limit recruitment deviations from differing too greatly from the assumed relationship. The variance term was controlled by the fixed σR parameter.

Weak penalty functions were implemented to keep parameter estimates from hitting their bounds, which includes a symmetric-beta penalty on selectivity parameters (Methot et al., 2020). Parameter bounds were set to be relatively wide and were unlikely to truncate the search algorithm.

Uncertainty estimates for estimated and derived quantities were calculated based on the asymptotic standard error determined from the inversion of the Hessian matrix (i.e., the matrix of second derivatives is used to determine the level of curvature in the parameter phase space and calculate parameter correlation; Methot and Wetzel, 2013).

4.1.13. Estimated Parameters

A total of 296 parameters were estimated for the SEDAR 28 update base model (Table 12). These include year specific fishing mortality for the two directed fleets and shrimp bycatch fleet, logistic selectivity and retention parameters for each of the directed fleets, a catchability coefficient for the shrimp effort series, and parameters used to define growth, the stock-recruit relationship, and the stock-recruit deviations for the data-rich time-period.

4.1.14. Model Diagnostics

Residual Analysis

A wide variety of model diagnostics were implemented and analyzed to determine model performance, stability, uncertainty, and fit to the data. The primary approach used to address model fit and performance was residual analysis of model fit to each of the data sets. Any temporal trends in model residuals (or trends with age or length for compositional data) can be indicative of model misspecification and poor performance. It is not expected that any model will perfectly fit any of the observed data sets, but, ideally, residuals will be randomly distributed and conform to the assumed error structure for that data source. Any extreme patterns of positive or negative residuals are indicative of poor model performance and potential unaccounted for process or observation error.

Correlation Analysis

High correlation among parameters can lead to flat likelihood response surfaces and poor model stability. By performing a correlation analysis, modeling assumptions that lead to inadequate model parameterizations can be highlighted. Because of the highly parameterized nature of stock assessment models, it is expected that some parameters will always be correlated (e.g., stock recruit parameters). However, a large number of extremely correlated parameters warrant reconsideration of modeling assumptions and parametrization. A correlation analysis was carried out for the SEDAR 28 cobia update assessment and correlations with an absolute value greater than 0.7 were reported.

Profile Likelihood

Profile likelihoods are used to examine the change in log-likelihood for each data source in order to address the stability of a given parameter estimate, and to see how each individual data source influences the estimate. The analysis is performed by holding the given parameter at a constant value and rerunning the model. This is repeated for a range of reasonable parameter values. Ideally, the graph of likelihood values against parameter values will give a well-defined minimum indicating that each data source is in agreement. When a given parameter is not well estimated, the profile plot may show conflicting signals across the data sources. The resulting total likelihood surface will often be flat, indicating that multiple parameter values are equally likely given the data. In such instances, the model assumptions need to be reconsidered.

A similar procedure can be utilized to assess parameter correlation where two parameters are fixed across a range of values and the model is rerun for each combination of the fixed parameters. A contour plot, where the z-axis provides the negative log-likelihood value, can then be examined to determine the relationship between the parameters. Typically, profiling is carried out for a handful of key parameters, particularly those defining the stock-recruit relationship. For the SEDAR 28 update base model, profiles were carried out for steepness, virgin recruitment, stock-recruit variance, and a combination of steepness and stock-recruit variance. These runs were utilized to aid in determining the appropriateness of the fixed value for the recruit variance term in the final base model.

Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether a global as opposed to local minima has been found by the search algorithm. The premise is that all of the starting values are randomly altered (or 'jittered') by an input constant value and the model is rerun from the new starting values. If the resulting population trajectories across a number of runs converge to the same final solution, it can be reasonably assumed that a global minimum has been obtained. This process is not fault-proof and no guarantee can ever be made that the 'true' solution has been found or that the model does not contain misspecification. However, if the jitter analysis results are consistent, it provides additional support that the model is performing well and has come to a stable solution. For this assessment, a jitter value of 0.2 was applied to the starting values and 200 runs were completed.

Retrospective Analysis

A retrospective analysis is a useful approach for addressing the consistency of terminal year model estimates. The analysis sequentially removes a year of data at a time and reruns the model. If the resulting estimates of derived quantities such as SSB or recruitment differ significantly, particularly if there is serial over- or underestimation of any important quantities, it can indicate that the model has some unidentified process error, and requires reassessing model assumptions. It is expected that removing data will lead to slight differences between the new terminal year estimates and the updated estimates for that year in the model with the full data. Oftentimes additional data, especially compositional data, will improve estimates in years prior to the new terminal year, because the information on cohort strength becomes more reliable. Therefore, slight differences are expected between model runs as more years of data are peeled away. Ideally, the difference in estimates will be slight and more or less randomly distributed above and below the estimates from the model with the complete data sets. Typically, 5-10 year retrospective analyses are completed. A five-year retrospective was carried out for SEDAR 28 update assessment.

Continuity Model and Model Building Runs

The first step in model development was to create a continuity model that attempted to replicate, in as feasible a way as possible, the previous cobia assessment, SEDAR 28. A strict continuity model was not feasible for SEDAR 28, because the recreational data underwent a complete overhaul in methodology, and updated data through 2018 was not available using the same methodology as used during SEDAR 28. Therefore, continuity model building went through multiple stages in building a pseudo continuity model. This included updating the recreational landings data to the new FES estimates (through 2011 to demonstrate the impact of only the new recreational landings methodology on SEDAR 28 outputs) and updating all the data through 2018.

A comprehensive model building exercise was then undertaken to incorporate new data sources and address any model stability issues. The major changes between the final continuity model (not including updated data) and the final base model (i.e., the model parametrization described throughout Section 4.1) were: growth was fixed rather than estimated within the assessment, and the SEAMAP groundfish survey was no longer used to inform shrimp bycatch fleet selectivity.

Sensitivity Runs

Several sensitivity runs were also implemented with the base model in order to investigate critical uncertainty in data and reactivity to modeling assumptions. An exhaustive evaluation of model uncertainty was not carried out, but the three most important model uncertainties were investigated and are presented in this report. Each of these were also conducted for the SEDAR 28 assessment. The order in which they are presented is not intended to reflect their importance; each run included here provided important information for developing or evaluating the base case model.

Low M run:

The Lorenzen natural mortality rate at age was re-scaled to provide the same cumulative survival through the oldest observed age as would a constant M = 0.26 y-1 (Table 2). This M is equal to the base M used in the South Atlantic cobia stock assessment. The maximum age reported for Atlantic cobia was 16 years, which was 5 years older than the maximum age for the GOM – hence the M estimate for the South Atlantic was much lower than the GOM.

High M run:

The Lorenzen natural mortality rate at age was rescaled to provide the same cumulative survival through the oldest observed age as would a constant M = 0.50 y-1 (Table 2).

High discard mortality:

For this run, discard mortality rates for both the commercial and recreational fleets were doubled from 0.05 to 0.10.

4.2.Model Results

4.2.1. Estimated Parameters and Derived Quantities

Table 12 summarizes the estimated parameters and derived quantities as well as the SS3 estimated standard deviations. Most parameter estimates and variance appear reasonable indicating relatively well-estimated parameters.

Fishing Mortality

Total harvest rate (total biomass killed divided by total biomass) for the entire stock (Table 13, Figure 12) and fishing mortality by fleet (continuous rates) are provided in Figure 13 and Table 14. The stock became exploited in the 1950s and the harvest rate increased until the mid-1980s when harvest rate peaked. The highest exploitation rates occurred in the mid-1980s and since that time, the exploitation rate has remained relatively high with strong interannual variability.

The recreational fishery is the dominant source of mortality for cobia. The recreational fleet demonstrated an increasing trend in fishing mortality from 1950 to the mid-1980s. After 1980, the recreational harvest rate remained high and demonstrated high interannual variability, with generally higher values during the late 1980s compared to the decades thereafter. The fishing mortality for the shrimp bycatch fleet also increased from the 1950s to its peak value in the late 1980s. In the late 1990s, the shrimp harvest rate drastically declined until the late 2000s after which a steady harvest rate has persisted through the terminal year. Terminal year fishing mortality rates for the commercial, recreational, and shrimp bycatch fleets were 0.012, 0.545, and 0.067, respectively.

Selectivity

The estimated length-based selectivity functions for the directed fleets are provided in Figure 14 – Figure 16 with derived age-based selectivity provided in Figure 17. Both of the directed fleet selectivity curves (Figure 17) reach full selection (around age 2 for the recreational fishery and age 4 for the commercial fishery) and exhibit relatively young ages at 50% selectivity (around age 1 for recreational and age 2 for commercial). The recreational fishery exhibited a stronger selection pattern for younger fish. These results are in agreement with the observed age compositions from the two fisheries given the increased proportion of younger fish in the recreational fishery.

Retention functions for the time periods of 1927-1984 and 1985-2018 for each directed fleet are shown in Figure 18 – Figure 21. Fixed logistic retention functions with an inflection point of 40 cm FL and slope of 2 (almost knife-edge) were used to assume that some discarding occurred in the earlier time period. In the later time period, the estimated retention functions showed higher retention rates at slightly smaller sizes for the recreational fleet (inflection point of 76 cm FL and slope of 5) compared to the commercial fleet (inflection point of 80 cm FL and slope of 4).

Because no direct length data are available for cobia from the shrimp observer data, selectivity was fixed for the shrimp bycatch fleet. The selectivity curve assumed 100% vulnerability at age-0, and 0% for age-1+ (Figure 17).

Recruitment

With the recruit variance term fixed at 0.6, steepness was estimated to be 0.789 and virgin recruitment was estimated at 1,905,640 fish.

The estimated recruits are essentially a scatter plot with no well-defined underlying trend (Figure 22). Recruitment was forced to follow the stock-recruit curve for the historical time period and slowly decreased from virgin conditions as the stock became exploited (Figure 23, Table 15). Since the early-1980s (when recruitment deviations were estimated), recruitment has fluctuated between 824 thousand and 2.341 million fish with the exception of a particularly low recruitment of 155 thousand fish in 1983 (Figure 23, Table 15). Recruitment deviations were estimated through 2014, as there was little information in the compositions to inform the estimates past 2014. The terminal year recruitment was estimated to be near average (~1.5 million fish).

Recruitment since the late-1990s have been generally at the average level with a slightly smaller year class estimated in 2011 (~930 thousand fish) and 2015 (~891 thousand fish). (Figure 23 and Figure 24, Table 15). The bias adjustment on variance was phased in until the full adjustment was implemented in 1982 (Figure 25). The full bias adjustment was then phased out again starting in 2017, because the age composition data contains little information on younger year classes for the most recent years. Prior to 1962, recruitment is estimated as a function of spawning stock biomass based on the stock-recruit parameters (i.e., there is no deviation in recruitment estimates from the stock-recruit curve).

Biomass and Abundance Trajectories

Spawning stock biomass (number of eggs), abundance (number of fish), and total biomass (metric tons) have followed similar trends over the entire time series (Figure 26 – Figure 27, Table 15). Steady declines occurred as the stock moved away from virgin conditions and was increasingly exploited up until the mid-1980s. Biomass is predicted to have reached a minimum from 1984-1989 and then increased rapidly from 1989 to 1997. The predicted biomass declines from 1997 to 2007, increases until 2011 and then decreases through 2018. Total stock biomass in the most recent year is predicted to be 21% of the unfished total biomass.

Total abundance has shown similar trends as biomass and SSB (Table 15). Depletion levels (SSB/SSB_0) reached a low point of 12% in 1987. In the last two years, depletion has remained around 20%. Average age in the stock at virgin conditions was close to 2 years of age. Average age is now around age-1 (Figure 28).

4.2.2. Model Fit and Residual Analysis

Landings and Discards

Due to the comparatively small standard error assumed for the commercial and, to a lesser extent, recreational landings, both of these data sources were fit quite well (Figure 29, Table 16). The recreational landings were slightly underestimated for a few points in the late 1980s, with later overestimation for a handful of years. Overall, no strong residual patterns were noticeable and fits to the landings data were good. The negative log-likelihood values for the commercial and recreational landings were 0.003 and 12.776, respectively.

Predicted discards for the commercial fleet were within the observed confidence intervals across all years but did not fit observed estimates well, especially in the early time period (1993-1996) (Figure 30, Table 17). Predicted discards are higher than the observed estimates from 1993-1996 and 2010-2011 and slightly lower than observed estimates from 1998-2006 and 2015-2017. From the late 1980s to 2018 the model predicted a relatively stable discard proportion (discards / (landings + discards)). The negative log-likelihood value for commercial discards was -12.294.

Overall, predicted discards for the recreational fleet fit well in most years, except 1991 (Figure 31, Table 17). In most years, the predicted values are generally slightly lower than the observed estimates. In 1990, a two-fish bag limit was instituted for cobia for U.S. federal waters. There is evidence of a large increase in discards in 1991 suggesting the bag limit had an effect on discard rate. However, consistent with SEDAR 28, the bag limit was not implemented in the assessment model. The recreational length composition data shows some evidence that the size limit was not effective for a few years after implementation as a number of sub-legal fish are observed in the sampled landings from 1984-1987. The negative log-likelihood value for recreational discards was 52.359.

Shrimp Bycatch

The fit to the super-period median was good (Figure 32, Table 18). As expected, the predicted annual estimates of bycatch did not vary as strongly as the observed values nor were they similar in magnitude. The strong decline in the late 2000s and relatively low values in recent years (2003-2018) is a function of the decline in shrimp effort (Table 10). The negative log-likelihood value for shrimp bycatch was -2.303.

Shrimp Effort

Model fit to the shrimp effort series is nearly exact, even though it was given a relatively high standard error matching the other surveys (Figure 33, Table 19). The negative log-likelihood component for the shrimp effort series is -351.028.

CPUE indices

Observed and predicted CPUE are provided in Figure 33 and Table 20. The model fits the recreational SRHS index moderately well (likelihood component of -46.020). The model fits the recreational MRIP index slightly worse than the SRHS (likelihood component of -37.837). Both indices indicate a slight declining trend from 2010 to 2018.

Length Composition Data

Model fits to the retained and discarded length composition data are provided in Figure 34 – Figure 36. The aggregate fit to the length composition data were relatively good (Figure 37) and no strong residual patterning was evident (Figure 38). The negative log-likelihood for the commercial and recreational length composition data are 78.999 and 252.201, respectively.

Age Composition Data

The conditional age compositions were not fit well by the model given the small sample sizes and fixed growth parameter estimates (Figure 39). The input conditional-length-at-age data were from fishery-dependent samples from the recreational fishery, which has a minimum size limit of 83.8cm FL. Of the 1266 length-at-age samples, 914 were fish greater than the minimum size limit. The negative log-likelihood component for recreational age data is 342.37.

4.2.3. Correlation Analysis

A summary of notable correlations for the GOM cobia update base model is provided in Table 21. Only steepness and virgin recruitment are highly correlated (correlation coefficient -0.97). Correlation among these parameters is not unusual and Section 4.2.4 describes the paired parameter ranges that result in similar negative log-likelihood values. Among the selectivity estimates for the targeted fleets, only the logistic selectivity parameters for the commercial fleet were mildly correlated (correlation coefficient 0.81). Correlation among these parameters is also not unusual, especially for the selectivity parameters, because the parameters of selectivity functions are inherently correlated (i.e., as the value of one parameter changes the other value will compensate).

4.2.4. Profile Likelihoods

Profile likelihoods were calculated for each of the stock-recruit parameters and a contour likelihood was developed for the combination of steepness and recruitment variance. Virgin recruitment appeared to be well-estimated with most data sources agreeing on a value between 7.3 and 7.8 (in log space; Figure 40), while the final model estimated value was 7.55. The steepness profiles indicated that the model favored values above 0.7, but there was not a strong trough, which indicated that steepness was not well estimated and values between 0.7 and 0.99 were more or less equally likely (Figure 41). The model-estimated value for steepness was 0.789. The response surfaces for σR (recruitment variance) increased towards higher values, indicating that this parameter would have been poorly estimated (Figure 42). The variance term in the base model was fixed to increase model stability and a value of 0.6 was chosen, following the value used in SEDAR 28. Across the range of parameter values tested in the various profile likelihood runs, the model tended to converge towards similar terminal year spawning stock biomass estimates (Figure 43). The model was robust to changes in the recruit variance term and steepness values. The fact that all models tended to converge rather than diverge indicates that the model is relatively robust to those stock-recruit parameter estimates, and stock size and mortality estimates are not strongly impacted by changes in recruit parameters.

The two-parameter profile likelihood further elucidated the findings in the single parameter profiles. A contour plot of σR against steepness demonstrated the clear relationship between the two parameters (Figure 44). The contours are fairly steep across low values of steepness, but quite shallow tailing off towards high steepness and low σR combinations. Although the base model σR (0.6; fixed in the base model) and steepness (estimated at 0.789) provide the smallest negative log-likelihood value, a number of alternate pairings give approximately similar negative log-likelihood values. Steepness values above 0.6 and the associated σR pairings below 0.6 are almost equally probably given the data. Although a range of values were equally plausible, the likelihood profiles indicate that alternate values would be unlikely to alter the assessment results to any great degree.

4.2.5. Retrospective Analysis

Results of the retrospective illustrate a strong level of consistency within the model. As data are peeled off, the model estimates of spawning stock biomass in each successive terminal year do not change by a large margin and show no pathological trend of over or underestimation (Figure 45). However, the longer peels (beyond 3 years) indicate that the model may have a slight tendency to overestimate virgin recruitment. However, the magnitude of differences compared to the base model with the full data time series is minimal and there is no constant trend that might indicate model issues.

4.2.6. Jitter Analysis

Despite a relatively large jitter value (0.2) that randomly adjusted the starting parameter values, the model was able to converge to same likelihood of the base model in 94% of runs and no runs demonstrated a lower negative log-likelihood solution (Figure 46). In the few instances that the base solution was not reached, the catch data were often disproportionately dominating the total negative log-likelihood. Most likely this was due to difficulties estimating selectivity and R0. Given that the total negative log-likelihood values were much higher for these runs, it is probable that non-optimal solutions were found (i.e., the model search was stuck in local minima). If priors had been placed on a handful of parameters as is often done with double normal selectivity curves, it is probable that a higher percentage of jitter runs would have converged back to the base solution. However, given the consistency in parameter estimates (e.g., steepness) and the relatively few runs that performed poorly, the jitter analysis indicates that the model is fairly stable.

Continuity Model and Model Building Runs

As noted, a strict continuity model was not feasible due to the FES adjustments to the recreational catch and the methodology used to estimate recreational catch in 2013 no longer being supported (i.e., to estimate recreational catch through 2018 using the old methodology). Therefore, model building went through multiple stages to develop a pseudo continuity model. This included updating the recreational landings data to the new FES estimates (through 2011 to demonstrate the impact of only the new recreational landings methodology on SEDAR 28 outputs) and updating all the data through 2018.

After updating all data through 2018, the internal model estimates of key growth parameters and shrimp length-based selectivity were no longer consistent with the values used in the approved SEDAR 28 model (Table 22). To address growth, the parameters for L_{max} and K were fixed using the L_{∞} and K values recommended by the SEDAR 28 Data Workshop panel (Table 1). To address the selectivity patterns for the shrimp fishing fleet, the selectivity pattern was fixed to reflect 100% selection of the age 0 fish and 0% selection of ages 1+. In fixing this relationship, the SEAMAP data were no longer being used to inform any parameters.

The next step in model tuning involved bias adjustment for the recreational deviations, variance adjustment of the indices, and adjusting sample sizes in the composition data based on variability in the observed mean length by year using the iterative Francis weighting method (Francis 2011). This model tuning reduced the estimate of the steepness from 0.91 to 0.789 and increased the virgin SSB and virgin recruitment (Table 21).

Finally, the model in SS version 3.24 was converted to version 3.30 in order to benefit from updated projections features in the latest version of SS. The transition to 3.30 had no discernable effect on the model fit or parameter estimates (Table 22).

4.2.7. Sensitivity Model Runs

The results of three sensitivity runs are presented in Figure 47 including: a low natural mortality run, a high natural mortality run and a high discard mortality run. The low M run resulted in the largest fishing mortality as compared to the base run and the other two sensitivity runs. Given this level of natural mortality, the model predicted a higher virgin spawning stock biomass and lower current spawning stock biomass relative to the base model (Figure 47). These results are similar to what was observed in the SEDAR 28 low M sensitivity run.

Increasing the natural mortality rate in the high M run led to a stock that was experiencing less fishing mortality compared to the base case. Given this level of natural mortality, the model predicted a lower virgin spawning stock biomass and higher current spawning stock biomass relative to the base model (Figure 47). These results are similar to what was observed in the SEDAR 28 with the high M sensitivity run.

Increasing the discard mortality rate from 0.05 to 0.10 in the high discard mortality run had minimal impact on the stock dynamics as compared to the base case and predicted slightly greater productivity (Table 23).

4.3.Discussion

Since the SEDAR 28 assessment finalized in 2013 and the current update, there have been many changes in data processing best practices. The five main changes documented in this report are consistently used in recent SEDAR assessments. They are (1) incorporating the NOAA fishing effort survey in the recreational landings, (2) weighting commercial length data, (3) filtering the headboat data with consideration for core vessels, (4) accounting for bycatch reduction devices in the shrimp bycatch estimates, and (5) using new best practices for commercial discard estimation. The most significant of these was the change in FES and it is discussed in more detail in Section 5.3.4.

Aside from the changes mentioned above, the SEDAR 28 update base model utilized the same overall data structure. The majority of the length composition data, all of the age-composition data, and both indices of abundance came from the recreational fishery which is the primary fishery. The landings data are dominated by the recreational fishery; however, catches prior to 1981 are likely highly uncertain. Data on the size of discarded fish were lacking for the recreational fishery. The reef fish observer program provided some information on the size composition of released fish for the commercial fishery in recent years (2006-2018), though the annual sample sizes were too low to consider these compositions annually.

Since the SEDAR 28 assessment, there have also been a number of modeling best practices applied across SEDAR assessments. Three main differences between the current and previous methods are that recent SEDAR assessments (1) remove maximum sample size caps for composition data, (2) fix the shrimp bycatch fleet selectivity parameters, and (3) reconsider internally estimated growth. Although this was an update, these changes were deemed appropriate and, after encountering model instability without the new best practices, the changes were necessary to develop the current base model.

In the SEDAR 28 stock assessment, the parameters describing growth of cobia and the selectivity pattern of the shrimp fishery had the greatest uncertainty. These same modeling difficulties were present in the development of the SEDAR 28 update base model. Initially, growth parameters were freely estimated in the SEDAR 28 update model development, but the values departed from what was provided by the SEDAR 28 DW and caused bounding issues with retention parameters. It would also be inconsistent to use growth parameters that diverged from those used to inform the calculation of the natural mortality. For these reasons, the growth parameters were fixed to those provided by the SEDAR 28 DW as described in Section 3.2.5.

The SEDAR 67 vermilion snapper stock assessment report notes that the groundfish data had an overabundance of anomalously larger/old fish, which was likely due to the SEAMAP groundfish trawls not using bycatch reduction or turtle excluder devices (BRDs or TEDs) that are mandated for use on commercial shrimping boats (SEDAR 2020a). Observations of large cobia are also present in the SEAMAP trawl data, which are the only data available to determine the size composition of the shrimp fishery bycatch. Using those SEAMAP data to inform shrimp fishery selectivity caused more larger and older fish to be caught than is reasonable given the fact the shrimp trawls use TEDs and BRDs. Consequently, the shrimp fishery selectivity parameters were fixed in the SEDAR 28 update base model as described in Section 4.1.7.

The steady decline in total biomass and spawning stock biomass over the last decade (Figure 26 and Figure 27) is corroborated by the conclusions from the Something's Fishy with Cobia Response Summary (GMFMC 2020). The survey responses indicated an overall negative trend and comments indicated a decline in the GOM cobia population since 2010. Speculated reasons for the decline reported from the survey included water quality (freshwater influx and red-tide), removal of structure, and changes in migration. Available data for considering environmental effects could be reviewed and investigated for consideration in a future research track assessment. Other data, such as length composition data of discarded fish for the recreational fishery and shrimp fishery, could also be improved upon in the next research track assessment for cobia. Accurately estimating growth and the associated assumed natural mortality and correlations and uncertainty in stock recruitment are topics worth revisiting in future research assessments as well.

The GOM cobia stock is undergoing overfishing but is not overfished based on the definition of MSST ($SSB_{SPR30\%}$* (1-M), where M = 0.38 y^{-1} for the base model). Overall, the SEDAR 28 update base model appears to perform well, incorporates SEDAR assessment best practices, and in doing so improves upon the SEDAR 28 model used to provide management advice (SEDAR 2013; GMFMC 2013).

5. PROJECTIONS

5.1. Introduction

Projections starting in 2021 were run for two fishing mortality scenarios $F_{SPR30\%}$ and F_{OY}. Following SEDAR 28, $F_{SPR30\%}$ was used as the F_{MSY} proxy and F_{OY} was defined as 75% of $F_{SPR30\%}$. Projections were run assuming that selectivity, discarding, and retention associated with the most recent time period (1985-2018) remain the same into the future. Furthermore, the projections were run assuming that average recent recruitment (2005 to 2014) would continue into the future instead of using the stock-recruit relationship directly. Given the uncertainty in stock-recruit parameter estimates along with the impact of fixing one of these parameters (considering the high correlation among them), it is unlikely the stock-recruit function provides an accurate representation of stock productivity dynamics. In order to implement this approach, the final SEDAR 28 update base model was transitioned to the SS3.3 framework.

It is worth mentioning that transitioning from recreational landings estimated using the coastal household telephone survey to landings estimated using the fishing effort survey (FES) was expected to increase catch limit recommendations relative to past assessments. Understanding the magnitude of the increase due to the landings data transition would help establish a baseline from which to evaluate any changes in catch limits due to changes in biomass, recruitment or productivity. Analyses aimed at quantifying the magnitude of the catch limit increase are included to aid in interpreting the catch advice and are provided herein.

5.2. Projection Methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS base model (Table 24 provides a summary of projection settings). One exception was that the stock-recruit function was replaced with the mean recruitment from 2005-2014 (~1.263 million fish). These years were chosen because they represent typical recruitment levels from years with the most reliable estimates of year class strength. For all years of the projections, it was assumed that recent fishery dynamics would continue indefinitely. The selectivity and retention for each fleet was taken from the terminal year of the assessment and relative harvest rates for the directed fisheries (excluding shrimp bycatch) were assumed to stay in proportion to the terminal three-year average (2016 – 2018) values. Because the shrimp fishery is managed independently of the directed fisheries for vermilion snapper, it was assumed that the fishing mortality for the shrimp bycatch fishery would be constant throughout all years of the projections based on the terminal three-year average (2016 – 2018; fishing mortality = 0.068).

Due to the lag in reporting and verification of fishery statistics, finalized landings statistics were only available through 2018. For the purpose of projections, preliminary landings and an averaging approach were used to bridge the gap between the terminal assessment year (2018) and the first year of management advice (2021). The commercial and the recreational preliminary landings estimates for 2019 are available through 12/31/2019 (35,225 and 595,797 lbs. whole weight, respectively). Because recreational 2019 landings were reported in weight, an average 2016-2018 model estimated weight of retained fish (25.06lbs) was used to convert the preliminary 2019 MRIP weight to MRIP numbers. Then, the average of the 2016-2018 MRIP to FES conversion factor (5.26) was used to convert the 2019 MRIP numbers to the 2019 FES numbers that were then used to develop model projections. Landings for 2020 were estimated using the average landings from 2017-2019.

$F_{SPR\ 30\%}$ was determined using long-term 30 year projections assuming that equilibrium was obtained over the last 5 years (2044-2048). For SPR-based analysis, the harvest rate (biomass killed / total biomass) that led to SPR 30% (SSB_{EQUIL} / SSB_0 = 0.3) was obtained by iteratively adjusting yield streams. In other words, the directed fleets fishing mortality rates were scaled up or down by the same proportional amount, while the fishing mortality rates exerted by the shrimp fleet remained constant (i.e., the shrimp bycatch mortality rate was treated in a similar way as natural mortality), until the yield that achieved SPR 30% was achieved.

The minimum stock size threshold (MSST) was determined by multiplying the reference spawning stock biomass, $SSB_{SPR\ 30\%}$, by 1 minus the natural mortality rate (M) and was used to determine stock status. The maximum fishing mortality threshold (MFMT) was equivalent to the equilibrium harvest rate ($F_{SPR\ 30\%}$; biomass killed / total biomass) that achieved $SSB_{SPR\ 30\%}$, and was used to assess whether overfishing was occurring in a given year.

Once the proxy values were calculated, 2018 stock status was used to determine whether a rebuilding plan was required (i.e., if SSB < MSST then cobia would be considered overfished and a rebuilding plan would be required). Because cobia have not been declared overfished since the SEDAR 28 assessment was completed, a rebuilding plan is not currently in place.

Projections undertaken to quantify the effect of transitioning the recreational landings data were conducted using the SEDAR 28 base model (terminal year 2011) with the recreational data updated to the new FES values. Assumed 2012 removals were used during SEDAR 28 projections to provide management advice beginning in 2013. To conduct the FES exploratory projection, 2012 recreational landings set equal to observed 2012 FES data (142.489 thousand fish) and 2012 commercial landings set equal to observed 2012 landings (63.349 metric tons). Landings were converted to F's for forecast using the same version of SS used in SEDAR 28 (SS3.24). Further following the methods from SEDAR 28, the shrimp effort was fixed throughout the time series and recruitment was taken from SR relationship.

5.3.Projection Results

5.3.1. Biological Reference Points

The harvest rate that results in SPR 30% over the long-term (30 years) was 0.231 (Table 25). The resulting SSB at SPR 30% was 5,406 metric tons and the minimum stock size threshold (MSST) was 3,352 metric tons. The MSST was calculated as (1-M) * $SSB_{SPR30\%}$, where M = 0.38 y^{-1} for the base model.

5.3.2. Stock Status

Using SPR 30% as the basis for defining MSST and MFMT, the assessment indicates that Gulf of Mexico cobia are at risk of becoming overfished in the near future without timely and appropriate management of the fishery. In 2018, the stock was estimated to have had a harvest rate of 0.37 which was equivalent to 159% of MFMT. The 2016-2018 average harvest rate was estimated to have been 0.33 or 144% of MFMT (Table 25). By either metric, cobia were estimated to have been undergoing overfishing in recent years. The terminal year depletion (SSB_{2018}/SSB_0) estimate of 21% is well below the 30% target; however, SSB remained above MSST (SSB_{2018}/MSST = 111%) indicating that the stock was not currently overfished (Table 25 and Table 26). The Kobe plot (Figure 48, Table 26) indicates that over the course of the years included in the assessment (i.e., 1927 - 2018), the stock has experienced overfishing every year from 1975 through 2018 with the exception of 1983 and 2009. As expected, prolonged overfishing reduced stock biomass below $SSB_{SPR30\%}$ from 1980 to 2018. Using (1-M) * $SSB_{SPR\ 30\%}$ as the basis for MSST, the stock was estimated to have been overfished from 1985 to 1991 and then again in 2005 before gradually recovering in recent years.

5.3.3. Overfishing Limits

Because stock status indicated that the stock was not overfished, no rebuilding plan is necessary for cobia. Therefore, short-term (10 year) forecasts were carried out at the MSY proxy (i.e., F = $F_{SPR30\%}$) in order to determine the overfishing limits. Forecasts begin in 2021, because the 2019 fishing year was already completed and TACs have already been set for 2020. Since the stock is currently below the SPR 30% target, forecasts indicate that a reduction in yield is required in the near-term in order to allow the stock to build towards the target SPR (Table 27, Figure 49). An optimum yield (OY; yield resulting from fishing at 75% of $F_{SPR30\%}$) projection was also completed. The results of the OY runs are presented in Table 28. The trends are the same as the OFL run, but result in a relatively higher equilibrium SPR (35%) with slightly lower annual yield.

Constant catch projections were not explicitly requested in the TOR’s. However, since the Gulf of Mexico Fisheries Management Council often adopts constant TACs for management, various averages of the P* based ABC and OY yield streams (Table 27 and Table ***28***) were calculated to provide constant catch management alternatives. Using the ABC yield stream in Table 27, the 5-year (2021 – 2025) average yield was 3.19 million pounds and the 10-year (2021 – 2030) average yield was 3.29 million pounds. Using the OY yield stream in Table 28, the 5-year (2021 – 2025) average yield was 2.69 million pounds and the 10-year (2021 – 2030) average yield was 2.83 million pounds.

5.3.4. FES-only projections

Updating the SEDAR 28 base model with the FES recreational landings resulted in notably increased estimates of virgin spawning stock biomass, recruitment, and projected yields (Table 29). With the introduction of FES data, the SEDAR 28 virgin spawning stock biomass estimate increased by 144% and the average recent (2002 – 2011) SSB and recruitment estimates increased by 92% and 90%, respectively (Table 29). Estimates of stock productivity were also affected, with the original SEDAR 28 model estimating ln(R0) = 6.94 and steepness = 0.92 and the FES adjusted model estimating ln(R0) = 7.81 and steepness = 0.664. The models fit using FES data estimated a population that was both more abundant and more productive than previously estimated in SEDAR 28 which when carried forward into the projections resulted in predictable increases to the sustainable yield estimates.

5.4.Discussion

Gulf of Mexico cobia are in a precarious state with overfishing occurring and biomass at reduced levels (2018 SPR = 0.21). However, the stock is not yet overfished meaning there is time for prudent management to recover the stock without necessitating a rebuilding plan. Catch monitoring data indicates that fishers have not removed more than 88.6% of the stock ACL in any given year since 2012 (Southeast Regional Office annual catch limit monitoring). The average removal over that same period (2012 – 2019) is in fact much lower at only 56.3%. Especially concerning is that during this period of less than full utilization, the model continued to estimate that overfishing was occurring and that stock biomass continued to fall (Table 26). As future yield recommendations are considered, it will be critical for the Council to understand how the change to FES data has affected the current yield advice and how the magnitude of current yield advice relates to the results from SEDAR 28.

The SEDAR 28 Update Assessment Panel decided that recent recruitment was an appropriate assumption for the basis of projections because the estimated stock-recruit parameters were likely inappropriate for such a highly productive species. However, because the dependency between spawners and recruits is eliminated through using a mean recruitment and removing the S/R function in the projections, recruitment never falters even at extremely low levels of SSB (i.e., recruitment overfishing is not possible). Clearly, some relationship must exist between mature fish and resulting recruits. The constant recruitment assumption is appropriate for short-term projections where SSB is not likely to decrease rapidly, but can lead to inappropriate long-term or equilibrium projections. Therefore, the current projections must be interpreted carefully due to the strong assumptions that were made and catch limits based on SPR 30% should be updated regularly to account for changes in recruitment dynamics. Additionally, parameter uncertainty estimates used to project error distributions in SS3 throughout the forecast timeframe for derived quantities (e.g., yield) are unrealistically small. The reduced uncertainty estimates result from a combination of fixed inputs (e.g., natural mortality, length-weight relationship, growth, etc…) that lack directly specified uncertainty. Therefore, assessment uncertainty for the SEDAR 28 update may be better accounted for by using an alternate method as the basis for the ABC instead of the P* approach.

Proposing to increase the stock ACL from 1.66 million pounds to around 3 million pounds seems extreme if taken out of context, and without clarification could introduce doubts over the validity of the assessment or the projection methodology. The transition from the coastal household telephone survey recreational landings estimates to the FES recreational landings estimates contributed to the majority of the change in yield recommendations. As summarized in Table 27, had the FES recreational landings been available during SEDAR 28 the equilibrium yield estimate would have been about 4.87 million pounds rather than the 2.66 million pounds estimated at the time. Assuming the ABC from the hypothetical SEDAR 28 FES run had been about 4.5 million pounds, the current recommendation of around 3 million pounds would represent a roughly 33% decrease in yield rather than the large increase in yield that it appears to be.

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7. RESEARCH RECOMMENDATIONS

Landings:

- Expand observer coverage
- Increase sampling of length and age composition data from commercial landings

CPUE Indices:

- Top priority should be given to the construction of defensible abundance indices for cobia from the commercial and recreational data
- Re-examine Stevens and MacCall method to obtain subset of data

Life history:

- Implement tagging study to evaluate genetic samples to determine more precise stock boundaries as well as movement studies to identify spawning areas
- Research into cobia release mortality
- Improve data collection on the relationship of the proportion mature with age and length

Discard Data:

- Improve reporting and intercept rates
- Increase sampling for length and age composition from commercial and recreational discards

Assessment:

- Explore assumption of logistic selectivity for recreational and commercial fisheries
- Sensitivity explorations into uncertainty in landings data

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9. Tables

Table 1. Length-weight function used to convert fork length (FL) of Gulf of Mexico cobia to weight in kilograms.

Sex	Model	n	FL.range	a	SE.a	b	SE.b	MSE	R2
Male	Ln(Wt) = a+b*Ln(FL)	304	310-1450	-21.046	0.391	3.392	0.057	0.189	0.921
Female	Ln(Wt) = a+b*Ln(FL)	851	315-1639	-20.231	0.234	3.278	0.034	0.164	0.918
Comb.	Ln(Wt) = a+b*Ln(FL)	6463	99-1639	-18.539	0.080	3.034	0.012	0.168	0.913
Comb.1	Wt=aFL^b			0.000	3.030				

Table 2. Age-specific natural mortality (per year) for the base model and sensitivity runs for Gulf of Mexico cobia based on the Lorenzen (1996) method for all data combined.

Age	Base M	Low M Sensitivity	High M Sensitivity
0	0.546	0.374	0.719
1	0.599	0.410	0.788
2	0.485	0.332	0.639
3	0.432	0.296	0.569
4	0.404	0.276	0.531
5	0.387	0.265	0.509
6	0.376	0.258	0.495
7	0.370	0.253	0.487
8	0.366	0.250	0.481
9	0.363	0.249	0.478
10	0.361	0.247	0.476
11	0.360	0.247	0.474

Table 3. Growth parameters recommended for Gulf of Mexico cobia.

Parameter	All	Females	Males
L (mm)	1281.5	1362.6	1221.7
K	0.42	0.41	0.36
t_0	-0.53	-0.50	-0.50

Table 4. Gulf of Mexico cobia commercial landings in pounds whole weight and metric tons.

Year	Handline (lb)	Longline (lb)	Other (lb)	Total (mt)
1927	5,511		3,939	4.290
1928	13,312		9,515	10.350
1929	8,588		6,139	6.680
1930	8,365		5,979	6.510
1931	6,093		4,355	4.740
1932	3,385		2,420	2.630
1933				2.990
1934	4,315		3,085	3.360
1935				3.020
1936	3,441		2,459	2.680
1937	1,166		834	0.910
1938	4,315		3,085	3.360
1939	3,732		2,668	2.900
1940	816		584	0.640
1941				0.180
1942				0.180
1943				0.180
1944				0.180
1945	175		125	0.140
1946				0.180
1947				0.180
1948	2,508		1,792	1.950
1949	15,978		11,422	12.430
1950	25,717		18,383	20.000
1951	29,041		20,759	22.590
1952	21,926		15,674	17.050
1953	16,853		12,047	13.110
1954	15,337		10,963	11.930
1955	17,844		12,756	13.880
1956	8,747		6,253	6.800
1957	15,045		10,755	11.700
1958	14,229		10,171	11.070
1959	24,084		17,216	18.730

Table 4 Continued. Gulf of Mexico cobia commercial landings in pounds whole weight and metric tons.

