Stock Assessment Report on the Red Drum *Sciaenops ocellatus* South Carolina Sub-Stock, 1981-2023

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EXECUTIVE SUMMARY

Red Drum in South Carolina are managed as part of the US Atlantic Coast southern stock, assessed by the Atlantic States Marine Fisheries Commission in June 2024. The peer reviewed assessment, accepted for use in management by the commission, modeled landings and fishery-independent data from 1981 to 2022 (terminal year for stock status 2021) to conclude the southern stock was overfished with overfishing occurring. Overfishing was indicated by high levels of fishing mortality (F; reported as age-2 F) that led to terminal year spawning potential ratios (SPR; $\overline{SPR}_{2019-2021} = 0.207$) below the defined $SPR_{30\%}$ threshold. Concomitantly, prolonged high F led to decreased spawning stock biomass (SSB) in the terminal years, reducing it below the defined threshold ($SSB_{30\%} = 9{,}917\ \text{mt}$ vs. $\overline{SSB}_{2019-2021} = 8{,}737\ \text{mt}$). ASMFC has set a management target of $SPR_{40\%}$, which requires a 28.1% regional reduction of total removals (harvest + dead discards) based on equilibrium projections at $F_{40\%}$ ($F_{40\%} = 0.301$ vs. $\bar{F}_{2019-2021} = 0.526$).

The purpose of this assessment was to evaluate the status of the sub-stock of Red Drum in SC, which represents a sub-component of the ASMFC assessed southern stock. The assessment was conducted using Stock Synthesis 3, an integrated statistical catch-at-length and -age model, with the original model based on the ASMFC southern stock model. This represents the second assessment of the SC sub-stock, with a previous assessment completed in 2017 through a 2016 terminal year (Murphy 2017). Herein, as done in the most recent ASMFC assessment and the previous SC assessment (Murphy 2017), we aligned data sources with a fishing year definition (September 1 – August 31). We calculated recreational dead discards assuming an 8% discard mortality rate, consistent with previous research and assessments. We defined the assessment period as 1981-2023, with some 2023 data still considered preliminary (e.g., marine recreational fisheries program (MRIP)) or unavailable (e.g., some age data from fishery-independent surveys).

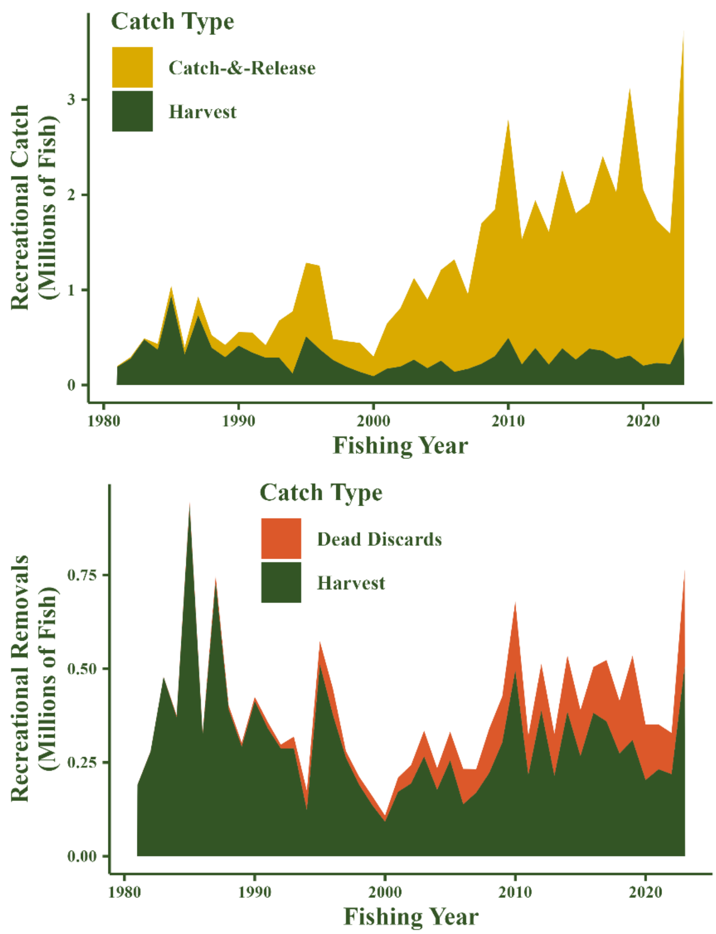


Figure 1: Recreational catch (top; harvest (green) + discards (yellow)) and removals (bottom; harvest (green) + dead discards (orange)) in SC from 1981-2023 (pers. comm. NOAA Offices of Fisheries Statistics). Note, harvest time series is the same in both figures and the fishing year runs form September 1 – August 31 annually (e.g., 2023 fishing year is 9/1/2023-8/31/2024). Dead discards calculated as 8% of fish reported released.

Recreational Landings and Discards

Red Drum landings in South Carolina are, and traditionally have been, exclusively recreational. A June 1987 law outlawed commercial harvest in SC, a pre-emptive move to discourage the development of a Red Drum commercial fishery in the state. MRIP provides a time series of SC harvest and live discard data for Red Drum for the 1981-2023 fishing years (Figure 1). Recreational harvest was high in the mid- to late-1980s, prior to the implementation of management measures. Direct harvest was reduced in the 1990s due to implementation of a series of management measures from the late-1980s through early-1990s. Since the late-1990s, total catch (Figure 1, top panel), and subsequently total removals (harvest + dead discards; Figure 1, bottom panel), have steadily increased due to the growth of the catch-and-release fishery in coastal SC. Removals since the early 2010s have been at, or exceeded, removals in the mid- to late-1980s with 2023 removals being the second highest observed throughout the entire time series.

Indices of Relative Abundance

For the SC sub-stock model, SC fishery-independent surveys were used to develop indices of long-term monitoring programs, namely the historical rotenone and stop net surveys, as well as the contemporary trammel net and adult Red Drum and shark longline surveys. These represent a mixture of recruitment, sub-adult, and adult relative abundance indices for SC Red Drum that were standardized using spatiotemporal Generalized Linear Mixed Effects Models (GLMMs) to account for environmental impact on abundance. The historical rotenone survey indicated above average recruitment in 1986, though a stable to decreasing trend through the survey's terminal year (1993). The stop net survey, which provided an index of sub-adult abundance from 1986-1993, varied without trend. In contrast, the trammel net survey, a sub-adult index, suggests a rapid decline in sub-adult abundance from the early-1990s through 1999, followed by higher abundances from 2000-2005 but then a decreasing trend to an all-time low in 2019. The adult Red Drum and shark longline survey, an adult index of relative abundance, suggests a decreasing adult abundance, with lowest abundances in 2010-2011 and 2021-2022.

Stock Synthesis Model

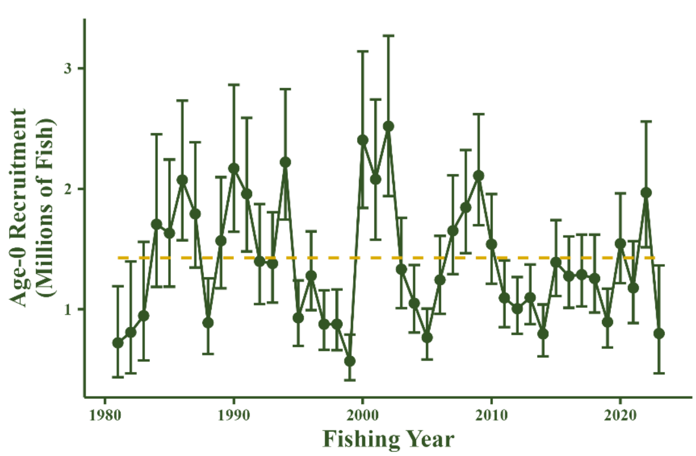


Figure 2: Annual age-0 recruitment (~ 4 months old; green line and dots) along with predicted average recruitment (dashed yellow line) for 1981-2023. Included is an approximate 95% confidence interval on annual recruitment (error bars).

Recruitment

The model estimated recruitment suggests variation around the time series average of 1.43 million recruits in SC, with individual year estimates ranging from a low of 0.57 million (1999) to a high of 2.52 million (2002; Figure 2). Modeled recruitment found ten year classes (1986, 1990-1991, 1994, 2000-2002, 2008-2009, and 2022) during the time series that were significantly above average, with only one (2022) occurring since 2010. Conversely, 15 year classes (1981-1982, 1988, 1995, 1997-1999, 2004-2005, 2011-2014, 2019, and 2023) were significantly below average, with six occurring since 2010.

Population Numbers

Population numbers increased through the 1980s, 1990s, and early-2000s. The rebound was supported by average to above average recruitment in coastal SC from 1984-1993 and the early-2000s (Figure 2) along with a series of fisheries management regulations restricting the exploitation of Red Drum in SC. Since the early-2000s, Red Drum numbers in SC have declined, from a series high of 5.96 million fish in 2002 to generally less than 3.5 million fish since 2014, with a recent low of 2.99 million fish in 2019.

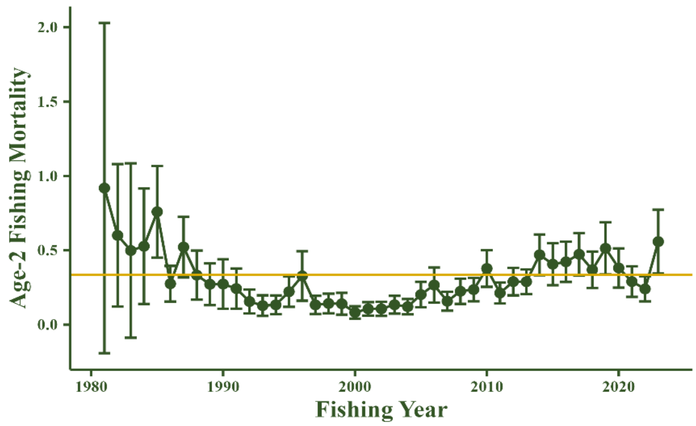


Figure 3: Age-2 fishing mortality (green line and circles) with 95% confidence intervals (error bars) throughout the assessment time series. Note, yellow horizontal line represents age-2 F associated with threshold SPR ($SPR_{30\%}$).

Fishing Mortality

With the series of regulation changes in the late-1980s and early-1990s, fishing mortality on age-2 Red Drum decreased in SC from series highs exceeding 0.6, with a maximum 0.92 (1981), to a series low of 0.08 by 2000 (Figure 3). Since, age-2 F has increased, exceeding $F_{threshold}$ ($F_{30\%} = 0.33$) since 2014, with the exception of 2021 and 2022. The terminal year age-2 fishing mortality was the highest observed since 1985.

Spawning Potential Ratio

Spawning potential ratio (SPR) varied throughout the time series (Figure 4). At the beginning of the time series, SPR was well below the threshold ($SPR_{30\%}$), though enactment of initial fishing regulations and some relatively strong year classes allowed SPR to rise above the threshold by 1989 and the target ($SPR_{40\%}$) by 1991, where it generally remained through the late-2000s. Since the early-2000s, annual SPR has decreased from the series' highs exceeding 0.7 (2000-2001), generally falling below target since 2010 and below the threshold since 2014. The terminal year SPR, 0.137, was the lowest observed since the early- to mid-1980s.

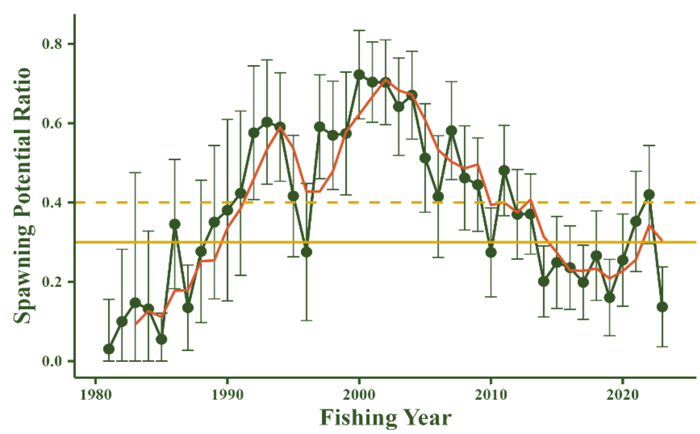


Figure 4: Target ($SPR_{40\%}$; dashed yellow line), threshold ($SPR_{30\%}$; solid yellow line), annual (green line and circles) and 3-yr average (red line) SPR for South Carolina Red Drum. For annual estimates, 95% confidence intervals are represented by the error bars.

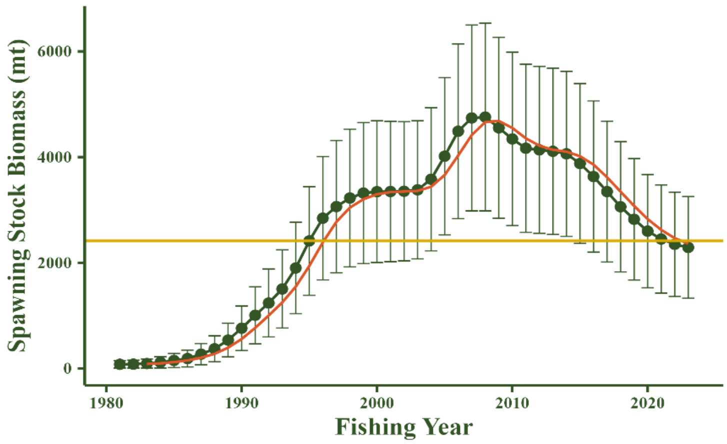


Figure 5:Threshold ($SSB_{30\%}$; yellow line), annual (green line and circles) and 3-yr average (red line) SSB for South Carolina Red Drum. For annual estimates, 95% confidence intervals are represented by the error bars.

Spawning Stock Biomass

Spawning stock biomass (SSB) varied throughout the time series (Figure 5). At the beginning of the time series, SSB was well below the threshold ($SSB_{30\%}$ = 2,416 mt), though enactment of initial fishing regulations and relatively strong recruitment allowed SSB to rise above the threshold by 1996, reaching a time series peak of 4,757 mt in 2008. Since 2008, annual SSB has decreased, first falling below the threshold again in 2022.

<u>Stock Status</u>

Overfishing Status

The thresholds for overfishing and overfished status used in the SEDAR 93 benchmark stock assessment were used for the SC sub-stock assessment. An $SPR_{30\%}$ was used as the threshold to define overfishing. The 3-yr terminal average SPR (2021-2023) was 0.303, higher than the $SPR_{30\%}$ threshold indicating overfishing was not currently occurring in the terminal year. However, this terminal year 3-yr average was bolstered by relatively strong year classes in 2020 and 2022. Before this, 3-yr average SPRs indicated overfishing occurred from 2015-2021. Without strong recruitment classes, overfishing has become common in recent years and strong recruitment years have become less common, suggesting increased risk of using the terminal year 3-yr average SPR estimates for management decisions. To this point, the terminal year SPR estimate was 0.137, the lowest recorded value since 1987.

Overfished Status

The spawning stock biomass has been in decline in the most recent 20 years, with a terminal 3-yr average SSB of 2,363 mt. Therefore, the SC sub-stock of Red Drum was overfished in the terminal year for the first time since the mid-1990s. Annual SSB estimates fell below the SSB threshold in 2022. The data provide a clear indication that the stock is overfished.

Projections

As Red Drum in SC are deemed overfished and given the low SPR estimates with 3-yr average being just at the threshold (SPR_{30}) and terminal year SPR below the threshold, reductions are necessary for sustainability of this stock. The current ASMFC FMP manages overfishing by reducing *F* to a level that results in an $SPR_{40\%}$ (SPR_{target}). Under current fishing effort, a reduction of 20.1% is needed to achieve an $SPR_{40\%}$. Once a 20.1% reduction in *F* is achieved, it would take 7 years for the stock to rebound to a threshold of 2,416 mt ($SSB_{30\%}$). However, to achieve a target SSB of 3,229 mt ($SSB_{40\%}$), the *F* would need to maintained at a reduced level for more than 40 years. A reduction of 20.1% includes a very strong year class that has only occurred once in the last 15 years. Without several more strong year classes, this projection would not likely occur. The regional model used a terminal year of 2019-2021, which did not include the large 2022 year class. To be consistent with the regional model and provide a more realistic expectation of needed projections, a projection with a 2019-2021 terminal year was implemented on the SC sub-stock model. A reduction of 23.8% is needed to achieve an $SPR_{40\%}$ (SPR_{target}). Once a 23.8% reduction is achieved, it would take 7 years for the stock to rebound to a threshold SSB of 2,416 mt ($SSB_{30\%}$) and 32 years to achieve a target SSB of 3,229 mt ($SSB_{40\%}$).

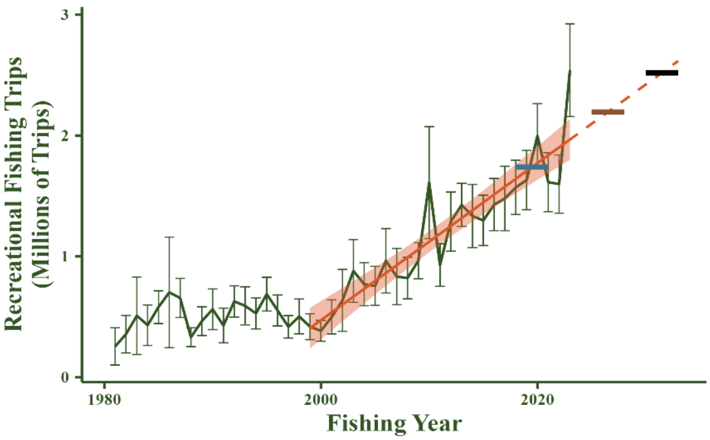


Figure 6: MRIP estimated trips (solid green line) identifying Red Drum as a primary or secondary target species or reporting capturing Red Drum in South Carolina annually. Shown also is a linear model of effort increase with time since 1999 (orange solid line), extrapolation of model past 2023 (orange dashed line) and linear model predicted average effort in 2018-2021 (blue bar), 2025-2028 (brown bar), and 2030-2033 (black bar). 95% confidence intervals about annual MRIP estimates (green error bars) and linear model (orange shaded region) also shown.

Note, the projections above assume no further increases in effort nor shifts in angler behavior in response to regulation changes. The first of these assumptions is unlikely, given we have seen consistent, linear increases in effort expended on Red Drum for the past 25 years (Figure 6). Under continued effort increases, additional reductions in annual total removals (harvested and discard mortality) are necessary to achieve target SPR.

<u>Conclusion</u>

The updated benchmark stock assessment suggests SC Red Drum benefited from initial management regulations in the late-1980s and early-1990s and a sustained period of average to above average recruitment from 1984-1993. These combined to allow age-2 fishing mortality to decrease through the 1990s and spawning potential ratio and spawning stock biomass to increase through the early- and late-2000s, respectively. However, while direct harvest has remained relatively constant from 1990 through the terminal year, dead discards arising from a growing catch-and-release fishery has led to an increase in total removals (a.k.a., dead removals) since the early-2000s. Increases in total removals resulted in increasing age-2 fishing mortality and decreasing spawning potential since the early-2000s, such that the stock has generally been experiencing overfishing since the mid-2010s. Additionally, increasing F and decreasing SPR has resulted in decreasing spawning stock biomass since the late-2000s, with SSB falling below threshold levels, and hence being deemed overfished, in 2022. Based on the lag between SPR and SSB, we anticipate SSB continuing to decline at least in the short-term and only rebound if fishing mortality is reduced and average to above average recruitment continues. Projections indicate the need for a 23.8% reduction in annual total removals is needed to achieve an $SPR_{40\%}$ using the terminal years 2019-2021 as completed in SEDAR 93, assuming no further increase in effort or increase in total removals. Further increases in angler behavior would necessitate greater catch reductions.

Summary of changes from the ASMFC Benchmark Assessment for the Southern Stock

- Increased terminal year to 2023
- Removed fishery-dependent and -independent data sources from FL and GA
- Standardized indices through spatiotemporal methods, where appropriate and suggested by information criterion (sdmTMB; recommended by ASMFC peer review)
- Fixed most growth parameters to ASMFC model estimates (all except the parameter for the growth coefficient *k* at age 1) to address growth concerns in model, likely caused by lack of age data within a sub-stock
- Truncated longline time series to 2010-2023 (recommended by ASMFC peer review) to remove potential bias from early year bait interactions)
- Used conditional age-at-length for trammel net index (recommendation to use conditional age-at-length composition with length composition from ASMFC peer review) to address concerns with potential "double dipping" with the use of marginal age composition and unconnected length compositions
- Used marginal age compositions for stop net index without length compositions (recommended by ASMFC) to correct potential "double dipping" data bias
- Partially fixed trammel net index selectivity to increase model performance
- Partially fixed stop net index selectivity to increase model performance
- Francis reweighting of composition data
- Reduced estimates of initial *F* to account for 1 fishing fleet rather than 3 fishing fleets (removal of GA and FL data sources)
- Reduced estimates of initial recruit deviations to account for 1 state sub-stock rather than entire 3 state stock (match removal of GA and FL data sources)
- Tuned bias adjustments for recruitment deviations using SS user manual (Methot et al. 2024)
- Tuned sigmaR fixed estimates using methods in SS user manual (Methot et al. 2024)

LIST OF ABBREVIATIONS

ACCSP	Atlantic Coastal Cooperative Statistics Program
ACFCMA	Atlantic Coastal Fisheries Cooperative Management Act
ALK	Age-Length Key
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
CHTS	Coastal Household Telephone Survey
CPUE	Catch per Unit Effort
DO	Dissolved oxygen (mg/L)
DOY	Day of Year
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
F	Fishing Mortality
FES	Fishing Effort Survey
FHOC	Fish Habitat of Concern
FHS	For-Hire Survey
FD	Fishery-Dependent
FI	Fishery-Independent
FL	Fork Length
FMP	Fishery Management Plan
GLM	Generalized Linear Model
GLMM	Generalized Linear Mixed Effects Model
MGFTP	Marine Game Fish Tagging Program
MRFSS	Marine Recreational Fisheries Statistics Survey
MRIP	Marine Recreational Information Program
MRRI	SCDNR Marine Resources Research Institute
MSP	Maximum Spawning Potential
NMFS	National Marine Fisheries Service
OY	Optimum Yield
PSE	Percent Standard Error
PSU	Practical Salinity Unit
RSE	Relative Standard Error
SAFMC	South Atlantic Fisheries Management Council
SCAA	Statistical Catch-at-Age
SCDNR	South Carolina Department of Natural Resources
SEDAR	SouthEast Data, Assessment, and Review
SL	Standard Length
SPR	Spawning Potential Ratio
SS	Stock Synthesis
SSB	Spawning Stock Biomass
SSBR	Spawning Stock Biomass per Recruit
TL	Total Length
VPA	Virtual Population Analysis
YOY	Young-of-the-Year

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Management

1.1.1 Management Unit

The Atlantic States Marine Fisheries Commission (ASMFC) manages Red Drum under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) in U.S. Atlantic coast waters from FL through NJ. Two management stocks have been defined: a southern stock, which occurs from the east coast of FL through SC, and a northern stock, which occurs from NC through NJ. Herein, this assessment is looking at the dynamics of a sub-stock found within the larger, broader geographic scale of the southern stock as defined by ASMFC.

1.1.2 Regional Management History

ASMFC adopted a Fishery Management Plan (FMP) in October 1984, which was designed to address recreational-commercial conflicts, and examine data needs to define optimum yield (ASMFC 1984). At the time, ASFMC managed Red Drum in tandem with the South Atlantic Fishery Management Council (SAFMC), with SAFMC and ASMFC managing Red Drum in federal and state waters, respectively. The original FMP recommended states institute a 14″ (356 cm) total length (TL) minimum length limit with comparable mesh size regulations instituted to minimize harvest of small fish in directed fisheries. Similarly, it recommended states bar possession of more than 2 fish at 32″ (81 cm) TL and greater day^{-1} and prohibit purse seining for Red Drum.

Additional changes to Red Drum management occurred in November 1990 when the SAFMC adopted language consistent with the Magnuson-Stevens Fishery Conservation and Management Act of 1976, which included defining overfishing and optimum yield (OY). Further, the SAFMC FMP prohibited harvest of Red Drum within the Exclusive Economic Zone (EEZ), a moratorium which remains in effect today. The SAFMC also recommended states implement measures to constrain harvest and defined OY as the harvest amount that could be taken while maintaining spawning stock biomass per recruit (SSBR) at or above 30% (i.e., spawning potential ratio, or SPR, of 30%). The adoption of the SAFMC FMP, and its recommendations, precipitated Amendment 1 to the ASMFC Red Drum FMP (effective October 1991), which adopted the SAFMC FMP for Red Drum and recommended complimentary measures for states to achieve OY. Amendment 1 to the ASMFC FMP recommended states adopt either an 18-27″ (46-69 cm) TL slot limit and 5 fish person^{-1} bag limit or a 14-27″ (36-69 cm) TL slot limit and 5 fish person^{-1} bag limit.

In October 1998, Amendments 1 and 2 to the SAFMC FMP both went into effect. Amendment 1 updated the definition of maximum sustainable yield (MSY) to $SPR_{30\%}$ (i.e., $SPR_{threshold}$ defining overfishing) and OY as $SPR_{40\%}$ (i.e., SPR_{target}). Amendment 2 identified, described, and recommended measures to protect Essential Fish Habitat (EFH) and EFH Habitat Areas of Particular Concern for Red Drum as part of the SAFMC's comprehensive habitat amendment (SAFMC 1998).

In 1999, the SAFMC recommended management authority for Red Drum be transferred to the states under the ACFCMA. The subsequent amendment to the ASMFC FMP, Amendment 2, moved the management authority of Red Drum from the SAFMC to the States in June 2002 (ASMFC 2002) and serves as the current management plan. The amendment required states to implement recreational creel and size limits to achieve the fishing mortality target, including a maximum size limit of 27″ (69 cm) TL, and maintain existing or more conservative commercial regulations. A harvest moratorium and Presidential Executive Order, enacted in 2007, prevents any harvest or sale of Red Drum from federal waters.

Outside of ASFMC Addendum I to Amendment 2 to the Red Drum FMP (August 2013), which updated the habitat section of Amendment 2, the regional FMP requirements set forth in the original ASMFC FMP and modified in Amendment 1 remain in place today. In short, this includes defining $SPR_{threshold}$ as $SPR_{30\%}$ and SPR_{target} as $SPR_{40\%}$ (which was previously defined as OY). The regulatory side includes a minimum 14″ (36 cm) TL size limit and a maximum 27″ (69 cm) TL size limit, with a recommendation that states implement either a 14-23″ (36-58 cm) TL or 18-27″ (46-69 cm) TL 9″ slots. Further, states are required to implement recreational creel and size limits, within the above bounds, that achieve the fishing mortality target (i.e., $SPR_{40\%}$) and maintain existing or more conservative commercial regulations while the harvest or sale of Red Drum from federal waters remains illegal.

1.1.3 SC Management History

In parallel with the development and amendments of the regional ASMFC FMP, SC enacted a series of regulations and laws to constrain Red Drum harvest in SC, beginning with the implementation of a 14″ TL (36 cm) TL minimum size limit from June 1 to September 1 and a possession limit of 1 fish greater than 32″ (81 cm) TL in June 1986 (Table 1.1). Several additional regulatory changes were implemented through June 1993 (Table 1.1) to bring the state into compliance with the original ASMFC FMP, SAFMC FMP, and Amendment 1 to the ASMFC FMP. SC regulations included designation of Red Drum as a game fish (effective June 30, 1987), which prohibited the sale of native fish effectively banning commercial harvest, and culminating in a 14-27″ (36-69 cm) TL slot limit and 5 fish $person^{-1}$ daily bag limit (effective June 11, 1993).

Additional measures to constrain Red Drum harvest in SC and achieve the fishing mortality target based on regional or state assessments (see below) were implemented in 2001, 2007, and 2018 (Table 1.1). As a result, today's regulations for Red Drum specifies a 15-23″ (38-58 cm) TL slot limit, a 2 fish $person^{-1}$ day^{-1} and 6 fish $boat^{-1}$ day^{-1} bag limit while maintaining gamefish status and hence a ban on commercial and recreational sell.

1.2 Stock Assessment History

Red Drum are assessed and managed regionally through the implementation of ASMFC coastwide stock assessments. Nine previous assessments have been completed for Red Drum in Atlantic waters, though stock definitions have changed over time (Vaughan and Helser 1990; Vaughan 1992; Vaughan 1993; Vaughan 1996; Vaughan and Carmichael 2000; SEDAR 2009; SEDAR 2015; ASMFC 2017, ASMFC 2024b). There has also been one state-specific assessment of the SC sub-stock (Murphy 2017).

1.2.1 Regional Stock Assessments

The first three assessments focused on one Atlantic coastwide (NJ through east coast of FL) stock that used catch curves and virtual population analyses (VPAs) to assess young Red Drum (Vaughan and Helser 1990; Vaughen 1992; Vaughan 1993). The analyses focused on the catch age composition of Red Drum ages 0-5 to focus on populations prior to migration, to remove the effect of emigration as fishing pressure was predominantly inshore on the younger ages. Management of the species focused on escapement through age-5, which was deemed to be too low for sustainability in these early assessments. Paired with high mortality and low SPR, the original FMPs and FMP amendments were established to manage the population (Section 1.1.2).

In the 1996 assessment, enough scientific evidence was provided to split the Atlantic coastwide stock into a northern and southern stock, with the division at the NC and SC state line (Vaughan 1996). The assessment continued to use VPAs but with indices of abundance and catch rather than just catch. One concerning trend apparent in the assessment was the increasing number of Red Drum being released alive as the number of dead discards is assumed to be 8% of the live releases. Increasing live releases and the application of an 8% post-release morality rate to live releases led to an increase in estimated dead discards. The highly regulated recreational fishery was becoming more of a catch and release fishery, with the number of dead discards proportionally increasing each year with the increase in live releases. High mortality and low SPR estimates were still the conclusion (Vaughan 1996).

The 2000 benchmark stock assessment examined more VPA models, as well as a simple statistical catch-at-age model for both stocks (SCAA; Vaughan and Carmichael 2000). The forward projecting SCAA depicted an increasing SPR, but overfishing was still occurring within the southern stock. In 2009, SEDAR 18 used new SCAA models that allowed for more data to be used (SEDAR 2009). The *F* could be estimated using catch, indices, age composition, and life history information (growth, maturity, and natural mortality), that could then be used to estimate SPR for status determination. The increase in data and model complexity led to increased uncertainty in the model estimates, which was noted by the peer review panel (RP) when the model was accepted for management. The new SCAA model was the first to conclude overfishing was not occurring for the southern Red Drum stock.

With the development of Stock Synthesis (SS), an integrated analysis framework (Methot and Wetzel 2013), subsequent Red Drum assessments attempted to transition to the new model (SEDAR 44; SEDAR 2015). The early models had poor stability and resulted in SPR estimates that indicated overfishing throughout the entire time series. The model was not accepted by the South Atlantic State/Federal Fisheries Management Board for management use and another stock assessment was undertaken. The 2017 benchmark assessment (SEDAR44) used the SCAA used in SEDAR 18 and had similar results to SEDAR 18 indicating overfishing was not occurring (ASMFC 2017). The fishery-independent indices corroborated the model results, so the issue was believed to be a scaling problem within the SS model. Additional research into potential models was conducted in 2022 with the development of a simulation assessment that tested SS capabilities with data sources available for the Red Drum stock (ASMFC 2022). The conclusion from the simulation assessment was that SS was the preferred modeling software for the next benchmark assessment.

In 2024, ASMFC completed a new benchmark assessment of Red Drum (SEDAR 93), using the SS framework, where SC is again represented in the southern stock (ASMFC 2024b). The SEDAR 93 assessment updated the annual time step from a calendar year definition (used in all previous assessments) to a fishing year (Sept. 1 – Aug. 31) definition more aligned with Red Drum life history and fishery interactions with the species. It used available catch (harvest and live discard), length- and age-composition (catch and surveys), FI index data, and life history information available from fishing year 1981 (Sept. 1, 1981 – Aug. 31, 1982) through fishing year 2022 (Sept. 1, 2022 – Aug. 31, 2023). SEDAR 93 maintained the FMP defined SPR threshold ($SPR_{30\%}$) as the biological reference point to identify overfishing and defined an analogous spawning stock biomass (SSB) threshold as the spawning stock biomass associated with equilibrium fishing at $SPR_{30\%}$, called $SSB_{30\%}$. The SSB threshold defined the biological reference point defining an overfished stock status, with a target SSB identified as $SSB_{40\%}$ based on equilibrium SSB when fishing at $SPR_{40\%}$. As several data sources were unavailable for fishing year 2022, the terminal year for stock status determination based on 3-yr average SPR and SSB estimates relative to $SPR_{30\%}$ and $SSB_{30\%}$ was 2021. SEDAR 93 passed peer review in August 2024 and was accepted by the ASMFC Sciaenids Management Board for management use (October 2024). The SEDAR 93 model indicated the southern stock has been experiencing overfishing annually since fishing year 2013 and based on 3-yr averages since 2013 (2012-2014 avg. SPR). The southern stock was below $SSB_{30\%}$ annually since the 2019 fishing year and transitioned to overfished (based on 3-yr SSB averages) in 2019 (2018-2020 avg. SSB).

1.2.2 Previous SC Stock Assessments

SC Red Drum have been assessed as part of the ASMFC assessments since the 1980s (see previous section), within either a coastwide stock or southern stock. However, a SC sub-stock assessment was desired given the mid-2010s assessment's (SEDAR 2015; ASMFC 2017) uncertainty regarding stock status, concerns due to declining trends in SC FI indices, and declining angler satisfaction (Murphy 2017). The 2017 SC sub-population assessment used a SCAA model, a SS model including tag-recapture data, and a SS model excluding tag-recapture data. All three models used length-and age-composition data, catch, effort, and indices of relative abundance with a fishing year definition as defined in the recent regional benchmark. All three models had similar results suggesting the abundance of Red Drum in SC was low in the terminal year. Abundance of juveniles and sub-adult Red Drum increased in years with above average recruitment, despite high levels of fishing, but above average recruitment was highly variable. In fact, recruitment slowly declined overall through the time series. Fishing mortality did decrease in the 1990s with the implementation of management actions, and the abundance of sub-adults and adults increased in subsequent years. With the increased popularity of the catch-and-release fishery, the fishing mortality rate started to increase after 2000 (increased number of dead discards, defined as 8% of live discards), and recruitment declined rapidly in the late 2000s. The conclusion of the 2017 SC sub-stock model was the population was experiencing overfishing.

1.3 Purpose

The intent of this assessment is to adapt the methods of SEDAR 93 southern stock model to assess the SC sub-stock. As such, this assessment uses only South Carolina catch (harvest and live discards with 8% discard mortality rate) and FI index data, with the goal being to provide the necessary information for management strategies within SC. The breadth of data collected in SC is suitable to complete a full stock assessment of the sub-stock. Additionally, SCDNR tagging data suggests most sub-adult and adults tagged in SC exhibit localized home ranges, with few recaptures occurring out of the state. Thus, the state sub-stock assessment was developed to investigate potential localized depletion of Red Drum, above and beyond what is suggested by the SEDAR 93 southern stock assessment. This report is not an exhaustive list of details about Red Drum, but a distilled synthesis of information necessary to complete a SC sub-stock assessment. For more information about Red Drum, the southern stock of Red Drum, or model considerations in SEDAR 93, please refer to the ASMFC report (ASMFC 2024b).

2. LIFE HISTORY

The majority of life history information used in the SEDAR 93 southern stock was derived from age and reproductive data collected from fish captured in SC. While samples were provided from FL and GA, more than 50% of the samples were from SC. As such, no attempt was made to re-evaluate SC specific life history inputs herein.

2.1 Stock Definition

Found in nearshore and estuarine waters of the U.S. Atlantic Ocean from Massachusetts into the Gulf to northern Mexico (Lux and Mahoney 1969; Mercer 1984), Red Drum are split into three stocks: North Atlantic Stock, South Atlantic Stock (southern stock), and Gulf Stock. These stocks have different life history characteristics and genetic structures (Turner et al. 1999; Chapman et al. 2002; Cushman et al. 2014). Additionally, conventional tagging studies from SC indicate little movement between states, thus little movement between stocks. Given the stock structure along the Atlantic coast, Red Drum found in SC waters are considered a sub-stock within the broader southern stock with evidence to suggest localized depletion could be of concern based on movement and migration data from tagging studies (see Section 2.2).

2.2 Migration Patterns

Tagging information provides the best insight into the movement and migration of Red Drum along the Atlantic coast. Red Drum have been tagged by GA, SC, NC, and VA. While there is clear evidence of adult Red Drum movement between VA and NC, there is a conspicuous lack of evidence of broad-scale movement in the southern states (GA and SC). Of 1,780 fish tagged in GA, 85.3% were recaptured within GA state waters, 11.0% were recaptured in SC, and 3.7% were recaptured in FL (ASMFC 2024b).

In SC, based on recaptures of 47,520 fish, 99.7% were recaptured in SC with only 0.3% recaptured in neighboring states. Those recaptured out of SC were recaptured in NC (n = 83), GA (n = 31), FL (n = 29), and NJ (n = 1). These patterns also were consistent when considering only recaptures of adult (>75 cm TL; n = 6,905) fish, with 99.8% being recaptured in SC. Looking at cumulative percentage recaptured as a function of straight-line distance, regardless of age, most were recaptured within 50 km of their original tagging location with only 147 fish recaptured >150 km (maximum 467 km) from their original tagging location and a tendency for larger distances moved with more time-at-large (Figure 2.1). Thus, raising the possibility of localized depletion of Red Drum along coastal SC because of localized fishing pressure.

2.3 Age and Growth

The Red Drum age data collected from the southern stock used in SEDAR 93 were provided by state and academic agencies from FL (only east coast FL used) through SC. Ages were available from 30,054 Red Drum, of which 19,949 were collected and processed by SC (Table 2.1). Across all years, fish captured and aged from SC represented 66% of the available age data for the southern stock, including the oldest fish aged. Age and growth life history traits estimated by the SEDAR 93 southern stock were maintained for the SC sub-population assessment given these values were not likely to change from the full population to a partial population.

2.3.1 Maximum Age

The current maximum observed age of Red Drum based on sectioned otoliths is 41 years in SC, which also represents the oldest fish aged for the southern stock in SEDAR 93.

2.3.2 Growth

Red Drum growth has been well documented to be heavily influenced by seasonal factors, as well as varying based on year class strength (Porch et al. 2002; Cadigan 2009), making it difficult to estimate Red Drum growth using traditional von Bertalanffy growth models (Porch et al. 2002; Cadigan 2009). While growth can be captured by other means more appropriately (Porch et al. 2002; Cadigan 2009), SS is not compatible with these more custom growth models (Methot et al. 2024). SEDAR 93 resolved the conflict by using the age-varying Brody growth coefficient (*k*) von Bertalanffy growth function (Methot et al. 2024; age-varying *k* growth), which allows growth to be defined by von Bertalanffy growth parameters: L_∞, k_{base}, k_{mult1}, and k_{mult2}. Multipliers are used at specified ages to allow the growth coefficient to change. The multipliers allow growth to change outside of the typical von Bertalanffy growth model based on the observed growth of the species through time. The *k*-multiplier is applied at user-specified break points in the life of the Red Drum, effectively changing the *k* growth parameter at that age and older, until the maximum age of the fish or another break point is specified. The resulting flexibility, paired with the allowance of variation in growth through specified smallest/largest sizes and coefficients of variation (CVs) around the values, creates a more biologically realistic growth curve for a species with dynamic growth.

Two break points are implemented for the *k* growth parameter within the SC sub-stock model, which were the same points in SEDAR 93 (ASMFC 2024b). The break points were calculated externally using segmented regression on observed mean length-at-age data from the southern stock within a von Bertalanffy growth model, then applied to the SS model. The best fit model suggested breaks for the southern stock at ages 1.250 and 6.167 years, with estimated parameter estimates for L_∞, k_{base}, k_{mult1}, and k_{mult2} of 113 cm TL, 0.296, 0.731 (corresponding $k = 0.216$) and 0.192 (corresponding $k = 0.041$), respectively (Table 2.2). The final southern stock base model used these values as starting points for the model; however, the parameters were allowed to vary within the model with the data input through various other data sources. This results in a model estimated (internal estimate) of von Bertalanffy growth parameters based on the population model and data interactions. Given the loss of age-at-length data from removing GA and FL data sources, von Bertalanffy asymptotic length (L_∞) and the base Brody coefficient (k_{base}) growth parameters were fixed at the final value estimates from the southern stock model within the SC sub-population model (Figure 2.2; Section 4.1.2.5).

