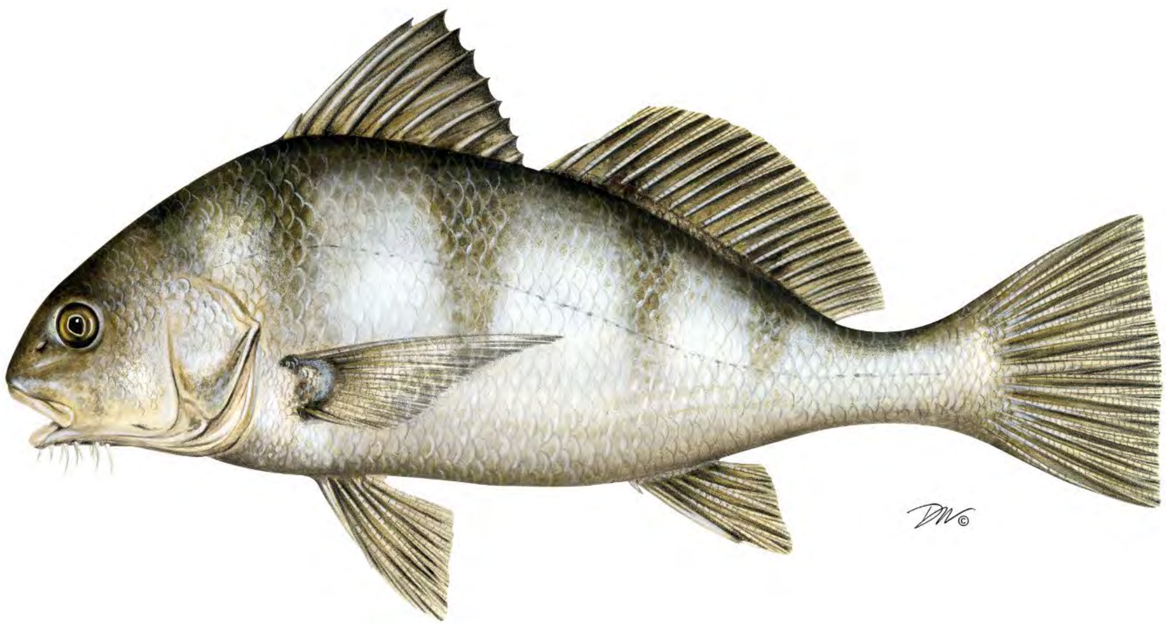
Atlantic States Marine Fisheries Commission

2023 Black Drum Benchmark Stock Assessment and Peer Review Report



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Sustainable and Cooperative Management of Atlantic Coastal Fisheries

ACKNOWLEDGEMENTS

The Atlantic States Marine Fisheries Commission (ASMFC) thanks all of the individuals who contributed to the 2023 Black Drum Benchmark Stock Assessment. The ASMFC specifically thanks members of the Black Drum Technical Committee (TC) and Black Drum Stock Assessment Subcommittee (SAS) who developed the consensus stock assessment report, the Peer Review Panel (RP) for conducting a thorough review of the stock assessment, and ASMFC staff for coordinating the assessment and peer review.

The TC and SAS would like to acknowledge all the data providers that supported the assessment through gathering and preparing data sets, and Mike Rinaldi (ACCSP) for validating and providing commercial landings data from partner agencies. Several assessment resources with open source software were crucial to this assessment including the National Oceanic and Atmospheric Administration (NOAA) Fisheries research track assessment of index-based assessment methods (https://github.com/cmlegault/IBMWG), the JABBA modeling framework (https://github.com/jabbamodel), and the Stock Synthesis modeling framework (https://github.com/nmfs-stock-synthesis).

The RP much appreciated the very collegial nature of the review deliberations. The SAS was very responsive to the RP's comments, questions, and additional tasks. The RP expresses thanks to the SAS for the significant amount of work involved in the assessment and the extensive and thorough assessment report detailing the data, analyses, exploration, and modeling. The RP also acknowledges ASMFC staff for their invaluable assistance during the review process.

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PREFACE

The 2023 Black Drum Benchmark Stock Assessment and Peer Review Report is divided into two parts:

Part A – 2023 Black Drum Benchmark Stock Assessment Peer Review
PDF pages 1-21

Part A provides a summary of the stock assessment results supported by a panel of independent experts through the ASMFC external peer review process. The Peer Review Terms of Reference provides a detailed evaluation of how each Stock Assessment Term of Reference was addressed by the Black Drum Stock Assessment Subcommittee (SAS).

Part B – 2023 Black Drum Benchmark Stock Assessment
PDF pages 22-339

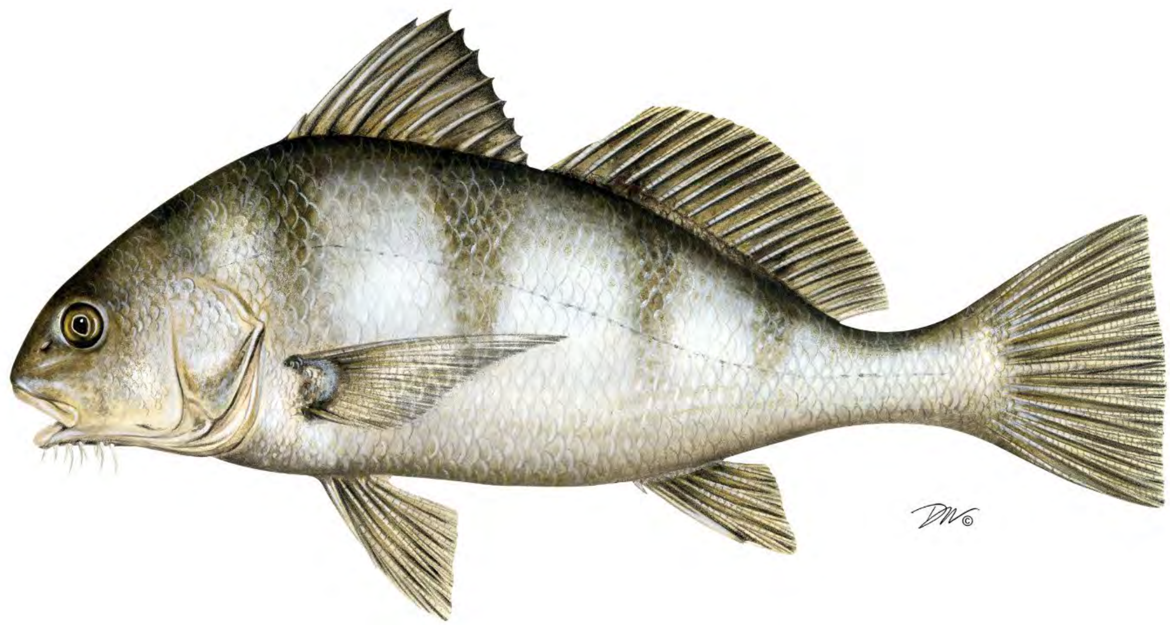
Part B includes the benchmark assessment of the black drum (*Pogonias cromis*) stock along the U.S. Atlantic coast. It was prepared by the SAS and Black Drum Technical Committee (TC). The analyses and descriptions stem from data and summary reports provided by federal and state marine resource management agencies to the ASMFC.

Part B is further subdivided into fourteen Sections, with **Sections 1-12 & 14** providing the original benchmark stock assessment as presented to the Peer Review Panel. During the Peer Review Workshop, the Peer Review Panel and SAS discussed the analyses and models used to make stock status determinations. Additional analyses were conducted during the Peer Review Workshop and the Peer Review Panel recommended a modification to the base model which the SAS supported.

Section 13 presents the Addendum to the assessment report, which provides details on the modified base model developed following the Peer Review Workshop. The Addendum includes stock status determinations used for final management advice from this stock assessment which update the stock status information in **Section 8** presented during the Peer Review Workshop.

Atlantic States Marine Fisheries Commission

2023 Black Drum Benchmark Stock Assessment Peer Review



Conducted on
January 18-20, 2023

Prepared by the
ASMFC Black Drum Benchmark Stock Assessment Peer Review Panel

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INTRODUCTION

An independent peer review of the Black Drum stock assessment was conducted during a hybrid in-person/webinar Review Workshop on January 18-20, 2023, at the ASMFC office in Arlington, VA. The Review Panel (RP) was comprised of Marcel Reichert, PhD, Maia Sosa Kapur, and Gary Nelson, PhD. Dr. Nelson was unable to attend the review meeting, but provided comments and questions prior to the Review Workshop, and contributed to this report. The Panel was assisted by the Atlantic States Marine Fisheries Commission's (ASMFC) Director of Fisheries Science, Patrick Campfield and Tracey Bauer, Fishery Management Plan Coordinator. Supporting information for the stock assessment was presented by the ASMFC Black Drum Stock Assessment Subcommittee (SAS) members Chris McDonough (SCDNR-Chair), Margaret Conroy, DE DNREC), Linda Barry (NJ DEP), Jeff Kipp (ASMFC), and Harry Rickabaugh (MD DNR). The SAS also provided additional clarification and analyses, and answered RP questions.

The RP met with SAS members via webinar on January 12, 2023, for introductions, to seek clarification on general aspects of the assessment report, and discuss areas of the assessment the Panel would like to focus on during the review. During the meeting the SAS provided a broad overview of the assessment. The RP had only a few clarifying questions and did not request additional analyses at that time. The RP concluded the focus of discussions during the Review Workshop should be on the JABBA-select model.

During the Review Workshop, the RP was able to conduct a thorough review of the Black Drum assessment. This report summarizes its findings and recommendations.

EXECUTIVE SUMMARY

The purpose of the 2023 stock assessment review was to evaluate work conducted by the Stock Assessment Subcommittee in relation to their Terms of Reference. The assessment included several advances since the previous assessment in 2015, including developments in data poor stock assessment modeling approaches and the availability of additional (new) data collected following the previous assessment. In addition, the improved data on recreational fisheries (MRIP) had a significant impact relative to the previous assessment.

Black Drum is a relatively fast-growing species with a relatively early maturity, high fecundity, and long lifespan (67 years). Black Drum harvest is dominated by recreational catches and is, both in the commercial and recreational sector, generally considered a bycatch fishery. The 2015 stock assessment concluded that Black Drum was considered not overfished and overfishing was not occurring.

The current stock assessment was completed in the fall of 2022 and had terminal year of 2020. The Review Panel concluded that the Stock Assessment Subcommittee thoroughly addressed all Terms of Reference for the assessment and documented them in detail in the Stock Assessment Report.

Along the Southeast coast of the United States, Black Drum remains essentially a data-limited stock. Given the available data (and model inputs), the Review Panel agreed with the Stock Assessment Subcommittee's recommendation to accept the JABBA-select model as most appropriate for use in stock status determination and management. However, the Review Panel recommended a different base model run that combined the two Mid-Atlantic fleets, with one selectivity, for use in stock status determination and for management advice. The Stock Assessment Subcommittee agreed with this recommendation, and the accompanying results and analyses were provided by the SAS as an addendum to the Assessment Report. The Review Panel noted this run does not change the stock status, but resulted in a more robust model.

The Review Panel agrees with the Stock Assessment Subcommittee that Black Drum is not overfished and overfishing is not occurring. The stock assessment is robust for biomass status (SB_{2020}/SB_{MSY} = 2.99, not overfished) and robust, but with higher uncertainty, for exploitation status (H_{2020}/H_{MSY} = 0.28, not overfishing). The results of the assessment using the JABBA-select model are appropriate for use in management. However, specific uncertainties specified in this report should be taken into account in terms of management risk.

Based on the uncertainty, stock status, and potential future data, the Review Panel recommends a next stock assessment to be conducted in 5 years, and advises monitoring the stock in the intermediate years using harvest trends and other information. If warranted, future assessment timing can then be adjusted. The Stock Assessment Subcommittee and Review Panel provided several research recommendations intended to improve future stock assessments.

TERMS OF REFERENCE

1. Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment.

The Review Panel (RP) concluded the data collection and resulting analyses were thoroughly described and detailed by the Stock Assessment Subcommittee (SAS) in the Assessment Report. As Black Drum is a relatively data poor-stock, there were limitations that constrained assessment model choice. In addition, there were data limitations for 2020, the terminal year of the assessment, due to the COVID pandemic's disruption of annual data collection.

<u>Life History and Biological Data</u>
Stock definition and assessment delineation were appropriate. The assumption of a closed stock structure for the extent of the assessed population is reasonable. Note, possible recruitment from of the Gulf of Mexico may occur, and conceivably contribute to uncertainty (see details in section 4 below).

Length data from the recreational harvest was dominated by information from the southern states (NC to FL). This is where most of the recreational landings occur. Commercial length data were mostly from North Carolina, with landings from Virginia, North Carolina, and Florida dominating the commercial harvest. The RP agreed the length information was sufficient to represent the harvest and overall population for the assessment, but more comprehensive length data will improve future assessment efforts.

The availability of age data was (still) very limited, preventing an age-structured model.
The oldest fish was 67 years, collected in the 2000s; however, the oldest fish from the southern region was 48 years (collected between 2000 and 2009). Realizing this is a region-wide assessment, the RP wondered if the considerably younger maximum age information was a function of sample size in the southern range, or if that southern population indeed has a lower maximum age. This was relevant as it influences the estimate of natural mortality. The SAS indicated the relatively limited age data and fishery-independent source of aged fish was most likely the cause for the lower max. age. As this was a coastwide assessment, 67 years was selected as the maximum age for the entire population range. The RP agreed this was a reasonable assumption but highlighted the value of more comprehensive age data collection in the future.

The RP had considerable discussion on the SAS's growth modeling and the resulting Von Bertalanffy (VB) growth parameters used in the Jabba-select model. One of the RP's concerns was that the VB model did not seem to fit well to the individual data (Figure 21 in Appendix 1). The RP recommends including a refitting of the growth model in a future assessment. The RP also noted the sex-specific growth curves may have been statistically different, and perhaps treated as separate inputs in the modeling effort. However, given the generally large sample sizes in the length at age, small statistical differences may not represent a relevant "biological" difference. After some discussion the RP agreed with the SAS to combine the data for males and females in the growth model, but made recommendations for a future assessment (see also comments in JABBA-select model discussion below).

Natural mortality was estimated using the Then et al (2015) method. The SAS clarified that a subset of the Then et al data was not explored, in order to eliminate species with a life history different from Black Drum. The approach has been used in assessments of other species (e.g., Scamp, SEDAR 68). An age varying natural mortality (see Lorenzen 1996 and 2000, SEDAR 68, 2021, Lorenzen et al 2022, and Hamel and Cope, 2022) scaled to the Then estimate was explored by the SAS. However, the preferred JABBA model does not allow the use of an age varying M. The age varying mortality was included in the Stock Synthesis model, which was eventually not selected as a preferred assessment method.

Harvest

Black Drum harvest is dominated by recreational hook and line fisheries. [Add key areas.] The Review Panel asked if there was an attempt to estimate NC wave 1 MRIP numbers prior to 2005. This was not done because wave 1 numbers were generally very small with only a few years contributing more than 1% to the overall harvest.

The commercial harvest was obtained from the ACCSP data warehouse and State sources. Landings were appropriately characterized and documented. The commercial harvest is dominated by landings in Virginia, North Carolina, and Florida (Table 2 in ASMFC, 2022).

Discards and discard mortality

There was limited discard information available, and the RP asked if other methods for discards were investigated. The one data source for commercial fisheries (NC DMF Program 466) is from an area where a significant part of the commercial harvest occurs (Table 2 in ASMFC, 2022). Data for the recreational fisheries, comprising the majority of total harvest, originated from the coastwide MRIP survey information. As a result, other methods to investigate discards were not explored.

Dead discards were estimated using an 8% discard mortality across all fisheries, ages, and time periods. Although the actual overall Black Drum discard mortality is largely unknown, the RP found this estimate reasonable based on the available information, including the fact that Black Drum is a relatively "hardy" fish and is generally fished in shallow waters, possibly limiting barotrauma.

The increase in discards in the mid-2010s (Figure 19) is likely due to a change in regulations in North Carolina, where a significant part of the harvest occurs. The RP discussed the reason why a drop in recreational discards, but not in recreational harvest, occurred in 2019 and 2020 (e.g., Figure 19 of the Assessment Report). This drop may have been a result of reduced data collection during the COVID-19 pandemic or fishery regulations. However, all indications suggested the drop in discards did reflect fisher behavior in those years. The RP recommended that the trend in recreational discards relative to harvest should be monitored in future years.

Fishery-independent data sources and indices

The review of fishery-independent data sources was thorough and well documented in the Assessment Report. NEAMAP and state agency fishery-independent data sets were considered. Sample sizes were too low for inclusion in any of the assessment models. The description of available indices and the choices for indices used in the various analyses was sufficiently detailed and justified.

The Georgia Trammel net index was not used in the base assessment model as its trends conflicted with trends from other indices. This could be because the population in Georgia is following a different pattern, or because of issues with the survey itself. The RP noted the Georgia index is based on number of fish per set. However, there was a change in the survey in 2007 that resulted in a 50% reduction in the trammel net length. A gear comparison study by GA DNR staff using Speckled Trout data indicated no difference in catchability between the nets used before and after the change in net length. However, as species behavior is likely different between Speckled Trout and Black Drum, there may have been a change in Drum catchability. This should be investigated further and may (partially) explain the apparent conflict between the GA index and other indices.

The only index used in the JABBA-select model was the MRIP index. The Assessment Report detailed the changes and calibration in the collection of recreational data, that is considered superior to previously collected data. The new method resulted in significant changes in recreational harvest and effort, and affected the continuity run of the DB-SRA model used in the previous assessment.

The RP noted that despite the improvements, recreational data still remain relatively uncertain, and are subject to management changes that may affect catchability. Regulations for other species may affect Black Drum harvest and catchability. For example, stricter regulations of other species may result in shifts toward targeting Black Drum.

The New Jersey Ocean Trawl Survey (see Figure 46 in Assessment Report) was used as an indication of range expansion only. The high variability in the time series was part of the reason the New Jersey Trawl was not used as an index or abundance.

Across survey data sets, variance was investigated in several ways. The SAS presented reasonable estimates of overall variability in the data. The inclusion or elimination of data sources was decided through in-depth analyses and the SAS thoroughly documented their decisions. The RP agreed with pertinent decisions by the SAS.

The RP agreed that all presented fishery-independent data streams, except the Georgia trammel net survey, are useful for tracking black drum populations.

2. Evaluate empirical indicators of stock abundance, stock characteristics, and fishery characteristics for their appropriateness to monitor the stock between assessments.

Fishery-independent data (indices of abundance) are generally the preferred source of information to monitor fish abundance and population trends. As no coastwide fishery-independent surveys are available for Black Drum at this time, trends in several existing surveys can be monitored for indications of changes to the population. Surveys in areas where the harvest is largest should be considered especially informative for potential impacts of exploitation and other factors that may impact the Back Drum population.

Trends in recreational (MRIP) and commercial harvest, effort, and discards, in conjunction with management regulations, can provide information on both the exploitation pressure and potential population trends. Given the harvest is dominated by recreational fisheries and the MRIP index was used in the JABBA-select model in the assessment, monitoring of recreational data may be most beneficial.

Age information is an important interim data source and can be used as an indicator of potential recruitment pulses (year class strength) and overall changes in the population age structure. However, the RP realizes that age information may not always be readily available due to processing time of the samples.

3. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points.

Several models were presented for consideration in the Stock Assessment Report. Two data-poor methods were presented, both of which used catch and survey (MRIP CPUE index) data. The index data were used to determine either stock status (Skate) or relative stock health (Itarget), then both incorporated catch history to set catch advice. The iTarget and Skate models were thoroughly described, and choices made relative to data inputs and parameters were reasonable. The RP noted that iTarget-like methods are inherently oscillatory, as the population and survey will respond at a lag to management changes, and are predicated upon scientists' confidence in the input data sets. The RP suggested that future investigations of the iTarget method consider using the log-ratios of biomass (Plagyani et al, 2018) and carefully consider the length of the survey time period used (Carvalho et al, 2018). Both methods required a large amount of subjective decision making, such as the relative weight to place upon catch data. The RP agreed with the SAS's recommendation to reject both the iTarget and Skate models for use in stock status determination and management.

A depletion-based stock reduction analysis (DB-SRA) was presented as a continuity model, as this was the preferred model used in the previous Black Drum stock assessment. Based on available data and method development, two critical changes were made to the model: use of re-calibrated/estimated recreational harvest (see Assessment Report for a detailed description), and a change in the natural mortality based on the Then et al. method (see above). Both changes were appropriate and significantly improved the model.

The JABBA-Select model (Winker et al, 2020) was selected due to its ability to allow for the separation of observation and process error, to incorporate uncertainty through prior distributions on influential parameters, and to incorporate selectivity and life history attributes into the estimation of reference points. This latter point is what distinguishes JABBA-select from the previous (2015) assessment framework and is especially important, given the wide geographic range of black drum and the variation in length-based selectivity across fleets. The proportion of the population selected at length likely varies due to a combination of regulation (size minimums vary across states), targeting (fishermen report targeting of sub-adults), and availability (preliminary tagging research suggests fish out-migrate from the Southern Atlantic as they reach maturity). The JABBA-select model was appropriately described.

The RP agreed with the SAS's recommendation to accept JABBA-select as the most appropriate model, given the data availability and inputs for use in stock status determination and management. The JABBA-select model, as expected, presented a superior representation of overall uncertainty and agreed with the DB-SRA model in terms of stock status.

The RP extensively discussed data inputs, parameter choices, priors, and other model specifics for the JABBA-Select model. The RP focused on three key considerations with respect to JABBA-Select model inputs and configuration: I) the estimation of the growth curve, II) the treatment of observation uncertainty in the MRIP CPUE index, and III) the specification of fishery fleets, particularly the definition of selectivity curves for each fleet.

The following sections summarize the chief concerns discussed during the Review, and important tasks to be revisited for the next assessment. To be clear, based upon the sensitivity analyses and discussions held during the review, we did not feel that any of these issues were alarming enough to require a change to the base model, with the exception of the Mid-Atlantic fleet disaggregation, described below. None of the sensitivity runs associated with these discussions resulted in changes to the *qualitative* stock status.

<u>Growth Curve Parameterization</u>

Parameters of the von Bertalanffy growth function (VBGF) were fit to data from the entire region, though these data were extensively filtered beforehand to remove outliers. Efforts to obtain accurate estimates of the uncertainty in the VBGF parameters when re-fitting the data to individual length-at-age data during the review were not successful. Based on a visual inspection of the data, the RP believes that a) it is plausible that there is not strong sexual dimorphism in length-at-age for Black Drum, supporting the continued use of a singular curve for the entire stock, and 2) there is likely more variability in length-at-age than is currently represented in the base model and its attendant sensitivities. The removal of outliers before VBGF estimation (done on a per-sex basis) might mask differences across space, and under-estimate the uncertainty of growth present in the population.

The RP requested that for future assessments, scientists perform the parameter estimation to a dataset of *individual* length-at-age observations by sex, without the extensive filtration (e.g., removal of outliers) and without the averaging steps described in Appendix 1 of the Assessment Report. First, it must be confirmed whether or not there is sexually significant dimorphism in length-at-age. See an example of comparing VB parameter estimates for significant differences in Kapur et al, 2020.

Regardless of the outcome, the authors must then determine whether and how to incorporate the attendant uncertainty in the length-at-age curve into their assessment. Because JABBA-Select can only use a single input growth curve, the authors could choose to run two additional sensitivity models using "high" and "low" growth scenarios, with these scenarios characterized by the 95% confidence interval around the predicted length-at-age. If the male and female curves are quite distinct, authors could consider modifying the model inputs to a “female-only” model, with associated changes to weight-at-age, maturity-at-age, and input indices and catches.

This effort is important as the growth parameterization explicitly informs the conversion of fish lengths-at-age to weights, and therefore exploitable biomass. The impact of this uncertainty on the resultant reference points could not be evaluated within the scope of the review, and it is imperative it is addressed for the next assessment.

Note the RP's feedback is based on the understanding that the mean length-at-age data were used in the JABBA-select model. In addition to the methodological feedback, the RP recommends the SAS remove reference to the individual length-at-age parameter fits in the Stock Assessment Report.

Observation uncertainty in the MRIP CPUE index

The MRIP index, based on recreational harvest and effort data, was the only available coastwide index used in the model. The unscaled data were used to develop the CPUE time series, in numbers of fish per angler per hour. The SAS chose to provide the MRIP index as numbers, not biomass, to the JABBA-select model to avoid compounding the uncertainty in weight-at-age described above. The putative standard errors in the MRIP index were quite small, on the order of 0.063, likely due to the high number of angler intercepts that comprise the dataset. Based on work by Francis et al. (2003), the SAS decided to add an additional SE of 0.165 to bring the total input uncertainty in line with what is expected of fishery-dependent CPUE indices. The JABBA model estimated only minimal (<0.05) additional SE on top of this, and the fits to the survey, while statistically satisfactory, are generally flat, as is the process error curve. A sensitivity run with the additive SE of 0.165 removed suggested the model could indeed be more responsive to these input data, with better fits to the index, more variability in process error, and quantitative (but not qualitative) adjustments to terminal reference points. The JABBA model again estimated only minimal additional SE in this case, suggesting the large input SE of 0.165 is possibly too high. The RP recommends that assessors investigate alternative approaches to specifying the input SE for the index, as the assessment’s responsiveness to population trends is wholly dependent on the degree to which it must fit the signal in the CPUE data. One option is to use the square-root of the number of intercepts in the standardization process, to reduce the influence of the high number of data inputs.

Specification of Fishery Fleets and Selectivity Curves

Much discussion focused upon the use of the specified fishery fleets as proxies for geographic areas. This “areas-as-fleets” approach was not explicitly indicated in the report. The SAS stated that the partitioning of fleets into South and Mid-Atlantic, and the use of the inverse of the maturity curve as the descending limb of the selectivity curve for the South Atlantic, was chosen to mimic the hypothesis that fish emigrate from the South Atlantic upon maturity. Thus, the included fleet selectivity is a combination of gear selectivity and species availability, that are difficult to separate.

To be clear, the assumption of a closed stock structure for the extent of the assessed population is reasonable. However, possible recruitment from of the Gulf of Mexico as demonstrated in other species (e.g., Karnauskas et al, 2022 for Red Snapper) may occur, and possibly contribute to uncertainty. The RP also noted that this issue is not unique to the JABBA-select model. The availability issue was discussed in the framework of Black Drum life history, including migration of various life stages to different habitats (see section 3.1.2 of the Assessment Report for details).

In the original base model, the Mid-Atlantic fleet was split into two components (‘early’ and ‘late’) corresponding to seasonal trends in availability to that fleet. The RP stated that this decision over-complicated, and could potentially bias, the model, as catches are modeled at a yearly time step. There is no reason to account for seasonal dynamics in availability. A sensitivity run showed that “collapsing” the MA fleet to a single fleet with a logistic selectivity curve had slight changes to the terminal reference points. The effects were not very large because the MA fleet accounts for a small amount of annual harvest, and the reference points in JABBA-select are weighted by fleet. The RP and SAS agreed to incorporate the change to a single MA fleet into a new base model, as this approach is more parsimonious (fewer parameters) and more in keeping with the model structure of a single year time step with no seasonal dynamics.

The original Assessment Report has a fairly sparse description of how the input selectivity curves were chosen. It appears that many parameters were specified by visual inspection of the data, or by using proxies for out-migration, such as the inverse of the maturity curve. The RP was not comfortable with these “eyeballed” approaches, particularly as the specified curves appeared to either disregard capture of small fish (in the case of the MA_Early fleet) or over-estimate availability of larger fish (SA_fleet). The RP asks that the authors formulate a more rigorous, defensible, and reproducible approach for defining selectivity curves for the next assessment. This is particularly important as the original JABBA-Select paper indicated that dome-shaped selectivity can induce bias up to 30% in derived quantities, when the underlying selectivity is in fact logistic.

A sensitivity analysis in which both SA fleets used logistic selectivity curves showed an expected, though not large, change in the harvest rate associated with maximum sustainable yield, H_{MSY}. This was particularly pronounced in years with strong recruitment pulses (e.g., 2008-2010), where the H_{MSY} was reduced compared to the base model, and the subsequent ratio (H/H_{MSY}) was therefore higher. For management, this means the specification of availability to the SA fleet has the potential to alter the perception of how exploited the stock is, particularly in years of high variability. The stock has not experienced strong variation over the time series, and is fairly long lived. Therefore, the RP does not feel this is of immediate concern to management, but is worth solidifying.

Potential approaches for revisiting selectivity include a quantile analysis, where catch-at-length data for given fleets are binned, and the inflection point of the ascending selectivity curve is the length below which 50% of the observed catches are found; optimization exercises, such a logistic regression, or nonlinear least-squares regression using the double-normal curve, to identify the parameterization of curves that best fit the observed lengths-at-capture; or a re-analysis of the tagging data, that would help elucidate potential movement rates at size (or age) amongst the modeled region. This last suggestion is a significant undertaking likely requiring a dedicated scientist, and should only be undertaken if scientists are confident that using the areas-as-fleets approach is indeed appropriate for the stock. It is worthwhile to consider the interaction between gear selectivity, movement, and assessment selectivity (Waterhouse et al., 2014 and Hurtado-Ferro et al., 2014) as these decisions are made.

4. Evaluate the diagnostic analyses performed.

The various sensitivity runs provided information about the influence of parameter choice on model behavior and stock status, as well as explore “alternative states of nature”. Several sensitivity runs included alternate selectivities for various fleets and a change in catchability in the MRIP index. These runs did not result in a significant change in biomass trend and qualitative stock status. Model explorations using sensitivity runs with different values for steepness (h) and natural mortality (M) resulted in the expected changes in the biomass and fishery trends, but also did not change the qualitative stock status.

The RP requested three additional sensitivity runs: 1) a run with the MA_early and MA_late fleets collapsed into a single fleet, with a logistic selectivity curve; 2) a run with no additive SE on the input MRIP CPUE index; 3) a run with logistic selectivity for the SA_early and SA_late fleets. The justification for these runs and results are described in more detail above.

Based upon results of the sensitivity runs, the SAS and RP agreed the base model should be modified to reflect the dis-aggregation of the MA_early and MA_late fleets as this approach is more parsimonious (fewer parameters) and more in keeping with the model structure of a single year time step with no seasonal dynamics. The observation error and SA selectivity issues will be addressed in subsequent assessments. Finally, the retrospective analysis in the JABBA-select model did not show a significant retrospective pattern and did not raise serious concerns.

5. Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure the implications of uncertainty in technical conclusions are clearly stated.

Uncertainty was characterized by the use of the JABBA-Select framework that utilizes Bayesian statistics in the estimation of parameters and attendant confidence intervals; the investigation of various sensitivity runs that explored a limited number of data treatments and parameter values; and a retrospective analysis that explored the impact of recent years of data upon derived quantities. The RP was satisfied with the extent of the uncertainty characterization approaches. Discussions during the review highlighted that specification of the form and parameterization of the selectivity curve is likely the chief uncertainty, in terms of likely changes to management quantities.

6. Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.

The RP agreed with the SAS that, given the available data, the JABBA-select model provides the best, most robust estimates for relative stock biomass and fishing mortality estimates, and is appropriate for use in management. The stock status determination using the JABBA-select model generally agreed with the results from the updated DB-SRA model used in the previous assessment.

7. Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.

The choice of reference points and the estimation method was appropriate given the data and assessment model choice. Using the recommended (new) JABBA-select base run, the median SB_{2020}/SB_{MSY} was 2.99, indicating the stock was not overfished in the terminal year of the stock assessment. The H_{2020}/H_{MSY} was 0.28, indicating the stock was not experiencing overfishing in the terminal year of the stock assessment.

The RP agrees with the SAS that the assessment is robust for biomass status (not overfished) and robust, but with a higher uncertainty, for exploitation status (not overfishing). The results of the assessment using the JABBA-select model are appropriate for use in management, but specific uncertainties as specified elsewhere in this report should be taking into account in terms of management risk. See also comments below in reference to future stock assessments.

8. Review the research, data collection, and assessment methodology recommendations provided by the Technical Committee and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

Several of the research recommendations listed in the previous assessment were, at least partially, addressed between the assessments (see Section 9: Research Recommendations in the Assessment Report). The available new information improved the current stock assessment.

The Assessment Report included several research recommendations in order of priority (Section 9). The RP agrees with the SAS's research recommendations, and advises to prioritize the following:

1) An increase in biological sampling in both the commercial and recreational fisheries. In particular, an increase in age samples representative of the coastwide population structure of Black Drum (> 1,000 age samples/year) would further strengthen the currently used assessment model, and potentially support an age-structured model. This is particularly important for areas and fisheries where biological information is relatively underrepresented. Age information can also be valuable as an important interim data source and may be used as an indicator of potential recruitment pulses (year class strength), and overall changes in the population age structure.

2) Only one coastwide index was available for the assessment. The development of additional fishery-independent indices of relative abundance would improve future assessments, especially if the indices are coastwide. Alternatively, calibrating various statewide fishery-independent indices could possibly provide a coastwide index. However, as the SAS indicated, it may be

impossible to develop such an index because of the differences in survey specifics. Furthermore, it is unlikely that surveys will be developed for Black Drum specifically. A multispecies survey could be designed with collecting Black Drum data in mind.

3) The available discard information was limited, contributing to uncertainty in the assessment. Collection of coastwide discard data, including biological data and discard mortality estimates, should be improved, especially in the recreational hook and line fishery. This is especially important given management regulations (size and bag restrictions) and because Black Drum is considered primarily a bycatch species in a multi-species fishery.

In addition, the RP recommended adding the following to the research recommendations:

1) An explanation for the reduction in large recruitment events should be investigated as it may affect the stock's resilience to harvest and other impacts on the population, including climate change and management. It may also affect the stock/recruit relationship.

2) More region-specific reproductive information, including fecundity estimates, possible age-varying spawning frequency and batch fecundity, and detailed spatial variability in length of the spawning season will improve future assessments.

3) Investigate the effect of the change in the Georgia trammel net survey methods (shortening of the net) on the catchability of Black Drum. The survey showed an abundance trend different from other surveys. It is unclear if this was a result of change in the survey or a different population trend in the Georgia region. The catchability was investigated for Speckled Trout, but not for Black Drum, that may have responded differently to the gear change.

9. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

Given the uncertainty in the model, the age structure, including a maximum reported age of 67 years, and current management of Black Drum, the RP agrees with the SAS's recommendation to conduct the next benchmark assessment in 5 years. The RP further agrees with annual monitoring of the population using the SAS proposed stock indicators, with a potential change in the assessment timing if stock indicators warrant such change.

10. Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.

The SAS completed the full analysis, including sensitivity runs and retrospective analysis, of the recommended base run in the weeks following the Review Workshop. The RP conducted a desk review of this base run and the associated analyses, and had no additional comments. The updated information is included in this final RP report.

ADVISORY REPORT

A. Biological Reference Points and Stock Status

The JABBA-Select model analyses provided terminal year spawning biomass and harvest relative to MSY based reference (SB_{2020}/SB_{MSY} and H_{2020}/H_{MSY}), as well as related uncertainty estimates. The Black Drum stock along the coast of the southeastern US is not overfished (SB_{2020}/SB_{MSY} =2.99), nor is overfishing occurring (H_{2020}/H_{MSY} = 0.28) in the terminal year (2020) of the assessment. The assessment was robust for overfished status, but exploitation status had a higher uncertainty. The population seems relatively stable in recent years given the various population trends, while the recreational harvest increased slightly overall.

B. Stock Identification, Distribution, and Management Unit

The Black Drum population off the southeastern US represents the northernmost part of the species' overall distribution. Given the available information, including genetic analyses, the stock is well defined and can be considered a closed stock. Note some limited exchange or recruitment from the Gulf of Mexico and Caribbean is likely. Given the available information on stock structure, a single, coast wide management unit for Black Drum from Florida to New Jersey is appropriate.

C. Landings

Black Drum is largely considered a bycatch fishery, but some directed effort occurs. Harvest in the area is dominated by recreational fisheries, in particular landings from the southern states (North Carolina to Florida). The commercial harvest is concentrated in Virginia, North Carolina, and Florida.

Given the stock status and the uncertainty thereof, recent trends in harvest and relative abundance indices, and the fact that this is largely a bycatch fishery, the RP concluded the recent harvest is likely sustainable. However, it is recommended that trends in harvest, abundance, as well as recruitment (lack of recent large recruitment events) should be monitored to ensure sustainability.

D. Data and Assessment

Black Drum off the southern coast of the US remains largely a data poor species. The available data for the assessment originated from the recreational and commercial fisheries (harvest, effort, discard, and limited biological data) and several fishery-independent surveys (abundance and biological data). Age and discard data were especially limited. As is common for stock assessments, additional information for parameter estimates, including discard mortality and natural mortality, came from other sources such as meta-analyses and related species.

Several models suitable for the available data were explored. The iTarget, Skate, and the Stock Synthesis models were rejected, and the JABBA-select model was deemed most appropriate and robust for stock status determination and management recommendations. The DB-SRA model used in the previous assessment was applied for continuity, but with two significant updates: 1) use of re-calibrated/estimated recreational harvest, and 2) a change in the natural mortality based on the Then et al. method (see TOR 2). Both changes were appropriate and significantly improved the model.

The Review Panel recommended a JABBA-Select base run with combined Mid-Atlantic fleets was the most robust and appropriate for stock status determination. This base run was different than recommended in the Assessment Report and did not result in a change in the overall stock status.

E. Fishing Mortality

Fishing mortality remained relatively stable in recent years. The stock assessment indicated the stock is not undergoing overfishing, but with some uncertainty in that estimate. Harvest and bycatch trends should be monitored for changes in harvest patterns.

F. Recruitment

Black Drum is a fast-growing species with an early maturity, a long life-span (max. age of 67 years), and high life-time fecundity. Drum life-history may result in a relatively modest, but not to be disregarded, susceptibility to overexploitation. However, less frequent large recruitment events in the Mid-Atlantic have been observed in the last decade. Generally, these periodic strong year-classes provide resilience to exploitation and it is recommended that recruitment patterns should be monitored in future years.

Although there are no strong indications of consistent low recent recruitment in Black Drum, the RP mentioned that recent SEDAR stock assessments have noted several species in the region with observed recruitment failures (e.g., Red Grouper, Red Porgy, and Scamp). It has been suggested that changes in the environment may have resulted in a possible regime shift in various species. Timing of reproduction may be an important factor in species vulnerability.

G. Spawning Stock Biomass

The spawning stock biomass remained relatively stable in recent years and the stock assessment indicated with relatively high certainty the stock was not overfished. However, trends should be monitored for changes in the spawning stock biomass.

H. Bycatch

There is limited discard information available for Black Drum. The one data source for commercial fisheries (NC DMF Program 466) is from an area where a significant part of the commercial harvest occurs. The data for the recreational fisheries originated from the coastwide MRIP information. The dead discards were estimated using an 8% discard mortality across all fisheries, ages, and time periods. Although the actual overall Black Drum discard mortality is largely unknown, this seems to be a reasonable estimate based on the available information, including the fact that Black Drum is a relatively “hardy” fish and is fished in relatively shallow waters, possibly limiting barotrauma. A drop in recreational discards, but not in recreational harvest in

2019 and 2020 was noted and may have been a result of data collection during the COVID-19 pandemic and fisheries management. However, all indications suggested the drop in discards did reflect fisher behavior in those years.

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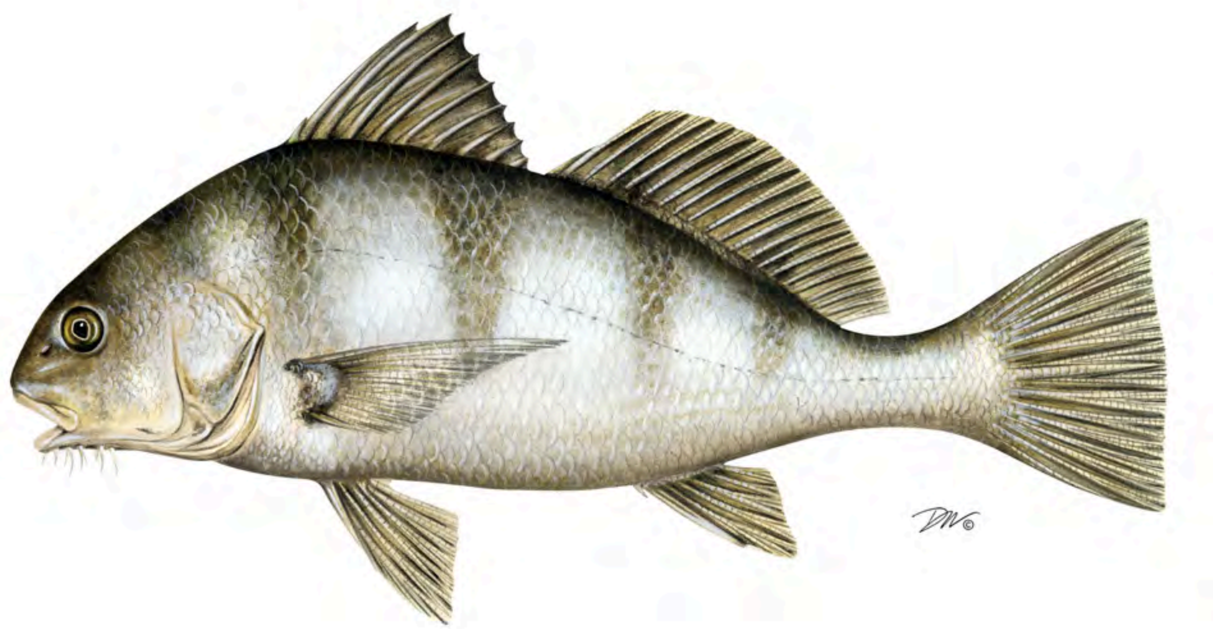
Atlantic States Marine Fisheries Commission

2023 Black Drum Benchmark Stock Assessment Report



Prepared by the
Black Dum Stock Assessment Subcommittee

May 1, 2023

EXECUTIVE SUMMARY

The black drum (*Pogonias cromis*) is the largest member of the family Sciaenidae found along the Atlantic coast of the United States. They are common from the Mid-Atlantic region to the Gulf of Mexico, but considered rare north of Delaware Bay. Adult black drum make long migrations along the U.S. Atlantic coast north/inshore in the spring and south/offshore in the fall, while juvenile black drum are more sedentary. Black drum have an unusual combination of life history characteristics as they grow quickly and are relatively long-lived. Unlike most other long-lived species, black drum are sexually mature at a relatively young age and can spawn millions of eggs annually. Multiple lines of evidence suggest that black drum on the U.S. Atlantic coast are from a common stock.

Fisheries are primarily recreational, while smaller-scale harvest in commercial fisheries occurs primarily north of South Carolina. Regionally, the majority of fishery removals have come from the South Atlantic. Mid-Atlantic removals have been variable and were largest in 2008 and 2009 when they were nearly the same magnitude (in pounds) as in the South Atlantic. Within the Mid-Atlantic, most removals have come from the period most closely associated with the spawning adult migration earlier in the year (January-August), while a smaller component has come later in the year (September-December) when primarily age-0 and age-1 fish are available to the fishery.

No coastwide management program, whether among the states or at the federal level, existed for black drum on the Atlantic coast prior to the development of the Interstate Fishery Management Plan (FMP) in 2013. In 2013, the Commission adopted the Interstate FMP for black drum, which requires all states to implement a maximum possession limit and a minimum size limit of no less than 14 inches in addition to maintaining their previous regulations. Further, the FMP establishes a management framework to adaptively respond to future concerns or changes in the fishery or population.

The first coastwide stock assessment of black drum on the Atlantic coast was completed in 2015. Depletion-Based Stock Reduction Analysis (DB-SRA) was used to provide management advice. DB-SRA was developed as a data-poor method using a fishery removal time series to estimate sustainable catch levels according to maximum sustainable yield (*MSY*)-based reference points and annual population dynamics parameters including exploitable biomass and exploitation. The stock was determined not to be overfished nor experiencing overfishing. Given DB-SRA was developed primarily to generate sustainable catch levels, this status determination was made based on several lines of evidence including the results of DB-SRA, black drum life history characteristics, vulnerability to fisheries, empirical trends from indices of abundance, and the harvest history.

This first assessment was being conducted as the FMP was implemented and the assessment data time series included a terminal year of 2012, so effects of regulations required by the FMP, most notably the first regulations in North Carolina (2014), a primary contributor of black drum catch, were not assessed during the assessment. Another notable development since this first assessment was the redesign of effort surveys used to estimate recreational catch of black drum which led to significant increases in estimates during years before and after the assessment. This change was anticipated to change the scale of biomass and reference point estimates making the previous assessment estimates incompatible with updated recreational catch estimates.

There have been improvements in age and size composition sampling in recent years since the first assessment, but there remain limitations that preclude coastwide composition data for harvested black drum. Overall, it's clear the South Atlantic is better sampled for composition data than the Mid-Atlantic. Discard size and age composition data also remain a major data limitation for black drum assessment.

Indices of black drum abundance from several fishery-independent surveys along the coast were considered in this current assessment, mostly tracking young-of-year and sub-adult black drum abundance. Additionally, one fishery-dependent time series of catch-per-unit-effort (CPUE) was developed from recreational fishery data covering all exploitable sizes.

Empirical stock indicators were developed as part of this current stock assessment that can be monitored annually between stock assessments. These indicators included five indicators of year class strength, two indicators of multiple sub-adult age class abundances, one indicator of exploitable abundance, one indicator of range expansion, and six indicators of fishery characteristics (regional catch time series).

Empirical indicators show increased fishery removals in the last twenty years and less frequent large recruitment events in the Mid-Atlantic in the last ten years. There are no clear indications of a declining trend in recruitment or exploitable abundance from abundance indicators, with the exception of the anomalous GA trammel index, but there is a declining trend in the final two years of the recreational discard time series that may be reflective of abundance in addition to other factors. There is some indication of northern range expansion. Overall, stock indicators do not appear negative at this time, but should be monitored closely for any sign of change.

This assessment also transitioned from DB-SRA used during the first assessment to an age-structured production type model (JABBA-Select) that incorporates total fishery removal data as well as an index of relative abundance. The recreational CPUE was used as the index of abundance as it includes data on the full, exploitable age range from the entire coast.

Spawning biomass (*SB*) was estimated to increase throughout the assessment time series (1982-2020), though there were wide credible intervals indicating high uncertainty in absolute biomass estimates. Relative biomass was estimated with more certainty. Exploitation generally follows the removal time series with higher exploitation estimated during the mid-1980s and since 2000. Credible intervals of relative exploitation are also quite wide. Most of the intervals through time indicate exploitation less than the harvest rate associated with *MSY* (H_{MSYy}), but there is some low probability of exploitation exceeding H_{MSYy} during the higher exploitation years.

Overfished is defined as spawning biomass falling below spawning biomass associated with *MSY* (i.e., $SB_y/SB_{MSY} < 1$). The 2020 median relative spawning biomass estimated with the final base model was 2.99, indicating the stock was not overfished in the terminal year of the stock assessment. Overfishing is defined as exploitation exceeding exploitation associated with *MSY* (i.e., $H_y/H_{MSYy} > 1$). The 2020 median relative exploitation estimated with the final base model was 0.28 indicating the stock was not experiencing overfishing in the terminal year of the stock assessment.

Results indicate greater certainty that the stock has not been depleted to an overfished status in the terminal year of the assessment, while there is less certainty about the exploitation status. All of the 95% credible interval for the SB_{2020}/SB_{MSY} estimate is above the overfished threshold, while 2020 exploitation shows some low probability of exceeding the H_{MSY} threshold. This low risk of overfishing according to the credible intervals extends back for much of the last twenty years of the time series. A sensitivity analysis included results of several alternative model configurations to assess impact of key assumptions and uncertainties on base model estimates. Stock status estimates from all alternative model configurations are consistent with final base model estimates through time.

In addition to generally high uncertainty in model estimates, there is additional uncertainty due to data limitations. The one-way trip increasing trend in both removals and the recreational CPUE for the assessment time period may indicate that the stock either had been lightly exploited in the 1980s, which has allowed for the recent increase in exploitation of the predicted high biomass, or was overfished and rebuilding throughout the assessment time series. The latter scenario is contrary to the TC's expert opinion that the stock was not overfished at the beginning of the time period, and there were minimal regulation changes aimed specifically at black drum in the 1980s to induce a rebuilding period. However, it is also possible that recruitment overfishing is occurring or could begin to occur prior to detection with currently available data, due to sub-adult black drum accounting for the majority of removals and the lack of an index that solely tracks mature biomass. With over 30 cohorts contributing to *SSB*, recruitment overfishing may not be evident within current data streams for an extended number of years, leading to an overfished state being reached prior to removals and the recreational CPUE index indicating a sustained downward trend. The TC concurs with the model-derived stock status but acknowledges the lack of contrast in both removals and the recreational CPUE coupled with model uncertainty will require close monitoring of stock indicators and a more conservative approach to managing the fishery.

The TC recommends that a new benchmark stock assessment be completed for the black drum stock in five years (2027). However, the TC also recommends annually reviewing the stock indicators established in this assessment updated with new data to identify any concerning trends in a timely manner. Should any concerning trends occur, the TC may recommend an expedited assessment to be completed before 2027.

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TERMS OF REFERENCE

For the 2023 ASMFC Black Drum Benchmark Stock Assessment

Board Approved [October 2021]

Terms of Reference for the Black Drum Assessment

1. **Characterize precision and accuracy of fishery-dependent and fishery-independent data used in the assessment, including the following but not limited to:**
    a. **Provide descriptions of each data source (e.g., geographic location, sampling methodology, potential explanation for outlying or anomalous data).**
    b. **Describe calculation and potential standardization of abundance indices.**
    c. **Discuss trends and associated estimates of uncertainty (e.g., standard errors).**
    d. **Justify inclusion or elimination of available data sources.**

2. **Discuss the effects of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size) on model inputs and outputs.**

3. **Review estimates and PSEs of MRIP recreational fishing estimates. Request participation of MRIP staff in the data workshop process to compare historical and current data collection and estimation procedures and to describe data caveats that may affect the assessment.**

4. **Identify and develop simple, empirical indicators of stock abundance, stock characteristics, and fishery characteristics that can be monitored annually between stock assessments.**

5. **Develop models used to estimate population parameters (e.g., *F*, biomass, abundance) and biological reference points, and analyze model performance.**
    a. **Describe stability of model (e.g., ability to find a stable solution, invert Hessian).**
    b. **Justify choice of CVs, effective sample sizes, or likelihood weighting schemes.**
    c. **Perform sensitivity analyses for starting parameter values, priors, etc. and conduct other model diagnostics as necessary.**
    d. **Clearly and thoroughly explain model strengths and limitations.**
    e. **Briefly describe history of model usage, its theory and framework, and document associated peer-reviewed literature. If using a new model, test using simulated data.**
    f. **If multiple models were considered, justify the choice of preferred model and the explanation of any differences in results among models.**

6. **State assumptions made for all models and explain the likely effects of assumption violations on synthesis of input data and model outputs. Examples of assumptions may include (but are not limited to):**
    a. **Choice of stock-recruitment function.**
    b. **No error in the catch-at-age or catch-at-length matrix.**
    c. **Calculation of *M*. Choice to use (or estimate) constant or time-varying *M* and catchability.**
    d. **Choice of equilibrium reference points or proxies for MSY-based reference points.**
    e. **Choice of a plus group for age-structured species.**
    f. **Constant ecosystem (abiotic and trophic) conditions.**

7. **Characterize uncertainty of model estimates and biological or empirical reference points.**

8. **Perform retrospective analyses, assess magnitude and direction of retrospective patterns detected, and discuss implications of any observed retrospective pattern for uncertainty in population parameters (e.g., *F*, *SSB*), reference points, and/or management measures.**

9. **Recommend stock status as related to reference points (if available). For example:**
    a. **Is the stock below the biomass threshold?**
    b. **Is *F* above the threshold?**

10. **Other potential scientific issues:**
    a. **Compare trends in population parameters and reference points with current and proposed modeling approaches. If outcomes differ, discuss potential causes of observed discrepancies.**
    b. **Compare reference points derived in this assessment with what is known about the general life history of the exploited stock. Explain any inconsistencies.**

11. **If a minority report has been filed, explain majority reasoning against adopting approach suggested in that report. The minority report should explain reasoning against adopting approach suggested by the majority.**

12. **Develop detailed short and long-term prioritized lists of recommendations for future research, data collection, and assessment methodology. Highlight improvements to be made by next benchmark review.**

13. **Recommend timing of next benchmark assessment and intermediate updates, if necessary relative to biology and current management of the species**

1 INTRODUCTION

1.1 Management Unit Definition

The management unit for black drum (*Pogonias cromis*) under the Atlantic States Marine Fisheries Commission's (ASMFC or Commission) Interstate Fishery Management Plan (FMP; ASMFC 2013) is defined as the range of the species within U.S. waters of the northwest Atlantic Ocean from the estuaries eastward to the offshore boundaries of the Exclusive Economic Zone (EEZ). The selection of this management unit is based on the distribution of the species along the Atlantic coast, as noted in tagging studies from Maryland, Virginia, South Carolina, and Georgia, and historical harvest patterns that have identified fisheries for black drum from Florida north through New Jersey.

1.2 Regulatory History

1.2.1 Interstate Management

No coastwide management program, whether among the states or at the federal level, existed for black drum on the Atlantic coast prior to the development of the Interstate FMP in 2013. In 2013, the Commission adopted the Interstate FMP for black drum, which requires all states to implement a maximum possession limit and a minimum size limit of no less than 14 inches in addition to maintaining their previous regulations. Further, the FMP establishes a management framework to adaptively respond to future concerns or changes in the fishery or population.

In March 2017, a report on Sciaenid Fish Habitat (Odell et al. 2017) was released, which included information on habitat for several species, including black drum, during all stages of their lives, their associated Essential Fish Habitats and Habitat Areas of Particular Concern, threats and uncertainties to their habitats, and recommendations for habitat management and research. This report is meant to be a resource when amending FMPs in the future for these species.

The Board approved Addendum I to the black drum FMP in May 2018. The addendum allows Maryland to reopen its black drum commercial fishery in the Chesapeake Bay with a daily vessel limit of up to 10 fish and a 28-inch minimum size. Maryland reopened this fishery in February 2019.

1.2.2 State Management

At this time, eight states and one additional jurisdiction (Potomac River Fisheries Commission, PRFC) have implemented harvest regulations for black drum (Table 1).

New Jersey: New Jersey has a 10,000-pound commercial trip limit with a 65,000 pound annual quota. There is a 16-inch total length (TL) minimum size limit for both the recreational and commercial fisheries, and recreational anglers are allowed three fish per person per day. These regulations have been in effect since 2001

Delaware: Delaware entered a joint management plan for black drum in Delaware Bay with the state of New Jersey in March 2010. This bi-state FMP established the same recreational size and bag limits (16-inch TL minimum size limit and three fish per person per day) and commercial quota (65,000 pound annual quota) as New Jersey for the shared waters of the Delaware Bay and River. Upon adoption of the ASMFC Interstate FMP for black drum, these regulations were extended to all Delaware waters.

Maryland: In 1994, Maryland implemented a 16-inch TL minimum size limit for both the commercial and recreational fisheries, with a recreational bag limit of one fish per person per day. Commercial harvesters had a 30,000 pound annual quota in Chesapeake Bay. Beginning in 1999, a six fish possession limit per boat was implemented for the recreational fishery in Chesapeake Bay. In addition, the Chesapeake Bay and coastal bays closed to commercial fishing for black drum. In the Atlantic Ocean, an annual total allowable landings (TAL) of 1,500 pounds was implemented for the commercial fishery. Beginning in 2019, the commercial fishery in Chesapeake Bay reopened (the coastal bays remained closed), with a minimum size limit of 28 inches TL and a daily catch and possession limit of ten black drum per vessel per day, regardless of the number of commercial licensees on board. The Atlantic Ocean annual TAL remained 1,500 pounds, with a 16-inch minimum size limit. The recreational fishery continues to have a one fish per person per day and a six fish per boat per day daily catch limit.

Potomac River Fisheries Commission: The Potomac River Fisheries Commission implemented a one fish per person per day bag limit and a 16-inch TL minimum size limit for both recreational and commercial fisheries in the Potomac River in 1993.

Virginia: The minimum size limit for black drum in Virginia’s commercial and recreational fisheries has been 16 inches TL since 1987. In 1992, a one fish possession limit (recreational and commercial) per person per day was established for anyone using hook and line, rod and reel, or hand line. The commercial Black Drum Harvesting and Selling permit was created in 1987. This permit is required to land more than one black drum per day for commercial purposes. Until 1993, any harvester was able to obtain a permit, but by 1993 harvesters were required to be a registered commercial harvester to obtain the Black Drum Harvesting and Selling permit. In 1994, the issuance of the Harvesting and Selling permit became dependent on previous permit and documentation of harvest requirements for the 1988-1993 period to limit entry into the commercial black drum fishery. In addition, any harvester active in 1992 or 1993 was required to have reported that activity in order to maintain a permit in 1994. Since 2002, the annual commercial quota has been 120,000 pounds in order to cap landings.

North Carolina: North Carolina black drum regulations have been in effect since 2014. There is a commercial and recreational slot limit of 14-25 inches TL, with an allowance of one black drum over 25 inches TL. Recreational anglers are allowed ten fish per person per day. Commercial harvesters have a 500 pounds trip limit.

South Carolina: Regulations in South Carolina have been in place since 2007. South Carolina has a recreational and commercial slot limit of 14-27 inches TL and a possession limit of five fish per person per day.

Georgia: Georgia first enacted black drum regulations in 1998, with a 10 inch TL minimum size limit and a bag limit of fifteen fish per person per day for both the commercial and recreational fisheries. In 2014, the minimum size limit was raised to 14 inches TL.

Florida: Black drum regulations have been in place in Florida since 1989. Florida has a 14-24 inch TL slot limit for both the recreational and commercial fisheries, with one fish larger than 24 inches allowed for recreational anglers. There is a five fish per person per day bag limit for recreational anglers. The commercial fishery has a 500 pounds per day per person or vessel (whichever is lesser) trip limit. In 1995, gill nets and all other entangling gear were banned from use in Florida waters.

1.3 Assessment History

Prior to 2015, the only stock assessments conducted on Atlantic coast black drum were two assessments conducted at the state/regional level. The first was conducted on black drum in Florida waters (Murphy and Muller 1995) and utilized CPUE data, landings data, and state surveys. Both catch per commercial trip and number of black drum kept by recreational anglers showed decreases after 1989. Florida black drum condition appeared favorable due in part to a combination of very conservative fishing mortality (*F*) estimates, new regulations, and recent high recruitment events. The second assessment was conducted on black drum in the Chesapeake Bay (Jones and Wells 2001) and evaluated yield-per-recruit estimates under different potential mortality rates from catch curve analysis (total mortality, *Z*) and maximum age (natural mortality, *M*) and mean age-at-capture. Estimates of current *F* (*Z-M*) were determined to be lower than *F* that maximizes yield (F_{max}). In turn, overfishing, specifically growth overfishing, was determined unlikely under fishing practices in the Chesapeake Bay at the time.

The most recent stock assessment was completed in 2015 and was also the first coastwide stock assessment of the Atlantic coast black drum population (ASMFC 2015). This assessment relied heavily on the observed fishery removal time series and data-poor, catch-based biomass dynamics assessment approaches. Approaches used included Catch-MSY, Depletion-Corrected Average Catch (DCAC), and Depletion-Based Stock Reduction Analysis (DB-SRA). Per-recruit analyses were also conducted to estimate reference points from available life history information, but no independent, age-structured estimate of fishing mortality was available to compare to reference points.

Ultimately, DB-SRA (Dick and MacCall 2011) was selected as the preferred method to provide management advice. DB-SRA was developed as a data-poor method to estimate sustainable catch levels according to maximum sustainable yield (*MSY*)-based reference points and annual population dynamics parameters including exploitable biomass and exploitation. The analysis uses a Pella-Tomlinson surplus production model to estimate stock carrying capacity (*K*) necessary to have sustained an observed time series of fishery removals resulting in recent relative stock biomass levels. Distributions of four leading parameters are specified typically based on existing information on the assessed species, meta-analysis of multiple species, and/or expert opinion. Leading parameters include *M*, the ratio of fishing mortality associated with *MSY* and natural mortality (F_{MSY}/M), the ratio of biomass associated with *MSY* and *K* (B_{MSY}/K), and the ratio of biomass in a recent year and *K* (i.e., depletion, B_y/K). The analyzed time series is assumed to start at the beginning of the fishery so that biomass in the first year is at carrying capacity.

The analysis implements Monte Carlo simulation to iteratively sample the leading parameter distributions and project the surplus production model forward to solve for carrying capacity given the sampled leading parameters and observed fishery removal time series. Parameter draws from iterations that don't match the sampled depletion level to a certain tolerance are rejected while those that do are retained to characterize distributions of final parameter estimates including biomass and exploitation associated with *MSY* (B_{MSY}, U_{MSY}).

A fishery removal time series including recreational harvest, recreational dead discards, and commercial landings from 1900-2012 was used in the analysis. *M* was estimated from maximum observed age, while F_{MSY}/M and B_{MSY}/K were specified according to published meta-analyses. Depletion in the assessment terminal year of 2012 (B_{2012}/K) was specified based on expert opinion from an understanding of the historical development of the black drum fishery that the stock had not been overfished while also recognizing that some depletion had taken place through observed fishery removals (uniform distribution bounded by 0.5 and 0.9).

Being a data-poor, simplistic approach intended as a stop-gap analysis until sufficient data become available to apply more data-rich methods, there are several notable limitations of the analysis. The reference point estimates are largely dependent on and sensitive to the prior information, particularly for depletion (Wetzel and Punt 2011, ASMFC 2015). The analysis does not incorporate any process error and the stock is assumed not to deviate from the deterministic production dynamics. A drawback of this analysis is the requirement to start at an unfished state, requiring the assumption about when this occurred and the use of highly uncertain data during the early years of the time series. As a production-based method, the assumptions of standard production models apply (constant productivity parameters, no lag between productivity and recruitment). The stock is analyzed as a lumped biomass resulting in potential biases if the age structure or fishery characteristics (i.e., selectivity) change during the time series.

The median B_{MSY} was estimated as 47.26 million pounds, while the median biomass in 2012 (B_{2012}) was estimated to be greater at 90.78 million pounds. The median carrying capacity estimate was 135.20 million pounds and median depletion in 2012 was estimated to be 0.70. Median U_{MSY} was estimated as 0.046 while median 2012 exploitation (U_{2012}) was estimated to be lower at 0.013. The terminal year overfishing limit (*OFL*; $U_{MSY}*B_{2012}$) was treated as a catch threshold to acknowledge uncertainty in the analysis and provide a precautionary reference point given it would be greater than *MSY* for a stock specified as not overfished. The median *OFL* was estimated to be 4.12 million pounds, greater than the observed removals in 2012 (1.09 million pounds). *MSY* ($B_{MSY}*U_{MSY}$) was treated as a catch target and the median DB-SRA estimate was 2.12 million pounds. The observed removals exceeded this catch target during three years of the time series (2000, 2008, 2009), but were below this target in the terminal year.

The stock was determined not to be overfished nor experiencing overfishing. Given methods used in the assessment were developed primarily to generate sustainable catch levels, this status determination was made based on several lines of evidence including the results of DB-SRA, black drum life history characteristics, vulnerability to fisheries, empirical trends from indices of abundance, and the harvest history. Due to the optimistic status determinations, the ASMFC Black Drum Technical Committee (TC) recommended the next assessment be conducted in five years and provided the following high priority research recommendations, ideally to be addressed before the next assessment so more advanced methods could be applied to estimate stock status:

- Age otoliths that have been collected and archived.
- Collect information to characterize the size composition of fish discarded in recreational fisheries.
- Collect information on the magnitude and sizes of commercial discards. Obtain better estimates of bycatch of black drum in other fisheries, especially juvenile fish in South Atlantic states.
- Increase biological sampling in commercial fisheries to better characterize the size and age composition of commercial fisheries by state and gear.
- Increase biological sampling in recreational fisheries to better characterize the size and age composition by state and wave.
- Obtain estimates of selectivity-at-age for commercial fisheries by gear, recreational harvest, and recreational discards.
- Continue all current fishery-independent surveys and collect biological samples for black drum on all surveys.
- Develop fishery-independent adult surveys. Consider long line and purse seine surveys. Collect age samples, especially in states where maximum size regulations preclude the collection of adequate adult ages.

An external Peer Review Panel concurred with the results of the assessment and provided a few additional recommendations to consider for future assessments:

- Develop a protocol to alert the SAS to any major changes in harvest and *F* that could trigger a reassessment of the reference points similar to the 'rumble strips' approach developed by the Mid-Atlantic Fishery Management Council (MAFMC) for data-poor stocks.

- Increase age sampling along the coast. Juvenescence of the population is a good indicator of overfishing, and the availability of age data is crucial to being alerted to such changes in age structure.

- Indices, such as the South Carolina trammel net survey, could be used directly in an extended version of DB-SRA. The implementation of xDB-SRA could instead specify stock status at an earlier time period, thus allowing the most recent catches to inform population dynamics and thus stock status.

This assessment was being conducted as the FMP was implemented (2013) and the assessment data time series included a terminal year of 2012, so effects of regulations required by the FMP, most notably the first regulations in North Carolina (2014), a primary contributor of black drum catch, were not assessed during the assessment. Another notable development since this assessment was the redesign of effort surveys used to estimate recreational catch of black drum which led to significant increases in estimates during years before and after the assessment (Section 4.2.1). This change was anticipated to change the scale of biomass and reference point estimates making the previous assessment estimates incompatible with updated recreational catch estimates.

The TC met two times since the 2015 stock assessment to review updated data sets and determine need for a new stock assessment, a less formal but similar process to the 'rumble strips' approach recommended by the Peer Review Panel. The first meeting occurred in June 2019, the year before the five year recommended timeframe for the next assessment. No concerning trends were identified in available data sets and the TC recommended the assessment be postponed for at least three years, with the TC meeting a second time to consider initiating a benchmark stock assessment which would allow inclusion of new data sets and assessment methodologies.

During the 2020 FMP Review process, the Black Drum Plan Review Team (PRT) recommended the Sciaenid Management Board consider the use of a Traffic Light Analysis (TLA) to evaluate stock status in the absence of an updated stock assessment. The TLA is currently used to monitor other Sciaenid species (spot, Atlantic croaker) for potential management intervention.

The second TC meeting occurred in 2021 with the added consideration of whether the next evaluation of the black drum stock should be through a benchmark assessment or a TLA. The TC recommended initiating a benchmark stock assessment with an added component focused on development of a 'rumble strip' approach that would be easily applied, take minimal time to complete, and be reviewed annually in some formal process or structure, but not necessary to trigger any predefined action (as the TLA path would). Term of reference (TOR) 4 was included in this assessment to address this recommendation. Work could be done to extend the 'rumble strip' approach developed in this assessment to include management triggers in a TLA framework following the assessment if deemed necessary. The TC noted data remain limited and that data-poor assessment approaches would likely continue as the basis of management advice from the next assessment. The developments since the 2015 assessment discussed previously (implementation of the FMP and response by the stock, recreational catch estimate changes) as well as potential for fishing effort shifting towards black drum due to recent regulations for other species (e.g., southern flounder) were topics discussed during both TC meetings.

2 LIFE HISTORY

The black drum is the largest member of the family Sciaenidae found along the Atlantic coast of the United States. Black drum range from Argentina to New England with infrequent reports as far north as Canada (Bleakney 1963). They are common from the Mid-Atlantic region to the Gulf of Mexico but considered rare north of Delaware Bay (Murdy et al. 1997). Black drum have an unusual combination of life history characteristics as they grow quickly and are relatively long-lived. Unlike most other long-lived species, black drum are sexually mature at a relatively young age and can spawn millions of eggs annually.

2.1 Stock Definitions

Multiple lines of evidence suggest that black drum on the U.S. Atlantic coast are from a common stock and have been summarized by Jones and Wells (1998). However, black drum form at least three distinct populations in the waters of the U.S., one encompassing the entire Atlantic coast of the U.S. and two in the Gulf of Mexico (Gold and Richardson 1998). More recent evidence using nuclear microsatellite markers indicates genetically distinct populations in the Gulf of Mexico and the Atlantic coast of the U.S. (Leidig 2014). Leidig (2014) found that along the U.S. Atlantic coast, there appears to be weak, but significant, genetic divergence among southern states, specifically between the Carolinas and Florida. An isolation-by-distance pattern was also observed from North Carolina to Florida. On a larger scale, results suggest lack of genetic divergence between Delaware and Virginia and the southern states, which may be influenced by the migratory aspect of life history patterns of black drum. This supports the management of black drum as one unified stock along the U.S. Atlantic coast and indicated the need for common management regulations among Atlantic states. Growth parameters are nearly identical for black drum captured in Florida, Virginia, and Delaware suggesting growth within populations may not vary significantly by latitude despite small differences. Tagging data has shown that large adults move from Florida to the Chesapeake Bay indicating mixing within the Atlantic coast stock (Murphy et al. 1998).

2.2 Migration Patterns

Adult black drum along the U.S. Atlantic coast make long migrations north/inshore in the spring and south/offshore in the fall. Juvenile black drum in the southeast U.S. and Gulf of Mexico appear to be more sedentary compared to the northeastern U.S., as many researchers have reported little movement of tagged fish from release sites (Music and Pafford 1984; Beaumariage and Wittich 1966; Simmons and Breuer 1962). Osburn and Matlock (1984) suggested managing Texas bays as “closed systems” for black drum due to substantial intra-bay movement and little (<14% of all tag returns) inter-bay movement. However, there is believed to be a significant proportion of adult fish that migrate extensively along the Atlantic coast. Two fish tagged in Florida in February were recaptured in the Chesapeake Bay by recreational anglers in May and June of the same year, nearly 1,370 kilometers away (Murphy et al. 1998). Mass emigration of young-of-the-year (YOY) has been documented in Delaware Bay (Thomas and Smith 1973) and the Chesapeake Bay (Frisbie 1961) in the fall. Northward movement of adults in the spring has been attributed to a spawning migration, as it coincides with peak spawning along the Atlantic coast (Murphy et. al. 1998). Adults and juveniles have also been shown to move back and forth between areas with greater food abundances from marine protected areas as well as migrating longer distances along the Atlantic coast (Reyier et al. 2020). While black drum are known to migrate substantial distances along the eastern U.S., the amount of time spent in transport is likely low as one individual moved 229 km in five days in Virginia (Lucy and Bain 2003).

2.3 Age and Growth

Researchers have looked at various hard parts to age adult black drum. Scales have been found to be inaccurate and imprecise when ageing black drum greater than ten years of age (Richards 1973). Instead, thin sections of otoliths processed by a low speed IsoMet™ saw are the most accurate, precise, and discernible hard parts to interpret. Between-reader precision for otolith thin sections was 100% versus 27.3% for dorsal spines and 47.4% for fin rays (Jones and Wells 1998). Black drum otolith age has been validated indirectly through intra-year progression of annulus formation (Beckman et al. 1990), directly by mark-recapture studies (Murphy et al. 1998), and by radiocarbon dating (Campana and Jones 1998). Black drum age data available for the assessment are summarized in Table 2. Maximum age has been reported at 67 years old (Virginia Marine Resources Commission 2013, personal communication).

Black drum are generally considered long-lived and fast growing as they have been reported to obtain 80% of their growth potential over 20% of their life span (Jones and Wells 1998). The International Game Fish Association all-tackle world record weighed 51.36 kilograms (IGFA 2008) while the largest individual ever captured was 66.22 kilograms (Thomas 1971). Black drum exhibit similar growth rates along the Atlantic coast of the U.S. although some geographic variation in growth rate has been documented between fish in northeast Florida and Virginia (Bobko 1991). While growth in warmwater estuaries has been shown to be influenced by environmental factors (Olsen 2019), variation in growth between studies along the Atlantic coast may be more attributable to differences in spatial and temporal scale of sampling (Murphy and Taylor 1989; Bobko 1991). As reported in Bobko (1991), average length and weight of fish in Murphy and Taylor's 1989 study from Florida were significantly different from the average length and weight of Virginia fish. A small proportion (>12%) of Murphy and Taylor's sample were greater than 75 cm while Bobko did not obtain data from fish less than 83 cm. Absence of size classes can lead to different results in growth analyses and may account for the discrepancy between the two studies. Linear regressions of total weight vs. TL performed on black drum captured in Virginia (Bobko 1991) predicted weights that were significantly heavier than for those of Florida (Murphy and Taylor 1989) and Louisiana (Beckman et al. 1990). There is no evidence of sex-specific growth although maturity schedules differ by sex (Murphy and Taylor 1989; Bobko 1991). Atlantic coast black drum appear to grow slower than fish from the Gulf of Mexico; however, they attain higher maximum sizes (Jones and Wells 1998).

Growth estimates with von Bertalanffy growth models were updated during this assessment with the available age data and are described further in Appendix 1. This growth analysis did not detect any significant difference in growth between sexes or between regions (South Atlantic vs. Mid-Atlantic), supporting the use of a single growth function to describe black drum growth along the Atlantic coast.

2.4 Reproduction

Black drum spawn in coastal bays and estuaries along the Atlantic coast from Florida to New Jersey. Black drum spawning has been documented in every calendar month for the Gulf of Mexico and the South Atlantic coast of the U.S. although spawning varies throughout their range (Leard et al. 1993). Spawning in Louisiana waters of the Gulf of Mexico occurs from February through April with peak activity occurring in February and March (Fitzhugh and Beckman 1987). On the Atlantic coast of Florida, black drum spawning occurs from January to March (Murphy and Taylor 1989). Spawning off of the southeast coast from Georgia to North Carolina has been shown to occur from November through April through detection of drumming activity for spawning aggregations (Rice et al. 2016). In the Chesapeake Bay, spawning occurs in April and May (Bobko 1991; Jones and Wells 1994). Black drum eggs were found inside the mouth of the Chesapeake Bay during mid to late May, but not after June 7th, indicating spawning completion (Joseph et al. 1964). Spawning in the Delaware Bay occurs from April through early June (DDFW unpublished data) with peak spawning occurring in the middle of May (Thomas 1971; Wang and Kernehan 1979).

Black drum are batch spawners and exhibit multiple oocyte development stages within female ovaries during spawning (Murphy and Taylor 1989; Fitzhugh et al. 1993; Nieland and Wilson 1993; Wells 1994). Discrepancies in the literature exist regarding patterns of oocyte development. Fitzhugh et al. (1993) reported asynchronous recruitment of vitellogenic oocytes while Nieland and Wilson (1993) and Wells (1994) observed group synchronous oocyte development. Spawning frequency has been estimated to be three to four days (Fitzhugh et al. 1993; Nieland and Wilson 1993). Batch size may vary with reproductive period or size of the individual. Fitzhugh et. al. (1993) and Wells (1994) found that the relationship between batch fecundity and body size to be variable in Louisiana waters, while Nieland and Wilson (1993) found that batch fecundity was positively correlated with total weight, fork length (FL), and age. Mean batch fecundity was estimated at 1.22 million to 1.6 million hydrated oocytes for black drum in Louisiana (Nieland and Wilson 1993; Fitzhugh et. al. 1993). Total fecundity, a function of the length of spawning season, spawning frequency, and batch fecundity, has been estimated at 5.5 to 26.6 million eggs per female in Virginia for black drum ranging from 985 to 1,165 mm TL (Bobko 1991). Fitzhugh et al. (1993) estimated annual fecundity for Louisiana drum between 660-876 mm as high as 32 million eggs per fish. The overall mean annual fecundity for 41 black drum sampled by Nieland and Wilson (1993) was reported as 37.67 million ova.

Developing ovaries have been found in black drum as small as 270 mm (Pearson 1929). Simmons and Breuer (1962) reported length and age at maturity to be 320 mm and two years. Murphy and Taylor (1989) examined sex specific maturity schedules and found 50% of the males in northeast Florida waters occurred at 590 mm (4 to 5 years old) were mature and that males reached 100% maturity at 675 mm (6 years old). Whereas, females achieved 100% maturity at sizes of 650 mm and ages from 5-6 years old. Fitzhugh et al. (1993) found length at first maturity to be similar to Murphy and Taylor (640 mm) with corresponding ages of 3 to 8 years.

In the previous ASMFC black drum assessment (ASMFC 2015), size and age at maturity was estimated using a logistic regression. Data for the final model were composites of South Carolina Department of Natural Resources (SC DNR), Virginia Marine Resources Commission (VMRC), and Chesapeake Bay Multispecies Monitoring and Assessment Program (CHESMMAP) data sets for length and SC DNR and VMRC data sets for age at maturity. The length distributions by data set indicated that the CHESMMAP data set was primarily younger immature fish with only a few older mature fish. This was the reason for the difference in the maturity curve for CHESMMAP data while the composite model was driven primarily by the VMRC and SC DNR data sets which had very similar maturity curves. The estimated length at 50% maturity was 675 mm TL with full maturity being reached at approximately 850 mm TL. Both males and females reached 50% maturity at approximately age-4 with full maturity occurring at age-7. Given their age range, black drum appear to mature relatively early and can have many years, if not decades of reproductive potential.

2.5 Natural Mortality

Little research has been reported on black drum mortality. The long life span of this species suggests that natural mortality is relatively low. Due to the size of adult black drum, most of the mortality caused by predation likely occurs at larval and juvenile stages. Abundance of jellyfish on spawning grounds in Chesapeake Bay is believed to be a major source of mortality on eggs and larvae. Peaks in jellyfish abundance may be responsible for episodic periods of reduced black drum recruitment (Cowan et al. 1992). Jones and Wells (1998) converted estimates of instantaneous total mortality, *Z*, to annual total mortality, *A*, of less than 13% for black drum in the Chesapeake Bay. Their estimate of total mortality may be low as current exploitation patterns are believed to be much greater than those witnessed more than two decades ago. Furthermore, their estimate assumes low *F* on young fish throughout the stock’s range. It is evident from landings data that exploitation patterns differ by latitude as older, larger fish comprise a bigger proportion of harvest in the Mid-Atlantic while younger, smaller fish are harvested in greater numbers in the southeastern states. Stocks with low natural mortality, *M*, typically do not have surplus natural mortality that can be transferred to fishing mortality (Murphy and Taylor 1989). However, as stated previously, black drum differ from most species that have low natural mortality in that they mature early and are highly fecund. The reproductive strategy of broadcasting eggs over a number of suitable, but diverse, habitats up and down the Atlantic coast may enable the species to mitigate adverse environmental impacts to recruitment.

In the previous ASMFC black drum assessment (ASMFC 2015), natural mortality was estimated using Hoenig (1983) and Hewitt and Hoenig (2005) methods utilizing the von Bertalanffy parameters from the age and growth estimates. For the Hoenig (1983) estimates, natural mortality ranged from 0.063 to 0.091 depending on maximum age of individual data sets, while the Hewitt and Hoenig (2005) estimates of *M* were only slightly lower with a range of 0.0448-0.0652. For the DB-SRA model used, natural mortality was drawn from a lognormal distribution with expectation equal to the Hoenig (1983) natural mortality estimate using the maximum age observed coastwide of 67 years old (0.063). For this current assessment, the TC decided to transition to the Then et al. (2015) non-linear least squares estimator of natural mortality. This study used an updated and more robust data set than the data set used in Hoenig (1983). The non-linear least squares estimator was recommended by the authors among the methods applied in their study. The Then et al. (2015) estimator provides a higher estimate of natural mortality using the maximum age observed coastwide of 67 years old (0.1041).

2.6 Feeding and Diet

Larval black drum feed primarily on zooplankton (Benson 1982), while small juveniles feed largely on copepods, amphipods, annelids, isopods, mollusks, polychaetes, and small fish (Thomas 1971; Peters and McMichael 1990). Peters and McMichael (1990) found that as juveniles increase in size their consumption of shrimp, crabs, fish, and mollusks became more dominant, with the crossover correlating with the development of pharyngeal molars. Adult black drum are primarily benthic feeders, schooling in spatial patches where food is plentiful (Simmons and Breuer 1962), capable of crushing the shells of mollusks and crabs with their strong pharyngeal teeth (Simmons and Breuer 1962). Adult black drum feed on several commercially and recreationally important shellfish species. Captive black drum were capable of consuming more than two commercial-sized oysters per kilogram of body weight per day (Cave and Cake 1980). Plunket (2003) reported black drum fed on blue crab, mud crab, ribbed mussels, and dwarf surf clams. Delaware Bay commercial watermen associate black drum abundance (presumably adults) with large sets of blue mussels (*Mytilus edulis*) (De Sylva et al. 1962). Adult black drum sampled from the commercial and recreational fisheries in Delaware and New Jersey commonly contained blue mussels and soft-shelled clams within their stomachs (J. Zimmerman, Delaware Division Fish and Wildlife, personal communication). Black drum have also been shown to shift diet preferences dependent on both water quality and prey abundance preferring bivalves under better water quality conditions over smaller, less mobile invertebrates under poor water quality conditions (Rubio et al. 2018).

3 HABITAT DESCRIPTION

3.1 Brief Overview of Habitat Requirements

3.1.1 Spawning, egg, larval habitat

Spawning: Black drum spawn from April to June in the northern range (Joseph et al. 1964; Richards 1973; Silverman 1979). Spawning has been documented in the mouth of the Chesapeake Bay and seaside inlets on the Eastern shore (Chesapeake Bay Program 2004). The presence of a large spring/early summer fishery during this time period in the Delaware Bay also provides evidence of spawning occurring inshore and in the spring. Evidence in Florida suggests spawning occurs in deep waters inshore, from November through April, with peaks in February and March (Murphy and Taylor 1989).

Larval: Larval black drum tend to settle in salt marshes and estuaries (Odell et al. 2017). Peters and McMichael (1990) reported black drum larvae in the bays of Florida, where salinities ranged from 22 – 30 ppt. Thomas and Smith (1973) observed larval drum disperse into the shore zone and into creeks and ditches in the Delaware Bay in June. They were typically found in areas with little or no current and often over a mud bottom. Gold and Richardson (1998) characterized black drum as estuarine-dependent in the early years. Work by Rooker et al. (2004) on strontium concentrations deposited in otoliths supported movement into lower-salinity, estuarine environments during early life stages.

3.1.2 Juvenile and adult habitats

Juvenile: Black drum juveniles have been found in salt marshes and estuaries along the coast, suggesting these areas serve as nurseries for sub-adults (Pearson 1929; Murphy and Muller 1995; Odell et al. 2017). Beach seine sampling in Florida nearshore lagoons found high numbers of juveniles, suggesting juvenile black drum remain inshore. Juveniles tolerate a wide range of salinities and temperatures but have been found often in low to medium salinities and over unvegetated mud bottoms in Florida waters (Peters and McMichael 1990). Thomas and Smith (1973) reported catching juveniles in waters with a salinity range from 0 – 28 ppt in the Delaware Bay estuary. As juveniles grow, they range into higher salinity areas, similar to adult habitat (Rooker et al. 2004). Richards (1973) correlated muddy, nutrient rich, marsh habitat during the first three months of life with rapid growth.

Murphy and Taylor (1989) noticed the capture of small drum throughout the year by recreational anglers and commercial harvesters in Florida's nearshore areas, suggesting year-round occupation of these nearshore estuarine to marine habitats. Increased abundance of black drum in recent years has occurred in South Carolina estuaries as part of a general increase in diversity and abundance of estuarine taxa that has been hypothesized to be a response to significantly warmer winters and summers over a 30 year period (Kimball et al. 2020).

Adult: Data suggests adults are euryhaline, although high salinities tend to cause stress as do sudden drops in temperature (Simmons and Breuer 1962). Adults move between estuaries and nearshore shelf waters, although they tend to move to deeper channel areas as they grow and mature (ASMFC 2011). Black drum move offshore at sexual maturity and form large, offshore schools that migrate extensively (Simmons and Breuer 1962). Work by Rooker et al. (2004) on strontium concentrations deposited in otoliths supports movement into more saline, oceanic conditions when older.

4 FISHERY-DEPENDENT DATA SOURCES

4.1 Commercial

4.1.1 Data Collection and Treatment

4.1.1.1 Landings

Modern commercial landings (1950 to present) for the Atlantic coast have been collected by state and federal agencies and are provided to the Atlantic Coastal Cooperative Statistics Program (ACCSP) where they are maintained in the ACCSP Data Warehouse. The Data Warehouse was queried in Fall 2021 for all black drum landings (monthly summaries by state and gear type) from 1950 to 2020 for the east coast of Florida (Miami-Dade/Monroe County border), and all other Atlantic states. Landings data from ACCSP were reviewed and approved by state representative partners. In cases where discrepancies occurred, data directly from state databases was preferred to ACCSP Data Warehouse values. This included data from New Jersey (2004-2018), Delaware (1985-1996, 2002, 2005), Maryland (2013-2020), Virginia (1989, 1994, 1996, 1999-2020), North Carolina (1972-1977, 2000), and Florida (2020).

Landings data collection by state is discussed below and summarized for all Atlantic states in Table 3.

Historical commercial landings reported in this assessment (1900-1949) were compiled in the previous stock assessment from U.S. Fish Commission annual reports (1900-1944) and provided by the National Marine Fisheries Service (NMFS; 1945-1949). These data were compiled to support assessment methods requiring a complete catch history.

New Jersey
New Jersey collects weights and sometimes gear type using dealer and landing reports from the black drum fishery. The New Jersey black drum fishery is one of the few in the state where recreational anglers can sell their recreational limit with no additional license, but these fish are assumed to make up a small percentage of the total catch and are not reported.

Delaware
Commercial harvesters are required to submit logbooks on a monthly basis since 1985. Total harvest, effort as trip days and net yards, port landed, and location fished are required data elements.

Maryland
Maryland Department of Natural Resources (MD DNR) has a mandatory reporting system for commercial harvesters. Catch in pounds, days fished, area fished, and amount and type of gear used were reported by month prior to 2006. A daily trip log was phased in from 2002 to 2005 with all harvesters using the daily log beginning in 2006. Effort data is only available for 1980–1984, 1990 and 1992–2020. Landings prior to 1981 are from NMFS.

Virginia
NMFS collected landings data for Virginia from 1950 through 1992. From 1973 to 1992, Virginia implemented a voluntary monthly inshore dealer reporting system, which was intended to supplement NMFS data. However, it was discovered that better inshore harvest data were required so the VMRC implemented a Mandatory Reporting Program (MRP) to collect Virginia commercial landings data that began January 1, 1993. The program currently is a complete census of all commercial inshore and offshore harvest in a daily format. Data collected are species type, date of harvest, species (unit and amount), gear type, gear (amount and length), area fished, dealer, vessel (name and number), hours fished (man and gear), crew amount, and county landed.

In 2001, several fields listed above (gear length, man hours, vessel information: name and number, and crew amounts) were added to come in compliance with the ACCSP-identified critical data elements. Also, data collection gaps in the NMFS offshore collection program were identified and all offshore harvest that was not a federally permitted species or sold to a federally permitted dealer was added to the MRP. The MRP reports are collected on daily trip tickets annually distributed to all commercially licensed harvesters and aquaculture product owners. All harvesters and product owners must report everything harvested and retained on the daily tickets. The daily tickets are put in monthly folders and submitted to VMRC. The monthly folders are provided by the VMRC and due by the 5th of the following month.

North Carolina
The NMFS, prior to 1978, collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries (NC DMF) entered into a cooperative program with the NMFS to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers. The NC DMF Trip Ticket Program (NCTTP) began on January 1, 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e., trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest. The annual landings are reported on an annual basis of January through December. Data used to calculate the annual landings for North Carolina from 1950 to 2020 included landings from the NCTTP (1994 to 2020) and landings from NMFS (1950 to 1993). Prior to 1972, monthly landings were not recorded for North Carolina.

South Carolina
Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish and Wildlife Service or NMFS personnel. In 1972, SC DNR began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the DNR are required from all

licensed wholesale dealers in South Carolina. Until fall of 2003, those monthly reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, vessel and harvester information. Validation of landings is accomplished via dockside sampling.

At a minimum, South Carolina's trip-ticket program collects data on commercial effort, commercial catch, and economical value. At a minimum, effort data includes gear types and quantity, location, and hours fished. Catch data includes species, disposition of catch, and quantity (lbs) landed. Finally economic data includes the wholesale price paid to harvesters.

Unlimited commercial harvest of black drum had been allowed in South Carolina prior to August 2007; however, since enactment of the current regulations at that time (14-27 inch slot limit and 5 fish per person per day) both the commercial and recreational fisheries are subject to those rules. The history of black drum landings in South Carolina is not very consistent with no true directed commercial fishery.

Georgia
Prior to 1982, the NMFS and its predecessor agencies had been responsible for the collection of commercial fisheries landings data in Georgia. In 1982, with funding from NMFS, the Georgia Department of Natural Resources (GADNR) began collecting weekly and monthly commercial landings data from coastal Georgia. These included catch, area, effort, gear, value, and associated data at various levels of detail depending on fishery and data needs. In 2001, Georgia implemented a trip ticket program in accordance with the minimum requirements set forth by the ACCSP partners. Additional data elements were added and the Georgia landings database was upgraded to meet the requirements. Trip level data are collected for all trips landing products in Georgia. Data collected include trip start and unloading dates, area fished, harvester and dealer, gear, species, market size, quantity, and value.

Florida
Prior to 1986, commercial landings data were collected by the NMFS from monthly dealer reports. The Florida Marine Information System or Trip Ticket (TTK) System began in 1984, which requires wholesale dealers to report each purchase of saltwater products from licensed commercial fishers on a monthly basis (weekly for quota-managed species). Conversely, commercial fishers must have Saltwater Products Licenses to sell saltwater products to licensed wholesale dealers. Each trip ticket includes the Saltwater Products License number, the wholesale dealer license number, the date of the sale, the gear used, trip duration (time away from the dock), area fished, depth fished, number of traps or number of sets where applicable, species landed, quantity landed, and price paid per pound. During the early years of the program some data fields were deleted from the records, e.g., Saltwater Products License number for much of 1986, or were not collected, e.g., gear used was not a data field until about 1991.

In addition, black drum became a “restricted species” in September 2013 so only fishers who have a Restricted Species Endorsements on their Saltwater Products License are qualified to sell black drum.

4.1.1.2 Discards

North Carolina

NC DMF Program 466 provides year-round onboard observations of protected species bycatch from commercial anchored gillnet fishing operations fishing with an Estuarine Gillnet Permit (EGNP).

Data on gear and catch characteristics by area and season are collected from onboard EGNP permitted fishing vessels that are engaged in anchored gill-net fishing operations in estuarine waters. State estuarine waters are divided into management units A, B, C, D1, D2, and E based on the division’s Endangered Species Act Section 10 Incidental Take Permit (ITP) for sea turtles (Figure 1). Observer effort is based on a sea day schedule that stratifies observed trips across management units, seasons, and mesh size categories proportional to fishing effort averaged over the previous five years. For each onboard trip, observers identify and count both kept and discarded catch, and attempt to record length and weight data from as many specimens as possible. The program began in 2001, but was limited in its spatiotemporal scope (i.e., Pamlico Sound during fall flounder season). In 2004, coverage was expanded into areas A and C, but this expansion was hit or miss in years 2007 through 2012. Year-round statewide coverage of large and small mesh anchored gillnets began in 2013. In years without the expanded coverage, observations were conducted in the months of September – December, primarily in Pamlico Sound. Due to COVID-19 pandemic, onboard observations ceased in March 2020. A date for resuming onboard observations has not been set at the time of this writing.

Trips are observed per management unit based on the mean number of trips per month and management unit reported to the NCTTP for the previous five-year period. Per the sea turtle ITP, the division is required to observe a minimum of 7% (goal of 10%) of anchored large mesh gill net trips and a minimum of 1% (goal of 2%) of anchored small mesh gill net trips by management unit by season. The mesh size categories in the sea turtle ITP (large mesh = > 4-inch stretched mesh (ISM), small mesh = < 4-inch ISM) are different than the categories in the trip ticket program (large mesh = > 5-inch ISM, small mesh = < 5-inch ISM).

NOAA Shrimp Fishery Observer Program

Bycatch data from shrimp trawl fisheries in the South Atlantic collected during the NOAA Shrimp Fishery Observer Program were reviewed during this assessment due to frequent bycatch of other sciaenid species (Atlantic Croaker, spot, and weakfish) in these fisheries. However, occurrences of black drum were very low and shrimp trawl bycatch does not appear to be a significant source of mortality. Black drum were only encountered during 50 of 4,861 observed tows and were not observed during 11 of 19 years.

4.1.1.3 Biological Sampling

Delaware

Mature black drum were sampled in April, May, and June from the commercial fishery in the Delaware Bay. These months were chosen as they encompass the time of year when greater than 80% of the commercial harvest (Glanden and Newlin 2013) and greater than 90% of the recreational harvest occur (DDFW unpublished data). All fish were measured for TL to the nearest mm. Total weight (kg) and sex were recorded. Gonad weight (g) was recorded for fish sampled from 2009-2013. Sagittal otoliths were removed and placed in envelopes with sample number, location, date, fishery, and gear type. One otolith was chosen randomly from each pair and processed for age determination. Otoliths were thin sectioned on a Hillquist high speed saw and mounted on microscope slides. Slides were viewed at 24X magnification.

Maryland

The MD DNR has monitored commercial pound nets primarily in the Chesapeake Bay and mouth of the Potomac River since 1993. No cooperating harvesters could be located on the Potomac River in 2009 and sampling was not conducted in this area that year, but resumed in 2010. The lower portions of other rivers such as the Nanticoke and Honga rivers have been sampled sporadically depending on year. Each site was generally sampled once every two weeks from late May - early September, weather and harvester's schedule permitting. The commercial harvesters set their nets as part of their regular fishing activity. Net soak time and manner in which they were fished were consistent with the harvester's day-to-day operations. All black drum captured were measured to the nearest mm TL (maximum or pinched). Other data collected includes water temperature (°C), salinity (ppt), and soak time (duration in minutes).

Virginia

Commercial length frequency data were obtained by the VMRC Biological Sampling Program (BSP). Black drum lengths and weights were collected at local fish houses by gear, area fished, and individual watermen.

Fish were measured for both TL and FL (mm) and individual weight (nearest 0.01 lb). Typically in this program, otoliths, as well as sex and maturity data, are collected from a subsample of fish encountered. However, due to the infrequency of black drum encounters, sampling is more opportunistic and all fish encountered by technicians are sampled. Similarly, a subsample of collected age samples would be selected for full ageing, but considering the often limited sample size, VMRC's ageing lab processes every otolith collected throughout the year.

Major commercial gears for Virginia are pound nets, anchored and drift gill nets, trot-lines, and to a lesser degree haul seines and hand-lines. Commercial samples were taken throughout the year and from all areas where black drum were landed. Fishery-dependent length frequency data collection for black drum in Virginia began in 1989. Black drum sampling events have remained relatively infrequent throughout the lifetime of the program, but sampling does occur in a representative manner annually. Virginia has collected 3,532 length and 2,313 age samples since 1989, averaging 104 lengths and 68 ages on a yearly basis.

North Carolina
Biological samples (lengths and aggregate weights) were obtained from the NC DMF commercial fisheries-dependent sampling programs (P400s). Black drum lengths were collected at local fish houses by gear, market grade, and area fished. Individual fish were measured (mm, centerline length-CL) and total weight (0.1 kg) of all fish measured in aggregate was obtained. Subsequent to sampling a portion of the catch, the total weight of the catch by species and market grade was obtained for each trip, either by using the trip ticket weights or some other reliable estimate. The number of individuals, aggregate weight, and length frequencies of each species in a sample were expanded to represent the species quantities in the sampled catch (trip ticket). Expansion was accomplished by matching at the market grade level biological fish house sample data (mean weight or length data) to the corresponding trip ticket market grade harvest. For example, the TL frequency of a species within a catch was derived by expanding the length frequency of the individuals measured in the subsample of a market grade (culled samples) to the total market category weight of that species in the sampled trip.

Estuarine Gill Net Sampling

Sampling of the estuarine gill net fishery was initiated by the NC DMF in April 1991 to determine relative abundance, age, size, and composition of species taken in the Pamlico Sound area. Two modes of sampling were included in the project: at-sea sampling and fish house sampling as catches are unloaded to the seafood dealer. Most sampling was conducted at the fish house after harvesters landed and graded their catch. In 1994, at-sea and fish house sampling of estuarine gill nets was expanded to include all other areas within North Carolina.

Flounder Pound Net Fishery

Flounder pound net catches were typically sampled at fish houses late-August through early-December, based on availability of landings and when the season was open. Since most flounder pound net catches are culled at the fishing site, random stratified (graded) samples were collected. For each species, a representative number of random basket samples (50 lb) were obtained from each size category (jumbo, large, medium, small, etc.), with more samples for larger fish.

Long Haul Seine Fishery

During the fishing season (April-November), long haul catches were sampled at the fish house where the catch was landed. Samples may be either graded or ungraded catches (sorted by market category). For each economically important (marketable) species, as many random samples (usually 50 lb cartons) as possible were obtained from each market category.

Ocean Gill Net Fishery

Traditional, anchored, and runaround ocean gill net catches were sampled at the fish house where the catch was landed. For all gear types, the captain or crew members were interviewed, when available, to obtain information including area and depth fished, days at sea, gear(s) used, including mesh size and length of gill nets. Random samples of culled catches were taken to ensure adequate coverage of all species in the catches.

Winter Trawl Fishery

Winter trawl catches were sampled at the fish house where the catch was landed. When available, the vessel's captain or a crew member was interviewed to obtain information on area and depth fished, number and duration of tows, days on the fishing grounds, and gear(s) used (including headrope length, body mesh size, and tail bag mesh size). To ensure adequate coverage of all sizes and species in the catches, and since some culling already has taken place at sea, stratified random samples of the graded catch were taken.

Florida

The Florida FWC Fisheries Dependent Monitoring (FDM) program participates in the Trip Interview Program (TIP), a cooperative effort with the NMFS Southeast Fisheries Science Center (SEFSC), in which field biologists visit docks and fish houses to conduct interviews with commercial fishers. The goal of TIP is to obtain representative samples from targeted fisheries on the level of individual fishing trips. Sampling priority is given to federally managed fisheries and their associated catches. Biologists collect data about the fishing trip such as catch and effort, as well as biological information such as length, weight, otoliths and spines (for ageing), and soft tissues for mercury testing and DNA analysis. These data provide estimates of the age distribution of the commercial catch and can be used to validate the catch, effort, and species identifications in the trip ticket data (Chagaris et al. 2012).

For the TIP program, a representative sample is a sample that meets sound statistical criteria for (at minimum) describing a population. The populations are defined by fishery-time-area strata. For practical reasons area is defined here by area of landing, not the fishing area. Agents are assigned target numbers of measurements needed for stock assessment. Sampling targets will be assigned according to the historical landings within the fisheries (Saari and Beerkircher 2013).

For each trip, a maximum of 30 random age samples are collected per species and lengths and weights are measured opportunistically for all randomly selected fish (regardless of species). The standard procedure is to measure all fish in fork (center-line) length. Length measurements are taken to the nearest tenth cm or in mm and most weight measurements are in gutted pounds. A detailed explanation of the standard sample work-up for data collection is described in the TIP user manual (Saari and Beerkircher 2013). Black drum is on the list of species to be sampled, but they are considered low priority.

4.1.2 Total Catch

4.1.2.1 Landings

Overall, total commercial landings of black drum have been relatively small and characteristic of bycatch in fisheries directed at other species, never exceeding 700,000 pounds in a year (Figure

2, Table 4). Aside from a few anomalously large events in early U.S. Fish Commission annual reports and a period of relatively low catch during WWII years, landings of black drum generally increased from the early 1900s to the highest levels of the time series in the 1960s. Landings averaged 434,000 pounds in the 1960s. Landings then declined through the 1970s. Landings increased slightly in the late 1980s and have been relatively stable since, averaging 258,000 pounds since 1986.

Modern commercial landings (1950-2020) have primarily come from Virginia in the Mid-Atlantic (36% of the coastwide total) and North Carolina (27% of the coastwide total) and Florida (22% of the coastwide total) in the South Atlantic. Other Mid-Atlantic states have been secondary contributors including New Jersey (8% of the coastwide total), Delaware (3% of the coastwide total), and Maryland (4% of the coastwide total). Other South Atlantic states (Georgia and South Carolina) combined have contributed less than 1% of the coastwide total.

Five gear types have accounted for the majority (89%) of coastwide modern landings including gill nets (39%), fixed nets (22%), haul seines (12%), trawls (9%), and hand lines (7%). More recently, since 1992, the majority of coastwide landings have come from gill nets (66%). Landings by state and gear are further discussed in Section 4.4 when defining commercial fleets for evaluating composition sampling data.

Monthly data for landings become available in the early 1970s, but are very limited until the late 1970s (Table 5). Complete monthly data become available in the 1990s. Monthly data become available for most Mid-Atlantic landings in 1989, but the landings needed to be split into seasons (January-August and September-December) back to 1981 to be compatible with the data time series and assessment model used in this assessment (Section 7.3). Five-year averages of monthly proportions from 1989-1993 were applied to prior landings to assign these landings to months and seasons.

Since 1990, landings in the Mid-Atlantic have come primarily during the period most closely associated with the spawning adult migration to this region in the late spring and early summer (Figure 3). More limited landings have occurred in the period later in the year when primarily young fish are available to the fishery in this region. Landings in the South Atlantic have been more spread out, reported in all months throughout the year, but do indicate peaks of landings late in the year (October and November; Figure 4).

4.1.2.2 Discards

Dead discards of black drum in North Carolina estuarine gillnet fisheries estimated from Program 466 observer data are provided in Table 6. Estimates average 29,669 fish from 2004-2020 and average less than 2% of recreational removals in numbers during these years. Due to the low magnitude of these discards, lack of estimates prior to 2004, and lack of sufficient biological data for converting these estimates to weight, these data were not considered further in the assessment. These data should be revisited to evaluate any increases in discards during future stock assessments.

4.1.2.3 Size Composition

The size and age composition data available from commercial fisheries were collectively evaluated for utility in the assessment in Appendix 1 and Section 4.4.

4.1.3 Limitations and Potential Biases

Collection of commercial landings data has been designed as a census to capture total landings, but methods to collect these data have changed through time likely leading to changes in uncertainty. There are no quantitative measures of uncertainty accompanying commercial landings data, but Table 3 shows changes to landings data collection methodology by state through time. Each methodology is anticipated to be an improvement to the data collection methodology that preceded it. Commercial landings data uncertainty was an issue addressed during a Best Practices Workshop convened by SEDAR (SEDAR 2015). The recommendation produced from this workshop was to assume uncertainty decreases as the data collection methodology changes through time, resulting in time blocks of decreasing uncertainty levels from historic to current data collection methods. Data prior to 1950 are considered particularly uncertain.

4.2 Recreational

4.2.1 Marine Recreational Information Program

4.2.1.1 Introduction and Methodology

The primary source of black drum recreational catch data along the Atlantic coast is the Marine Recreational Information Program (MRIP), formerly the Marine Recreational Fisheries Statistics Survey (MRFSS). MRIP consists of three general surveys to estimate recreational catch, the Access Point Angler Intercept Survey (APAIS), the Fishing Effort Survey (FES), and the For-Hire Survey (FHS). The APAIS is a “dockside” survey where interviewers intercept anglers at public water access points returning from fishing trips to collect information on species targeted during the trip, catch, and fishing area. Data are used to estimate species-specific catch rates by disposition, characterize the size structure and weight of fish harvested, and determine the proportion of fishing effort occurring in three general areas of marine waters (inland, state seas from the coastline out to three miles, and the federal EEZ beyond three miles from the coastline). Dispositions include harvested and either available for inspection (i.e., landed, Type A catch) or unavailable for inspection (e.g., fileted at sea, Type B1 catch) and released alive (Type B2 catch). The FES is a mail-based survey that collects data on fishing effort by anglers from U.S. households fishing from shore and private/rental boats to estimate total fishing effort. The FHS is the counterpart to the FES that collects data on fishing effort by for-hire charter boat and headboat captains through a telephone survey. Components of the MRIP survey have undergone design changes since the start of the program in 1981, with a brief description of survey design changes below. Interested readers who would like more details on the survey design changes are encouraged to review the resources available through the NMFS Office of Fisheries Statistics (www.fisheries.noaa.gov/recreational-fishing-data/about-marine-recreational-information-program).

MRIP implements a stratified sampling design, stratifying by state, year, wave (bimonthly period starting with January-February as wave 1), and fishing mode (shore, private/rental boat, party boat, and charterboat). Catch rate data collected during the APAIS for each stratum are applied to total effort data from the FES and FHS to estimate total harvested catch (Type A+B1 catch) and total catch released alive (Type B2 catch). Total effort directed at black drum is estimated from all effort using data on species targeted during the trip collected during the APAIS. Area data collected during the APAIS are used for post-stratification of estimates by area.

Biological data collected during the APIAS sampling include FL and weight of Type A fish. Both are collected opportunistically but field interviewers are instructed to measure and weigh up to fifteen fish of each available species from each angler interviewed. The individual fish are to be selected from the total landed catch at random to avoid any size-bias in the resultant sample. These data are used to estimate harvest in weight and the size composition of harvested fish. No hard parts (e.g., otoliths) are collected for age data.

Two significant changes have occurred to the MRIP survey methodologies since the previous assessment based on external reviews and recommendations. The APAIS was redesigned in 2013 to improve the sampling design and the use of APIAS data in catch estimation methods. This included expanded sampling into the nighttime, a recommendation from the previous stock assessment due to anecdotal reports of nighttime black drum fisheries. In 2018, the telephone-based effort survey used historically to collect effort data from U.S. households (Coastal Household Telephone Survey-CHTS) was replaced with the current mail-based FES. Since the terminal data year of the previous black drum stock assessment (2012) was before these changes, all estimates used in the assessment were based on the old APAIS design and CHTS effort data. A calibration study indicated the transition to the FES generally resulted in significant increases in effort estimates and, therefore, total catch estimates relative to the CHTS. MRIP now provides all estimates prior to these design changes with calibrations applied to correct for both the APIAS redesign changes (estimates prior to 2013) and the transition to the mail-based FES (estimates prior to 2018) and this is the first assessment to report these calibrated black drum catch estimates.

In addition to these calibrations handled internally by MRIP, black drum total catch estimates were adjusted with several post hoc methods within this assessment to improve the data and make them compatible with assessment approaches.

MRIP only provides released alive catch estimates in numbers because no biological data are available from this catch. These catch estimates were converted to weight estimates during the previous stock assessment to support biomass dynamics assessment methods by borrowing individual weight observations from harvested fish according to regulatory history and life history of black drum. Fish released alive in the South Atlantic were assumed to be the same size as fish harvested during periods when there were no regulations and anglers could indiscriminately harvest (and release) a mix of sizes from the sub-adult size range available to this fishery. Individual weight observations were borrowed from harvested fish within South

Atlantic states during pre-regulatory periods, averaged, and applied to released alive catch estimates in the same state.

In the Mid-Atlantic, where life history controls sizes available to the fishery, the year was split into an early period (waves 2-3, March-June) when the catch is from the mature spawning stock and would not be affected by the 16 inch minimum size limits, a middle period (wave 4, July-August) that is a more transitory period with mature fish emigrating and young, small fish becoming available, and a late period (waves 5-6, September-December) when primarily YOY fish remain available. Individual weight observations were borrowed from these periods, averaged, and applied to released alive catch estimates during the same period.

Mean weight data were updated during this assessment for periods that had additional data since the previous assessment. Additionally, the late period in the Mid-Atlantic, which is most likely to see regulatory impacts to the released alive size structure, was further limited to years before 16 inch minimum size limits went into effect in each state, which was not done in the previous assessment. Mean weight data are reported in Table 7. Individual weight observations were limited (<10) in New Jersey, Maryland, and Virginia during the late period and were borrowed from Delaware to estimate mean weight. Figure 5 shows released alive catch estimates using mean weight data from the previous assessment and updated data during this assessment.

There are some occurrences where harvested black drum were reported and no biological data (i.e., Type A fish) were available, resulting in non-zero harvest estimates in numbers and missing harvest estimates in weight. MRIP applies an initial imputation methodology, but not all occurrences are addressed. For black drum, this occurred in 1988 and 1992. Following the approach in the previous stock assessment, individual weight observations were pooled from like strata until ten or more observations were available to calculate a mean weight. Data were subsequently collapsed over wave groupings (1-3 or 4-6), modes, and finally years with similar regulations until at least 10 observations were available. The mean weight was then applied to the harvest estimate in numbers to generate a harvest estimate in weight. The addition of these estimates to the harvest time series is shown in Figure 6.

Finally, the FHS was not implemented until 2000 and 2004 in Florida and all other Atlantic coast states, respectively. For-hire effort was estimated through the CHTS prior to this survey. To calibrate pre-FHS catch estimates to the FHS effort, effort-based ratios estimated in the SEDAR 64 stock assessment (Dettloff and Matter 2019) were applied to the estimates. Due to the small proportion of black drum caught by for-hire modes, these calibrations had minimal effect on the coastwide estimates of harvested black drum (Figure 7) and released alive black drum (Figure 8).

4.2.1.2 Effort

Directed black drum trips, defined here as trips where anglers identified black drum as the primary or secondary species targeted during their trip, were relatively stable and low through the 1980s and 1990s (Figure 9). Directed trips then followed an increasing trend through the remainder of the time series with some notable increases from 2008-2011, 2013-2014, and 2017-2018.

There have been similar trends in South Atlantic states which account for the majority of directed black drum trips (Figure 10). Mid-Atlantic states show more variable trends.

4.2.1.3 Catch Rates

Catch rate data collected during intercepts of anglers by the APAIS were used to generate an index of abundance. The intercept data set includes catch rate data for all species caught, and a method for identifying intercepts that are informative of black drum abundance is necessary to filter the data set. Two methods for selecting intercepts were evaluated, a cluster analysis following the methods of Shertzer and Williams (2008) and the directed trips method. The cluster analysis identifies other species that are caught frequently with black drum during intercepted angler trips. The assumption underlying this cluster analysis method is that species caught frequently on the same trips as black drum cohabitate and are vulnerable to the same gear while species rarely or never caught on the same trips as black drum do not cohabitate. If anglers caught species that cohabitate with black drum, they were fishing in black drum habitat and could have caught black drum making that trip an informative trip for black drum relative abundance. Intercepts with anglers reporting black drum catch and/or catch of co-occurring species are retained in the data set while all other intercepts are assumed not to be representative of black drum abundance and are excluded from the data set. The directed trips method selects any intercepts when the anglers identify black drum as either the primary or secondary species targeted during their trip and any additional intercepts that reported catching black drum. As with the previous assessment, 1981 data were dropped from the data set due to wave 1 in Florida, a period of relatively high catch in later years, not being sampled in this year. Intercepts of headboat anglers were also excluded from the data set due to low sample sizes and discontinued sampling of this mode by MRIP in the South Atlantic (Section 4.2.2.1).

The delta method (Lo et al. 1992) was used to generate an index of abundance from the data set using each selection method. The delta method uses two generalized linear models (GLMs), a Gaussian GLM to model log-transformed positive observations of the response variable, catch (Type A1+B1+B2) per angler hour, and a binomial GLM to model the proportion of observations that are positive (i.e., caught at least one black drum). The final index is the product of the year effects from the two GLMs. A bias correction is applied to the positive model year effect to account for transformation from log space back to CPUE. Variables considered for effects on catchability in initial GLMs were state, mode, area, wave, and angler avidity. Mid-Atlantic states were collapsed into two groupings, Chesapeake Bay states (VA and MD) and Delaware Bay states (DE and NJ), due to low sample sizes. Angler avidity was defined as the median number of days fished in the past two months across anglers on a trip and was categorized in 10 day increments. Model selection was completed by dropping any explanatory variables that accounted for less than a 0.5% reduction in model deviance.

The cluster analysis was the method used during the previous black drum stock assessment (ASMFC 2015). However, it became apparent during this assessment that shifts in angler behavior since the previous assessment have resulted in inflated catch rates with the cluster analysis data set. Anglers have reported targeting black drum at a greater rate in recent years resulting in a greater proportion of intercepts in the cluster analysis data set being directed black drum effort (Figure 11). This directed black drum effort is more successful than effort where anglers did not report targeting black drum and is more likely incidental effort from intercepts directed at the associated species identified with the cluster analysis (Figure 12). The increasing proportion of directed effort is particularly apparent in NC and SC after 2015, resulting in an index that abruptly shifts in 2016 relative to the directed trips index (Figure 13). Therefore, the cluster analysis methodology was not pursued further and the directed trips methodology was selected to generate an index data set.

A total of 22,993 trips were retained for the directed trips data set. Sample sizes by factor are provided in Table 8. The same variables were retained in both GLMs and included year, state, mode, and wave (Table 9 and Table 10). Residual plots show no residual patterning for the positive observation (Figure 14) or proportion positive (Figure 15) GLMs. Both the nominal and standardized indices generally increase through time (Table 11 and Figure 16). The standardized index shows less interannual variability than the nominal index, a lower relative abundance from the late 1990s through the early 2000s, and a lower rate of increase since 2010. CVs of the standardized index are quite small, averaging 0.074. To generate a weight-based CPUE for potential use in biomass dynamics assessment approaches, an annual mean weight was calculated for each catch disposition (harvest and released) from the total catch (total catch weight/total catch numbers) and an overall annual mean weight was estimated as an average across dispositions weighted by proportion of total catch accounted for by each disposition. The overall mean weight was multiplied by the numbers-based index to generate a weight-based CPUE (Table 11). The weight-based CPUE follows a similar trend as the numbers-based CPUE, but with more interannual variability (Figure 17).

4.2.1.4 Total Catch

Annual catch in terms of harvest, releases, dead discards, and total removals (harvest + dead discards) are presented here. Catch in numbers is reported, but catch in weight, the unit used in biomass dynamics assessment approaches, is the primary focus. Dead discards were calculated based on an 8% discard mortality rate for released black drum, consistent with the previous stock assessment and based on rates estimated for a similar species (i.e., red drum).

4.2.1.4.1 Harvest

The transition from the CHTS to the FES resulted in a significant increase in calibrated harvest estimates relative to the estimates used in the previous stock assessment (Figure 18). With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 270% during the time series of the replaced, telephone-based CHTS (1981-2017). The calibrated estimates follow a similar trend, but indicate a relatively dampened peak in 2008, an anomalous estimate given considerable attention in the previous stock assessment, and diverge from the uncalibrated estimates in the last few overlapping years.

Final harvest estimates decreased in the late 1980s and remained below 3 million pounds through the mid-1990s (Table 12, Figure 19). Harvest increased in the late 1990s and became relatively stable in the early to mid-2000s (average of 4.9 million pounds from 2000-2007). Harvest was highest around 2010, with the three highest harvests exceeding 7.5 million pounds in 2008, 2009, and 2011. Harvest decreased after 2011 and was slightly higher than harvest in the early to mid-2000s through the remainder of the 2010s (average of 5.2 million pounds from 2012-2020).

Florida has accounted for the majority of harvest in most years, followed by North Carolina (since the mid-1990s) and South Carolina (Figure 20). Harvest in Mid-Atlantic states has been variable, with higher proportions coming from New Jersey since 2000. Harvest has been roughly split between inland and coastal waters, with very little harvest from offshore waters (Figure 21). The majority of black drum have been harvested by anglers fishing from private and rental boats followed by anglers fishing from shore (Figure 22). Charter boat harvest has been variable and small, while there has been very little harvest by party boat (i.e., headboat) anglers. Harvest occurs throughout the year and varies seasonally among years (Figure 23).

Proportional standard error (PSE) for harvest estimates is higher in the 1980s, exceeding 40% in several years (Table 12, Figure 24). PSEs then decline and remain below 40%. Estimates with PSEs below 40% are considered valid inputs for stock assessment models, while estimates with values between 40% and 60% should be used with caution, and any estimates with PSEs >60% should be used with extreme caution (ACCSP 2016). Although below 40%, estimates from 2015-2017 had high PSEs (>29%) relative to surrounding years.

4.2.1.4.2 Releases

The transition from the CHTS to the FES resulted in a significant increase in calibrated released alive estimates (Figure 25). With calibrations applied for both the APAIS changes and effort survey methodology changes, estimates increased an average of 342% during the time series of the replaced, telephone-based CHTS (1981-2017). The calibrated estimates follow a similar trend, but indicate a period of relatively lower releases in the early 2000s, a period of relatively higher releases in the early 2010s, and a noticeably higher relative estimate in 2017.

Final release estimates generally increase from the lowest levels in the early 1980s (average of 25 thousand fish and 56 thousand pounds from 1981-1984) until plateauing at the highest level in the mid-2010s (average of 5.1 million fish and 10.8 million pounds from 2015-2018) and then decline sharply during the final two years of the time series (Table 12, Figure 19, Figure 26).

Florida accounted for the majority of releases in earlier years, though this has been declining through time (Figure 27). Releases have been increasing from the Carolinas in recent years. Releases have been roughly split between inland and coastal waters, with very little releases in offshore waters (Figure 28). The majority of black drum have been released by anglers fishing from private and rental boats followed by anglers fishing from shore (Figure 29). Black drum have been released throughout the year, with a majority being released later in the year (September-December; Figure 30).

PSEs are high in the 1980s during years of near zero release estimates, exceeding 40% in most years and 60% in the first three years (Table 12, Figure 24). PSEs then decline for the remainder of the time series as this component of catch increases and remain below 40%.

4.2.1.4.3 Dead Discards

Dead discards are calculated with a constant mortality rate and, therefore, follow the same trend as releases with a lower magnitude (Table 12, Figure 26). Dead discards increase from an average of 5 thousand pounds during the early 1980s (1981-1984) to a peak of 867 thousand pounds in the mid-2000s (2015-2018).

4.2.1.4.4 Total Removals

Total recreational removals have primarily been from harvest and, therefore, the trend and magnitude follow the harvest closely (Table 12, Figure 31). However, dead discards have accounted for an increasing proportion of removals, averaging 11% over the last decade vs. an average of 0.5% in the 1980s, leading to a more rapid increase in total removals in recent years relative to the harvest alone.

4.2.1.5 Size Composition

4.2.1.5.1 Harvest

The mean size of black drum harvested along the coast was relatively stable prior to the requirement of coastwide regulations implemented in the FMP (2014; Figure 32). This mean size varied from 11.95 inches FL in 1995 to 16.78 inches FL in 2004 and averaged 14.71 inches FL from 1981-2013. Following the implementation of the FMP in 2014, and driven by North Carolina’s implementation of the first black drum regulations in the state, there was an increase in mean size to an average of 17.34 inches FL from 2014-2020. Harvest shifted from a bimodal distribution during the pre-FMP period with distinct peaks at sizes typical of age-0 and age-1 fish to a more unimodal distribution post-FMP with harvest primarily of age-1+ fish (Figure 33). The descending tail of the distribution is similar during both periods.