Year	Handline (lb)	Longline (lb)	Other (lb)	Total (mt)
1960	33,123		23,677	25.760
1961	20,352		14,548	15.830
1962	33,700		5,800	17.920
1963	42,000		2,800	20.320
1964	27,400		600	12.700
1965	22,700		2,800	11.570
1966	31,400		11,200	19.320
1967	24,300		23,800	21.820
1968	51,000		38,300	40.500
1969	42,900		32,600	34.250
1970	59,900		59,700	54.250
1971	66,100		44,300	50.080
1972	51,200		36,300	39.690
1973	35,400		52,200	39.730
1974	45,600		55,300	45.770
1975	47,800		49,900	44.310
1976	69,100	127	47,900	53.070
1977	64,500		47,810	50.940
1978	62,356		51,106	51.460
1979	58,144		42,842	45.810
1980	71,258		47,845	54.020
1981	86,138		56,922	64.890
1982	79,806		47,328	57.670
1983	98,561		51,986	68.280
1984	124,268		33,979	71.780
1985	135,223	**	37,615	78.450
1986	159,649	4,238	30,013	87.950
1987	174,586	8,646	49,772	105.690
1988	163,172	13,395	56,628	105.770
1989	225,910	11,793	66,115	137.810
1990	169,632	6,619	64,171	109.050
1991	161,148	19,210	93,502	124.220

Table 4 Continued. Gulf of Mexico cobia commercial landings in pounds whole weight and metric tons.

Year	Handline (lb)	Longline (lb)	Other (lb)	Total (mt)
1992	191,904	22,664	132,256	157.310
1993	184,195	24,864	144,023	160.150
1994	174,849	19,345	157,620	159.580
1995	183,322	13,722	133,997	150.150
1996	222,452	27,020	116,387	165.950
1997	167,120	22,815	111,752	136.840
1998	165,682	17,889	104,859	130.830
1999	148,751	24,599	111,328	129.120
2000	135,175	26,167	50,732	96.190
2001	113,289	19,821	44,603	80.610
2002	124,232	24,324	35,088	83.300
2003	135,850	30,027	29,026	88.400
2004	118,026	27,795	33,609	81.390
2005	86,520	19,603	30,874	62.140
2006	86,451	25,246	39,890	68.760
2007	103,955	15,292	28,148	66.860
2008	91,327	19,384	29,362	63.530
2009	95,604	9,785	32,440	62.520
2010	166,639	5,931	22,733	88.590
2011	205,392	10,225	24,793	109.040
2012	102,137	11,328	26,200	63.350
2013	112,844	11,996	26,497	68.640
2014	114,536	16,996	32,828	74.550
2015	84,965	18,921	28,408	60.010
2016	76,533	17,180	30,041	56.130
2017	67,102	12,446	34,294	51.640
2018	46,603	7,191	19,460	33.230

Table 5. Gulf of Mexico cobia recreational landings in numbers of fish.

Year	Historical	FHWAR	MRIP	Headboat	TPWD	LA
1950	2,500					
1951	12,500					
1952	25,000					
1953	50,000					
1954	75,000					
1955		90,656				
1956		100,566				
1957		110,476				
1958		120,386				
1959		130,296				
1960		140,205				
1961		142,723				
1962		145,241				
1963		147,758				
1964		150,276				
1965		152,794				
1966		158,834				
1967		164,875				
1968		170,916				
1969		176,957				
1970		182,998				
1971		199,633				
1972		216,267				
1973		232,902				
1974		249,536				
1975		266,171				
1976		266,638				
1977		267,106				
1978		267,573				
1979		268,041				
1980		268,508				
1981			165,749	1,744	862	
1982			455,077	2,545	862	

Table 5 Continued. Gulf of Mexico cobia recreational landings in numbers of fish.

Year	Historical	FHWAR	MRIP	Headboat	TPWD	LA
1983			227,967	2,015	1,272	
1984			323,946	2,153	532	
1985			143,632	2,040	786	
1986			155,244	2,550	326	
1987			144,853	2,654	821	
1988			166,993	2,809	521	
1989			134,874	2,744	312	
1990			153,660	2,880	440	
1991			98,270	3,597	1,005	
1992			182,927	3,958	2,735	
1993			130,550	5,227	513	
1994			152,809	5,033	1,142	
1995			116,994	4,868	799	
1996			215,707	4,276	3,105	
1997			223,861	4,512	2,501	
1998			134,058	2,966	2,138	
1999			172,957	2,897	1,838	
2000			128,013	2,119	836	
2001			171,567	2,319	1,714	
2002			123,740	2,391	1,000	
2003			152,259	2,264	1,208	
2004			144,431	1,507	1,538	
2005			107,561	2,511	1,080	
2006			162,234	1,803	1,581	
2007			188,798	2,750	1,486	
2008			120,583	1,938	2,250	
2009			100,332	2,325	1,985	
2010			167,947	2,362	1,020	
2011			202,510	2,054	806	
2012			138,911	2,501	1,077	
2013			119,643	2,050	663	
2014			136,657	2,199	1,108	16,557
2015			109,365	1,791	1,107	9,660
2016			135,252	1,878	896	14,281
2017			95,690	1,418	703	5,615
2018			139,527	1,200	1,055	6,942

Table 6. Gulf of Mexico cobia commercial discards in numbers of fish.

Year	Longline	Vertical Line	FL Vertical Line
1993	256	1038	105
1994	372	1074	109
1995	377	1150	117
1996	511	1405	142
1997	484	1391	141
1998	416	1350	137
1999	459	1542	156
2000	398	1511	153
2001	349	1147	116
2002	448	1380	140
2003	607	1066	108
2004	559	1024	104
2005	447	735	74
2006	552	744	75
2007	394	470	48
2008	457	532	54
2009	206	536	54
2010	133	358	36
2011	218	464	47
2012	208	486	49
2013	245	549	56
2014	349	552	56
2015	430	596	60
2016	380	517	52
2017	306	459	46
2018	194	336	34

Table 7. Gulf of Mexico cobia recreational discards in numbers of fish.

Year	MRIP	Headboat	TPWD
1981	22,947	0	103
1982	40,496	0	125
1983	33	0	1
1984	65,012	1,014	334
1985	2,033	0	32
1986	114,815	134	58
1987	44,799	1,142	407
1988	142,070	4,229	591
1989	220,671	460	428
1990	190,636	1,070	5,604
1991	683,467	7,690	9,156
1992	246,139	13,923	9,151
1993	158,160	946	2,183
1994	220,466	1,474	2,796
1995	156,992	1,443	815
1996	176,233	1,486	12,779
1997	222,401	3,986	2,495
1998	247,969	489	6,071
1999	304,098	778	6,329
2000	228,938	859	3,859
2001	285,426	516	3,347
2002	281,145	447	8,440
2003	174,906	353	1,775
2004	185,056	91	2,187
2005	135,326	609	897
2006	161,455	467	3,721
2007	164,611	493	2,633
2008	289,853	1,022	5,201
2009	182,186	1,373	3,733
2010	173,563	968	4,314
2011	292,471	817	2,715
2012	200,456	1,703	1,934
2013	162,342	1,195	1,357

Table 7 Continued. Gulf of Mexico cobia recreational discards in numbers of fish.

Year	MRIP	Headboat	TPWD
2014	231,477	1,888	2,315
2015	307,365	1,555	7,537
2016	186,858	1,316	1,558
2017	173,480	1,218	925
2018	336,401	1,210	998

Table 8. Annual shrimp bycatch estimates for Gulf of Mexico cobia in numbers of fish.

Year	Estimated Shrimp Bycatch
1972	170,600
1973	97,900
1974	496,200
1975	237,500
1976	151,200
1977	78,700
1978	79,500
1979	1,087,000
1980	348,600
1981	113,300
1982	306,600
1983	494,800
1984	325,100
1985	363,700
1986	400,200
1987	543,000
1988	261,200
1989	561,600
1990	436,100
1991	524,300
1992	546,300
1993	169,100
1994	172,100
1995	158,000
1996	522,400
1997	783,800
1998	493,300
1999	394,100
2000	131,900
2001	253,800
2002	188,700
2003	40,400
2004	25,700

Table 8 Continued. Annual shrimp bycatch estimates for Gulf of Mexico cobia in numbers of fish.

Year	Estimated Shrimp Bycatch
2005	52,200
2006	142,300
2007	35,900
2008	13,200
2009	16,900
2010	5,200
2011	30,400
2012	11,600
2013	9,100
2014	2,400
2015	4,000
2016	4,700
2017	13,800

Table 9. Annual sample size (n) of length and age composition data for Gulf of Mexico cobia.

Year	Commercial Lengths from TIP (n)	Discarded Commercial Lengths from RFOP (n)	Recreational Lengths (n)	Recreational Ages (n)
1981			50	
1982			96	
1983			87	
1984	259		119	
1985	206		91	
1986	187		209	
1987	89		169	27
1988	61		124	48
1989	39		116	198
1990	73		112	176
1991	136		150	60
1992	179		256	7
1993	174		250	2
1994	205		292	6
1995	192		274	33
1996	211		358	322
1997	270		347	194
1998	227		447	3
1999	240		461	3
2000	167		258	3

Table 9 Continued. Total annual sample size (n) of length and age composition data for Gulf of Mexico cobia.

Year	Commercial Lengths from TIP (n)	Discarded Commercial Lengths from RFOP (n)	Recreational Lengths (n)	Recreational Ages (n)
2000	167		258	3
2001	142		326	2
2002	198		276	2
2003	218		393	
2004	145		289	9
2005	75		203	2
2006	50	4	273	5
2007	60	6	297	6
2008	30	6	224	15
2009	44	13	224	9
2010	67	4	241	3
2011	69	22	235	5
2012	160	19	312	4
2013	167	22	333	32
2014	149	18	369	23
2015	183	17	310	13
2016	180	7	287	8
2017	145	8	212	31
2018	127	10	196	16

Table 10. Annual standardized estimates and associated log-scale standard errors for the Gulf of Mexico shrimp fishery effort.

Year	Standardized Shrimp Effort	SE
1945	0.001	0.200
1946	0.005	0.200
1947	0.025	0.200
1948	0.065	0.200
1949	0.104	0.200
1950	0.186	0.200
1951	0.236	0.200
1952	0.279	0.200
1953	0.288	0.200
1954	0.375	0.200
1955	0.371	0.200
1956	0.476	0.200
1957	0.556	0.200
1958	0.719	0.200
1959	0.774	0.200
1960	0.773	0.200
1961	0.477	0.200
1962	0.823	0.200
1963	0.932	0.200
1964	1.098	0.200
1965	0.711	0.200
1966	0.600	0.200
1967	0.720	0.200
1968	0.844	0.200
1969	0.924	0.200
1970	0.649	0.200
1971	0.735	0.200
1972	1.028	0.200
1973	1.046	0.200
1974	1.080	0.200
1975	0.829	0.200
1976	1.152	0.200

Table 10 Continued. Annual standardized estimates and associated log-scale standard errors for the Gulf of Mexico shrimp fishery effort.

Year	Standardized Shrimp Effort	SE
1977	1.431	0.200
1978	1.992	0.200
1979	2.097	0.200
1980	1.542	0.200
1981	1.592	0.200
1982	1.523	0.200
1983	1.649	0.200
1984	1.691	0.200
1985	1.821	0.200
1986	1.918	0.200
1987	2.229	0.200
1988	1.684	0.200
1989	2.012	0.200
1990	1.959	0.200
1991	1.873	0.200
1992	1.627	0.200
1993	1.523	0.200
1994	1.667	0.200
1995	1.432	0.200
1996	1.535	0.200
1997	1.568	0.200
1998	1.703	0.200
1999	1.775	0.200
2000	1.587	0.200
2001	1.541	0.200
2002	1.366	0.200
2003	1.112	0.200
2004	0.858	0.200
2005	0.516	0.200
2006	0.685	0.200
2007	0.671	0.200
2008	0.576	0.200

Table 10 Continued. Annual standardized estimates and associated log-scale standard errors for the Gulf of Mexico shrimp fishery effort.

Year	Standardized Shrimp Effort	SE
2009	0.675	0.200
2010	0.479	0.200
2011	0.457	0.200
2012	0.629	0.200
2013	0.465	0.200
2014	0.611	0.200
2015	0.470	0.200
2016	0.533	0.200
2017	0.532	0.200
2018	0.512	0.200

Table 11. Standardized indices of relative abundance and associated log-scale standard errors for Gulf of Mexico cobia.

Year	Headboat CPUE	Headboat SE	MRIP CPUE	MRIP SE
1981			0.816	0.436
1982			1.220	0.281
1983			0.791	0.391
1984			0.726	0.353
1985			0.671	0.402
1986	0.487	0.166	0.542	0.258
1987	0.466	0.251	0.783	0.239
1988	0.610	0.231	0.989	0.247
1989	0.527	0.206	1.074	0.275
1990	0.679	0.296	1.673	0.238
1991	0.922	0.186	1.659	0.203
1992	1.022	0.095	1.126	0.157
1993	1.241	0.231	1.061	0.201
1994	1.087	0.171	1.421	0.175
1995	1.055	0.206	0.697	0.227
1996	1.194	0.231	1.217	0.184
1997	1.325	0.151	1.401	0.163
1998	1.050	0.246	1.205	0.148
1999	1.095	0.060	1.124	0.123
2000	0.837	0.196	0.820	0.140
2001	1.082	0.126	0.957	0.131
2002	0.962	0.121	0.977	0.124
2003	0.763	0.156	1.054	0.128
2004	0.818	0.356	0.866	0.141
2005	1.044	0.286	0.814	0.161
2006	1.132	0.321	0.797	0.153
2007	1.177	0.171	0.863	0.154
2008	1.261	0.151	0.929	0.149
2009	1.123	0.166	0.796	0.171
2010	1.487	0.276	0.973	0.169
2011	1.229	0.226	1.122	0.153
2012	1.502	0.141	0.871	0.152

Table 11 Continued. Standardized indices of relative abundance and associated log-scale standard errors for Gulf of Mexico cobia.

Year	Headboat CPUE	Headboat SE	MRIP CPUE	MRIP SE
2013	1.203	0.191	0.825	0.177
2014	1.200	0.141	1.354	0.137
2015	0.818	0.176	0.853	0.144
2016	0.962	0.126	0.990	0.159
2017	0.877	0.276	1.037	0.169
2018	0.761	0.271	0.905	0.188

Table 12. List of Stock Synthesis parameters for Gulf of Mexico cobia. The list includes predicted parameter values, lower and upper bounds of the parameters, associated standard deviations and coefficients of variation, the prior type and densities (value, SD) assigned to the parameters as applicable, and phases (negative identifies parameters that were fixed). Parameters designated as fixed were held at their initial values and have no associated range or SD.

Label	Value	Range	SD	CV	Prior	Phase
L_at_Amin_Fem_GP_1	33.898	(30,60)	1.059	0.031		3
L_at_Amax_Fem_GP_1	128.100	(100,150)				-3
VonBert_K_Fem_GP_1	0.420	(0.05,0.8)				-3
CV_young_Fem_GP_1	0.168	(0.01,0.5)	0.014	0.083		5
CV_old_Fem_GP_1	0.106	(0.01,0.5)	0.006	0.057		5
Wtlen_1_Fem_GP_1	0.000	(0,1)			Normal (0,0.1)	-3
Wtlen_2_Fem_GP_1	3.030	(0,4)			Normal (3.03,0.8)	-3
Mat50%_Fem_GP_1	70.000	(50,100)				-3
Mat_slope_Fem_GP_1	-0.065	(-1,0)				-3
Eggs_scalar_Fem_GP_1	1.000	(0,3)				-3
Eggs_exp_wt_Fem_GP_1	1.000	(0,3)				-3
RecrDist_GP_1	0.000	(0,0)				-4
RecrDist_Area_1	0.000	(0,0)				-4
RecrDist_month_1	0.000	(0,0)				-4
CohortGrowDev	1.000	(0.1,10)			Normal (1,1)	-1
FracFemale_GP_1	0.600	(1e-06,0.999999)				-99
SR_LN(R0)	7.553	(1,20)	0.138	0.018		1
SR_BH_steep	0.789	(0.2,1)	0.095	0.12		4
SR_sigmaR	0.600	(0,2)				-4
SR_regime	0.000	(-5,5)				-4
SR_autocorr	0.000	(0,0)				-99
Main_RecrDev_1982	0.548	(-5,5)	0.182	0.332		2
Main_RecrDev_1983	-2.085	(-5,5)	0.394	-0.189		2
Main_RecrDev_1984	0.014	(-5,5)	0.141	9.835		2
Main_RecrDev_1985	-0.366	(-5,5)	0.216	-0.59		2
Main_RecrDev_1986	0.366	(-5,5)	0.178	0.486		2
Main_RecrDev_1987	0.019	(-5,5)	0.231	11.973		2
Main_RecrDev_1988	-0.189	(-5,5)	0.245	-1.298		2

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
Main_RecrDev_1989	0.363	(-5,5)	0.172	0.474		2
Main_RecrDev_1990	0.551	(-5,5)	0.155	0.281		2
Main_RecrDev_1991	0.486	(-5,5)	0.176	0.362		2
Main_RecrDev_1992	-0.225	(-5,5)	0.222	-0.986		2
Main_RecrDev_1993	0.414	(-5,5)	0.144	0.348		2
Main_RecrDev_1994	0.083	(-5,5)	0.193	2.338		2
Main_RecrDev_1995	0.378	(-5,5)	0.151	0.399		2
Main_RecrDev_1996	0.091	(-5,5)	0.187	2.054		2
Main_RecrDev_1997	0.026	(-5,5)	0.178	6.947		2
Main_RecrDev_1998	0.027	(-5,5)	0.188	6.914		2
Main_RecrDev_1999	0.079	(-5,5)	0.185	2.352		2
Main_RecrDev_2000	0.004	(-5,5)	0.181	44.841		2
Main_RecrDev_2001	0.053	(-5,5)	0.175	3.319		2
Main_RecrDev_2002	-0.262	(-5,5)	0.234	-0.894		2
Main_RecrDev_2003	0.028	(-5,5)	0.19	6.816		2
Main_RecrDev_2004	0.110	(-5,5)	0.192	1.743		2
Main_RecrDev_2005	0.034	(-5,5)	0.199	5.852		2
Main_RecrDev_2006	-0.079	(-5,5)	0.202	-2.552		2
Main_RecrDev_2007	0.012	(-5,5)	0.195	16.628		2
Main_RecrDev_2008	0.211	(-5,5)	0.185	0.878		2
Main_RecrDev_2009	-0.151	(-5,5)	0.221	-1.462		2
Main_RecrDev_2010	0.155	(-5,5)	0.155	1.003		2
Main_RecrDev_2011	-0.382	(-5,5)	0.22	-0.576		2
Main_RecrDev_2012	-0.013	(-5,5)	0.161	-12.778		2
Main_RecrDev_2013	-0.133	(-5,5)	0.172	-1.295		2
Main_RecrDev_2014	-0.166	(-5,5)	0.176	-1.06		2
Late_RecrDev_2015	-0.348	(-5,5)	0.242	-0.695		5
Late_RecrDev_2016	-0.104	(-5,5)	0.238	-2.281		5
Late_RecrDev_2017	-0.000	(-5,5)	0.33	-2405.844		5
Late_RecrDev_2018	0.030	(-5,5)	0.607	20.196		5
F_fleet_1_YR_1927_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1928_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1929_s_1	0.000	(0,2.9)	0	0		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_1_YR_1930_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1931_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1932_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1933_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1934_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1935_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1936_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1937_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1938_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1939_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1940_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1941_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1942_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1943_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1944_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1945_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1946_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1947_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1948_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1949_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1950_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1951_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1952_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1953_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1954_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1955_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1956_s_1	0.000	(0,2.9)	0	0		1
F_fleet_1_YR_1957_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1958_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1959_s_1	0.002	(0,2.9)	0	0		1
F_fleet_1_YR_1960_s_1	0.002	(0,2.9)	0	0		1
F_fleet_1_YR_1961_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1962_s_1	0.002	(0,2.9)	0	0		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico Cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_1_YR_1963_s_1	0.002	(0,2.9)	0	0		1
F_fleet_1_YR_1964_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1965_s_1	0.001	(0,2.9)	0	0		1
F_fleet_1_YR_1966_s_1	0.002	(0,2.9)	0	0		1
F_fleet_1_YR_1967_s_1	0.002	(0,2.9)	0	0		1
F_fleet_1_YR_1968_s_1	0.005	(0,2.9)	0.001	0.218		1
F_fleet_1_YR_1969_s_1	0.004	(0,2.9)	0.001	0.252		1
F_fleet_1_YR_1970_s_1	0.006	(0,2.9)	0.001	0.155		1
F_fleet_1_YR_1971_s_1	0.006	(0,2.9)	0.001	0.162		1
F_fleet_1_YR_1972_s_1	0.005	(0,2.9)	0.001	0.196		1
F_fleet_1_YR_1973_s_1	0.005	(0,2.9)	0.001	0.186		1
F_fleet_1_YR_1974_s_1	0.007	(0,2.9)	0.001	0.151		1
F_fleet_1_YR_1975_s_1	0.007	(0,2.9)	0.002	0.287		1
F_fleet_1_YR_1976_s_1	0.009	(0,2.9)	0.002	0.221		1
F_fleet_1_YR_1977_s_1	0.009	(0,2.9)	0.002	0.215		1
F_fleet_1_YR_1978_s_1	0.010	(0,2.9)	0.003	0.299		1
F_fleet_1_YR_1979_s_1	0.010	(0,2.9)	0.002	0.206		1
F_fleet_1_YR_1980_s_1	0.013	(0,2.9)	0.003	0.236		1
F_fleet_1_YR_1981_s_1	0.016	(0,2.9)	0.004	0.248		1
F_fleet_1_YR_1982_s_1	0.016	(0,2.9)	0.004	0.245		1
F_fleet_1_YR_1983_s_1	0.021	(0,2.9)	0.005	0.235		1
F_fleet_1_YR_1984_s_1	0.022	(0,2.9)	0.003	0.138		1
F_fleet_1_YR_1985_s_1	0.039	(0,2.9)	0.007	0.181		1
F_fleet_1_YR_1986_s_1	0.049	(0,2.9)	0.008	0.162		1
F_fleet_1_YR_1987_s_1	0.063	(0,2.9)	0.01	0.159		1
F_fleet_1_YR_1988_s_1	0.053	(0,2.9)	0.008	0.15		1
F_fleet_1_YR_1989_s_1	0.066	(0,2.9)	0.01	0.152		1
F_fleet_1_YR_1990_s_1	0.057	(0,2.9)	0.009	0.159		1
F_fleet_1_YR_1991_s_1	0.055	(0,2.9)	0.008	0.146		1
F_fleet_1_YR_1992_s_1	0.054	(0,2.9)	0.007	0.13		1
F_fleet_1_YR_1993_s_1	0.047	(0,2.9)	0.006	0.129		1
F_fleet_1_YR_1994_s_1	0.047	(0,2.9)	0.006	0.128		1
F_fleet_1_YR_1995_s_1	0.041	(0,2.9)	0.006	0.147		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_1_YR_1996_s_1	0.044	(0,2.9)	0.006	0.137		1
F_fleet_1_YR_1997_s_1	0.037	(0,2.9)	0.005	0.134		1
F_fleet_1_YR_1998_s_1	0.036	(0,2.9)	0.005	0.139		1
F_fleet_1_YR_1999_s_1	0.038	(0,2.9)	0.005	0.132		1
F_fleet_1_YR_2000_s_1	0.031	(0,2.9)	0.004	0.131		1
F_fleet_1_YR_2001_s_1	0.027	(0,2.9)	0.004	0.149		1
F_fleet_1_YR_2002_s_1	0.029	(0,2.9)	0.004	0.138		1
F_fleet_1_YR_2003_s_1	0.031	(0,2.9)	0.004	0.13		1
F_fleet_1_YR_2004_s_1	0.032	(0,2.9)	0.005	0.158		1
F_fleet_1_YR_2005_s_1	0.023	(0,2.9)	0.004	0.172		1
F_fleet_1_YR_2006_s_1	0.023	(0,2.9)	0.003	0.132		1
F_fleet_1_YR_2007_s_1	0.022	(0,2.9)	0.003	0.139		1
F_fleet_1_YR_2008_s_1	0.020	(0,2.9)	0.003	0.146		1
F_fleet_1_YR_2009_s_1	0.018	(0,2.9)	0.002	0.11		1
F_fleet_1_YR_2010_s_1	0.023	(0,2.9)	0.003	0.132		1
F_fleet_1_YR_2011_s_1	0.030	(0,2.9)	0.004	0.133		1
F_fleet_1_YR_2012_s_1	0.018	(0,2.9)	0.002	0.113		1
F_fleet_1_YR_2013_s_1	0.019	(0,2.9)	0.002	0.104		1
F_fleet_1_YR_2014_s_1	0.022	(0,2.9)	0.003	0.137		1
F_fleet_1_YR_2015_s_1	0.018	(0,2.9)	0.003	0.162		1
F_fleet_1_YR_2016_s_1	0.018	(0,2.9)	0.002	0.111		1
F_fleet_1_YR_2017_s_1	0.018	(0,2.9)	0.003	0.171		1
F_fleet_1_YR_2018_s_1	0.012	(0,2.9)	0.002	0.173		1
F_fleet_2_YR_1950_s_1	0.001	(0,2.9)	0	0		1
F_fleet_2_YR_1951_s_1	0.007	(0,2.9)	0.001	0.146		1
F_fleet_2_YR_1952_s_1	0.014	(0,2.9)	0.003	0.216		1
F_fleet_2_YR_1953_s_1	0.028	(0,2.9)	0.006	0.212		1
F_fleet_2_YR_1954_s_1	0.044	(0,2.9)	0.01	0.23		1
F_fleet_2_YR_1955_s_1	0.054	(0,2.9)	0.012	0.221		1
F_fleet_2_YR_1956_s_1	0.062	(0,2.9)	0.014	0.226		1
F_fleet_2_YR_1957_s_1	0.070	(0,2.9)	0.016	0.229		1
F_fleet_2_YR_1958_s_1	0.079	(0,2.9)	0.018	0.229		1
F_fleet_2_YR_1959_s_1	0.088	(0,2.9)	0.02	0.227		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_2_YR_1960_s_1	0.098	(0,2.9)	0.023	0.234		1
F_fleet_2_YR_1961_s_1	0.103	(0,2.9)	0.024	0.233		1
F_fleet_2_YR_1962_s_1	0.106	(0,2.9)	0.025	0.236		1
F_fleet_2_YR_1963_s_1	0.110	(0,2.9)	0.026	0.236		1
F_fleet_2_YR_1964_s_1	0.115	(0,2.9)	0.027	0.235		1
F_fleet_2_YR_1965_s_1	0.120	(0,2.9)	0.028	0.233		1
F_fleet_2_YR_1966_s_1	0.126	(0,2.9)	0.03	0.238		1
F_fleet_2_YR_1967_s_1	0.131	(0,2.9)	0.031	0.237		1
F_fleet_2_YR_1968_s_1	0.137	(0,2.9)	0.032	0.233		1
F_fleet_2_YR_1969_s_1	0.145	(0,2.9)	0.034	0.234		1
F_fleet_2_YR_1970_s_1	0.153	(0,2.9)	0.036	0.235		1
F_fleet_2_YR_1971_s_1	0.170	(0,2.9)	0.04	0.236		1
F_fleet_2_YR_1972_s_1	0.188	(0,2.9)	0.045	0.24		1
F_fleet_2_YR_1973_s_1	0.211	(0,2.9)	0.051	0.242		1
F_fleet_2_YR_1974_s_1	0.237	(0,2.9)	0.057	0.24		1
F_fleet_2_YR_1975_s_1	0.266	(0,2.9)	0.065	0.244		1
F_fleet_2_YR_1976_s_1	0.276	(0,2.9)	0.067	0.243		1
F_fleet_2_YR_1977_s_1	0.289	(0,2.9)	0.069	0.239		1
F_fleet_2_YR_1978_s_1	0.307	(0,2.9)	0.073	0.238		1
F_fleet_2_YR_1979_s_1	0.334	(0,2.9)	0.079	0.236		1
F_fleet_2_YR_1980_s_1	0.364	(0,2.9)	0.085	0.234		1
F_fleet_2_YR_1981_s_1	0.250	(0,2.9)	0.054	0.216		1
F_fleet_2_YR_1982_s_1	0.651	(0,2.9)	0.125	0.192		1
F_fleet_2_YR_1983_s_1	0.185	(0,2.9)	0.037	0.199		1
F_fleet_2_YR_1984_s_1	0.735	(0,2.9)	0.114	0.155		1
F_fleet_2_YR_1985_s_1	0.508	(0,2.9)	0.104	0.205		1
F_fleet_2_YR_1986_s_1	0.732	(0,2.9)	0.128	0.175		1
F_fleet_2_YR_1987_s_1	0.589	(0,2.9)	0.108	0.183		1
F_fleet_2_YR_1988_s_1	0.618	(0,2.9)	0.108	0.175		1
F_fleet_2_YR_1989_s_1	0.560	(0,2.9)	0.1	0.179		1
F_fleet_2_YR_1990_s_1	0.676	(0,2.9)	0.125	0.185		1
F_fleet_2_YR_1991_s_1	0.443	(0,2.9)	0.082	0.185		1
F_fleet_2_YR_1992_s_1	0.583	(0,2.9)	0.103	0.177		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_2_YR_1993_s_1	0.363	(0,2.9)	0.065	0.179		1
F_fleet_2_YR_1994_s_1	0.475	(0,2.9)	0.085	0.179		1
F_fleet_2_YR_1995_s_1	0.315	(0,2.9)	0.058	0.184		1
F_fleet_2_YR_1996_s_1	0.516	(0,2.9)	0.09	0.174		1
F_fleet_2_YR_1997_s_1	0.564	(0,2.9)	0.095	0.168		1
F_fleet_2_YR_1998_s_1	0.398	(0,2.9)	0.07	0.176		1
F_fleet_2_YR_1999_s_1	0.574	(0,2.9)	0.096	0.167		1
F_fleet_2_YR_2000_s_1	0.446	(0,2.9)	0.083	0.186		1
F_fleet_2_YR_2001_s_1	0.594	(0,2.9)	0.101	0.17		1
F_fleet_2_YR_2002_s_1	0.468	(0,2.9)	0.084	0.179		1
F_fleet_2_YR_2003_s_1	0.538	(0,2.9)	0.097	0.18		1
F_fleet_2_YR_2004_s_1	0.569	(0,2.9)	0.111	0.195		1
F_fleet_2_YR_2005_s_1	0.384	(0,2.9)	0.076	0.198		1
F_fleet_2_YR_2006_s_1	0.483	(0,2.9)	0.09	0.187		1
F_fleet_2_YR_2007_s_1	0.548	(0,2.9)	0.098	0.179		1
F_fleet_2_YR_2008_s_1	0.413	(0,2.9)	0.076	0.184		1
F_fleet_2_YR_2009_s_1	0.302	(0,2.9)	0.058	0.192		1
F_fleet_2_YR_2010_s_1	0.411	(0,2.9)	0.074	0.18		1
F_fleet_2_YR_2011_s_1	0.558	(0,2.9)	0.096	0.172		1
F_fleet_2_YR_2012_s_1	0.401	(0,2.9)	0.071	0.177		1
F_fleet_2_YR_2013_s_1	0.376	(0,2.9)	0.069	0.184		1
F_fleet_2_YR_2014_s_1	0.516	(0,2.9)	0.092	0.178		1
F_fleet_2_YR_2015_s_1	0.435	(0,2.9)	0.08	0.184		1
F_fleet_2_YR_2016_s_1	0.497	(0,2.9)	0.089	0.179		1
F_fleet_2_YR_2017_s_1	0.374	(0,2.9)	0.076	0.203		1
F_fleet_2_YR_2018_s_1	0.545	(0,2.9)	0.126	0.231		1
F_fleet_3_YR_1945_s_1	0.000	(0,2.9)	0	0		1
F_fleet_3_YR_1946_s_1	0.001	(0,2.9)	0	0		1
F_fleet_3_YR_1947_s_1	0.003	(0,2.9)	0	0		1
F_fleet_3_YR_1948_s_1	0.008	(0,2.9)	0.001	0.119		1
F_fleet_3_YR_1949_s_1	0.014	(0,2.9)	0.001	0.074		1
F_fleet_3_YR_1950_s_1	0.024	(0,2.9)	0.002	0.083		1
F_fleet_3_YR_1951_s_1	0.031	(0,2.9)	0.003	0.098		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_3_YR_1952_s_1	0.036	(0,2.9)	0.004	0.11		1
F_fleet_3_YR_1953_s_1	0.037	(0,2.9)	0.004	0.107		1
F_fleet_3_YR_1954_s_1	0.049	(0,2.9)	0.005	0.103		1
F_fleet_3_YR_1955_s_1	0.048	(0,2.9)	0.005	0.104		1
F_fleet_3_YR_1956_s_1	0.062	(0,2.9)	0.006	0.097		1
F_fleet_3_YR_1957_s_1	0.072	(0,2.9)	0.007	0.097		1
F_fleet_3_YR_1958_s_1	0.094	(0,2.9)	0.009	0.096		1
F_fleet_3_YR_1959_s_1	0.101	(0,2.9)	0.01	0.099		1
F_fleet_3_YR_1960_s_1	0.101	(0,2.9)	0.01	0.099		1
F_fleet_3_YR_1961_s_1	0.062	(0,2.9)	0.006	0.097		1
F_fleet_3_YR_1962_s_1	0.107	(0,2.9)	0.01	0.093		1
F_fleet_3_YR_1963_s_1	0.121	(0,2.9)	0.012	0.099		1
F_fleet_3_YR_1964_s_1	0.143	(0,2.9)	0.014	0.098		1
F_fleet_3_YR_1965_s_1	0.092	(0,2.9)	0.009	0.097		1
F_fleet_3_YR_1966_s_1	0.078	(0,2.9)	0.008	0.102		1
F_fleet_3_YR_1967_s_1	0.094	(0,2.9)	0.009	0.096		1
F_fleet_3_YR_1968_s_1	0.110	(0,2.9)	0.011	0.1		1
F_fleet_3_YR_1969_s_1	0.120	(0,2.9)	0.012	0.1		1
F_fleet_3_YR_1970_s_1	0.084	(0,2.9)	0.008	0.095		1
F_fleet_3_YR_1971_s_1	0.096	(0,2.9)	0.009	0.094		1
F_fleet_3_YR_1972_s_1	0.134	(0,2.9)	0.013	0.097		1
F_fleet_3_YR_1973_s_1	0.136	(0,2.9)	0.013	0.095		1
F_fleet_3_YR_1974_s_1	0.140	(0,2.9)	0.014	0.1		1
F_fleet_3_YR_1975_s_1	0.108	(0,2.9)	0.01	0.093		1
F_fleet_3_YR_1976_s_1	0.150	(0,2.9)	0.015	0.1		1
F_fleet_3_YR_1977_s_1	0.186	(0,2.9)	0.018	0.097		1
F_fleet_3_YR_1978_s_1	0.259	(0,2.9)	0.025	0.096		1
F_fleet_3_YR_1979_s_1	0.273	(0,2.9)	0.027	0.099		1
F_fleet_3_YR_1980_s_1	0.201	(0,2.9)	0.02	0.1		1
F_fleet_3_YR_1981_s_1	0.207	(0,2.9)	0.02	0.097		1
F_fleet_3_YR_1982_s_1	0.198	(0,2.9)	0.019	0.096		1
F_fleet_3_YR_1983_s_1	0.214	(0,2.9)	0.021	0.098		1
F_fleet_3_YR_1984_s_1	0.220	(0,2.9)	0.021	0.095		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_3_YR_1985_s_1	0.237	(0,2.9)	0.023	0.097		1
F_fleet_3_YR_1986_s_1	0.249	(0,2.9)	0.024	0.096		1
F_fleet_3_YR_1987_s_1	0.290	(0,2.9)	0.028	0.097		1
F_fleet_3_YR_1988_s_1	0.219	(0,2.9)	0.021	0.096		1
F_fleet_3_YR_1989_s_1	0.262	(0,2.9)	0.025	0.096		1
F_fleet_3_YR_1990_s_1	0.255	(0,2.9)	0.025	0.098		1
F_fleet_3_YR_1991_s_1	0.244	(0,2.9)	0.024	0.098		1
F_fleet_3_YR_1992_s_1	0.212	(0,2.9)	0.021	0.099		1
F_fleet_3_YR_1993_s_1	0.198	(0,2.9)	0.019	0.096		1
F_fleet_3_YR_1994_s_1	0.217	(0,2.9)	0.021	0.097		1
F_fleet_3_YR_1995_s_1	0.186	(0,2.9)	0.018	0.097		1
F_fleet_3_YR_1996_s_1	0.200	(0,2.9)	0.019	0.095		1
F_fleet_3_YR_1997_s_1	0.204	(0,2.9)	0.02	0.098		1
F_fleet_3_YR_1998_s_1	0.222	(0,2.9)	0.022	0.099		1
F_fleet_3_YR_1999_s_1	0.231	(0,2.9)	0.022	0.095		1
F_fleet_3_YR_2000_s_1	0.206	(0,2.9)	0.02	0.097		1
F_fleet_3_YR_2001_s_1	0.200	(0,2.9)	0.02	0.1		1
F_fleet_3_YR_2002_s_1	0.178	(0,2.9)	0.017	0.096		1
F_fleet_3_YR_2003_s_1	0.145	(0,2.9)	0.014	0.097		1
F_fleet_3_YR_2004_s_1	0.112	(0,2.9)	0.011	0.099		1
F_fleet_3_YR_2005_s_1	0.067	(0,2.9)	0.007	0.104		1
F_fleet_3_YR_2006_s_1	0.089	(0,2.9)	0.009	0.101		1
F_fleet_3_YR_2007_s_1	0.087	(0,2.9)	0.009	0.103		1
F_fleet_3_YR_2008_s_1	0.075	(0,2.9)	0.007	0.093		1
F_fleet_3_YR_2009_s_1	0.088	(0,2.9)	0.009	0.102		1
F_fleet_3_YR_2010_s_1	0.062	(0,2.9)	0.006	0.096		1
F_fleet_3_YR_2011_s_1	0.059	(0,2.9)	0.006	0.101		1
F_fleet_3_YR_2012_s_1	0.082	(0,2.9)	0.008	0.098		1
F_fleet_3_YR_2013_s_1	0.061	(0,2.9)	0.006	0.099		1
F_fleet_3_YR_2014_s_1	0.079	(0,2.9)	0.008	0.101		1
F_fleet_3_YR_2015_s_1	0.061	(0,2.9)	0.006	0.098		1
F_fleet_3_YR_2016_s_1	0.069	(0,2.9)	0.007	0.101		1
F_fleet_3_YR_2017_s_1	0.069	(0,2.9)	0.007	0.101		1

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
F_fleet_3_YR_2018_s_1	0.067	(0,2.9)	0.006	0.09		1
LnQ_base_Recreational_Combined_2(2)	-5.730	(-25,25)				-1
LnQ_base_Shrimp_Bycatch_3(3)	2.040	(-10,20)	0.097	0.048		1
LnQ_base_MRIP_4(4)	-6.559	(-25,25)				-1
Size_inflection_Com_Combined_1(1)	83.806	(40,150)	2.33	0.028		5
Size_95%width_Com_Combined_1(1)	21.956	(1,60)	3.243	0.148		5
Retain_L_infl_Com_Combined_1(1)	40.000	(30,100)				-6
Retain_L_width_Com_Combined_1(1)	2.000	(0,20)				-4
Retain_L_asymptote_logit_Com_Combined_1(1)	10.000	(-10,10)				-2
Retain_L_maleoffset_Com_Combined_1(1)	0.000	(-1,2)				-4
DiscMort_L_infl_Com_Combined_1(1)	-5.000	(-10,10)				-2
DiscMort_L_width_Com_Combined_1(1)	1.000	(-1,2)				-4
DiscMort_L_level_old_Com_Combined_1(1)	0.050	(-1,2)				-2
DiscMort_L_male_offset_Com_Combined_1(1)	0.000	(-1,2)				-4
Size_inflection_Recreational_Combined_2(2)	55.806	(40,125)	2.53	0.045		5
Size_95%width_Recreational_Combined_2(2)	25.457	(1,60)	2.736	0.107		5
Retain_L_infl_Recreational_Combined_2(2)	40.000	(30,100)				-6
Retain_L_width_Recreational_Combined_2(2)	2.000	(0,20)				-6
Retain_L_asymptote_logit_Recreational_Combined_2(2)	10.000	(-10,10)				-2
Retain_L_maleoffset_Recreational_Combined_2(2)	0.000	(-1,2)				-4
DiscMort_L_infl_Recreational_Combined_2(2)	-5.000	(-10,10)				-2
DiscMort_L_width_Recreational_Combined_2(2)	1.000	(-1,1)				-4
DiscMort_L_level_old_Recreational_Combined_2(2)	0.050	(-1,2)				-2
DiscMort_L_male_offset_Recreational_Combined_2(2)	0.000	(-1,2)				-4
SizeSel_P1_MRIP_4(4)	1.000	(1,62)				-1
SizeSel_P2_MRIP_4(4)	62.000	(1,62)				-1
minage@sel=1_Com_Combined_1(1)	0.000	(0,15)				-1
maxage@sel=1_Com_Combined_1(1)	15.000	(0,15)				-1
minage@sel=1_Shrimp_Bycatch_3(3)	0.000	(0,0.1)				-1
maxage@sel=1_Shrimp_Bycatch_3(3)	0.000	(0,1)				-1
Retain_L_infl_Com_Combined_1(1)_BLK1repl_1985	76.494	(70,100)	1.353	0.018		6

Table 12 Continued. List of Stock Synthesis parameters for Gulf of Mexico cobia.