2.4 Reproduction

Herein we report on the understanding of Red Drum reproduction, based on peer-reviewed studies, previous assessments, and data submitted by data providers for the SEDAR 93 stock assessment (ASMFC 2024b).

2.4.1 Spawning Seasonality

Spawning occurs throughout the species range between August and October (Murphy and Taylor 1990; Ross et al. 1995; Luczkovich et al. 1999; Lowerre-Barbieri et al. 2008). Peak timing of spawning aggregations has a spatial component, with lower latitudes occurring later than higher latitudes. The Gulf and FL spawning aggregations peak in September to October (Murphy and Taylor 1990). Aggregations were monitored via acoustic telemetry off the coast of GA between August and mid-October (Lowerre-Barbieri et al. 2008). In SC, histological analyses reveal peak spawning occurs between August and September (SCDNR unpublished data), while peak spawning in NC is between August and October (Ross et al. 1995; Luczkovich et al. 1999). In all locations, the spawning season occurs within a 45-60 day window.

2.4.2 Sexual Maturity

During SEDAR 93 (ASMFC 2024b), the maturity ogive of the southern stock was re-assessed using updated histological maturity assessments available from SC and to reflect our fishing year definition (September 1 – August 31) assuming a September 1 birthdate. As all data needed in the SC sub-stock were already derived for SEDAR 93 southern stock, there was no need to re-analyze the data for the current assessment. Best fit logistic size- and age-at-maturity ogives, as estimated in SEDAR 93 (ASMFC 2024b) are provided in Table 2.3. The length-at-maturity ogive suggested 50% maturity for females is attained at 77 cm TL (95% CI: 75-78 cm TL; Figure 2.3)

2.4.3 Sex Ratio

The literature supports the assumption of a 1:1 sex ratio for Red Drum (Ross et al. 1995; Wilson and Nieland 1994) and a 1:1 sex ratio has been assumed in all previous state and regional assessments. Herein, we continue to assume a 1:1 sex ratio for the SC sub-stock for the current assessment.

2.4.4 Spawning Frequencies

Spawning frequencies were estimated using SC data on histologically derived reproductive stage information. Adult female Red Drum captured from mid-August through September (n = 168 mature females) were used to estimate the probability of females actively spawning on any given day (Brown-Peterson et al. 2011). The resulting probability (29.8%) was divided by the number of mature females encountered to determine the spawning frequency (Spawning Frequency = 1/daily probability of spawning = 1/.298 ≈ 3.4 days). The spawning frequency was then used to estimate the number of spawns (# of spawns = spawning season length/spawning frequency = 45 / (1/.298) ≈ 13.4 spawns). These estimates are consistent with estimates available from the northern Gulf, where Wilson and Nieland (1994) estimated a spawning frequency of females of every 2 to 4 days.

2.4.5 Spawning Location

Adult Red Drum spawn in nearshore environments, with locations in SC documented in passes and channels (Wenner 2000). Additional evidence reveals spawning locations coincide with high salinity estuaries (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994; Luczkovich et al. 1999; Beckwith et al. 2006).

2.4.6 Batch Fecundity

The FL Fish and Wildlife Research Institute conducted a batch fecundity study in 2008 using Red Drum collected from Tampa Bay (S. Burnsed, pers. comm.). These estimates were limited geographically and in the number of small mature females in the analysis, so SEDAR 93 (ASMFC 2024b) used female spawning stock biomass as a proxy. The use of spawning stock biomass as a proxy for reproductive potential is common when batch fecundity, and hence estimates of annual egg production, estimates are unavailable for the population. The proxy use was maintained in the SC sub-stock model.

2.5 Natural Mortality

Natural mortality, *M,* is a crucial component of stock assessments that contributes to a large source of uncertainty in most models (Vetter 1998, Hampton 2000, Maunder et al. 2023). It is difficult to estimate given it's caused by natural death of individuals in a population, as well as human-induced events not associated with fishing, and can be confused with emigration on an individual level (Gulland 1983; Hilborn and Walters 1992; Quinn and Deriso 1999; Haddon 2011; Maunder et al. 2023). Even after *M* is estimated for a population, its treatment within a model can vary (constant, size-dependent, or age-dependent) and potentially impact model performance (Hilborn and Walters 1992; Quinn and Deriso 1999; Haddon 2011; Lorenzen 2022).

For SEDAR 93 (ASMFC 2024b), estimates of *M* were calculated using the 'generalized length-inverse mortality (GLIM)' paradigm (Lorenzen 2022), which estimates *M* in relation to a von Bertalanffy growth parameterization with age varying growth coefficient, *k*. Estimates of constant *M* were then scaled based on the longevity model (Hamel and Cope 2022) where $M_{scalar} = 5.4/t_{max}$ and t_{max} represents the maximum age for the SC sub-stock (i.e., $t_{max} = 41$). Natural mortality estimated in SEDAR 93 was used in the SC sub-stock assessment (Table 2.4; Figure 2.4).

2.6 Habitat Description

Red Drum habitat information has been well documented through time in multiple areas of the species range. A detailed report on sciaenid species habitat has been produced by Odell et al. (2017). Additionally, fish habitat of concern (FHOC) designations have been examined by the ASMFC in 2024 (ASMFC 2024a). Additional details on Red Drum habitat use can also be found in the regional assessment (ASMFC 2024b).

2.6.1 Spawning, Egg and Larval Habitat

2.6.1.1 Spawning Habitat

Spawning aggregations of Red Drum form in summer at nearshore habitats within estuaries close to inlets, passes, bay mouths, or other similar environments deep in the estuary (Pearson 1929; Miles 1950; Simmons and Breuer 1962; Yokel 1966; Jannke 1971; Setzler 1977; Music and Pafford 1984; Holt et al. 1985; Peters and McMichael 1987; Murphy and Taylor 1990; Johnson and Funicelli 1991). Red Drum spawn between August and October in a 45-to-60-day window, using high-salinity estuarine areas (Murphy and Taylor 1990; Johnson and Funicelli 1991; Nicholson and Jordan 1994; Woodward 1994; Luczkovich et al. 1999; Beckwith et al. 2006; Renkas 2010). Research in the Indian River Lagoon, FL, used acoustic telemetry to document large adult Red Drum forming spawning aggregations within the estuary and collected preflexion (2-3 mm) larval Red Drum up to 90 km away from the nearest Ocean inlet (Reyier and Shenker 2007; Reyeir et al. 2011).

Laboratory studies indicate spawning activities are temperature dependent, with optimal conditions occurring between 22° and 25°C but spawning likely between 22° and 30 °C (Holt et al. 1981). In SC, Charleston Harbor environmental conditions were mimicked in a mariculture setting and eggs were released when temperatures dropped below 30°C but release ceased below 25°C (Renkas 2010). Released pelagic eggs hatch within 18 to 30 hours and are carried by currents to estuarine environments that serve as nursery habitats due to high productivity levels (Peters and McMichael 1987; Beck et al. 2001; Sink et al. 2018).

2.6.1.2 Eggs and Larvae Habitat

Red Drum eggs are found in high salinity estuaries along the southeast Atlantic coast, which are necessary for eggs to stay pelagic (Holt et al. 1981; Nelson et al. 1991; Reyier and Shenker 2007; Renkas 2010). Laboratory studies revealed optimal hatching conditions for Red Drum eggs were 25°C and 30 ppt, and below 15 ppt, eggs would sink (Holt et al. 1981; Neill 1987). Eggs and larvae are transported further into the estuarine habitats spawning adults aggregate in, where Red Drum remain until late juvenile stages (Holt et al. 1983; Peters and McMichael 1987; Johnson and Funicelli 1991; Nelson et al. 1991; Pattillo et al. 1997; Rooker and Holt 1997; Rooker et al. 1998; Stunz et al. 2002).

Speed of hatching and larval development is temperature dependent (Holt et al. 1981; Sink et al. 2018). Larvae settle within 20 days of hatching (Rooker et al. 1999; FWCC 2008), but this has been documented to occur faster in the Charleston Harbor (Daniel 1988). Late-stage larvae and juveniles utilize demersal habitats in lower salinity environments (Pearson 1929; Mansueti 1960; Bass and Avault 1976; Setzler 1977; Weinstein 1979; Holt et al 1983; McGovern 1986; Peters and McMichael 1987; Daniel 1988; Holt et al. 1989; Comyns et al. 1991; Rooker and Holt 1997). Larvae develop rapidly but growth is still dependent on environmental conditions (Baltz et al. 1998). Information about survival of larval and juvenile Red Drum are lacking, which limits the ability to relate young-of-year abundance to adult abundance (Cushing 1975; Houde 1987; Rooker et al. 1999).

2.6.2 Juvenile and Adult Habitats

2.6.2.1 Juvenile Habitat

Juvenile Red Drum remain in estuaries but utilize a wider range of demersal habitats in lower salinity reaches of the estuaries, such as emergent wetlands, estuarine scrub/shrub, submerged aquatic vegetation, oyster reefs, shell banks, and unconsolidated bottoms (SAFMC 1998; Odell et al. 2017). Habitat preference for juveniles is to associate with structure and vegetation for protection, as small Red Drum over sand bottoms are more vulnerable to natural predators (Stunz and Minello 2001). Additionally, vegetated areas and protected, calmer waters provide more protection than areas predominated by wave actions (Stunz and Minello 2001). Juveniles inhabit small creeks that still contain water at low tide, but during their first winter will move into deeper channels that have more stable temperature conditions (Peters and McMichael 1987; Wenner 1992; FWCC 2008). Warmer temperatures in the spring allow juvenile Red Drum to move back into shallower areas (Pearson 1929).

2.6.2.2 Sub-Adult Habitat

As juveniles continue to develop, Red Drum disperse throughout the estuaries, leaving the nursery habitat around 20 cm TL (10 months of age; C. Wenner, pers. comm.). Sub-adults do not sexually mature until 3 to 5 years of age; during this time, they remain in estuaries within a wider range of habitats depending on temperature and food availability (Pafford et al. 1990; Woodward 1994). Even with increased movements within an estuary, sub-adult Red Drum are vulnerable to exploitation due to possessing small geographical ranges within an estuary (Beaumarriage 1969; Osburn et al. 1982; Music and Pafford 1984; Pafford et al. 1990; Wenner et al. 1990; Ross and Stevens 1992; Woodward 1994; Marks and DiDomenico 1996; Adams and Tremain 2000; Troha 2023). The small geographical range and high exploitation rates of sub-adults lead to concerns about localized depletion within a given estuary, thus justification for exploring a sub-stock level assessment in context to a whole population assessment.

2.6.2.3 Adult Habitat

There is a lack of information about the habitat used by mature Red Drum. Spending time in coastal waters, adult Red Drum have seasonal movements inshore. High salinity surf zones and artificial reefs are noted as EFH for Red Drum by the SAFMC's habitat plan (SAFMC 1998). Also, adult Red Drum are targeted by fishermen on nearshore and offshore hard/live bottom habitats. Nicholson and Jordan (1994) documented high site fidelity at natural and artificial reefs along tide rips or plumes of major rivers, furthering the concern for potential localized depletion in specific highly fished system. In SC, tagged adult Red Drum moved an average of 46 km after being at-large for 15+ years (0.6-179 km; SCDNR unpublished data). In GA, adults moved 9-22 km offshore in the winter, then returned to the same locations where they were tagged (Nicholson and Jordan 1994).

2.6.3 Fish Habitat of Concern

The ASMFC Habitat Committee produced fish habitats of concern (FHOC) designations for Red Drum based on life stage in 2024 (ASMFC 2024a). Early juvenile FHOCs listed protected marshes in various salinity gradients and tidal creek habitat (Peters and McMichael 1987; Wenner 1992; FWCC 2008). Designations for sub-adults were wider ranging environments within the estuary, specifically listing submerged aquatic vegetation, oyster reefs, tidal creeks, and marshes (Pafford et al. 1990; Wenner 1992; Adams and Tremain 2000). Adult habitat designations were inlets, channels, sounds, outer bars, and some specific areas within estuaries related to spawning activities (Murphy and Taylor 1990; Johnson and Funicelli 1991; Reyier et al. 2011).

3. DATA

3.1 Fisheries-Dependent

3.1.1 Commercial Fishery

Red Drum commercial fisheries (fleets) were closed in SC on June 30, 1987 (Table 1.1). Prior to its closure, commercial landings were small compared to all other data sources used in SEDAR 93. The largest annual landings from 1981-1987 were 14,689 pounds. Similarly, commercial fisheries of Red Drum were closed in GA and FL, with very low commercial catches of Red Drum from 1981-1990. SEDAR 93 excluded the small amount of commercial catch in the southern stock (ASMFC 2024b), which was a decision maintained in the SC sub-stock assessment. Also, no historic or contemporary commercial discard estimates of Red Drum in commercial fleets are currently available. Fisheries-dependent data only included recreational removals (harvest and live discards).

3.1.2 Recreational Fishery

3.1.2.1 Marine Recreational Information Program

The Marine Recreational Information Program (MRIP) estimates the recreational landings of Red Drum. Beginning in 1979 as the Marine Recreational Fisheries Statistics Survey (MRFSS), the MRIP program has undergone several program changes, including the program name change in 2008. MRIP collects data on recreational catch and effort through three surveys: the Access Point Angler Intercept Survey (APAIS), the Fishing Effort Survey (FES), and the For-Hire Survey (FHS). The APAIS is a dockside survey collecting data on the catch composition, fishing areas, biological information on the catch, and fishing effort through a stratified sampling design by state, year, wave (bimonthly period), and fishing mode (shore, private/rental boat, headboat, and charterboat). Catch is reported on species available for inspection by dockside interviewers (Type A catch), species reported by anglers but not available to interviewers (Type B1 catch), and species released alive by anglers (Type B2 catch). The FES is a mail-based survey sent to anglers to collect additional data to ascertain fishing effort by anglers that fish from shore and private/rental boats. The FHS survey works similar to FES but targets for-hire charter boat and headboat captains contacted by telephone to provide fishing effort estimates from these groups. Total effort data from the FES and FHS are applied to the APAIS catch data to provide information on harvested (Type A+B1 catch) and released alive (Type B2 catch) catch. Biological data collected during the APAIS interactions provide opportunistic information about the fork length (FL) and weight of species observed by the interviewer (interviewers only measure up to 15 fish interaction^{-1}). More information about the MRIP surveys can be found at www.fisheries.noaa.gov/recreational-fishing-data/about-marine-recreational-informationprogram.

Several changes have occurred to the MRIP survey methodologies, two of significance to the current assessment. These changes are part of the program development, based on external reviews of the methodology. The first significant change occurred prior to the last assessment in 2013, when the APAIS was redesigned to improve sampling and use of data. One major change since the last stock assessment was the transition from the telephone-based survey (Coastal Household Telephone Survey (CHTS)) to the mail-based FES survey currently used. Historical estimates collected from CHTS have been calibrated by MRIP to provide more consistent data back to 1981. Calibration to the Methods from FES resulted in a documented increase in fishing effort when compared to CHTS, thus an increase in catch. Ongoing MRIP evaluations recently indicated potential overestimation of private/rental and shore fishing effort through a small-scale pilot study. These studies are currently being expanded, but effects on private/rental and shore effort estimates, and therefore catch estimates, were not available in time for the current assessment. See the MRIP website for more details on this development (https://www.fisheries.noaa.gov/recreational-fishing-data/fishingeffort-survey-research-and-improvements). Potential impacts from the overestimation were investigated through sensitivity analysis in consultation with MRIP staff.

3.1.2.2 Recreational Removals

For the assessment, we compiled estimates of Red Drum harvested (Type A + B1) and released (Type B2) from the MRIP program annually by fishing year. The compiled time series represents fishing years 1981 through 2023. Dead discards, and subsequently total removals (harvest + dead discards), were calculated based on an 8% discard mortality rate for recreationally captured and released Red Drum, consistent with SEDAR 93 (ASMFC 2024b).

3.1.2.2.1 Harvest

Recreational harvest (Type A + B1) of Red Drum in SC declined from historic levels in the 1980s, with a peak harvest of 936,790 fish in 1985 to series lows in the early-2000s, with a minimum of 91,930 fish harvested in 2000 (Table 3.1; Figure 3.1). Based on 3-yr averages, an approximate 80% reduction in direct harvest relative to the peak in the mid-1980s was observed, largely driven by a series of management regulation changes in the late-1980s and early-1990s (Table 3.2) and concomitant shift in fisherman behaviors. Harvest again rose through the 2000s reaching a secondary high in the early-2010s (2010 = 495,529 fish) before stabilizing through the 2017 fishing year (Table 3.1; Figure 3.1) at levels still approximately 45% lower than the peak harvest observed in the mid-1980s. Since the most recent regulatory change (Table 3.2), harvest initially declined before rapidly increasing to 506,526 in the terminal year, the largest harvest observed since 1995 (Table 3.1; Figure 3.1).

3.1.2.2.2 Recreational Discards

In contrast to recreational harvest, recreational live discards have steadily increased throughout the time series from a series low of an estimated 8,250 live discards in 1981 to an all-time high of 3,218,423 live discards in fishing year 2023 (Table 3.1; Figure 3.1). The increase in live discards results in a concomitant increase in dead discards with the assumption that an 8% mortality rate occurs for live discards, which was used in SEDAR 18, SEDAR 44, and SEDAR 93. The application of dead discards being directly proportional to live discards results in arise from less than 10,000 dead discards annually from 1981-1986 to greater than 100,000 dead discards annually since 2008 peaking at 257,474 Red Drum in 2023 with a 3-yr average peak of 176,386 dead discards (2017-2019; Table 3.1; Figure 3.1).

3.1.2.2.3 Total Catch and Removals

While implemented management strategies helped (at least initially) decrease the harvest of Red Drum in SC, the recreational fishery has evolved into a largely catch-and-release fishery with continuing increasing effort (Figure 3.2). These combined effects have led to an overall increase in Red Drum catch (Harvest + Live Discards) throughout the time series, particularly since a low in 2000 (298,879 fish caught; Table 3.1; Figure 3.1). Since, total catch has increased dramatically, peaking at 3,724,949 fish caught in fishing year 2023 across SC.

Regarding total removals (Harvest + Dead Discards), after annual removals peaked at 945,238 Red Drum in 1985, removals declined to a time series low of 108,486 individuals in 2000 (Table 3.1; Figure 3.1). Based on 3-yr averages, the trend represents a 74% reduction in removals relative to the peak in the mid-1980s. Subsequently, total removals increased through the early-2010s, with a peak at 679,772 Red Drum removed in 2010 (Table 3.1; Figure 3.1) before stabilizing through 2017 at approximately 474,165 individuals annually. Since the most recent regulatory change (Table 3.2), removals initially declined before rapidly increasing to 794,000 fish in the terminal year, the largest annual removals observed since 1985 (Table 3.1; Figure 3.1). Estimated dead discards from released fish has led to dead discards accounting for over 20% of annual removals (Harvest + Dead Discards) for each of the last 22 years, with dead discards accounting for 40% of the removals in three of those years (2006, 2019, and 2020) and greater than 30% of removals annually since 2017.

3.1.2.2.4 Percent Standard Errors

Through time, PSE estimates on Red Drum harvest and discards via the recreational fishery, as estimated using the MRIP survey, in SC have decreased (Figure 3.3). PSE on harvest estimates decreased from greater than 30% from 1981-1984, exceeding 50% in 1983 (69.4%) to generally less than 20% since the late-2000s, only exceeding 30% in 1990 and 1998. Similarly, PSE on live discards decreased from greater than 50% from 1981-1984 to generally less than 20% since 2001, with a low of 8.7% in 2013. Since 1986, Red Drum discard PSE has exceeded 30% in only 5 years: 1989-1991, 1993, and 1996.

3.1.2.3 Catch Composition

3.1.2.3.1 Harvest

Biological sampling from the APAIS survey means MRIP also provides annual size composition data of harvested Red Drum from SC (Figure 3.4). Prior to initial management regulations in 1986 (Table 1.1 and Table 3.2), the majority of Red Drum harvested ranged in size from 26 to 50 cm TL (10-20" TL), though there were some removals of individuals both smaller (e.g., 1981, 1985, and 1986) and larger (e.g., all years, particularly 1983 and 1986). Beginning in the 1986 fishing year through the 1992 fishing year, some version of a 14" (36 cm) TL minimum length limit and restriction on harvest of fish greater than 32" (82 cm) TL was in place (Table 1.1 and Table 3.2), which constrained the harvest size composition, though there was continued evidence of some harvest of larger fish and illegal harvest of smaller fish (Figure 3.4). From fishing years 1993-2000, the harvest of Red Drum in SC was constrained by a 14-27" (36-68 cm) TL slot limit (Table 1.1 and Table 3.2). The further restriction in the sizes of harvested fish due to changing slot limits can be observed in the remainder of the MRIP size composition data (Figure 3.4), with a further constraint of a 15-24" (38-61 cm) TL slot from 2001-2006 and then a 15-23" (38-58 cm) TL slot since 2007 (Table 1.1 and Table 3.2).

3.1.2.3.2 Discards

Recreational data collected by MRIP does not collect length and age data on fish released alive. Only lengths measured by a creel clerk within the MRIP program are maintained in the dataset, thus lengths from live releases are not notated. Given an assumed mortality rate of released Red Drum, information about the length and age of fish that die during or after recreational release is also not available. Several data sources have been considered that can ascertain more information about the catch-and-release fishery through tagging programs and phone applications designed around citizen science (e.g., iAngler (http://angleractionfoundation.com/iangler) and MyFishCount (https://www.myfishcount.com/)). However, citizen science programs with available phone applications are relatively new with a limited amount of data to date and are not incorporated into the current assessment. Efforts during the regional assessment (ASMFC 2024b) focused on tagging programs to provide potential sizes of tagged Red Drum, as well as recaptured Red Drum that were released again.

Specific information about the tagging program run by SCDNR were considered in SEDAR 93 and SC sub-stock assessment can be found in SEDAR 93 report (ASMFC 2024b). Instructions to volunteer anglers varied through time (Table 3.3), so the time series was broken into segments with only data with limited instruction bias used within the assessment. Using years with instructions not to tag fish under a specified size or over a specified size, biases the data by excluding actual releases from the data set that would have been represented if they were collected under a different scenario (Figure 3.5-Figure 3.7). Thus, data from 1989-1992 and 2011-2021 were used as proxy data for the size of fish released alive in SC (Figure 3.7). However, there is still a bias against large "bull" Red Drum given participants in the tagging study commonly avoid targeting these large Red Drum while participating in the study. The bias was discussed during the regional assessment, and ultimately it was deemed length composition data from this tagging data were biased and not recommended for use for informing selectivity.

3.1.3 SC Conventional Tagging Programs

The SCDNR conventional tagging programs began in 1975 with the Marine Game Fish Tagging Program (MGFTP) and has since grown in popularity, participation, and the addition of the Inshore Fisheries Fishery-Independent Tagging Program. These programs are an excellent outreach opportunity that fosters a mechanism to engage the public with conscientious angling tactics and best fishing practices. Data from the conventional tagging programs provided valuable information on movement and migration, gear selectivity, and exploitation rates, useful for stock assessments. Due to the instructions within a tagging program about the size of targetable Red Drum for the program, the full selectivity of the recreational fishery could not be ascertained. Thus, lengths provided by the tagging programs could only be used to help inform the retention curves within the model rather than provide length compositions for discards. Additionally, data from the tagging programs were used to understand the low migration rates between states, thus informing the need to examine potential localized depletion within a sub-stock.

The SCDNR conventional tagging programs have tagged 172,087 Red Drum available for this assessment, with 46,506 recaptures (Table 3.4; Figure 3.8). Using the conventional tagging data, the proportion of recreationally captured fish released (as opposed to harvested) following capture has increased since the 1980s, when the release rate was less than 25%. Now release rates have exceeded 75% since 2000 (Figure 3.9). Days at large, defined as the number of days between initial tagging and recapture, has varied widely from <1 day at large to 8,937 days-at-large (Figure 3.10). There have been 12,488 recaptures with days-at-large >365 days (Table 3.4). The largest day-at-large report came from a Red Drum tagged on 3/25/1996 in Cape Romain and recaptured on 9/12/2020 in Cape Romain. It grew from 59.7 cm to 76.2 cm TL. The largest straight-line distance moved by an individual was 467 km (at-large for 739 days); however, only 28 fish moved >250 km from the original tagging location.

3.1.4 SC Supplemental Recreational Sampling

Additional age-length data are collected by several recreational fishery monitoring programs run by SCDNR Inshore Fisheries-Dependent Biological Sampling Program that were used in the external von Bertalanffy and natural mortality estimates in the SEDAR 93 southern stock and the SC sub-stock assessment. These data were used to generate age composition data for the recreational fishery. The SCDNR Inshore Fisheries Research Section collects biological data on recreationally important species and recreational fisheries through the fishery-dependent freezer fish program and a fishery-dependent tournament sampling program. The programs capture data on the size, age, and sex composition of recreationally harvested species, including Red Drum.

3.1.4.1.1 Freezer Fish Program

The Freezer Fish Program, began in 1995 by the Inshore Fisheries Research Section, allows recreational fishermen to drop off recreationally important finfish to freezers run by SCDNR. Chest freezers are placed near collaborating marinas, landings, or bait shops along the SC coast to increase fish collection from areas not always captured in SCDNR sampling effort. Anglers can fillet the Red Drum first, then place the carcass with head and tail intact into the provided bags along with the catch data filled out on a catch information card. The bag is then deposited into the freezer, where SCDNR staff can collect the fish and data. All Red Drum donated to the program are examined in the lab with lengths, sex, and maturity status (if available) determined, and genetic samples and otoliths for aging are collected.

Although participation is limited, 2,283 Red Drum were collected by the Inshore Freezer Fish Program (Table 3.5), ranging in size from 34.3-81.0 cm TL (average = 48.4 cm TL; Table 3.6). However, the average number of collections has decreased significantly in recent years. An average of 156 Red Drum were collected annually from 1995-2013 (n=1,412), but from 2004-2022 an average of 46 have been donated annually.

3.1.4.1.2 <u>Tournament Program</u>

Additional samples have been provided by participants of Recreational Angler tournaments since 1986. The Inshore Fisheries Section coordinates with tournaments, providing weigh-masters at the event in exchange for the opportunity to collect biological samples from Red Drum captured. All Red Drum sampled by the program are examined with lengths, sex, and maturity status (through gross and histological sampling) determined, and genetic samples and otoliths for aging are collected.

Since 1986, 1,023 Red Drum have been sampled at tournaments (Table 3.5) ranging from 27.7 cm TL to 115.0 cm TL (average 55.2 cm TL; Table 3.6).

3.2 Fisheries-Independent

Four different fishery-independent surveys conducted by the SCDNR Inshore Fisheries Research Section encounter Red Drum in sufficient numbers (both frequency and percent positive) for index development. These surveys have been considered in previous state (e.g., Murphy 2017) and regional (e.g., SEDAR 93 (ASMFC 2024b)) assessments and were continued to be used herein. These represent a mixture of both historic (rotenone and stop net) and contemporary (trammel net and adult Red Drum and shark longline) surveys. Descriptions of each, as adapted from SEDAR 93 (ASMFC 2024b) are provided below.

3.2.1 Rotenone Survey

3.2.1.1 Data Collection and Treatment

SCDNR began the Inshore Fisheries Rotenone Survey in 1986 to provide estimates of key estuarine species, including Red Drum, within sub-tidal saltmarsh creek habitats that are utilized as primary nursery habitats for these species. Monitoring the smaller creeks (less than 5 m wide and 1 m deep) that dominate the SC marsh environment, the survey allowed for the evaluation of the relative abundance of newly recruited Red Drum.

3.2.1.1.1 <u>Survey Methods</u>

A fixed station sampling design was used with 7 stations sampled from 1986 through 1988 and 4 stations in 1989 through 1994 (Table 3.7). A 50 m section of the creeks, that were less than 5 m wide and less than 1 m deep at low tide, were blocked with two block nets (0.8 mm square mesh) roughly 1 hour prior to local low tide. The nets were weighed down with heavily weighted foot ropes and suspended between poles installed into the creek on opposite banks. Rotenone (100-200 ml of 5% Fish Tox, Wolfolk Chemical Works, Fort Valley, GA) was added at the upstream net and carried with the ebbing flow to the downstream net. Potassium permanganate was added at the downstream net to oxidize the rotenone leaving the site. A 3.2 mm bar mesh seine was pulled through the site three times and dip nets were also used to collect fish between the two block nets. Water quality parameters, such as temperature, salinity, and dissolved oxygen (DO), were measured at the site before rotenone was introduced.

3.2.1.1.2 <u>Biological Sampling</u>

Fish collected in the down-stream net and collected between block nets were returned to the lab for identification and enumeration of TL, standard length (SL), and weight. Ages were estimated using length of capture, since Red Drum captured were smaller than the size where length distribution would overlap between ages (Figure 3.11). Also, most Red Drum captured were immature, so sex information was limited. The survey serves as a representation of Red Drum recruitment (Table 3.6) as only one individual captured was older than age-1 through the history of the survey.

3.2.1.1.3 Index Development

As noted above, the survey represents recruitment of Red Drum and as such was evaluated and developed as a survey of Red Drum year class strength (i.e., a recruitment index), with early juvenile Red Drum recruiting to the survey in August and being tracked through July the following year (Table 3.8). There is no need for the development of age or length compositions, as it is assumed to be a survey of recruitment with a sampling year of August-July. The index was treated in the same manner during SEDAR 93 (ASMFC 2024b), albeit the index standardization methodology was updated to address reviewer comments during that assessment process.

The recruitment index was standardized using the R package *sdmTMB* (Anderson et al. 2024), a flexible application that allows for fitting a wide range of generalized linear models (GLM) and generalized linear mixed effects models (GLMM) with and without spatial and/or spatiotemporal random fields. For the rotenone survey, given the fixed survey design and limited number of fixed stations, no attempt to fit spatial or spatiotemporal fields was attempted; station was instead considered as a potential fixed effect in the best fit model. Other potential fixed effects considered were year class (discrete), sampling period within the year (either month (discrete) or day of year (continuous; 9/1 = day 1)), water temperature (°C, continuous), and salinity (PSU, continuous). We assumed a negative binomial error distribution for all candidate models. Continuous covariates were fitted with a smoother using a cubic regression spline smoothing basis (Wood 2011; Wood 2017). Prior to model development, any collections identified as not suitable for index development were removed from consideration.

Bayesian Information Criterion (BIC) selected the best fit model,

$$Catch = Year\ Class + s(DOY, bs =' cr') + s(Temp, bs =' cr') + 1.$$

Year class effects were estimated using the best fit model and a fine scale grid of plausible combinations of Year Class and the covariates day of year (DOY) and water temperature (Temp). Plausible combinations were developed to ensure only the covariate combinations observed in the data were contained within the grid. Predicted catch from the resultant grid was then determined using the best fit model, with a subsequent call to the *sdmTMB* function "get_index" (Anderson et al. 2024) to extract the relevant abundance index by fishing year from the prediction grid.

Diagnostics of the model fit were evaluated using the package *DHARMa* (Hartig 2022) to evaluate residual diagnostics for hierarchical (multi-level/mixed) regression models.

3.2.1.2 Trends

The proportion of rotenone surveys positive for young-of-the-year (YOY) Red Drum exceeded 33% in all years, with generally 100s of YOY being captured annually (Table 3.9). The exceptions being fishing years 1988 and 1992-1993. Average recruitment estimated from the SCDNR rotenone survey was highly variable throughout the time series, with above average recruitment in 1986 and 1990 and below average recruitment in 1989 and 1992 (Table 3.10, Figure 3.12). In other years, the abundance of Red Drum in the survey did not deviate from the survey average.

Residual diagnostics suggested no significant non-normality, over- or under-dispersion, or residual outliers for the best fit GLM including year class, day of year, and water temperature as fixed effects (Figure 3.13). Further, there was no patterning of residuals with respect to predicted values, fishing year, day of year, or water temperature (Figure 3.14 and Figure 3.15).

3.2.1.3 Potential Biases, Uncertainty, and Measures of Precision

The SCDNR rotenone survey covers a relatively short period of the model time series with interannual variability and high relative standard errors (RSEs; Table 3.10), with annual RSEs ranging from 0.256 to 0.594 in 1986 and 1992, respectively. The survey also lacks spatial coverage with only nine fixed stations, where most occurred in one river drainage (Wando River in Charleston Harbor). However, the index correlates well with other surveys operating during the period and represents a true recruitment index. Further, while standardizing the survey, the best fit model had no significant effect from site or stratum within the data, suggesting synchrony in year class signals across space as noted in Arnott et al. (2010). Given the detected synchrony, lack of conflict with other data sources, and the period covered by the survey having a general lack of information on recruitment, the survey was determined to be appropriate for use within the model.

3.2.2 Stop Net Survey

3.2.2.1 Data Collection and Treatment

The stop net survey provided relative abundance information for species, like Red Drum, that use salt marsh edge habitats in estuaries. The survey indexed the relative abundance of numerous species and has been used in previous assessments of the southern population of Red Drum (ASMFC 2024b).

3.2.2.1.1 <u>Survey Methods</u>

Beginning in 1985, SCDNR developed the stop net survey using a 366 m long by 3 m deep multifilament nylon mesh block net with 51 mm stretch mesh set at high tide in an intertidal area. The net is staked into the marsh edge on one end, while the other end is pulled over the non-vegetated bottom parallel to the shore and secured in the marsh. Fish enclosed within the net, roughly a 12,000 m^2 area, were collected with large dip nets as the tide retreated. Red Drum were placed in oxygenated holding tanks to be measured and tagged. Water quality parameters, such as temperature, salinity, and dissolved oxygen were also recorded.

Several sites were sampled from 1985 through 1998, but only one station had monthly sampling from 1986 through 1993, and another station had regular sampling in the summers from 1990 through 1994 (Table 3.11). Only these two stations were used to develop the index.

3.2.2.1.2 <u>Biological Sampling</u>

Successfully tagged individuals were released, while some individuals were retained to collect data on weight, age, sex, maturity, and contaminant analysis. Age for smaller Red Drum was estimated based on the length of the individual with nearly 100% certainty for individuals less than 2.5 years of age because TL does not overlap between age-0, age-1, and early age-2 individuals (Figure 3.10). Ages from larger Red Drum were ascertained using otolith thin section methodology and/or scale methodology; however, all ages derived via scales were excluded from this assessment. A summary of the biological information provided for the assessment from the SCDNR stop net survey is found in Table 3.6.

3.2.2.1.3 <u>Index and Composition Development</u>

The stop net survey was standardized using the R package *sdmTMB* (Anderson et al. 2024), a flexible application that allows for fitting a wide range of GLM and GLMM both with and without spatial and/or spatiotemporal random fields. For the stop net survey, given the fixed survey design and limited number of fixed stations, no attempt to fit spatial or spatiotemporal fields was attempted; station was instead considered as a potential fixed effect in the best fit model. Other potential fixed effects considered were fishing year (discrete), sampling period within the year (either month (discrete) or day of year (continuous; 9/1 = day 1)), water temperature (°C, continuous), and salinity (PSU, continuous). We assumed a negative binomial error distribution for all candidate models. Continuous covariates were fitted with a smoother using a cubic regression spline smoothing basis (Wood 2011; Wood 2017). Prior to model development, any collections identified as not suitable for use for index development were removed from consideration.

BIC selected the best fit model,

$$Catch = Fishing\ Year + Station + Month + 1.$$

Year class effects were estimated using the best fit model and a grid of all possible combinations of fishing year, month, and station. Predicted catch from the resultant grid was then determined using the best fit model, with a subsequent call to the *sdmTMB* function "get_index" (Anderson et al. 2024) to extract the relevant abundance index by fishing year from the prediction grid. Residual diagnostics of the model fit were evaluated using the package *DHARMa* (Hartig 2022).

Age compositions for the survey were developed using paired TL and age measurements made on all individuals encountered by the survey. Annual age compositions for the survey were not directly available, owing to the stratified random sampling design used to select fish to sacrifice for age determination via otoliths. Thus, to develop annual marginal age compositions we used proportional odds logistic regression to develop smoothed annual age-length-keys (ALK) conditional on the model

$$Age = a * TL + b * Year + c,$$

where Age is an ordered (smallest to largest) observed integer, biological age based on otolith or length derived age estimates, TL is a 2-cm TL bin and $Year$ represents the fishing year of capture (Agresti 2002; Ogle 2018; Stari et al. 2010; Venables and Ripley 2002). The resultant best fit model was used to determine the biological age of all un-aged Red Drum captured from the stop net survey for which a TL was available. These smoothed ALK "aged" fish were then added to the fish directly aged to develop marginal age compositions for each fishing year.

Marginal age compositions were calculated using the same samples of Red Drum as the length compositions would use and are highly correlated. The use of the same data, independent of each other when they are highly correlated, is a form of "double dipping" data sources. Thus, the length compositions used for the Stop Net survey in SEDAR 93 were not used in the SC sub-stock model, as recommended by the SEDAR 93 peer reviewers.

3.2.2.2 Trends

The proportion of stop net survey collections positive for sub-adult Red Drum exceeded 90% in all fishing years, with on average 926 individuals captured annually (Table 3.12). Overall, the survey shows a stable sub-adult Red Drum population along the coast during the late-1980s and early-1990s (Table 3.10, Figure 3.16).

Residual diagnostics suggested no significant non-normality, over- or under-dispersion, or residual outliers for the best fit GLM including year class, station, and month as fixed effects (Figure 3.17). Further, there was no patterning of residuals with respect to predicted values, fishing year, station, or month (Figure 3.18 and Figure 3.19).

3.2.2.3 Composition Data

The all-years pooled length and age compositions for the survey can be found in Figure 3.20 and Figure 3.21, respectively. Modes in the pooled length composition reflect cohorts of Red Drum encountered by the survey, with the modes at 24-28 cm, 36-40 cm, and >56 cm TL corresponding to age-0, age-1, and age-2+ Red Drum encountered by the survey, respectively. The pooled age composition clearly showed that most fish captured in the survey are either age-0 or age-1, with fewer age-2, age-3 and age-4+ fish encountered. Year specific length- and age-compositions are available in Figure 3.22 and Figure 3.23.

3.2.2.4 Potential Biases, Uncertainty, and Measures of Precision

The stop net survey is limited spatially (two fixed stations) and temporally (9 years with few within year sampling events), which leads to increased RSEs (0.19-025; Table 3.10). However, it is one of two surveys providing information about the relative abundance of Red Drum in SC in the 1980s. As such, the survey provides valuable historical information on trends of the sub-adult population, which has always been the primary life history stage of Red Drum targeted by fisheries, lending to its usefulness herein. The stop net survey shows the same peaks in abundance with the rotenone survey when lagged one year (*i.e.*, rotenone peak in 1986 is seen in stop net survey in 1987; Table 3.10; Figure 3.12 and Figure 3.16).

3.2.3 Trammel Net Survey

3.2.3.1 Data Collection and Treatment

Beginning in the fall of 1990, The SCDNR trammel net survey has been conducted in nine strata in the five major SC estuaries (Table 3.13; Figure 3.24), with the survey designed to examine the relative abundance of several key estuarine species, including Red Drum, in lower portions of the estuary in moderate- to high-salinity waters in and around salt-marsh and oyster reef habitats. The survey has been used in multiple stock assessments, including in previous regional (ASMFC 2024b) and state specific Red Drum assessments (Murphy 2017).

3.2.3.1.1 <u>Survey Methods</u>

The trammel net survey uses a stratified-random fixed station sampling design with 12-14 stations selected each sampling day from a pool of 27 to 36 stations stratum^{-1}. Adjacent stations, unless separated by a barrier (e.g., tidal creek) cannot be sampled on the same day; otherwise, stations are randomly selected without replacement. 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). Nets are set along the shoreline 10-20 m from an intertidal march in less than 2 m depth during an ebbing tide. Once set, the boat makes two passes along the length of the enclosed water body at idle speed (taking <10 minutes), during which time field personnel disturb the water surface with wooden poles to promote fish entrapment. Field staff then retrieve the net and place netted fish in a live well. Additional data collected during each collection includes location (site nested in stratum nested in estuary, latitude, and longitude), as well as water temperature (°C), salinity (PSU), DO (mg L^{-1}), and tidal stage.