Mid-Atlantic states harvested larger and more variable sizes than South Atlantic states (Figure 34). The impacts of varying state-specific regulations on harvested sizes can be seen in Delaware (16 inch TL minimum size and 3 fish bag limit in 2010), North Carolina (14 inch TL minimum size, 25 inch TL maximum size, 10 fish bag limit in 2014), South Carolina (14 inch TL minimum size, 27 inch TL maximum size, 5 fish bag limit in 2007), and Georgia (10 inch TL minimum size and 15 fish bag limit in 1998). There was a decrease in sizes harvested in VA around the mid-1990s, though this change doesn’t coincide with any regulation changes for the recreational fishery.

There is also more seasonal influence on the size structure in the Mid-Atlantic region. Mature adults are the primary catch during waves earlier in the year when spawning adults migrate to this region, while primarily age-0 and age-1 fish are available to fisheries in this region later in the year (Figure 35).

These size composition data are further evaluated and discussed in Section 4.4.

4.2.1.5.2 Discards

MRIP cannot sample black drum released alive for biological data, so there are no size composition data available for this component of the catch and removals (i.e., dead discards).

4.2.1.6 Limitations and Potential Biases

All data provided by anglers during the APAIS, including catch and species targeted during the trip, is voluntary.

The COVID-19 pandemic disrupted APAIS sampling and led to some imputation of catch rate data with data from surrounding years to estimate total catch in 2020. The proportion of catch rate data imputed from surrounding years varied among states from 0% to 99% for harvest estimates and from 0% to 32% for released alive estimates (Table 13). These imputed catch rate data were excluded from the data set used to calculate CPUE.

The MRIP was not designed to generate index of abundance data, so there are some limitations to consider with the CPUE data set. There is the potential for biases in targeting data if anglers are influenced by their catch when reporting targeted species following the trip. For example, an angler going out on a fishing trip without a particular target that happens to catch black drum may be influenced to report black drum as the intended target species when returning from the trip while the same angler would not have reported this if no black drum were caught. This situation would inflate the catch rates if it were a common occurrence. The MRIP design changes that have occurred through time (e.g., site selection methodology, inclusion of nighttime sampling) are accounted for in total catch estimates through calibration factors, but raw intercept data used for the index are not adjusted for these changes. This could be an area of future research by using the MRIP site-use weighting factors which are only available since 2004. As with any fishery-dependent index of abundance, there is the potential for temporal changes in catchability and hyperstability. These could occur due to advances in technology, increased knowledge of black drum fishing practices, etc.

4.2.2 Other Recreational Catch Data

4.2.2.1 Southeast Region Headboat Survey

Headboats in the South Atlantic have been sampled by the Southeast Region Headboat Survey since 1983 to generate catch estimates for this recreational fishing mode. Black drum were rare encounters in this fishery with harvest estimates totaling 1,999 fish from 1983-2020. Therefore, these data were not considered further in the assessment, but should be revisited to evaluate any increases in catch during future stock assessments.

4.2.2.2 Historical Recreational Catch

4.2.2.2.1 1981 Wave 1 Catch

The MRFSS started estimating catch coastwide in wave 2 (March-April) of 1981. This start misses the wave 1 period in Florida which has been a period of relatively high catch in later years. Best practice recommendations from SEDAR (SEDAR 2015) were followed to estimate 1981 wave 1 Florida catch to fill in total annual catch for this year. Stratum-specific wave 1: waves 2-6 harvest estimate ratios from 1982-1984 were highly variable (CVs>1), so the average wave 1 harvest from 1982-1984 (370,659 pounds) was used as a proxy for the 1981 wave 1 harvest estimate. This accounts for 31% of Florida's 1981 total harvest and 23% of the coastwide 1981 total harvest. Estimates of black drum releases from 1982-1984 for wave 1 in Florida were zero in each year, so no additional catch was added to the 1981 released alive estimate.

4.2.2.2.2 Catch Prior to 1981

Recreational catch estimates prior to the MRFSS were developed during the previous stock assessment to support assessment methods requiring a complete catch history. Estimates from 1950-1980 were generated by extrapolating state-specific CPUE during the early years of the MRFSS (1981-1985) to total effort estimates from historical surveys on saltwater fishing participation. This assumes recreational CPUE prior to 1981 is static. Due to the change in MRIP methodologies since the previous stock assessment and resultant increases to catch estimates, these historical catch estimates were updated with CPUE data from the newly calibrated MRIP catch estimates. In addition to the updated CPUE data, an alternative set of years to average CPUE across was explored.

Within each state, all years from 1981 up to the year before regulations were implemented (Table 1) were used for average CPUE to extrapolate historical effort estimates. This alternative was considered based on the assumption that implementation of regulations (e.g., bag limits) would be the driver of CPUE changes which allowed for more years of CPUE data during the early part of the MRIP when data are most uncertain. The alternative CPUE data resulted in slightly increased harvest estimates with a similar trend (Figure 36). Similarly, these alternative data resulted in slightly increased release estimates, but with a trend more similar to the harvest catch estimates. These catch estimates using alternative CPUE data (Table 14) were considered an improvement and were used in place of the catch estimates with static CPUE years across states. There are no measures of precision for these estimates and they are considered less certain than the estimates from the designed survey used by MRIP in subsequent years.

Estimates prior to 1950 were extrapolated back to 1900 (Table 15, Figure 37), the assumed start of the catch history in the previous assessment, using exponential regression on the increasing harvest estimated from 1950-1975. Recreational dead discards were assumed to be zero in these early years due to the low estimates in the 1950s. These estimates are also considered less certain than modern estimates from MRIP.

4.2.2.3 Supplemental Biological Sampling

There are several recreational fishery monitoring efforts by state agencies conducted aside from the general MRIP survey. The primary purpose of these efforts has been to provide supplemental age-length key data for generating age composition data. These data are further evaluated and discussed in Section 4.4.

New Jersey

Sampling occurs at one tournament in the peak of the New Jersey black drum fishery season. The volunteers or staff are staged near the weigh-in stations. They only sample fish from the harvesters who are willing work with them. This means that the sampling is not inclusive of all fish and most likely less inclusive of the smaller fish. The weight and length are recorded and, if possible, otoliths are extracted.

Delaware

Mature black drum were sampled in April, May, and June from the recreational fisheries in the Delaware Bay. These months were chosen as they encompass the time of year when greater than 90% of the recreational harvest occur (DDFW unpublished data). All fish were measured for TL to the nearest mm. Total weight (kg) and sex were recorded. Gonad weight (g) was recorded for fish sampled from 2009-2013. Sagittal otoliths were removed and placed in envelopes with sample number, location, date, fishery, and gear type. One otolith was chosen randomly from each pair and processed for age determination. Otoliths were thin sectioned on a Hillquist high speed saw and mounted on microscope slides. Slides were viewed at 24X magnification.

The racks of 519 recreationally-harvested fish were sampled from 2008 – 2021 with 503 used for age determination. Sample sizes ranged from 10 in 2016 to 93 in 2009. The average length of sampled fish was 930 mm (min. 422 mm TL, max. 1,371 mm TL) while the average age was 11.5 years (min. 2 years, max. 57 years).

Virginia

Beginning in 2007, the VMRC operates a recreational carcass recovery program known as the Marine Sportfish Collection Project. The goal of this project is to both supplement the Biological Sampling Program with species that are traditionally scarce in the commercial sector, and serve to characterize VA's recreational fishing activity. Chest freezers are established near the fish cleaning stations at a rotating series of marinas and boat ramps in the Chesapeake Bay region, depending on seasonality and freezer availability. Each freezer is marked with an identifying sign and a list of target fish species. Cooperating anglers place the filleted carcasses, with head and tail intact, in a bag, drop in a completed donation form, and then place the bag in the freezer. Each fish is identified to species, the fish length is measured, sex is determined when possible, and the otoliths are removed. These otoliths are incorporated into the subsampling scheme of VMRC's ageing lab, with their original recreational status recorded for later reference.

Black drum recovered through this program can be subdivided into two groups, those caught and subsequently donated within the bay, and those recovered from the eastern shore of Virginia. Within the bay, a wide range of sizes have been donated to the program, ranging from sub-legal to greater than 50 inches. These fish have ranged from less than 1 year of age to 64 years of age. The second group, those from the Eastern shore, primarily consists of large adult fish that are regularly greater than 40 inches. These fish vary in age from their early 40s to early 60s.

The number of black drum collected by the Marine Sportfish Collection Project has varied greatly from year to year, with a peak of 228 fish donated in 2008 and only 9 fish donated in 2020. Overall, 1,022 black drum have been recovered through this program since 2007, ranging in length from 192 to 1,350 mm.

North Carolina
In 2014, the NC DMF initiated a formal Carcass Collection Program. The objective of the project is to develop a statewide freezer collection program in order to obtain fishery-dependent length, sex, and age samples of recreationally important fish. Since the beginning of the program, the NC DMF has maintained eight operational freezer sites where carcass collection occurs. Sites include tackle stores, fishing piers, shore access points and local NC DMF offices. NC DMF staff make scheduled checks to freezers to collect carcasses and resupply freezers with collection bags and information cards. Fish samples collected from the freezers are processed and entered into the NC DMF biological database. Information collected includes species of fish, length of fish, sex, otoliths for ageing and catch information (fishing mode, date, location etc.).

Samples of black drum collected annually have ranged from 12 (2020) to 142 (2017) with a total of 224 collected from 2014 to 2020. The majority of black drum collected in the carcass collection program are age-2 with some age-1 to age-4 fish. This range of ages is consistent with the size of fish that can be legally harvested in the 14 to 25 inch TL slot limit. One age-13 fish was collected; anglers may retain one fish over 25 inches TL.

South Carolina
Inshore Fisheries-Dependent Biological Sampling Programs

Given the limited information on the size and age of recreationally harvested fish from South Carolina waters, the SC DNR Inshore Fisheries Research Section conducts two fishery-dependent biological sampling programs, namely a fishery-dependent freezer fish program and a fishery-dependent tournament sampling program. Both are designed to collect biological information on the size, age, and sex composition of recreationally harvested priority species. Black drum are included as a priority species of interest for both programs.

Freezer Fish Program

Since 1995, Inshore Fisheries has operated a freezer drop off program for recreationally important inshore finfish, enabling us to obtain fish from areas and habitats not always represented in SC DNR monthly field sampling. Chest freezers are located near collaborating marinas, landings, or bait shops along the South Carolina coast. Participating anglers place the filleted rack with head and tail intact in one of the provided bags, drop in the completed catch information card, and deposit the bag in the freezer. Freezers are checked periodically by SC DNR staff and provided fish racks are brought back to SC DNR facilities for processing. Once in the lab, fish are identified to species, lengths are recorded, sex and maturity status are determined when possible, genetic samples are collected, and otoliths are removed. Otoliths are aged annually with each recreational capture day considered an independent collection event.

The average size black drum donated was 437.5 mm TL (min. 247 mm TL, max. 1,210 mm TL) with a total of 597 length samples. The age range was 0-47 years with ages 1-3 accounting for the majority (85%) of the ages and an average age of 1.6 years with a total of 570 age samples. There were 266 males and 279 females.

Tournament Program

Inshore Fisheries began participating in Recreational Angler tournaments in 1986. Inshore staff act as weigh master at tournaments and collect biological samples from fish of participating anglers. Similar to the freezer fish program, fish are identified to species, lengths are recorded, sex and maturity status are determined through gross and histological sampling, genetic samples are collected, and otoliths are removed.

The average size black drum sampled through tournaments was 552 mm TL (min. 232 mm TL, max. 1,225 mm TL) with a total of 514 length samples. The age range was 0-34 years with ages 1-4 accounting for the majority (85%) of the ages and an average of 3.3 years with a total of 470 age samples. There were 232 males and 267 females.

State Finfish Survey

Implemented in 1988, the State Finfish Survey (SFS) was designed to address specific data gaps, within the MRFSS, as identified by SC DNR staff. These data gaps included the lack of length data from species of concern to the SC DNR and the lack of seasonal and area-specific catch frequencies. Another concern was the lack of catch and effort data from private boat anglers, which make up a majority of the angling trips in South Carolina coastal waters. These data gaps were initially addressed by interviewing inshore anglers targeting red drum and spotted seatrout at specific sample locations. Since 2002, more emphasis has been placed on acquiring length data from all finfish retained by anglers (including black drum), canvassing at additional sampling locations, and interviewing all private fishing boats within all South Carolina coastal areas. Broadening the scope of the survey may decrease some of the bias associated with the previous SFS protocol.

Sampling is conducted at public and selected private (with owner's permission) boat landings from January through December using a questionnaire and interview protocols similar to those of the MRFSS. However, the SFS questionnaire focuses on vessel surveys rather than individual angler surveys and primarily targets private boats. Interviews are obtained from cooperative anglers at each sampling site. If an angler is unwilling to participate, they can decline to be interviewed. Assigned Creel Clerks interview as many anglers as time allows at any given site.

The sampling schedule is determined by "needs assessments" of the SC DNR Marine Resources Division and creel clerks. Individual Creel Clerks are assigned to a sampling region and will determine their daily sampling schedules based on local conditions (i.e., weather, landing closures, or events), additional job duties, and research and management initiatives. Attempts are made to assess all sampling sites equally, and individual creel clerks randomly rotate between all sampling locations within their region. Creel clerks will remain at landings with fishing activity. If landings have little or no fishing activity creel clerks will move on to alternative sampling locations in close proximity.

The SFS uses a questionnaire and interview protocol similar to MRFSS/MRIP, with the same staff conducting both surveys since 2013. Data collected for the SFS questionnaire include:

1. Mode fished (i.e., private, charter, shore)
2. Specific body of water fished
3. Area fished (inshore, 0-3 miles, > 3 miles)
4. Utilization of artificial reef/reef name
5. Resident county of boat owner
6. Species targeted
7. Number of anglers participating on the vessel
8. Amount of time spent fishing for the trip
9. Expense of the trip (all anglers)
10. Angling trips the previous year, average of all anglers participating
11. Catch and disposition by species (includes both landed and released fish)
12. Length measurements obtained, with anglers permission, for retained species; 1988 – March 2009: length measurements mid-line length (ML); April 2009 – present: TL measurements

Intercept data are coded and key entered into an existing Access database. Queries are used to look for and correct anomalous data and a component of the database records are checked against the raw intercept forms.

For the period January 1988 through February 2013, data are available from each month of the year. Beginning in 2013, SFS staff took on the duty of conducting the MRIP survey in SC and as a result the traditional SFS survey only operates during the months of January and February (no MRIP sampling during this period). Intercepts of black drum during January and February are low and serve limited utility for assessment, but traditional SFS data from March-December are generally included in MRIP landings reported for South Carolina since 2013.

The SFS collects information on both the nature of individual fishing trips and biological information on the species captured during the trip from cooperating anglers. Trip level information includes the date, location (intercept site, fishing location, and locale (estuarine, nearshore, offshore), fishing mode (private, shore, charter, etc.), purpose of the trip, target (primary and secondary) species, and angler information such as the number of anglers, hours fished, and average number of trips during the previous year across anglers in the party. Recorded biological information includes the species caught and the number and dispositions of caught fish. For those fish harvested, length information is verified for creel clerks, and provide an analogous data set to that obtained from the harvested fish encountered by the MRFSS/MRIP APAIS. For released fish, the creel clerks obtain information on the number of legal sized fish released and the number of illegal (i.e., outside the slot limit for black drum) fish released as well as self-reported size information from the anglers on these released fish.

Charterboat Logbook Program

The SC DNR issues licenses to charter vessels on a fiscal year (July 1 – June 30). In 1993, SC DNR's Marine Resources Division (MRD) initiated a mandatory trip-level logbook reporting system for all charter vessels to collect basic catch and effort data. Under state law, vessel owners/operators purchasing South Carolina Charter Vessel Licenses and carrying anglers on a for-hire basis, are required to submit trip level reports of their fishing activity. Logbook reports are submitted to the SC DNR Fisheries Statistics section monthly either in person, by mail, fax, or scan and beginning in 2016, electronically through a web-based application. Reporting compliance is tracked by staff, and charter vessel owners/operators failing to submit reports can be charged with a misdemeanor. The charterboat logbook program is a complete census and should theoretically represent the total catch and effort of the charterboat trips in waters off of SC.

The charterboat logbook reports include: date, number of anglers, fishing locale (inshore, 0-3 miles, >3 miles), fishing location (based on a 10x10 mile grid map), fishing method, hours fished, target species, depth range (minimum/maximum), catch (number of landed vs. released fish by species), and estimated landed pounds per vessel per trip. The logbook forms have remained similar throughout the program's existence with a few exceptions: in 1999 the logbook forms were altered to begin collecting the number of fish released alive and the number of fish released dead (prior to 1999 only the total numbers of fish released were recorded) and in 2008 additional fishing methods were added to the logbook forms, including cast, cast and bottom, and gig. Furthermore, the fishing method dive was added in 2012.

After being tracked for compliance, each charterboat logbook report is coded and entered, or uploaded into an existing database. Since the inception of the logbook program, a variety of staff have coded the charterboat logbook data. From approximately 1999 to 2006, only information that was explicitly filled out by the charterboat owners/operators on the logbook forms were coded and entered into the database. No efforts were made to fill in incomplete reports. From 2007 to present, staff have tried to fill in these data gaps through outreach with charterboat owners/operators by making assumptions based on the submitted data (i.e., if a location description was given instead of a grid location – a grid location was determined; if fishing method was left blank – it was determined based on catch, etc.). From 1999 to 2006, each individual trip recorded was reviewed to look for anomalies in the data. Starting in 2007, queries were used to look for and correct anomalous data and staff began checking a component of the database records against the raw logbook reports. Coding and QA/QC measures prior to 1999 were likely similar to those used from 1999 to present; however, details on these procedures are not available since staff members working on this project prior to 1998 are no longer with SC DNR. Data are not validated in the field and currently no correction factors are used to account for reporting errors via paper submission; however, the online system is built with error messages and constraints to prevent common reporting mistakes and overlaps in the data. Recall periods for logbook records are typically one month or less. However, in the case of delinquent reports, recall periods could be up to several months. The electronic reporting application has already shown a decrease in recall bias.

As a census of the catch and effort of the South Carolina charterboat owners/operators, the SC DNR charterboat logbook program serves as a mechanism to understand temporal changes in angler behavior with regards to fishing practices, fishing locations, and within year timing of fishing activities for this sector of the South Carolina recreational fishery. Cursory investigations of the charterboat logbook data suggests shifts in charterboat owner/operators behavior through time, with an increase in the rate of catch-and-release fishing practices as well as a shift to more effort to nearshore waters, which given black drum life history suggests increasing fishing pressure on the adult component of the black drum stock found along coastal South Carolina.

Georgia

In the fall of 1997, the GADNR initiated the Marine Sportfish Carcass Recovery Project. This project takes advantage of the fishing efforts of hundreds of anglers by turning filleted fish carcasses that anglers would normally discard into a source of much needed data on Georgia's marine sportfish. Chest freezers are placed near the fish cleaning stations at 20 locations along coastal Georgia. Each freezer is marked with an identifying sign and a list of target fish species. Cooperating anglers place the filleted carcasses, with head and tail intact, in a bag, drop in a completed angler information card, and then place the bag in the freezer. Each fish is identified to species, the fish length is measured, sex is determined when possible, and the otoliths are removed. Otoliths have been aged through 2017.

The average size black drum donated is 399.8 mm FL (min. 216 mm FL, max. 1,300 mm FL). Most of the donated fish have been aged between 0 and 3 years with a maximum age of 49 years. The number of black drum collected by the Carcass Recovery Project ranged from 8 in 2005 to 183 in 2019 and 2020 with an average of 63.3 fish collected each year. A total of 1,518 black drum has been processed by staff between 1997 and 2020. To date, 975 black drum have been aged.

Florida

The following program objectives are described in Vecchio et al. (2022) and GSMFC (2006).

Representative Biological Sampling Program (REPBIO/MARFIN)

The Representative Biological (RepBio) sampling program conducts supplemental biological sampling along the Gulf and Atlantic coast of Florida. The survey began a pilot phase in 2018 and was fully implemented in January of 2019, along the Gulf coast of Florida. A randomized draw process is used to ensure representative collection of biological samples, along with a species list that prioritizes collection of biological samples from data-poor, state-managed, and federally managed species when encountered. Interviews of recreational anglers are conducted at fishing access points identified via the MRIP Site Register and assigned via a weekly draw by sub-region. Biological sampling of harvested species includes collection of length measurements (midline length in mm), whole weight (in kg) and collection of aging structures (otoliths or spines) (Vecchio et al. 2022).

Opportunistic Biological Sampling (FIN-BIOSTAT)

The Fisheries Information Network (FIN) is a state-federal cooperative program to collect, manage, and disseminate statistical data and information on the marine commercial and recreational fisheries of the Southeast Region. This region includes Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, Puerto Rico, South Carolina, Texas, and the U.S. Virgin Islands. The FIN consists of two components: Commercial Fisheries Information Network (ComFIN) and the Southeast Recreational Fisheries Information Network [RecFIN(SE)] (GSMCFC 2006).

Opportunistic biological sampling was conducted at angler intercept sites along the Atlantic coast of Florida. Sampling assignments were conducted opportunistically to maximize the number of biological samples collected, primarily from busy charter landing sites. While the sampling sites were not selected using a randomized methodology, the fish sampled were not sampled in a biased manner. Biological sampling of intercepted fish included collection of length measurements (midline length in mm), whole weight (in kg) and collection of aging structures (otoliths or spines). Species targeted (though sampling will not be limited to these) for increased levels of sampling (FIN Biological Sampling document) and processing are red snapper, king mackerel, southern flounder, gulf flounder, and greater amberjack.

Since 2003 only 56 black drum were sampled by supplemental recreational sampling programs on Florida’s Atlantic coast. Most were sampled opportunistically for length and age, and some include weight and sex. Samples that were not weighed were previously filleted (n=21). Sample sizes varied from 1 to 19 fish (average = 4.7 fish/year) measured each year.

4.3 Total Fishery Removals

The following is a review of fishery removal data summarized across sectors. These data represent a primary data source for the assessment.

Black drum removals have come predominately from harvest in recreational fisheries along the coast (Table 16, Figure 38). Total removals increased through the mid-1970s, peaking at 4 million pounds in 1976, then declined for several years into the early 1980s. Removals during this time period are predicated on the saltwater participation and static CPUE data used to estimate historical recreational catch. The smaller component of removals, commercial landings, also increased in this early period, but peaked earlier (mid-1960s) before declining. There were very few recreational dead discards during these earlier years.

A large pulse of removals occurred in the mid-1980s, averaging 3.9 million pounds from 1983-1987, and then declined to the lowest level since the 1940s in 1990 (945 thousand pounds). Removals increased through the 1990s and were variable, but with no discernible trend through most of the 2000s. Removals increased sharply to the highest levels in 2008 and 2009. Removals then declined and were variable, but with no discernible trend throughout the 2010s. Recreational dead discards steadily increased from very low levels in the 1980s while commercial landings have been relatively stable since the 1990s.

Regionally, the majority of removals have come from the South Atlantic (Figure 39). Mid-Atlantic removals have been variable and were largest in 2008 and 2009 when they were nearly the same magnitude as in the South Atlantic. Within the Mid-Atlantic, most removals have come from the period most closely associated with the spawning adult migration earlier in the year (January-August), while a smaller component has come later in the year (September-December) when primarily age-0 and age-1 fish are available to the fishery (Figure 40).

4.4 Fishery Removal Composition Data Evaluation

Black drum catch size and age composition data were identified as primary limitations during the previous stock assessment that precluded models designed to track the length or age structure of the population through time (ASMFC 2015), the ideal models for a long-lived species exploited at various life stages such as black drum. There were several research recommendations provided during the assessment focused on addressing these limitations, but these recommendations were generalized and did not tie directly to any analyses conducted during the assessment. Several aspects of the available catch composition data were evaluated in this assessment to (1) better understand spatial and temporal limitations to characterizing complete catch composition, (2) identify subsets of data that might be informative to the assessment, and (3) support detailed research recommendations.

Methods
The first step of this evaluation was to identify an appropriate fleet structure for all coastwide black drum harvest. Commercial fleets were structured with a pragmatic approach considering composition sampling coverage (or lack thereof) and magnitude of harvest over the last ten years of the assessment time series (2011-2020; Table 17). All commercial harvest north of Maryland was grouped into a fleet (North Gill Net fleet). Of the states grouped, only DE and NJ are considerable contributors to commercial harvest. While NJ harvesters have caught a considerable portion of their harvest with fixed nets (primarily pound nets), DE harvesters have caught black drum almost exclusively with gill nets and this is the only gear that has been sampled for composition data by DE. No other states in this fleet have conducted commercial harvest composition sampling. Due to close spatial proximity of DE and NJ, assuming harvesters from both these states, regardless of gear, are harvesting from the same size structure aggregation is considered a more appropriate assumption than grouping NJ fixed net harvest with states further to the south that sample composition data from these gears.

Similar to the North Gill Net fleet, harvesters from the Chesapeake Bay states (MD and VA) are assumed to be harvesting from the same size structure aggregation of black drum due to the close spatial proximity of these states. VA accounts for a considerable portion of recent black drum commercial harvest, while MD does not and is not likely to have a measurable impact to composition data regardless of how it's harvest is grouped. These states were not collapsed further with the North Gill Net fleet because harvesters have generally used different gill net mesh sizes in DE and VA (J. Zimmerman, DE DFW, and E. Simpson, VMRC, personal communication), the dominant gear category in both these states. Further, Chesapeake Bay states have conducted composition sampling from various gears that contribute to the harvest and comparison of size distributions from these data indicate differences in size selectivity (Appendix 1: Figure 3). Therefore, Chesapeake Bay states' harvest was grouped into gear-specific fleets including a gill net fleet (MDVA Gill Net fleet), fixed gear fleet (MDVA Fixed fleet), and hook and line fleet (MDVA Hook&Line fleet).

Commercial harvest in NC was separated from harvest in Chesapeake Bay states due to differences in size distributions available to fisheries in these states, with primarily mature adults available to the Mid-Atlantic fisheries, including VA and MD, and primarily immature, sub-adults available to the South Atlantic fisheries, including NC. NC conducts composition sampling according to a predefined fishery structure. However, due to sampling limitations in some of these fisheries in recent years and minor contributions of these fisheries to commercial harvest, they were collapsed into better-sampled fisheries based on similarities in size distribution of the harvest (Figure 41). Specifically, the ocean gill net fishery and the dominant estuarine gill net fishery both harvest strongly bimodal size distributions and were collapsed into the NC Gill Net fleet. The long haul fishery, trawl fishery, and the dominant fixed gear fishery harvest similar dome-shaped size distributions and were collapsed into the NC Fixed fleet.

FL is the only other South Atlantic state that has contributed considerable commercial harvest in recent years. The other South Atlantic states of GA and SC were grouped with FL, but this grouping will not have an impact on composition data given how small these states' landings have been. FL and NC harvest was separated due to different regulatory histories. FL commercial harvest has been caught with two major gear categories in recent years, cast nets and hook and line gears (Table 18). Commercial harvest composition sampling has occurred, but has been opportunistic and inconsistent between these gear categories through time. A comparison of length distributions between these gear categories and the recreational harvest with hook and line gears during a period with relatively consistent composition sampling indicates the recreational harvest size distribution falls between the size distribution of harvest by each commercial gear category (Figure 42). Therefore, the FL commercial fishery collectively across all gears was assumed to be harvesting from the same size distribution available to recreational anglers and all commercial harvest was combined into a single fleet (South All Gear fleet) with its length distribution to be characterized by the recreational harvest size distribution as a proxy.

Percentages of coastwide annual commercial harvest by each fleet (excluding confidential data years) are provided in Table 19.

Recreational harvest fisheries were structured by state due to differences in regulations through time, a dominant gear (hook and line) used in these fisheries within states, and consistent MRIP sampling among states through time. Recreational harvest by state is in Table 20.

As a first metric for the evaluation of composition data, length samples were tabulated by fleet and compared to a threshold of thirty samples. A sample size of thirty serves as a general rule of thumb for minimum sample size necessary to estimate parameters of a normal distribution. Per capita thresholds (e.g., one in a thousand harvested fish measured for length) were considered but not recommended due to lack of guidance on an appropriate threshold and ease of understanding and fulfilling raw sample size thresholds during sampling. Two comparisons were made for recreational fleets, one with samples collected by MRIP and one with the addition of samples collected by supplemental recreational sampling programs considered to collect length data representative of the recreational harvest.

As a second metric, age samples were tabulated and compared to thresholds recommended by Coggins et al. (2013) for age-length key data sample sizes sufficient to estimate mortality levels. An analysis of growth along the coast with age-length data indicated no significant differences in regional growth (Appendix 1), so it was considered appropriate to collapse all age-length data along the coast for an age-length key. Two comparisons were made, one comparing total sample size to a threshold range of 500-1,000 samples and one comparing length bin-specific sample sizes to a threshold of 10 samples. Length bins were specified according to the methodology in Coggins et al. (2013). Total sample sizes less than 500 and bin-specific sample sizes less than 10 were considered insufficient, total samples sizes between 500 and 1,000 were consider likely to be sufficient, and total samples sizes greater than 1,000 and bin-specific samples sizes of at least 10 were considered sufficient.

A supplementary analysis on age sample size using data collected directly from black drum was conducted to identify an optimal sample size according to the methodology in Quinn and Deriso (1999). This analysis calculates the total sample size required (**across all ages in the catch**) to estimate age composition at various levels of precision (CVs) for each age, based on variability of length-at-age in previously collected data. The increase in sample size (i.e., sampling cost) for, say, the most prevalent age in the data, can be compared against the associated increase in precision of estimated catch for this age to identify the best balance of these two sampling considerations. Using the VA fishery-dependent age data from the last five years of the assessment time series, age-10 fish were sampled most frequently (Table 21). Using a criterion established by VMRC (H. Liao, VMRC, personal communication) to stop increasing sample size when more than 100 additional samples are required to decrease the coefficient of variation (CV) by 0.01 indicates an optimal total sample size of 606 age samples (Table 22). This sample size, or the closest sample size without exceeding this sample size, can then be viewed for other ages in the catch to determine the associated level of precision for the respective age's catch estimate. The optimal sample size identified here produces a CV for catch of age-10 fish of 0.12 and a weighted average CV of ≈0.14 for the 10 most frequent ages in the data (according to the closest sample size not exceeding that identified for age-10). This sample size aligns well with the threshold range recommended by Coggins et al. (2013).

A third and final metric was the ability to track cohorts in age composition data. To track cohort progression through years, age composition data needed to meet three criteria as follows:

1. There are multiple-year data available;

2. There are multiple ages (especially older ages) in the data within each year;

3. The abundance of younger ages cannot be extremely higher than the older ages, otherwise, the changes in abundance of the older ages may not be observed.

First, we had age composition data from 2008 to 2019, providing an opportunity to track cohort progression through 12 years. Second, we collapsed the length data and age-length data over gears and states by year to increase the age range in age composition data. Finally, we used ages older than age-3 so that we may be able to observe the change in abundance of older ages.

Results

MRIP length sampling appears insufficient for characterizing the size structure of the recreational harvest in South Atlantic states during the early part of the time series, but sufficient since the early 1990s in FL and NC (Table 23). Sampling generally remains insufficient in GA and SC until the mid-2010s. Sampling is insufficient for characterizing the size structure of the harvest in Mid-Atlantic states in almost all years, including recent years. If collapsed to the regional level due to similar regulations (all Mid-Atlantic states have 16 inch minimum size limits which would not impact the primary fishery on spawning adults in the spring), sampling remains insufficient in the Mid-Atlantic. This is supported by the PSEs associated with MRIP catch-at-length estimates for the Mid-Atlantic region. 70% of the harvested fish over the last ten years have PSEs for their length estimates greater than 60%, while 18% do in the South Atlantic (Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division [March 9, 2022]). However, adding supplemental data may provide sufficient data at the regional level in the Mid-Atlantic since 2006 (Table 24). Supplemental sampling may also support sufficient data for SC back to the mid-1990s.

NC commercial harvest has been sufficiently sampled since about 1999 and FL MRIP sampling has been sufficient as a proxy for the other South Atlantic commercial landings since the early 1990s (Table 25). Commercial length sampling for Mid-Atlantic fleets has been inconsistent and insufficient in most years, including in recent years. Given relative magnitude of commercial landings (Table 19), the MDVA Gill Net fleet represents the greatest limitation in characterizing the size distribution of coastwide commercial landings in recent years.

Age sampling has improved since the previous stock assessment (terminal year of 2012) and total sample sizes are likely sufficient since 2014 (Table 26). Coverage across the size range available to South Atlantic fisheries has generally been sufficient and consistent for the last ten years of the assessment time series, while coverage of the size range available to Mid-Atlantic fisheries has been less consistent (Table 27). The year 2018 appears the best sampled and serves as a standard to evaluate coverage of the size structure in surrounding and future years.

The age composition data from 2008 to 2019 identified four strong cohorts, Year-class 2001, 2005, 2007, and 2011 (Figure 43). Among them, Year-class 2001 can be tracked for 11 of 12 years. Year-class 2015 could be a strong cohort and we may be able to track its progression in the coming years.

Discussion

There have been improvements in sampling in recent years, but there remain limitations that preclude coastwide composition data for harvested black drum. Overall, it’s clear the South Atlantic is better sampled for composition data than the Mid-Atlantic. TC members identified barriers to sampling, particularly in Mid-Atlantic states, that may preclude meeting the thresholds identified in this evaluation that should be considered for assessment moving forward. The black drum fisheries in Mid-Atlantic states are primarily short pulse fisheries and limit the number of fish caught and, therefore, the likelihood of intercepting these fish during sampling. There are also cost-benefit barriers due to low priority and value of black drum and difficulties processing (i.e., handling, storing, transporting the large, mature fish caught in these states).

It is important to note that this evaluation only included black drum harvest. Black drum discards, a portion of which die due to interaction with the fishery, have become an increasingly large portion of the total fishery removals through time. There are currently no direct data to characterize the size and age structure of recreational discards. Discard size and age composition data remain a major data limitation for black drum assessment.

The sample size thresholds applied in this evaluation should generally be viewed as liberal thresholds for black drum due to two reasons. First, the threshold of thirty used for length sample sizes has generally been discussed in terms of truly random sampling. Fish species including black drum often aggregate with like-sized individuals, resulting in a lack of independence among individuals sampled during a sampling trip (Nelson 2014). This clustered population structure results in individual length observations containing less power than would be obtained from an individual observation from a randomly distributed population. Secondly, the simulated populations Coggins et al. (2013) used to provide guidance on sample size thresholds were simulated with a CV for length-at-age of 0.10. Available black drum age data indicates a weighted average CV across the age range (weighted by frequency of occurrence in the data set) of 0.14, with higher CVs for the younger ages and typically lower CVs for older age classes (Table 2). The greater variability in black drum growth would require greater sample sizes to achieve the same precision of estimates (e.g., mortality) obtained from the populations simulated by Coggins et al. (2013).

With the above caveats in mind, adequate sample sizes for composition data depend on numerous factors such as survey design, variance in the population being sampled, and desired precision of estimates; therefore, these likely vary across black drum fisheries. The thresholds used here, particularly for length sample sizes, were constant and meant to serve as approximations to visualize patterns in sampling intensity. These sample size thresholds should be refined and tailored to respective fisheries and desired levels of precision in composition data to serve as future sampling targets. Simulation analyses specific to black drum, similar to those employed by Coggins et al. (2013) are one avenue for this future research.

Despite the limitations on coastwide composition data, results from the cohort tracking analysis provide information that can be used to verify indices of abundance. The relative abundances among ages within each year provided information about cohort progression; however, the absolute abundance of each cohort among years provided no information about mortality. This is mainly because the sample sizes of effort to catch certain cohorts varied dramatically among years. For example, there were 19, over 60, and over 80 fish of Year-class 2001 appearing in 2008, 2009, and 2010 age composition, respectively, presenting a positive correlation between the ages and number of fish in those ages. In addition, a catch curve within one year may be used to estimate morality when recruitment is relatively consistent among years. However, our cohort analysis indicated that the recruitment of black drum varied dramatically, and as a result, we found no catch curve within each year can be used to estimate mortality.

Research recommendations from this evaluation are provided in Section 9.

5 FISHERY-INDEPENDENT DATA SOURCES

Indices of black drum abundance from ten fishery-independent surveys were considered in the assessment. These included all the indices used in the previous assessment and two indices not used in the previous assessment, the New Jersey Ocean Trawl Survey and the NEAMAP Trawl Survey. The New Jersey Ocean Trawl Survey index was not used in the previous assessment because it surveys the northern fringe of the population which resulted in high variability including ten years with no black drum observations. Since the previous assessment, this survey has encountered black drum more consistency and was reconsidered for developing stock indicators. The NEAMAP Trawl Survey index was not considered in the previous assessment due to a short time series that started in 2007. The time series has added eight years to the original six years of data available in the previous assessment and was reconsidered during this assessment for developing stock indicators.

Methods to calculate indices of abundance are provided in Table 28. All fishery-independent indices of abundance are provided in Table 29 and described further below.

5.1 Northeast Area Monitoring and Assessment Program

5.1.1 Data Collection and Treatment

5.1.1.1 Survey Methods

Northeast Area Monitoring and Assessment Program (NEAMAP) has two cruises a year, occurring in the spring and fall. Each cruise samples approximately 150 stations broken down into 15 regions ranging from Cape Hatteras, NC north to Cape Cod, MA.

NEAMAP samples nearshore waters to a depth of 60 feet and includes the sounds to 120 feet. At each station the net is trawled along the bottom for 20 minutes, at a speed of 2.9-3.3 knots. Sampling sites are selected for each cruise of the NEAMAP SNE/MA Near Shore Trawl Survey using a stratified random design. Prior to each survey, a SAS program is used to randomly select the cells to be sampled from each region / depth stratum during that cruise. Again, the number of cells selected in a particular stratum is approximately proportional to the surface area of that stratum. Once these 150 ‘primary’ sampling sites (i.e., those to be sampled during the upcoming cruise) are generated, the program selects a set of ‘alternate’ sites. In instances where sampling a primary site is not possible due to fixed gear, bad bottom, vessel traffic, etc., an alternate site is selected in its stead. If an alternate site is sampled in the place of an untowable primary site, the alternate site is required to occupy the same region / depth stratum as the aberrant primary site. Usually, the alternate site chosen is the closest towable alternate to that primary.

To assure comparability with the Northeast Fisheries Science Center (NEFSC) trawl survey, NEAMAP adopted the bottom trawl developed for the NEFSC by the joint Mid-Atlantic/New England Trawl Survey Advisory Panel. A 4-seam, 3 bridle, 400 x 12 cm net with a “cookie sweep” footrope and 2.54 cm knotless liner in the cod end with Thyboron Type IV 66 inch doors is used.

During science operations, trawl monitoring sensors provide near-real-time measures of gear performance, enabling the captain and crew to adjust tow speeds and scope to obtain the optimum fishing geometry of the net. Equally important, these data are saved to computer files which, when combined with tow distance information from the GPS, allow subsequent data analyses (such as the generation of abundance estimates) to be performed on an area-swept basis. Such analyses provide standard adjustments for tow-to-tow differences in tow speed, tow duration, current speed, and so on. NEAMAP Mid-Atlantic uses a suite of net monitoring sensors to assure that tows are conducted in a consistent manner and that the net is fishing within specified limits.

5.1.1.2 Biological Sampling Methods

After the completion of each tow, the catch is sorted by species and modal size groups. For species of management interest, a subsample from each size group is selected for detailed processing. Experience shows that a subsample of 3-5 individuals (3 for very common species, 5 for all others) per species-size group per tow is sufficient for this full processing. The data collected from each of these subsampled specimens includes: length (to the nearest mm), total weight (g), sex (macroscopic), and eviscerated weight (g).

Stomachs are removed and those containing prey are preserved onboard for subsequent diet analysis at the shore-based Virginia Institute of Marine Science (VIMS) laboratory. Otoliths or other appropriate ageing structures (e.g., vertebrae, scales, spines, etc.) are removed from each subsampled specimen for later age determination.

For all species, managed and unmanaged aggregate weights are recorded by species-size group, and individual length measurements (which also yield count data) are taken for either all or a representative subsample.

5.1.1.3 Catch Estimation Methods

Abundance estimates are presented as the (back-transformed) geometric mean, using only the strata of importance for each species. Black drum captured in this survey are captured almost exclusively in the fall and are nearly all smaller (<30cm). These smaller fish have nearly all been age-0 so the fall index may be used as representing primarily YOY abundance.

5.1.2 Trends

The fall index has varied without pattern, but with high variability within a small range of values (Figure 44).

5.2 New Jersey Ocean Trawl Survey

5.2.1 Data Collection and Treatment

5.2.1.1 Survey Methods

The survey area consists of New Jersey coastal waters from Ambrose Channel, or the entrance to New York Harbor, south to Cape Henlopen Channel, or the entrance to Delaware Bay, and from about the 3-fathom isobath inshore to approximately the 15-fathom isobath offshore (Figure 45). This area is divided into 15 sampling strata. Latitudinal boundaries are identical to those that define the sampling strata of the NMFS Northwest Atlantic groundfish survey. Exceptions are those strata at the extreme northern and southern ends of New Jersey. Where NMFS strata extended into New York or Delaware waters, truncated boundaries were drawn which included only waters adjacent to New Jersey, except for the ocean waters off the mouth of Delaware Bay, which were also included.

Longitudinal boundaries consist of the 5, 10, and 15-fathom isobaths. Where these bottom contours were irregular, stratum boundaries were smoothed by eye. As a result, the longitudinal strata boundaries for the New Jersey survey area are similar, but not identical, to the corresponding NMFS boundaries.

Each stratum is divided by grid lines into blocks which represent potential sampling sites; each block is identified by a number assigned sequentially within each stratum. The dimensions of mid-shore (5-10 fathoms) and offshore (10-15 fathoms) blocks are 2.0 minutes longitude by 2.5 minutes latitude; inshore (3-5 fathoms) blocks were 1.0 minutes longitude by 1.0 minutes latitude. Inshore block dimensions were smaller because inshore strata were narrower and of much less area compared to mid- and offshore strata; small block size permits a greater number of potential sampling sites than would be possible with the larger dimensions. This is important for statistical analysis and follows the strategy of NMFS for their groundfish survey. Dimensions of blocks transected by stratum boundaries have less area than described above; blocks reduced in area by more than one-half were generally not assigned a number.

Sampling sites in 1988-91 were determined by blindly picking disks numbered to correspond to stratum blocks and mixed to assure randomness. In 1992 this method was replaced by using a computer to generate random numbers.

Samples are collected with a three-in-one trawl, so named because all the tapers are three to one. The net is a two-seam trawl with forward netting of 12 cm (4.7 inches) stretch mesh and rear netting of 8 cm (3.0 inches) and is lined with a 6.4 mm (0.25 inch) bar mesh liner. The headrope is 25 m (82 feet) long and the footrope is 30.5 m (100 feet) long.

The trawl bridle is 20 fathoms long, the top leg consisting of 0.5 inch wire rope and the bottom leg comprised of 0.75 inch wire rope covered with 2 3/8-inch diameter rubber cookies. A 10-fathom groundwire, also made of 0.75-inch wire rope covered with 2 3/8-inch diameter rubber cookies, extends between the bridle and trawl doors.

Prior to August 2015, the trawl doors were wood with steel shoes, 8 ft x 4 ft 2 in, and weighed approximately 1000 lbs each. They were replaced by Thyboron type 11, 60” otter trawl doors with 1.81 m2 area and 328 kg weight. During this same cruise, a SIMRAD PX and PI net monitoring system was incorporated with sensors measuring wing spread, vertical net opening and bottom contact.

Prior to the January 2011 survey cruise, surface and bottom water samples were collected with a 1.2 L Kemmerer bottle for measurement of salinity and dissolved oxygen, the former analyzed with a conductance meter and the latter by the Winkler titration method. Surface and bottom temperatures were measured with a thermistor. These water samples were collected prior to trawling for each biological sample. Starting January, 2011, water chemistry data is collected via a YSI 6820 multiparameter water quality SONDE from the bottom, mid-point and surface of the water column. Parameters collected included depth, temperature, dissolved oxygen and specific conductance. All water chemistry data continued to be collected prior to sample trawling.

Trawl samples are collected by towing the net for 20 minutes, timed from the moment the winch brakes are set to stop the deployment of tow wire to the beginning of haulback. Enough tow wire is released to provide a wire length to depth ratio of at least 3:1, but in shallow (< 10 m) water this ratio is often much greater, in order to provide separation between the vessel and the net. Following haulback, the catch is dumped into a 4 x 8-ft sorting table where fishes and macroinvertebrates are sorted by species into plastic buckets and fish baskets.

5.2.1.2 Biological Sampling Methods

The total weight of each species is measured with an electronic scale, to the hundredths of a kilogram, and the length of all individuals comprising each species caught, or a representative sample by weight for large catches, is measured to the nearest cm FL or TL, depending on tail shape, is measured for all fishes except stingrays, which have disk width measured instead. For invertebrates, carapace width is measured on crabs, carapace length (in mm) on lobster, mantle length on squid, and shell length on whelks. Catches containing large numbers of relatively small specimens are often mixed and the mix subsampled by weight. The mix is then sorted and measured and species components later extrapolated, based upon their representation in the subsample, to determine contribution to the total catch.

5.2.1.3 Catch Estimation Methods

The index for the NJ Ocean Trawl survey was subset temporally to just the October cruises since this period caught black drum more consistently than any of the other cruises (January, April, June, and August). The data were further subset to reflect the spatial occurrence of this species in this survey primarily in the sampling strata with depths up to 60 feet, known as the inshore and midshore strata, leaving out the offshore strata (> 60 to 90 foot depth). Length frequency distributions show that the October survey catches mostly young-of-year fish as the size ranges from 2 to 42 cm with the majority measuring less than 30 cm. The index is calculated as a stratified arithmetic mean catch and biomass per tow of the subset data.

5.2.2 Trends

Within the first 10 years of the survey through 1998, black drum were rarely encountered with 8 of those 11 years showing 0 catches for this species. However, since 1999, black drum have been encountered in 18 of the 21 years through 2019, with this species showing up in every year since 2011. The mean CPUE showed an increasing trend from 1999 through 2009, with biannual spikes from 2005 to a time series high of 1.73 in 2009 after which it moderated from 2012 through 2019 with index values ranging from 0.05 to 0.50 (Table 29, Figure 46). Spatial trends of the species occurrence in this survey show black drum occurring further north within the last 2 decades (Figure 47). Within the first 11 years of the survey, no black drum were encountered north of Ship Bottom, NJ. Within the following 2 decades, this species has been caught from Ship Bottom north to the survey's northernmost sampling stratum off Sandy Hook.

The catches have increased in these northern strata within the last decade (2010-2019) over the catches seen from 2000-2009. These results seem to indicate a northerly extension of black drum distribution within the last two decades and strengthen the case for using this survey's data as a range expansion indicator.

5.3 PSEG Seine Survey

5.3.1 Data Collection and Treatment

The Public Service Enterprise Group's (PSEG) Baywide Beach Seine Survey was initiated in 1995 to complement the New Jersey Department of Environmental Protection's (NJDEP) seine survey, providing sampling beyond the geographical boundaries of the respective study area to more fully characterize target species abundance and distribution patterns within the estuary. To enhance compatibility with the results being generated from the existing agency sampling program, the sampling gear and deployment procedures for the Baywide Beach Seine Survey were developed following the methods described in Baum (1994), and through personal communications with subsequent NJDEP principal investigators.

5.3.1.1 Survey Methods

Beach seine sampling was conducted during daylight once per month in June and November, and twice per month during July through October. Daylight is defined as the period one hour after sunrise to one hour before sunset. Samples were taken at 40 fixed stations in the Delaware Bay and lower River. Sampling at all stations was conducted within the period of two hours before to two hours after high slack water specific to that particular location.

Seine hauls were taken with a 100 x 6-ft (30.5 x 1.8-m) bagged haul seine with a 1/4-inch (6.25 mm) nylon mesh, identical to the gear employed by NJDEP in the beach seine program conducted upstream of the present study. The seine is set perpendicularly from shore, by boat, until the bag is reached, at which time the remainder of the net is set in an arc-like fashion back to shore. The direction of the set was chosen relative to prevailing tidal current, wind, and surf conditions to produce the most effective net deployment. The standard sampling effort was a single haul at each station.

5.3.1.2 Biological Sampling Methods

With each collection, finfish were identified to the lowest practical taxonomic level (usually species), counted, and measured. A subsample of 100 specimens of each target species was measured to the nearest mm FL was measured for all species with emarginated or forked caudal fins; for other species, TL was measured.

5.3.1.3 Catch Estimation Methods

A YOY index of abundance from 1995-2020 was developed from this survey. Length data was only available for 56.5% of the black drum caught in the time series, but only 4 of 1000 fish were greater than 300mm TL (which were removed from the data set), so all data are assumed to track YOY abundance. Stations were collapsed into two areas, the DE side of the bay and the

NJ side of the bay, to incorporate this variable as a factor in the GLM. Stations north of the confluence with the Salem River were excluded from the data set since their sampling was suspended in 2016, and only three black drum were captured at these stations during the entire time series. A negative binomial GLM was used to develop the index of abundance. The unit of effort was black drum caught per net set. Year, month, and area were included in the final GLM as factors. There were no patterns in residuals. The dispersion parameter is 1.25.

5.3.2 Trends

The standardized index showed high interannual variability, with no clear trend over the time series (Table 29, Figure 48).

5.4 Delaware Trawl Survey

5.4.1 Data Collection and Treatment

5.4.1.1 Survey Methods

16-ft Trawl Survey

The Delaware Division of Fish and Wildlife (DE DFW) has conducted a 16-foot bottom trawl survey in the Delaware Estuary for juvenile finfish since 1980. The survey uses a 4.9-m semi-balloon otter trawl, consisting of a 5.2-m headrope and a 6.4-m footrope with a 3.8-cm stretch-mesh number 9 thread body. A 1.3-cm knotless stretch-mesh liner is inserted in the cod-end. The net is equipped with 30.5-cm x 61-cm doors constructed of 1.9-cm marine plyboard doors with 1.3-cm x 5.1-cm shoes. The doors are towed via bridle warps of 30-m no-lay line. Tows are made against current for ten minutes. The survey is conducted monthly at 39 fixed stations in the Delaware Estuary (Delaware waters) from April through October.

30-ft Trawl Survey

The DE DFW also conducted a 30-foot trawl survey in the Delaware Bay from 1966-71, 1979-84, and 1990 - present. The net used has a 9.3-m headrope and a 12.0-m footrope. It is comprised of 7.6-cm stretch-mesh in the wings and body, with a (5.1-cm) stretch-mesh cod-end. The net is attached to the trawl doors with 12.0-m leglines. The doors were 1.37-m x 0.71-m and were constructed of 1.9-cm virgin pine lumber, with 5.1-cm x 1.9-cm milled steel shoe bottom runners. Tows are made using the 19-m R/V First State, which tows for twenty minutes against the current. Sampling was conducted from March through December at nine fixed stations on the Delaware side of the Delaware Bay.

5.4.1.2 Biological Sampling Methods

Upon completion of each tow, the sample was emptied on the deck and sorted by species. Aggregate weights were taken for each species. Species represented by less than 50 individuals were measured for FL to the nearest half-centimeter. Species with more than fifty individuals were randomly sub-sampled (50 measurements) for length with the remainder being enumerated.

5.4.1.3 Catch Estimation Methods

16-ft Trawl Survey

A geometric mean for each year of the CPUE (defined as catch per tow) is the selected index of abundance for YOY. The TC decided to subset the survey data to the years 1990-2020 due to a vessel change in 1990. Only tows in August, September, and October were included because catches in other months were low and consisted of adults. The index was not standardized.

30-ft Trawl Survey

A geometric mean for each year of the CPUE (defined as catch per nautical mile) is the selected index of abundance for YOY. The TC decided to subset the survey data to the years 1990-2020. Catch rates in the first year of the survey (1966) were extremely high and there was concern that factors other than abundance contributed to the peak. There were also breaks in sampling in the 1980s and the survey continued in 1990 with a new vessel.

Only tows in August, September, October, November, and December were included because catches in other months were very low and consisted of adults. Adults which comprise the spawning ages seen in the spring are typically close to shore (where the adult trawl does not go) and are large enough to evade towed gear like trawls most of the time. The index was not standardized.

5.4.2 Trends

16-ft Trawl Survey

CPUE is provided in Table 29 and Figure 49. CPUE has ranged from 0 in 1997 and 2010 to 0.004 in 1993. The index shows moderate interannual variability with stable, but low relative abundance from 2008 to 2020. Most frequently the catch per tow is zero as is seen in Figure 50 which shows the frequency histogram. The trawl survey samples primarily migrating fish as the YOY are more prevalent in the tidal tributaries of the Bay (where this survey does not sample consistently) where they stay until they decide to migrate southward. Additionally, black drum are somewhat structure oriented which may take them out of the path of the trawl.

30-ft Trawl Survey

CPUE is provided in Table 29 and Figure 51. CPUE has ranged from 7x10-6 in 1992 to 0.03 in 1995. The index shows high interannual variability with stable, but low relative abundance from 2008 to 2020. Most frequently the catch per tow is zero as is seen in Figure 52 which shows the frequency histogram. Black drum are somewhat structure oriented which may take them out of the path of the trawl. Additionally, the YOY are more prevalent in the tidal tributaries of the Bay where they stay until they decide to migrate southward, while this survey samples in the Bay and is not close to shore.

5.5 Maryland Coastal Bays Seine Survey

5.5.1 Data Collection and Treatment

5.5.1.1 Survey Methods

The MD DNR has conducted the Coastal Bays Fisheries seine survey in Maryland's Coastal Bays since 1972, sampling with a standardized protocol since 1989. The survey samples shallow regions of the Coastal Bays frequented by juvenile fishes.

A 30.5 m X 1.8 m X 6.4 mm mesh (100 ft X 6 ft X 0.25 in. mesh) bag seine was used at 18 fixed sites in depths less than 1.1 m (3.5 ft) along the shoreline. A 15.24 m (50 foot) version of the previously described net was used at site S019 due to it is restricted sampling area. However, some sites necessitated varying this routine to fit the available area and depth. GPS coordinates were taken at the start and stop points as well as an estimated percent of net open. Other site parameters recorded include: depth, bottom substrate, SAV percent coverage, dominate SAV type, water temperature, salinity, dissolved oxygen, secchi depth, and tide state.

Shore beach seine sampling was conducted at 19 fixed sites once per month in June and September from 1993 – 2020, and in July or August and September prior to 1993.

5.5.1.2 Biological Sampling Methods

Fishes and invertebrates were identified, counted, and measured for TL in millimeters. At each site, a sub-sample of the first 20 fish (when applicable) of each species were measured and the remainder counted. A total of 620 black drum were captured in the survey from 1989 – 2020 (years with standardized sampling methodology), with annual catches ranging from zero (for three years) to 77.

5.5.1.3 Catch Estimation Methods

An index of YOY abundance was calculated for 1989-2020 using only September sampling trips and includes only black drum 230mm TL or less. Ninety-five percent of all black drum encountered were captured during September trips. In the absence of age data, length frequency was examined using five-millimeter bins to determine a likely break point of age-0 fish. Length frequency declined from the 175 mm bin to the 230 mm bin. There were no fish captured in the 235 mm bin and only one or two fish in each of the 240, 245, and 250 mm TL bins, with no fish in the next four bins. Seven fish that were 275 mm TL or grater were assumed to be age-1+. While the five fish from 240 to 250 mm TL bins may have been age-0 fish, the decision was made to use the more conservative 230 mm TL cutoff to subset the data. The YOY index is calculated as the geometric catch per haul of the subset data.

5.5.2 Trends

The geometric mean catch per haul was highly variable and showed no significant trend (Table 29, Figure 53). There were three years of zero catch all within the first five years of the index.

The index generally increased through 2000 and has remained variable at a moderate level in recent years.

5.6 North Carolina Fishery Independent Gill Net Survey – Program 195

5.6.1 Data Collection and Treatment

5.6.1.1 Survey Methods

The NC DMF independent gill net study (Program 915) started in 1998 on the New, Neuse, Pamlico and Pungo river systems (River Independent Gill Net Survey (RIGNS). Sampling in Pamlico Sound (The Pamlico Sound Independent Gill Net Survey (PSIGNS) was initiated in May of 2001 (Figure 54). Sampling in the RIGNS was dropped after 2000 and resumed in 2003 to present. The PSIGNS has sampled continuously since 2001. Sampling in the Cape Fear and New river systems began in April 2008. The goals of the program are to provide CPUE data for coastal fishes, to supplement age, growth, and reproduction studies, to evaluate catch rates and species distribution for use in management plans, and to characterize habitat use. The survey provides annual or seasonal indices of abundance in major North Carolina estuaries for key estuarine species including black drum. CPUE data from fishery independent surveys standardizes effort to provide a relative index of abundance to track stock trends.

Survey in all regions uses a stratified random design. Strata includes area and depth (greater or less than six feet). Cape Fear sampling is an exception as it does not sample deep strata due to currents. For each grid selected, both the shallow and deep strata are sampled with a separate array (or gang) of nets. An array of nets consists of 30-yard segments of 3, 3½, 4, 4½, 5, 5½, 6, and 6½ in stretched mesh webbing (240 yards of gill net). Catches from this array of gill nets comprise a single sample, with two samples (one for the shallow strata, one for the deep strata) collected for each sampling trip. If adverse weather conditions or other factors prevented the primary grid in an area from being sampled, alternative grids for that area are randomly selected to increase flexibility and ensure completion of sampling requirements each month. The period of December 16 through February 14 was dropped after the first complete year of sampling, beginning in 2003, due to low catch rates and safety concerns associated with fewer daylight hours and cold water and air temperatures occurring during that period. Soak times are standardized to 12 hours and are set at dusk and fished at dawn, with the exception of a 4-hour dusk time soak occurring in the Southern IGNS during the months of April through September (shortened soak times in the southern region began in July 2008).

Nets were deployed parallel or perpendicular (depending on region) to the shore based on the strata and common fishing techniques for each area. Gear was typically deployed within an hour of sunset and fished the following morning with effort made to keep all soak times within 12 hours. The 12-hour soak time allowed for uniform effort and kept the study in compliance with the terms and conditions of NMFS biological opinions to the USFWS under Endangered Species Act Section 7 Consultations F/SER/2000/01313, F/SER/2003/00306, F/SER/2007/00902, F/SER/2009/00925, and F/SER/2010/06460. This action was taken to minimize interactions with endangered and threatened sea turtles. All gill nets are constructed with a hanging ratio of 2:1

and a vertical height between six and seven feet (deep nets changed to 10 feet depth in 2005). Each net is inspected upon retrieval for damage caused by blue crabs, boats, snags, and general wear. Based on the net configuration and depths set, all gill nets are floating and fish the entire water column.

Physical and environmental conditions including surface and bottom water temperature (°C), salinity (ppt), dissolved oxygen (mg/L), bottom composition, and a qualitative assessment of sediment size are recorded upon retrieval of the nets on each sampling trip. All attached submerged aquatic vegetation (SAV) in the immediate sample area is identified to species and density of coverage is estimated visually when possible. Additional habitat data recorded includes distance from shore, presence or absence of sea grass or shell, and substrate type.

All core sampling used to generate standardized index occurs from February 15 to December 15. Within each region, each area and depth strata is sampled twice per month (only once during partial months of February and December). For example, for a complete month in Pamlico Sound, 32 core samples are completed (8 areas x twice a month x 2 samples: Figure 2). The same number would be completed for the Pamlico and Neuse IGNS. For the Southern IGNS (New and Cape Fear rivers) 12 samples are completed each full month, comprised of eight from New River (2 areas-upper and lower x twice a month x 2 samples-shallow and deep) and 4 from Cape Fear (1 area x four times a month x 2 shallow samples). Sampling intensity changes are noted in potential biases and uncertainties section.

5.6.1.2 Biological Sampling Methods

All black drum are enumerated and an aggregate weight (nearest 0.01 kilogram (kg)) is obtained for each net (mesh size) fished. All individuals are measured to the nearest millimeter TL. Specimens are also retained and taken to the lab where age structures (otoliths) are removed, sex, and maturity stage of gonads are determined. All aging is conducted following the black drum protocol in Program 930 (P930).

5.6.1.3 Catch Estimation Methods

Relative Abundance by Year

An index of relative abundance and associated standard errors were developed using data from 2003 to 2019. Data from the New and Cape Fear rivers were not used due to the short time-series; only data from the Pamlico Sound and Pamlico, Pungo, and Neuse rivers was used. The index was based on data collected from February to December from shallow (<6 ft) and deep (>6 ft) samples. Catch rates of black drum were calculated annually and expressed as an overall abundance along with corresponding length frequency distributions. The overall abundance was defined as the number of black drum captured per sample (240-yards of gill net). Due to disproportionate sizes of each strata and region, the final abundance estimate was weighted. The total area of each region by strata was quantified using the one-minute by one-minute grid system and then used to weight the observed catches for calculating the abundance index.

Relative Abundance by Age Class and Year
An index of relative abundance and associated standard errors were developed using data from NC DMF Program 915 from 2003 to 2019. Data from the New and Cape Fear rivers were not used due to the short time-series; only data from the Pamlico Sound and Pamlico, Pungo, and Neuse rivers was used. The index was based on data collected from February to December from shallow (<6 ft) and deep (>6 ft) samples. Catch rates of black drum were calculated annually and expressed as an overall abundance by age class. A six-month age-length key with length cut-offs (January - June and July - December) was used to convert TL of black drum caught to an estimated age based on a January 1 birthday. The overall abundance for each age class was defined as the number of black drum captured per sample (240-yards of gill net). Due to disproportionate sizes of each strata and region, the final abundance estimates were weighted. The total area of each region by strata was quantified using the one-minute by one-minute grid system and then used to weight the observed catches for calculating the abundance index.

5.6.2 Trends

Relative Abundance by Year
A total of 5,259 black drum have been caught in the survey from 2003 to 2019. The annual weighted black drum index of abundance has ranged from a high of 1.12 in 2016 to a low of 0.32 in 2013 (Table 29, Figure 55). Proportional Standard Error (PSE) has ranged from 10 to 36. Black drum caught in the survey had a mean size of 12 inches TL and ranged from four to 31 inches TL (Figure 56). A total of 1,480 age structures have been collected from the survey from 2011 to 2019. Ages have ranged from zero to 23 years; however, 86% of the fish were age-0 and age-1.

Relative Abundance by Age Class and Year
A total of 5,259 black drum have been caught in the survey from 2003 to 2019. Ageing structures were obtained from 1,480 black drum from the survey. Ages have ranged from 0 to 23 years old; however, only fish up to age-3 were included in the analysis due to the small sample size. The six-month age-length key indicated good separation for fish up to age-2. The annual weighted index of abundance has ranged from 0.04 to 0.66 for age-0, 0.02 to 0.91 for age-1, 0 to 0.52 for age-2, and 0 to 0.49 for age-3 black drum (Table 30). Proportional Standard Error (PSE) was lower for age-0 and age-1 fish and ranged from 11 to 50. PSEs ranged from 0 to 100 for age-2 and age-3 fish. Overall, the index was able to track four strong cohort progressions through the time-series (2005, 2007, 2011, 2015; Figure 57).

5.7 South Carolina Trammel Net Survey

5.7.1 Data Collection and Treatment

5.7.1.1 Survey Methods

The SC DNR established the SC DNR trammel net survey in the fall of 1990 as a survey of lower estuary, generally moderate- to high-salinity, salt-marsh edge and oyster reef habitats; these habitats dominate the coastal South Carolina estuarine shoreline environment. The survey was designed to provide relative abundance indices for key estuarine species (primarily red drum), as the habitat sampled serves as a primary habitat for a host of recreationally important estuarine species. The survey indexes the relative abundance of numerous species throughout the five major estuaries found along the South Carolina coast and has been used in the previous benchmark stock assessments as an index of relative abundance for black drum.

The SC DNR trammel net survey employs a stratified random sampling design. On each sampling day (one stratum is sampled per day), trammel nets are typically set at 10-12 sites, although weather, tide, or other constraints sometimes hinders this target. Sites are selected at random (without replacement) from a pool of 27-55 possible sites per stratum, with the exception that adjacent sites (unless separated by a creek or other barrier) cannot be sampled on the same day to avoid sampling interference.

Fish are collected using a 183 x 2.1 m trammel net fitted with a polyfoam float line (12.7 mm diameter) and a lead core bottom line (22.7 kg). The netting comprises an inner panel (0.47 mm #177 monofilament; 63.5 mm stretch-mesh; height = 60 diagonal meshes) sandwiched between a pair of outer panels (0.9 mm #9 monofilament; 355.6 mm stretch-mesh; height = 8 diagonal meshes). The trammel net is set along the shoreline (10-20 m from an intertidal marsh flat, <2 m depth) during an ebbing tide using a fast-moving Florida net boat. Each end is anchored on the shore, or in shallow marsh. Once the net has been set, the boat makes two passes along the length of the enclosed water body at idle speed (taking <10 minutes), during which time the water surface is disturbed with wooden poles to promote fish entrapment. The net is then immediately retrieved and netted fish are removed from the webbing as they are brought on board and placed in a live-well. Once the net has been fully retrieved, all fish are identified to species and counted. Measurements (TL and SL) are taken from all individuals of target species (including black drum), and from up to 25 individuals of non-target species. Most fish (>95%) are released alive at the site of capture once length measurements are obtained. Any black drum greater than 150 mm TL released at the site of capture and not previously tagged are tagged, with disc belly tags.

Additional data collected during each collection includes location (site nested in stratum nested in area; latitude and longitude) and a suite of physical and environmental variables. Physical and environmental variables recorded include depth (m), air temperature (°C), water temperature (°C), salinity (PSU), dissolved oxygen (mg L^{-1}), and tidal stage.

At present (2021), seven strata, from south to north, are surveyed: Port Royal Sound (PR), ACE Basin (AB), Ashley River (AR), Charleston Harbor (CH), Wando River (LW), Cape Romain (CR), and Winyah Bay (WB). These seven strata are found in the five primary South Carolina estuaries, Port Royal Sound (PR), St. Helena Sound (AB), Charleston Harbor (AR, CH, LW), Cape Romain and Bulls Bay (CR), and Winyah Bay (WB). Note however, the time series of sampling in each estuary has varied through time. Limited historical data is also available from additional strata and areas within current strata but are generally excluded from the development of relative abundance indices due to temporal length of surveys in these areas.

5.7.1.2 Biological Sampling Methods

Life history sampling of priority species, including black drum, is performed through the application of length distribution subsampling, with the number sacrificed for life histories studies varying depending on the species. Sacrificed black drum have several additional biological variables ascertained (e.g., weight (g) and macroscopic reproductive stage) and biological samples retained (e.g., otoliths for age and growth studies, scales for age and growth studies and ageing methodology comparisons, gonad tissues for histological determination of reproductive status, and muscle tissues for contaminant analysis).

5.7.1.3 Catch Estimation Methods

The index of abundance for the South Carolina trammel net index was initially estimated as the nominal mean CPUE of the number of fish per set using the combined data set of all ages and lengths for all estuarine strata as well as for each strata individually. A normalized arithmetic mean CPUE index was then calculated with the index normalized to the average catch from 2010-present. Z-scores for both nominal and normalized indices were estimated (Z, calculated using average and standard error of catch form 2010-present) as well as confidence intervals and relative standard error (CV).

The age-specific indices were calculated for two different groups (age-0 and age-1) using monthly size cut-offs based on the length distribution for each age group (age-0, age-1, and age-2+). Abundances for each group (based on the monthly size cut-offs) were then used to estimate CPUE. Both nominal and normalized indices were calculated for each age group.

5.7.2 Trends

The SC DNR trammel net survey catches black drum in all months of the year and the catch index was calculated as an index of relative abundance using the arithmetic mean as well as a normalized arithmetic mean with the relative index normalized to the average catch from 2010 to present. Additionally, age-specific indices were calculated for age-0 and age-1. Since the trammel survey samples estuarine shallow water (< 2 m) habitats it catches primarily age-1 black drum, with the age-1 index having very similar trends to the overall abundance index (Figure 58, Figure 59).

The overall trend for the combined age index showed peaks in abundance occurring in 1992, 2000, 2002, 2016 and 2019 (Table 29, Figure 58). These peaks in abundance for the combined index corresponded to similar peaks in the age-1 abundance index which showed peaks in abundance for all of those years (Figure 59).

The age-0 index had peaks in 1999, 2007, and 2015, which did track a few of the larger cohorts seen in the age-1 index, but was not as variable as the age-1 index (Figure 60).

5.8 Georgia Marine Sportfish Population Health Survey (MSPHS) – Trammel Net

5.8.1 Data Collection and Treatment

5.8.1.1 Survey Methods

To determine the relative abundance of various inshore finfish species, the trammel net survey was conducted in Altamaha and Wassaw sounds from September through November 2003-2020 (Figure 61). In the Altamaha River Region, 25 stations were sampled each month from a pool of 64 total stations using a stratified random station design. In a given survey month, each selected station is sampled one time. In Wassaw Sound, 25 stations were selected and sampled from a pool of 38 total stations using a stratified random station design. In a given survey month, each selected station is sampled one time.

All sampling occurred during the last three hours of ebb tide and only during daylight hours. Station pools in both survey areas were determined by initial surveys, which identified locations that could be effectively sampled with survey gear.

Survey gear is a three panel trammel net. From 2003-2007, the net was 182.9 m (600 ft) long by 2.1 m (7 ft) deep. The net was shortened to 91.4 m (300 ft) long by 2.1 m (7 ft) deep in 2007. The two outer panels are 35.6 cm (14 in) stretched mesh, and the inner panel has 7 cm (2.75 in) stretched mesh. The net has a 2.5 cm (1 in.) diameter float rope and a 75 kg (165 lb) lead line. An 11.3 kg (25 lb) anchor chain is attached to each end of the lead line, and a large orange bullet float is attached to each end of the float line.

A sampling event consists of a single net set. The net is deployed by boat starting at the bank following a semicircular path and ending back on the same bank. Net deployment is performed against the tidal current. Immediately after deployment, the net is actively fished by making two to three passes with the boat in the area enclosed by the net. After the last pass is made, the net is retrieved starting with the end that was first set out. As the net is retrieved, catch is removed and put inside a holding pen tied to the side of the boat.

A minimum of 25 stations are sampled in each sound system during each month of the sampling season (September – November). The time series covers 2003-present. Effort appears lower in 2003–2008 because only sites that are in the current station pool are used for analysis.

5.8.1.2 Biological Sampling Methods

After the net is fully retrieved, all catch is processed for information and released. The catch is identified to species and counted. All finfish specimens are measured, centerline in millimeters. In addition to catch information, temporal, spatial, weather, hydrographic and physio-chemical data are collected during each sampling event.

5.8.1.3 Catch Estimation Methods

Age-at-length data for the months of September—November from Georgia's Marine Sportfish Carcass Recovery Program were used to evaluate the ages of black drum encountered in the trammel net survey. In the case of black drum, specimens collected during the survey most often represented age-0 fish, with 87% of all fish captured were at or below 280 mm FL. Although this process involved considerable subjectivity and ignored possible interannual variability in average growth rates, there was little likelihood that any significant error was introduced as only a very small fraction of the specific aged cohort individuals fell within the zone of overlap. Most of the data used to construct juvenile indices were drawn from months when no overlap at all is present. All fish greater than 280 mm FL were excluded for analysis.

Given the short sampling period of the trammel net sampling (September-November) all three months in each survey were used in these estimates. After partitioning out age-specific cohort individuals, numbers of individuals caught were logarithmically transformed (ln(n+1)) prior to abundance calculations, as this transformation has repeatedly been shown to best normalize collection data for aggregative organisms such as fishes. Annual juvenile CPUE indices were calculated as the weighted geometric mean catch per net set. Strata-specific means and variances were calculated and then combined, weighted by stratum areas according to the formulae supplied by Cochran (1977). Since stratum areas are quite variable, use of a weighted mean provided an index that more closely mirrors actual population sizes than a simple mean. Resulting average catch rates (and the 95% confidence intervals as estimated by + 2 standard errors) are then back-transformed to the weighted geometric means. CV is expressed as the log transformed mean catch divided by the standard deviation, E(Yst) / STD (Cochran 1977).

5.8.2 Trends

CPUE by year for 2003 through 2020 are provided (Table 29). Since 2009, CPUE has varied widely for black drum in the trammel net survey ranging from a survey low of 0.02 in 2011 to a survey high of 0.22 in 2012 (Figure 62). CPUE is higher during the earlier years of the survey however there is a higher standard error associated with these survey years due to reduced effort. Essentially this survey is a measure of annual recruitment and is largely driven by spawning success and environmental effects on larval/juvenile fish survivability through the winter/spring/summer. The index generally tracks well with annual MRIP estimates with a one-year lag.

5.9 Florida Fishery Independent Monitoring Program 183-m Center Haul Seine

5.9.1 Data Collection and Treatment

5.9.1.1 Survey Methods

The objectives of the 183-m center bag (haul) seine technique are to: 1) estimate abundance of sub-adult and adult fishes which inhabit shoreline habitats within select Florida estuaries; 2) obtain data on size composition, habitat use, and spatial and temporal distribution of sub-adult and adult fishes; and 3) provide data and biological samples for use in species-specific studies (FWC FWRI 2020b). The seine is deployed by boat to crew members on the shoreline. Samples collected with 183-m seines in Tampa Bay and Charlotte Harbor were pre-stratified by the presence or absence of overhanging shoreline vegetation. Samples collected with 183-m seines in the northern and southern IRL were post-stratified by the presence or absence of overhanging shoreline vegetation. Samples collected with this gear were not stratified by habitat type in Cedar Key, Apalachicola Bay, and northeast Florida (Figure 63).

All sampling was conducted during daytime hours (one hour after sunrise to one hour before sunset) (FWC FWRI 2020a). Additional sampling details are described in the FIM program's Procedure Manual (FWC FWRI 2020b).

The median number of sets for the 183-m seine in IR is 264 and has ranged from 237 (2001) to 410 (2011) sets.

5.9.1.2 Biological Sampling Methods

Environmental data consisting of water chemistry, habitat characteristics, and physical parameters such as current and tidal conditions were recorded for each sample. All fish and selected invertebrate species captured were identified to the lowest practical taxonomic level, counted, and a random sample of at least 10 individuals were measured (standard length for teleosts, precaudal length for sharks, disc width for rays, carapace width for crabs, and post-orbital head length for shrimp) (FWC FWRI 2020a). Standard lengths (SL) are taken to the nearest mm. A detailed explanation of the standard sample work-up for data collection is described in the FIM program's Procedure Manual (FWC FWRI 2020b).

5.9.1.3 Catch Estimation Methods

Using data from stratified-random sampling (SRS), an age-1+ (post-YOY) index of abundance from the 183-m seine was developed for black drum in the Indian River Lagoon (IRL). Study areas included in the analyses were selected based upon adequate sample sizes of the target species or years of available data. Therefore, only data from the 183-m seine in the IRL is considered. It is not recommended to combine northeast Florida (JX) with the IRL due to habitat differences. JX is primarily a riverine system with only river sampling, whereas black drum in the IRL are encounter in the bays.

A simplified age-1+ index was developed by using black drum standard lengths (SL mm) sampled by the 183-m seine survey in the IRL (1999-2020). The standard lengths of age-1+ are assumed to be at least 150 SL mm from January to June (Figure 64) to minimize overlap with age-0 fish.

Indices of abundance

An age-1+ yearly index of abundance in the IRL from January 1 to June 1 is estimated by standardizing CPUE data (catch per set) from the 183-m haul seine. Possible covariates include year, month, strata (bay and sampling zone), shore type (terrestrial, other), bottom type (mud, other), bottom vegetation (submerged aquatic vegetation and/or algae, other), secchi depth, salinity, dissolved oxygen, wind speed, and pH. Continuous variables (secchi depth, salinity, dissolved oxygen, wind speed, and pH) were natural log transformed (ln [X+1]) prior to the analysis to normalize the data. Covariates other than year were removed if there were less than

10 positive observations for each level. There were less than 10 positive sets in years 2000, 2001, and 2006, however these years were retained for continuity in the index.

Correlation analysis did not reveal any significant collinearity between covariates and nonlinear effects were not readily apparent. Plots of mean CPUE versus year by zone and bay suggest there may be an interaction between year and zone/bay.

Zero inflation and overdispersion (the relationship between the variance and the mean) is common for CPUE data. Thus, a negative binomial error distribution (NB model) was preferred that can accommodate such a high degree of overdispersion and zero inflation.

A full negative binomial model had a dispersion of 1.36. For the negative binomial, a backward stepwise model selection routine used both the change in deviance and change in AIC to identify covariates for removal. Covariates were removed that either resulted in a lower deviance or a lower AIC value. This method selected pH, followed by dissolved oxygen and bottom type for removal. The remaining covariates of the final negative binomial were year, strata, month, bottom vegetation, shore type, secchi depth, and windspeed and the dispersion was 1.37.

Confidence intervals were estimated by simulating the distribution of the predicted means using 10000 randomly generated residuals; each residual was a random normal deviate times the standard error for its predicted mean on the log scale. These estimates were back-transformed to numbers per set and the distribution was described in term of percentiles and a mean. Model estimates are then compared with the nominal stratified random sample mean.

5.9.2 Trends

Nominal and standardized annual indices of age-1+ black drum abundance show similar trends (Table 29, Figure 65). An increase after 2012 may be primarily driven by two strong cohorts in 2011 and 2012; however, the CV of the index is greater than 30% in all years and close to 50% in some years. This high level of uncertainty may indicate that this index is uninformative and does not adequately capture changes in abundance.

6 STOCK INDICATORS

In TOR 4 the TC was tasked with identifying and developing simple, empirical indicators of stock abundance, stock characteristics, and fishery characteristics that can be monitored annually between stock assessments. Multiple index data sets were proposed and evaluated according to both their correlation with each other and their ability to detect trends. There were several groups of indices evaluated as possible indicators of abundance and, to some extent, indicators of stock characteristics. Both recreational and commercial catch indices were evaluated as indicators of fishery characteristics.

6.1 Data Sets

The indices evaluated include: MRIP CPUE, FL Haul Seine, GA Trammel, SC Trammel, NC Gillnet, MD Seine, DE 16ft Trawl, DE 30ft Trawl, PSEG Seine, NJ Ocean Trawl, and NEAMAP. Descriptions of these indices can be found in Section 4 (MRIP CPUE) and Section 5 (fishery-independent indices).

Various indices track different life stages and characteristics. MRIP CPUE tracks exploitable abundance over a wide range of ages while the other fishery-independent indices are narrowly focused on size/age groups. NC Gillnet tracks sub-adult abundance (age-0 through age-3). SC Trammel tracks YOY through age-1. The FL Haul Seine tracks sub-adults with the exception of YOY fish (ages-1 through age-3). PSEG Seine, MD Seine, GA Trammel, DE 16ft Trawl, and DE 30ft Trawl all track YOY. NEAMAP and NJ Ocean Trawl also track YOY fish, but were evaluated as a measure of range expansion and not necessarily as a measure of year class strength.

Catch time series evaluated include recreational harvest, recreational released alive, and commercial landings for South Atlantic and Mid-Atlantic separately due to the differences in size/age structure components of the population present in these regions. Descriptions of these time series and their data collection can be found in Section 4.

6.2 Data Exploration and Analysis

6.2.1 Correlation Analysis

As part of the analysis to provide context on potential indices as abundance indicators, the TC sought to measure the strength of association between the indices using correlation analysis. Correlation is a bivariate analysis to measure the strength and direction of association between two indices. Correlation coefficient ranges between -1 and +1 with highest strength (perfect degree of association) at the ends of the range weakening as the correlation coefficient value goes towards 0 which is no correlation. A positive correlation coefficient indicates that the indices move in similar directions.

Methods

Pearson’s correlation, Kendall rank correlation, and Spearman’s rank correlation were all considered as methods of measurement. For Pearson’s correlation, both variables are assumed to be continuous, normally distributed, have a linear relationship, homoscedasticity, and an absence of outliers. Spearman’s and Kendall correlations assume only that pairs of observations are independent, two variables have a monotonic relationship and are measured on an ordinal, interval, or ratio scale. Spearman’s and Kendall correlations are rank correlations, meaning that they measure monotonic relationships while Pearson’s measures linear relationship. The Spearman’s rank correlation test does not assume any particular distribution of the data and thus is appropriate correlation analysis when the variables are measured on a scale that is at least ordinal, but not necessarily normally distributed. It determines whether the variables are monotonically related.

Shapiro-Wilks Normality Test
Because the choice of correlation test and power test depend in part on whether the variables are normally distributed, Shapiro-Wilks tests for normality were performed for each of the indices utilizing the Shapiro.test() function in R (Table 31). Significant non-normality was determined using p-values with an alpha level set at 0.05. For most of the indices (9 out of 16), the Shapiro-Wilks test indicated that the populations may not be normally distributed.

Spearman's Rank Correlation
Associations between the chosen stock indicator indices were evaluated using Spearman's rank analysis (Spearman 1904). Spearman's rank analysis is a non-parametric test for a monotonic relationship between two variables. Each index value is ranked relative to the other values and the rankings are compared to the ordered rankings of another index. Spearman's rho, the association statistic, is more robust to outliers than Pearson's correlation coefficient due to a conversion of each index value to an ordered rank (Croux and Dehon 2010). Spearman's rho requires the less restrictive assumption of a monotonic relationship, as opposed to the assumed linear relationship for the Pearson's correlation coefficient, does not assume normal distribution of the variables, and does not assume continuity. Because the populations may not be normally distributed, Spearman's rank correlation is more appropriate than the other methods considered. The strength of the association is determined by the Spearman's rho with a value of -1 indicating a perfect negative association, +1 indicating a perfect positive association, and 0 indicating no association. Statistical significance of the Spearman correlation is determined by the p-value relative to a selected alpha level. An alpha level of 0.05 was selected for these tests.

The indices were initially grouped by predominant size range within each survey between YOY and mixed-age, which included YOY fish as well as older and larger individuals. The YOY indices included fishery-independent surveys from the Mid-Atlantic region (DE 16' Trawl, DE 30' Trawl, MD Seine, NEAMAP Trawl, NJ Ocean Trawl, and PSEG Seine) plus Georgia's Trammel net index. Mixed-age indices included MRIP, NC P915 Gill Net, and SC Trammel. The FL Haul Seine index was evaluated in preliminary correlation analyses, but ultimately dropped from the analysis due to concerns using this index as a measure of abundance as indicated by the large CVs (Section 5.9.2) and power analysis results (Section 6.2.2). Pairwise comparisons were run within each group of indices as well as across both groups.

Age-specific indices were available from the NC P915 Gill Net (YOY through age-3) and SC Trammel (YOY and age-1) surveys. Pairwise comparisons were performed with these surveys' YOY indices to each of the other YOY indices. The age-1 to age-3 indices were lagged from one to three years and evaluated in pairwise comparisons with the YOY indices to identify possible associations attributable to YOY fish recruiting to the older indices.

In another analysis, correlation among all YOY indices including the YOY portion of mixed-age indices were analyzed.

Finally, YOY and mixed-age correlations were determined in a pairwise fashion between the groups.

Results

YOY Index Association

There were positive associations among all the Mid-Atlantic YOY indices (MD Seine, DE 30' Trawl, DE 16' Trawl, PSEG Seine, NEAMAP Trawl and NJ Ocean Trawl) with significant correlations found in 6 pairwise comparisons: MD Seine with DE 16' Trawl, MD Seine with PSEG Seine, DE 30' Trawl with DE 16' Trawl, DE 30' Trawl with PSEG Seine, DE 16' Trawl with PSEG Seine, and NEAMAP Trawl with NJ Ocean Trawl (Table 32). The Spearman's Rho values either met or exceeded 0.5 in four of these associations. As these surveys sample overlapping or nearby areas, the positive and significant correlations are not surprising. Within the South Atlantic YOY indices, there were no significant correlations with each other. The GA Trammel index had negative associations with the other two South Atlantic indices (SC Trammel YOY and NC P915 Gill Net YOY) as well as showing negative associations with three of the Mid-Atlantic indices. The SC Trammel YOY index showed a negative association with the previously mentioned GA Trammel and the DE 30' Trawl, and a positive association with the other indices. Surprisingly it showed a positive, mildly correlated but significant association with the NJ Ocean Trawl.

Mixed-Age Index Association

There was only one significant correlation within the mixed-age indices: SC Trammel with NC P915 Gill Net with a Spearman's Rho value of 0.51 (Table 33). As these surveys occur in adjoining states, their positive association is not surprising.

Mixed-Age and YOY Index Association

There were only two significant correlations when mixed-age and YOY indices were compared (Table 34). Both involved the MRIP index and were only mildly positively associated: Spearman's Rho values of 0.36 with MD Seine and 0.46 with NJ Ocean Trawl.

Lagged and YOY Index Association

There were a total of 14 significant correlations between the age lagged indices and YOY indices, all of which were positive (Table 35). Of these associations, 11 resulted in Spearman's Rho values exceeding 0.50. The SC Trammel age-1 index lagged by one year showed significant correlations with the SC Trammel YOY, NC P915 Gill Net lagged indices for age-1 and age-2, the PSEG Seine, and the NJ Ocean Trawl. The NC P915 Gill Net age-1 index lagged by one year showed significant correlations with, (as previously mentioned) SC Trammel age-1 lagged index, NC P915 Gill Net's indices for YOY and for age-2 lagged by two years, DE 30' and 16' Trawl indices, and PSEG Seine. The NC P915 Gill Net index for age-2 lagged by two years showed significant correlations with the NC P915 Gill Net YOY index, DE 16' Trawl index, and PSEG Seine index. The NC P915 Gill Net index for age-3 lagged by three years showed only a significant correlation with NC P915 Gill Net's index for YOY.

Discussion
All significant correlations were positive indicating that these indices are showing similar trends in abundance. Among all the indices, the NC P915 Gill Net age-1 index lagged by one year and the PSEG Seine index had the greatest number of significant associations with other indices with six each. Many of the correlations involved survey indices arising from the same general area (or in the cases of the lagged indices, within the same survey for different ages). However, strong correlations were seen between the lagged South Atlantic indices and those for Delaware Bay, possibly indicating the YOY in Delaware Bay recruit into the age-1 plus cohorts in the South Atlantic. This theme is echoed in the NJ Ocean Trawl index's moderate but significant correlations with SC Trammel's indices for YOY and age-1 lagged by 1 year. The GA Trammel index showed no significant associations with any of the other indices. The declining trend shown over time in this index contrasts with the more positive trends seen in the other indices and is borne out by the negative Spearman's Rho values seen in several of the pairwise comparisons. The NEAMAP Trawl index was only significantly correlated with NJ Ocean Trawl index which is unsurprising as the two surveys' sample areas overlap considerably along the New Jersey coast.

6.2.2 Power Analysis

Index data sets were evaluated for ability to detect trends in abundance using two power analysis methods, a traditional power analysis and a simulation-based power analysis. Power analysis estimates the statistical power of detecting a specified change in abundance over a specified time period and provides additional context on using these data sets as indicators of abundance changes between stock assessments.

Methods
Simulation Power Analysis

A simulation-based power analysis, following the methods in Schrandt et al. (2021), was also performed for a single index, the FL Haul Seine (age-1+), as an illustrative example. These methods better accommodate observed counts (catch data) that may be overdispersed and zero-inflated by assuming alternative error distributions, such as the negative binomial. These methods can also accommodate multiple sources of random variation (e.g., within and between study sites), where random effects models (i.e., mixed effects models) are recommended.

A generalized linear mixed model (GLMM) framework was applied that assumed a negative binomial error structure. Since analytical power formulae are unavailable for these models, power was estimated via Monte Carlo simulation. First, a negative binomial GLMM with year, secchi depth, and wind speed as continuous independent variables, bottom vegetation (SAV/Algae, Other) and shore type (Terrestrial, Other) as covariates, and nested random effects of strata (bay + zone) by each year and month combination was fit to observed data. The predicted catch rate, averaged over years, and the estimated overdispersion parameter were assumed to be representative of expected annual catch rates and variability. These values were used as a starting point in the simulation.

Next, exponential changes in population abundances of +/- 50% over five years were simulated given the starting abundance estimated using observed data. Error was incorporated into the sampling process by drawing simulated samples (number of sets for six months over five years) from a negative binomial distribution with means (expected counts that decrease or increase, year after year) and overdispersion parameters from the initial negative binomial model fit to observed data.

For each simulated data set, a negative binomial model was fit with year as a continuous predictor variable (expressed as an integer ranging from 1 to 5) and the estimated slope associated with year along with its 95% confidence limits was extracted. This process was repeated 5,000 times for each level of percent annual change. The simulated populations were representative of those under average wind speed and secchi depth.

A measure of coverage and significance was estimated from the 5,000 estimated slopes associated with each level of percent annual change, as defined by Schrandt et al. (2021): "Coverage was assigned a 1 for the simulation replicates for which the true slope (the known, simulated annual percent increase or decrease) was contained within the 95% confidence interval (CI) of the estimated slope, and a 0 if it was not. Significance was assigned a 1 for the simulation replicates for which the upper 95% CI of the slope estimate was <0 (indicating a negative trend) or the lower 95% CI of the slope estimate was >0 (indicating a positive trend), and 0 otherwise. This step provided a measure of how often we detected a statistically significant temporal trend. Power for each replicate was calculated by multiplying the binary variables coverage and significance." Average power of the 5,000 replicates indicates how well the model correctly detected a temporal trend.

All data analyses were conducted in R v. 4.0.2 (R Core Team, 2020) using the package "glmmTMB" (Brooks et al. 2017) for model fitting.

Traditional Power Analysis

The traditional power analysis used the methods proposed by Gerrodette (1987; 1991). The analysis estimates the probability of making a type II error (β; incorrectly accepting the null hypothesis of no trend) when applying linear regression to the data set given the variability in the data (i.e., CV). Power is defined as 1-β, ranging from 0 to 1, and indicates greater power to detect a trend as it increases from 0 to 1.

The power analysis can evaluate decreasing and increasing trends, with the latter being more difficult to detect. However, a decreasing trend would be more likely to initiate action in response to between-assessment review of the indicators (e.g., trigger an expedited assessment) and was the focus of this power analysis. The power analysis can also evaluate exponential or linear change, with the latter being more difficult to detect (though preliminary analysis suggested differences within a few percentage points). Exponential change was the focus of this analysis because it assumes the index data are lognormally distributed (as opposed to normally distributed for linear change), a common assumption for these data sets in stock assessment models. The time period for this analysis was set to five years which is the default increment between assessments of Commission-managed species. The median CV during the index time series (Table 37), as a representation of previously observed observation error, was used as a measure of data variability at the beginning of the projected declining trend. The CV for the index was assumed to be dependent on 1/sqrt(index), as proposed for CPUE data in Gerrodette (1987). This relationship results in an increasing CV as the index declines, making it more difficult to detect a decreasing trend than the other relationships proposed (CV=sqrt(index) and constant CV). The power to detect a 50% decline in abundance and the percent decline that can be detected with a power of 0.8, a power benchmark commonly set for indices of abundance (ASMFC 2017, 2020), is reported for each data set.

Results

For the FL Haul Seine using the simulated power analysis, the power to detect a 50% decline in abundance was estimated to be 0.11 (Table 36). This index could not detect any decline with a power of 0.80 but could detect a 10-fold increase in the population with a power of 0.88. These results are based on a mean starting relative abundance of 0.23 and a theta (dispersion parameter as calculated as mean + (1/theta)*mean^2) of 0.14.

For the indices analyzed in the traditional power analysis, power to detect a 50% decline in abundance ranged from 0.14-1.0 (Table 37). The NJ Ocean Trawl index, which is being proposed as an indicator of range expansion, had the lowest power, while the MRIP CPUE, used as the primary index in modeling approaches, had the highest power. Indices tracking multiple age classes, with the exception of the FL Haul Seine survey, had greater power (>=0.6), while indices tracking only YOY abundance had lower power (<0.40). Similarly, indices tracking multiple age classes could detect smaller five-year declines (<65 %) with a power of 0.80 than YOY indices (>85% decline). Notably, the NJ Ocean Trawl index could not detect any decline with a power of 0.80.

Discussion

Although the traditional power analysis could be more readily applied to index data sets during this assessment, the lognormal distribution assumption underlying this analysis may be violated as these index data can be more variable than expected under this distribution (overdispersed). The comparison of power analysis methods for the FL Haul Seine index demonstrated the effect of this violation, with the simulation-based power analysis assuming a negative binomial distribution estimating lower power than the traditional power analysis. If this is the case for other index data sets, the traditional power analysis may overestimate absolute power and may serve as a better understanding of relative power among data sets. For example, we may expect to see trends earlier in the indicators that track age classes beyond just YOY, while YOY indicators generally have similar, lower power to detect trends. The power analysis suggests the range expansion indicator should be viewed as a more qualitative indicator not likely to reflect quantitative trends in the underlying population abundance. Expanding the simulation-based power analysis to other indicator data sets should be a future research priority.

These analyses also highlight some of the concerns with using the FL Haul Seine survey index as an indicator as this index had power estimated with the traditional power analysis comparable to the noisier indices tracking only YOY abundance and lower than other indicator options that track multiple age classes. The power estimated with the simulation-based power analysis was quite low and indicated this survey is unlikely to detect declining trends between assessments.

6.2.3 Recreational Released Alive Analysis

The number of black drum estimated to have been released alive by recreational anglers has trended down over the last two years of the time series (Figure 19). This trend was seen in both regions, though the trend in the South Atlantic drives the overall trend due to the much greater magnitude of catch in this region (Figure 74). Although this trend is from the time series high and the estimate in the terminal year remains above the time series mean, it is important to understand the drivers of this trend in the case that it continues in post-assessment updates of the indicators. This trend could be indicative of abundance declines, specifically YOY and age-1 abundance since most of these fish must be released due to minimum size limits, declines in effort, or a combination of both. Therefore, these estimates were evaluated at finer temporal and spatial resolutions than the final indicator structure to better understand this indicator and the trends being observed.

First, the total released alive catch was broken down by state for the states contributing the vast majority of the catch to the coastwide total (NC, SC, and FL; Figure 66). The trend in catch is similar across states, with declines from 2018-2020 and extending back to 2016 in NC and 2015 in SC. The initial increase in released alive catch in NC is likely driven by the coincidental implementation of a minimum size in 2014 that protects YOY fish and an above average year class measured in the NC Gillnet survey, while the initial increase in SC is likely driven by a strong year class measured in several FI surveys (2015; NC Gillnet, SC Trammel, PSEG Seine, DE 16ft Trawl surveys) and the cohort analysis. As a measure of effort, directed trips (trips targeting black drum) show less consistent patterns with variability among years and states (Figure 67). There was a decline in trips in FL which appears to at least partially account for the trend in catch in this state but declines in effort are less apparent in NC and SC. Dividing the catch by number of trips shows variable CPUE in FL, but more steady declines in NC and SC (Figure 68).

The estimates were then broken down by wave due to increasing vulnerability of YOY fish to the recreational fishery throughout the calendar year to determine if angler behavior may have changed to avoid these sub-legal fish in recent years leading to effort-driven declines in seasonal catch. The seasonal data show the latest waves (September/October and November/December) are the primary contributors to the total released alive catch in NC and SC, presumably YOY fish becoming vulnerable to the recreational fishery (Figure 69). There was not as clear a seasonal pattern in released alive catches in FL. There are some differences between the primary waves in NC and SC, but they generally follow a declining trend since around the period the annual totals started declining. CPUE during these waves in NC and SC shows steady declines (Figure 70).

While these declines may be an abundance signal, other extraneous factors may be causing or contributing to the declines. For example, angler behavior changes not captured by the number of trips (e.g., gear size changes, location changes) may have affected effort leading to a decline in catch. It's also important to note that these declines are from time series highs and the 2019-2020 values are still relatively high. In addition, the noticed decline occurred in 2019 and 2020. Because the COVID-19 pandemic regulations disrupted the APAIS, MRIP filled gaps in the 2020 catch data with data collected in 2018 and 2019 (Section 4.2.1.6). Therefore, it is difficult to determine how much of the 2020 indications are due to the proxy data carrying forward what was seen in 2019 and how much was truly 2020. We recommend this trend be monitored closely between assessments.

6.3 Selected Indicators

A number of the studied time series could be used to indicate stock abundance, stock characteristics, or fishery characteristics. Data sets recommended for stock indicators are discussed below.

Abundance Indicators
The selected abundance indicators included MRIP CPUE, SC Trammel, NC Gillnet, MD Seine, DE 16ft Trawl, DE 30ft Trawl, PSEG Seine, and the GA Trammel (Table 38).

Stock Characteristics Indicators
The NJ Ocean Trawl has been selected as an indicator of range expansion, a stock characteristic (Table 38).

Fishery Characteristics Indicators
Catch, a fishery characteristic, is characterized by time series including MRIP recreational harvest (pounds), MRIP recreational released alive (numbers), and commercial landings (pounds; Table 38).

6.3.1 Results – Indications Since Previous Assessment

Abundance Indicators

The abundance indices for subadult and ages 0-1 are holding steady. The YOY abundance indices are highly variable but seem to have had fewer and lower highs in the period after 2010 than in the period before. Several of the Mid-Atlantic surveys (DE Trawls, MD Seine) and the GA Trammel saw greater recruitment events in the 1990s and 2000s than they did in more recent years. Other YOY indices such as the PSEG Seine are more stable. The MRIP CPUE is increasing (Figure 71).

Stock Characteristics Indicator - Range Expansion

The NJ Ocean Trawl is currently the lone range expansion indicator. The trawl caught very few black drum in the 1990s. However, in the 2000s there were some relatively high catches with high variability but with even the low catches being higher than in the 1990s. A moderate level of catch occurred in the 2010s without the highs of the 2000s, but above the 1990s level (Figure 72).

Fisheries Characteristics Indicators - Catch

The recreational harvest is holding steady with three relatively low years in 2018, 2019, and 2020 (Figure 73).

Recreational released alive had been increasing until the last two years where number of fish released alive trended down significantly (Figure 74).

Commercial landings have been lower and steady in recent years (Figure 75).

6.4 Discussion

The indices with the highest power to detect a -50% change are the MRIP CPUE, NC Gillnet, and SC Trammel. MRIP has significant positive correlation with MD Seine and NJ Ocean Trawl. There is quite a bit of positive correlation within the Mid-Atlantic, though the power of each index alone to detect -50% change is only moderate at 0.23-0.38.

The GA Trammel index was the lone YOY-only index in the South Atlantic and its trend was not correlated with other indices in the South Atlantic or Mid-Atlantic. Although this index appears to be tracking an abundance signal different than the abundance signal elsewhere along the coast, there is no clear explanation for the difference at this time and the TC believes this index should continue to be monitored with this caveat in mind.

Though the NJ Ocean Trawl was selected as an indicator of range expansion, it was not selected as an abundance indicator due to the fact that it had the lowest power with an inability to detect a decline with a power of 0.80 and a power of only 0.67 to detect a 99.5% decline. In addition, in the correlation analysis of YOY and lagged, it had significant low positive correlation with SC age-0 and age-1 and significant fairly high positive correlation with NEAMAP and no significant correlation with any other of the indices.

Likewise, NEAMAP was not selected as an abundance indicator since it correlated significantly only with NJ Ocean Trawl, and was seen as redundant with the NJ Ocean Trawl indicator (spatial overlap, high correlation). It lacks the historical perspective provided by the NJ Ocean Trawl, and so is not recommended for as a range expansion indicator at this time either.

FL Haul seine was considered, but because of the low power to detect decreases despite being a multi-age index, it was not selected as an indicator.

No single index seems to have high power to detect change along with broad correlation with other indices. Therefore, multiple indicators have been selected for abundance.

Though the catch indices (recreational harvest, recreational released alive, and commercial landings) are good indicators of the fishery characteristics, there are many extraneous pressures on these indices (market, regulations on other species, changing popularity of the species, etc.) that preclude them from being appropriate abundance indicators.

7 METHODS

Six assessment methods were applied to available black drum data sets. Four of these methods are described in the following section. The final two methods, Simple Stock Synthesis and a Stock Synthesis model fit to length data, are described in Appendix 2. Results from the Simple Stock Synthesis model were similar to the DB-SRA model described below. The Stock Synthesis model fit to length data was still in a state of development at the end of the assessment and needs further development before being considered as a potential candidate for management advice. Some results from the Simple Stock Synthesis model are discussed in Section 7.4 as they supported understanding of model behaviors with various data sets included.

7.1 Index-based methods

For this assessment, two index-based management methods were investigated: Itarget and Skate. Both methods were included in the 2020 Index-Based Methods Working Group (IBMWG) topic-based Research Track Assessment which evaluated several index-based methods to provide catch advice and determine stock status for stocks exhibiting strong retrospective patterns with age-structured stock assessments (MAFMC 2020). This assessment utilized relevant portions of the R code created by the IBMWG (available at https://github.com/cmlegault/IBMWG) and followed similar analyses within these methods. The data inputs included total removals (commercial and recreational landings plus recreational dead discards; Table 16) and the MRIP CPUE index (fish per angler hour) in pounds for the years 1982-2020 (Table 11). These methods and the analyses are described in the following sections.

7.1.1 Itarget Method

The Index target (Itarget) method was proposed in Geromont and Butterworth (2015a) as a management procedure for data-poor fish stocks and utilized catch history and a CPUE index of abundance for data inputs. This method compares the most recent five-year average index to a target index value based on a multiple of the average index over a specified reference period in the index time series. With the goal of the stock's relative abundance achieving the target level, the catch advice, or total allowable catch (*TAC*), is calculated by adjusting (up or down based on the comparison of the recent index average to the target index) the average catch of the same reference period as the survey index. The formulas for the *TAC* for the succeeding year (*y+1*) are shown below:

$$TAC_{y+1} = 0.5C_{reference}\ \{1+[(I_{recent} - I_{threshold}) / (I_{target} - I_{threshold})]\}\ \text{for}\ I_{recent} >= I_{threshold}$$

and

$$TAC_{y+1} = 0.5C_{reference}\ [(I_{recent} / I_{threshold})^2]\ \text{for}\ I_{recent} < I_{threshold}$$

where:

$C_{reference}$ = average catch over the reference period

I_{recent} = average of most recent 5-year average of the index

$I_{threshold}$ = 0.8 * average index over the reference period

I_{target} = index multiplier * average index over the reference period

For this assessment, the initial analysis utilized the same reference period timespan (the latest 25 years) and the same initial index multiplier (1.5) as the IBMWG (Figure 76). Using these parameter inputs, the recent catch (5.88 million lbs) is higher than the target catch (4.05 million lbs) and the recent index (0.99) is below the target index (1.39). However, the TC was concerned that the index multiplier may be too high considering that the resulting target index has been surpassed only once (with 1989's value of 1.59, which may be anomalous) and the stock is believed to have been in a relatively good condition during the data time series. The next highest index value of 1.24 occurred in 2009 while most of the other index values fall below 1.00 (only 9 index values exceeded 1.00 in the 39-year time series). The index multiplier can be tuned to individual fisheries to reflect expert opinion on depletion and stock status, and resource behavior (Geromont and Butterworth 2015b). To address this concern, additional runs were conducted using a range of index multipliers from 1.00 through 1.40 in 0.05 increments (Figure 77). With the index multiplier values of 1.00 and 1.05, the recent average index was >= the target index and the target catch was higher than the reference period average catch. With the index multiplier values >= 1.10, an increasing target index exceeded the recent index, and a decreasing target catch fell below the reference period average catch.

Another set of runs used a similar range of index multipliers (1.00-1.40) but extended the reference period to the full 39-year time series (1982-2020) of the data. With the additional years, the reference period average index fell to 0.88, the threshold index to 0.70, and the reference period average catch to 4.72 million pounds. In this scenario, reference period average catch remained below target, and the recent index remained above the target index for index multiplier values from 1.00 through 1.10 (Figure 78). With index multiplier values greater than 1.10, an increasing target index exceeded the recent index, and a decreasing target catch fell below the reference period average catch.

A final set of runs used a 34-year reference period from 1982–2015 which excluded the last 5 years, as directed angler effort had shown a marked increase since 2016. The same range of index multipliers (1.00-1.40) as the previous two runs was used. The reference period average index fell again to 0.86 as did the threshold index (0.69). The reference period average catch of 4.45 million lbs was the lowest of the three runs. As with the runs using the full time series, reference period average catch remained below target, and the recent index remained above the target index for index multiplier values from 1.00 through 1.10 (Figure 79). With an index multiplier of 1.15, the recent index basically equaled the target index, and the reference period average catch was only slightly higher than the target catch. With index multiplier values greater than or equal to 1.20, an increasing target index exceeded the recent index, and a decreasing target, catch fell below the reference period average catch.

7.1.2 Skate Method

The Skate method was developed by the New England Fishery Management Council (NEFMC) for use in evaluating the stocks of 7 skate species within the Northeast Skate Complex FMP. This method utilizes a time-series of catch and a survey index to produce catch advice. Relative fishing mortality is calculated from the median value of annual catch (smoothed over 3 years) divided by the annual 3-year moving average index over the entire time series minus the years since the previous assessment (8 years since the terminal year of 2012 for data in the 2015 ASMFC Black Drum Stock Assessment). The catch advice is calculated by multiplying the relative fishing mortality with the terminal 3-year moving average survey index. Biomass reference points are derived from survey data with the B_{MSY} proxy defined as the 75th percentile of the survey biomass time series through the previous assessment (NEFMC 2020). The biomass threshold is calculated as 0.5 * B_{MSY} proxy. Fishing mortality reference points are derived from the percent change of the 3-year moving average survey biomass of the terminal year from that of the previous year. If the terminal year value shows a decline by more than the average CV of the survey time series, fishing mortality is deemed to be above F_{MSY} and overfishing is occurring (NEFMC 2020). The acceptable biological catch generated by this method was considered by the IBMWG as a possible overfishing limit, so the annual catch target (*ACT*) became the IBM-generated catch advice reduced by 25% to account for unspecified scientific uncertainty (MAFMC 2020).

This assessment utilized the MRIP CPUE index and total removals history from the years 1982-2012 (the terminal year of data from the previous black drum stock assessment) for the reference period. The biomass target (75th percentile index value) was 0.97 with the biomass threshold calculated at 0.48. The survey time series CV was 26.76. Following the NEFMC Northeast Skate Complex FMP protocol for determining stock status, the 2018-2020 average index (0.991) is above both the biomass threshold (0.485) and the B_{MSY} proxy (0.970), and it increased by 3.5% over the 2017-2019 index value of 0.957 (Table 39; Figure 80). Thus, the black drum stock would not be considered overfished nor would overfishing be occurring. However, a plot of the smoothed catch with the estimated *ABC* and *ACT* levels shows the annual removals have been over both levels since 2008 (Figure 80), suggesting that the stock may have been experiencing overfishing for the past 13 years, a contradiction from the determination from the index-only findings.

An examination of the relative *F* over the time series seemed to show a consistent increase in exploitation since 2000 as the relative *F* values from that year forward are all higher than those from the years before 2000 (Figure 80). A run using only the years 2000-2012 for the reference period yielded the following results: B_{MSY} proxy = 1.093, biomass threshold = 0.547, median relative *F* = 6,983.381, *ABC* = 6.92 million lbs, and *ACT* = 5.19 million lbs. The terminal smoothed index value was slightly lower than the increased B_{MSY} proxy but still higher than the biomass threshold (Figure 81). With the increased *ABC* and *ACT* levels, the catch history now falls mostly in between these levels for the last 11 years. Using only the recent years' (2000-2012) data yielded results more consistent between the index and catch history, i.e., the stock is not overfished nor experiencing overfishing based on the index calculations.

7.2 Depletion-Based Stock Reduction Analysis

7.2.1 Background and Data

The black drum DB-SRA developed for management advice during the previous assessment in 2015 was updated during this assessment as a continuity run and bridge to the previous assessment, and also as a potential analysis to inform stock status determination in this assessment. See Section 1.4 and ASMFC (2015) for background information on this analysis.

There were two changes to the inputs for the DB-SRA that have occurred since the previous assessment. The first is that the removal time series was changed based on the changes to the MRIP survey design and resultant calibrations applied to all historical estimates (Section 4.2.1). These calibrations resulted in significant increases in the magnitude of removals relative to the previous assessment (Figure 82). Additionally, removal data since the previous assessment (2013-2020) were added to the analysis and the removals have remained around the higher levels observed towards the end of the previous assessment. The second change was the update of the Hoenig (1983) natural mortality estimator by Then et al. (2015) that was adopted in this assessment (Section 2.5).

The DB-SRA was first updated with just the new removal data using the Hoenig (1983) natural mortality estimate from the previous assessment as the mean for the input distribution (Figure 83) to isolate the effect of the new removal data in the continuity analysis (***New_Catch*** continuity run). Other input distributions, F_{MSY}/M, B_{MSY}/K, and B_{2012}/K, also remained the same as specified in the previous assessment. This included changing the depletion input (B_{2012}/K) from the terminal year in the previous assessment (2012) to a year earlier than the terminal year in this assessment to maintain consistent prior information on depletion levels. An additional run of the DB-SRA (***Then_M*** continuity run) is included here with the Then et al. (2015) natural mortality estimate used as the mean of the input distribution (Figure 84) and the new removal data to complete the continuity analysis and provide a candidate analysis for stock status determination in this assessment with the best available information for inputs.

7.2.2 Results

Ten thousand iterations were conducted in each of the updated DB-SRA runs and >98% of the iterations were retained for final distributions from each run (9,834 for the ***New_Catch*** run and 9,964 for the ***Then_M*** run).

Exploitation with just the new removal data was generally estimated to have been lower in years before 1998 and higher since relative to the estimates in the previous assessment (Figure 85). This effect is driven by the updated relative removals (scaled to time series mean) being lower in early years and generally higher in later years relative to the removal data in the previous assessment (Figure 86). The higher natural mortality in the ***Then_M*** run indicates reduced longevity (fewer fish living to older ages) and less standing stock (i.e., a smaller carrying capacity – Table 40), resulting in a greater proportion of the biomass removed by the fisheries and higher exploitation. These estimates are similar to the previous assessment in years prior to 1970, but have regularly exceeded estimates from the previous assessment since the 1970s, much earlier than the ***New_Catch*** run.

The median U_{MSY} estimates were very similar between the previous assessment and the ***New_Catch*** run, but much higher with the higher natural mortality (Table 40). For both continuity runs, the annual exploitation was estimated to be below U_{MSY} throughout the time series, a departure from the previous assessment when a large pulse of harvest estimated by MRIP in the Mid-Atlantic recreational fishery in 2008 resulted in exploitation exceeding U_{MSY}. Exploitation decreased sharply after 2009 and was well below U_{MSY} in the terminal year of the previous assessment across runs. Exploitation increased since the terminal year of the previous assessment and was at its highest sustained level of the time series, but has remained below U_{MSY} including in the terminal year of this assessment.

The stock was estimated to be less depleted (B_y/K) with just the new removal data in years prior to the 2000s relative to the previous assessment, but then estimates converge on the estimates from the previous assessment due to a greater rate of depletion from higher exploitation during these years (Figure 87). With the higher natural mortality, the stock is slightly less depleted due to a greater estimate of the intrinsic rate of population increase parameter (r, Table 40) allowing for a more resilient stock able to replenish biomass lost to removals through annual production. Depletion in the terminal year of the previous assessment is very similar across runs. Depletion has steadily continued since the previous assessment and both continuity runs estimate very similar depletion in the terminal year of this assessment.

B_{MSY} and K estimates increased significantly from estimates during the previous assessment due to the increased magnitude of the removal data. These parameter estimates are greater with the lower natural mortality used in previous assessment. Biomass in the terminal year remains above B_{MSY} for both continuity runs (Figure 88). This biomass condition is strongly influenced by the input choice for depletion.

As with the biomass parameters, the catch reference points established in the previous assessment also increased significantly in magnitude. The median 2012 *OFL*, established as a catch threshold, increased from 4.12 million pounds to 10.80 and 13.34 million pounds for the ***New_Catch*** and ***Then_M*** runs, respectively. In all runs, the 2012 removals were below the interquartile range of their respective *OFL* estimates. The 2020 *OFL* was lower than the 2012 *OFL* within each continuity run due to the continued depletion of biomass, but the removals in 2020 were below interquartile ranges of these threshold 2020 *OFL* estimates. The median *MSY* estimate, established as a catch target, increased from 2.12 million pounds in the previous assessment to 5.57 and 6.81 million pounds for the ***New_Catch*** and ***Then_M*** runs, respectively. Removals exceeded the median *MSY* estimates from continuity runs more frequently than in the previous assessment during overlapping years (Figure 89). In the previous assessment, removals only exceeded the median *MSY* in three years (2000, 2008, 2009). In the continuity runs, removals exceeded median *MSY* during eight and five years prior to 2013 in the ***New_Catch*** and ***Then_M*** runs, respectively. Removals exceeded the median *MSY* from the ***New_Catch*** run every year since the previous stock assessment except 2019, while removals exceeded the median *MSY* from the ***Then_M*** run during three years since the previous assessment (2013, 2016, 2017). These results indicate a greater exploitation according to the updated removal data that has extended into years since the previous assessment, but not an overfishing condition according to the reference point structure adopted in the previous assessment.

7.3 JABBA-Select

7.3.1 Model Background

JABBA-Select was developed as an extension to the Just Another Bayesian Biomass Assessment (JABBA) surplus production modeling framework (Winker et al. 2018) as a means of incorporating life history and fishery selectivity information into an age-structured production type model (Winker et al. 2020). JABBA is a state-space Bayesian modeling framework that is well suited to handle both observation and process error in the dynamics of the modeled stock through state-space formulations while incorporating existing information and uncertainty about model parameters adequately through the use of Bayesian prior distributions. JABBA-Select requires the same data sets as a surplus production model including a time series of total fishery removals and an index of abundance. Further, the model requires information on biomass depletion at the start of the modeled time series, life history inputs including von Bertalanffy growth parameters describing growth, maturity parameters, length-weight relationship parameters, natural mortality, steepness of the Beverton-Holt stock-recruitment relationship, and unfished stock size, and selectivity patterns for each index of abundance, fishing fleet, and selectivity period within each fishing fleet. Inputs are summarized in Table 41 (fixed inputs) and Table 42 (input prior distributions).

The extension of JABBA-Select uses several key components that increase flexibility relative to typical biomass-aggregated production models like JABBA to make it more suitable for stocks exploited under selectivity patterns that differ from their maturity patterns and change through time. The model uses a reparameterization of the surplus production *r* parameter, H_{MSY} or harvest rate associated with *MSY*, and the parameter defining the shape of the surplus production curve, *m*, to link a traditional Pella-Tomlinson surplus production model with age-structured per-recruit models. If there are multiple fleets fishing with different selectivity patterns, the overall annual H_{MSY} (H_{MSYy}) represents fleet-specific H_{MSYs}s (where $_s$ is fleet *s* with a unique selectivity pattern) by averaging $H_{MSYs}s$ weighted by the fleets' relative contributions to total fishery removals in year *y*. Further, $H_{MSYs}s$ can vary through time due to regulation changes. These two effects can result in time-varying H_{MSYy} which is akin to time-varying *r* in a traditional surplus production model.

JABBA-Select also links the surplus production model and age-structured per-recruit models to account for distortion of biomass from an index of abundance tracking biomass (exploitable biomass; *EB*) that is not equal to spawning biomass (*SB*). If selectivity-at-age is different than maturity-at-age, *SB* will change at a different rate than *EB* across different levels of relative *SB* (i.e., depletion). This effect needs to be accounted for when fitting to the index of abundance to avoid biasing production which is a function of *SB*. The age-structured per-recruit models are used to estimate this relationship by calculating the ratio of *SB* and *EB* according to the maturity and selectivity, respectively, as *SB* changes in response to varying *F* levels. For example, if immature biomass is selected, *EB* will increase relative to *SB* as fishing mortality increases and *SB* becomes more depleted (Figure 90). This relationship is estimated prior to fitting the surplus production model using the means of the *M* and *h* priors and is treated as a fixed input assumed constant. Any deviations from this relationship are expected to be handled through process error (Winker et al. 2020).

The modeling procedures start off with a Monte Carlo simulation to generate a prior distribution for the production model parameters H_{MSY} and m. One thousand samples of *M* and *h* are drawn from prior distributions and used along with the other life history and selectivity inputs to iteratively solve for MSY-based reference points *MSY*, F_{MSY}, and SB_{MSY} with the per-recruit models by finding the *F* that maximizes yield. Unfished spawning biomass (SB_0) is solved by setting *F* to zero. These pre-recruit model parameters are used to calculate the surplus production parameters H_{MSY} and m that are implicit of the age-structured processes using equations 1 and 2, respectively.

$$\text{Equation 1: } H_{MSY} = \frac{MSY}{SB_{MSY}}$$

$$\text{Equation 2: } \frac{SB_{MSY}}{SB_0} = m^{\left(-\frac{1}{m-1}\right)}$$

Due to the correlation typical of surplus production model parameters, JABBA-Select uses the samples from the simulation to generate a multivariate normal prior so these parameters can be estimated jointly in the production model. If there are multiple fishing fleets and/or selectivity periods, ratios of H_{MSY} for the first fleet (H_{MSY1}) and subsequent fleets/selectivity periods ($H_{MSYs>1}$) from the simulation are fit to a gamma probability density function. The estimated shape and scale parameters are used in conjunction with the multivariate normal prior for H_{MSY1} and m to generate priors for the $H_{MSYs>1}$ parameters. The m parameter is generally less sensitive to different selectivity patterns than H_{MSY} (Winker et al. 2020), so the m parameter used in the subsequent surplus production model is an average across all fleets selectivity patterns when there are multiple fleets.

The surplus production model is then applied to observed catch and index time series in a Markov chain Monte Carlo (MCMC) analysis to update the prior distributions and estimate posterior distributions of key management parameters (e.g., MSY reference points, proxy per-recruit reference points such as $SB_{40\%}$).