Label	Value	Range	SD	CV	Prior	Phase
Retain_L_width_Com_Combined_1(1)_BLK1repl_1985	5.032	(0,20)	1.051	0.209		6
Retain_L_infl_Recreational_Combined_2(2)_BLK1repl_1985	80.379	(70,100)	0.519	0.006		6
Retain_L_width_Recreational_Combined_2(2)_BLK1repl_1985	4.079	(0,20)	0.258	0.063		6

Table 13. Estimates of annual exploitation rate (total biomass killed / total biomass) combined across all fleets for Gulf of Mexico cobia, which was used as the proxy for annual fishing mortality rate.

Year	SEDAR28Update	SEDAR28
1927	0.000	0.001
1928	0.001	0.003
1929	0.000	0.002
1930	0.000	0.002
1931	0.000	0.001
1932	0.000	0.001
1933	0.000	0.001
1934	0.000	0.001
1935	0.000	0.001
1936	0.000	0.001
1937	0.000	0.000
1938	0.000	0.001
1939	0.000	0.001
1940	0.000	0.000
1941	0.000	0.000
1942	0.000	0.000
1943	0.000	0.000
1944	0.000	0.000
1945	0.000	0.000
1946	0.000	0.000
1947	0.000	0.002
1948	0.000	0.005
1949	0.001	0.011
1950	0.003	0.022
1951	0.008	0.038
1952	0.014	0.055
1953	0.028	0.086
1954	0.042	0.124
1955	0.052	0.149
1956	0.059	0.171
1957	0.067	0.195
1958	0.075	0.225
1959	0.085	0.252
1960	0.094	0.276
1961	0.098	0.261
1962	0.101	0.292
1963	0.106	0.310

Table 13 Continued. Estimates of annual exploitation rate (total biomass killed / total biomass) combined across all fleets for Gulf of Mexico cobia, which was used as the proxy for annual fishing mortality rate.

Year	SEDAR28Update	SEDAR28
1964	0.110	0.329
1965	0.114	0.311
1966	0.120	0.316
1967	0.125	0.335
1968	0.133	0.364
1969	0.140	0.382
1970	0.148	0.386
1971	0.162	0.419
1972	0.178	0.468
1973	0.198	0.510
1974	0.221	0.559
1975	0.245	0.585
1976	0.257	0.625
1977	0.270	0.664
1978	0.287	0.734
1979	0.308	0.780
1980	0.331	0.782
1981	0.247	0.706
1982	0.532	1.007
1983	0.196	0.874
1984	0.571	1.038
1985	0.355	1.086
1986	0.491	1.370
1987	0.397	1.119
1988	0.430	1.245
1989	0.421	1.435
1990	0.446	0.933
1991	0.322	0.838
1992	0.405	0.904
1993	0.301	0.962
1994	0.346	0.888
1995	0.257	0.665
1996	0.370	0.823
1997	0.399	0.916
1998	0.308	0.682
1999	0.408	0.841
2000	0.328	0.773

Table 13 Continued. Estimates of annual exploitation rate (total biomass killed / total biomass) combined across all fleets for Gulf of Mexico cobia, which was used as the proxy for annual fishing mortality rate.

Year	SEDAR28Update	SEDAR28
2001	0.410	0.856
2002	0.337	0.669
2003	0.387	0.951
2004	0.390	0.898
2005	0.276	0.701
2006	0.341	0.794
2007	0.381	0.928
2008	0.300	0.685
2009	0.226	0.526
2010	0.308	0.616
2011	0.382	0.758
2012	0.300	
2013	0.279	
2014	0.362	
2015	0.314	
2016	0.355	
2017	0.275	
2018	0.366	

Table 14. Annual apical estimates of fishing mortality by fleet for Gulf of Mexico cobia.

Year	Commercial	Recreational	Shrimp Bycatch
1925	0.000	0.000	0.000
1926	0.000	0.000	0.000
1927	0.000	0.000	0.000
1928	0.001	0.000	0.000
1929	0.000	0.000	0.000
1930	0.000	0.000	0.000
1931	0.000	0.000	0.000
1932	0.000	0.000	0.000
1933	0.000	0.000	0.000
1934	0.000	0.000	0.000
1935	0.000	0.000	0.000
1936	0.000	0.000	0.000
1937	0.000	0.000	0.000
1938	0.000	0.000	0.000
1939	0.000	0.000	0.000
1940	0.000	0.000	0.000
1941	0.000	0.000	0.000
1942	0.000	0.000	0.000
1943	0.000	0.000	0.000
1944	0.000	0.000	0.000
1945	0.000	0.000	0.000
1946	0.000	0.000	0.001
1947	0.000	0.000	0.003
1948	0.000	0.000	0.008
1949	0.001	0.000	0.014
1950	0.001	0.001	0.024
1951	0.001	0.007	0.031
1952	0.001	0.014	0.036
1953	0.001	0.028	0.037
1954	0.001	0.044	0.049
1955	0.001	0.054	0.048
1956	0.000	0.062	0.062
1957	0.001	0.070	0.072
1958	0.001	0.079	0.094
1959	0.002	0.088	0.101
1960	0.002	0.098	0.101
1961	0.001	0.103	0.062

Table 14 Continued. Annual apical estimates of fishing mortality by fleet for Gulf of Mexico cobia.

Year	Commercial	Recreational	Shrimp Bycatch
1962	0.002	0.106	0.107
1963	0.002	0.110	0.121
1964	0.001	0.115	0.143
1965	0.001	0.120	0.092
1966	0.002	0.126	0.078
1967	0.002	0.131	0.094
1968	0.005	0.137	0.110
1969	0.004	0.145	0.120
1970	0.006	0.153	0.084
1971	0.006	0.170	0.096
1972	0.005	0.188	0.134
1973	0.005	0.211	0.136
1974	0.007	0.237	0.140
1975	0.007	0.266	0.108
1976	0.009	0.276	0.150
1977	0.009	0.289	0.186
1978	0.010	0.307	0.259
1979	0.010	0.334	0.273
1980	0.013	0.364	0.201
1981	0.016	0.250	0.207
1982	0.016	0.651	0.198
1983	0.021	0.185	0.214
1984	0.022	0.735	0.220
1985	0.039	0.508	0.237
1986	0.049	0.732	0.249
1987	0.063	0.589	0.290
1988	0.053	0.618	0.219
1989	0.066	0.560	0.262
1990	0.057	0.676	0.255
1991	0.055	0.443	0.244
1992	0.054	0.583	0.212
1993	0.047	0.363	0.198
1994	0.047	0.475	0.217
1995	0.041	0.315	0.186
1996	0.044	0.516	0.200
1997	0.037	0.564	0.204
1998	0.036	0.398	0.222

Table 14 Continued. Annual apical estimates of fishing mortality by fleet for Gulf of Mexico cobia.

Year	Commercial	Recreational	Shrimp Bycatch
1999	0.038	0.574	0.231
2000	0.031	0.446	0.206
2001	0.027	0.594	0.200
2002	0.029	0.468	0.178
2003	0.031	0.538	0.145
2004	0.032	0.569	0.112
2005	0.023	0.384	0.067
2006	0.023	0.483	0.089
2007	0.022	0.548	0.087
2008	0.020	0.413	0.075
2009	0.018	0.302	0.088
2010	0.023	0.411	0.062
2011	0.030	0.558	0.059
2012	0.018	0.401	0.082
2013	0.019	0.376	0.061
2014	0.022	0.516	0.079
2015	0.018	0.435	0.061
2016	0.018	0.497	0.069
2017	0.018	0.374	0.069
2018	0.012	0.545	0.067

Table 15. Predicted biomass (metric tons), spawning stock biomass (SSB, metric tons), abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB_0) for Gulf of Mexico cobia.

Year	Biomass	SSB	Abundance	Recruits	Depletion
1925	20410.100	18016.500	2843.600	1905.640	1.000
1926	20410.100	18016.500	2843.600	1905.640	1.000
1927	20410.100	18016.500	2843.600	1905.650	1.000
1928	20406.500	18012.800	2843.370	1905.620	1.000
1929	20398.400	18004.800	2842.860	1905.560	0.999
1930	20395.200	18001.700	2842.690	1905.540	0.999
1931	20393.000	17999.500	2842.570	1905.530	0.999
1932	20392.900	17999.400	2842.580	1905.520	0.999
1933	20394.700	18001.200	2842.700	1905.540	0.999
1934	20395.900	18002.400	2842.770	1905.550	0.999
1935	20396.400	18002.900	2842.800	1905.550	0.999
1936	20397.100	18003.600	2842.840	1905.550	0.999
1937	20398.000	18004.500	2842.890	1905.560	0.999
1938	20400.100	18006.600	2843.030	1905.580	0.999
1939	20399.700	18006.200	2842.990	1905.570	0.999
1940	20399.700	18006.200	2842.990	1905.570	0.999
1941	20401.700	18008.100	2843.120	1905.590	1.000
1942	20403.600	18010.000	2843.230	1905.600	1.000
1943	20405.100	18011.500	2843.320	1905.610	1.000
1944	20406.200	18012.600	2843.380	1905.620	1.000
1945	20407.000	18013.400	2843.430	1905.620	1.000
1946	20407.500	18014.100	2843.320	1905.630	1.000
1947	20407.100	18014.300	2842.720	1905.630	1.000
1948	20403.000	18013.600	2839.560	1905.620	1.000
1949	20387.400	18006.800	2831.980	1905.580	0.999
1950	20347.800	17979.600	2821.430	1905.380	0.998
1951	20257.600	17908.400	2801.220	1904.880	0.994
1952	20050.600	17726.600	2774.080	1903.560	0.984
1953	19732.300	17428.600	2741.070	1901.350	0.967
1954	19211.900	16929.300	2698.310	1897.480	0.940
1955	18528.900	16273.800	2636.830	1892.080	0.903
1956	17808.400	15579.900	2582.750	1885.890	0.865
1957	17129.100	14925.600	2522.300	1879.580	0.828
1958	16465.300	14301.300	2461.930	1873.060	0.794
1959	15804.700	13686.500	2391.070	1866.110	0.760
1960	15132.100	13059.000	2328.220	1858.400	0.725
1961	14472.000	12421.600	2276.050	1849.850	0.689

Table 15 Continued. Predicted biomass (metric tons), spawning stock biomass (SSB, metric tons), abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB0) for Gulf of Mexico cobia.

Year	Biomass	SSB	Abundance	Recruits	Depletion
1962	13963.000	11888.500	2274.130	1842.060	0.660
1963	13573.400	11508.300	2218.530	1836.110	0.639
1964	13194.600	11203.100	2167.400	1831.070	0.622
1965	12809.000	10860.600	2111.940	1825.110	0.603
1966	12465.100	10503.800	2120.580	1818.540	0.583
1967	12211.900	10194.300	2127.290	1812.510	0.566
1968	12014.800	10005.900	2106.410	1808.670	0.555
1969	11781.600	9813.770	2070.970	1804.630	0.545
1970	11506.700	9574.050	2033.620	1799.380	0.531
1971	11214.000	9270.470	2035.750	1792.400	0.515
1972	10888.500	8934.270	2007.220	1784.180	0.496
1973	10476.400	8586.190	1937.760	1775.080	0.477
1974	9935.990	8108.330	1876.920	1761.490	0.450
1975	9319.120	7523.620	1814.670	1742.860	0.418
1976	8703.570	6916.610	1782.280	1720.710	0.384
1977	8219.320	6463.160	1709.920	1701.910	0.359
1978	7748.640	6086.810	1626.970	1684.540	0.338
1979	7213.620	5663.090	1511.460	1662.740	0.314
1980	6605.590	5152.260	1423.190	1632.650	0.286
1981	6059.850	4600.640	1407.980	1594.300	0.255
1982	6267.530	4735.160	1433.320	2341.170	0.263
1983	5111.120	3433.950	1624.450	155.630	0.191
1984	5739.030	4454.880	890.120	1354.640	0.247
1985	3536.110	2879.100	908.810	824.250	0.160
1986	3446.160	2342.270	824.560	1601.160	0.130
1987	3356.760	2230.730	1087.940	1111.960	0.124
1988	3786.060	2480.370	1009.910	937.670	0.138
1989	3753.100	2769.740	903.880	1688.230	0.154
1990	3855.080	2622.610	1173.340	2001.810	0.146
1991	4394.040	2658.990	1452.260	1884.890	0.148
1992	5566.000	3690.900	1585.780	1018.790	0.205
1993	5622.430	4159.900	1229.390	1988.020	0.231
1994	5955.900	4488.770	1557.730	1452.740	0.249
1995	6066.390	4303.330	1444.300	1933.430	0.239
1996	6718.380	5025.600	1673.690	1500.990	0.279
1997	6537.710	4764.460	1519.810	1390.340	0.264
1998	6034.490	4572.070	1369.210	1380.120	0.254

Table 15 Continued. Predicted biomass (metric tons), spawning stock biomass (SSB, metric tons), abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB0) for Gulf of Mexico cobia.

Year	Biomass	SSB	Abundance	Recruits	Depletion
1999	5987.050	4596.860	1322.450	1454.760	0.255
2000	5377.380	3987.900	1285.050	1306.340	0.221
2001	5382.080	4003.660	1249.790	1372.840	0.222
2002	4997.680	3656.860	1233.800	979.690	0.203
2003	4950.000	3727.230	1080.830	1315.330	0.207
2004	4641.480	3453.370	1166.890	1399.510	0.192
2005	4669.280	3204.680	1281.500	1270.080	0.178
2006	5332.340	3816.510	1341.250	1189.000	0.212
2007	5447.280	4034.350	1285.600	1320.150	0.224
2008	5270.350	3860.590	1310.600	1593.510	0.214
2009	5729.660	4084.810	1513.840	1125.110	0.227
2010	6424.580	4832.330	1389.620	1586.390	0.268
2011	6421.680	4893.610	1551.020	930.370	0.272
2012	5883.140	4383.840	1248.070	1313.850	0.243
2013	5802.900	4532.640	1321.590	1173.830	0.252
2014	5848.500	4405.950	1309.540	1128.190	0.245
2015	5435.840	4107.760	1231.950	891.470	0.228
2016	5234.690	4056.600	1095.330	1137.890	0.225
2017	4836.770	3677.180	1138.940	1262.880	0.204
2018	5106.320	3725.010	1261.780	1301.590	0.207

Table 16. Observed (Obs) and predicted (Exp) landings by fleet for the commercial and recreational fisheries in weight (ww, metric tons) and number (1000s of fish) for Gulf of Mexico cobia. Observed landings prior to 1963 for the commercial fishery and prior to 1981 for the recreational fishery are a linear extrapolation from virgin conditions. Note that the standard errors for the commercial and recreational landings were 0.01 and 0.15, respectively. Therefore, the model was forced to fit the commercial data more closely, because there is less uncertainty in the commercial landings data.

Year	Commercial (Obs, ww)	Commercial (Exp, ww)	Commercial (Exp, Number)	Recreational (Obs, Number)	Recreational (Exp, Number)	Recreational (Exp, ww)
1927	4.286	4.286	0.293	0.000	0.000	0.000
1928	10.354	10.354	0.708	0.000	0.000	0.000
1929	6.680	6.680	0.457	0.000	0.000	0.000
1930	6.506	6.506	0.445	0.000	0.000	0.000
1931	4.739	4.739	0.324	0.000	0.000	0.000
1932	2.633	2.633	0.180	0.000	0.000	0.000
1933	2.995	2.995	0.205	0.000	0.000	0.000
1934	3.357	3.357	0.230	0.000	0.000	0.000
1935	3.016	3.016	0.206	0.000	0.000	0.000
1936	2.676	2.676	0.183	0.000	0.000	0.000
1937	0.907	0.907	0.062	0.000	0.000	0.000
1938	3.357	3.357	0.230	0.000	0.000	0.000
1939	2.903	2.903	0.199	0.000	0.000	0.000
1940	0.635	0.635	0.043	0.000	0.000	0.000
1941	0.181	0.181	0.012	0.000	0.000	0.000
1942	0.181	0.181	0.012	0.000	0.000	0.000
1943	0.181	0.181	0.012	0.000	0.000	0.000
1944	0.181	0.181	0.012	0.000	0.000	0.000
1945	0.136	0.136	0.009	0.000	0.000	0.000
1946	0.181	0.181	0.012	0.000	0.000	0.000
1947	0.181	0.181	0.012	0.000	0.000	0.000
1948	1.950	1.950	0.133	0.000	0.000	0.000
1949	12.428	12.428	0.849	0.000	0.000	0.000
1950	20.003	20.003	1.366	2.500	2.500	26.398
1951	22.588	22.588	1.542	12.500	12.500	132.183
1952	17.055	17.055	1.163	25.000	25.000	264.270
1953	13.108	13.108	0.895	50.000	50.000	526.931
1954	11.929	11.929	0.817	75.000	75.000	784.438
1955	13.880	13.880	0.955	90.656	90.656	939.318
1956	6.804	6.804	0.471	100.566	100.567	1028.910
1957	11.702	11.702	0.817	110.476	110.477	1117.790
1958	11.067	11.067	0.778	120.386	120.387	1205.010

Table 16 Continued. Observed (Obs) and predicted (Exp) landings by fleet for the commercial and recreational fisheries in weight (ww, metric tons) and number (1000s of fish) for Gulf of Mexico cobia.

Year	Commercial (Obs, ww)	Commercial (Exp, ww)	Commercial (Exp, Number)	Recreational (Obs, Number)	Recreational (Exp, Number)	Recreational (Exp, ww)
1959	18.733	18.733	1.326	130.296	130.298	1292.760
1960	25.763	25.763	1.836	140.205	140.208	1375.220
1961	15.830	15.830	1.137	142.723	142.728	1379.680
1962	17.916	17.916	1.301	145.241	145.247	1372.800
1963	20.320	20.320	1.491	147.758	147.766	1388.910
1964	12.700	12.700	0.935	150.276	150.287	1408.110
1965	11.566	11.566	0.853	152.794	152.809	1427.710
1966	19.322	19.322	1.433	158.834	158.855	1456.330
1967	21.817	21.817	1.637	164.875	164.903	1486.240
1968	40.505	40.505	3.066	170.916	170.955	1531.180
1969	34.245	34.245	2.601	176.957	177.011	1581.730
1970	54.248	54.248	4.130	182.998	183.071	1629.320
1971	50.075	50.075	3.834	199.633	199.742	1747.570
1972	39.688	39.688	3.069	216.267	216.429	1870.620
1973	39.733	39.733	3.093	232.902	233.141	2006.270
1974	45.766	45.766	3.583	249.536	249.882	2119.980
1975	44.315	44.315	3.509	266.171	266.666	2214.440
1976	53.069	53.069	4.275	266.638	267.276	2146.990
1977	50.941	50.941	4.174	267.106	267.970	2123.580
1978	51.464	51.464	4.250	267.573	268.815	2114.900
1979	45.805	45.805	3.797	268.041	269.808	2121.380
1980	54.023	54.023	4.504	268.508	271.220	2093.410
1981	64.889	64.889	5.512	168.355	188.026	1390.670
1982	57.665	57.665	4.991	458.484	440.118	3215.580
1983	68.285	68.285	6.337	231.254	152.563	929.069
1984	71.777	71.777	6.413	326.631	354.254	3168.740
1985	78.453	78.453	5.877	146.458	89.886	1153.680
1986	87.949	87.948	7.644	158.120	143.001	1551.720
1987	105.686	105.681	9.383	148.328	110.296	1188.510
1988	105.772	105.768	9.908	170.323	147.083	1496.580
1989	137.805	137.798	12.182	137.930	128.566	1386.930
1990	109.050	109.047	9.527	156.980	141.421	1546.600
1991	124.217	124.219	11.669	102.872	120.959	1232.160
1992	157.312	157.316	14.646	189.620	201.238	2066.350
1993	160.150	160.114	14.226	136.290	138.172	1479.210

Table 16 Continued. Observed (Obs) and predicted (Exp) landings by fleet for the commercial and recreational fisheries in weight (ww, metric tons) and number (1000s of fish) for Gulf of Mexico cobia.

Year	Commercial (Obs, ww)	Commercial (Exp, ww)	Commercial (Exp, Number)	Recreational (Obs, Number)	Recreational (Exp, Number)	Recreational (Exp, ww)
1994	159.575	159.540	13.138	158.984	160.705	1862.790
1995	150.153	150.129	12.918	122.661	123.826	1362.260
1996	165.946	165.926	13.868	223.088	200.502	2282.170
1997	136.839	136.836	11.735	230.874	220.465	2436.800
1998	130.826	130.832	11.001	139.162	149.588	1689.510
1999	129.124	129.140	10.643	177.692	197.074	2269.390
2000	96.192	96.212	8.007	130.968	143.395	1634.290
2001	80.607	80.619	6.786	175.600	185.402	2088.950
2002	83.297	83.315	7.057	127.131	140.785	1578.210
2003	88.404	88.421	7.492	155.731	160.848	1799.960
2004	81.386	81.397	6.772	147.476	149.131	1704.900
2005	62.139	62.143	5.389	111.152	110.947	1214.780
2006	68.757	68.763	5.984	165.618	158.684	1732.830
2007	66.855	66.852	5.724	193.034	179.481	1991.920
2008	63.534	63.536	5.373	124.771	133.286	1497.750
2009	62.516	62.509	5.294	104.642	108.849	1220.780
2010	88.585	88.550	7.482	171.329	167.030	1872.940
2011	109.045	109.004	8.916	205.370	200.965	2336.540
2012	63.349	63.346	5.349	142.489	150.278	1683.010
2013	68.643	68.643	5.537	122.356	130.657	1540.170
2014	74.550	74.549	6.102	156.521	175.288	2027.060
2015	60.006	60.015	4.962	121.923	142.921	1638.310
2016	56.132	56.141	4.608	152.307	155.282	1792.660
2017	51.636	51.640	4.182	103.426	108.081	1266.890
2018	33.226	33.228	2.763	148.724	160.029	1823.660

Table 17. Observed (Obs) and predicted (Exp) discards by fleet for the commercial and recreational fisheries in weight (ww, metric tons) and number (1000s of fish) for Gulf of Mexico cobia. Note that the standard error for the commercial and recreational discards were 0.5 and 0.5, respectively.

Year	Commercial (Obs, Number)	Commercial (Exp, Number)	Commercial (Exp, ww)	Recreational (Obs, Number)	Recreational (Exp, Number)	Recreational (Exp, ww)
1981				23.050	8.619	0.110
1982				40.621	32.384	0.390
1983				0.034	1.105	0.030
1984				66.360	20.368	0.230
1985				2.065	148.652	20.410
1986				115.007	195.570	29.910
1987				46.348	220.296	32.020
1988				146.890	194.869	31.590
1989				221.559	160.063	23.980
1990				197.310	277.314	38.970
1991				700.313	228.058	34.000
1992				269.213	292.041	46.430
1993	1.399	2.208	0.535	161.289	134.647	21.790
1994	1.555	2.470	0.524	224.736	236.488	34.790
1995	1.644	2.295	0.532	159.250	145.404	23.060
1996	2.058	2.535	0.556	190.498	268.638	40.840
1997	2.016	2.067	0.477	228.882	256.541	41.150
1998	1.903	1.772	0.408	254.529	163.856	25.920
1999	2.157	1.726	0.392	311.205	224.937	34.860
2000	2.062	1.410	0.317	233.656	178.424	27.610
2001	1.612	1.187	0.269	289.289	225.258	35.020
2002	1.968	1.286	0.288	290.032	178.614	27.960
2003	1.781	1.206	0.282	177.034	172.201	27.340
2004	1.687	1.274	0.276	187.334	212.244	31.390
2005	1.256	1.119	0.247	136.832	163.133	24.990
2006	1.371	1.119	0.254	165.643	201.971	31.780
2007	0.912	0.995	0.227	167.737	214.304	33.500
2008	1.043	0.973	0.217	296.076	173.998	26.380
2009	0.796	1.015	0.224	187.292	148.045	22.950
2010	0.527	1.172	0.277	178.845	170.302	27.430
2011	0.729	1.576	0.344	296.003	261.334	40.090
2012	0.743	0.834	0.200	204.093	147.361	24.300
2013	0.850	0.872	0.195	164.894	150.819	23.050

Table 17 Continued. Observed (Obs) and predicted (Exp) discards by fleet for the commercial and recreational fisheries in weight (ww, metric tons) and number (1000s of fish) for Gulf of Mexico cobia.

Year	Commercial (Obs, Number)	Commercial (Exp, Number)	Commercial (Exp, ww)	Recreational (Obs, Number)	Recreational (Exp, Number)	Recreational (Exp, ww)
2014	0.957	1.020	0.232	235.680	202.203	31.870
2015	1.086	0.816	0.187	316.457	159.647	25.460
2016	0.949	0.695	0.162	189.732	157.937	25.110
2017	0.811	0.705	0.156	175.623	134.440	20.290
2018	0.564	0.522	0.115	338.609	218.124	33.210

Table 18. Observed and predicted shrimp bycatch in 1000s of fish for Gulf of Mexico cobia. Observed shrimp bycatch is calculated using a Bayesian WinBUGS program (SEDAR28U-WP-15), which provides median estimates by year and ‘super-period’. Because the super-period median is itself a Bayesian estimate, it does not represent the frequentist median. Similarly, since the assessment model is configured to fit the Bayesian super-period median, it is not directly constrained to fit the observed bycatch values (yearly fluctuations in bycatch are constrained by forcing the model to fit the shrimp effort time series).

Year	Observed	Expected
1972	170.600	170.479
1973	97.900	170.479
1974	496.200	170.479
1975	237.500	170.479
1976	151.200	170.479
1977	78.700	170.479
1978	79.500	170.479
1979	1087.000	170.479
1980	348.600	170.479
1981	113.300	170.479
1982	306.600	170.479
1983	494.800	170.479
1984	325.100	170.479
1985	363.700	170.479
1986	400.200	170.479
1987	543.000	170.479
1988	261.200	170.479
1989	561.600	170.479
1990	436.100	170.479
1991	524.300	170.479
1992	546.300	170.479
1993	169.100	170.479
1994	172.100	170.479
1995	158.000	170.479
1996	522.400	170.479
1997	783.800	170.479
1998	493.300	170.479
1999	394.100	170.479
2000	131.900	170.479
2001	253.800	170.479
2002	188.700	170.479
2003	40.400	170.479
2004	25.700	170.479

Table 18 Continued. Observed and predicted shrimp bycatch in 1000s of fish for Gulf of Mexico cobia.

Year	Observed	Expected
2005	52.200	170.479
2006	142.300	170.479
2007	35.900	170.479
2008	13.200	170.479
2009	16.900	170.479
2010	5.200	170.479
2011	30.400	170.479
2012	11.600	170.479
2013	9.100	170.479
2014	2.400	170.479
2015	4.000	170.479
2016	4.700	170.479
2017	13.800	170.479

Table 19. Observed and predicted shrimp fishery effort.

Year	Observed	Expected	SE
1945	0.001	0.001	0.009
1946	0.005	0.005	0.009
1947	0.025	0.025	0.009
1948	0.065	0.065	0.009
1949	0.104	0.104	0.009
1950	0.186	0.186	0.009
1951	0.236	0.236	0.009
1952	0.279	0.279	0.009
1953	0.288	0.288	0.009
1954	0.375	0.375	0.009
1955	0.371	0.371	0.009
1956	0.476	0.476	0.009
1957	0.556	0.556	0.009
1958	0.719	0.719	0.009
1959	0.774	0.774	0.009
1960	0.773	0.773	0.009
1961	0.477	0.477	0.009
1962	0.823	0.823	0.009
1963	0.932	0.932	0.009
1964	1.098	1.098	0.009
1965	0.711	0.711	0.009
1966	0.600	0.600	0.009
1967	0.720	0.720	0.009
1968	0.844	0.844	0.009
1969	0.924	0.924	0.009
1970	0.649	0.649	0.009
1971	0.735	0.735	0.009
1972	1.028	1.028	0.009
1973	1.046	1.046	0.009
1974	1.080	1.080	0.009
1975	0.829	0.829	0.009
1976	1.152	1.152	0.009
1977	1.431	1.431	0.009
1978	1.992	1.992	0.009
1979	2.097	2.097	0.009
1980	1.542	1.542	0.009
1981	1.592	1.592	0.009

Table 19 Continued. Observed and predicted shrimp fishery effort.

Year	Observed	Expected	SE
1982	1.523	1.523	0.009
1983	1.649	1.649	0.009
1984	1.691	1.691	0.009
1985	1.821	1.821	0.009
1986	1.918	1.918	0.009
1987	2.229	2.229	0.009
1988	1.684	1.684	0.009
1989	2.012	2.012	0.009
1990	1.959	1.959	0.009
1991	1.873	1.873	0.009
1992	1.627	1.627	0.009
1993	1.523	1.523	0.009
1994	1.667	1.667	0.009
1995	1.432	1.432	0.009
1996	1.535	1.535	0.009
1997	1.568	1.568	0.009
1998	1.703	1.703	0.009
1999	1.775	1.775	0.009
2000	1.587	1.587	0.009
2001	1.541	1.541	0.009
2002	1.366	1.366	0.009
2003	1.112	1.112	0.009
2004	0.858	0.858	0.009
2005	0.516	0.516	0.009
2006	0.685	0.685	0.009
2007	0.671	0.671	0.009
2008	0.576	0.576	0.009
2009	0.675	0.675	0.009
2010	0.479	0.479	0.009
2011	0.457	0.457	0.009
2012	0.629	0.629	0.009
2013	0.465	0.465	0.009
2014	0.611	0.611	0.009
2015	0.470	0.470	0.009
2016	0.533	0.533	0.009
2017	0.532	0.532	0.009
2018	0.512	0.512	0.009

Table 20. Observed versus predicted standardized fishery-dependent catch-per-unit-effort (CPUE) indices and associated lognormal standard error (as estimated by the GLM standardization model) for Gulf of Mexico cobia. Values are normalized to the mean and standard error has been normalized to an average value of 0.2 within each sector to preserve interannual variability in the weighting of data sets in the assessment.

Year	Headboat (Obs)	Headboat (Exp)	Headboat (SE)	MRIP (Obs)	MRIP (EXP)	MRIP (SE)
1981				0.816	1.092	0.473
1982				1.220	0.985	0.318
1983				0.791	1.151	0.428
1984				0.726	0.685	0.390
1985				0.671	0.649	0.439
1986	0.487	0.609	0.148	0.542	0.636	0.295
1987	0.466	0.587	0.234	0.783	0.776	0.277
1988	0.610	0.746	0.213	0.989	0.763	0.285
1989	0.527	0.720	0.188	1.074	0.711	0.312
1990	0.679	0.653	0.279	1.673	0.854	0.275
1991	0.922	0.863	0.168	1.659	1.092	0.241
1992	1.022	1.083	0.078	1.126	1.168	0.194
1993	1.241	1.207	0.213	1.061	1.042	0.238
1994	1.087	1.066	0.153	1.421	1.157	0.212
1995	1.055	1.252	0.188	0.697	1.190	0.265
1996	1.194	1.222	0.213	1.217	1.256	0.221
1997	1.325	1.227	0.133	1.401	1.167	0.200
1998	1.050	1.189	0.229	1.205	1.091	0.185
1999	1.095	1.076	0.043	1.124	1.013	0.160
2000	0.837	1.015	0.178	0.820	0.999	0.177
2001	1.082	0.979	0.108	0.957	0.953	0.168
2002	0.962	0.949	0.103	0.977	0.944	0.161
2003	0.763	0.940	0.138	1.054	0.854	0.166
2004	0.818	0.823	0.339	0.866	0.877	0.178
2005	1.044	0.918	0.269	0.814	0.993	0.198
2006	1.132	1.038	0.304	0.797	1.035	0.191
2007	1.177	1.029	0.153	0.863	0.992	0.192
2008	1.261	1.022	0.133	0.929	1.032	0.186
2009	1.123	1.146	0.148	0.796	1.182	0.209
2010	1.487	1.286	0.259	0.973	1.137	0.207
2011	1.229	1.132	0.208	1.122	1.145	0.190
2012	1.502	1.188	0.123	0.871	1.029	0.189
2013	1.203	1.103	0.173	0.825	1.040	0.214
2014	1.200	1.071	0.123	1.354	1.012	0.174

Table 20 Continued. Observed versus predicted standardized fishery-dependent catch-per-unit-effort (CPUE) indices and associated lognormal standard error (as estimated by the GLM standardization model) for Gulf of Mexico cobia.

Year	Headboat (Obs)	Headboat (Exp)	Headboat (SE)	MRIP (Obs)	MRIP (EXP)	MRIP (SE)
2015	0.818	1.040	0.158	0.853	0.965	0.182
2016	0.962	0.984	0.108	0.990	0.871	0.196
2017	0.877	0.917	0.259	1.037	0.900	0.206
2018	0.761	0.924	0.254	0.905	0.959	0.225

Table 21. Summary of moderately correlated (correlation coefficient > 0.9) parameters for Gulf of Mexico cobia.

Parameter 1	Parameter 2	Correlation
Size_95%width_Com_Combined_1(1)	Size_inflection_Com_Combined_1(1)	0.813
SR_BH_steep	SR_LN(R0)	-0.970

Table 22. Summary of key model building runs towards the SEDAR 28 Update Base Model for Gulf of Mexico cobia. Note that steps within each model progression are not shown due to the vast number of intermediate runs conducted. Gray cells denote parameter values that were fixed in the respective model runs.

Model Short Name	Description	SS Version	NLL	Gradient	Estimated Parameters (Bounded)	Steepness	Sigma R	Ln(R0)	Virgin SSB	Virgin Recruitment (1000s)	L_{max}	K
S28	SEDAR 28 (2013) Stock Assessment Report Base Model; terminal year 2011	3.24	1127.210	0.014	227 (0)	0.925	0.6	6.94	7235.4	1033.13	133.3	0.21
Step 1	**S28** model + rec. landings updated to FES estimates; terminal year 2011	3.24	1176.810	0.007	227 (0)	0.664	0.6	7.81	17642.4	2455.41	140.5	0.18
Step 2	**S28** model + all data inputs updated through terminal year 2018	3.24	3164.280	0.012	304 (0)	0.713	0.6	7.84	15952.2	2546.16	110.5	0.37
Step 3a	**Step 2** model + fixed steepness of 0.8	3.24	3146.150	0.002	303 (0)	0.800	0.6	7.71	14446.4	2231.90	113.9	0.33
Step 3b	**Step 2** model + fixed shrimp selectivity + fixed Lmax and K	3.24	3301.150	0.127	296 (0)	0.913	0.6	7.41	15497.9	1658.40	128.1	0.42
Step 4	**Step 3b** model + Francis reweighting and variance adjustment	3.24	279.742	0.013	296 (0)	0.789	0.6	7.55	18007.0	1904.46	128.1	0.42
S28U	**Step 4** model transitioned to SS3.30 to facilitate mean recruitment projections	3.3	279.795	0.009	316 (0)	0.789	0.6	7.55	18016.5	1905.64	128.1	0.42

Table 23. Summary of sensitivity runs conducted on the SEDAR28 Update Base Model for Gulf of Mexico cobia. R_0 is the unfished number of recruits (1000s of fish) and current conditions are for 2018. Both Biomass (B) and Spawning Stock Biomass (SSB) units are in metric tons.

Model	R_0	Steepness	B_0	$B_{current}$	SSB_0	$SSB_{current}$	$SSB_{current}/SSB_0$
Base model	1906	0.789	20410	5106	18017	3725	0.210
Low M	1139	0.879	29344	3927	27410	2952	0.110
High M	3216	0.789	16745	7151	13739	5027	0.370
High Discard M	1857	0.821	19883	5140	17553	4065	0.230

Table 24. Settings used for Gulf of Mexico cobia projections.

Parameter	Value	Comment
Relative F	Average from 2016 – 2018	Average relative fishing mortality over terminal three years (2016-2018) of model
Selectivity	Estimates from 2018	Fleet specific selectivity estimated in terminal year
Recruitment	1,263,050	Bias adjusted geometric mean recruitment averaged over recent time period (2005 – 2014)
		Time-invariant in projections
Shrimp Bycatch	F = 0.0684	Average shrimp bycatch fishing mortality over terminal three years (2016-2018) of model
		Time-invariant in projections
2019 Landings	Comm. = 15.98 (mt ww), Rec. = 125,043 fish	Provisoinal 2019 Landings adjusted to FES (SERO)
2020 Landings	Comm. = 33.61 (mt ww), Rec. = 125,731 fish	Three year (2017-2019) average.

Table 25. Summary of MSRA benchmarks and reference points for the SEDAR28 Update Gulf of Mexico cobia assessment. SSB is in metric tons, whereas F is a harvest rate (total biomass killed / total biomass).