3.2.3.1.2 <u>Biological Sampling</u>

Each specimen is identified to species level and counted. The TL and SL for each Red Drum is measured. Most specimens are released alive (>95%), and any Red Drum greater than 35 cm TL are tagged (if not previously done so). Roughly 300-500 Red Drum are sacrificed annually through a length distribution subsampling process to provide additional life history information about the species. These additional biological variables include weight (g) and biological samples retained for age and growth studies (otoliths and scales), histological determination of reproductive status (gonad tissues), and contaminant analysis (muscle tissues).

A combination of age methodologies is used to age Red Drum encountered by the SCDNR trammel net survey, dependent on the size of the individual fish. Smaller individuals (<2.5 years old), prior to significant overlap in length distribution of individual cohorts, can be reliably aged exclusively using TL, with near 100% certainty in the age determination as verified by otolith thin section methodology (Figure 3.11). The ages of larger, and hence generally older, individuals have been determined via a combination of scale readings and otolith thin-section techniques, though all scale derived ages were excluded from consideration during the assessment. A summary of the life history information provided to the assessment from the trammel net survey is found in Table 3.6.

3.2.3.1.3 Index and Composition Development

The trammel net index was standardized using the R package *sdmTMB* (Anderson et al. 2024), a flexible application that allows for fitting a wide range of GLM and GLMM both with and without spatial and/or spatiotemporal random fields. For the trammel net survey, given the large number of stations (e.g., discrete locations) sampled through the years and broad geographic range (relative to the coast of SC) covered, we fit a spatiotemporal GLMM using the coordinates (latitude and longitude) of individual sampling locations to develop a spatial mesh and fishing year as the temporal variable.

The spatial component is included as random fields using a triangulated mesh with vertices, known as knots, to approximate the spatial variability of observations. The framework uses bilinear interpolation to approximate a continuous spatial field (Rue et al. 2009; Lindgren et al. 2011) from the estimated values of the spatial surface at these knot locations to other locations including those of actual observations. For our application, the spatial "mesh" was constructed using a minimum distance of 0.6 km, which represents the minimum distance between knots before a new mesh vertex is added and is based on a balance between the general minimum distance between individual fixed stations in the trammel net survey (~0.5-1 km), the length of the trammel net (~0.18 km), and the desire to minimize model overfitting. Preliminary investigations were conducted to evaluate the impact of model results based on the minimum distance between knots. To add spatiotemporal random fields, we included fishing year as a time argument to indicate the time slice at which spatial random fields should be estimated. These fields were assumed to be independently and identically distributed.

Outside of the spatiotemporal component, other considered fixed and random effects were fishing year (discrete; fixed), sampling period within the year (either month (discrete; fixed) or day of year (continuous: 9/1 = day 1; fixed)), water temperature (°C, continuous; fixed), salinity (PSU, continuous; fixed) and station (discrete, random). We assumed a delta-truncated negative binomial error distribution for all candidate models, with the same model structure assumed for both the delta and truncated negative binomial sub-models. Continuous covariates were fitted with a smoother using a cubic regression spline smoothing basis (Wood 2011; Wood 2017). Prior to model development, any collections identified as not suitable for use for index development were removed from consideration.

BIC selected the best fit model, which included the spatiotemporal random field effect of location and fishing year, the fixed effects of fishing year, month, and tidal stage, and the random effect of station. Year class effects were estimated using the best fit model and a grid of combinations of fishing year, coordinates of trammel net stations, tidal stages, and month. Predicted catch from the resultant grid was then determined using the best fit model, with a subsequent call to the *sdmTMB* function "get_index" (Anderson et al. 2024) to extract the relevant abundance index by fishing year from the prediction grid. Residual diagnostics of the model fit were evaluated using the package *DHARMa* (Hartig 2022).

Length compositions for the survey were developed from the observed TL measurements made on all individuals encountered by the survey for each fishing year. There was no need for expansion of the length compositions given the survey sampling design. Compositions were developed using 2 cm length bins (e.g., 0-19 mm TL = 0 cm bin, 20-39 mm TL = 2 cm bin, etc.).

In the stock synthesis framework, the model can also utilize conditional age-at-length information where information on aged fish in length bins (i.e., raw ALK) by year and survey can be directly incorporated into the model to inform selectivity, growth, and natural mortality. To facilitate the incorporation of conditional age-at-length information from the SCDNR trammel net survey, raw age (length and otolith derived) and length information were provided. Since the age composition is "conditional" on the length bin the age is assigned to, conditional age-at-length data can be and need to be used in conjunction to length compositions.

3.2.3.2 Trends

The proportion of trammel net survey collections positive for sub-adult Red Drum exceeded 23% in all fishing years, with 42% (11,010 out of 26,461 collections) positive across all years combined (Table 3.14). Individual year proportion positives ranged from a low of 24% in 2019 to a high of 63% in 1991, though there was a general decrease in proportion positive beginning in the 2010s (Table 3.14). Overall, the SCDNR trammel net survey shows a decrease in abundance of sub-adult Red Drum along coastal SC during the survey period through at least the late 2010s, though there may be indications of a slight recovery since (Table 3.10; Figure 3.25). On an annual basis, catch trammel net^{-1} was above the long-term average in 1991-1993, 1995, and 2001-2005 while remaining below the long-term average in 1998-1999, 2006, 2011-2021, and 2023 (Figure 3.25).

DHARMa residual diagnostics suggested slight patterning to the residuals, illustrated by failed tests for non-normality and residual outliers but no over- or under-dispersion for the best fit GLMM (Figure 3.26). While there was a significant pattern of model residuals as a function of predicted value, month and tidal stage, there was no patterning of residuals with respect to fishing year (Figure 3.27 and Figure 3.28). The observed residual patterning was minor in all cases (Figure 3.26-Figure 3.28) and additional model exploration with alternative error distributions and covariates could not produce any model that passed all DHARMa residual diagnostic tests, likely due to the large sample size of individual collections (n = 26,461) represented by the trammel net index. The spatiotemporal patterning of residuals for the trammel net index is provided in Figure 3.29.

3.2.3.3 Composition Data

Modes in the pooled length composition reflect cohorts of Red Drum encountered by the survey, with the modes at 24-28 cm, 38-42 cm, and >58 cm TL (Figure 3.30) corresponding to age-0, age-1, and age-2+ (Figure 3.31) Red Drum encountered by the survey, respectively. The pooled age composition showed that most fish captured in the survey are age-0, age-1, age-2, or age-3, with fewer age-4+ fish encountered. Year specific length- and age-compositions show some interannual variability but overall was consistent through time (Figure 3.32-Figure 3.35).

3.2.3.4 Potential Biases, Uncertainty, and Measures of Precision

Overall, the trammel net survey exhibits low relative standard errors (RSEs <0.2; Table 3.10), except the first three years with an overall range of 0.100 – 0.408. Further, with the expansion of the survey spatially and the long time series (34 years), there is high confidence in the index and it provides the most comprehensive insight into the long-term trends in sub-adult Red Drum populations along coastal SC.

3.2.4 Longline Survey

3.2.4.1 Data Collection and Treatment

To monitor populations of large sub-adult and adult Red Drum in SC's estuarine and coastal ocean waters, the SCDNR began longline sampling in Charleston Harbor in 1994. Though the contemporary adult Red Drum and shark longline survey (a.k.a, longline survey) traces its roots to this historic survey, it was not until 2007 that the survey expanded spatially along coastal SC (Figure 3.24) and additional collection level information (e.g., bait type, number of hooks lost due to bite offs, etc.) pertinent to the development of relative abundance indices began to be collected. One primary focus of the survey is to develop an index of Red Drum relative abundance, as well as collect biological information (size, sex, etc.) and samples (otoliths, gonads, muscle, fin clips, etc.) from random sub-samples of Red Drum. Further, released Red Drum (and some sharks) are tagged to collect migration and stock identification data.

The survey has been used in multiple stock assessments, including in previous regional (ASMFC 2024b) and state specific Red Drum assessments (Murphy 2017).

3.2.4.1.1 <u>Survey Methods</u>

Since 2007, the longline contemporary survey has employed a stratified-random fixed station survey design with stations located within four SC estuaries, Port Royal Sound, St. Helena Sound, Charleston Harbor, and Winyah Bay, as well as nearshore coastal and live bottom habitats near the mouths of these estuaries (Figure 3.24). The survey samples four strata (Port Royal Sound, St. Helena Sound, Charleston Harbor, and Winyah Bay) during each of three six-week sampling periods (1 = Aug. 1-Sept. 15, 2 = Sept. 16-Oct. 31, and 3 = Nov. 1-Dec.15). During each 6-week period, thirty fixed-stations, from a pool of 43-81 stations strata^{-1}, are randomly selected without replacement for sampling resulting in 120 stations and 360 collections sampled per six-week sampling period and field season, respectively. Fish are collected using a bottom longline consisting of a 610 m monofilament mainline (272 kg test), weighted (≥15 kg) and buoyed to the surface at each end, equipped with forty gangions constructed of 0.5 m, 91 kg test monofilament with a size 120 stainless steel longline snap, 4/0 swived, and a 15/0 non-stainless steel Mustad circle hook. The mainline is equipped with stop sleeves every 30 m (21 line^{-1}) to prevent gangions from sliding together when a large fish is captured. Longlines were baited with Atlantic Mackerel (*Scomber scombrus*), half Atlantic Mackerel and half Striped Mullet (*Mugil cephalus*; bait study in Charleston Harbor in 2011/2012), or all Striped Mullet. Due to switching of bait types in the early years of the survey and SEDAR93 peer review comments (ASMFC 2024b), only collections baited exclusively with Striped Mullet were retained herein, resulting in a truncation of the index to 2010-present.

For each collection, the station location (site nested in strata, latitude/longitude, and location (inshore vs. offshore) was recorded. Gear was only set during daylight hours, and soak times were limited to 45 minutes unless conditions or events dictated otherwise. A beginning and end depth is recorded at each station. Additional data collected during each collection includes water temperature (°C), salinity (PSU), and DO (mg L^{-1}).

3.2.4.1.2 <u>Biological Sampling</u>

Staff bring each fish captured on board, where they remove the hook, measure (mid-line length (ML) and TL) and weigh each fish and retain a fin tissue sample for genetic analysis. A randomly selected subsample of Red Drum are sacrificed for age estimation, reproductive workup, and contaminant analysis on muscle tissue, but the rest are tagged (with a nylon dart tag and PIT tag) and released. Those sacrificed for life history studies have otoliths removed with all ages determined via otolith thin-section techniques. A summary of the life history information provided for the assessment from the longline survey is found in Table 3.6.

3.2.4.1.3 Index and Composition Development

The longline index was standardized using the R package *sdmTMB* (Anderson et al. 2024), a flexible application that allows for fitting a wide range of GLM and GLMM both with and without spatial and/or spatiotemporal random fields. For the longline survey, given the large number of stations (e.g., discrete locations) sampled through the years and broad geographic range (relative to the coast of SC) covered, we fit a spatiotemporal GLMM using the coordinates (latitude and longitude) of individual sampling locations to develop a spatial mesh and fishing year as the temporal variable.

The spatial component is included as random fields using a triangulated mesh with vertices, known as knots, to approximate the spatial variability of observations. The framework uses bilinear interpolation to approximate a continuous spatial field (Rue et al. 2009; Lindgren et al. 2011) from the estimated values of the spatial surface at these knot locations to other locations including those of actual observations. For this application, the spatial "mesh" was constructed using a minimum distance of 1.2 km, which represents the minimum distance between knots before a new mesh vertex is added, as a balance between the general minimum distance between individual fixed stations in the longline survey, the length of the mainline (~0.61 km), and the desire to minimize model overfitting. Preliminary investigations were conducted to evaluate the impact of model results based on the minimum distance between knots. To add spatiotemporal random fields, we included fishing year as a time argument to indicate the time slice at which spatial random fields should be estimated. These fields were assumed to be independently and identically distributed.

Outside of the spatiotemporal component, other considered fixed and random effects were fishing year (discrete; fixed), sampling period within the year (either month (discrete; fixed) or day of year (continuous: 9/1 = day 1; fixed)), depth (m, continuous; fixed), water temperature (^{o}C, continuous; fixed), salinity (PSU, continuous; fixed) and station (discrete, random). The natural log of the number of hooks was included in the model as an offset term, to account for lost hooks due to bite offs. We assumed a delta-truncated negative binomial error distribution for all candidate models, with the same model structure assumed for both the delta and truncated negative binomial sub-models. Continuous covariates were fitted with a smoother using a cubic regression spline smoothing basis (Wood 2011; Wood 2017). Prior to model development, any collections identified as not suitable for use for index development, including any collections made outside of the months of August through December, were removed from consideration.

BIC selected the best fit model, which included the spatiotemporal random field effect of location and fishing year, the fixed effects of fishing year, day of year, and water temperature, and the random effect of station. Year class effects were estimated using the best fit model and a fine scale grid of plausible combinations of fishing year and the covariates DOY and water temperature. Plausible combinations of continuous covariates (e.g. grid of observed combinations of DOY and water temperature) were developed to ensure only the covariate combinations observed in the data were contained within the grid. Predicted catch from the resultant grid was then determined using the best fit model, with a subsequent call to the *sdmTMB* function "get_index" (Anderson et al. 2024) to extract the relevant abundance index by fishing year from the prediction grid. Residual diagnostics of the model fit were evaluated using the package *DHARMa* (Hartig 2022).

Length compositions and conditional age-at-length compositions were calculated for the longline survey with length and otolith derived ages using the same methods employed for the trammel net survey.

3.2.4.2 Trends

The proportion of longline survey collections positive for large sub-adult and adult Red Drum exceeded 35% in all fishing years, with 43% (1,897 out of 4,439 collections) positive across all years combined (Table 3.15). Individual year proportion positives ranged from a low of 37% to a high of 55% in 2018 and 2016, respectively (Table 3.15). Overall, the index suggests a stable abundance of Red Drum since 2010, though there are indications of an increasing trend through the mid-2010s followed by a decrease in abundance through the terminal year (Table 3.10; Figure 3.36). On an annual basis, catch longline^{-1} was above the long-term average in 2015-2016 while remaining below the long-term average in 2010-2011 and 2022 (Table 3.10; Figure 3.36).

DHARMa residual diagnostics suggested slight under-dispersion of the best fit GLMM as illustrated by a failed dispersion test, but no indication of residual non-normality or outliers (Figure 3.37). Further, when residuals were plotted against fitted values, fishing year, day of year, and water temperature, there was no apparent trend in residuals (Figure 3.38 and Figure 3.39) and Traditional model exploration with alternative error distributions and covariates could not produce any model that passed all DHARMa residual diagnostic tests. The spatiotemporal patterning of residuals for the index is provided in Figure 3.40.

3.2.4.3 Composition Data

The all-years pooled length and age compositions for the survey can be found in Figure 3.41 and Figure 3.42, respectively. Due to slowing growth in large sub-adult and adult Red Drum captured by the survey, there is little structure in the length composition to inform year class strength, with the survey generally capturing Red Drum between 80 and 108 cm TL. The pooled age composition shows individuals begin recruiting to the gear at age-3, with a broad range of ages encountered. Year specific length- and age-compositions are available in Figure 3.43 and Figure 3.44.

3.2.4.4 Potential Biases, Uncertainty, and Measures of Precision

Overall, the longline survey exhibits low relative standard errors (RSEs; <0.2, Table 3.10), with an overall range of 0.10 – 0.18. The treatment herein differed slightly from treatment during SEDAR 93 (ASMFC 2024b), with the exclusion of years 2007-2009 from the index to remove the need for accounting for the bait change. The alteration was based on a recommendation from the SEDAR 93 peer review panel as accounting for the bait effect, with what was likely already higher abundances, based on high catches with inferior bait, in those earlier years, led to relative abundance estimates exceeding those in later years. Further, the time series is growing in length, with the anticipation that the increased survey length will improve our understanding of abundance changes in the adult population that may manifest slowly as the survey integrates data over many age classes.

4. ASSESSMENT

4.1 Method

All methods from the SEDAR 93 benchmark stock assessment (ASMFC 2024b) were followed unless otherwise documented. Model work for the SC sub-stock model were based on the SEDAR

93 benchmark model files, with only SC data sources, changes recommended by SEDAR 93 peer review, and changes necessary for model performance

The SC sub-stock model was completed in Stock Synthesis (SS) version 3.30 and the r4ss R package was used to examine and summarize outputs (Taylor et al. 2009, 2021; Methot and Wetzel 2013; Methot et al. 2024). More information can be found in the SS user's manual (Methot et al. 2024), the SS GitHub repository (https://github.com/nmfs-stock-synthesis/nmfs-stocksynthesis.github.io), and the r4ss GitHub repository (https://r4ss.github.io/r4ss/; Taylor et al. 2021). Stock Synthesis is a forward-projecting, length- and age-based, integrated fish population analysis model that requires four input files: a starter file containing filenames and details about output reporting, a data file containing model dimensions and the data, a control file specifying model parameterization and set-up, and a forecast file containing specifications for reference points and forecasts (Methot et al. 2024). The SS model is a flexible framework that allows multiple fisheries, surveys, sexes, and areas to be modeled, which has become used around the world for stock assessments. Model code is available at the SS GitHub repository.

4.1.1 Dimensions

The first deviation from the SEDAR 93 benchmark assessment was the exclusion of all data sources from GA and FL. The intent of the SC sub-stock model was to evaluate Red Drum along coastal SC, so the geographical range of the modeled stock was limited to only SC.

The second deviation was to increase the terminal year for management advice from 2021 to 2023. All data sources were available for 2022 and 2023 (except age composition data for MRIP and the longline index, as well as age composition data from the trammel net survey). The originating year of 1981 was maintained and was as the model fishing year definition of September to August of the following year.

These deviations result in a model time series of recruitment, abundance, spawning stock biomass (SSB), spawning potential ratio (SPR), and fishing mortality (F) for fishing year 1981 through 2023 based on observed SC recreational catch (harvest + live discards) and associated composition data, as well as fishery-independent composition and relative abundance data from four SCDNR monitoring programs in the base model.

4.1.2 Structure and Configuration

4.1.2.1 Catch

The model included all recreational catch and discards of Red Drum captured in SC as reported in MRIP (section 3.1.2). Commercial data available from 1981 to 1987 were deemed to be minimal (section 3.1.1), so were excluded from the model as done in SEDAR 93 (ASMFC 2024b).

4.1.2.2 Survey Indices

Herein, we included the same four indices of relative abundance available from SCDNR used in SEDAR 93, updated through 2023, where appropriate (see section 3.2), and standardized using the *sdmTMB* framework with the consideration of spatiotemporal effects, where appropriate, as recommended by the SEDAR 93 review panel (ASMFC 2024b).

The rotenone survey was included as an age-0 recruitment survey (e.g., survey type 33 in SS) with no associated lengths or ages.

The base model incorporated marginal annual age composition data from the stop net survey but did not include annual length composition data. Length data were used in SEDAR 93, but peer reviewers criticized this decision as "double dipping" the data sources (SEDAR 2024) and recommended exclusion, as employed here, in future assessments when marginal annual age compositions were included as input.

The base model incorporated length and conditional age-at-length composition data from the trammel net, a deviation from SEDAR 93 (ASMFC 2024b). Therein, marginal annual age compositions were considered. The deviation from the treatment of the data stream in SEDAR 93 stemmed from four primary observations and concerns experienced by the model developers during development of the base model. First, during SEDAR 93 there was difficulty resolving the combination of age-based distribution changes between the longline and trammel net survey and apparent overlap in length compositions. Hence, we pursued the current approach, which based on preliminary investigations did resolve some selectivity estimation concerns while providing more robust data for growth estimation. Second, preliminary investigations suggested improved SS model diagnostics via this treatment. Finally, the current treatment appeared to minimize minor data conflicts between different sources.

The base model incorporated annual conditional age-at-length composition data from the longline survey but excluded associated annual length compositions, which is analogous to treatment of composition data for the survey in SEDAR 93 (ASMFC 2024b). In the benchmark development, it was noted the longline composition data showed decreasing size and age that were not consistent within the model. The decision was made to keep the longline index and age-at-length data but remove the length composition data.

4.1.2.3 Length Composition

All annual age length compositions for the current assessment were compiled using 2 cm bins and were consistent with treatment of length compositions in SEDAR 93 (ASMFC 2024b).

Annual length compositions for the recreational fleet were available and included from 1981-2023 (Figure 4.1), with lengths ranging from 12 to 136 cm TL. Lengths were input as TL, requiring data collected as FL (a.k.a., mid-line length (ML)) to be converted using stock-specific relationships estimated during SEDAR 93 (ASMFC 2024b; Table 4.1). The same bin structure was used for the SC Trammel Net Survey length frequencies, where lengths ranged from 16 to 120 cm TL, with length compositions available for 1991-2023 (Figure 4.1).

4.1.2.4 Age Composition

Annual conditional age-at-length data were input for the recreational fleet from 1981-2023, trammel net, and adult red drum & shark longline, as well as marginal age composition for the stop net survey was used (Figure 4.1). Ages were tracked within the model using an annual time step from age-0 through age-41. The annual time step was based on a September through August fishing year definition.

4.1.2.5 Growth

Growth was based on an age-specific k von Bertalanffy growth model outlined in the regional benchmark stock assessment (ASMFC 2024b; Table 4.2; Figure 4.2). All parameters not estimated within the model were fixed to the values output by the SEDAR 93 benchmark stock assessment to ensure biological growth exhibited by the population was maintained with the truncated data from the removal of FL and GA samples. However, the k multiplier parameters at age-1 and age-6 were estimated within the sub-stock model to improve estimates of growth within the SC data sources. Fixing the k multiplier parameter for each age break to the SEDAR 93 benchmark values resulted in model configuration problems with patterned deviations in residuals within the length compositions and age compositions.

4.1.2.6 Biological Parameters

Natural Mortality

Natural mortality at age-2 was fixed to the regional benchmark fixed value (ASMFC 2024b; Table 4.2; Figure 4.2). For the regional benchjmark, the fixed age-2 natural mortality estimates were externally calculated based on the external age-specific k growth model and the Lorenzen (2022) generalized length-inverse mortality paradigm (GLIM).

Maturity and Reproduction

Reproduction was assumed to occur on September 1 each year. Age-at-settlement in the model was fixed to 4 months old, hence recruitment estimates represent the recruitment of 4-month old juveniles to the population.

A 1:1 sex ratio is used within the model to estimate a female only spawning stock biomass, but otherwise the model does not differentiate between sexes. Maturity is fixed with the same parameters as used in the SEDAR 93 benchmark stock assessment (Table 4.2; Figure 4.2). First maturity was allowed at age 2, with 50% maturity between age 4 and 5, and 99% maturity at age 7.

Fecundity

Female spawning stock biomass was used as a proxy for reproductive potential in the SC sub-stock model, which was the same as the SEDAR 93 treatment (ASMFC 2024b). Fecundity information remains limited, limiting the use of egg based metrics of reproductive potential.

4.1.2.7 Stock-Recruitment

A Beverton-Holt functional form for the stock-recruitment relationship was assumed and the steepness parameter fixed at 0.99 (Table 4.2), the same treatment of stock-recruitment in SEDAR 93, specifically the steepness parameter in (ASMFC 2024b). Fixing steepness to 0.99, which was recommended by reviewers of the simulation assessment (ASMFC 2022), essentially means recruitment varies around virgin recruitment (R_0) recruitment. Virgin recruitment, R_0, was estimated within the model but the variation around the stock-recruitment relationship (σ_R: standard deviation of log(recruitment)) was fixed at 0.37 (Table 4.2). While fixed recruitment variation (i.e., fixed σ_R) was also used in the SEDAR 93 benchmark stock assessment, σ_R was tuned in the state sub-stock model using recommendations and techniques found in the SS user manual (Methot et al. 2024). Recruitment deviations were estimated from 1970 to 2024, with early estimates being required by the model to allow non-equilibrium age structure at the start of the assessment (Methot et al. 2024). However, to adjust for the model recruit estimates occurring on a log scale, a bias adjustment is needed during data-rich years (Methot and Taylor 2011). Using tuning methods recommended by the SS user manual (Taylor et al. 2021; Methot, Jr. et al. 2024), a bias adjustment began in 1975 with full bias adjustment starting in 1986 and maintained until the end of the modeled time series.

4.1.2.8 Fishing Mortality, Selectivity, and Retention

Several methods exist within the SS framework regarding how the model estimates fishing mortality (F). Herein, we chose to estimate F using the new fleet specific parameter hybrid approach (SS F Method 4; Methot et al. 2024). This newer method is the recommended approach for modeling F in SS when F represents a "tuned" fleet-specific F.

For reporting purposes, the fleet-specific annual F values can be calculated as the numbers-weighted F for particular ages. Within the assessment, numbers-weighted F was calculated for age-2 to correspond with the age range primarily targeted by the recreational fishery due to the slot limit regulation (Methot et al. 2024). This modeling choice was consistent with the regional benchmark stock assessment (ASMFC 2024b). F-at-age is also provided based on the selectivity and retention estimates for the recreational fleet by fishing year.

Selectivity of the recreational fishing fleet total catch was modeled the same as in the SEDAR 93 benchmark (ASMFC 2024b), namely using a length-based double normal, time invariant selectivity pattern (selectivity type 24; Methot et al. 2024). This pattern is very flexible, allowing for the fit of length-based dome shaped selectivity through the estimation of six model parameters: 1) initial length where selectivity begins increasing (*start_logit*), 2) ascending width of the selectivity curve (*ascend_se*, parameter value in ln(width)), 3) beginning size for the plateau where selectivity is maximized (*peak*; in cm), 4) width of full selectivity plateau (i.e., width of dome; *top_logit*) defined as logistic between peak and maximum length, 5) descending width of the selectivity curve (*descend_se*, parameter value in ln(width)), and 6) selectivity in the final length bin (*end_logit*; Table 4.3). In the base model, as was done in SEDAR 93 (ASMFC 2024b), the width of the full selectivity plateau (i.e., *top_logit*) parameter was fixed to allow peak selectivity between approximately 40 and 75 cm TL, to match outside estimates of selectivity within the SC recreational fishery provided by Troha (2023) based on tag-recapture data. Additionally, large "bull" Red Drum, much larger than the current regulatory slot limit, are targeted in a catch-and-release trophy fishery though length compositions from this segment of the fishery are not available. Because there are not any data sources to inform the selectivity of these larger individuals, herein, as was done in SEDAR 93 (ASMFC 2024b), we used a strong informative normal prior to control selectivity of Red Drum larger than the slot limit. Also consistent with the benchmark assessment (ASMFC 2024b), the initial length where selectivity begins increasing was fixed to -999, a special code to allow for logistic decay through the minimum length bin.

While the selectivity pattern defines the recreational fishing fleet total catch selectivity pattern, inclusion of a recreational fleet retention curve and discard mortality estimates allow for fits to sub-components of the total catch, namely retained catch and discarded catch and the associated composition data for these sub-components. For the retention curve, we assumed a dome-shaped retention model which, in a single sex model, uses five parameters to estimate a flexible double logistic retention pattern (Methot et al. 2024). The five parameters are the 1) ascending limb inflection point (*infl*), 2) ascending limb slope (*width*), 3) maximum retention controlling the height of the asymptote (*asymptote_logit*), 4) descending limb inflection point (*dome_infl*) and 5) descending limb slope (*dome_slope*; Table 4.4). Discarded catch is defined as live discards or dead discards, based on an 8% assumed discard mortality rate used in previous Red Drum stock assessments (SEDAR 18, SEDAR 44).

Since selectivity was considered time invariant, effects of regulation changes and their effects on fisherman behavior, sizes retained, and sizes discarded by the recreational fleet are modeled as changes in retention. This is accomplished through the use of retention time blocks (Table 4.4), specifically five time blocks designed to capture the various bag limit, vessel limit, and size limit regulations that have been implemented in SC (Table 1.1 and Table 3.2) throughout the time series. The retention blocks were established during the regional benchmark model development and maintained in the SC sub-stock stock assessment.

Selectivity of the indices matched closely with the SEDAR 93 benchmark assessment, except when parameters needed to be fixed that were hitting the bounds during model development. The rotenone survey was defined as a recruitment survey (special type = 33) with age-0 selectivity specified in SS for young-of-year catches (Methot et al. 2024). Both the stop net and trammel net indices selectivity was modeled using a double-normal, dome-shaped age-based selectivity pattern (selectivity type = 20) with most parameters for each index fixed at the values estimated in the benchmark assessment (Table 4.3). The non-fixed parameter exceptions were the peak of the selectivity curve for the trammel net survey and both the width and descending slope of the selectivity curve for the stop net survey (Table 4.3). The selectivity of the longline survey was modeled using a double normal, logistic length-based selectivity pattern (selectivity type = 24; Table 4.3). All parameters for the longline selectivity curve were fixed in the benchmark stock assessment based on expert opinion, model exploration, and model diagnostics (ASMFC 2024b); herein we fixed all longline selectivity parameters to the same values used in the regional benchmark assessment (Table 4.3). During development, releasing these parameters was explored in the SC sub-stock assessment but the same issue of the model trying to push the selectivity to the largest sizes/ages was experienced as in the benchmark assessment. Values were maintained as fixed estimates from the Troha (2023) study. All other priors used in the benchmark stock assessment to constrain parameters from excessively high variance were maintained in the SC sub-stock stock assessment.

Time series of all available data sources is shown in Figure 4.1.

4.1.3 Optimization and Weighting

Each data component within SS is assigned a variance based on an assumed error structure. Error structures in the SC sub-stock model were maintained from the SEDAR 93 benchmark stock assessment, with all fishing fleets assumed to have a lognormal error structure using PSEs as the measure of variance. We assumed a multinomial error structure for length and age compositions and an effective sample size. Here we deviate slightly from the regional benchmark stock assessment, as we used the Francis data re-weighting (Francis 2011) methods outlined in Methot et al. (2024) to adjust the effective sample size for the multinomial error structure. The Francis re-weighting (2011) method adjusts the sample sizes to create a model fit to the survey that matches expected mean length or age, ultimately "down-weighting" less informative data sources. The incorporation of the method allows for the abundance of the species estimated within a model to be informed from the indexed surveys with support from composition data, rather than composition data overwhelming indices. The Francis re-weighting was applied five times to the SC sub-stock model through tuning methods allowed in the r4ss package (Taylor et al. 2021).

4.1.4 Diagnostics

Model convergence was measured with several approaches that follow recommendations by Carvalho et al. (2021). The Hessian matrix was examined as to whether it was positive definite, and an inverted Hessian matrix was used to compare to the convergence criterion (Methot and Wetzel 2013). The maximum gradient component was compared to the preferred final convergence criterion of 0.0001, with an ideal scenario occurring when the maximum gradient component is less than the preferred value (Carvalho et al. 2021). The parameters were inspected to determine if any were estimated on a bound. When a parameter is estimated on or near a bound, it can indicate an issue with model structure and/or model performance in relation to the data provided. Additionally, a jitter analysis was conducted using 200 iterations where the parameter starting values were varied along a jitter factor (0.1) to determine if the model converged on a solution with the lowest possible negative log likelihood and tests the sensitivity to the starting values of the estimated parameters (Cass-Calay et al. 2014). The r4SS package was used to automate the jitter analysis (Taylor et al. 2021; R Core Team 2024).

The model fit to landings, discards, indices, and length/age composition were also evaluated as part of the diagnostics. Observed versus predicted values were visually compared for obvious concerns to the fit, then standardized residuals were calculated. To determine goodness-of-fit, the root mean square error (RMSE) was estimated for each index and length/age composition. The RMSE is the deviation of the unexplained variance and the smaller the value, the more precise the model fit (Winker et al. 2018; Carvalho et al. 2021). A joint-index residual plot that incorporates the lognormal residuals of abundance with the RMSE was used to better visualize the model fit and provide information on potential areas of model conflict (using boxplots) and highlight areas of systematically auto-correlated residual patterns (using a loess smoother; Winker et al. 2018). The RMSEs were calculated and joint-index residual plot created with the JABBA analysis available in the ss3diags package (Winker et al. 2023) in R (R Core Team 2024). The standardized residuals were also analyzed via the runs test to determine if there were apparent trends in the residuals over time and outliers were identified using the three-sigma limit to determine non-random variation (Punt et al. 2014; Anhøj and Olesen 2014; Carvalho et al. 2021; Winker et al. 2023). The runs test was completed using the ss3diags package (Winker et al. 2023) in R (R Core Team 2024).

Likelihood component profiles were conducted on the three recruitment parameters used in the model to examine the parameters informative capability within the model (Carvalho et al. 2021). Large changes in the likelihoods reveal the importance of the estimated parameter in the model construction. The recruitment parameters, particularly R_0, are used to scale between unfished (virgin) recruitment to the unfished biomass (Lee et al. 2014; Maunder and Piner 2015). By completing model runs under a profile of differing parameters values (*i.e.*, R_0, σ_R, and steepness), the change in likelihoods can be examined to determine the informative value of datasets, potential conflict in datasets, and/or potential model misspecification (Maunder and Starr 2001; Carvalho et al. 2021). For this assessment, likelihood profiles were completed for all three recruitment parameters: R_0, σ_R, and steepness.

4.1.5 Retrospective Analysis

Another way to assess model uncertainty is to develop a retrospective analysis to examine how estimates change based on the terminal year definition (Mohn 1999; Harley and Maunder 2003). A retrospective "peel" is accomplished by removing the terminal year of the model several times and reevaluating the results to determine if a bias occurs from the inclusion of any one year of data from the end of the time series. The degree of bias in the retrospective analysis can be evaluated by using the Mohn's ρ metric (Mohn 1999), which for a long lives species has ρ values between -0.15 and -0.2 (Hurtado-Ferro et al. 2015). A 6-yr retrospective analysis was conducted to be consistent with the regional assessment.

4.1.6 Sensitivity Analyses

A series of ten sensitivity analyses were chosen to test model sensitivity and stability based on the model assumptions and data configurations. Many of the sensitivity analyses completed were also completed in SEDAR 93 (ASMFC 2024b), as they were still of interest regarding their impact on the SC sub-stock model. To test configuration of data inputs, a sensitivity analysis was run by dropping the SC longline survey (**Drop Longline**), testing its ability to inform the model. Additionally, the contribution and configuration of data sources within a model can be manipulated by weighing it differently from other data sources (Method 1990; Francis 2011; Thorson et al. 2017). The data weighting within a model was tested by using the Dirichlet-Multinomial Error (DM) approach for integrated data weighting (**DM weighting**) rather than the Francis re-weighting completed in the base SC sub-stock model (Thorson et al. 2017). A sensitivity run without data weighting was also conducted (**unweighted**). The start year of the base model was 1981, so a sensitivity analysis was done to test this configuration choice by running the model with a 1989 start year (**Start 1989**), similar to previous iterations of the regional assessment. The treatment of recruitment in the model was also tested by changing the steepness parameter within the model configuration, which was under much scrutiny in the ASMFC 2024 benchmark peer review (SEDAR 2024). Sensitivity runs were completed by locking the steepness at 0.84 rather than 0.99 (**Steepness=0.84**), as suggested by the peer review, as well as allowing the model to freely estimate the steepness (**Steepness Estimated**).

Several sensitivity analyses were also designed to explore the base model's sensitivity to assumptions regarding natural mortality (M) and discard mortality. Natural mortality is notoriously difficult to estimate within integrated assessments, as it is typically confounded with other variables such as selectivity patterns, retention patterns, and fishing mortality. However, M is critical to establishing model scale and subsequent stock status. Hence, the sensitivity of the model to the choice of M, is typically evaluated, which was done here. Two alternative M values were evaluated as a standard source of uncertainty in stock assessment, namely either increasing (**M+20%**) or decreasing (**M-20%**) base model age-2 M by 20% relative to the base model estimate. As with the base model, M values for other ages are then calculated internally in SS. The next test examined the assumption of discard mortality at 8%, consistent with past Red Drum assessments which developed a mean range among multiple studies (SEDAR 2009). However, the peer reviewers from the ASMFC 2022 simulation analysis recommended lowering the discard mortality rate to 4%. The ASMFC 2024 benchmark did not lower the discard mortality rate but did complete a sensitivity analysis at the 4% rate (**4% Discard**). A recent discard mortality study documented a discard mortality rate of 4.8% for recreationally released adult Red Drum in SC (Ballenger and Frazier 2021), so testing a 4% discard mortality to be consistent with the benchmark was deemed appropriate.

4.1.6.1 Recreational Effort Estimates

The current methods for recreational fishing effort estimate have come under considerable scrutiny in recent years. Particularly, the use of the FES estimates, implemented by MRIP in 2015. These modified estimates are currently under additional review, as pilot studies indicated FES could potentially be skewed based on the way questions were asked during the interview process, resulting in effort estimates being underestimated up to 32% or overestimated up to 40% (Andrews et al. 2018; Andrews 2022). The ASMFC 2024 benchmark used a reduction of 30% effort, and hence an assumed 30% reduction in harvest and live discards to test the sensitivity of the model to this potential estimation error, which was followed in this assessment (**70% MRIP**). Additionally, the ASMFC 2024 benchmark peer review recommended combining multiple sensitivity analyses to see the overall impact of multiple sources of uncertainty in one run. The recommendation was to combine the adjusted MRIP catch estimates with decreased discard mortality rate (**MRIP and 4% Discard**), increased natural mortality (**MRIP and M +20%)**, and decreased natural mortality (**MRIP and M -20%**; SEDAR 2024). These sensitivities were also conducted in this assessment.

4.1.7 Reference Point Calculations

As done in SEDAR 93 (ASMFC 2024b), reference points for the model include $F_{30\%}$, $SPR_{30\%}$, and $SSB_{30\%}$ as thresholds and $F_{40\%}$, $SPR_{40\%}$, and $SSB_{40\%}$ as targets (Table 4.5). These are based on ASMFC Red Drum Amendment 2, which defines the overfishing threshold as $SPR_{30\%}$ and target SPR of $SPR_{40\%}$ (ASMFC 2002). Notably, Amendment to the ASMFC Red Drum FMP does not define an overfished threshold or spawning stock biomass (ASMFC 2002). Herein, we follow the recommendations of the Red Drum simulation assessment (ASMFC 2022) and the new regional benchmark assessment (ASMFC 2024b) and define the overfished threshold as $SSB_{30\%}$ and target SSB as $SSB_{40\%}$.

To calculate SPR, the spawning potential per recruit under the current year's fishing pressure is divided by what the spawning potential per recruit would be under no fishing pressure with the following equation:

$$SPR_y = \frac{\sum_a Mat_a B_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a B_a \prod_1^a e^{-M_a}},$$

where the maturity (Mat_a) and weight-at-age vectors are used through the maximum age of 41 years (ASMFC 2022). The $F_{xx\%}$ benchmarks are in terms of age-2 fishing mortality and are the levels of fishing mortality that achieve the SPR of the same percentage given terminal year life history characteristics, selectivity and retention patterns. The $SSB_{xx\%}$ benchmarks are the levels of equilibrium SSB associated with a stock fished at the SPR of the same percentage.

4.2 Results

4.2.1 Base Run—Diagnostics

The final model resulted in a maximum gradient component of 0.000105, slightly higher than the convergence criterion of 0.0001; however, the small increase over the recommendation in a sub-stock model seemed reasonable. None of the 71 estimated parameters or 54 estimated recruitment deviations were estimated at their bounds (Table 4.6-Table 4.9). Additionally, no parameters were highly correlated (>±0.95), and no parameters had low correlations (<0.01) with other parameters.

Of the 200 jitter runs conducted, all runs converged with 190 converging with a negative loglikelihood identical to the base model (negative loglikelihood = 1776.4; Table 4.10). The remaining 10 runs all converged on negative loglikelihoods higher than the base model, indicating a global minimum was reached and the model is insensitive to starting parameter estimates. The estimated SSB was similar for 189 of the 200 jitter runs, estimated to be higher in 3 runs, and estimated to be lower in 8 runs (Figure 4.3). Two of the runs with lower SSB estimates fell outside of the SSB 95% confidence intervals. The SPR estimate was similar for 189 runs, higher for 9 runs, and lower for 2 runs (Figure 4.3), where only 1 run ended with a terminal year estimate outside of the 95% confidence interval.