Annual production is estimated in the first year (P_{init}) with equation 3.1 and all subsequent years (P_y) with equation 3.2:

$$\text{Equation 3.1: } P_{init} = \psi e^{\eta_y - 0.5\sigma_\eta^2}$$

$$\text{Equation 3.2: } P_y = \left(P_{y-1} + \frac{\sum_s \Upsilon_{s,y-1} H_{MSYs}}{1-m^{-1}} P_{y-1}\left(1 - P_{y-1}^{m-1}\right) - \frac{\sum_s C_{s,y-1}}{SB_0}\right) e^{\eta_y - 0.5\sigma_\eta^2}$$

where ψ is a scaling for initial biomass depletion in the first year, η_y is the lognormal process error term for year *y*, σ_η^2 is the process variance, $C_{s,y-1}$ is the removals of fleet *s* in year *y-1*, and $\Upsilon_{s,y-1}$ (i.e., $\frac{C_{s,y}}{\sum_s C_{s,y}}$) is a multiplier to weight H_{MSYs} relative to removals by fleet *s* in year *y*. The process error allows for deviation from deterministic formulations due to stochasticity in recruitment, natural mortality, selectivity, etc.

Annual spawning stock biomass is estimated with equation 4:

$$\text{Equation 4: } SB_y = P_y SB_0$$

Indices of abundance are predicted with the observation equation 5:

$$\text{Equation 5: } \ln(I_{i,y}) \sim Normal(\ln(q_i EB_{i,y}), \sigma_{\varepsilon y,i}^2)$$

where $I_{i,y}$ is the relative abundance index *i* in year *y*, q_i is the catchability coefficient for abundance index *i*, $EB_{i,y}$ is the *EB* for index *i* in year *y* predicted from equation 4 according to the expected relationship between the EB_i and *SB* ratio and the depletion of *SB*, and $\sigma_{\varepsilon y,i}^2$ is the total observation variance in year *y* for index *i*. Observation error consists of three additive components that can be switched on or off in any combination. The first component is the externally estimable SE (e.g., from a standardization model), the second component is an additional input SE that can account for sources of error that can't be estimated externally such as interannual variability in catchability, and the third component is an internally estimable SE when fitting to the index in the model.

The JABBA-Select modeling framework is executed in R (R Core Team 2020, version 4.0.2) with a 'Prime' file that sets up all model specifications, passes these to the model source code (JABBA_SELECTv1.1.R), within which the MCMC part of the analysis is implemented in JAGS (Plummer 2003, version 4.3.0). The JABBA GitHub repository (https://github.com/JABBAmodel) was used to download source code, view examples, and guide development of the black drum configuration.

A sciaenid species similar to black drum, silver kob (*Argyrosomus japonicus*), was used for the application of JABBA-Select in Winker et al. (2020) as well as the example in the GitHub user guide. Winker et al. (2020) also applied simulation analysis to test the performance of JABBA-Select as an estimation model (EM) relative to three other EMs, a state-space formulation of a traditional Pella-Tomlinson surplus production model and two traditional age-structured production models, one with a deterministic recruitment function and one with a stochastic recruitment function. Four operating models (OM) were used to simulate known populations including a base OM with the dynamics similar to the EMs (i.e., correctly specified EMs), an OM with higher natural mortality and lower steepness, an OM with dome-shaped fishery selectivity instead of logistic fishery selectivity, and an OM with a one-way trip trajectory (declining abundance) that contains little information about the stock's productivity. All OMs included a change in fishery selectivity part way through the time series. All EMs were configured to model the change in selectivity (the surplus production model was configured for this by way of a time-varying index catchability coefficient) and the same configuration of each EM was applied to simulated data from each OM as separate scenarios, thereby introducing misspecification in the later three scenarios. Notably, in the case of the one-way trip scenario, similar to the situation faced in this assessment with black drum data sets, JABBA-Select estimated absolute quantities SB_y and MSY with reduced accuracy relative to the base scenario, but was less affected when estimating the relative quantity SB_y/SB_0. Collectively across scenarios, JABBA-Select was shown to perform at least as well as the traditional age-structured production models and better than the traditional surplus production model. JABBA-Select was able to consistently produce unbiased estimates of H_{MSYs} parameters. JABBA-Select was also a superior performer for adequately characterizing uncertainty of stock status estimates.

7.3.2 Configuration for Black Drum

Note: The model configuration described in this section has been revised in response to the recommendations of the Peer Review Panel. Changes are fully detailed later in this report in Section 13: Addendum to the Stock Assessment Report.

The modeled time series was 1982-2020. The start year was chosen as 1982 because this is the first year with index of abundance data and to exclude an anomalous seasonal breakdown of removals in the Mid-Atlantic in 1981 (Figure 40, see fleet structure below).

Fishing Fleets

Coastwide fisheries of black drum were split into three fishing fleets due to expected differences in selectivity patterns. The first fleet included all South Atlantic states where primarily sub-adult fish are available to the fisheries (SA fleet). Mid-Atlantic states were grouped and split into two seasonal fleets, a fleet fishing January-August when primarily spawning adults are available to the fisheries (MA_early fleet) and a fleet fishing September-December when mature fish have largely emigrated from the area and primarily young fish (age-0 and age-1) remain available to the fisheries (MA_late fleet).

The SA fleet accounts for the majority of removals through time, while the MA_early fleet is the second largest fleet and the MA_late fleet only accounts for small and variable removals (Table 16).

There are no existing estimates of selectivity for black drum on the Atlantic coast. The process to specify length-based selectivity included four guidelines:

1. Inspect available length composition data and regulation history to identify likely changes in selectivity.
2. Combine length data across a constant selectivity period and scale proportion-at-length to the maximum proportion-at-length across the length range to inform ascending

selectivity in fisheries encountering immature fish (SA fleet, MA_late fleet) and descending selectivity in fisheries not encountering the full sub-adult size range (MA_late fleet).

3. Use 1-maturity-at-length for emigration from sub-adult fisheries (SA fleet, dome shaped selectivity) and maturity-at-length for recruitment to mature spawning adult fisheries (MA_early fleet, logistic selectivity).

4. Assume an ascending selectivity shifted slightly left of length composition data (all from harvested fish) for fisheries encountering immature fish (SA fleet and MA_late fleet) to account for dead discards of sub-legal fish.

SA Fleet

Length data from the South Atlantic were combined across periods with constant regulations from 1981-1988 (no state regulations), 1989-1997 (FL implemented a slot size limit and bag limit in 1989), 1998-2006 (GA implemented a minimum size and bag limit in 1998), 2007-2013 (SC implemented a slot size limit and bag limit in 2007), and 2014-2020 (NC implemented a slot size limit and bag limit in 2014, GA increased the minimum size). MRIP data were prioritized due to the statistical design of the survey and the majority of removals coming from recreational fisheries, but supplementary fishery-dependent data were included as a secondary check, with some cautions. Supplementary data do not have the spatial, temporal, or designed coverage of MRIP and can include biases (e.g., citation data representative of trophy fisheries, not general harvest). Periods prior to 2014 showed little evidence of a selectivity change in the South Atlantic overall, while data after 2014 showed a clear reduction in selectivity of smaller sizes (Figure 91). Based on these comparisons, the SA fleet was broken into two selectivity periods, 1982-2013 and 2014-2020.

Dome shaped selectivity for the first period ascends, reaching 95% selectivity at 220 mm, plateaus at full selectivity for 300 mm, and descends following 1-maturity-at-length (Table 41 and Figure 92). Selectivity approaches zero near 800 mm. Ascending selectivity shifts to the right in the second selectivity period, reaching 95% selectivity at 375 mm, and is then equal to selectivity in the first period for larger sizes (Figure 93).

MA_early Fleet

Mid-Atlantic state size regulations (only minimum size limits of 16 inches, ≈400 mm) are assumed not to have affected removals during the early period in the Mid-Atlantic when mature spawning adults are available to the fisheries, so selectivity is assumed constant for this fleet. The available length data become noticeably more noisy for this fleet and the maturity ogive is considered a better approximation of selectivity. Logistic selectivity follows the maturity-at-length, reaching 95% selectivity at 740 mm (Table 41 and Figure 94).

MA_late Fleet

Length data from the late period in the Mid-Atlantic were combined across periods with constant regulations from 1981-1986 (no state regulations), 1987-1993 (VA implemented a 16 inch minimum size in 1987), 1994-2000 (MD implemented a 16 inch minimum size in 1994), 2001-2009 (NJ implemented a 16 inch minimum size in 2001), 2010-2020 (DE implemented a 16 inch minimum size in 2010). MRIP data were again prioritized here due to the statistical design of the survey and the majority of removals coming from recreational fisheries. There were also no supplementary data for this fleet prior to 1994. The limited data were categorized into less than 16 inches and ≥ 16 inches to determine any indication of selectivity changes due to 16 inch minimum size limits. There was a clear shift in these categories during the dominant catch wave (wave 5) after 1993 (Table 43). Interestingly, this time period aligns with MD's implementation of the minimum size limit despite MD being a relatively small contributor to removals of this fleet. Given this shift, the MA_late fleet was broken into two selectivity periods, 1982-1993 and 1994-2020.

Dome shaped selectivity in the first period ascends, reaching 95% selectivity at 180 mm, plateaus for a small range, then descends sharply (Table 41 and Figure 95). Selectivity for sizes larger than ≈300 mm remains at 1% due to intermittent occurrences of larger fish in the size composition data. Selectivity in the second period shifts slightly to the right and increases for the larger sizes (Figure 96), matching that of the MRIP CPUE (see below) due to more widespread minimum size limits and reduced vulnerability of more available small fish.

Index of Abundance

The numbers-based MRIP CPUE was used as an index of coastwide abundance (JABBA-Select includes options for numbers-based and weight-based indices of abundance). The SEs estimated for this index from the standardization analysis were considered underestimated (median=0.063; Table 11), so an additional fixed SE (0.165) was added resulting in a median SE corresponding to a CV of 0.176. This is the center of the range of CVs (0.15-0.20) typical of CPUE data sets (Francis et al. 2003). Both the NC Gillnet and SC Trammel survey indices were considered during model development, but ultimately excluded due to the limited biomass range tracked and poor model diagnostics indicative of inability to relate the *EB* tracked by these indices to *SB*.

The MRIP CPUE was estimated using catch rate data from the entire coast and represents a mix of the three fishing fleets with its own unique selectivity (Table 41 and Figure 97). Selectivity was set as a hybrid between the two dominant catch fleets, SA and MA_early. Selectivity for the sub-adult portion of the size range (< ≈620 mm) follows selectivity of the SA fleet in the first period. The bulk of the black drum spawning migration occurs over three months in the Mid-Atlantic (April-June; Figure 3) with these large, mature fish being relatively unavailable the remaining three quarter of the year, so the descending selectivity descends to 0.25 and remains constant for all mature sizes. Catch rate data include all dispositions caught by the fishery (harvested, released alive, released dead), so regulations are assumed not to have changed the selectivity of this total catch (i.e., no significant change in angler behavior affecting sizes caught such as gear changes), just the selectivity of fish retained for harvest.

Selectivity patterns collectively across fleets and the MRIP CPUE are shown in Figure 98.

Life History Fixed Inputs
Fixed inputs for life history information included von Bertalanffy growth parameters describing growth updated during this assessment (Appendix 1), maturity parameters from the previous assessment using coastwide and sex-aggregate data, and length-weight relationship parameters from the previous assessment (Table 41 and Figure 98). Length-based maturity parameters were used from age-based maturity converted to length with growth model parameters. There were no coastwide length-weight relationship parameters, so those from the model with the highest R^2 were used (NC DMF data).

Prior Distributions
The lognormal prior distribution for unfished spawning biomass (Table 42, Figure 99) was specified as an uninformative prior converted from bounds (i.e., uniform distribution) using the methods of Winker et al. (2018) due to the superior convergence properties of lognormal priors. The same bounds used for carrying capacity in the previous assessment were used here, a lower bound equal to maximum observed annual removals (2008, unchanged from previous assessment) and an upper bound equal to one hundred times the maximum observed removals. These bounds correspond to the stock being exploited to extinction and only 1% of the biomass being removed during the year of greatest observed exploitation, a level unlikely for a stock that has been identified as in need of management. These bounds also correspond to a CV of the converted lognormal distribution of 1.66, near the center of the range of CVs recommended in the JABBA-Select user guide (1.00-2.00).

The prior distribution for depletion in the start year (Table 42, Figure 99) was specified as a beta distribution from the two available options (beta and lognormal) because of this distribution being bounded between 0 and 1. The distribution was set to be as uninformative as possible while maintaining the expert opinion from the previous assessment that the stock was lightly exploited and had not been overfished. That is, the mean and CV were set so that the density of the distribution was concentrated between 0.4, the location of B_{MSY}/K common of many species (Thorson et al. 2012), and 1, while being centered between the bounds used for the uniform distribution of terminal depletion in DB-SRA during the previous assessment (0.5 and 0.9).

The lognormal prior distribution for natural mortality (Table 42 and Figure 99) has a mean equal to the estimate updated during this assessment with the Then et al. (2015) estimator and maximum observed age (67, also the maximum age used in per-recruit model calculations). The CV is the same used in Winker et al. (2020) (0.25). The beta prior for steepness of the Beverton-Holt stock-recruitment relationship (Table 42, Figure 99) was specified according to meta-analysis by Shertzer and Conn (2012) of demersal marine species displaying a periodic reproductive strategy. The bootstrapped estimates were used as a better approximation of uncertainty.

Both the additional observation variance and process variance were estimated within the model using default uninformative prior specifications for these parameters (inverse gamma with both gamma scaling parameters = 0.001; Winker et al. 2018).

The Monte Carlo simulations of H_{MSY} and *m* and resultant multivariate normal prior distribution are provided in Figure 100. H_{MSY} ratios for subsequent fleets and selectivity periods are provided in Figure 101. For black drum, the *m* parameter was largely robust to selectivity pattern with the exception of the first selectivity period of the MA_late fleet (Figure 102). This impacts the average slightly in the direction of a lower productivity (i.e., higher *m*).

Reference Points
MSY-based reference points were estimated internally in JABBA-Select and are recommended for stock status determination. Uncertainty in productivity parameters, *h* and *M*, were incorporated into the analysis and accounted for in MSY-based reference point estimates. Specifically, overfished is defined as spawning biomass falling below spawning biomass associated with *MSY* ($SB_y/SB_{MSY} < 1$). Overfishing is defined as exploitation exceeding exploitation associated with *MSY* ($H_y/H_{MSYy} > 1$). The JABBA-Select model was applied in the assessment with the primary objective being to estimate stock status. Given high uncertainty in absolute biomass estimates and that *MSY* estimates are in terms of *SB* with no way to monitor in real time what portion of the removals is *SB*, the TC does not recommend using point estimates of *MSY* for application as catch targets in the fisheries.

MCMC Settings and Diagnostics
Three parallel Markov chains were run with 20,000 iterations each. The first 5,000 iterations of each chain were discarded as a burn-in period and every 3rd iteration after the burn-in period was retained from each chain for posterior distribution estimates. Convergence to posterior distributions was evaluated by visual inspection of trace plots and results of the Geweke convergence test and the Heidelberger and Welch diagnostic test. The Geweke convergence test evaluates the null hypothesis that MCMC chains are from a stationary distribution by comparing the mean of the first 10% of the chain to the mean of the last 50% of the chain, rejecting the null hypothesis if these means are significantly different according to a specified alpha level (e.g., 0.05). The Heidelberger and Welch diagnostic test similarly evaluates the null hypothesis that a sampled value comes from a stationary distribution using a test statistic. Model fit to the index data is assessed by standard deviation of the normalized residuals (SDNR) being $\leq$ ≈1 (Francis 2011), visual inspection of residual plots, and residual runs test.

7.3.3 Results

Note: The model results described in this section have been revised in response to the recommendations of the Peer Review Panel. Changes are fully detailed later in this report in Section 13: Addendum to the Stock Assessment Report.

Base Model Estimates

The model converged to posterior distributions for each parameter according to stable behavior of the chains in trace plots (Figure 103) and the results of the Geweke and Heidelberger and Welch tests (Table 44, all p-values>0.05).

The model fit the general trend of the MRIP CPUE, but there were two periods of positive residuals around 2000 and at the end of the time series (Figure 104). Despite these residuals, the runs test p-value (0.145) indicated random residuals and the SDNR was 0.51. Annual process error deviates did not follow any systematic trending that would clearly indicate model misspecification (Figure 105).

Parameter posterior distributions are compared to prior distribution in Figure 106. The posterior to prior variance ratio (PPVR) is provided to assess the degree of influence the data have on the posterior distribution. The smaller the PPVR, the more the posterior is influenced by the data and the less it is influenced by the prior distribution. The posterior to prior mean ratio (PPMR) is provided to assess the direction in which the posteriors are influenced by the data relative to the prior, with values <1 indicating shifts of the posterior to the left, values >1 indicating shifts of the posterior to the right, and a value of 1 indicating no movement. The SB_0, H_{MSY1}, and *m* parameters were more strongly influenced by the data, while the depletion parameter (*psi*) was more strongly influenced by the prior. The influence the data did have on the depletion parameter indicated a more depleted stock (PPMR<1). The data indicated a larger stock that is slightly more productive (higher H_{MSY1} and lower *m*). The estimated process error parameter was small and typical of a long-lived stock with many ages contributing to the spawning stock biomass (Winker 2018). The additional observation error parameter was also small and resulted in a median total observation error corresponding to a CV of 0.182.

The spawning biomass was estimated to increase throughout the time series, though there were wide credible intervals indicating high uncertainty in absolute biomass estimates (Table 45, Figure 107). Relative biomass was estimated with more certainty (Table 45 and Figure 108).

Exploitation generally follows the removal time series with higher exploitation estimated during the mid-1980s and since 2000 (Table 46 and Figure 108). Credible intervals of relative exploitation are also quite wide. Most of the intervals through time indicate exploitation less than H_{MSYy}, but there is some low probability of exploitation exceeding H_{MSYy} during the higher exploitation years.

The base model is interpreting the increasing trend in both MRIP CPUE and fishery removals as indication that the stock was lightly exploited in earlier years allowing for surplus biomass to recruit to the less vulnerable spawning stock and build up over time (Figure 108). Some positive anomalies in biomass during the late 2000s and early 2010s (Figure 105), likely due to some strong year classes that were not fully exploited to the threshold level, appear to have offset the increased removals and a more drastic increase in exploitation to allow for the trend to continue increasing, albeit at a reduced rate that starts to flatten out from the increased exploitation since about 2000 (Figure 108).

Retrospective Analysis

A retrospective analysis was conducted with a five-year peel from the assessment terminal year. Mohn's rho values were calculated according to the methodology of Hurtado-Ferro et al. (2014).

Estimates from the retrospective with Mohn's rho values are provided in Figure 109. Mohn's rho values range from -0.02 for relative biomass estimates to 0.074 for relative exploitation estimates. These values indicate a more conservative pattern with a tendency to underestimate relative biomass and overestimate relative fishing mortality as years are peeled from the time series. The magnitude of the Mohn's rho values indicate no significant retrospective bias according to the rule of thumb proposed by Hurtado-Ferro et al. (2014) for long-lived species (-0.15 – 0.20).

Sensitivity Analysis

A sensitivity analysis was conducted by running alternative model configurations to assess impact of key assumptions and uncertainties identified by the TC. Nine alternative configurations were included in the analysis (Table 47).

Three configurations included alternate assumptions on the key life history parameters influencing productivity, *h* and *M*. The ***low M*** configuration included a natural mortality prior distribution with a mean (0.068) lower than the base model (0.1041) and closer to the Hoenig (1983) estimate used in the previous assessment (0.063). Attempts were made to lower the mean to 0.063, but a small number (3%) of *M-h* draws with low *M* and high *h* caused errors in the per-recruit calculations that cascaded through the modeling software and 0.068 was the lowest mean that avoided these errors. The alternative prior distribution includes a significant portion of its density at or below the 0.063 mean value used in the previous assessment (Figure 110). The ***ll h*** configuration included a steepness prior distribution parameterized with the likelihood estimates from Shertzer and Conn (2012) as opposed to bootstrapped estimates. These parameters included a slightly larger mean (increased from 0.72 to 0.75) and greater precision (CV decreased from 0.25 to 0.20). The ***low h*** configurations included a steepness prior distribution with a mean decreased by 0.1 from 0.72 to 0.62.

Four configurations included alternate selectivity assumptions. The ***MRIP sel*** configuration decreased the selectivity for the largest sized fish from 0.25 in the base model to 0.1 due to uncertainty in vulnerability of spawning adults relative to sub-adults that account for the majority of recreational catch. The ***SA adults*** configuration increased the selectivity for the largest sized fish from 0 in the base model to 0.06 based on small reported catches of these sized fish and potential for small scale directed fishing at trophy sized fish such as tournaments and charter boat operations. The ***SA descend*** configuration shifts descending selectivity of the SA fleet to the left by 100 mm, reducing the size range available to this fishery. The ***MA_early sel*** configuration shifted selectivity of the MA_early fleet to the right of the selectivity pattern in the base model due to available length composition data peaking at larger sizes than full maturity.

The last two configurations dealt with the start year depletion assumption and uncertainty about a potential shift in catchability for the MRIP CPUE in recent years. The ***uni dep*** configuration included a beta prior distribution parameterized as a uniform distribution over the full range of values 0 to 1 (mean=0.5, CV=0.577). This configuration was included due to the use of a uniform prior distribution on the depletion assumption for DB-SRA in the previous assessment. One distinction due to the constraints of the JABBA-Select software is that the beta distribution can only be parameterized as a uniform distribution over the full range of values (including overfished levels <0.4) whereas the DB-SRA uses a true uniform distribution with bounds that were set at levels representative of a stock that is not overfished (0.5 and 0.9). The ***MRIP q*** configuration included a second catchability coefficient parameter for the MRIP CPUE allowing for a unique catchability coefficient in years after 2015. This configuration was included due to the positive residuals since 2016 in the base model and the apparent shift in catchability identified and discussed in Section 4.2.1.3. This configuration acknowledges the possibility that the directed trips data set used to calculate the MRIP CPUE did not completely account for the apparent change in catchability. This configuration was also considered for the base model, but was not selected due to lower deviance information criterion (DIC) of the final base model presented here, indicating the additional *q* parameter was not justified by improved fit to the data, and a similar group of residuals around 2000 that changed after the same amount of time being observed at the end of the time series.

Sensitivity configurations estimated median SB_{MSY} similar to the base model, but with varying high levels of uncertainty about the magnitude of this biomass (Figure 111). As for relative biomass, all configurations estimate very similarly with a few notable departures (Figure 112). The ***uni dep*** configuration estimates a more depleted stock at the beginning of the time series. When no prior information is passed to the model, the model interprets the increasing MRIP CPUE as indication of a stock rebuilding from a depleted state. This is contrary to all other data sets and the TC's belief of stock status at the time and this run is considered a more unlikely "state of nature". The biomass increases more rapidly during the 1980s, then follows the trend of the base configuration with the median estimate in the terminal year indicating a spawning biomass above SB_{MSY} that falls just within the base model 95% credible interval. The ***MRIP q*** configuration estimates a similar trend as the other configurations for most of the time series, but then starts to diverge with a declining trend in the last decade. Lastly, the ***low M*** and ***low h*** configuration, both of which suggest lower productivity, estimate similar increasing trends, but shifted down to slightly lower relative biomasses.

The ***uni dep*** configuration estimates a similar trend in exploitation but with greater relative exploitation including several years with the median estimates exceeding 1 (Figure 113). Both exploitation (Figure 114) and productivity (H_{MSY}) estimates (Figure 115) are impacted. The lower relative biomass estimated for this configuration with the same observed removals leads to a greater proportion of stock biomass removed by fishing. This configuration also estimates a lower H_{MSY} resulting in greater differences in relative exploitation between this configuration and base model. Greater estimates of relative exploitation from the ***low M*** and ***low h*** configurations are primarily due to lower H_{MSY} estimates informed by lower productivity in the priors of these configurations. The ***low M*** configuration estimated median relative exploitation that exceeded 1 in two years (2000 and 2016) and shows greater divergence from the base model since the SA fleet selectivity change in 2014. Alternate selectivity configurations show some sensitivity of exploitation estimates during periods of the time series, with SA fleet selectivity shifted to a smaller dome and fishing mortality concentrated on immature fish that haven't had a chance to contribute to spawning biomass (***SA descend***) resulting in smaller H_{MSY} and SA fleet selectivity increased for the largest sizes (***SA adults***) spreading fishing mortality from sub-adult fish to some mature adults resulting in greater H_{MSY} estimates.

7.4 Methods Discussion

Both the Itarget and Skate methods showed initial promise for a data limited species with their requirements of only a catch history and a survey index of relative abundance as inputs. However, the one-way upward trajectories for both the MRIP CPUE index and the black drum catch history defied expectations that would normally show decreases in relative abundance with an extended period of increasing harvests and created complications for applying these index-based methods to black drum. Notably, catch advice and interpretation of overfishing status from the methods was sensitive to treatment of early years of data with smaller removals and low exploitation that, according to the CPUE, did not have adverse effects on abundance.

For the Itarget method, if the stock is believed to be near its carrying capacity, lower values for the index multiplier would be justified. However, if the stock is much more depleted (current expert opinion is that depletion is between 0.4 and 1), a higher index multiplier would be warranted. Yet these higher multipliers set target catch levels at much lower levels than have been landed within the last decade. If the index values showed a corresponding decreasing trend with the increased removals, the catch advice supplied by the Itarget method would seem more relevant.

For the Skate method, using only the recent years' (2000-2012) data yielded results more consistent between the index and catch history, i.e., the stock is not overfished nor experiencing overfishing based on the index calculations. However, the TC was not comfortable with the possibly arbitrary decision to exclude the data prior to 2000.

The use of an index derived from fisheries-dependent data (MRIP, upon which a significant portion of the catch history was based) instead of a purely fisheries-independent survey may have complicated the efficacy of these methods as they are both meant to use the relationship between an independent index and catch history to derive catch advice that ultimately allows a stock to achieve or maintain a target abundance level. The uncertainties related to the lack of a fisheries-independent index of relative abundance, specification of the actual depletion status of the stock (to define the appropriate index multiplier for Itarget), and the conflicting signals of stock status between the index and catch history in Skate, all led the TC to reject these methods for this assessment. These methods with their current data inputs may be useful as annual indicators to show current relationships between stock and removals (Itarget) and the ongoing trend of relative *F* (Skate), but further research is needed that could be applied after the stock assessment.

For the model-based approaches, trends in abundance over time differed between the DB-SRA and Simple Stock Synthesis model (Appendix 2) compared to the JABBA-Select model. The DB-SRA and Simple Stock Synthesis models both had a decline in abundance over time while abundance in the JABBA-Select model increased over time. Such different trends are due to the inputs, assumptions, and structure used for each model.

The DB-SRA model used in the previous assessment and the Simple Stock Synthesis model both assume the black drum population started at an unexploited state in 1900 and abundance was at 70%, on average, of the unexploited state at or near the end of the time series. When combined with the increase in removals, especially in the last 20 years, and no information on abundance changes, this assumption and the structure of these two models results in a declining trend in abundance over time. For both models, the lowest abundance occurred in 2020, the final year in the current assessment.

The JABBA-Select model is based on a surplus production model and uses the MRIP CPUE and removal data as inputs. JABBA-Select does not require the assumption that the modeled time series starts when the stock is unexploited and does not make an assumption about depletion at or near the end of the time series, but rather makes an assumption about depletion at the start of the time series (here 1982) with use of a prior distribution (beta distribution with density constrained in a not overfished state). The MRIP CPUE index generally increased during 1982-2020, which implies that black drum abundance increased during this time. Also during this time period there was an increase in removals. Given these inputs and the structure of the JABBA-Select model, the abundance estimates from this model generally increased over time so that abundance in 2020 is not the lowest but is one of the highest estimates during 1982-2020.

One of the primary differences between the DB-SRA and Simple Stock Synthesis models compared to the JABBA-Select model is the inclusion of the MRIP CPUE index. When trying to include the MRIP CPUE in the Simple Stock Synthesis model, the fit to the MRIP index was poor (Appendix 2: Fig. 10) and there were opposite trends in abundance implied by the depletion assumption compared to the MRIP CPUE index (Appendix 2: Fig. 10). The DB-SRA model produced a declining trend in abundance similar to the Simple Stock Synthesis model and would also have an opposite trend in abundance compared to that implied by the MRIP CPUE index.

As part of our modeling decisions, the TC felt that the MRIP CPUE did generally track population abundance and was the only index thought to track the entire coastwide stock. The MRIP CPUE had a non-decreasing trend similar to all of the fishery-independent indices. Therefore, we had no reason not to include the MRIP CPUE index in this assessment, especially as the inclusion of abundance indices was one of the improvements suggested by the reviewers during the previous benchmark assessment. In addition to including the MRIP CPUE index, the JABBA-Select model (1) differentiates between exploitable biomass and spawning biomass, which are different for black drum due to life history and exploitation patterns, and accounts for this difference when estimating annual production as the ratio of these two biomasses changes, (2) requires one less assumption about biomass depletion than DB-SRA and Simple Stock Synthesis, (3) does not require use of early, uncertain catch data, and (4) accounts for changes to fishery selectivity through time and resultant impacts to productivity. Finally, the DB-SRA and Simple Stock Synthesis models were created to provide advice on catch limits, not determine stock status. Therefore, we chose to use the JABBA-Select model over the DB-SRA or Simple Stock Synthesis models for stock status determination.

8 STOCK STATUS

Note: The stock status determinations described in this section have been revised in response to the recommendations of the Peer Review Panel. Changes are fully detailed later in this report in Section 13: Addendum to the Stock Assessment Report.

Overfished is defined as spawning biomass falling below spawning biomass associated with *MSY* ($SB_y/SB_{MSY} < 1$). Overfishing is defined as exploitation exceeding exploitation associated with *MSY* ($H_y/H_{MSYy} > 1$).

The 2020 median relative spawning biomass estimated with the base model was 2.92, indicating the stock was not overfished in the terminal year of the stock assessment (Table 45). The 2020 median relative exploitation estimated with the base model was 0.29, indicating the stock was not experiencing overfishing in the terminal year of the stock assessment (Table 46).

Results indicate greater certainty that the stock has not been depleted to an overfished status in the terminal year of the assessment, while there is less certainty about the exploitation status. Figure 116 shows the time series of stock status estimates with uncertainty around terminal year determinations. All of the 95% credible interval is above the overfished threshold, while exploitation shows some low probability of exceeding the threshold within the 95% credible interval. This low risk of overfishing according to the credible intervals extends back for much of the last twenty years of the time series. The sensitivity analysis included some configurations that estimated median relative exploitation that exceeds the threshold in recent years, while no sensitivity configuration estimated median relative biomass below the threshold since the 1980s.

There are several important points of context to consider with this stock status determination estimated from the JABBA-Select model:

- Empirical indicators show increased fishery removals in the last twenty years and less frequent large recruitment events in the Mid-Atlantic in the last ten years. There are no clear indications of a declining trend in recruitment or exploitable abundance from abundance indicators, with the exception of the anomalous GA trammel index, but there is a declining trend in the final two years of the recreational discard time series that may be reflective of abundance in addition to other factors. There is some indication of northern range expansion. Overall, stock indicators do not appear negative at this time, but should be monitored closely for any sign of change.

- The one-way trip increasing trend in both removals and the MRIP CPUE for the assessment time period may indicate that the stock either had been lightly exploited in the 1980s, which has allowed for the recent increase in exploitation of the predicted high biomass, or was overfished and rebuilding throughout the assessment time series. The latter scenario is contrary to the TC's expert opinion that the stock was not overfished at the beginning of the time period, and there were minimal regulation changes aimed specifically at black drum in the 1980s to induce a rebuilding period. However, it is also possible that recruitment overfishing is occurring or could begin to occur prior to detection with currently available data, due to sub-adult black drum accounting for the majority of removals and the lack of an index that solely tracks mature biomass. With over 30 cohorts contributing to *SSB*, recruitment overfishing may not be evident within current data streams for an extended number of years, leading to an overfished state being reached prior to removals and the MRIP CPUE index indicating a sustained downward trend. The TC concurs with the model-derived stock status but acknowledges the lack of contrast in both removals and the MRIP CPUE coupled with model uncertainty will require close monitoring of stock indicators and a more conservative approach to managing the fishery.

9 RESEARCH RECOMMENDATIONS

The TC recommends that a new benchmark stock assessment be completed for the black drum stock in five years (2027). However, the TC also recommends annually reviewing the stock indicators established in this assessment updated with new data to identify any concerning trends in a timely manner. Should any concerning trends occur, the TC may recommend an expedited assessment to be completed before 2027.

The TC is hopeful that high priority research recommendations identified below will be addressed/initiated prior to completion of the next benchmark stock assessment. Progress will lead to advances that can better inform stock status in future stock assessments, but the TC also acknowledges many of these as long-term efforts needed to develop ongoing time series to enable transition to more advanced/complex stock assessment models.

HIGH PRIORITY

- Develop fishery-independent adult surveys. Consider purse seine and long line surveys with bait and sampling areas appropriate to target black drum. Collect age samples, especially in states where maximum size regulations preclude the collection of adequate adult ages. ***long-term***
- Conduct a high reward tagging program to obtain return rate estimates. Continue and expand current tagging programs to obtain total mortality, catch and release mortality, and growth information and movement-at-size data. ***long-term***
- Increase biological sampling in commercial fisheries, particularly gill nets in Virginia (see Section 4.4), to better characterize size and age composition of commercial landings. These data would help improve data sets for selectivity estimates and eventual extensions to length/age-structured assessment approaches. ***long-term***

- Increase biological sampling in recreational fisheries, particularly harvest in the Mid-Atlantic region and releases coastwide (see Section 4.4), to better characterize size and age composition of recreational catch. These data would help improve data sets for selectivity estimates and eventual extensions to length/age-structured assessment approaches. ***long-term***
- Continue all current fishery-independent surveys recommended as stock indicators for black drum and collect biological samples for black drum on all surveys. ***long-term***
- Evaluate use of MRIP site-use weighting factors to improve CPUE estimates. ***short-term***
- Skate and Itarget with their current data inputs should be evaluated as annual indicators to show current relationships between stock and removals (Itarget) and the ongoing trend of relative *F* (Skate). ***short-term***
- A process should be developed for appropriately combining MRIP and supplemental recreational sampling program data for characterizing the size structure of the recreational harvest. The process needs to consider spatial information, as there are likely spatial effects within states' supplemental sampling programs (e.g., VMRC Freezer Program representing Eastern Shore harvest). ***short-term***

MODERATE PRIORITY

- Age otoliths that have been collected and archived (≈ 500 sub-adults samples from GA). ***short-term***
- Improve sampling of concentrated, targeted nighttime fisheries in the Mid-Atlantic region (e.g., Delaware Bay). Although the MRIP APAIS design changed to expand to nighttime sampling, data are too limited (e.g., only four potential nighttime black drum intercepts in DE APAIS data) to evaluate whether this change was sufficient for black drum fisheries. ***long-term***
- The recreation released alive trend and harvest trend provided a mixed signal. In order to identify which factor, a change in stock abundance vs. a change in fishing behavior, drove the mixed signal, we analyzed the released alive data by breaking them down by wave. However, such an analysis may provide limited information on fishing behavior change, therefore, we recommend to directly collect such information via a one-time pilot study (≈three years) during existing creel surveys (e.g., MRIP APAIS). For example, anglers may report if they know where, when, and how to catch legal black drum (potentially increasing catch rate) meanwhile deliberately avoiding catching sublegal fish (potentially decreasing released alive quantity). Anglers don't need to share their specific skills during the creel survey by simply checking a box before "When", "Where", and "How" along with targeted species data currently collected. Such information may potentially provide better information to understand drivers of these trends in the future stock assessment. ***short-term***
- Conduct tagging study to determine survival, migration, and contribution of YOY fish spawned in the Mid-Atlantic to the overall sub-adult stock. ***long-term***

LOW PRIORTY

- Expand simulation-based power analysis to other index data sets used for stock indicators of black drum. ***short-term***
- Conduct reproductive studies that provide updated estimates and an expanded spatial coverage, including: age and size-specific fecundity, spawning frequency, spawning behaviors by region, and movement and site fidelity of spawning adults. ***long-term***
- There is uncertainty about selectivity between gill net types fished (anchor and drift) in Virginia and the appropriateness of combining these gears into a fleet. There are no composition data collected from drift gill nets, so this remains an uncertainty that should be researched in the future. ***short-term***

Lastly, the TC acknowledges some progress, summarized below, has been made on research recommendations from the previous stock assessment.

PARTIALLY ADDRESSED

- Collect genetic material (i.e., create "genetic tags") over a long time span to obtain information on movement and population structure, and potentially estimate population size. ***See Section 2.1 and Leidig 2014.***
- Obtain better estimates of harvest from the black drum recreational fishery (especially in states with short seasons). ***MRIP changes discussed in Section 4.2.1.1 were generally seen as improvements to catch estimates, though the exception remains nighttime fishery sampling identified as a moderate research recommendation above.***
- Collect information on the magnitude and sizes of commercial discards. Obtain better estimates of bycatch of black drum in other fisheries, especially juvenile fish in south Atlantic states. ***An ongoing observer program now provides monitoring of the primary suspected commercial black drum discard fishery (Section 4.1.1.2). Recent estimates have been small in comparison to total fishery removals, but this source of catch should continue to be monitored in future stock assessments for signs of increase. South Atlantic shrimp trawl fishery observer data were also reviewed during this assessment and do not indicate these fisheries are a significant source of black drum fishery removals.***

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11 TABLES

Table 1. History of jurisdictional regulations specific to black drum. Bold indicates changes to existing regulations.

Year	Jurisdiction	Recreational		Commercial			Notes
		Size limit	Bag limit	Size limit	Trip Limit	Annual Quota	
1987	VA	16" min		16" min	1/person/day commercial limit without Black Drum Harvesting and Selling permit		
1989	FL	14" min 24" max*	5/person/day, *including 1 fish >24"	14" min 24" max	500 lbs/day/person or vessel (whichever is lesser)		
1992	VA	16" min	**1/person/day**	16" min	1/person/day commercial limit without Black Drum Harvesting and Selling permit		
1993	PRFC	16" min	1/person/day	16" min	1/person/day		
1994	VA	16" min	1/person/day	16" min	1/person/day commercial limit without Black Drum Harvesting and Selling permit		**Limited entry in the commercial fishery**
1994	MD	16" min	1/person/day	16" min		30,000 lbs (Ches. Bay)	
1995	FL	14" min 24" max*	5/person/day, *including 1 fish >24"	14" min 24" max	500 lbs/day/person or vessel (whichever is lesser)		**No gill nets or other entangling nets shall be used in any Florida waters**

Table 1. Continued.

Year	Jurisdiction	Recreational		Commercial			Notes
		Size limit	Bag limit	Size limit	Trip Limit	Annual Quota	
1998	GA	10" min	15/person/day	10" min	15/person/day		
1999	MD	16" min	1/person/day **Max of 6/vessel (Ches. Bay)**	16" min		**1,500 lbs (Atlantic Ocean)**	**Ches. and Coastal bays closed to commercial harvest**
2001	NJ	16" min	3/person/day	16" min	10,000 lbs	65,000 lbs	
2002	VA	16" min	1/person/day	16" min	1/person/day commercial limit without Black Drum Harvesting and Selling permit	**120,000 lbs**	
2007	SC	14" min 27" max	5/person/day	14" min 27" max	5/person/day		Commercial fishery primarily bycatch
2010	DE	16" min	3/person/day	16" min	10,000 lbs	65,000 lbs	Regulations only for DE River and DE Bay
2013	DE	16" min	3/person/day	16" min	10,000 lbs	65,000 lbs	**Effective for all DE waters**
2014	GA	**14" min**	15/person/day	**14" min**	15/person/day		
2014	NC	14" min 25" max*	10/person/day	14" min 25" max*	500 lbs/trip		*One fish over 25" may be retained
2019	MD	16" min	1/person/day Max of 6/vessel	16" min Atlantic **28" Ches.**	**10/vessel/day from Chesapeake Bay**	1,500 lbs (Atlantic Ocean)	Coastal bays closed to commercial harvest

Table 2. Summary statistics for black drum age data collected along the coast.

Age	Mean Total Length (inches)	CV Total Length (inches)	n	Age	Mean Total Length (inches)	CV Total Length (inches)	n
0	9.02	0.157	1,515	32	45.61	0.062	39
1	13.67	0.214	3,474	33	45.85	0.050	38
2	18.08	0.130	1,194	34	45.27	0.045	32
3	22.25	0.126	465	35	46.04	0.058	34
4	25.93	0.103	216	36	46.89	0.061	25
5	29.50	0.086	154	37	46.54	0.051	31
6	31.10	0.077	167	38	45.53	0.079	36
7	32.31	0.083	187	39	45.52	0.075	44
8	33.61	0.074	192	40	46.51	0.054	55
9	34.62	0.056	270	41	46.65	0.053	27
10	35.42	0.051	219	42	47.16	0.055	31
11	36.09	0.051	179	43	46.65	0.045	26
12	37.00	0.045	116	44	48.67	0.058	24
13	37.35	0.084	116	45	46.75	0.041	32
14	37.28	0.063	104	46	47.27	0.053	21
15	38.85	0.062	90	47	48.01	0.071	36
16	39.48	0.055	92	48	47.73	0.051	14
17	39.82	0.051	115	49	47.60	0.075	20
18	39.82	0.084	65	50	46.19	0.101	13
19	40.38	0.055	69	51	47.63	0.080	18
20	41.48	0.078	47	52	48.46	0.040	11
21	41.75	0.052	40	53	50.47	0.069	5
22	42.07	0.065	34	54	49.15	0.053	9
23	42.71	0.060	58	55	47.83	0.076	7
24	43.44	0.066	41	56	47.77	0.027	3
25	43.01	0.056	36	57	47.78	0.063	2
26	44.04	0.050	24	58	46.50	NA	1
27	44.66	0.056	30	60	48.23	NA	1
28	44.22	0.054	42	61	50.98	NA	1
29	44.61	0.041	25	64	51.87	0.019	2
30	43.54	0.084	21	67	44.02	NA	1
31	44.83	0.052	48				

Table 3. Commercial landings data collection methodology by state.

	1950-1977	1978-1985	1986-1988	1989	1990-1993	1994	1995-2000	2001-2003	2004	2005	2006	2007-today
ME DMR	Annual	Annual	Annual	Annual	Monthly	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Trip
NH FGD	Annual	Annual	Annual	Annual	Monthly	Mixed	Mixed	Mixed	Trip	Trip	Trip	Trip
MA DMF	Annual	Annual	Annual	Annual	Monthly	Mixed	Mixed	Mixed	Mixed	Trip	Trip	Trip
RI DFW	Annual	Annual	Annual	Annual	Monthly	Mixed	Mixed	Mixed	Mixed	Trip	Trip	Trip
CT DEEP	Annual	Annual	Annual	Annual	Monthly	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Trip
NY DEC	Annual	Annual	Annual	Annual	Annual	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
NJ DEP	Annual	Annual	Annual	Annual	Annual	Mixed	Mixed	Mixed	Mixed	Trip	Trip	Trip
DE DFW	Annual	Annual	Monthly	Monthly	Monthly	Monthly	Mixed	Mixed	Mixed	Mixed	Mixed	Trip
MD DNR	Annual	Annual	Annual	Annual	Annual	Mixed	Mixed	Mixed	Mixed	Mixed	Trip	Trip
VMRC	Annual	Annual	Annual	Annual	Annual	Mixed	Mixed	Mixed	Mixed	Trip	Trip	Trip
NC DMF	Annual	Monthly	Monthly	Monthly	Monthly	Trip	Trip	Trip	Trip	Trip	Trip	Trip
SC DNR	Annual	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Trip	Trip	Trip
GA DNR	Annual	Monthly	Monthly	Mixed	Mixed	Mixed	Mixed	Trip	Trip	Trip	Trip	Trip
FL FWC	Annual	Monthly	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip

Annual summaries | Monthly summaries | Mixed (trip reports and monthly summaries) | Trip reports (all fisheries)

Table 4. Total commercial landings of black drum along the U.S. Atlantic coast from 1900-2020.

Year	*Pounds*	*Year*	*Pounds*	*Year*	*Pounds*	*Year*	*Pounds*	*Year*	*Pounds*
1900	0	1925	253,330	1950	269,400	1975	319,911	2000	240,184
1901	58,330	1926	35,540	1951	332,700	1976	188,653	2001	184,992
1902	187,520	1927	98,113	1952	239,800	1977	176,969	2002	555,499
1903	0	1928	140,937	1953	291,600	1978	174,465	2003	289,312
1904	453,080	1929	148,933	1954	554,700	1979	165,345	2004	162,751
1905	0	1930	98,689	1955	260,200	1980	141,397	2005	131,179
1906	0	1931	214,139	1956	311,600	1981	241,603	2006	225,931
1907	0	1932	107,235	1957	286,700	1982	221,878	2007	293,104
1908	0	1933	123,059	1958	138,800	1983	195,235	2008	404,705
1909	0	1934	126,500	1959	345,400	1984	162,611	2009	286,163
1910	0	1935	72,000	1960	339,100	1985	121,857	2010	212,998
1911	0	1936	252,700	1961	393,500	1986	346,246	2011	190,986
1912	0	1937	196,500	1962	597,400	1987	245,421	2012	238,344
1913	0	1938	288,300	1963	528,900	1988	294,404	2013	292,882
1914	0	1939	26,300	1964	281,700	1989	140,276	2014	261,363
1915	0	1940	9,900	1965	401,500	1990	201,132	2015	241,286
1916	0	1941	16,800	1966	664,100	1991	245,665	2016	227,546
1917	0	1942	32,200	1967	392,500	1992	210,156	2017	291,429
1918	536,332	1943	0	1968	453,600	1993	252,520	2018	246,840
1919	0	1944	33,800	1969	286,300	1994	292,933	2019	257,397
1920	60,680	1945	243,800	1970	228,400	1995	270,741	2020	188,417
1921	68,809	1946	94,000	1971	316,200	1996	312,550		
1922	0	1947	184,900	1972	187,076	1997	313,849		
1923	61,454	1948	192,100	1973	170,096	1998	134,622		
1924	0	1949	81,900	1974	188,044	1999	335,031		

Table 5. Percentage of coastwide commercial landings of black drum without month data. Increasingly dark green color indicates increasing monthly coverage.

1950	100.00%	**1971**	######	**1992**	0.27%	**2013**	0.00%
1951	100.00%	**1972**	79.22%	**1993**	3.08%	**2014**	0.00%
1952	100.00%	**1973**	82.42%	**1994**	0.50%	**2015**	0.00%
1953	100.00%	**1974**	87.32%	**1995**	3.43%	**2016**	0.00%
1954	100.00%	**1975**	85.56%	**1996**	0.00%	**2017**	0.00%
1955	100.00%	**1976**	95.41%	**1997**	0.00%	**2018**	0.00%
1956	100.00%	**1977**	92.67%	**1998**	0.00%	**2019**	0.00%
1957	100.00%	**1978**	30.32%	**1999**	0.00%	**2020**	0.00%
1958	100.00%	**1979**	25.82%	**2000**	0.00%		
1959	100.00%	**1980**	6.44%	**2001**	0.00%		
1960	100.00%	**1981**	27.48%	**2002**	0.00%		
1961	100.00%	**1982**	26.37%	**2003**	0.00%		
1962	100.00%	**1983**	54.86%	**2004**	0.00%		
1963	100.00%	**1984**	57.99%	**2005**	0.00%		
1964	100.00%	**1985**	51.28%	**2006**	0.00%		
1965	100.00%	**1986**	66.10%	**2007**	0.00%		
1966	100.00%	**1987**	55.99%	**2008**	0.00%		
1967	100.00%	**1988**	60.66%	**2009**	0.00%		
1968	100.00%	**1989**	20.99%	**2010**	0.00%		
1969	100.00%	**1990**	2.15%	**2011**	0.00%		
1970	100.00%	**1991**	0.00%	**2012**	0.00%		

Table 6. Black drum dead discard estimates (number of fish) from North Carolina commercial estuarine gillnet fisheries.

Year	Dead Discards
2004	15,881
2005	12,851
2006	9,035
2007	15,630
2008	127,861
2009	7,189
2010	1,694
2011	13,348
2012	793
2013	39,359
2014	30,429
2015	86,517
2016	87,059
2017	17,130
2018	4,655
2019	32,841
2020	2,099

Table 7. Mean weight data used to convert MRIP released alive estimates in numbers to weight. A single asterisk indicates data were borrowed from DE waves 5-6 and two asterisks indicate data were borrowed from VA waves 5-6.

State & Waves	2015 Assessment			Current Assessment		
	Years	Mean Weight (lbs)	n	Years	Mean Weight (lbs)	n
NJ waves 2-3	1981-2012	23.92	81	1981-2020	36.99	248
NJ wave 4	1981-2012	7.59	6	1981-2020	17.58	14
NJ waves 5-6	1981-2012	33.29	3*	1981-2000	NA	0*
DE waves 2-3	1981-2012	36.29	40	1981-2020	32.35	126
DE wave 4	1981-2012	2.75	33	1981-2020	5.24	41
DE waves 5-6	1981-2012	0.89	63	1981-2009	0.69	62
MD waves 2-3	1981-2012	37.82	15	1981-2020	48.42	37
MD wave 4	1981-2012	43.72	20	1981-2020	50.69	30
MD waves 5-6	1981-2012	NA	0**	1981-1994	NA	0*
VA wave 2-3	1981-2012	29.87	52	1981-2020	37.56	205
VA wave 4	1981-2012	20.14	12	1981-2020	15.67	24
VA waves 5-6	1981-2012	5.68	46	1981-1987	13.31	3*
NC all waves	1981-2012	1.52	4,145	1981-2013	1.59	4,622
SC all waves	1981-2006	2.17	598	1981-2006	2.55	606
GA all waves	1981-1997	1.53	686	1981-1997	1.74	668
FL all waves	1981-1988	2.02	500	1981-1988	1.96	476

Table 8. Sample sizes of recreational fishing trips from the directed trips data set by factor considered in the standardization of MRIP CPUE.

Year	Area			Angler Avidity (hours)						Mode			Wave						State					
	State Seas (≤3 miles)	EEZ (>3 miles)	Inland	[0,10)	[10,20)	[20,30)	[30,40)	[40,50)	[50,62]	Charter	Private /Rental Boat	Shore	1	2	3	4	5	6	FL	GA	NC	NJ and DE	SC	VA and MD
1982	27	1	52	51	17	5	3	2	2	0	37	43	0	4	33	12	27	4	45	19	4	0	12	0
1983	41	1	132	140	23	4	2	0	5	31	73	70	11	15	70	36	22	20	79	20	0	1	5	69
1984	31	2	99	91	24	8	3	1	5	1	50	81	11	23	30	13	20	35	105	15	0	0	8	4
1985	63	29	107	155	16	12	6	2	8	27	87	85	6	17	74	29	24	49	71	50	4	1	6	67
1986	14	11	271	237	31	15	2	5	6	42	204	50	18	23	98	65	48	44	86	109	8	5	18	70
1987	39	3	248	247	29	9	2	2	1	33	202	55	16	50	63	58	67	36	75	132	26	2	23	32
1988	7	3	73	66	11	3	0	1	2	2	59	22	26	22	34	1	0	0	53	20	1	0	5	4
1989	10	2	89	79	12	7	0	2	1	9	78	14	10	9	16	26	24	16	28	51	3	0	11	8
1990	14	15	74	81	11	4	1	3	3	3	76	24	8	13	33	15	13	21	51	13	8	2	7	22
1991	31	5	132	119	26	15	7	0	1	7	105	56	12	10	20	22	39	65	95	36	23	6	3	5
1992	30	3	176	162	27	15	1	3	1	11	127	71	0	29	55	32	37	56	111	44	14	0	13	27
1993	80	20	194	203	53	13	8	11	6	13	135	146	19	35	72	28	55	85	171	24	47	5	16	31
1994	126	11	220	256	50	24	12	8	7	13	187	157	42	73	52	57	47	86	235	25	68	0	12	17
1995	288	6	205	355	81	40	11	7	5	12	164	323	34	56	49	44	142	174	140	29	263	3	19	45
1996	262	12	211	364	66	20	19	6	10	12	188	285	12	43	51	88	162	129	120	13	292	2	39	19
1997	125	11	194	240	58	13	7	5	7	8	197	125	7	46	67	75	72	63	124	15	124	7	47	13
1998	225	7	244	314	88	36	18	11	9	8	214	254	35	59	48	65	145	124	244	14	166	7	27	18
1999	338	12	401	537	118	52	18	17	9	17	359	375	73	93	65	112	207	201	403	23	254	1	61	9
2000	261	9	389	470	102	37	19	9	22	16	358	285	55	119	100	103	161	121	364	72	164	2	47	10
2001	214	8	503	514	122	39	15	21	14	16	411	298	69	72	93	122	192	177	428	45	198	14	24	16
2002	229	6	450	494	109	35	31	8	8	22	398	265	34	77	100	175	178	121	284	51	265	24	34	27
2003	262	11	506	577	110	48	21	13	10	39	433	307	57	95	166	135	178	148	316	96	273	24	37	33
2004	189	3	392	397	112	34	20	7	14	17	339	228	39	48	111	76	173	137	254	47	207	20	29	27
2005	160	6	335	414	48	16	9	10	4	55	265	181	56	53	112	57	102	121	213	41	136	64	30	17
2006	210	10	413	485	93	29	11	9	6	38	390	205	66	109	111	90	125	132	283	46	153	59	73	19
2007	386	7	469	636	128	46	22	17	13	30	406	426	48	82	140	100	150	342	372	63	277	40	59	51
2008	386	17	748	838	175	71	37	9	21	81	597	473	74	105	299	154	259	260	381	103	376	133	75	83
2009	232	10	559	588	121	46	15	17	14	76	432	293	69	123	239	101	153	116	290	51	201	111	72	76
2010	294	8	606	662	130	50	33	14	19	43	522	343	110	99	195	139	202	163	397	60	322	48	43	38
2011	528	4	478	783	122	51	27	19	8	58	344	608	46	84	143	95	367	275	305	22	526	69	47	41
2012	346	3	502	611	154	39	29	10	8	61	419	371	81	90	119	131	177	253	253	50	457	35	47	9
2013	312	6	362	490	94	50	22	14	10	10	320	350	52	72	164	103	138	151	178	38	294	45	86	39
2014	295	2	445	548	103	58	13	12	8	36	375	331	40	43	190	98	181	190	273	38	251	40	104	36
2015	371	6	476	619	146	44	19	14	11	38	435	380	29	67	171	115	256	215	203	62	330	55	143	60
2016	341	5	731	803	149	69	21	22	13	102	638	337	92	88	211	154	286	246	233	103	373	14	299	55
2017	382	9	763	838	171	69	29	23	24	79	645	430	49	154	220	162	275	294	245	99	425	25	294	66
2018	406	11	835	983	155	54	37	14	9	139	646	467	49	173	278	206	342	204	211	109	448	68	338	78
2019	259	13	823	811	154	68	30	21	11	96	700	299	46	119	294	184	288	164	196	107	338	66	305	83
2020	243	16	705	689	159	57	28	20	11	113	592	259	44	40	170	219	229	262	180	75	386	26	261	36

Table 9. Deviance summary table for the final positive observation GLM used to estimate MRIP CPUE.

Factor	Df	Resid. Df	Resid. Dev	Deviance	% Deviance Reduced
NULL	1	16,855	13,644	13,644	-
year	38	16,817	13,261	383	2.59
mode	2	16,815	13,052	209	1.52
state	5	16,810	12,942	110	0.78
wave	5	16,805	12,842	101	0.71

Table 10. Deviance summary table for the final proportion positive observation GLM used to estimate recreational CPUE.

Factor	Df	Resid. Df	Resid. Dev	Deviance	% Deviance Reduced
NULL	1	22,992	26,679	26,679	-
year	38	22,954	26,419	260	0.81
state	5	22,949	24,264	2,155	8.07
wave	5	22,944	23,241	1,023	3.82
mode	2	22,942	23,098	143	0.53

Table 11. Recreational CPUE estimated from MRIP APAIS data selected with the directed trips method.

Year	n	Proportion Positive	Numbers-Based CPUE			Weight-Based CPUE
			Nominal Index	Standardized Index	Standardized Index CV	Index
1982	80	0.713	0.249	0.247	0.096	0.378
1983	174	0.598	0.168	0.234	0.101	0.897
1984	132	0.682	0.244	0.281	0.096	0.751
1985	199	0.573	0.422	0.228	0.073	0.933
1986	296	0.720	0.309	0.330	0.078	0.952
1987	290	0.762	0.279	0.277	0.156	0.594
1988	83	0.446	0.171	0.250	0.124	0.590
1989	101	0.832	0.301	0.318	0.121	1.591
1990	103	0.650	0.248	0.272	0.091	0.596
1991	168	0.774	0.303	0.309	0.087	0.773
1992	209	0.746	0.268	0.302	0.077	0.891
1993	294	0.721	0.286	0.299	0.071	0.652
1994	357	0.700	0.271	0.271	0.063	0.788
1995	499	0.790	0.477	0.309	0.065	0.555
1996	485	0.843	0.386	0.307	0.072	0.838
1997	330	0.818	0.402	0.342	0.065	0.997
1998	476	0.794	0.332	0.337	0.057	0.970
1999	751	0.807	0.388	0.352	0.061	0.835
2000	659	0.754	0.388	0.346	0.060	1.046
2001	725	0.728	0.393	0.344	0.062	0.823
2002	685	0.756	0.411	0.355	0.059	0.800
2003	779	0.751	0.353	0.323	0.064	0.749
2004	584	0.680	0.294	0.266	0.066	0.854
2005	501	0.667	0.291	0.282	0.062	0.675
2006	633	0.698	0.327	0.332	0.058	1.050
2007	862	0.785	0.473	0.394	0.055	0.897
2008	1,151	0.731	0.369	0.346	0.059	1.095
2009	801	0.659	0.336	0.338	0.058	1.237
2010	908	0.689	0.338	0.325	0.058	0.802
2011	1,010	0.715	0.428	0.336	0.060	0.805
2012	851	0.730	0.380	0.314	0.063	1.093
2013	680	0.722	0.462	0.375	0.062	0.813
2014	742	0.706	0.406	0.345	0.060	0.844
2015	853	0.720	0.490	0.387	0.057	1.041
2016	1,077	0.758	0.513	0.412	0.058	1.003
2017	1,154	0.752	0.458	0.390	0.056	0.957
2018	1,252	0.728	0.472	0.391	0.058	0.944
2019	1,095	0.719	0.433	0.390	0.058	0.972
2020	964	0.763	0.434	0.365	0.140	1.057

Table 12. Black drum recreational catch data from the MRFSS/MRIP time period.

Year	Harvest				Released Alive			Dead Discards	Total Removals	
	Number	Number PSE	Pounds	Pounds PSE	Number	Number PSE	Pounds	Pounds	Pounds	% Dead Discards
1981	573,206	0.24	1,645,760	0.33	29,080	0.78	55,210	4,417	1,650,177	0.3
1982	835,033	0.30	1,277,641	0.29	3,400	1.03	8,686	695	1,278,336	0.1
1983	881,917	0.26	3,447,000	0.28	31,861	0.72	61,566	4,925	3,451,925	0.1
1984	1,108,633	0.27	2,957,380	0.48	36,368	0.56	99,978	7,998	2,965,378	0.3
1985	790,724	0.21	3,378,976	0.31	65,736	0.41	123,277	9,862	3,388,839	0.3
1986	1,925,455	0.48	5,706,344	0.54	160,277	0.34	308,765	24,701	5,731,045	0.4
1987	1,206,446	0.41	2,621,030	0.45	153,819	0.46	297,507	23,801	2,644,831	0.9
1988	442,169	0.24	1,082,395	0.20	88,864	0.53	170,728	13,658	1,096,053	1.2
1989	269,659	0.28	1,585,848	0.40	77,526	0.39	152,454	12,196	1,598,044	0.8
1990	308,587	0.29	721,464	0.27	147,434	0.31	277,257	22,181	743,645	3.0
1991	599,109	0.27	1,704,244	0.38	393,172	0.25	778,461	62,277	1,766,521	3.5
1992	657,468	0.19	2,151,294	0.20	212,341	0.24	411,014	32,881	2,184,175	1.5
1993	757,859	0.26	1,815,101	0.30	628,905	0.29	1,215,118	97,209	1,912,310	5.1
1994	710,829	0.16	2,483,012	0.18	445,868	0.24	880,583	70,447	2,553,458	2.8
1995	1,274,729	0.19	2,218,969	0.17	488,675	0.14	949,080	75,926	2,294,895	3.3
1996	868,496	0.13	2,090,661	0.15	473,343	0.19	1,571,600	125,728	2,216,389	5.7
1997	486,143	0.16	1,730,315	0.19	594,796	0.22	1,419,995	113,600	1,843,915	6.2
1998	864,886	0.20	2,867,573	0.20	1,095,887	0.20	2,778,588	222,287	3,089,860	7.2
1999	1,379,761	0.11	3,908,975	0.15	1,381,018	0.14	2,637,856	211,028	4,120,003	5.1
2000	1,856,802	0.19	6,679,779	0.19	1,047,135	0.18	2,090,586	167,247	6,847,026	2.4
2001	1,415,566	0.19	4,207,530	0.18	1,537,390	0.24	2,855,750	228,460	4,435,990	5.2
2002	1,625,540	0.13	4,243,122	0.15	1,110,556	0.18	1,925,485	154,039	4,397,161	3.5
2003	2,873,788	0.23	7,066,793	0.20	1,017,935	0.12	1,951,942	156,155	7,222,948	2.2
2004	992,899	0.17	4,243,320	0.24	1,135,547	0.36	2,585,777	206,862	4,450,182	4.6
2005	1,238,842	0.21	3,315,984	0.18	1,183,849	0.21	2,476,053	198,084	3,514,068	5.6
2006	1,153,278	0.20	4,115,605	0.22	1,418,715	0.20	4,025,619	322,050	4,437,655	7.3
2007	2,098,926	0.13	4,995,036	0.16	2,723,416	0.15	5,971,005	477,680	5,472,716	8.7
2008	2,277,842	0.12	10,716,306	0.14	2,770,784	0.15	5,275,213	422,017	11,138,323	3.8
2009	1,750,360	0.23	9,043,543	0.20	2,093,287	0.21	5,005,542	400,443	9,443,986	4.2
2010	1,863,550	0.13	5,772,021	0.14	2,806,086	0.20	5,771,077	461,686	6,233,707	7.4
2011	2,867,610	0.22	7,668,210	0.25	2,046,444	0.18	4,091,363	327,309	7,995,519	4.1
2012	1,196,197	0.17	3,374,032	0.17	1,980,435	0.22	7,683,926	614,714	3,988,746	15.4
2013	2,783,783	0.12	6,307,931	0.14	2,642,403	0.16	5,465,736	437,259	6,745,190	6.5
2014	1,251,561	0.17	5,221,523	0.17	3,688,016	0.17	6,852,215	548,177	5,769,700	9.5
2015	890,095	0.14	4,780,158	0.30	5,179,832	0.13	11,545,462	923,637	5,703,795	16.2
2016	2,041,701	0.33	6,713,322	0.34	4,922,569	0.17	10,241,996	819,360	7,532,682	10.9
2017	1,743,542	0.26	6,344,762	0.29	5,018,452	0.15	10,246,312	819,705	7,164,467	11.4
2018	1,440,745	0.15	5,144,020	0.15	5,375,863	0.11	11,298,446	903,876	6,047,896	14.9
2019	1,438,609	0.12	4,169,758	0.11	3,469,125	0.12	8,053,561	644,285	4,814,043	13.4
2020	1,254,912	0.13	5,500,339	0.14	2,583,158	0.12	5,619,316	449,545	5,949,884	7.6

Table 13. MRIP 2020 black drum recreational catch estimates with percentage of imputed data from surrounding years due to COVID-19 sampling restrictions.

State	Harvest (pounds)			Released Alive (number)		
	Harvest	PSE	Percentage Imputed Data	Released Alive	PSE	Percentage Imputed Data
NEW JERSEY	535,249	43.9	99%	10,474	64.5	32%
DELAWARE	90,950	69.1	89%	8,301	33.5	32%
MARYLAND	53,825	68.1	0%	1,997	72.7	0%
VIRGINIA	251,724	60.7	20%	142,394	48.4	11%
NORTH CAROLINA	612,932	16.5	17%	704,357	18.9	8%
SOUTH CAROLINA	493,001	19	13%	678,836	16.9	7%
GEORGIA	298,894	31.8	33%	239,371	46.2	5%
FLORIDA	3,163,767	22.3	12%	797,425	27.4	26%

Table 14. Historical recreational catch estimates of black drum (1950-1980) estimated with saltwater angler participation data and MRIP CPUE data.

Year	*Harvest*	*Released Alive*		*Dead Discards*	*Total Removals*	
	Pounds	*Number*	*Pounds*	*Pounds*	*Pounds*	*% Dead Discards*
1950	1,226,337	92,478	183,424	14,674	1,241,011	1.2
1951	1,264,558	95,360	189,141	15,131	1,279,690	1.2
1952	1,302,780	98,243	194,857	15,589	1,318,369	1.2
1953	1,341,002	101,125	200,574	16,046	1,357,048	1.2
1954	1,379,223	104,007	206,291	16,503	1,395,727	1.2
1955	1,417,445	106,890	212,008	16,961	1,434,406	1.2
1956	1,455,667	109,772	217,725	17,418	1,473,085	1.2
1957	1,493,888	112,654	223,442	17,875	1,511,764	1.2
1958	1,532,110	115,537	229,158	18,333	1,550,443	1.2
1959	1,600,076	94,475	198,762	15,901	1,615,977	1.0
1960	1,638,459	96,721	203,508	16,281	1,654,739	1.0
1961	1,794,716	121,530	246,596	19,728	1,814,443	1.1
1962	1,746,258	119,390	242,557	19,405	1,765,662	1.1
1963	1,784,971	121,489	244,059	19,525	1,804,495	1.1
1964	1,893,028	134,511	269,459	21,557	1,914,585	1.1
1965	2,019,890	146,840	290,466	23,237	2,043,127	1.1
1966	2,079,971	151,207	297,078	23,766	2,103,737	1.1
1967	2,247,594	163,777	324,060	25,925	2,273,519	1.1
1968	2,289,103	168,170	331,206	26,497	2,315,599	1.1
1969	2,388,793	176,840	349,880	27,990	2,416,784	1.2
1970	2,492,137	176,733	337,950	27,036	2,519,173	1.1
1971	2,968,108	191,334	371,794	29,744	2,997,851	1.0
1972	3,078,942	196,946	377,257	30,181	3,109,122	1.0
1973	3,272,770	213,662	417,703	33,416	3,306,187	1.0
1974	3,538,029	232,333	456,550	36,524	3,574,553	1.0
1975	3,635,545	238,051	466,435	37,315	3,672,860	1.0
1976	3,445,112	226,475	445,338	35,627	3,480,739	1.0
1977	3,160,219	206,970	411,616	32,929	3,193,149	1.0
1978	2,882,733	195,813	390,005	31,200	2,913,933	1.1
1979	3,056,911	200,326	399,695	31,976	3,088,886	1.0
1980	2,642,363	184,061	371,098	29,688	2,672,051	1.1

Table 15. Historical recreational catch estimates of black drum (1900-1949) extrapolated with exponential regression.

Year	*Harvest Pounds*	*Year*	*Harvest Pounds*
1900	145,186	1925	423,273
1901	151,535	1926	441,782
1902	158,162	1927	461,101
1903	165,078	1928	481,264
1904	172,297	1929	502,310
1905	179,831	1930	524,275
1906	187,695	1931	547,201
1907	195,902	1932	571,130
1908	204,469	1933	596,105
1909	213,410	1934	622,172
1910	222,743	1935	649,379
1911	232,483	1936	677,776
1912	242,649	1937	707,415
1913	253,260	1938	738,349
1914	264,335	1939	770,637
1915	275,894	1940	804,336
1916	287,959	1941	839,509
1917	300,551	1942	876,220
1918	313,694	1943	914,536
1919	327,411	1944	954,528
1920	341,729	1945	996,269
1921	356,672	1946	1,039,835
1922	372,269	1947	1,085,306
1923	388,548	1948	1,132,765
1924	405,539	1949	1,182,300

Table 16. Regional total fishery removals of black drum (pounds). Asterisks indicate confidential data that have been redacted.

Year	*Mid-Atlantic January-August*			*Mid-Atlantic September-December*			*South Atlantic*			Total
	Recreational		*Commercial Landings*	*Recreational*		*Commercial Landings*	*Recreational*		*Commercial Landings*	
	Harvest	*Dead Discards*		*Harvest*	*Dead Discards*		*Harvest*	*Dead Discards*		
1981	0	0	65,433	366,219	0	967	1,279,541	4,417	175,203	**1,891,780**
1982	0	0	57,648	0	0	852	1,277,641	695	163,378	**1,500,214**
1983	1,539,971	0	105,541	0	0	1,559	1,907,028	4,925	88,135	**3,647,160**
1984	77,375	2,231	92,927	0	0	1,373	2,880,005	5,767	68,311	**3,127,989**
1985	225,757	0	61,584	594	130	910	3,152,626	9,732	59,363	**3,510,696**
1986	1,205,067	110	225,546	24,789	0	3,332	4,476,487	24,591	117,368	**6,077,291**
1987	381,902	0	135,420	3,948	2	2,000	2,235,180	23,798	108,001	**2,890,252**
1988	57,594	0	175,998	0	0	2,600	1,024,801	13,658	115,806	**1,390,457**
1989	604,115	0	83,009	1,796	0	1,486	979,936	12,196	55,781	**1,738,320**
1990	18,176	0	156,974	3,275	306	2,849	700,013	21,874	41,309	**944,777**
1991	89,681	1,127	192,910	9,529	19	1,825	1,605,034	61,132	50,930	**2,012,186**
1992	273,501	0	162,882	186,654	0	2,756	1,691,139	32,881	44,518	**2,394,331**
1993	0	0	117,612	13,903	507	1,184	1,801,198	96,702	133,724	**2,164,830**
1994	4,328	1,266	223,139	36,180	137	207	2,442,504	69,044	69,587	**2,846,391**
1995	284,546	12,474	123,808	2,229	3,352	1,092	1,932,193	60,100	145,841	**2,565,636**
1996	105,830	63,413	163,315	8,130	1,023	13,144	1,976,701	61,292	136,091	**2,528,939**
1997	10,275	22,974	203,857	38,485	307	13,002	1,681,555	90,318	96,990	**2,157,764**
1998	234,582	60,825	88,170	17,125	2,258	2,497	2,615,866	159,204	43,955	**3,224,482**
1999	14,214	0	190,293	138,965	155	4,433	3,755,796	210,873	140,305	**4,455,034**
2000	31,164	0	117,445	38,679	457	5,895	6,609,936	166,790	116,844	**7,087,210**
2001	366,253	9,171	86,104	15,367	7,356	1,619	3,825,910	211,933	97,269	**4,620,982**
2002	102,841	8,398	36,314	149,471	11,408	13,231	3,990,810	134,234	505,954	**4,952,661**
2003	607,404	17,479	119,415	122,953	2,286	11,511	6,336,436	136,390	158,386	**7,512,260**
2004	1,106,347	39,301	*	25,189	786	*	3,111,784	166,775	*	**4,612,933**
2005	472,325	34,038	73,759	9,630	6,274	7,130	2,834,029	157,772	50,290	**3,645,248**
2006	1,382,108	133,367	*	1,126	11,152	*	2,732,371	177,531	*	**4,663,586**
2007	790,407	89,732	130,547	202,031	5,464	1,509	4,002,598	382,484	161,047	**5,765,820**
2008	4,990,002	35,160	82,187	110,744	21,548	961	5,615,560	365,310	321,557	**11,543,028**
2009	4,683,317	121,199	116,681	11,929	16,716	4,305	4,348,297	262,528	165,177	**9,730,149**
2010	660,999	46,933	126,645	17,363	5,141	1,416	5,093,659	409,612	84,937	**6,446,705**
2011	1,428,764	60,820	108,624	226,610	16,000	3,980	6,012,836	250,489	78,382	**8,186,505**
2012	75,504	327,395	127,045	611	2,458	2,533	3,297,917	284,861	108,766	**4,227,090**
2013	188,279	36,214	128,301	34,163	5,851	8,455	6,085,489	395,194	156,126	**7,038,072**
2014	132,453	45,763	117,601	16,819	15,928	958	5,072,251	486,486	142,804	**6,031,063**
2015	486,115	175,181	138,857	16,575	37,001	879	4,277,468	711,454	101,550	**5,945,081**
2016	197,401	70,059	109,343	50,965	905	470	6,464,956	748,396	117,734	**7,760,228**
2017	301,120	97,751	66,684	212,197	12,135	580	5,831,445	709,819	224,165	**7,455,896**
2018	1,070,865	78,290	116,859	5,890	12,393	658	4,067,265	813,192	129,323	**6,294,735**
2019	339,116	100,566	155,547	3,182	6,963	184	3,827,460	536,756	101,666	**5,071,439**
2020	727,660	55,339	60,510	204,088	7,323	1,895	4,568,591	386,884	126,013	**6,138,302**

Table 17. Percentage of coastwide black drum commercial landings contributed by each state over the last ten years of the assessment time series (2011-2020). Asterisks indicate confidential data that have been redacted.

State	Percentage
RI	0.01
CT	*
NY	0.08
NJ	4.2
DE	*
MD	0.62
VA	32.53
NC	38.64
SC	0.02
GA	*
FL	14.14

Table 18. Percentage of black drum commercial landings by gear type over the last ten years of the assessment time series (2011-2020) from states accounting for at least 1% of the landings. Asterisks indicate confidential data and/or data less than 0.5% of the coastwide landings redacted to protect confidentiality.

State	Gear Type Name	Percentage of State Landings	Percentage of Coastwide Landings
New Jersey	FIXED NETS	*	*
	GILL NETS	19.02	0.8
	HAND LINE	*	*
	HOOK AND LINE	*	*
	NOT CODED	*	*
	PURSE SEINES	*	*
	TRAWLS	12.78	0.54
Delaware	GILL NETS	*	*
	HOOK AND LINE	*	*
	NOT CODED	*	*
Virginia	DREDGE	*	*
	FIXED NETS	2.64	0.86
	GILL NETS	90.87	29.57
	HAND LINE	*	*
	HAUL SEINES	*	*
	HOOK AND LINE	1.69	0.55
	LONG LINES	*	*
	NOT CODED	*	*
	OTHER GEARS	*	*
	TRAWLS	*	*
North Carolina	BY HAND	*	*
	DIP NETS AND CAST NETS	*	*
	DREDGE	*	*
	FIXED NETS	26.08	10.08
	GILL NETS	70.5	27.24
	HAUL SEINES	*	*
	HOOK AND LINE	*	*
	LONG LINES	*	*
	NOT CODED	*	*
	POTS AND TRAPS	*	*
	RAKES, HOES, AND TONGS	*	*
	SPEARS AND GIGS	1.36	0.53
	TRAWLS	*	*
Florida	BY HAND	*	*
	DIP NETS AND CAST NETS	25.7	3.63
	GILL NETS	*	*
	HAND LINE	*	*
	HAUL SEINES	11.16	1.58
	HOOK AND LINE	58.98	8.34
	NOT CODED	*	*
	POTS AND TRAPS	*	*
	SPEARS AND GIGS	*	*
	TRAWLS	*	*

Table 19. Percentage of coastwide black drum commercial landings contributed by each fleet. Color coding is by year, with color gradients from dark green cells indicating the greatest contributors to dark red cells indicating the smallest contributors. Note years with one or two confidential records are not included. Asterisks indicate confidential data that have been redacted.

Year	North Gill Net	MDVA Gill Net	MDVA Fixed	MDVA Hook&Line	NC Gill Net	NC Fixed	South All Gear
1989	9%	31%	10%	10%	1%	14%	25%
1992	12%	63%	2%	2%	1%	2%	18%
1993	16%	18%	11%	1%	3%	37%	12%
1994	21%	52%	2%	1%	6%	5%	12%
1995	20%	25%	1%	1%	21%	27%	7%
1998	9%	55%	3%	0%	14%	6%	12%
1999	38%	18%	2%	0%	27%	10%	5%
2001	12%	29%	1%	4%	28%	14%	10%
2005	10%	45%	1%	5%	23%	11%	4%
2007	14%	*	*	*	39%	11%	4%
2012	13%	39%	2%	1%	31%	9%	6%
2013	14%	31%	1%	1%	31%	12%	10%
2014	11%	33%	1%	0%	13%	7%	35%
2016	23%	23%	1%	2%	25%	15%	12%
2017	8%	13%	1%	1%	48%	15%	14%
2018	16%	28%	1%	3%	33%	11%	8%
2019	7%	44%	3%	7%	17%	14%	8%

Table 20. Recreational harvest of black drum (thousands of fish) by state and year.

Year	New Jersey	Delaware	Maryland	Virginia	North Carolina	South Carolina	Georgia	Florida
1981	0	9	0	2	0	31	14	518
1982	0	0	0	0	3	19	15	799
1983	3	0	16	14	0	102	34	712
1984	0	0	2	1	0	31	34	1,041
1985	0	1	1	3	18	24	94	651
1986	18	101	4	6	30	39	121	1,606
1987	0	6	1	8	90	40	80	981
1988	0	0	0	1	13	16	67	344
1989	0	0	6	4	1	49	69	141
1990	0	11	0	2	8	18	38	231
1991	0	5	0	1	18	8	82	485
1992	0	0	0	8	30	26	38	555
1993	0	7	0	3	98	31	43	575
1994	0	0	0	12	132	9	27	530
1995	0	0	5	12	931	62	40	225
1996	0	0	0	6	469	94	12	287
1997	0	0	0	1	107	71	21	286
1998	0	1	3	5	105	35	13	703
1999	0	1	1	9	374	131	18	845
2000	0	4	1	9	294	339	149	1,061
2001	9	3	0	2	401	25	24	951
2002	7	8	6	7	847	126	54	569
2003	32	0	3	17	1,268	614	77	864
2004	20	1	1	4	297	71	61	536
2005	21	2	0	9	465	278	37	426
2006	65	38	1	1	276	273	55	444
2007	42	9	0	46	876	240	99	787
2008	117	21	0	71	926	97	169	877
2009	69	1	0	42	450	46	42	1,101
2010	13	4	7	5	650	85	138	962
2011	23	1	0	127	1,259	30	26	1,402
2012	1	0	0	8	556	91	43	497
2013	11	2	0	6	1,512	144	65	1,044
2014	0	1	2	11	109	97	48	984
2015	11	0	1	2	276	37	48	515
2016	6	0	0	6	459	256	96	1,218
2017	18	1	1	17	356	242	64	1,045
2018	40	9	1	4	135	197	129	926
2019	8	1	5	7	156	349	158	756
2020	28	5	14	17	213	198	101	678

Table 21. Percentage of age samples for the top ten most frequently sampled ages in the VA fishery-dependent age data from 2016-2020.

Age	Past CAA %
3	8.11
4	5.54
9	9
10	9.1
11	6.82
12	4.06
14	4.65
15	3.86
16	4.06
17	7.02
Total	62.22

Table 22. Total sample size (across all ages in the catch) and associated CV of the catch-at-age estimate for the most prevalent age (age-10).

Sample Size	CV
569	0.1
533	0.14
568	0.12
606	0.12
560	0.15
554	0.2
594	0.18
596	0.2
559	0.2
585	0.14

Table 23. Number of length samples collected by MRIP from black drum harvested by recreational anglers. Cells shaded in red indicate sample sizes less than 30. Cells shaded in gray indicate no estimated harvest.

Year	Mid-Atlantic	NJ	DE	MD	VA	NC	SC	GA	FL
1981	1	NA	0	NA	1	NA	3	8	19
1982	NA	NA	NA	NA	NA	1	10	13	58
1983	31	1	NA	20	10	NA	3	17	64
1984	4	NA	NA	3	1	NA	13	18	112
1985	42	NA	1	12	29	2	4	71	61
1986	55	1	13	1	40	5	11	134	65
1987	32	NA	3	0	29	45	17	171	69
1988	1	NA	NA	NA	1	16	15	44	50
1989	16	NA	NA	13	3	1	21	96	11
1990	8	NA	7	NA	1	6	5	5	9
1991	9	NA	8	NA	1	22	3	5	50
1992	15	NA	NA	NA	15	7	20	33	39
1993	23	NA	21	NA	2	61	16	16	57
1994	3	NA	NA	NA	3	121	5	23	86
1995	5	NA	NA	0	5	390	14	19	31
1996	7	NA	2	NA	5	339	40	2	49
1997	3	NA	2	NA	1	144	66	6	40
1998	4	NA	1	0	3	167	21	6	93
1999	1	NA	0	1	0	248	44	7	177
2000	4	NA	1	1	2	178	37	44	138
2001	10	7	1	NA	2	173	6	18	176
2002	19	2	11	1	5	219	15	43	77
2003	17	3	NA	2	12	198	21	78	95
2004	19	14	1	2	2	127	13	30	79
2005	19	10	3	NA	6	89	17	18	68
2006	53	41	9	2	1	104	155	32	69
2007	23	5	6	NA	12	191	105	79	110
2008	83	67	15	NA	1	363	50	112	174
2009	86	42	29	NA	15	191	26	37	141
2010	19	10	6	0	3	258	19	76	136
2011	24	11	7	NA	6	567	13	17	82
2012	21	6	13	NA	2	237	16	25	60
2013	17	3	7	NA	7	154	48	21	77
2014	11	1	4	2	4	33	41	42	88
2015	17	9	4	2	2	75	20	31	52
2016	20	7	4	2	7	114	111	65	61
2017	17	3	1	2	11	161	140	50	62
2018	42	10	20	2	10	128	162	53	59
2019	29	6	6	2	15	106	148	63	48
2020	58	10	29	1	18	215	136	67	91

Table 24. Number of length samples collected by MRIP and supplemental sampling programs conducted by state agencies from black drum harvested by recreational anglers. Cells shaded in red indicate sample sizes less than 30. Cells shaded in gray indicate no estimated harvest.

Year	Mid-Atlantic	NJ	DE	MD	VA	NC	SC	GA	FL
1981	1	NA	0	NA	1	NA	3	8	19
1982	NA	NA	NA	NA	NA	1	10	13	58
1983	31	1	NA	20	10	NA	3	17	92
1984	4	NA	NA	3	1	NA	13	18	212
1985	42	NA	1	12	29	2	4	71	78
1986	55	1	13	1	40	5	24	134	65
1987	32	NA	3	0	29	45	45	171	69
1988	1	NA	NA	NA	1	16	20	44	50
1989	16	NA	NA	13	3	1	35	96	11
1990	8	NA	7	NA	1	6	11	5	9
1991	9	NA	8	NA	1	22	20	5	50
1992	15	NA	NA	NA	15	7	26	33	39
1993	23	NA	21	NA	2	61	24	16	57
1994	3	NA	NA	NA	3	121	24	23	86
1995	5	NA	NA	0	5	390	23	19	31
1996	7	NA	2	NA	5	339	96	2	49
1997	3	NA	2	NA	1	144	142	6	40
1998	4	NA	1	0	3	167	54	6	93
1999	16	NA	0	1	15	248	92	7	177
2000	59	NA	1	1	57	178	182	44	138
2001	11	7	1	NA	3	173	52	18	176
2002	27	2	11	1	13	219	178	43	77
2003	17	3	NA	2	12	198	111	78	96
2004	19	14	1	2	2	127	51	30	79
2005	19	10	3	NA	6	89	49	18	68
2006	53	41	9	2	1	104	188	32	70
2007	63	5	6	NA	52	191	132	79	112
2008	343	67	49	NA	227	363	62	112	174
2009	247	42	123	NA	82	191	54	37	141
2010	165	10	89	0	66	258	39	76	136
2011	126	11	76	NA	39	567	30	17	83
2012	55	6	31	NA	18	237	27	25	63
2013	70	3	43	NA	24	154	66	21	97
2014	149	1	27	2	119	33	45	42	103
2015	79	9	4	2	64	75	22	31	71
2016	119	7	15	2	95	114	127	65	61
2017	54	3	1	2	48	161	174	50	63
2018	194	10	62	2	120	128	173	53	61
2019	130	6	54	2	68	106	167	63	61
2020	105	10	67	1	27	215	138	67	100

Table 25. Number of length samples collected from commercial harvest by fleet and year. Cells shaded in red indicate sample sizes less than 30. Cells shaded in gray indicate no recorded harvest.

Year	North Gill Net	MDVA Gill Net	MDVA Fixed	MDVA Hook&Line	NC Gill Net	NC Long Fixed	South All Gear*
1989	0	25	12	0	0	0	11
1990	0	4	35	0	0	0	9
1991	0	87	22	0	0	0	50
1992	0	39	0	0	0	0	39
1993	0	11	84	0	0	0	57
1994	0	129	5	0	26	19	86
1995	0	1	5	0	19	145	31
1996	0	28	35	0	19	182	49
1997	0	203	7	0	25	65	40
1998	0	77	18	1	27	44	93
1999	0	201	10	NA	116	472	177
2000	0	110	12	0	247	516	138
2001	0	104	46	5	170	243	176
2002	0	39	35	17	579	1,254	77
2003	0	4	25	0	384	193	96
2004	0	0	73	0	271	94	79
2005	0	11	14	0	394	84	68
2006	0	3	14	0	1,070	783	70
2007	0	3	15	0	1,557	346	112
2008	0	0	14	0	1,972	1,016	174
2009	63	1	39	0	1,012	126	141
2010	84	23	14	1	471	190	136
2011	59	0	5	0	1,165	216	83
2012	23	20	16	0	1,199	254	63
2013	45	26	48	0	1,039	174	97
2014	58	7	39	0	693	60	103
2015	90	0	20	0	473	99	71
2016	0	392	59	0	794	297	61
2017	63	0	48	28	1,097	80	63
2018	86	74	49	57	472	196	61
2019	6	2	46	16	287	248	61
2020	45	3	28	0	246	19	100

*South All Gear fleet sample sizes are from a proxy data set (MRIP length sampling).

Table 26. Number of black drum age samples collected by state, region, and coastwide. Cells shaded in red indicate samples sizes less than 500, cells shaded in yellow indicate samples sizes of 500 to 1,000, and cells shaded in green indicate sample sizes greater than 1,000.

Year	Coastwide	Mid-Atlantic	South Atlantic	NJ	DE	MD	VA	NC	SC	GA	FL
1981	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0
1983	22	0	22	0	0	0	0	0	0	0	22
1984	101	0	101	0	0	0	0	0	0	0	101
1985	27	0	27	0	0	0	0	0	1	0	26
1986	46	0	46	0	0	0	0	0	46	0	0
1987	73	0	73	0	0	0	0	0	73	0	0
1988	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0
1991	26	0	26	0	0	0	0	0	26	0	0
1992	38	0	38	0	0	0	0	0	38	0	0
1993	87	0	87	0	0	0	0	0	87	0	0
1994	29	0	29	0	0	0	0	0	29	0	0
1995	16	0	16	0	0	0	0	0	16	0	0
1996	52	0	52	0	0	0	0	0	52	0	0
1997	66	0	66	0	0	0	0	0	66	0	0
1998	83	6	77	0	0	0	6	0	46	31	0
1999	141	80	61	0	0	0	80	0	42	19	0
2000	182	42	140	0	0	0	42	0	113	27	0
2001	148	86	62	0	0	0	86	0	35	27	0
2002	242	70	172	0	0	0	59	0	135	37	0
2003	180	36	144	0	0	0	11	0	76	67	1
2004	68	18	50	0	0	0	14	0	29	21	0
2005	62	28	34	0	0	0	8	0	26	8	0
2006	51	15	36	0	0	0	7	0	27	9	0
2007	139	57	49	0	0	0	35	0	24	23	2
2008	409	206	176	0	26	0	171	0	10	166	0
2009	317	171	83	0	97	0	61	0	25	58	0
2010	394	211	172	0	129	0	71	0	19	153	0
2011	368	115	205	0	90	0	19	175	13	13	4
2012	458	55	387	0	33	0	19	307	11	45	24
2013	422	108	294	0	58	0	42	178	24	51	41
2014	670	178	468	0	62	0	102	393	7	47	21
2015	576	144	397	0	78	0	55	358	2	16	21
2016	1,108	400	702	0	11	0	372	571	20	106	5
2017	812	153	618	0	59	0	63	562	31	20	5
2018	735	320	373	0	105	0	215	350	11	0	12
2019	558	139	419	0	47	0	92	375	19	0	25
2020	208	73	74	0	67	0	6	64	1	0	9

Table 27. Number of black drum age samples collected along the coast by length bin and year. Length bins were converted from data in millimeters and were structured according to the methodology in Coggins et al. 2013. Cells shaded in red indicate sample sizes less than ten and cells shaded in green indicate sample sizes of at least ten.

Bin (inches)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
4.5276	0	0	0	0	0	0	3	5	0	0
6.1024	0	5	7	3	4	5	18	15	3	0
7.6772	70	47	38	99	129	96	139	73	51	8
9.252	44	35	12	25	58	60	54	17	35	2
10.827	23	63	14	79	47	90	83	49	69	4
12.402	7	40	31	37	22	65	39	20	43	5
13.976	8	98	57	128	45	208	85	51	102	17
15.551	23	71	79	62	43	128	100	63	74	13
17.126	7	10	37	15	18	35	70	26	11	8
18.701	13	12	27	21	11	22	52	45	21	14
20.276	2	3	4	3	3	7	12	12	11	2
21.85	5	5	8	6	11	12	12	22	14	2
23.425	1	1	0	4	3	3	5	14	2	1
25	14	1	0	2	8	3	5	8	8	0
26.575	4	1	1	8	4	12	4	18	8	3
28.15	3	0	2	8	1	3	5	6	3	2
29.724	12	6	17	26	8	9	19	22	13	18
31.299	5	8	14	18	15	16	7	14	7	4
32.874	19	9	13	34	31	82	9	26	9	8
34.449	24	5	11	24	26	105	11	49	15	8
36.024	4	4	5	9	17	54	8	17	5	4
37.598	6	4	5	16	8	52	15	45	16	11
39.173	2	0	1	1	6	7	2	12	11	4
40.748	2	0	2	3	8	10	3	25	9	7
42.323	1	2	1	1	2	2	1	11	5	1
43.898	10	5	4	4	6	9	4	16	10	1
45.472	6	5	8	6	4	4	1	8	2	0
47.047	3	2	0	1	0	1	1	1	1	0
48.622	2	0	0	1	2	1	2	1	0	0
50.197	0	0	3	2	0	1	1	1	0	0
51.772	0	0	0	0	1	0	1	1	0	0
53.346	0	0	1	0	0	0	0	0	0	0
54.921	0	0	0	0	0	0	0	0	0	0
56.496	0	0	0	0	0	0	0	0	0	0
58.071	0	0	0	0	0	0	0	0	0	0
59.646	0	0	0	0	0	0	0	0	0	0
61.22	0	0	0	0	0	0	0	0	0	0
62.795	0	0	0	0	0	0	0	0	0	0

Table 28. Methods used to calculate black drum indices of abundance.

Survey	Index calculation method	Details
MRIP CPUE	Delta method (Lo et al. 1992)	CPUE~year+state+mode+wave Presence ~year+state+mode+wave
NEAMAP Trawl	Stratified geometric mean	$\overline{\log Y_s} = \frac{\sum_{k=1}^{n} \log(Y_k + 1)}{n}$ $\bar{Y} = e^{\sum_{s=1}^{N} N_s \overline{\log Y_s}}$
NJ Ocean Trawl	Stratified arithmetic mean	$\bar{Y} = \frac{1}{N} \sum_{s=1}^{N} N_s \bar{Y_s}$
PSEG Seine	Negative binomial GLM	Catch~year+month+area
DE 16ft Trawl	Geometric mean	$\overline{\log Y} = \frac{\sum_{k=1}^{n} \log(Y_k + 1)}{n}$ $\bar{Y} = e^{\overline{\log Y}}$
DE 30ft Trawl	Geometric mean	$\overline{\log Y} = \frac{\sum_{k=1}^{n} \log(Y_k + 1)}{n}$ $\bar{Y} = e^{\overline{\log Y}}$
MD Seine	Geometric mean	$\overline{\log Y} = \frac{\sum_{k=1}^{n} \log(Y_k + 1)}{n}$ $\bar{Y} = e^{\overline{\log Y}}$
NC Gill Net	Stratified arithmetic mean	$\bar{Y} = \frac{1}{N} \sum_{s=1}^{N} N_s \bar{Y_s}$
SC Trammel	Stratified arithmetic mean	$\bar{Y} = \frac{1}{N} \sum_{s=1}^{N} N_s \bar{Y_s}$
GA Trammel	Stratified geometric mean	$\overline{\log Y_s} = \frac{\sum_{k=1}^{n} \log(Y_k + 1)}{n}$ $\bar{Y} = e^{\sum_{s=1}^{N} N_s \overline{\log Y_s}}$
FL Haul Seine	Negative binomial GLM	Catch~year+strata+month+bottom vegetation+shore type+secchi depth+windspeed

Table 29. Fishery-independent indices of abundance for black drum on the Atlantic coast.

Year	FL Haul Seine Survey		GA Trammel Net Survey		SC Trammel Net Survey		NC Gill Net Survey		MD Seine Survey		DE 16 FT Trawl Survey		DE 30 FT Trawl Survey		PSEG Seine Survey		NJ Ocean Trawl Survey		NEAMAP Trawl Survey	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1989									0.00	0.00							0.00	0.00		
1990									0.00	0.00	0.01	0.96	0.09	0.75			0.00	0.00		
1991					0.47	0.31			0.15	0.72	0.04	0.43	0.10	0.66			0.02	1.00		
1992					0.56	0.31			0.93	0.24	0.01	0.99	0.04	0.70			0.01	1.00		
1993					0.39	0.19			0.00	0.00	0.89	0.15	1.19	0.38			0.03	0.74		
1994					0.14	0.24			0.04	0.98	0.11	0.29	0.19	0.44			0.00	0.00		
1995					0.10	0.25			1.10	0.18	0.53	0.16	1.77	0.29	0.34	0.32	0.00	0.00		
1996					0.08	0.24			0.20	0.53	0.15	0.29	0.90	0.42	0.20	0.35	0.00	0.00		
1997					0.08	0.18			0.23	0.64	0.00	0.00	0.08	0.61	0.05	0.49	0.00	0.00		
1998					0.14	0.13			0.94	0.20	0.15	0.26	0.14	0.48	0.43	0.37	0.00	0.00		
1999	0.25	0.48			0.86	0.18			0.39	0.43	0.20	0.22	0.48	0.32	0.28	0.33	0.20	0.79		
2000	0.22	0.48			0.35	0.14			1.47	0.18	0.45	0.17	0.82	0.34	0.36	0.32	0.00	0.00		
2001	0.15	0.47			0.12	0.16			0.44	0.31	0.49	0.17	0.38	0.53	0.94	0.29	0.06	0.85		
2002	0.45	0.40			0.33	0.12			0.98	0.17	0.23	0.26	0.11	0.58	0.29	0.25	0.31	0.43		
2003	0.48	0.40	0.18	0.34	0.20	0.14	0.83	0.25	0.74	0.31	0.28	0.22	0.43	0.37	0.23	0.26	0.00	0.00		
2004	0.43	0.39	0.24	0.25	0.19	0.16	0.35	0.19	0.16	0.54	0.02	0.49	0.06	0.52	0.16	0.28	0.07	0.41		
2005	0.19	0.44	0.32	0.19	0.08	0.16	0.37	0.24	0.21	0.43	0.69	0.18	0.83	0.31	0.44	0.24	0.94	0.46		
2006	0.16	0.45	0.35	0.15	0.26	0.11	0.71	0.10	0.15	0.43	0.01	0.99	0.24	0.43	0.03	0.46	0.05	1.00		
2007	1.28	0.38	0.21	0.28	0.30	0.18	0.63	0.20	1.12	0.20	0.32	0.21	1.49	0.33	0.60	0.23	1.45	0.22	0.21	0.32
2008	1.54	0.38	0.11	0.42	0.29	0.15	1.02	0.13	0.08	0.66	0.05	0.39	0.28	0.42	0.19	0.27	0.09	0.89	0.19	0.38
2009	0.30	0.42	0.22	0.18	0.26	0.13	0.59	0.19	0.42	0.35	0.09	0.33	0.14	0.37	0.08	0.33	1.73	0.77	0.66	0.15
2010	0.58	0.41	0.02	0.53	0.12	0.14	0.40	0.32	0.08	0.66	0.00	0.00	0.20	0.45	0.09	0.32	0.00	0.00	0.11	0.41
2011	0.41	0.40	0.03	0.46	0.12	0.24	0.62	0.17	0.37	0.39	0.03	0.52	0.09	0.54	0.45	0.24	0.46	0.60	0.28	0.27
2012	0.84	0.36	0.14	0.23	0.19	0.16	0.39	0.15	0.42	0.32	0.05	0.41	0.13	0.48	0.27	0.26	0.11	0.46	0.09	0.41
2013	2.23	0.36	0.02	0.63	0.23	0.23	0.32	0.16	0.33	0.35	0.08	0.30	0.51	0.35	0.50	0.24	0.05	0.63	0.21	0.35
2014	2.05	0.36	0.08	0.35	0.30	0.25	0.59	0.20	0.51	0.32	0.24	0.25	0.77	0.44	0.17	0.27	0.07	0.26	0.20	0.86
2015	2.24	0.37	0.07	0.33	0.40	0.13	0.80	0.36	0.16	0.42	0.38	0.23	0.32	0.35	0.74	0.23	0.49	0.78	0.30	0.58
2016	1.33	0.35	0.13	0.28	0.42	0.12	1.12	0.14	0.36	0.32	0.12	0.32	0.15	0.37	0.18	0.27	0.05	1.00	0.05	0.52
2017	2.58	0.36	0.12	0.27	0.19	0.11	0.92	0.20	0.48	0.34	0.11	0.30	0.28	0.41	0.37	0.24	0.36	0.91	0.41	0.30
2018	1.22	0.36	0.11	0.28	0.21	0.14	0.37	0.14	0.62	0.37	0.21	0.27	0.82	0.34	0.61	0.23	0.44	0.51	0.40	0.37
2019	1.50	0.35	0.12	0.29	0.35	0.16	0.75	0.15	0.04	0.98	0.10	0.32	0.16	0.41	0.08	0.33	0.23	0.41	0.11	0.45
2020	1.59	0.41	0.05	0.35	0.15	0.20			0.42	0.21	0.23	0.24	0.48	0.35	0.57	0.23			0.63	0.29

Table 30. Annual weighted black drum index of relative abundance (number per set, ages 0-3) from the NC DMF Independent Gill Net Survey (Program 915) in the Pamlico Sound and Neuse, Pamlico, and Pungo river systems from 2003–2020*. N=number of samples; Index=black drum per gill net set; SE=Standard Error; PSE=Proportional Standard Error. *Sampling in this program was suspended in February 2020 due to COVID-19 restrictions.

		Age-0			Age-1			Age-2			Age-3		
Year	N	Index	SE	PSE	Index	SE	PSE	Index	SE	PSE	Index	SE	PSE
2003	476	0.11	0.03	27	0.12	0.04	33	0.52	0.15	29	0.04	0.01	25
2004	640	0.06	0.03	50	0.18	0.04	22	0.00	0.00	.	0.08	0.05	63
2005	608	0.29	0.08	28	0.02	0.01	50	0.04	0.02	50	0.01	0.01	100
2006	640	0.13	0.03	23	0.57	0.06	11	0.01	0.00	0	0.00	0.00	.
2007	640	0.31	0.08	26	0.12	0.03	25	0.18	0.07	39	0.02	0.01	50
2008	640	0.04	0.01	25	0.90	0.12	13	0.04	0.02	50	0.04	0.03	75
2009	640	0.36	0.10	28	0.05	0.01	20	0.15	0.04	27	0.03	0.01	33
2010	640	0.27	0.13	48	0.09	0.02	22	0.01	0.01	100	0.03	0.01	33
2011	618	0.46	0.10	22	0.11	0.02	18	0.02	0.01	50	0.03	0.02	67
2012	628	0.09	0.03	33	0.27	0.04	15	0.02	0.01	50	0.00	0.00	.
2013	628	0.10	0.03	30	0.09	0.02	22	0.10	0.03	30	0.03	0.01	33
2014	628	0.38	0.10	26	0.11	0.03	27	0.04	0.02	50	0.05	0.03	60
2015	626	0.66	0.25	38	0.11	0.04	36	0.02	0.01	50	0.00	0.00	.
2016	628	0.17	0.04	24	0.91	0.13	14	0.03	0.01	33	0.00	0.00	.
2017	628	0.24	0.06	25	0.33	0.06	18	0.28	0.12	43	0.05	0.02	40
2018	628	0.10	0.03	30	0.13	0.03	23	0.06	0.02	33	0.06	0.02	33
2019	628	0.14	0.05	36	0.56	0.10	18	0.02	0.01	50	0.02	0.01	50
2020*													

Table 31. Results for the Shapiro-Wilk Test Statistic to determine whether populations are normally distributed. Significant p-values are highlighted in yellow.

Survey Index	Age Type	Shapiro-Wilk Test Statistic	p-value
DE 16' Trawl	YOY	0.383	0.000
DE 30' Trawl	YOY	0.279	0.000
GA Trammel	YOY	0.926	0.163
MD Seine	YOY	0.885	0.003
MRIP	Mixed-Age	0.975	0.541
NC P915 Gill Net	Mixed-Age	0.927	0.196
NC P915 Gill Net	YOY	0.895	0.056
NC P915 Gill Net	Age-1 Lagged	0.770	0.001
NC P915 Gill Net	Age-2 Lagged	0.737	0.001
NC P915 Gill Net	Age-3 Lagged	0.906	0.136
NEAMAP Trawl	YOY	0.886	0.072
NJ Ocean Trawl	YOY	0.607	0.000
PSEG Seine	YOY	0.940	0.134
SC Trammel	Mixed-Age	0.858	0.001
SC Trammel	YOY	0.534	0.000
SC Trammel	Age-1 Lagged	0.891	0.005

For alpha > 0.05, null hypothesis not rejected (population normally distributed)
For alpha <=0.05, null hypothesis rejected (population may not be normally distributed)

Table 32. YOY index correlation results. Significant p-values are highlighted in yellow. P-values in red font indicate ties in rankings and are not exact.

YOY Indices	GA Trammel			SC Trammel YOY			NC P915 Gill Net YOY			MD Seine			DE 30' Trawl			DE 16' Trawl			PSEG Seine			NEAMAP Trawl		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
SC Trammel YOY	-0.06	0.81	18																					
NC P915 Gill Net YOY	-0.19	0.47	17	0.37	0.15	17																		
MD Seine	0.10	0.70	18	0.07	0.72	30	0.17	0.52	17															
DE 30' Trawl	-0.08	0.75	18	-0.04	0.83	30	0.16	0.54	17	0.23	0.21	31												
DE 16' Trawl	0.05	0.85	18	0.05	0.79	30	0.39	0.13	17	0.41	0.02	31	0.83	0.00	31									
PSEG Seine	-0.35	0.15	18	0.26	0.19	26	0.17	0.52	17	0.45	0.02	26	0.50	0.01	26	0.65	0.00	26						
NEAMAP Trawl	-0.03	0.92	14	0.25	0.38	14	0.41	0.17	13	0.38	0.18	14	0.28	0.33	14	0.32	0.26	14	0.42	0.13	14			
NJ Ocean Trawl	0.21	0.41	17	0.37	0.05	29	0.45	0.07	17	0.16	0.39	31	0.15	0.42	30	0.17	0.37	30	0.31	0.13	25	0.72	0.01	13

Table 33. Mixed-age index correlation results. Significant p-values are highlighted in yellow.

Mixed-Age	SC Trammel			NC P915 Gill Net		
	ρ	p-value	n	ρ	p-value	n
NC P915 Gill Net	0.51	0.04	17			
MRIP	0.35	0.06	30	0.46	0.06	17

Table 34. YOY and mixed-age index correlation results. Significant p-values are highlighted in yellow. P-values in red font indicate ties in rankings and are not exact.

YOY & Mixed-Age Indices	GA Trammel			MD Seine			DE 30' Trawl			DE 16' Trawl			PSEG Seine			NEAMAP Trawl			NJ Ocean Trawl		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
SC Trammel	0.07	0.79	18	0.01	0.95	30	0.00	0.99	30	0.05	0.81	30	-0.06	0.75	26	-0.25	0.39	14	0.19	0.32	29
NC P915 Gill Net	0.01	0.98	17	-0.03	0.90	17	-0.01	0.96	17	0.15	0.57	17	-0.12	0.65	17	-0.15	0.63	13	-0.11	0.67	17
MRIP	-0.29	0.24	18	0.36	0.04	32	0.27	0.14	31	0.21	0.26	31	0.31	0.12	26	0.03	0.91	14	0.46	0.01	31

Table 35. Lagged age and YOY index correlation results. Significant p-values are highlighted in yellow. P-values in red font indicate ties in rankings and are not exact.

	SC Trammel Age-1 Lagged			NC P915 Gill Net Age-1 Lagged			NC P915 Gill Net Age-2 Lagged			NC P915 Gill Net Age-3 Lagged		
	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n	ρ	p-value	n
GA Trammel	0.08	0.74	18	-0.05	0.86	16	0.11	0.69	15	-0.21	0.48	14
SC Trammel YOY	0.48	0.01	30	0.19	0.47	16	0.18	0.51	15	0.48	0.08	14
SC Trammel Age-1 Lagged												
NC P915 Gill Net YOY	0.09	0.73	17	0.54	0.03	16	0.59	0.02	15	0.63	0.02	14
NC P915 Gill Net Age-1 Lagged	0.67	0.00	16									
NC P915 Gill Net Age-2 Lagged	0.69	0.00	15	0.88	0.00	15						
NC P915 Gill Net Age-3 Lagged	0.30	0.30	14	0.49	0.08	14	0.47	0.09	14			
MD Seine	0.22	0.24	30	0.32	0.22	16	0.26	0.35	15	-0.25	0.39	14
DE 30' Trawl	-0.03	0.87	30	0.57	0.02	16	0.34	0.22	15	0.26	0.38	14
DE 16' Trawl	0.07	0.71	30	0.69	0.00	16	0.58	0.02	15	0.21	0.48	14
PSEG Seine	0.56	0.00	26	0.66	0.01	16	0.54	0.04	15	0.25	0.39	14
NEAMAP Trawl	0.10	0.74	14	0.24	0.45	14	0.03	0.94	11	0.25	0.49	10
NJ Ocean Trawl	0.44	0.02	29	0.32	0.23	16	0.33	0.23	15	0.26	0.36	14

Table 36. Simulation based power analysis results for the FL Haul Seine survey index. This index was unable to detect a decline (evaluated from 10% to 90%) with a power of 0.80.

Index	Years	Life Stage Tracked	Initial Relative Abundance	Overdispersion Parameter	Power to Detect -50% change	-% Change Detected with Power=0.80	+% Change Detected with Power=0.80
FL Haul Seine	1999-2020	Age-1+	0.23	0.14	0.11	-	>900%

Table 37. Traditional power analysis results for index data sets considered for indicators. Data sets with an asterisk next to the median CV had at least one year with no black drum catch that was excluded from the time series. Two asterisks in the final column indicate inability to detect a decline with a power of 0.80 and the value in the parentheses is the power to detect a 99.5% decline.

Index	Years	Life Stage Tracked	Median CV	Power to Detect -50% change	-% Change Detected with Power=0.80
MRIP	1982-2020	Exploitable Abundance	0.063	1.00	24.5
NC Gillnet	2003-2019	Sub-Adult Abundance	0.186	0.60	63.5
SC Trammel	1991-2020	YOY/Age-1	0.163	0.69	57.0
PSEG Seine	1995-2020	YOY	0.273	0.38	84.5
MD Seine	1989-2020	YOY	0.355*	0.28	97.0
GA Trammel	2003-2020	YOY	0.286	0.36	87.5
DE 16ft Trawl	1990-2020	YOY	0.286*	0.36	87.5
DE 30ft Trawl	1990-2020	YOY	0.419	0.23	99.5
NEAMAP	2007-2020	YOY	0.375	0.26	98.5
FL Haul Seine	1999-2020	Age-1+	0.394	0.25	99.0
NJ Ocean Trawl	1989-2019	NA *(Range Expansion)*	0.743*	0.14	NA (0.67)**

Table 38. Selected Indicators

Selected Indicators			
Abundance		Stock Characteristics	Fishery Characteristics
MRIP CPUE	Coastwide	NJ Ocean Trawl	MRIP rec harvest
PSEG Seine	Mid-Atlantic		MRIP rec released alive
MD Seine	Mid-Atlantic		commercial landings
DE 16ft Trawl	Mid-Atlantic		
DE 30ft Trawl	Mid-Atlantic		
NC Gillnet	South Atlantic		
SC Trammel	South Atlantic		
GA Trammel	South Atlantic		

Table 39. Annual MRIP CPUE index values, 3-year moving average of the index, % change from the previous year's moving average value, annual total removals, 3-year smoothed removals and relative *F* for black drum from the Skate method.

Year	Annual Index	3-Year Moving Average Index	% change from previous	Annual removals	catch_3yr_smooth	Relative F
1982	0.378392914			1,500,214		
1983	0.897491699			3,647,160		
1984	0.750900932	0.6755952		3,127,989	2,758,454	4,083.00
1985	0.933019012	0.8604705	27.36	3,510,696	3,428,615	3,984.58
1986	0.952098399	0.8786728	2.12	6,077,291	4,238,659	4,823.93
1987	0.593584107	0.8262338	-5.97	2,890,252	4,159,413	5,034.18
1988	0.58957066	0.7117511	-13.86	1,390,457	3,452,667	4,850.95
1989	1.591410086	0.924855	29.94	1,738,320	2,006,343	2,169.36
1990	0.595860217	0.9256137	0.08	944,777	1,357,851	1,466.97
1991	0.773355141	0.9868751	6.62	2,012,186	1,565,094	1,585.91
1992	0.890844157	0.7533532	-23.66	2,394,331	1,783,764	2,367.77
1993	0.65239466	0.772198	2.50	2,164,830	2,190,449	2,836.64
1994	0.78804678	0.7770952	0.63	2,846,391	2,468,518	3,176.60
1995	0.554842079	0.6650945	-14.41	2,565,636	2,525,619	3,797.38
1996	0.838001625	0.7269635	9.30	2,528,939	2,646,989	3,641.16
1997	0.9971404	0.7966614	9.59	2,157,764	2,417,446	3,034.47
1998	0.969649505	0.9349305	17.36	3,224,482	2,637,062	2,820.60
1999	0.834844033	0.933878	-0.11	4,455,034	3,279,093	3,511.27
2000	1.045977059	0.9501569	1.74	7,087,210	4,922,242	5,180.45
2001	0.822732192	0.9011844	-5.15	4,620,982	5,387,742	5,978.51
2002	0.799780941	0.8894967	-1.30	4,952,661	5,553,618	6,243.55
2003	0.749062046	0.7905251	-11.13	7,512,260	5,695,301	7,204.45
2004	0.853785281	0.8008761	1.31	4,612,933	5,692,618	7,107.99
2005	0.674538907	0.7591287	-5.21	3,645,248	5,256,814	6,924.80
2006	1.050325207	0.8595498	13.23	4,663,586	4,307,255	5,011.06
2007	0.896642437	0.8738355	1.66	5,765,820	4,691,551	5,368.92
2008	1.095461676	1.0141431	16.06	11,543,028	7,324,144	7,222.00
2009	1.236682902	1.0762623	6.13	9,730,149	9,012,999	8,374.35
2010	0.802450319	1.044865	-2.92	6,446,705	9,239,961	8,843.21
2011	0.804794056	0.9479758	-9.27	8,186,505	8,121,120	8,566.80
2012	1.0934962	0.9002469	-5.03	4,227,090	6,286,767	6,983.38
2013	0.812755557	0.9036819	0.38	7,038,072	6,483,889	7,174.97
2014	0.843829337	0.9166937	1.44	6,031,063	5,765,408	6,289.35
2015	1.041010468	0.8991985	-1.91	5,945,081	6,338,072	7,048.58
2016	1.002706843	0.9625155	7.04	7,760,228	6,578,791	6,835.00
2017	0.956757365	1.0001582	3.91	7,455,896	7,053,735	7,052.62
2018	0.943726214	0.9677301	-3.24	6,294,735	7,170,286	7,409.39
2019	0.971618396	0.9573673	-1.07	5,071,439	6,274,024	6,553.41
2020	1.056752558	0.9906991	3.48	6,138,302	5,834,825	5,889.60

Table 40. DB-SRA parameter estimates from the previous 2015 stock assessment and both continuity runs during this assessment. All catch and biomass parameters are in millions of pounds.

Quantity	*Run*	*Estimate Quantile*		
		25%	***50%***	***75%***
MSY	2015 Assessment	1.60	2.12	3.05
	New_Catch	4.23	5.57	8.12
	Then_*M*	5.24	6.81	9.91
2012 OFL	2015 Assessment	2.60	4.12	6.98
	New_Catch	6.99	10.80	18.34
	Then_*M*	8.62	13.34	22.95
2020 OFL	New_Catch	6.16	9.97	17.60
	Then_*M*	7.80	12.60	22.25
U_{MSY}	2015 Assessment	0.033	0.046	0.062
	New_Catch	0.033	0.046	0.063
	Then_*M*	0.054	0.074	0.099
2012 Exploitation	2015 Assessment	0.007	0.013	0.020
	New_Catch	0.011	0.018	0.028
	Then_*M*	0.013	0.023	0.037
2020 Exploitation	New_Catch	0.016	0.028	0.046
	Then_*M*	0.020	0.035	0.059
B_{MSY}	2015 Assessment	34.58	47.26	69.61
	New_Catch	91.37	123.58	177.80
	Then_*M*	70.06	95.85	139.81
2012 Biomass	2015 Assessment	57.75	90.78	156.97
	New_Catch	153.63	241.02	400.86
	Then_*M*	117.13	187.95	316.73
2020 Biomass	New_Catch	135.10	222.10	382.20
	Then_*M*	105.86	175.75	304.18
K	2015 Assessment	93.50	135.20	203.76
	New_Catch	250.86	354.64	518.14
	Then_*M*	189.29	275.74	412.61
2012 Depletion (B_{2012}/K)	2015 Assessment	0.600	0.704	0.802
	New_Catch	0.600	0.699	0.796
	Then_*M*	0.601	0.701	0.799
2020 Depletion (B_{2020}/K)	New_Catch	0.525	0.649	0.767
	Then_*M*	0.537	0.664	0.782
r	2015 Assessment	0.049	0.070	0.099
	New_Catch	0.050	0.071	0.099
	Then_*M*	0.079	0.112	0.156

Table 41. Fixed input parameters used in JABBA-Select per-recruit model estimates. All size inputs are in millimeters.

Parameter	*Description*	*Value*
a_{min}	Minimum age	0
a_{max}	Maximum age	67
L_{inf}	von Bertalanffy growth asymptotic length	1,156
k	von Bertalanffy growth coefficient	0.133
a_0	von Bertalanffy growth age at size 0	-1.77
a	length-weight relationship alpha (grams vs mm)	3.20E-05
b	length-weight relationship beta (grams vs mm)	2.8977
a_{50}	age at 50% maturity	4.1
a_{95}	age at 95% maturity	5.7
$SL_{50,1}$	SA_1 size at 50% ascending selectivity	185
$SL_{95,1}$	SA_1 size at 95% ascending selectivity	220
$SL_{desc,1}$	SA_1 size descending selectivity starts	520
$SL_{width,1}$	SA_1 width descending selectivity	90
$SL_{min,1}$	SA_1 constant selectivity following descent	0
$SL_{50,2}$	SA_2 size at 50% ascending selectivity	330
$SL_{95,2}$	SA_2 size at 95% ascending selectivity	375
$SL_{desc,2}$	SA_2 size descending selectivity starts	520
$SL_{width,2}$	SA_2 width descending selectivity	90
$SL_{min,2}$	SA_2 constant selectivity following descent	0
$SL_{50,3}$	MA_early size at 50% ascending selectivity	620
$SL_{95,3}$	MA_early size at 95% ascending selectivity	740
$SL_{50,4}$	MA_late_1 size at 50% ascending selectivity	180
$SL_{95,4}$	MA_late_1 size at 95% ascending selectivity	190
$SL_{desc,4}$	MA_late_1 size descending selectivity starts	210
$SL_{width,4}$	MA_late_1 width descending selectivity	20
$SL_{min,4}$	MA_late_1 constant selectivity following descent	0.01
$SL_{50,5}$	MA_late_2 size at 50% ascending selectivity	190
$SL_{95,5}$	MA_late_2 size at 95% ascending selectivity	220
$SL_{desc,5}$	MA_late_2 size descending selectivity starts	250
$SL_{width,5}$	MA_late_2 width descending selectivity	20
$SL_{min,5}$	MA_late_2 constant selectivity following descent	0.25
$SL_{50,6}$	MRIP CPUE size at 50% ascending selectivity	185
$SL_{95,6}$	MRIP CPUE size at 95% ascending selectivity	220
$SL_{desc,6}$	MRIP CPUE size descending selectivity starts	520
$SL_{width,6}$	MRIP CPUE width descending selectivity	90
$SL_{min,6}$	MRIP CPUE constant selectivity following descent	0.25

Table 42. Input prior distributions used in the JABBA-Select model.

JABBA-Select Parameter	*Description*	*Prior Distribution*	*Prior Distribution Parameters*
SB_0	Unfished Spawning Biomass (pounds)	Lognormal	Mean = 222,111,320 CV = 1.66
$\Psi = SB_{1982}/SB_0$	1982 Spawning Biomass Depletion (psi)	Beta	Mean = 0.70 CV = 0.17
M	Natural Mortality	Lognormal	Mean = 0.1041 CV = 0.25
h	Beverton-Holt Stock-Recruitment Steepness	Beta	Mean = 0.72 CV = 0.25
q	MRIP CPUE catchability coefficient	Uniform	Lower bound = 1e-29 Upper bound = 1,000
σ_{est}^2	Estimated additional observation variance	Inverse-gamma	Shape = 0.001 Scale = 0.001
σ_{η}^2	Process variance	Inverse-gamma	Shape = 0.001 Scale = 0.001

Table 43. Percentage of MRIP recreational harvest in waves 5 and 6 less than 16 inches during constant regulation time periods in the Mid-Atlantic.