Criteria	Definition	SEDAR 28 Update Value
Base M	Fully selected ages of Lorenzen M	0.38
Steepness	Estimated SR parameter (not used in projections)	0.713
Virgin Recruitment	Estimated SR parameter (not used in projections)	2.73E+07
Generation Time	Fecundity-weighted mean age	5.51
SSB Unfished	Estimated virgin spawning stock biomass	18016
Mortality Rate Criteria		
$F_{SPR30\%}$	Equilibrium F that achieves $SPR_{30\%}$	0.231
MFMT $F_{SPR30\%}$	$F_{SPR30\%}$	0.231
F at Optimum Yield	0.75 * Directed F at $F_{SPR30\%}$	0.179
$F_{Current}$	Average (F_{2016} - F_{2018})	0.33
$F_{Current}/MFMT_{FSPR30\%}$	Current stock status based on $F_{SPR30\%}$	1.44
Biomass Criteria		
$SSB_{FSPR30\%}$	Equilibrium SSB at $F_{SPR30\%}$	5406
$MSST_{FSPR30\%}$	(1-M)*$SSB_{FSPR30\%}$	3352
SSB at Optimum Yield	Equilibrium SSB when Directed F = 0.75 * Directed F at $F_{SPR30\%}$	6227
SSB_0	Virgin SSB	18016
$SSB_{Current}$	SSB_{2018}	3725
$SSB_{Current}/ SSB_{FSPR30\%}$	Current stock status based on $SSB_{FSPR30\%}$	0.69
$SSB_{Current}/ MSST_{FSPR30\%}$	Current stock status based on $MSST_{FSPR30\%}$	1.11
$SSB_{Current}/ SSB_0$	2018 SPR	0.21

Table 26. Time series of fishing mortality and SSB relative to associated SPR based biological reference points (i.e., $F_{SPR30\%}$ and $SSB_{FSPR30\%}$). $MSST_{FSPR30\%}$ is calculated as (1-M) * $SSB_{FSPR30\%}$. SPR was calculated as annual SSB divided by SSB_0 (18017 mt). SSB is in metric tons, whereas F is a harvest rate (total biomass killed / total biomass). Red text identifies years exceeding the thresholds.

YEAR	F	$F/F_{SPR30\%}$	SSB	$SSB/SSB_{FSPR30\%}$	$SSB/MSST_{FSPR30\%}$	SPR
1927	0.00	0.00	18017	3.33	5.37	1.00
1928	0.00	0.00	18013	3.33	5.37	1.00
1929	0.00	0.00	18005	3.33	5.37	1.00
1930	0.00	0.00	18002	3.33	5.37	1.00
1931	0.00	0.00	18000	3.33	5.37	1.00
1932	0.00	0.00	17999	3.33	5.37	1.00
1933	0.00	0.00	18001	3.33	5.37	1.00
1934	0.00	0.00	18002	3.33	5.37	1.00
1935	0.00	0.00	18003	3.33	5.37	1.00
1936	0.00	0.00	18004	3.33	5.37	1.00
1937	0.00	0.00	18005	3.33	5.37	1.00
1938	0.00	0.00	18007	3.33	5.37	1.00
1939	0.00	0.00	18006	3.33	5.37	1.00
1940	0.00	0.00	18006	3.33	5.37	1.00
1941	0.00	0.00	18008	3.33	5.37	1.00
1942	0.00	0.00	18010	3.33	5.37	1.00
1943	0.00	0.00	18012	3.33	5.37	1.00
1944	0.00	0.00	18013	3.33	5.37	1.00
1945	0.00	0.00	18013	3.33	5.37	1.00
1946	0.00	0.00	18014	3.33	5.37	1.00
1947	0.00	0.00	18014	3.33	5.37	1.00
1948	0.00	0.00	18014	3.33	5.37	1.00
1949	0.00	0.00	18007	3.33	5.37	1.00
1950	0.00	0.01	17980	3.33	5.36	1.00
1951	0.01	0.03	17908	3.31	5.34	0.99
1952	0.01	0.06	17727	3.28	5.29	0.98
1953	0.03	0.12	17429	3.22	5.20	0.97
1954	0.04	0.18	16929	3.13	5.05	0.94
1955	0.05	0.23	16274	3.01	4.85	0.90
1956	0.06	0.26	15580	2.88	4.65	0.86
1957	0.07	0.29	14926	2.76	4.45	0.83

Table 26 Continued. Time series of stock status.

YEAR	F	$F/F_{SPR30\%}$	SSB	$SSB/SSB_{FSPR30\%}$	$SSB/MSST_{FSPR30\%}$	SPR
1958	0.08	0.33	14301	2.65	4.27	0.79
1959	0.08	0.37	13687	2.53	4.08	0.76
1960	0.09	0.41	13059	2.42	3.90	0.72
1961	0.10	0.42	12422	2.30	3.71	0.69
1962	0.10	0.44	11889	2.20	3.55	0.66
1963	0.11	0.46	11508	2.13	3.43	0.64
1964	0.11	0.48	11203	2.07	3.34	0.62
1965	0.11	0.49	10861	2.01	3.24	0.60
1966	0.12	0.52	10504	1.94	3.13	0.58
1967	0.13	0.54	10194	1.89	3.04	0.57
1968	0.13	0.58	10006	1.85	2.99	0.56
1969	0.14	0.60	9814	1.82	2.93	0.54
1970	0.15	0.64	9574	1.77	2.86	0.53
1971	0.16	0.70	9270	1.71	2.77	0.51
1972	0.18	0.77	8934	1.65	2.67	0.50
1973	0.20	0.86	8586	1.59	2.56	0.48
1974	0.22	0.96	8108	1.50	2.42	0.45
1975	0.25	1.06	7524	1.39	2.24	0.42
1976	0.26	1.11	6917	1.28	2.06	0.38
1977	0.27	1.17	6463	1.20	1.93	0.36
1978	0.29	1.24	6087	1.13	1.82	0.34
1979	0.31	1.33	5663	1.05	1.69	0.31
1980	0.33	1.44	5152	0.95	1.54	0.29
1981	0.25	1.07	4601	0.85	1.37	0.26
1982	0.53	2.30	4735	0.88	1.41	0.26
1983	0.20	0.85	3434	0.64	1.02	0.19
1984	0.57	2.47	4455	0.82	1.33	0.25
1985	0.36	1.54	2879	0.53	0.86	0.16
1986	0.49	2.12	2342	0.43	0.70	0.13
1987	0.40	1.72	2231	0.41	0.67	0.12
1988	0.43	1.86	2480	0.46	0.74	0.14
1989	0.42	1.82	2770	0.51	0.83	0.15
1990	0.45	1.93	2623	0.49	0.78	0.15
1991	0.32	1.39	2659	0.49	0.79	0.15
1992	0.40	1.75	3691	0.68	1.10	0.20
1993	0.30	1.30	4160	0.77	1.24	0.23
1994	0.35	1.50	4489	0.83	1.34	0.25

Table 26 Continued. Time series of stock status.

YEAR	F	$F/F_{SPR30\%}$	SSB	$SSB/SSB_{FSPR30\%}$	$SSB/MSST_{FSPR30\%}$	SPR
1995	0.26	1.11	4303	0.80	1.28	0.24
1996	0.37	1.60	5026	0.93	1.50	0.28
1997	0.40	1.73	4764	0.88	1.42	0.26
1998	0.31	1.33	4572	0.85	1.36	0.25
1999	0.41	1.77	4597	0.85	1.37	0.26
2000	0.33	1.42	3988	0.74	1.19	0.22
2001	0.41	1.77	4004	0.74	1.19	0.22
2002	0.34	1.46	3657	0.68	1.09	0.20
2003	0.39	1.68	3727	0.69	1.11	0.21
2004	0.39	1.69	3453	0.64	1.03	0.19
2005	0.28	1.20	3205	0.59	0.96	0.18
2006	0.34	1.48	3817	0.71	1.14	0.21
2007	0.38	1.65	4034	0.75	1.20	0.22
2008	0.30	1.30	3861	0.71	1.15	0.21
2009	0.23	0.98	4085	0.76	1.22	0.23
2010	0.31	1.33	4832	0.89	1.44	0.27
2011	0.38	1.66	4894	0.91	1.46	0.27
2012	0.30	1.30	4384	0.81	1.31	0.24
2013	0.28	1.21	4533	0.84	1.35	0.25
2014	0.36	1.57	4406	0.81	1.31	0.24
2015	0.31	1.36	4108	0.76	1.23	0.23
2016	0.36	1.54	4057	0.75	1.21	0.23
2017	0.28	1.19	3677	0.68	1.10	0.20
2018	0.37	1.59	3725	0.69	1.11	0.21

Table 27. Results of projections that achieve an SPR of 30% in equilibrium for Gulf of Mexico cobia. Recruitment is in 1000s of age-0 fish, F is the harvest rate (total biomass killed / total biomass), SSB is in metric tons, OFL is the overfishing limit in millions of pounds and ABC is the acceptable biological catch in millions of pounds based on P* of 0.434. Reference points are provided in Table 11.

YEAR	R	F	F/MFMT	SSB	$SSB/SSB_{FSPR30\%}$	SSB/MSST	SSB/SSB_0	OFL	ABC
2021	1263.05	0.230	0.996	4.66E+03	0.86	1.39	0.26	3.03	2.89
2022	1263.05	0.231	0.999	4.99E+03	0.92	1.49	0.28	3.21	3.11
2023	1263.05	0.231	1.000	5.19E+03	0.96	1.55	0.29	3.31	3.25
2024	1263.05	0.231	1.000	5.29E+03	0.98	1.58	0.29	3.37	3.32
2025	1263.05	0.231	1.000	5.35E+03	0.99	1.59	0.30	3.40	3.36
2026	1263.05	0.231	1.000	5.37E+03	0.99	1.60	0.30	3.41	3.38
2027	1263.05	0.231	1.000	5.39E+03	1.00	1.61	0.30	3.42	3.39
2028	1263.05	0.231	1.000	5.40E+03	1.00	1.61	0.30	3.42	3.39
2029	1263.05	0.231	1.000	5.40E+03	1.00	1.61	0.30	3.42	3.39
2030	1263.05	0.231	1.000	5.40E+03	1.00	1.61	0.30	3.43	3.40

Table 28. Results of projections at optimum yield (directed F = 0.75*Directed F at $F_{SPR30\%}$) including recruitment (R in 1000s of age-0 fish), fishing mortality (F), F/MFMT (MFMT = $F_{SPR30\%}$), spawning biomass (SSB in metric tons), $SSB/SSB_{FSPR30\%}$, $SSB/MSST_{FSPR30\%}$, SSB/SSB_0, and optimum yield (OY; retained yield in millions of pounds).

YEAR	R	F	F/MFMT	SSB	$SSB/SSB_{FSPR30\%}$	SSB/MSST	SSB/SSB_0	OY
2021	1263.05	0.178	0.771	4.66E+03	0.86	1.39	0.26	2.34
2022	1263.05	0.179	0.775	5.26E+03	0.97	1.57	0.29	2.60
2023	1263.05	0.179	0.777	5.66E+03	1.05	1.69	0.31	2.76
2024	1263.05	0.180	0.778	5.90E+03	1.09	1.76	0.33	2.86
2025	1263.05	0.180	0.778	6.04E+03	1.12	1.80	0.34	2.91
2026	1263.05	0.180	0.778	6.12E+03	1.13	1.83	0.34	2.95
2027	1263.05	0.180	0.778	6.17E+03	1.14	1.84	0.34	2.96
2028	1263.05	0.180	0.778	6.19E+03	1.15	1.85	0.34	2.97
2029	1263.05	0.180	0.778	6.21E+03	1.15	1.85	0.34	2.98
2030	1263.05	0.180	0.778	6.22E+03	1.15	1.85	0.35	2.98

Table 29. Summary of projections that achieve an SPR of 30% in equilibrium completed for Gulf of Mexico cobia using the original SEDAR28 Base Model, the SEDAR28 Base Model with the recreational data updated to the FES values, and the SEDAR28 Update Base Model. Shown are the terminal data year of each assessment, average (2002 – 2011) spawning stock biomass (SSB in metric tons), average (2002 – 2011) recruitment (R in number of fish), $F_{SPR30\%}$ (MFMT), virgin spawning biomass (SSB0 in metric tons), $SSB_{FSPR30\%}$, and equilibrium yield (retained yield in millions of pounds).

Model	Terminal Year	SSB	R	F_{SPR30}	SSB_0	SSB_{FSPR30}	Equil. Yield
SEDAR 28	2011	1896	751.5	0.378	7235	2065	2.66
SEDAR 28 FES	2011	3643	1429.5	0.094	17642	5280	4.87
SEDAR 28 Update	2018	3956	1270.9	0.231	18016	5406	3.43

10. Figures

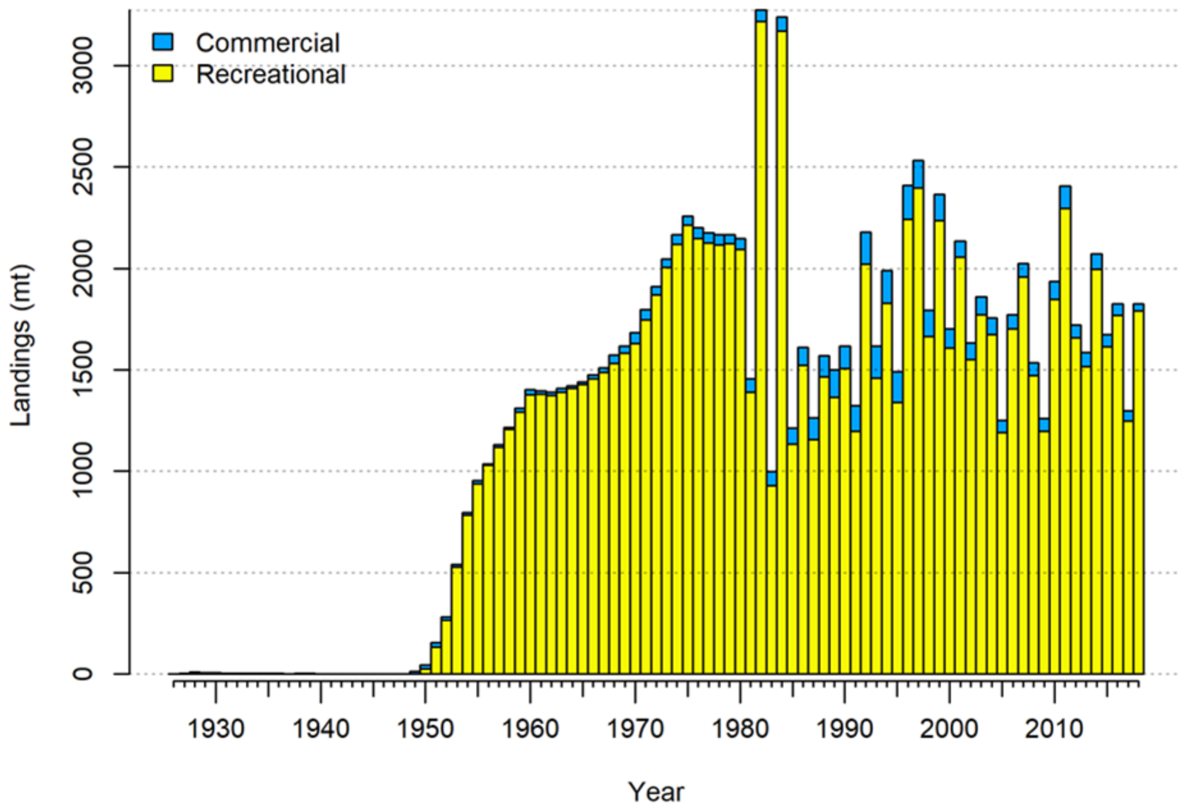


Figure 1. Gulf of Mexico cobia estimated landings history, 1927 - 2018.

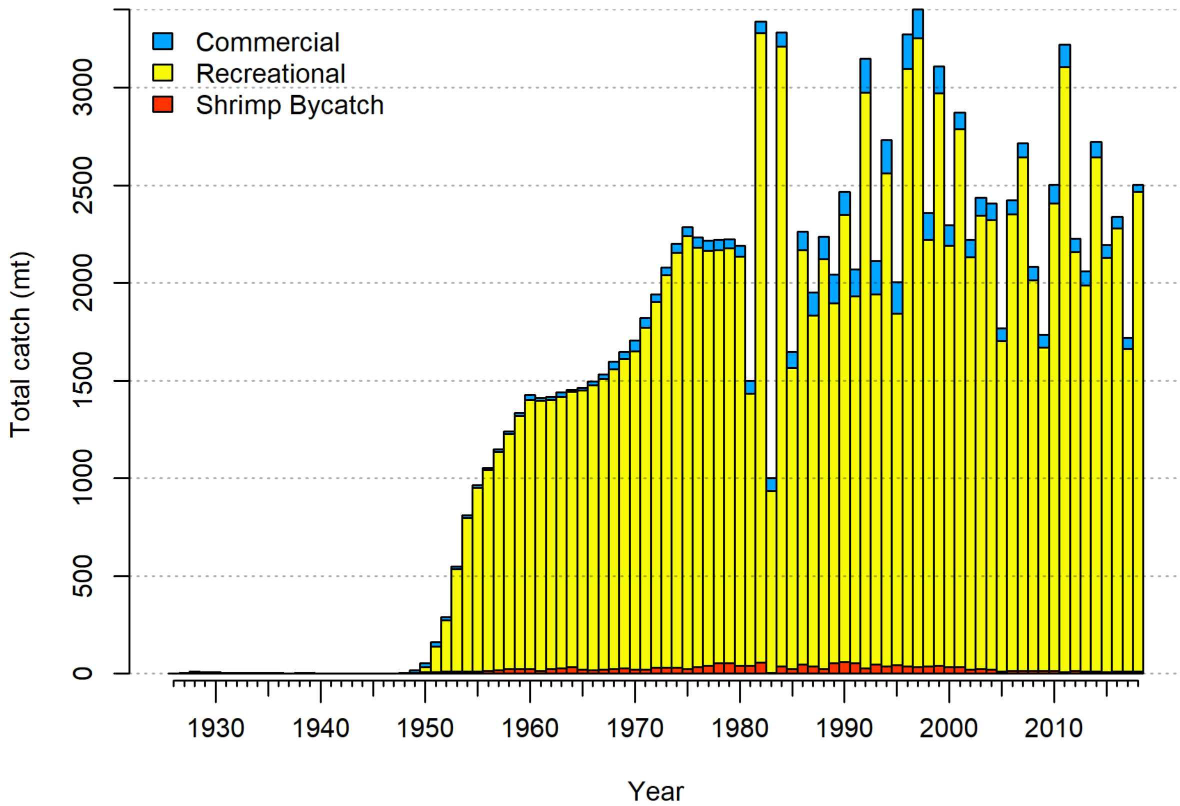


Figure 2. Gulf of Mexico cobia estimated catch history, 1927 - 2018. Estimated catch includes both landings and discards.

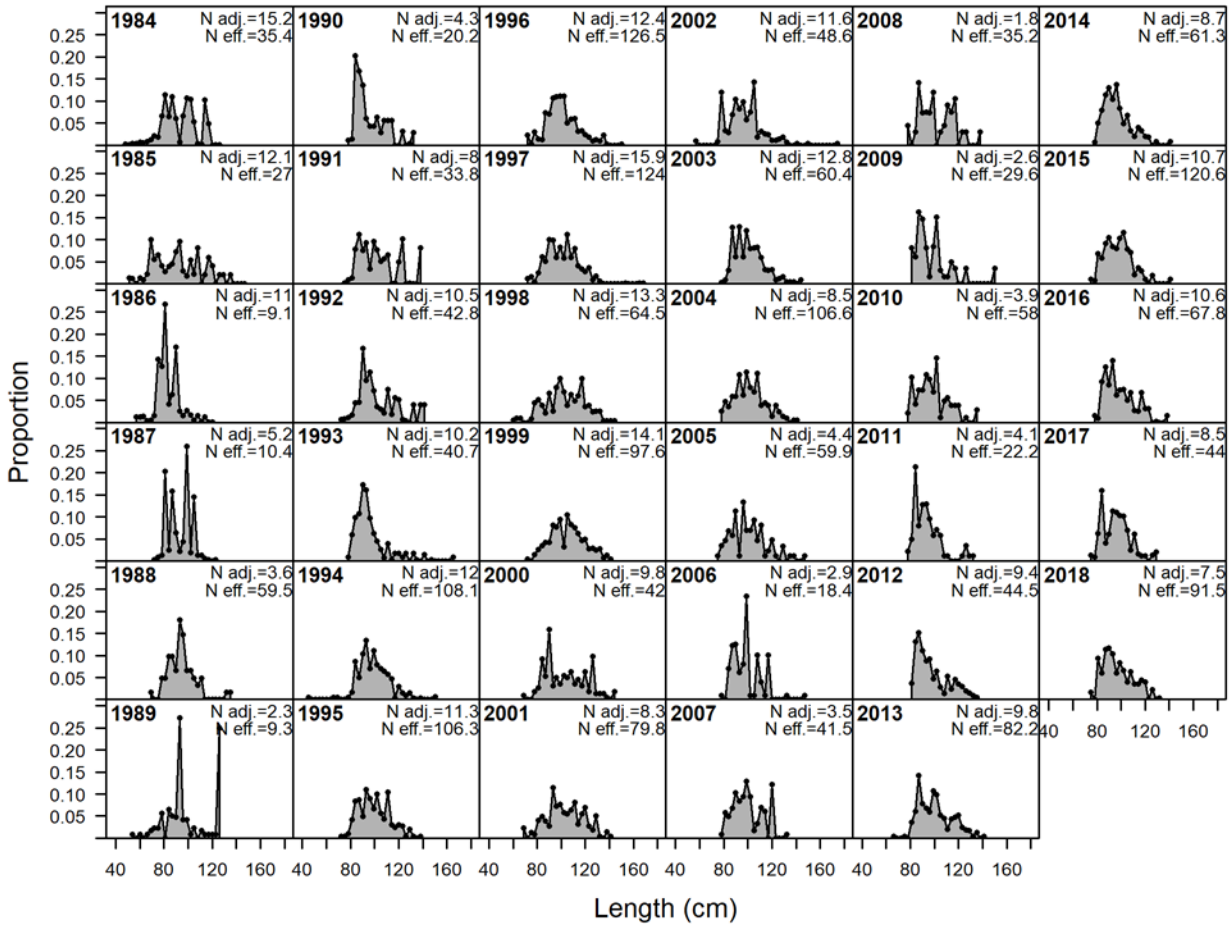


Figure 3. Observed length composition data (retained) of Gulf of Mexico cobia in the Commercial fishery. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported.

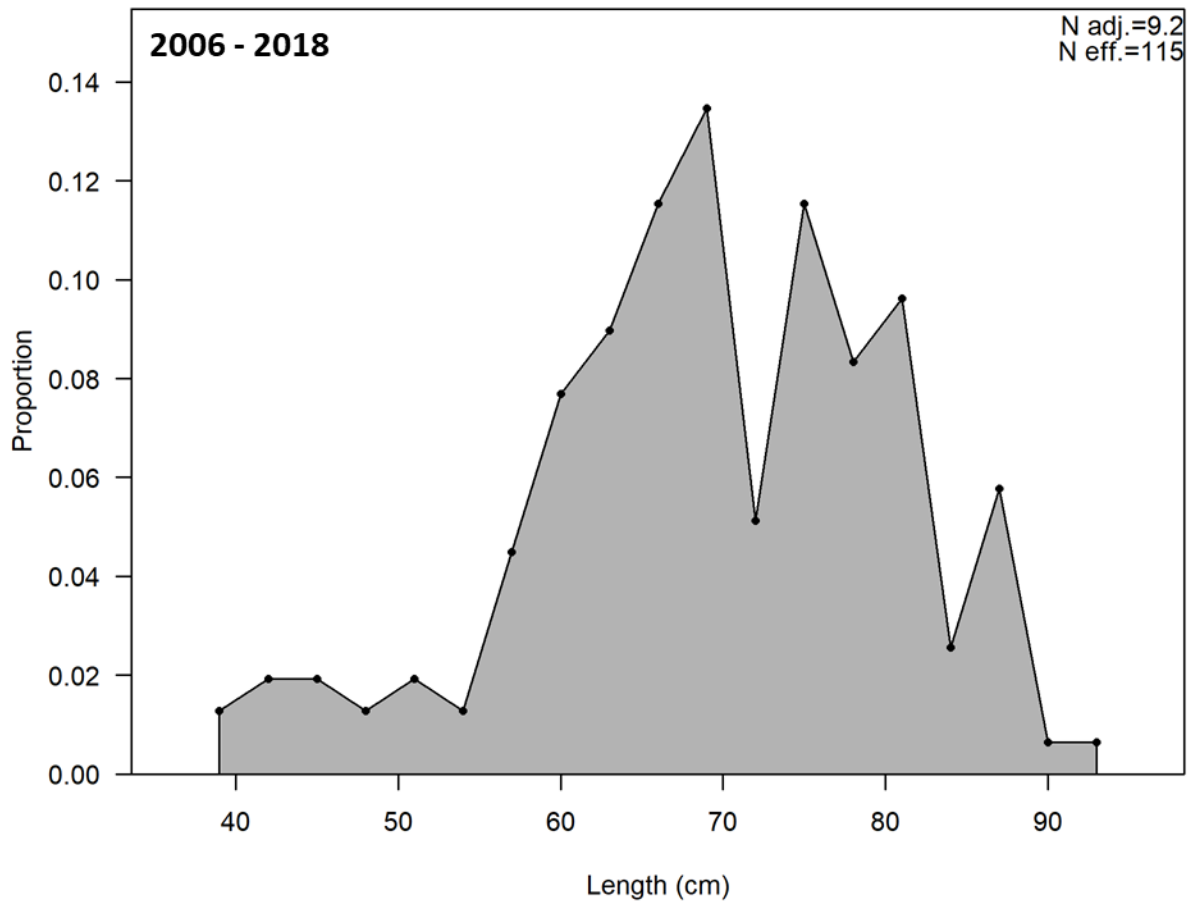


Figure 4. Observed length composition data (discarded) for Gulf of Mexico cobia from the Reef Fish Observer Program. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported.

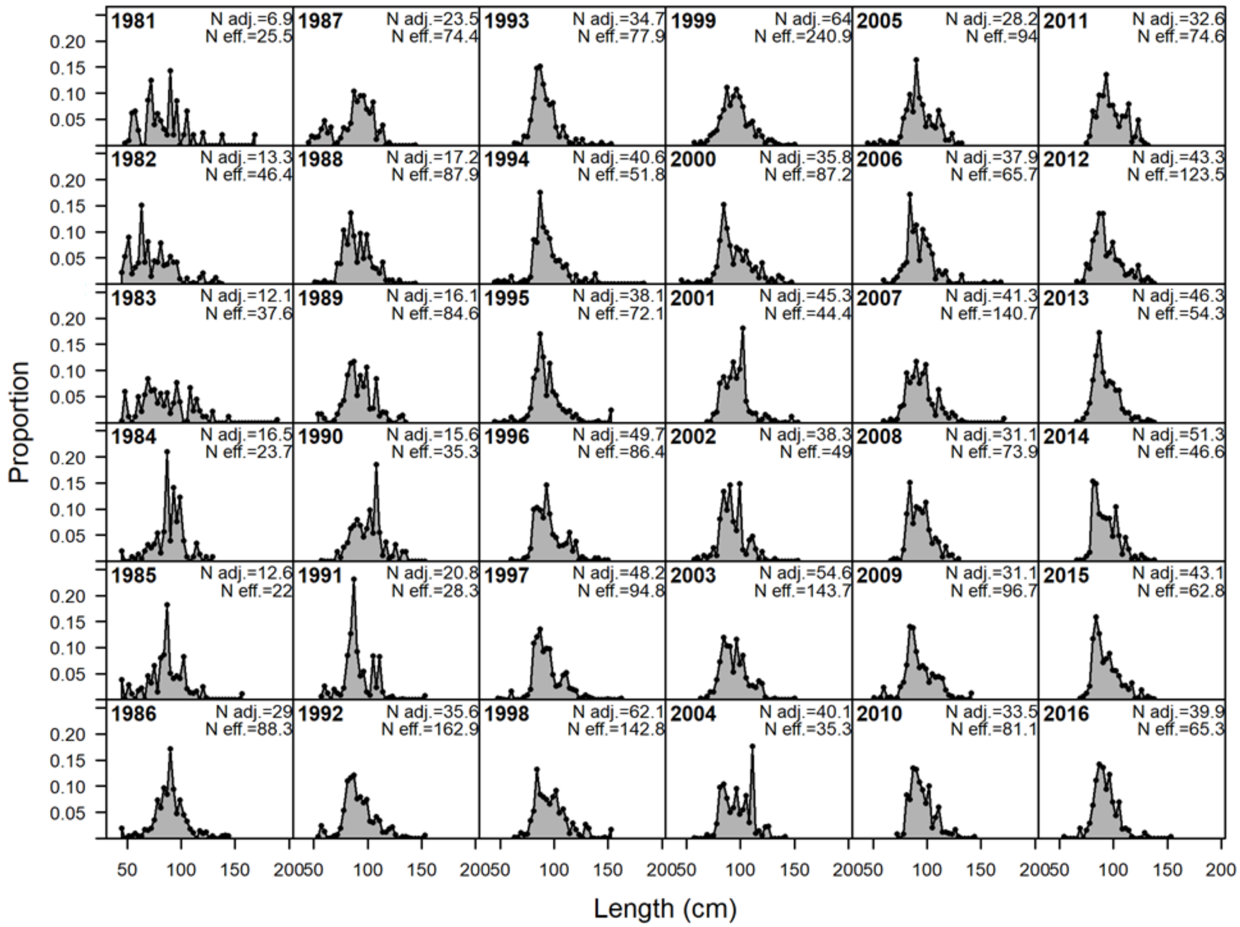


Figure 5. Observed length composition data (retained) of Gulf of Mexico cobia in the Recreational fishery. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported.

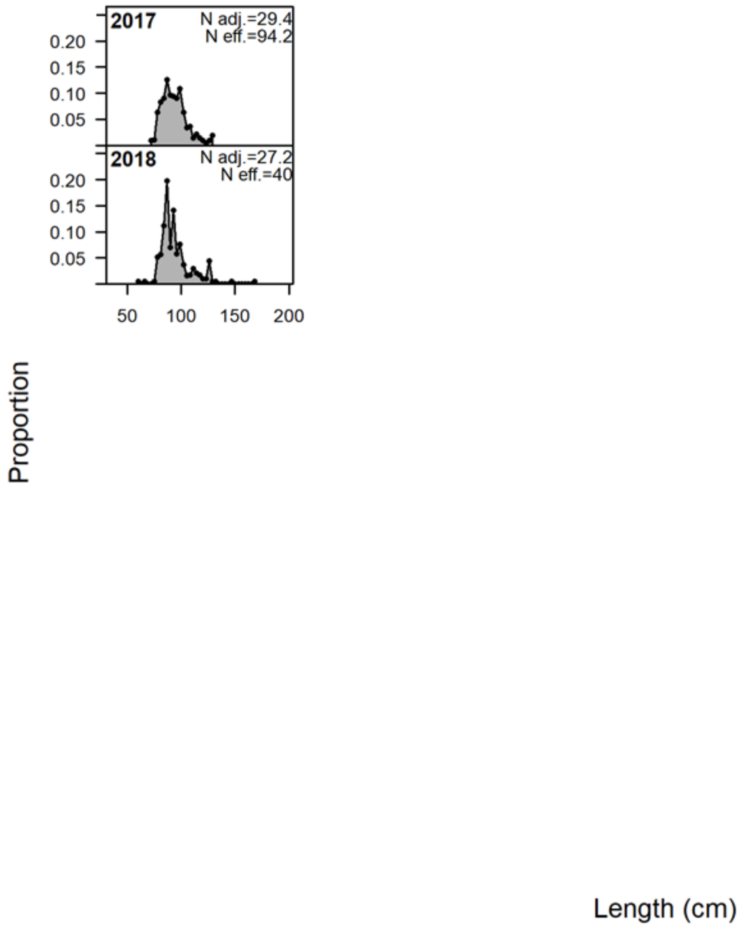


Figure 5 Continued. Observed length composition data (retained) of Gulf of Mexico cobia in the Recreational fishery. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported.

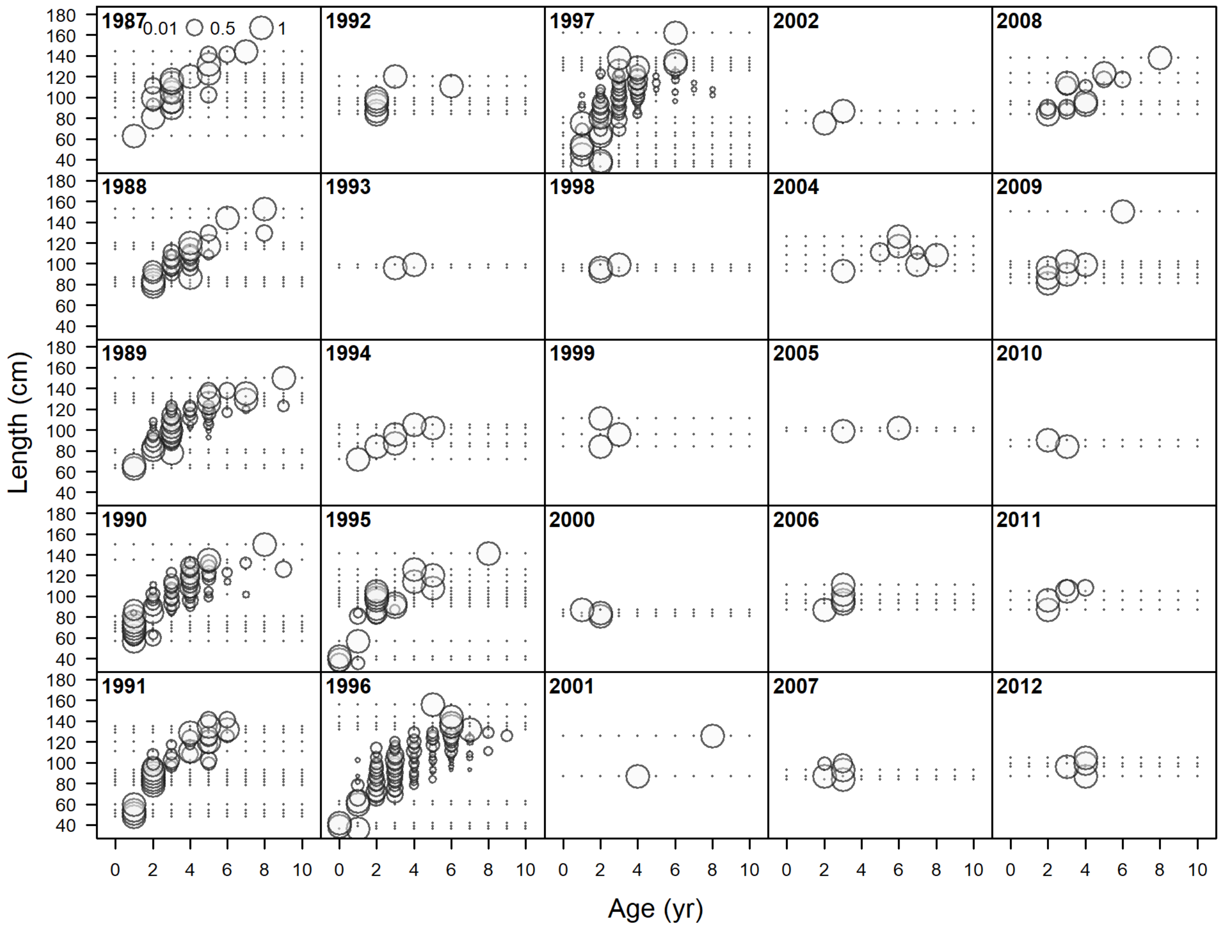


Figure 6. Observed conditional age-at-length data (retained) for Gulf of Mexico cobia in the Recreational fishery.

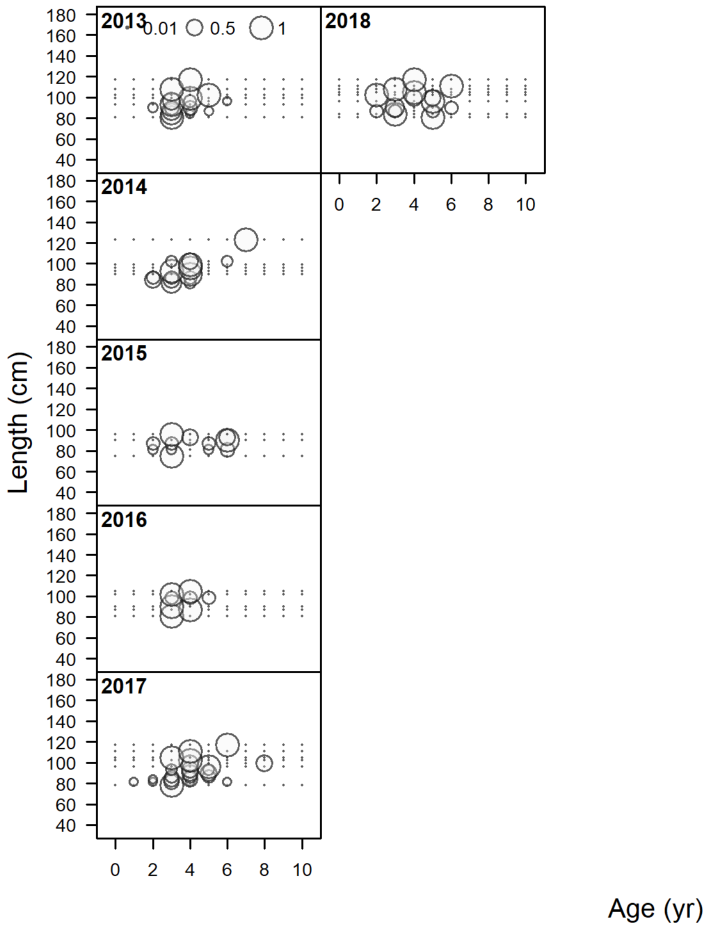


Figure 6 Continued. Observed conditional age-at-length data (retained) for Gulf of Mexico cobia in the Recreational fishery.

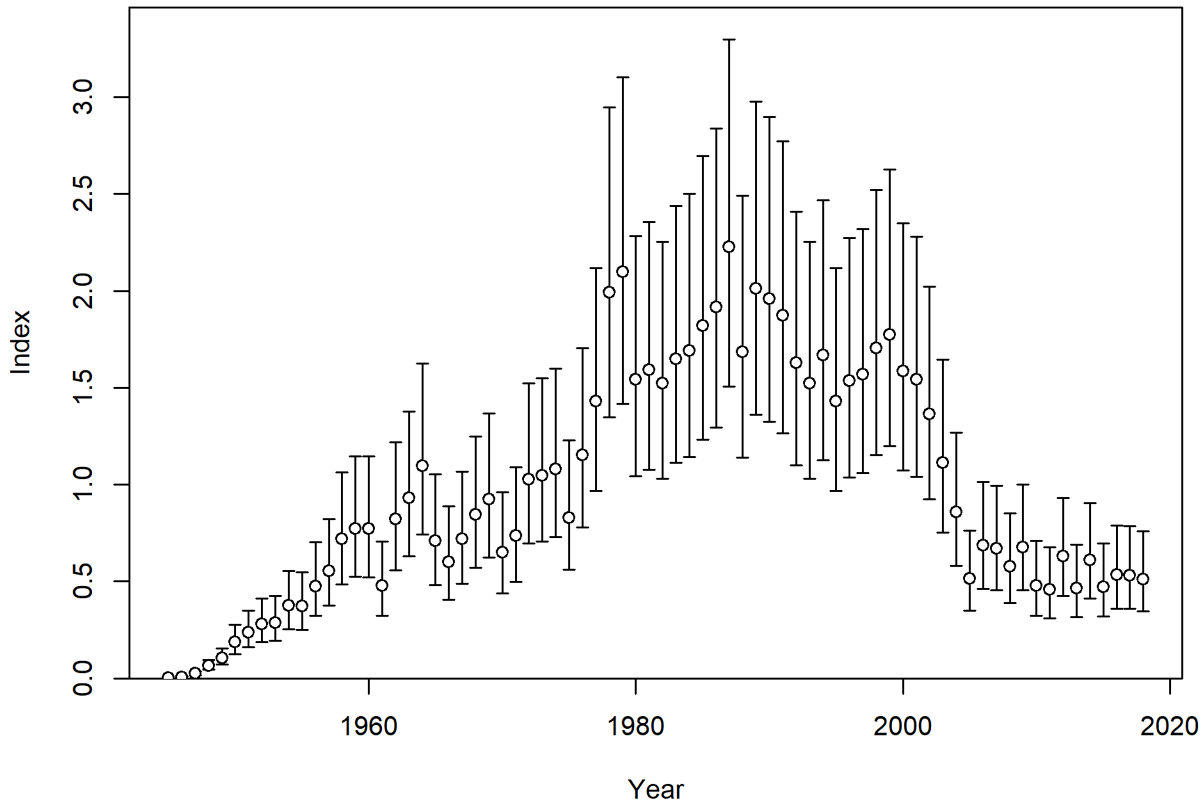


Figure 7. Standardized index of effort and standard errors (associated with input CVs relativized to mean of 0.2) from the shrimping fleet in the Gulf of Mexico.