Fits to the observed recreational catch were generally close in most years of the model, except for early year estimates and a few years between 2012-2019 (Table 4.11; Figure 4.4). Poor fits in the 1981-1985 estimates of the catch are not concerning given the PSEs for those years were high (range 0.377-0.619). MRIP advises using caution with estimates when PSEs are greater than 0.3 and refrain from using estimates with PSEs greater than 0.5 (NMFS OST 2021). Between 2012 and 2019, the model underestimated the catch for four years of those years. However, immediately after these years, the model fit exceptionally well to the rest of the catch. The recreational discards fit well throughout the entire model (Table 4.11; Figure 4.5).

The joint-index residual plot indicated a good fit to the fishery-independent surveys with an overall RMSE of 0.326 (Table 4.12; Figure 4.6), which was slightly higher than the recommended RMSE value (RMSE<0.3; Winker et al. 2018). The model picked up trends in increase and decrease for young-of-year abundance in the SC Rotenone for all but 2 years, for sub-adults in the Stop Net survey in all years, and for sub-adults in all but 5 years in the SC trammel net survey (Figure 4.7). The fit to the SC longline survey ran through most of the data point confidence intervals but did not pick up trends in the survey through time (Figure 4.7). However, there was no evidence to reject the hypothesis that residuals were randomly distributed ($p > 0.05$; Table 4.12; Figure 4.8). Additionally, only one residual fell out of the three-sigma test; 2011 of the SC Longline index (Figure 4.8), which warranted additional exploration of the data. While the index estimate of abundance was low in 2010 and 2011, no explanation warranted exclusion of this data in the ASMFC benchmark (ASMFC 2024b) or the current assessment. The index picked up on declining recruitment to the adult population that the model failed to capture for that time period. None of the indices failed the runs test (Figure 4.8).

The model fit well to the length compositions for the SC recreational fleet and SC Trammel net sub-adult survey with an overall RMSE of 0.05 from the joint-index residual plot (Table 4.12; Figure 4.9). The model captured the aggregated length compositions well, except for some difficulty in the model's ability to capture multimodal peaks in the length composition (Figure 4.10). These difficulties were captured in the SC recreational length compositions when the multimodal pattern had one extremely high peak and one or more much lower peaks (Figure 4.11). Additionally, this difficulty was present in the SC Trammel net sub-adult survey in years with three multimodal peaks (Figure 4.12). Length composition for the SC recreational fleet and the SC Trammel net sub-adult survey passed the runs test with a non-significant random distribution test ($p > 0.05$). Both length compositions passed the runs test; however, several early years of the SC recreational fleet length composition residuals failed the three-sigma limit (Figure 4.13). These residuals coincide with years that had high PSEs.

The model did not fit well to the age composition for the SC Stop Net sub-adult survey with a RMSE of 0.428 (Table 4.12; Figure 4.14); however, the age composition did pass the runs test with a non-significant random distribution test ($p = 0.280$) and no values falling out of the three-sigma limit (Table 4.12; Figure 4.14 and Figure 4.15). Pearson residuals from the age composition fit indicate age one and two Red Drum were more abundant in the data than the model predicted, with more age three and age four Red Drum predicted than were observed in the data (Figure 4.15). This is an indication that the estimated age-based selectivity could be too high for the data observed, which was observed in the aggregated age composition plot for the SC Stop Net sub-adult survey (Figure 4.16); however, when fully estimating the age-based selectivity for the SC Stop Net survey, the model wanted to drive selectivity higher for older ages.

Fits to the conditional age-at-length composition from the recreational fleet were well through most of the timeseries (Figure 4.17), except for the first few years of the model where PSEs were also high. This indicates the model was able to track the trends in the age structure from the recreational fleet. Fits to the conditional age-at-length composition from the SC Trammel net sub-adult survey were good except for the initial and terminal year of the model (Figure 4.18). Using a conditional age-at-length composition for the SC Trammel net sub-adult survey improved the model's ability to track age structure, compared to the marginal age-at-length data used in the ASMFC benchmark (ASMFC 2024b). Fits to the conditional age-at-length composition from the SC longline adult survey improved through time, but the model consistently estimated younger fish in the first few years of the survey (Figure 4.19). The same trend in age structure was seen in the ASMFC regional assessment (ASMFC 2024b). The length composition data were excluded from both stock assessments to address the disconnect between age and length data, but the age data was maintained to provide some information on adult growth and early recruitment deviations.

4.2.2 Base Run— Selectivity and Population Estimates

Length-based selectivity for the SC recreational fishery shows a steep entry into the fishery that coincides with Red Drum's quick growth through early life stages, then a quick descent out of the fishery as Red Drum move out of the estuaries (Figure 4.20). Descent from peak selectivity does not return to no selectivity, as some Red Drum are captured in the adult "bull" fishery, though these individuals are not retained. Retention estimates follow the appropriate management changes where fish selected are only retained in time periods where management allows based on size (Figure 4.21). The peak of the retention curve also appropriately tracks bag and vessel limit changes that occurred in the fishery.

Length-based selectivity for the SC longline survey was fixed at parameters established in SEDAR 93 southern stock (ASMFC 2024b; Figure 4.20). Age-based selectivity estimates for the SC Stop Net sub-adult survey and SC Trammel net sub-adult survey were partially fixed to control the selectivity estimates to values similar to those estimated in the regional assessment (ASMFC 2024b). The SC Trammel net sub-adult survey encounters a broader range of ages than the SC Stop Net sub-adult survey, that allows peaks at a slightly older age (Figure 4.22), though selectivities decline rapidly such that neither survey encounters Red Drum older than approximately 6 years old. This matches their expected life history and recruitment to the more offshore, adult population (see Section 2 LIFE HISTORY).

Recruitment deviations exhibit a high degree of interannual variability throughout the time series (Figure 4.23). There were several early years of negative recruitment deviations during a time with depleted exploitable biomass at the start of the assessment period. A longer period without positive recruitment deviations has occurred since 2009, indicating a declining trend in recruitment in most recent years. Within the 43-yr time series, nine years of significantly above average and nine years of significantly below average recruitment have occurred; however, only one (2022) above average recruitment year has occurred since 2010, while three below average recruitment years have occurred (Figure 4.24). Additionally, the average recruitment in the last 10 years is 31% lower than the average recruitment from 2000-2009, a 10-yr period when the stock was not overfished with overfishing not occurring.

Estimated population abundance has shown high variability through time, though an increasing trend is evident in the late 1980s, as well as a more recent decline (Table 4.13; Figure 4.25). Trends in spawning stock biomass (SSB) through time were more obvious, with an increase above the $SSB_{threshold}$ in the 1990s to a peak SSB abundance in 2008, with a subsequent decrease (Table 4.13; Figure 4.26). The SSB fell below the threshold for fishing at 30% SPR in 2022. The terminal year 3-yr average ($\overline{SSB_{2021,2022,2023}}$) was 2,363 mt, below the $SSB_{30\%}$ of 2,416 mt.

Fishing mortality indicates the stock was over-exploited in the 1980s, with age-2 F exceeding $F_{threshold}$ ($F_{30\%} = 0.33$) in most years (Table 4.14; Figure 4.27). With a series of regulation changes in the late-1980s, the Red Drum age-2 F decreased in SC from values exceeding 0.6, with a maximum of 0.92 (1981) to a series low of 0.08 by 2000 (Table 4.14; Figure 4.27). Following this minimum, age-2 F began a period of increase, with F once again exceeding $F_{threshold}$ generally since 2014. In 2021 and 2022, age-2 F did not exceed $F_{threshold\%}$. The terminal year age-2 F was the highest observed since 1985 at 0.56, well above $F_{30threshold\%}$. Year specific F-at-age estimates, derived from year specific selectivity and retention, are provided in Table 4.15.

As expected, static spawning potential ratio (SPR) generally increases as age-2 F decreases, and vice versa (Table 4.14; Figure 4.27 and Figure 4.28). As such, in the early-1980s, which was a period of high *F*, annual SPR estimates generally were well below target ($SPR_{40\%}$) and threshold ($SPR_{30\%}$) levels, though as *F* began to decline in the late-1980s and early-1990s through the early-2000s, annual SPR increased achieving series highs above 0.7 in 2000 and 2001. Since this time series peak, annual SPR has decreased falling once again below $SPR_{40\%}$ since 2010 and below $SPR_{30\%}$ in 2014 (Table 4.14; Figure 4.28). Again, a combination of slightly decreased recreational harvest and dead discards in 2021 and 2022 coupled with the first significantly above average recruitment event since 2010 in 2022 led to SPR rising above $SPR_{30\%}$ in 2021 and 2022; however, the estimate dropped to the lowest SPR since the late-1980s in the terminal year of the assessment, 2023, at 0.137. The 3-yr terminal average ($\overline{SPR_{2021,2022,2023}}$) is 0.303, above the SPR threshold at 0.3, but barely. Another year at current fishing levels without strong recruitment will push the 3-yr average into an overfishing status (Figure 4.29). Historical trends indicate strong recruitment years only occur every 7 to 12 years.

Likelihood profiles were completed for R_0, steepness, and σ_R parameters, ranging from 6.5 to 8.5 at 0.1 increments, 0.8 to 0.99 at 0.01 increments, and 0.25 to 0.6 at 0.25 increments respectively. For the R_0 parameter, there was a clear minimum in log-likelihood at 7.2-7.3, with this corresponding in minimum of likelihoods for harvest, length and recruitment data (Figure 4.30). The other model components either suggested lower levels of recruitment (e.g., equilibrium catch and age composition data) or higher levels of recruitment (e.g., discard and index data; Figure 4.30). This provides insight into some data conflicts within the model; however, a total likelihood is the balance of these information sources with a likelihood minimum at the base model estimate of 7.263 (Figure 4.30). The likelihood profile for steepness showed similar data conflicts with minimum likelihoods occurring at low values for discard and index data, but all other data sources having minimum likelihood at high values (Figure 4.31). The balance between these parameters is shown in the total likelihood occurring at its minimum at a steepness of 0.99, the fixed value used in the base model (Figure 4.31). The final likelihood profile shows the same pattern with recruitment reaching minimum likelihood when σ_R is low and length, discard, index, age, and harvests data reaching minimum likelihood when σ_R is high (Figure 4.32). When the total model likelihood is at the minimum, σ_R was estimated at 0.44. However, the value of σ_R was estimated using tuning methods outlined by the SS user manual (Methot et al. 2024), which recommended σ_R=0.37.

4.2.3 Retrospective Analysis

A retrospective bias did occur in the SC sub-stock model, with the retrospective pattern suggesting the model underestimates terminal year SSB (Mohn's ρ=-0.18; Figure 4.33). This was the same directional bias as indicated in SEDAR 93 southern stock, though they noted the bias was driven by a singular 3-yr peel which resulted in the use of 2019 fishing year as the terminal year (ASMFC 2024b). In the regional assessment, when this peel was removed Mohn's ρ increased to a level appropriate for a long-lived species. The singular 3-yr peel and the direction of the bias resulted in the ASMFC 2024 benchmark not creating a correction factor for the SSB estimate. When the same methods are applied for the SC sub-population stock assessment, the Mohn's ρ increased to -0.15, which is an acceptable Mohn's ρ for Red Drum (Figure 4.33). Retrospective biases did not occur for Relative SSB (Figure 4.33), Age-2 F, or SPR (Figure 4.34).

4.2.4 Evaluate Data Sources and Select Parameters

Thirteen sensitivity analyses were performed to test assumptions and data configurations of the model. The first ten analyses examined one parameter at a time, while the final three were a mix of mortality estimates changing to examine potential confounding issues.

4.2.4.1 Single Parameter Change Sensitivities

4.2.4.1.1 <u>Fishing Mortality and Spawning Potential Ratio</u>

All of the Age-2 F estimates fell within the 95% confidence intervals of the base model, a few early years when the longline data were dropped (Figure 4.35), indicating the age class data provided by the longline survey contributes to early estimates of F. Additionally, a few early years of the run when the model used Dirichlet data weighting were also outside of the 95% confidence intervals but still exhibited the same trend (Figure 4.35). Similarly, while the model indicates some initial year sensitivity of SPR to model assumptions, by the mid-1990s there is generally little difference in annual SPR estimates between runs, with all runs indicating terminal year SPR is below the $SPR_{threshold}$ (Figure 4.35). Given the 3-yr terminal average SPR was extremely close to $SPR_{threshold}$ (0.303 vs 0.30), two individual sensitivity runs (**Drop Longline** and **M-20%**) calculated terminal 3-yr average SPR that fall below $SPR_{threshold}$ indicating a change in fishing mortality based stock status to overfishing. The remaining eight runs resulted in terminal 3-yr SPR estimates above the threshold, so overfishing was not occurring which was in agreement with the base model; however, the highest of the eight had an SPR of 41.7% with the same overall trend as the base model. Without above average recruitment in the next few years, all runs indicate the stock will be experiencing overfishing within 1 to 2 years with current fishing effort.

4.2.4.1.2 Spawning Stock Biomass

All of the estimates of spawning stock biomass in the sensitivity runs fell within the 95% confidence intervals of the base run in the terminal year, except for the run with Dirichlet Multinomial weighting rather than Francis re-weighting, which resulted in a higher spawning stock biomass (Figure 4.36). However, the model using the DM method had a final gradient that was an order of magnitude higher than the base model (0.0014). The 3-yr average terminal estimates of SSB fall below the threshold for five of the ten runs, indicating these runs still result in an overfished status (Figure 4.36). The remaining five runs (**M+20%**, **Steepness=0.84**, **DM weighting**, **Start 1989**, and **4% Discard**) have terminal 3-yr SSB estimates above the threshold; however, all have the same downward trend. Without above average recruitment and no changes in current fishing pressures, these runs will also result in SSB estimates lower than the threshold in a few years.

4.2.4.2 MRIP Effort Estimates and Combined Sensitivity Analyses

When estimates of MRIP are changed to reflect the potential overestimated effort, the scale of the model changes for estimates of SSB, as well as the estimates of the thresholds of those parameters (Table 4.16). Changing MRIP estimates alone resulted in the same trends and relative relationship to thresholds, so the stock was still overfished with overfishing likely to occur in 1 to 2 years (Table 4.16; Figure 4.37).

When combining the potential MRIP overestimation with other mortality (i.e., increasing or decreasing age-2 M by 20% and decreasing discard mortality to 4%) sensitivity runs, the Age-2 F's never fell out of the 95% confidence intervals for the base run and the 3-yr terminal average indicated that overfishing is not occurring at this time (Figure 4.38). The trend in all sensitivity runs still indicates that the stock will likely experience overfishing in one to two years without above average recruitment. Estimates of spawning stock biomass fell within the 95% confidence interval of the base model for all additional sensitivity runs, except for the 70% MRIP and M+20% run where the SSB was slightly lower than the lower 95% confidence interval (Figure 4.39). However, the terminal year relative SSB ended at the same location as the base model, showing further evidence the threshold changed, and the conclusion would remain the same as the base model. Given all the sensitivity analyses come to the same conclusion as the base model, the SC sub-population model is largely insensitive to configuration choices.

4.3 Discussion

The model performed well, with good stability and positive diagnostics. Many sensitivity analyses revealed the model was insensitive to configuration choices. The few sensitivity analyses that changed the stock status results had more concerning diagnostics and therefore increases our confidence in the base model chosen for the SC sub-stock stock assessment.

The SC sub-stock was historically overfished with overfishing occurring in the 1980s. Implementation of successful management actions allowed the population to recover to sustainable levels in the 1990s and 2000s. During the years of sustainable harvest, a culture shift in the fishing community began in response to the management actions of the early-1990s. The interest in a catch-and-release fishery grew and has become an important component of the SC Red Drum fishery. However, the rise in the catch-and-release fishery, with concomitant increases in dead discards, has led to increases in exploitation rates, and hence decreases in static spawning potential ratio and spawning stock biomass, since recent highs in the early-2000s. As such, it is important to recognize that the expansion of a conservation minded catch-and-release fishery, with overall increases in effort, can still lead to increases in fishing mortality and subsequent declines in spawning stock biomass. This effect is exacerbated when environmental or other factors leads to an extended period of poor recruitment as generally observed since 2010 for Red Drum in SC. While most Red Drum captured in the catch-and-release fishery survive, effort has become so high that the mortality it causes exceeds the sustainable limits of the current population under current management levels. As such, for SSB to recover, total removals (thus the exploitation rate) must be decreased from current levels. The trends in *F*, SPR, and SSB are consistent in the SC sub-stock model and the regional model (ASMFC 2024b), as well as echoed in many data sources used to monitor the Red Drum population in SC and our neighboring states. Indices consistently indicate reduced abundance through most life stages in recent years. Length-frequencies and age-frequencies are impacted, in some cases showing clear truncation of the population, indicating depressed abundance. Concerns about the population are based on the wide breadth of information contained in this report.

5. STOCK STATUS

Overall, the model demonstrated the same trend of decreasing SPR and SSB values exhibited in the regional model (ASMFC 2024b). The 3-yr terminal average (2021-2023) of SSB was 2,363 mt, lower than the $SSB_{threshold}$ ($SSB_{30\%}$=2,431 mt). Thus, the stock is **overfished** in the terminal year. Annually an overfished status began in 2022, with the 3-yr average falling below the threshold in 2023 (Figure 4.26).

The 3-yr terminal average (2021-2023) SPR was 0.303 percent, above the $SPR_{threshold}$ (0.3), indicating the stock was **not experiencing overfishing** in the terminal year. However, the annual SPR in 2023 was 0.137, the lowest value since 1987, with indications the high 3-yr terminal average was caused by several factors, including a COVID induced temporary reduction in annual total removals in 2021 and 2022, average recruitment in 2020 which was the highest observed at that time since the late-2000s, and significantly above average recruitment in 2022. Historical patterns, and the increase in total removals in 2023, which resulted in increases in age-2 *F* and decrease in SPR, and expectation of a period of average to below average recruitment in the next few years suggests 3-yr average SPR will drop below 0.3 in the next year or two. This would change the fishing mortality stock status to **experiencing overfishing**.

Terminal year estimates of SSB and SPR are at or approaching values last seen in the 1980s, the last time the stock was defined as overfished with overfishing occurring. The management actions in the 1990s and a sustained period of average recruitment led to the population recovering in the 2000s. However, recent declining trends in recruitment and increased discard mortality have led to reduced SPR and SSB values again. Directed harvest has maintained at a relatively constant level, but the sharp increase in the catch and release fishery that has become popular has led to increasing discard mortality rates. Thus, total removals of Red Drum from SC have continued to climb, while SPR and SSB have decreased to low levels.

The time series of joint SSB and SPR status is provided in Figure 4.29 to show how the stock status has changed through time across coastal SC. The time series is based on 3-yr averages.

6. PROJECTIONS

Projections were completed on the 2024 regional benchmark stock assessments and resulted in a recommended 28.1% reduction in total removals to ensure F was reduced to levels to maintain an SPR_{target} of 0.4, as per Amendment 2 of the Fishery Management Plan (ASMFC 2002). These projections were completed by forward-projecting the population with recruitment defined by the stock-recruitment relationship in the model, F-at-age maintained at the 3-yr terminal average (2019-2021), and all other life history components maintained. These methods were held constant for projections on the SC sub-stock model, except the 3-yr terminal average was advanced to match the SC sub-stock model the change in years (2021-2023). Resulting projections suggest a reduction of 20.1% in total removals is needed to maintain an SPR_{target} of 0.4 (Figure 6.1). Once the 20.1% reduction is achieved and maintained, it will take seven years for the $SSB_{threshold}$ to be achieved (Figure 6.1). However, the SSB_{target} will not be attainable within a 40-yr projection period. With F reduced 20.1% constantly through time, the estimated biomass in 2063 will be 3,223 mt, below the SSB_{target} of 3,229 mt under the assumption of constant effort.

A major reason for the difference in needed reductions between the regional benchmark assessment and the SC sub-stock assessment was due to the large recruitment class that occurred in 2022. This large recruitment class was a part of the 2021-2023 terminal year average within the SC sub-stock model. Thus, the projections include a very large event that has only occurred once in 15 years. Given the rarity of this event, we felt a projection with the same terminal year as the regional benchmark assessment was necessary. When projections were completed on the SC sub-stock model with a terminal average of 2019-2021, a reduction of 23.8% in total removals is needed to maintain an SPR_{target} of 0.4 (Figure 6.2). After a reduction of 23.8% is achieved and maintained, it will take seven years for the $SSB_{threshold}$ of 2,416 mt ($SSB_{30\%}$) to be reached and 32 years to rebound to a SSB_{target} of 3,229 mt ($SSB_{40\%}$).

Projections were also estimated with a potential increase in effort through time. Fishing effort has increased linearly over the past 25 years (Figure 3.2). When this linear increase is applied to terminal year catch averages, potential future catch can be calculated. The 3-yr terminal average total removals in the SC sub-stock model was estimated at 482,000 Red Drum either harvested or deceased from discard mortality rate. With the anticipated effort increase over the next few years, total removals in 2028 are estimated to be 1,109,000 Red Drum. Under this scenario, the necessary reduction to account for the effort increase and maintain an SPR_{target} of 40% would be 66.5% reduction in total removals (Figure 6.3).

7. RESEARCH RECOMMENDATIONS

Herein, we build upon the research recommendations identified by the ASFMC Red Drum stock-assessment sub-committee as part of the regional benchmark assessment (ASMFC 2024b). As was done in the regional assessment, these are prioritized by priority (high, moderate, low) and timeframe (short-term and long-term).

7.1 Short-Term Research Recommendations

7.1.1 High Priority

- Develop methods (e.g., voluntary logbook programs, catch cards, app reporting) to estimate recreational discard catch length composition data for SC. Discard length compositions were identified as a crucial variable to improve future Red Drum assessments (ASMFC 2022) and no current program exists for providing un-biased Red Drum discard length compositions from SC waters. Such information is critical for better understanding the sizes/ages of dead discards.
- Collect data to estimate length/age-based movement rates (e.g., acoustic tagging) of sub-adults in inshore waters to the adult population in offshore/nearshore waters for development of multi-area assessment models. Such data is expected to be important for resolving lingering data conflicts in the base model presented herein.
- Information is needed to characterize temporal shifts, both historical and into the future, in fisherman behavior as it pertains to size/age-based selectivity. Current data limitations requires assuming constant selectivity of the recreational fleet across time, despite anecdotal evidence suggesting increasing selectivity on above slot-limit fish in SC. Data is lacking to characterize this increase, and hence to incorporate this shift in selectivity in the current model.

7.1.2 Moderate Priority

- Increase collection of otolith ages proportional to lengths. Conduct statistical analysis to determine appropriate sample sizes to adequately characterize the age-size composition of removals. Greater sampling would support development of seasonal models, which may be important for resolving lingering data conflict in the base model, particularly with respect to fitting length- and age-composition data.
- Determine batch fecundity estimates of Red Drum to support fecundity-based estimates of reproductive potential in assessment models. Age-specific spawning frequency and spawning season length need to be included for this indeterminate spawner.

7.1.3 Low Priority

- Increased age sampling of adults to better characterize year class strength when size-at-age overlaps considerably. Adult Red Drum grow very slowly, with 30+ year classes represented in the spawning stock. Only through increased age sampling will we be able to detect early signs of age-truncation of the spawning stock biomass, a clear signal of increasing exploitation.
- Further study is needed to determine discard mortality estimates for SC. Such studies should consider the impact of slot-size limit management and explore regulatory discard impacts due to high-grading. Further, studies should consider potential covariates affecting discard mortality, such as fishing depth, size, seasonality, terminal tackle, and handling practices.
- Determine contributions of stocked fish to wild populations and their impacts to our understanding of stock-recruitment dynamics and stock status for the SC sub-stock.
- Investigate reference points for Red Drum management, in particular given the recent literature related to the use of static spawning potential ratio.

7.2 Long-Term Research Recommendations

7.2.1 High Priority

- Expand tag-recapture analyses either through direct incorporation into an age-based integrated assessment framework or through external tag-recapture models capable of directly providing estimates of apparent survival, exploitation rates, movement rates, detection probability, etc.
- Explore the impact that sub-lethal stress of the catch-and-release of mature Red Drum prior to and during the spawning season has on annual reproductive output and year class strength.

7.2.2 Moderate Priority

- Identify impacts of water quality, environmental, ecosystem, and habitat changes on Red Drum stock dynamics, particularly recruitment. Incorporate into stock assessment models.
- Investigate a two-area model that separates fish between inshore/offshore areas to better differentiate life history stages (older sub-adults vs. mature adults) that cannot be as clearly separated by available data (i.e., lengths). Data to inform movement rates between areas will be needed which are essentially the same data to inform descending selectivity of the recreational fishery. Catch data will also need to be split into areas.

8. LITERATURE CITED

Adams, D. H. and D. M. Tremain. 2000. Association of large juvenile Red Drum, *Sciaenops ocellatus*, with an estuarine creek on the Atlantic coast of Florida. Environmental Biology of Fishes 58: 183–194. https://doi.org/10.1023/A:1007614930445

Agresti, A. 2002. Categorical Data. Second Edition. Wiley. https://doi.org/10.1002/0471249688

Anderson, S. C., E. J. Ward, P. A. English, L. A. K. Barnett, and J. T. Thorson. 2024. sdmTMB: An R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. https://doi.org/10.1101/2022.03.24.485545.

Andrews, R. 2022. Evaluating measurement error in the MRIP fishing effort survey: The effect of questions sequence on reporting of fishing activity. NOAA Fisheries Service, Office of Science and Technology, Washington, D.C. https://www.fisheries.noaa.gov/recreational-fishing-data/fishing-effort-survey-research-and-improvements

Andrews, W. R., K. J. Papacostas, and J. Foster. 2018. A Comparison of Recall Error in Recreational Fisheries Surveys with One- and Two-Month Reference Periods. North American Journal of Fisheries Management 38(6):1284–1298. https://doi.org/10.1002/nafm.10233

Anhøj, J., and A. V. Olesen. 2014. Run Charts Revisited: A Simulation Study of Run Chart Rules for Detection of Non-Random Variation in Health Care Processes. PLoS ONE 9(11):e113825. https://doi.org/10.1371/journal.pone.0113825

Arnott, S., W. Roumillat, J. Archambault, C. Wenner, J. Gerhard, T. Darden, and M. Denson. 2010. Spatial synchrony and temporal dynamics of juvenile Red Drum *Sciaenops ocellatus* populations in South Carolina, USA. Marine Ecology Progress Series 415:221–236. https://doi.org/10.3354/meps08710

ASMFC (Atlantic States Marine Fisheries Commission). 1984. Fishery Management Plan for Red Drum. 115 pages. Atlantic States Marine Fisheries Commission, Fisheries Management Report No. 5, Washington, D.C. https://asmfc.org/resources/management/management-plan/red-drum-fishery-management-plan/

ASMFC. 2002. Amendment 2 to the Interstate Fishery Management Plan for Red Drum. 159 pages. Atlantic States Marine Fisheries Commission, Fishery Management Report 38, Arlington, VA. https://asmfc.org/resources/management/management-plan/red-drum-amendment-2/

ASMFC. 2017. Red Drum benchmark stock assessment and peer review report. 126 pages. Atlantic States Marine Fisheries Commission, Washington, D.C. https://asmfc.org/resources/science/stock-assessment/red-drum-benchmark-stock-assessment-and-peer-review-report-2017/

ASMFC. 2022. Red Drum simulation assessment and peer review report. 567 pages. Atlantic States Marine Fisheries Commission, Washington, D.C. https://asmfc.org/resources/science/stock-assessment/red-drum-simulation-assessment-and-peer-review-report-2002/

ASMFC. 2024a. Fish habitat of concern designations for fish and shellfish species. Atlantic States Marine Fisheries Commission Habitat Committee, Arlington, VA. https://asmfc.org/resources/habitat/habitat-special-report/fish-habitat-of-concern-designations-for-fish-and-shellfish-species/

ASMFC. 2024b. 2024 Red Drum Benchmark Stock Assessment Report. 439 pages. Atlantic States Marine Fisheries Commission, Washington, D.C. https://asmfc.org/resources/science/stock-assessment/red-drum-benchmark-stock-assessment-and-peer-review-report-2024/

Ballenger, J. C., and B. S. Frazier. 2021. Post-release mortality of adult Red Drum caught by recreational anglers. 33 pages. South Carolina Department of Natural Resources, Final Project Report, Charleston, SC.

Baltz, D. M., J. W. Fleeger, C. F. Rakocinski, and J. N. McCall. 1998. Food, density, and microhabitat: Factors affecting growth and recruitment potential of juvenile saltmarsh fishes. Environmental Biology of Fishes 53: 89–103. https://doi.org/10.1023/A:1007471724608

Bass, R. J. and J. W. Avault Jr. 1975. Food habit, length-weight relationship, condition factor, and growth of juvenile Red Drum, *Sciaenops ocellatus*, in Louisiana. Transactions of the American Fisheries Society 104(1): 35–45. https://doi.org/10.1577/1548-8659(1975)104%3C35:FHLRCF%3E2.0.CO;2

Beaumarriage, D. S. 1969. Returns from the 1965 Schlitz tagging program, including a cumulative analysis of previous results. Florida Department of Natural Resources Technical Series 59: 1–38. https://sedarweb.org/documents/sedar-51-rd-09-returns-from-the-1965-schlitz-tagging-program-including-a-cumulative-analysis-of-previous-results/

Beck, M. W., K. L. Heck, K. W. Able, D. L. Childers, D. B. Eggleston, B. M. Gillanders, B. Halpern, C. G. Hays, K. Hoshino, T. J. Minello, R. J. Orth, P. F. Sheridan, and M. P. Weinstein. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. BioScience 51(8): 633–641. https://doi.org/10.1641/0006-3568(2001)051[0633:TICAMO]2.0.CO;2

Beckwith, A. B., G. H. Beckwith, Jr., and P. S. Rand. 2006. Identification of critical spawning habitat and male courtship vocalization characteristics of Red Drum, *Sciaenops ocellatus*, in the lower Neuse River estuary of North Carolina. North Carolina Sea Grant Fishery Research Grant Program, Final Report 05-EP-05.

Brown-Peterson, N. J., D. M. Wyanski, F. Saborido-Rey, B. J. Macewicz, and S.K. Lowerre-Barbieri. 2011. A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 3: 52-70. https://doi.org/10.1080/19425120.2011.555724

Buckley, J. 1984. Habitat suitability index models: Larval and juvenile Red Drum. U.S. Fish and Wildlife Service. pp. 1–25. https://apps.dtic.mil/sti/tr/pdf/ADA323409.pdf

Carvalho, F., H. Winker, D. Courtney, M. Kapur, L. Kell, M. Cardinale, M. Schirripa, T. Kitakado, D. Yemane, K. R. Piner, M. N. Maunder, I. Taylor, C. R. Wetzel, K. Doering, K. F. Johnson, and R. D. Methot. 2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research 240:105959. https://doi.org/10.1016/j.fishres.2021.105959

Cass-Calay, S. L., J. C. Tetzlaff, N. J. Cummings, and J. J. Isely. 2014. Model diagnostics for Stock Synthesis 3: Examples from the 2012 assessment of Cobia in the U.S. Gulf of Mexico. Collective Volume of Scientific Papers ICCAT 70(5):2069–2081. https://www.iccat.int/Documents/CVSP/CV070_2014/n_5/CV070052069.pdf

Comyns, B. H., J. Lyczkowski-Shultz, D. L. Nieland, and C. A. Wilson. 1991. Reproduction of Red Drum, *Sciaenops ocellatus*, in the Northcentral Gulf of Mexico: Seasonality and spawner biomass. U.S. Department of Commerce NOAA Technical Report NMFS 95: 17–26. http://hdl.handle.net/1969.3/24200

Cushman, E., M. Jamison, and T. Darden. 2014. Adult Red Drum genetic diversity and population structure. SEDAR Working Paper SEDAR44-DW01. https://sedarweb.org/documents/s44-dw01-adult-red-drum-genetic-diversity-and-population-structure/

Cushing, D. H. 1975. Marine ecology and fisheries. Cambridge University Press, Cambridge, England.

Daniel, III, L. B. 1988. Aspects of the biology of juvenile Red Drum, *Sciaenops ocellatus*, and Spotted Seatrout, *Cynoscion nebulosus*, (Pisces: Sciaenidae) in South Carolina. M.S. Thesis. College of Charleston, Charleston, SC.

Francis, R. I. C. C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(6):1124–1138. https://doi.org/10.1139/f2011-025

FWCC (Florida Fish and Wildlife Conservation Commission). 2008. Red Drum, *Sciaenops ocellatus* stock assessment. Florida Fish and Wildlife Conservation Commission: Red Drum 61.

Gulland, J. A. 1983. Fish Stock Assessment. A Manual of Basic Method. 241 pages. FAO/Wiley Series on Food and Agriculture, Rome.

Haddon, M. 2011. Modelling and Quantitative Methods in Fisheries, second ed. CRC Press, Boca Raton. https://doi.org/10.1201/9781439894170

Hamel, O. S. and J. M. Cope. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. Fisheries Research 256:106477. https://doi.org/10.1016/j.fishres.2022.106477

Hampton, J. 2000. Natural mortality rates in tropical tunas: size really does matter. Canadian Journal of Fisheries and Aquatic Sciences, 57(5):1002-1010. https://doi.org/10.1139/f99-287

Harley, S. J., and M. N. Maunder. 2003. Recommended diagnostics for large statistical stock assessment models. 36 pages. 16th Meeting of the Standing Committee on Tuna and Billfish, SCTB16 Working Paper MWG-3, Mooloolaba, Qld, Australia.

Hartig, F. 2022. DHARMa: Residual diagnostics for hierarchical (Multi-Level / Mixed) Regression Models. R Package Version 0.4.6, https://CRAN.R-project.org/package-DHARMa.

Hilborn, R., and C. J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. 570 pages. Chapman and Hall, London, UK. https://doi.org/10.2307/1312107

Houde E. D. 1987. Fish early life dynamics and recruitment variability. American Fisheries Society Symposium 2:17-29.

Hurtado-Ferro, F., C. S. Szuwalski, J. L. Valero, S. C. Anderson, C. J. Cunningham, K. F. Johnson, R. Licandeo, C. R. McGilliard, C. C. Monnahan, M. L. Muradian, K. Ono, K. A. Vert-Pre, A. R. Whitten, and A. E. Punt. 2015. Looking in the rear-view mirror: Bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science 72(1):99–110. https://doi.org/10.1093/icesjms/fsu198

Holt, G.J., S.A. Holt, and C.R. Arnold. 1985. Diel periodicity of spawning in sciaenids. Marine Ecology Progress Series 27: 1–7. https://www.int-res.com/articles/meps/27/m027p001.pdf

Holt, J., R. Godbout, and C. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of Red Drum *Sciaenops ocellatus*. Fishery Bulletin 79(3): 569–573.

Holt S. A., C. L. Kitting, and C. R. Arnold. 1983. Distribution of young Red Drums among different sea-grass meadows. Transactions of the American Fisheries Society 112: 267–271.

Holt, S. A., G. J. Holt, and C. R. Arnold. 1989. Tidal stream transport of larval fishes into non-stratified estuaries. Rapports du Conseil International pour l'Exploration de la Mer 191: 100–104.

Jannke, T. 1971. Abundance of young sciaenid fishes in Everglades National Park, Florida, in relation to season and other variables. University of Miami Sea Grant Technical Bulletin 11. https://repository.library.noaa.gov/view/noaa/40365/noaa_40365_DS1.pdf

Johnson, D. R. and N. A. Funicelli. 1991. Spawning of the Red Drum in Mosquito Lagoon on the east coast of Florida. Estuaries 14: 74–79. https://doi.org/10.2307/1351984

Johnson, G. D. 1978. Development of fishes of the mid-Atlantic Bight. An atlas of egg, larval and juvenile stages. Vol IV. U.S. Fish and Wildlife Service, Biological Services Program. FSW/OBS-78/12:190- 197.

Lee, H. H., K. R. Piner, R. D. Methot, and M. N. Maunder. 2014. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: An example using blue marlin in the Pacific Ocean. Fisheries Research 158:138–146. https://doi.org/10.1016/j.fishres.2013.12.017

Lindgren, F., H. Rue, and J. Lindstrom. 2011. An explicit link between Gaussian fields and Gaussian Markov random fields: the stochastic differential equation approach. Journal of the Royal Statistical Society: Statistical Methodology Series B 73(4):423-498. https://doi.org/10.1111/j.1467-9868.2011.00777.x

Lorenzen, K. 2022. Size- and age-dependent natural mortality in fish populations: Biology, models, implications, and a generalized length-inverse mortality paradigm. Fisheries Research 255:106454. https://doi.org/10.1016/j.fishres.2022.106454

Lorenzen, K., E. V. Camp, and T. M. Garlock. 2022. Natural mortality and body size in fish populations. Fisheries Research 252:106327. https://doi.org/10.1016/j.fishres.2022.106327

Lowerre-Barbieri, S. K., L. R. Barbieri, J. R. Flanders, A. G. Woodward, C. F. Cotton, and M. K. Knowlton. 2008. Use of passive acoustics to determine Red Drum spawning in Georgia waters. Transactions of the American Fisheries Society 137:562-575. https://doi.org/10.1577/T04-226.1

Luczkovich, J. J., H. J. Daniel, III, and M. W. Sprague. 1999. Characterization of critical spawning habitats of Weakfish, Spotted Seatrout and Red Drum in Pamlico Sound using hydroplane surveys. 128 pages. Completion Report, F-62, NC Division of Marine Fisheries, Morehead City, NC. http://hdl.handle.net/10342/7109

Lux, F. E. and J. V. Mahoney. 1969. First records of the channel bass, *Sciaenops ocellatus*, in the Gulf of Maine. Copeia 1969:632-633.

Lyczkowski-Shultz, J. and J. P. Steen, Jr. 1991. Diel vertical distribution of Red Drum *Sciaenops ocellatus* larvae in the northcentral Gulf of Mexico. Fishery Bulletin 89:631–641. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1991/894/lyczkowski-shultz.pdf

Mansueti, R. J. 1960. Restriction of very young Red Drum (*Sciaenops ocellata*) to shallow estuarine waters of the Chesapeake Bay during late autumn. Chesapeake Science 1: 207–210. https://doi.org/10.2307/1350403

Marks Jr., R. E. and G. P. DiDomenico. 1996. Tagging studies, maturity, and spawning seasonality of Red Drum (*Sciaenops ocellatus*) in North Carolina. Completion Report Grant F-43, 1–39.

Maunder, M. N., and K. R. Piner. 2015. Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science 72(1):7–18. https://doi.org/10.1093/icesjms/fsu015

Maunder, M. N., and P. J. Starr. 2001. Bayesian assessment of the SNA1 snapper (Pagrus auratus) stock on the north-east coast of New Zealand. New Zealand Journal of Marine and Freshwater Research 35(1):87–110. https://doi.org/10.1080/00288330.2001.9516980

Maunder, M. N., O. S. Hamel, H. Lee, K. R. Piner, J. M. Cope, A. E. Punt, J. N. Ianelli, C. Castillo-Jordan, M. S. Kapur, and R. D. Methot. 2023. A review of estimation methods for natural mortality and their performance in the context of fishery stock assessment. Fisheries Research 257, 106489. https://doi.org/10.1016/j.fishres.2022.106489

McGovern, J. C. 1986. Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes. MS Thesis. College of Charleston, Charleston, SC.

Mercer, L. P. 1984. A biological and fisheries profile of Red Drum, *Sciaenops ocellatus*. Special Scientific Report 41, North Carolina Division of Marine Fisheries, Morehead City, NC.

Methot, R. D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. International North Pacific Fisheries Commission Bulletin 50:259–277.

Methot, Jr., R. D., C. R. Wetzel, I. G. Taylor, K. L. Doering, E. F. Perl, and K. F. Johnson. 2024. Stock Synthesis User Manual Version 3.30.22.1. 256 pages. NOAA Fisheries, Seattle, WA. https://github.com/nmfs-ost/ss3-doc/releases

Methot, R. D., and I. G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(10):1744–1760. https://doi.org/10.1139/f2011-092

Methot, R. D., and C. R. Wetzel. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86–99. https://doi.org/10.1016/j.fishres.2012.10.012

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES Journal of Marine Science 56(4):473–488. https://doi.org/10.1006/jmsc.1999.0481

Murphy, M. D. 2017. An assessment of Red Drum in South Carolina, 1982-2016. 47 pages. St. Petersburg, FL.