Time Period	Percentage of catch <16"	
	Wave 5	Wave 6
1981-1986	90	NA
1987-1993	95	37
1994-2000	45	100
2001-2009	41	36
2010-2020	32	83

Table 44. **Estimated and derived (NA p-values) parameters with p-values for posterior distribution convergence tests.** *Note: Table has been updated in Section 13.4 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

Parameter	***LCI***	***Median***	***UCI***	***Geweke p-value***	***Heidelberger and Welch p-value***
SB_0	129	396	1,542	0.60	0.44
SB_{1982}/SB_0	0.336	0.588	0.827	0.84	0.74
m	0.438	0.716	1.180	0.91	0.99
$H_{MSY,1}$	0.009	0.032	0.110	0.98	0.42
$H_{MSY,2}$	0.011	0.043	0.147	0.95	0.41
$H_{MSY,3}$	0.039	0.157	0.540	0.78	0.69
$H_{MSY,4}$	0.005	0.020	0.073	0.73	0.92
$H_{MSY,5}$	0.022	0.092	0.331	0.72	0.88
q	0.000	0.000	0.000	0.83	0.43
σ_{est}^2	0.000	0.002	0.008	0.97	0.33
σ_{η}^2	0.001	0.003	0.019	0.62	0.12
SB_{MSY}	37	122	476	NA	NA
MSY_1	1	4	17	NA	NA
MSY_2	1	5	23	NA	NA
MSY_3	5	19	84	NA	NA
MSY_4	1	2	11	NA	NA
MSY_5	3	11	51	NA	NA

Table 45. Spawning biomass estimates from the JABBA-Select model. *Note: Table has been updated in Section 13.4 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

Year	SB (millions of pounds)			SB/SB_{MSY}			SB/SB_0		
	LCI	Median	UCI	LCI	Median	UCI	LCI	Median	UCI
1982	66	228	847	1.010	1.857	2.940	0.330	0.574	0.825
1983	67	235	870	1.056	1.908	3.015	0.346	0.588	0.836
1984	68	238	898	1.080	1.944	3.075	0.353	0.600	0.847
1985	69	243	925	1.100	1.979	3.141	0.362	0.611	0.858
1986	73	249	955	1.126	2.031	3.259	0.373	0.628	0.888
1987	72	251	974	1.130	2.037	3.271	0.372	0.632	0.889
1988	73	256	1,011	1.149	2.076	3.338	0.382	0.645	0.900
1989	77	263	1,040	1.196	2.141	3.423	0.395	0.665	0.927
1990	79	268	1,058	1.230	2.184	3.496	0.407	0.680	0.939
1991	82	275	1,081	1.276	2.244	3.588	0.426	0.698	0.958
1992	83	281	1,102	1.311	2.290	3.652	0.437	0.711	0.970
1993	83	285	1,114	1.336	2.324	3.666	0.446	0.722	0.974
1994	83	290	1,135	1.367	2.362	3.726	0.455	0.733	0.984
1995	86	296	1,159	1.407	2.412	3.787	0.469	0.751	1.014
1996	89	302	1,174	1.458	2.476	3.845	0.485	0.768	1.036
1997	95	309	1,195	1.500	2.538	3.931	0.499	0.787	1.065
1998	97	316	1,212	1.544	2.592	4.016	0.515	0.803	1.092
1999	98	323	1,214	1.583	2.632	4.067	0.526	0.815	1.111
2000	99	324	1,223	1.596	2.649	4.095	0.534	0.820	1.117
2001	95	323	1,226	1.585	2.628	4.063	0.528	0.815	1.112
2002	96	324	1,231	1.581	2.632	4.043	0.531	0.815	1.111
2003	93	321	1,220	1.582	2.613	4.007	0.526	0.810	1.100
2004	88	318	1,212	1.550	2.569	3.957	0.514	0.798	1.081
2005	92	322	1,228	1.576	2.610	3.996	0.526	0.810	1.104
2006	98	330	1,252	1.633	2.686	4.128	0.547	0.830	1.136
2007	104	338	1,277	1.687	2.754	4.218	0.562	0.849	1.168
2008	105	339	1,289	1.701	2.772	4.246	0.569	0.855	1.176
2009	101	335	1,290	1.667	2.738	4.178	0.560	0.845	1.157
2010	97	334	1,306	1.657	2.725	4.150	0.553	0.840	1.150
2011	99	338	1,312	1.681	2.751	4.193	0.559	0.848	1.154
2012	100	339	1,331	1.680	2.763	4.210	0.561	0.851	1.167
2013	106	348	1,376	1.736	2.842	4.346	0.581	0.874	1.204
2014	108	351	1,395	1.766	2.890	4.404	0.591	0.886	1.225
2015	111	358	1,430	1.792	2.945	4.543	0.602	0.903	1.252
2016	117	364	1,451	1.815	2.995	4.642	0.614	0.915	1.277
2017	115	363	1,457	1.815	2.982	4.609	0.610	0.913	1.277
2018	113	362	1,455	1.809	2.964	4.592	0.608	0.907	1.270
2019	111	359	1,455	1.796	2.940	4.529	0.599	0.902	1.263
2020	108	357	1,444	1.776	2.921	4.556	0.591	0.894	1.274

Table 46. Exploitation estimates from the JABBA-Select model. *Note: Table has been updated in Section 13.4 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

Year	*H*			H/H_{MSY}		
	LCI	*Median*	*UCI*	*LCI*	*Median*	*UCI*
1982	0.002	0.007	0.023	0.035	0.180	0.748
1983	0.004	0.016	0.054	0.034	0.178	0.782
1984	0.003	0.013	0.046	0.063	0.340	1.511
1985	0.004	0.014	0.051	0.063	0.345	1.551
1986	0.006	0.024	0.083	0.073	0.401	1.840
1987	0.003	0.012	0.040	0.038	0.214	0.993
1988	0.001	0.005	0.019	0.018	0.104	0.487
1989	0.002	0.007	0.023	0.015	0.082	0.385
1990	0.001	0.004	0.012	0.011	0.064	0.305
1991	0.002	0.007	0.025	0.027	0.148	0.697
1992	0.002	0.009	0.029	0.029	0.160	0.752
1993	0.002	0.008	0.026	0.035	0.198	0.922
1994	0.003	0.010	0.034	0.041	0.231	1.076
1995	0.002	0.009	0.030	0.030	0.166	0.766
1996	0.002	0.008	0.028	0.031	0.172	0.783
1997	0.002	0.007	0.023	0.027	0.148	0.670
1998	0.003	0.010	0.033	0.039	0.215	0.973
1999	0.004	0.014	0.045	0.064	0.350	1.564
2000	0.006	0.022	0.072	0.114	0.627	2.790
2001	0.004	0.014	0.048	0.059	0.321	1.433
2002	0.004	0.015	0.052	0.075	0.406	1.819
2003	0.006	0.023	0.081	0.096	0.518	2.316
2004	0.004	0.015	0.052	0.042	0.225	1.028
2005	0.003	0.011	0.040	0.040	0.219	0.984
2006	0.004	0.014	0.048	0.035	0.191	0.857
2007	0.005	0.017	0.056	0.057	0.307	1.357
2008	0.009	0.034	0.110	0.073	0.391	1.711
2009	0.008	0.029	0.097	0.057	0.308	1.383
2010	0.005	0.019	0.066	0.074	0.401	1.775
2011	0.006	0.024	0.082	0.077	0.419	1.856
2012	0.003	0.012	0.042	0.048	0.262	1.149
2013	0.005	0.020	0.067	0.094	0.523	2.274
2014	0.004	0.017	0.056	0.064	0.353	1.528
2015	0.004	0.017	0.053	0.051	0.283	1.231
2016	0.005	0.021	0.066	0.079	0.440	1.916
2017	0.005	0.021	0.065	0.073	0.400	1.735
2018	0.004	0.017	0.056	0.048	0.265	1.154
2019	0.003	0.014	0.046	0.045	0.251	1.111
2020	0.004	0.017	0.057	0.052	0.286	1.277

Table 47. Sensitivity configurations included in the sensitivity analysis of the JABBA-Select model.

Name	Description
low M	Natural mortality prior distribution mean decreased from 0.1041 to 0.068
ll h	Steepness prior distribution using likelihood parameters; mean increased from 0.72 to 0.75 and CV decreased from 0.25 to 0.20
low h	Steepness prior distribution mean decreased from 0.72 to 0.62
MRIP sel	MRIP CPUE constant selectivity for largest sizes decreased from 0.25 to 0.10
SA adults	SA fleet constant selectivity for largest sizes increased from 0 to 0.06 for both selectivity periods (SA_1 and SA_2)
SA descend	SA fleet descending selectivity start shifted 100 mm to the left from 520 mm to 420 mm for both selectivity periods (SA_1 and SA_2)
MA_early sel	MA_early fleet ascending selectivity shifted to the right; 50% selectivity parameter increased from 620 mm to 686 mm and 95% selectivity parameter increased from 740 mm to 808 mm
uni dep	Start year depletion prior distribution changed from beta distribution with mean 0.70 and CV 0.17 to uniform distribution over range 0 to 1 (beta mean=0.5, beta CV=0.577)
MRIP q	Additional MRIP CPUE catchability coefficient estimated for years 2016-2020

12 FIGURES

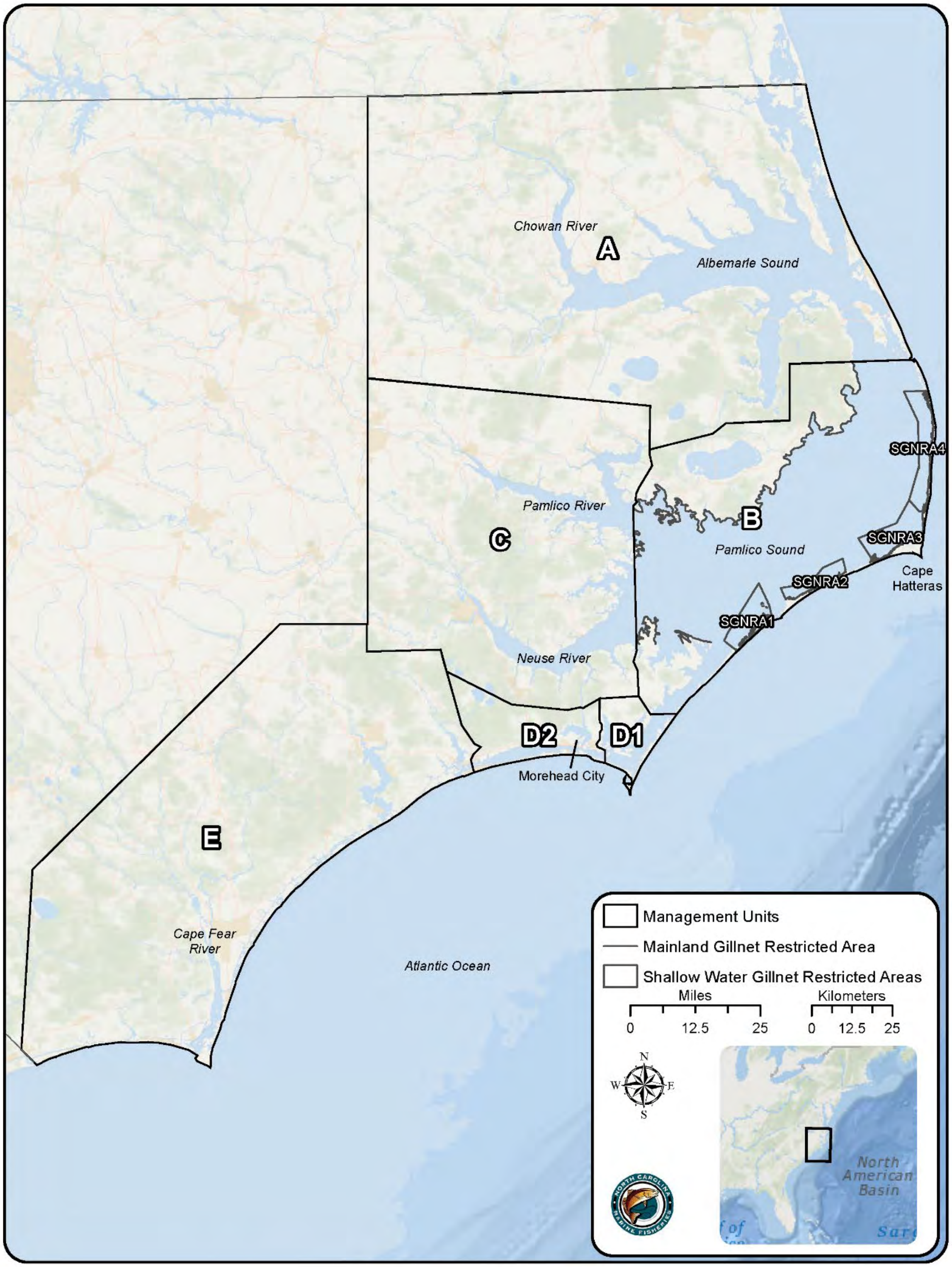

Figure 1. Incidental Take Permit Sea Turtle Management Areas.

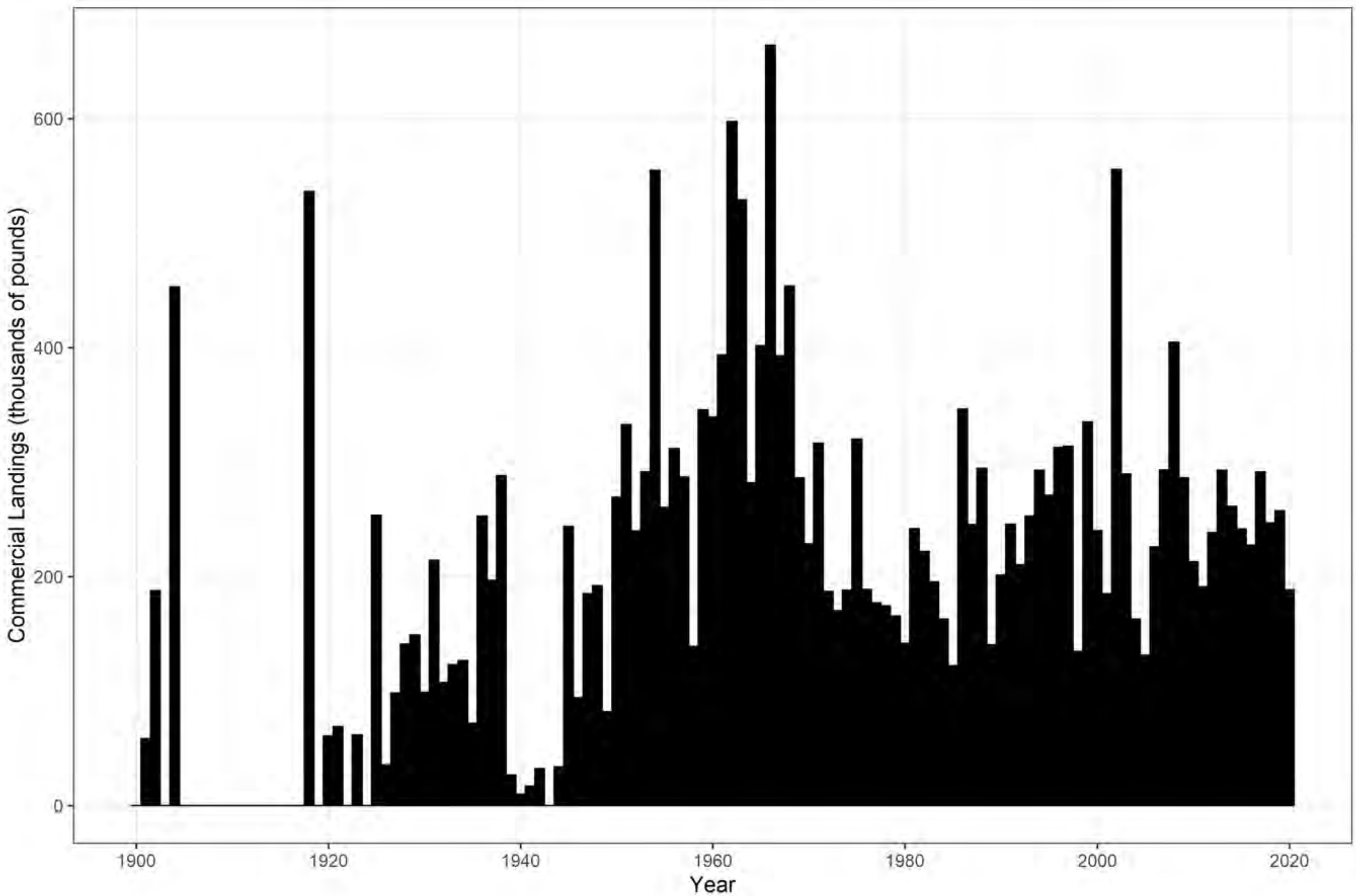

Figure 2. Total commercial landings of black drum along the U.S. Atlantic coast from 1900-2020.

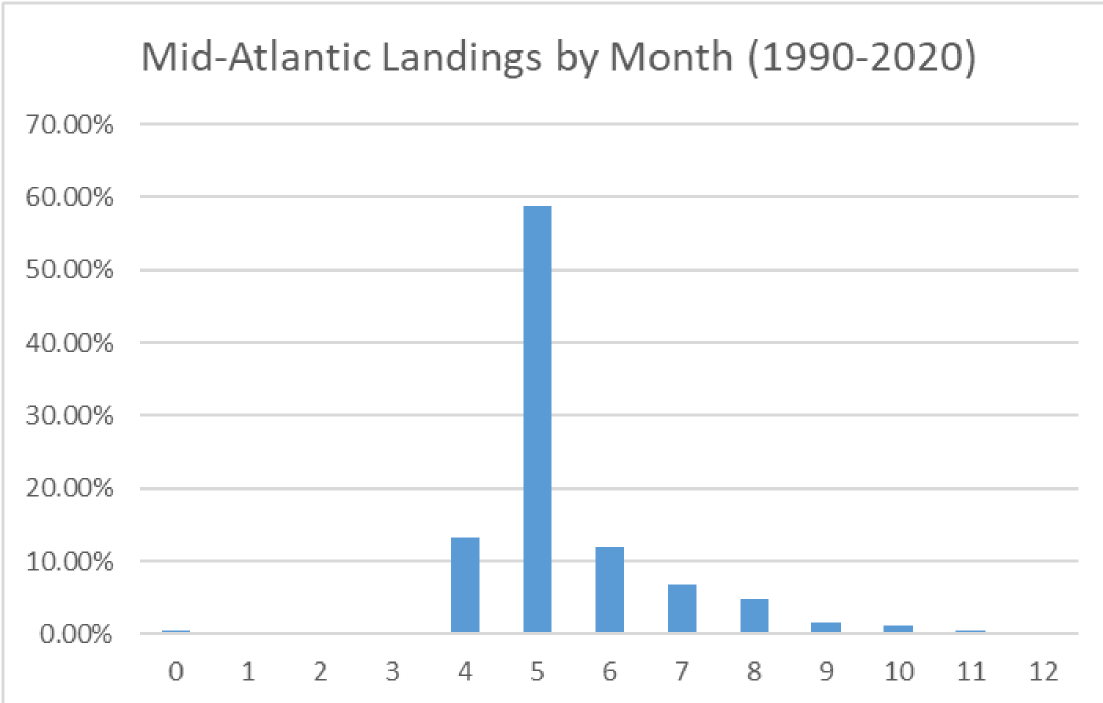

Figure 3. Percentage of Mid-Atlantic commercial landings of black drum from 1990-2020 by month.

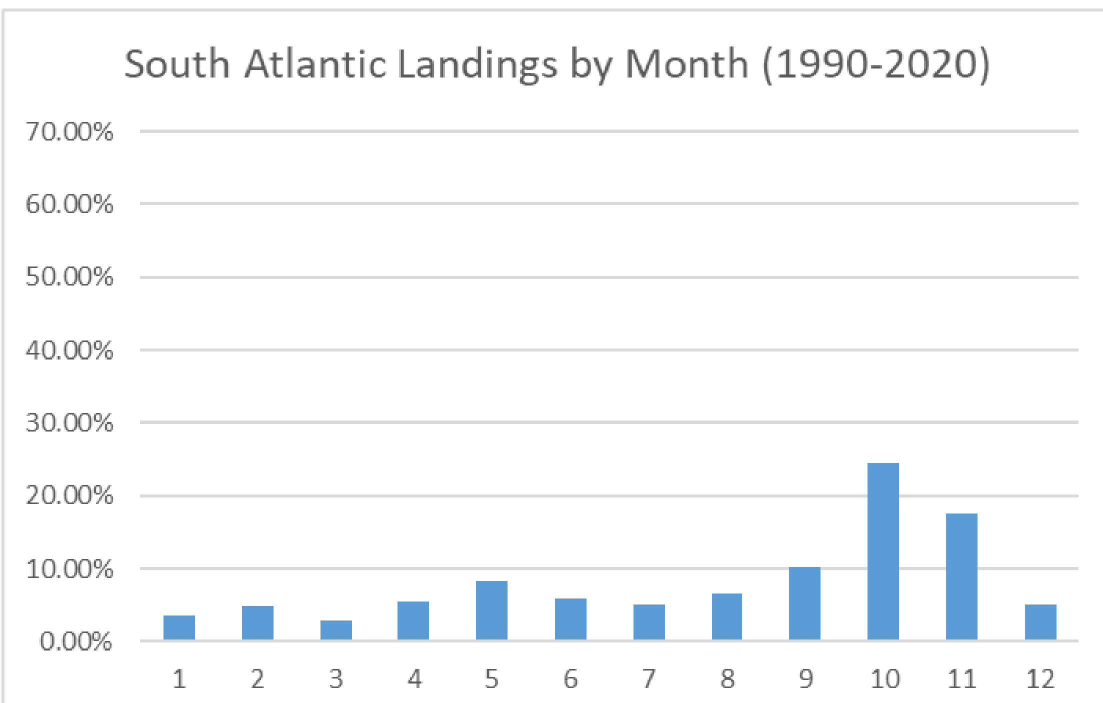

Figure 4. Percentage of South Atlantic commercial landings of black drum from 1990-2020 by month.

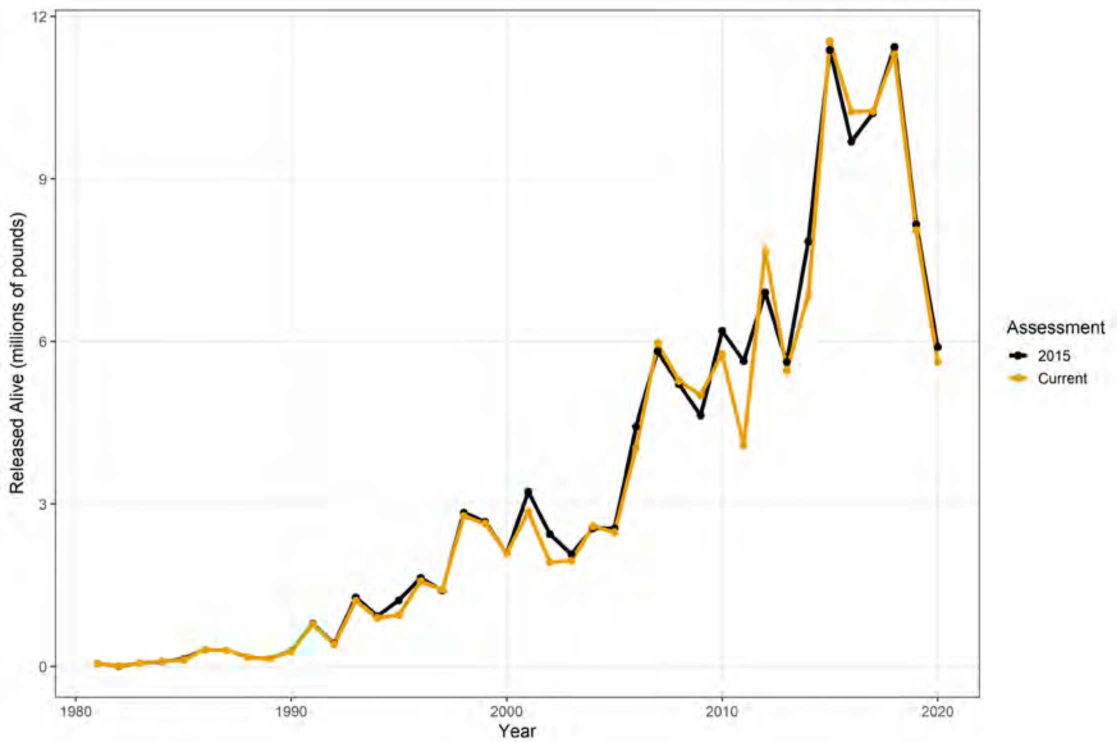

Figure 5. Weight estimates of recreational black drum releases compared between assessments.

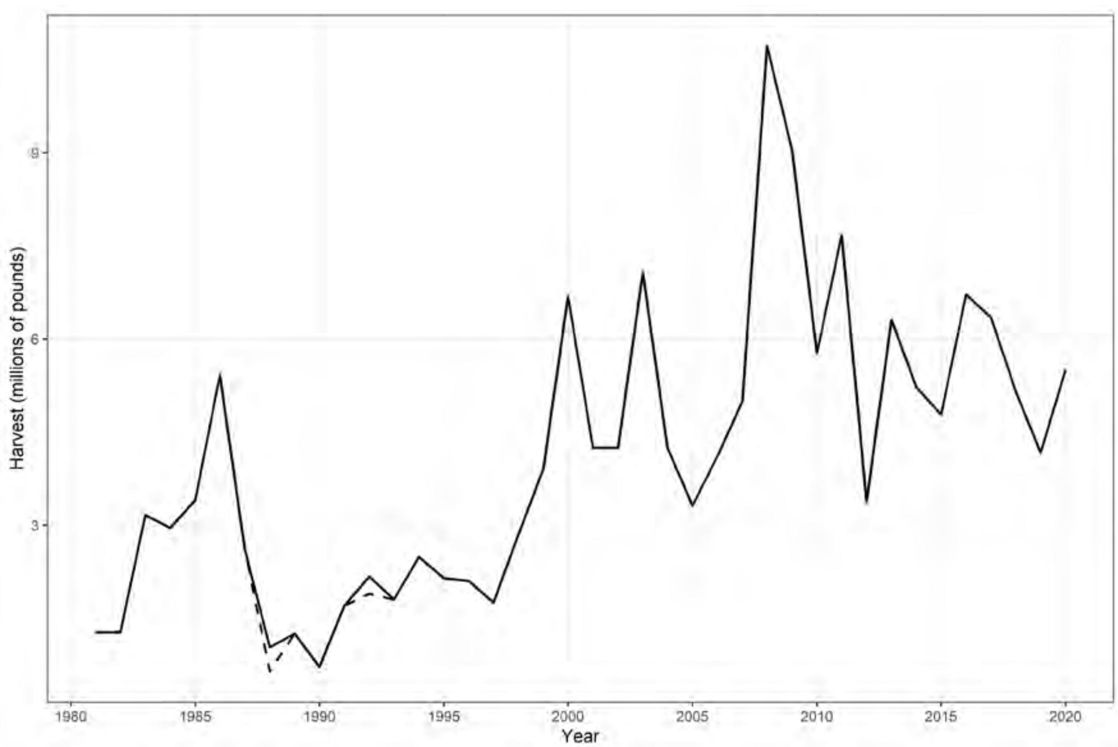

Figure 6. Black drum recreational harvest estimates with missing weight-based harvest estimates from MRIP (dashed line) and proxy harvest estimates added (solid line).

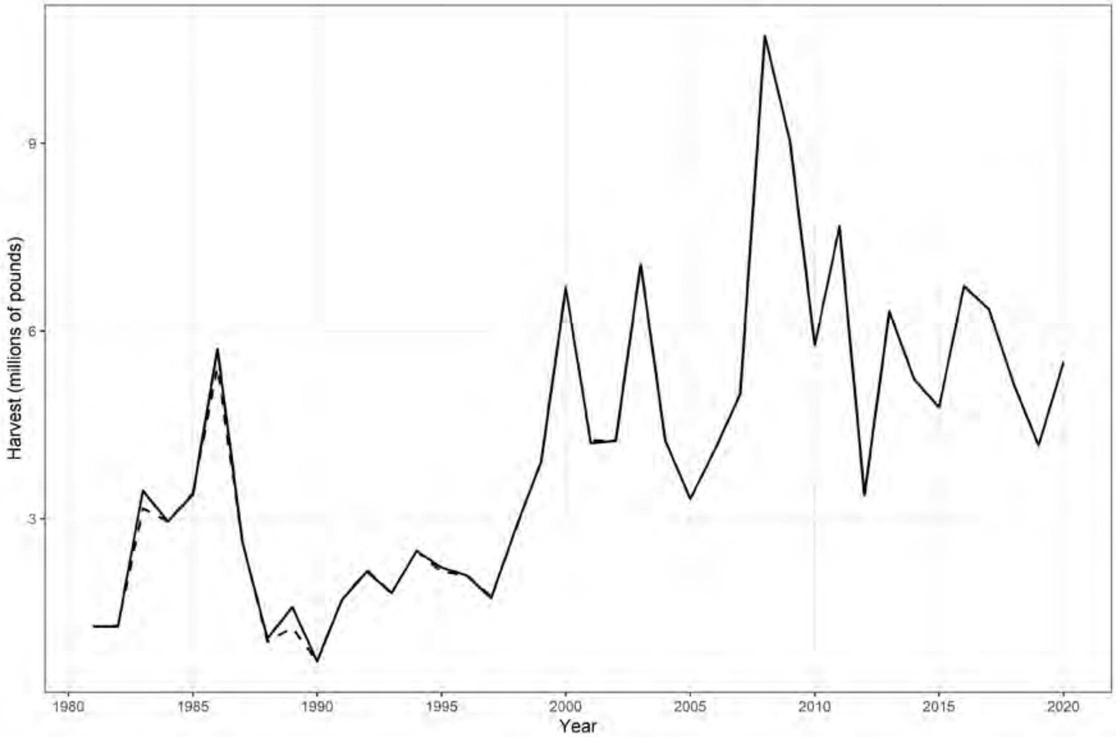

Figure 7. Back drum harvest estimated by MRIP (dashed line) compared to estimates calibrated to FHS effort (solid line).

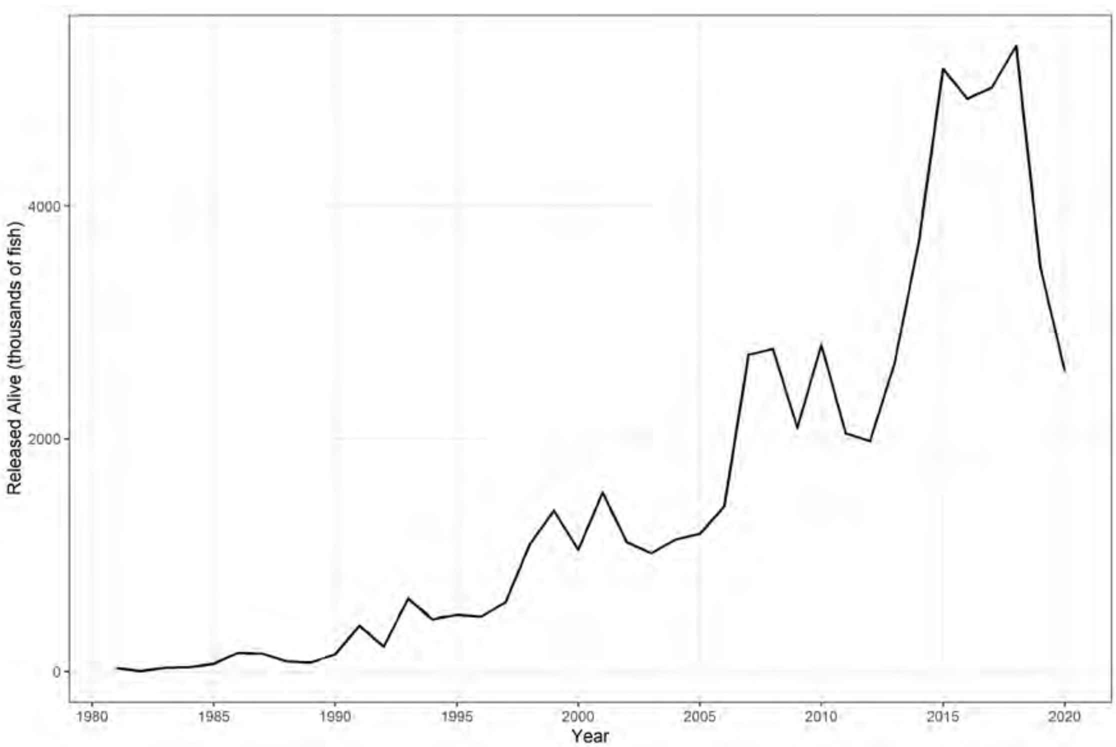

Figure 8. Back drum releases estimated by MRIP (dashed line obscured by solid line due to similarities of estimates) compared to estimates calibrated to FHS effort (solid line).

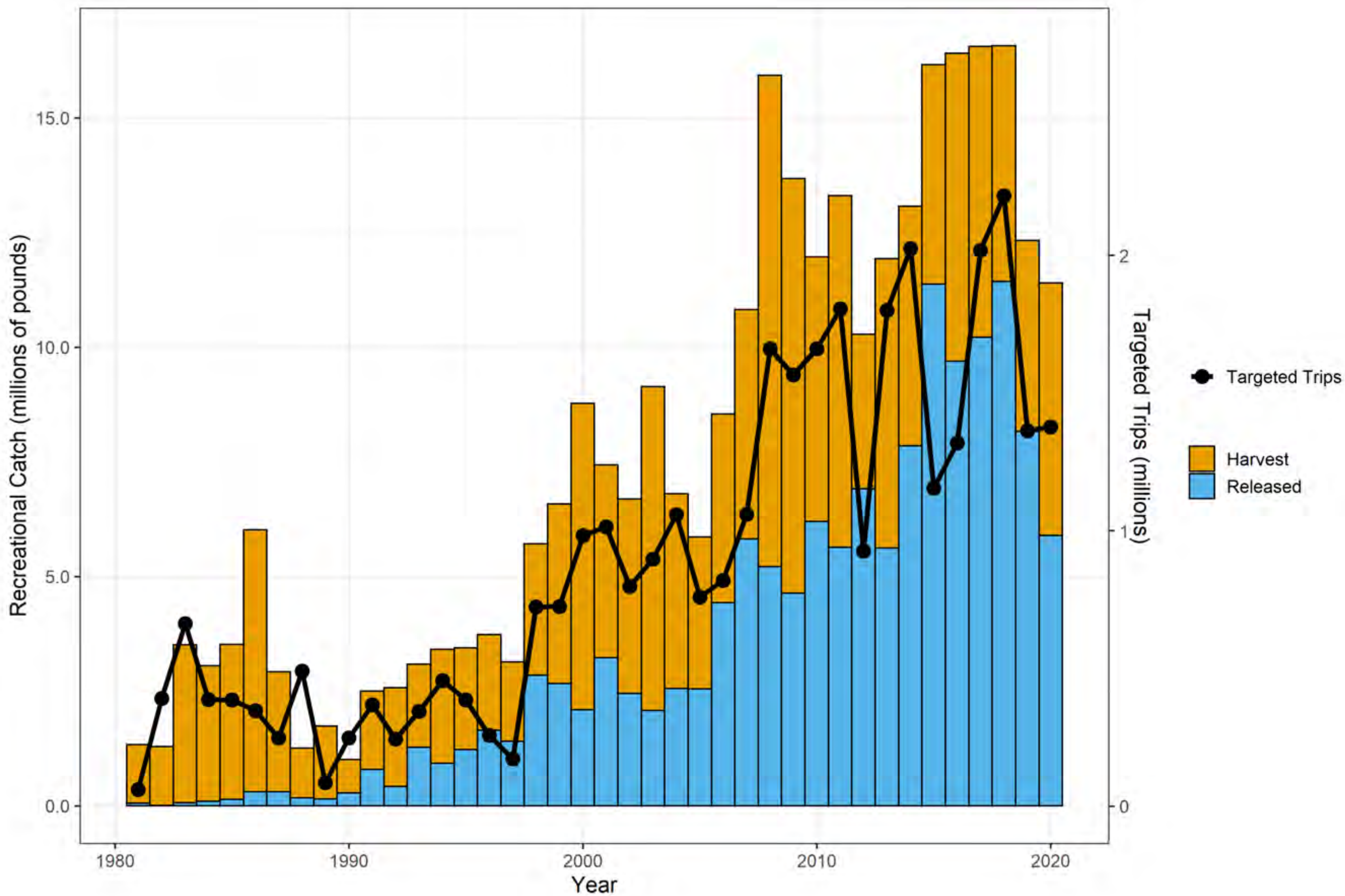

Figure 9. MRIP estimates of coastwide recreational fishing trips directed at black drum and total catch.

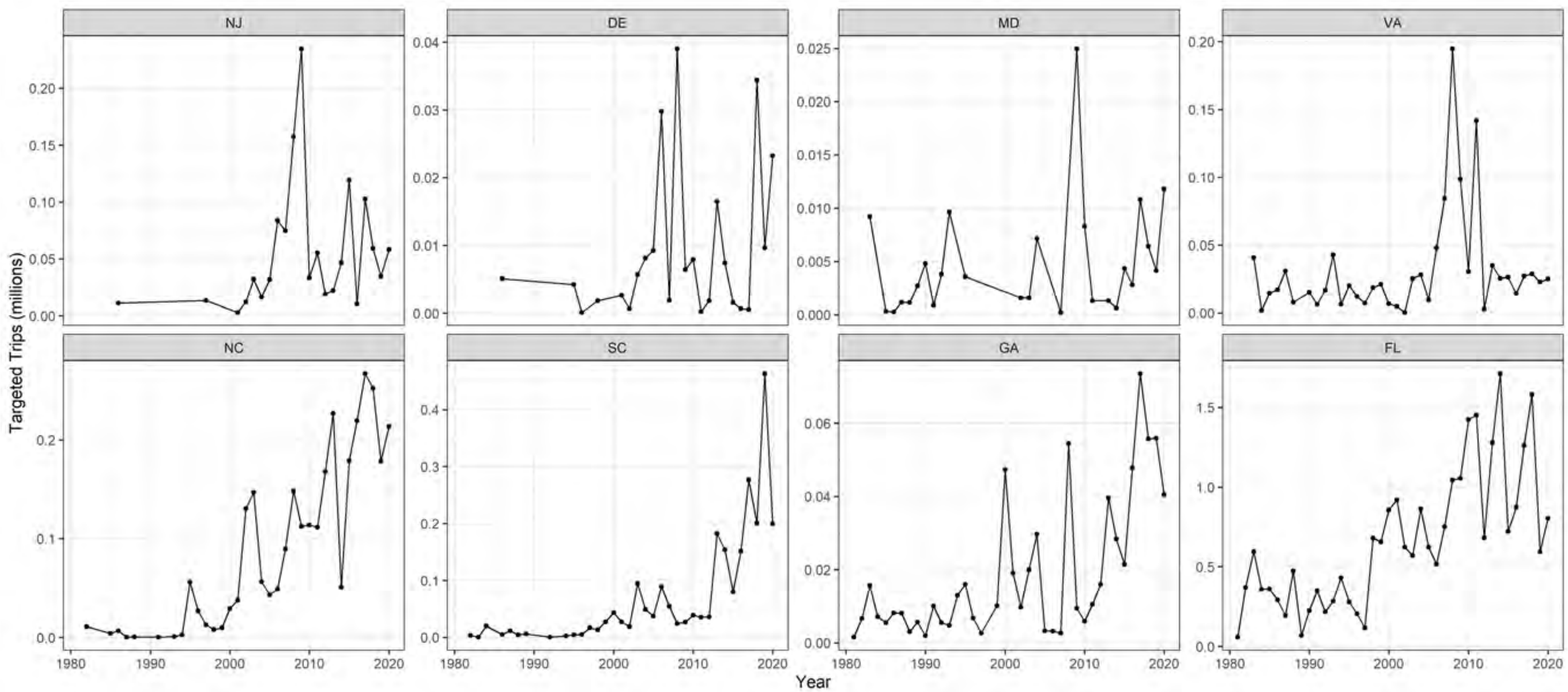

Figure 10. MRIP estimates of state-specific recreational fishing trips directed at black drum.

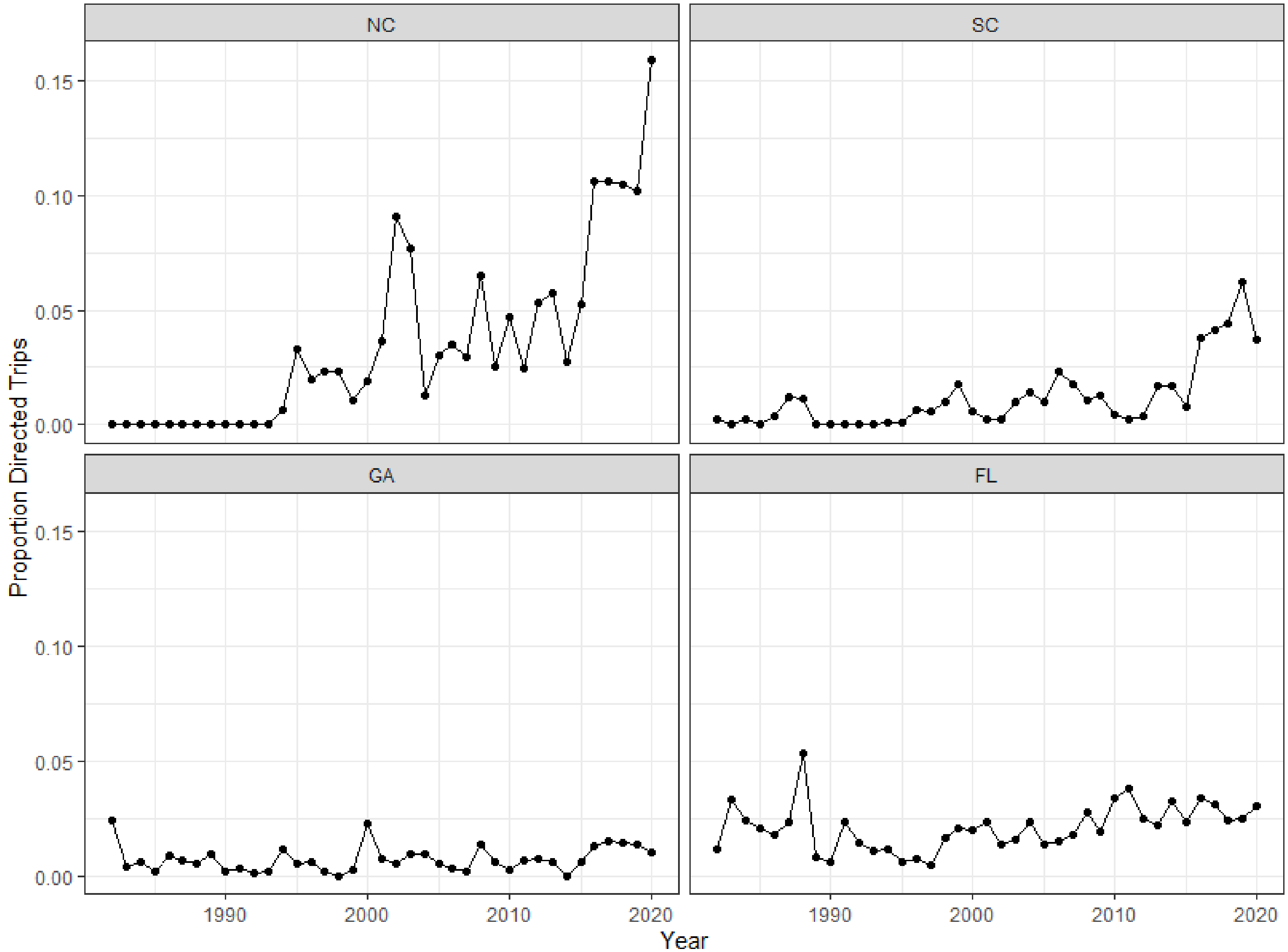

Figure 11. Proportion of South Atlantic APAIS intercepts retained in the cluster analysis data set for MRIP CPUE that identified black drum as a primary or secondary target species of the trip.

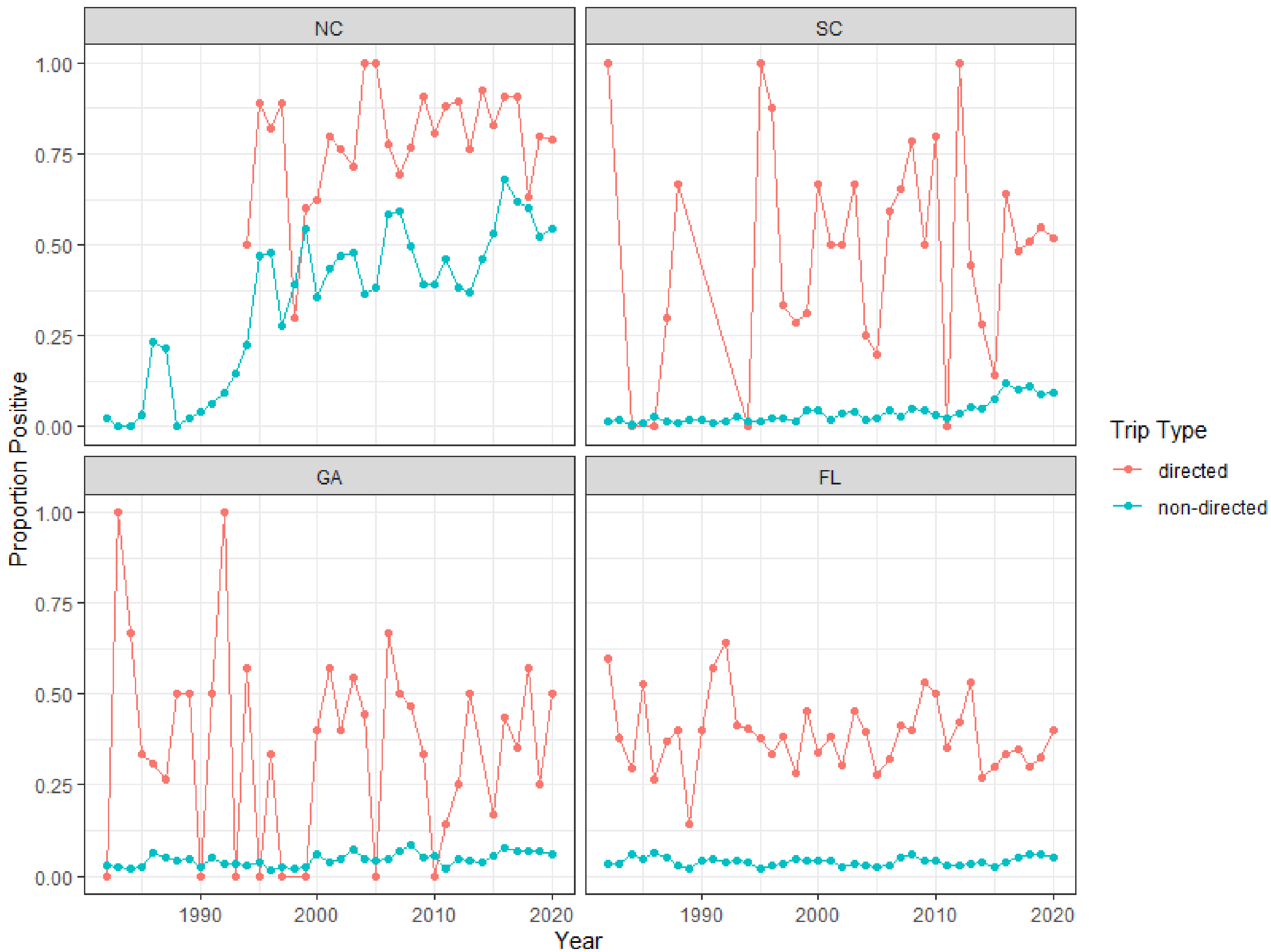

Figure 12. Proportion of South Atlantic APAIS intercepts retained in the cluster analysis data set for MRIP CPUE that caught black drum for trips that confirmed black drum as a target species and trips that did not confirm black drum as a target species.

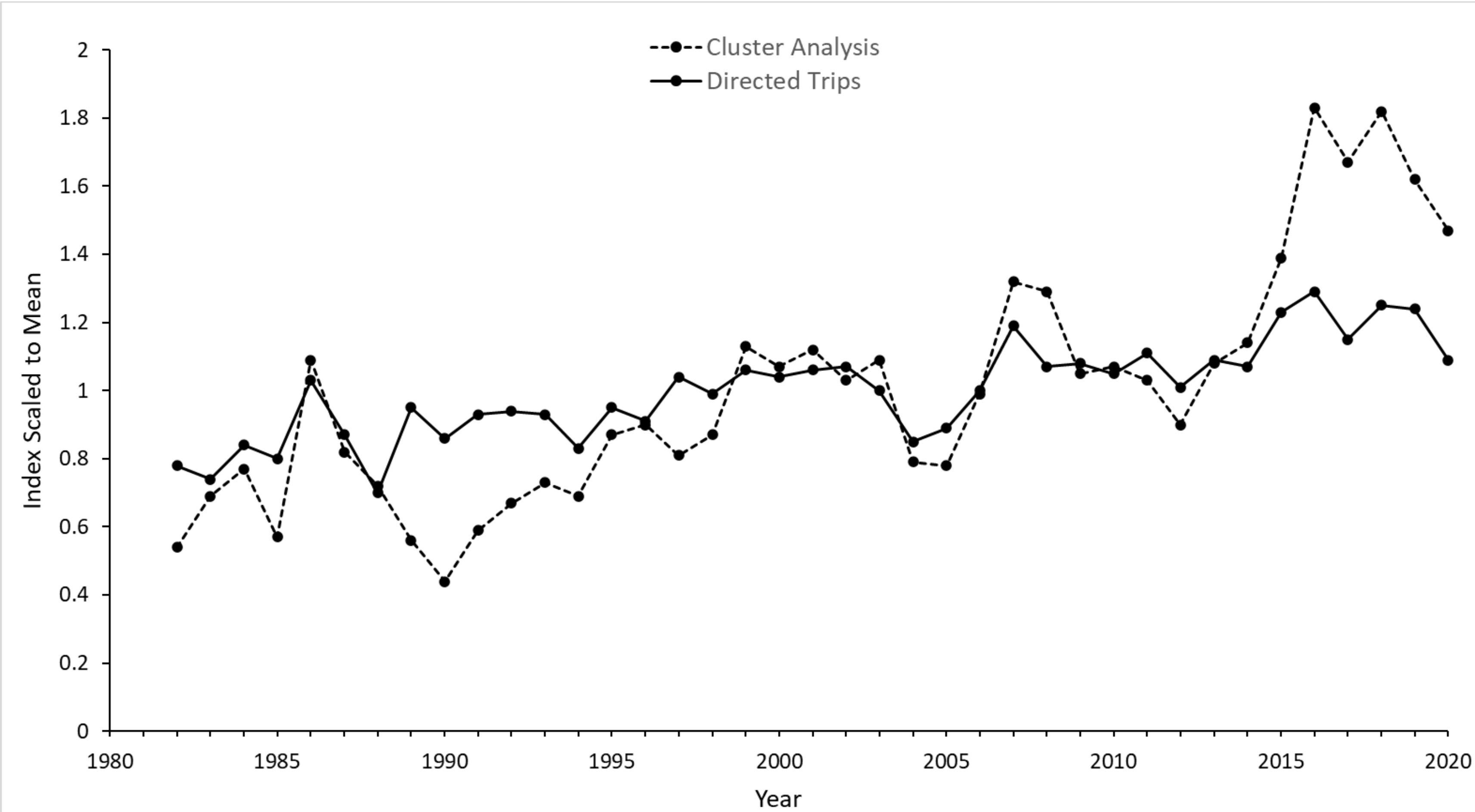

Figure 13. Comparison of MRIP CPUE estimated from the cluster analysis data set and directed trips data set.

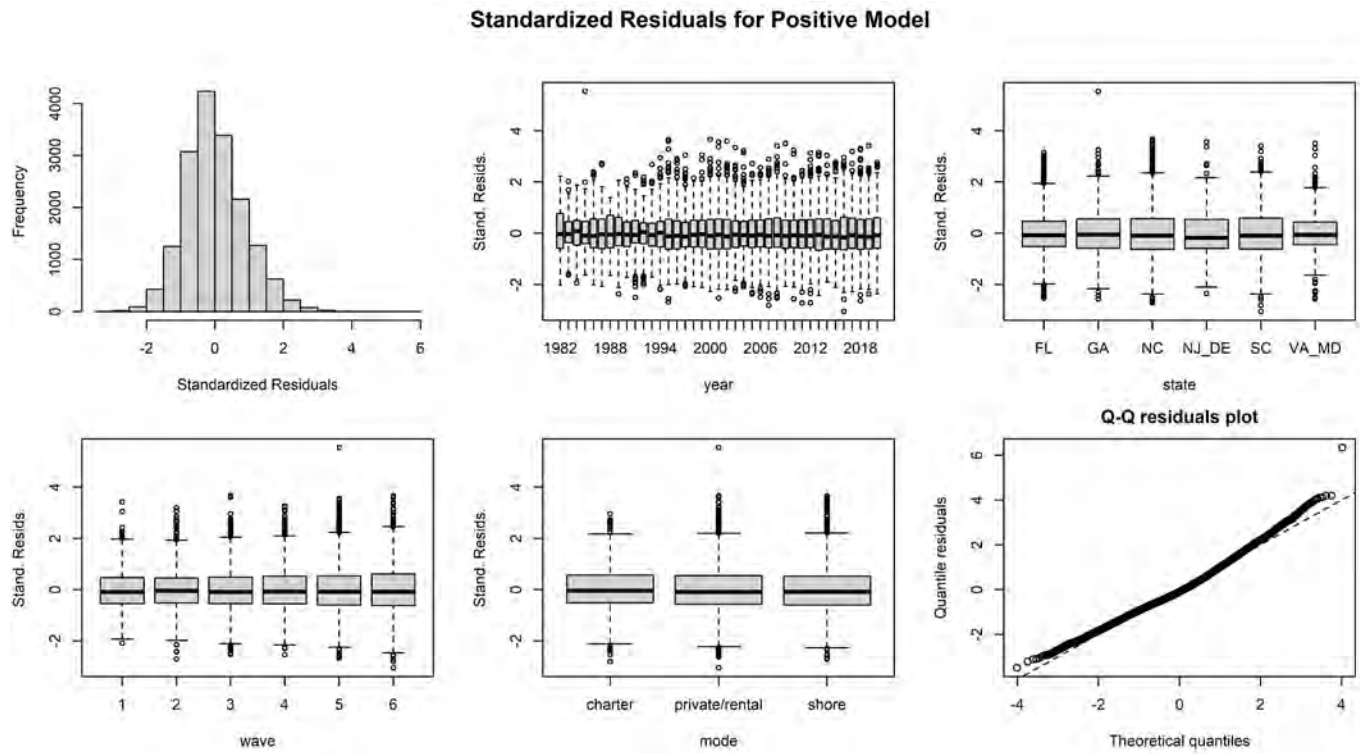

Figure 14. Residual plots for the positive observation GLM used to estimate MRIP CPUE.

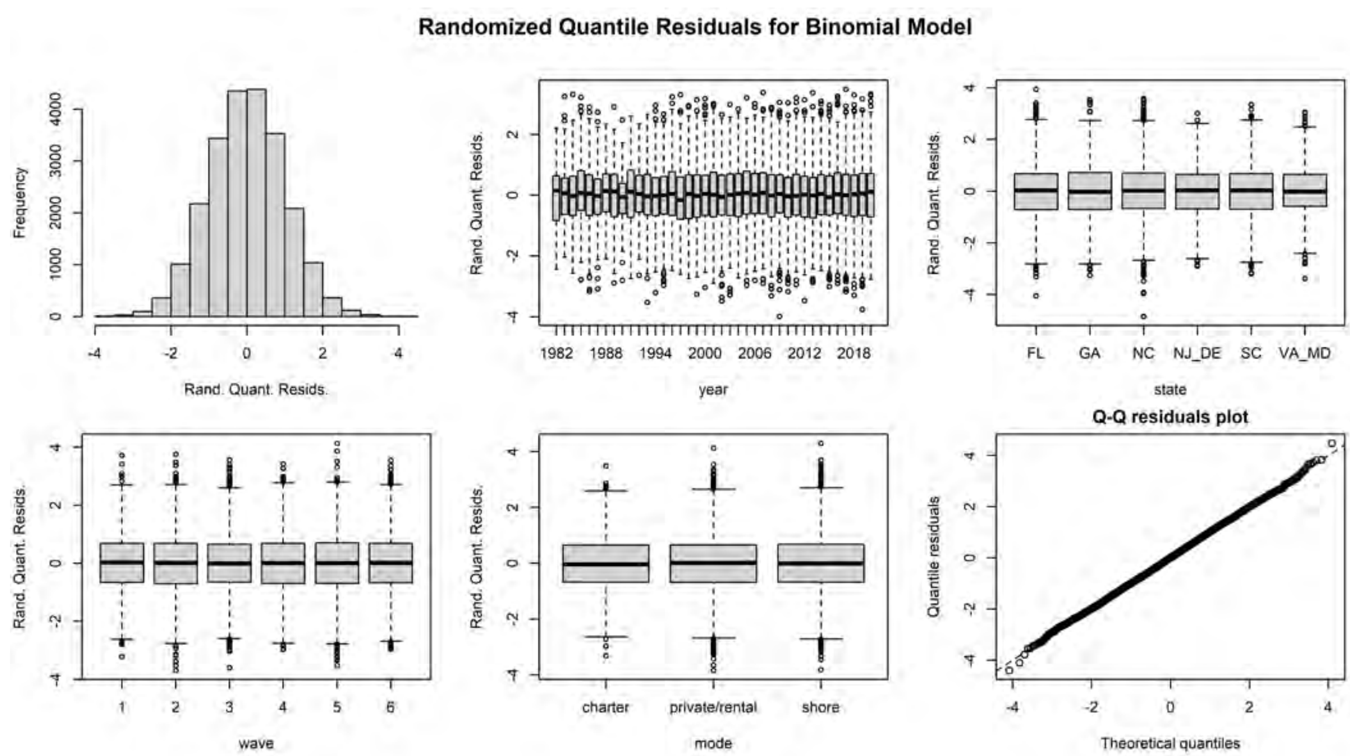

Figure 15. Residual plots for the proportion positive GLMN used to estimate MRIP CPUE.

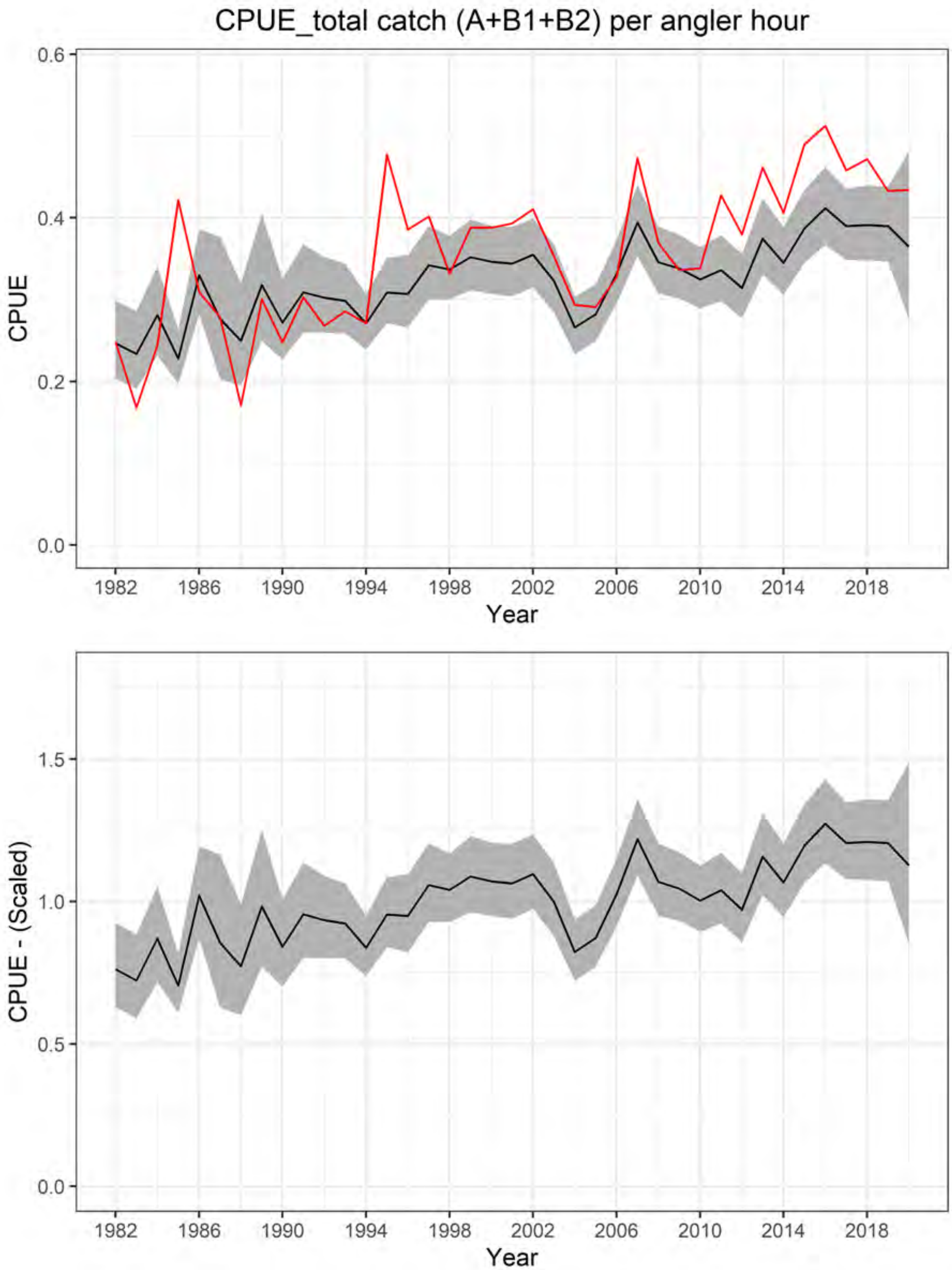

Figure 16. Recreational CPUE estimated from MRIP APAIS data selected with the directed trips method. The upper panel shows the nominal (red line) and standardized (black line) indices on their original scale and the lower panel shows the standardized index scaled to the time series mean. Shaded regions are 95% confidence intervals of the standardized index.

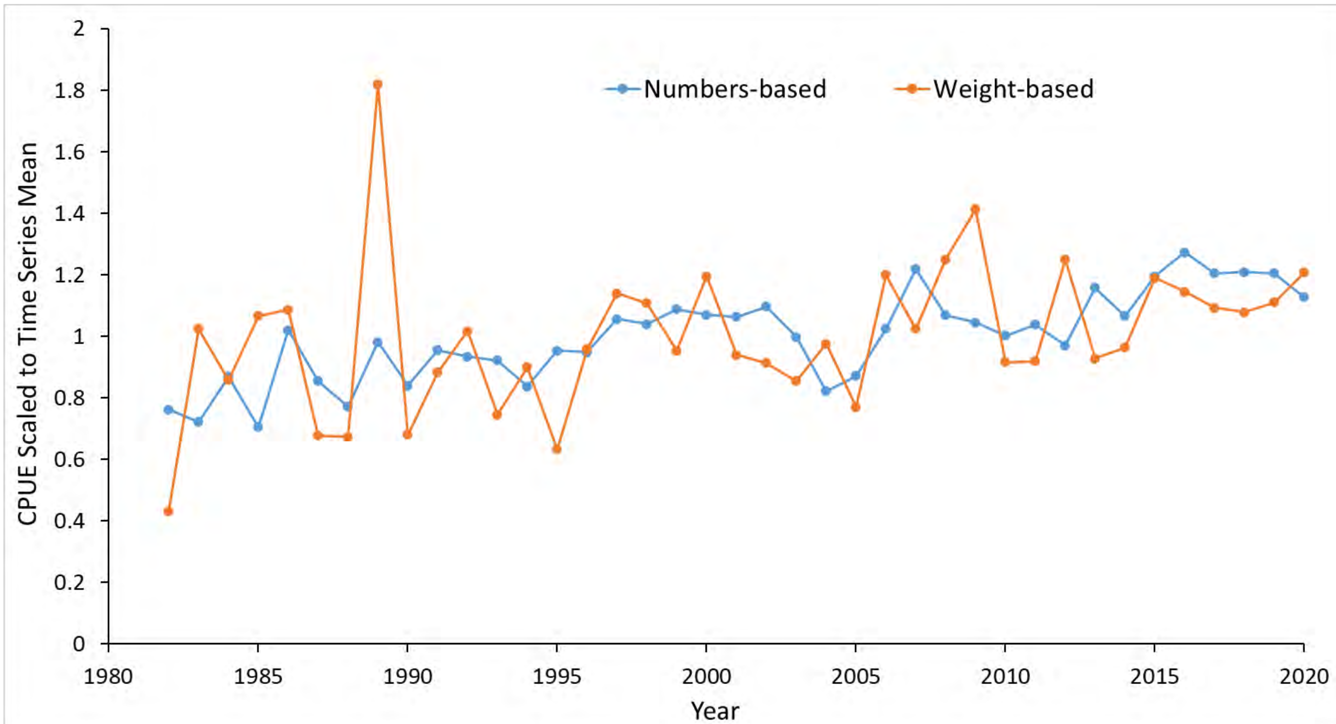

Figure 17. Comparison of numbers-based and weight-based recreational CPUE estimated from MRIP APAIS data selected with the directed trips method.

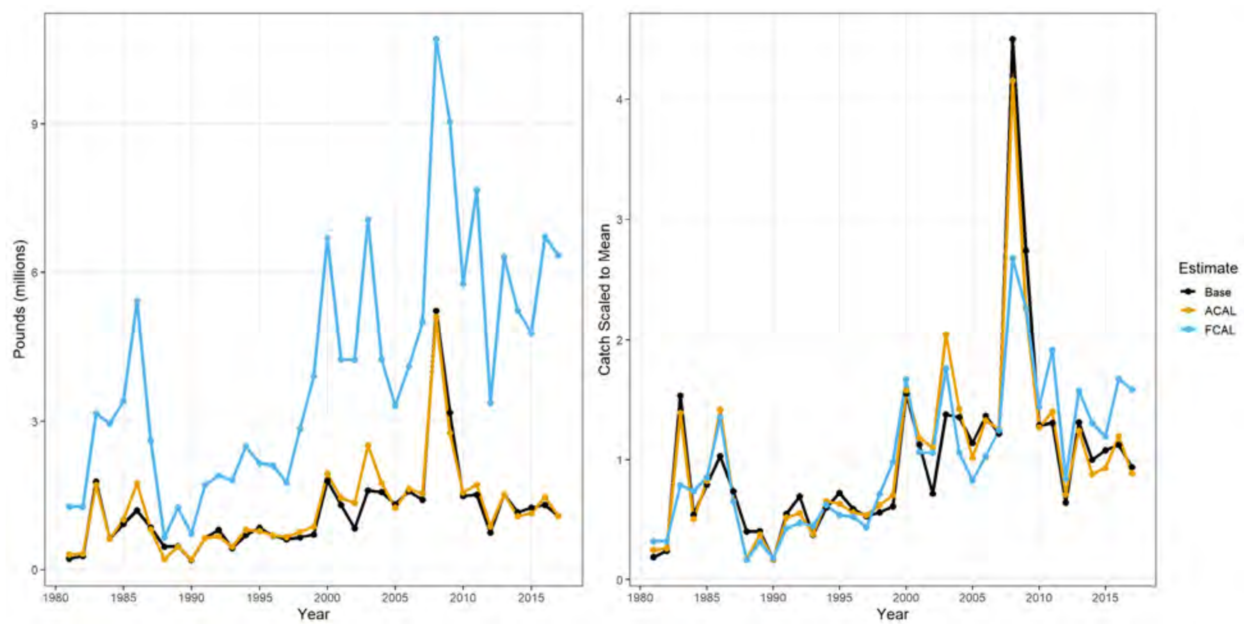

Figure 18. MRIP recreational harvest estimates of black drum before survey methodology change calibrations (Base), following calibration for changes to the APAIS (ACAL), and final estimates following calibrations for both changes to the APAIS and effort survey methodology (FCAL). Estimates on the right are divided by their time series mean to show differences in trends among estimates.

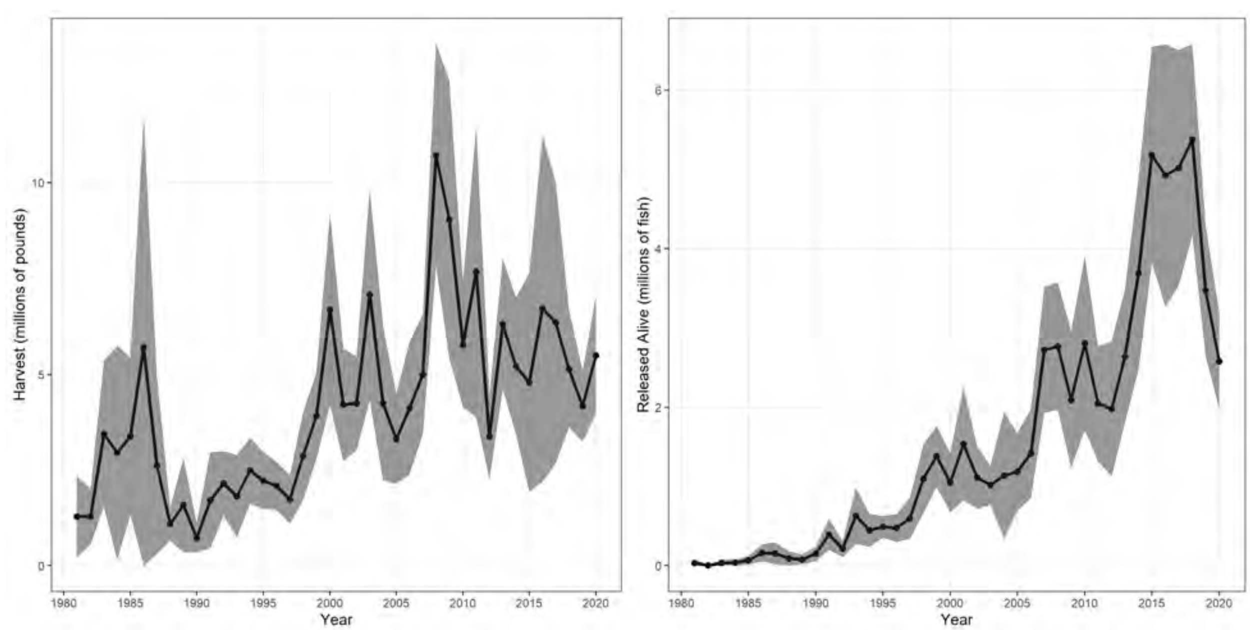

Figure 19. MRIP recreational catch estimates of black drum with 95% confidence intervals.

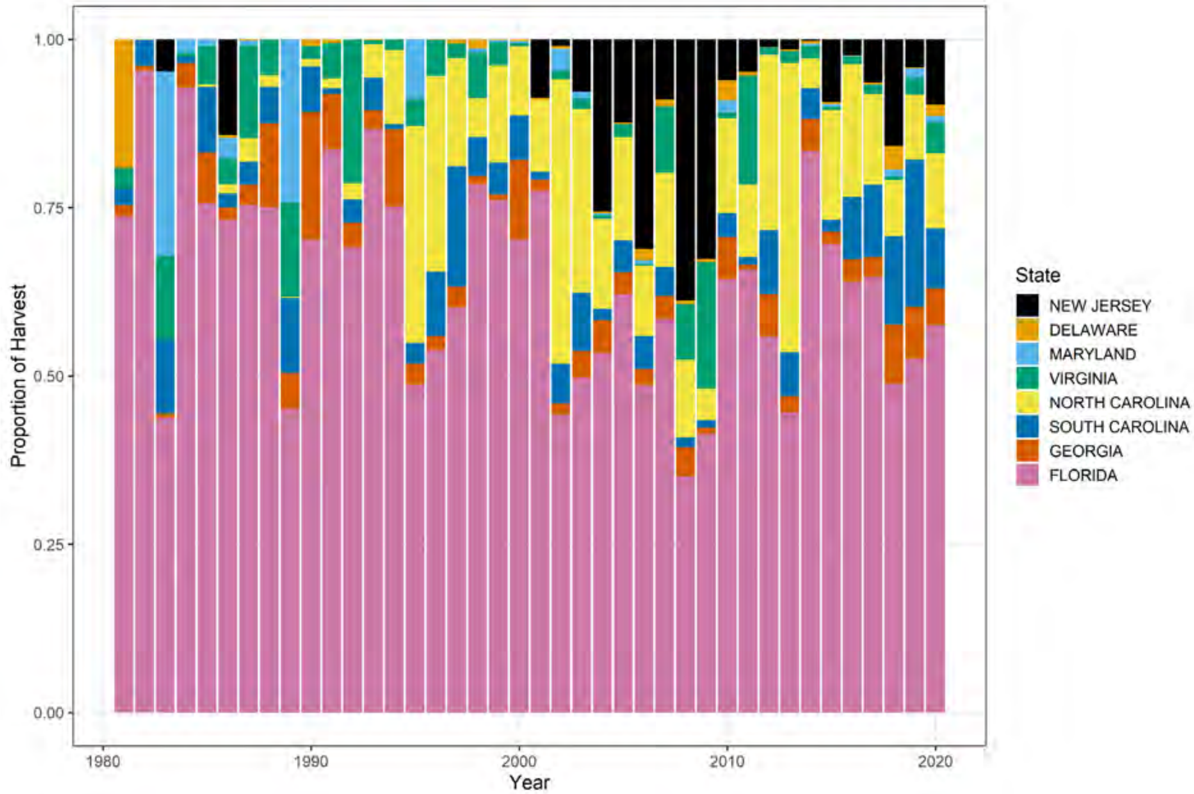

Figure 20. State proportional recreational harvest of black drum.

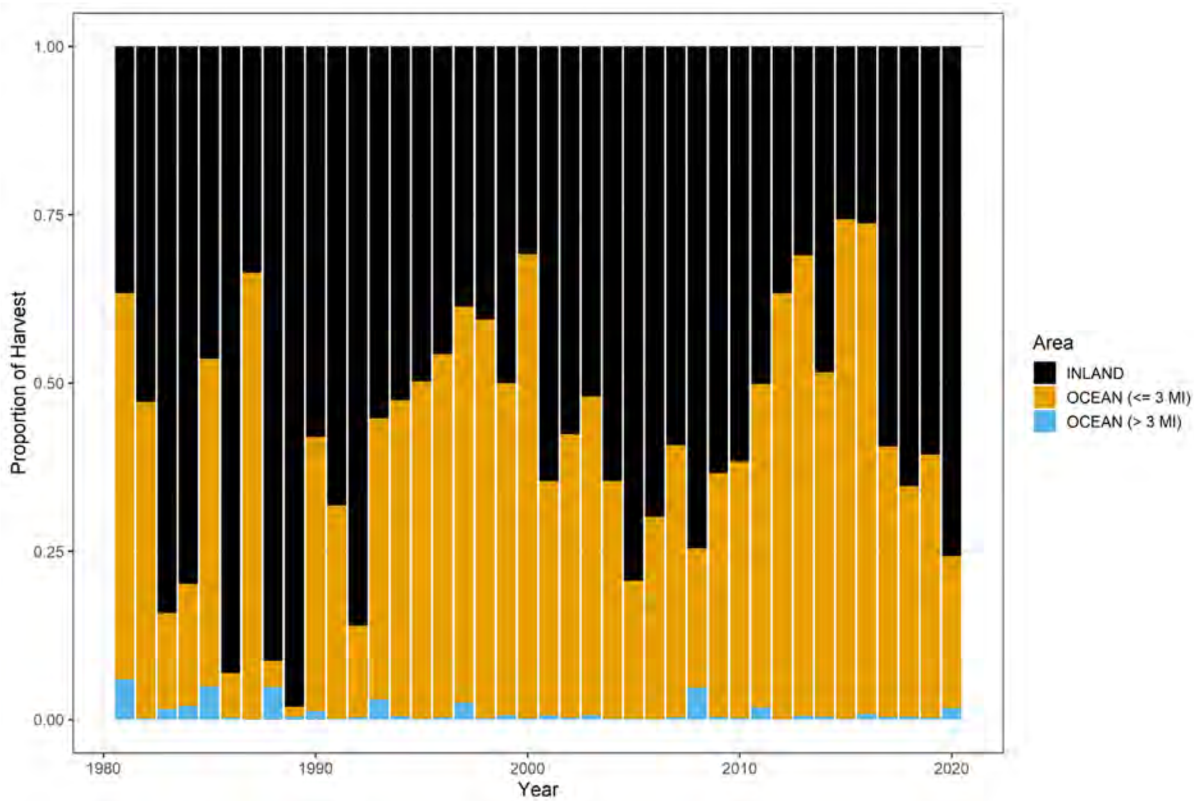

Figure 21. MRIP area proportional recreational harvest of black drum.

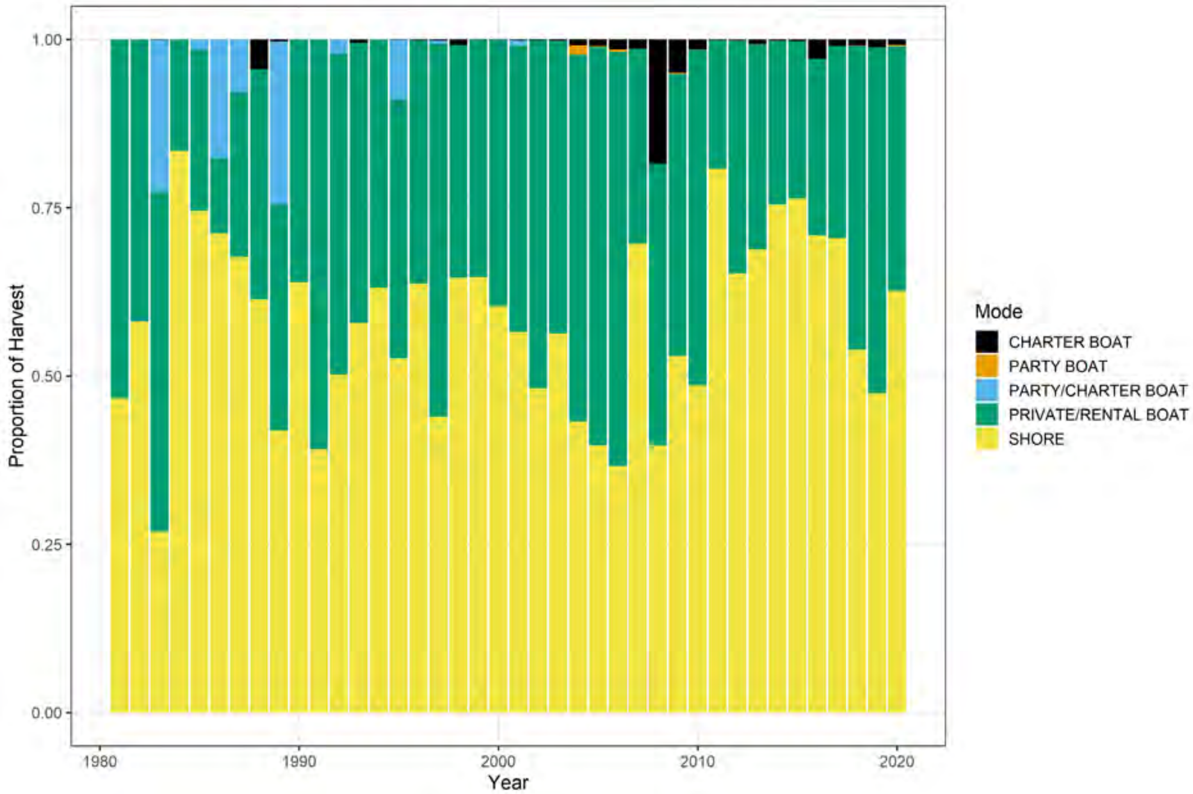

Figure 22. MRIP mode proportional recreational harvest of black drum.

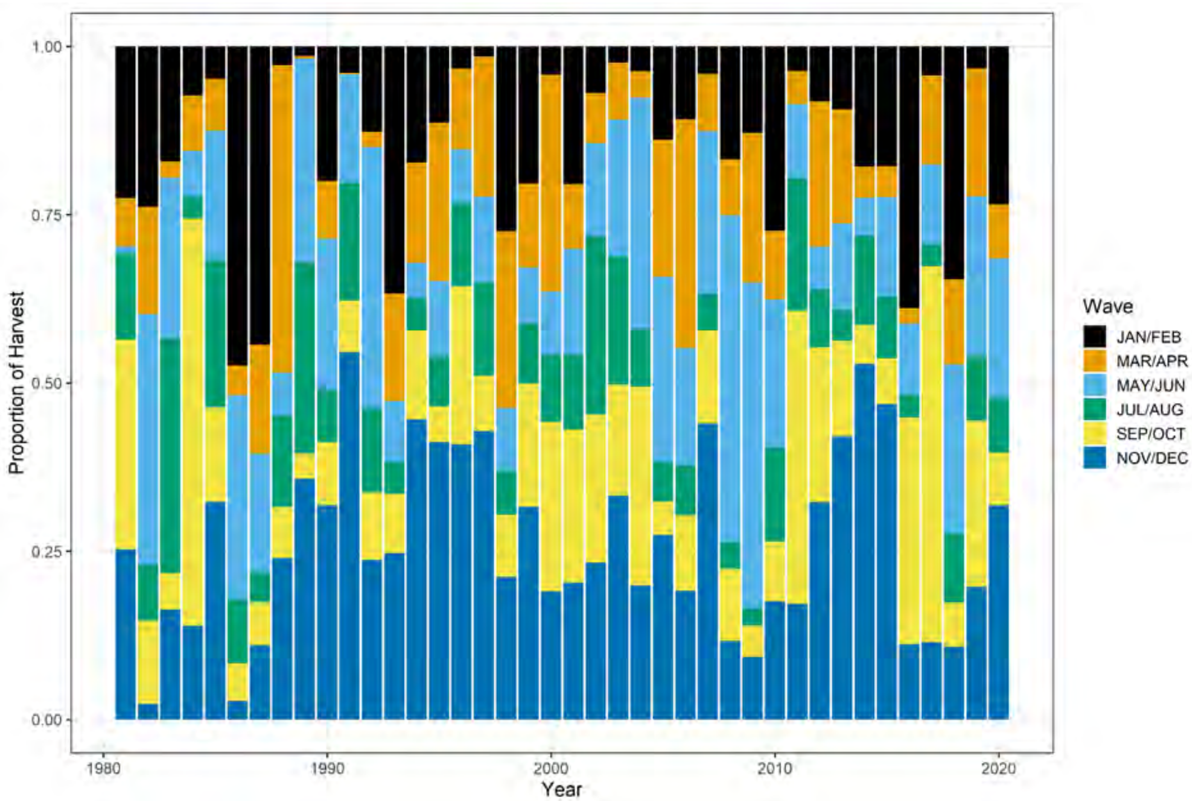

Figure 23. MRIP wave proportional recreational harvest of black drum.

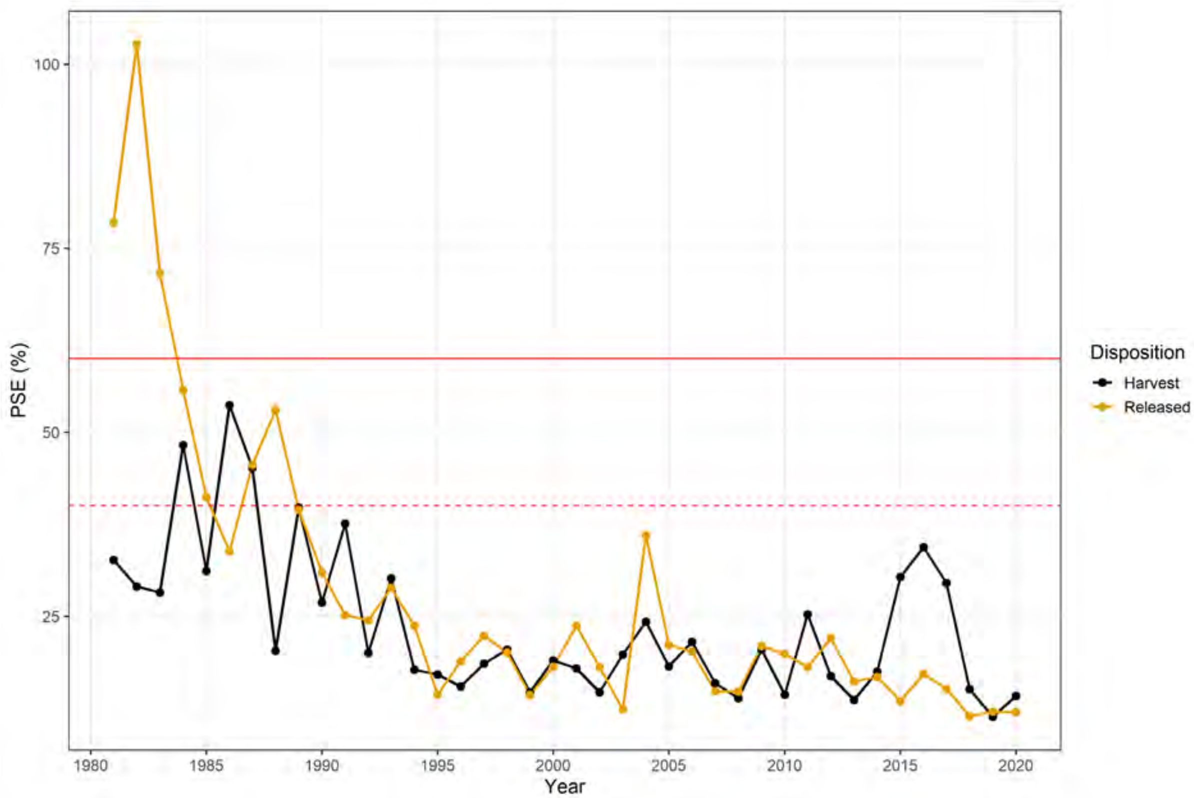

Figure 24. MRIP proportional standard errors (PSEs) for recreational catch estimates. The dashed red line indicates a PSE of 40% and the solid red line indicates a PSE of 60%.

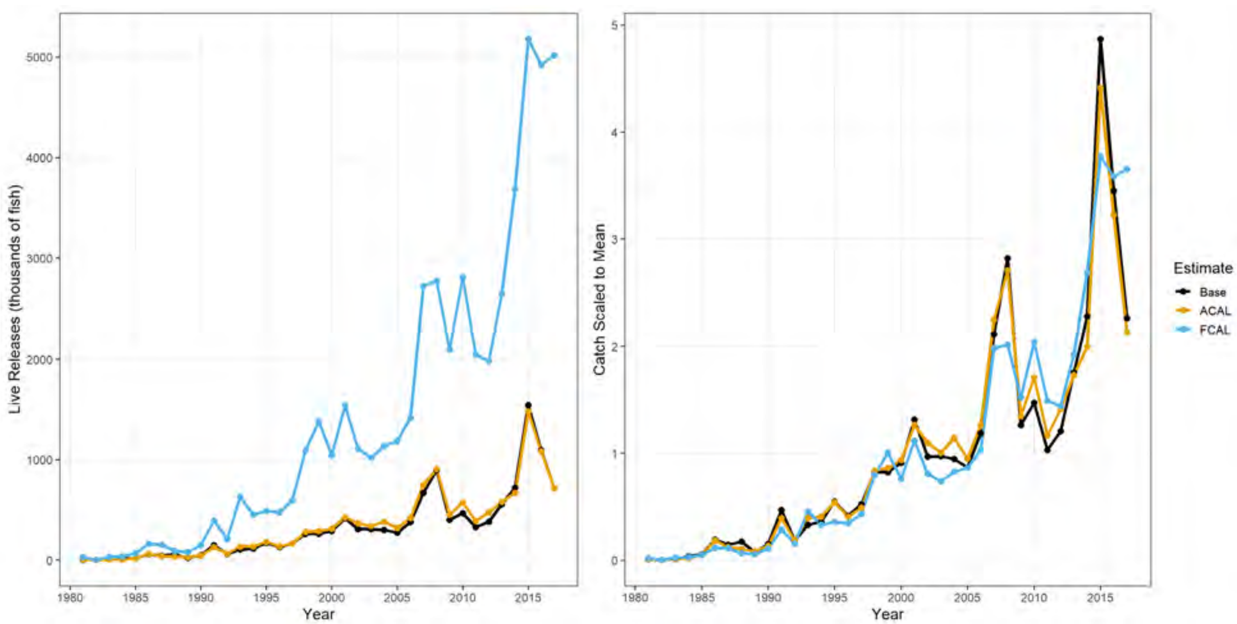

Figure 25. MRIP recreational release estimates of black drum before survey methodology change calibrations (Base), following calibration for changes to the APAIS (ACAL), and final estimates following calibrations for both changes to the APAIS and effort survey methodology (FCAL). Estimates on the right are divided by their time series mean to show differences in trends among estimates.

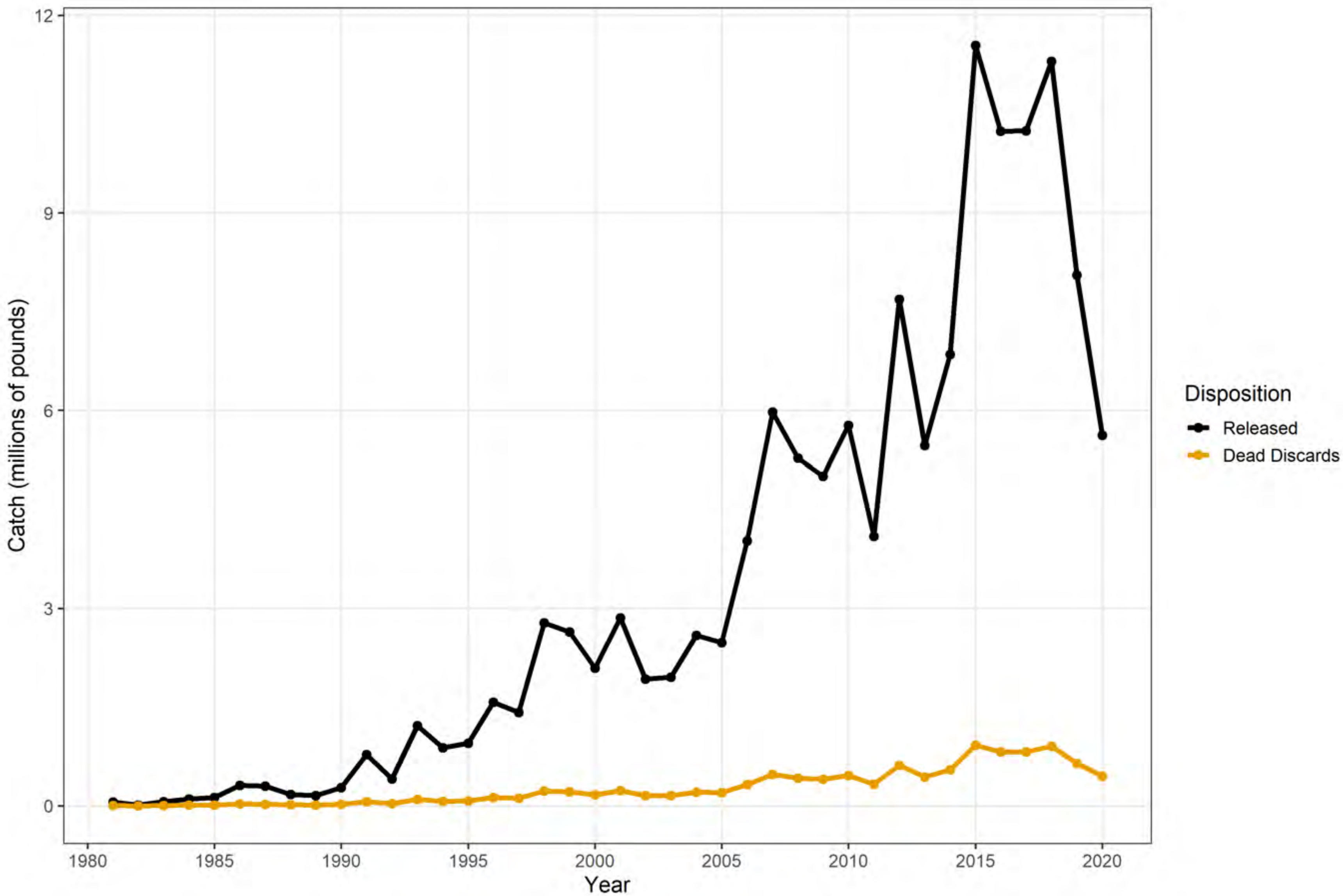

Figure 26. Black drum recreational releases and dead discards estimated in pounds from MRIP released alive estimates in numbers.

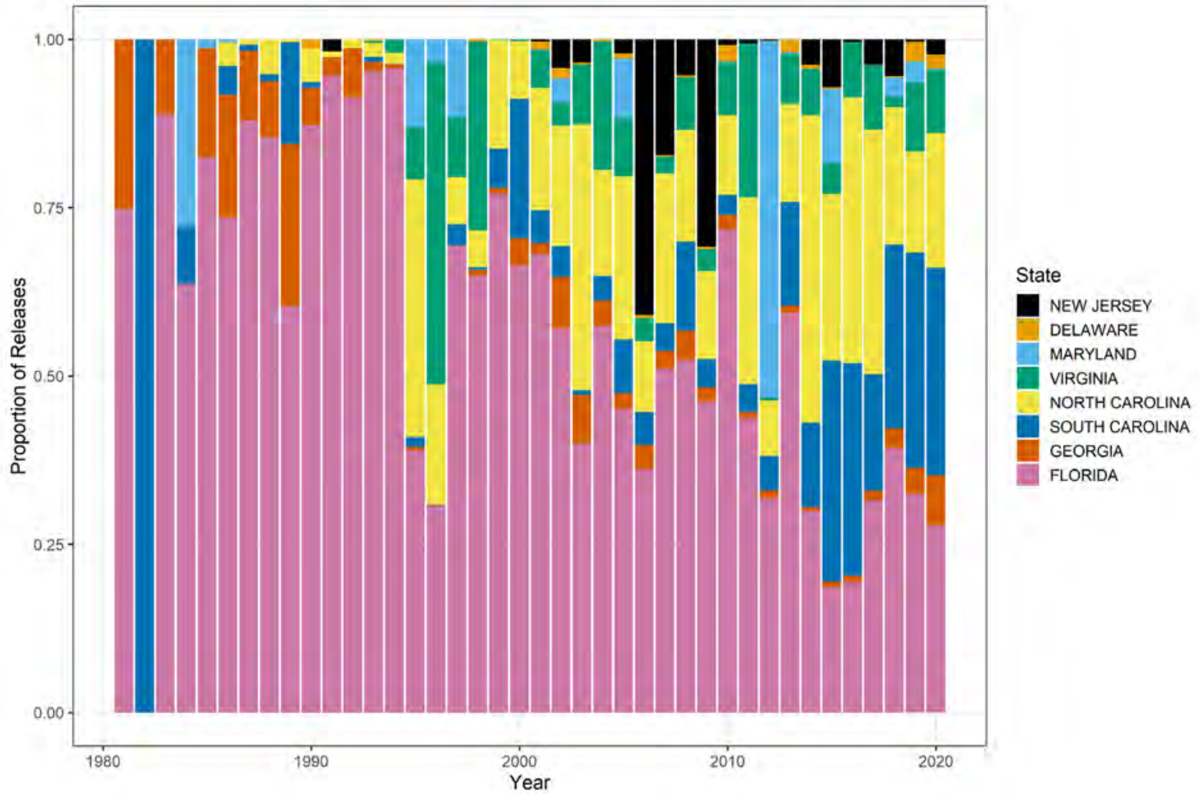

Figure 27. State proportional recreational releases of black drum.

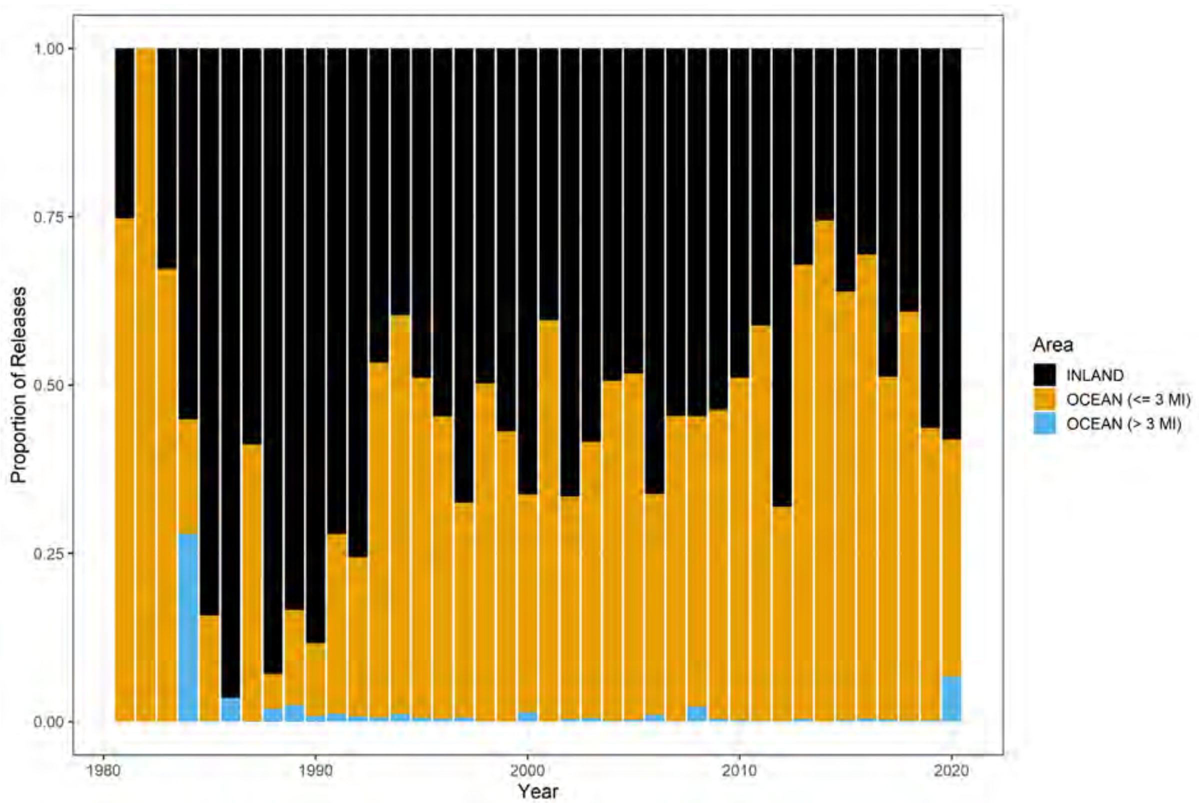

Figure 28. MRIP area proportional recreational releases of black drum.

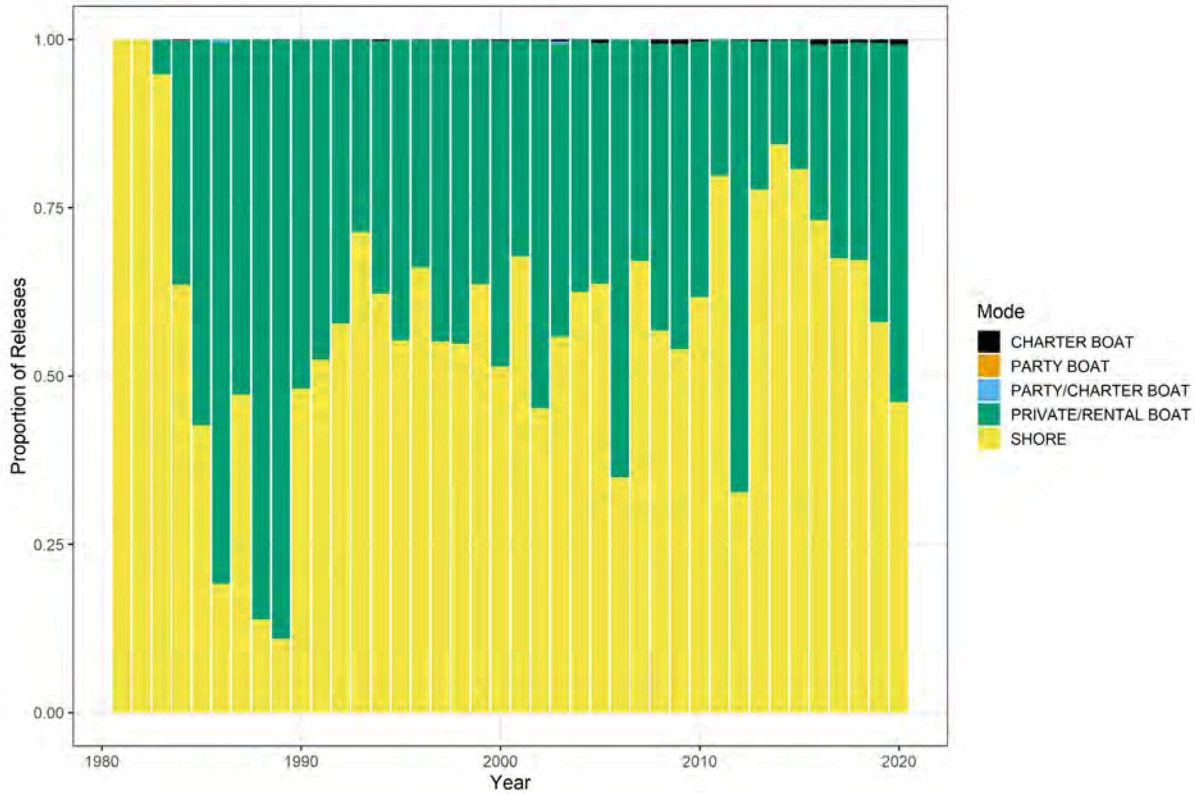

Figure 29. MRIP mode proportional recreational releases of black drum.

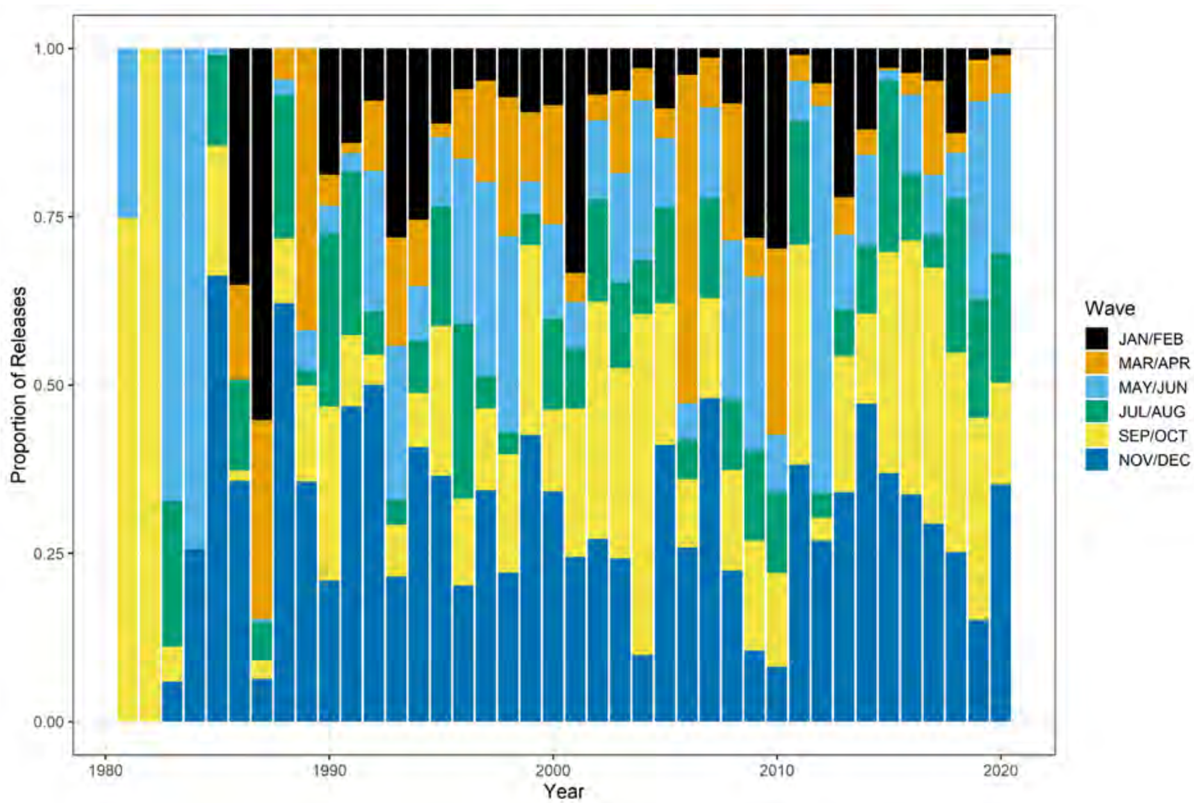

Figure 30. MRIP wave proportional recreational releases of black drum.

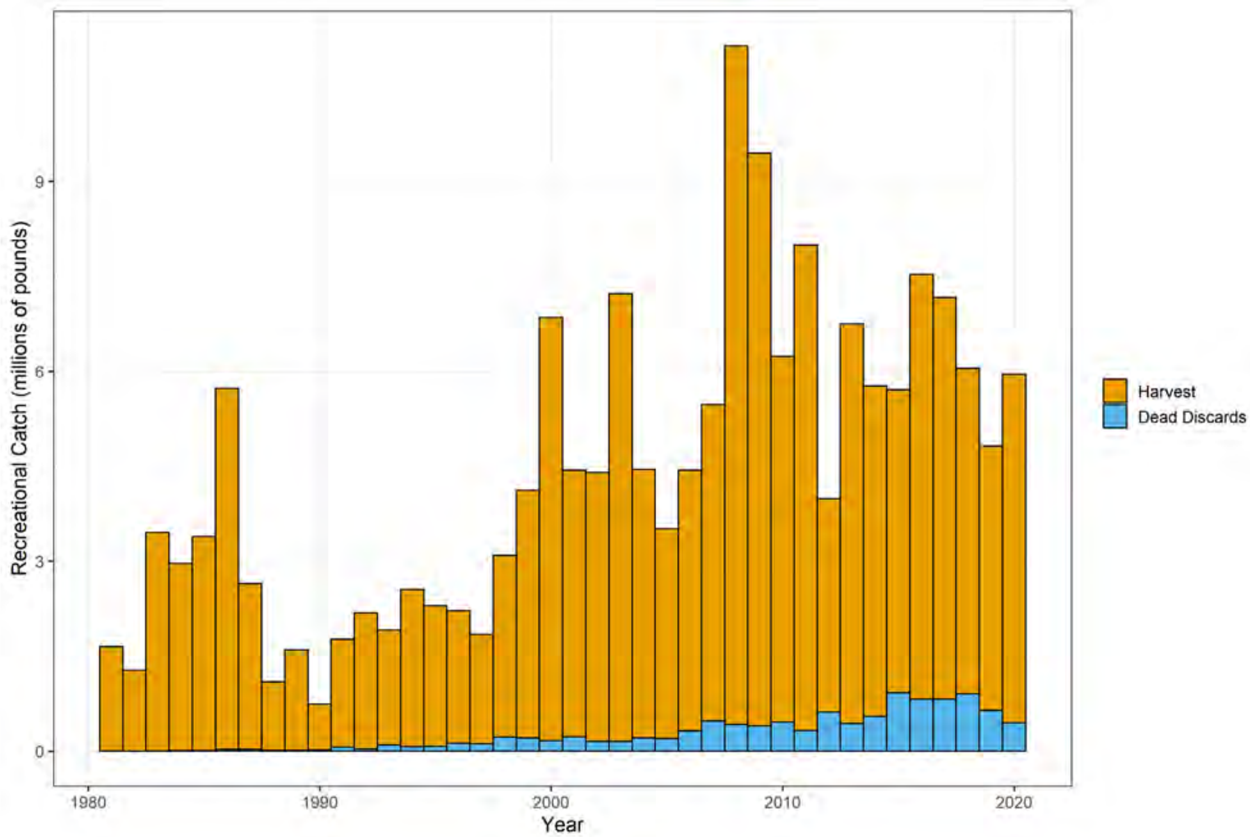

Figure 31. Recreational fishery removals from the MRFSS/MRIP time period.

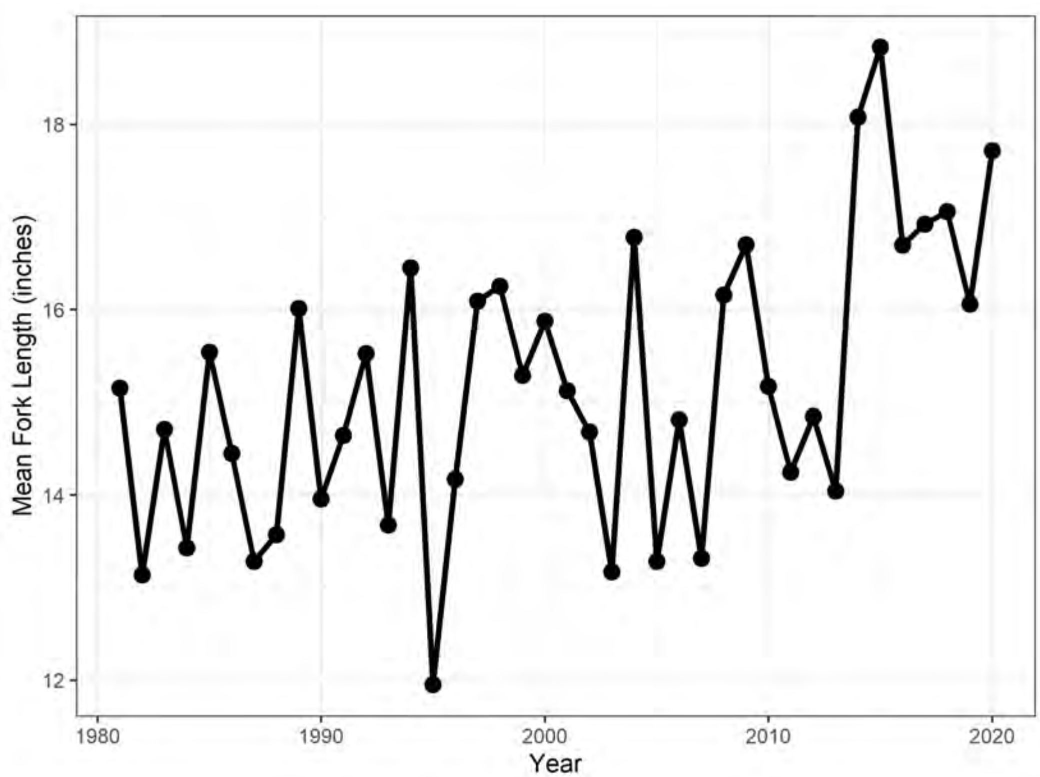

Figure 32. Mean fork length of black drum harvested in the recreational fishery.

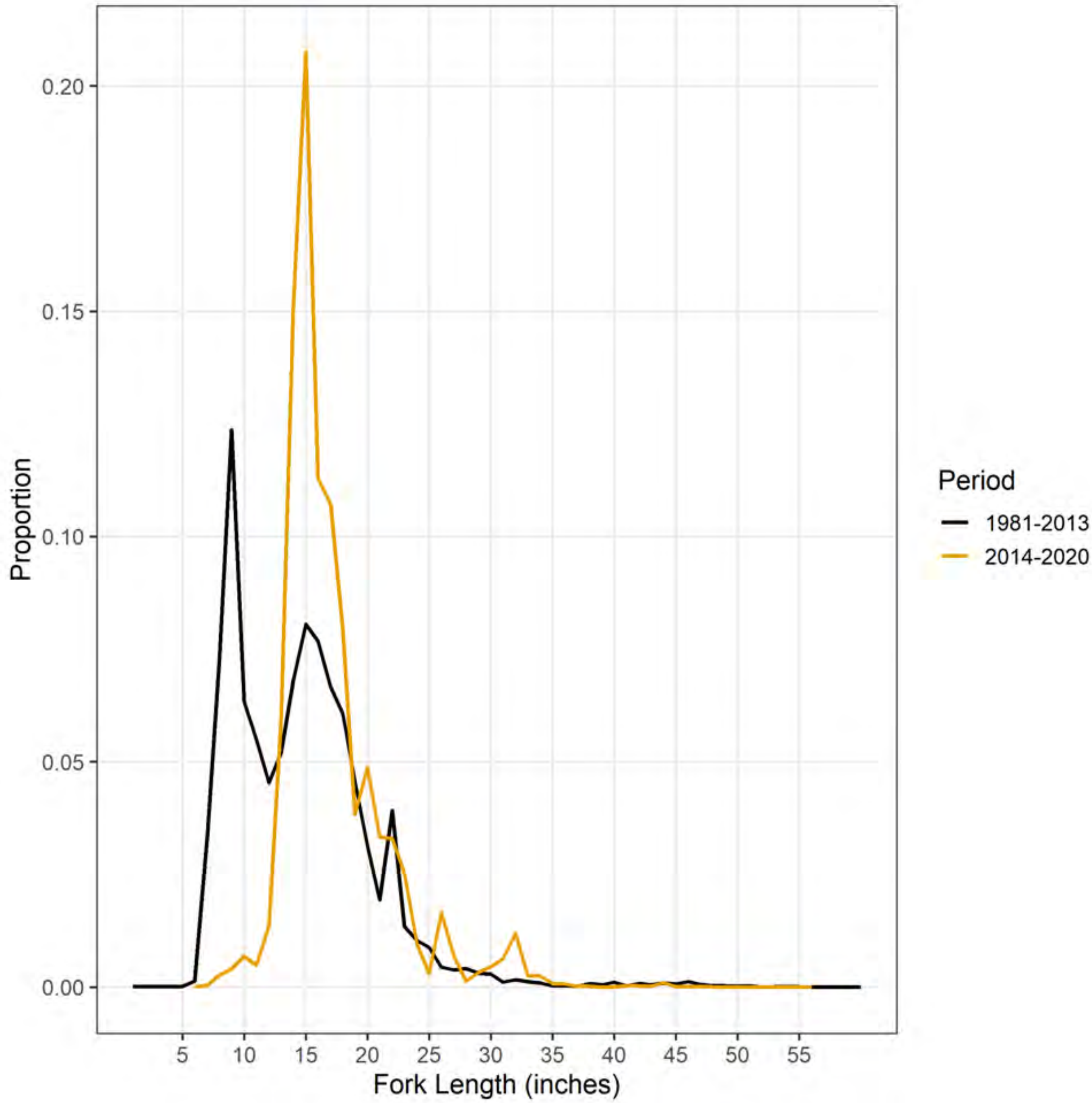

Figure 33. Size distribution of black drum harvested in the recreational fishery before and after the implementation of the FMP.

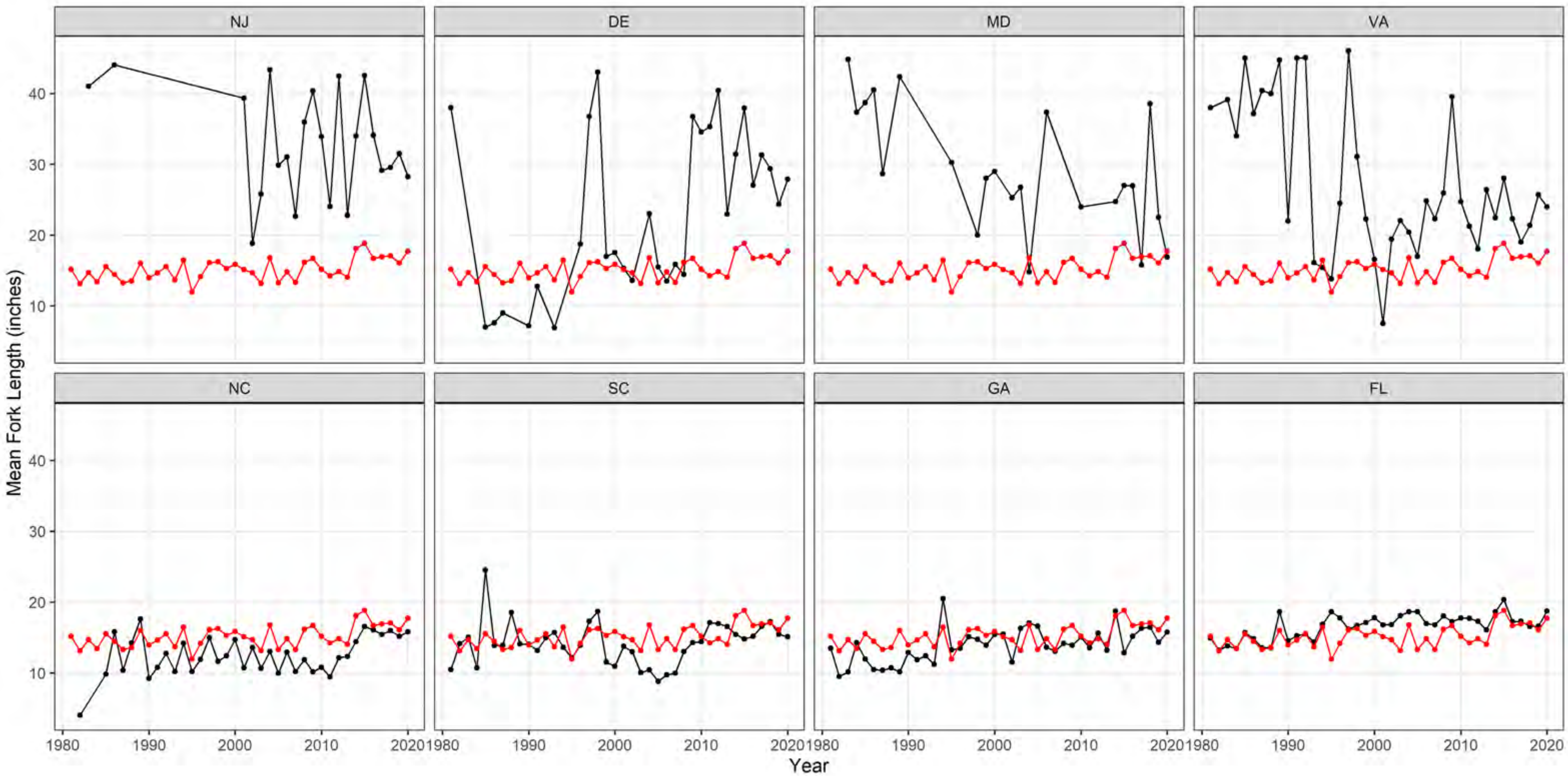

Figure 34. Mean fork length of black drum harvested in the recreational fishery in each state (black line) compared to all harvest coastwide (red line).