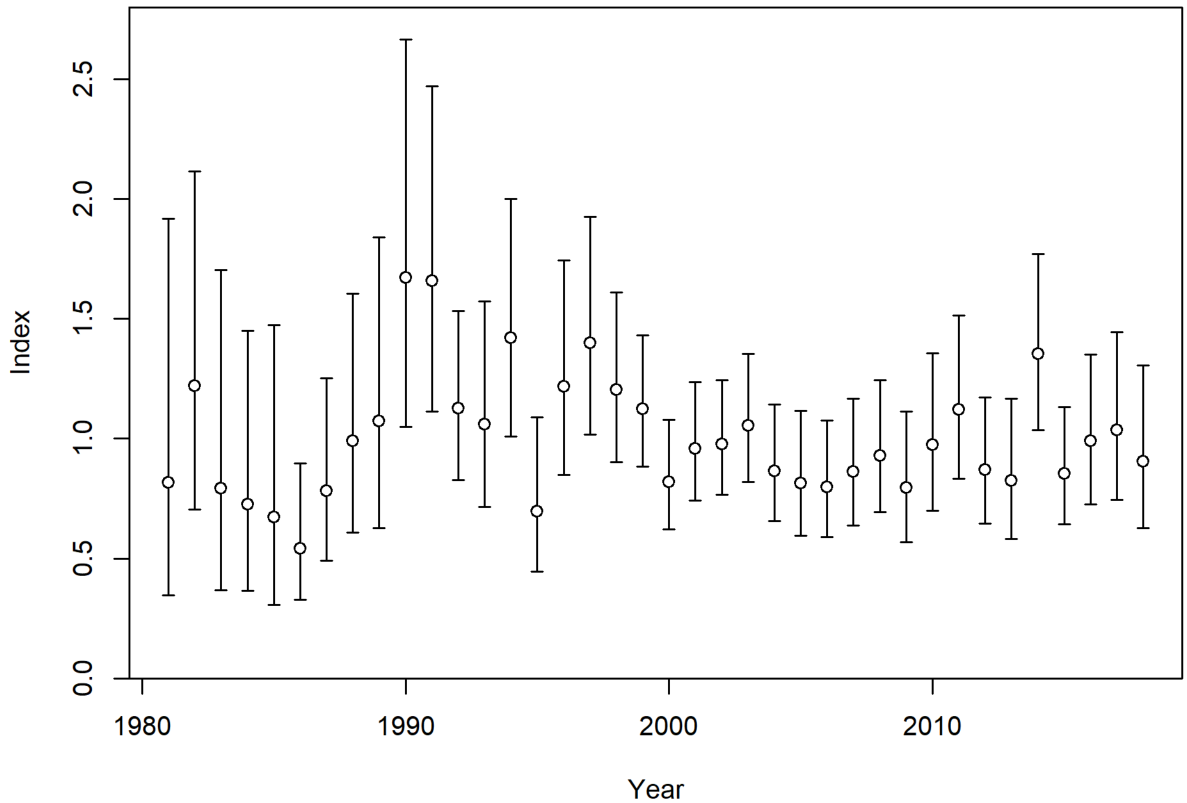


Figure 8. Standardized index of relative abundance and standard errors (associated with input CVs relativized to mean of 0.2) for Gulf of Mexico cobia from the recreational Charter/Private fishery.

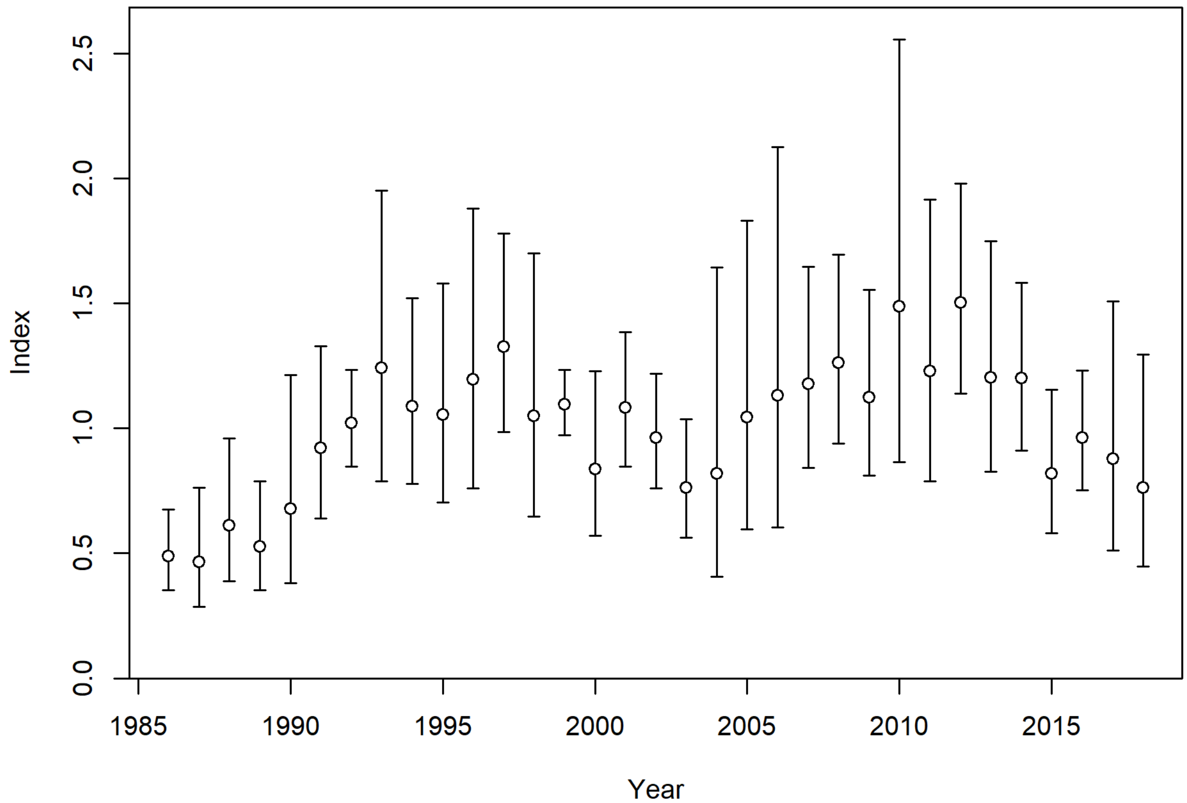


Figure 9. Standardized index of relative abundance and standard errors (associated with input CVs relativized to mean of 0.2) for Gulf of Mexico cobia from the recreational Headboat fishery.

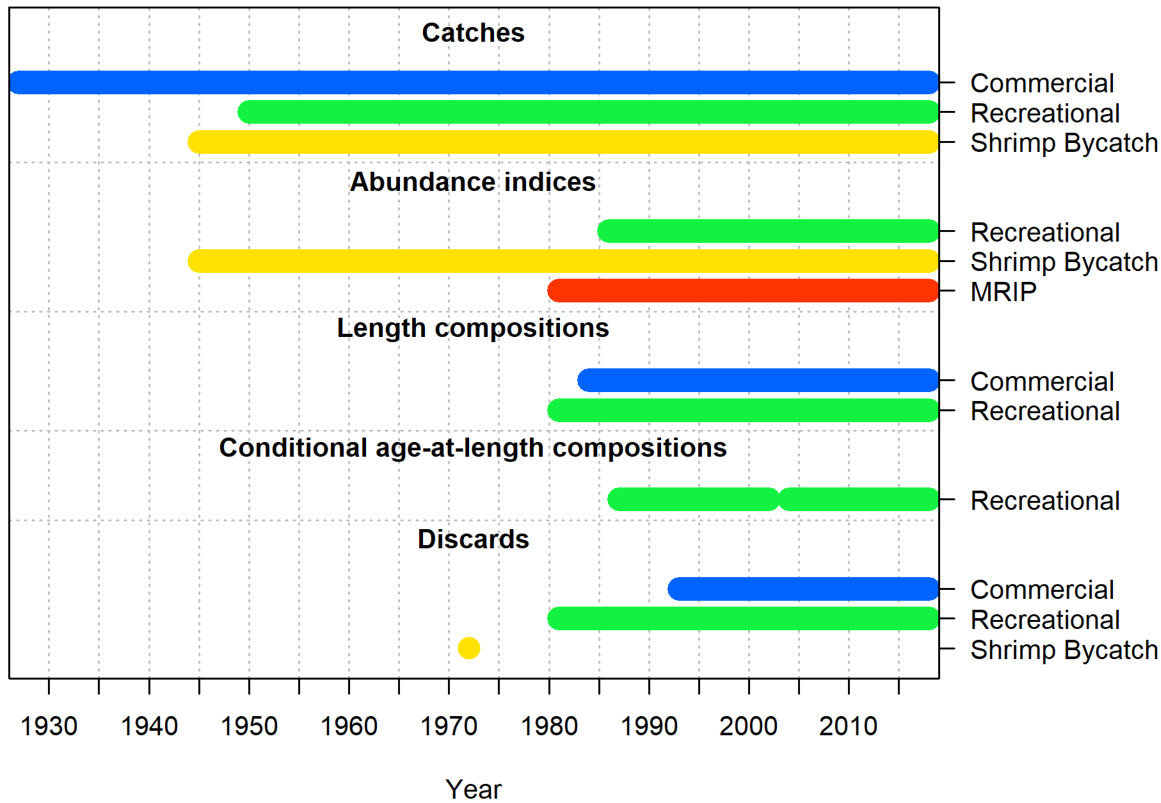


Figure 10. Data sources used in the assessment model for Gulf of Mexico cobia. Two recreational abundance indices are included: Recreational (Headboat) and MRIP (Charter/Private). The shrimp bycatch super-period actually covers years 1972-2017 (i.e., the median values correspond to observed and predicted bycatch values for these years).

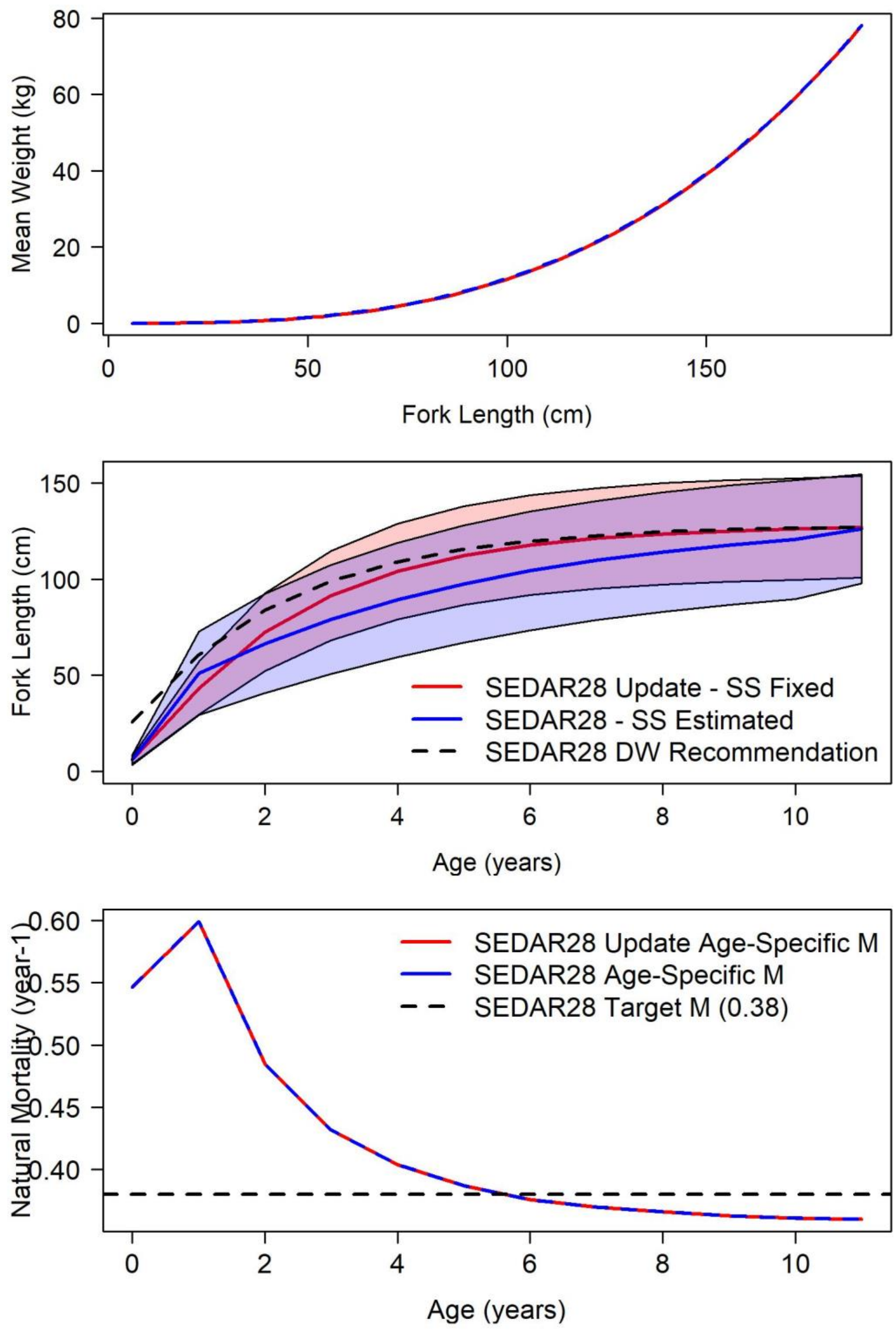
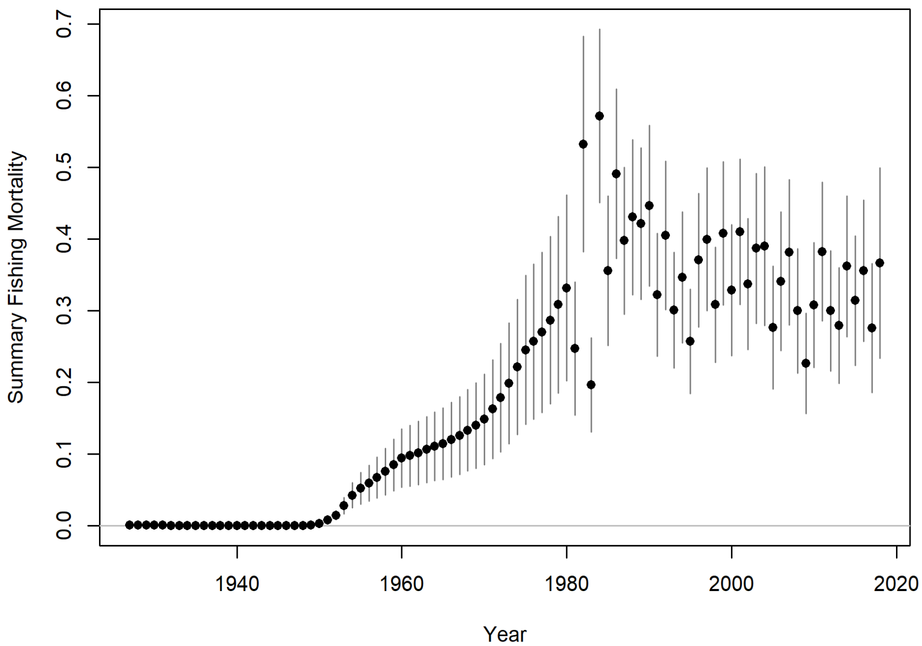


Figure 11. Mean weight-at-length (top panel), recommended and estimated growth curves with 95% confidence intervals (middle panel), and natural mortality (bottom panel) used in the assessment model for Gulf of Mexico cobia.

SEDAR28 Update



SEDAR28

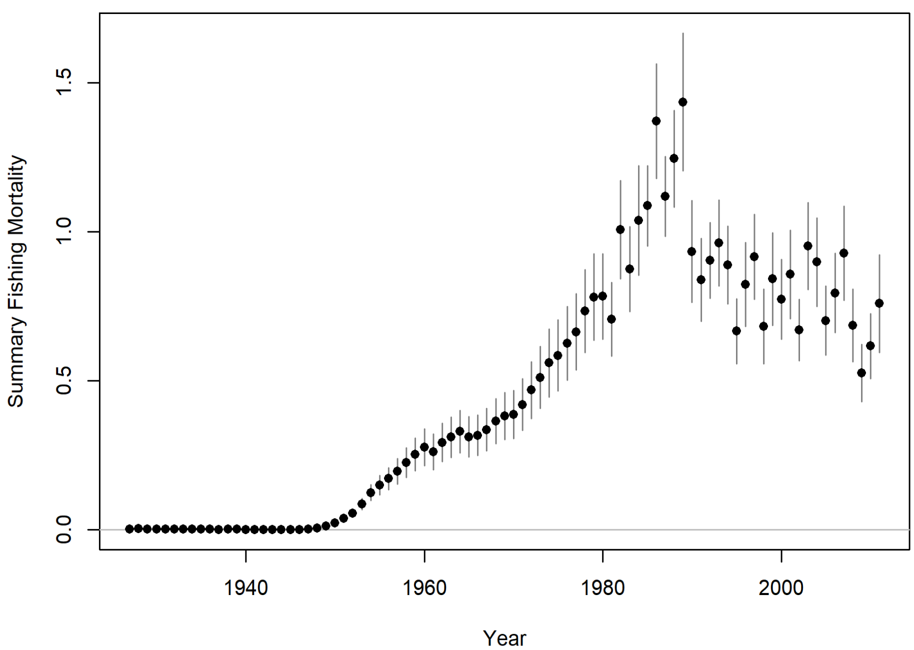
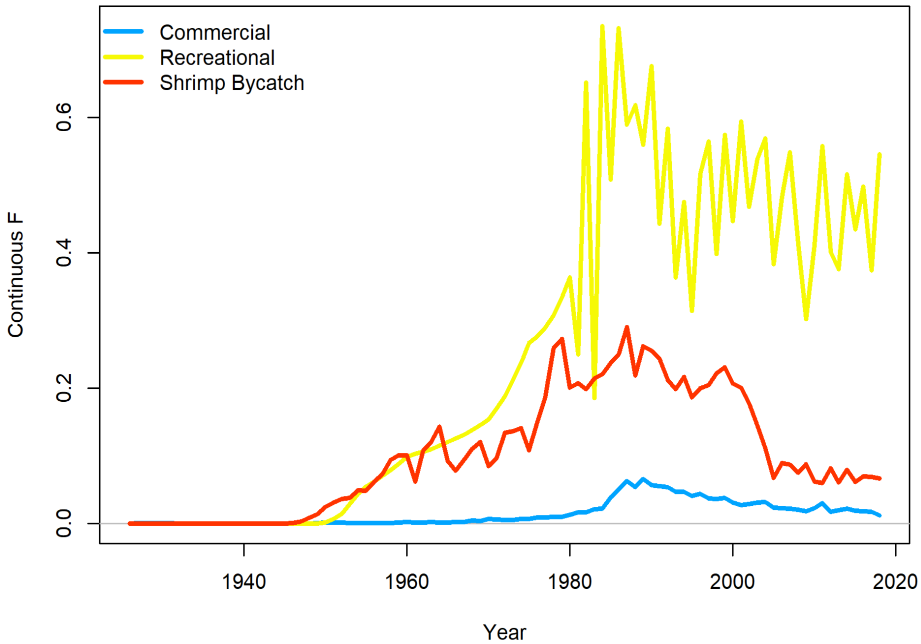


Figure 12. Annual exploitation rate (total kill/total biomass) for Gulf of Mexico cobia.

SEDAR28 Update



SEDAR28

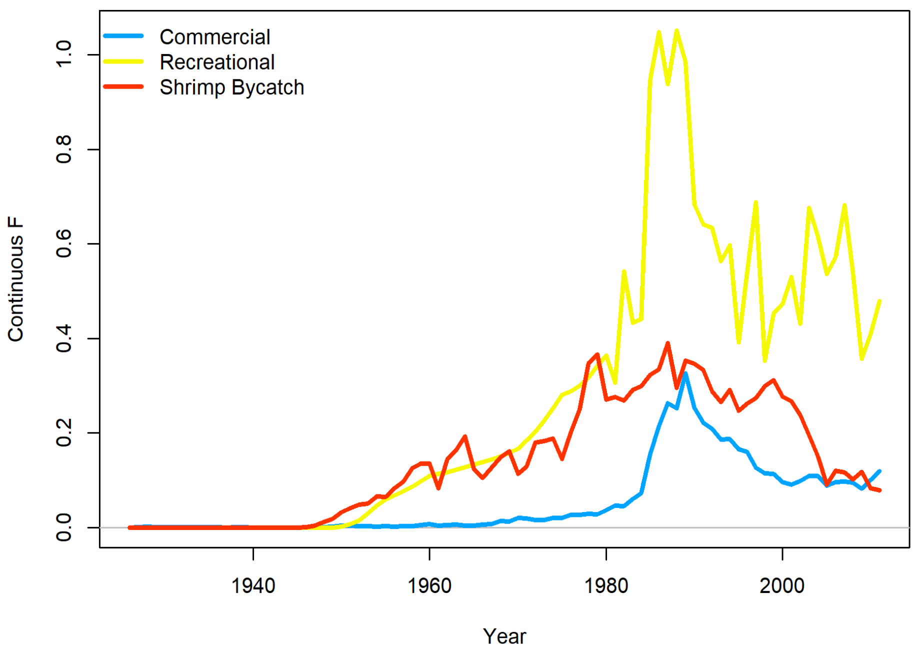


Figure 13. Fleet-specific estimates of instantaneous fishing mortality rate in terms of exploitable biomass for Gulf of Mexico cobia.

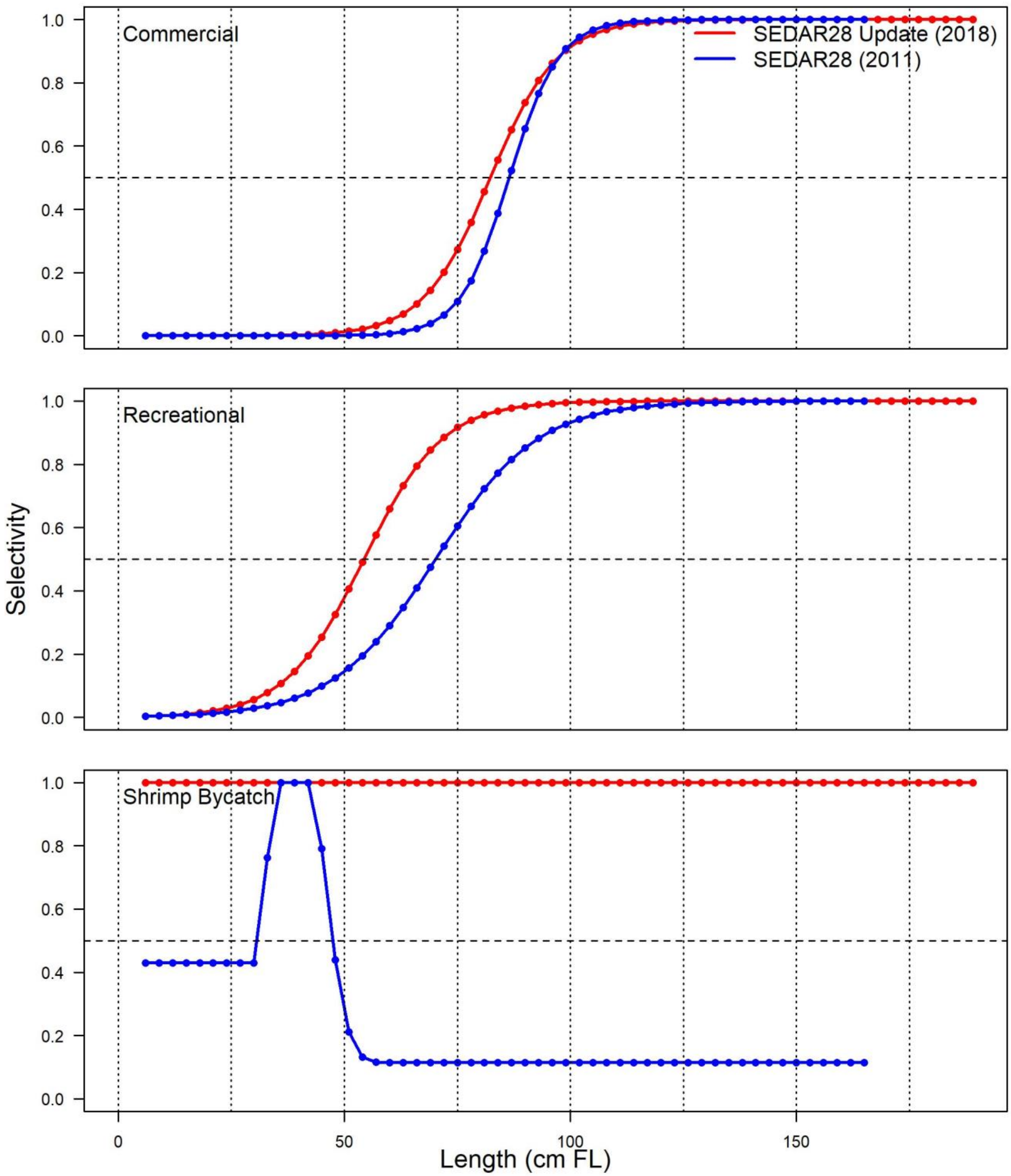


Figure 14. Length-based selectivity for each fleet for Gulf of Mexico cobia in the terminal year of the assessment (given in parentheses). Dashed horizontal line indicates 50%, whereas the dashed vertical lines identify lengths in 25 cm FL intervals.

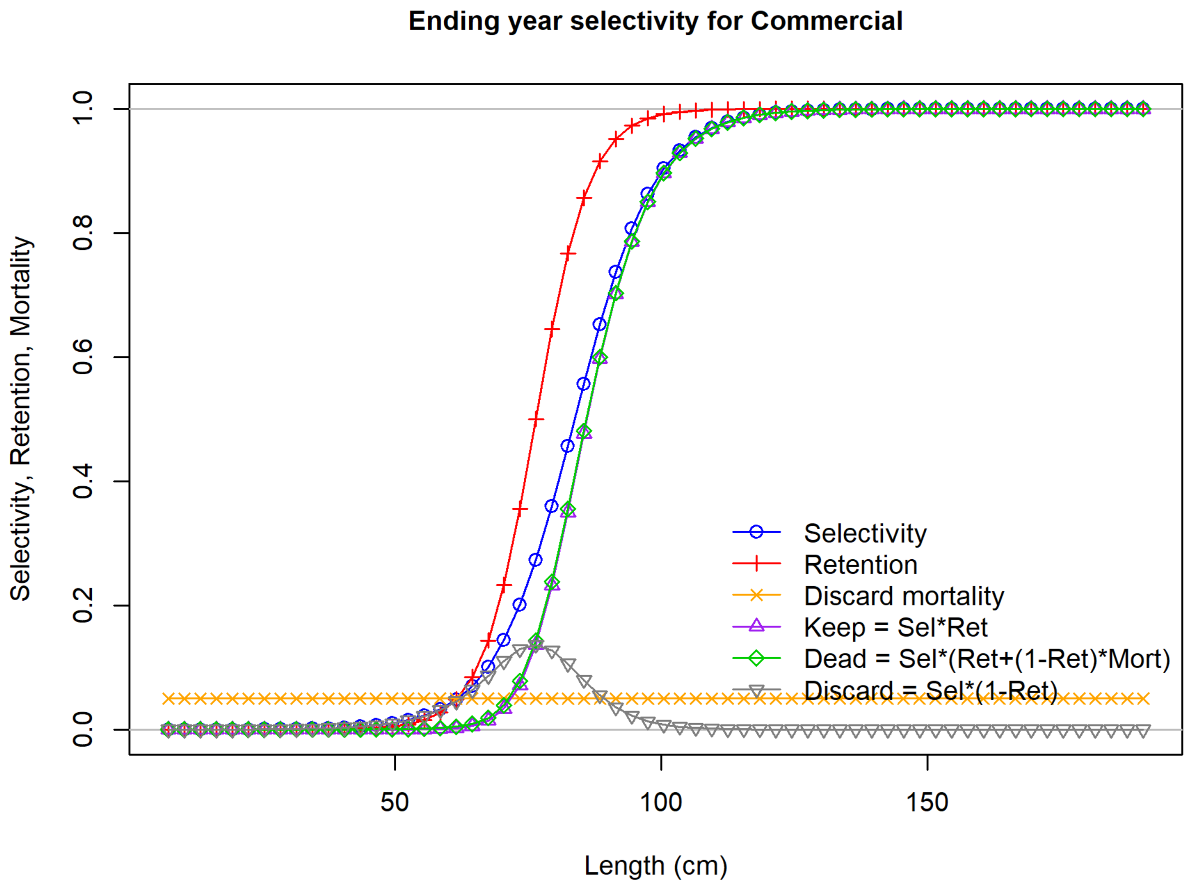


Figure 15. Length-based selectivity for the Commercial fishery. Selectivity (blue line) is constant over the entire assessment time period (1927 - 2018). Retention (red line) is shown for the most recent time period. Discard mortality (orange line) is constant at 0.05.

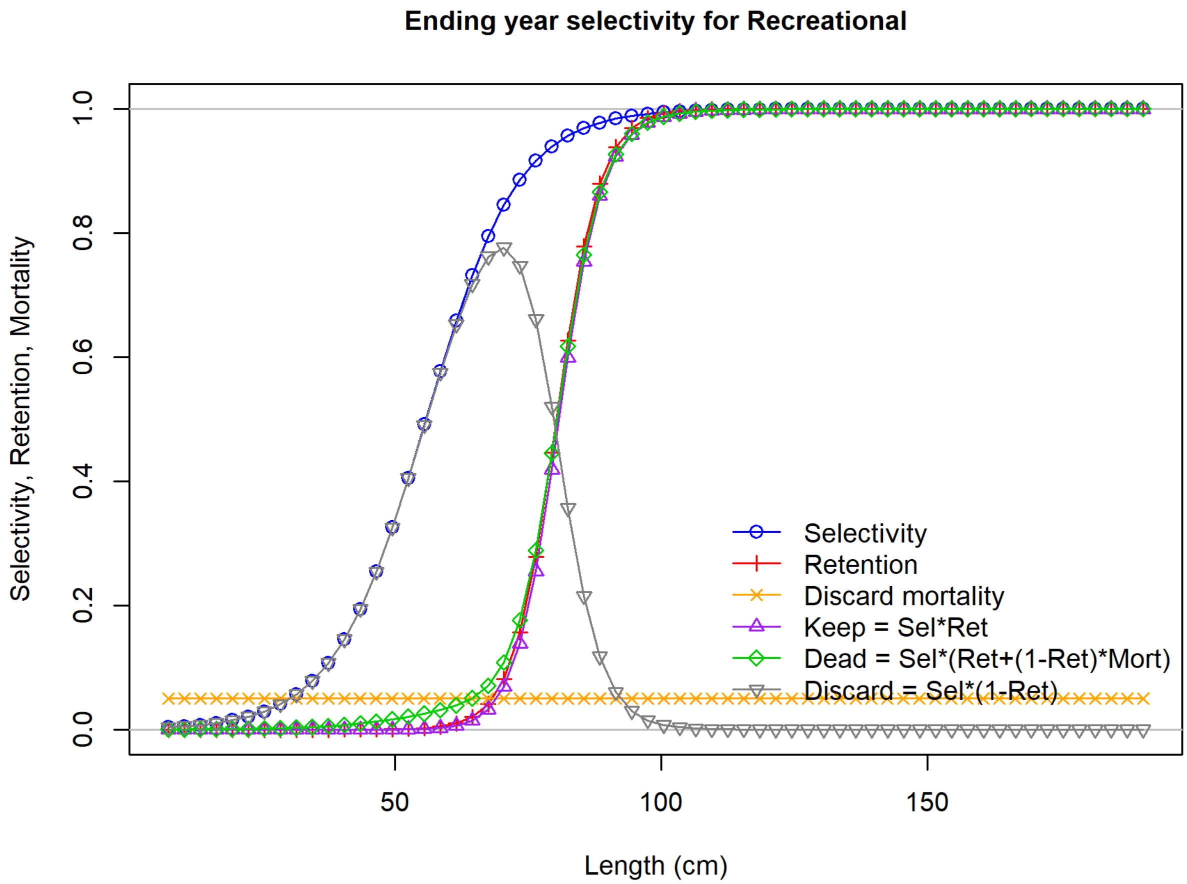


Figure 16. Length-based selectivity for the Recreational fishery. Selectivity (blue line) is constant over the entire assessment time period (1927 - 2018). Retention (red line) is shown for the most recent time period. Discard mortality (orange line) is constant at 0.05.

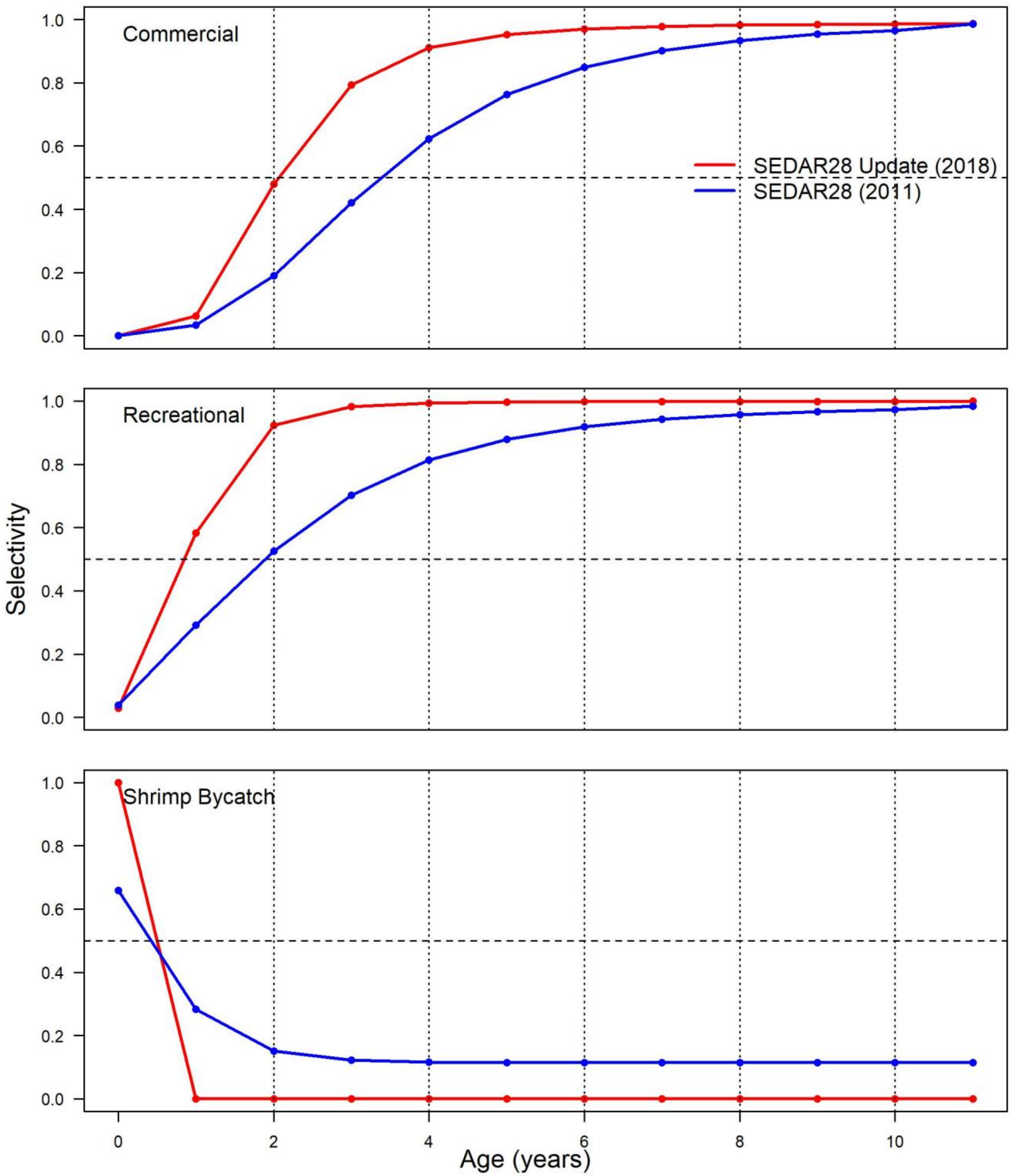


Figure 17. Derived age-based selectivity for each fleet for Gulf of Mexico cobia in the terminal year of the assessment (given in parentheses). Dashed horizontal line indicates 50%, whereas the dashed vertical lines identify ages in 2 year intervals.

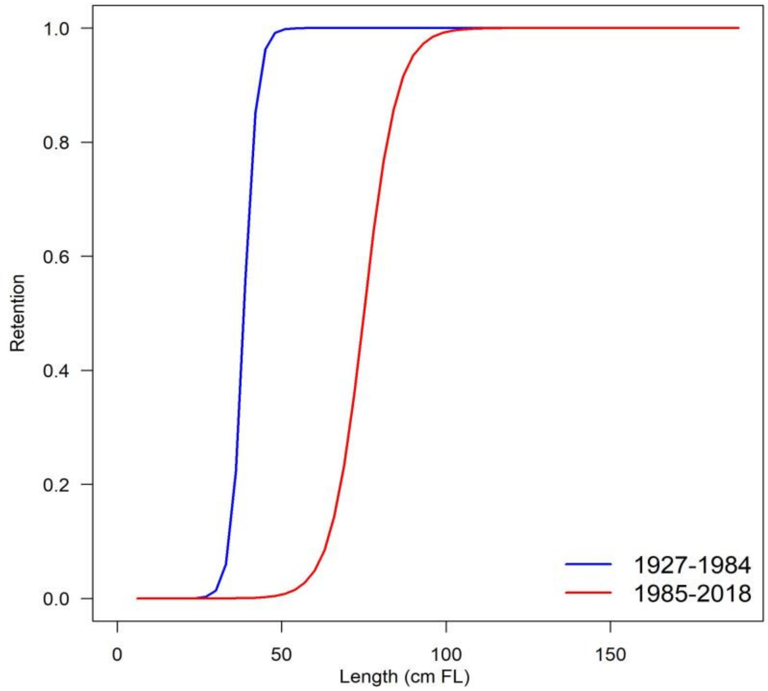


Figure 18. Retention patterns for the Commercial fishery before and after the implementation of a minimum size limit of 33 inches fork length (FL) in 1984.