Murphy, M. D. and R. G. Taylor. 1990. Reproduction, growth, and mortality of Red Drum *Sciaenops ocellat*us in Florida waters. Fishery Bulletin 88:531-542. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1990/883/murphy.pdf

Music, J.F. and J.M. Pafford. 1984. Population dynamics and life history aspects of major marine sportfishes in Georgia coastal waters. 416 pages. Georgia Department of Natural Resources Coastal Resource Division Contribution Series 38, Atlanta, GA. https://repository.library.noaa.gov/view/noaa/9198

Neill, W. H. 1987. Environmental requirements of Red Drum. In: Chamberlain, G. W. (ed) Manual on Red Drum Aquaculture. Preliminary draft of invited papers presented at the Production Shortcourse of the 1987 Red Drum Aquaculture Conference on 22–24 June 1987 in Corpus Christi, Texas. Texas A and M University, College Station, TX.

Nelson, D. M., E. A. Irlandi, L. R. Settle, M. E. Monaco, and L. Coston-Clements. 1991. Distribution and abundance of fishes and invertebrates in southeast estuaries. 167 pages. ELMR Report No. 9, NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. https://repository.library.noaa.gov/view/noaa/2875

NMFS OST (National marine Fisheries Service Office of Science and Technology). 2021. Marine Recreational Information Program Data User Handbook. 49 pages. Office of Science and

Technology. NOAA Fisheries, Washington, D.C. https://www.fisheries.noaa.gov/resource/document/mrip-data-user-handbook

Nicholson, N. and S. R. Jordan. 1994. Biotelemetry study of Red Drum in Georgia. Georgia Department of Natural Resources, Brunswick, GA.

Odell, J., D. H. Adams, B. Boutin, W. Collier II, A. Deary, L. N. Havel, J. A. Johnson Jr., S. R. Midway, J. Murray, K. Smith, K. M. Wilke, and M. W. Yuen. 2017. Atlantic Sciaenid habitats: A review of utilization, threats, and recommendations for conservation, management, and research. 144 pages. Atlantic States Marine Fisheries Commission Habitat Management Series No. 14, Arlington, VA. https://asmfc.org/resources/habitat/habitat-special-report/atlantic-sciaenid-habitats-a-review-of-utilization-threats-and-recommendations-for-conservation-management-and-research/

Ogle, D.H. 2018. Introductory Fisheries Analyses with R. Chapman and Hall/CRC. https://doi.org/10.1201/9781315371986

Osburn, H. R., G. C. Matlock, and A. W. Green. 1982. Red Drum (*Sciaenops ocellatus*) movement in Texas bays. Contributions in Marine Science 25: 85–97. http://hdl.handle.net/1969.3/19067

Pafford, J. M., A. G. Woodward, and N. Nicholson. 1990. Mortality, movement and growth of Red Drum in Georgia. Final report. Georgia Department of Natural Resources, Brunswick, GA.

Pattillo, M. E., T. E. Czapla, D. M. Nelson, and M. E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries, volume 2: species life history summaries. NOAA, NOS Strategic Environmental Assessments Division, Silver Spring, Maryland.

Pearson, J.C. 1929. Natural history and conservation of the redfish and other commercial sciaenids on the Texas coast. Bulletin of the U.S. Bureau of Fish Commission 44:129–214. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fish-bull/fb44.4.pdf

Peters, K. M. and R. H. McMichael. 1987. Early life history of the Red Drum, *Sciaenops ocellatus* (Pisces: Sciaenidae), in Tampa Bay, Florida. Estuaries 10(2): 92–107. https://doi.org/10.2307/1352173

Punt, A. E., F. Hurtado-Ferro, and A. R. Whitten. 2014. Model selection for selectivity in fisheries stock assessments. Fisheries Research 158:124–134. https://doi.org/10.1016/j.fishres.2013.06.003

Quinn, T.J., and Deriso, R.B. 1999. Quantitative Fish Dynamics. Oxford University Press. https://doi.org/10.1093/oso/9780195076318.001.0001

R Core Team. 2024. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna: R Foundation for Statistical Computing. https://www.r-project.org/

Renkas, B. 2010. Description of periodicity and location of Red Drum (*Sciaenops ocellatus*) spawning in Charleston Harber, South Carolina. M.S. Thesis. College of Charleston, Charleston, SC.

Reyier, E.A. and J.M. Shenker. 2007. Ichthyoplankton community structure in a shallow subtropical estuary of the Florida Atlantic Coast. Bulletin of Marine Science 80: 267-293. https://sedarweb.org/documents/s18rd21-icthyoplankton-community-structure-in-a-shallow-subtropical-estuary-of-the-florida-atlantic-coast/

Reyier, E.A., R.H. Lowers, D.M. Scheidt, and D.H. Adams. 2011. Movement patterns of adult Red Drum, *Sciaenops ocellatus*, in shallow Florida lagoons as inferred through acoustic telemetry. Environmental Biology of Fishes 90:343–360. https://doi.org/10.1007/s10641-010-9745-3

Rooker, J. R. and S. A. Holt. 1997. Utilization of subtropical seagrass meadows by newly settled Red Drum *Sciaenops ocellatus*: Patterns of distribution and growth. Marine Ecology Progress Series 158:139–149. https://www.researchgate.net/publication/250216508

Rooker, J. R., G. J. Holt, and S. A. Holt. 1998. Vulnerability of newly settled Red Drum (*Sciaenops ocellatus*) to predatory fish: is early-life survival enhanced by seagrass meadows? Marine Biology 131:145–151. https://doi.org/10.1007/s002270050305

Rooker, J. R., S. A. Holt, G. J. Holt, and L. A. Fuiman. 1999. Spatial and temporal variability in growth, mortality, and recruitment potential of post settlement Red Drum, *Sciaenops ocellatus*, in a subtropical estuary. Fishery Bulletin 97:581−590. https://spo.nmfs.noaa.gov/sites/default/files/14rooker.pdf

Ross, J. L. and T. M. Stevens. 1992. Life history and population dynamics of Red Drum (*Sciaenops ocellatus*) in North Carolina waters. Marine Fisheries Research. Completion Report, Project F-29. North Carolina Department of Marine Fisheries, Morehead City, NC.

Ross, J. L., T. M. Stevens, and D. S. Vaughan. 1995. Age, growth, mortality, and reproductive biology of Red Drums in North Carolina waters. Transactions of the American Fisheries Society 124:37-54. https://doi.org/10.1577/1548-8659(1995)124%3C0037:AGMARB%3E2.3.CO;2

Rue, H., S. Martino, and N. Chopin. Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. Journal of the Royal Statistical Society B 71:1-35. https://doi.org/10.1111/j.1467-9868.2008.00700.x

SAFMC (South Atlantic Fisheries Management Council). 1998. Habitat plan for the south Atlantic region: Essential fish habitat requirements for fishery management plans of the South Atlantic Fishery Management Council. SAFMC, Charleston, SC.

SEDAR (Southeast Data Assessment and Review). 2009. SEDAR 18 Stock Assessment Report Atlantic Red Drum. 544 pages. Southeast Data, Assessment and Review, Charleston, SC. https://sedarweb.org/assessments/sedar-18/

SEDAR. 2015. SEDAR 44 Atlantic Red Drum stock assessment report. 890 pages. Southeast Data, Assessment and Review, North Charleston, SC. https://sedarweb.org/assessments/sedar-44/

SEDAR. 2024. SEDAR 93 ASMFC Red Drum Review Workshop Report. 19 pages. Southeast Data, Assessment and Review, Charleston, SC. https://sedarweb.org/assessments/sedar-93-atlantic-red-drum/

Setzler, E. M. 1977. A quantitative study of the movement of larval and juvenile Sciaenidae and Engraulidae into the estuarine nursery grounds of Doboy Sound, Sapelo Island, Georgia. M.S. Thesis. University of Georgia.

Simmons, E.G. and J.P. Breuer. 1962. A study of redfish, *Sciaenops ocellatus* (Linnaeus), and Black Drum, *Pogonias cromis* (Linnaeus). Publications of the Institute of Marine Science 8:184–211.

Sink, T., R. Vega, and J. Butler. 2018. Red Drum: Reproductive biology, broodstock management, and spawning. 13 pages. Southern Regional Aquaculture Center, Stoneville, MS.

Stari, T., K.F. Preedy, E. McKenzie, W.S.C. Gurney, M.R. Heath, P.A. Kunzlik, and D.C. Spiers. 2010. Smooth age length keys: observations and implications for data collection on North Sea haddock. Fisheries Research 105(1):2-12. https://doi.org/10.1016/j.fishres.2010.02.004.

Stunz, G.W. and T. J. Minello. 2001. Habitat-related predation on juvenile wild-caught and hatchery-reared Red Drum *Sciaenops ocellatus* (Linnaeus). Journal of Experimental Marine Biology and Ecology 260:13–25. https://doi.org/10.1016/S0022-0981(01)00248-9

Stunz, G. W., T. J. Minello, and P. S. Levin. 2002. Growth of newly settled Red Drum *Sciaenops ocellatus* in different estuarine habitat types. Marine Ecology Progress Series 238:227-236. https://doi.org/10.3354/meps238227

Taylor, I. G., K. L. Doering, K. F. Johnson, C. R. Wetzel, and I. J. Stewart. 2021. Beyond visualizing catch-at-age models: Lessons learned from the r4ss package about software support stock assessments. Fisheries Research 239:105924. https://www.sciencedirect.com/science/article/pii/S0165783621000527

Taylor, I. G., I. J. Stewart, A. C. Hicks, T. M. Garrison, A. E. Punt, J. R. Wallace, C. R. Wetzel, J. T. Thorson, Y. Takeuchi, K. Ono, C. C. Monnahan, C. C. Stawitz, Z. T. A'mar, A. R. Whitten, K. F. Johnson, R. L. Emmet, S. C. Anderson, G. I. Lambert, M. M. Stachura, A. B. Cooper, A. Stephens, N. L. Klaer, C. R. McGilliard, I. Mosqueira, W. M. Iwasaki, K. L. Doering, A. M. Havron, N. Vaughan, L. S. Denson, A. J. Novak, H. Winker, L. Qi, M. Oshima, and E. Fletcher. 2009, November 10. r4ss: R Code for Stock Synthesis. The R Foundation. https://r4ss.github.io/r4ss/

Thorson, J. T., K. F. Johnson, R. D. Methot, and I. G. Taylor. 2017. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. Fisheries Research 192:84–93. https://doi.org/10.1016/j.fishres.2016.06.005

Troha, L. U. 2023. Estimating the tag-reporting rate and length-based selectivity of Red Drum (*Sciaenops ocellatus*) in South Carolina using a long-term tag-recapture study. University of Charleston, Charleston, SC.

Vaughan, D. S. and T. E. Helser. 1990. Status of the Red Drum stock of the Atlantic coast: Stock assessment report for 1989. 118 pages. NOAA Technical Memorandum NMFS-SEFSC-263, Beaufort Laboratory, Beaufort, NC. https://repository.library.noaa.gov/view/noaa/5927

Vaughan, D. S. 1992. Status of the Red Drum stock of the Atlantic coast: Stock assessment report for 1991. 63 pages. NOAA Technical Memorandum NMFS-SEFSC-297, Beaufort Laboratory, Beaufort, NC. https://staging-noaa.cdc.gov/view/noaa/9153

Vaughan, D. S. 1993. Status of the Red Drum stock of the Atlantic coast: Stock assessment report for 1992. 66 pages. NOAA Technical Memorandum NMFS-SEFSC-313, Beaufort Laboratory, Beaufort, NC. https://staging-noaa.cdc.gov/view/noaa/9159

Vaughan, D. S. 1996. Status of the Red Drum stock of the Atlantic coast: Stock assessment report for 1995. 56 pages. NOAA Technical Memorandum NMFS-SEFSC-380, Beaufort Laboratory, Beaufort, NC. https://staging-noaa.cdc.gov/view/noaa/30894

Vaughan, D. S. and J.T. Carmichael. 2000. Assessment of Atlantic Red Drum for 1999: Northern and southern regions. 83 pages NOAA Technical Memorandum NMFS-SEFSC-447, Beaufort Laboratory, Beaufort, NC. https://staging-noaa.cdc.gov/view/noaa/8504

Venables, W.N. and B.D. Ripley. 2002. Modern Applied Statistics with S. Fourth Edition. Springer.

Vetter, E. F. 1988. Estimation of natural mortality in fish stocks: a review. Fishery Bulletin 86:25– 43.

Weinstein, M. P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear, North Carolina. Fishery Bulletin 77(2):339–357.

Wenner, C. A., W. A. Roumillat, J. Moran, M. B. Maddox, L. B. Daniel III, and J. W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina: Part 1. South Carolina Department of Natural Resources, Marine Resources Research Institute, Final Report Project F-37.

Wenner, C. A. 1992. Red Drum: Natural history and fishing techniques in South Carolina. Marine Resources Research Institute. Report No. 17.

Wenner, C. A. 2000. Contributions to the biology of Red Drum *Sciaenops ocellatus*, in South Carolina. Final Report. National Marine Fisheries Service, St. Petersburg, Florida.

Wilson, C. A. and D. L. Nieland. 1994. Reproductive biology of Red Drum, *Sciaenops ocellatus*, from the neritic waters of the northern Gulf of Mexico. Fishery Bulletin 92:841-850. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1994/924/wilson1.pdf

Winker, H., F. Carvalho, M. Cardinale, L. Kell, M. Oshima, and E. Fletcher. 2023. ss3diags: Stock Synthesis Model Diagnostics for Integrated Stock Assessments. R package version 2.1.1, https://github.com/PIFSCstockassessments/ss3diags

Winker, H., F. Carvalho, and M. Kapur. 2018. JABBA: Just Another Bayesian Biomass Assessment. Fisheries Research 204:275–288. https://doi.org/10.1016/j.fishres.2018.03.010

Woodward, A. G. 1994. Tagging studies and population dynamics of Red Drum in coastal Georgia. Final Report. Georgia Department of Natural Resources, Brunswick, GA.

Yokel, B. 1966. A contribution to the biology and distribution of the Red Drum, *Sciaenops ocellatus*. M.S. Thesis. University of Miami, Miami, FL.

9. TABLES

Table 1.1 Red Drum Regulatory Timeline for the State of SC. All regulations formally voted into law by the South Carolina State Legislature. MLL = minimum length limit.

Regulatory Description	Action	Effective Date
14” (36 cm) TL MLL from June 1 to September 1, possession limit of 1 fish > 81 cm (32") TL	Amendment to Section 50-17-55, SC Code of Laws	June 9, 1986
14” (36 cm) TL MLL from June 1 to September 1, possession limit of 1 fish > 32” (82 cm) TL, 20 fish possession limit, gamefish status (prohibiting the sale of native fish, except maricultured fish).	Amendment adding Section 50-17-56 to SC Code of Laws	June 30, 1987
14” (36 cm) TL MLL from June 1-October 1, possession limit of 1 fish > 32” (82 cm) TL, 20 fish possession limit, gamefish status.	Amendment to Section 50-17-55, SC Code of Laws	April 5, 1988
14” (36 cm) TL MLL, 81 cm (32") TL maximum size limit, possession limit of 1 fish > 32” (82 cm) TL, 20 fish possession limit, gamefish status.	Amendment to Section 50-17-510, SC Code of Laws	June 6, 1990
14” (36 cm) TL MLL, 81 cm (32") TL maximum size limit, possession limit of 1 fish > 32” (82 cm) TL, 5 fish possession limit, gamefish status.	Amendment to Section 50-17-520, SC Code of Laws	April 29, 1991
14-27” (36-69 cm) slot limit, 5 fish possession limit, gamefish status.	Amendment to Section 50-17-510, SC Code of Laws	June 11, 1993
15-24” (38-61 cm) TL slot limit, 2 fish possession limit, gamefish status.	Amendment to Section 50-5-1705 and -1710, SC Code of Laws	August 31, 2001
15-23” (38-58 cm) slot limit, 3 fish possession limit, gamefish status.	Amendment to Section 50-5-1705 and -1710, SC Code of Laws	June 15, 2007
15-23” (38-58 cm) slot limit, 2 fish $person^{-1}$ day^{-1} and no more than 6 fish $boat^{-1}$ day^{-1} possession limit, gamefish status.	Amendment to Section 50-5-1705, SC Code of Laws	July 1, 2018

Table 2.1 Number of Red Drum otolith age samples collected by state within the southern stock from 1981-2022 (Adapted from ASMFC 2024b). Note, SC totals do not include age-0, age-1, and young age-2 reliably aged via length.

Year	Florida	Georgia	South Carolina	Total
1981	312	-	-	**312**
1982	187	-	-	**187**
1983	-	-	-	**-**
1984	-	-	1	**1**
1985	-	-	140	**140**
1986	-	-	943	**943**
1987	-	-	393	**393**
1988	-	-	305	**305**
1989	-	-	614	**614**
1990	-	-	820	**820**
1991	-	-	673	**673**
1992	-	-	357	**357**
1993	-	-	518	**518**
1994	-	-	391	**391**
1995	-	-	317	**317**
1996	-	13	453	**466**
1997	-	345	340	**685**
1998	-	334	317	**651**
1999	-	237	196	**433**
2000	41	141	1,089	**1,271**
2001	108	197	749	**1,054**
2002	96	633	926	**1,655**
2003	117	462	460	**1,039**
2004	131	215	403	**749**
2005	155	345	330	**830**
2006	172	154	579	**905**
2007	143	291	590	**1,024**
2008	97	15	864	**976**
2009	116	-	951	**1,067**
2010	113	-	705	**818**
2011	171	-	606	**777**
2012	174	-	540	**714**
2013	281	81	407	**769**
2014	242	241	381	**864**
2015	166	270	637	**1,073**
2016	188	343	623	**1,154**
2017	179	448	699	**1,326**
2018	166	452	489	**1,107**
2019	109	469	252	**830**
2020	113	352	424	**889**
2021	221	203	335	**759**
2022	66	-	132	**198**
Total	**3,864**	**6,241**	**19,949**	**30,054**
Percent	**12.86%**	**20.77%**	**66.38%**	

Table 2.2 Von Bertalanffy growth parameters with age varying k estimated for Red Drum captured in SC, GA, and FL. Values originally reported in ASMFC (2024b).

Parameter	Value	Description
L_{∞}	1,132	Asymptotic length
k_{base}	0.296	Base Brody growth coefficient; in effect from age-0 to age-1
k_{age1}	0.216	Brody growth coefficient in effect from age-1 to age-6
k_{age6}	0.041	Brody growth coefficient in effect from age-age-6+

Table 2.3 Length and age-at-maturity as estimated using logistic regressions fit to histologically derived maturity status information from SC. Total lengths were measured to the nearest mm TL while ages (in yrs) were aged to the nearest month, assuming a September 1st birthday. Parameters a and b (±SE) are for the logistic function $Prop.Mat. = e^{Z}/(1 + e^{1})$ where $Z = a + b * X$ and X is either total length or age. 50% maturity represents the total length or age where the proportion mature equals 0.5 with 95% CI of estimate in parentheses.

Type	Sex	n	a	±SE	b	±SE	50% Maturity
Length	Female	1,132	-16.282	1.0945	0.021265	0.0013822	766 (753 – 778)
	Male	941	-10.008	0.6711	0.014865	0.0009597	673 (658 – 688)
Age	Female	1,119	-6.539	0.4999	1.546	0.1292	4.2 (4.0 – 4.4)
	Male	938	-4.068	0.3442	1.207	0.1079	3.4 (3.2 – 3.6)

Table 2.4 Natural mortality-at-weight (M_w) or -length (M_L) of Red Drum for the SC sub-stock ($t_{max} = 41$). The 'Mortality-weight' model (M_w) followed Lorenzen (1996). The 'Length-Inverse' estimates of M_L followed Lorenzen (2022) using the Hamel and Cope (2022) constant M estimate. The 'Length-inverse' model scaled the cumulative mortality rate predicted for age-2 to -41 to the longevity-based constant M estimate for the SC sub-stock. Note, this is equivalent to the M estimates provided for the southern stock in SEDAR 93 (ASMFC 2024b; see Table 16).

Age (yr)	**Length (mm)**	M_W	M_L
0.5	165	0.517	0.749
1.5	383	0.250	0.322
2.5	528	0.190	0.233
3.5	646	0.160	0.191
4.5	740	0.142	0.167
5.5	816	0.131	0.151
6.5	854	0.125	0.144
7.5	866	0.124	0.142
8.5	876	0.123	0.141
9.5	887	0.122	0.139
10.5	897	0.120	0.137
11.5	906	0.119	0.136
12.5	915	0.118	0.135
13.5	924	0.117	0.133
14.5	933	0.116	0.132
15.5	941	0.116	0.131
16.5	949	0.115	0.130
17.5	956	0.114	0.129
18.5	963	0.113	0.128
19.5	970	0.113	0.127
20.5	977	0.112	0.126
21.5	983	0.111	0.125
22.5	989	0.111	0.125
23.5	995	0.110	0.124
24.5	1000	0.110	0.123
25.5	1006	0.109	0.123
26.5	1011	0.109	0.122
27.5	1016	0.108	0.121
28.5	1021	0.108	0.121
29.5	1025	0.107	0.120
30.5	1029	0.107	0.120
31.5	1034	0.107	0.119
32.5	1038	0.106	0.119
33.5	1041	0.106	0.118
34.5	1045	0.106	0.118
35.5	1049	0.105	0.118
36.5	1052	0.105	0.117
37.5	1055	0.105	0.117
38.5	1058	0.104	0.117
39.5	1061	0.104	0.116
40.5	1064	0.104	0.116
41	1066	0.104	0.116

Table 3.1 Recreational Red Drum catch estimates for the SC sub-stock SS model from MRIP. Dead discards calculated via application of 8% discard mortality rate to estimated live releases. Catch represents total catch (Harvest + Live Releases) while removals represents total removals (Harvest + Dead Discards). PSE = percent standard error.

	Harvest (A + B1)		**Released (B2)**			**Total**	
Fishing Year	**Estimate**	**PSE**	**Estimate**	**PSE**	**Dead Discards**	**Catch**	**Removals**
1981	190,749	0.399	8,250	0.683	660	198,998	191,409
1982	278,714	0.340	16,276	0.578	1,302	294,990	280,016
1983	478,431	0.671	11,368	0.694	909	489,799	479,340
1984	371,253	0.346	60,672	0.683	4,854	431,924	376,107
1985	936,790	0.182	105,595	0.391	8,448	1,042,385	945,238
1986	322,742	0.223	72,401	0.283	5,792	395,144	328,534
1987	731,584	0.177	197,706	0.265	15,816	929,289	747,400
1988	391,156	0.264	132,208	0.279	10,577	523,365	401,733
1989	291,995	0.205	129,298	0.337	10,344	421,293	302,339
1990	413,518	0.308	142,824	0.425	11,426	556,342	424,944
1991	341,090	0.246	210,954	0.394	16,876	552,044	357,966
1992	287,175	0.220	131,613	0.285	10,529	418,788	297,704
1993	287,908	0.265	388,095	0.305	31,048	676,003	318,956
1994	122,373	0.241	651,377	0.211	52,110	773,750	174,483
1995	511,541	0.36	773,679	0.208	61,894	1,285,220	573,435
1996	376,764	0.254	877,556	0.412	70,204	1,254,320	446,968
1997	262,624	0.174	220,327	0.193	17,626	482,951	280,250
1998	191,353	0.168	268,826	0.200	21,506	460,179	212,859
1999	137,131	0.257	304,859	0.228	24,389	441,990	161,520
2000	91,930	0.235	206,949	0.232	16,556	298,879	108,486
2001	171,745	0.181	474,572	0.192	37,966	646,317	209,711
2002	194,054	0.200	614,351	0.201	49,148	808,405	243,202
2003	266,136	0.252	859,112	0.191	68,729	1,125,248	334,865
2004	176,804	0.187	721,043	0.195	57,683	897,847	234,487
2005	255,953	0.251	953,098	0.144	76,248	1,209,050	332,201
2006	138,470	0.272	1,181,791	0.166	94,543	1,320,261	233,013
2007	169,646	0.261	785,016	0.175	62,801	954,663	232,447
2008	222,174	0.294	1,476,917	0.181	118,153	1,699,091	340,327
2009	303,117	0.183	1,541,421	0.148	123,314	1,844,538	426,431
2010	495,529	0.159	2,303,042	0.146	184,243	2,798,571	679,772
2011	216,037	0.209	1,314,782	0.131	105,183	1,530,818	321,220
2012	388,883	0.272	1,553,512	0.119	124,281	1,942,395	513,164
2013	214,357	0.148	1,394,642	0.087	111,571	1,608,999	325,928
2014	385,279	0.158	1,875,949	0.129	150,076	2,261,228	535,355
2015	266,713	0.265	1,537,668	0.179	123,013	1,804,381	389,726
2016	382,327	0.201	1,531,860	0.158	122,549	1,914,187	504,876
2017	359,495	0.180	2,047,330	0.169	163,786	2,406,825	523,281
2018	273,897	0.156	1,750,990	0.157	140,079	2,024,887	413,976
2019	309,624	0.245	2,816,141	0.206	225,291	3,125,766	534,915
2020	203,177	0.180	1,849,158	0.157	147,933	2,052,335	351,110
2021	231,865	0.155	1,496,345	0.165	119,708	1,728,211	351,573
2022	218,917	0.164	1,373,790	0.143	109,903	1,592,707	328,820
2023*	506,526	0.158	3,218,423	0.150	257,474	3,724,949	794,000

* – Fishing year 2023 data are preliminary

Table 3.2 Red Drum recreational regulations in SC simplified by regulations predominate in given fishing years. MLL = minimum length limit.

Fishing Year	Regulations	Effective Date
Pre-1986	No Regulations	
1986	14” (36 cm) TL MLL from June 1- Sept.1; 1 fish > 32” (81 cm) person^{-1} day^{-1}	June 9, 1986
1987	14” (36 cm) TL MLL from June 1- Sept. 1; 1 fish >32” (81 cm TL) person^{-1} day^{-1}; commercial harvest prohibited	June 30, 1987
1988	14” (36 cm) TL MLL from June 1-Oct. 1; 20 fish person^{-1}day^{-1} and 1 fish >32” (81 cm) TL person^{-1} day^{-1}; commercial harvest prohibited	April 5, 1988
1989		
1990	14” (36 cm) TL MLL; 20 fish person^{-1}day^{-1} and 1 fish >32” (81 cm) TL person^{-1} day^{-1}; commercial harvest prohibited	June 6, 1990
1991	14” (36 cm) TL MLL; 5 fish person^{-1}day^{-1} and 1 fish 1 fish >32” (81 cm) TL person^{-1} day^{-1}; commercial harvest prohibited	April 29, 1991
1992		
1993	14-27” (36-69 cm) TL slot limit; 5 fish person^{-1}day^{-1}; commercial harvest prohibited	June 11, 1993
1994		
1995		
1996		
1997		
1998		
1999		
2000		
2001	15-24” (38-61 cm) TL slot limit; 2 fish person^{-1}day^{-1}; commercial harvest prohibited	August 31, 2001
2002		
2003		
2004		
2005		
2006		
2007	15-23” (38-58 cm) TL slot limit; 3 fish person^{-1}day^{-1}; commercial harvest prohibited	June 15, 2007
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		
2017		
2018	15-23” (38-58 cm) TL slot limit; 2 fish person^{-1}day^{-1} and 6 fish boat^{-1} day^{-1}; commercial harvest prohibited	July 1, 2018
2019		
2020		
2021		
2022		
2023		

Table 3.3 MGFTP guidance to anglers for tagging Red Drum throughout coastal SC.

Years	Guidance
1978-1992	Any size Red Drum
1993-2010	≥18” (46 cm) TL
2011-2019	Fish <27” (68 cm) TL – T-bar Tag
	Fish ≥27” (69 cm) TL – Nylon Dart Tag
2020-2022	Previous tag types + only fish ≥10” (25 cm) TL
	Tag one Red Drum per “school” per day

Table 3.4 Number of recaptures as a function of years-at-large from the SCDNR conventional tagging programs.

Years-at-Large	Recaptures
0-1	33,910
1-2	8,898
2-3	2,388
3-4	561
4-5	209
5-6	92
6-7	63
7-8	43
8-9	48
9-10	44
10-11	29
11-12	28
12-13	18
13-14	10
14-15	11
15-16	7
16-17	6
17-18	9
18-19	9
19-20	6
20-21	2
21-22	4
22-23	1
23-24	2
24-25	1

Table 3.5 Fishery-dependent biological samples collected via the SCDNR freezer and tournament programs. Table adapted from ASMFC (2024b; Table 27).

Description	Tournament Program	Freezer Program	Fishery-Dependent Samples
Years	**1986-2022**	**1995-2022**	**1986-2022**
Red Drum Investigated	**1,023**	**2,283**	**3,306**
Total Length (mm)	**1,021**	**2,275**	**3,296**
Midline Length (mm)	**1,049**	**2,485**	**3,534**
Standard Length (mm)	**1,019**	**2,236**	**3,255**
Weight (g)	**986**	**5**	**991**
Age (Yrs)	**1,007**	**2,229**	**3,236**
Length	161	859	1,020
Scale	17	1	18
Otoliths	829	1,369	2,198
Sex	**1,017**	**2,282**	**3,299**
Macroscopic	971	2,278	3,249
Histology	46	4	50
Maturity Status/Stage	**969**	**2,200**	**3,169**
Macroscopic	923	2,196	3,119
Histology	46	4	50

Note: Data was not updated to reflect collections made after December 31, 2022.

Table 3.6 Summary of life history information collected via the SCDNR during fishery-independent and fishery-dependent sampling program efforts. Bold numbers represent years or sample sizes. Only sample sizes, by sex and maturity status where indicated, are provided for sex and maturity status. All lengths in mm, all weights in g, and all ages in yrs. Age-Length = ages determined based on length at capture and capture month; Age-Otolith = ages determined by otolith thin section aging techniques.

	Fishery-Independent Data							**Fishery-Dependent Data**			
Variable	**Rotenone**	**Stop Net**	**Trammel Net**	**Electrofishing**	**Longline – Historic**	**Longline**	**Misc.**	**Tournament**	**Freezer**	**SFS**	**Total**
Years	**1986-1994**	**1985-1998**	**1987-2023**	**2001-2023**	**1994-2006**	**2007-2023**	**1994-1997**	**1986-2022**	**1995-2022**	**1988-2022**	**1985-2023**
Fishing Years	**1985-1993**	**1984-1987**	**1986-2023**	**2000-2023**	**1994-2006**	**2007-2023**	**1994-1997**	**1986-2022**	**1995-2022**	**1987-2021**	**1984-2023**
Red Drum	**1,679**	**8,121**	**85,858**	**15,664**	**3,709**	**8,659**	**4,643**	**1,023**	**2,283**	**11,487**	**143,126**
Total Length	**1,588**	**8,107**	**85,536**	**15,659**	**3,689**	**8,593**	**4,632**	**1,021**	**2,275**	**2,814**	**133,914**
Range	5-489	33-910	152-1,130	19-952	507-1,246	571-1,223	158-977	277-1,150	343-810	294-680	5-1,223
$\bar{X} \pm SE$	49 ± 1.4	432 ± 1.8	535 ± 0.6	416 ± 1.0	971 ± 1.3	954 ± 0.9	526 ± 2.2	551 ± 4.5	484 ± 1.7	458 ± 1.1	–
Midline Length	**–**	**24**	**3,390**	**18**	**3,687**	**8,494**	**–**	**26**	**202**	**8,673**	**24,514**
Range	–	339-730	215-982	270-746	491-1,154	534-1,145	–	358-642	348-670	220-1,361	220-1,361
$\bar{X} \pm SE$	–	444 ± 23.0	543 ± 2.5	488 ± 31.3	908 ± 1.2	891 ± 0.8	–	458 ± 16.5	452 ± 5.6	457 ± 0.9	–
Standard Length	**1,679**	**1,023**	**33,519**	**11,119**	**106**	**8,659**	**230**	**1,109**	**2,236**	**–**	**59,680**
Range	4-398	26-673	123-955	15-790	655-989	577-1,005	127-713	225-920	283-669	–	4-1,005
$\bar{X} \pm SE$	38 ± 1.1	241 ± 3.1	385 ± 0.8	323 ± 1.1	749 ± 4.6	793 ± 0.8	361 ± 6.2	452 ± 5.7	396 ± 3.4	–	–
Weight	**722**	**806**	**3,554**	**818**	**105**	**8,659**	**160**	**986**	**5**	**–**	**15,815**
Range	1-1,261	1-5,950	95-8,850	1-7,000	5,000-17,070	1,110-26,500	259-7,500	279-14,629	862-4,042	–	1-26,500
$\bar{X} \pm SE$	22 ± 2.3	507 ± 28.2	1,513 ± 23.1	1,086 ± 32.4	7,687 ± 168.6	8,212 ± 23.0	1,105 ± 79.3	2,094 ± 43.3	1,931 ± 28.5	–	–
Age-Length	**1,581**	**5,251**	**34,912**	**11,374**	**–**	**–**	**2,098**	**161**	**859**	**–**	**56,236**
Range	0.00-1.00	0.2-2.17	0.75-2.67	0.08-2.75	–	–	0.75-2.17	1.08-2.00	1.00-2.25	–	0.00-2.75
$\bar{X} \pm SE$	0.29 ± 0.01	1.21 ± 0.00	1.30 ± 0.00	1.36 ± 0.00	–	–	1.35 ± 0.01	1.45 ± 0.03	1.47 ± 0.01	–	–
Age-Otolith	**6**	**154**	**2,055**	**224**	**106**	**1,361**	**51**	**829**	**1,369**	**–**	**6,155**
Range	0.92-1.92	1.08-3.83	0.75-22.17	0.83-5.08	3.17-32.67	3.00-40.25	1.58-3.83	0.92-41.08	0.92-5.08	–	0.83-41.08
$\bar{X} \pm SE$	1.08 ± 0.17	2.16 ± 0.05	2.49 ± 1.07	2.25 ± 0.05	8.92 ± 5.50	15.84 ± 0.22	2.55 ± 0.09	2.77 ± 0.12	2.12 ± 0.01	–	–
Sex	**–**	**–**	**674**	**193**	**16**	**1,171**	**–**	**46**	**4**	**–**	**2,104**
Female	–	–	320	105	9	673	–	25	3	–	1,135
Male	–	–	337	84	7	495	–	20	1	–	944
Unknown	–	–	17	4	–	3	–	1	–	–	25
Maturity Status	**–**	**–**	**674**	**189**	**16**	**1,168**	**–**	**45**	**4**	**–**	**2,096**
Female	–	–	320	105	9	673	–	25	3	–	1,135
Immature	–	–	275	100	1	45	–	24	3	–	448
Mature	–	–	44	74	8	626	–	1	–	–	753
Unknown	–	–	1	–	–	2	–	–	–	–	3
Male	–	–	337	84	7	495	–	20	1	–	944
Immature	–	–	219	74		12	–	13	1	–	319
Mature	–	–	116	10	7	483	–	7	–	–	623
Unknown	–	–	2	–	–	–	–	–	–	–	2

* – Histology only derived sex and maturity information

Table 3.7 Fixed stations sampled by year as part of the rotenone survey. Collection sites are arranged via estuary, from the South to the North.

Estuary	St. Helena Sound / ACE Basin			North Edisto and Stono		Charleston Harbor								
River	**Coosaw River**		**South Edisto**	**North Edisto**	**Stono**	**Ashley**	**Wando**							**Isle of Palms Sound**
Year	**Brickyard Creek**	**Triple Creek**	**South Edisto**	**Tom Post Creek**	**Stono River**	**Orange Grove Creek**	**Beresford Creek**	**Deep Creek**	**Foster Creek**	**Horlbeck Creek**	**Lachicotte Creek**	**Pita Creek**	**Wards Bridge**	**Inlet Creek**
1986	–	–	–	–	–	–	7	–	–	–	7	7	–	7
1987	1	7	5	1	5	1	8	–	–	–	8	12	–	8
1988	–	7	7	–	7	–	–	–	–	–	–	7	–	–
1989	–	–	–	–	–	–	1	7	10	–	10	9	1	–
1990	–	–	–	–	–	–	–	12	12	–	12	12	–	–
1991	–	–	–	–	–	–	–	13	12	–	12	12	–	–
1992	–	–	–	–	–	–	–	6	6	1	6	6	–	–
1993	–	–	–	–	–	–	–	4	4	–	4	4	–	–
1994	–	–	–	–	–	–	–	4	4	–	4	4	–	–
Total	**1**	**14**	**12**	**1**	**12**	**1**	**16**	**46**	**48**	**1**	**63**	**73**	**1**	**15**

Table 3.8 Size distribution by month of Red Drum encountered by the rotenone survey. The year is aligned to start with August, the first month in which newly born Red Drum recruit to the gear. Green shaded cells represent age-0 Red Drum monthly throughout the year. Note, very few age-1+ Red Drum (denoted by pink shaded cells) are encountered by this survey, with those individuals only captured during the months of August and July.

	Month												
TL (mm)	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Total**
475	–	–	–	–	–	–	–	–	–	–	–	1	**1**
450	–	–	–	–	–	–	–	–	–	–	–	–	**0**
425	–	–	–	–	–	–	–	–	–	–	–	–	**0**
400	–	–	–	–	–	–	–	–	–	–	–	–	**0**
375	–	–	–	–	–	–	–	–	–	–	–	–	**0**
350	–	–	–	–	–	–	–	–	–	–	–	–	**0**
325	–	–	–	–	–	–	–	–	–	–	–	1	**1**
300	2	–	–	–	–	–	–	–	–	–	–	–	**2**
275	2	–	–	–	–	–	–	–	–	–	–	2	**4**
250	–	–	–	–	–	–	–	–	–	–	1	2	**3**
225	–	–	–	–	–	–	–	–	–	–	–	6	**6**
200	–	–	–	–	–	–	–	–	–	–	11	2	**13**
175	–	–	–	–	–	–	–	–	–	10	41	2	**52**
150	–	–	–	–	–	–	–	–	3	14	50	–	**67**
125	–	–	–	–	–	–	–	–	17	34	9	–	**60**
100	–	–	–	–	–	–	–	–	26	16	–	–	**42**
75	–	–	–	34	6	1	5	20	39	1	–	–	**106**
50	–	–	1	27	42	2	28	29	9	–	–	–	**138**
25	–	18	65	141	46	7	6	4	–	–	–	–	**287**
0	75	608	202	12	–	–	–	–	–	–	–	–	**897**
Total													**1,679**

Table 3.9 SCDNR rotenone survey sample size (Collections), % of collections positive for Red Drum, and number of Red Drum collected by Year Class.

Year Class	Collections	% Positive	Red Drum
1986	49	67.35	561
1987	46	54.35	169
1988	15	33.33	12
1989	50	44.00	247
1990	47	72.34	455
1991	44	54.55	287
1992	16	37.50	8
1993	16	43.75	27

Table 3.10 Indices of abundance for the southern stock of Red Drum. Indices are scaled to their means. RSEs are provided. Note, indices were developed for the electrofishing and historic longline survey and considered but not included in the base model and hence not presented.

	Rotenone		**Stop Net**		**Trammel Net**		**Longline**	
Fishing Year	**Index**	**RSE**	**Index**	**RSE**	**Index**	**RSE**	**Index**	**RSE**
1986	2.11	0.256	0.75	0.249				
1987	0.79	0.272	1.08	0.241				
1988	0.38	0.563	1.03	0.236				
1989	0.68	0.251	0.89	0.191				
1990	2.42	0.300	0.89	0.200	1.02	0.408		
1991	0.72	0.266	1.25	0.203	1.90	0.271		
1992	0.25	0.594	1.11	0.216	1.99	0.225		
1993	0.65	0.497	0.99	0.220	1.64	0.154		
1994					0.93	0.140		
1995					1.70	0.137		
1996					0.90	0.133		
1997					0.86	0.117		
1998					0.60	0.118		
1999					0.44	0.129		
2000					1.14	0.125		
2001					1.32	0.111		
2002					1.64	0.107		
2003					1.91	0.100		
2004					1.61	0.103		
2005					1.36	0.103		
2006					0.64	0.113		
2007					0.83	0.109		
2008					1.01	0.111		
2009					1.41	0.105		
2010					1.08	0.100	0.64	0.144
2011					0.70	0.109	0.47	0.147
2012					0.63	0.120	1.18	0.137
2013					0.75	0.120	1.21	0.121
2014					0.60	0.135	0.97	0.113
2015					0.55	0.127	1.28	0.115
2016					0.42	0.137	1.49	0.103
2017					0.70	0.143	0.81	0.120
2018					0.54	0.131	1.25	0.127
2019					0.35	0.176	1.19	0.112
2020					0.74	0.142	1.01	0.115
2021					0.56	0.155	1.02	0.140
2022					0.88	0.133	0.52	0.176
2023					0.67	0.148	0.96	0.125

Table 3.11 Fixed stations sampled by year as part of the stop net survey. Collection sites are arranged via SC estuary, from the South to the North. Note, year represents calendar year though the index was developed using fishing years (Sept. 1 – Aug. 31). Gray shaded cells are the years and sites considered for initial index development, prior to subsequent sub-sampling based on availability of covariate information.