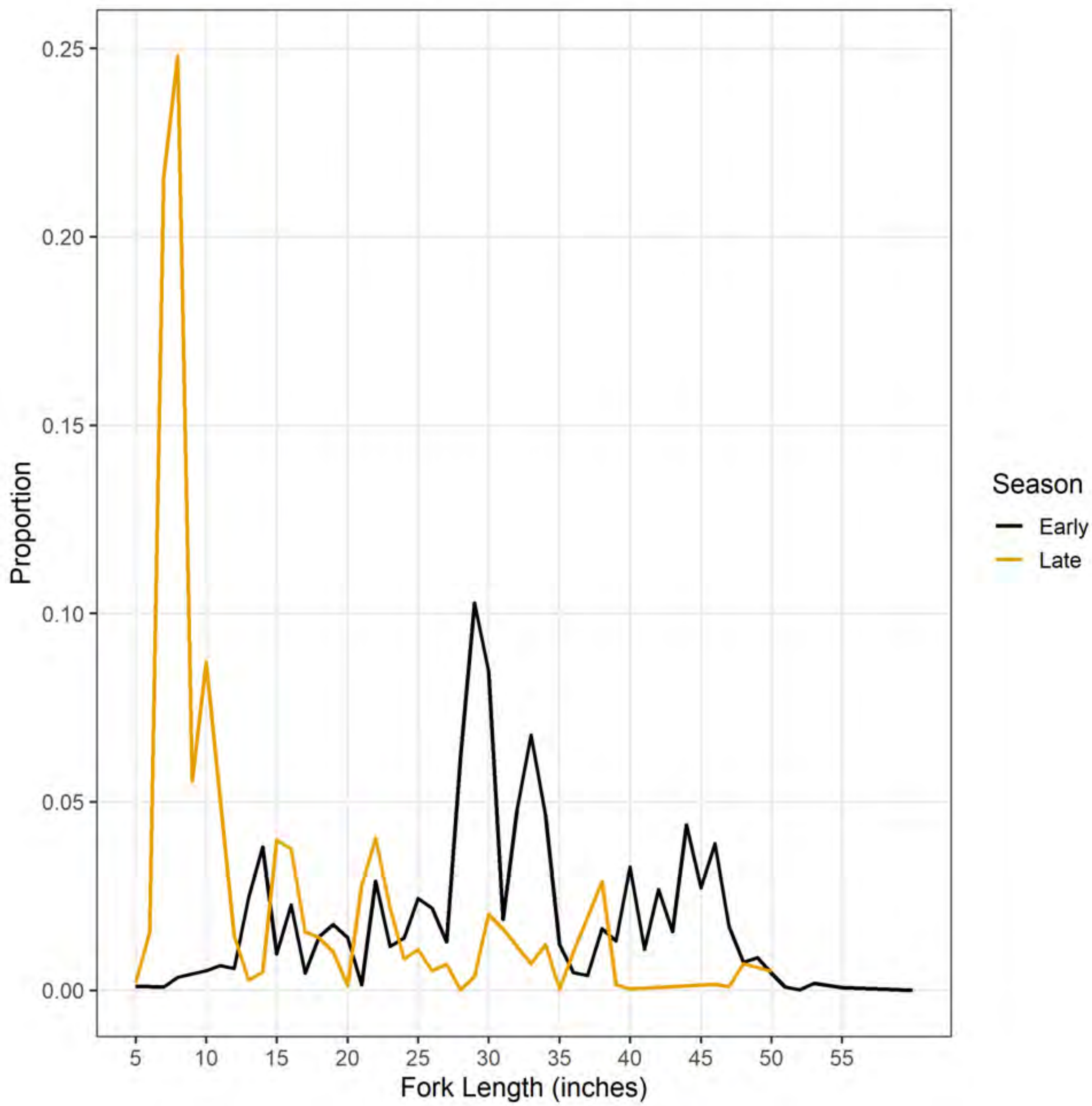

Figure 35. Size distribution of black drum harvested in the Mid-Atlantic recreational fishery earlier in the year (waves 2-4, March-August) and later in the year (waves 5-6, September-December).

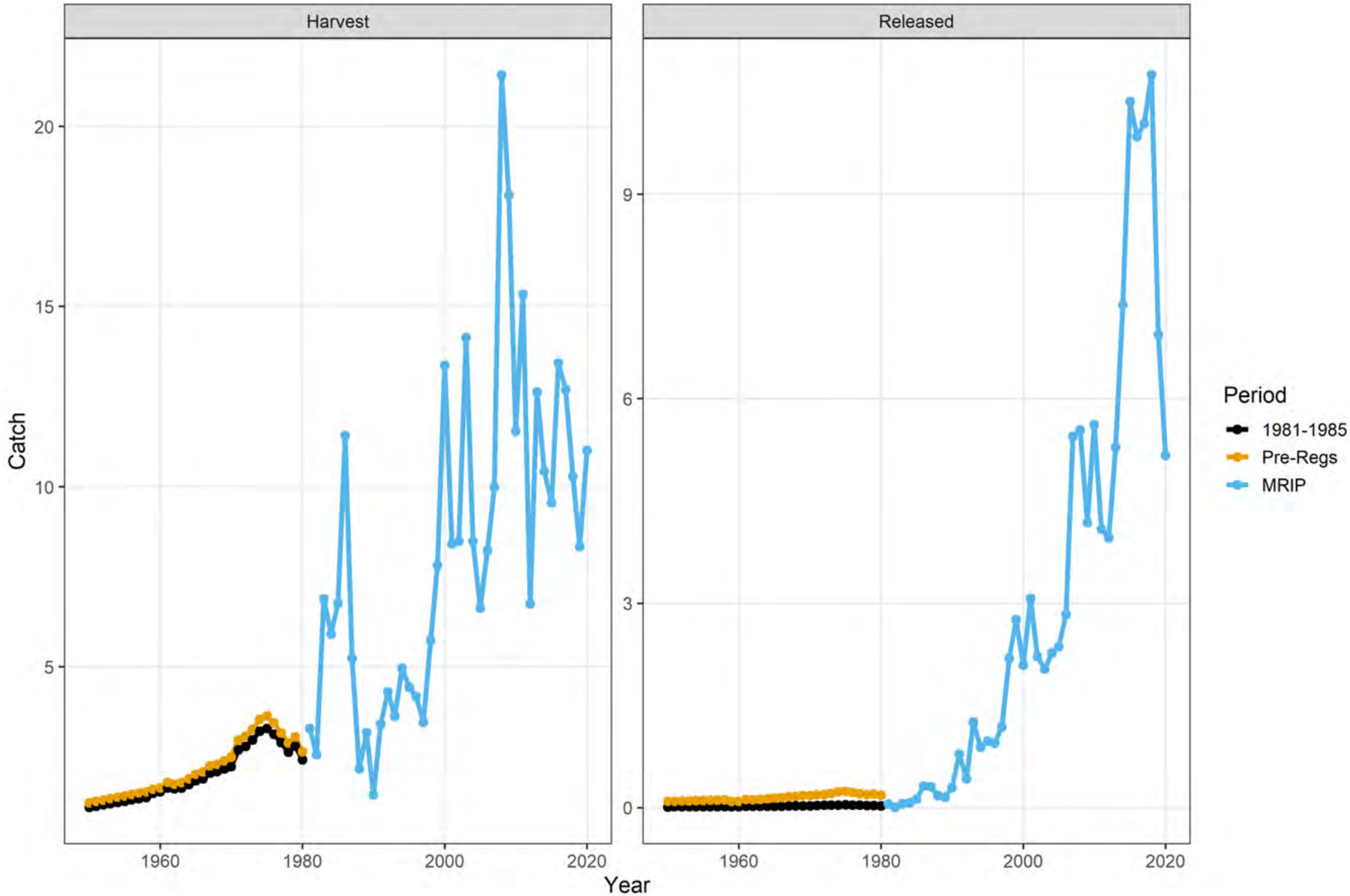

Figure 36. Historical recreational catch estimates using MRIP CPUE data from 1981-1985 for all states and MRIP CPUE data from all years before implementation of regulations in each state. Estimates after 1980 are from MRIP.

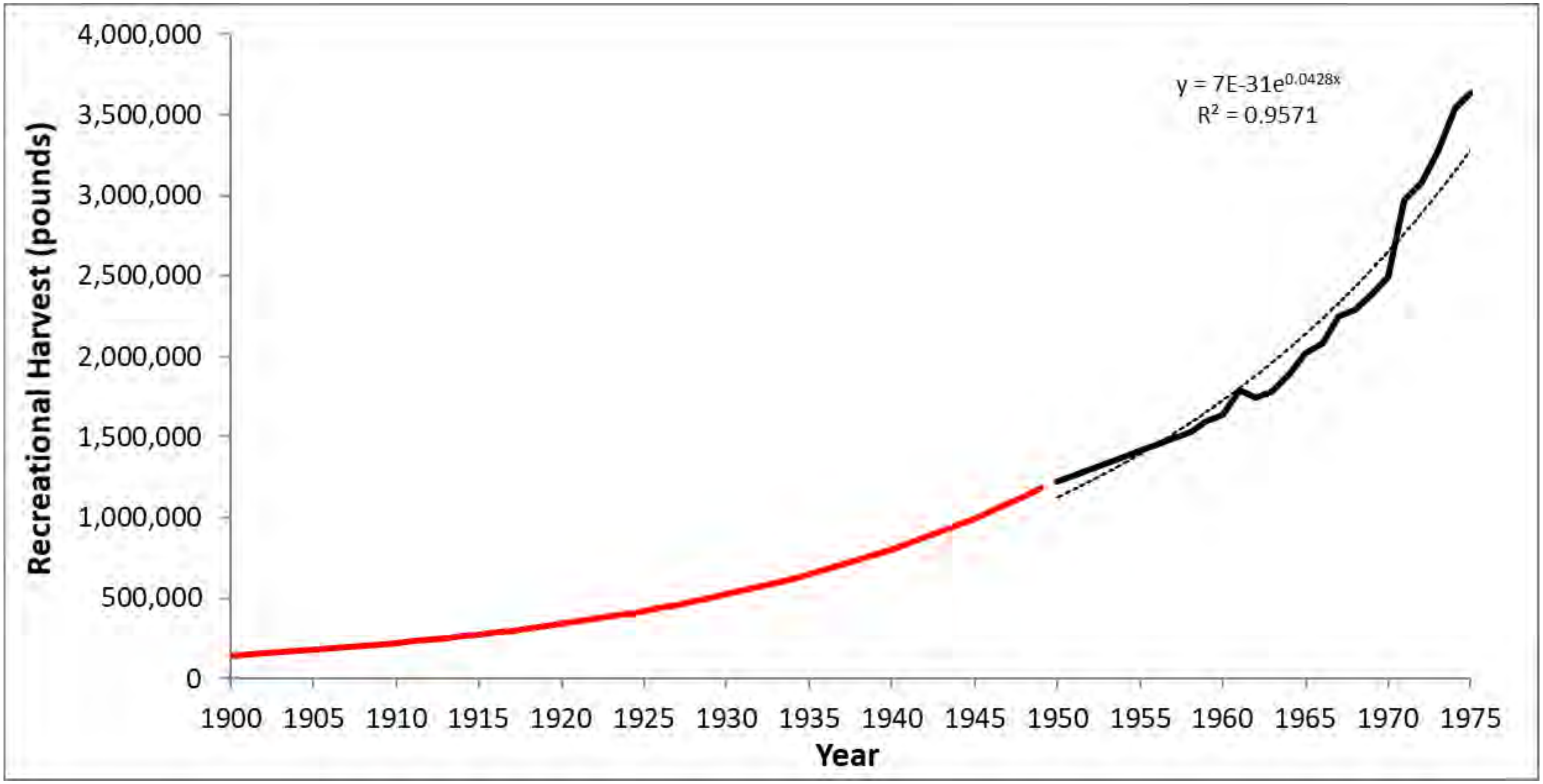

Figure 37. Black drum recreational harvest estimates from 1900-1975. The dashed line is the estimated trendline from the exponential regression fit to historical estimates from 1950-1975 (solid black line). The red line indicates estimates extrapolated with exponential regression.

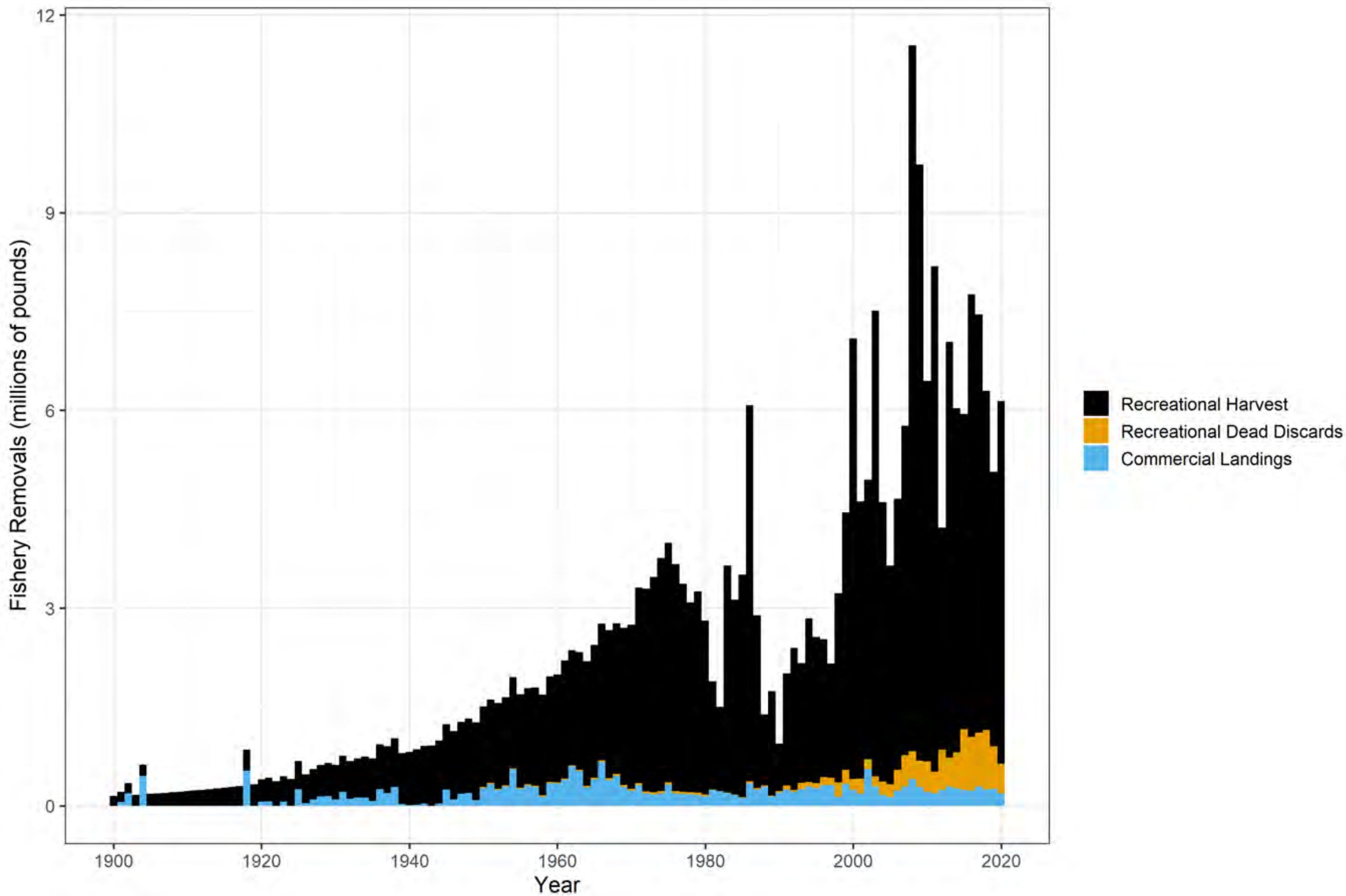

Figure 38. Total fishery removals of black drum by sector and disposition from 1900-2020.

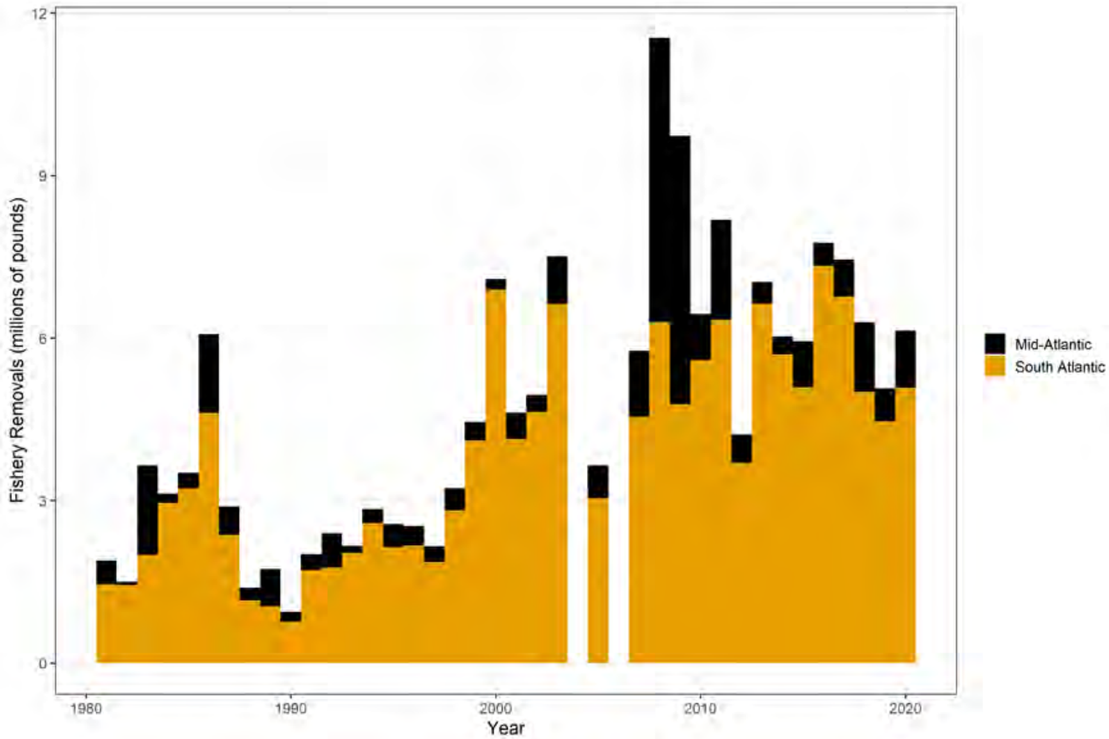

Figure 39. Total fishery removals of black drum by region from 1981-2020. Missing values indicate confidential data that have been redacted.

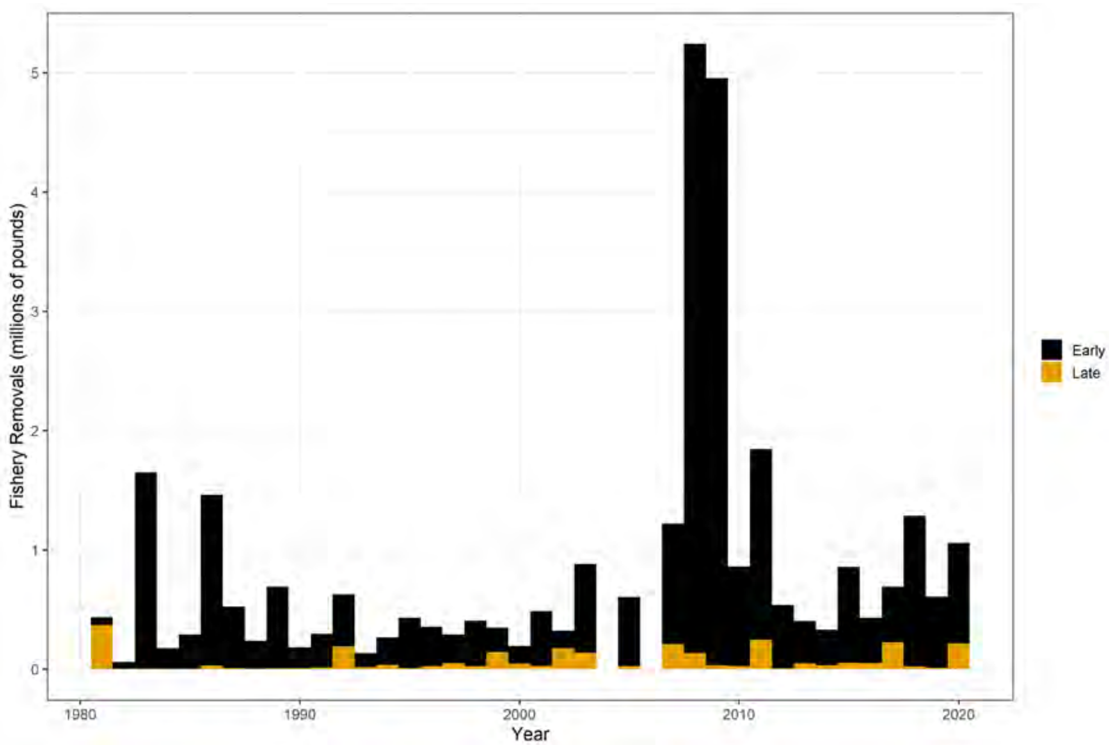

Figure 40. Total fishery removals of black drum in the Mid-Atlantic by season from 1981-2020. The early season is January-August and the late season is September-December. Missing values indicate confidential data that have been redacted.

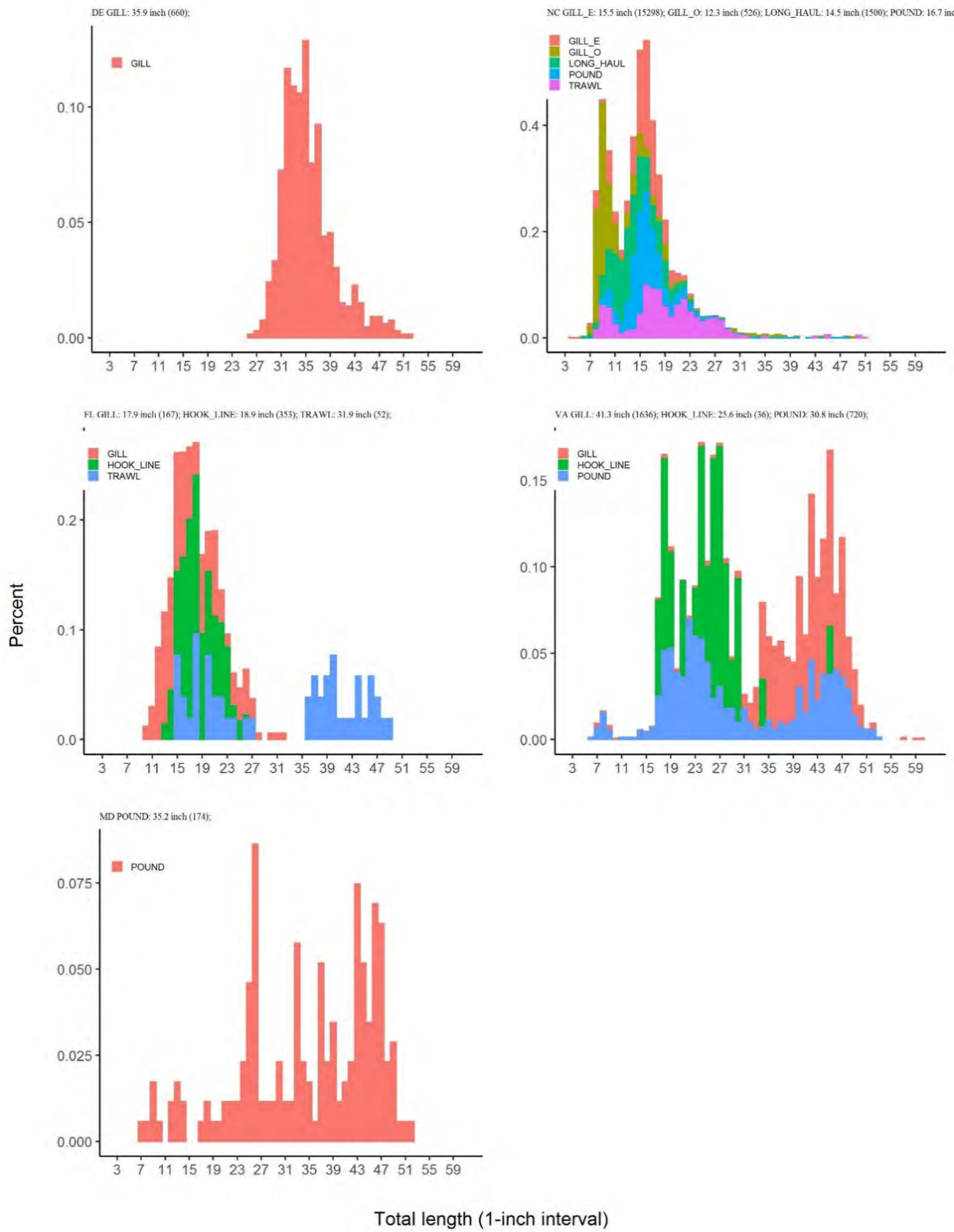

Figure 41. Length frequency distribution landed by commercial gear within each state.

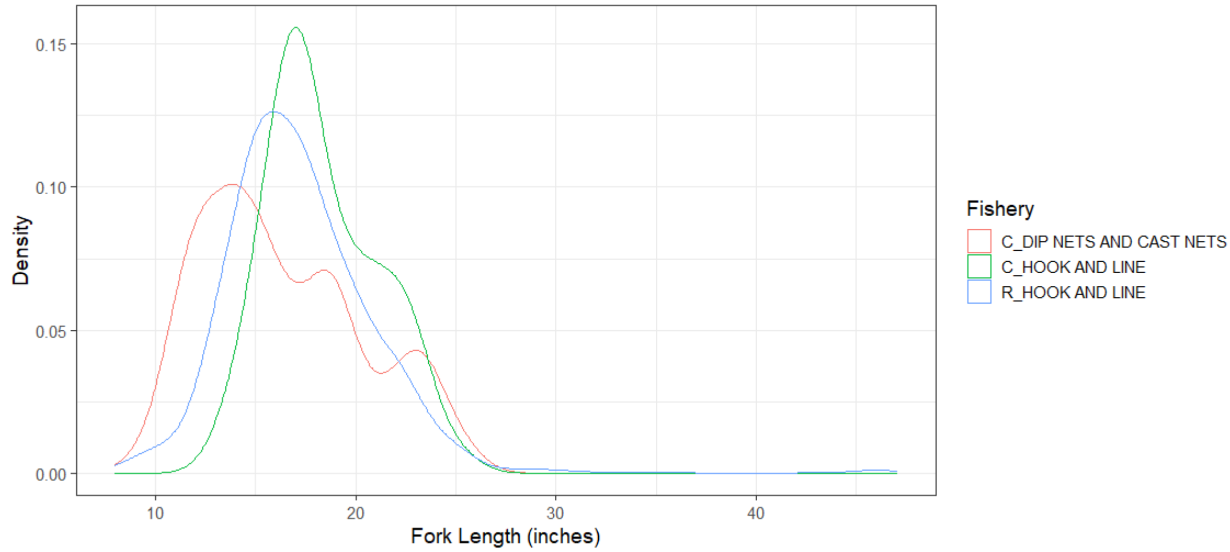

Figure 42. Size distributions of FL black drum harvest from the recreational fishery (R_HOOK AND LINE) and two major commercial gear categories (C_DIP NETS AND CAST NETS, C_HOOK AND LINE) during 1996-2003.

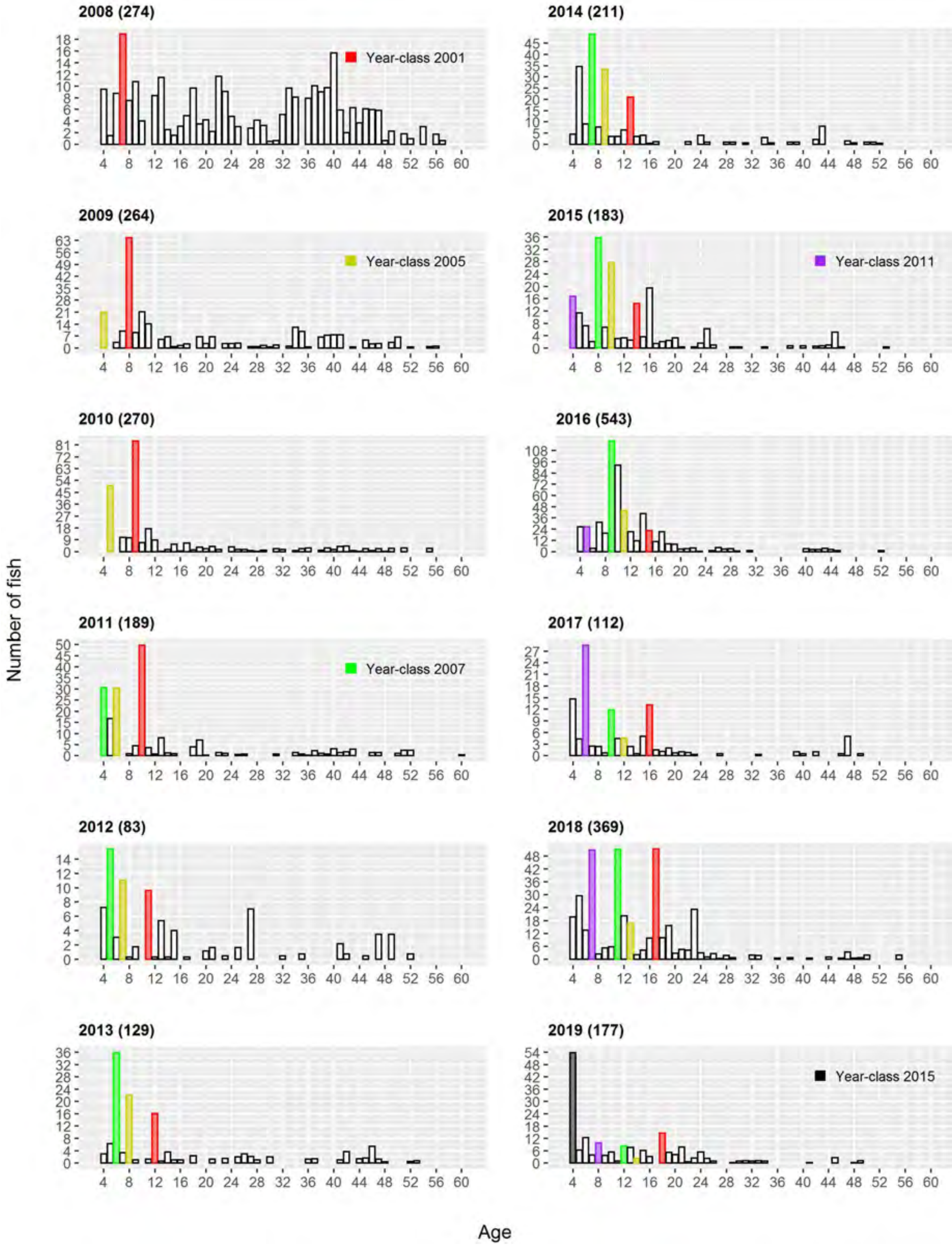

Figure 43. Coastwide annual age distributions from 2008 to 2019 with removal of fish younger than age-4. Four strong cohorts are identified, they are Year-class 2001 (Red), 2005 (Yellow), 2007 (Green), and 2011 (Pink). Year-class 2015 (Blue) could be a strong cohort.

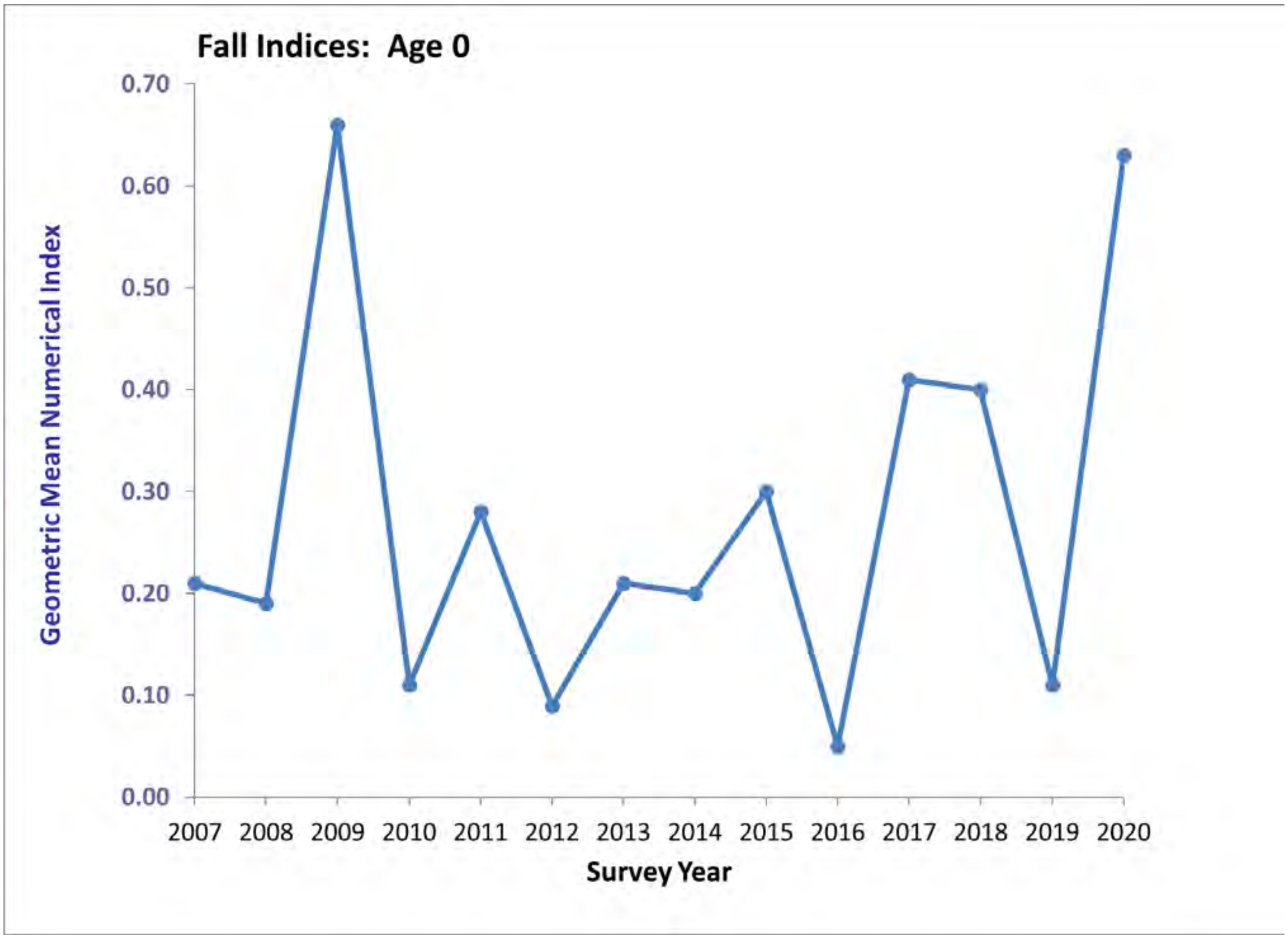

Figure 44. Northeast Area Monitoring and Assessment Program (NEAMAP) black drum geometric mean YOY index from 2007-2020.

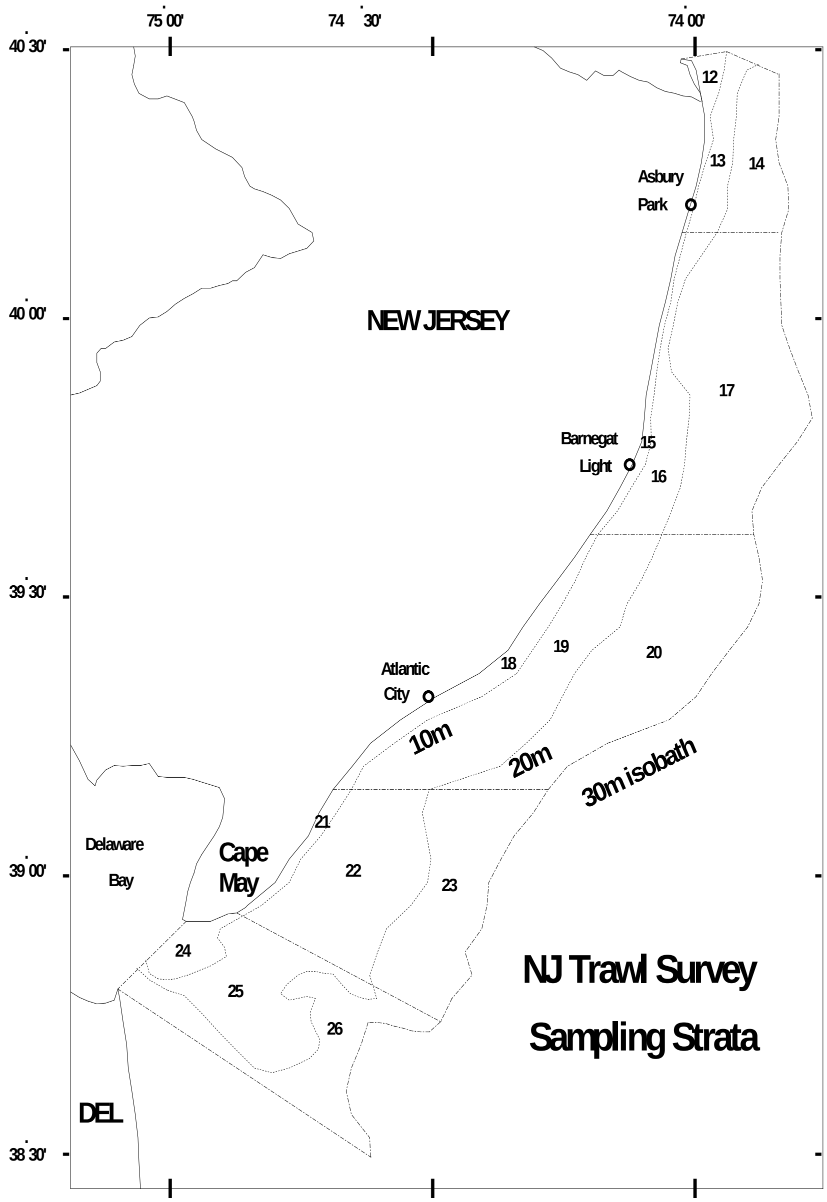

Figure 45. New Jersey Ocean Trawl Survey sampling strata.

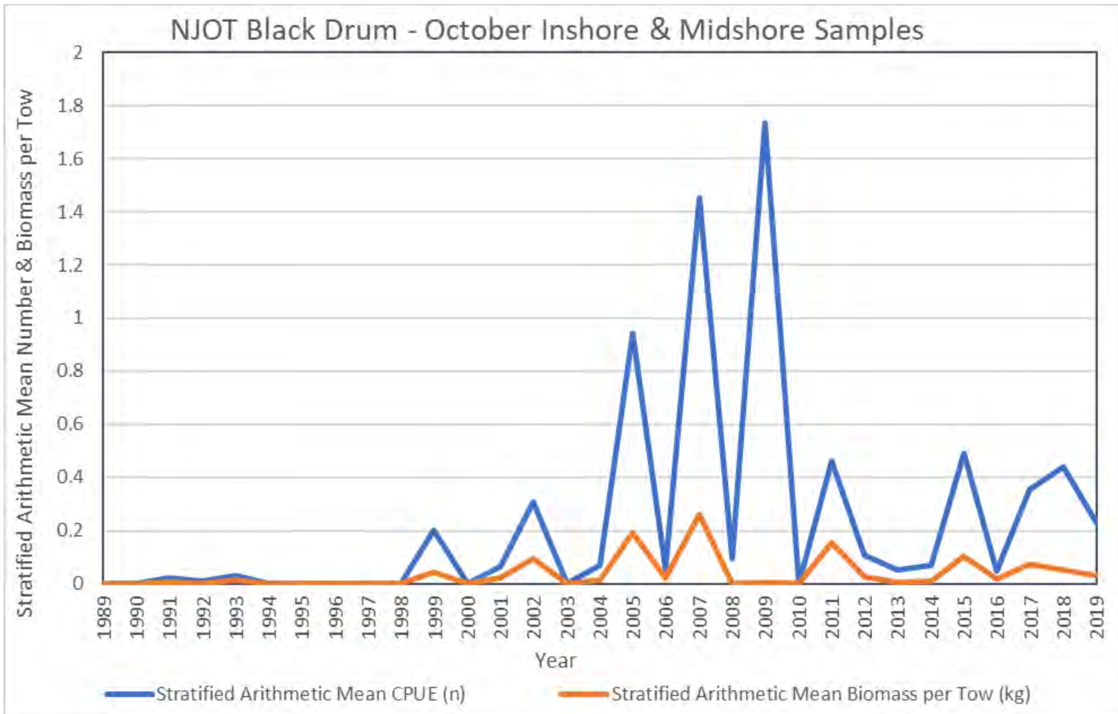

Figure 46. Black drum mean CPUE in blue and mean biomass per tow (kg) in orange from New Jersey Ocean Trawl Survey's October cruises subset to sampling strata <= 60' depths.

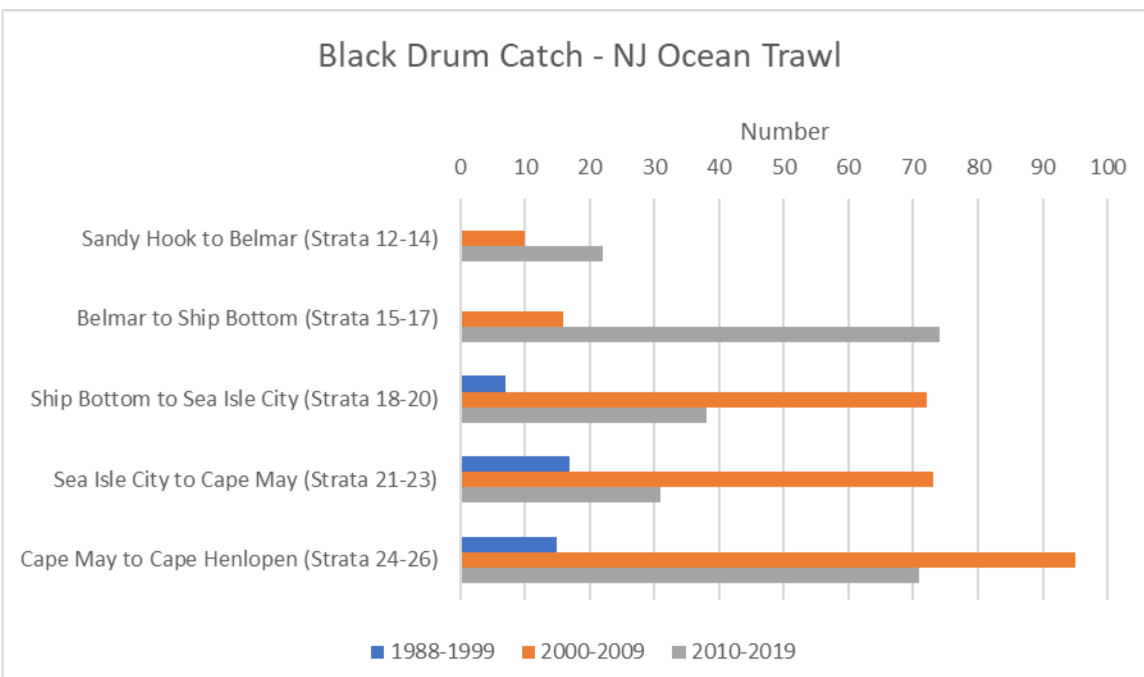

Figure 47. Black drum catches in total number for the New Jersey Ocean Trawl Survey (all cruises) by stratum groupings from north to south on the Y-axis. Catches are subset by decade with the earliest (1988-1999) in blue, 2000-2009 in orange, and 2010-2019 in gray.

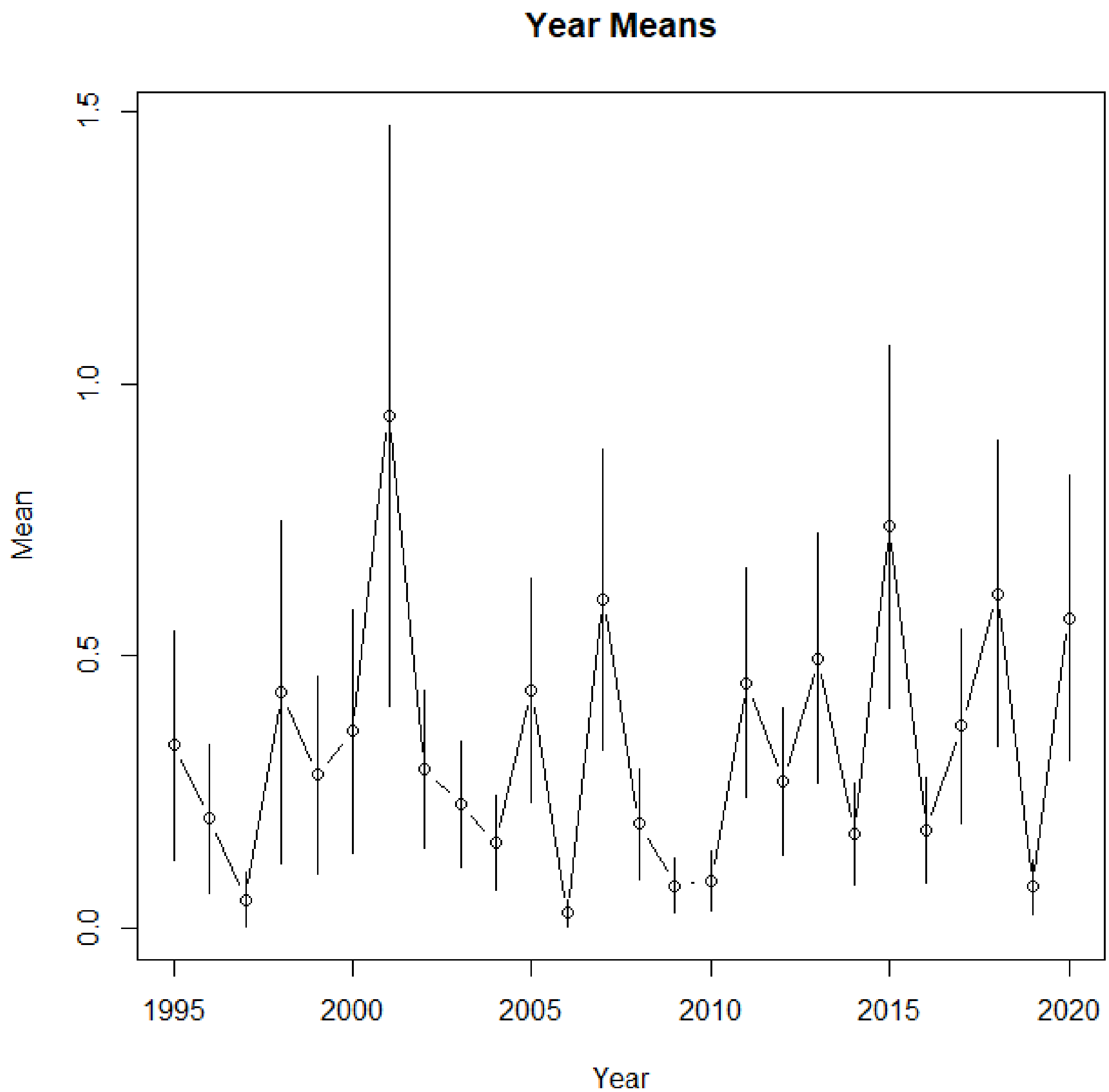

Figure 48. PSEG Seine Survey index.

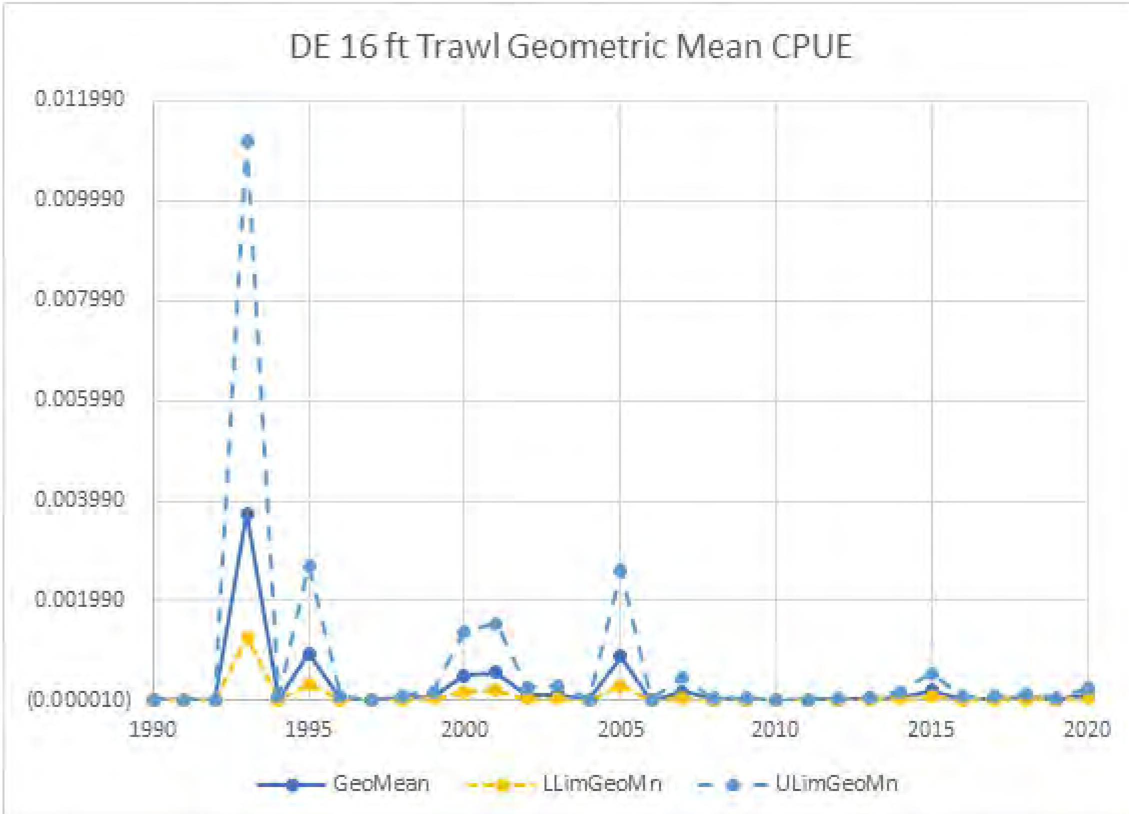

Figure 49. Geometric mean of black drum in number of fish per tow from the Delaware 16 ft Trawl Survey from 1990-2020.

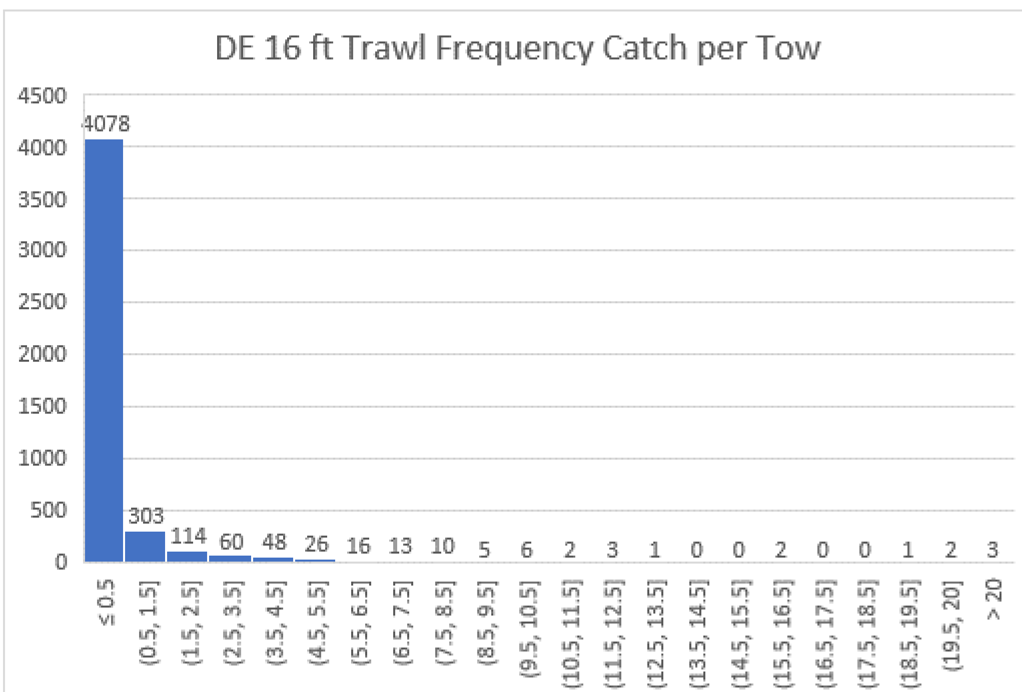

Figure 50. Frequency of number of fish per tow of black drum in the Delaware 16 ft Trawl Survey.

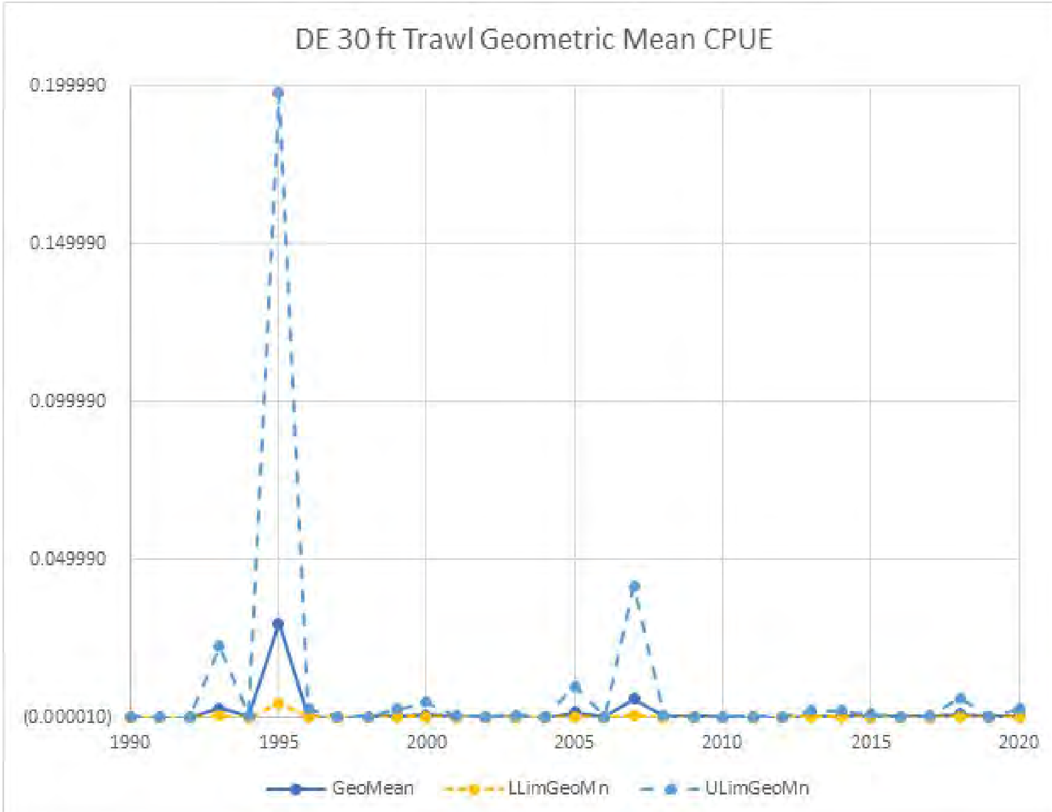

Figure 51. Geometric mean of black drum in number of fish per tow from the Delaware 30 ft Trawl Survey from 1990-2020.

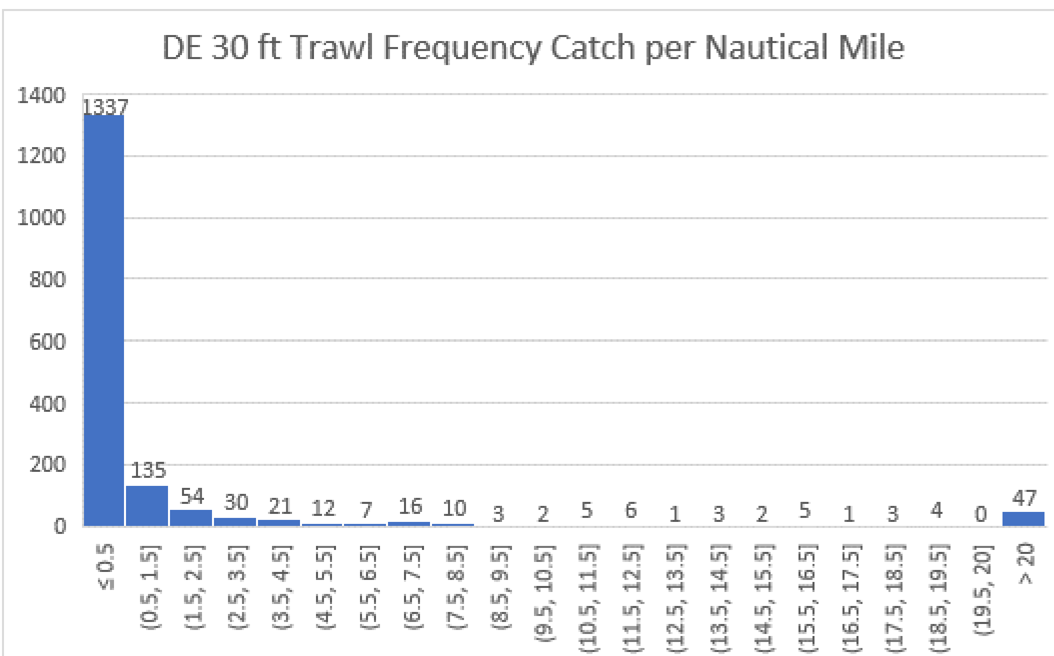

Figure 52. Frequency of number of fish per tow of black drum in the Delaware 30 ft Trawl Survey.

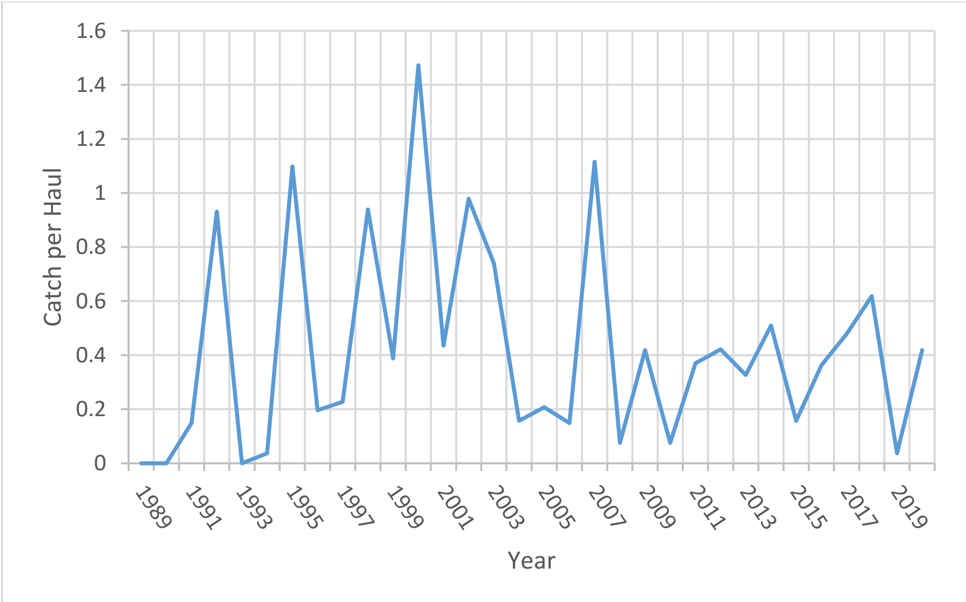

Figure 53. Geometric mean catch per haul of young of the year black drum from the Maryland Coastal Bays Seine Survey, 1989-2020.

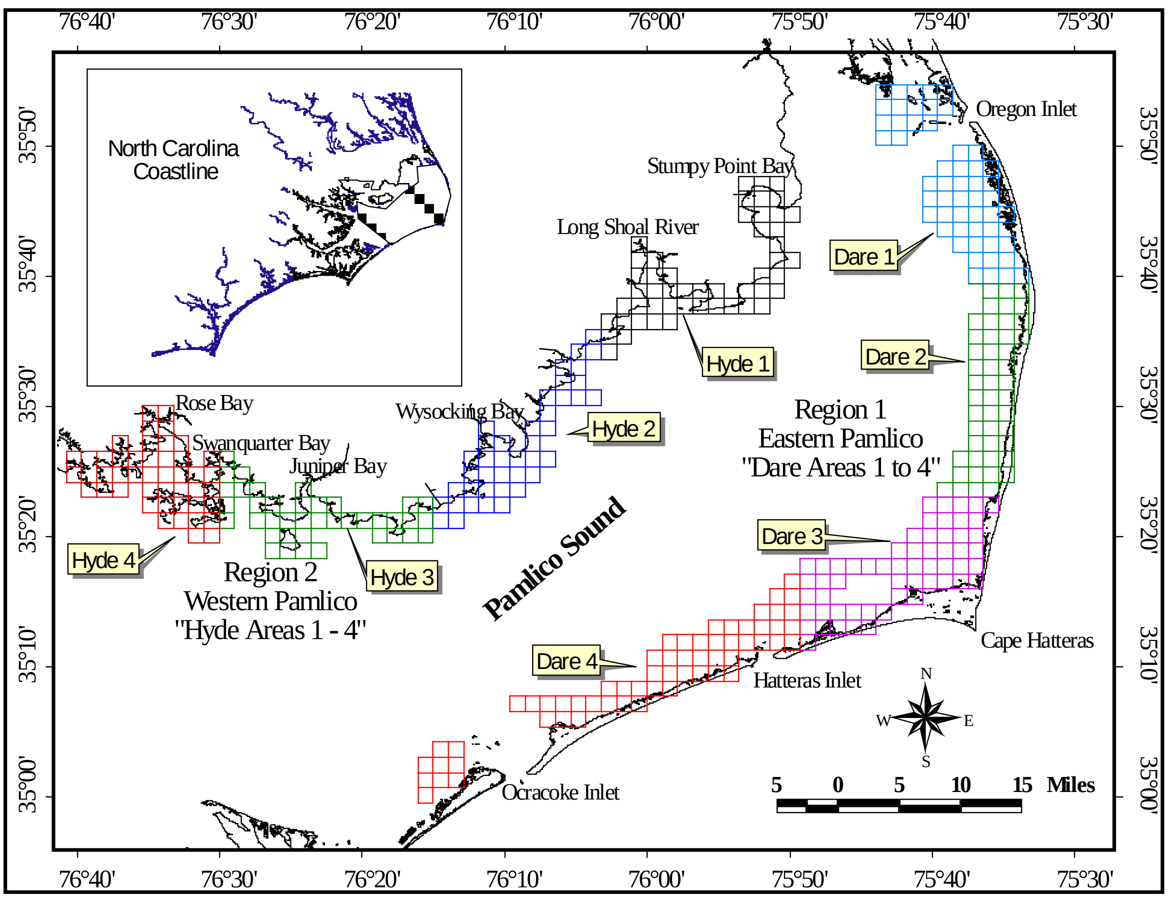

Figure 54. The region and areas sampled as part of the Pamlico Sound Independent Gill Net survey.

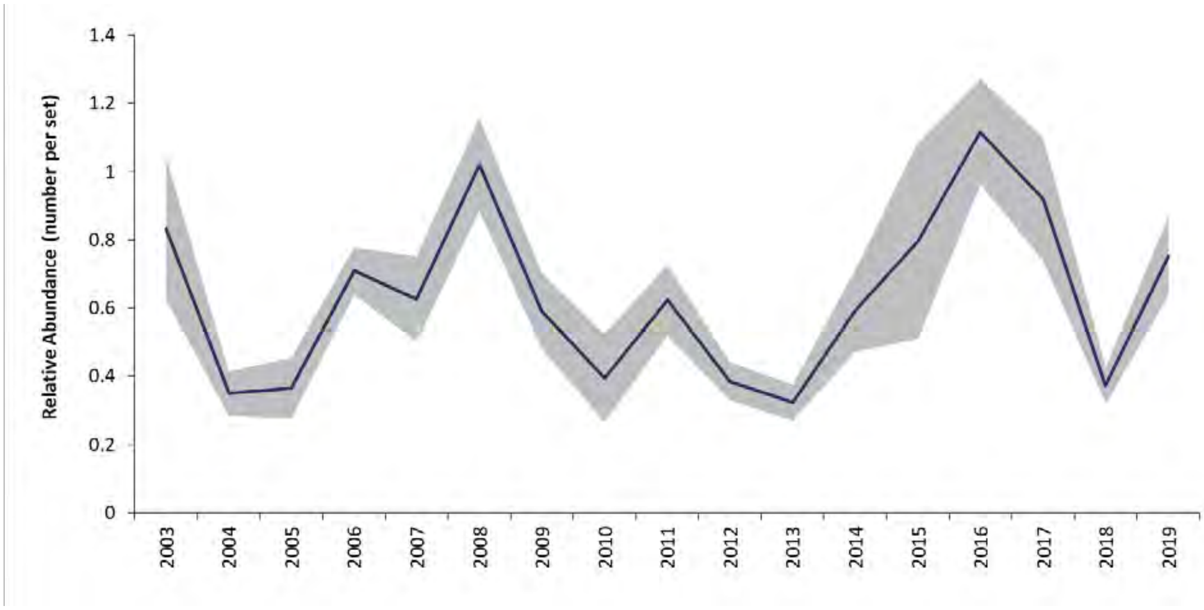

Figure 55. Annual weighted black drum index of relative abundance (number per set) from the NC DMF Independent Gill Net Survey (Program 915) in the Pamlico Sound and Neuse, Pamlico, and Pungo river systems from 2001–2020*. Shaded area represents + one standard error. *Sampling in this program was suspended in February 2020 due to COVID-19.

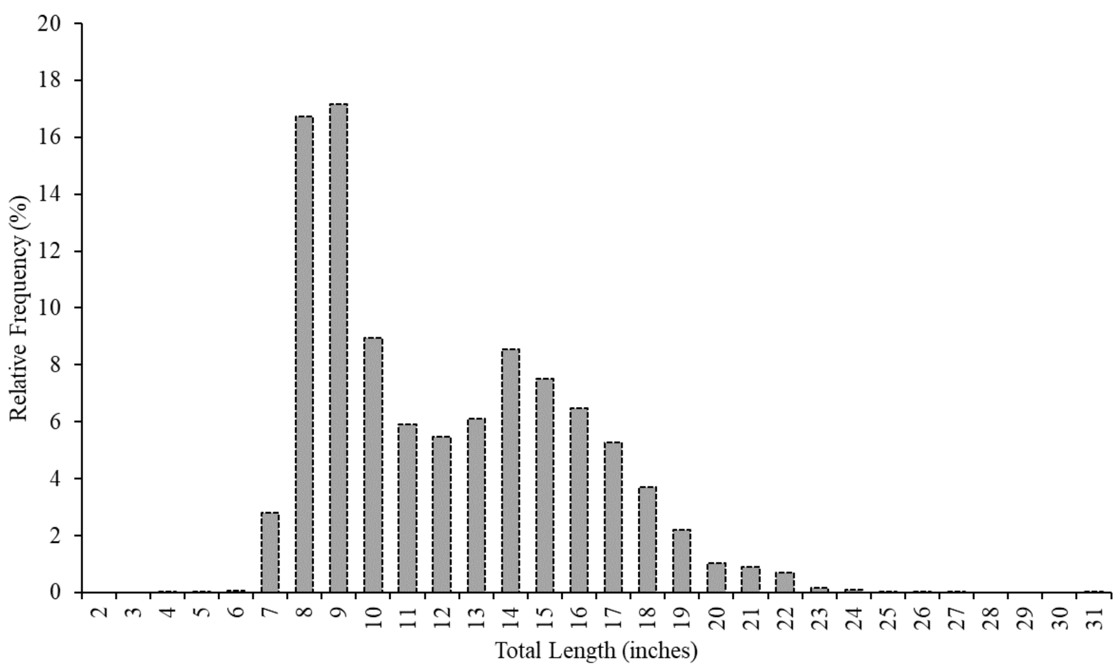

Figure 56. Relative frequency (%) of black drum by size class in total length (inches) from the North Carolina Independent Gill Net Survey (Program 915).

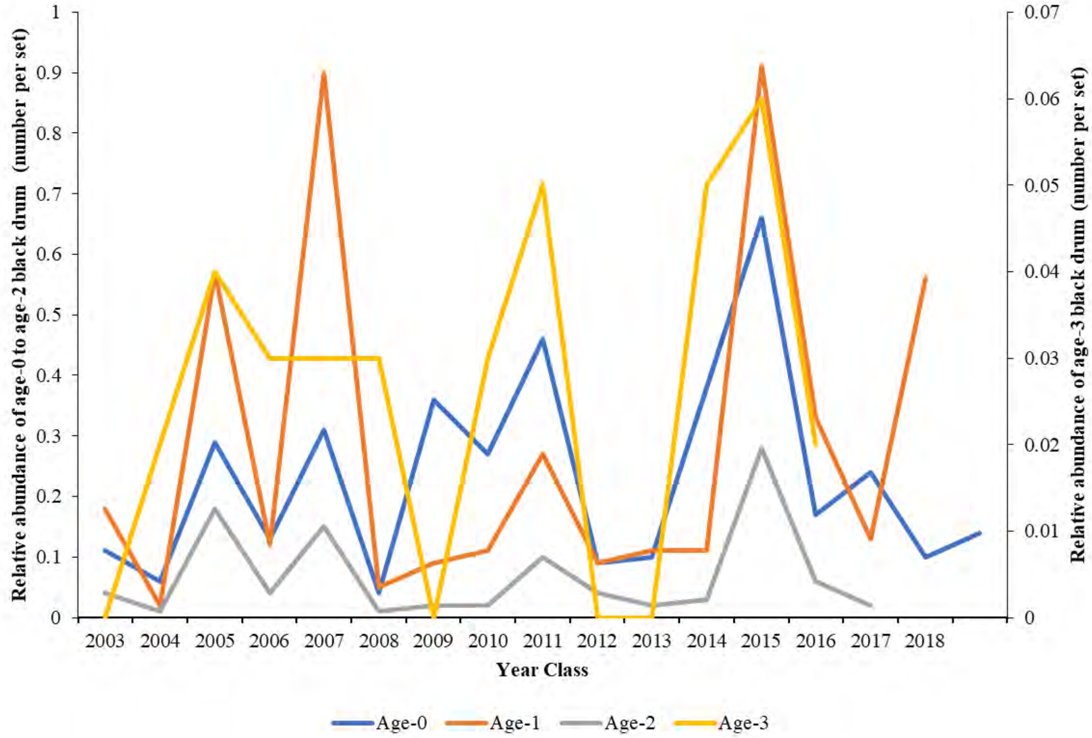

Figure 57. Annual weighted black drum index of relative abundance (number per set) from the NC DMF Independent Gill Net Survey (Program 915) in the Pamlico Sound and Neuse, Pamlico, and Pungo river systems from 2003–2019. Values lagged to track cohort progression.

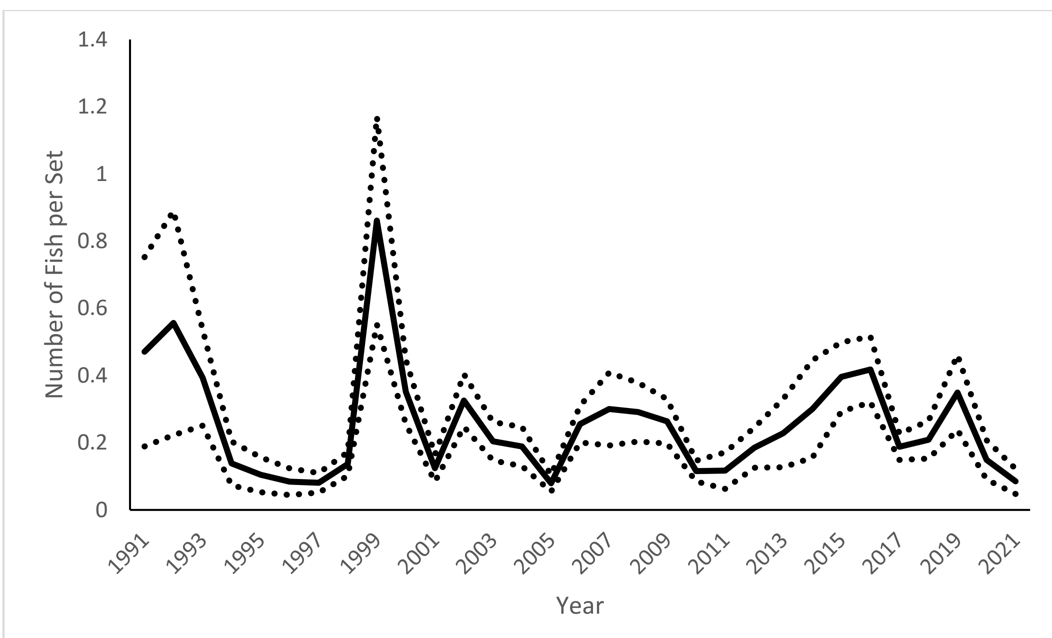

Figure 58. South Carolina Trammel Survey index of relative abundance of black drum (number of fish per set) from 1991-2021 for all ages combined. The dotted lines represent the 95% confidence intervals.

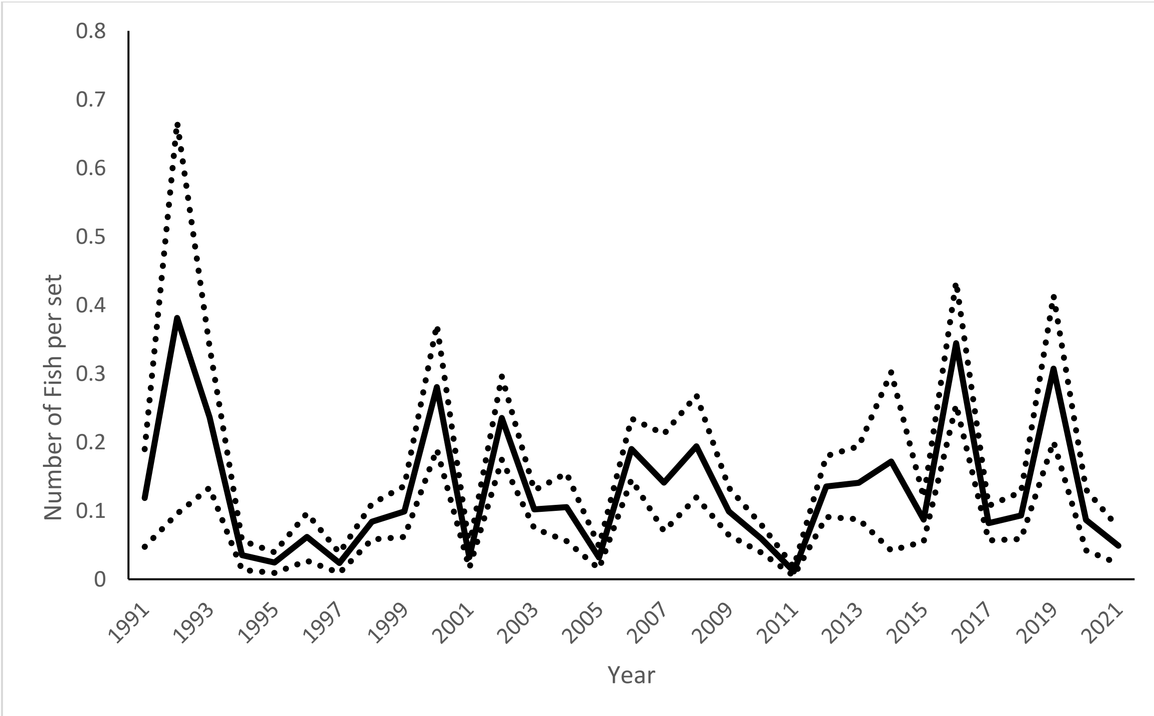

Figure 59. South Carolina Trammel Survey index of relative abundance of age-1 black drum (number of fish per set) from 1991-2021. The dotted lines represent the 95% confidence intervals.

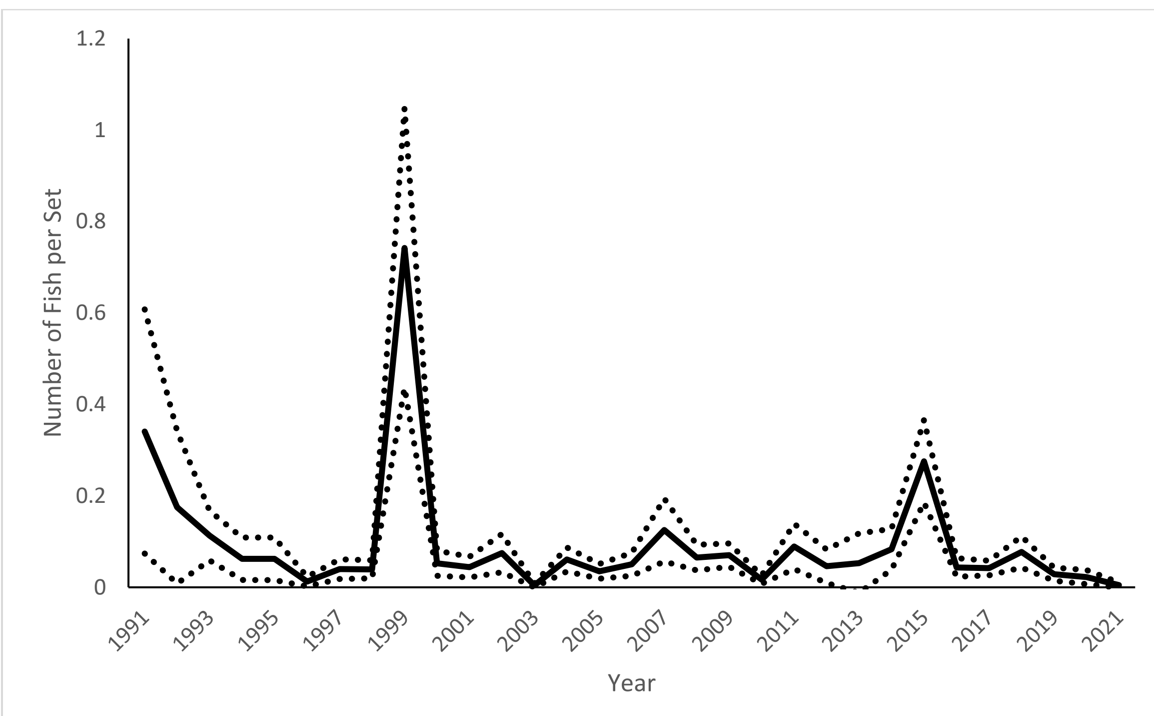

Figure 60. South Carolina Trammel Survey index of relative abundance of age-0 black drum (number of fish per set) from 1991-2021. The dotted lines represent the 95% confidence intervals.

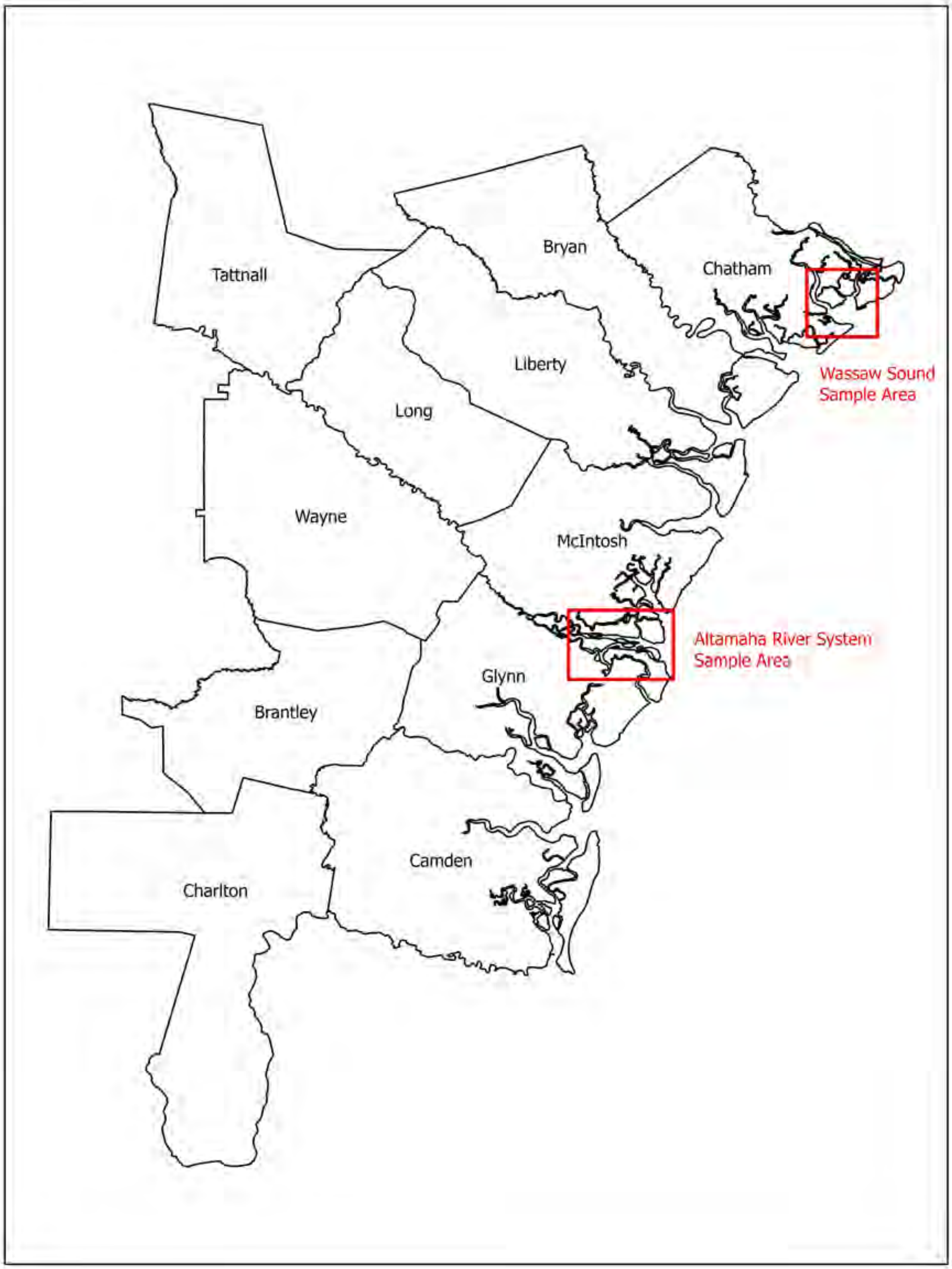

Figure 61. Georgia Trammel Net Survey sampling areas.

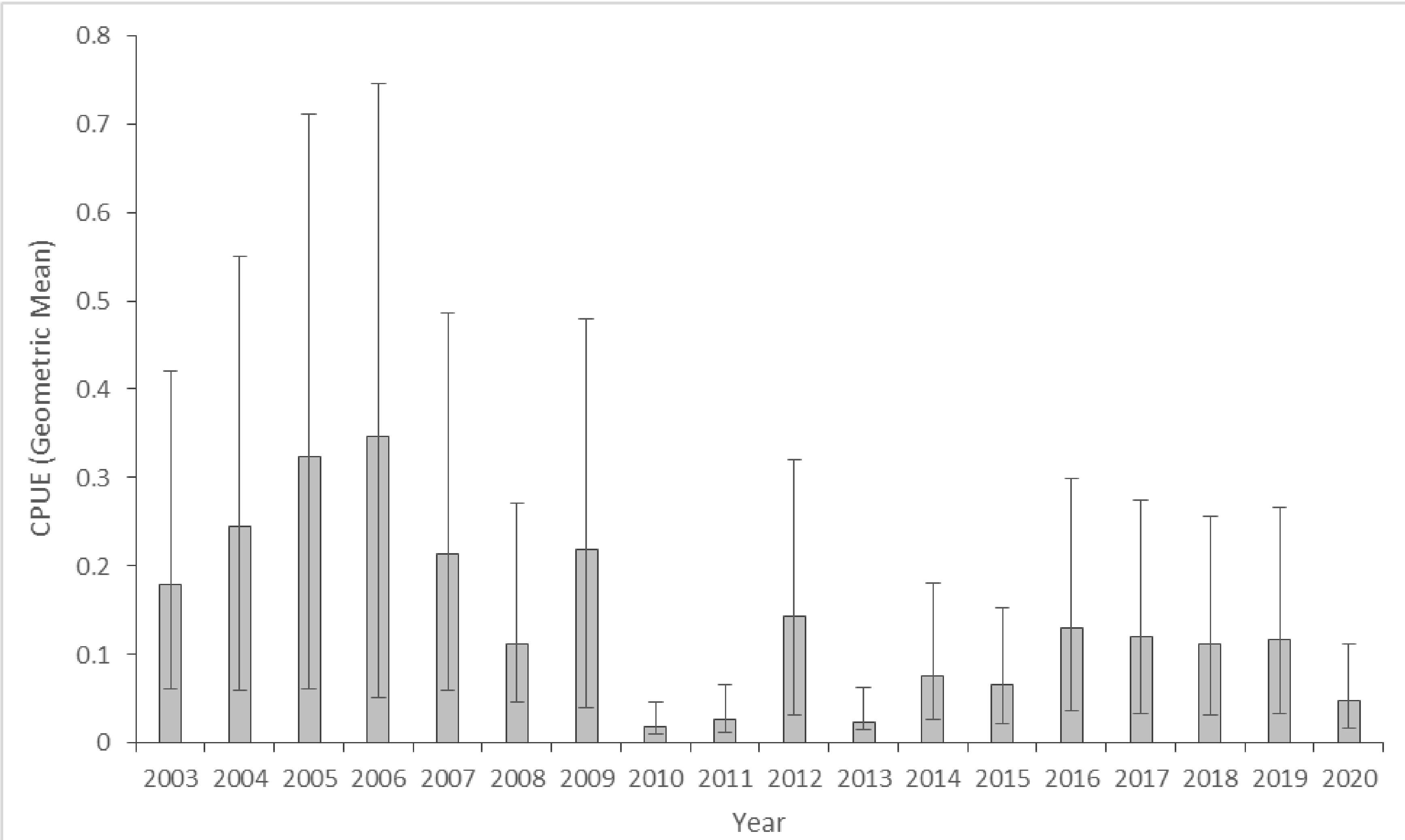

Figure 62. Annual geometric mean of black drum in the Georgia Trammel Net Survey (number of fish per set), 2003-2020. Error bars represent standard error.

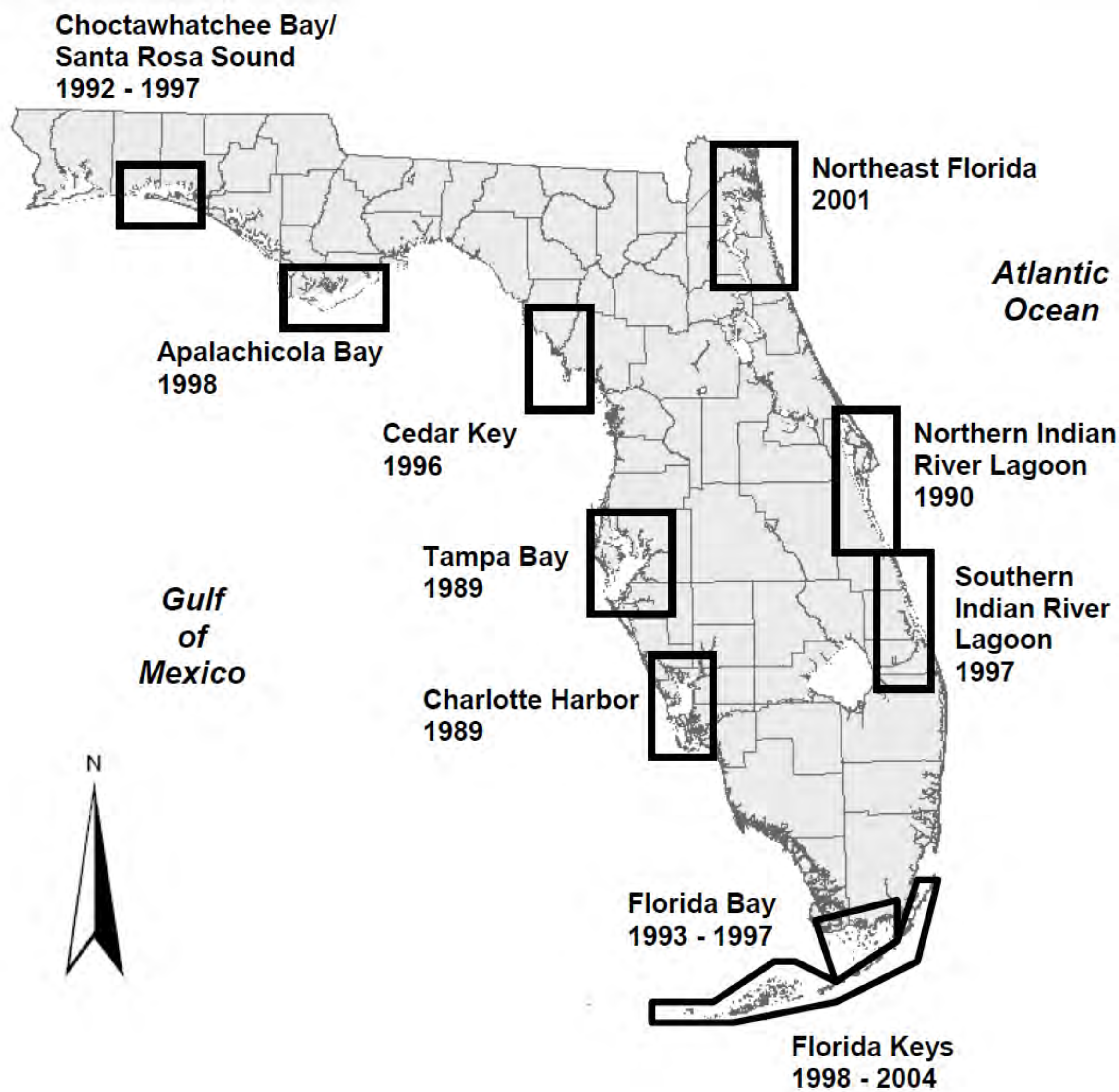

Figure 63. Locations of Fisheries-Independent Monitoring program field laboratories. Years indicate initiation of sampling. If sampling was discontinued at a field lab, the last year of sampling is also provided (FWRI 2020).

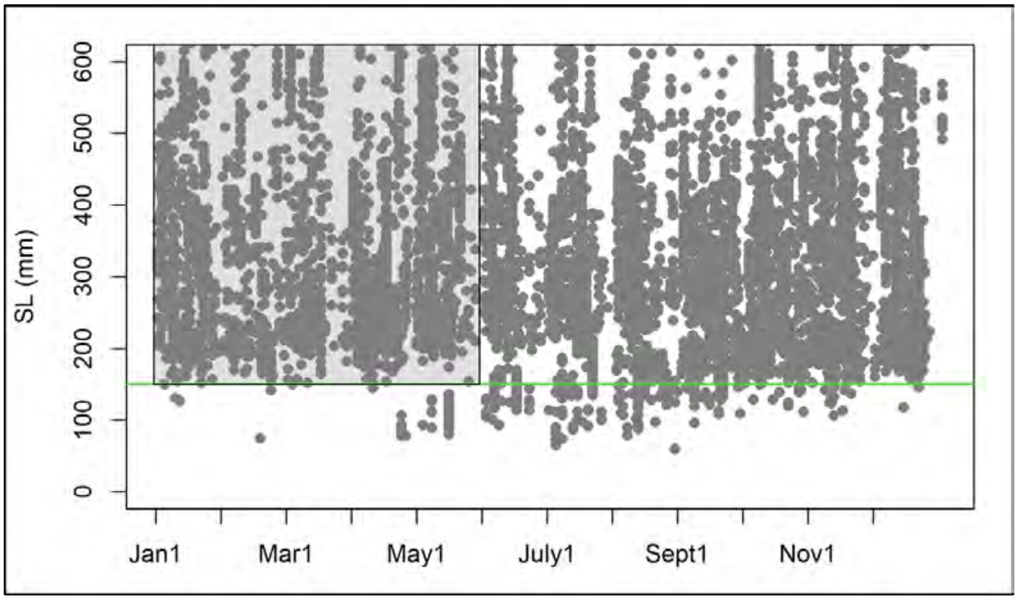

Figure 64. Black drum standard lengths (SL mm) sampled by the 183-m seine survey in the IRL (1999-2020). Post-YOY minimum length is assumed to be 150 SL mm (green line) from January 1 to June 1 (shaded region). The shaded region identifies sampled black drum that were used to develop an age-1+ index of abundance.

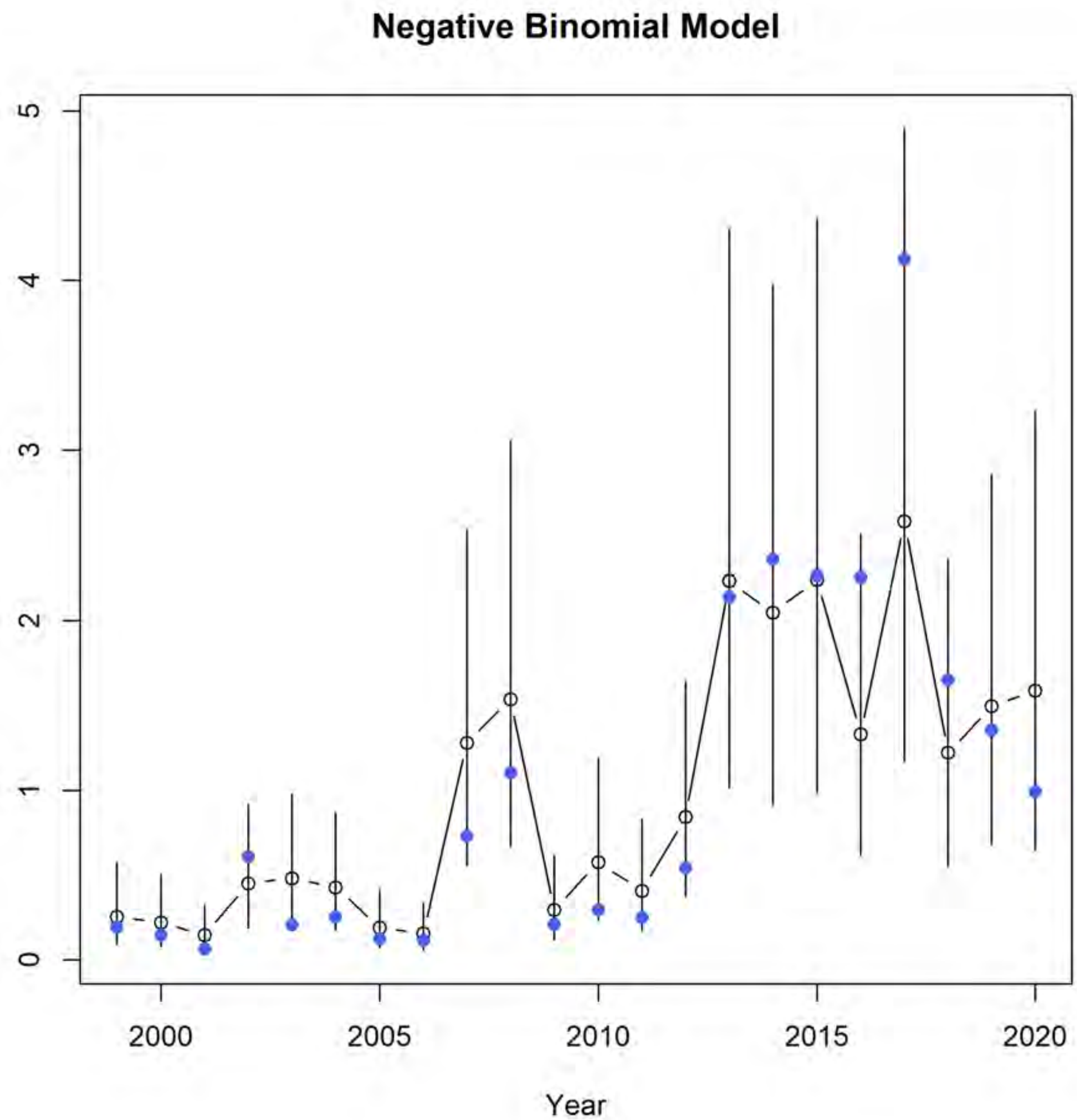

Figure 65. Black drum age-1+ FIM index (183-m seine) from the IRL, 1999-2020. Means relative to the overall mean and 95% confidence intervals of a standardized CPUE index assuming a negative binomial error structure are shown by the black open points and lines, respectively. Nominal means by year relative to the overall mean are shown by the blue closed points.

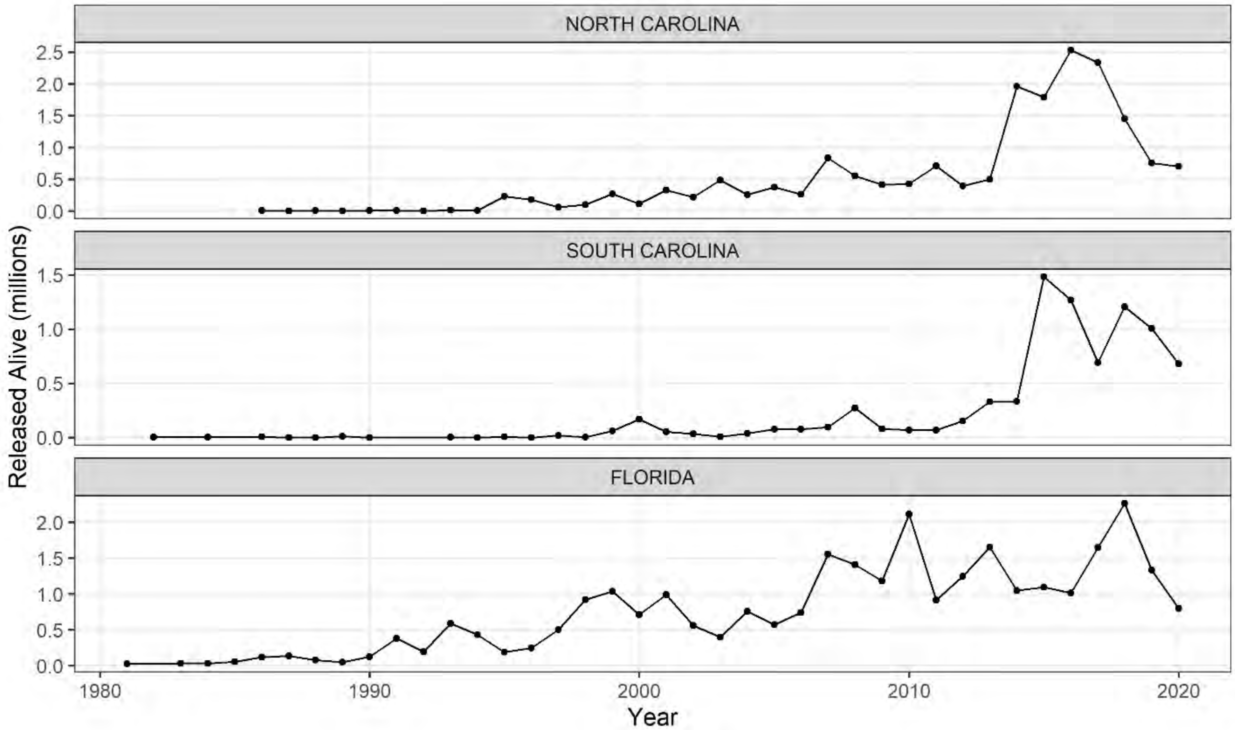

Figure 66. MRIP estimates of released alive black drum for the primary contributor states.

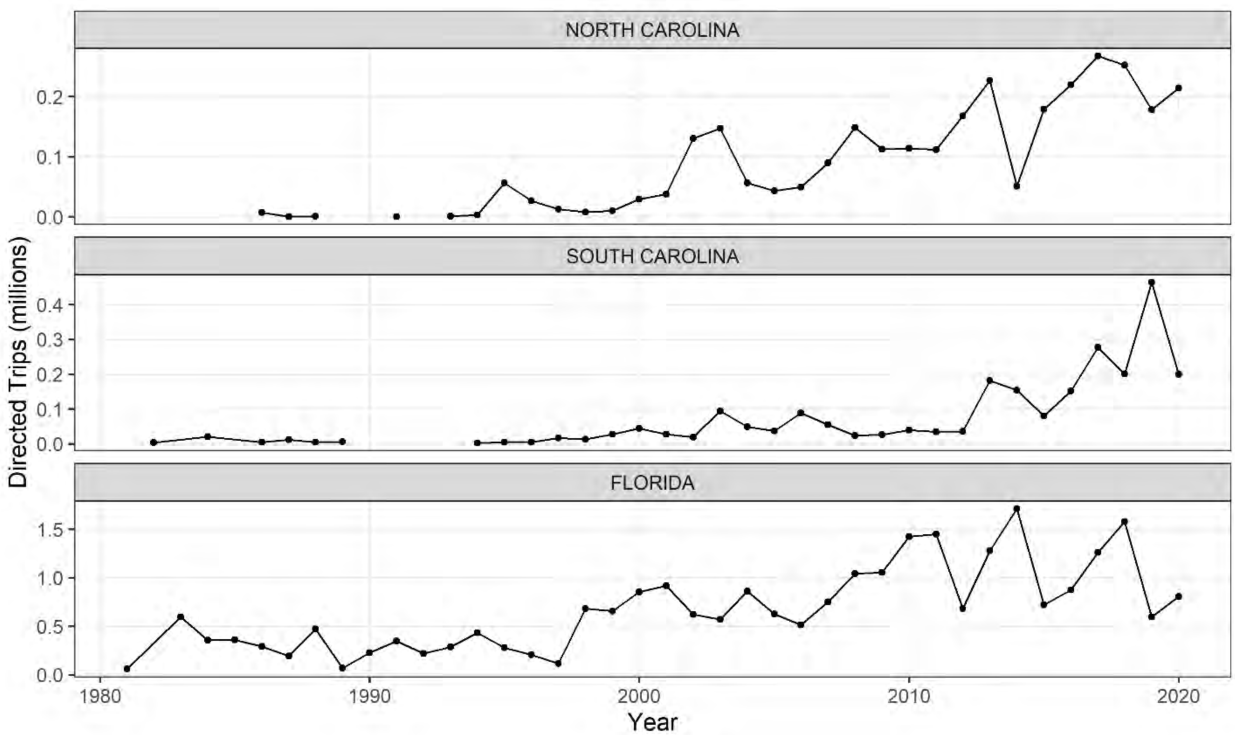

Figure 67. MRIP estimates of directed black drum trips for the primary contributor states.

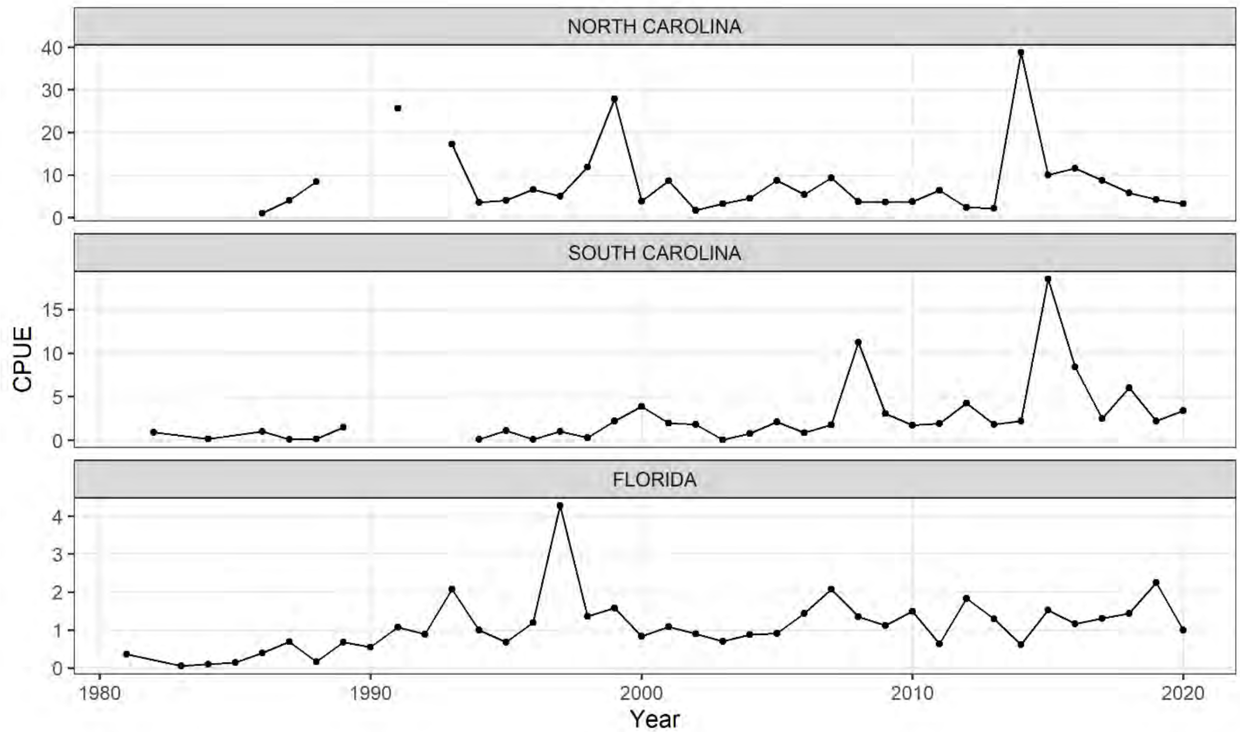

Figure 68. Estimates of CPUE (released alive black drum per directed trip) for the primary contributor states.

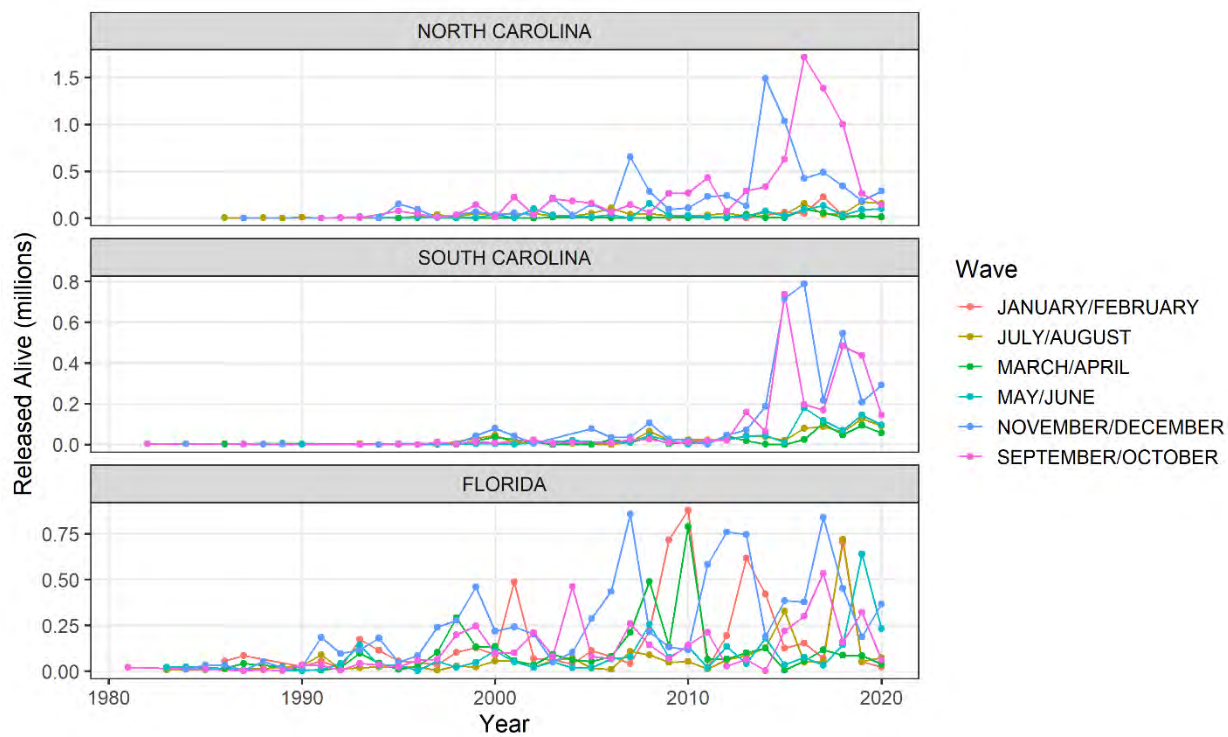

Figure 69. MRIP estimates of released alive black drum by wave for the primary contributor states.

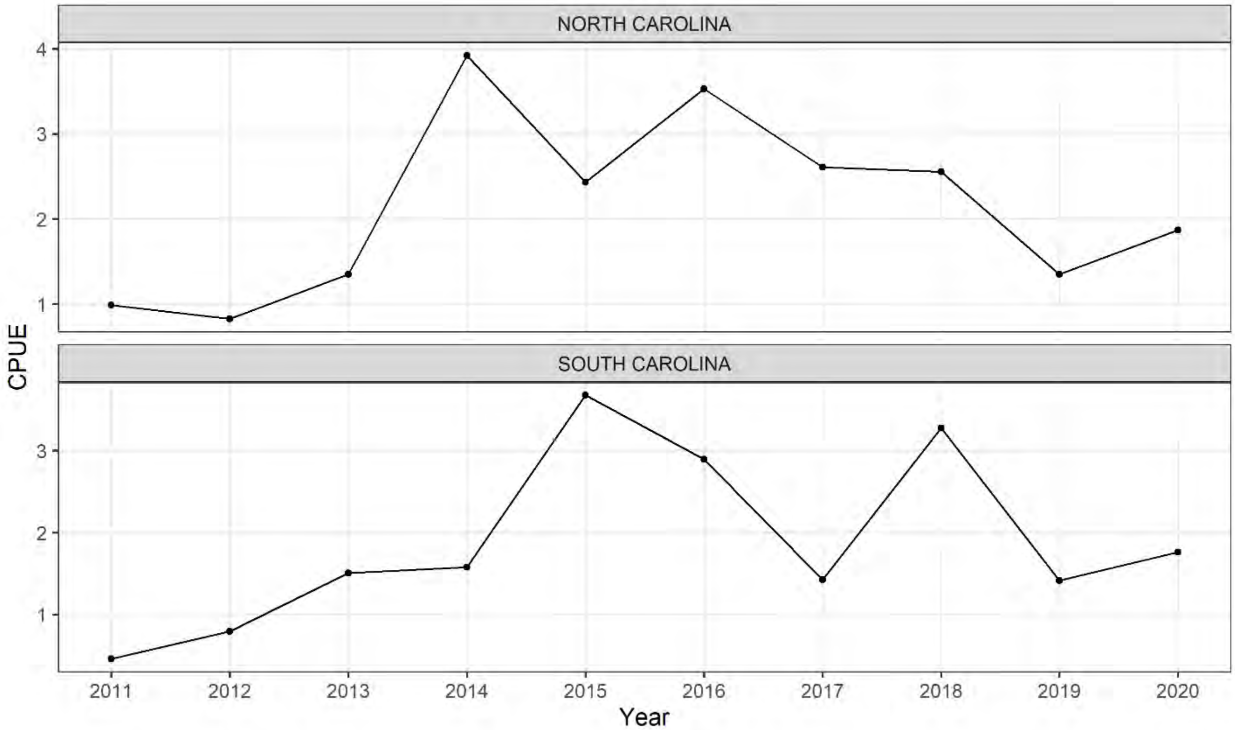

Figure 70. Estimates of CPUE (released alive black drum per directed trip) for NC and SC from September-December.

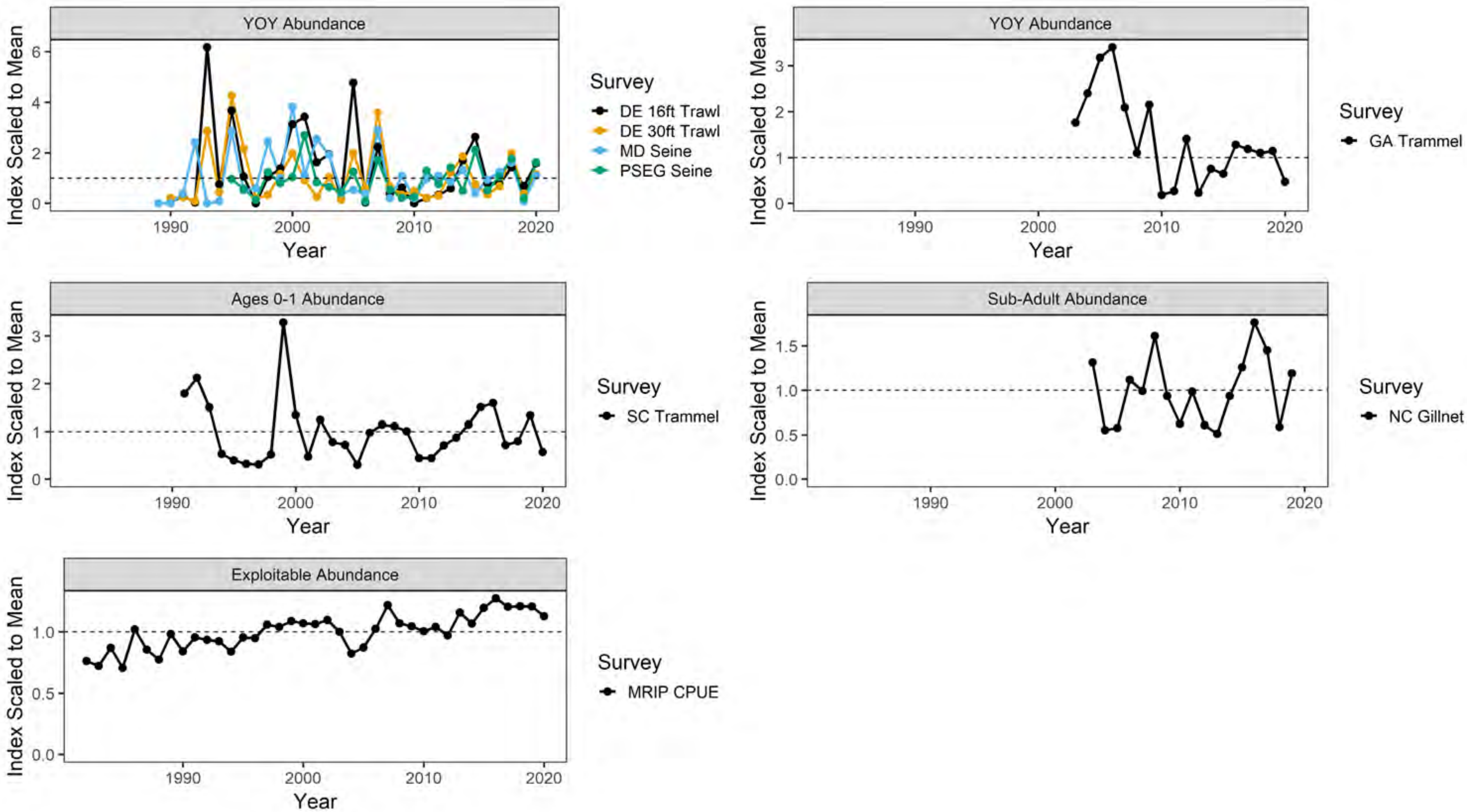

Figure 71. Abundance Indicators. The GA Trammel YOY index, the lone YOY index in the South Atlantic, is included on a separate panel because it is not similar to other YOY indices (all from the Mid-Atlantic) according to correlation analyses.

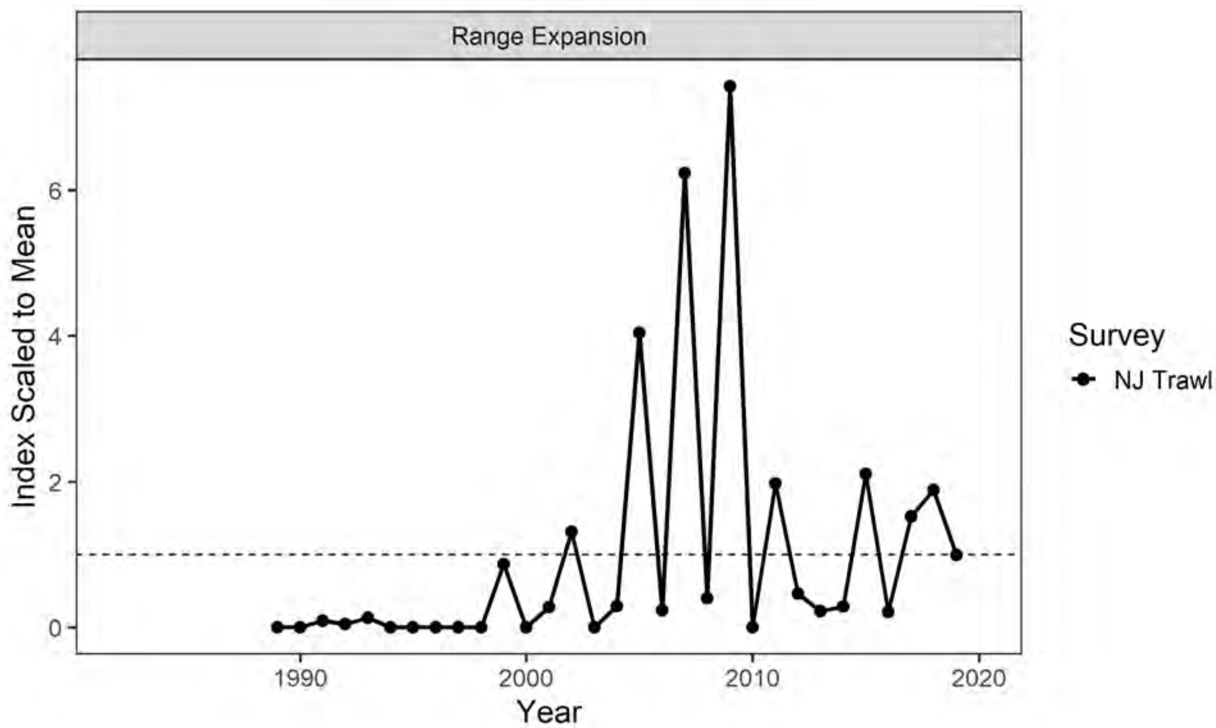

Figure 72. Range Expansion Indicator - NJ Ocean Trawl.