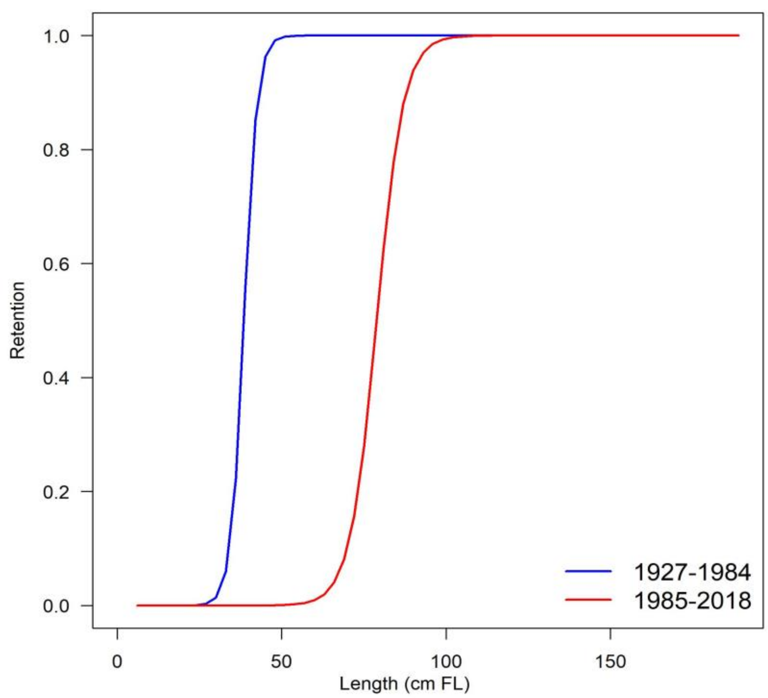
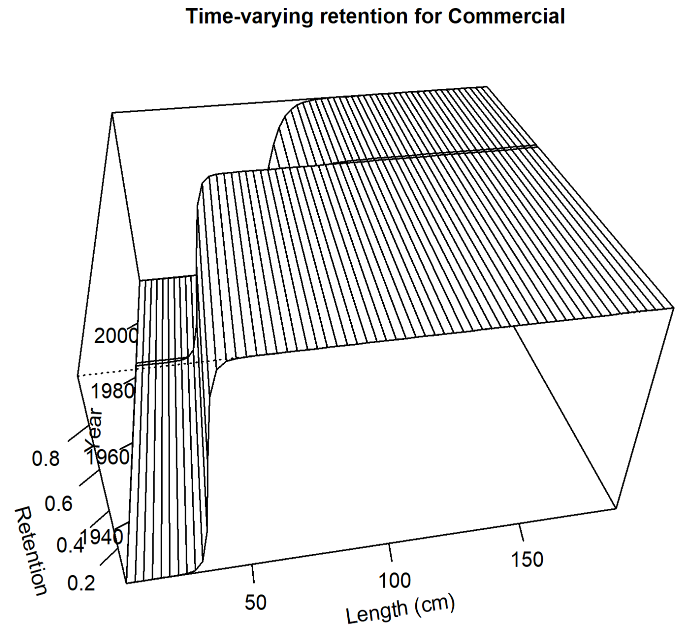


Figure 19. Retention patterns for the Recreational fishery before and after the implementation of a minimum size limit of 33 inches fork length (FL) in 1984.

SEDAR28 Update



SEDAR28

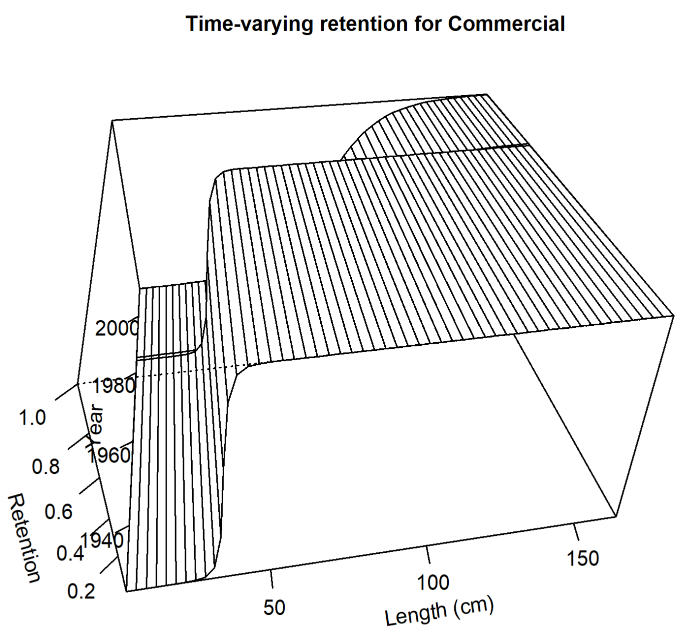
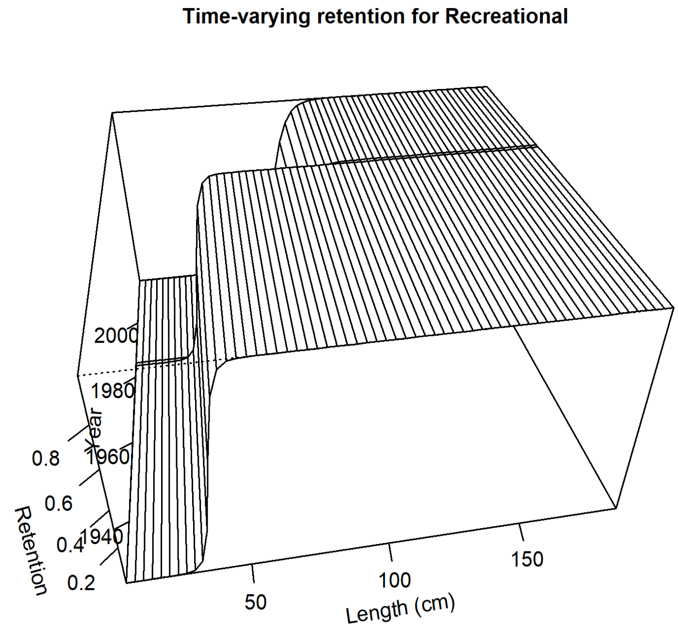


Figure 20. Time-varying retention at length for the Commercial fishery for Gulf of Mexico cobia from SEDAR28 Update (Upper Panel) and SEDAR28 (Lower Panel).

SEDAR28 Update



SEDAR28

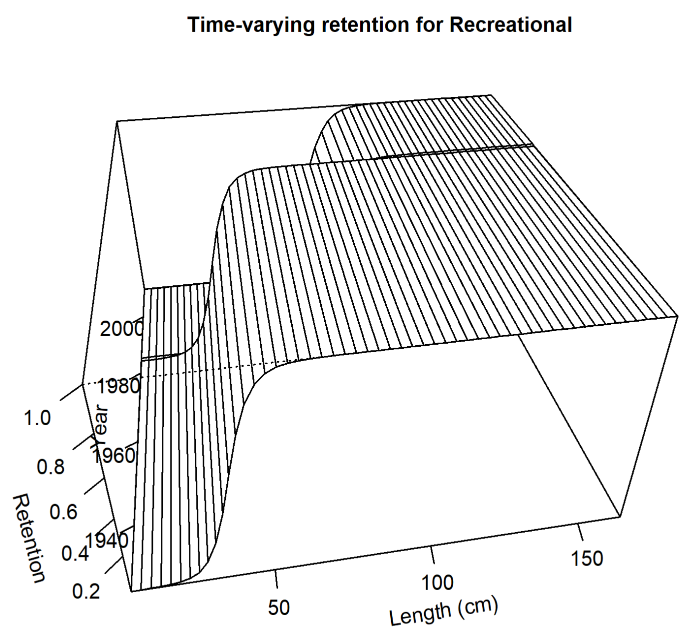
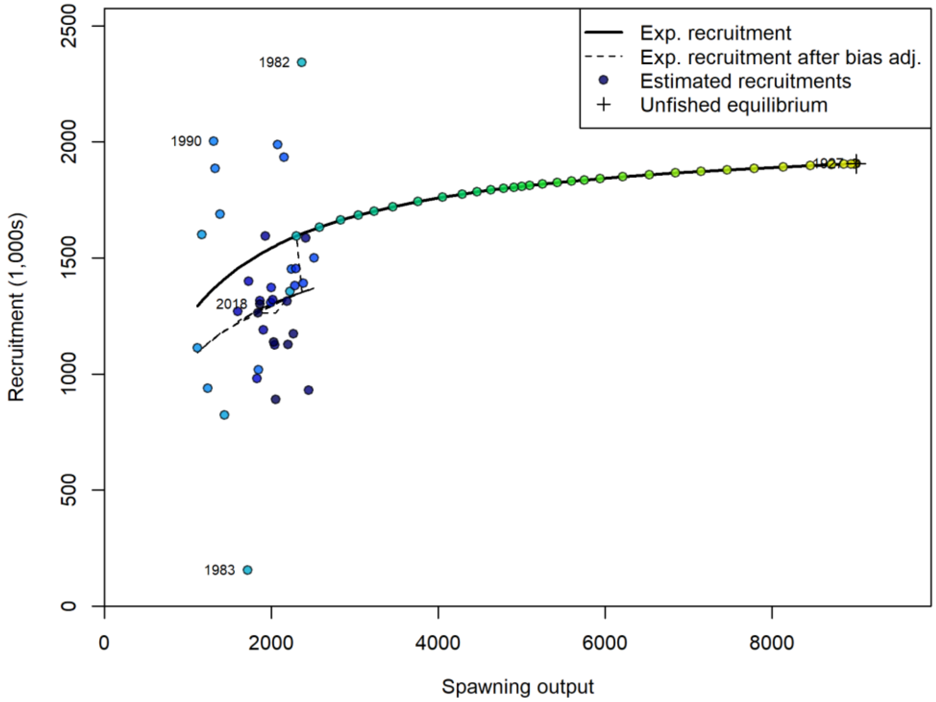


Figure 21. Time-varying retention at length for the Recreational fishery for Gulf of Mexico cobia from SEDAR28 Update (Upper Panel) and SEDAR28 (Lower Panel).

SEDAR28 Update



SEDAR28

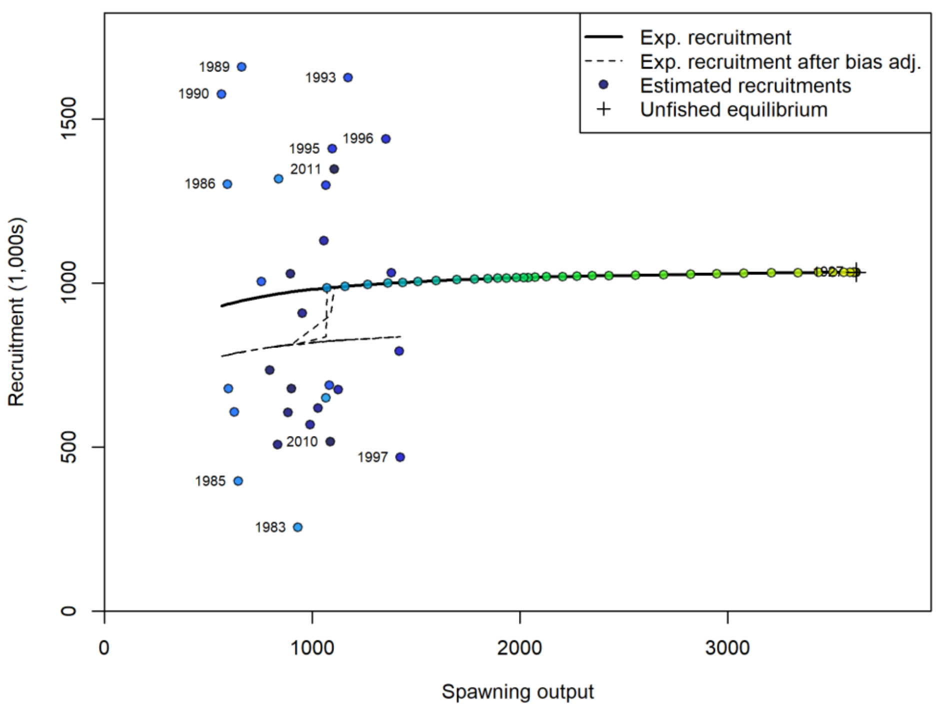
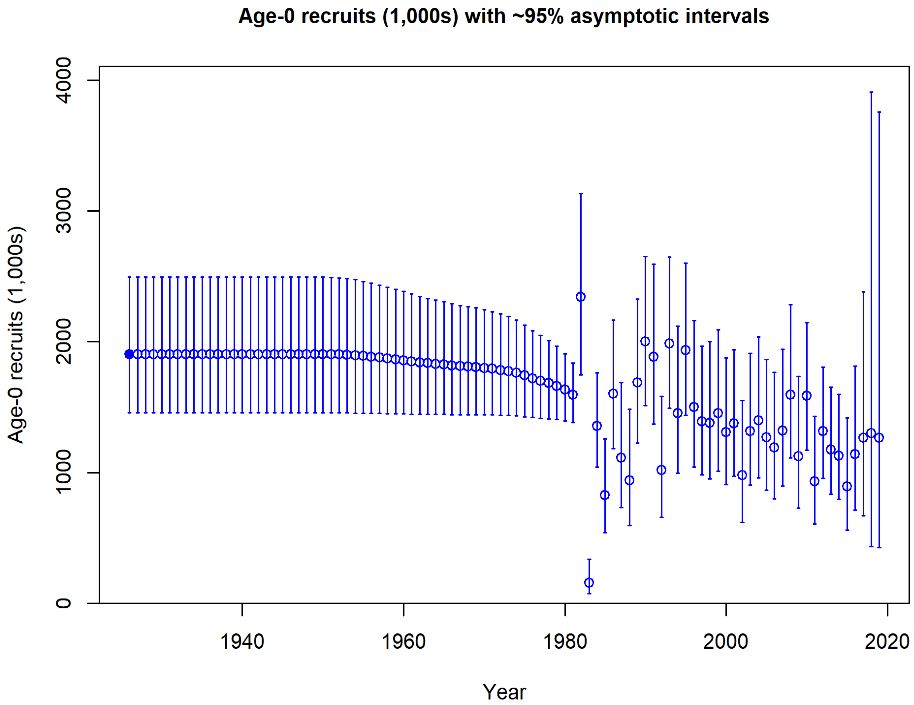


Figure 22. Predicted stock-recruitment relationship for Gulf of Mexico cobia (steepness estimated at 0.789, SigmaR fixed at 0.6). Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (green line).

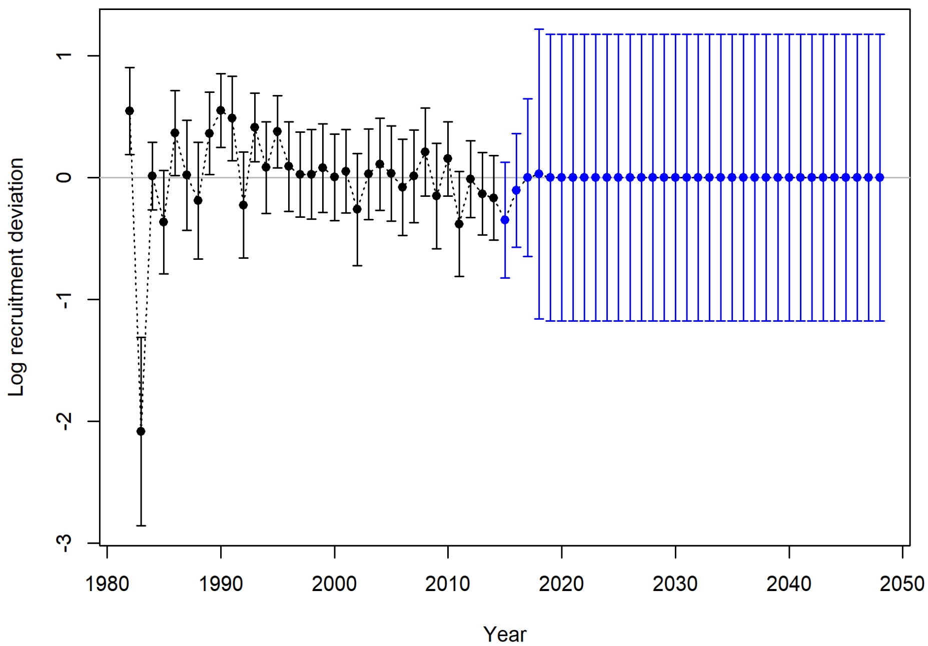
SEDAR28 Update



SEDAR28

Figure 23. Estimated Age-0 recruitment with 95% confidence intervals for Gulf of Mexico cobia (steepness estimated at 0.789, SigmaR fixed at 0.6).

SEDAR28 Update



SEDAR28

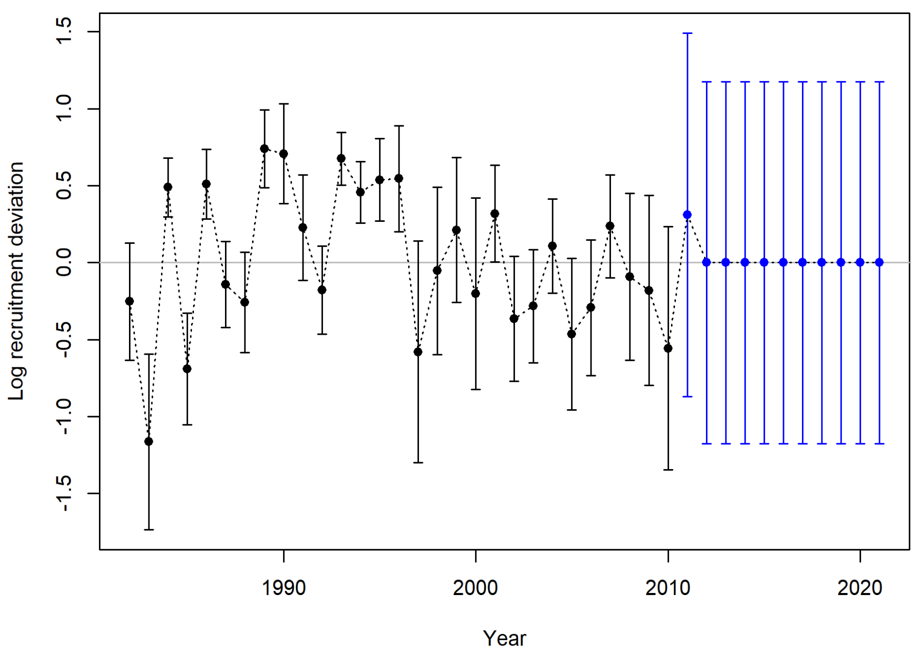
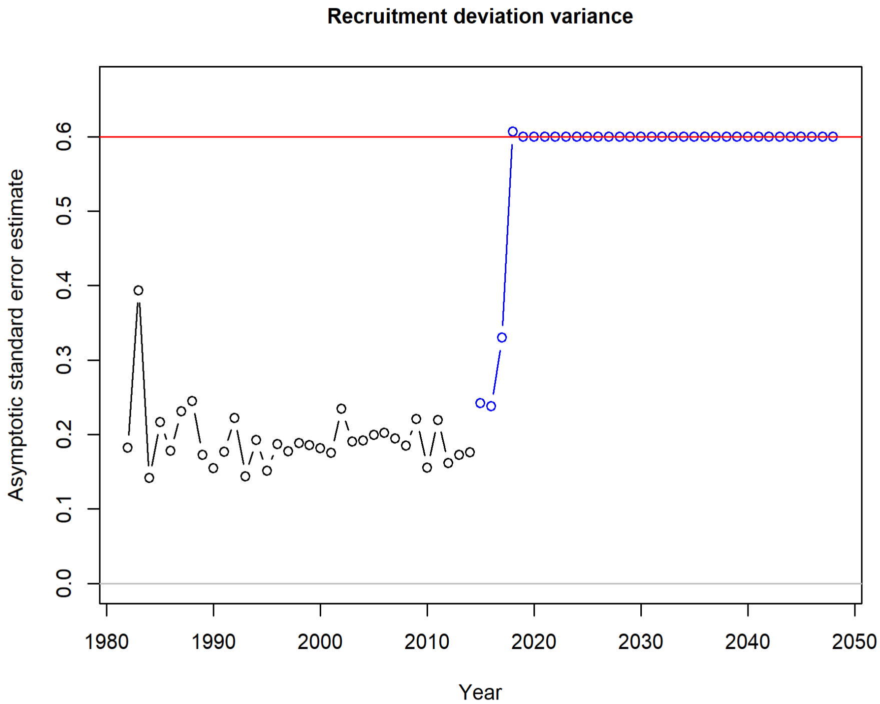


Figure 24. Estimated log recruitment deviations for Gulf of Mexico cobia (steepness estimated at 0.789, SigmaR fixed at 0.6).

SEDAR28 Update



SEDAR28

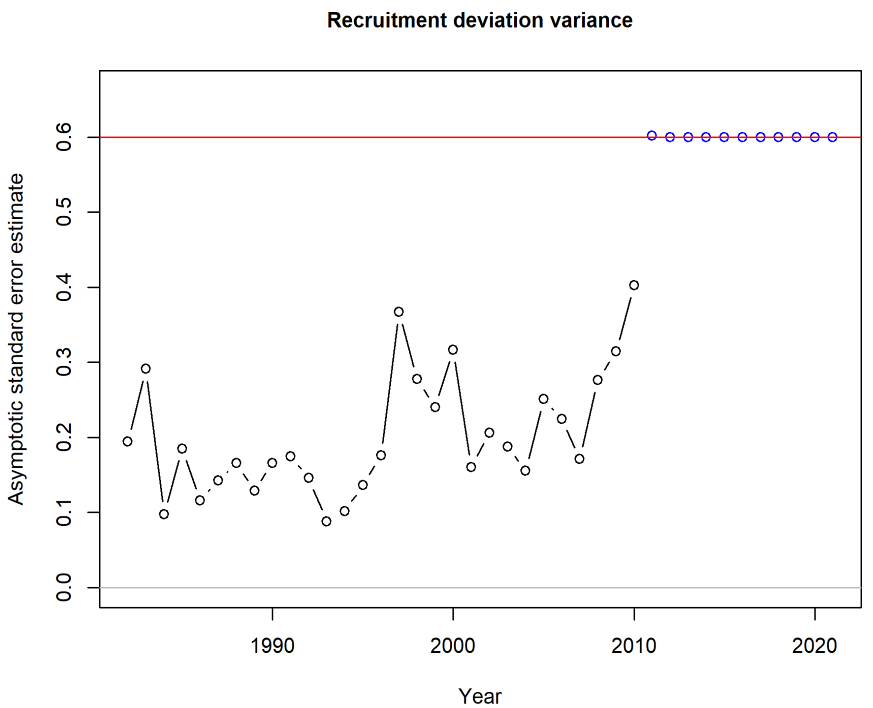


Figure 25. Asymptotic standard errors for recruitment deviations for Gulf of Mexico cobia. The red line represents the fixed value of 0.6 for sigma R used in the model.

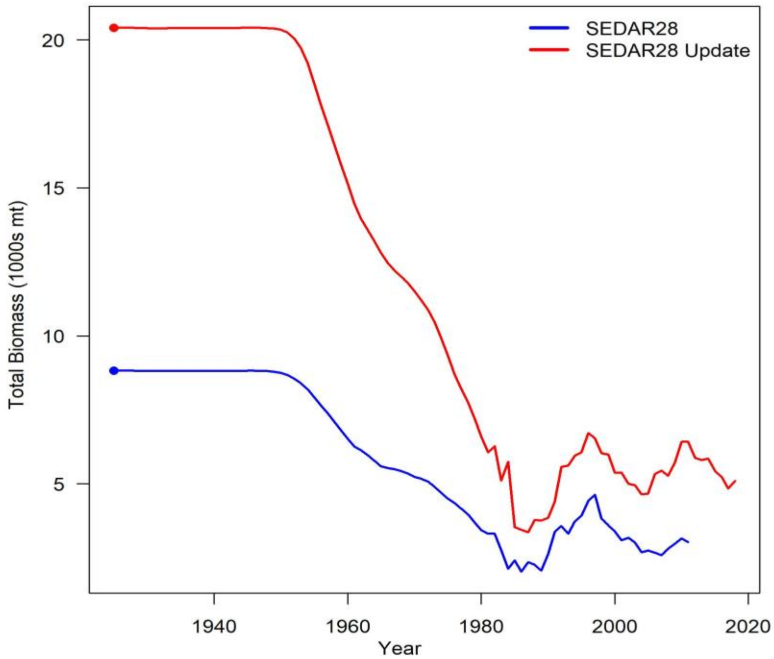


Figure 26. Estimate of total biomass (in 1000s of metric tons) for Gulf of Mexico cobia.

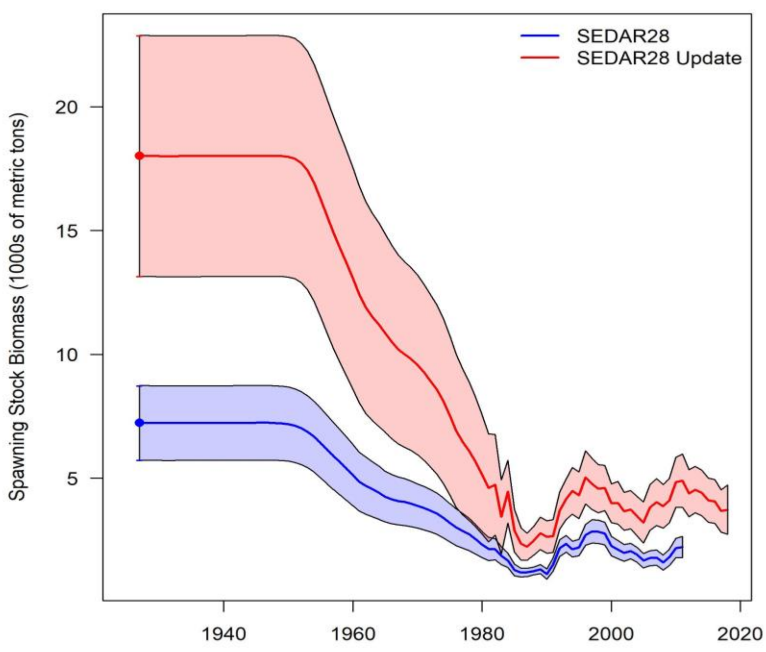
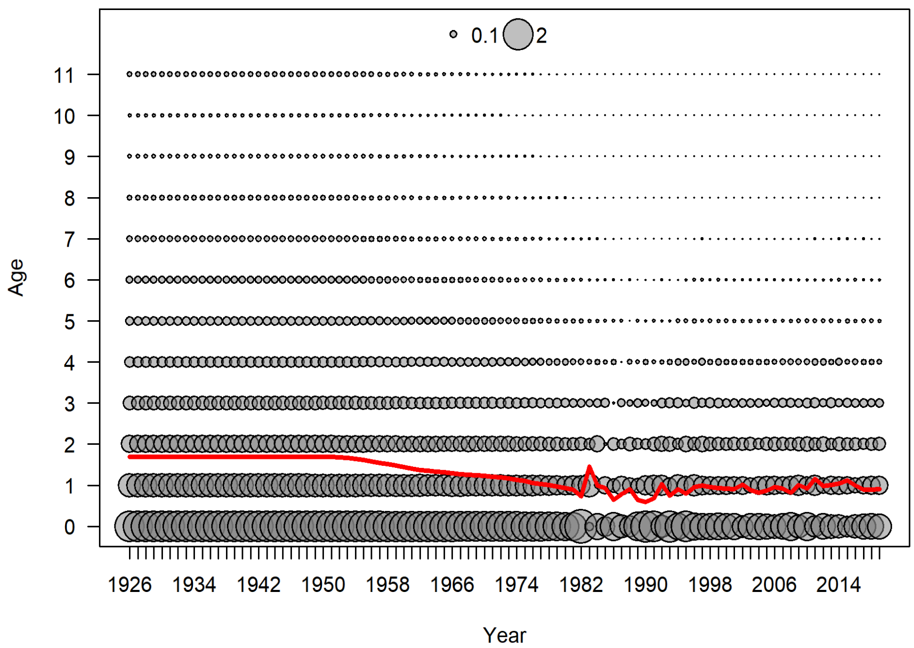


Figure 27. Estimate of spawning stock biomass (in 1000s of metric tons) for Gulf of Mexico cobia.

SEDAR28 Update



SEDAR28

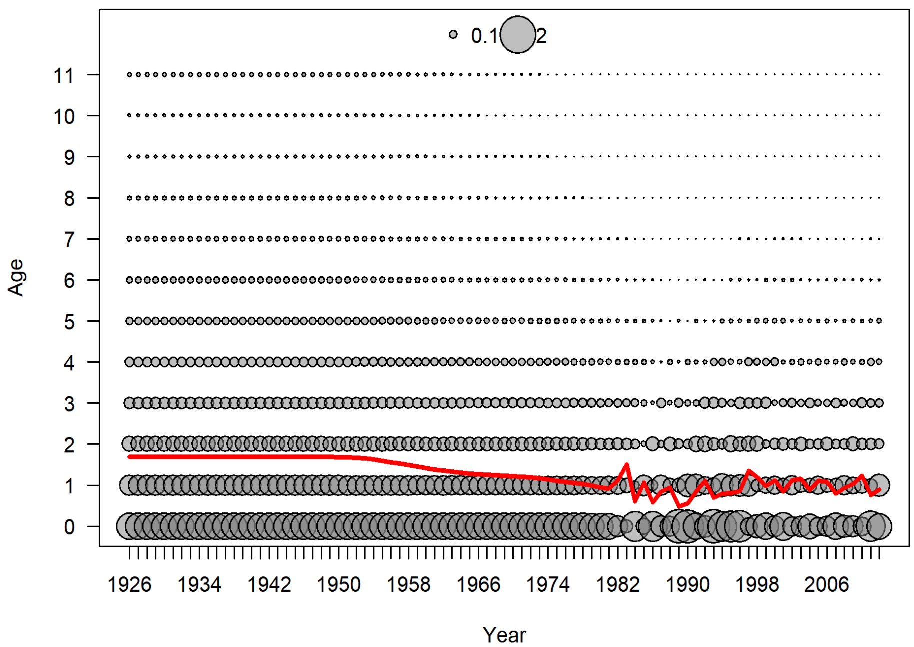


Figure 28. Predicted numbers at age (bubbles) and mean age of Gulf of Mexico cobia (red line).

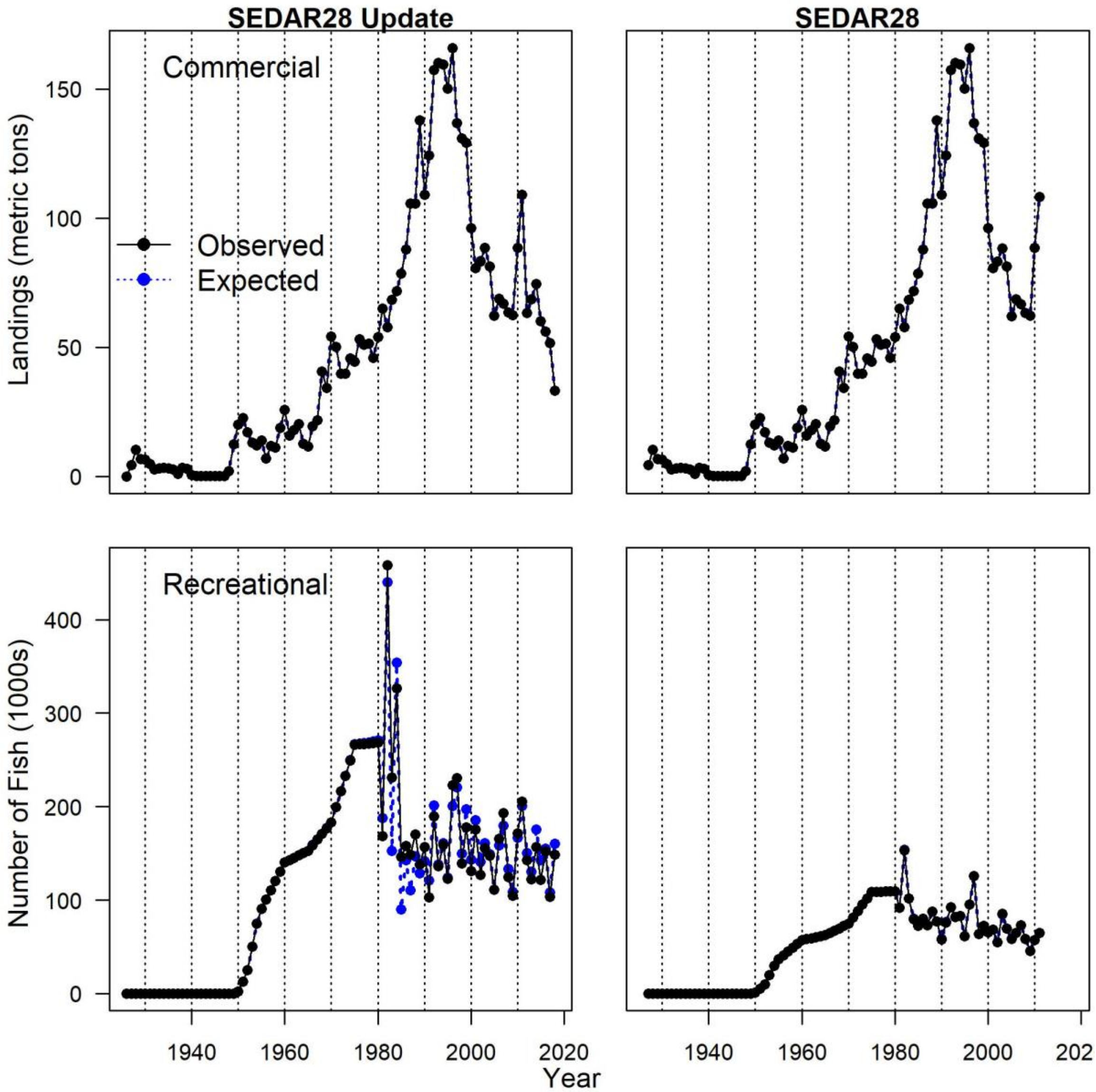


Figure 29. Gulf of Mexico cobia observed and expected landings by fishery for SEDAR28 Update (left panels) and SEDAR28 (right panels). Commercial and recreational landings are in metric tons and numbers of fish, respectively. Dashed vertical lines identify ten year intervals.

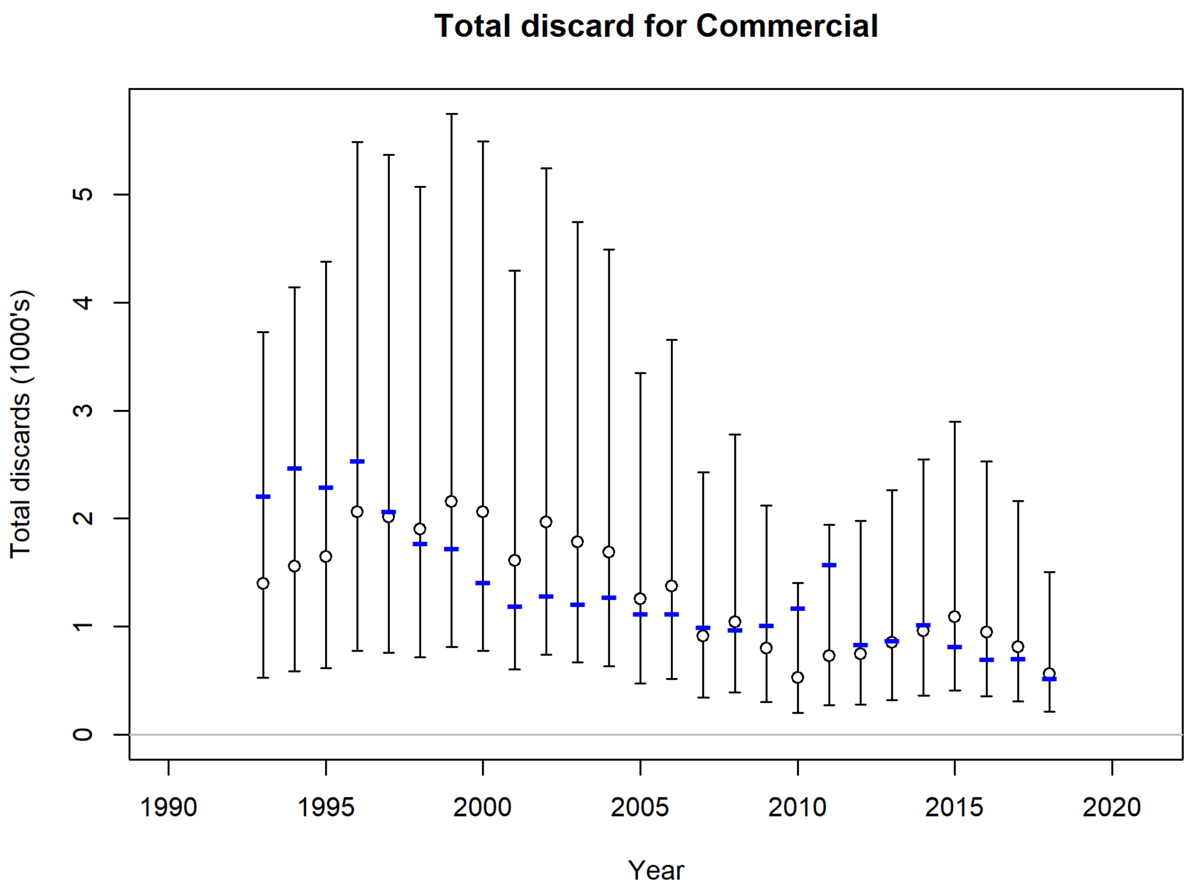


Figure 30. Observed (open dots) and predicted (blue dashes) discards (1000s of fish) of Gulf of Mexico cobia from the Commercial fishery.

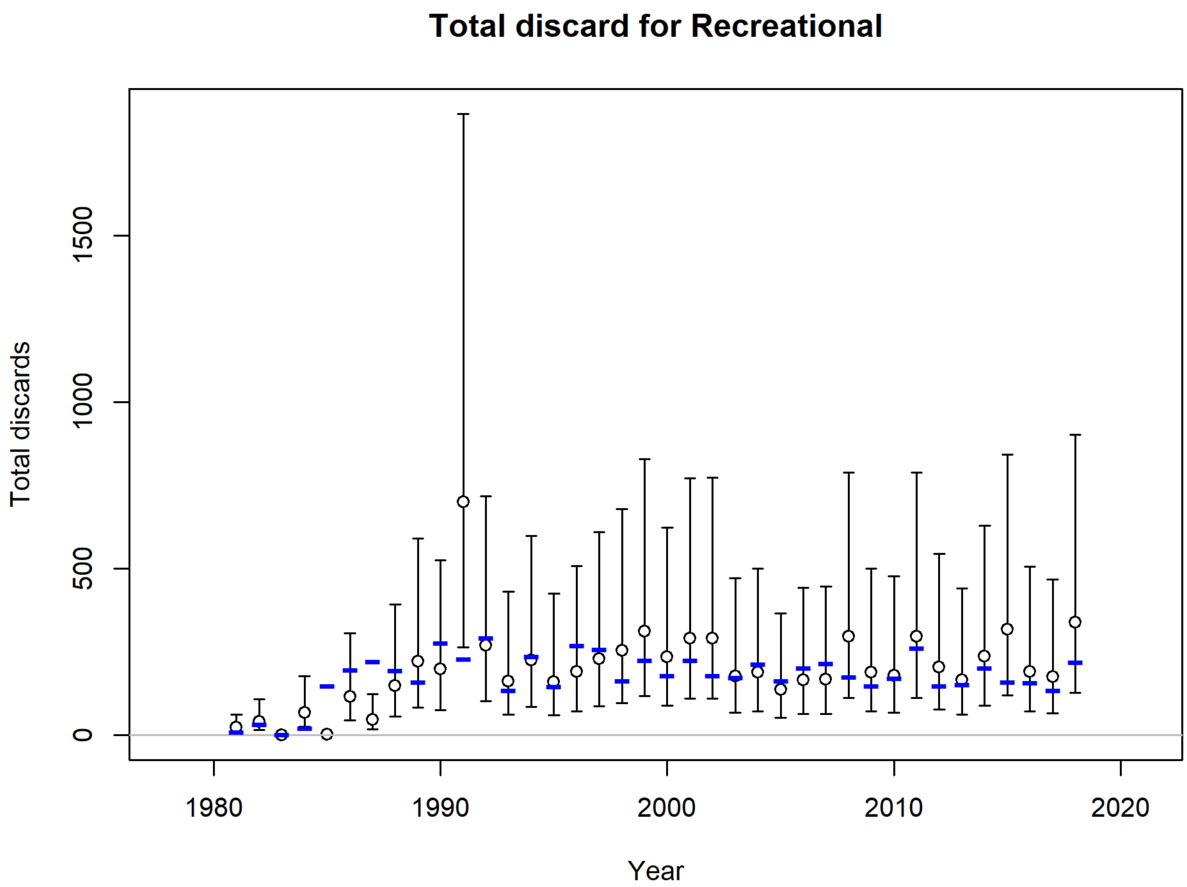


Figure 31. Observed (open dots) and predicted (blue dashes) discards (1000s of fish) of Gulf of Mexico cobia from the Recreational fishery.