Year	Port Royal Sound			Charleston Harbor			Bulls Bay			
	Callawassie Creek	Turtle Creek	Triple Creek*	Crab Bank	Ft. Sumter	Grice Gove	Anderson Creek	Bulls Island	Town Creek^	Total
1985	–	–	–	–	–	1	–	–	–	**1**
1986	–	–	–	–	–	6	–	–	–	**6**
1987	–	–	1	1	–	14	–	–	–	**16**
1988	–	–	–	–	1	13	–	–	–	**14**
1989	4	2	–	–	5	13	1	1	1	**27**
1990	–	1	–	–	–	12	–	7	–	**20**
1991	–	–	–	–	–	13	–	4	–	**17**
1992	–	–	–	–	–	13	–	4	–	**17**
1993	–	–	–	–	–	12	–	5	–	**17**
1994	–	–	–	–	–	9	–	2	–	**11**
1995	–	–	–	–	–	1	–	–	–	**1**
1996	–	–	–	–	–	1	–	1	–	**2**
1997	–	–	–	–	–	–	–	–	–	**0**
1998	–	–	–	–	–	1	–	–	–	**1**
Total	**4**	**3**	**1**	**1**	**6**	**109**	**1**	**24**	**1**	**150**

* – St. Helena Sound / ACE Basin
^ – North Inlet

Table 3.12 Stop net survey sample size (Collections), % of collections positive for Red Drum, and number of Red Drum collected by fishing year.

Fishing Year	Collections	% Positive	Red Drum
1986	13	92.31	633
1987	13	92.31	905
1988	13	100.00	842
1989	19	94.74	1051
1990	18	100.00	977
1991	17	100.00	1263
1992	16	100.00	956
1993	15	100.00	777

Table 3.13 Fishing years (and months within years) SCDNR has sampled individual trammel net contemporary strata. Shaded cells include the years (and months) included in the development of relative abundance indices for individual species.

Estuary	Port Royal Sound		St. Helena Sound		Charleston Harbor		Cape Romain			Winyah Bay
Fishing Year	CT	BR	AB	AR	CH	LW	CR	MB	RH	WB
1990	-	-	Jun	Nov	Nov-Aug	Nov-Aug	Feb-Apr	-	Feb-Apr	-
1991	-	-	-	Jul-Aug	Sep-Aug	Sep-Aug	-	-	-	-
1992	-	-	-	Jan-Aug	Sep-Aug	Sep-Aug	-	-	-	Oct-Aug
1993	Aug	-	Jan-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Jan-Aug	Oct-Nov	Oct-Jul	Sep-Jun
1994	Oct-Dec	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Aug	Oct-Aug	-
1995	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Jul-Aug	Jul-Aug	-
1996	Jun-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-
1997	Sep-Jul	Oct-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	-
1998	Sep-Mar	Oct-Mar	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	-
1999	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	-
2000	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Jun
2001	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Jul-Aug
2002	Jun	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Jan-Aug
2003	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2004	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2005	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2006	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2007	-	-	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2008	Aug	Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2009	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2010	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2011	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2012	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2013	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2014	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2015	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2016	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2017	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2018	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2019[c,d]	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2020[c,d]	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2021[d]	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug
2022[e]	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug

Table 3.13: *cont.*

Estuary	Port Royal Sound		St. Helena Sound		Charleston Harbor			Cape Romain		Winyah Bay
Fishing Year	**CT**	**BR**	**AB**	**AR**	**CH**	**LW**	**CR**	**MB**	**RH**	**WB**
2023[e]	Sep-Aug	Sept-Aug	Sep-Aug	Sep-Aug	Sep-Aug	Sep-Aug	-	Sep-Aug	Sep-Aug	Sep-Aug

[a] – Only quarterly sampling occurred in Port Royal Sound through June 2020, with two strata being defined and sampled: Colleton River (CT) and Broad River (BR)

[b] – The Cape Romain strata has undergone revision through time. From calendar year 1994-1996 there was a single stratum sampled, referred to as the Cape Romain (CR) stratum; from 1997 through June 2020, two strata were sampled monthly, called Muddy and Bulls Bay and Romain Harbor.

[c] – Sampling in 2020 was affected due to social distancing protocols put into place due to COVID-19 as well as a survey design change that was implemented in July 2020 (see below for details). Sampling was halted midway through March 2020 monthly sampling, with no sampling in April-June. Sampling resumed in July, but was limited through August, with sampling under the new survey intensity fully implemented in September 2020.

[d] – To ensure financial solvency of the survey while maintaining the continuity of the long-term survey, the sampling intensity of the survey was modified in July 2020. Changes included 1) a merging of the traditional Colleton River and Broad River strata in Port Royal Sound into the combined Port Royal Sound Stratum, 2) a merging of the traditional Muddy and Bulls Bay (MB) and Romain Harbor (RH) strata into the combined Cape Romain stratum with only stations in either the traditional MB or RH stratum selected for sampling in a given sampling month, and 3) moving to sampling the remaining seven strata twice per quarter instead of the traditional monthly sampling employed in most strata prior (increased frequency of within year sampling in Port Royal Sound; decreased frequency of within year sampling in other strata).

[e] – Funding increases allowed for survey expansion. The survey moved to sampling two southern (CT, BR, or AB), two Charleston Harbor (AR, CH, or LW) and two northern (MB, RH, or WB) strata monthly, sampling each of the nine contemporary strata 8 times annually. Strata for sampling monthly was selected randomly, with each strata sampled twice per quarter.

Table 3.14 Trammel net survey sample size (Collections), % of collections positive for Red Drum, and number of Red Drum collected by fishing year.

Year	Collections	% Positive	Red Drum
1990	63	50.79	356
1991	145	63.45	1,282
1992	241	54.36	1,530
1993	415	55.42	2,766
1994	629	49.28	2,208
1995	687	47.45	3,397
1996	791	44.75	3,025
1997	867	45.67	2,567
1998	962	41.68	2,438
1999	892	37.00	1,543
2000	810	42.59	2,877
2001	858	53.26	3,622
2002	570	51.26	4,256
2003	938	56.50	5,361
2004	956	52.41	4,162
2005	949	50.79	4,049
2006	915	41.64	2,233
2007	932	44.21	2,825
2008	864	45.83	2,891
2009	950	46.00	3,696
2010	1045	46.22	3,743
2011	1067	37.86	2,520
2012	943	34.78	1,891
2013	932	38.41	2,086
2014	883	32.05	1,257
2015	950	31.79	1,492
2016	848	30.78	1,081
2017	853	28.25	1,494
2018	927	31.18	1,439
2019	649	23.73	533
2020	630	37.94	1,088
2021	609	32.18	896
2022	722	38.78	1,687
2023	669	32.59	1,216

Table 3.15 Longline survey sample size (Collections), % of collections positive for Red Drum, and number of Red Drum collected by fishing year.

Year	Collections	% Positive	Red Drum
2010	260	37.7	371
2011	274	40.5	327
2012	237	46.0	512
2013	304	45.7	558
2014	350	44.3	569
2015	320	49.4	825
2016	336	54.5	966
2017	350	40.6	514
2018	354	37.0	639
2019	344	47.1	639
2020	342	46.2	694
2021	345	34.2	433
2022	268	37.3	355
2023	355	37.5	660

Table 4.1 Length-length relationships estimated for Red Drum in SEDAR 93 southern stock (ASMFC 2024b). All length units are in mm. FL = Fork Length, SL = Standard Length, TL = Total Length.

Dep. Variable	Ind. Variable	n	a	SE	b	SE	r^2	Dependent Range	Independent Range
TL	SL	52,909	8.095	0.091	1.2	2.24E-04	0.998	5-1,183	4-1,005
TL	FL	20,366	-20.339	0.276	1.091	3.59E-04	0.998	19-1,246	19-1,154
FL	SL	8,184	30.551	0.363	1.087	7.23E-04	0.996	19-1,135	15-1,005
FL	TL	20,366	20.206	0.247	0.914	3.01E-04	0.998	19-1,154	19-1,246
SL	FL	8,184	-26.355	0.35	0.917	6.10E-04	0.996	15-1,005	19-1,135
SL	TL	52,909	-6.046	0.077	0.832	1.55E-04	0.998	4-1,005	5-1,183

Table 4.2 Life history parameters used in Stock Synthesis for Red Drum in the SC sub-stock model.

Parameter	Value	Source
Age-2 Natural Mortality	0.233	ASMFC 2024b; Table 51
A_{min} (age for first size-at-age, L_{min})	five months old	ASMFC 2024b; Table 51
L_{min} (TL cm)	21.3	ASMFC 2024b; Table 60
L_{∞} (TL cm)	107.5	ASMFC 2024b; Table 60
Maximum age	41	ASMFC 2024b; Table 51
von Bertalanffy Base k (youngest ages)	0.426	ASMFC 2024b; Table 60
k age break points	1, 6	ASMFC 2024b; Table 51
Age break point k multiplier at age 1	Estimated	NA
Age break point k multiplier at age 6	Estimated	NA
Length-at-age CV for smallest sizes	0.186	ASMFC 2024b; Table 60
Length-at-age CV for largest sizes	0.021	ASMFC 2024b; Table 60
Length-weight relationship alpha (TL cm-kg)	1.36E-05	ASMFC 2024b; Table 51
Length-weight relationship beta (TL cm-kg)	2.982	ASMFC 2024b; Table 51
Female age-at-50% maturity (yrs)	4.2	ASMFC 2024b; Table 51
Female maturity slope	-1.55	ASMFC 2024b; Table 51
R_0 (thousands of fish)	Estimated	NA
σ_R	0.37	Section 4.1.4
Steepness	0.99	ASMFC 2022

Table 4.3 Configuration details for fishing fleets and surveys in the SC sub-stock model based on the ASMFC model.

Fleet Name	Years	Discard Mortality	Timing	Catch Error Type	Selectivity	Retention Periods	Composition Error Type
Recreational	1981-2023	0.08	NA	Lognormal	Double Normal Length and Age Derived	1981-1989, 1990-1992, 1993-2000, 2001-2006, 2007-2017, 2018-2023	Multinomial
Rotenone	1986-1993	NA	October 15	Lognormal	Age-0 Recruitment (SS special survey type 33)	NA	NA
Stop Net	1987-1993	NA	July 1	Lognormal	Double Normal Age	NA	Multinomial
Trammel	1991-2023	NA	July 1	Lognormal	Double Normal Length and Age Derived	NA	Multinomial
Longline	2010-2023	NA	October 15	Lognormal	Double Normal Length and Age Derived	NA	Multinomial

Table 4.4 Retention block details for fishing fleets in the SC sub-stock model.

Fleet	Years	Parameters	Regulation Change
Recreational	1990-1992	Inflection, Width, Asymptote	Minimum size season to full year
Recreational	1993-2000	Dome Inflection, Dome Width	Maximum size
Recreational	2001-2006	Inflection, Width, Asymptote, Dome Inflection, Dome Width	Minimum size increase, Maximum size decrease, Bag limit decrease
Recreational	2007-2017	Asymptote	Bag limit increase
Recreational	2018-2022	Asymptote	Bag limit decrease, Vessel limit

Table 4.5 Fishing mortality and spawning stock biomass reference points and status measures for Red Drum. Spawning stock biomass measures are in metric tons.

Measure	Description	Type
Overfishing and Target Spawning Potential Ratio and Fishing Mortality Reference Points		
$SPR_{30\%}$	Static spawning potential ratio resulting in 30% of unfished equilibrium spawning stock biomass given terminal year life history characteristics, selectivity, and retention patterns	Threshold
$F_{30\%}$	Age-2 fishing mortality associated with $SPR_{30\%}$	Threshold
$SPR_{40\%}$	Static spawning potential ratio resulting in 30% of unfished equilibrium spawning stock biomass given terminal year life history characteristics, selectivity, and retention patterns	Target
$F_{40\%}$	Age-2 fishing mortality associated with $SPR_{40\%}$	Target
$\overline{SPR_{y-2,y-1,y}}$	3-yr running average static spawning potential ratio in year y	Population Measure
$SPR\ Status_y$	3-yr running average SPR in year y relative to SPR threshold: $\overline{SPR_{y-2,y-1,y}} > SPR_{30\%} = \text{Not Overfishing}$ $\overline{SPR_{y-2,y-1,y}} < SPR_{30\%} = \text{Overfishing}$	Fishing Mortality Status
Overfished and Target Spawning Stock Biomass Reference Points		
$SSB_{30\%}$	30% of unfished equilibrium spawning stock biomass	Threshold
$SSB_{40\%}$	40% of unfished equilibrium spawning stock biomass	Target
$\overline{SSB_{y-2,y-1,y}}$	3-yr running average spawning stock biomass in year y	Population Measure
$SSB\ Status_y$	3-yr running average SSB in year y relative to SSB threshold: $\overline{SSB_{y-2,y-1,y}} > SSB_{30\%} = \text{Not Overfished}$ $\overline{SSB_{y-2,y-1,y}} < SSB_{30\%} = \text{Overfished}$	Biomass Status

Table 4.6 Fishing fleet initial fishing mortality, selectivity, retention, discard mortality, survey catchability, and survey selectivity parameters for the SC sub-stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
Initial Fishing Mortality					
InitF_seas_1_flt_1SC_Recreational	Estimated	1.618	0.2050	0	2
Recreational Fleet Selectivity					
Size_DblN_peak	Estimated	41.233	1.2440	25	50
Size_DblN_top_logit	Fixed	-0.580	NA	NA	NA
Size_DblN_ascend_se	Estimated	4.673	0.2277	0	6
Size_DblN_descend_se	Estimated	2.756	0.9403	0	6
Size_DblN_start_logit	Fixed	-999	NA	NA	NA
Size_DblN_end_logit	Estimated	-1.472	0.2061	-5	5
Recreational Fleet Selectivity (w/ Retention Blocks)					
Retain_L_infl	Estimated	21.408	1.7273	20	50
Retain_L_infl_BLK1_1990	Estimated	34.378	0.9307	20	50
Retain_L_infl_BLK1_2001	Estimated	38.786	0.3537	20	50
Retain_L_width	Estimated	2.669	1.3615	0.1	10
Retain_L_width_BLK1_1990	Estimated	2.854	0.5656	0.1	10
Retain_L_width_BLK1_2001	Estimated	1.075	0.1892	0.1	10
Retain_L_asymptote_logit	Estimated	5.708	2.9346	-10	10
Retain_L_asymptote_logit_BLK3_1990	Estimated	5.577	3.0205	-10	10
Retain_L_asymptote_logit_BLK3_2001	Estimated	0.626	0.3230	-10	10
Retain_L_asymptote_logit_BLK3_2007	Estimated	-0.027	0.1870	-10	10

Table 4.6: *cont.*

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
Retain_L_asymptote_logit_BLK3_2018	Estimated	-0.583	0.1688	-10	10
Retain_L_dome_infl	Estimated	70.313	2.3869	40	136
Retain_L_dome_infl_BLK2_1993	Estimated	55.859	1.8043	40	136
Retain_L_dome_infl_BLK2_2001	Estimated	59.225	0.6037	40	136
Retain_L_dome_width	Estimated	8.145	1.6973	0.1	10
Retain_L_dome_width_BLK2_1993	Estimated	6.157	0.9399	0.001	10
Retain_L_dome_width_BLK2_2001	Estimated	1.989	0.3219	0.001	10
Discard Mortality					
DiscMort	Fixed	0.080	NA	NA	NA
Survey Catchability					
LnQ_Rotenone	Derived	-7.511	NA	NA	NA
LnQ_Stop Net	Derived	-7.343	NA	NA	NA
LnQ_Trammel	Derived	-7.066	NA	NA	NA
LnQ_Longline	Derived	-6.004	NA	NA	NA
Length-Based Survey Selectivity					
Size_inflection_Longline	Fixed	91.500	NA	NA	NA
Size_95%width_Longline	Fixed	9.000	NA	NA	NA
Age-Based Survey Selectivity					
Age_DblN_peak_Stop Net	Fixed	1.029	NA	NA	NA
Age_DblN_top_logit_Stop Net	Estimated	-9.239	3.9356	-15	3
Age_DblN_ascend_se_Stop Net	Fixed	0.629	NA	NA	NA
Age_DblN_descend_se_Stop Net	Estimated	0.106	0.1237	0.001	4
Age_DblN_start_logit_Stop Net	Fixed	-999	NA	NA	NA
Age_DblN_end_logit_Stop Net	Fixed	-999	NA	NA	NA
Age_DblN_peak_Trammel	Estimated	1.779	0.0385	0.1	2.75
Age_DblN_top_logit_Trammel	Fixed	-11.255	NA	NA	NA
Age_DblN_ascend_se_Trammel	Fixed	0.563	NA	NA	NA
Age_DblN_descend_se_Trammel	Fixed	0.642	NA	NA	NA
Age_DblN_start_logit_Trammel	Fixed	-999	NA	NA	NA
Age_DblN_end_logit_Trammel	Fixed	-999	NA	NA	NA

Table 4.7 Life history parameters for the SC sub-stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
NatM_Lorenzen	Fixed	0.233	NA	NA	NA
L_at_Amin	Fixed	21.325	NA	NA	NA
L_at_Amax	Fixed	107.465	NA	NA	NA
VonBert_K_young	Fixed	0.42621	NA	NA	NA
Age_K_mult_Age_1	Estimated	0.516	0.0036	0.01	1
Age_K_mult_Age_6	Estimated	0.260	0.0170	0.01	1
CV_young	Fixed	0.186	NA	NA	NA
CV_old	Fixed	0.021	NA	NA	NA
Wtlen_1	Fixed	0.0000136	NA	NA	NA
Wtlen_2	Fixed	2.920	NA	NA	NA
Age_@_Mat50%	Fixed	4.2	NA	NA	NA
Mat_slope	Fixed	-1.546	NA	NA	NA

Table 4.8 Recruitment parameters for the SC sub-stock model.

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
Spawner-Recruit Parameters					
LN(R_0R0)	Estimated	7.263	0.0873	6	13
BH_steepness	Fixed	0.99	NA	0.2	0.99
σ_R	Fixed	0.367	NA	0.1	2
Early Recruitment Deviations					
1970	Deviation	-0.063	0.356277	-5	5
1971	Deviation	0.122	0.353759	-5	5
1972	Deviation	-0.070	0.355271	-5	5
1973	Deviation	0.051	0.353156	-5	5
1974	Deviation	-0.040	0.35329	-5	5
1975	Deviation	-0.088	0.352592	-5	5
1976	Deviation	-0.072	0.350084	-5	5
1977	Deviation	-0.114	0.344268	-5	5
1978	Deviation	-0.234	0.331228	-5	5
1979	Deviation	-0.261	0.300767	-5	5
1980	Deviation	-0.747	0.294999	-5	5
Main Recruitment Deviations					
1981	Deviation	-0.421	0.244128	-5	5
1982	Deviation	-0.308	0.266508	-5	5
1983	Deviation	-0.171	0.243172	-5	5
1984	Deviation	0.387	0.183905	-5	5
1985	Deviation	0.313	0.154754	-5	5
1986	Deviation	0.534	0.125952	-5	5
1987	Deviation	0.360	0.125427	-5	5
1988	Deviation	-0.362	0.154866	-5	5
1989	Deviation	0.191	0.115339	-5	5
1990	Deviation	0.504	0.0981674	-5	5
1991	Deviation	0.395	0.0936956	-5	5
1992	Deviation	0.055	0.106195	-5	5
1993	Deviation	0.039	0.0987106	-5	5
1994	Deviation	0.512	0.091908	-5	5
1995	Deviation	-0.362	0.126651	-5	5
1996	Deviation	-0.044	0.0818684	-5	5
1997	Deviation	-0.422	0.0962088	-5	5
1998	Deviation	-0.422	0.0987148	-5	5
1999	Deviation	-0.853	0.124515	-5	5
2000	Deviation	0.587	0.0766588	-5	5
2001	Deviation	0.441	0.086146	-5	5
2002	Deviation	0.633	0.0784547	-5	5
2003	Deviation	-0.004	0.0963511	-5	5
2004	Deviation	-0.242	0.0986769	-5	5
2005	Deviation	-0.559	0.108101	-5	5
2006	Deviation	-0.074	0.0856528	-5	5
2007	Deviation	0.209	0.0831358	-5	5
2008	Deviation	0.320	0.0808908	-5	5
2009	Deviation	0.454	0.080542	-5	5
2010	Deviation	0.139	0.0849259	-5	5
2011	Deviation	-0.202	0.0994353	-5	5
2012	Deviation	-0.287	0.0957573	-5	5
2013	Deviation	-0.199	0.0994561	-5	5

Table 4.8: *cont.*

Parameter	Type	Final Value	SE	Lower Bound	Upper Bound
2014	Deviation	-0.521	0.117939	-5	5
2015	Deviation	0.038	0.093776	-5	5
2016	Deviation	-0.049	0.099769	-5	5
2017	Deviation	-0.038	0.096531	-5	5
2018	Deviation	-0.063	0.113729	-5	5
2019	Deviation	-0.402	0.118286	-5	5
2020	Deviation	0.146	0.0919154	-5	5
2021	Deviation	-0.125	0.117954	-5	5
2022	Deviation	0.389	0.111924	-5	5
2023	Deviation	-0.513	0.257088	-5	5
Forecast Recruitment Deviations					
2024+	Deviation	0.000	58.0000	-5	5

Table 4.9 Age-2 fishing mortality (F) parameter estimates for the SC sub-stock SS base model.

Year	Final Value	SE	Year	Final Value	SE	Year	Final Value	SE
1981	0.918	0.5662	1996	0.327	0.0848	2011	0.213	0.0362
1982	0.600	0.2446	1997	0.133	0.0311	2012	0.289	0.047
1983	0.499	0.2991	1998	0.142	0.0336	2013	0.289	0.0424
1984	0.527	0.1981	1999	0.140	0.0374	2014	0.470	0.0699
1985	0.759	0.1571	2000	0.082	0.0213	2015	0.407	0.0722
1986	0.275	0.0612	2001	0.106	0.0230	2016	0.423	0.0693
1987	0.522	0.1041	2002	0.106	0.0242	2017	0.473	0.0730
1988	0.333	0.0842	2003	0.134	0.0306	2018	0.369	0.0627
1989	0.271	0.0715	2004	0.121	0.0263	2019	0.513	0.0896
1990	0.273	0.0853	2005	0.202	0.0435	2020	0.381	0.0673
1991	0.243	0.0690	2006	0.266	0.0602	2021	0.290	0.0525
1992	0.156	0.0408	2007	0.157	0.0323	2022	0.240	0.0429
1993	0.128	0.0354	2008	0.224	0.0433	2023	0.558	0.1096
1994	0.133	0.0322	2009	0.236	0.0403			
1995	0.222	0.052	2010	1.412	0.0629			

Table 4.10 Jitter analysis results for the SC sub-stock SS model. The -LL column shows the change in total negative log-likelihood relative to the base model.

-LL	**Δ -LL**	**Frequency**	**Converged?**
1776.4	0	190	Yes
1787.35	10.95	1	Yes
1844.27	67.87	1	Yes
1904.51	128.11	1	Yes
1961.72	185.32	1	Yes
2028.47	252.07	1	Yes
2209.56	433.16	1	Yes
2429.02	652.62	1	Yes
2470.71	694.31	1	Yes
2476.75	700.35	1	Yes
2541.95	765.55	1	Yes

Table 4.11 Model estimated annual catch (harvest, live discards, dead discards, total (harvest + live discards) and removals (harvest + dead discards) and difference from observed catch (see Table 3.1) for the SC sub-stock SS model. All catches are in terms of 1,000s of fish.

	Model Estimated Catch (1,000s of Fish)					Difference (Estimated – Observed; 1,000s of fish)				
Year	Harvest	Live Discards	Dead Discards	Total	Removals	Harvest	Live Discards	Dead Discards	Total	Removals
1981	347.6	48.1	3.8	395.7	351.5	156.9	39.8	3.2	196.7	160.1
1982	282.7	36.5	2.9	319.2	285.6	4.0	20.2	1.6	24.2	5.6
1983	305.5	42.5	3.4	348.0	308.9	-172.9	31.1	2.5	-141.8	-170.4
1984	462.4	66.4	5.3	528.8	467.7	91.2	5.7	0.5	96.9	91.6
1985	826.7	114.5	9.2	941.2	835.8	-110.1	8.9	0.7	-101.2	-109.4
1986	377.9	56.2	4.5	434.1	382.4	55.1	-16.2	-1.3	38.9	53.8
1987	844.0	147.8	11.8	991.8	855.8	112.4	-49.9	-4.0	62.5	108.4
1988	475.1	111.5	8.9	586.5	484.0	83.9	-20.7	-1.7	63.2	82.3
1989	351.0	108.6	8.7	459.6	359.7	59.0	-20.7	-1.7	38.3	57.3
1990	330.9	233.4	18.7	564.3	349.6	-82.6	90.6	7.2	8.0	-75.4
1991	392.1	224.8	18.0	616.8	410.0	51.0	13.8	1.1	64.8	52.1
1992	278.9	149.0	11.9	427.9	290.8	-8.3	17.4	1.4	9.1	-6.9
1993	247.3	420.0	33.6	667.3	280.9	-40.6	31.9	2.6	-8.7	-38.0
1994	249.6	471.2	37.7	720.8	287.3	127.2	-180.2	-14.4	-53.0	112.8
1995	474.4	689.8	55.2	1164.1	529.6	-37.1	-83.9	-6.7	-121.1	-43.9
1996	427.5	945.9	75.7	1373.4	503.2	50.8	68.3	5.5	119.1	56.2
1997	176.8	326.3	26.1	503.1	202.9	-85.8	106.0	8.5	20.2	-77.3
1998	163.5	333.0	26.6	496.5	190.1	-27.9	64.1	5.1	36.3	-22.7
1999	145.8	296.5	23.7	442.3	169.5	8.7	-8.3	-0.7	0.3	8.0
2000	89.0	210.6	16.9	299.6	105.9	-2.9	3.7	0.3	0.8	-2.6
2001	170.8	492.7	39.4	663.4	210.2	-1.0	18.1	1.4	17.1	0.5
2002	203.0	615.7	49.3	818.6	252.2	8.9	1.3	0.1	10.2	9.0
2003	280.8	835.8	66.9	1116.6	347.6	14.6	-23.3	-1.9	-8.7	12.8
2004	180.5	718.6	57.5	899.1	238.0	3.7	-2.4	-0.2	1.3	3.5
2005	203.3	1035.3	82.8	1238.6	286.1	-52.7	82.2	6.6	29.5	-46.1
2006	185.1	1153.4	92.3	1338.5	277.4	46.7	-28.4	-2.3	18.2	44.4
2007	133.7	844.5	67.6	978.2	201.3	-35.9	59.5	4.8	23.5	-31.2
2008	258.2	1308.1	104.6	1566.2	362.8	36.0	-168.9	-13.5	-132.9	22.5
2009	309.0	1528.0	122.2	1837.0	431.3	5.9	-13.4	-1.1	-7.5	4.8
2010	515.9	2425.1	194.0	2941.1	709.9	20.4	122.1	9.8	142.5	30.2
2011	247.7	1239.4	99.2	1487.1	346.8	31.6	-75.3	-6.0	-43.7	25.6
2012	255.1	1519.2	121.5	1774.3	376.6	-133.8	-34.3	-2.7	-168.1	-136.5
2013	210.3	1358.4	108.7	1568.7	319.0	-4.1	-36.2	-2.9	-40.3	-6.9
2014	316.4	1865.5	149.2	2181.9	465.6	-68.9	-10.5	-0.8	-79.4	-69.7
2015	217.6	1509.0	120.7	1726.6	338.3	-49.1	-28.7	-2.3	-77.8	-51.4
2016	321.4	1605.8	128.5	1927.1	449.8	-61.0	73.9	5.9	12.9	-55.1

Table 4.11: *cont.*

	Model Estimated Catch (1,000s of Fish)					Difference (Estimated – Observed; 1,000s of fish)				
Year	**Harvest**	**Live Discards**	**Dead Discards**	**Total**	**Removals**	**Harvest**	**Live Discards**	**Dead Discards**	**Total**	**Removals**
2017	361.7	1781.9	142.6	2143.5	504.2	2.2	-265.5	-21.2	-263.3	-19.1
2018	262.7	1837.1	147.0	2099.8	409.7	-11.2	86.1	6.9	74.9	-4.3
2019	344.2	2355.5	188.4	2699.7	532.6	34.5	-460.6	-36.9	-426.1	-2.3
2020	206.1	1762.0	141.0	1968.1	347.0	2.9	-87.1	-7.0	-84.2	-4.1
2021	237.2	1472.1	117.8	1709.3	355.0	5.3	-24.2	-1.9	-18.9	3.4
2022	195.6	1434.6	114.8	1630.2	310.4	-23.3	60.8	4.9	37.4	-18.5
2023	533.5	3144.1	251.5	3677.6	785.0	26.9	-74.3	-5.9	-47.4	21.0

Table 4.12 Results of the runs test (*p*) and joint-index residual RMSE for each fishery-independent survey, length composition, and age composition.

		Runs Test statistics				JABBA statistics	
Data Source	**Quantity**	***p* value**	**Test**	**σ*3 low**	**σ*3 high**	**RMSE**	**Number of Observations**
SC Rotenone	CPUE	1	Passed	-1.757	1.757	55.80%	8
SC Stop Net	CPUE	1	Passed	-0.47	0.47	16.40%	8
SC Trammel Net	CPUE	0.696	Passed	-0.754	0.754	25.50%	34
SC Longline	CPUE	0.935	Passed	-0.91	0.91	36.80%	14
SC Recreational Fleet	Length	0.315	Passed	-0.092	0.092	6.20%	43
SC Trammel Net	Length	0.163	Passed	-0.074	0.074	2.80%	33
SC Stop Net	Age	0.28	Passed	-0.943	0.943	42.80%	8

Table 4.13 Annual and 3-yr average estimates of spawning stock biomass (SSB) based on the SS SC sub-stock base model. Also provide are model estimates of virgin (i.e., equilibrium carrying capacity) estimates of biomass and SSB. $SSB_{30\%}$, the SSB threshold, is the SSB under equilibrium catches while fishing at $SPR_{30\%}$ given terminal year selectivity, retention, and life history characteristics. $SSB_{30\%}$ is the $SSB_{threshold}$ denoting biomass based stock status, and hence an overfished determination. Stock status is based on 3-yr average SSB relative to $SSB_{30\%}$.

	Virgin		Spawning Stock Biomass					
				Annual		3-yr Avg.		
Year	B	SSB	$SSB_{30\%}$	SSB	$SSB/SSB_{30\%}$	SSB	$SSB/SSB_{30\%}$	Status
1981	20242	8102	2416	78	0.032			
1982	20242	8102	2416	81	0.034			
1983	20242	8102	2416	93	0.038	84	0.035	Overfished
1984	20242	8102	2416	115	0.048	96	0.040	Overfished
1985	20242	8102	2416	151	0.062	120	0.049	Overfished
1986	20242	8102	2416	187	0.078	151	0.063	Overfished
1987	20242	8102	2416	271	0.112	203	0.084	Overfished
1988	20242	8102	2416	371	0.154	276	0.114	Overfished
1989	20242	8102	2416	537	0.222	393	0.163	Overfished
1990	20242	8102	2416	761	0.315	556	0.230	Overfished
1991	20242	8102	2416	1005	0.416	768	0.318	Overfished
1992	20242	8102	2416	1238	0.512	1001	0.414	Overfished
1993	20242	8102	2416	1504	0.622	1249	0.517	Overfished
1994	20242	8102	2416	1901	0.787	1548	0.641	Overfished
1995	20242	8102	2416	2414	0.999	1940	0.803	Overfished
1996	20242	8102	2416	2844	1.177	2386	0.988	Overfished
1997	20242	8102	2416	3063	1.267	2773	1.148	Not Overfished
1998	20242	8102	2416	3225	1.335	3044	1.260	Not Overfished
1999	20242	8102	2416	3318	1.373	3202	1.325	Not Overfished
2000	20242	8102	2416	3345	1.384	3296	1.364	Not Overfished
2001	20242	8102	2416	3348	1.386	3337	1.381	Not Overfished
2002	20242	8102	2416	3353	1.388	3349	1.386	Not Overfished
2003	20242	8102	2416	3381	1.399	3361	1.391	Not Overfished
2004	20242	8102	2416	3581	1.482	3438	1.423	Not Overfished
2005	20242	8102	2416	4016	1.662	3659	1.514	Not Overfished
2006	20242	8102	2416	4489	1.858	4029	1.667	Not Overfished
2007	20242	8102	2416	4740	1.962	4415	1.827	Not Overfished
2008	20242	8102	2416	4757	1.969	4662	1.929	Not Overfished
2009	20242	8102	2416	4554	1.885	4684	1.938	Not Overfished
2010	20242	8102	2416	4343	1.797	4551	1.884	Not Overfished
2011	20242	8102	2416	4167	1.725	4355	1.802	Not Overfished
2012	20242	8102	2416	4137	1.712	4216	1.745	Not Overfished
2013	20242	8102	2416	4109	1.701	4138	1.712	Not Overfished
2014	20242	8102	2416	4062	1.681	4103	1.698	Not Overfished
2015	20242	8102	2416	3878	1.605	4017	1.662	Not Overfished
2016	20242	8102	2416	3632	1.503	3857	1.596	Not Overfished
2017	20242	8102	2416	3347	1.385	3619	1.498	Not Overfished
2018	20242	8102	2416	3060	1.266	3346	1.385	Not Overfished
2019	20242	8102	2416	2822	1.168	3076	1.273	Not Overfished
2020	20242	8102	2416	2599	1.076	2827	1.170	Not Overfished
2021	20242	8102	2416	2450	1.014	2624	1.086	Not Overfished

Table 4.13: *cont.*

				Spawning Stock Biomass				
	Virgin			Annual		3-yr Avg.		
Year	B	SSB	$SSB_{30\%}$	SSB	$SSB/SSB_{30\%}$	SSB	$SSB/SSB_{30\%}$	Status
2022	20242	8102	2416	2349	0.972	2466	1.020	Not Overfished
2023	20242	8102	2416	2290	0.948	2363	0.978	Overfished

Table 4.14 Annual and 3-yr average estimates of age-2 fishing mortality (F) and static spawning potential (SPR) based on the SS SC sub-stock base model. $F_{30\%}$, the fishing mortality threshold, is the age-2 F associated with terminal year selectivity, retention, and life history characteristics and fishing at $SPR_{30\%}$. $SPR_{30\%}$ is the $SPR_{threshold}$ denoting fishing mortality based stock status, and hence an overfishing determination. Stock status based on 3-yr average SPR relative to $SPR_{30\%}$.

	Age-2 Fishing Mortality					**Static Spawning Potential**						
		Annual		**3-yr Avg.**			**Annual**		**3-yr Avg.**			
Year	**$F_{30\%}$**	**F**	**$F/F_{30\%}$**	**F**	**$F/F_{30\%}$**	**$SPR_{30\%}$**	**SPR**	**$SPR/SPR_{30\%}$**	**SPR**	**$SPR/SPR_{30\%}$**	**SPR Status**
1981	0.335	0.918	2.74			0.3	0.030	0.10			
1982	0.335	0.600	1.79			0.3	0.100	0.33			
1983	0.335	0.499	1.49	0.672	2.008	0.3	0.147	0.49	0.093	0.308	Overfishing
1984	0.335	0.527	1.57	0.542	1.619	0.3	0.132	0.44	0.126	0.421	Overfishing
1985	0.335	0.759	2.27	0.595	1.776	0.3	0.055	0.18	0.111	0.371	Overfishing
1986	0.335	0.275	0.82	0.520	1.554	0.3	0.345	1.15	0.177	0.592	Overfishing
1987	0.335	0.522	1.56	0.519	1.548	0.3	0.135	0.45	0.178	0.595	Overfishing
1988	0.335	0.333	0.99	0.377	1.125	0.3	0.277	0.92	0.252	0.841	Overfishing
1989	0.335	0.271	0.81	0.375	1.121	0.3	0.350	1.17	0.254	0.846	Overfishing
1990	0.335	0.273	0.81	0.292	0.873	0.3	0.381	1.27	0.336	1.120	Not Overfishing
1991	0.335	0.243	0.72	0.262	0.783	0.3	0.423	1.41	0.385	1.283	Not Overfishing
1992	0.335	0.156	0.46	0.224	0.668	0.3	0.576	1.92	0.460	1.533	Not Overfishing
1993	0.335	0.128	0.38	0.175	0.524	0.3	0.603	2.01	0.534	1.780	Not Overfishing
1994	0.335	0.133	0.40	0.139	0.415	0.3	0.590	1.97	0.590	1.965	Not Overfishing
1995	0.335	0.222	0.66	0.161	0.481	0.3	0.416	1.39	0.536	1.788	Not Overfishing
1996	0.335	0.327	0.98	0.228	0.679	0.3	0.275	0.92	0.427	1.424	Not Overfishing
1997	0.335	0.133	0.40	0.227	0.679	0.3	0.591	1.97	0.427	1.425	Not Overfishing
1998	0.335	0.142	0.43	0.201	0.600	0.3	0.570	1.90	0.479	1.595	Not Overfishing
1999	0.335	0.140	0.42	0.139	0.414	0.3	0.574	1.91	0.578	1.927	Not Overfishing
2000	0.335	0.082	0.25	0.122	0.363	0.3	0.722	2.41	0.622	2.073	Not Overfishing
2001	0.335	0.106	0.32	0.109	0.327	0.3	0.704	2.35	0.667	2.222	Not Overfishing
2002	0.335	0.106	0.32	0.098	0.293	0.3	0.703	2.34	0.710	2.366	Not Overfishing
2003	0.335	0.134	0.40	0.115	0.345	0.3	0.642	2.14	0.683	2.276	Not Overfishing
2004	0.335	0.121	0.36	0.120	0.359	0.3	0.671	2.24	0.672	2.239	Not Overfishing
2005	0.335	0.202	0.60	0.152	0.455	0.3	0.512	1.71	0.608	2.027	Not Overfishing
2006	0.335	0.266	0.80	0.196	0.586	0.3	0.415	1.38	0.533	1.775	Not Overfishing
2007	0.335	0.157	0.47	0.209	0.623	0.3	0.581	1.94	0.503	1.676	Not Overfishing
2008	0.335	0.224	0.67	0.216	0.645	0.3	0.462	1.54	0.486	1.620	Not Overfishing
2009	0.335	0.236	0.70	0.206	0.615	0.3	0.445	1.48	0.496	1.653	Not Overfishing

Table 4.14: *cont.*

	Age-2 Fishing Mortality					Static Spawning Potential					
		Annual		3-yr Avg.			Annual		3-yr Avg.		
Year	$F_{30\%}$	F	$F/F_{30\%}$	F	$F/F_{30\%}$	$SPR_{30\%}$	SPR	$SPR/SPR_{30\%}$	SPR	$SPR/SPR_{30\%}$	SPR Status
2010	0.335	0.378	1.13	0.279	0.834	0.3	0.274	0.91	0.394	1.312	Not Overfishing
2011	0.335	0.213	0.64	0.275	0.822	0.3	0.481	1.60	0.400	1.333	Not Overfishing
2012	0.335	0.289	0.86	0.293	0.876	0.3	0.370	1.23	0.375	1.250	Not Overfishing
2013	0.335	0.289	0.86	0.264	0.787	0.3	0.371	1.24	0.407	1.358	Not Overfishing
2014	0.335	0.470	1.40	0.349	1.043	0.3	0.201	0.67	0.314	1.047	Not Overfishing
2015	0.335	0.407	1.21	0.388	1.159	0.3	0.249	0.83	0.274	0.912	Overfishing
2016	0.335	0.423	1.26	0.433	1.293	0.3	0.236	0.79	0.229	0.762	Overfishing
2017	0.335	0.473	1.41	0.434	1.296	0.3	0.199	0.66	0.228	0.759	Overfishing
2018	0.335	0.369	1.10	0.422	1.259	0.3	0.266	0.89	0.233	0.778	Overfishing
2019	0.335	0.513	1.53	0.452	1.349	0.3	0.160	0.53	0.208	0.694	Overfishing
2020	0.335	0.381	1.14	0.421	1.257	0.3	0.255	0.85	0.227	0.757	Overfishing
2021	0.335	0.290	0.86	0.395	1.178	0.3	0.352	1.17	0.256	0.853	Overfishing
2022	0.335	0.240	0.72	0.304	0.907	0.3	0.420	1.40	0.342	1.141	Not Overfishing
2023	0.335	0.558	1.67	0.363	1.083	0.3	0.137	0.46	0.303	1.010	Not Overfishing

Table 4.15 Base model estimated fishing mortality at age (F-at-age) based on year specific recreational fleet selectivity, retention, and total removals (harvest + dead discards). Note, at the hundredths place F for age-16+ does not change, driven by the plateau in length-based, and hence age-based, selectivity.