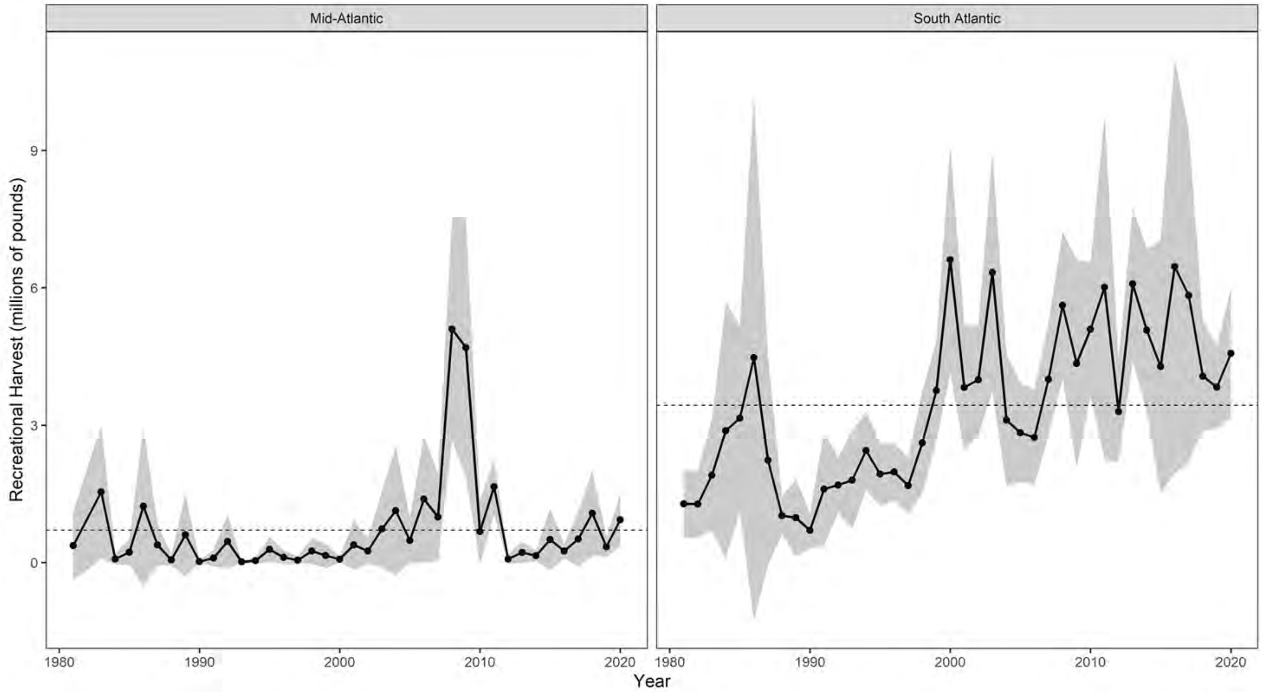

Figure 73. MRIP Recreational Harvest in millions of pounds for Mid-Atlantic and South Atlantic

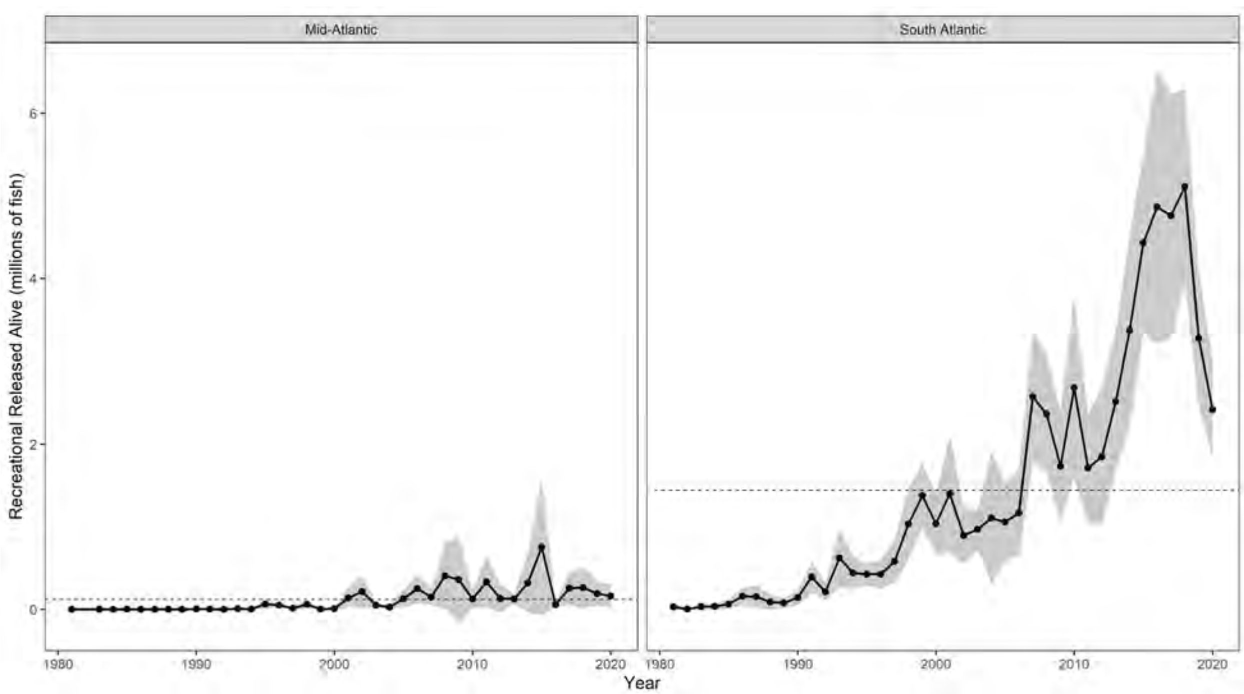

Figure 74. MRIP Recreational Released Alive in millions of fish for Mid-Atlantic and South-Atlantic

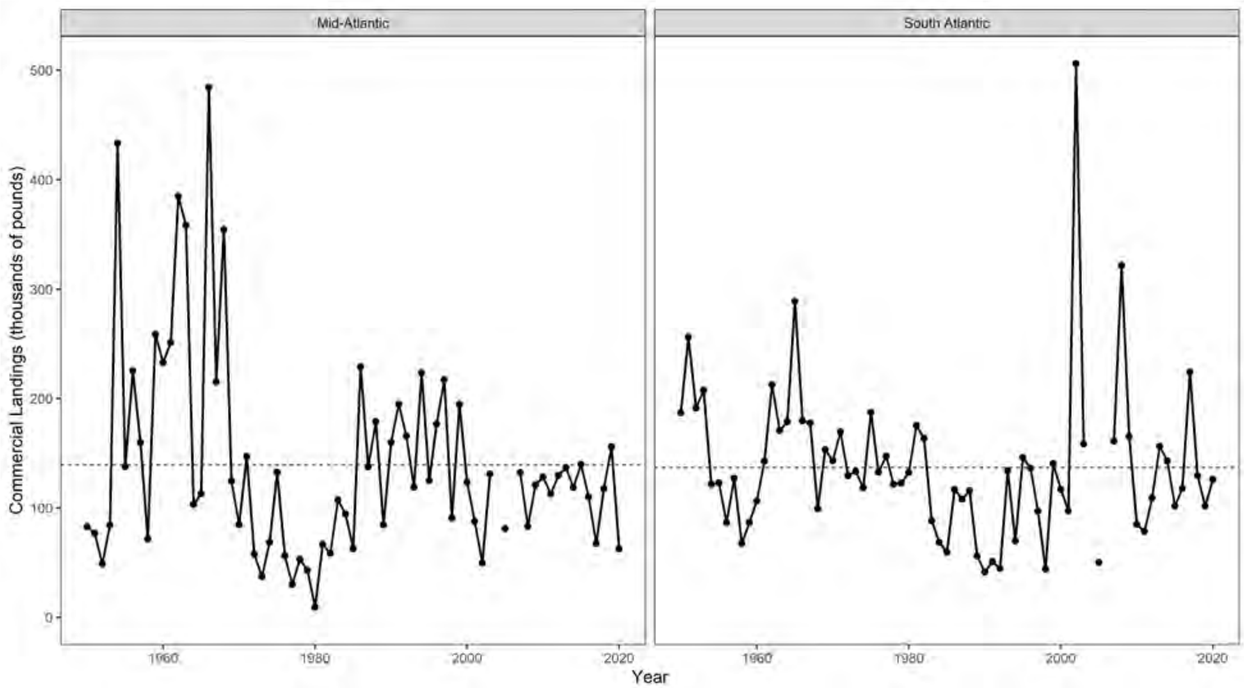

Figure 75. Commercial landings in thousands of pounds for Mid-Atlantic and South Atlantic. Missing values indicate confidential data that have been redacted.

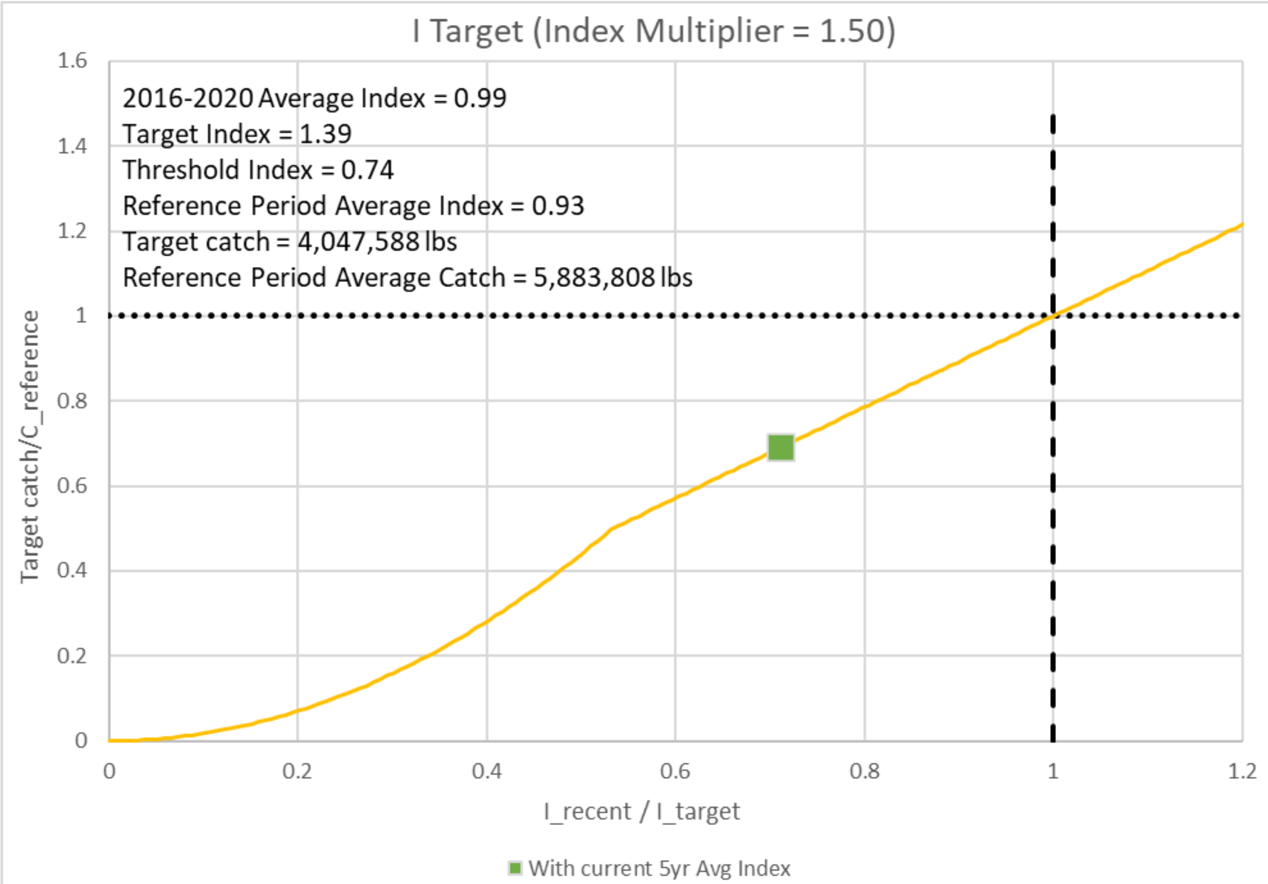

Figure 76. Itarget method's relationship between target catch and relative index (orange line) using the last 25 years (1996-2020) as the reference period and 1.5 as the index multiplier. The green square shows the corresponding X and Y values of this relationship with the current 5-year average index.

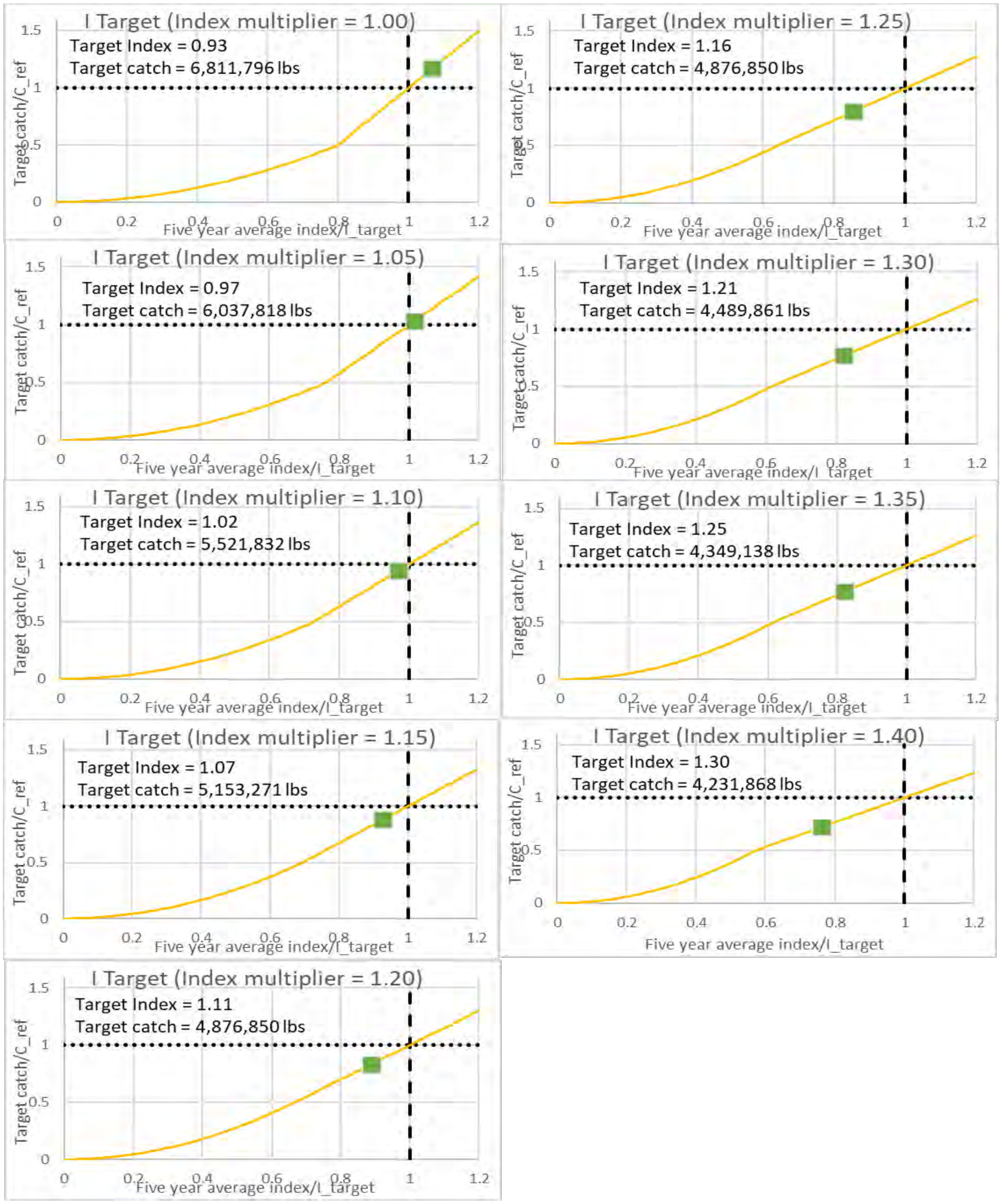

Figure 77. Itarget method's relationships between target catch and relative index (orange line) using the last 25 years (1996-2020) as the reference period and 1.00 – 1.40 as the index multiplier. The green square shows the corresponding X and Y values of this relationship with the current 5-year average index (0.99). The reference period average index and catch and the threshold index are the same as those shown in Figure 76.

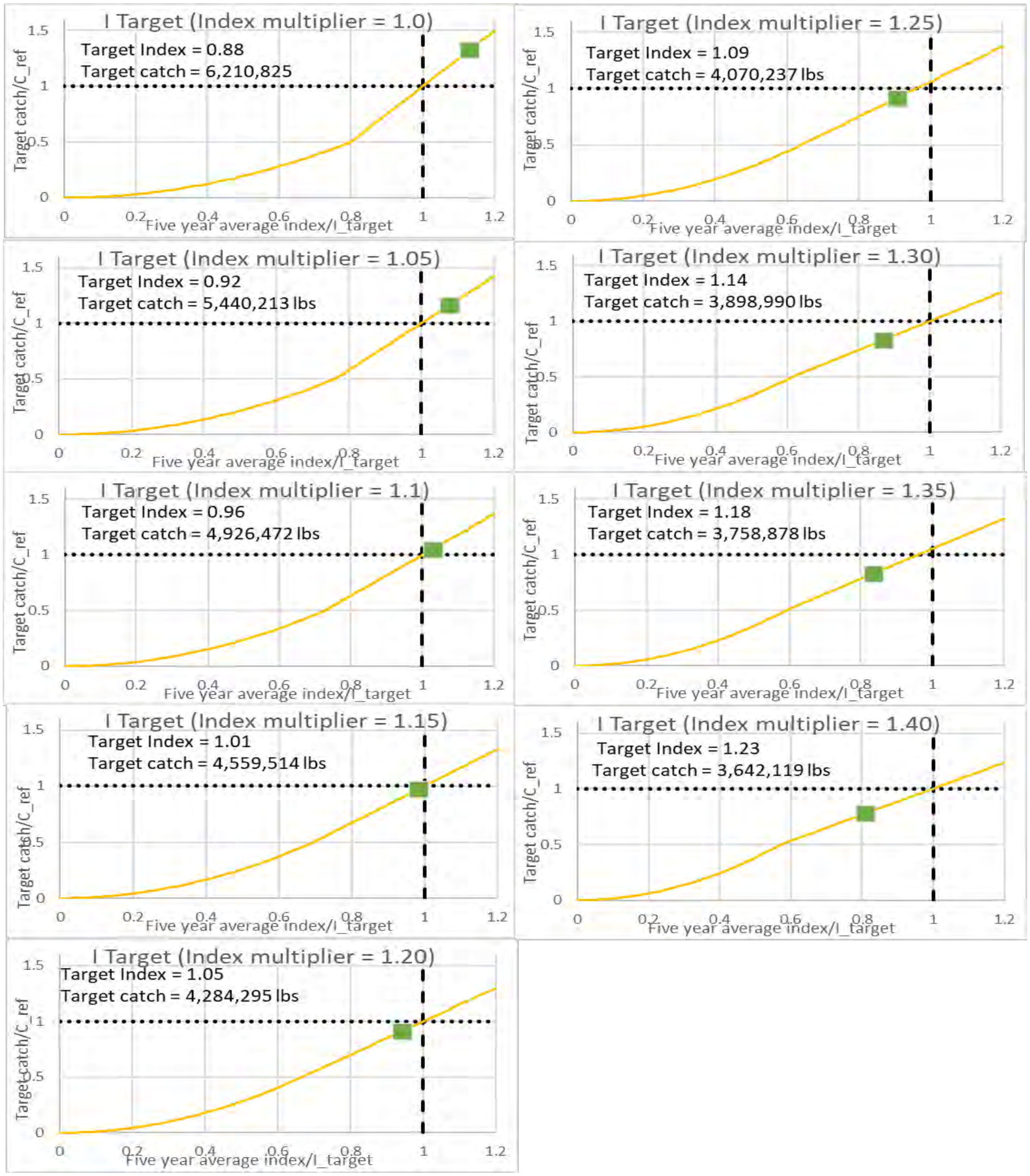

Figure 78. Itarget method's relationships between target catch and relative index (orange line) using the full time series (1982-2020) as the reference period and 1.00 – 1.40 as the index multiplier. The green square shows the corresponding X and Y values of this relationship with the current 5-year average index (0.99). The reference period average index = 0.88; reference period average catch = 4.72 million lbs; and the threshold index = 0.70.

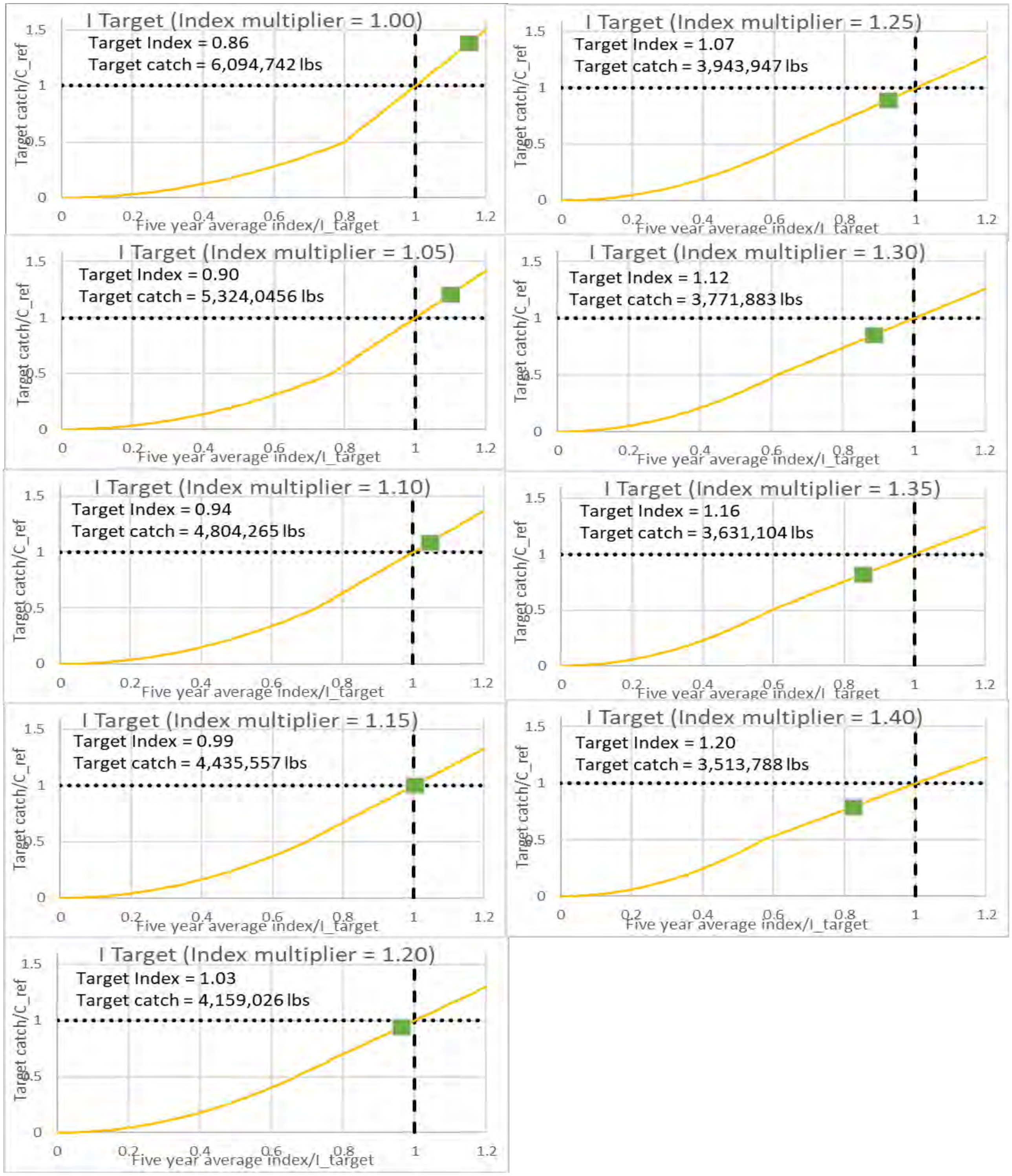

Figure 79. Itarget method's relationships between target catch and relative index (orange line) using the earliest 34 years (1982-2015) as the reference period and 1.00 – 1.40 as the index multiplier. The green square shows the corresponding X and Y values of this relationship with the current 5-year average index (0.99). The reference period average index = 0.86; reference period average catch = 4.45 million lbs; and the threshold index = 0.69.

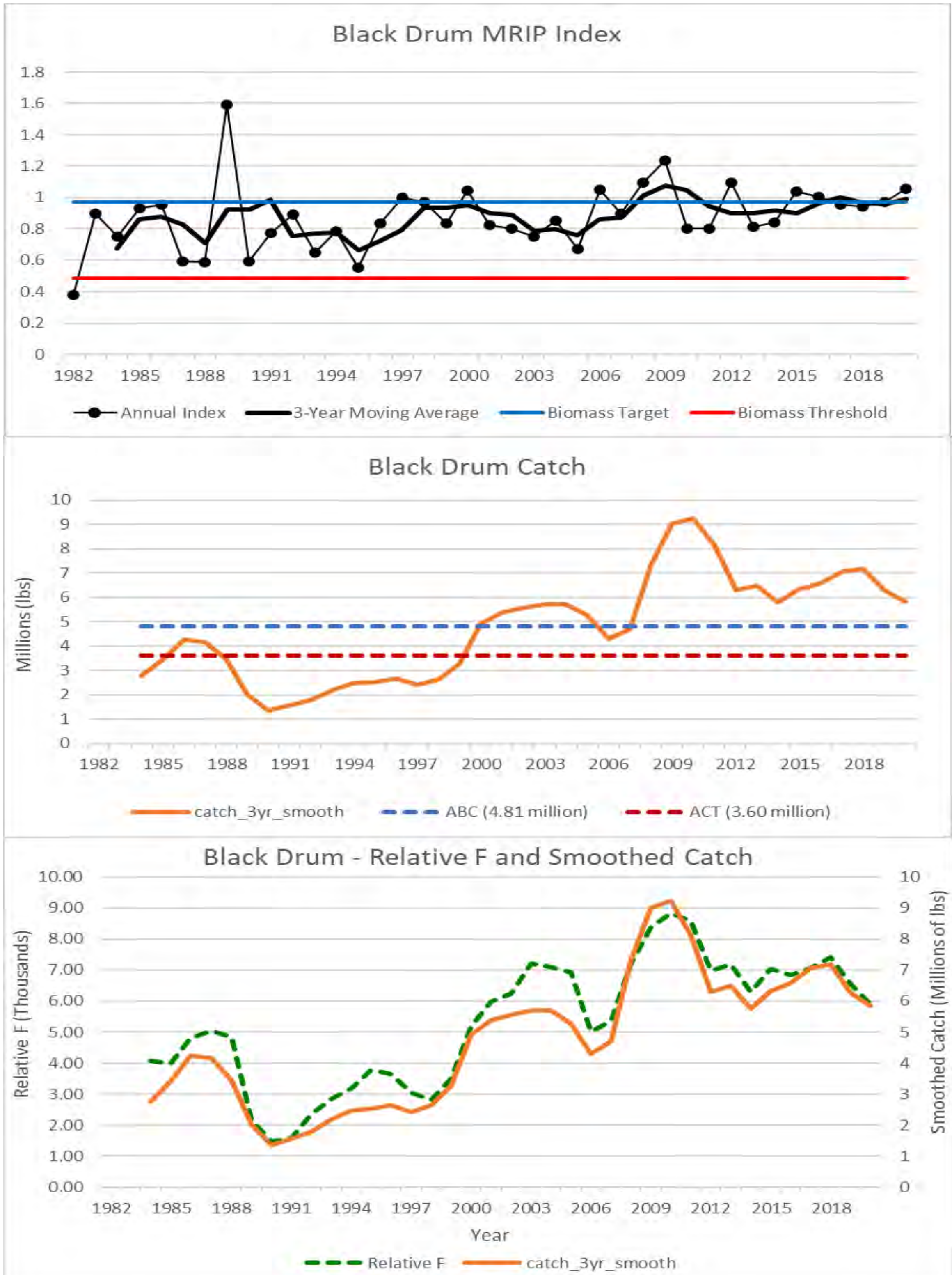

Figure 80. MRIP CPUE index (annual and smoothed) with biomass target and threshold levels (top), smoothed catch with ABC and ACT levels (middle), and relative *F* with smoothed catch (bottom) for black drum with the Skate method.

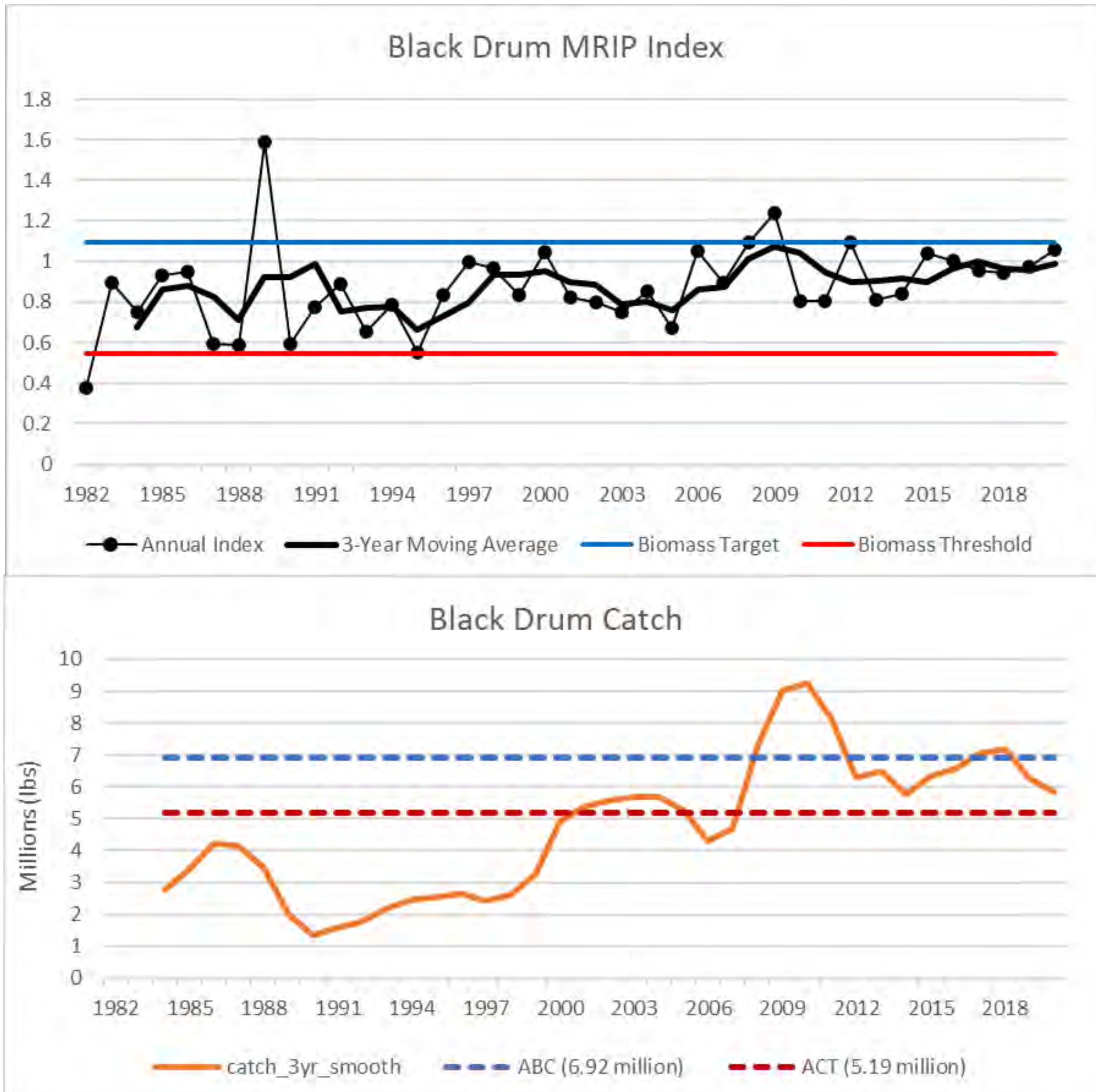

Figure 81. MRIP CPUE index (annual and smoothed) with biomass target and threshold levels (top), and smoothed catch with ABC and ACT levels (bottom) for black drum with the Skate method using only the years 2000-2012 for determining biomass target and threshold levels and median relative *F*.

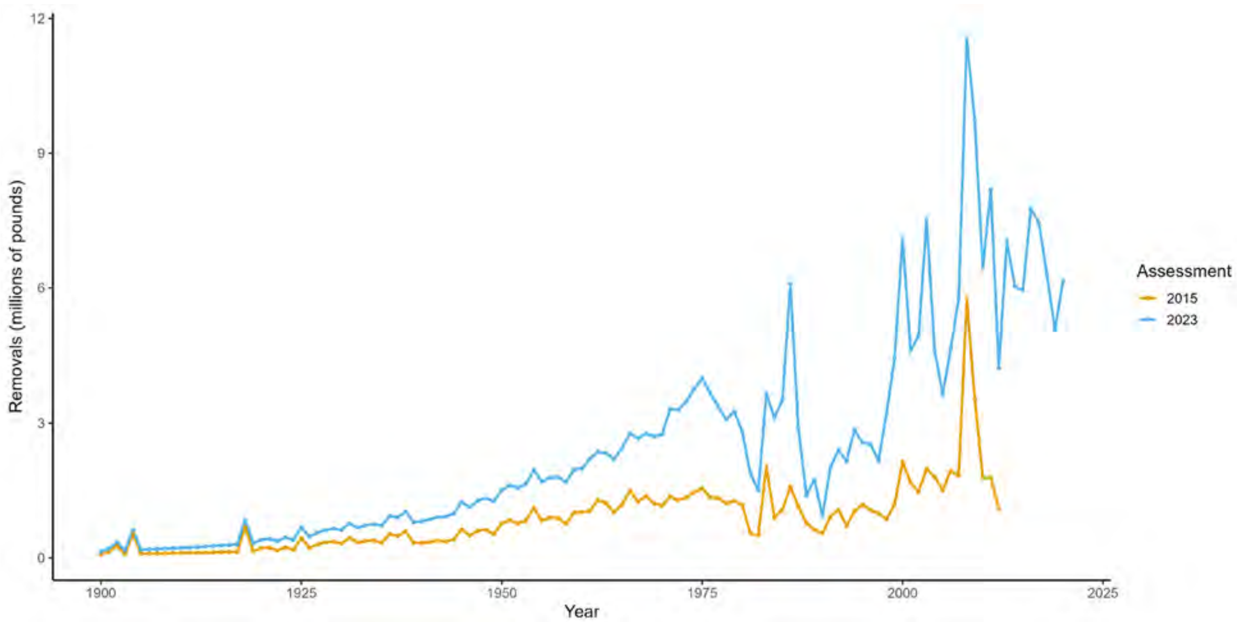

Figure 82. Fishery removal data time series of black drum used in DB-SRA during the current 2023 assessment (blue line, 2020 terminal data year) and the previous 2015 assessment (yellow line, 2012 terminal data year).

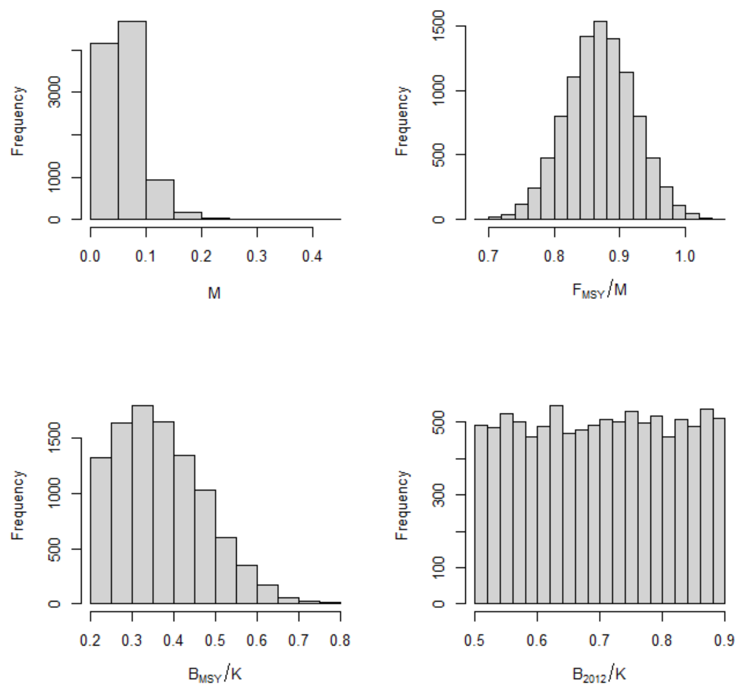

Figure 83. Input distributions for DB-SRA parameters used in the *New_Catch* continuity run with the Hoenig (1983) natural mortality estimate used in the previous assessment.

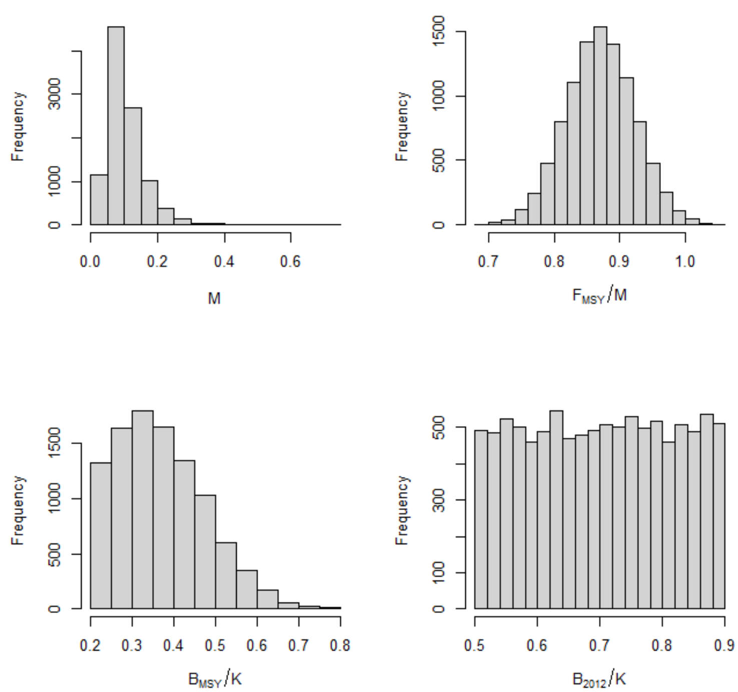

Figure 84. Input distributions for DB-SRA parameters used in the *Then_M* continuity run with the Then et al. (2015) natural mortality estimate adopted in this assessment.

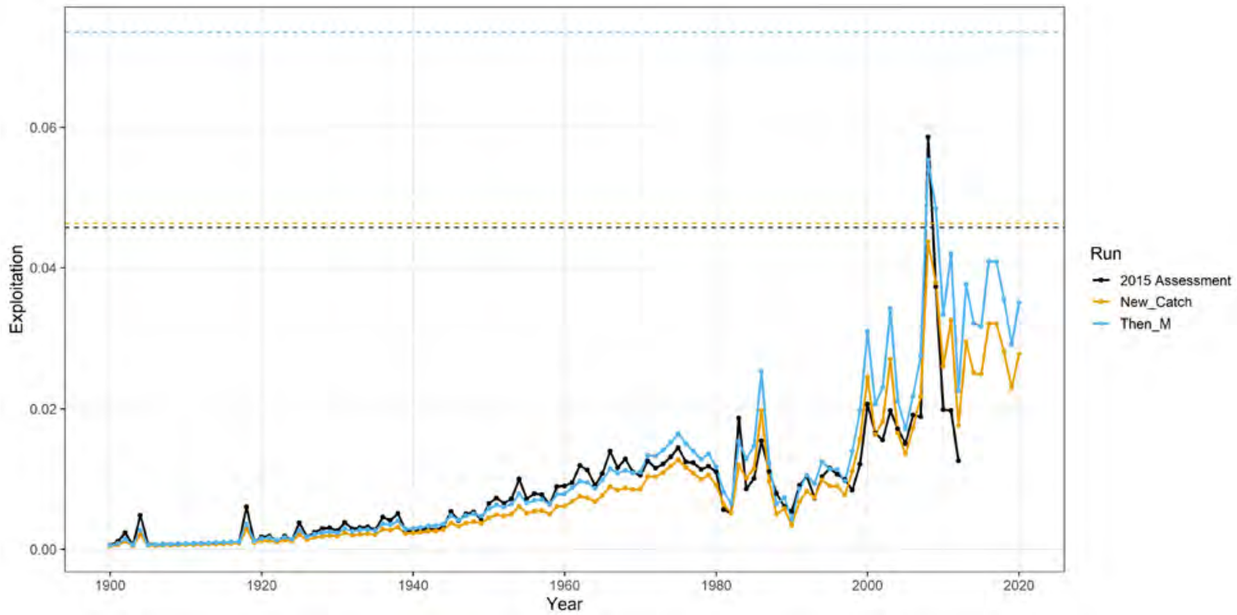

Figure 85. Median exploitation (solid lines) and U_{MSY} estimates (dashed lines) from the DB-SRA during the 2015 assessment and updated through 2020 in this assessment.

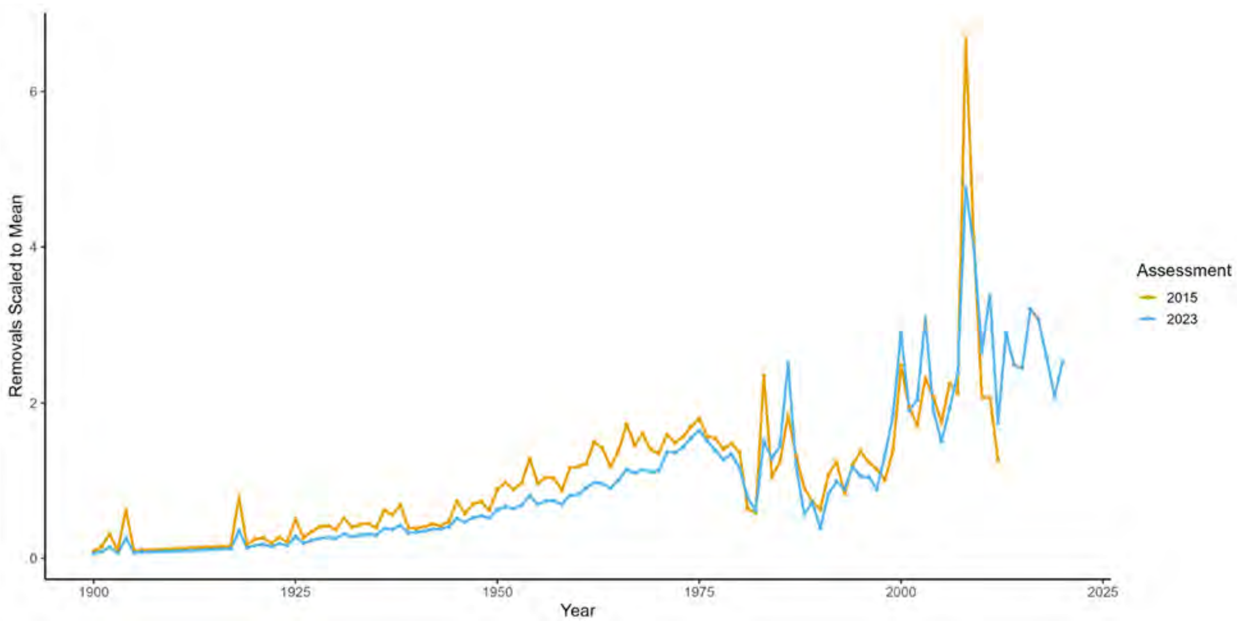

Figure 86. Fishery removal data time series of black drum used in DB-SRA during the current 2023 assessment (2020 terminal data year) and the previous 2015 assessment (2012 terminal data year) scaled to the time series mean.

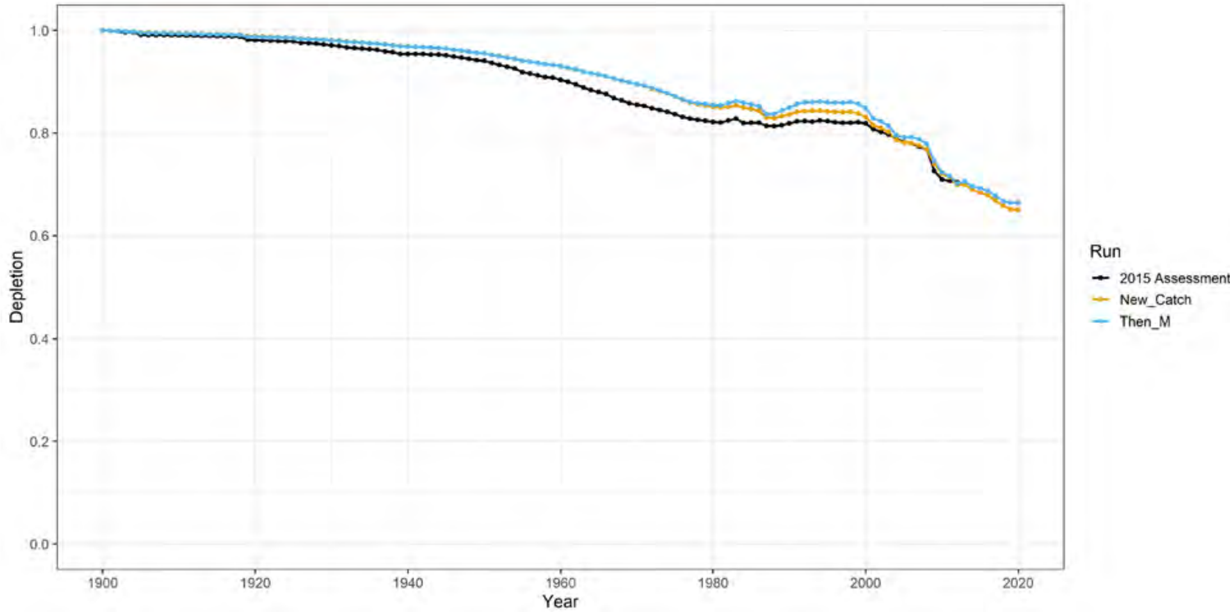

Figure 87. Median depletion (B_y/K) estimates from the DB-SRA during the 2015 assessment and updated through 2020 in this assessment.

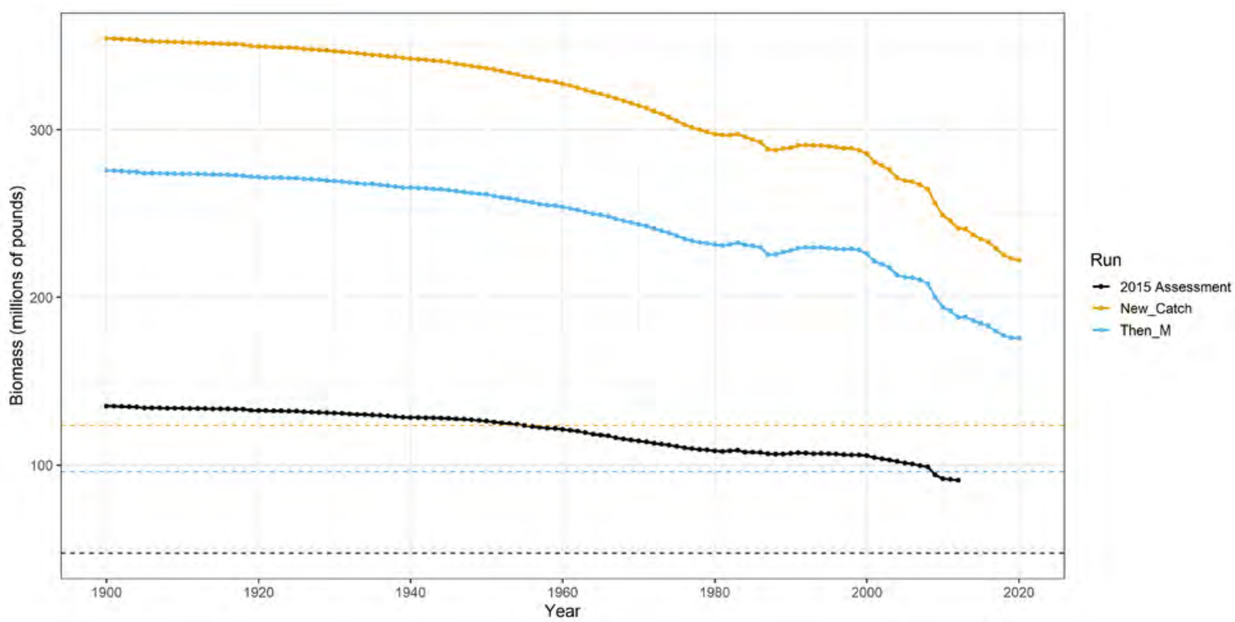

Figure 88. Median biomass (solid lines) and B_{MSY} estimates (dashed lines) from the DB-SRA during the 2015 assessment and updated through 2020 in this assessment.

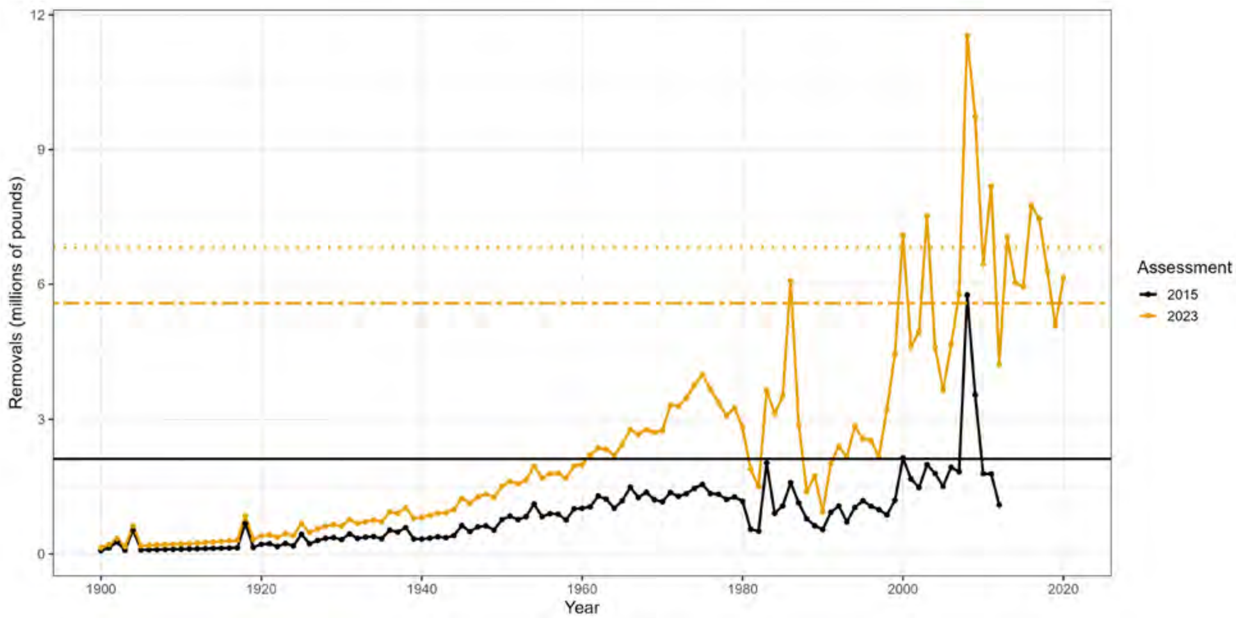

Figure 89. Fishery removal data time series of black drum used in DB-SRA during the current 2023 assessment (2020 terminal data year) and the previous 2015 assessment (2012 terminal data year) compared to median MSY estimates during each assessment (horizontal lines). The lower dot-dashed line is the MSY estimate from the *New_Catch* continuity run and the dotted line is the MSY estimate from the *Then_M* continuity run.

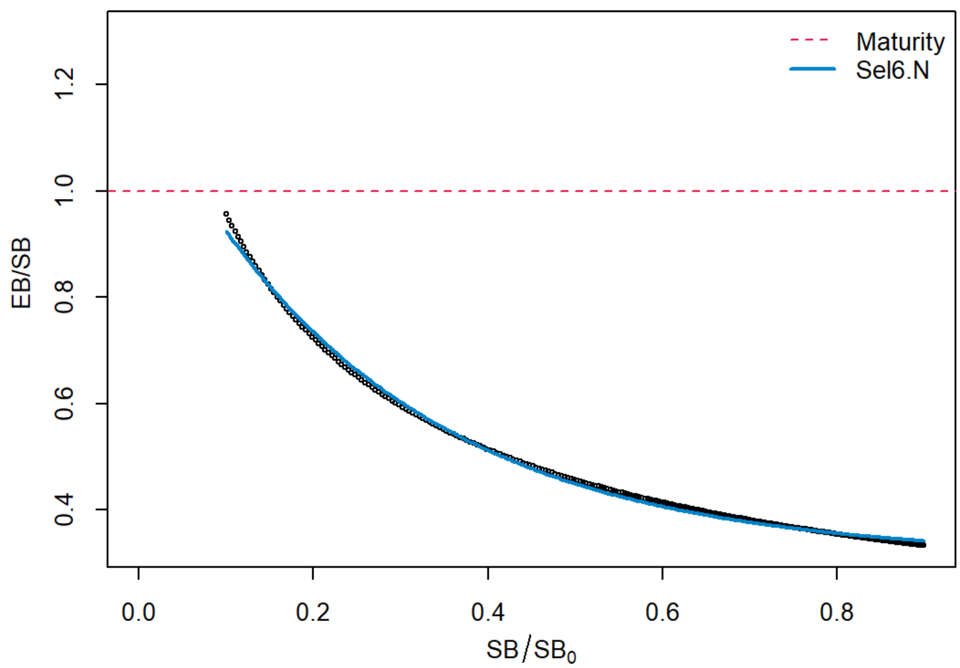

Figure 90. Ratio of biomass tracked by MRIP CPUE (exploitable biomass, *EB*) and spawning biomass (*SB*) relative to the spawning biomass depletion for the JABBA-Select model. Circles are expected values according to the per-recruit models and the solid blue line is predicted values from equation 12 in Winker et al. 2020. The dashed line indicates the relationship if selectivity were equal to the maturity ogive.

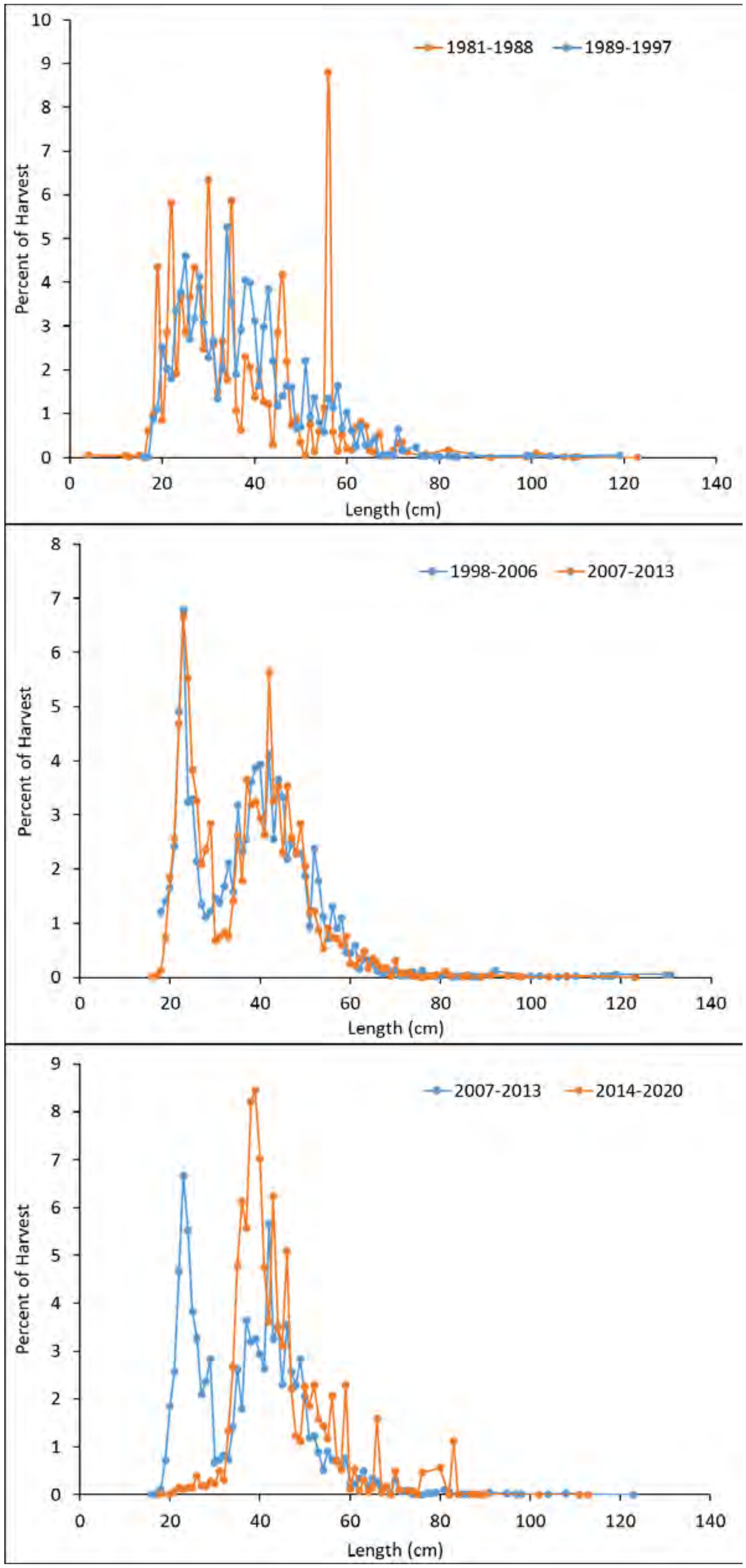

Figure 91. Comparison of MRIP length composition data aggregated over constant management periods in the South Atlantic.

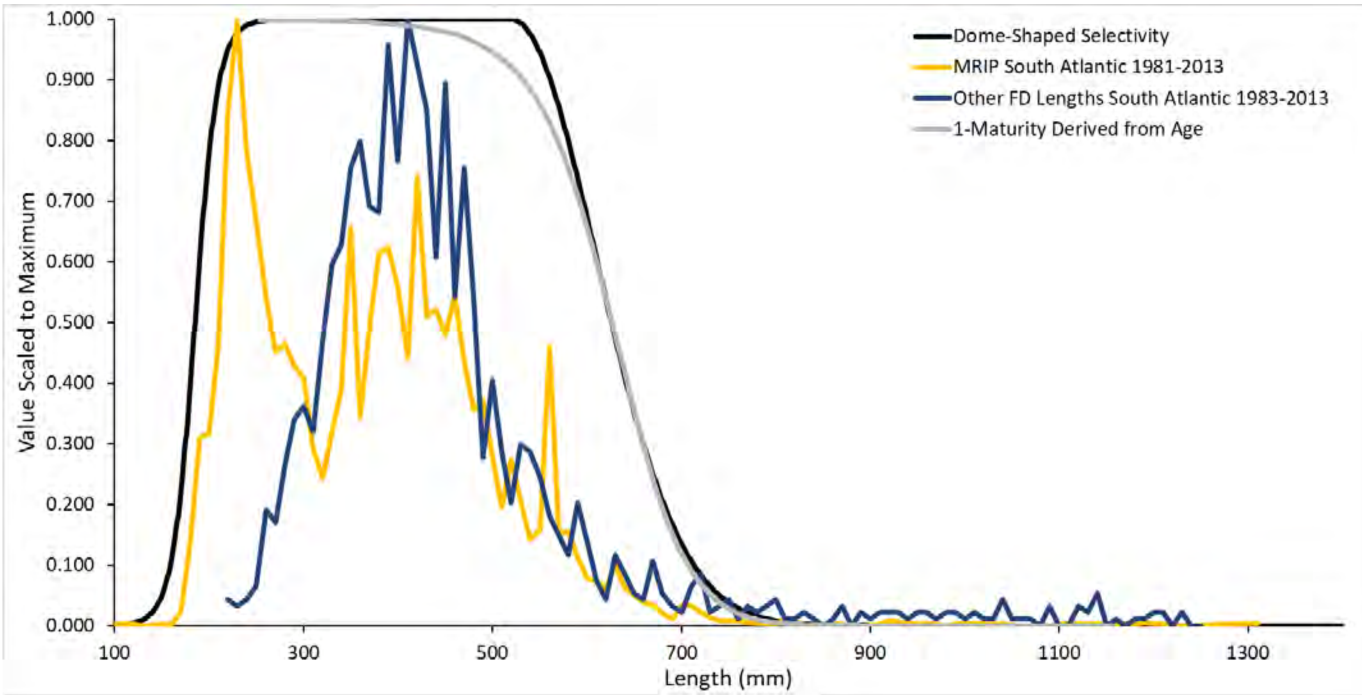

Figure 92. Length selectivity used for the first selectivity period of the SA fleet (SA_1) in JABBA-Select compared to data used to specify selectivity.

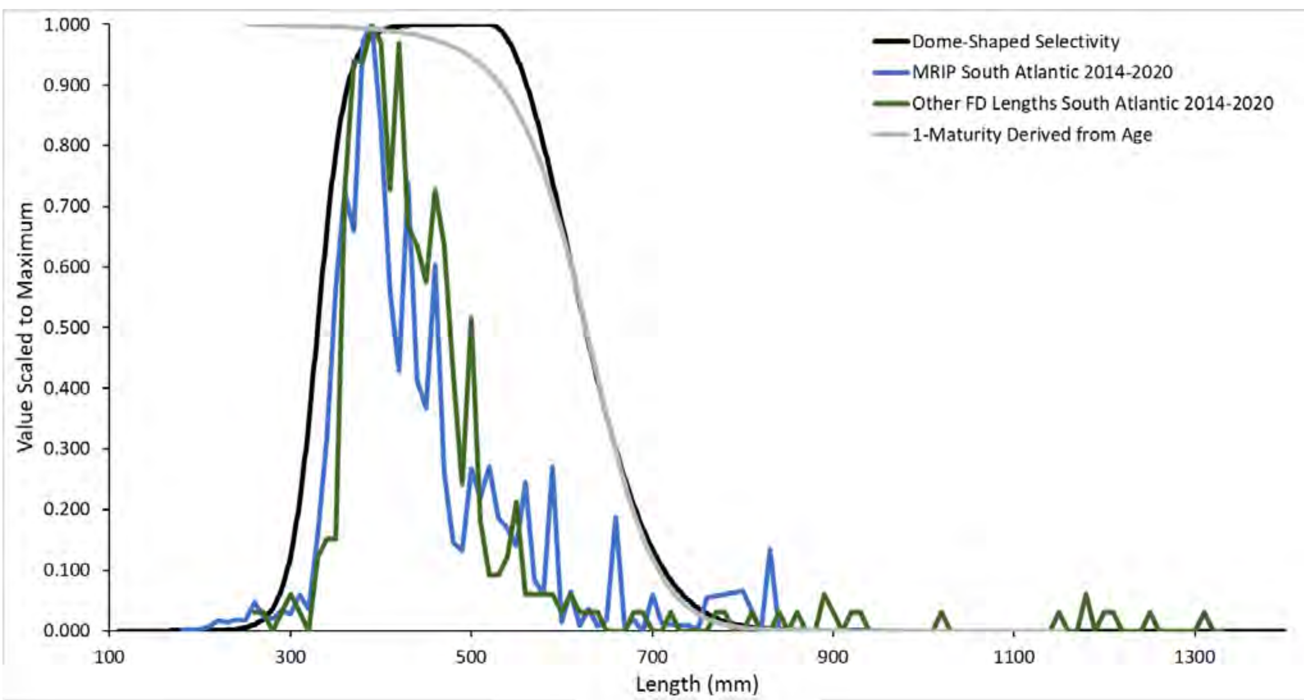

Figure 93. Length selectivity used for the second selectivity period of the SA fleet (SA_2) in JABBA-Select compared to data used to specify selectivity.

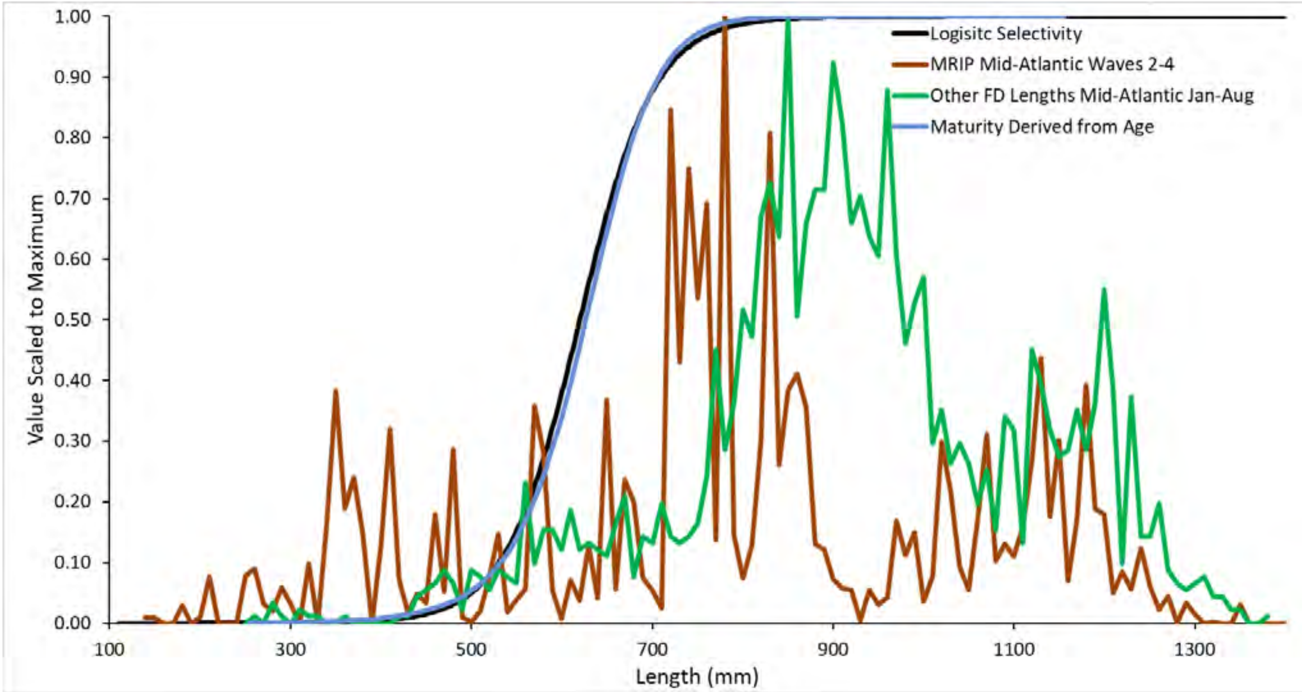

Figure 94. Length selectivity used for the MA_early fleet in JABBA-Select compared to data used to specify selectivity.

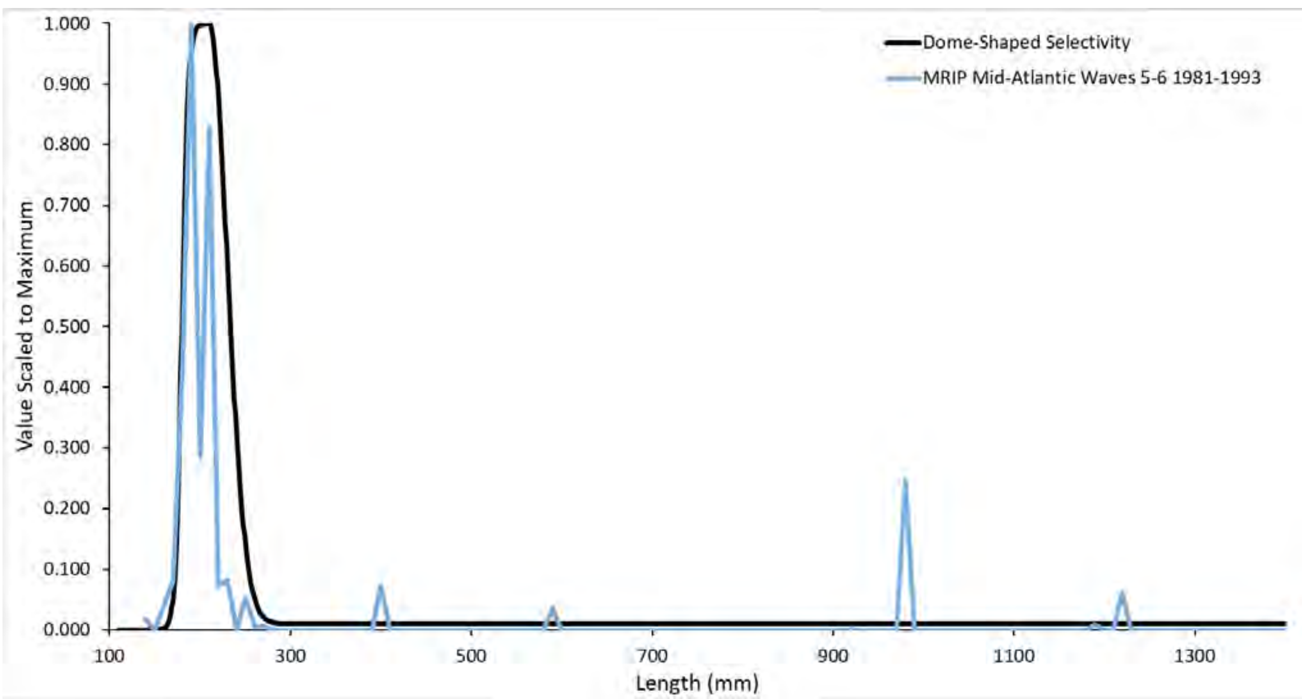

Figure 95. Length selectivity used for the first selectivity period of the MA_late fleet (MA_late_1) in JABBA-Select compared to data used to specify selectivity.

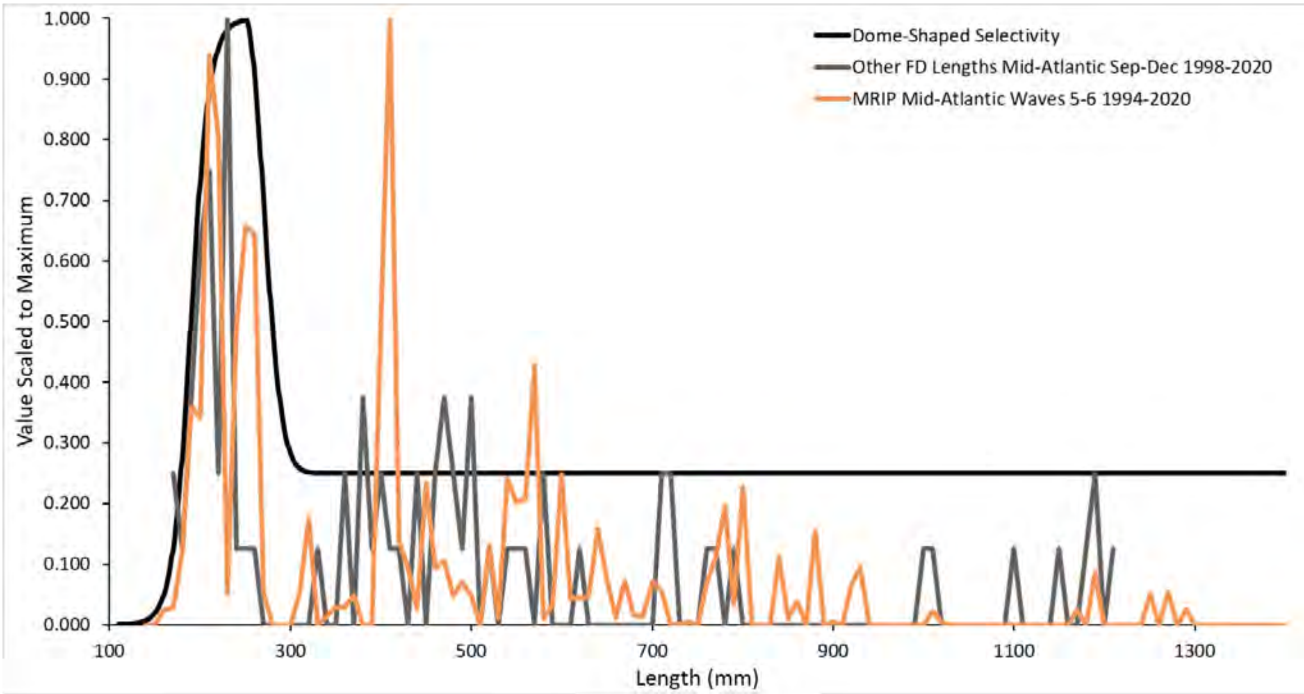

Figure 96. Length selectivity used for the second selectivity period of the MA_late fleet (MA_late_2) in JABBA-Select compared to data used to specify selectivity.

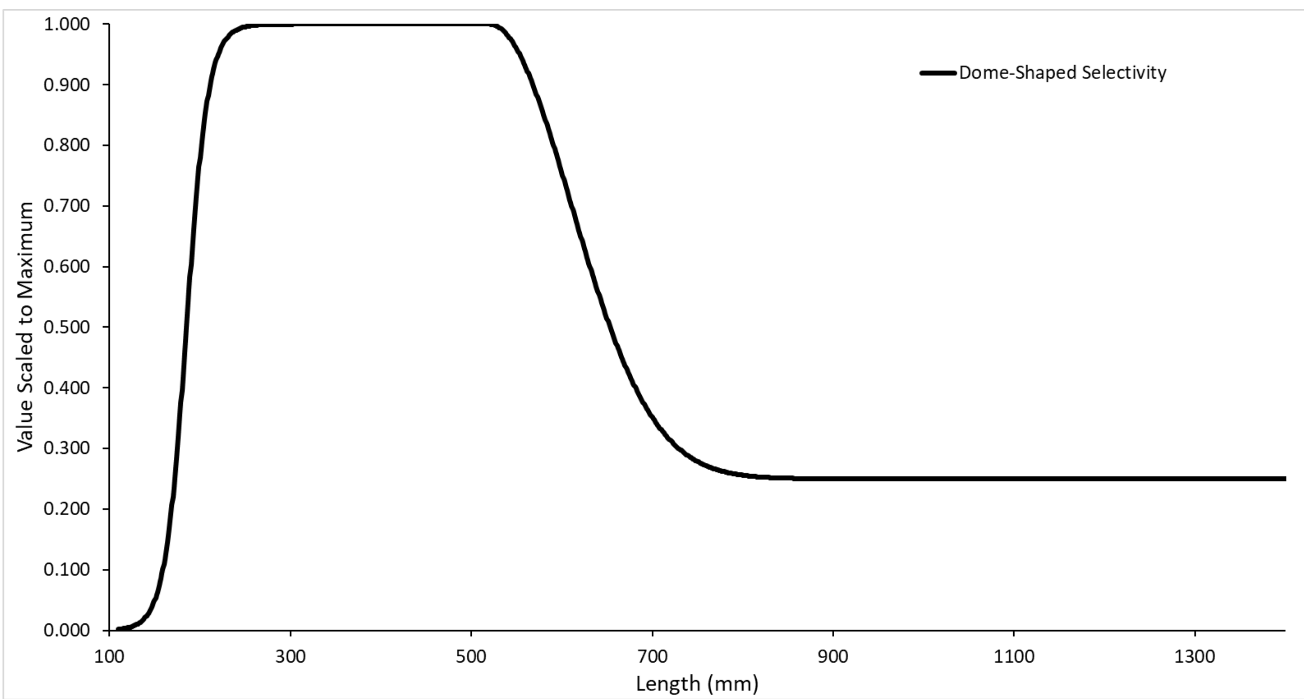

Figure 97. Length selectivity used for the MRIP CPUE in JABBA-Select.

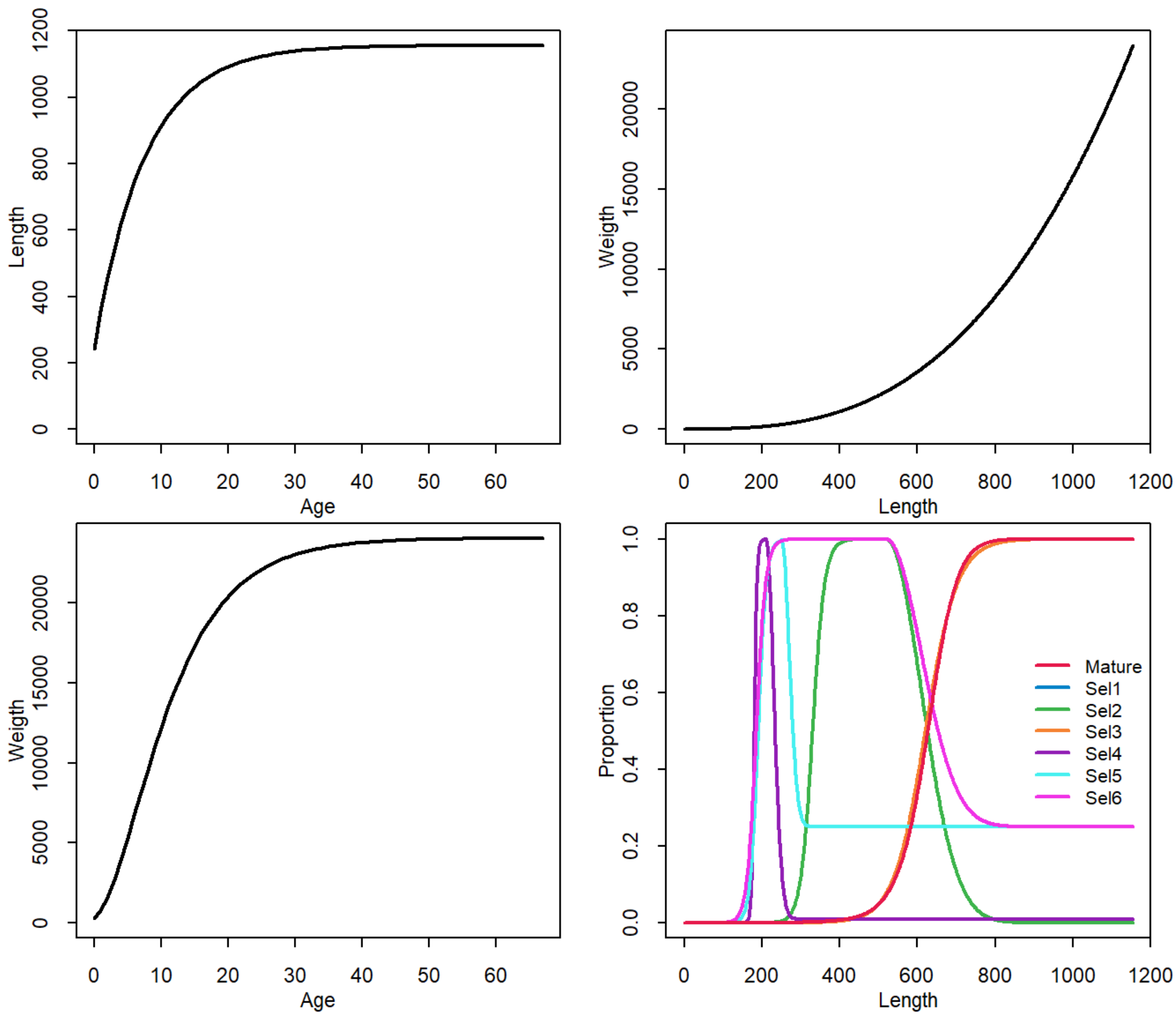

Figure 98. Life history and selectivity patterns used in JABBA-Select. Selectivity patterns are for the first selectivity period of the SA fleet (SA_1, Sel1), the second selectivity period of the SA fleet (SA_2, Sel2), the MA_early fleet (Sel3), the first selectivity period of the MA_late fleet (MA_late_1, Sel4), the second selectivity period of the MA_late fleet (MA_late_2, sel5), and the MRIP CPUE (Sel6).

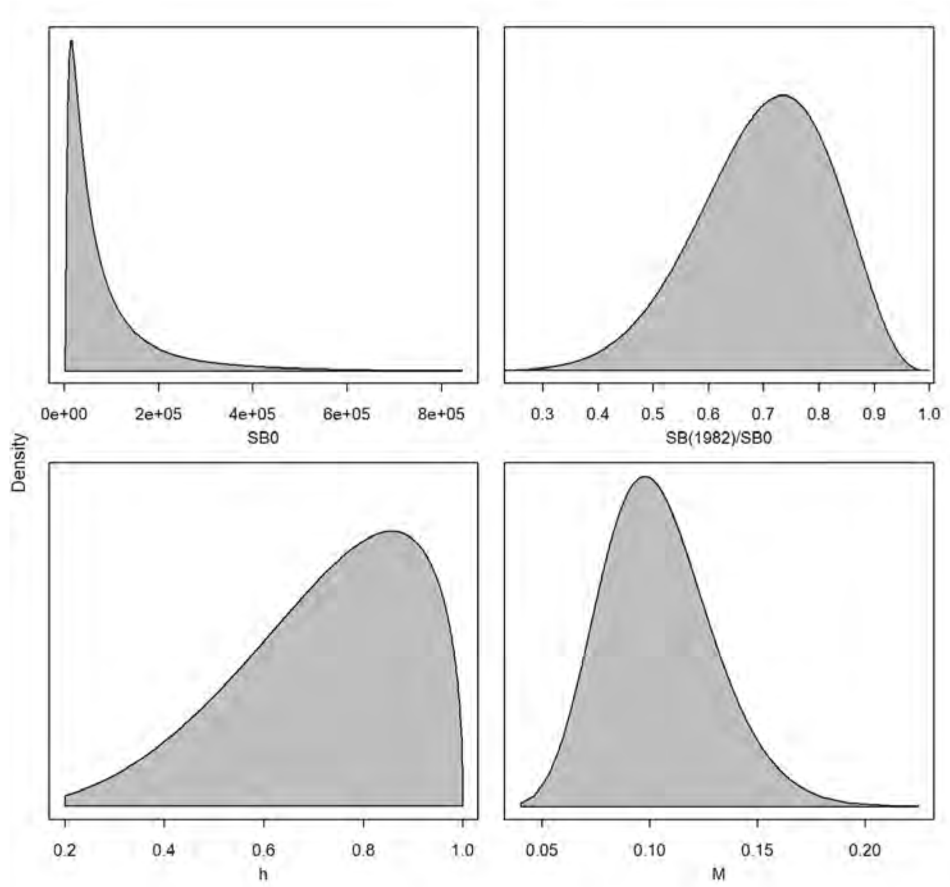

Figure 99. Input prior distributions used in JABBA-Select for unfished spawning biomass (metric tons), depletion in the first year, Beverton-holt stock-recruitment relationship steepness, and natural mortality.

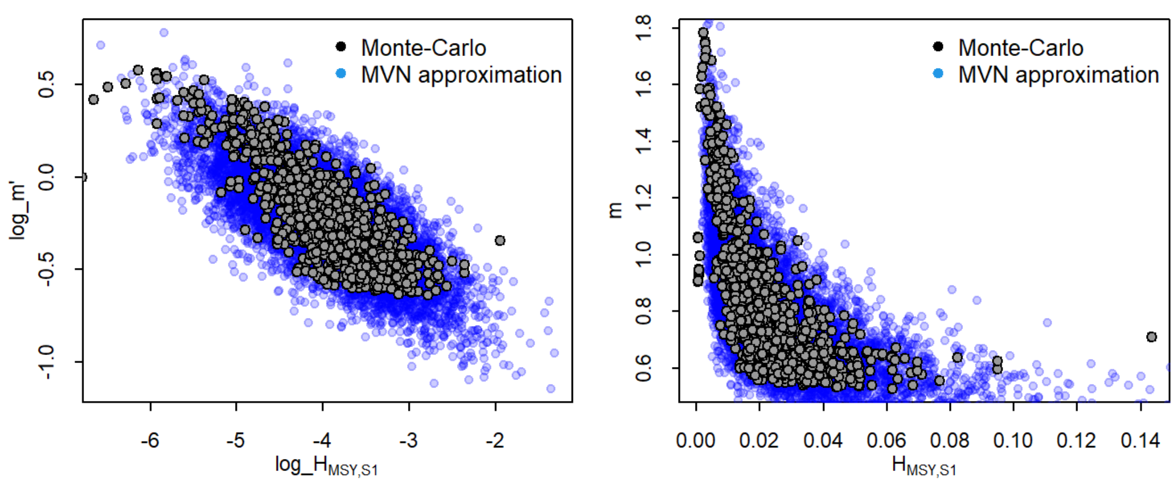

Figure 100. Multivariate normal (MVN) prior distribution of log($H_{MSY,s1}$) and log(m) generated from the per-recruit model Monte Carlo simulations using JABBA-Select (left) and converted from the log scale (right).

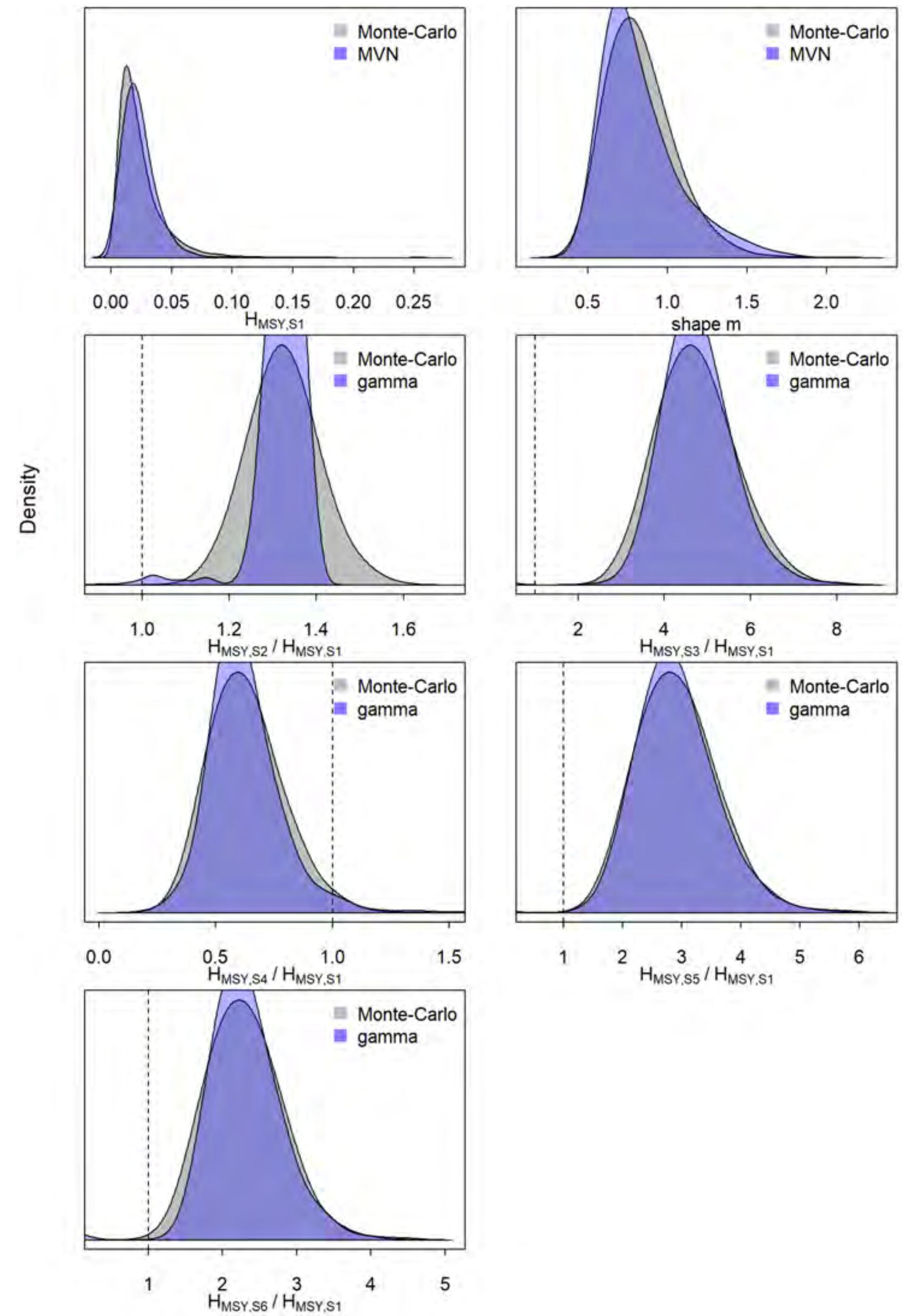

Figure 101. Distributions of $H_{MSY,s1}$ (first selectivity period of the SA fleet, SA_1), *m*, and ratios of other fleet-specific H_{MSY}s to $H_{MSY,1}$ from the per-recruit model Monte Carlo simulations using JABBA-Select (grey) and prior distributions generated from multivariate normal (MVN) prior distribution ($H_{MSY,s1}$ and *m*, top panel) and gamma prior distribution (H_{MSY} ratios, other panels) in purple. $H_{MSY,s2}$ is for the second selectivity period of the SA fleet (SA_2), $H_{MSY,s3}$ is for the MA_early fleet, $H_{MSY,s4}$ is for the first selectivity period of the MA_late fleet (MA_late_1), $H_{MSY,s5}$ is for the second selectivity period of the MA_late fleet (MA_late_2), and $H_{MSY,s6}$ if for the MRIP CPUE.

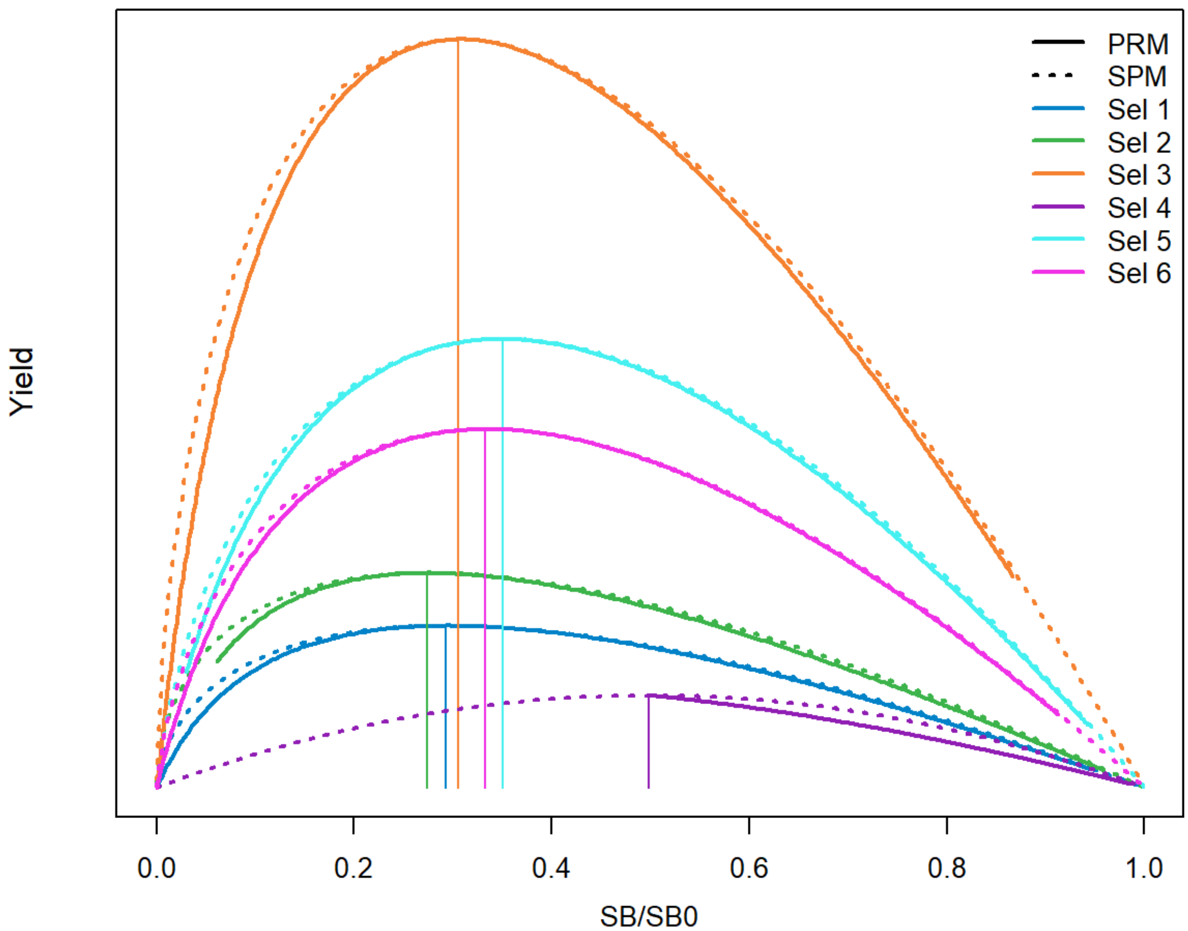

Figure 102. **Yield curves associated with each of the black drum selectivity patterns used in JABBA-Select produced from the per-recruit models (solid curves) and the surplus production function (dashed curves). The solid vertical lines indicate the relative spawning biomass where yield is maximized (i.e., SB_{MSY}/SB_0). Sel 1 is the first selectivity period of the SA fleet (SA_1), Sel 2 is the second selectivity period of the SA fleet (SA_2), Sel 3 is the MA_early fleet, Sel 4 is the first selectivity period of the MA_late fleet (MA_late_1), Sel 5 is the second selectivity period of the MA_late fleet (MA_late_2), and Sel 6 is the MRIP CPUE.**

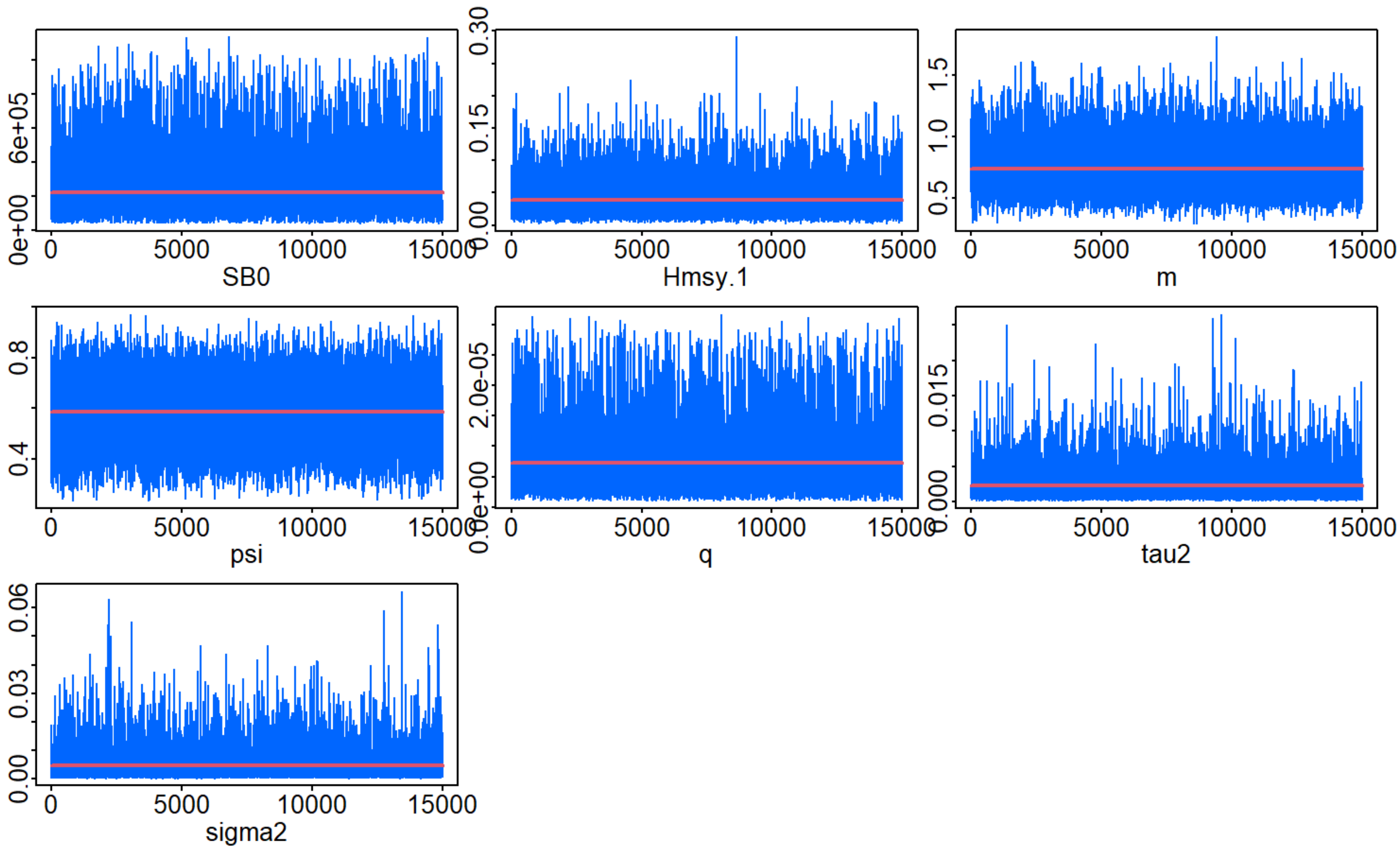

Figure 103. **Trace plots of the Markov chains from the JABBA-Select model. *SB_0* is in metric tons.** *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

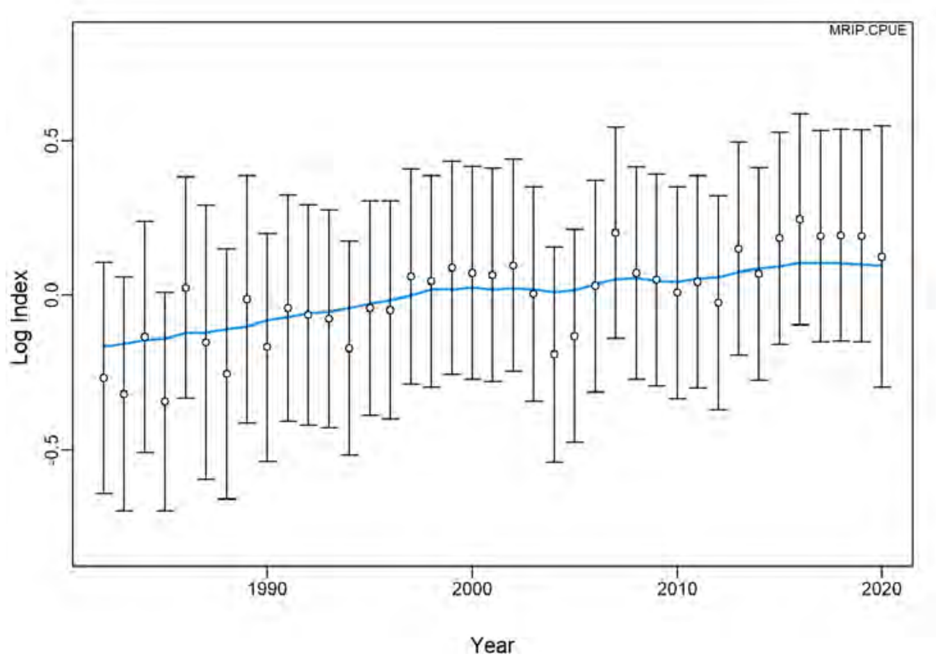

Figure 104. JABBA-Select fit to the MRIP CPUE. The blue line is the model predictions of the observed CPUE (circles). Error bars are 95% confidence intervals of observed CPUE based on total observation error. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

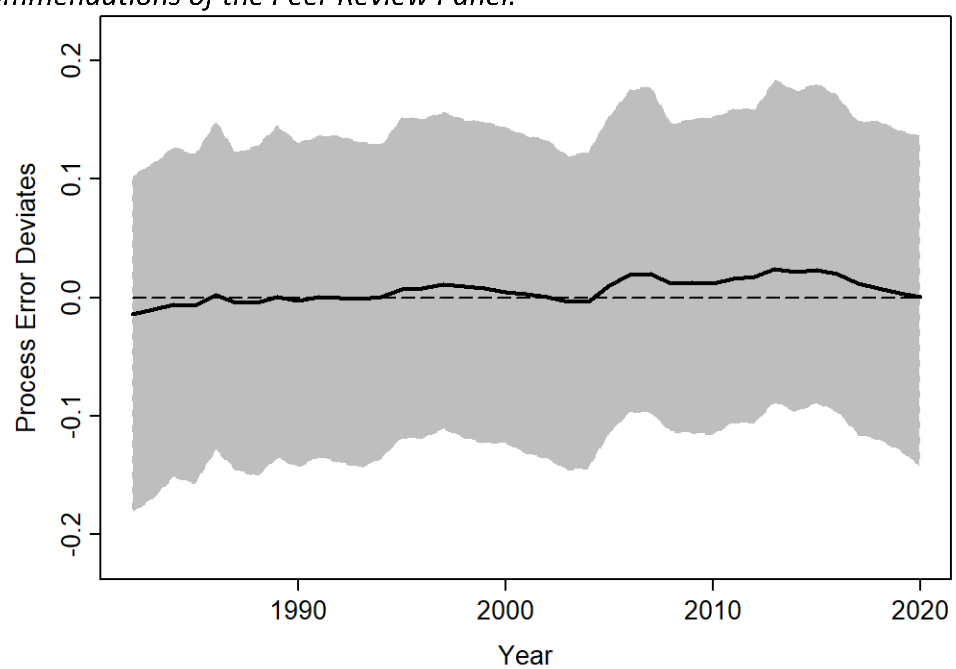

Figure 105. Annual process error deviates (i.e., difference between deterministic expectation of log(*SBy*) and stochastic realization of log(*SBy*)) estimated in JABBA-Select. The solid line is the median and the shaded region is the 95% credible interval. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

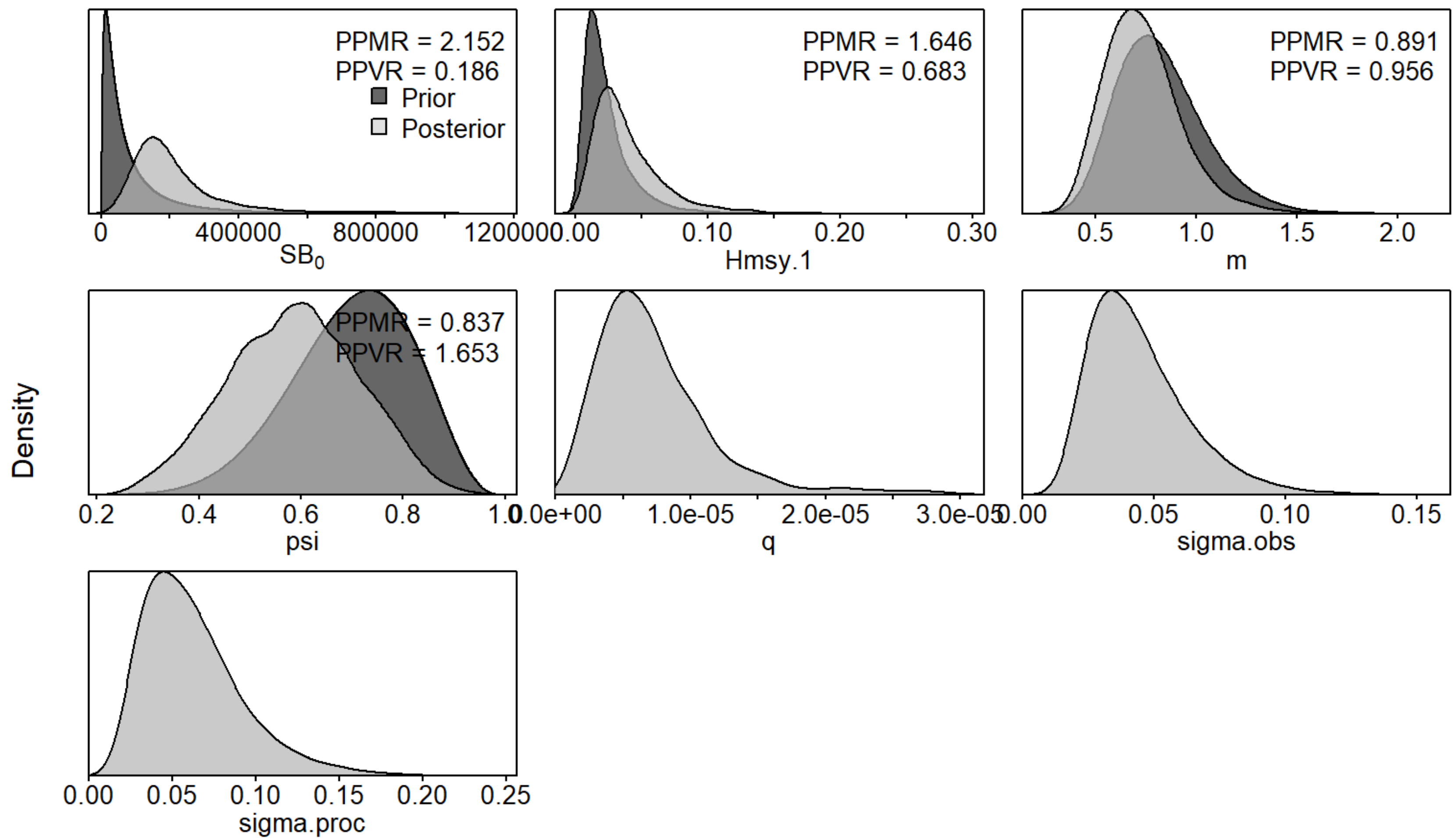

Figure 106. **Prior and posterior distributions of parameters estimated in JABBA-Select. *SB_0* is in metric tons. PPVR is the posterior to prior variance ratio and PPMR is posterior to prior mean ratio.** *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

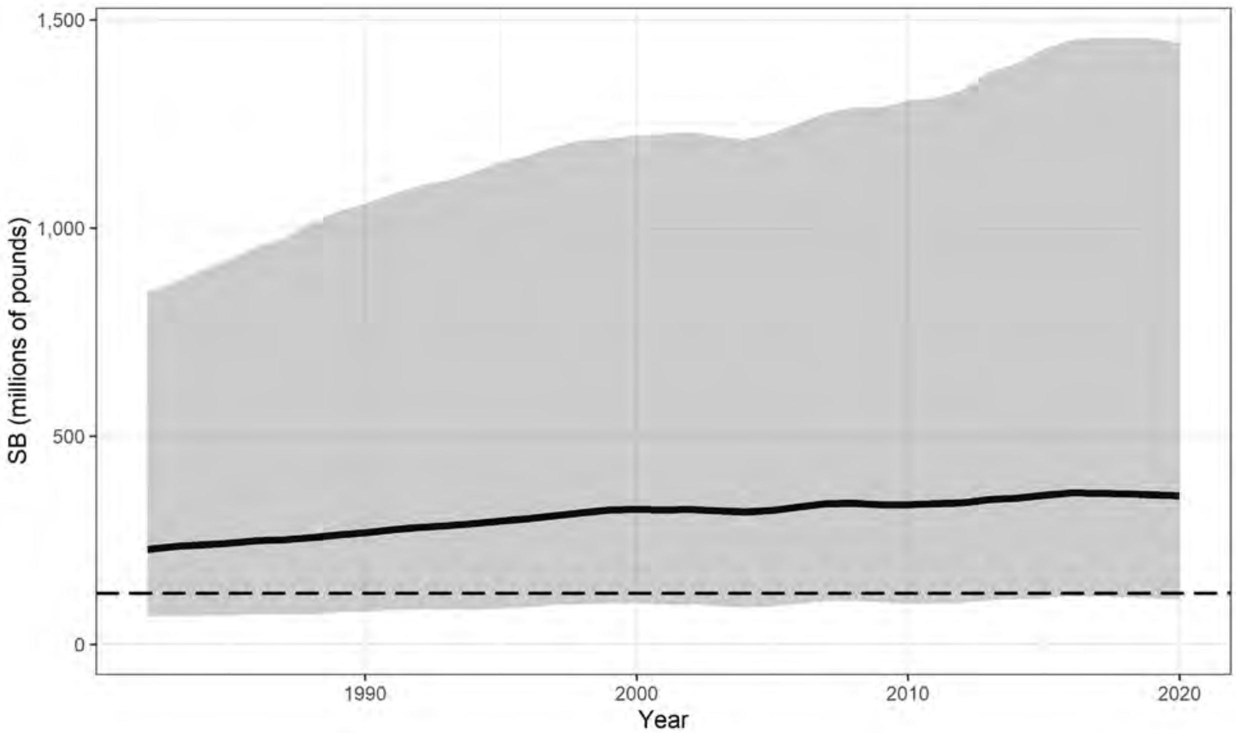

Figure 107. Spawning biomass estimated in JABBA-Select. The solid line is the median and the shaded region is the 95% credible interval. The dashed line is the median SB_{MSY} estimate. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

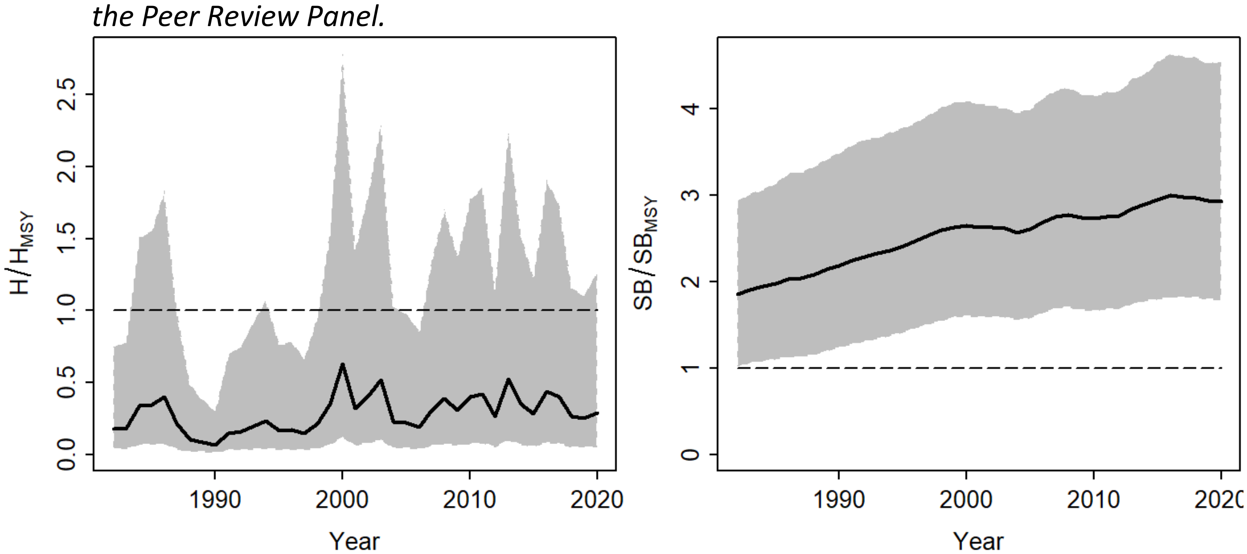

Figure 108. Exploitation (left) and spawning biomass (right) relative to threshold reference points estimated in JABBA-Select. The solid line is the median and the shaded region is the 95% credible interval. The dashed line indicates the estimate at its respective threshold level. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

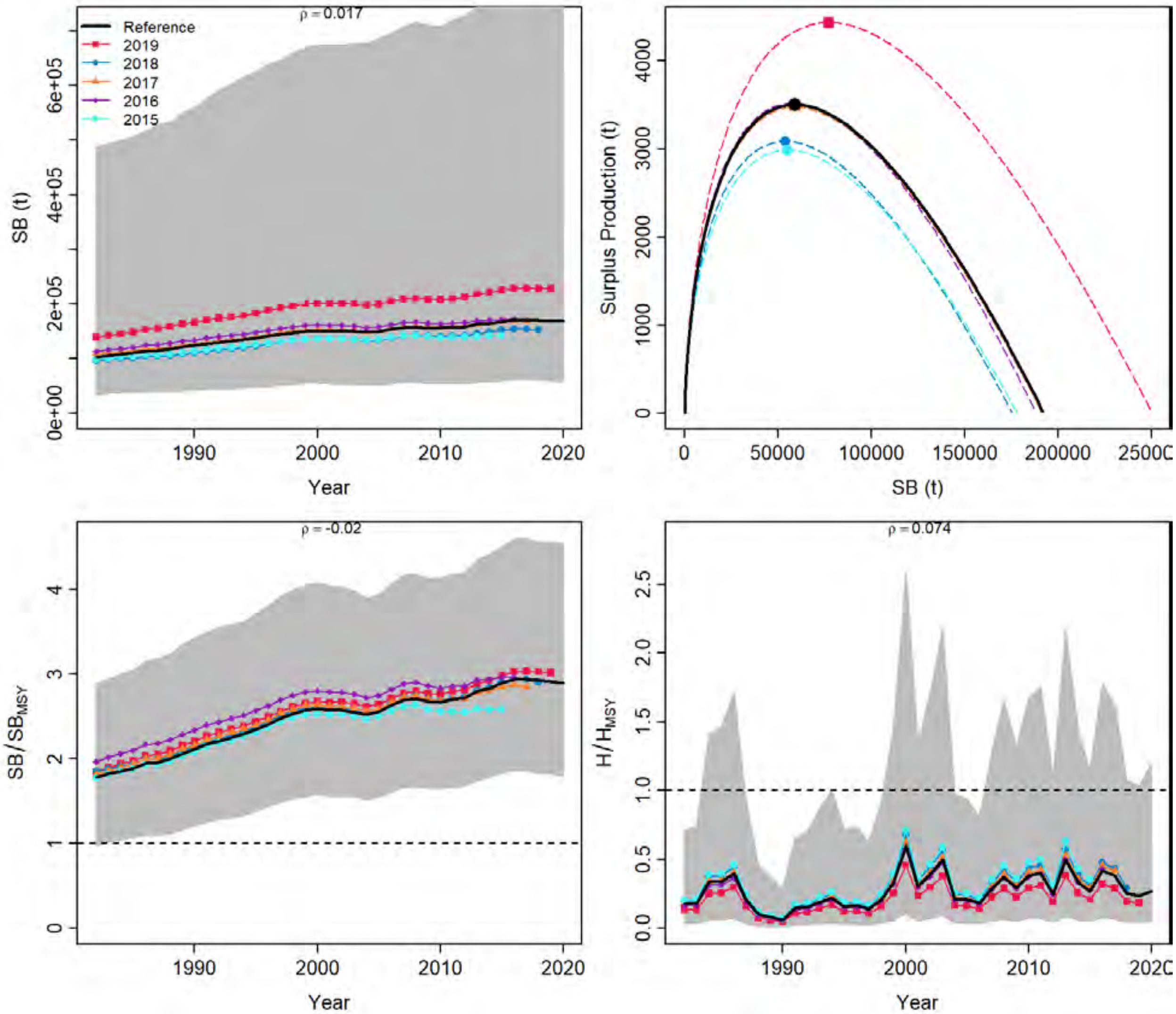

Figure 109. **Estimates from JABBA-Select retrospective analysis. Mohn's rho values are printed at the top of each panel for the respective parameter.** *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

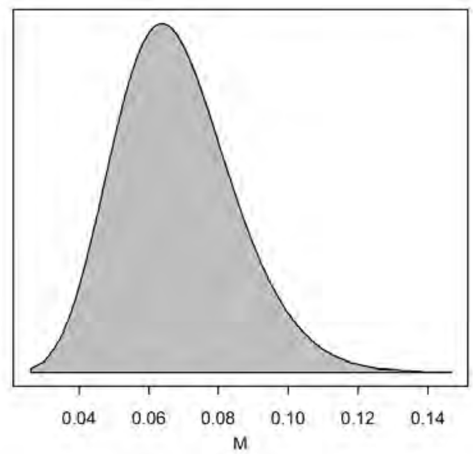

Figure 110. Prior distribution of natural mortality used in the *low M* sensitivity configuration for the JABBA-Select sensitivity analysis.