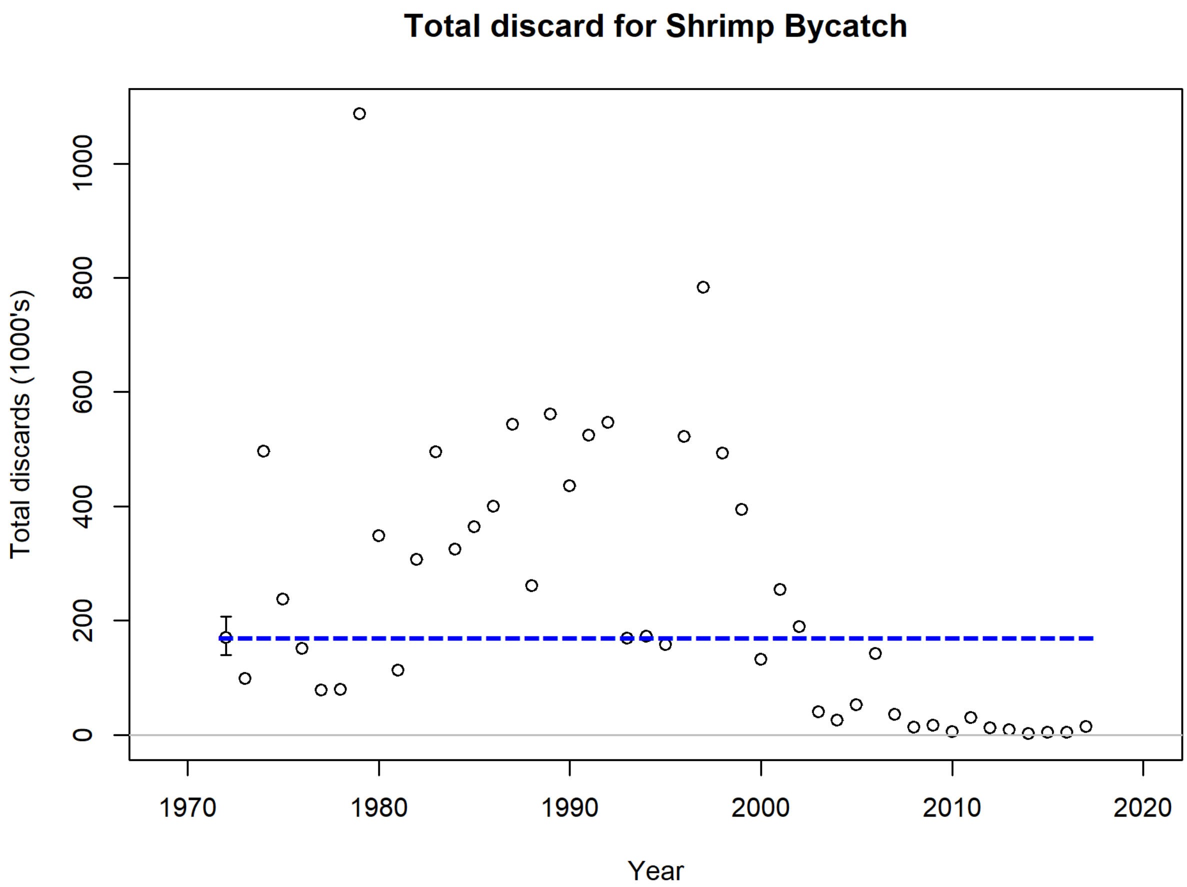


Figure 32. Observed and predicted shrimp bycatch super-period medians in 1000s of dead discards. The blue line represents the assessment model estimated median and the black circles are the bycatch observations produced by the WinBUGS program. The first circle represents the Bayesian median that the assessment model is attempting to fit.

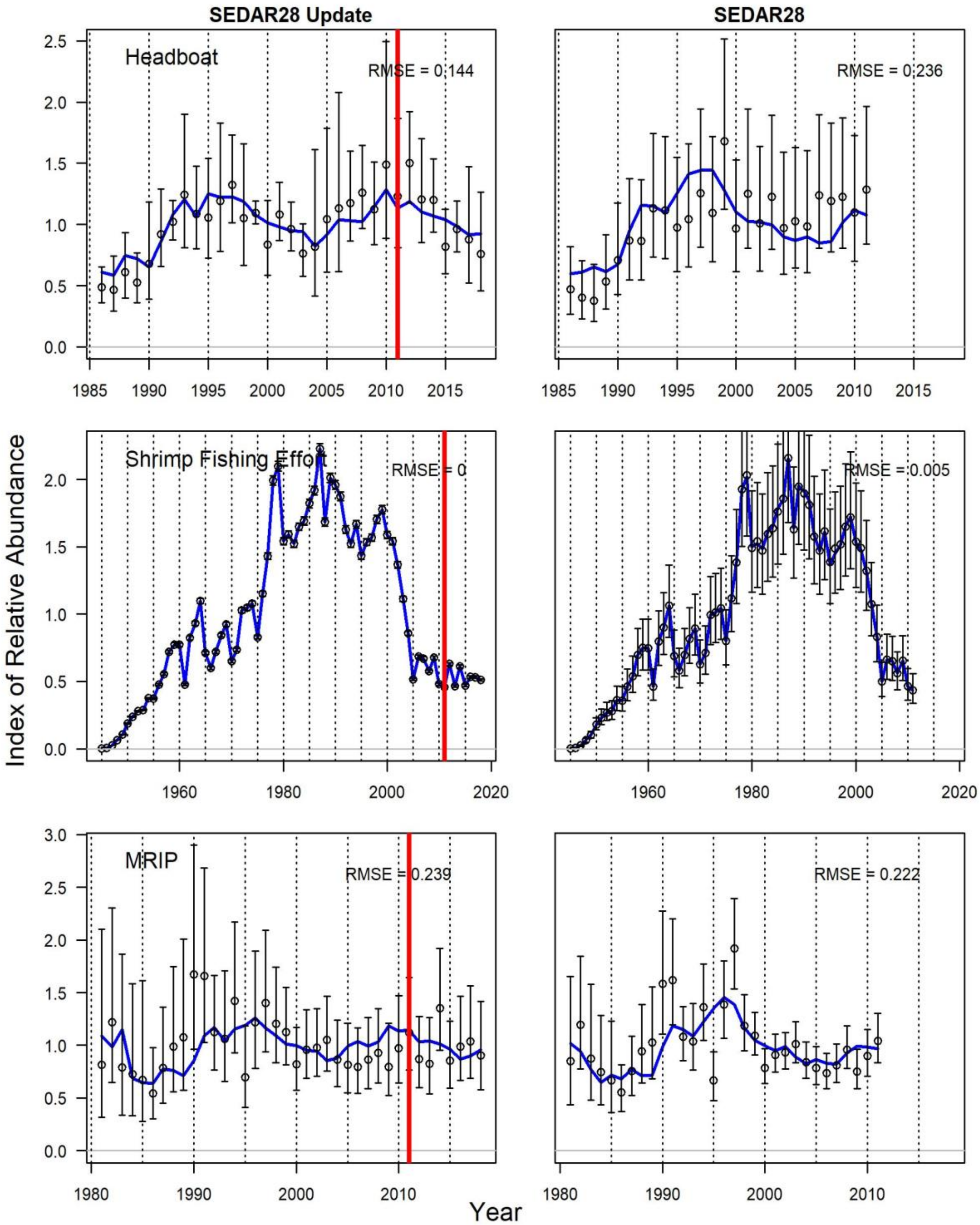
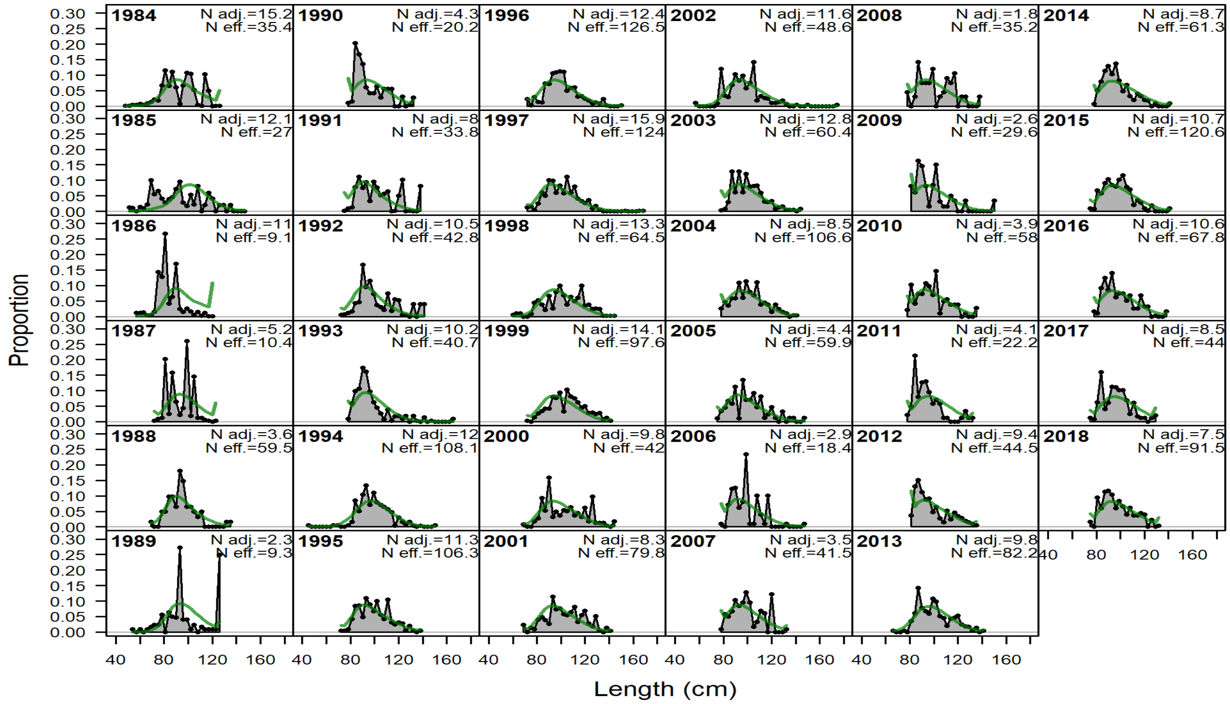


Figure 33. Gulf of Mexico cobia observed and expected indices for SEDAR28 Update (left panels) and SEDAR28 (right panels). The red line is used to identify the more recent time period of data available for the SEDAR28 Update whereas dashed vertical lines identify five year intervals. The root mean squared error (RMSE) is also provided. For SEDAR 28 Update the standard errors are scaled by the variance adjustment.

SEDAR28 Update



SEDAR28

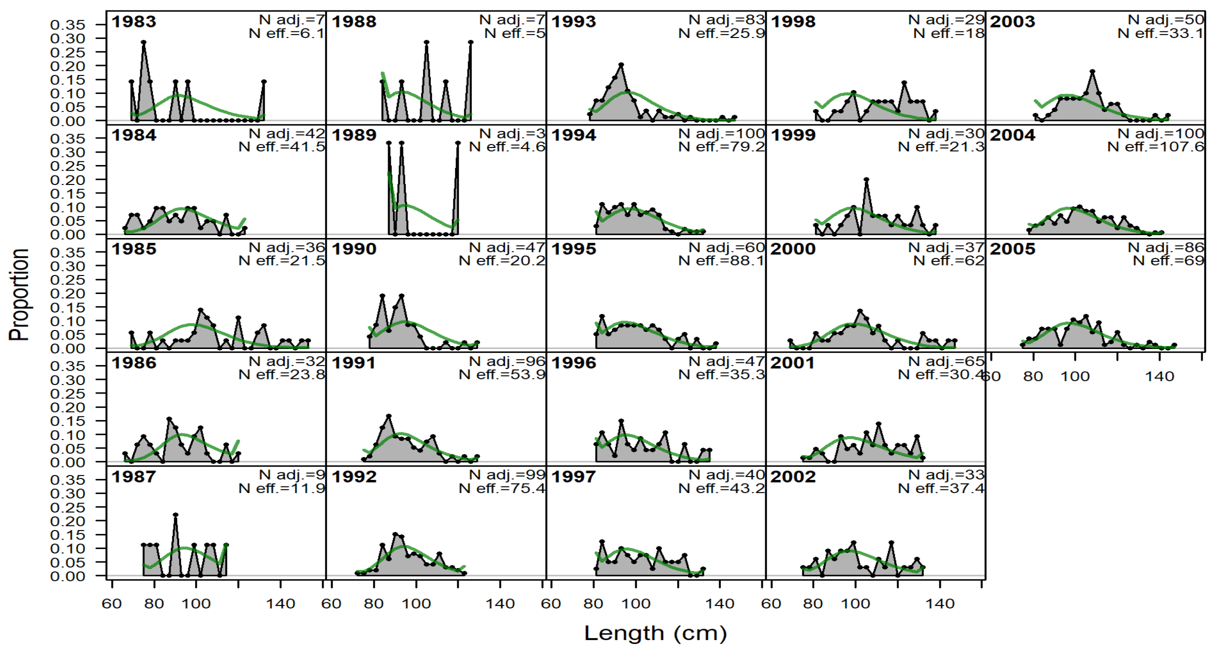
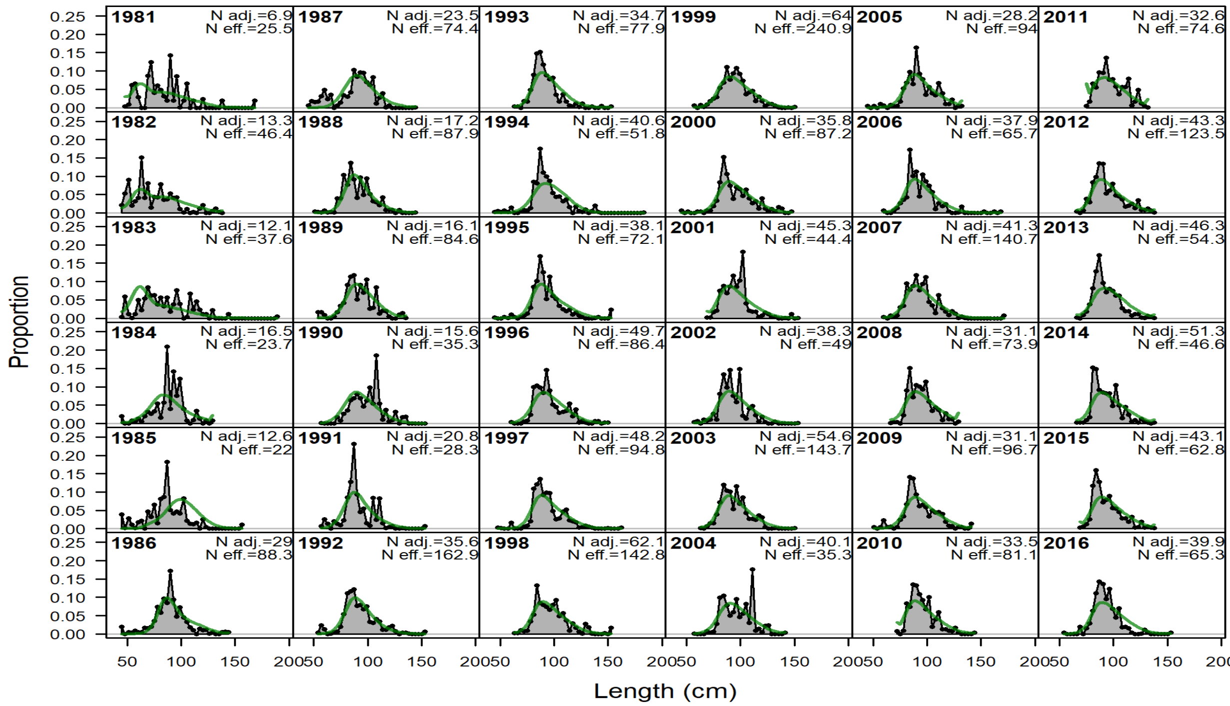


Figure 34. Observed and predicted length compositions for Gulf of Mexico cobia in the Commercial fishery. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 Update (Upper Panel). Input sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 (Lower Panel).

SEDAR28 Update



SEDAR28

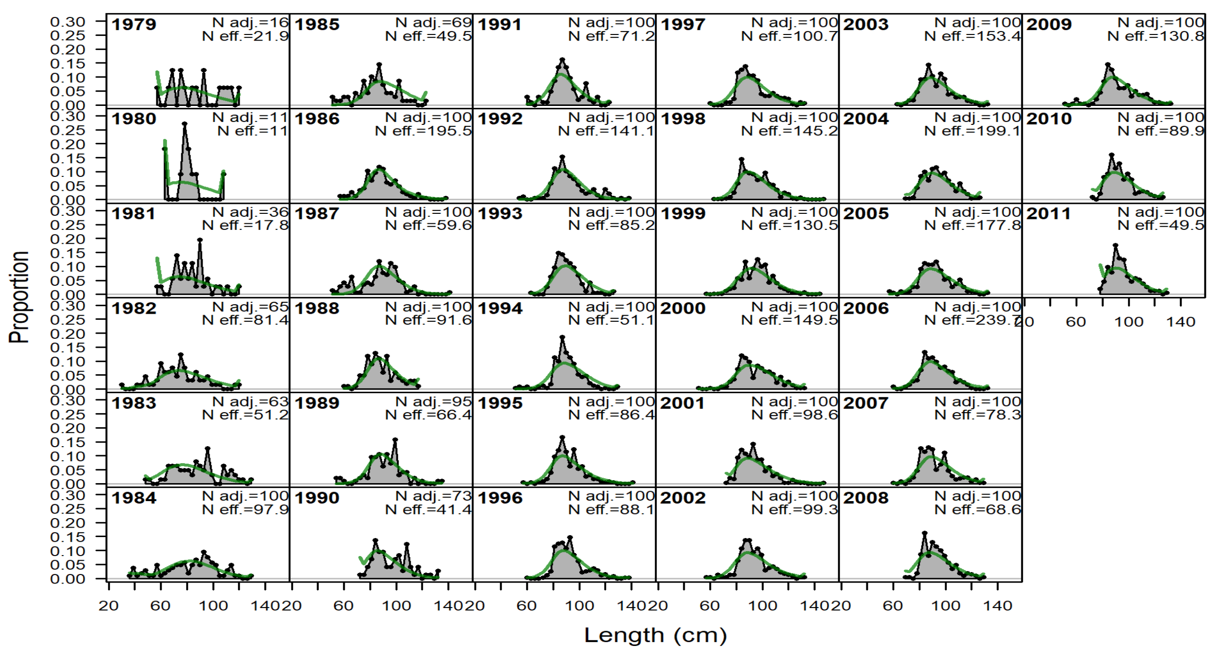


Figure 35. Observed and predicted length compositions for Gulf of Mexico cobia in the Recreational fishery. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 Update (Upper Panel). Input sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 (Lower Panel).

SEDAR28 Update

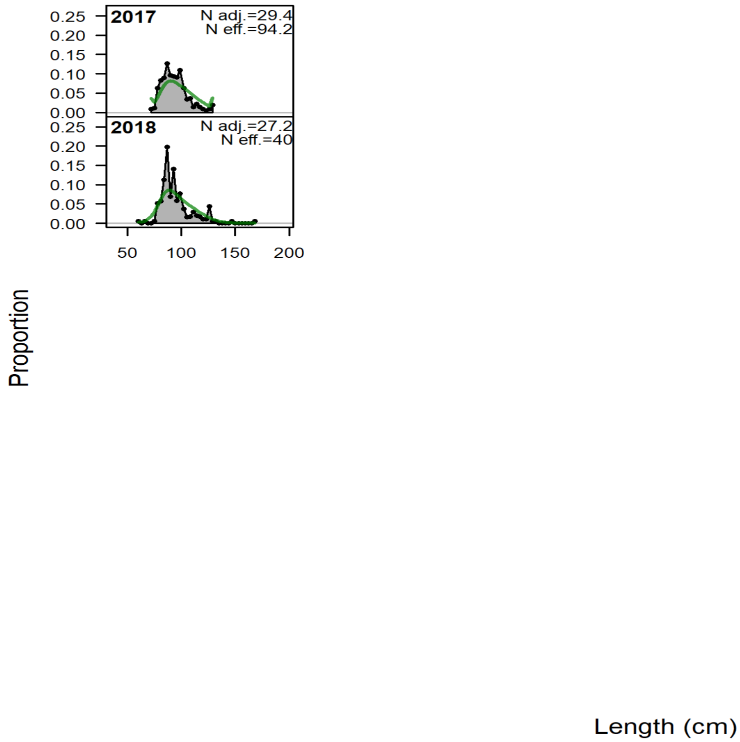
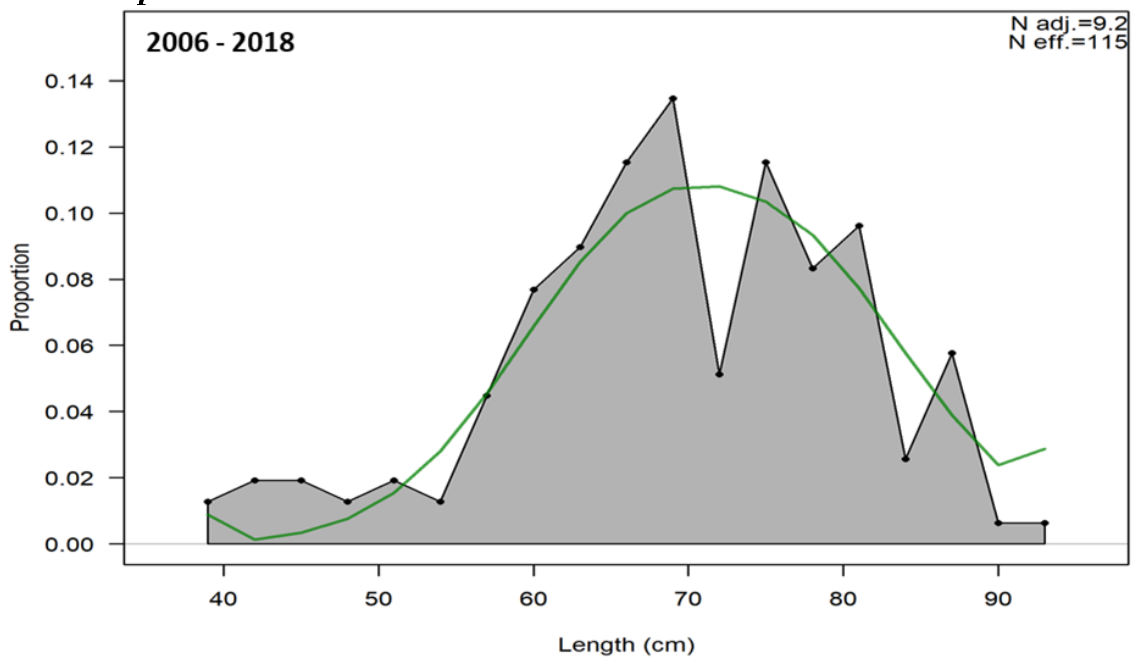


Figure 35 Continued. Observed and predicted length compositions for Gulf of Mexico cobia in the Recreational fishery. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 Update (Upper Panel). Input sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 (Lower Panel).

SEDAR28 Update



SEDAR28

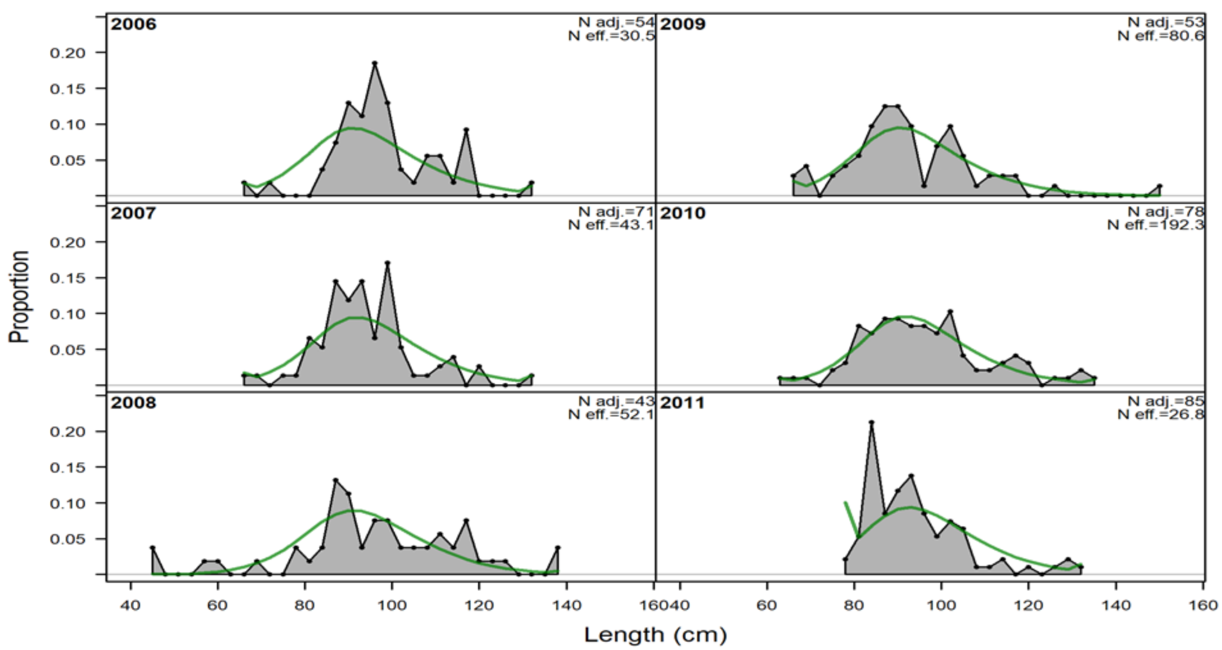
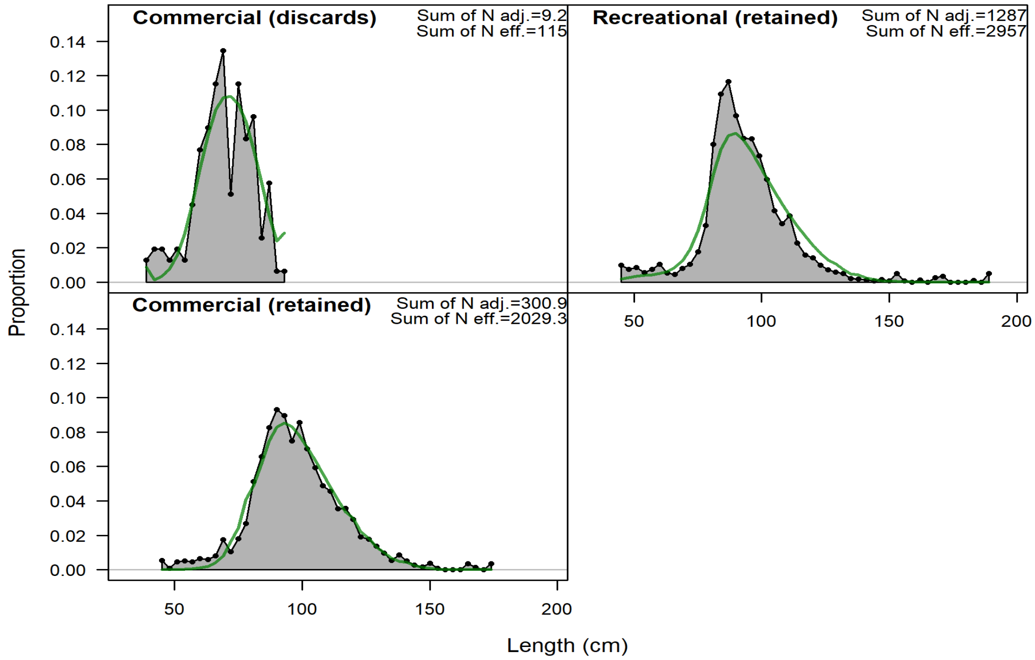


Figure 36. Observed and predicted discard length compositions for Gulf of Mexico cobia in the Commercial fishery. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 Update (Upper Panel). Input sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 (Lower Panel). The top panel shows the discard only RFOP length data for SEDAR28 Update. The bottom plots (by years) include the all samples from the RFOP + Commercial data combined from SEDAR28.

SEDAR28 Update



SEDAR28

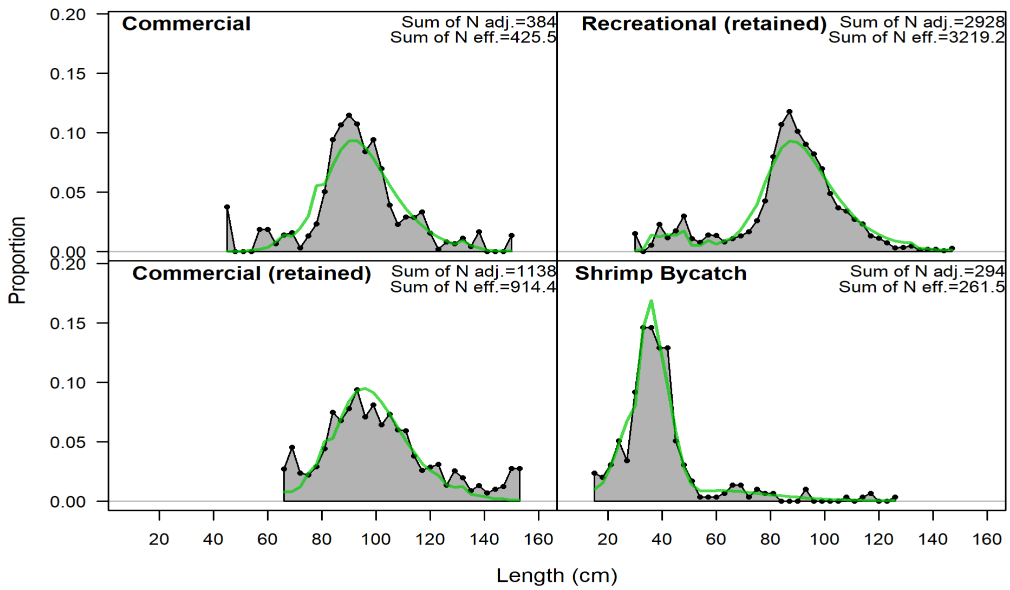
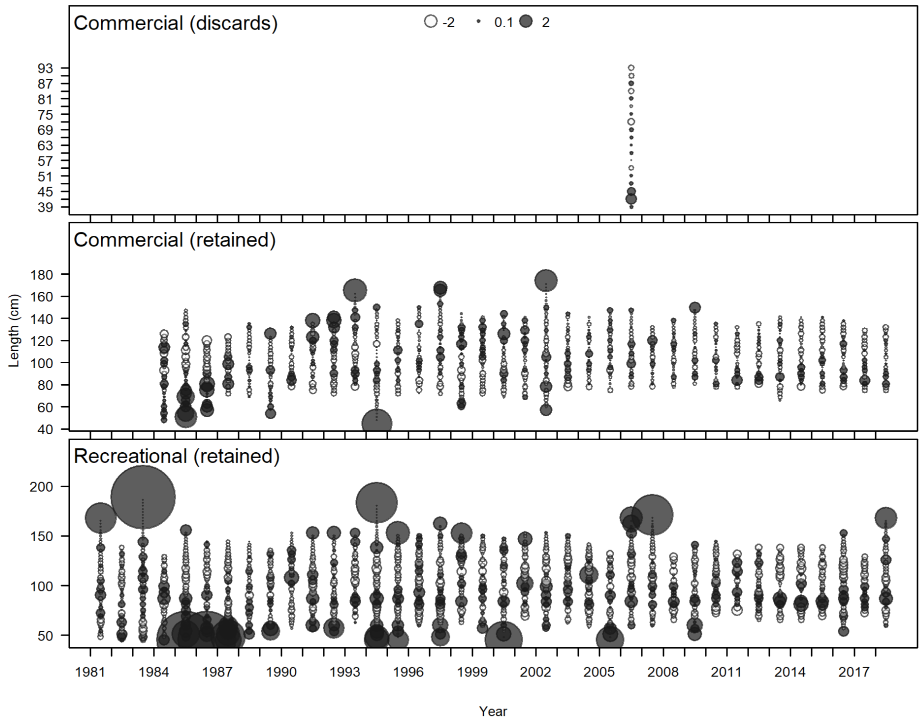


Figure 37. Model fits to the length composition of discarded or retained catch aggregated across years within a given fleet for Gulf of Mexico cobia. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. Francis reweighted sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 Update (Upper Panel). Input sample sizes (N adj.) and effective sample sizes (N eff.) estimated by SS are reported for the SEDAR 28 (Lower Panel).

SEDAR28 Update



SEDAR28

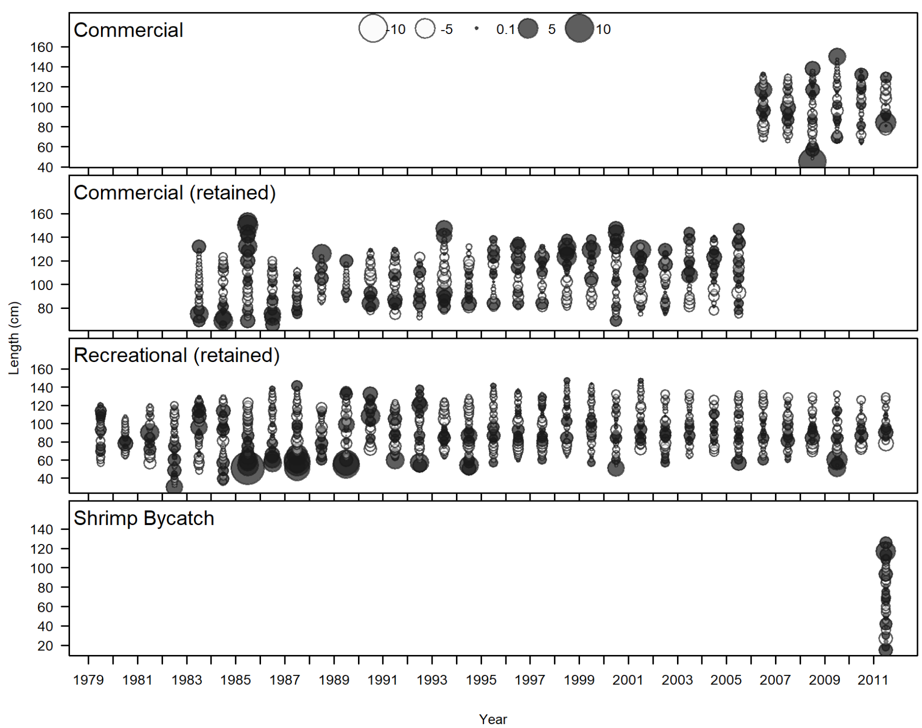
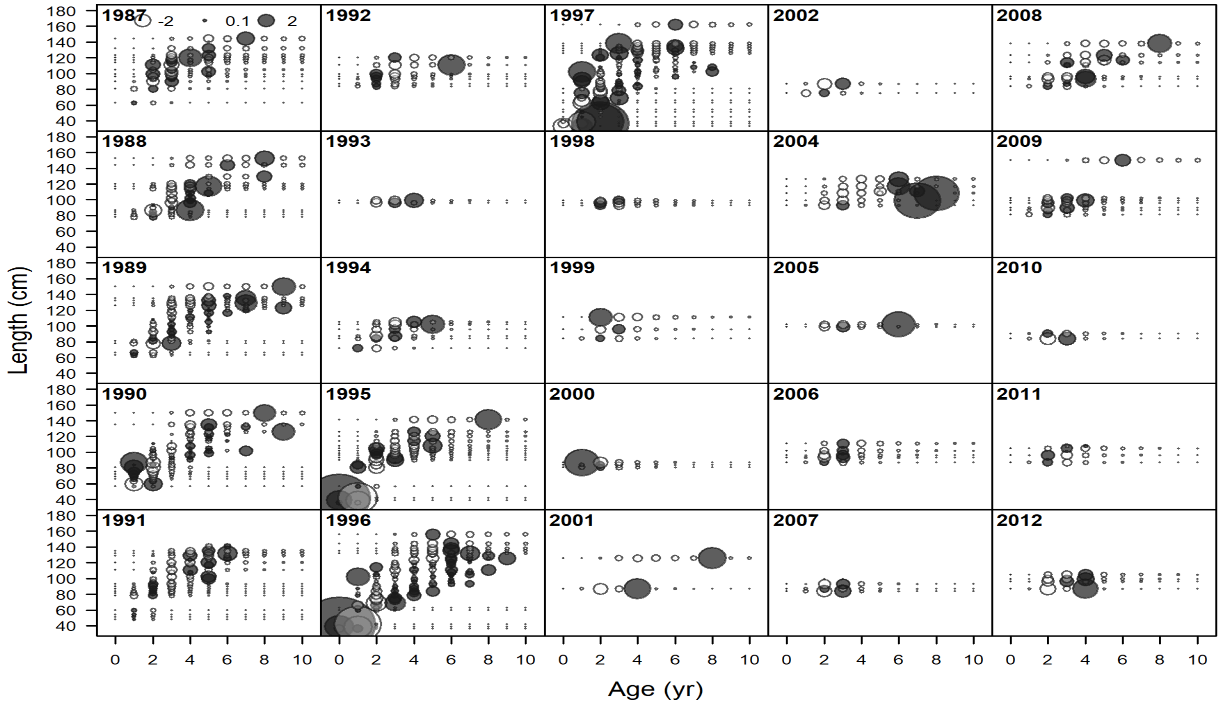


Figure 38. Pearson residuals for discard and retained length composition data by year compared across fleets for Gulf of Mexico cobia for SEDAR28 Update (Upper panel) and SEDAR28 (Lower Panel). Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

SEDAR28 Update



SEDAR28

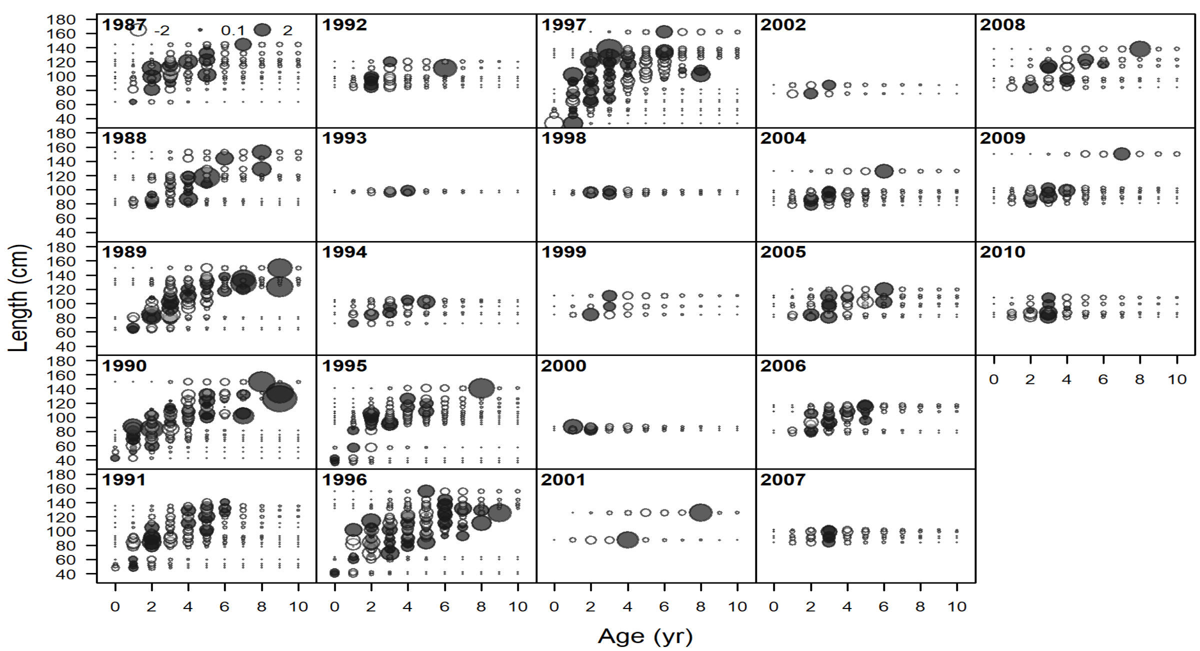


Figure 39. Pearson residuals of conditional age composition fits for Gulf of Mexico cobia in the Commercial fishery. Solid circles are positive residuals (observed > expected) and open circles are negative residuals (observed < expected).