	Age																
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+
1981	0.28	1.07	1.22	1.13	0.82	0.46	0.32	0.29	0.26	0.25	0.24	0.23	0.23	0.23	0.23	0.23	0.23
1982	0.19	0.70	0.80	0.74	0.54	0.30	0.21	0.19	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
1983	0.15	0.58	0.66	0.61	0.45	0.25	0.17	0.16	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12
1984	0.16	0.61	0.70	0.65	0.47	0.26	0.18	0.17	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
1985	0.23	0.88	1.01	0.93	0.68	0.38	0.27	0.24	0.22	0.21	0.20	0.19	0.19	0.19	0.19	0.19	0.19
1986	0.08	0.32	0.36	0.34	0.25	0.14	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1987	0.16	0.61	0.69	0.64	0.47	0.26	0.18	0.16	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13
1988	0.10	0.39	0.44	0.41	0.30	0.17	0.12	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08
1989	0.08	0.32	0.36	0.33	0.24	0.14	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1990	0.08	0.32	0.36	0.34	0.25	0.14	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1991	0.08	0.28	0.32	0.30	0.22	0.12	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1992	0.05	0.18	0.21	0.19	0.14	0.08	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 4.15: *cont.*

	Age																
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1993	0.08	0.29	0.33	0.30	0.22	0.12	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1994	0.08	0.30	0.34	0.32	0.23	0.13	0.09	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
1995	0.13	0.49	0.56	0.52	0.38	0.21	0.15	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1996	0.19	0.73	0.83	0.77	0.56	0.32	0.22	0.20	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1997	0.08	0.30	0.34	0.31	0.23	0.13	0.09	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
1998	0.08	0.32	0.36	0.34	0.25	0.14	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1999	0.08	0.31	0.36	0.33	0.24	0.14	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2000	0.05	0.18	0.21	0.19	0.14	0.08	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2001	0.08	0.28	0.32	0.30	0.22	0.12	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2002	0.08	0.28	0.32	0.30	0.22	0.12	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2003	0.09	0.36	0.41	0.38	0.28	0.15	0.11	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
2004	0.09	0.32	0.37	0.34	0.25	0.14	0.10	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2005	0.14	0.54	0.61	0.57	0.42	0.23	0.16	0.15	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
2006	0.19	0.71	0.81	0.75	0.55	0.31	0.21	0.19	0.18	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.15
2007	0.14	0.51	0.59	0.54	0.40	0.22	0.16	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11
2008	0.19	0.73	0.84	0.78	0.57	0.32	0.22	0.20	0.18	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16
2009	0.20	0.77	0.88	0.82	0.59	0.33	0.23	0.21	0.19	0.18	0.17	0.17	0.17	0.17	0.16	0.16	0.16
2010	0.33	1.23	1.41	1.31	0.95	0.53	0.37	0.33	0.31	0.29	0.28	0.27	0.27	0.27	0.26	0.26	0.26
2011	0.18	0.69	0.79	0.74	0.54	0.30	0.21	0.19	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
2012	0.25	0.94	1.08	1.00	0.73	0.41	0.29	0.26	0.23	0.22	0.21	0.21	0.21	0.20	0.20	0.20	0.20
2013	0.25	0.94	1.08	1.00	0.73	0.41	0.28	0.25	0.23	0.22	0.21	0.21	0.20	0.20	0.20	0.20	0.20
2014	0.41	1.53	1.75	1.63	1.19	0.66	0.46	0.41	0.38	0.36	0.35	0.34	0.33	0.33	0.33	0.33	0.33
2015	0.35	1.33	1.51	1.41	1.03	0.57	0.40	0.36	0.33	0.31	0.30	0.29	0.29	0.29	0.28	0.28	0.28
2016	0.37	1.38	1.57	1.46	1.07	0.60	0.42	0.37	0.34	0.32	0.31	0.30	0.30	0.30	0.30	0.30	0.29
2017	0.41	1.54	1.76	1.64	1.19	0.67	0.47	0.42	0.38	0.36	0.35	0.34	0.34	0.33	0.33	0.33	0.33
2018	0.40	1.49	1.70	1.58	1.15	0.64	0.45	0.40	0.37	0.35	0.34	0.33	0.32	0.32	0.32	0.32	0.32
2019	0.55	2.07	2.37	2.20	1.60	0.90	0.63	0.56	0.52	0.49	0.47	0.46	0.45	0.45	0.44	0.44	0.44
2020	0.41	1.54	1.76	1.63	1.19	0.66	0.46	0.42	0.38	0.36	0.35	0.34	0.33	0.33	0.33	0.33	0.33
2021	0.31	1.17	1.34	1.24	0.91	0.51	0.35	0.32	0.29	0.27	0.26	0.26	0.25	0.25	0.25	0.25	0.25
2022	0.26	0.97	1.11	1.03	0.75	0.42	0.29	0.26	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21
2023	0.60	2.26	2.57	2.39	1.74	0.97	0.68	0.61	0.56	0.53	0.51	0.50	0.49	0.49	0.48	0.48	0.48

Table 4.16 Age-2 *F,* spawning potential ratio, and spawning stock biomass estimates from the base SC sub-population model and 70% MRIP sensitivity.

	Age2-F		SPR		SSB	
Year	**Base**	**70% MRIP**	**Base**	**70% MRIP**	**Base**	**70% MRIP**
1981	0.918	0.919	0.030	0.030	78	55
1982	0.600	0.600	0.100	0.100	81	57
1983	0.499	0.499	0.147	0.147	93	65
1984	0.527	0.527	0.132	0.132	115	81
1985	0.759	0.759	0.055	0.055	151	106
1986	0.275	0.275	0.345	0.345	187	131
1987	0.522	0.522	0.135	0.135	271	189
1988	0.333	0.333	0.277	0.277	371	260
1989	0.271	0.271	0.350	0.350	537	376
1990	0.273	0.273	0.381	0.381	761	532
1991	0.243	0.243	0.423	0.423	1,005	704
1992	0.156	0.156	0.576	0.576	1,238	867
1993	0.128	0.128	0.603	0.603	1,504	1,053
1994	0.133	0.133	0.590	0.590	1,901	1,331
1995	0.222	0.222	0.416	0.416	2,414	1,690
1996	0.327	0.327	0.275	0.275	2,844	1,991
1997	0.133	0.133	0.591	0.591	3,063	2,144
1998	0.142	0.142	0.570	0.570	3,225	2,257
1999	0.140	0.140	0.574	0.574	3,318	2,323
2000	0.082	0.082	0.722	0.722	3,345	2,342
2001	0.106	0.106	0.704	0.704	3,348	2,344
2002	0.106	0.106	0.703	0.703	3,353	2,347
2003	0.134	0.134	0.642	0.642	3,381	2,366
2004	0.121	0.121	0.671	0.671	3,581	2,507
2005	0.202	0.202	0.512	0.512	4,016	2,811
2006	0.266	0.266	0.415	0.415	4,489	3,142
2007	0.157	0.157	0.581	0.581	4,740	3,318
2008	0.224	0.224	0.462	0.462	4,757	3,330
2009	0.236	0.236	0.445	0.445	4,554	3,188
2010	0.378	0.378	0.274	0.274	4,343	3,040
2011	0.213	0.213	0.481	0.481	4,167	2,917
2012	0.289	0.289	0.370	0.370	4,137	2,896
2013	0.289	0.289	0.371	0.371	4,109	2,877

Table 4.16: *cont.*

Year	Age2-F		SPR		SSB	
	Base	70% MRIP	Base	70% MRIP	Base	70% MRIP
2014	0.470	0.470	0.201	0.201	4,062	2,843
2015	0.407	0.407	0.249	0.249	3,878	2,715
2016	0.423	0.423	0.236	0.236	3,632	2,542
2017	0.473	0.473	0.199	0.199	3,347	2,343
2018	0.369	0.369	0.266	0.266	3,060	2,142
2019	0.513	0.513	0.160	0.160	2,822	1,976
2020	0.381	0.381	0.255	0.255	2,599	1,819
2021	0.290	0.290	0.352	0.352	2,450	1,715
2022	0.240	0.240	0.420	0.420	2,349	1,644
2023	0.558	0.558	0.137	0.137	2,290	1,603

10. FIGURES

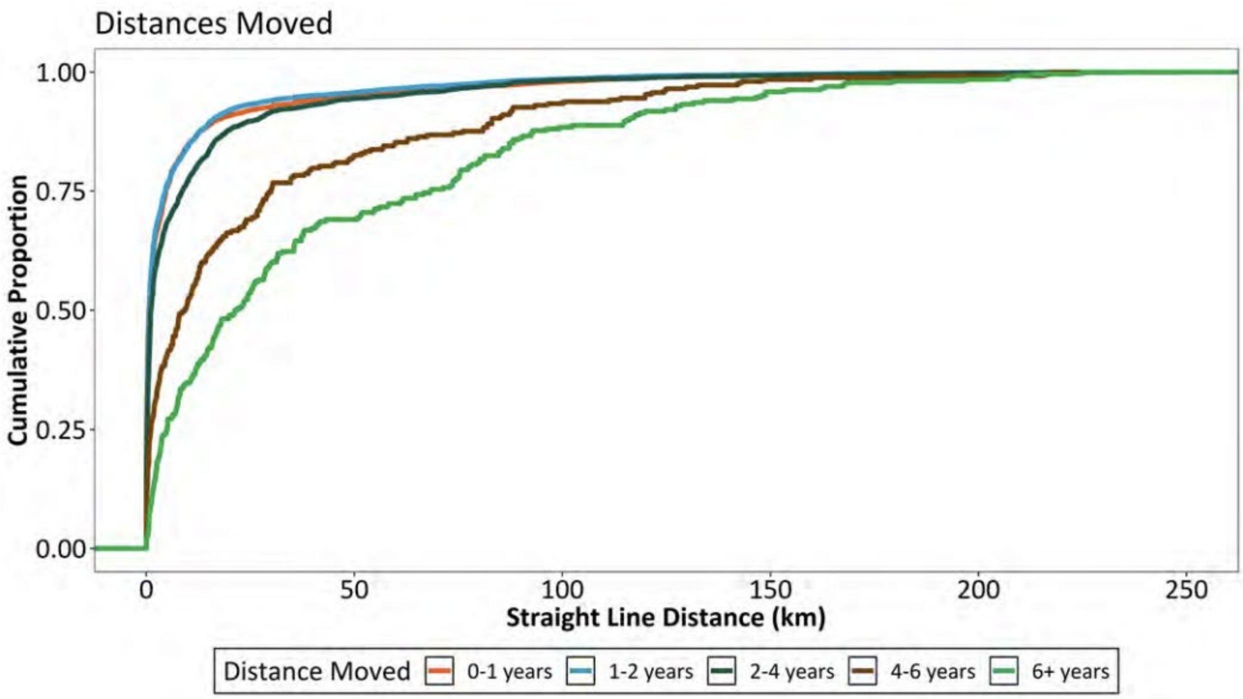


Figure 2.1 Cumulative proportion of tag recaptures as a function of straight-line distance (km) and time-at-large. Time-at-large is split into 5 groups: 0-1 years (orange), 1-2 years (blue), 2-4 years (dark green), 4-6 years (brown), and 6+ years (light green). Fish were tagged as part of SCDNR's Marine Gamefish Tagging and fishery-independent tagging programs.

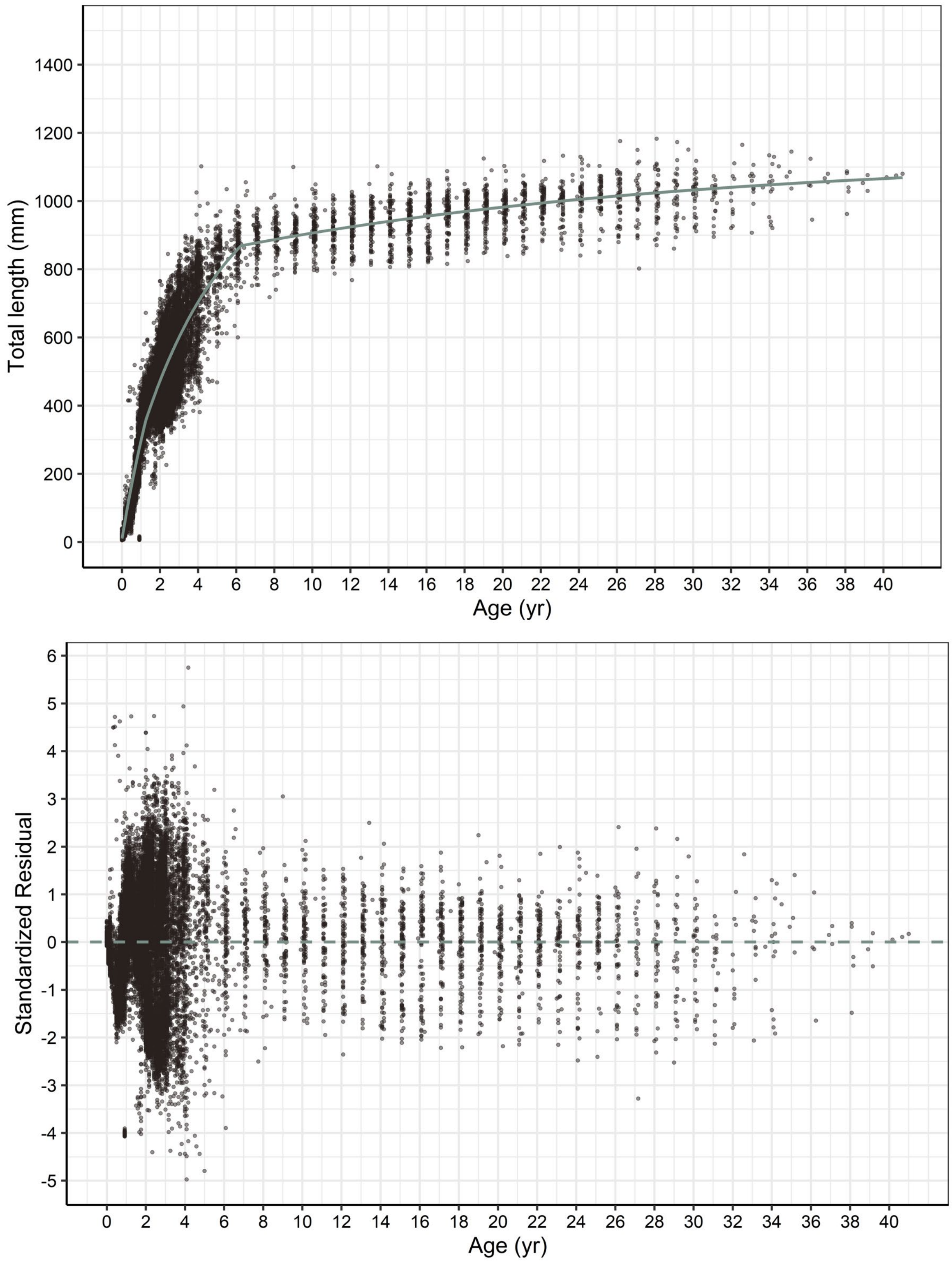


Figure 2.2 Red Drum length-at-age data collected from the Red Drum southern stock and the age-varying K growth model (blue line) as applied to the Red Drum length-at-age data (top) and the residuals from the model fit to the length-at-age data (bottom). (ASMFC 2024b Figure 12).

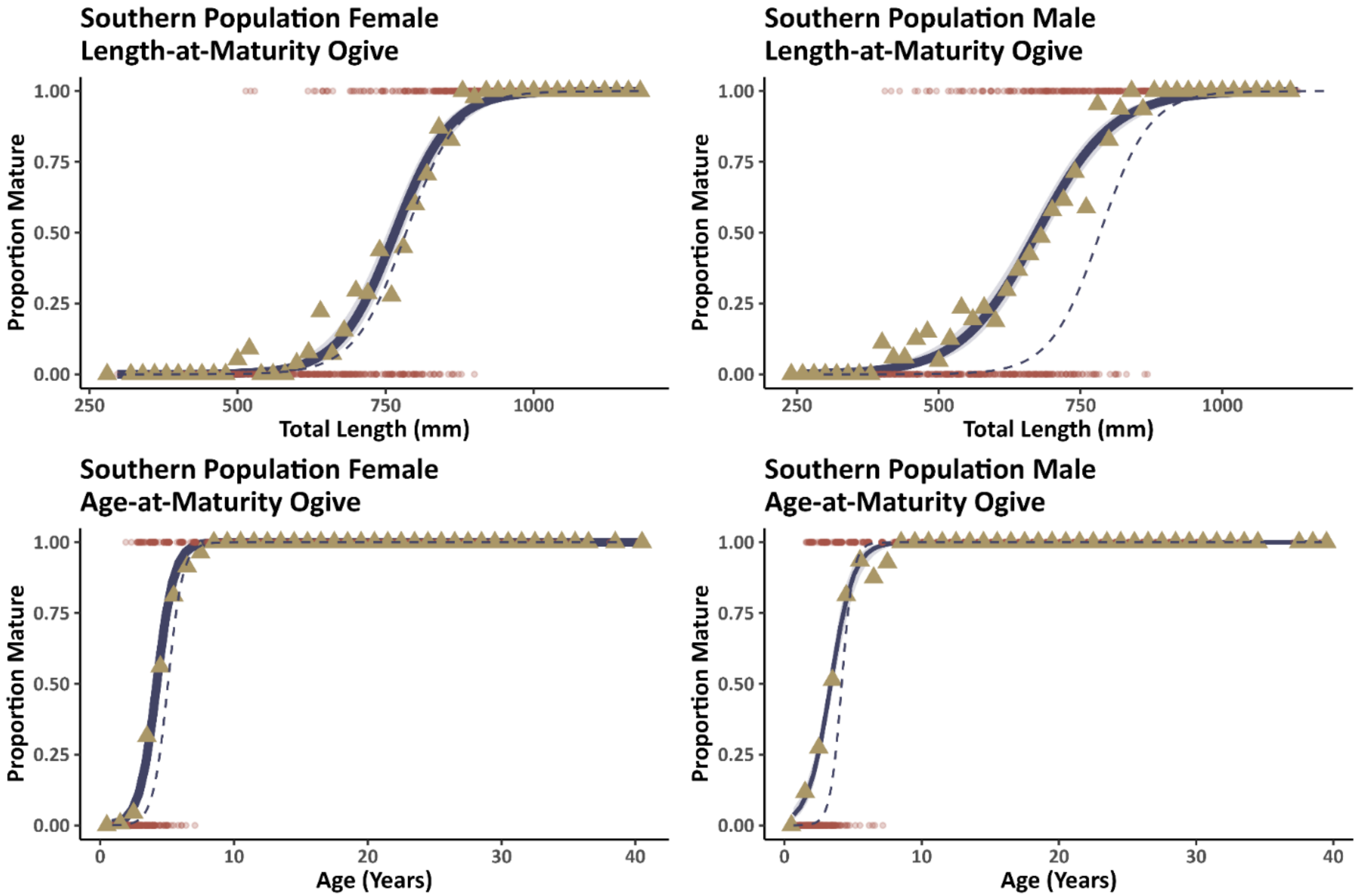


Figure 2.3 Best fit length- (top row) and age-at-maturity ogives (bottom row) for female (left column) and male (right column) Red Drum from the SC sub-stock (solid blue line). Shaded regions represent 95% confidence interval about the ogive. Dashed lines are the maturity ogives presented in SEDAR 44, tan triangles are observed proportion mature at length or age, and red circles are raw individual fish maturity data.

Figure 2.4 Externally derived weight-based (dashed line; `Mortality-weight` model (Lorenzen 1996)) or length-based (solid line; `Length-inverse` model (Lorenzen 2022)) M-at-age (adapted from Figure 21 in ASMFC 2024b).

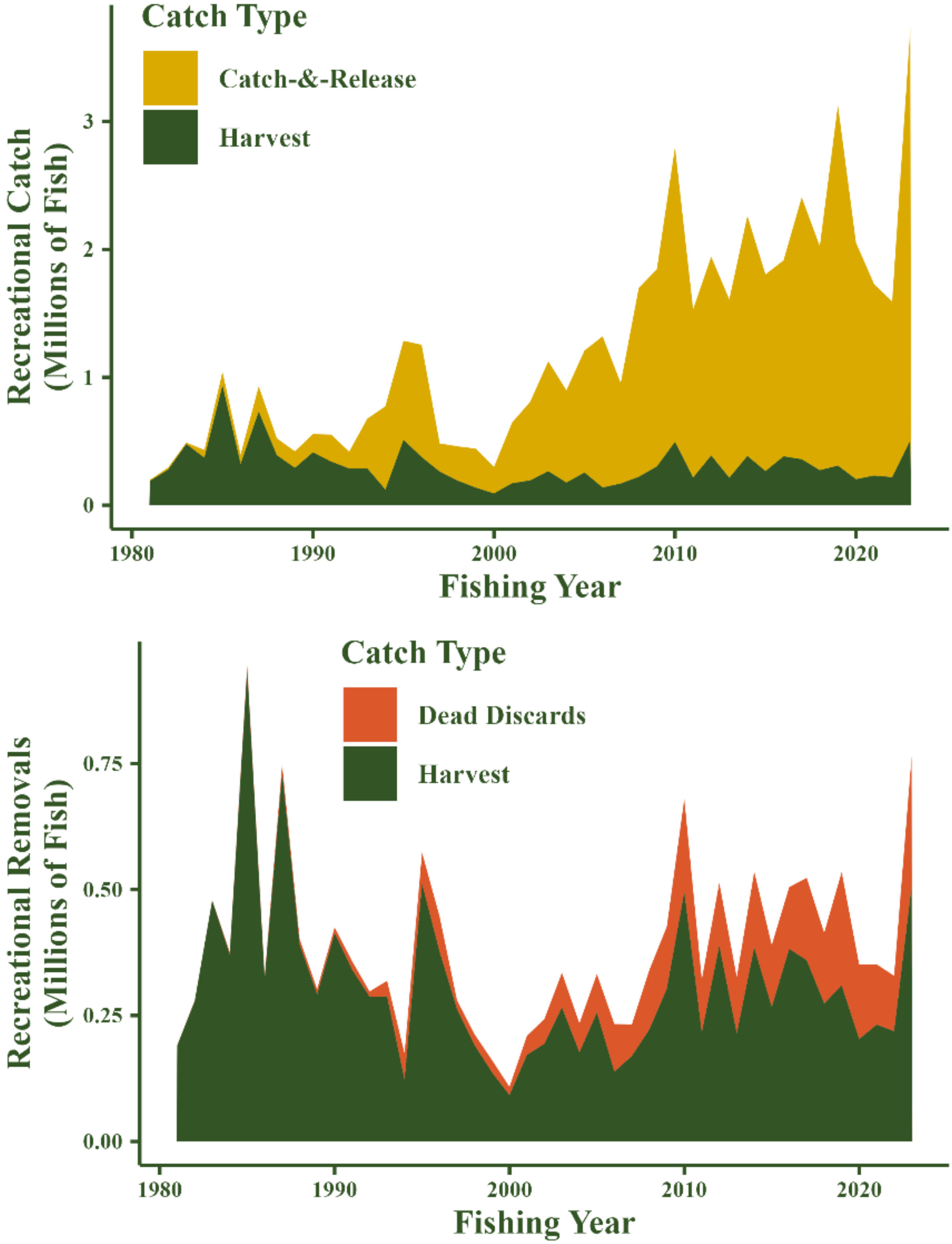


Figure 3.1 MRIP recreational catch estimates of Red Drum from SC. Top Panel – MRIP estimated harvest (Type A + B1) and live discards (Type B2). Bottom Panel – MRIP estimated harvest (Type A + B1) and dead discards, assuming an 8% mortality rate on all released discards.

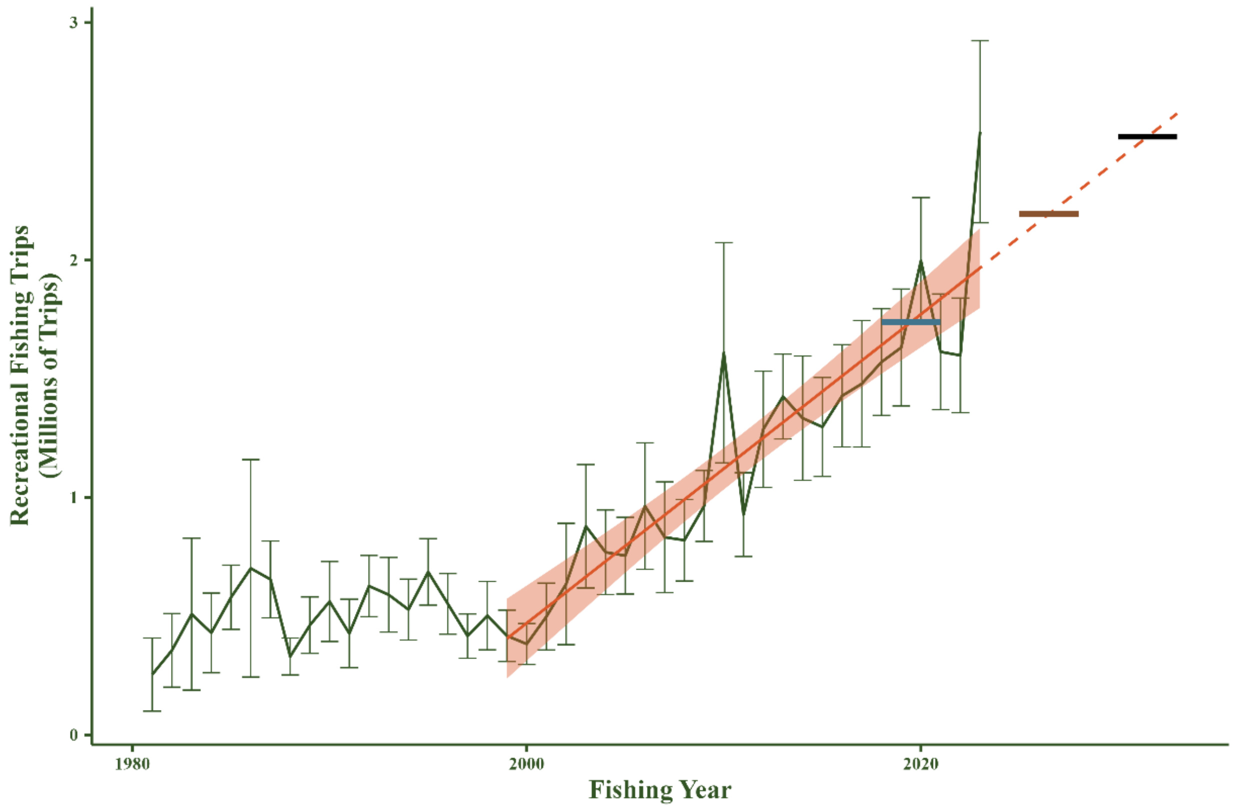


Figure 3.2 MRIP estimated trips (solid green line) identifying Red Drum as a primary or secondary target species or reporting capturing Red Drum in SC annually. Shown also is a linear model of effort increase with time since 1999 (orange solid line), extrapolation of model past 2023 (orange dashed line) and linear model predicted average effort in 2018-2021 (blue bar), 2025-2028 (brown bar), and 2030-2033 (black bar). 95% confidence intervals about annual MRIP estimates (green error bars) and linear model (orange shaded region) also shown.

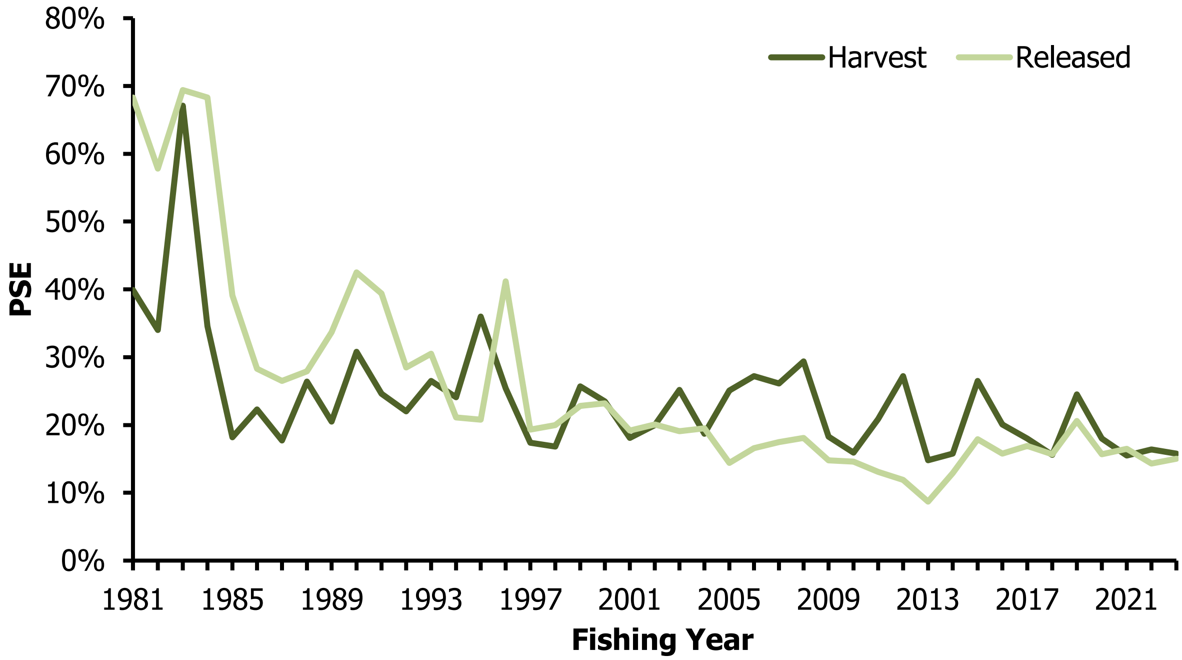


Figure 3.3 Proportional standard error of MRIP recreational catch estimates of Red Drum from SC. 2023 data are preliminary.

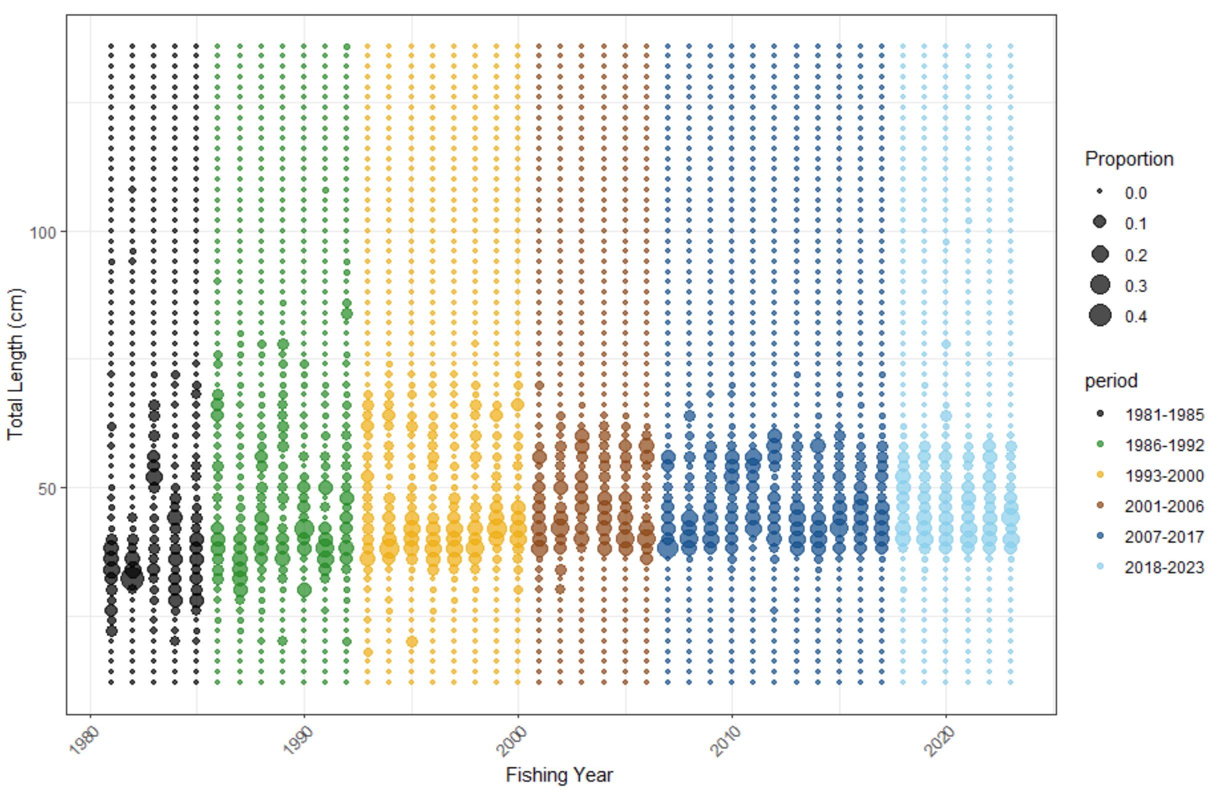


Figure 3.4 MRIP size composition estimates of recreational Red Drum harvest from SC. Data are color coded relative to selectivity blocks as defined in the assessment model based on SC regulatory changes. 2023 data are preliminary.

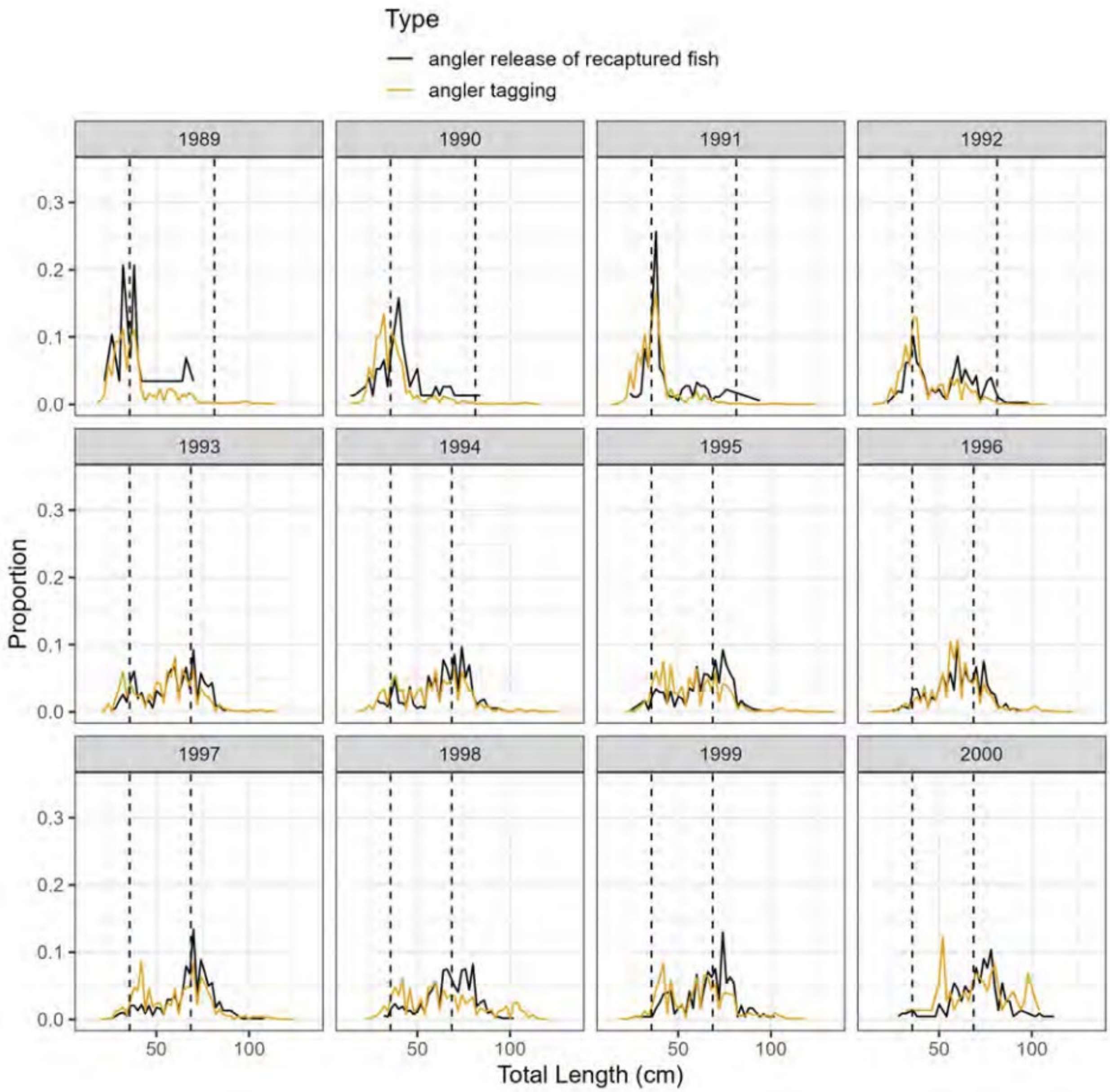


Figure 3.5 Size distributions of Red Drum tagged by volunteer anglers and recaptured and subsequently released by anglers participating in the SC MGFTP from 1989-2000. Horizontal dashed lines indicate slot size in place in SC each year. (ASMFC 2024b Figure 59).