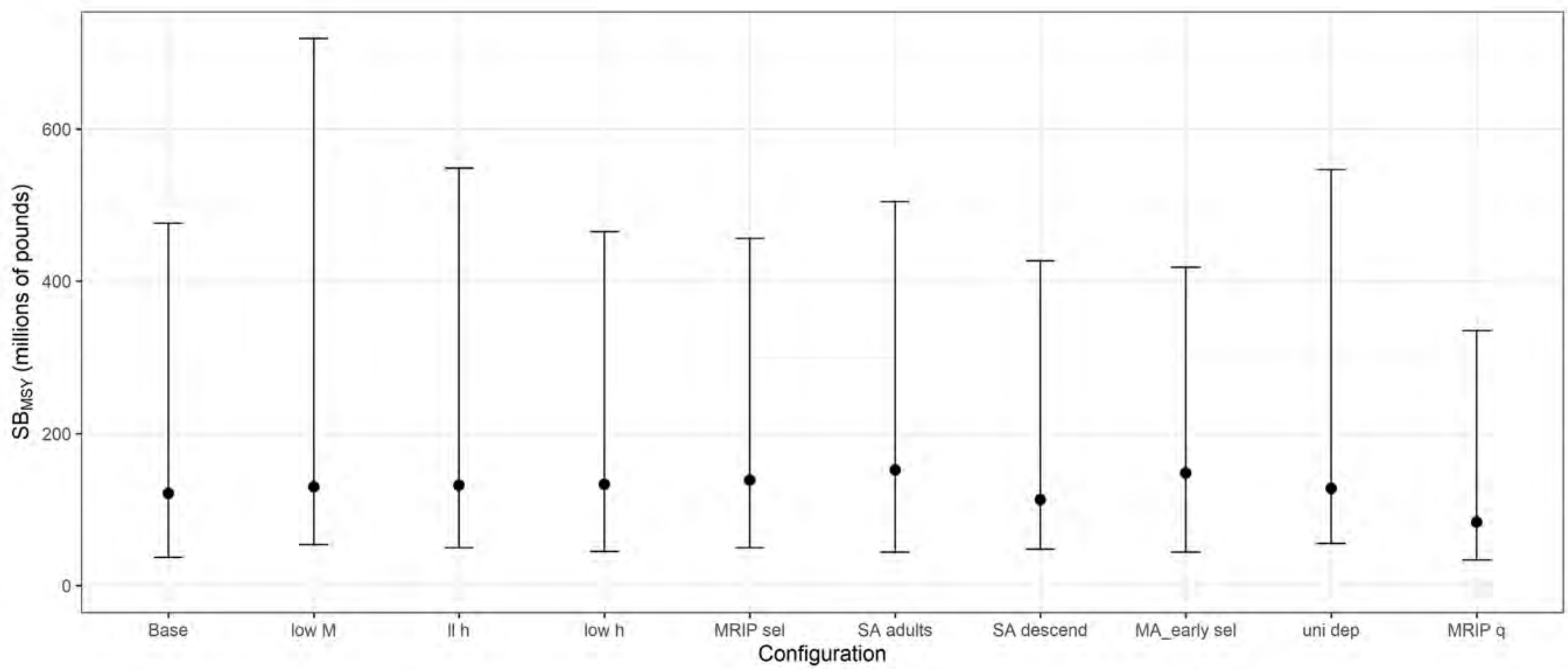

Figure 111. ***SB_{MSY}* estimates from the JABBA-Select sensitivity analysis. Circles are median estimates and the error bars are 95% credible intervals.**

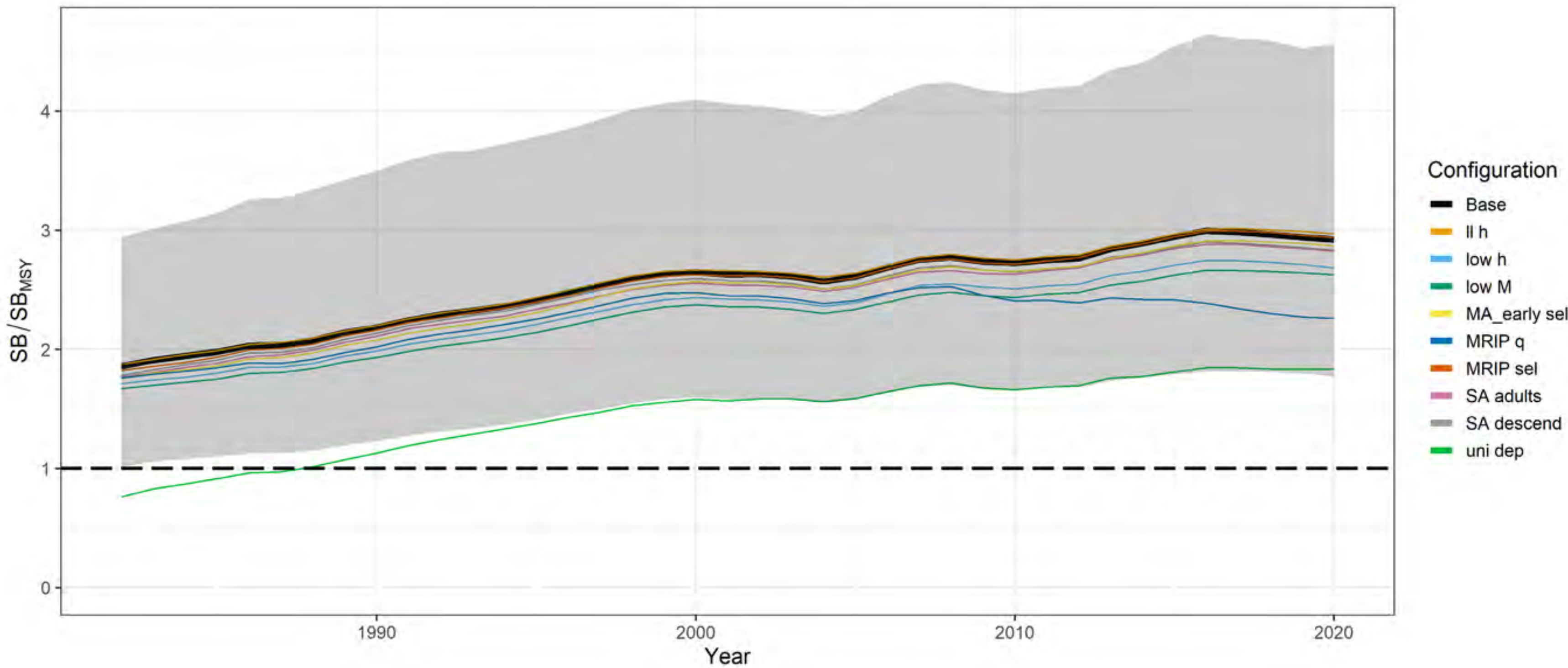

Figure 112. Relative biomass estimates from the JABBA-Select sensitivity analysis. The shaded region is the 95% credible interval of the base model. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

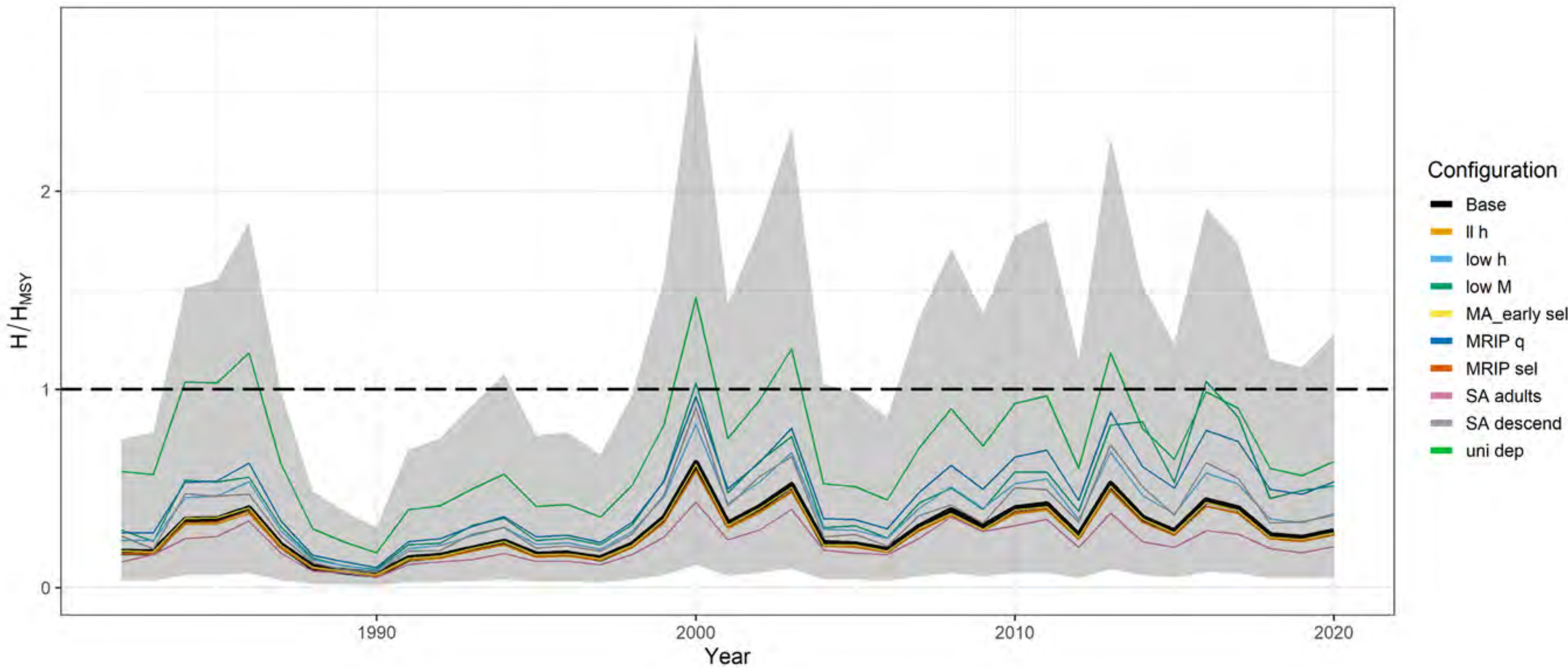

Figure 113. Relative exploitation estimates from the JABBA-Select sensitivity analysis. The shaded region is the 95% credible interval of the base model. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

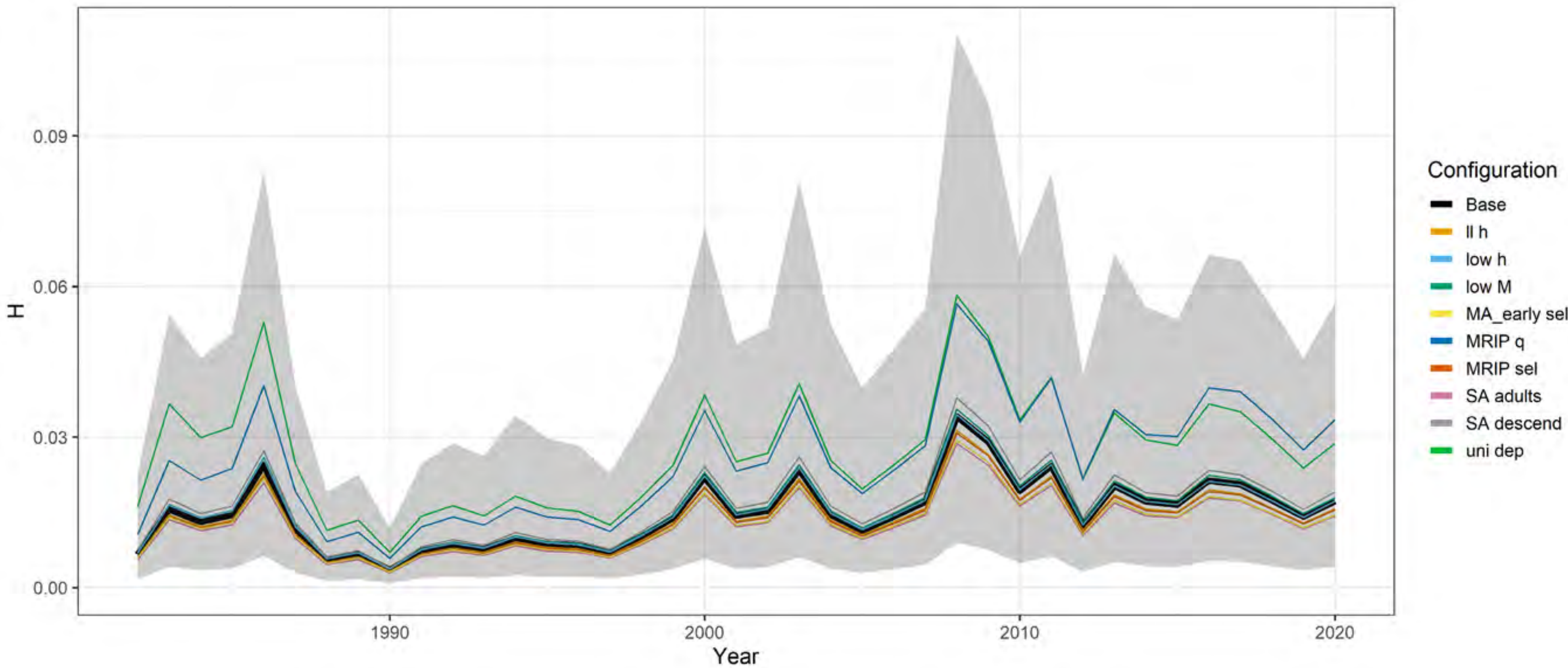

Figure 114. Exploitation estimates from the JABBA-Select sensitivity analysis. The shaded region is the 95% credible interval of the base model.

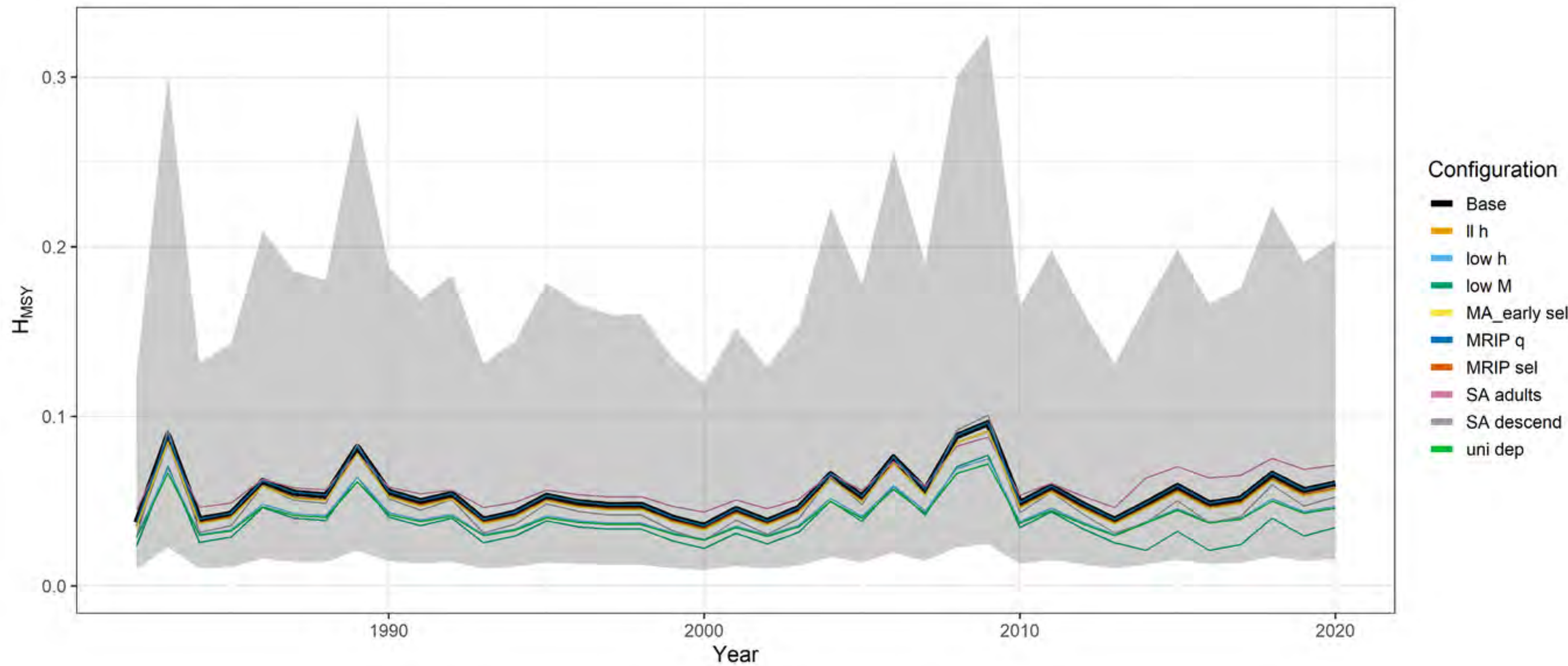

Figure 115. Exploitation associated with *MSY* estimates from the JABBA-Select sensitivity analysis. The shaded region is the 95% credible interval of the base model.

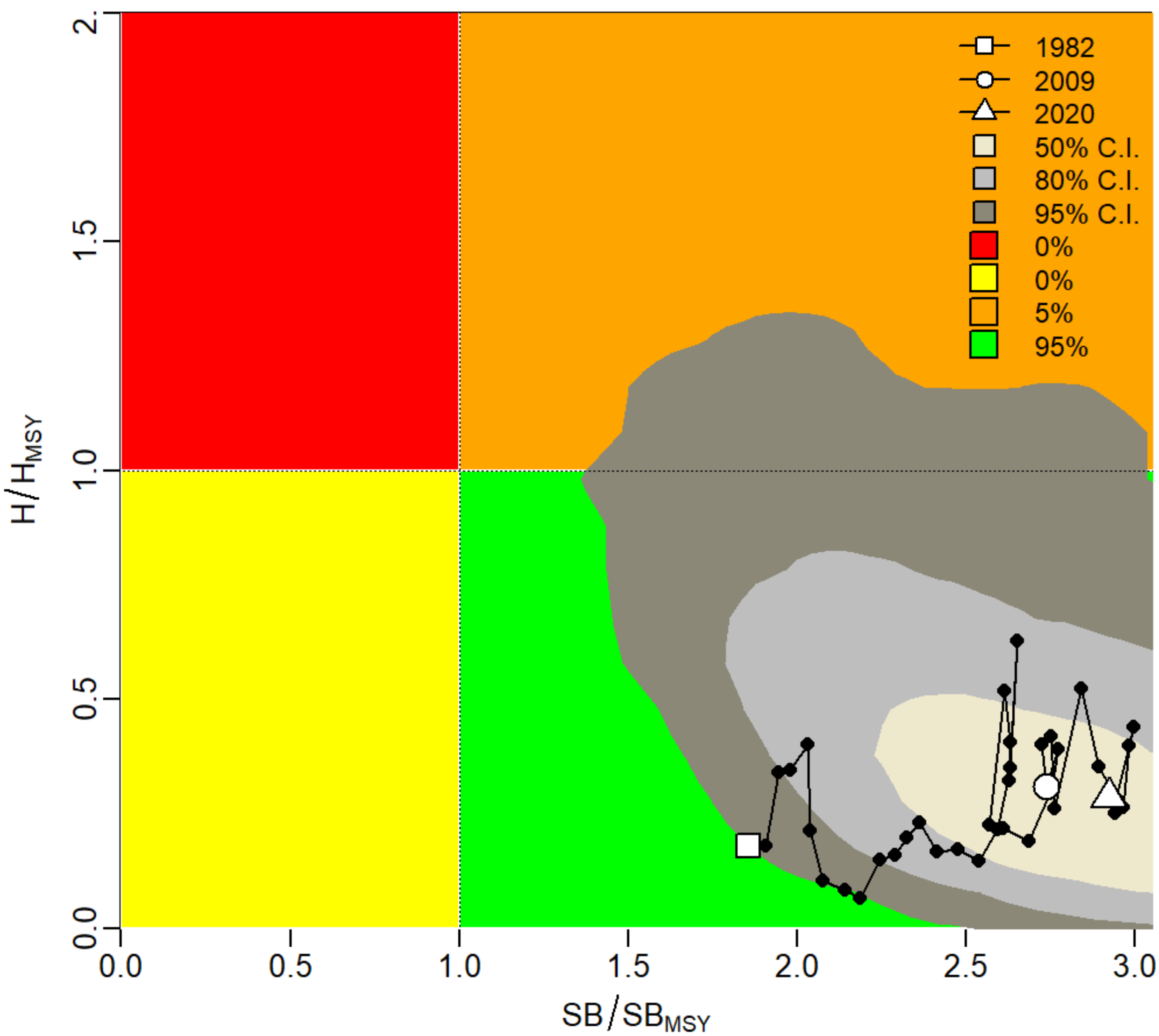

Figure 116. Kobe phase plot for the JABBA-Select model showing the estimated stock status trajectories. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal year of 2020. The probability of terminal year points falling within each quadrant is indicated in the figure legend. *Note: Figure has been updated in Section 13.5 based on changes that were made to the base model configuration in response to the recommendations of the Peer Review Panel.*

13 ADDENDUM TO THE 2023 BLACK DRUM STOCK ASSESSMENT REPORT

13.1 Background

During the Peer Review workshop in January 2023, the Peer Review Panel (Panel) and Black Drum Stock Assessment Subcommittee (SAS) discussed the need for seasonal fleets in the Mid-Atlantic region (MA_early and MA_late fleets, Section 7.3.2). The SAS noted that all available information indicates a vastly different size structure from the stock is available to the fisheries in the region during the earlier and latter parts of the calendar year. The Panel questioned whether this model complexity, including several assumptions about selectivity, was necessary given the small magnitude of removals accounted for by the MA_late fleet (Table 16, Figure 40).

The Panel requested an additional model run with the Mid-Atlantic removals throughout the calendar year collapsed into one fleet (MA fleet). The selectivity for this fleet was assumed to follow the logistic selectivity pattern of the MA_early fleet in the original base model configuration (Table 41, Figure 94) given this fleet accounts for the majority of removals in the Mid-Atlantic. All other model configuration details and inputs remained consistent with the original base model (Section 7.3.2).

Preliminary results of this simplified model configuration during the workshop indicated the model was not particularly sensitive to this change, presumably due to small magnitude of removals accounted for by the MA_late fleet. Through deliberations about this configuration change, the Panel and SAS agreed that the simplified model configuration with one Mid-Atlantic fleet provides an improvement over the original base model reviewed during the workshop and recommended that this simplified configuration be used as the base model to provide management advice.

The following sections provide full results of the new base model developed following he Peer Review workshop, including updated sensitivity analysis, retrospective analysis, and stock status determinations. These results replace the original base model results and stock status determinations in Sections 7.3 and 8, respectively, and are used for final management advice from this stock assessment.

13.2 Results

13.2.1 Base Model Estimates

The model converged to posterior distributions for each parameter according to stable behavior of the chains in trace plots (Figure 117) and the results of the Geweke and Heidelberger and Welch tests (Table 48, all p-values>0.05).

The model fit the general trend of the MRIP CPUE, but there were two periods of positive residuals around 2000 and at the end of the time series (Figure 118). Despite these residuals, the runs test p-value (0.145) indicated random residuals and the SDNR was 0.51. Annual process error deviates did not follow any systematic trending that would clearly indicate model misspecification (Figure 119).

Parameter posterior distributions are compared to prior distribution in Figure 120. The posterior to prior variance ratio (PPVR) is provided to assess the degree of influence the data have on the posterior distribution. The smaller the PPVR, the more the posterior is influenced by the data and the less it is influenced by the prior distribution. The posterior to prior mean ratio (PPMR) is provided to assess the direction in which the posteriors are influenced by the data relative to the prior, with values <1 indicating shifts of the posterior to the left, values >1 indicating shifts of the posterior to the right, and a value of 1 indicating no movement. The SB_0, H_{MSY1}, and *m* parameters were more strongly influenced by the data, while the depletion parameter (*psi*) was more strongly influenced by the prior. The influence the data did have on the depletion parameter indicated a more depleted stock (PPMR<1). The data indicated a larger stock that is slightly more productive (higher H_{MSY1} and lower *m*). The estimated process error parameter was small and typical of a long-lived stock with many ages contributing to the spawning stock biomass (Winker 2018). The additional observation error parameter was also small and resulted in a median total observation error corresponding to a CV of 0.182.

The spawning biomass was estimated to increase throughout the time series, though there were wide credible intervals indicating high uncertainty in absolute biomass estimates (Table 49, Figure 121). Relative biomass was estimated with more certainty (Table 49, Figure 122).

Exploitation generally follows the removal time series with higher exploitation estimated during the mid-1980s and since 2000 (Table 50, Figure 122). Credible intervals of relative exploitation are also quite wide. Most of the intervals through time indicate exploitation less than H_{MSYy}, but there is some low probability of exploitation exceeding H_{MSYy} during the higher exploitation years.

The base model is interpreting the increasing trend in both MRIP CPUE and fishery removals as indication that the stock was lightly exploited in earlier years allowing for surplus biomass to recruit to the less vulnerable spawning stock and build up over time (Figure 122). Some positive anomalies in biomass during the late 2000s and early 2010s (Figure 119), likely due to some strong year classes that were not fully exploited to the threshold level, appear to have offset the increased removals and a more drastic increase in exploitation to allow for the trend to continue increasing, albeit at a reduced rate that starts to flatten out from the increased exploitation since about 2000 (Figure 122).

13.2.2 Retrospective Analysis

A retrospective analysis was conducted with a five-year peel from the assessment terminal year. Mohn's rho values were calculated according to the methodology of Hurtado-Ferro et al. (2014).

Estimates from the retrospective with Mohn's rho values are provided in Figure 123. Mohn's rho values range from -0.05 for biomass estimates to 0.026 for relative exploitation estimates. These values indicate a more conservative pattern with a tendency to underestimate biomass and overestimate relative fishing mortality as years are peeled from the time series. The magnitude of the Mohn's rho values indicate no significant retrospective bias according to the rule of thumb proposed by Hurtado-Ferro et al. (2014) for long-lived species (-0.15 – 0.20).

13.2.3 Sensitivity Analysis

A sensitivity analysis was conducted by running alternative model configurations to assess impact of key assumptions and uncertainties identified by the TC. Nine alternative configurations were included in the analysis when done for the original base model that was peer reviewed during the Peer Review workshop (Table 47) and are described below. In addition to these alternative configurations, the original base model with seasonal Mid-Atlantic fleets (***Orig Base*** configuration) has been included in this updated sensitivity analysis for comparison to the final base model with one Mid-Atlantic fleet.

Three configurations included alternate assumptions on the key life history parameters influencing productivity, *h* and *M*. The ***low M*** configuration included a natural mortality prior distribution with a mean (0.068) lower than the base model (0.1041) and closer to the Hoenig (1983) estimate used in the previous assessment (0.063). Attempts were made to lower the mean to 0.063, but a small number (3%) of *M-h* draws with low *M* and high *h* caused errors in the per-recruit calculations that cascaded through the modeling software and 0.068 was the lowest mean that avoided these errors. The alternative prior distribution includes a significant portion of its density at or below the 0.063 mean value used in the previous assessment (Figure 110). The ***ll h*** configuration included a steepness prior distribution parameterized with the likelihood estimates from Shertzer and Conn (2012) as opposed to bootstrapped estimates. These parameters included a slightly larger mean (increased from 0.72 to 0.75) and greater precision (CV decreased from 0.25 to 0.20). The ***low h*** configurations included a steepness prior distribution with a mean decreased by 0.1 from 0.72 to 0.62.

Four configurations included alternate selectivity assumptions. The ***MRIP sel*** configuration decreased the selectivity for the largest sized fish from 0.25 in the base model to 0.1 due to uncertainty in vulnerability of spawning adults relative to sub-adults that account for the majority of recreational catch. The ***SA adults*** configuration increased the selectivity for the largest sized fish from 0 in the base model to 0.06 based on small reported catches of these sized fish and potential for small scale directed fishing at trophy sized fish such as tournaments and charter boat operations. The ***SA descend*** configuration shifts descending selectivity of the SA fleet to the left by 100 mm, reducing the size range available to this fishery. The ***MA_early sel*** configuration shifted selectivity of the MA_early fleet to the right of the selectivity pattern in the base model due to available length composition data peaking at larger sizes than full maturity.

The last two configurations dealt with the start year depletion assumption and uncertainty about a potential shift in catchability for the MRIP CPUE in recent years. The ***uni dep*** configuration included a beta prior distribution parameterized as a uniform distribution over the full range of values 0 to 1 (mean=0.5, CV=0.577). This configuration was included due to the use of a uniform prior distribution on the depletion assumption for DB-SRA in the previous assessment. One distinction due to the constraints of the JABBA-Select software is that the beta distribution can only be parameterized as a uniform distribution over the full range of values (including overfished levels <0.4) whereas the DB-SRA uses a true uniform distribution with bounds that were set at levels representative of a stock that is not overfished (0.5 and 0.9). The ***MRIP q*** configuration included a second catchability coefficient parameter for the MRIP CPUE allowing for a unique catchability coefficient in years after 2015. This configuration was included due to the positive residuals since 2016 in the base model and the apparent shift in catchability identified and discussed in Section 4.2.1.3. This configuration acknowledges the possibility that the directed trips data set used to calculate the MRIP CPUE did not completely account for the apparent change in catchability. This configuration was also considered for the base model, but was not selected due to lower deviance information criterion (DIC) of the final base model presented here, indicating the additional *q* parameter was not justified by improved fit to the data, and a similar group of residuals around 2000 that changed after the same amount of time being observed at the end of the time series.

Relative biomass estimates with the final base model are almost identical to estimates from the ***Orig Base*** configuration, with the exception of some slight divergence in the last few years of the time series (Figure 124). All sensitivity configurations estimate similar trends with one exception (Figure 125). The ***MRIP q*** configuration estimates a similar trend as the other configurations for most of the time series, but then starts to diverge with a declining trend in the last decade. Notably, the ***uni dep*** configuration estimates relative biomass more similar to the base model than seen for the ***Orig Base*** model in the original sensitivity analysis (Figure 112) with median estimates that remain above one throughout the time series. The base model estimates also fall more in the center of estimates form sensitivity configurations compared to the ***Orig Base*** run in the original sensitivity analysis which estimated among the highest relative biomass.

Relative exploitation estimates with the final base model are essentially identical to estimates from the ***Orig Base*** configuration (Figure 126). Sensitivity configurations estimate similar trends in relative exploitation (Figure 127) as well as a narrower distribution of estimates than seen in the original sensitivity analysis (Figure 113). The ***uni dep*** configuration still estimates some of the highest exploitation during the time series, but, unlike the original sensitivity analysis, these estimates remain less than one.

13.3 Stock Status

Overfished is defined as spawning biomass falling below spawning biomass associated with *MSY* ($SB_y/SB_{MSY} < 1$). Overfishing is defined as exploitation exceeding exploitation associated with *MSY* ($H_y/H_{MSYy} > 1$).

The 2020 median relative spawning biomass estimated with the base model was 2.99, indicating the stock was not overfished in the terminal year of the stock assessment (Table 49). The 2020 median relative exploitation estimated with the base model was 0.28, indicating the stock was not experiencing overfishing in the terminal year of the stock assessment (Table 50).

Results indicate greater certainty that the stock has not been depleted to an overfished status in the terminal year of the assessment, while there is less certainty about the exploitation status. Figure 128 shows the time series of stock status estimates with uncertainty around terminal year determinations. All of the 95% credible interval is above the overfished threshold, while exploitation shows some low probability of exceeding the threshold within the 95% credible interval. This low risk of overfishing according to the credible intervals extends back for much of the last twenty years of the time series. The sensitivity analysis included some configurations that estimated median relative exploitation that exceeds the threshold in recent years, while no sensitivity configuration estimated median relative biomass below the threshold since the 1980s.

There are several important points of context to consider with this stock status determination estimated from the JABBA-Select model:

- Empirical indicators show increased fishery removals in the last twenty years and less frequent large recruitment events in the Mid-Atlantic in the last ten years. There are no clear indications of a declining trend in recruitment or exploitable abundance from abundance indicators, with the exception of the anomalous GA trammel index, but there is a declining trend in the final two years of the recreational discard time series that may be reflective of abundance in addition to other factors. There is some indication of northern range expansion. Overall, stock indicators do not appear negative at this time, but should be monitored closely for any sign of change.

- The one-way trip increasing trend in both removals and the MRIP CPUE for the assessment time period may indicate that the stock either had been lightly exploited in the 1980s, which has allowed for the recent increase in exploitation of the predicted high biomass, or was overfished and rebuilding throughout the assessment time series. The latter scenario is contrary to the TC's expert opinion that the stock was not overfished at the beginning of the time period, and there were minimal regulation changes aimed specifically at black drum in the 1980s to induce a rebuilding period. However, it is also possible that recruitment overfishing is occurring or could begin to occur prior to detection with currently available data, due to sub-adult black drum accounting for the majority of removals and the lack of an index that solely tracks mature biomass. With over 30 cohorts contributing to *SSB*, recruitment overfishing may not be evident within current data streams for an extended number of years, leading to an overfished state being reached prior to removals and the MRIP CPUE index indicating a sustained downward trend. The TC concurs with the model-derived stock status but acknowledges the lack of contrast in both removals and the MRIP CPUE coupled with model uncertainty will require close monitoring of stock indicators and a more conservative approach to managing the fishery.

13.4 Addendum Tables

Table 48. JABBA-Select final base model estimated and derived (NA p-values) parameters with p-values for posterior distribution convergence tests.

Parameter	*LCI*	*Median*	*UCI*	*Geweke p-value*	*Heidelberger and Welch p-value*
SB_0	155	439	1,893	0.11	0.12
SB_{1982}/SB_0	0.298	0.549	0.815	0.09	0.26
m	0.332	0.627	1.165	0.45	0.31
$H_{MSY,1}$	0.008	0.031	0.107	0.81	0.23
$H_{MSY,2}$	0.010	0.041	0.143	0.76	0.25
$H_{MSY,3}$	0.036	0.150	0.533	0.40	0.24
q	0.000	0.000	0.000	0.13	0.06
σ^2_{est}	0.000	0.002	0.008	0.41	0.29
σ^2_{η}	0.000	0.003	0.021	0.57	0.48
SB_{MSY}	38	126	546	NA	NA
MSY_1	1	4	18	NA	NA
MSY_2	1	5	24	NA	NA
MSY_3	5	19	87	NA	NA

Table 49. Spawning biomass estimates from the JABBA-Select final base model.

Year	SB (millions of pounds)			SB/SB_{MSY}			SB/SB_0		
	LCI	Median	UCI	LCI	Median	UCI	LCI	Median	UCI
1982	69	234	1,200	0.973	1.862	3.300	0.294	0.533	0.805
1983	71	238	1,231	1.000	1.900	3.382	0.305	0.543	0.813
1984	73	242	1,253	1.017	1.932	3.449	0.316	0.552	0.821
1985	74	245	1,282	1.025	1.958	3.504	0.322	0.561	0.830
1986	77	253	1,313	1.056	2.016	3.615	0.333	0.577	0.849
1987	75	255	1,335	1.043	2.023	3.623	0.331	0.581	0.854
1988	75	260	1,361	1.054	2.064	3.695	0.340	0.593	0.867
1989	81	268	1,389	1.102	2.125	3.783	0.353	0.609	0.888
1990	81	275	1,415	1.130	2.170	3.842	0.364	0.624	0.896
1991	85	283	1,449	1.171	2.228	3.945	0.377	0.641	0.916
1992	87	288	1,453	1.196	2.276	3.997	0.388	0.654	0.928
1993	89	293	1,480	1.227	2.311	4.076	0.396	0.665	0.937
1994	91	299	1,489	1.258	2.355	4.135	0.405	0.677	0.952
1995	95	306	1,519	1.309	2.422	4.211	0.421	0.695	0.976
1996	98	312	1,553	1.351	2.484	4.316	0.434	0.713	1.001
1997	103	320	1,580	1.386	2.546	4.419	0.450	0.732	1.027
1998	106	328	1,615	1.426	2.604	4.495	0.461	0.750	1.051
1999	108	332	1,635	1.452	2.649	4.550	0.473	0.763	1.063
2000	108	334	1,651	1.468	2.674	4.553	0.474	0.768	1.076
2001	105	334	1,678	1.459	2.662	4.531	0.469	0.763	1.074
2002	105	335	1,692	1.461	2.661	4.545	0.471	0.763	1.066
2003	103	333	1,690	1.454	2.650	4.497	0.463	0.759	1.054
2004	98	330	1,697	1.413	2.613	4.439	0.451	0.748	1.034
2005	100	334	1,703	1.442	2.646	4.479	0.464	0.759	1.047
2006	106	342	1,716	1.503	2.723	4.606	0.484	0.784	1.074
2007	112	349	1,749	1.576	2.794	4.687	0.505	0.805	1.100
2008	114	353	1,750	1.589	2.819	4.728	0.507	0.812	1.108
2009	109	349	1,757	1.557	2.779	4.664	0.499	0.802	1.095
2010	106	348	1,770	1.543	2.768	4.636	0.496	0.798	1.093
2011	108	351	1,768	1.577	2.786	4.686	0.504	0.804	1.100
2012	109	353	1,768	1.585	2.812	4.717	0.509	0.812	1.117
2013	116	362	1,790	1.650	2.891	4.887	0.526	0.835	1.145
2014	117	366	1,811	1.672	2.934	4.958	0.533	0.848	1.166
2015	122	373	1,836	1.715	2.995	5.118	0.550	0.865	1.212
2016	125	379	1,853	1.750	3.045	5.201	0.555	0.877	1.236
2017	124	378	1,866	1.742	3.050	5.212	0.552	0.876	1.244
2018	120	378	1,866	1.726	3.036	5.160	0.548	0.874	1.231
2019	118	376	1,868	1.706	3.015	5.093	0.538	0.867	1.225
2020	113	373	1,858	1.661	2.989	5.114	0.527	0.860	1.220

Table 50. Exploitation estimates from the JABBA-Select final base model.

Year	*H*			H/H_{MSY}		
	LCI	*Median*	*UCI*	*LCI*	*Median*	*UCI*
1982	0.001	0.006	0.022	0.029	0.188	0.818
1983	0.003	0.015	0.051	0.028	0.188	0.863
1984	0.002	0.013	0.043	0.054	0.356	1.679
1985	0.003	0.014	0.048	0.054	0.362	1.743
1986	0.005	0.024	0.079	0.061	0.418	2.045
1987	0.002	0.011	0.038	0.032	0.224	1.129
1988	0.001	0.005	0.018	0.016	0.108	0.553
1989	0.001	0.006	0.021	0.012	0.086	0.441
1990	0.001	0.003	0.012	0.010	0.066	0.338
1991	0.001	0.007	0.024	0.023	0.152	0.766
1992	0.002	0.008	0.028	0.021	0.138	0.698
1993	0.001	0.007	0.024	0.031	0.198	0.993
1994	0.002	0.010	0.031	0.036	0.233	1.157
1995	0.002	0.008	0.027	0.026	0.170	0.841
1996	0.002	0.008	0.026	0.027	0.174	0.865
1997	0.001	0.007	0.021	0.023	0.146	0.723
1998	0.002	0.010	0.030	0.035	0.219	1.062
1999	0.003	0.013	0.041	0.054	0.339	1.635
2000	0.004	0.021	0.066	0.100	0.629	3.042
2001	0.003	0.014	0.044	0.051	0.324	1.571
2002	0.003	0.015	0.047	0.062	0.389	1.908
2003	0.004	0.023	0.073	0.081	0.510	2.553
2004	0.003	0.014	0.047	0.035	0.225	1.149
2005	0.002	0.011	0.037	0.035	0.220	1.107
2006	0.003	0.014	0.044	0.030	0.191	0.943
2007	0.003	0.016	0.052	0.048	0.298	1.429
2008	0.007	0.033	0.101	0.063	0.392	1.880
2009	0.006	0.028	0.090	0.049	0.310	1.510
2010	0.004	0.019	0.061	0.064	0.403	1.931
2011	0.005	0.023	0.075	0.065	0.411	1.981
2012	0.002	0.012	0.039	0.042	0.264	1.256
2013	0.004	0.019	0.061	0.083	0.522	2.431
2014	0.003	0.016	0.052	0.057	0.353	1.663
2015	0.003	0.016	0.049	0.046	0.282	1.302
2016	0.004	0.020	0.062	0.070	0.436	2.043
2017	0.004	0.020	0.060	0.062	0.386	1.813
2018	0.003	0.017	0.052	0.042	0.265	1.265
2019	0.003	0.013	0.043	0.040	0.250	1.230
2020	0.003	0.016	0.054	0.044	0.275	1.368

13.5 Addendum Figures

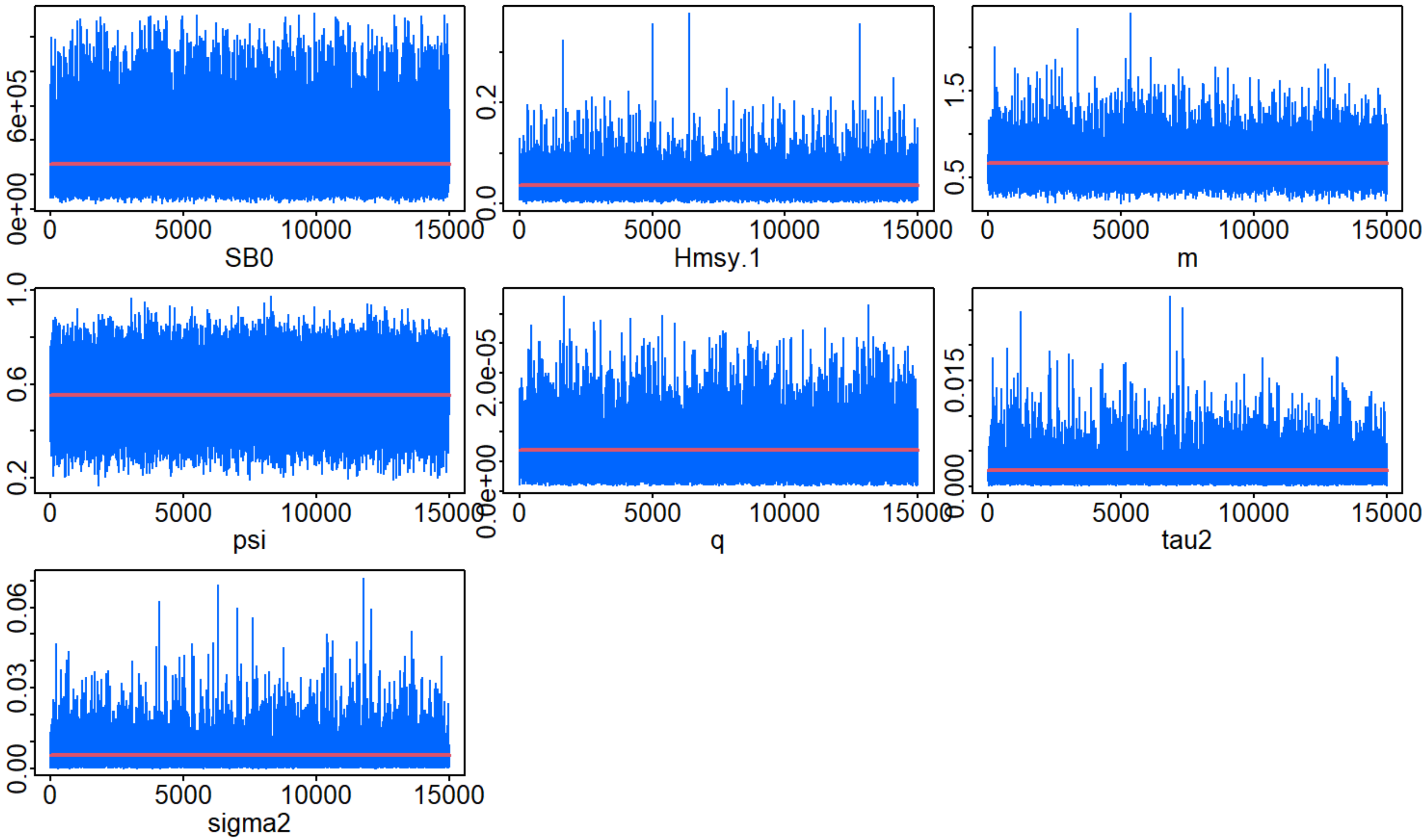

Figure 117. **Trace plots of the Markov chains from the JABBA-Select final base model. *SB₀* is in metric tons.**

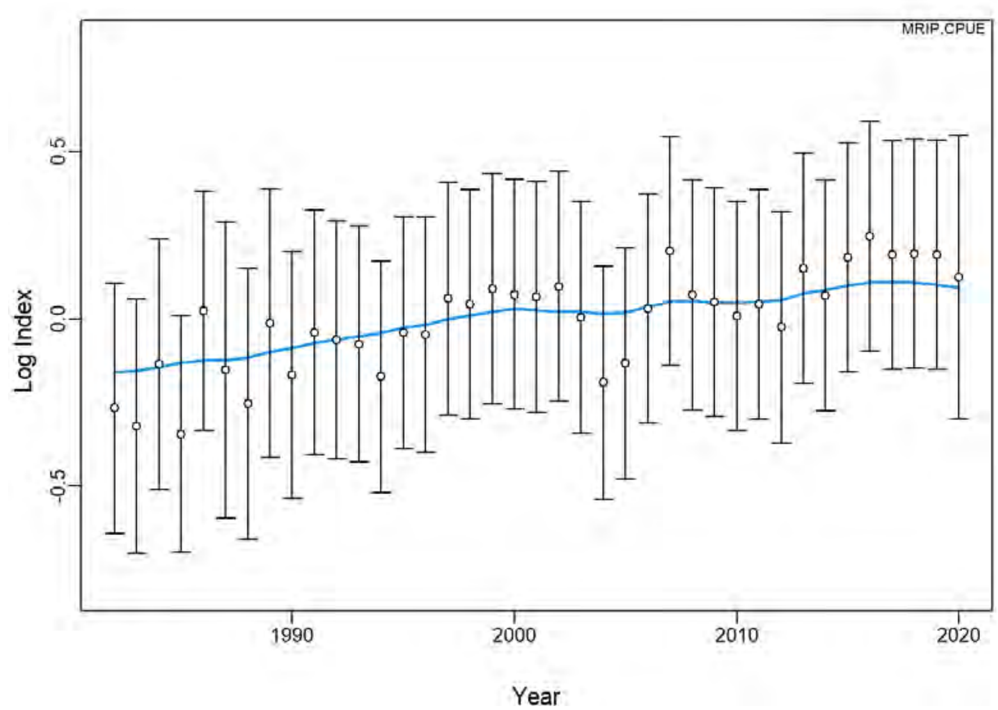

Figure 118. JABBA-Select final base model fit to the MRIP CPUE. The blue line is the model predictions of the observed CPUE (circles). Error bars are 95% confidence intervals of observed CPUE based on total observation error.

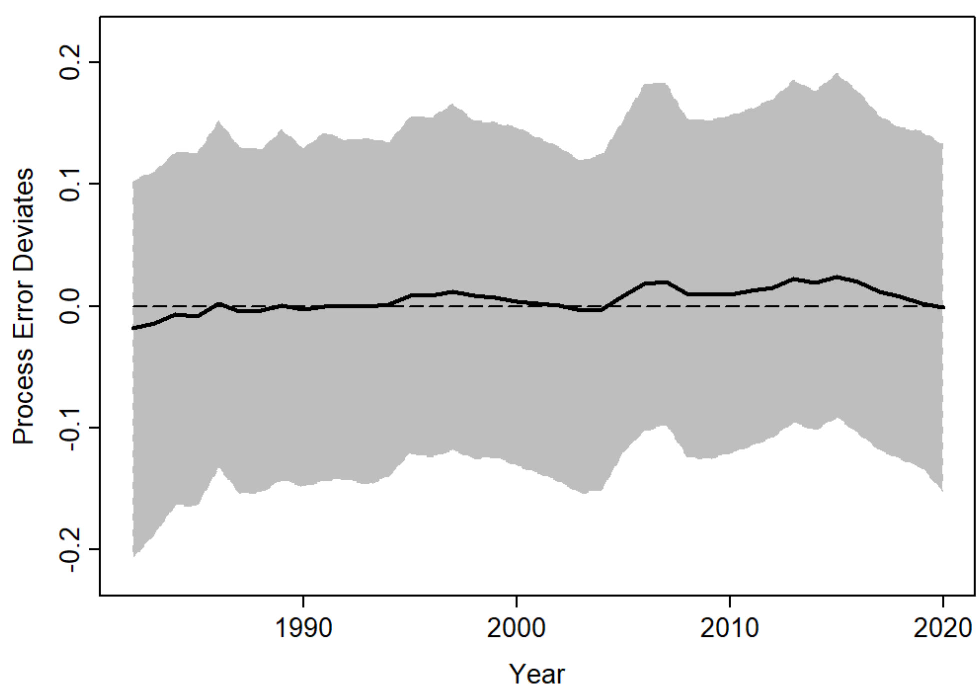

Figure 119. Annual process error deviates (i.e., difference between deterministic expectation of log(*SBy*) and stochastic realization of log(*SBy*)) estimated in the JABBA-Select final base model. The solid line is the median and the shaded region is the 95% credible interval.

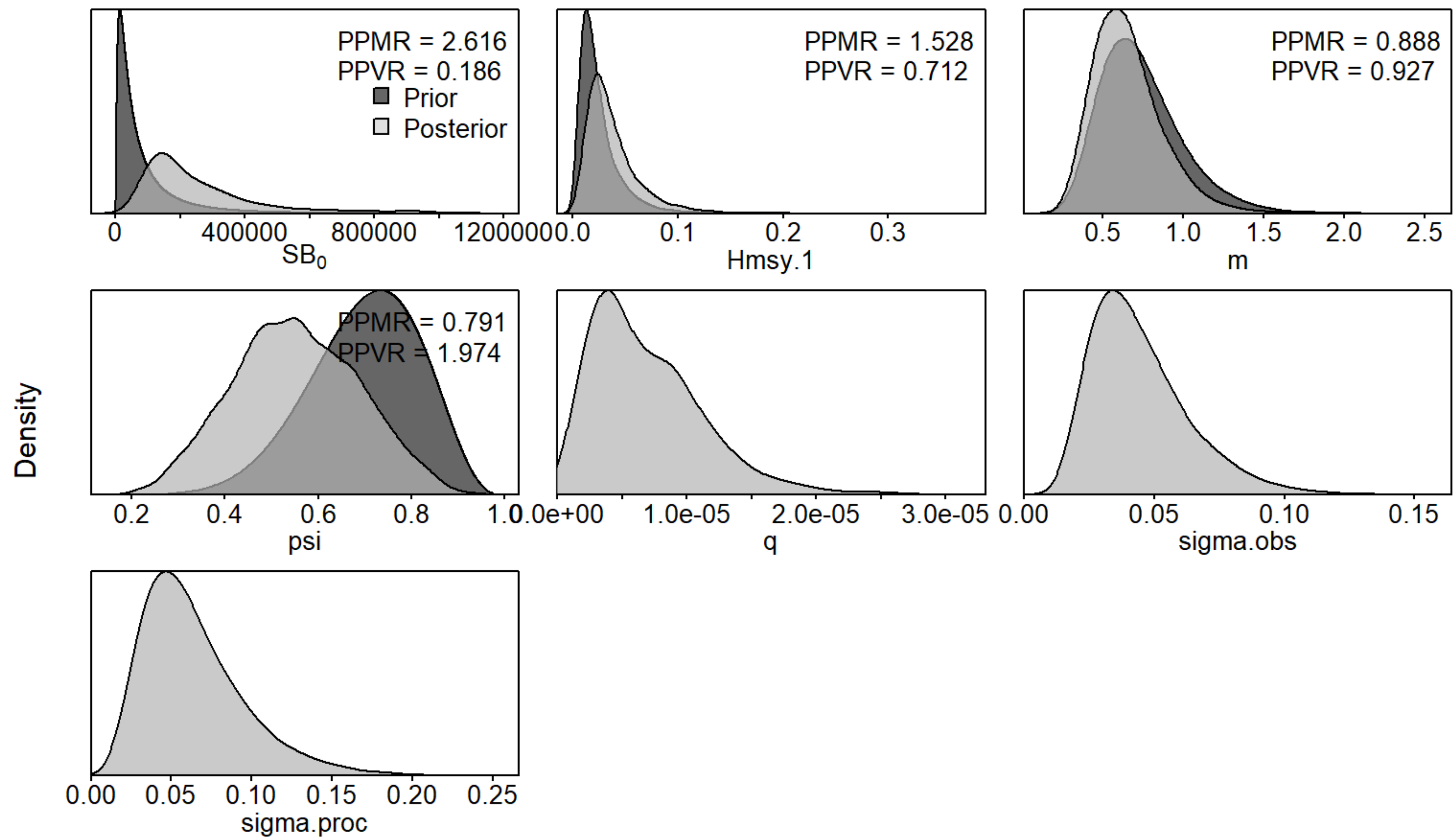

Figure 120. **Prior and posterior distributions of parameters estimated in JABBA-Select final base model. *SB_0* is in metric tons. PPVR is the posterior to prior variance ratio and PPMR is posterior to prior mean ratio.**

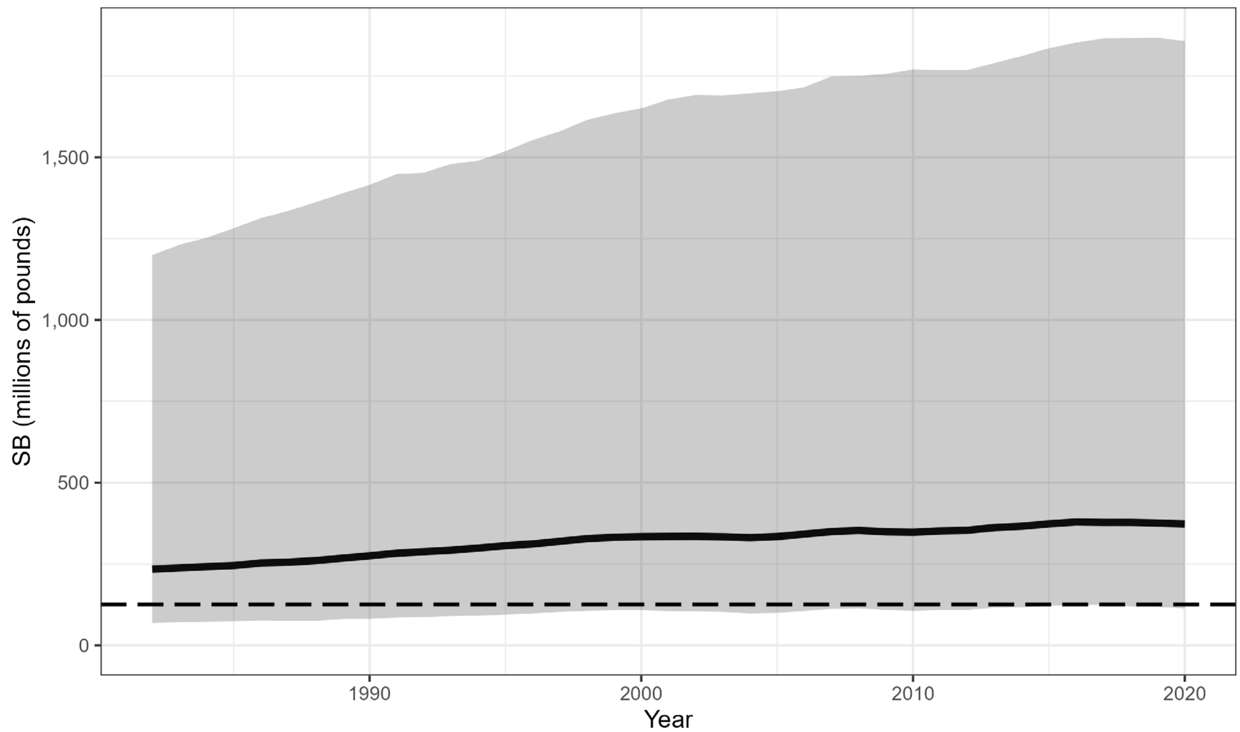

Figure 121. Spawning biomass estimated in the JABBA-Select final base model. The solid line is the median and the shaded region is the 95% credible interval. The dashed line is the median SB_{MSY} estimate.

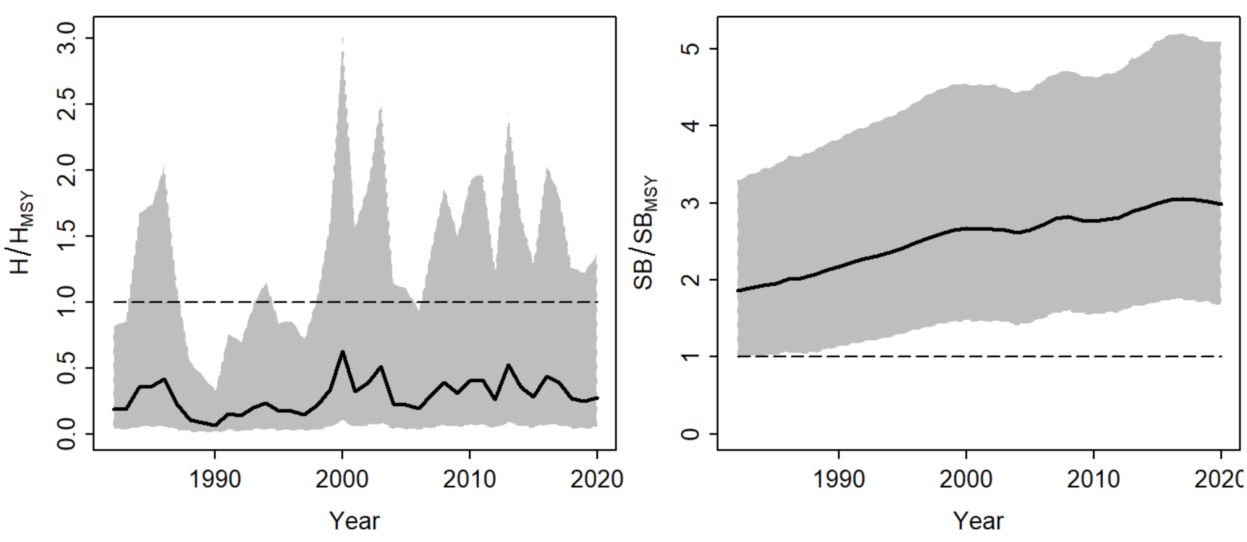

Figure 122. Exploitation (left) and spawning biomass (right) relative to threshold reference points estimated in the JABBA-Select final base model. The solid line is the median and the shaded region is the 95% credible interval. The dashed line indicates the estimate at its respective threshold level.

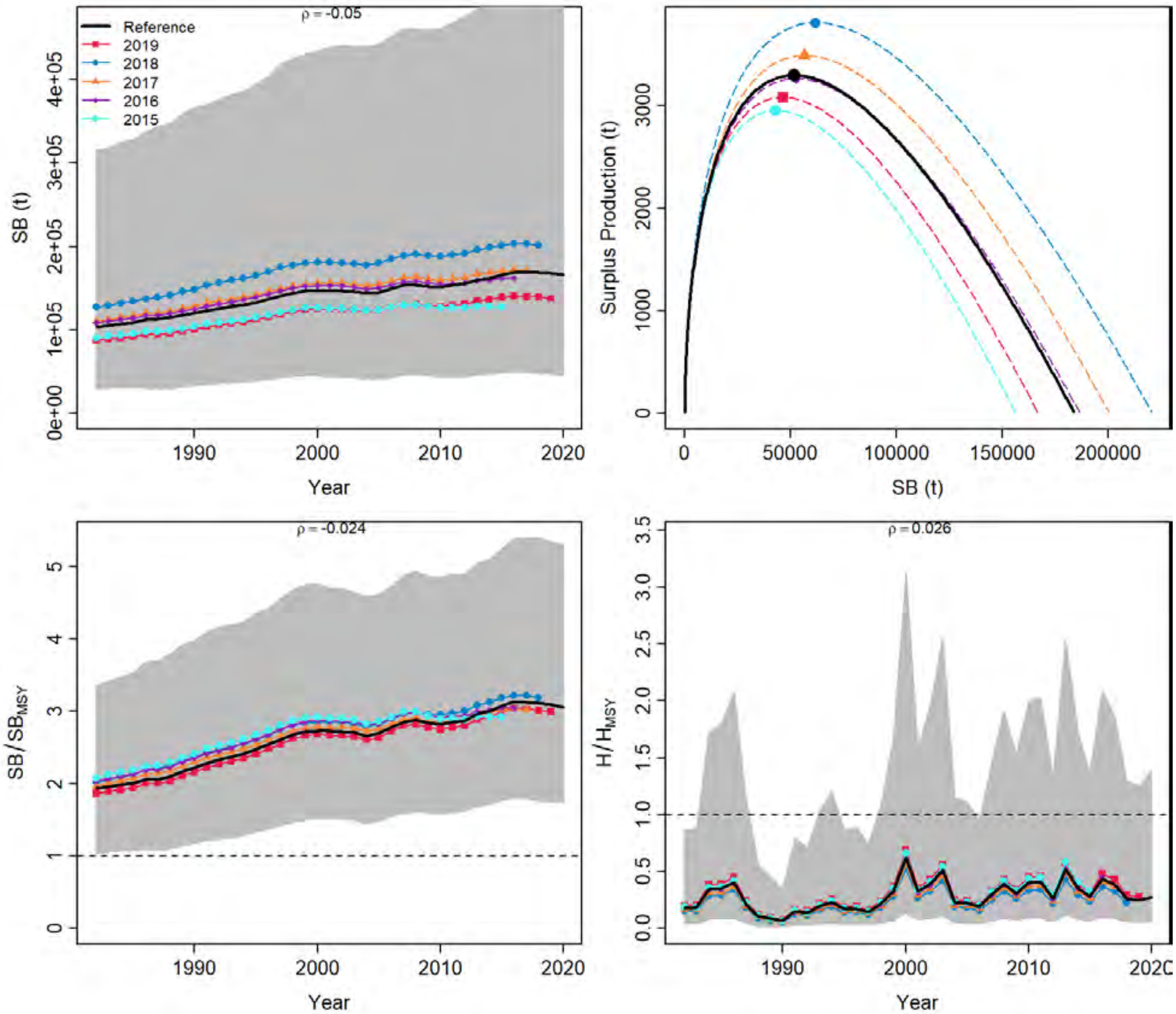

Figure 123. Estimates from JABBA-Select retrospective analysis for the final base model. Mohn's rho values are printed at the top of each panel for the respective parameter.

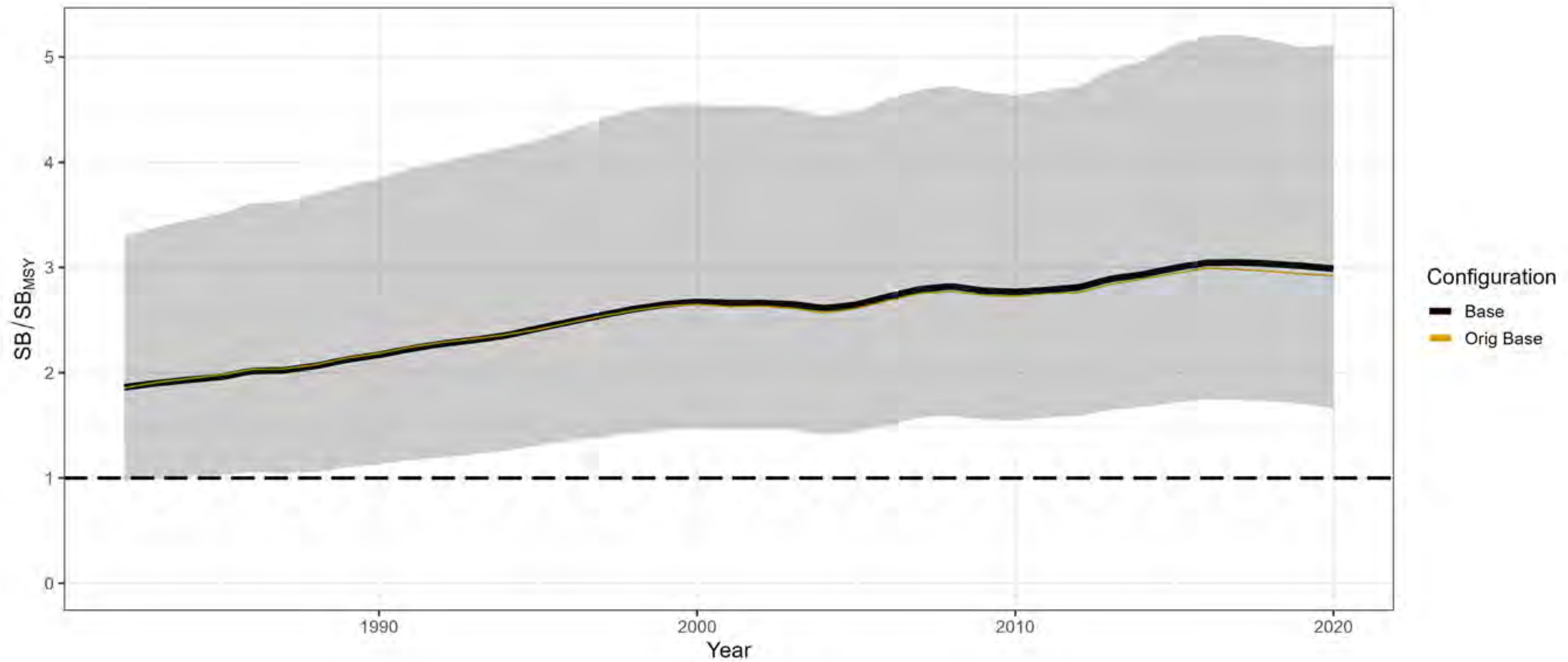

Figure 124. **Relative biomass estimates from the JABBA-Select final base model and *Orig Base* configuration reviewed during the Peer Review workshop. The shaded region is the 95% credible interval of the final base model.**

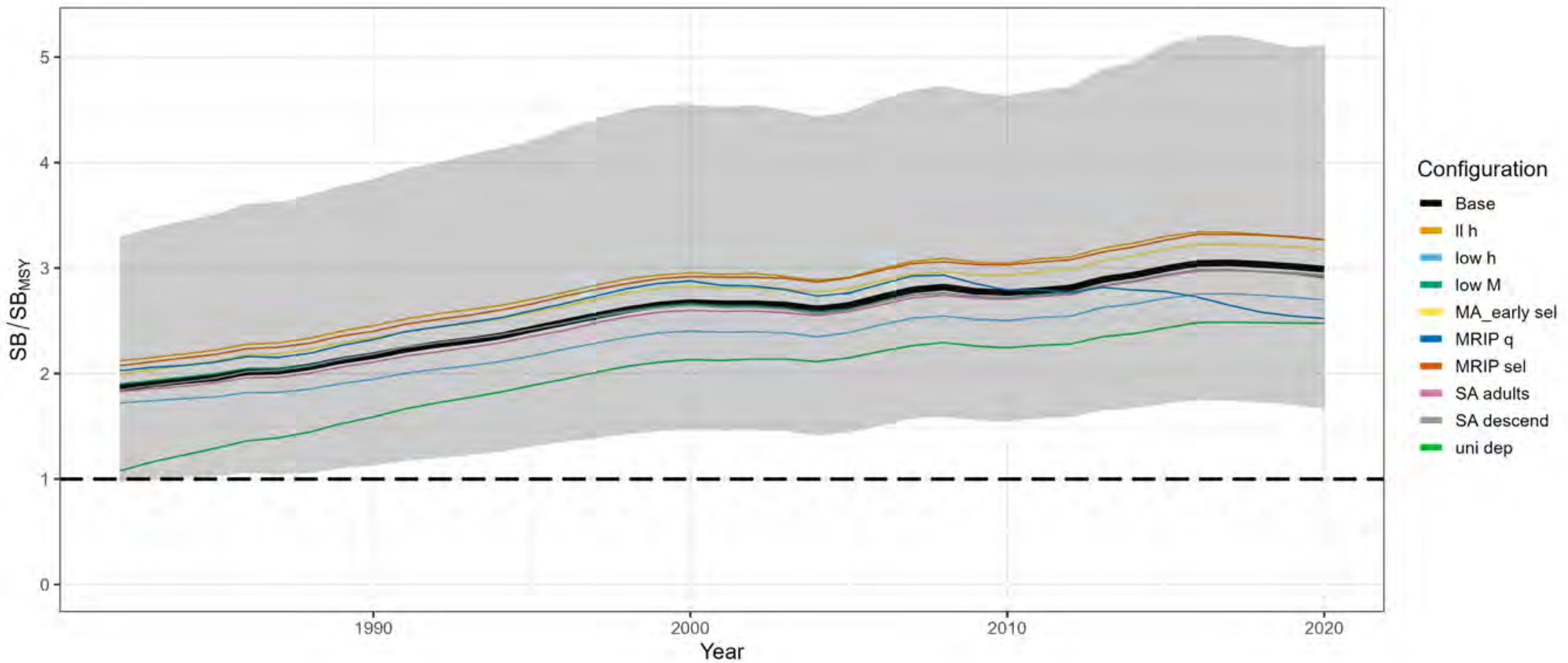

Figure 125. **Relative biomass estimates from the JABBA-Select sensitivity analysis for the final base model. The shaded region is the 95% credible interval of the final base model.**

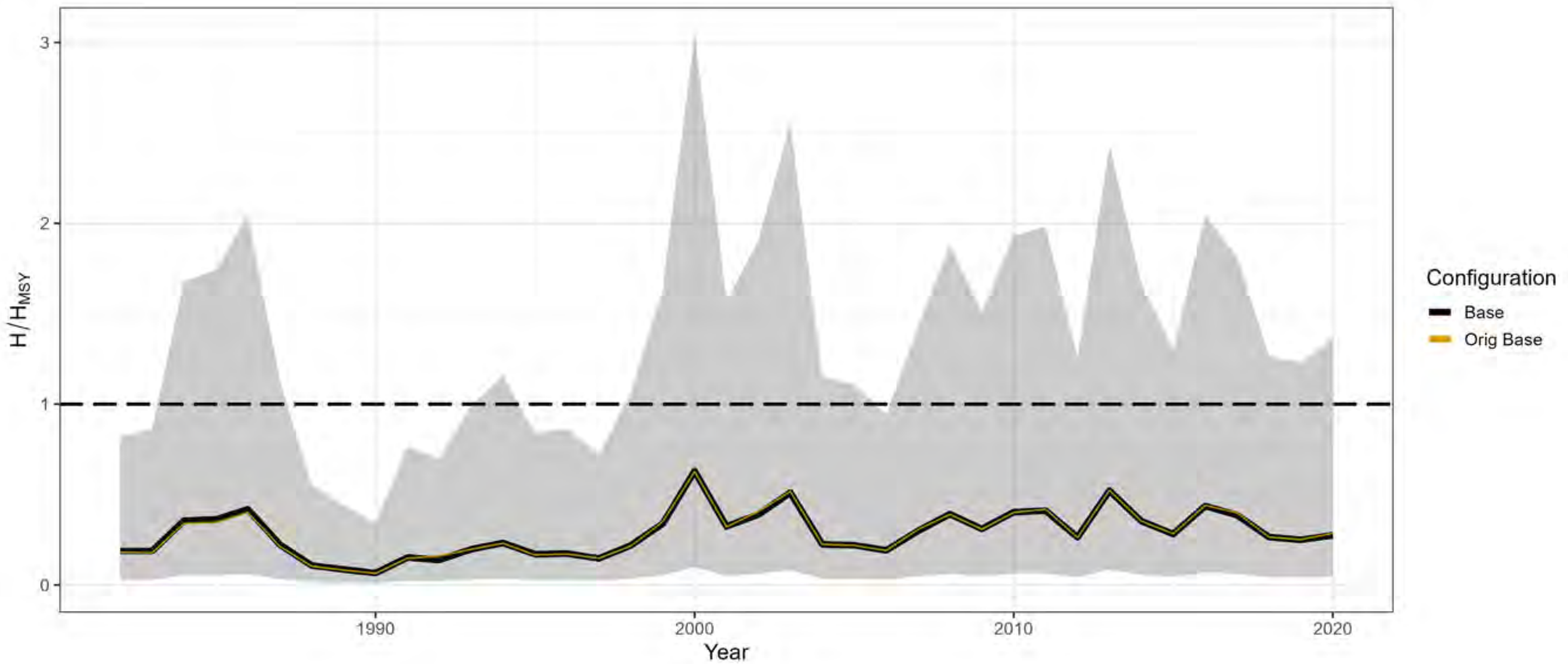

Figure 126. Relative exploitation estimates from the JABBA-Select final base model and *Orig Base* configuration reviewed during the Peer Review workshop. The shaded region is the 95% credible interval of the final base model.

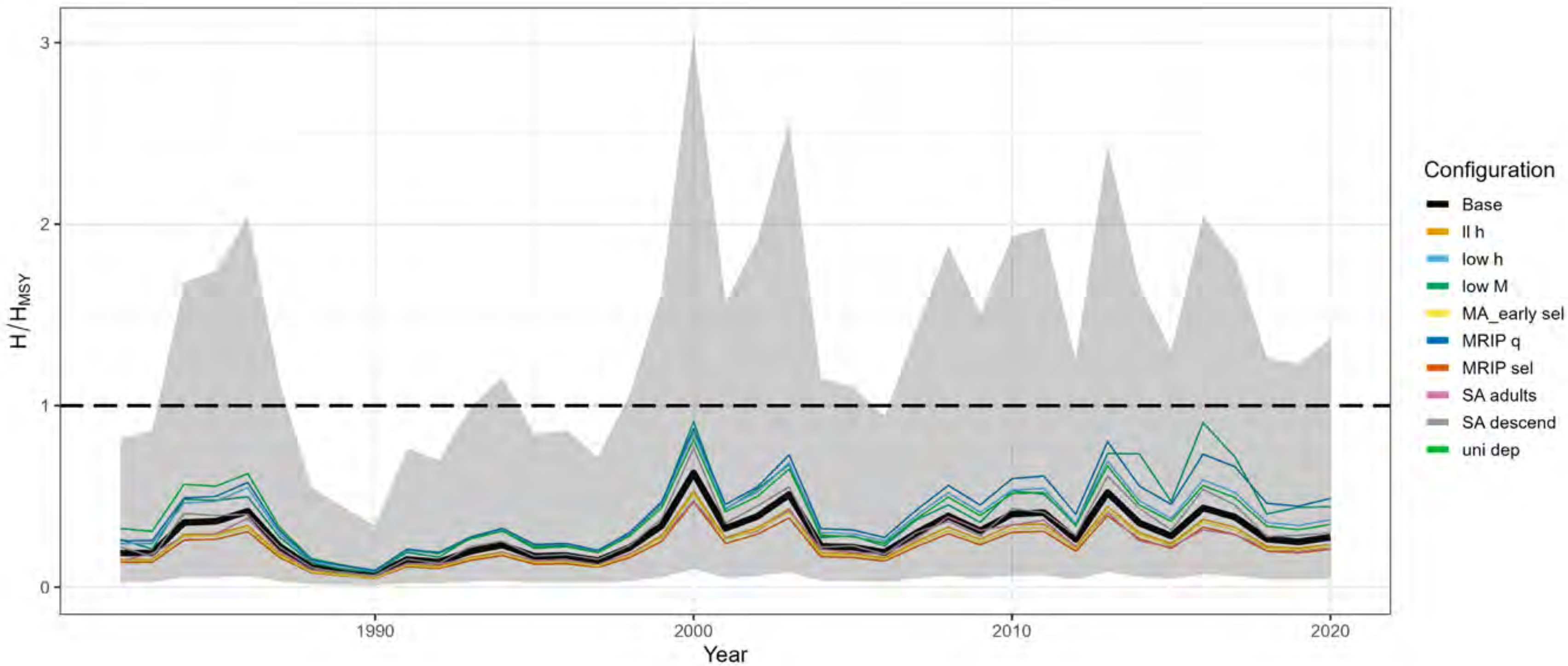

Figure 127. Relative exploitation estimates from the JABBA-Select sensitivity analysis for the final base model. The shaded region is the 95% credible interval of the final base model.

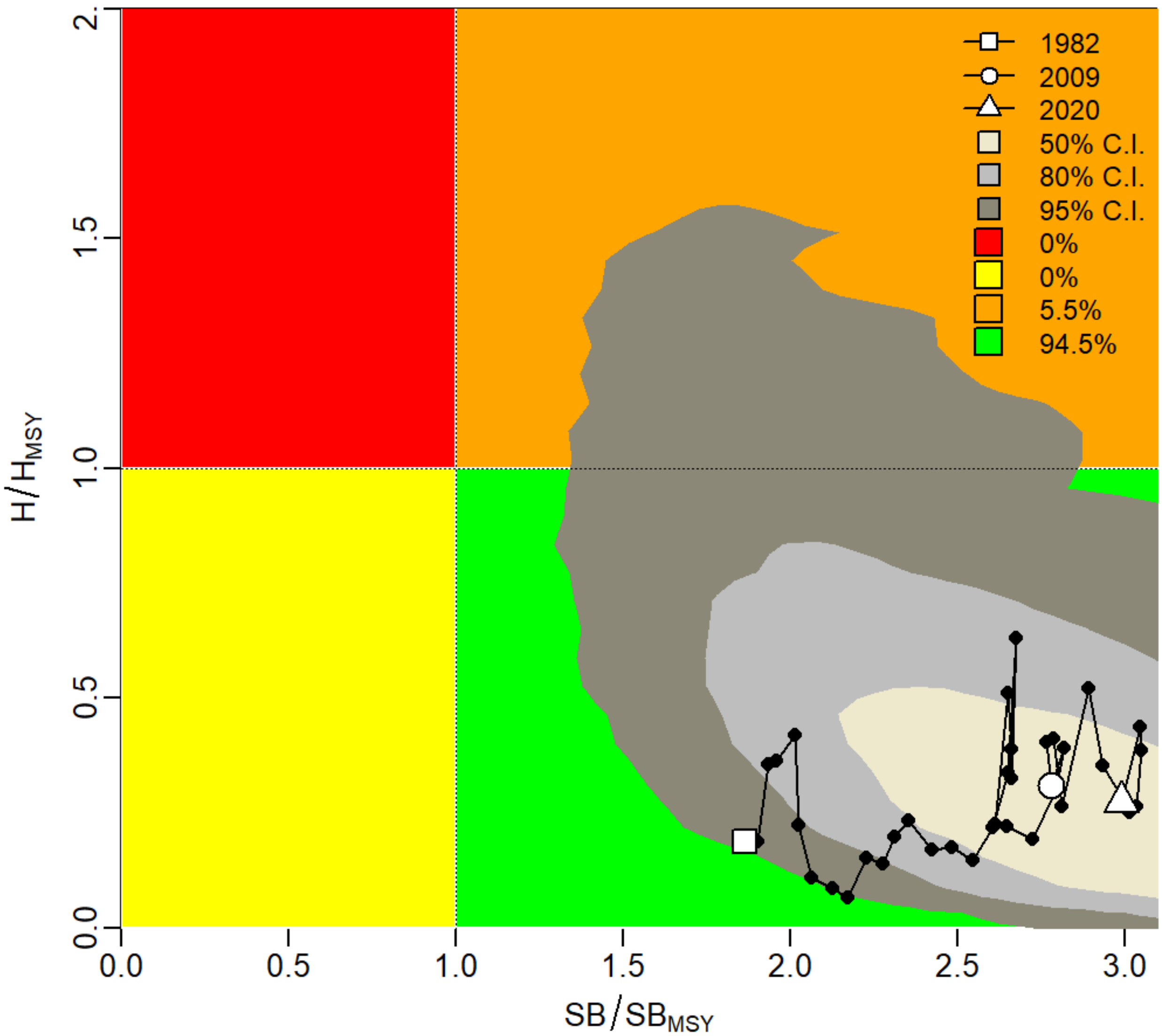

Figure 128. **Kobe phase plot for the JABBA-Select final base model showing the estimated stock status trajectories. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal year of 2020. The probability of terminal year points falling within each quadrant is indicated in the figure legend.**

14 APPENDICIES

Analyses and Applications of Black Drum Age and Length Data Collected by Atlantic States between 2008 and 2019

Hank Liao, Jeff Kipp, Chris Stewart,
Ethan Simpson, and Chris McDonough

(Working paper)

August 3, 2022

Age Data Working Group

ASMFC Black Drum TC and SASC

INTRODUCTION

Black Drum (*Pogonias cromis*) 2015 benchmark stock assessment used three catch-based methods to evaluate Black Drum stock status and estimate biological reference points. One of the reasons for using the data-poor methods is the lack of age-length data and length distribution data, the former represents the relationship between age and length, and the latter represents length distribution of a catch. After the last stock assessment, the state agencies along the east coast have continued to collect age-length and length data from both commercial and recreational fisheries, fishery-independent surveys for multiple years. The primary goal of this study is to find out if the age-length and length data are sufficient enough to provide information for tracking cohort progressions through years, and to update von Bertalanffy growth parameters for age-specific natural mortality estimate. The specific objectives are: 1) evaluate the length data collected by Atlantic states to see if the data from different units (gear, state, region) can be collapsed to increase sample sizes; 2) evaluate the age-length data collected by Atlantic states to see if the data can be used to convert length distribution to age distribution; 3) examine if converted age distributions can track cohort progressions through years; 4) explore the implication of such information in Black Drum stock assessment; 5) fit von Bertalanffy growth model to the age-length data to estimate the growth parameters; 6) discuss the implication of these parameters in estimation of age-specific natural mortality.

METHODS

Data collection

Atlantic state agencies collected all the data used in this study. There are three sets of data as follows:

1. Length data: total length and fork length in mm, cm, or inch;
2. Age-length data: otolith age, total and fork length in mm, cm, or inch;
3. Abundance index: Age-0 and Age-1.

Length data

DE, MD, VA, NC, SC, and FL collected either total, folk length or both. Some states collected the data as early as 1980, all the states collected the data to 2020. The data were collected mainly from commercial fisheries and some from recreational fisheries using a variety of gears.

Age-length data

DE, VA, NC, SC, and FL collected the age-length data. FL collected the data as early as 1983 whereas most of states collected the data to present. The fish and carcasses were collected from recreational and commercial fisheries, and fishery-independent surveys, however, mainly from the recreational fisheries. The otoliths were used to estimate ages.

Abundance index

NC provided an abundance index showing year-class strength ranging from 2001 to 2019. SC provided trammel net CPUE for Age-1 ranging from 1991 to 2021.

Data analysis

Length data

All the lengths in cm or inch were converted to mm. We used the fish with both total and folk length to develop a linear model and then used the model to convert folk length to total length for the fish who have only folk length as follows:

1. Assuming that the difference between total and folk length is normally distributed, we used boxplot function boxplot() in R (R Core Team 2021) to identify outliers of the differences, and removed any fish with those outliers;

2. We used the rest fish to develop a linear model, TOTAL = a + b x FOLK, where, FORK, TOTAL, a, and b stand for fork length, total length, intercept, and slope, respectively.

We used boxplot and Tukey test (TukeyHSD() in Package "stats" in R) to examine the differences in mean total length between gears with each state and between states within each gear to explore if we could collapse those units to increase sample sizes of length due to small sample size within some units. Based on the test results we collapse two or more gears and/or states to a fleet. We used the selected length data to make annual 1-inch length interval distributions for further age conversions.

Age-length data

We also standardized the length in the age-length data to total length in mm as described above. We used Kimura likelihood ratio test (Kimura 1980, growthlrt() function in Package "fishmethods" in R) to test differences in von Bertalanffy growth rate between sexes, states, and regions, to explore if we were able to collapse those units to increase the sample sizes of age-length data because it is difficult to collect Black Drum age-length data in general. Because there is no sex information in the age-length data collected from the fishery-independent surveys, we excluded all the fishery-independent surveys from Kimura test. More specific:

1. Assuming no significant difference in Black Drum growth rate between years, or at least no increasing or decreasing trend in their growth through years, we collapse all year data to test;

2. We used boxplot function to remove outliears by sex, state, and region, respectively, before testing the growth rates;

3. We used Kimura likelihood ratio test (fishmethods package in R) to test between sexes, any two states, and two regions (Mid-Atlantic region (DE, MD, and VA) versus South Atlantic region (NC, SC, GA, and FL)).

ALK and Conversion of length to age

Based on the Kimura test results we collapsed certain units to make annual ALKs. Here we included the age-length data from the fishery-independent surveys in the ALKs unlike in the Kimura tests described previously. This is because the fishery-independent data mainly consists of younger fish whereas the fishery-dependent data lacks of younger fish, and the combination of both will make the ALKs more representative of the relationship between age and length in the Black Drum population. Because there were few samples of age-length data before 2008, we removed any years before 2008 for further analysis. As a result, we converted the length distributions to age distributions from 2008 to present. In addition, for demonstration purpose of cohort progressions, we presented the conversions only from 2008 to 2019, making a 12-panel page (or 12 years in one page). We did the conversions as follows:

1. We used boxplot function on the age-length data to remove outliers by year;
2. We used the age-length data without outliers to make annual ALKs from 2008 to 2019;
3. We used each annual ALK to convert its corresponding length distribution to age distribution;
4. There were three sets of converted age distributions as follows:
    1) Age distribution from the length distribution with the fleet with the largest sample sizes;
    2) Age distribution from the coast-wide length data from all sources, commercial, recreational, and all gears;
    3) The 2) age distribution but with the most younger ages removed.

    The purpose to examine the three age distributions is to see which one would provide the most information on cohort progressions through years.

Comparison between the age distributions and abundance indices

We compared the strong cohorts identified by age distributions and abundance indices, expecting that the age distributions may verify the stock abundance through years identified by the abundance indices.

von Bertalanffy growth parameters

We assumed the age-specific natural mortality was constant through years, was the same between sexes, and between regions, therefore, we used the region-, year- and sex-pooled age-length data collected between 1983 and 2020 (the terminal year for 2023 stock assessment). We fitted von Bertalanffy growth model $L_t = L_\infty[1 - e^{-K(t-t_0)}]$ using nonlinear least square function (assuming additive error structure) to the data to estimate the growth parameters, L_∞, K, and t_0. Before fitting the model to the data, we used boxplot function to remove outliers from the data by assuming that the length is normally distributed at each age. We fitted the model to both the mean length- and individual length-at-age data, respectively, in order to find which model is more appropriate to describe the black drum growth. The estimates of L_∞, K, and t_0 together with the Black Drum age range will be used to estimate age-specific natural mortality in the stock assessment (Lorenzen 1996; Then et al. 2015).

RESULTS

Length data

Examination of length data

There were 2375 fish used to develop the linear model (Figure 1). This model was used to convert the folk length to total length for fish with folk length only. There are significant differences in mean length between gears within each state (Figure 2 and 3), and between states within each gear (Figure 4 and 5) except between FL gill net and FL hook and line (Top panel in Figure 3). Even though the lengths are significantly different between the majority of gears and all the states, in order to increase sample sizes we made several fleets (Table 1) for further analysis (Please see detailed analysis in Jeff's working paper).

Length distributions to be converted

From Table 1 we picked NC commercial length data from 2008 to 2019 as the first length distribution (Figure 6) to convert it to its age distribution. Then, we used all the length data collected by both commercial and recreational using a variety of gears to make the second length distribution (Figure 7) for age conversion.

Age-length data and ALKs

In general, the sample sizes of age-length data from each state are very small and even the coast-wide sample sizes are very small before 2008 (Table 2), therefore, we didn't use any age-length data collected before 2008. Black Drum growth rates are significantly different between all the paired states (Not showing figures here), and we believe that such differences are mainly resulted from small sample sizes. However, there is no significant difference in growth between male and female Black Drum when all years and states data are pooled (Figure 8 and 9). There is no significant difference in growth between Mid- and South Atlantic region (Figure 10 and 11). Based on the results, we collapsed sexes and states within each year to make an annual ALK. Figure 12 shows the age-length data we used to make the annual ALKs and Figure 13 shows the age distribution in each ALK.

Converted age distributions

NC age distribution

Since NC gill nets collected mainly small fish (the majority $<$ 24 inch) (Figure 6), its age distributions are mainly young fish (the majority younger than Age 4) (Figure 14). As a result, NC age distribution is not able to provide any information on cohort progressions through years.

Coastal wide age distribution

The coast-wide length data did include more large fish, however, no cohort progression can be tracked through years in the age distributions from 2008 to 2019 mainly because the abundances of Age 3 and younger are significantly higher than the fish older than Age 3 (Figure 15).

Coastal wide partial age distribution

After removing fish Age 3 and younger, we are able to track four strong cohort progressions (2001, 2005, 2007, 20011) through years (Figure 16). Some strong cohorts are tracked more easily than others, for example, Year-class 2001 can be tracked through 11 of 12 years (lost tracking in 2016). Year-class 2015 is identified as a strong cohort, we may be able to track its progression through years after collecting more age-length and length data in the coming years.

Comparison between the age distributions and abundance indices

The strong cohorts identified by the age distributions do match those identified by abundance indices provided by NC (Figure 17) and SC (Figure 18).

von Bertalanffy growth parameters

There were 9378 samples of black drum collected between 1983 and 2020 with both age and length, of which 221 samples were identified as outliers, and 9157 samples were kept for further analysis (Figure 19). Figure 20 and 21 show the von Bertalanffy growth curves estimated using the mean length- and individual length-at-age, respectively. The predicted length at Age 0 is 328 and 242 mm from the mean length- and individual length-at-age model, respectively. Based on the observed length data for Age 0 Black Drum, we believe that the model developed from the individual length-at-age data is more appropriate to describe the Black Drum growth rate. As a result, we will use L_∞ of 1156, K of 0.133, and t_0 of -1.77 (Figure 21) in the development of age-specific natural mortality.

DISCUSSION

This study used the observed length distribution (or raw length distribution) instead of the converted length distribution (or expanded length distribution) to track cohort progressions through years, providing three advantages as follows:

1. Catch in number is not required, as a result, no need to figure out how many catch is from which gear and how many fish should be converted from a catch in weight;

2. Since we are only interested in if the raw length can provide any information on cohort progression, we may collapse all the gears together because the gear selectivity will not influence our analysis as long as we have as a large sample size as possible and cover as a wide length range as possible;

3. When converting a length distribution to its age distribution, very often the length intervals in an ALK may not completely match those in the corresponding length distribution due to small sample sizes of and a wide range of Black Drum length. For example, an ALK lacks 10" interval whereas a length distribution lacks 11" interval. In this study we can delete the 10" interval from the ALK and the 11" interval from the length distribution, making the rest intervals completely match between the two. when an expanded length distribution is used, removal of any length intervals from the length distribution will underestimate the total catch in the CAA because the fish in the removed length intervals will not contribute to the CAA. To overcome such a loss of fish, people may pool two or more intervals together, which could result in pooling different cohorts together, reducing the CAA's ability to track cohort progression.

The results from this study are limited to tracking cohort progression through years, and may help identify which abundance index may be used in stock assessment. The method in this study may not be used to generate any CAAs since gear selectivity influences size of fish in catch and different states harvest different length ranges, as a result, pooling different gears and states may mistakenly distribute fish in catch into wrong length intervals.

We fitted the von Bertalanffy growth model to both mean length- and individual length-at-age. The mean-length method estimated a higher L_∞ and a lower K whereas the individual-length method estimated a lower L_∞ and a higher K, demonstrating an intrinsic inverse relationship between L_∞ and K (Quinn and Deriso 1999). Based on the values of L_∞ and K alone, we were unable to decide which method was more appropriate. However, there are two reasons for which we believe the individual-length method is more appropriate as follows:

1. The t_0 of -1.77 from the individual-length method is much closer to 0 than the t_0 of -3.28 from the mean-length method;

2. The predicted length at Age-0 from the individual-length method (242 mm) is much closer to the observed mean length at Age-0 than the one from mean-length method (328 mm).

Therefore, we believe that the individual-length method had a better fit, and its estimates of growth parameters are more representative of the Black Drum population growth.

The t_0 value closer to 0 in the individual-length method is most likely due to the significant large sample size of Age-0, in other words, it is a sample size effect. A simple way to get rid of a sample size effect is to fit the model to mean length-at-age data. However, in this case the mean-length method doesn't have a better fit and doesn't provide a more realistic estimate of length for Age-0 fish. As a result, we will use the parameters from the individual-length method for natural mortality estimation.

Goodyear (2019) discussed the influence of biased estimates of L_∞ and K on natural mortality estimate (M). The L_∞ and K of the individual-length method may not be free of biases even though the method seems having a better fit and providing a more realistic estimate of length at Age-0. A better fitting and a closer estimate of length to the observed mean length at Age-0 could simply describe the data better, and may not necessarily describe the population growth better when the age-length data are not representative of the population (Goodyear 2019). Therefore, we suggest that more effort should focus on improvement of age-length collection along Atlantic coast.

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Table 1: Sample sizes of the length data collected from commercial fisheries by fleet and year.

Year	DE North Gill Nets	MDVA Gill Nets	MDVA Fixed	MDVA Hook&Line	NC Ocean Gill Nets	NC Estuarine Gill Nets	NC Long Haul/ Trawls/Fixed	South All Gears
1989	0	25	12	0			0	11
1990	0	4	35	0			0	9
1991	0	87	22	0			0	50
1992	0	39	0	0			0	39
1993	0	11	84	0			0	57
1994	0	129	5	0	0	26	19	86
1995	0	1	5	0	17	2	145	31
1996	0	28	35	0	1	18	182	49
1997	0	203	7	0	1	24	65	40
1998	0	77	18	1	0	27	44	93
1999	0	201	10		2	114	472	177
2000	0	110	12	0	7	240	516	138
2001	0	104	46	5	4	166	243	176
2002	0	39	35	17	0	579	1254	77
2003	0	4	25	0	35	349	193	96
2004	0	0	73	0	2	269	94	79
2005	0	11	14	0	17	377	84	68
2006	0	3	14	0	18	1052	783	70
2007	0	3	15	0	17	1540	346	112
2008	0	0	14	0	57	1915	1016	174
2009	63	1	39	0	28	984	126	141
2010	84	23	14	1	2	469	190	136
2011	59	0	5	0	233	932	216	83
2012	23	20	16	0	14	1185	254	63
2013	45	26	48	0	50	989	174	97
2014	58	7	39	0	1	692	60	103
2015	90	0	20	0	4	469	99	71
2016	0	392	59	0	3	791	297	61
2017	63	0	48	28	10	1087	80	63
2018	86	74	49	57	3	469	196	61
2019	6	2	46	16	0	287	248	61
2020	45	3	28	0			19	100

Table 2: Sample sizes of the age-length data collected from coast-wide, by region, state, and year.

Year	Coastwide	Mid-Atlantic	South Atlantic	NJ	DE	MD	VA	NC	SC	GA	FL
1981	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0
1983	22	0	22	0	0	0	0	0	0	0	22
1984	101	0	101	0	0	0	0	0	0	0	101
1985	27	0	27	0	0	0	0	0	1	0	26
1986	46	0	46	0	0	0	0	0	46	0	0
1987	73	0	73	0	0	0	0	0	73	0	0
1988	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0
1991	26	0	26	0	0	0	0	0	26	0	0
1992	38	0	38	0	0	0	0	0	38	0	0
1993	87	0	87	0	0	0	0	0	87	0	0
1994	29	0	29	0	0	0	0	0	29	0	0
1995	16	0	16	0	0	0	0	0	16	0	0
1996	52	0	52	0	0	0	0	0	52	0	0
1997	66	0	66	0	0	0	0	0	66	0	0
1998	83	6	77	0	0	0	6	0	46	31	0
1999	141	80	61	0	0	0	80	0	42	19	0
2000	182	42	140	0	0	0	42	0	113	27	0
2001	148	86	62	0	0	0	86	0	35	27	0
2002	242	70	172	0	0	0	59	0	135	37	0
2003	180	36	144	0	0	0	11	0	76	67	1
2004	68	18	50	0	0	0	14	0	29	21	0
2005	62	28	34	0	0	0	8	0	26	8	0
2006	51	15	36	0	0	0	7	0	27	9	0
2007	139	57	49	0	0	0	35	0	24	23	2
2008	409	206	176	0	26	0	171	0	10	166	0
2009	317	171	83	0	97	0	61	0	25	58	0
2010	394	211	172	0	129	0	71	0	19	153	0
2011	368	115	205	0	90	0	19	175	13	13	4
2012	458	55	387	0	33	0	19	307	11	45	24
2013	422	108	294	0	58	0	42	178	24	51	41
2014	670	178	468	0	62	0	102	393	7	47	21
2015	576	144	397	0	78	0	55	358	2	16	21
2016	1108	400	702	0	11	0	372	571	20	106	5
2017	812	153	618	0	59	0	63	562	31	20	5
2018	735	320	373	0	105	0	215	350	11	0	12
2019	558	139	419	0	47	0	92	375	19	0	25
2020	208	73	74	0	67	0	6	64	1	0	9

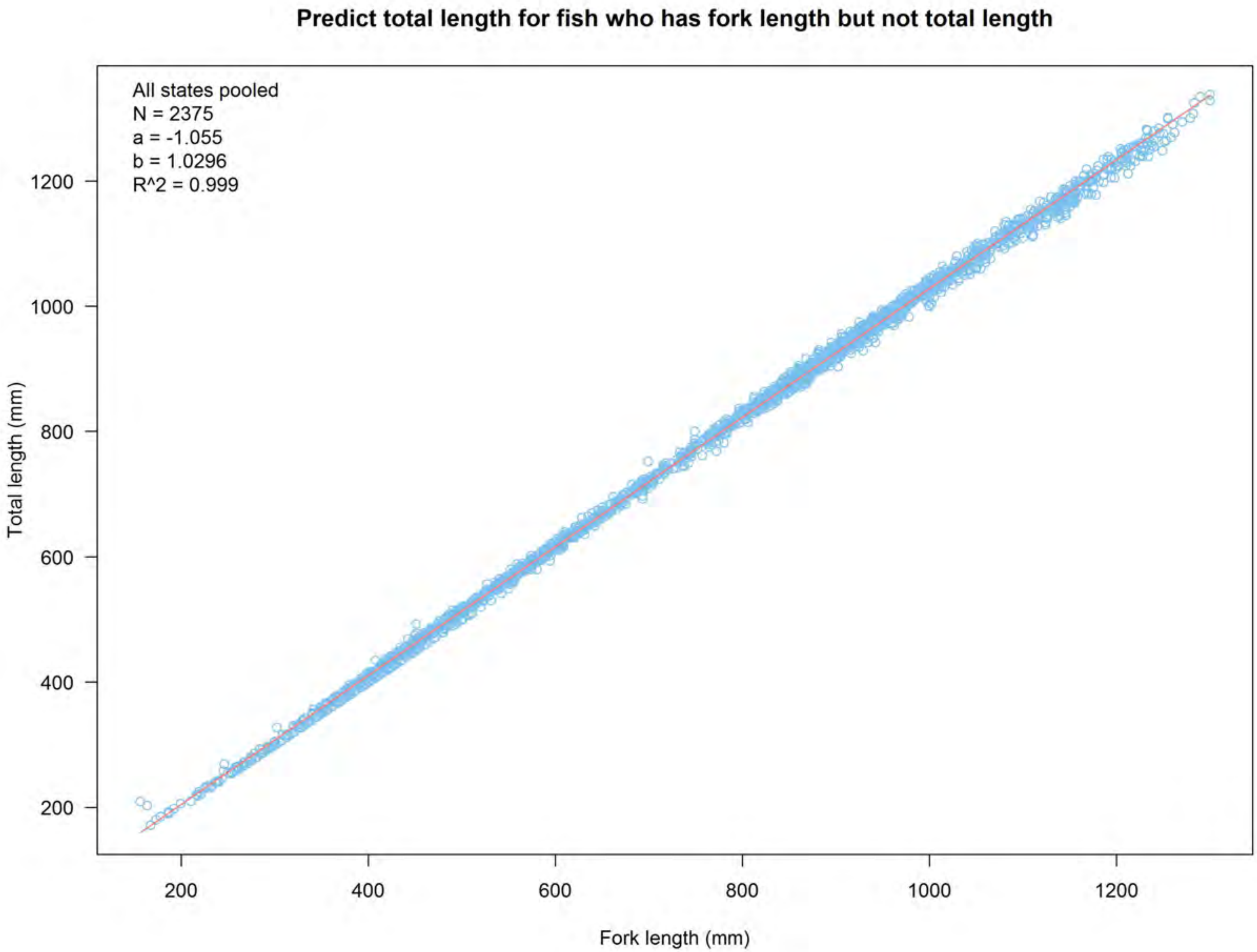


Figure 1: The relationship between fork and total length (mm) of Black Drum.

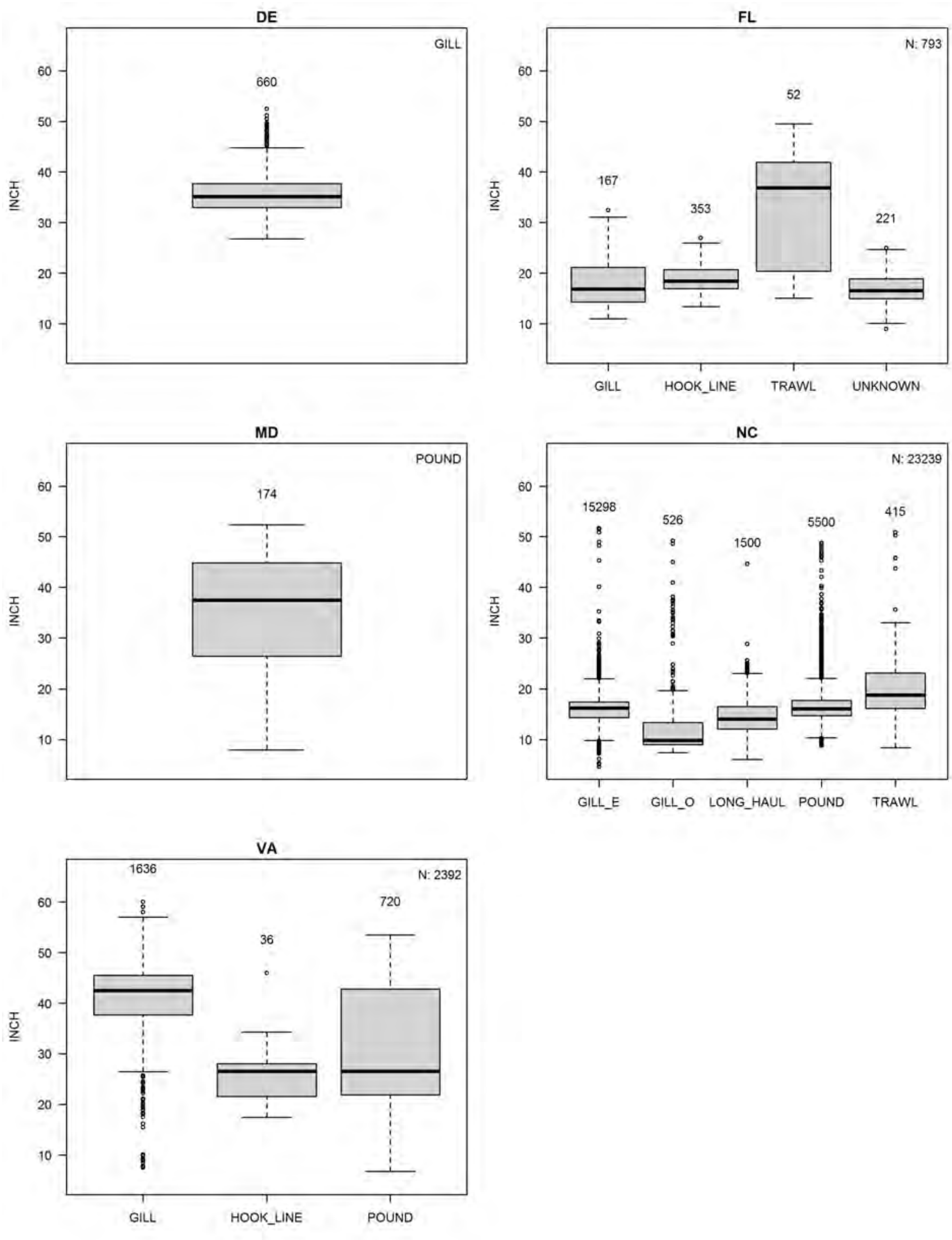


Figure 2: Comparison in the total length of Black Drum between gears within each state.

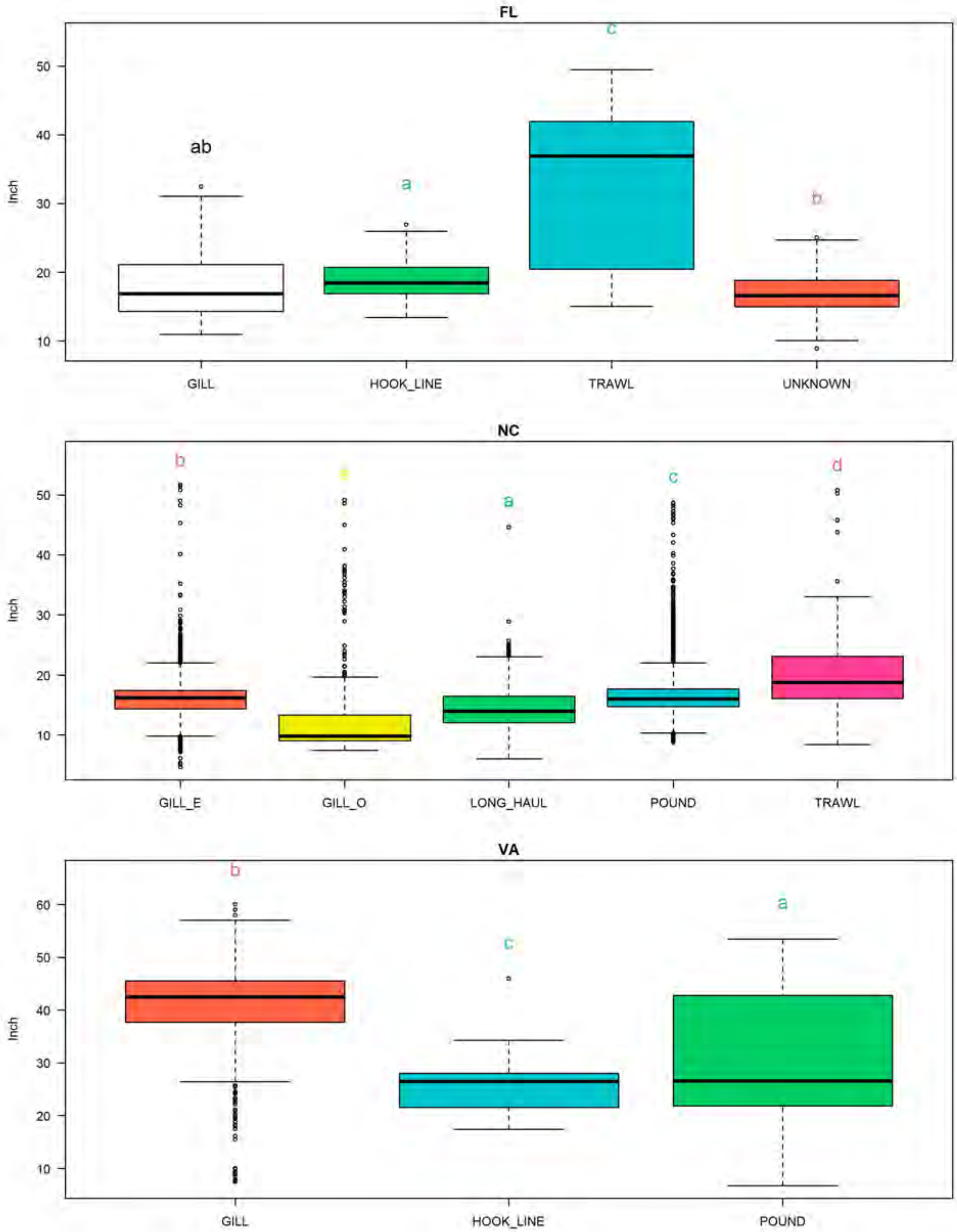


Figure 3: Tukey tests on the total length of Black Drum between gears within each state which has more than two gears. Two or more gears share the same letter are not significantly different.

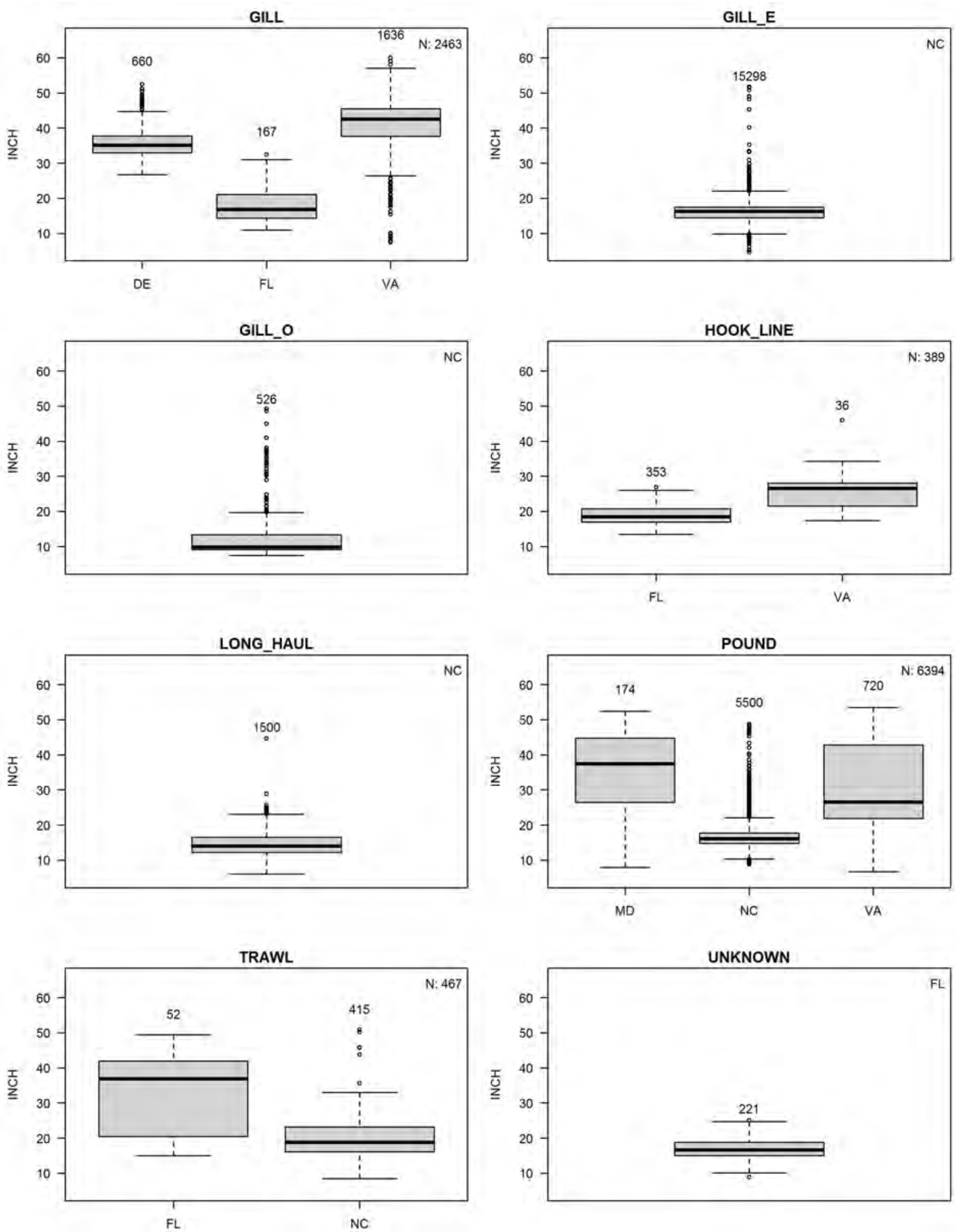


Figure 4: Comparison in the total length of Black Drum between states within each gear.

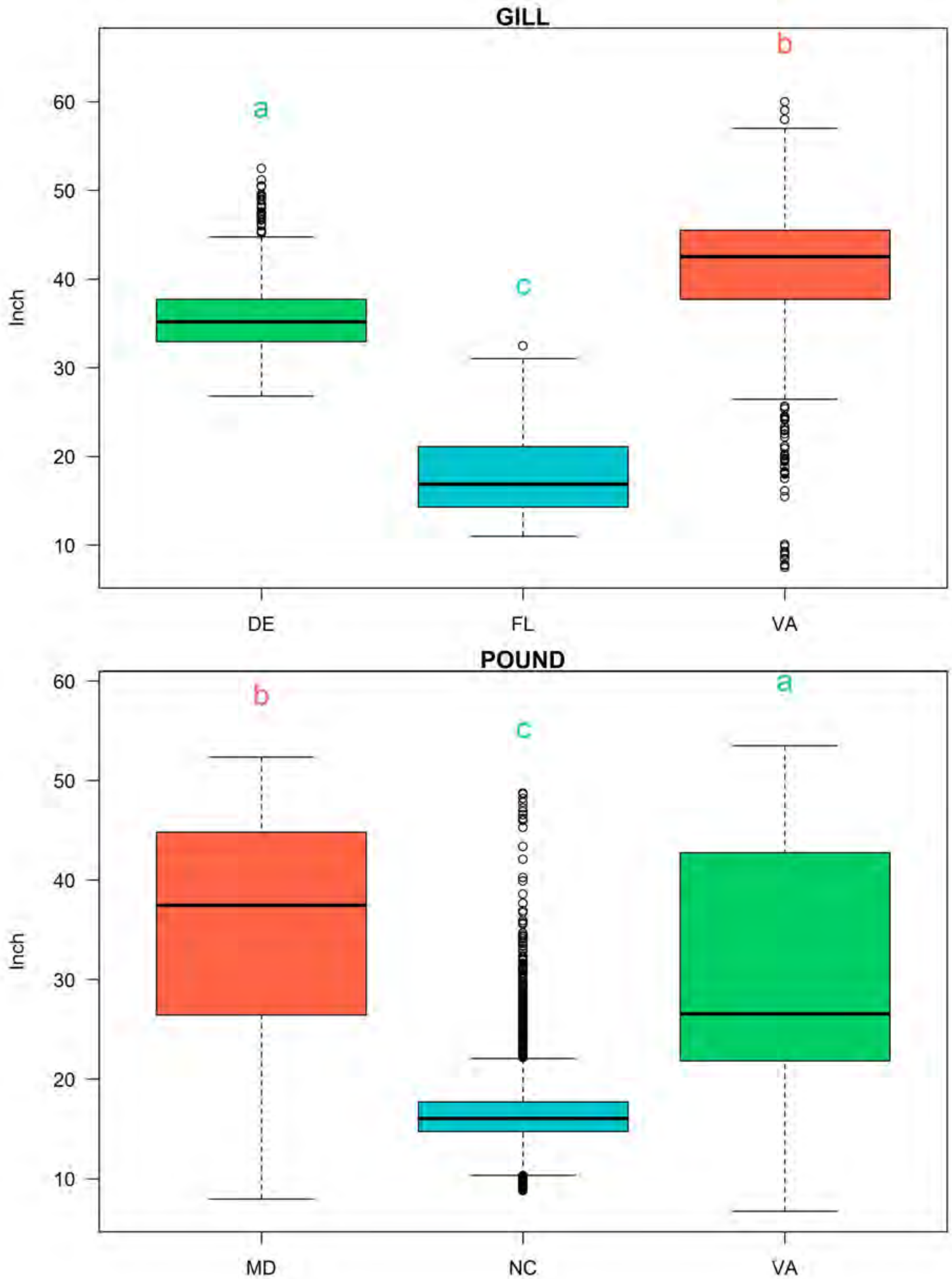


Figure 5: Tukey tests on the total length of Black Drum between states within each gear which has more than two states. Two or more states share the same letter are not significantly different.

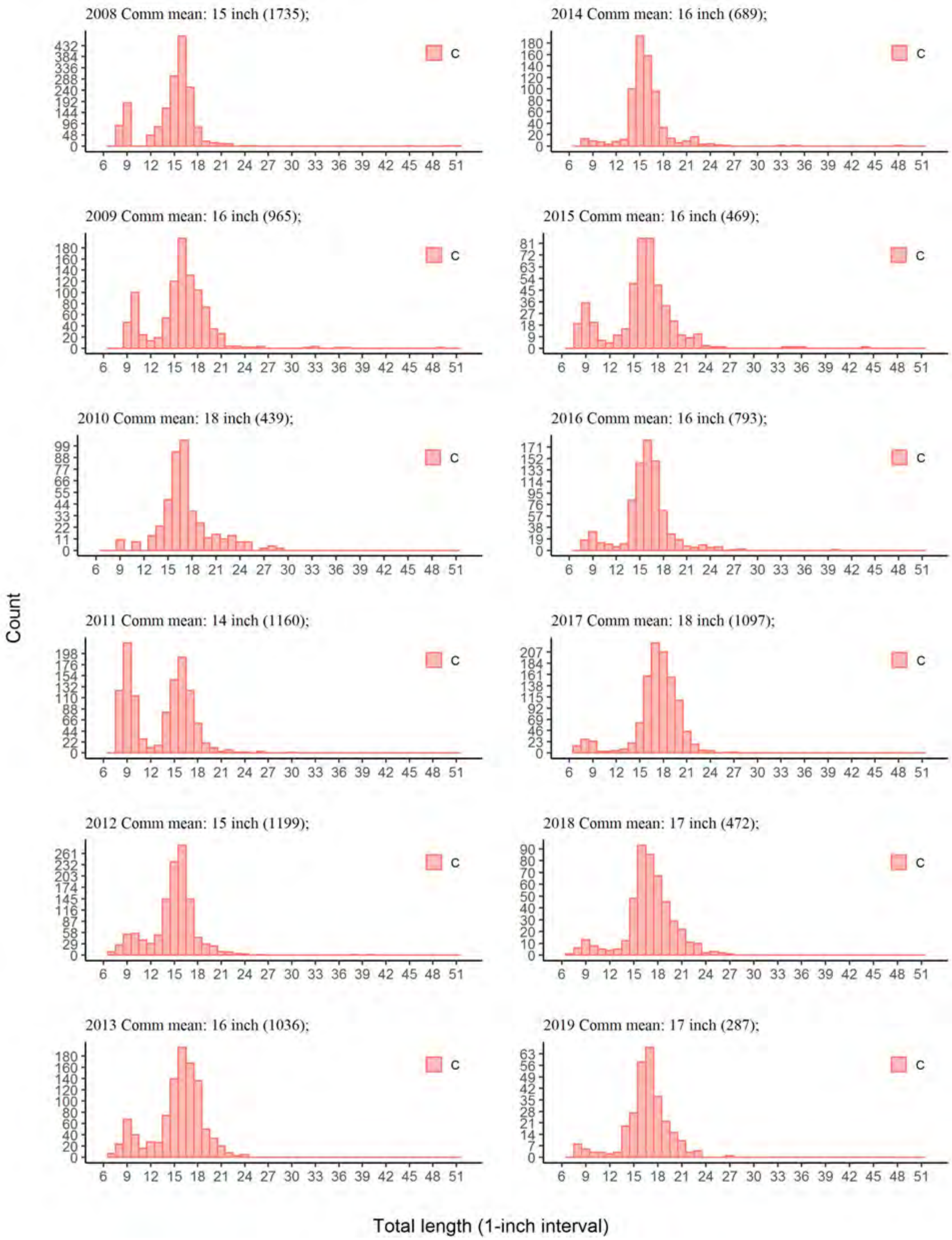


Figure 6: NC Black Drum length distribution (1-inch interval) collected from NC commercial fisheries from 2008 to 2019.