SEDAR28 Update

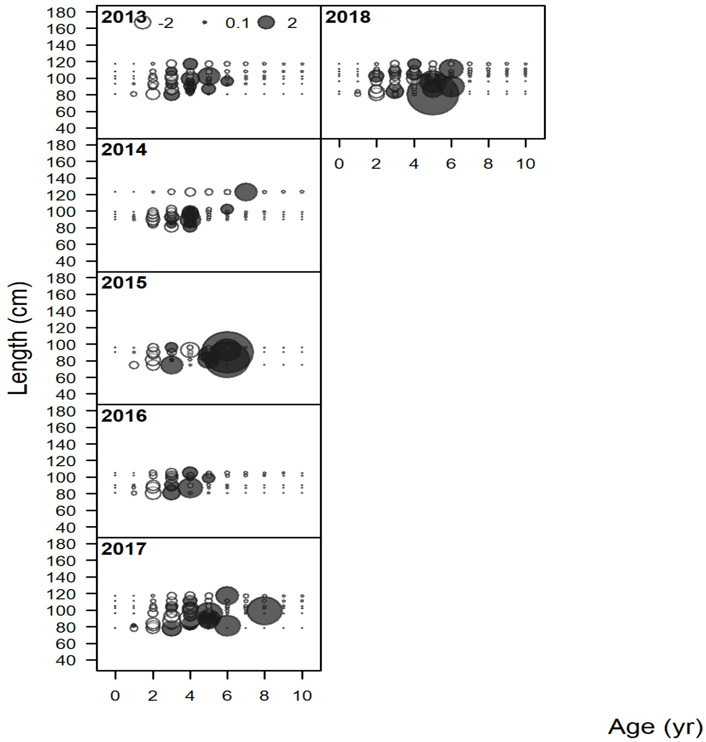


Figure 39 Continued. Pearson residuals of conditional age composition fits for Gulf of Mexico cobia in the Commercial fishery. Solid circles are positive residuals (observed > expected) and open circles are negative residuals (observed < expected).

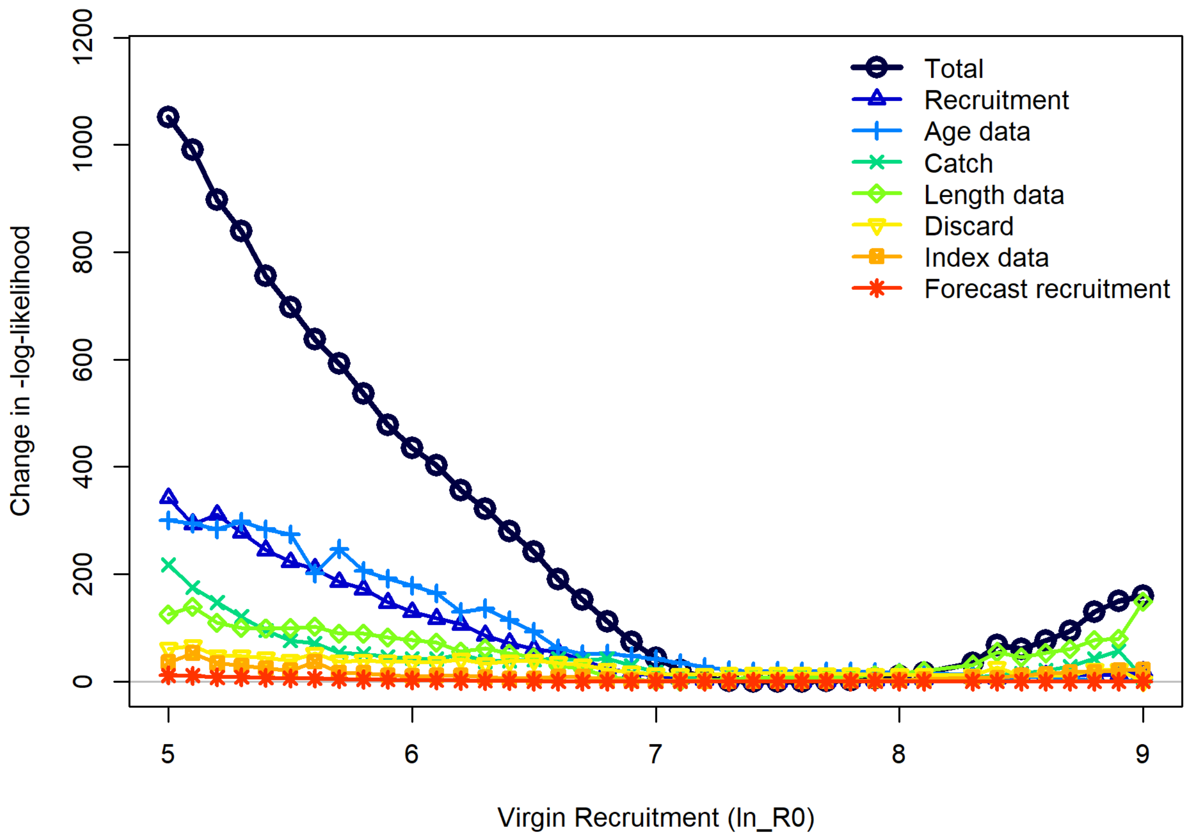


Figure 40. The profile likelihood for the virgin recruitment parameter of the Beverton – Holt stock-recruit function for Gulf of Mexico cobia. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed virgin recruitment parameter values tested in the profile diagnostic run.

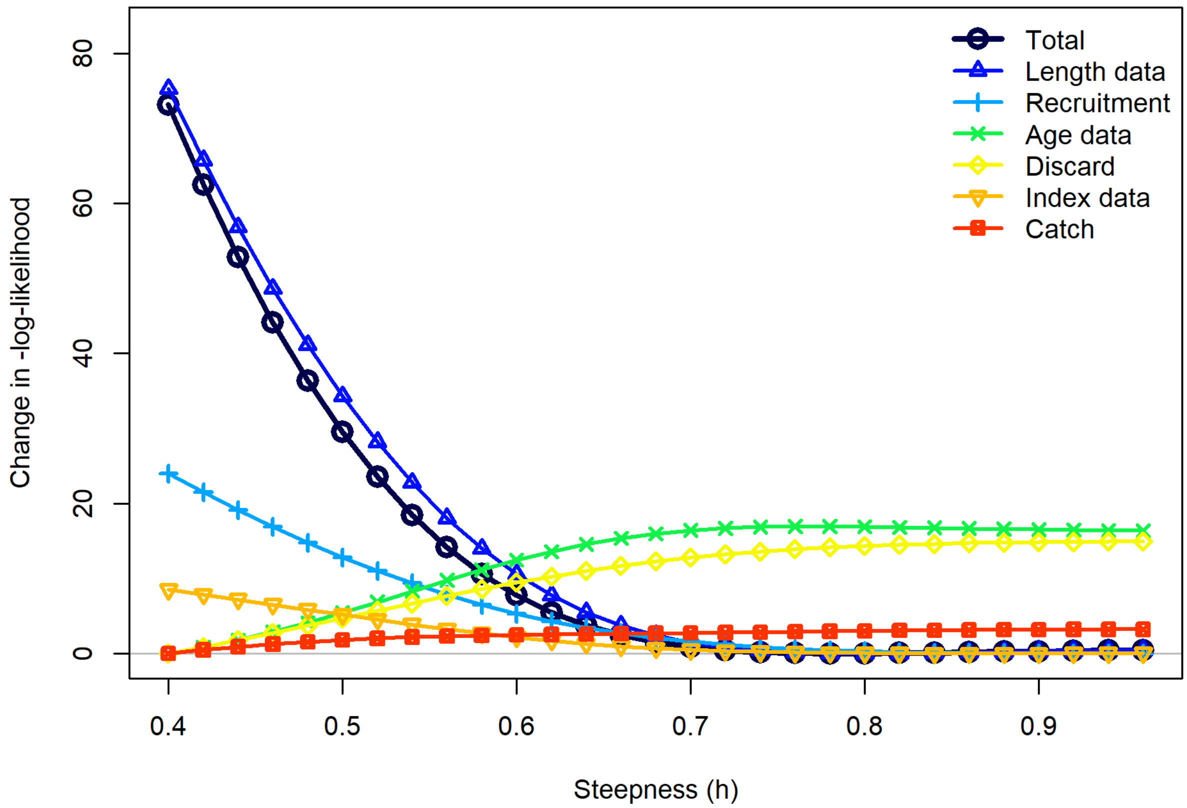


Figure 41. The profile likelihood for the steepness parameter of the Beverton-Holt stock-recruit function for Gulf of Mexico cobia. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.

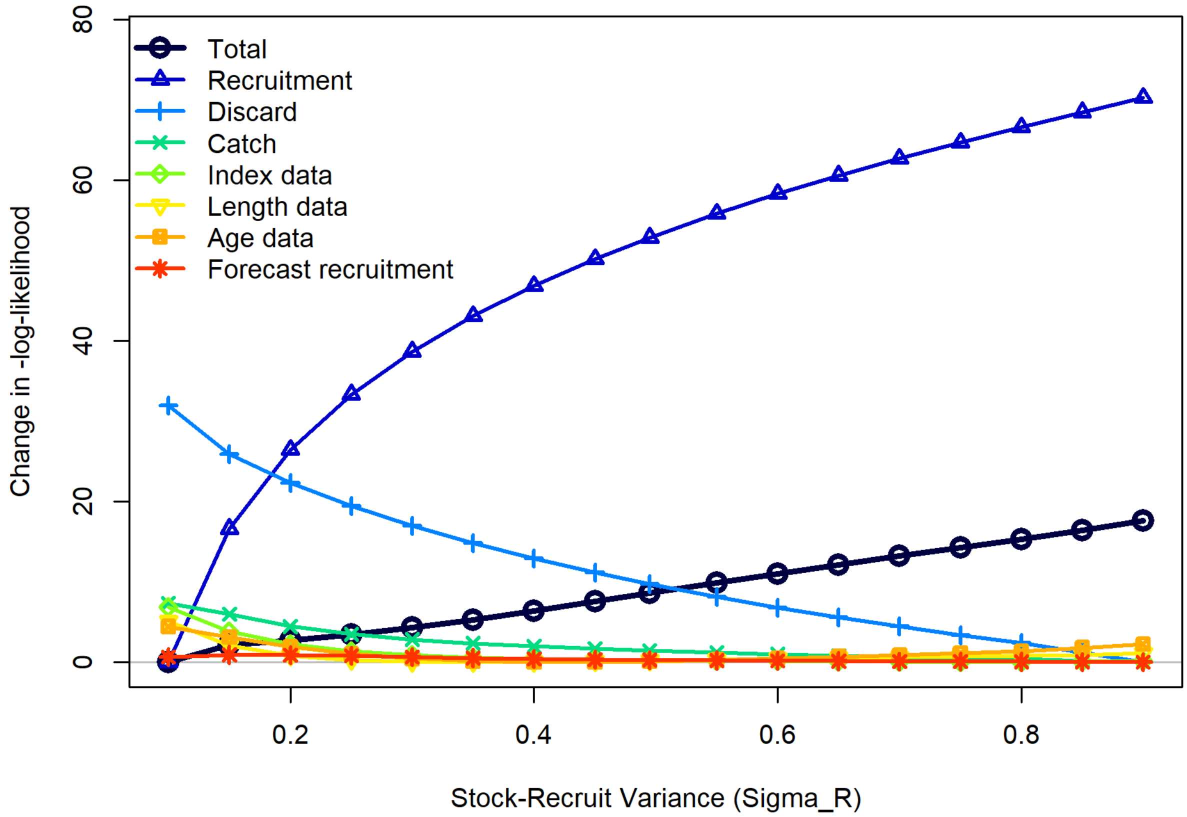


Figure 42. The profile likelihood for the variance parameter of the Beverton – Holt stock-recruit function for Gulf of Mexico cobia. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed variance parameter values tested in the profile diagnostic run.

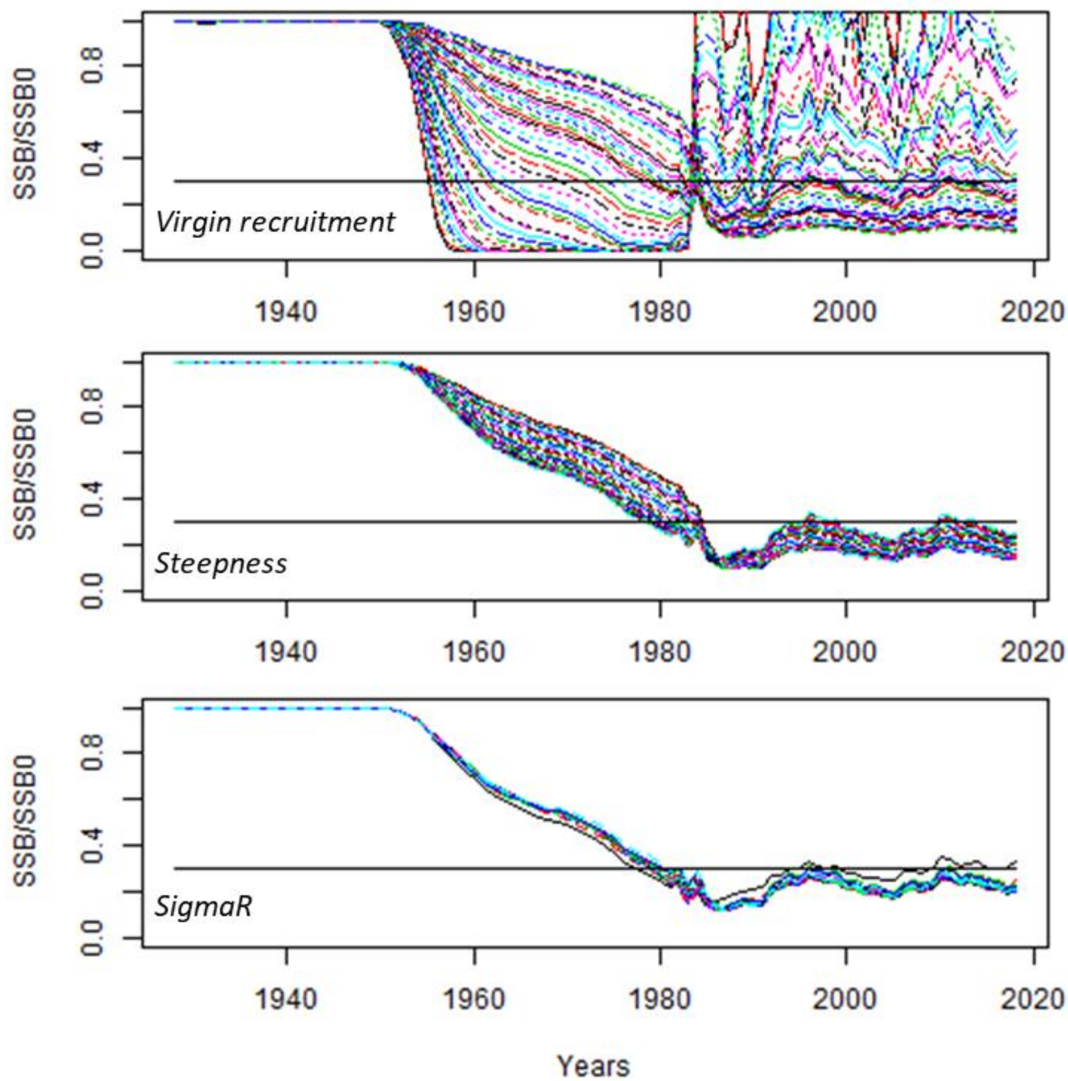


Figure 43. Trends in relative spawning stock biomass (SSB is in metric tons) of Gulf of Mexico cobia for each of the profile likelihood runs. The top panel represents the range of values for virgin recruitment (ln(R0)), the middle panel represents the range of values for steepness, and the bottom panel represents the range of values for the stock-recruit variance term (SigmaR). Note that not all of the values of the parameters used in the profile likelihood analyses may be realistic for cobia.

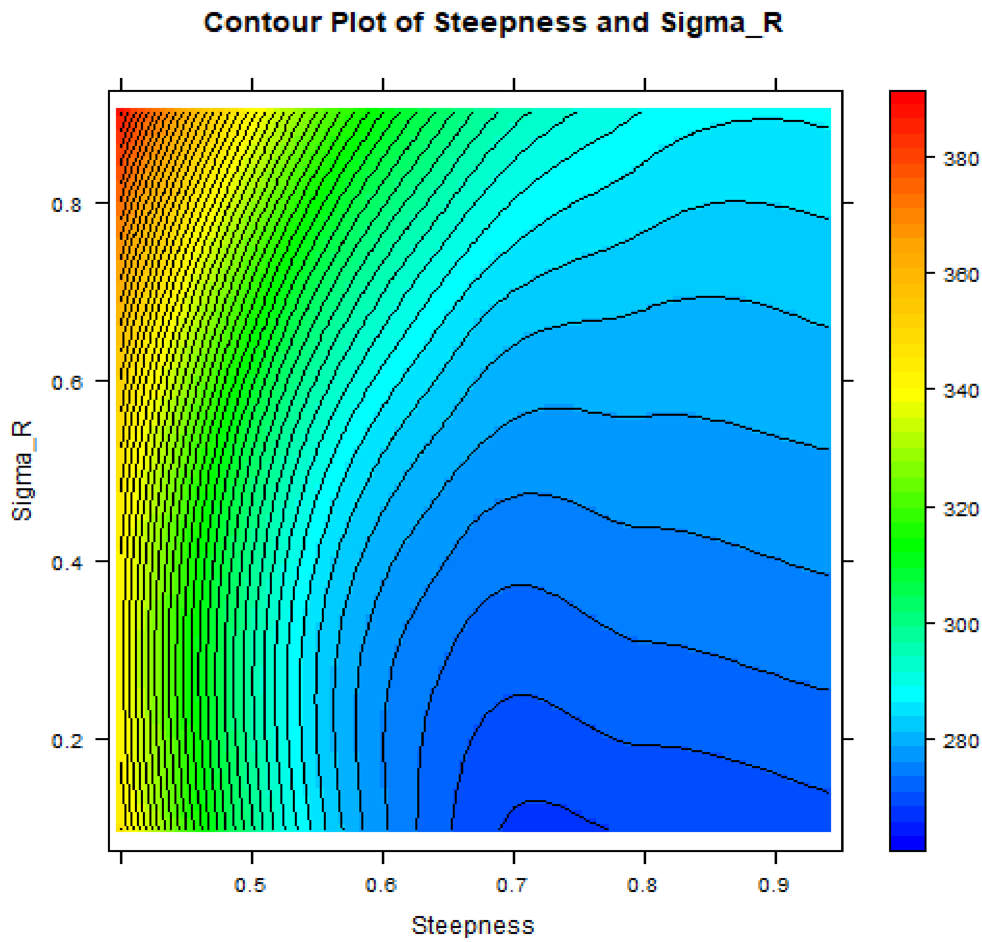


Figure 44. Profile likelihood contour plot of recruitment variance against steepness. Contours illustrate negative log-likelihood values (lower values demonstrate stronger fit to the data).

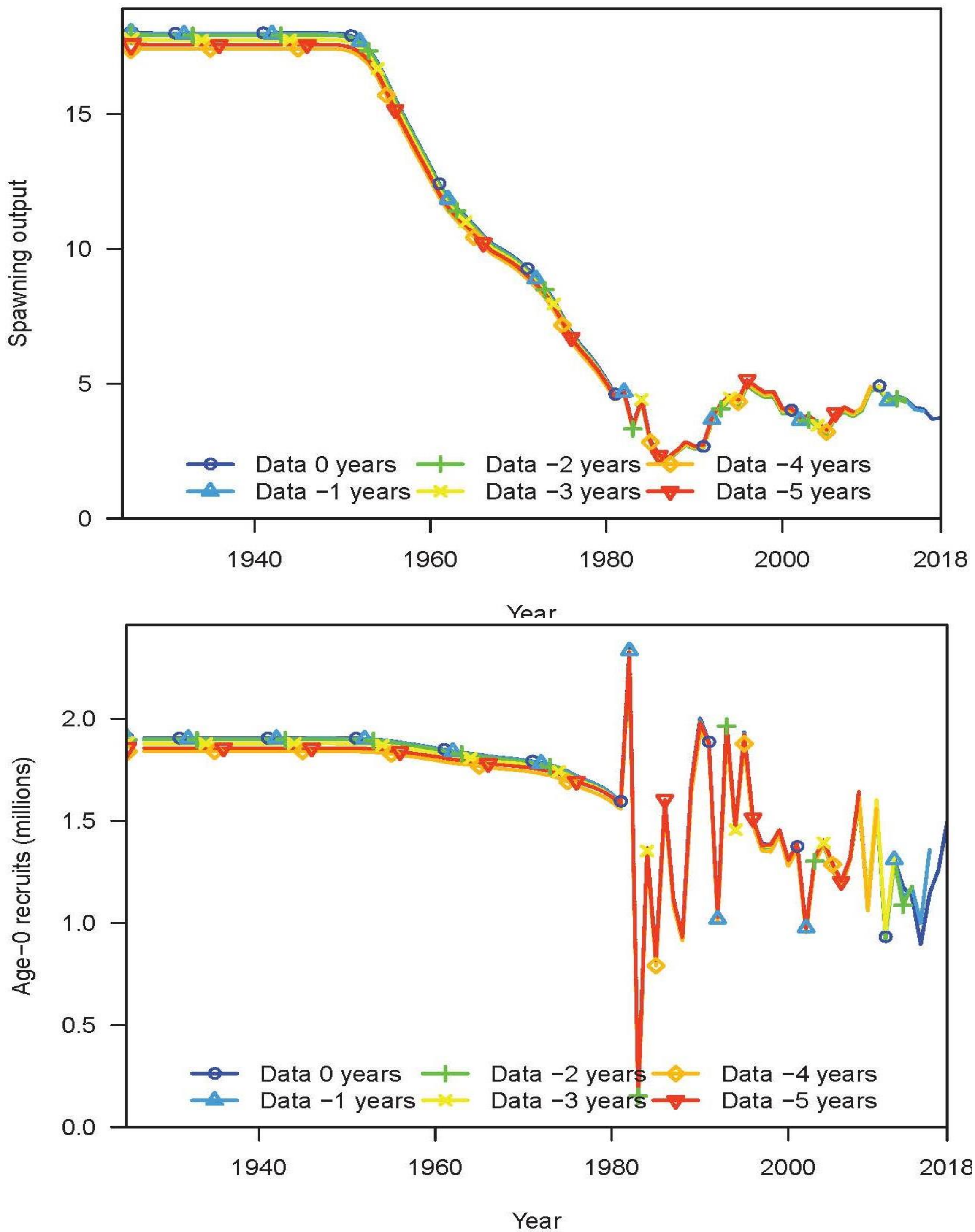


Figure 45. Results of a five-year retrospective analysis for spawning biomass (metric tons; top panel) and recruitment (millions of fish; bottom panel) for the Gulf of Mexico cobia Base Model. There is no discernible systematic bias, because each data peel is not consistently over or underestimating any of the population quantities.

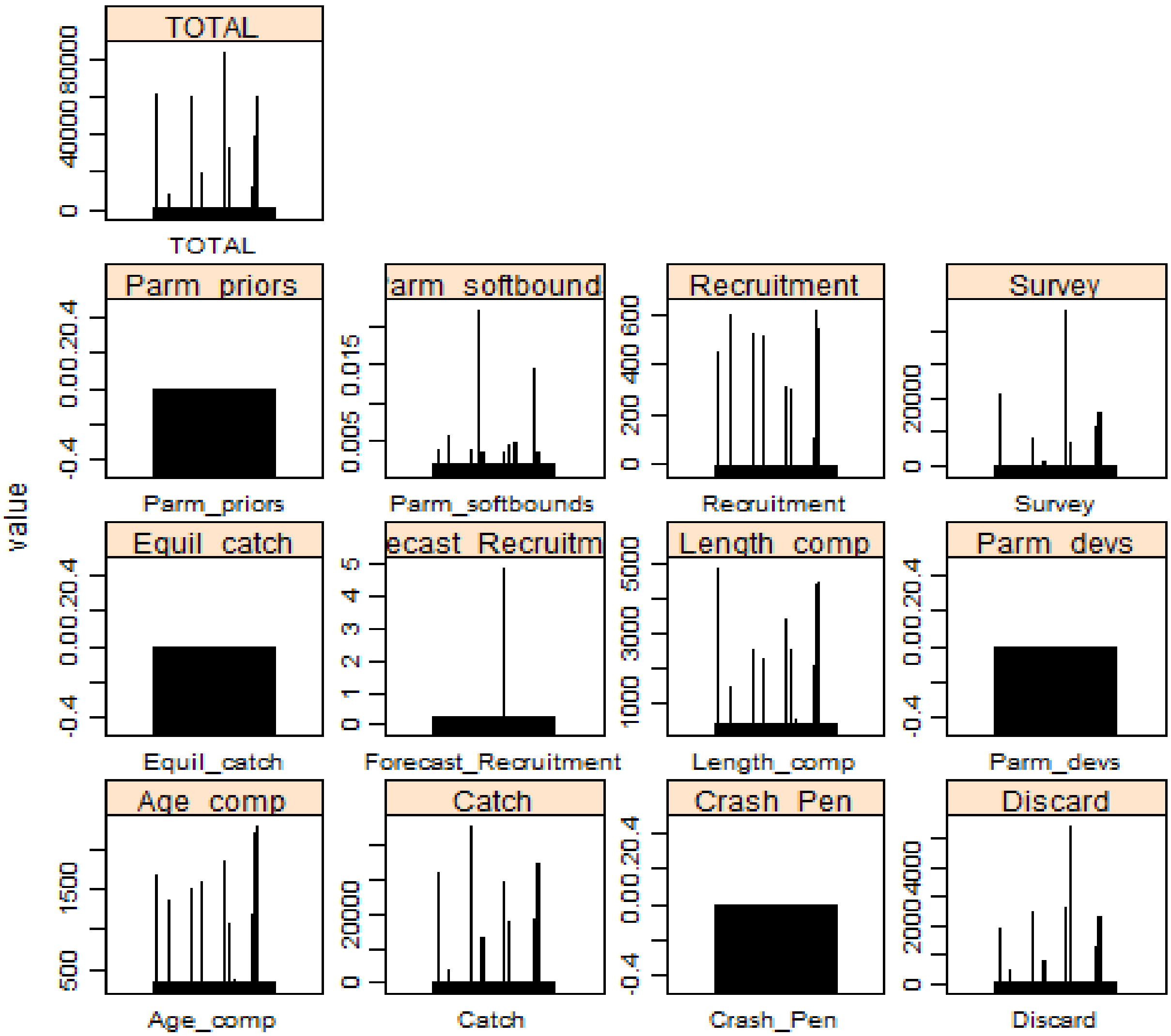


Figure 46. Results of the jitter analysis for various likelihood components for the Gulf of Mexico cobia Base Model. Each panel gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 20% from the base model best fit values.

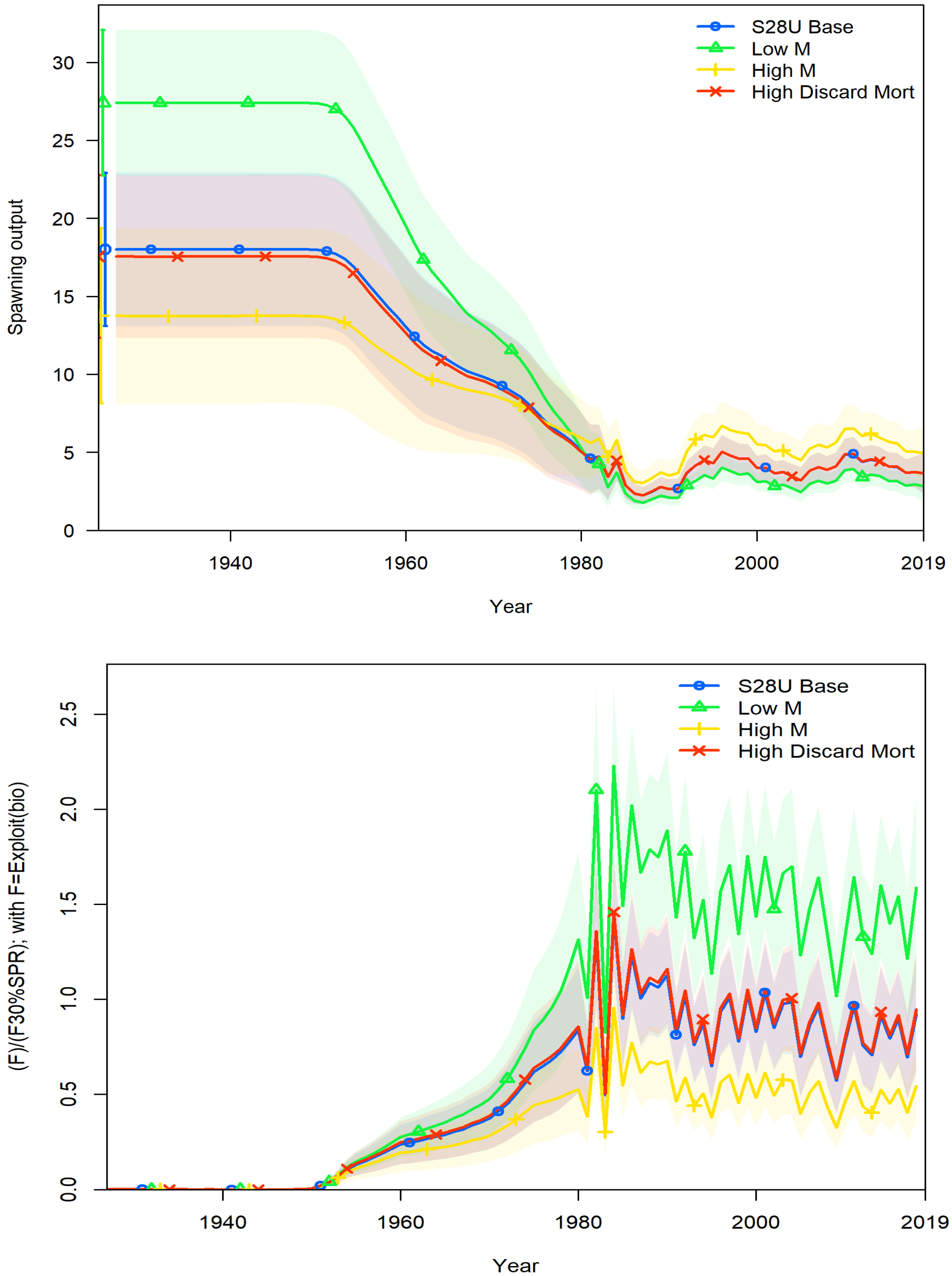


Figure 47. Estimates of spawning stock biomass (metric tons) and fishing mortality (total biomass killed / total biomass) for the Low M, High M, and High Discard Mortality Rate sensitivity runs conducted for Gulf of Mexico cobia.

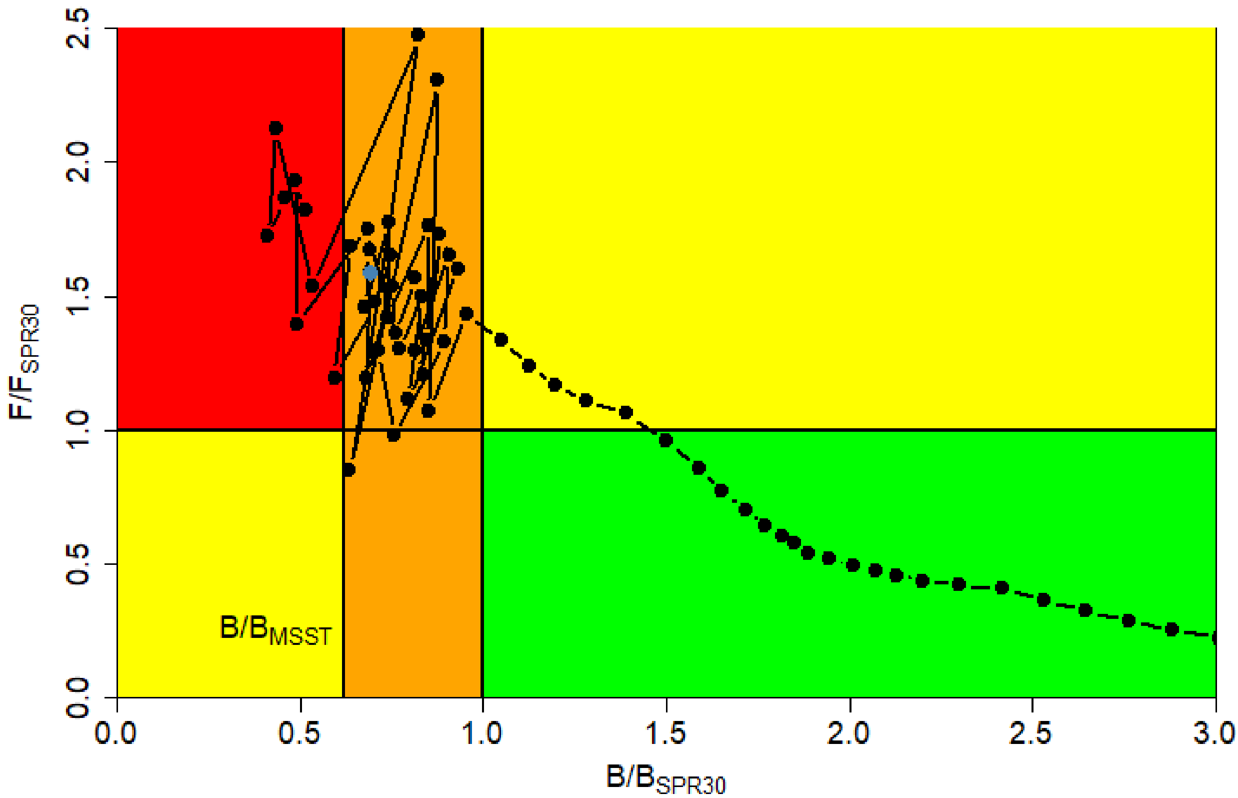


*Figure 48. Kobe plot illustrating the trajectory of stock status. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST = (1-M) * SSB$_{SPR30\%}$). The 2018 terminal year stock status is indicated by the gray dot.*

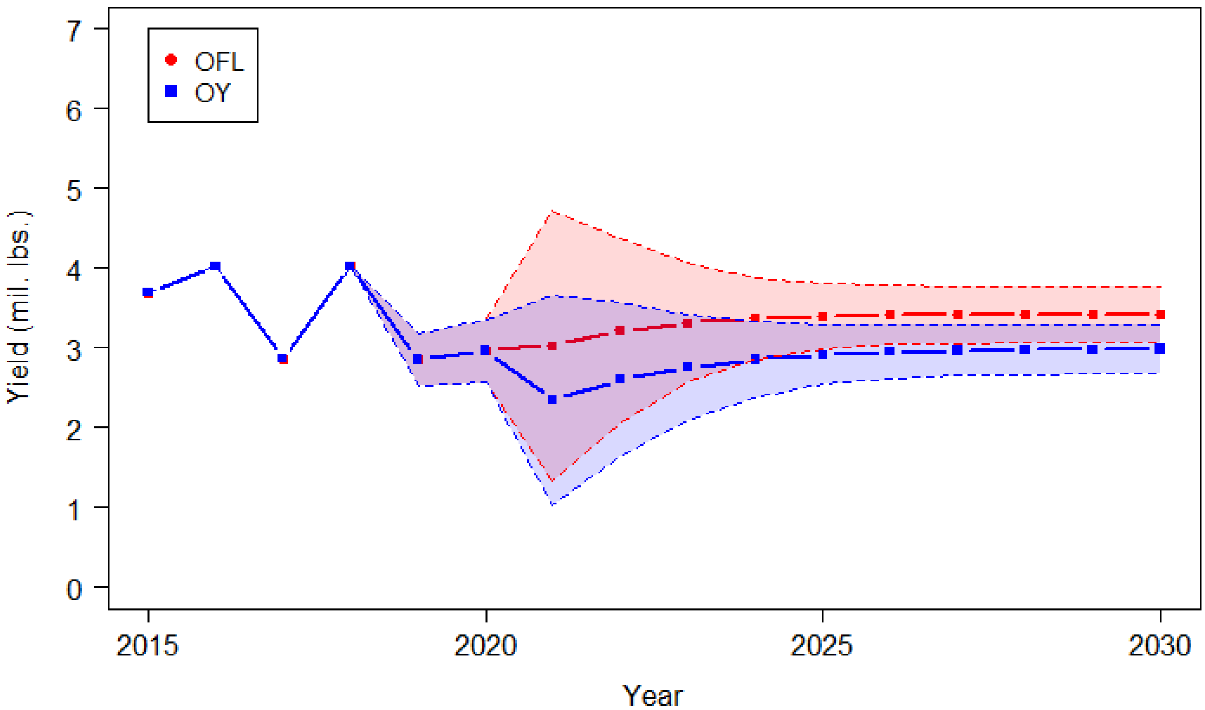


Figure 49. Historic (2015 – 2019) and forecasted yields with 95% uncertainty bands for the OFL projections (red) and Optimum Yield projections (OY; blue).