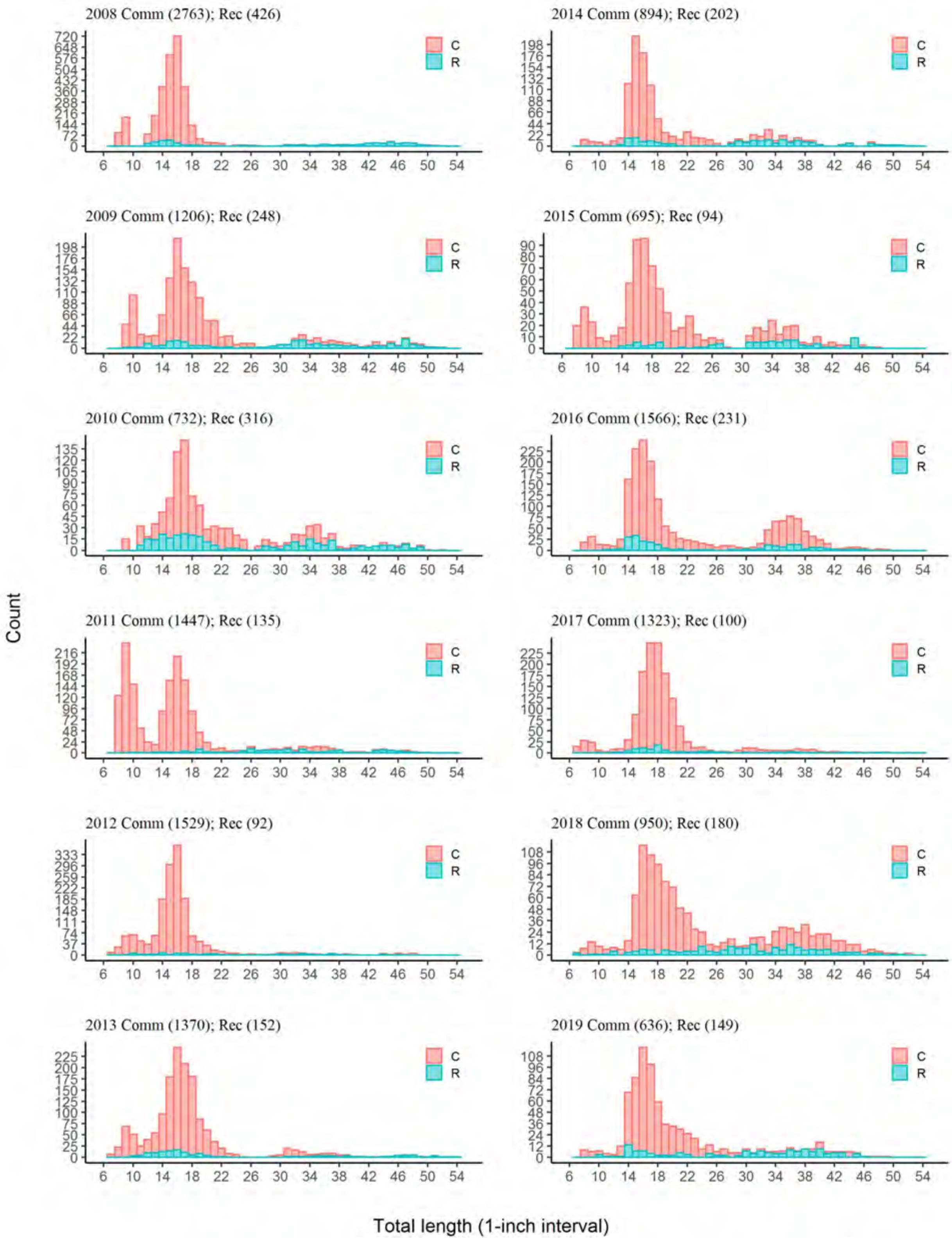


Figure 7: Coastal wide Black Drum length distribution (1-inch interval) collected from both commercial and recreational fisheries from 2008 and 2019.

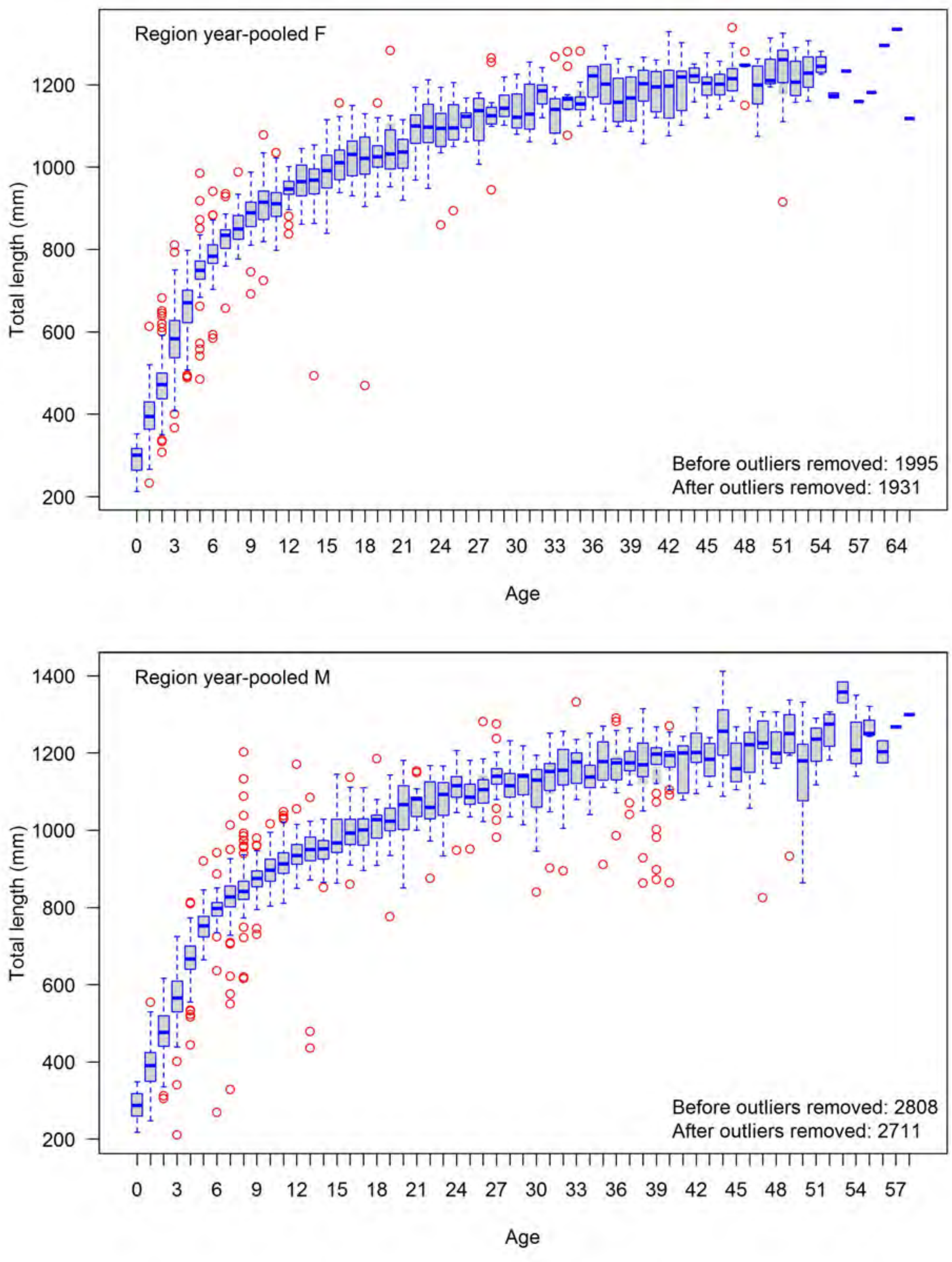


Figure 8: Age-length data before and after outlier removal by sex using boxplot function. "F" and "M" stand for female and male, respectively. One red circle represents one fish identified as an outlier.

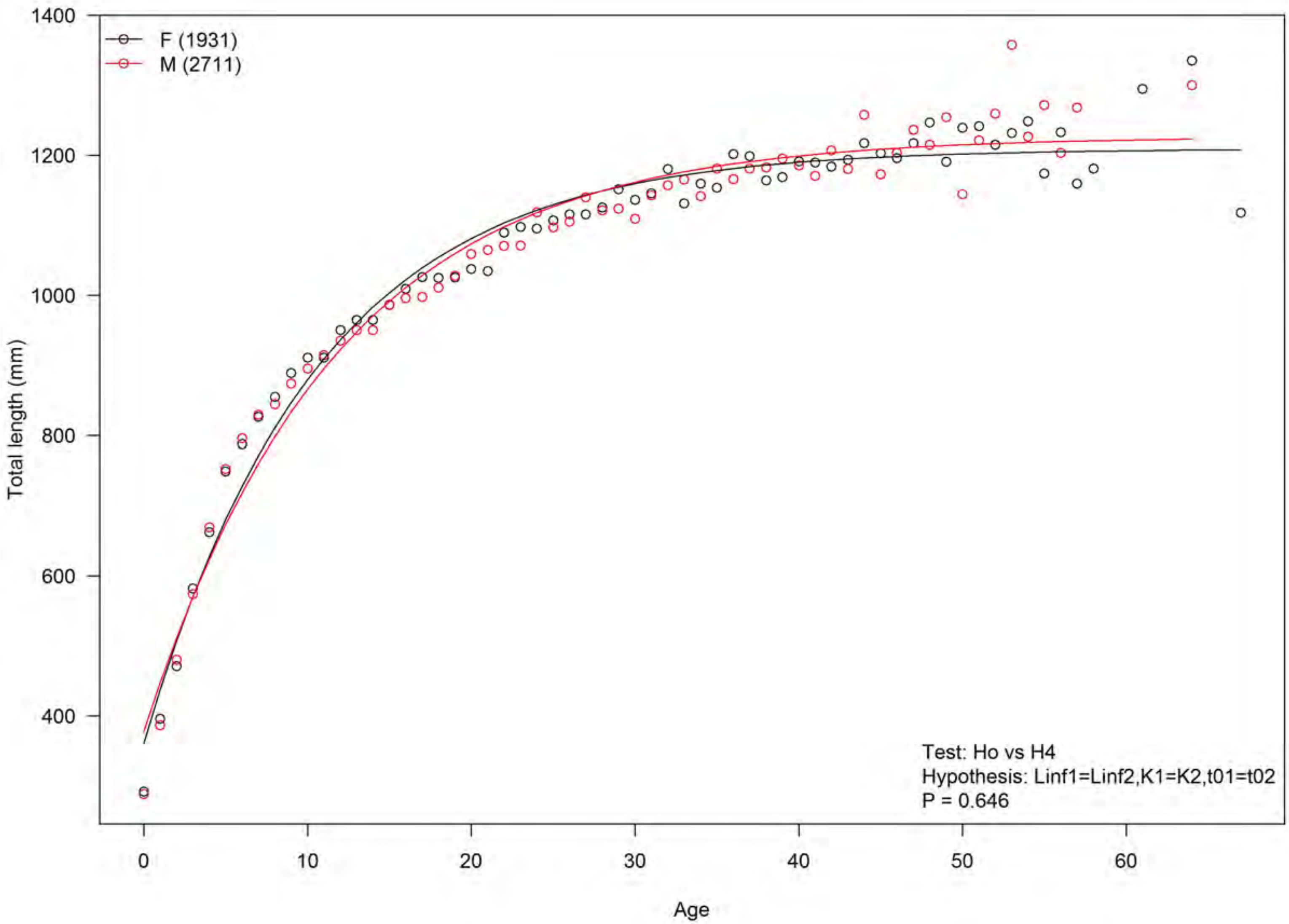
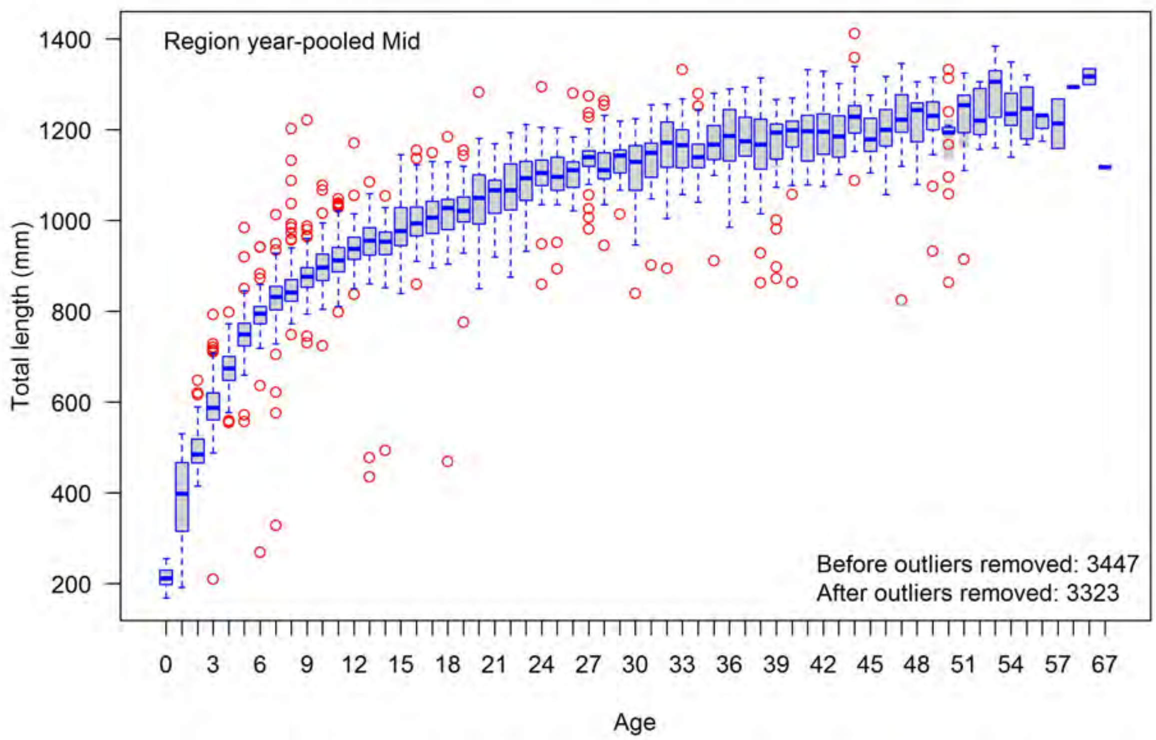


Figure 9: Kimura test on von Bertalanffy growth rates between coast wide and year-pooled female and male Black Drum. "F" and "M" stand for female and male, respectively. A data point is a mean length at age.



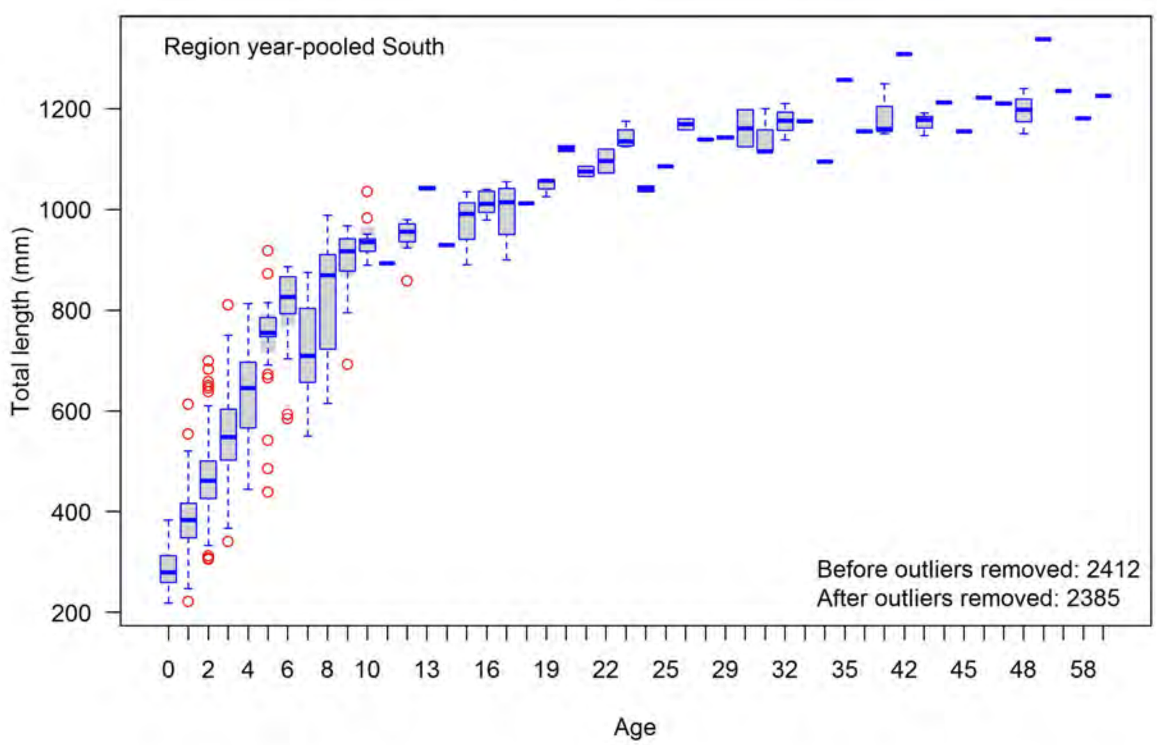


Figure 10: Age-length data before and after outlier removal by region using boxplot function. Mid-Atlantic includes NE, MD, and VA whereas South Atlantic includes NC, SC, GA, and FL. One red circle represents one fish identified as an outlier.

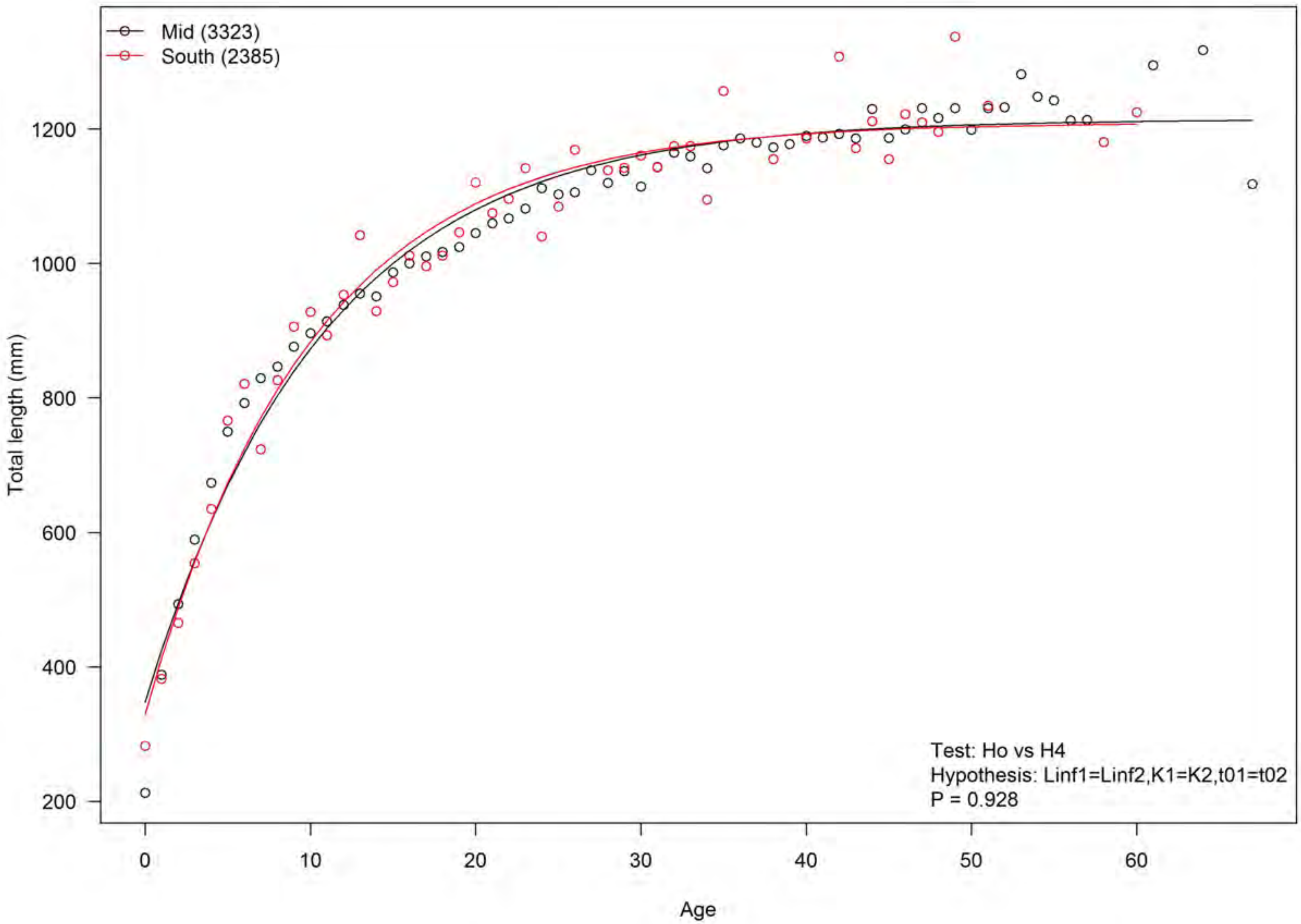


Figure 11: Kimura test on von Bertalanffy growth rates between coast wide and year-pooled Mid- and South Atlantic Black Drum. Mid-Atlantic includes NE, MD, and VA whereas South Atlantic includes NC, SC, GA, and FL. A data point is a mean length at age.

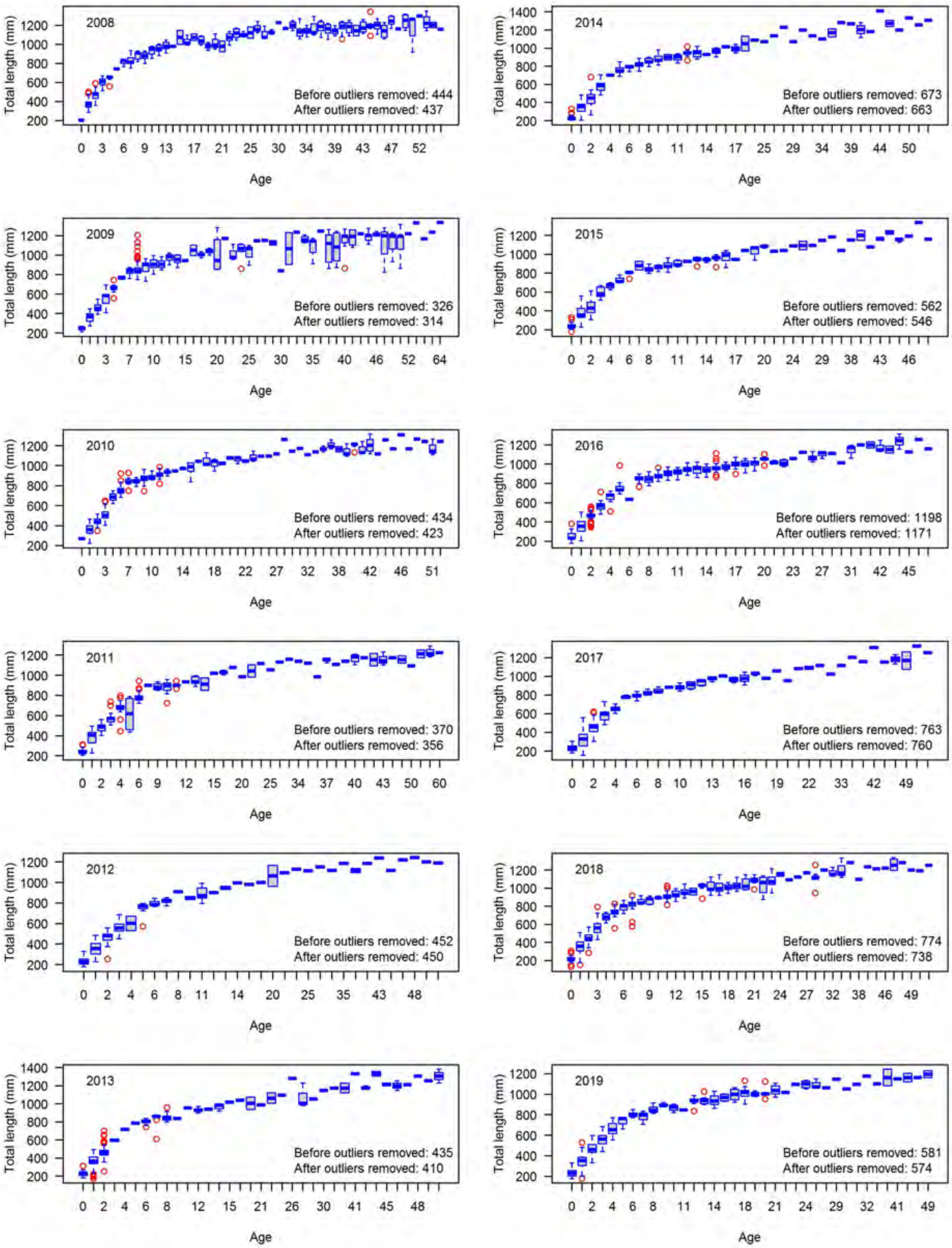


Figure 12: Coastal wide age-length data before and after outlier removal by year using boxplot function. One red circle represents one fish identified as an outlier.

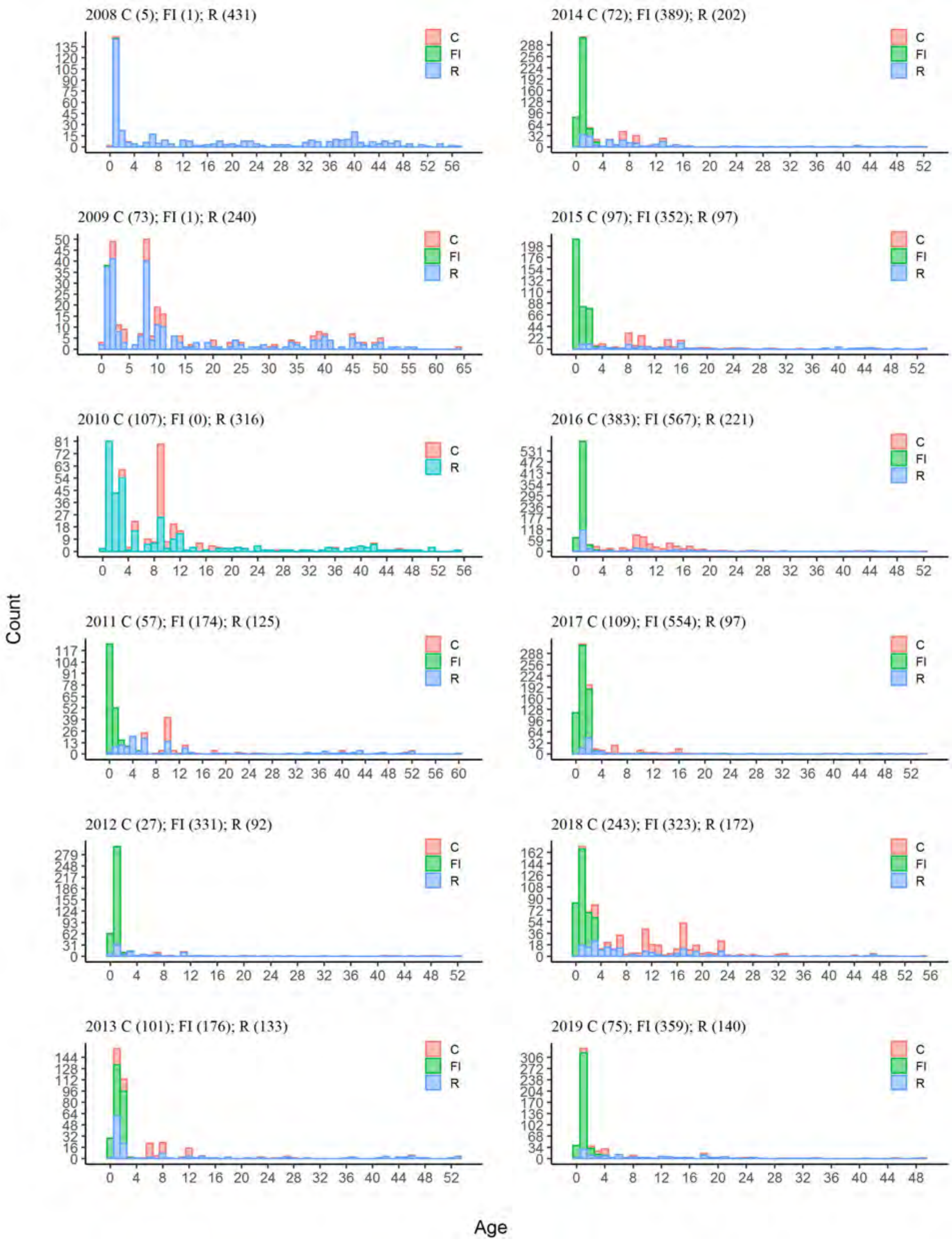


Figure 13: Coast-wide annual age distributions after outliers removed. "C", "FI", and "R" stand for the data collected from commercial fisheries, fishery independent survey, and recreational fisheries, respectively.

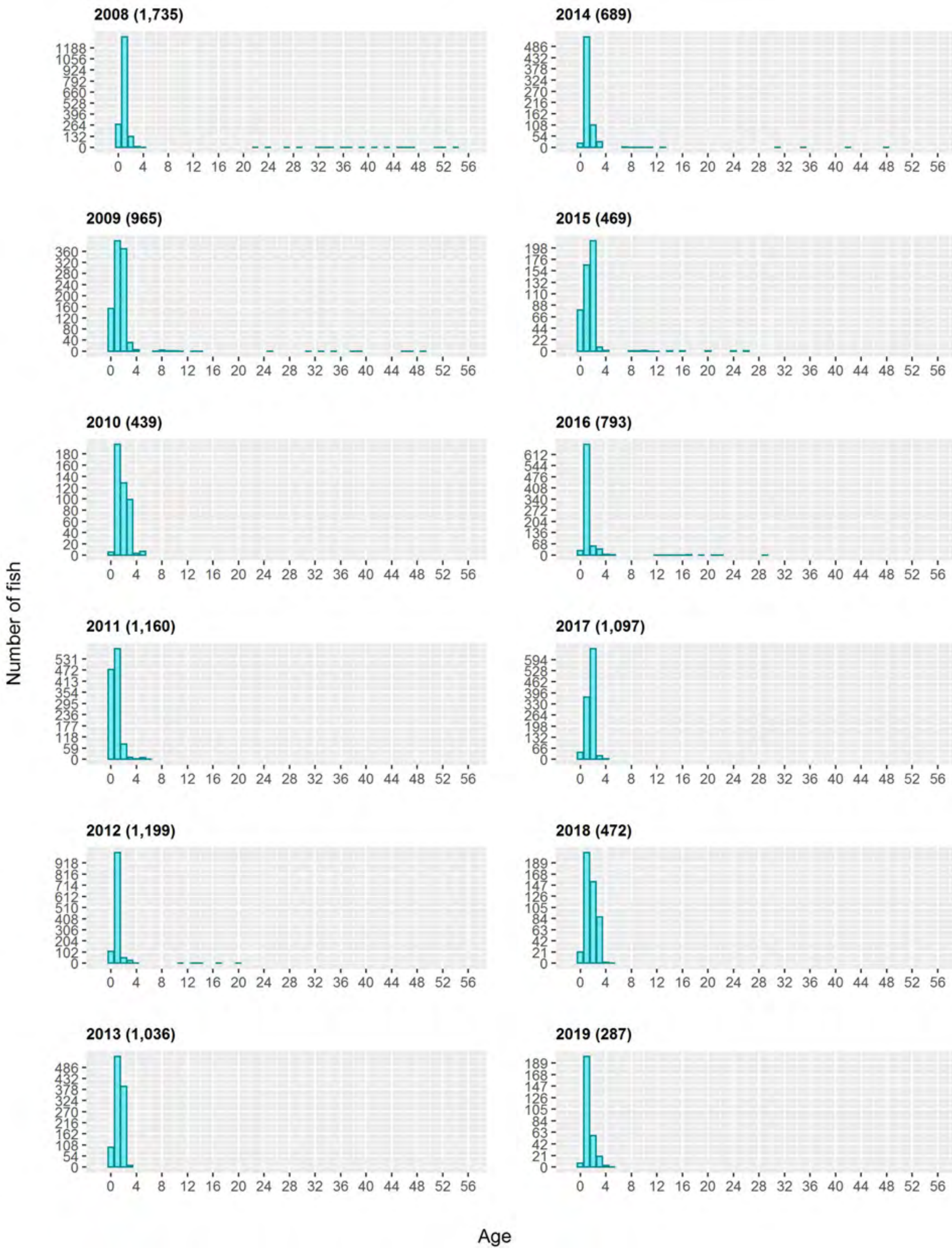


Figure 14: NC annual age distributions from 2008 to 2019 converted from NC annual length distributions using coast-wide annual ALKs.

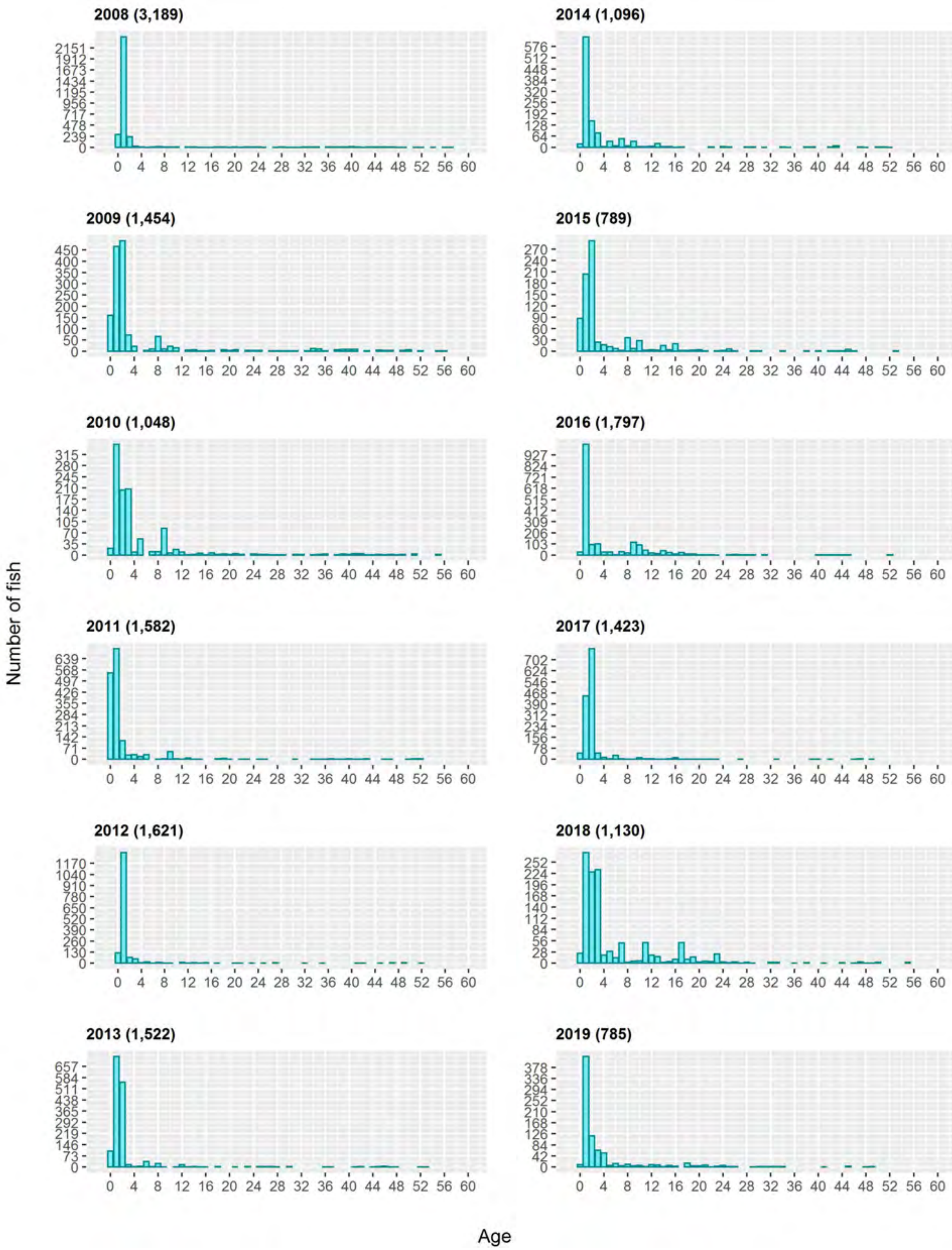


Figure 15: Coast-wide annual age distributions from 2008 to 2019 converted from coast-wide annual length distributions using coast-wide annual ALKs.

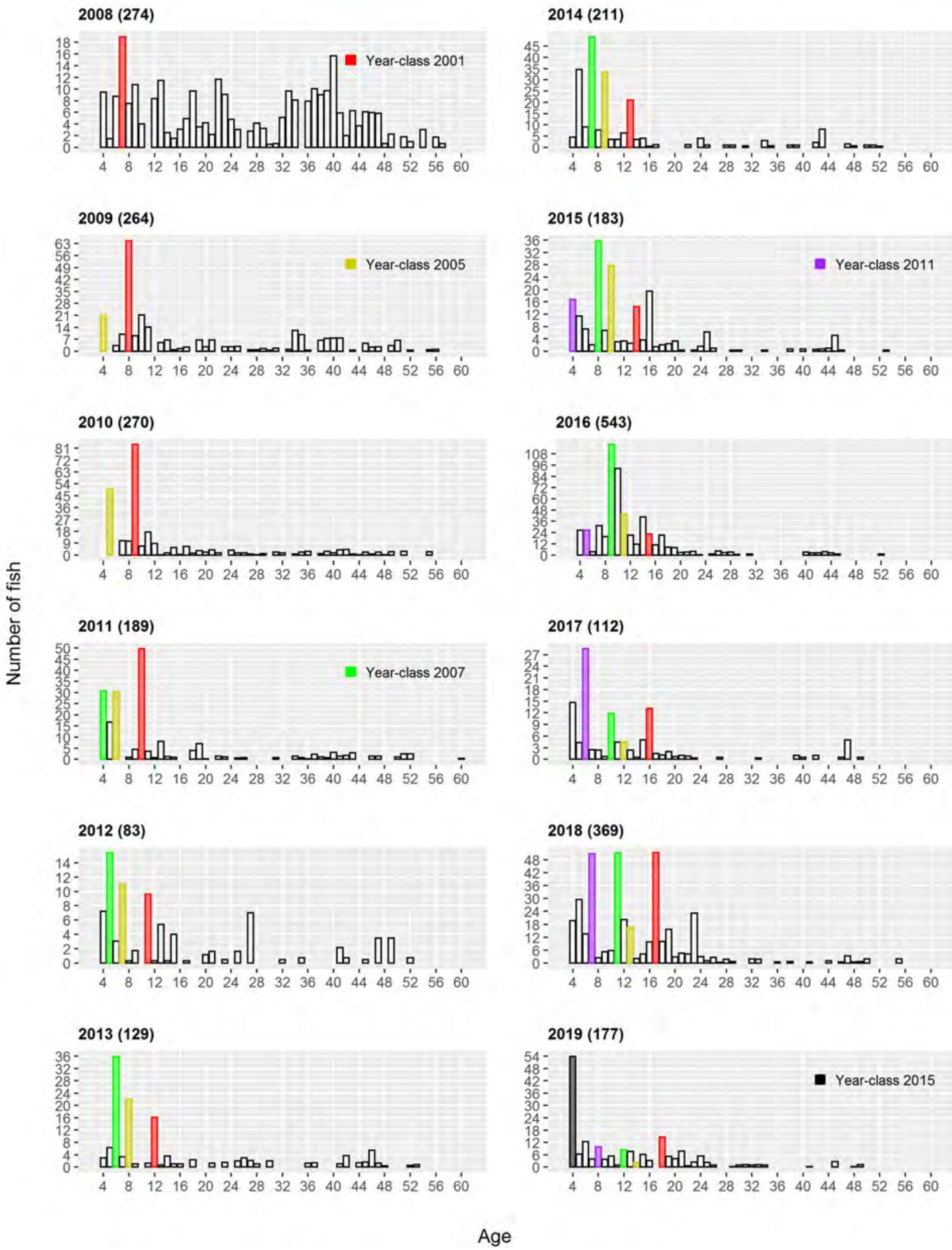


Figure 16: Coast-wide annual age distributions from 2008 to 2019 with removal of fish younger than Age 4.

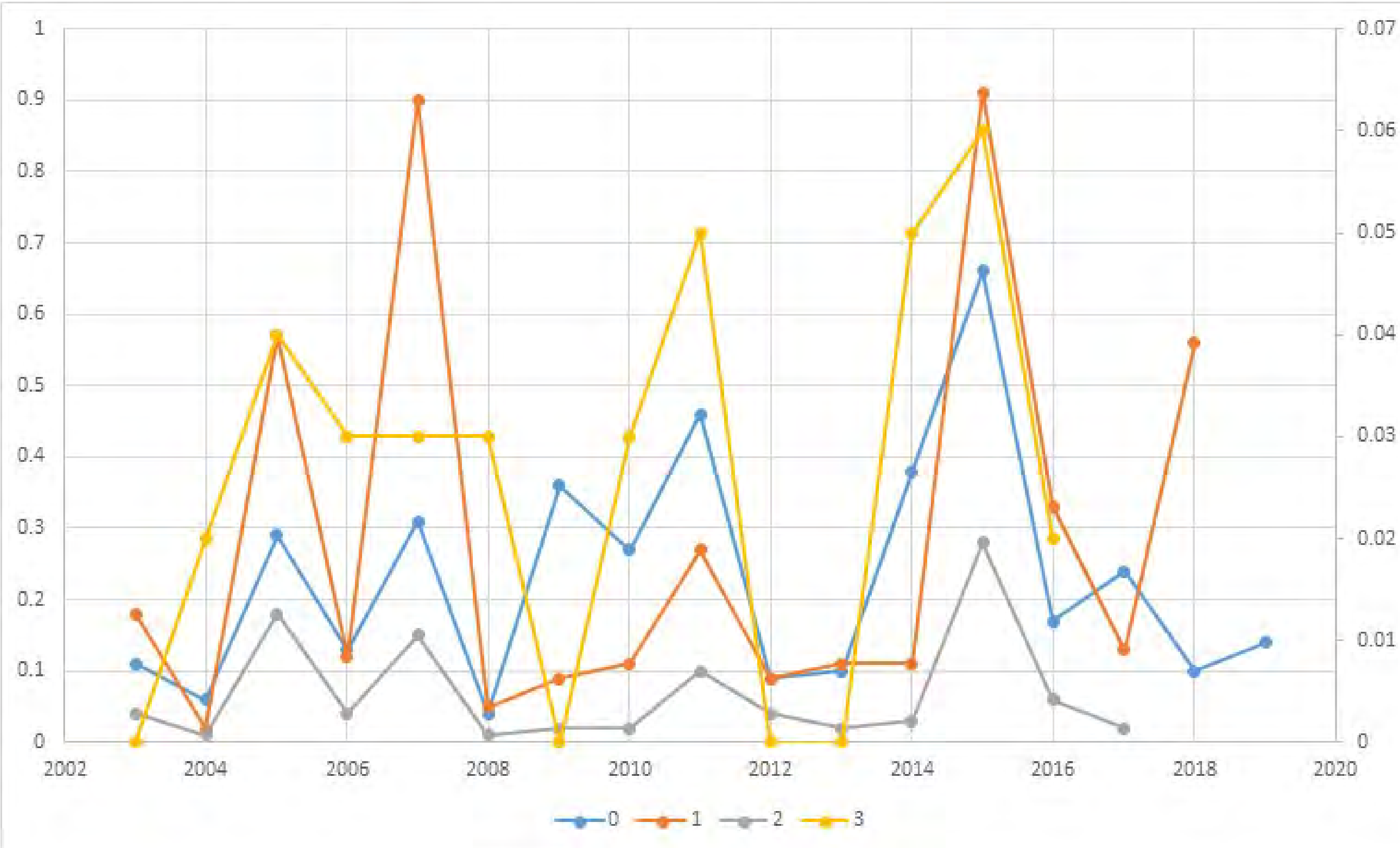


Figure 17: NC abundance indices. X-axis is year-class.

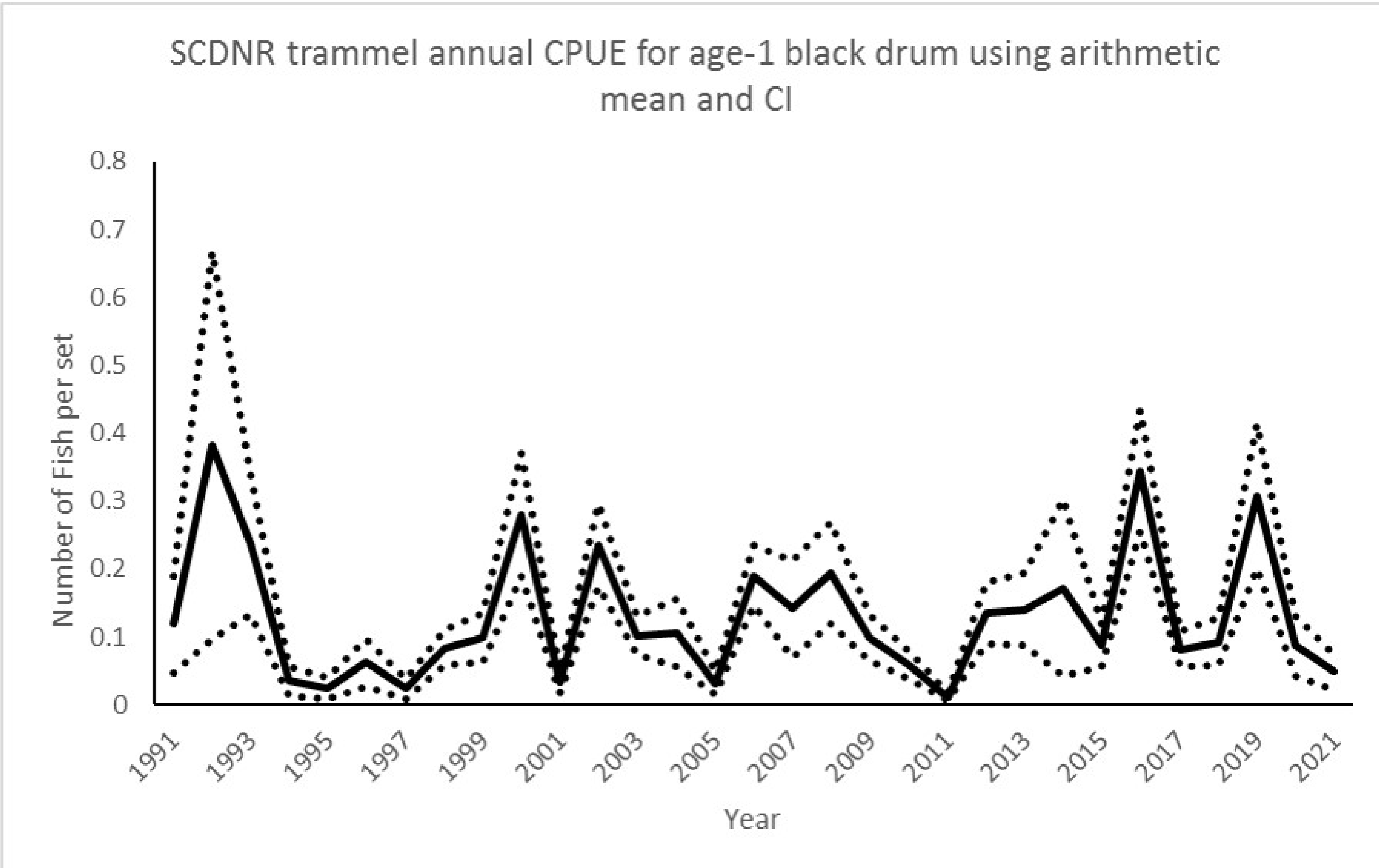


Figure 18: NC trammel net CPUE index for Age 1 of Black Drum.

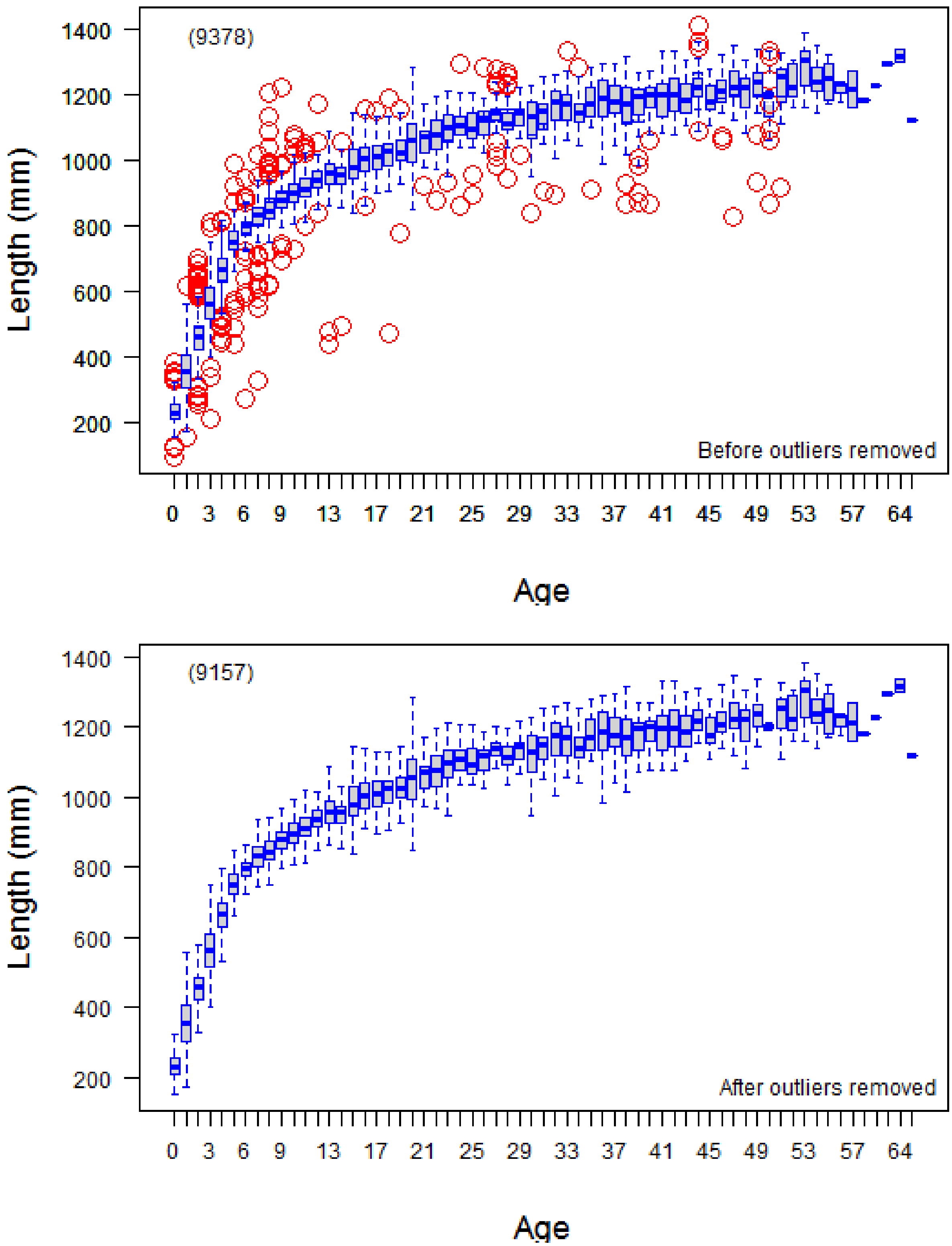


Figure 19: Outliers were moved from the coast-wide year- and sex-combined age-length data collected between 1983 and 2021 from recreational, commercial fisheries, and fishery-independent surveys. A red circle represents one fish identified as an outlier.

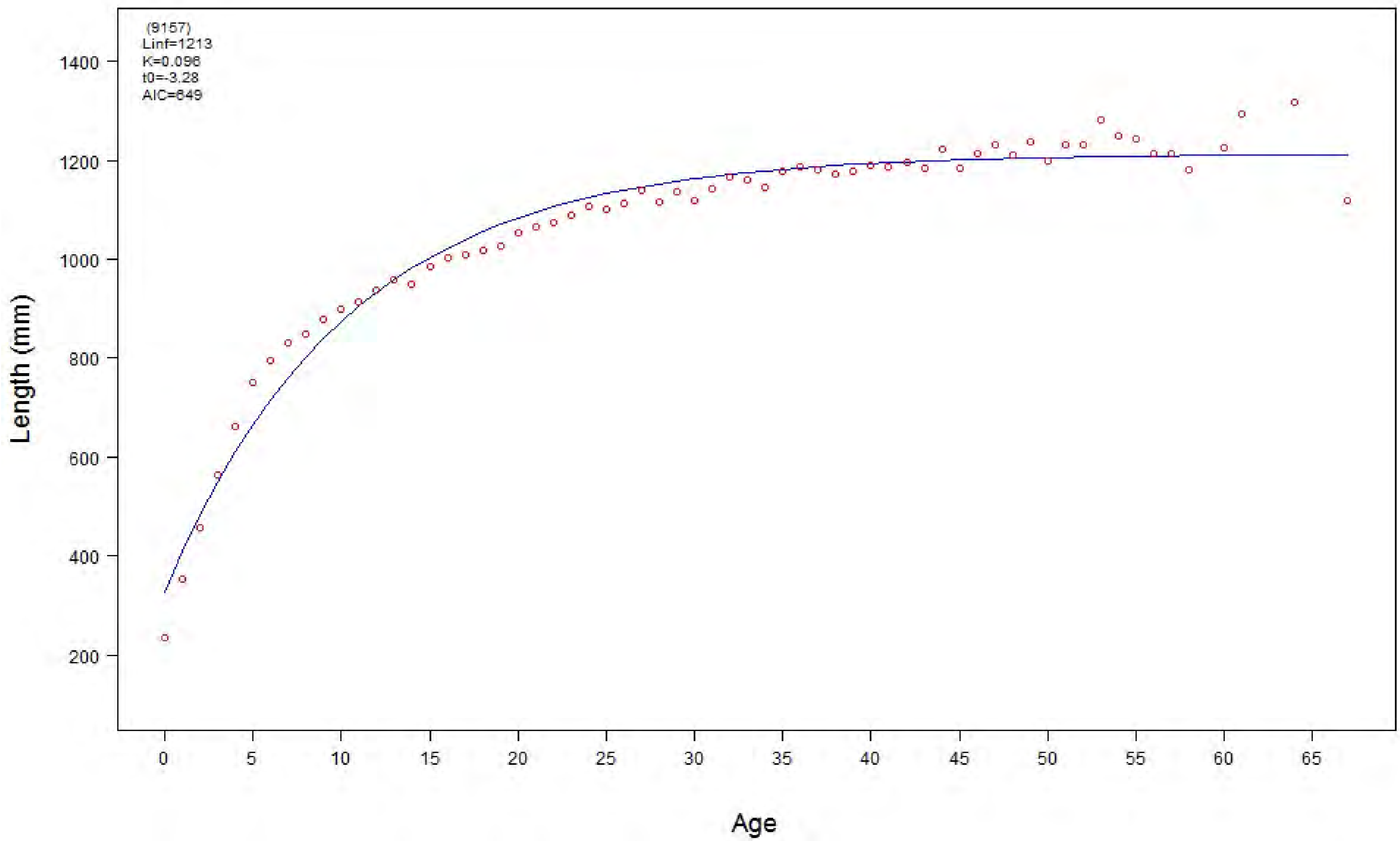


Figure 20: von Bertalanffy growth curve (blue line) with its parameters estimated using the region-, year-, and sex-pooled mean length-at-age data (red circles) collected between 1983 and 2020. The number in parenthesis is the sample size. The minimum age is 0 whereas the maximum age is 67.

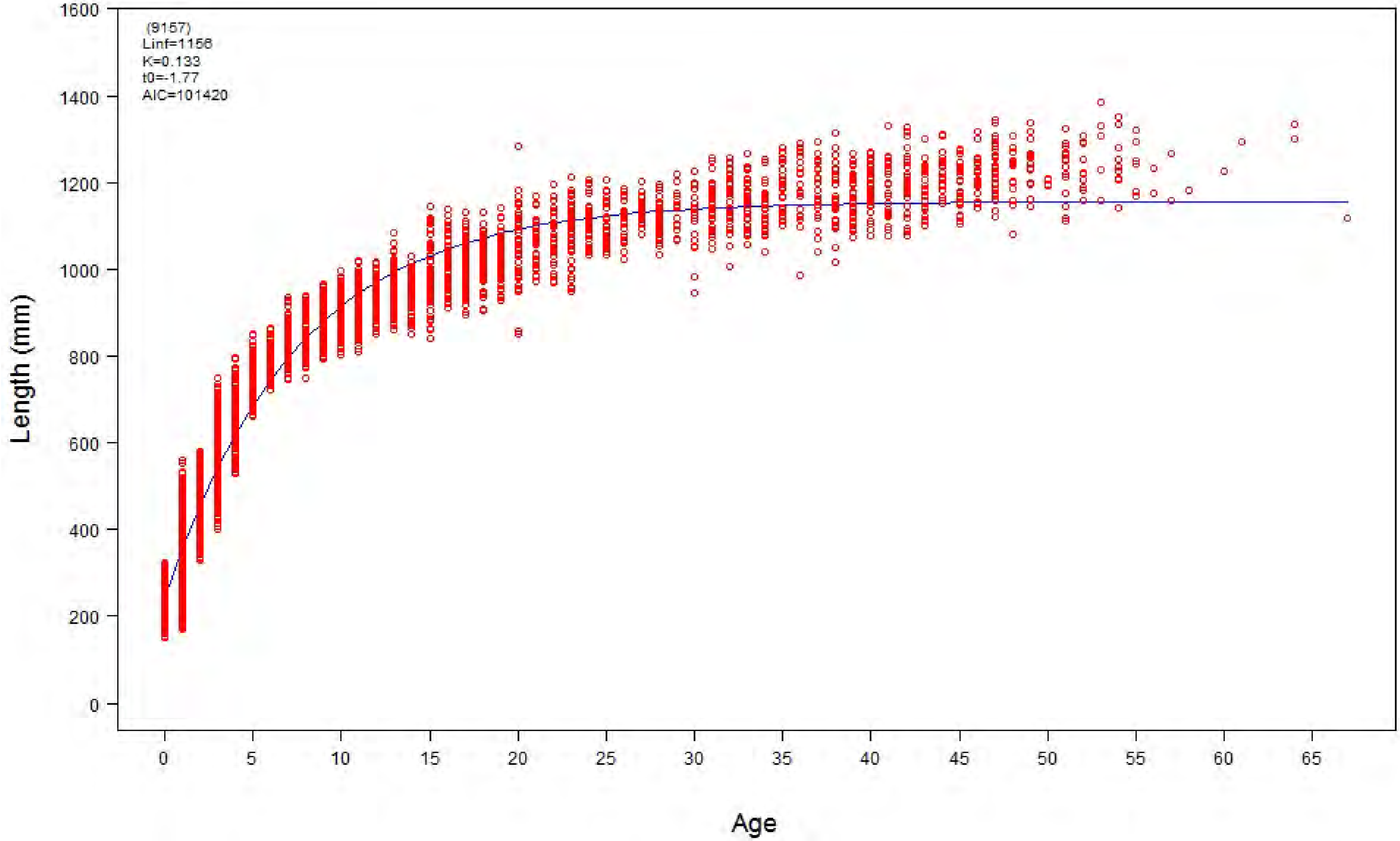


Figure 21: von Bertalanffy growth curve (blue line) with its parameters estimated using the region-, year-, and sex-pooled individual length-at-age data (red circles) collected between 1983 and 2020. The number in parenthesis is the sample size. The minimum age is 0 whereas the maximum age is 67.

Appendix 2: Development of Stock Synthesis models for the 2023 Black Drum Benchmark Stock Assessment

1 Introduction

Stock Synthesis is a flexible age-structured modeling framework that has been widely used in fish stock assessments around the world (Methot and Wetzel 2013). Stock synthesis can incorporate many different types of information, such as age, length, and tagging data, to inform estimates for a population. There have also been Stock Synthesis models developed for use in assessments that lack some or all of the above type of information. The Simple Stock Synthesis model is one type of Stock Synthesis model that was developed for use in situations where there is only historical catch and life history information (Cope 2013). The goal of the present study was to develop two different Stock Synthesis models for potential use in the 2023 Black Drum Benchmark Stock Assessment. The two different models are: (1) a Simple Stock Synthesis model and (2) a Stock Synthesis model fit to the length frequency distributions of total catches each year when length-frequency catch data is available.

2 Materials and Methods

2.1 Inputs common to both models

2.1.1 Biological

The growth model used was a von Bertanlanffy model with parameters $K = 0.133$, $L_\infty = 1115$ mm, $t_0 = -1.76$, and $CV = 0.1$ (Fig. 1). Natural mortality was assumed to vary by age and calculated using the Lorenzen curve. The weight W at length l was described by the function

$W(l) = al^b$, where the constants $a = 0.0000318$ and $b = 2.8977$ were estimated from paired observations of black drum length and weight.

2.1.2 Fishery removals

Both models utilized the time series of total removals along the entire Atlantic coast of the United States (Fig. 2).

2.2 Simple Stock Synthesis

Simple Stock Synthesis is based on the same idea as the Depletion-Based Stock Reduction Analysis (DB-SRA). DB-SRA uses a Monte Carlo approach to provide a distribution of catch that would be considered over fishing based on probability distributions for current depletion, natural mortality, the ratio of fishing mortality at MSY to natural mortality, and the ratio of biomass at MSY to initial biomass. Simple Stock Synthesis uses an age structured population dynamics model instead of a production model and therefore there are differences in some of the inputs needed for Simple Stock Synthesis compared to DB-SRA. A length-based selectivity curve was specified based on the length frequency distribution from coast wide MRIP data (Fig. 3). A change in the ascending portion of the selectivity curve was specified due to changes in regulations in 2014. Specific values used for the double-normal selectivity curve are in Table 1.

2.2.1 Base model

The base model used a beta distribution for the depletion and steepness parameters. For the depletion values, parameters of the beta distribution were $\alpha = 9.9$ and $\beta = 4.2$ and for steepness the parameters were $\alpha = 5.94$ and $\beta = 1.97$. The values for steepness were set to align with the JABBA-Select model and the values for steepness were taken from the meta-analysis in Shertzer and Conn (2012).

2.2.2 Other models

An attempt was made to incorporate the MRIP CPUE index (Fig. 4) into the Simple Stock Synthesis model based on comments from the previous black drum benchmark assessment, where reviewers suggested to try to include some of the available indices of abundance into the DB-SRA model. The MRIP CPUE index is the only index thought to provide some information on the coastwide exploitable portion of the black drum stock, and was therefore the only index selected for potential inclusion in the Simple Stock Synthesis model.

2.3 Stock Synthesis model fit to length data

This Stock Synthesis model was fit to length composition data from the MRIP during 1982-2020 (Fig. 5; Fig. 6) and the MRIP CPUE index of abundance during 1982-2020 (Fig. 4). An initial model was fit with selectivity specified as in the Simple Stock synthesis base model. Another model was run where some of the parameters of the double normal selectivity curve were estimated (Table 2). Finally, another model was run with a spline selectivity where some of the parameters were estimated (Table 3). Yearly recruitment deviations were estimated for all of these Stock Synthesis models fit to length data.

2.4 Code and data availability

All code and data for the Simple Stock Synthesis model and the Stock Synthesis model fit to length data are available at: https://github.com/mmace3/SSappendix.

3 Results

3.1 Simple Stock Synthesis

Base model

3.1.1 Parameter Estimates

All model runs had a maximum gradient component < 0.0001 and the difference between the observed and predicted survey value in the final year was < 0.01 for each run. The distribution of depletion values and steepness values used as input were similar to the specified distributions for these parameters. The distribution of depletion values used in model runs had a mean of 0.7 and a standard deviation of 0.12 and the distribution of steepness values had a mean of 0.75 and standard deviation of 0.14 (Fig. 7). As expected, depletion decreased over time from mean value of 1 in 1900 to 0.7 in 2020 (Fig. 8). The maximum value of depletion in 2020 was 0.29 and the minimum value was 0.98.

3.1.2 Reference Points

3.1.2.1 MSY

The median of the MSY distribution was 3,280 mt with a minimum of 827 mt and maximum of 47,055 mt (Fig. 9).

3.1.2.2 OFL

The median of the MSY distribution was 4,743 mt with a minimum of 872 mt and maximum of 90,391 mt (Fig. 9).

3.1.2.3 B_{MSY}

The median of the B_{MSY} distribution was 73,302 mt with a minimum of 27,314 mt and maximum of 1,020,680 mt (Fig. 9).

3.1.2.4 F_{MSY}

The median of the F_{MSY} distribution was 0.043, with a minimum of 0.0036 and maximum of 0.059 (Fig. 9).

Other models

When the MRIP CPUE index was included in the Simple Stock Synthesis model, the model did not converge unless extra variation (i.e., Q_extraSD parameter) was added to the standard deviation of the catchability coefficient for the MRIP CPUE index, and the observation error for the final depletion value was increased from 0.0001 to 0.1. After these modifications, the model converged, but there was a strong trend in the residuals for the MRIP CPUE index (Fig. 10). Additionally, the final depletion value in 2020 was above the specified value (Fig. 11). The trend in abundance implied by the MRIP CPUE index was different from the trend in abundance implied by the depletion assumption (Fig. 12). Therefore, the CPUE index was excluded from the base model.

3.2 Stock Synthesis fit to length data

Both models (double normal selectivity and spline selectivity) did not fit the length composition data well (Fig. 13-Fig. 16). Since neither model fit the length composition data well and both models produced unrealistically large estimates of abundance, no other results from either model are shown.

4 Conclusions

4.1 Simple Stock Synthesis

This type of model, along with DB-SRA, was developed to provide advice about catch limits in the short term (i.e., next year) and not stock status. Given that our goal is to try and determine stock status of black drum, these types of models are not well suited to our goals. Although these models could potentially be useful along with other lines of evidence to make some conclusions about stock status.

4.2 Stock Synthesis fit to length data

This model was not fitting the length composition data very well and could benefit from more development. Specifically, more work could be done on the selectivity portion of the model. Splitting the fishery removals into different fleets with at least one flat-topped selectivity fleet could help provide the model with more information about the older adult portion of the stock and result in a more reasonable estimate of abundance.

References

Cope, Jason M. 2013. "Implementing a Statistical Catch-at-Age Model (Stock Synthesis) as a Tool for Deriving Overfishing Limits in Data-Limited Situations." *Fisheries Research* 142: 3–14.

Methot, Jr., Richard D., and Chantell R. Wetzel. 2013. "Stock Synthesis: A Biological and Statistical Framework for Fish Stock Assessment and Fishery Management." *Fisheries Research* 142: 86–99.

Shertzer, Kyle W., and Paul B. Conn. 2012. "Spawner-Recruit Relationships of Demersal Marine Fishes: Prior Distribution of Steepness." *Bulletin of Marine Science* 88: 39–50.

Table 1. Parameter values used for double-normal length-based selectivity in the Simple Stock Synthesis model.

Label	Value
Size_DblN_peak_Fishery(1)	9.00
Size_DblN_top_logit_Fishery(1)	-5.75
Size_DblN_ascend_se_Fishery(1)	2.00
Size_DblN_descend_se_Fishery(1)	3.80
Size_DblN_start_logit_Fishery(1)	-5.00
Size_DblN_end_logit_Fishery(1)	-1.10
Size_DblN_peak_Fishery(1)_BLK1repl_2014	15.00

Table 2. Parameters used for double-normal length-based selectivity in the Stock Synthesis model fit to length data. For parameters that are not estimated, the specificed value is shown.

Parameter	Estimated	Value
Size_DblN_peak_Fishery(1)	Yes	-
Size_DblN_top_logit_Fishery(1)	Yes	-
Size_DblN_ascend_se_Fishery(1)	Yes	-
Size_DblN_descend_se_Fishery(1)	Yes	-
Size_DblN_start_logit_Fishery(1)	No	-5
Size_DblN_end_logit_Fishery(1)	Yes	-
Size_DblN_peak_MRIP(2)	Yes	-
Size_DblN_top_logit_MRIP(2)	Yes	-
Size_DblN_ascend_se_MRIP(2)	Yes	-
Size_DblN_descend_se_MRIP(2)	Yes	-
Size_DblN_start_logit_MRIP(2)	No	-5
Size_DblN_end_logit_MRIP(2)	Yes	-
Size_DblN_peak_Fishery(1)_BLK1repl_2014	Yes	-

Table 3. Parameters used for spline length-based selectivity in the Stock Synthesis model fit to length data. For parameters that are not estimated, the specificed value is shown.

Label	Estimated	Value
SizeSpline_Code_Fishery(1)	No	0
SizeSpline_GradLo_Fishery(1)	Yes	-
SizeSpline_GradHi_Fishery(1)	No	0
SizeSpline_Knot_1_Fishery(1)	No	10
SizeSpline_Knot_2_Fishery(1)	No	20
SizeSpline_Knot_3_Fishery(1)	No	25
SizeSpline_Knot_4_Fishery(1)	No	30
SizeSpline_Knot_5_Fishery(1)	No	40
SizeSpline_Knot_6_Fishery(1)	No	50
SizeSpline_Val_1_Fishery(1)	Yes	-
SizeSpline_Val_2_Fishery(1)	Yes	-
SizeSpline_Val_3_Fishery(1)	Yes	-
SizeSpline_Val_4_Fishery(1)	Yes	-
SizeSpline_Val_5_Fishery(1)	Yes	-
SizeSpline_Val_6_Fishery(1)	Yes	-
SizeSpline_Code_MRIP(2)	No	0
SizeSpline_GradLo_MRIP(2)	Yes	-
SizeSpline_GradHi_MRIP(2)	No	0
SizeSpline_Knot_1_MRIP(2)	No	10
SizeSpline_Knot_2_MRIP(2)	No	20
SizeSpline_Knot_3_MRIP(2)	No	30
SizeSpline_Knot_4_MRIP(2)	No	40
SizeSpline_Val_1_MRIP(2)	Yes	-
SizeSpline_Val_2_MRIP(2)	Yes	-

Table 3. Parameters used for spline length-based selectivity in the Stock Synthesis model fit to length data. For parameters that are not estimated, the specificed value is shown.

Label	Estimated	Value
SizeSpline_Val_3_MRIP(2)	Yes	-
SizeSpline_Val_4_MRIP(2)	Yes	-

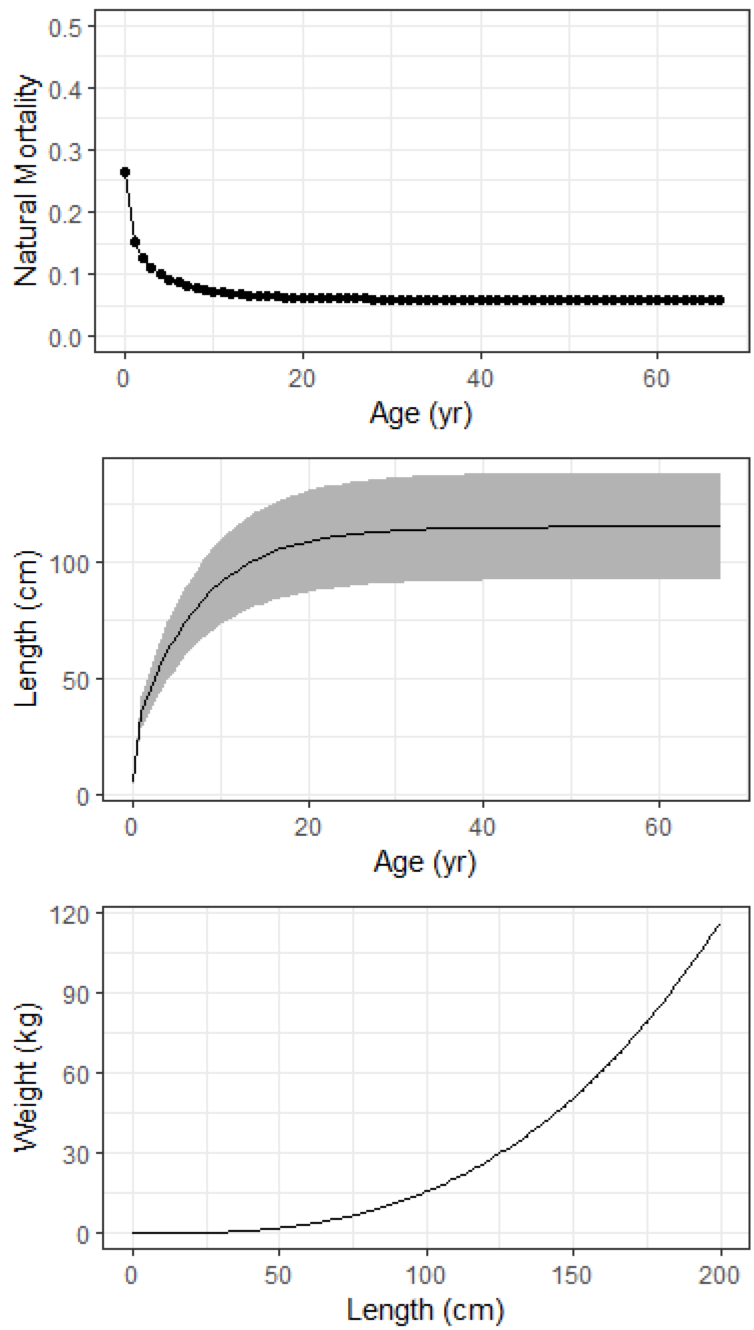


Fig. 1. Age-specific natural mortality, von Bertalanffy growth model, and length-weight relationship used in both Stock Synthesis models that were developed as part of the 2023 black drum benchmark stock assessment.

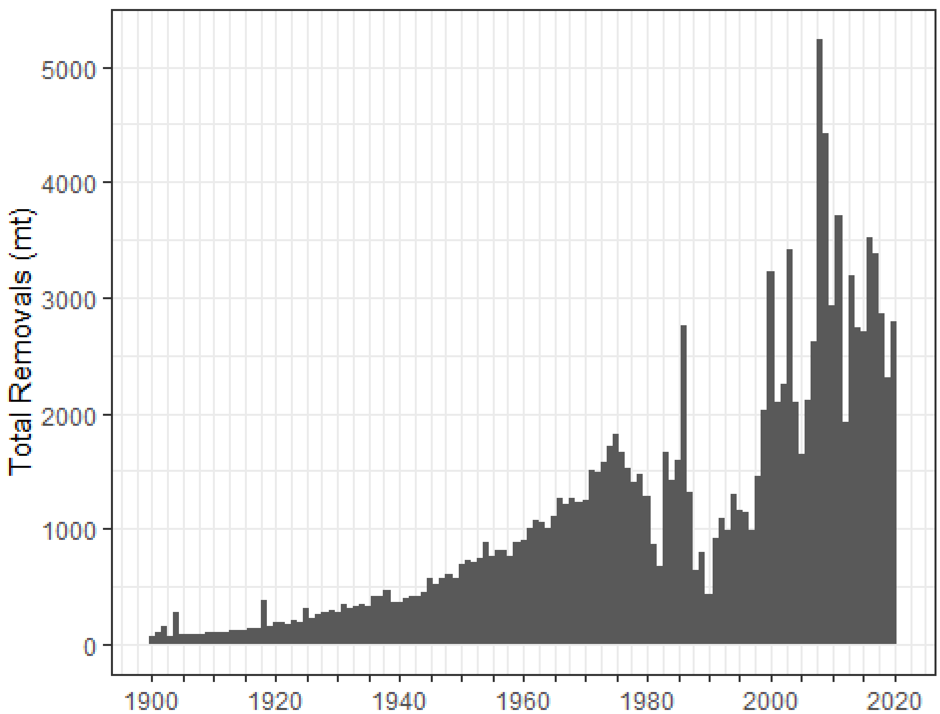


Fig. 2. Total coastwide removals of black drum during 1900-2020.

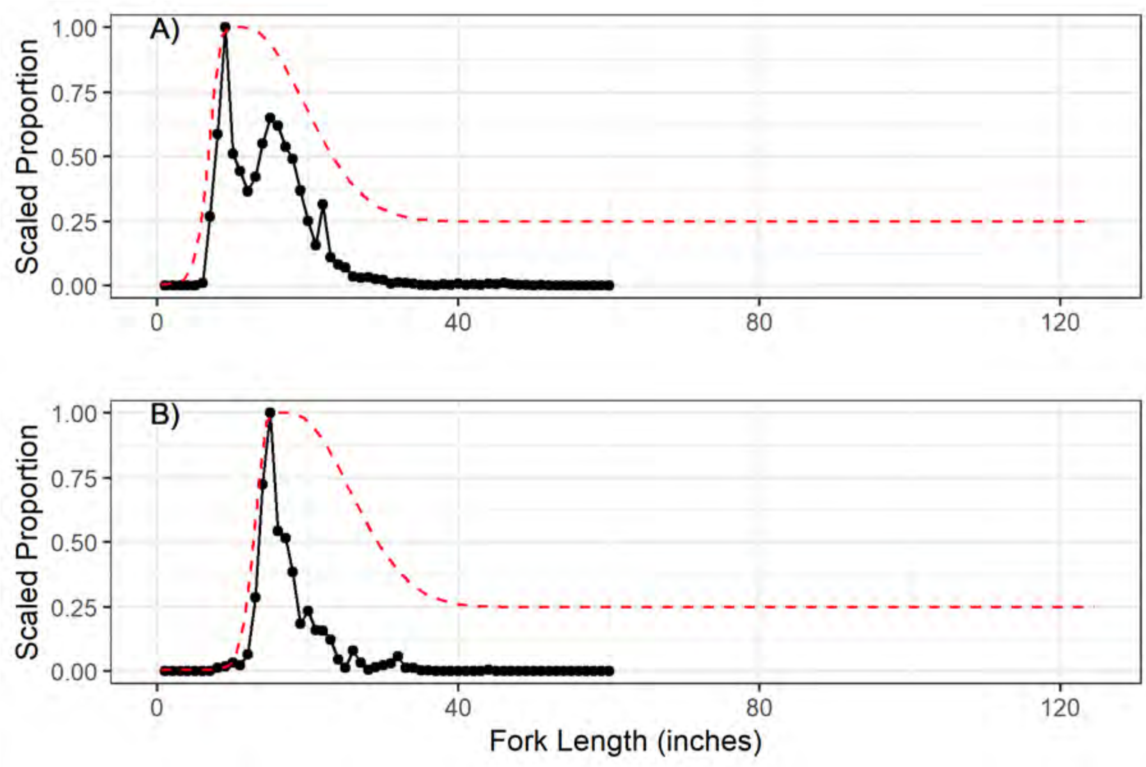


Fig. 3. Length specific selectivity curves for two different time periods (A-prior to 2014, B-2014-2020) that were used in the Simple Stock Synthesis model that was developed as part of the 2023 black drum benchmark stock assessment.

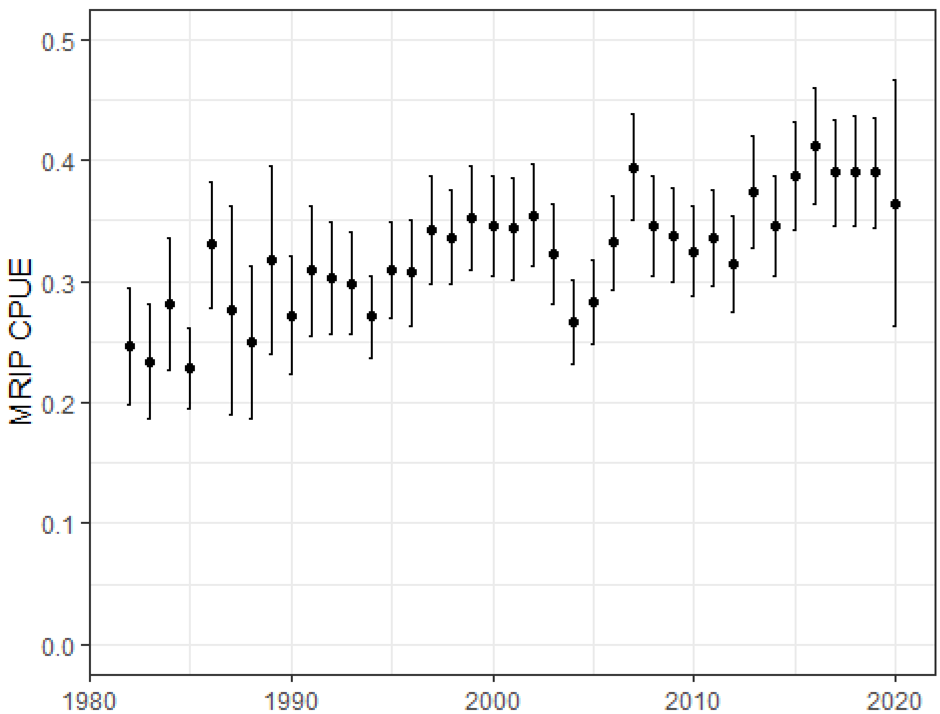


Fig. 4. MRIP CPUE index of abundance. Error bars are proportional standard errors.

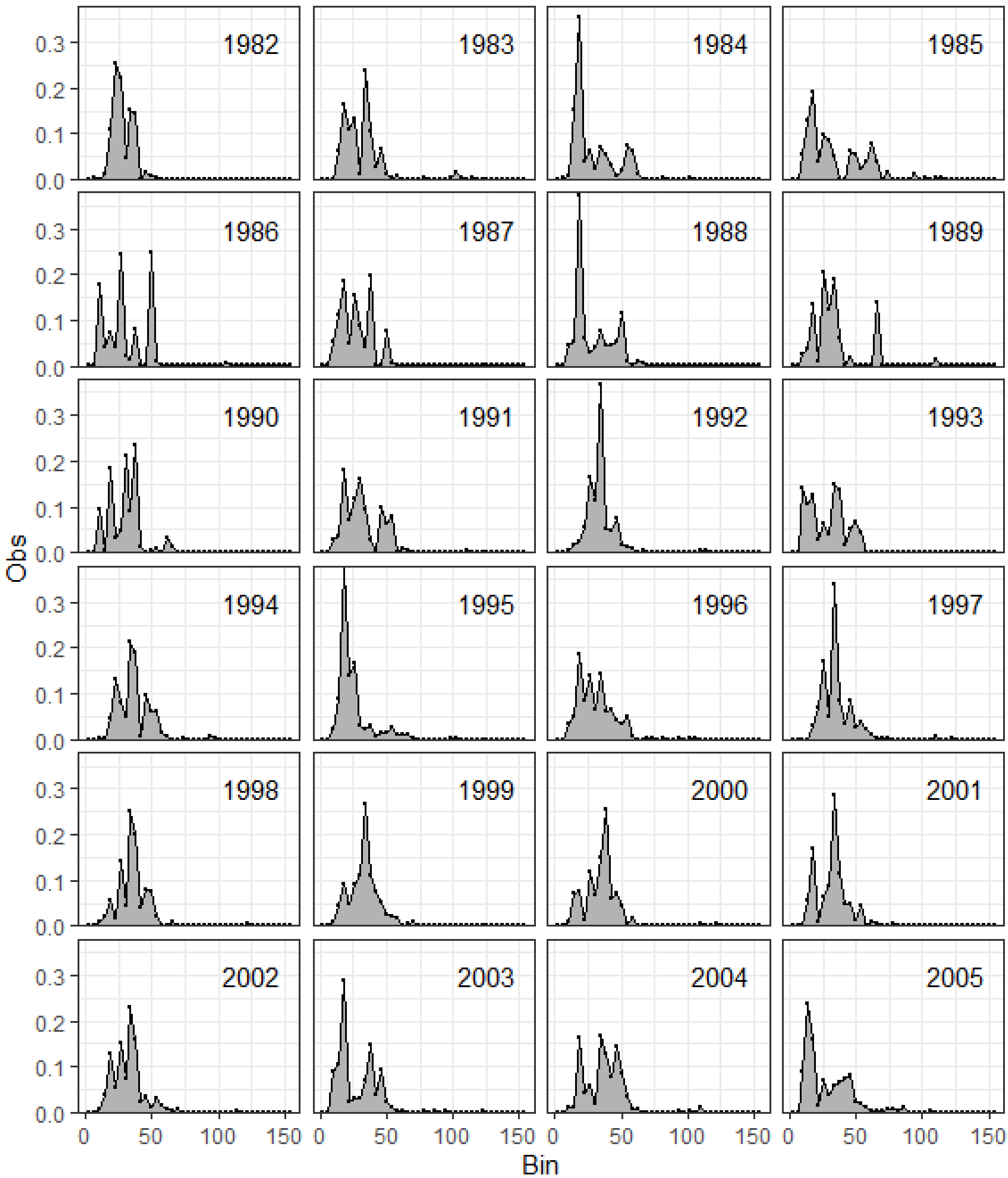


Fig. 5. Length composition data (cm) from MRIP data for 1982-2005.

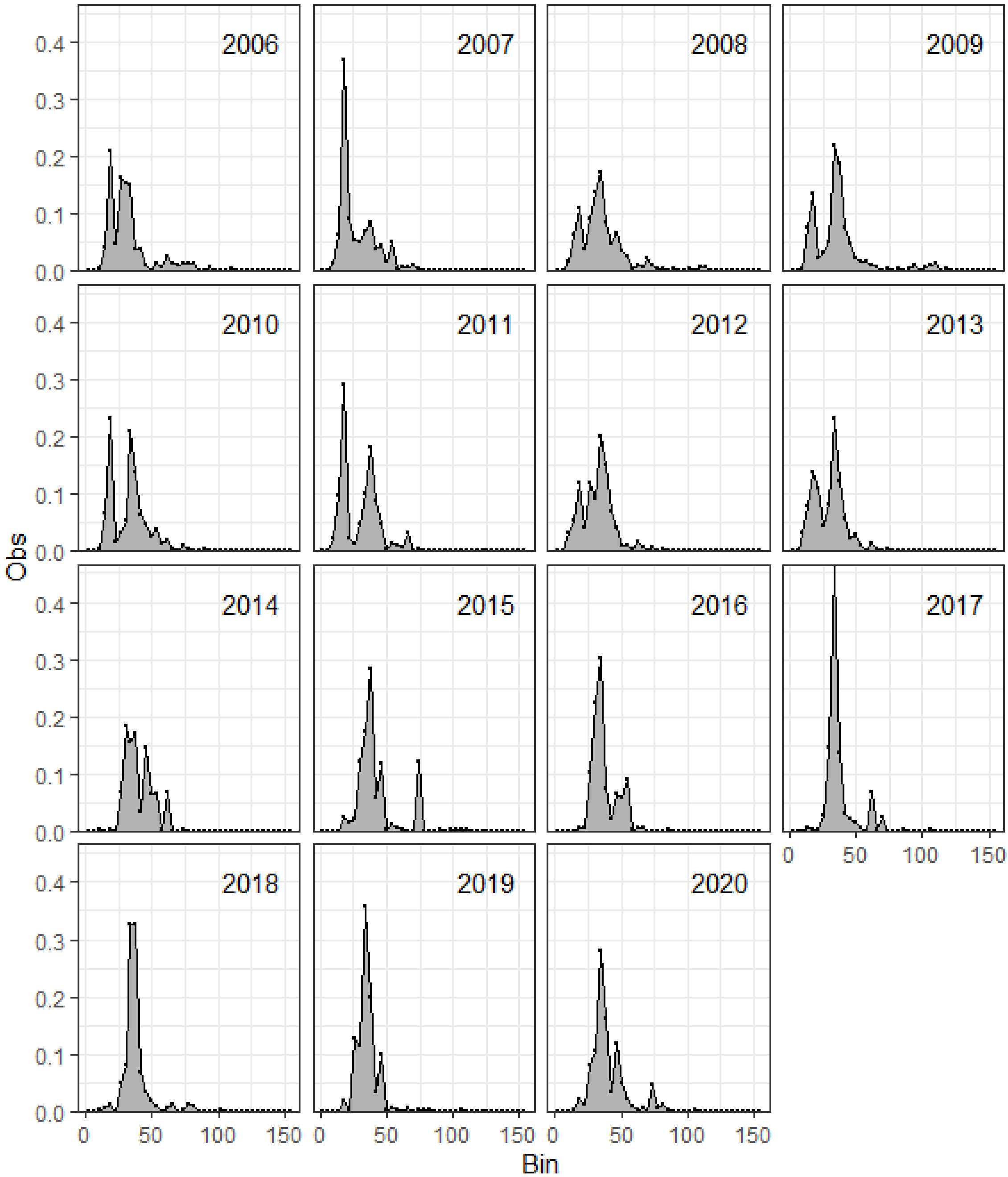


Fig. 6. Length composition data (cm) from MRIP data for 2006-2020.

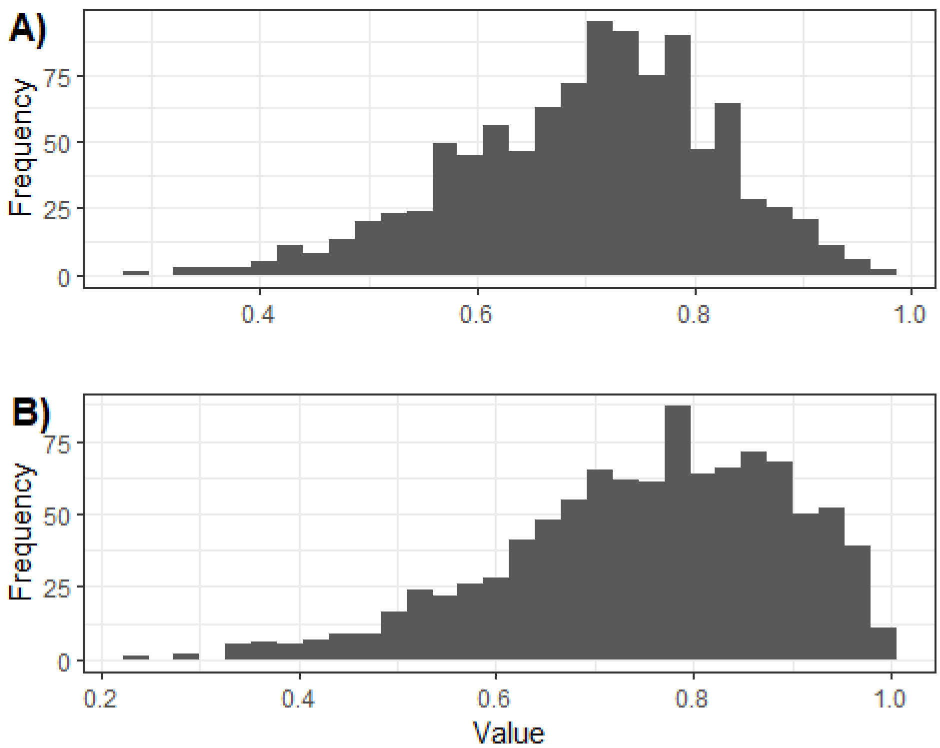


Fig. 7. Distribution of depletion (A) and steepness (B) values used in model runs (n = 1000) for the Simple Stock Synthesis model.

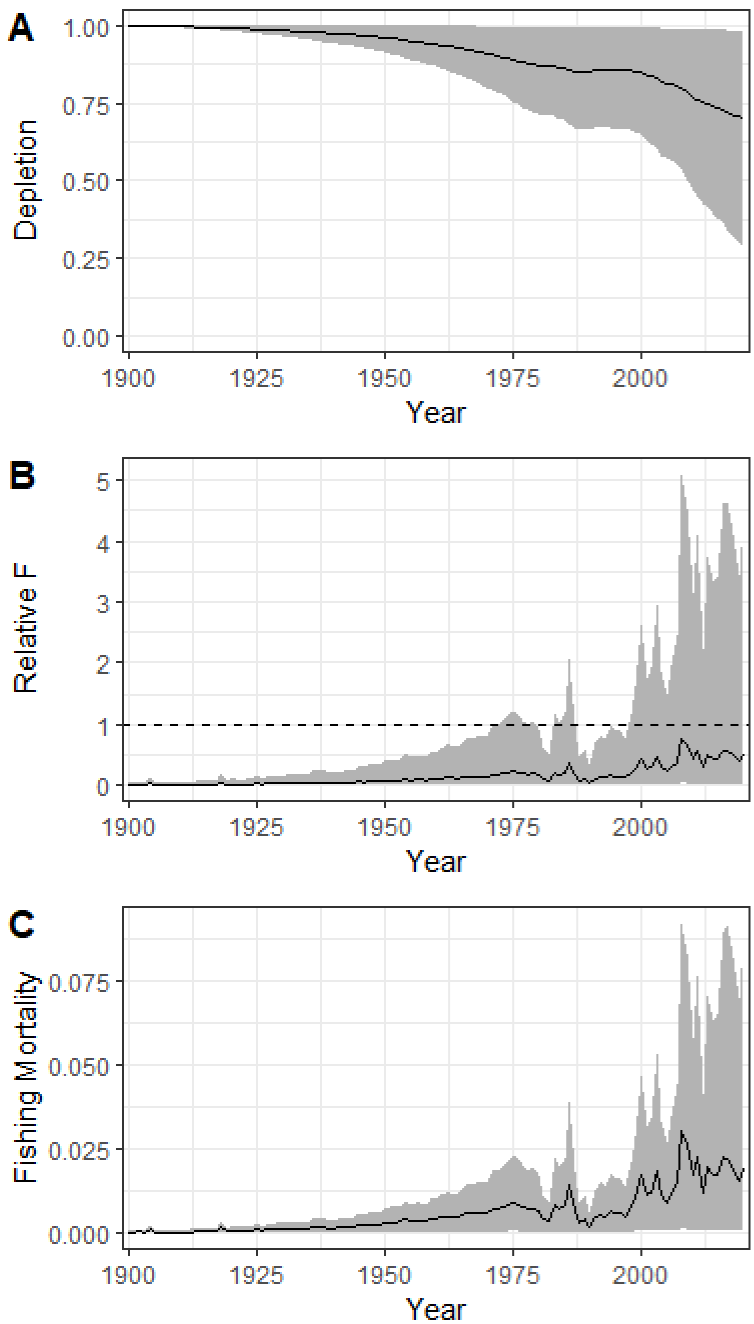


Fig. 8. Estimated depletion (A), relative *F* (B), and *F* (C) of the coastwide black drum stock during 1900-2020. Estimates are from the Simple Stock Synthesis base model. The black line is the mean value and the grey shaded area includes the minimum and maximum values from 1000 model runs.

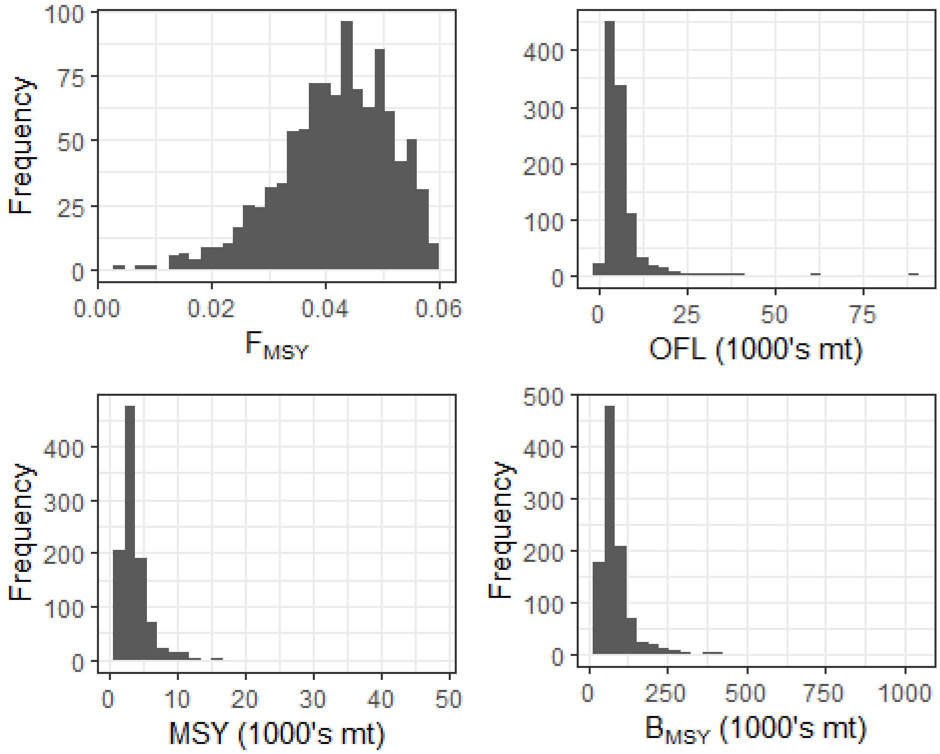


Fig. 9. Distribution of the estimated fishing mortality rate at maximum sustainable yield (F_{MSY}), overfishing limit in 2021 (OFL), maximum sustainable yield (MSY), and spawning stock biomass at maximum sustainable yield (B_{MSY}). Estimates are from the Simple Stock Synthesis base model with 1000 model runs.

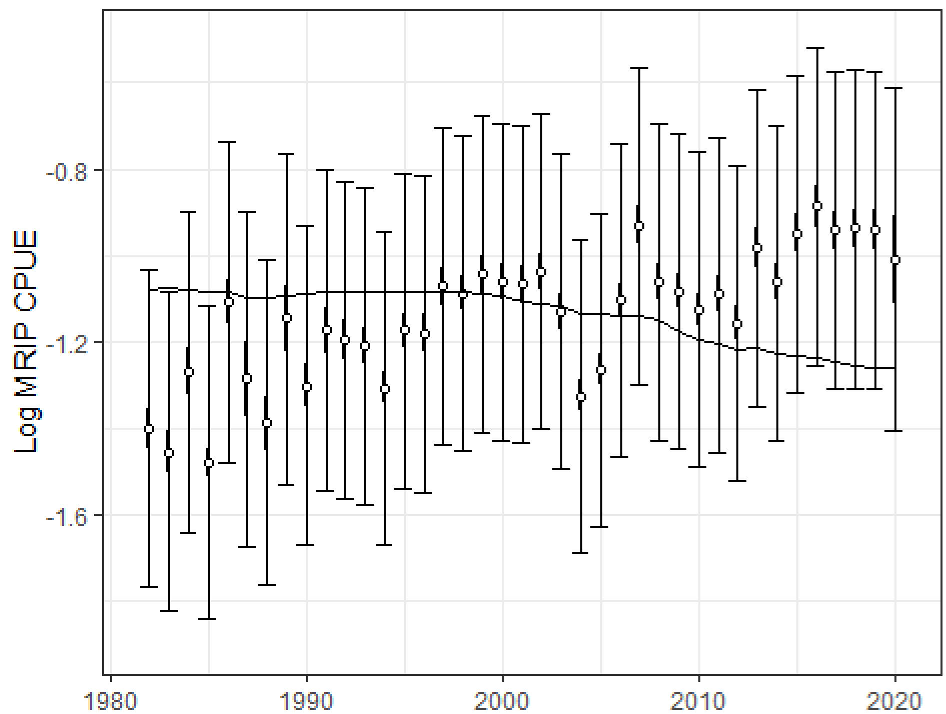


Fig. 10. Fit to log index data on log scale for MRIP CPUE. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

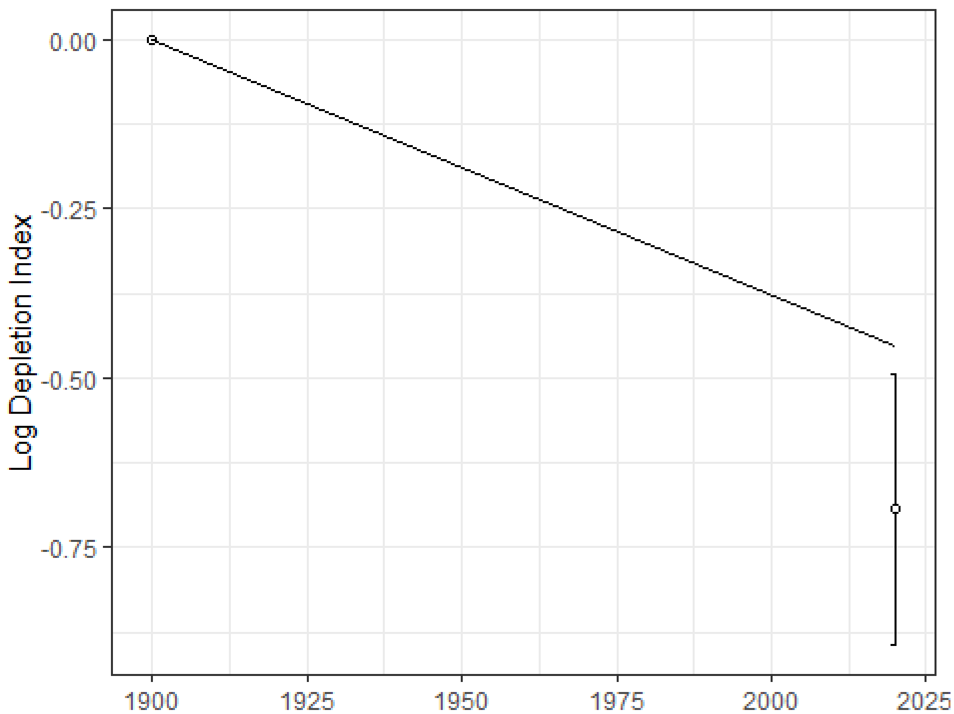


Fig. 11. Fit to log index data on log scale for Depletion index. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error.

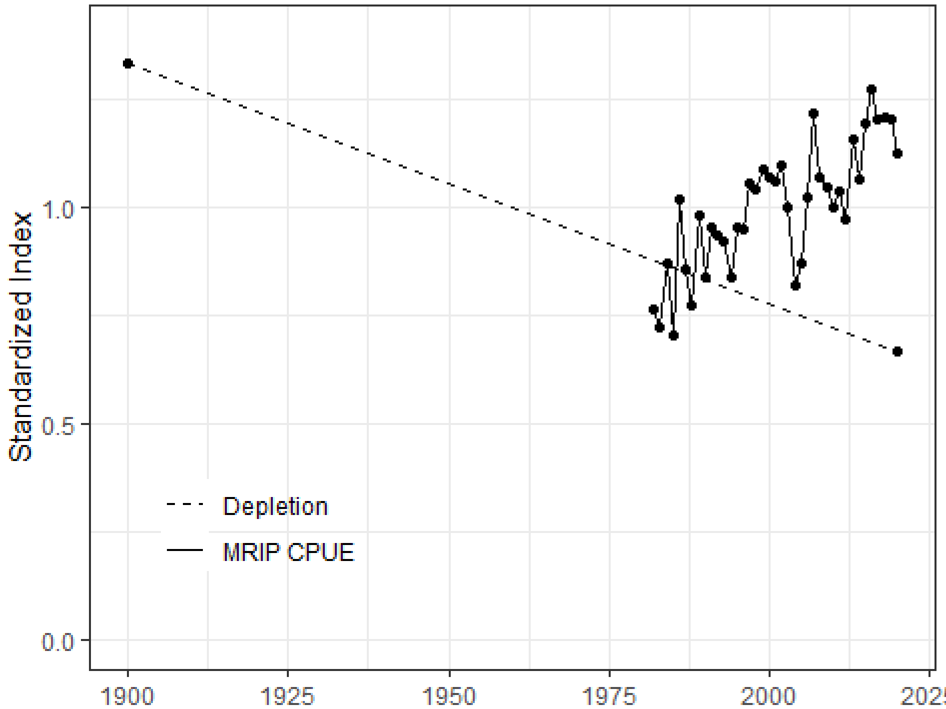


Fig. 12. Standardized indices overlaid. Each index is rescaled to have mean observation = 1.0.

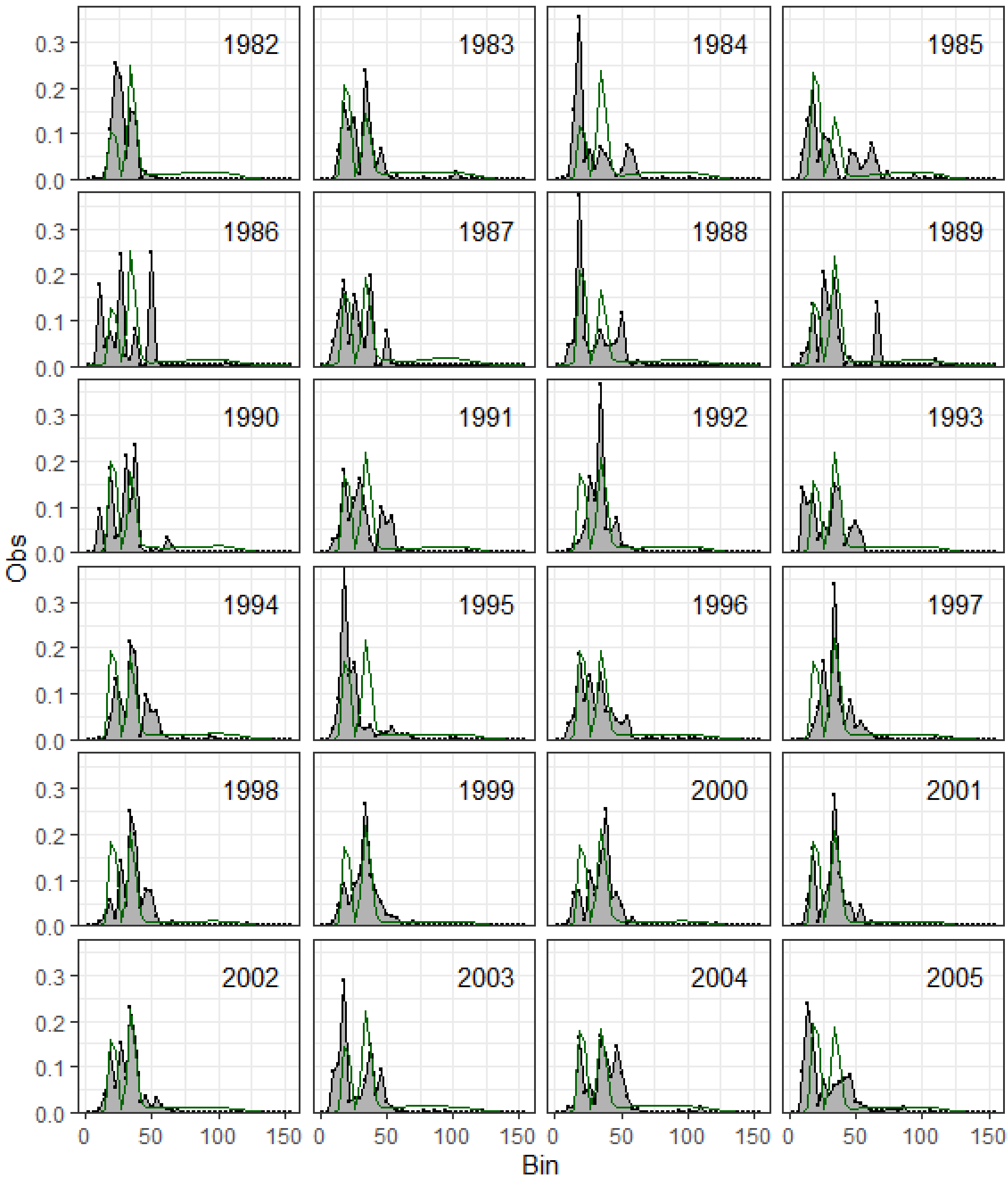


Fig. 13. Fit to length composition data (cm; 1982-2005) from Stock Synthesis Model using a double normal selectivity curve.

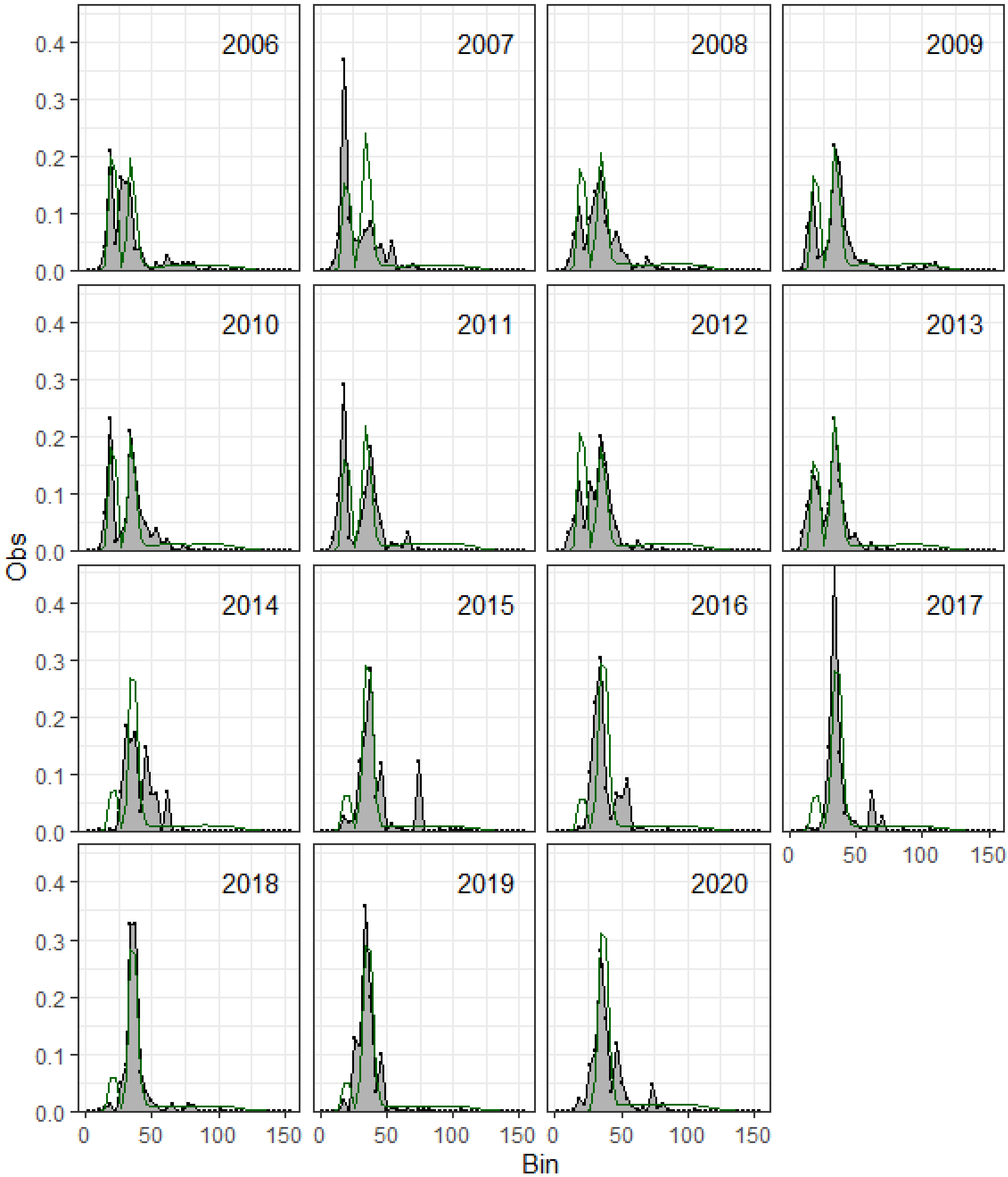


Fig. 14. Fit to length composition data (cm; 2006-2020) from Stock Synthesis Model using a double normal selectivity curve.

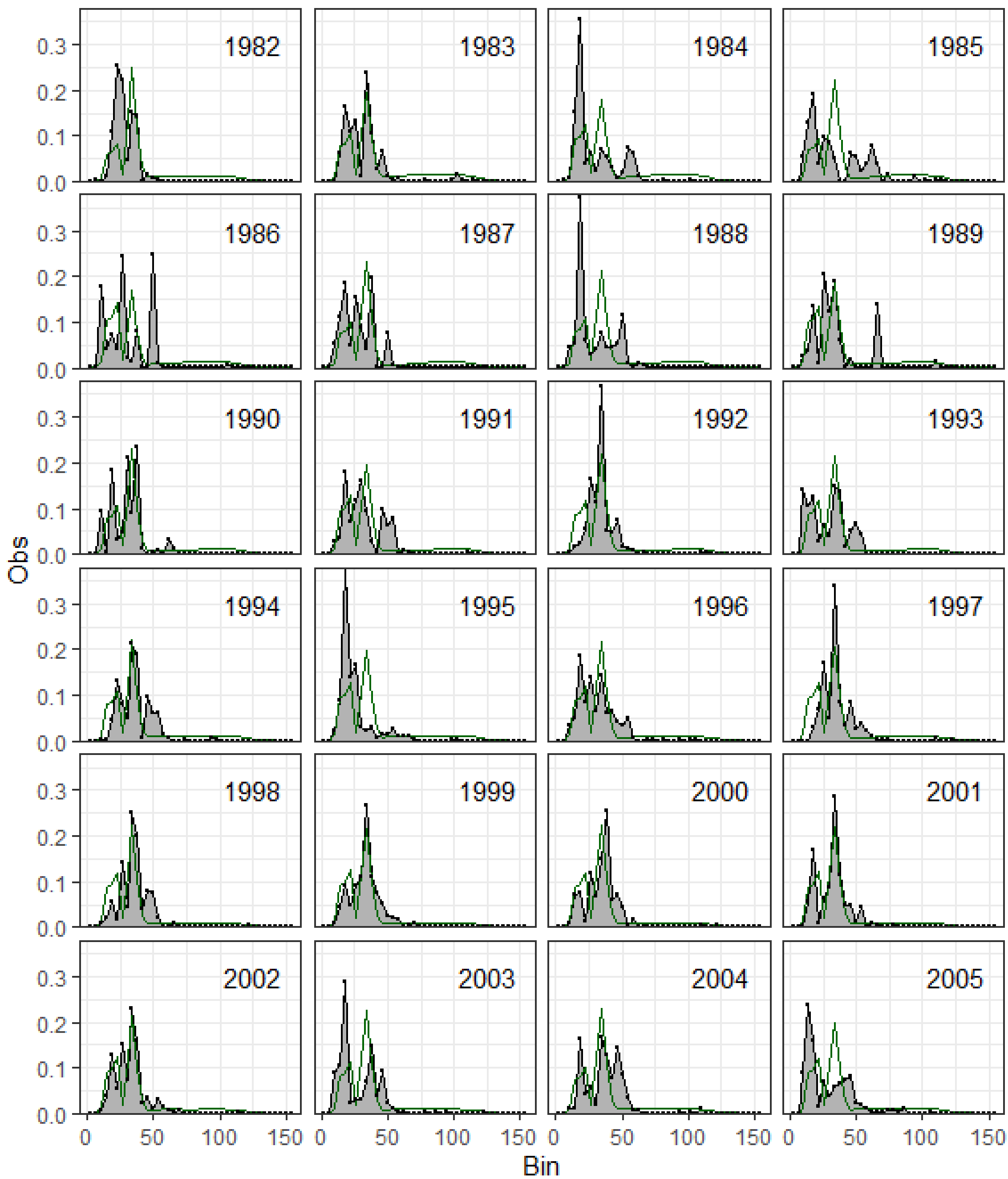


Fig. 15. Fit to length composition data (cm; 1982-2005) from Stock Synthesis Model using a spline selectivity curve.

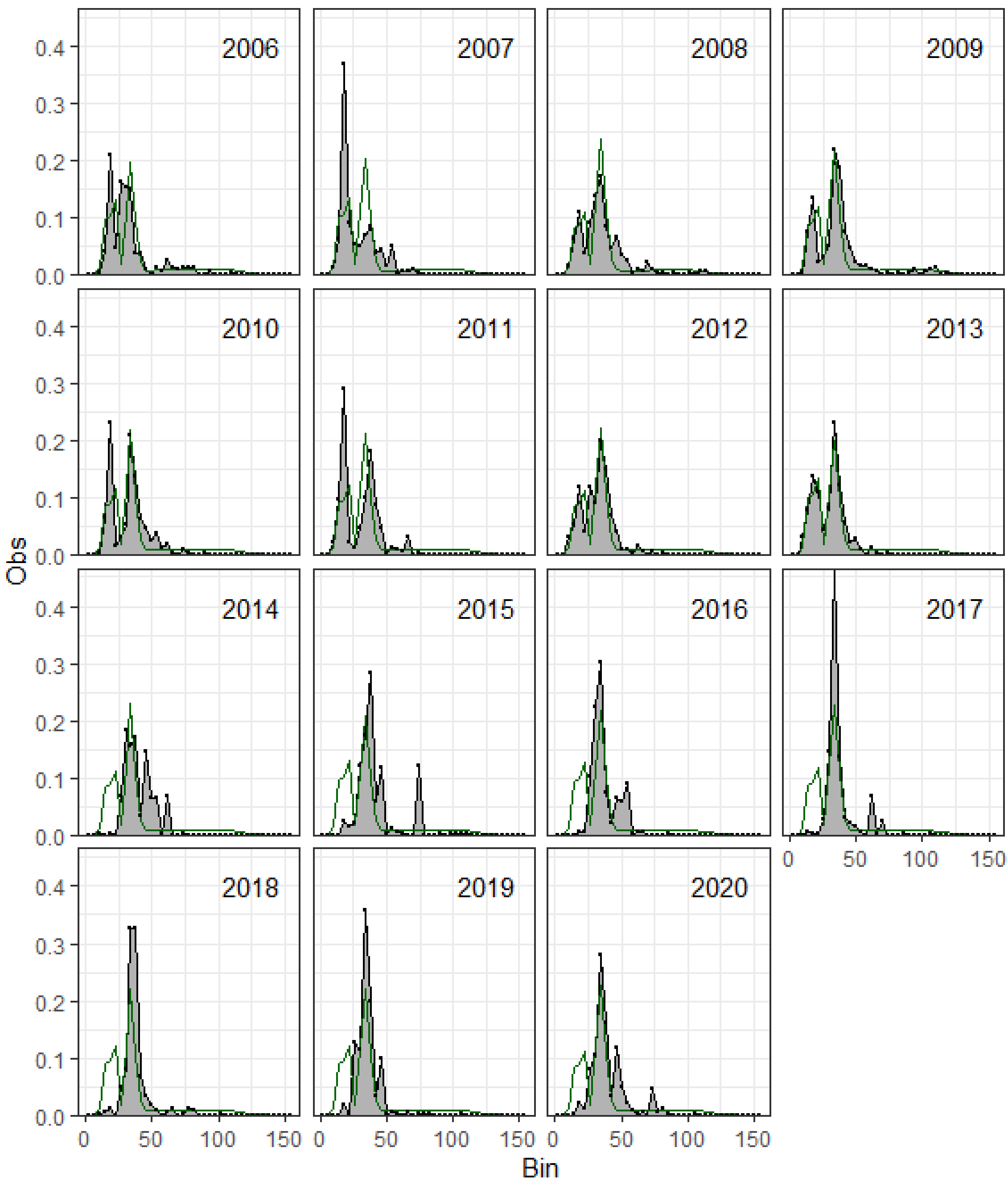


Fig. 16. Fit to length composition data (2006-2020) from Stock Synthesis Model using a spline selectivity curve.