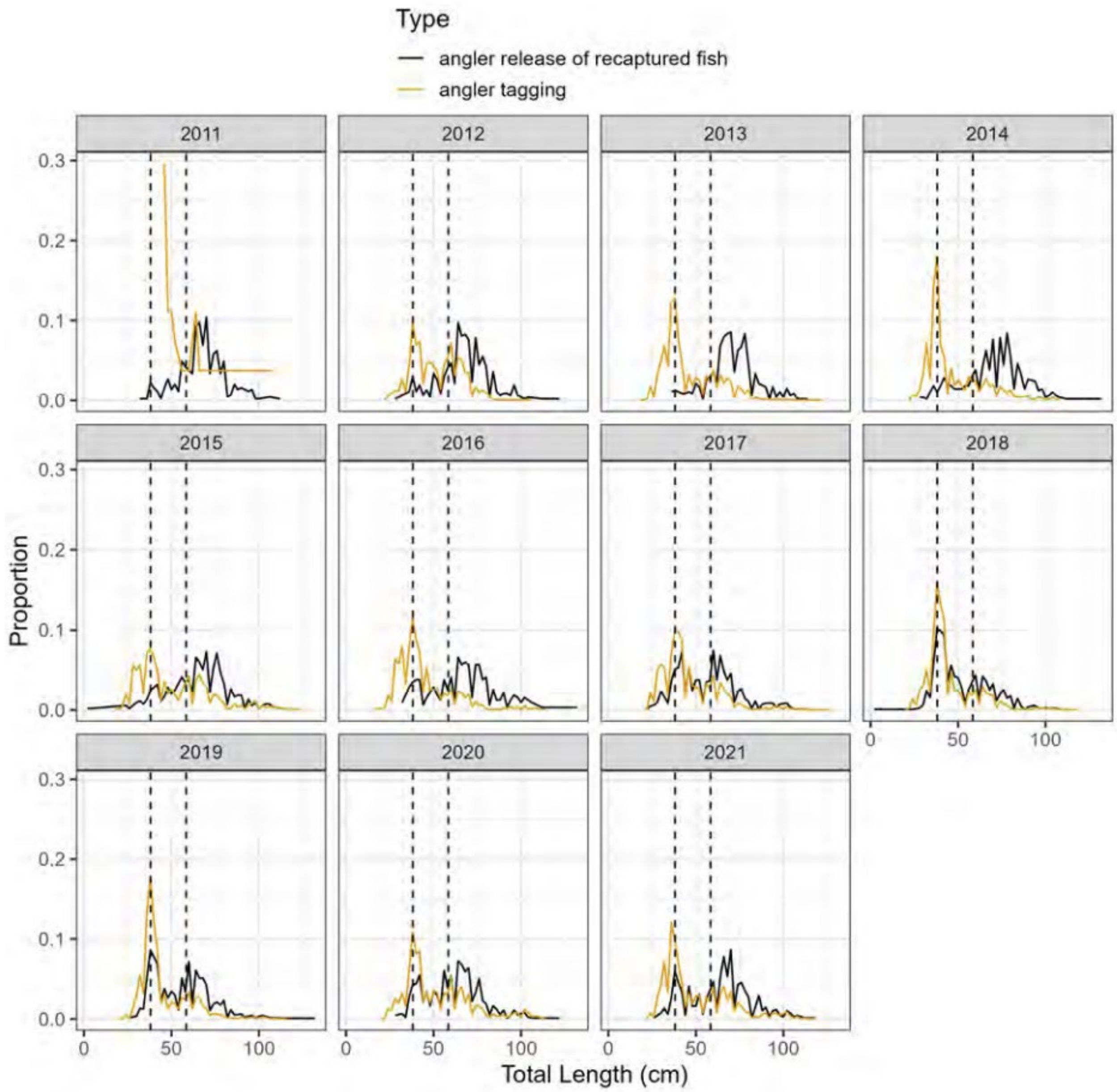


Figure 3.6 Size distributions of Red Drum tagged by volunteer anglers and recaptured and subsequently released by anglers participating in the SC MGFTP from 2011-2021. Horizontal dashed lines indicate slot size in place in SC each year. (ASMFC 2024b Figure 60).

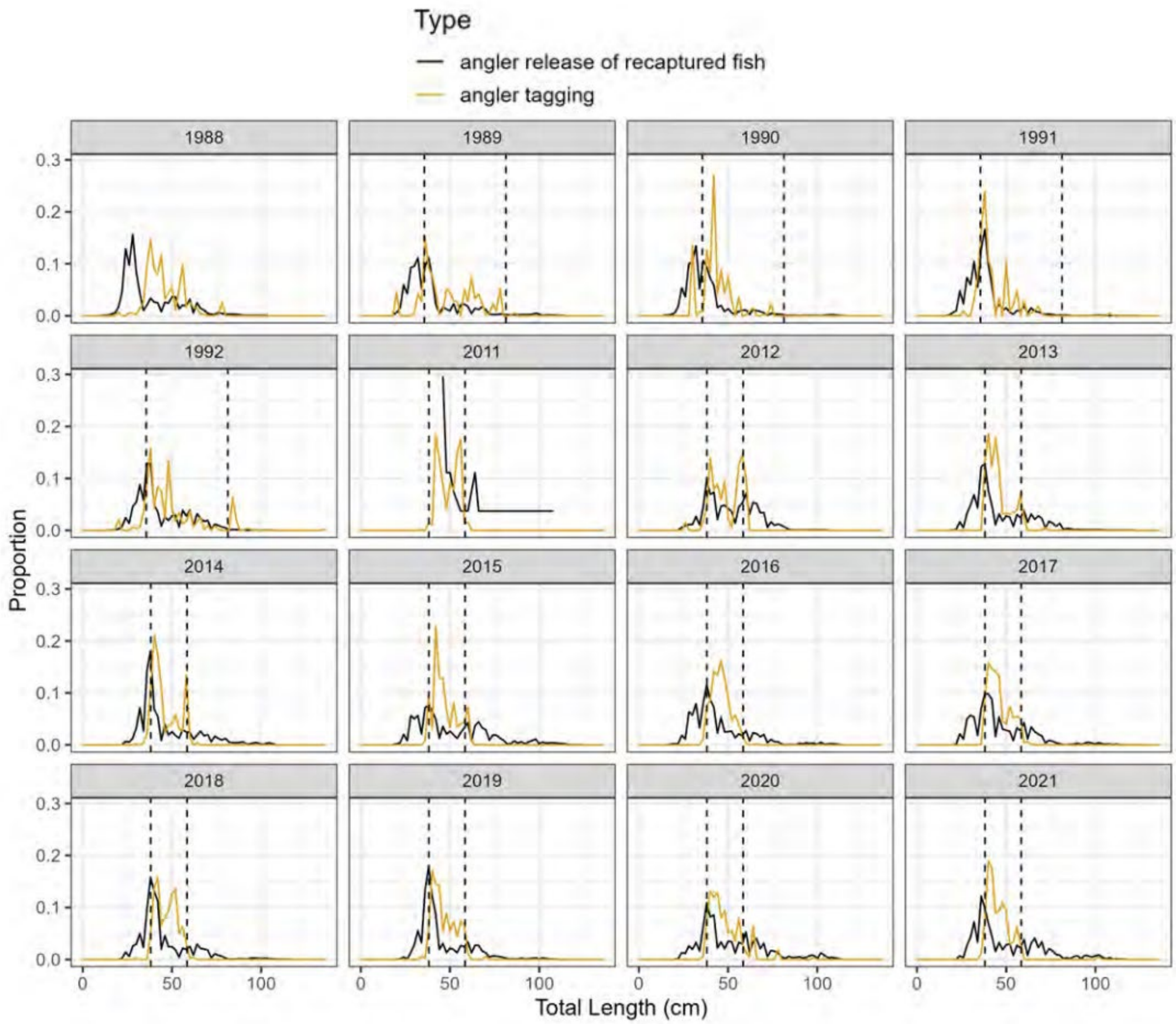
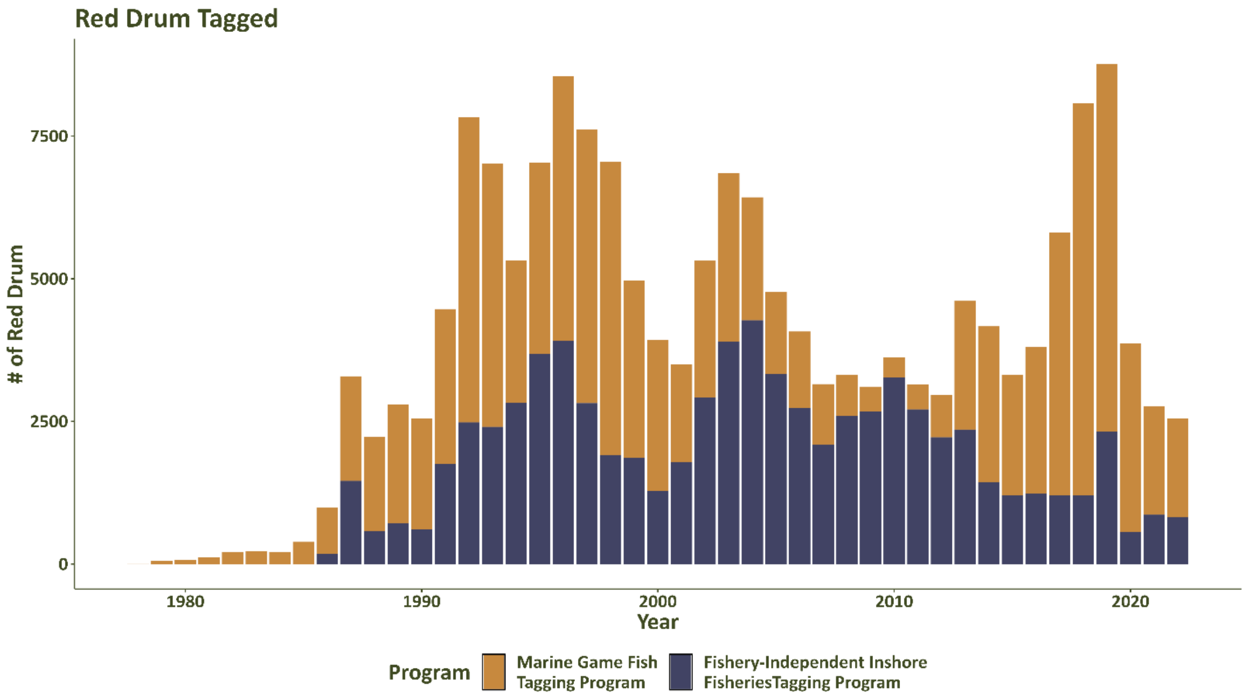


Figure 3.7 Size distributions of Red Drum tagged by volunteer anglers participating in the SC MGFTP and harvested Red Drum from MRIP estimates for SC from 1989-1992 and 2011-2021. Horizontal dashed lines indicate slot size in place in SC each year. (ASMFC 2024b Figure 61).



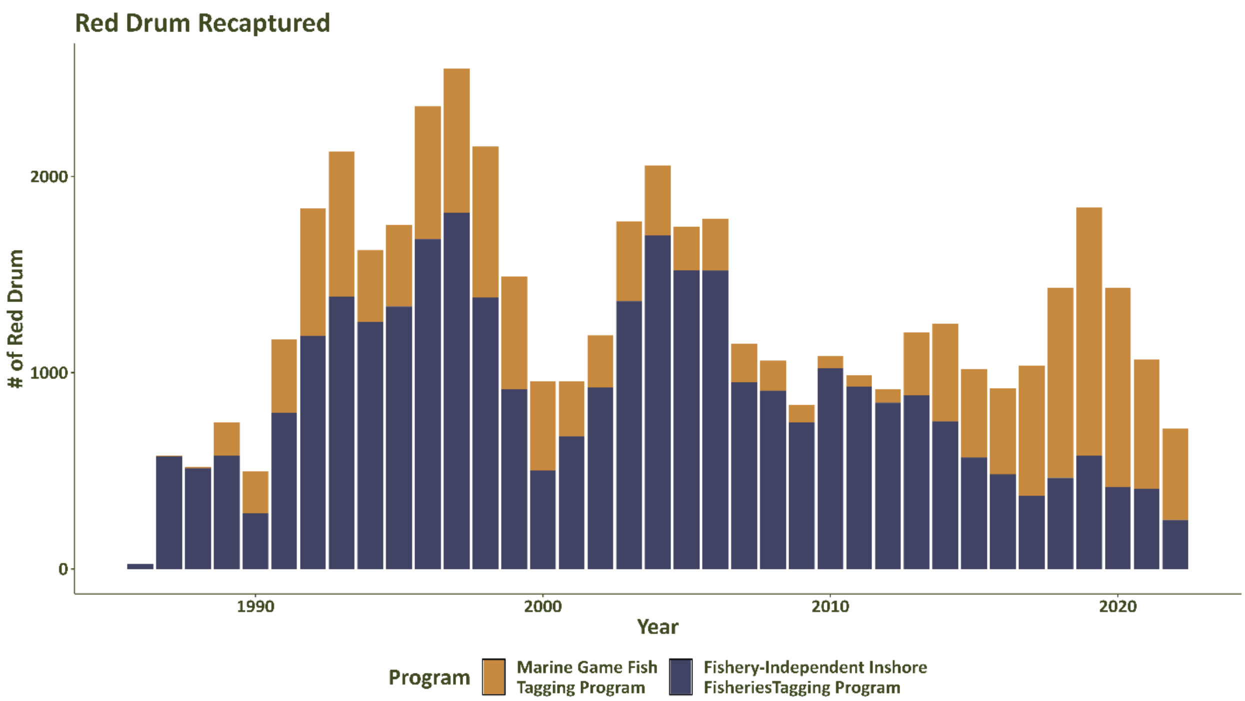


Figure 3.8 Number of Red Drum tagged (top) and reported recaptured (bottom) annually in SC by tagging program. Individuals tagged and recaptured in 2023 are not included.

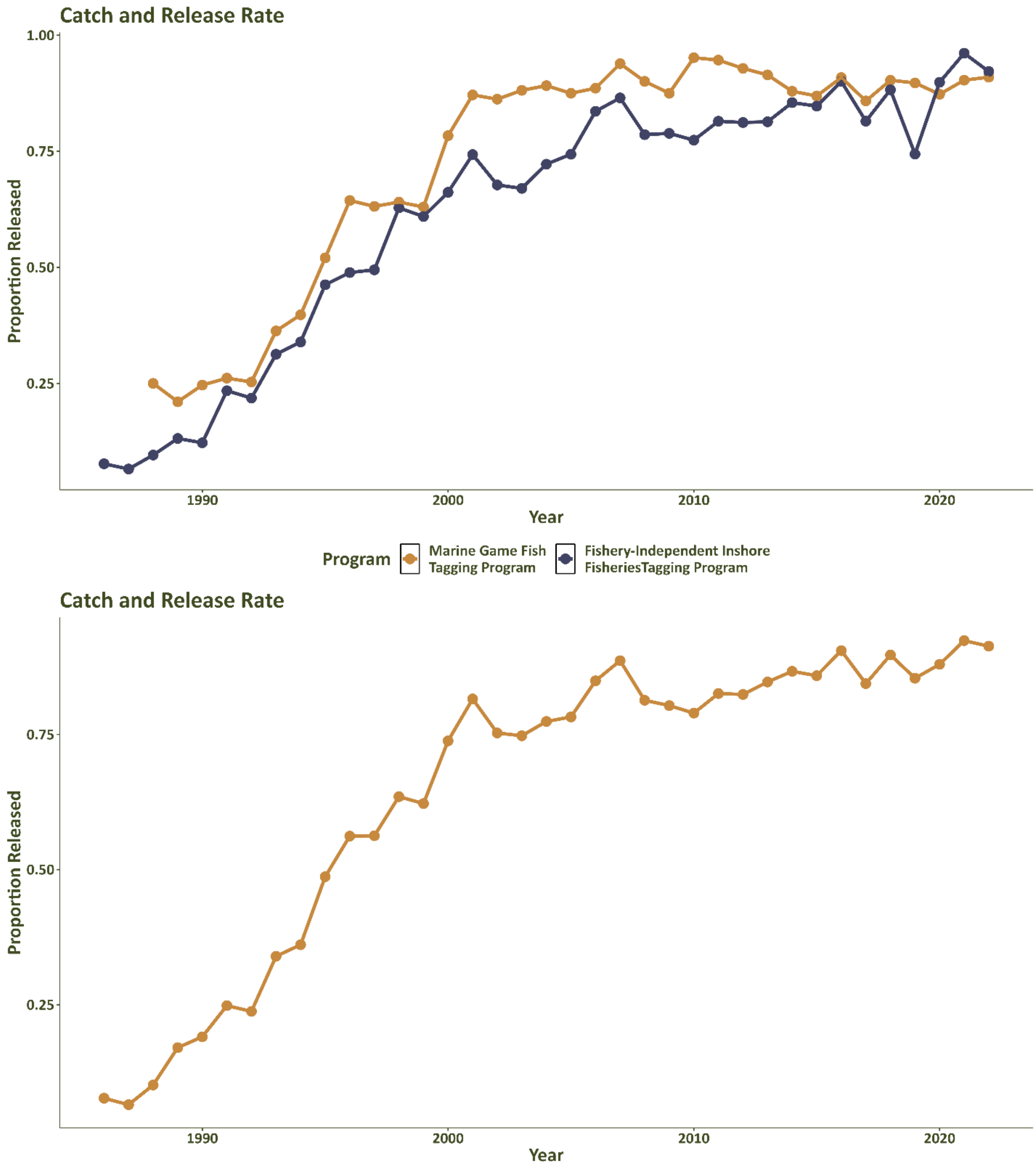


Figure 3.9 Proportion of recaptures released annually by program (top) and programs combined (bottom) for fish tagged as part of the SCDNR conventional tagging programs.

Tag Year	Recapture Year 86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
85		2																																			
86	26	64	10	11	1	1																															
87		479	288	46	9	1																															
88			212	309	27	7	3	1																													
89				377	130	42	10									1																					
90					318	257	81	33	1					1																							
91						852	693	214	64	8	7	1						1							1		1										
92							1027	957	246	50	15	4		1	1	1	4											1		1							
93								886	555	130	32	5	1	1		1					1																
94									740	668	196	39	13	4			4																				
95										876	870	260	46	12	4		1	4							1												
96											1205	1161	308	68	8	1	4	1			1		1						1	2	1						
97												901	846	217	27	7	3	6	2		2		1					2	3				1	1	1		
98													789	583	111	23	9	3	2							1				1	2	1	2				
99														503	369	105	49	10	3	1	2				1		2			1	1					1	
00															381	396	111	24	7	1	1	2		1	1	1	1			1		1					
01																389	384	133	45	14	4	2	1	1	1	1	3	3	1	1				1	1	1	
02																	579	677	252	65	18	6	3	2	3	6	4	2	2	2	4		1	1	3	1	1
03																		839	890	275	90	29	7	3	2	3	2	6	3	4			1			3	
04																			817	829	299	100	18	6	7	3	7	6	3	3	2	1	1	2		1	
05																				543	761	189	62	10	5	4	3	9	9	1	6	3		4	1		
06																					582	450	130	17	18	7	3	5	2	3	2	3	2		1	1	
07																						344	459	136	42	10	10	5	3	4	5	1	3		1	1	2
08																							354	368	164	43	16	7	5				1			1	
09																								281	423	124	27	14	8	2	1		3	1	2		
10																									417	402	131	24	11	4	4		1		1	4	1
11																										374	398	157	62	24	9	2	2	3	3	3	1
12																											307	433	164	32	13	7	2	4	3	2	1
13																												503	485	164	47	15	3	3	8		6
14																													430	377	87	20	7	4	2	3	
15																														369	297	54	14	5	5	2	5
16																															406	290	72	16	7	6	3
17																																586	428	85	23	21	3
18																																	812	703	107	41	6
19																																		923	651	142	39
20																																			557	403	61
21																																				389	281
22																																					295

Figure 3.10 Tag year (rows) and recapture year (columns) of the >47,800 recaptures of fish tagged as part of the SCDNR conventional tagging program. Individuals tagged and recaptured in 2023 are not included.

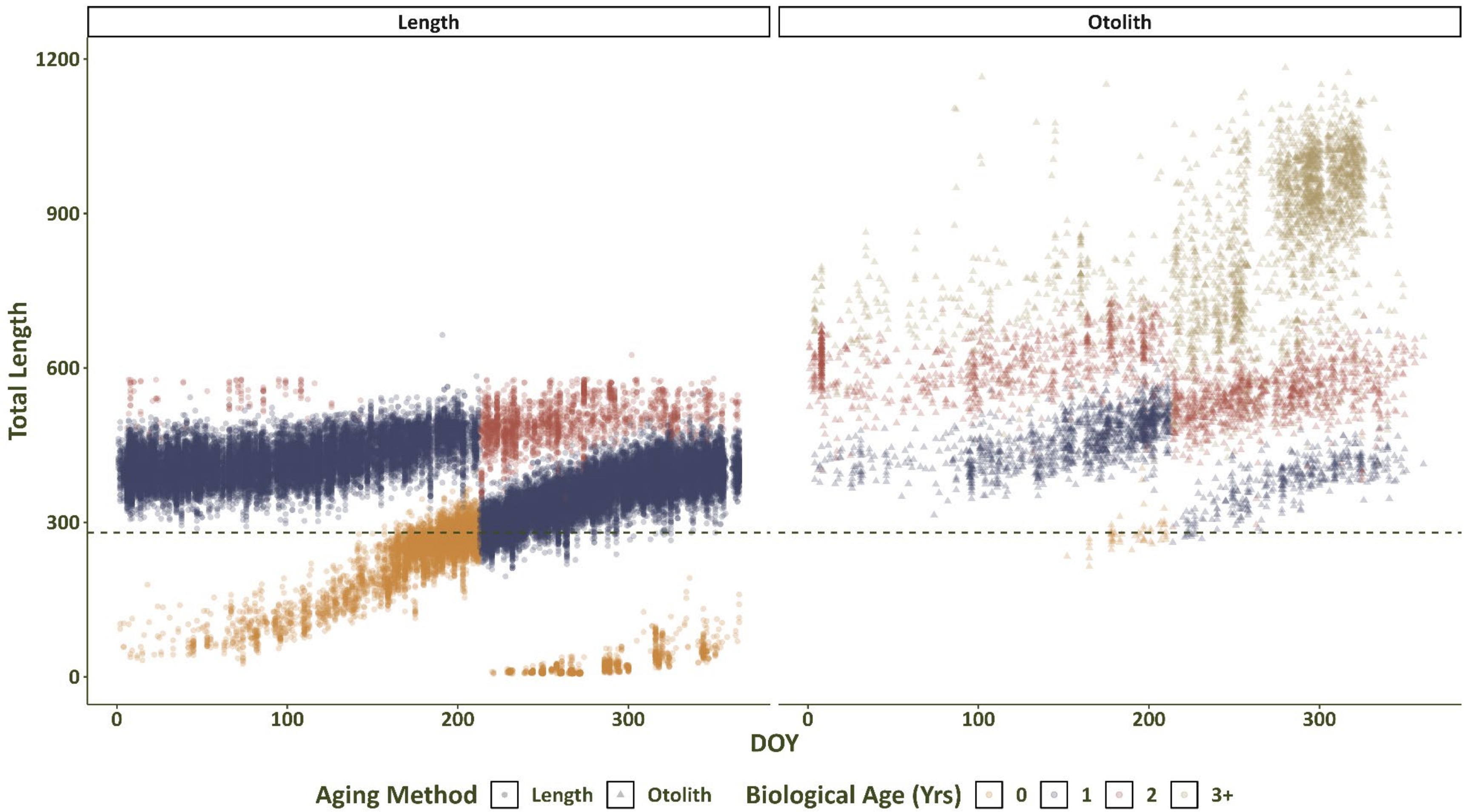


Figure 3.11 Length distribution, based on calendar year (Jan. 1 – Dec. 31), ageing methodology, and day of year of sampling, of Red Drum encountered by the SCDNR fishery-independent and fishery-dependent sampling programs. Ages are based on biological age, assuming a September 1 birthday. All fish with age determined using scales have been omitted.

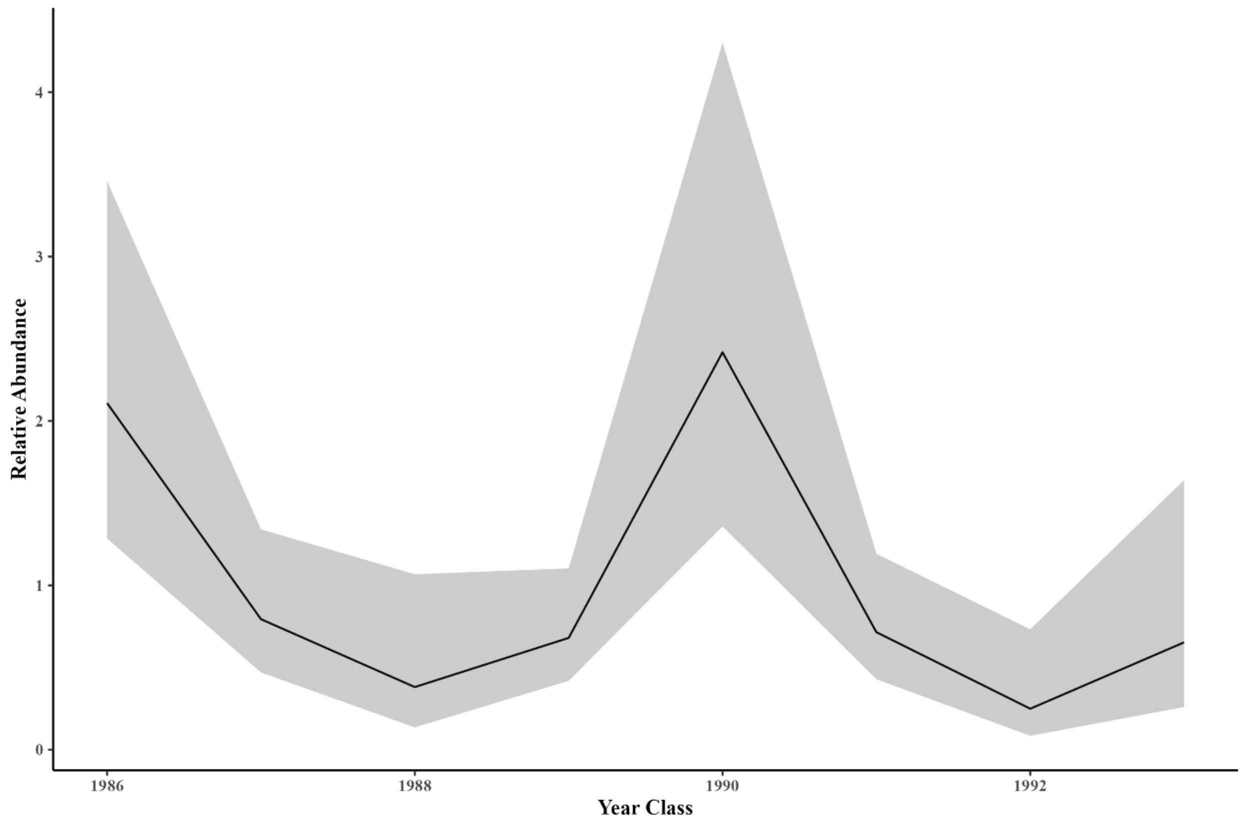


Figure 3.12 SC rotenone survey standardized relative abundance index (solid line) with 95% confidence interval (shaded region) from 1986-1993.

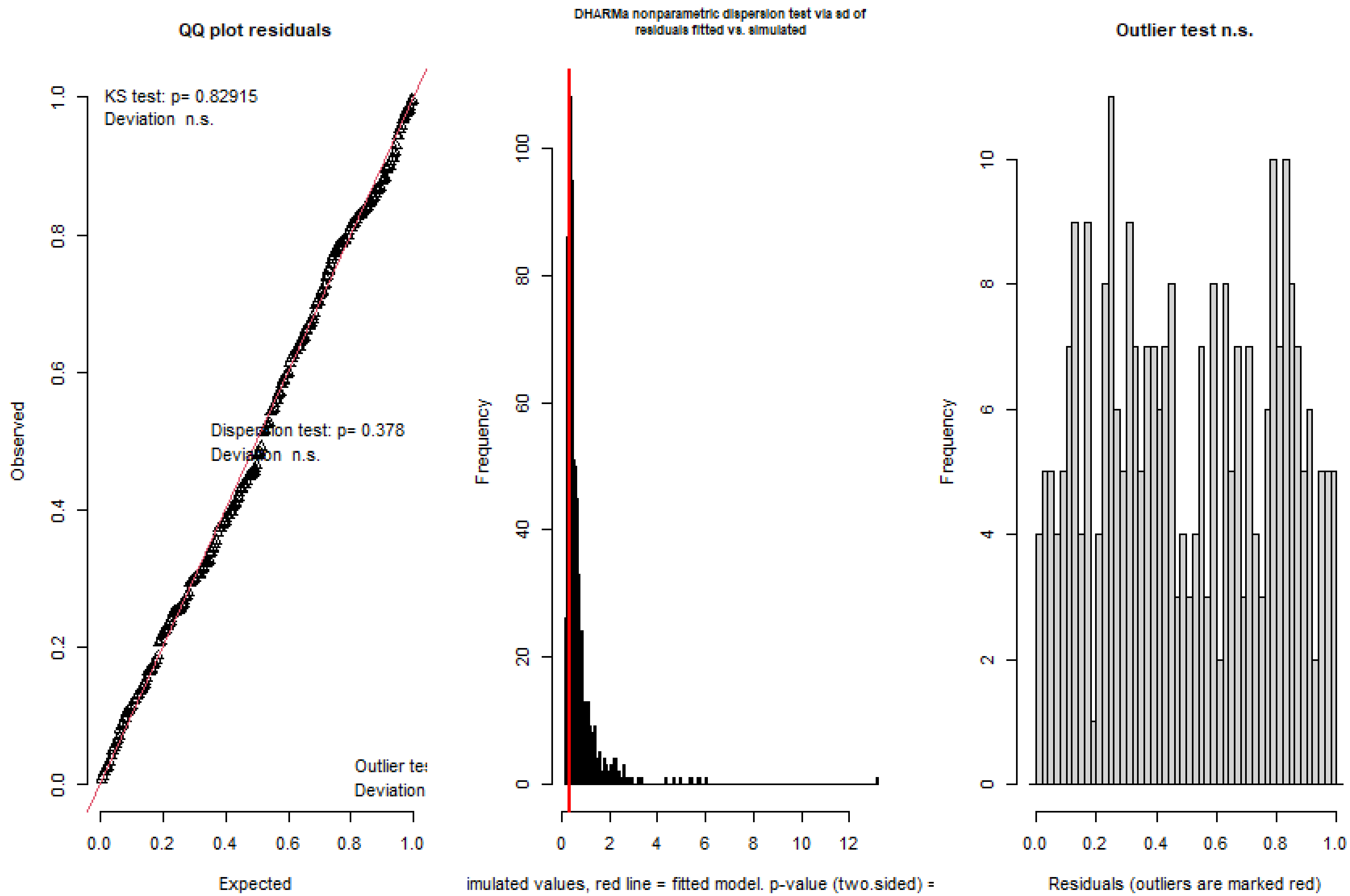


Figure 3.13 Results of tests related to residuals distribution, dispersion, and outliers for the best fit rotenone survey index.

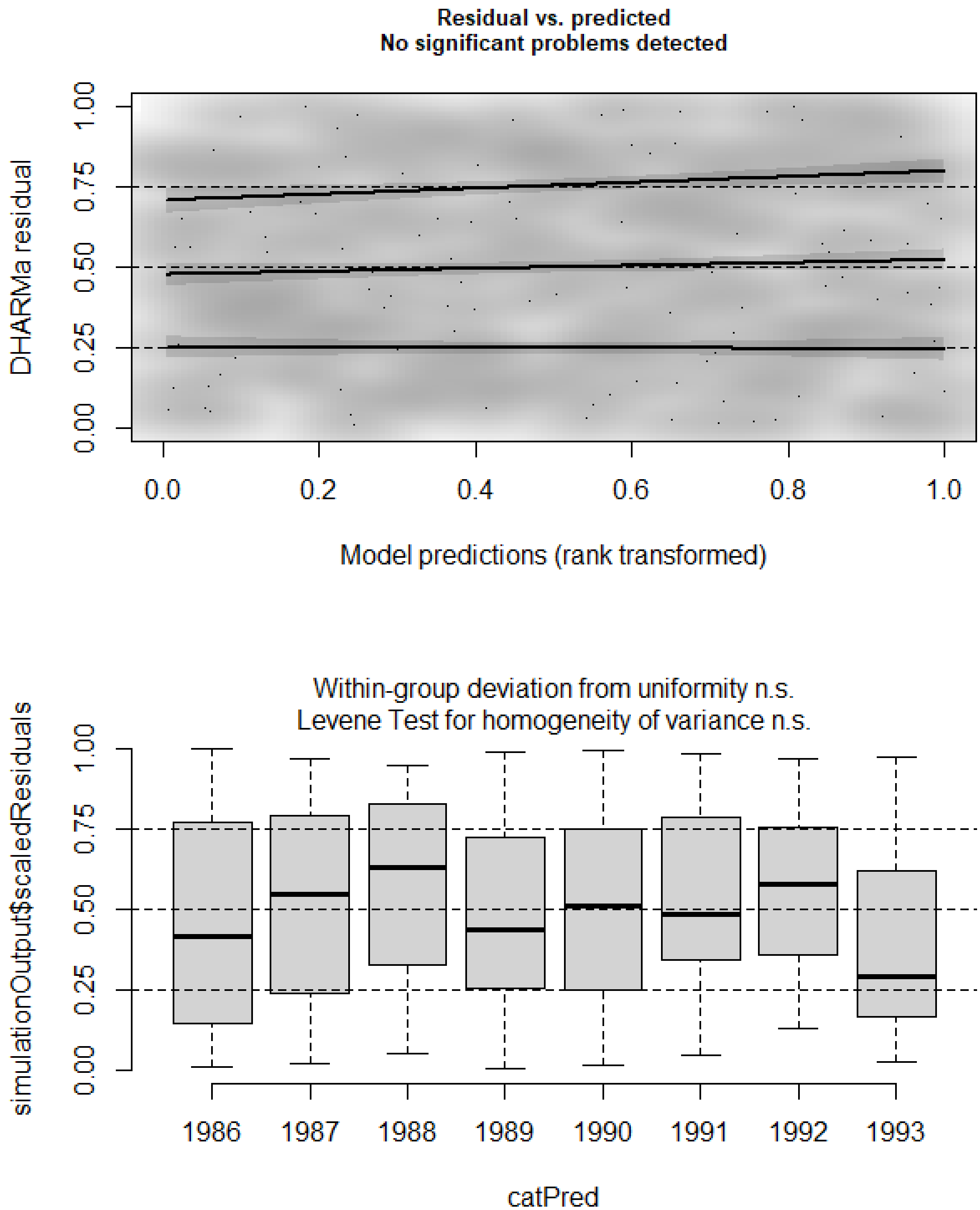


Figure 3.14 Residuals versus predicted values (top panel) and fishing year (bottom panel) for the best fit model for the SC rotenone survey.

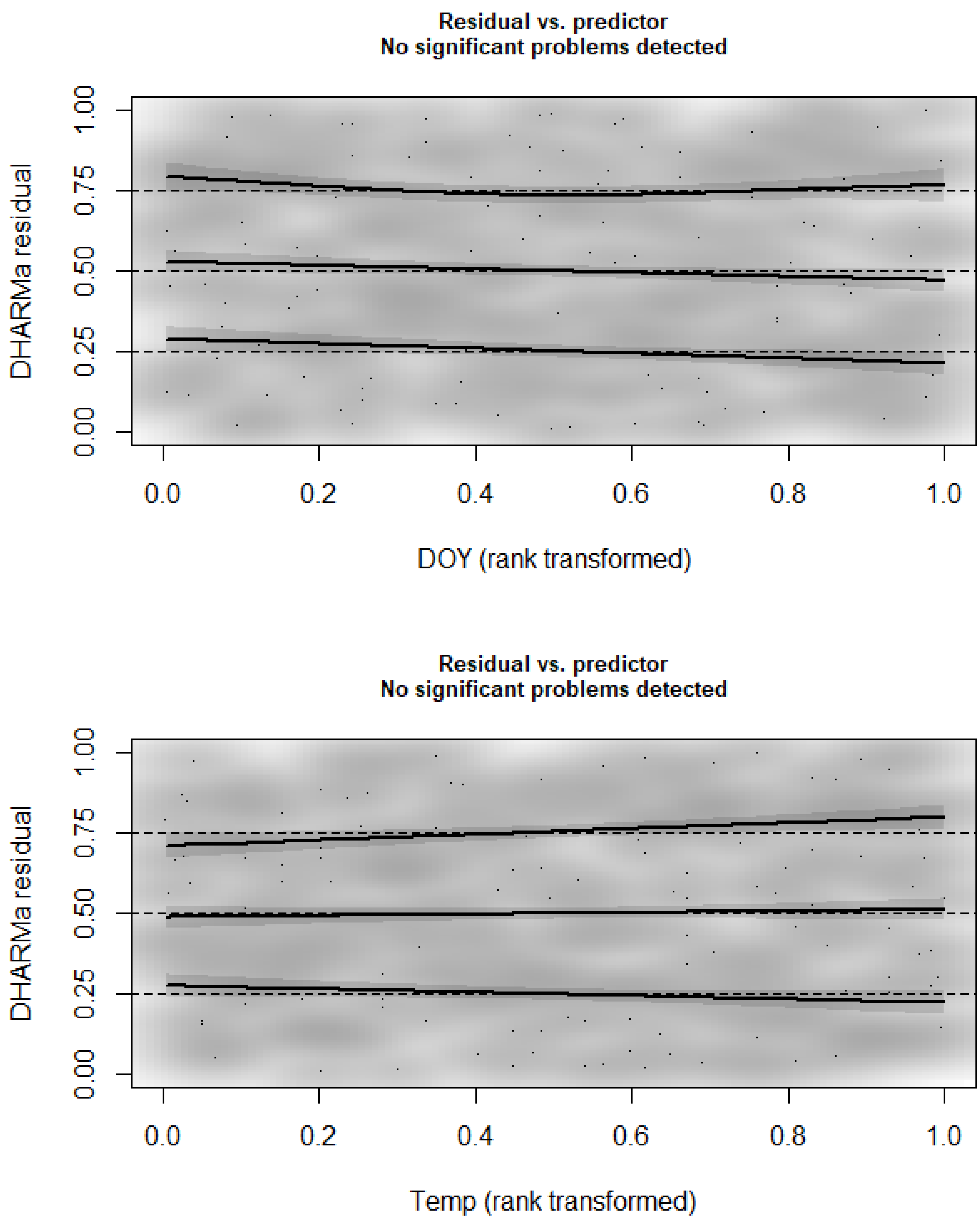


Figure 3.15 Residuals versus day of year (top panel) and water temperature (bottom panel) for the best fit model for the SC rotenone survey.

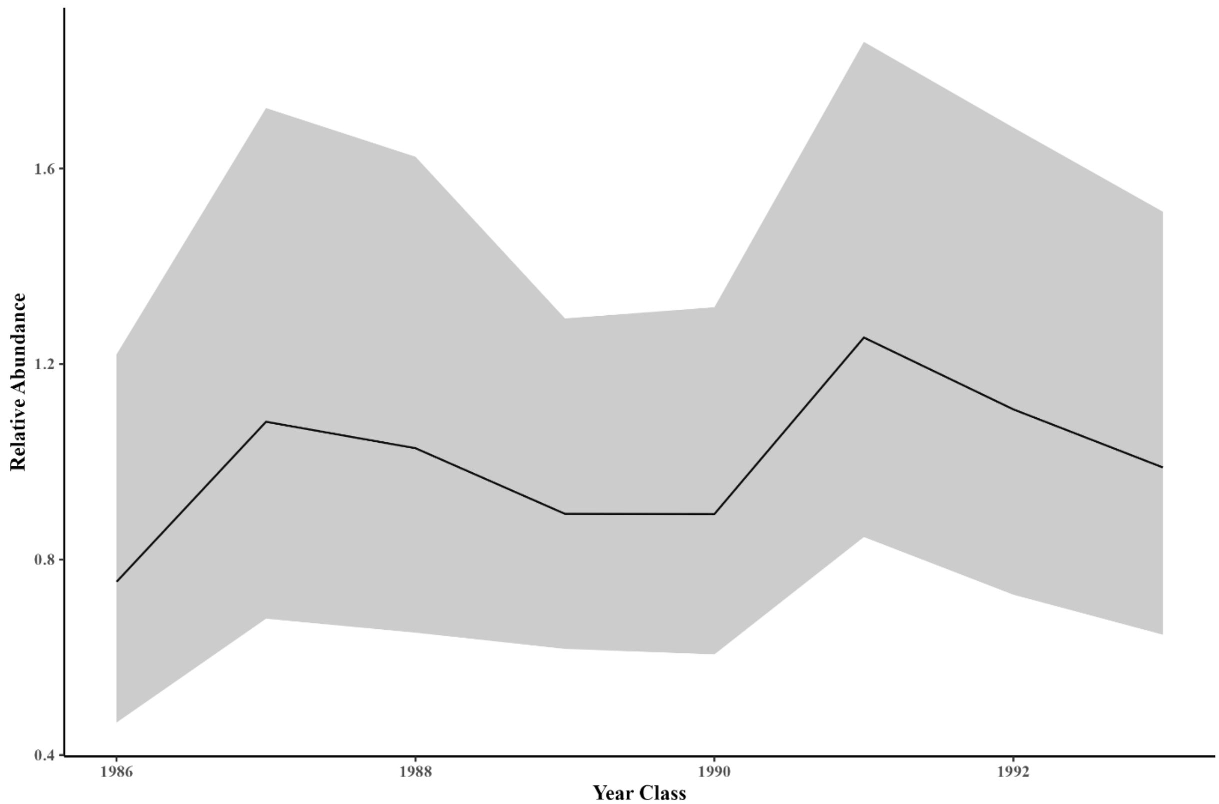


Figure 3.16 SC stop net survey standardized relative abundance index (solid line) with 95% confidence interval (shaded region) from 1986-1993.

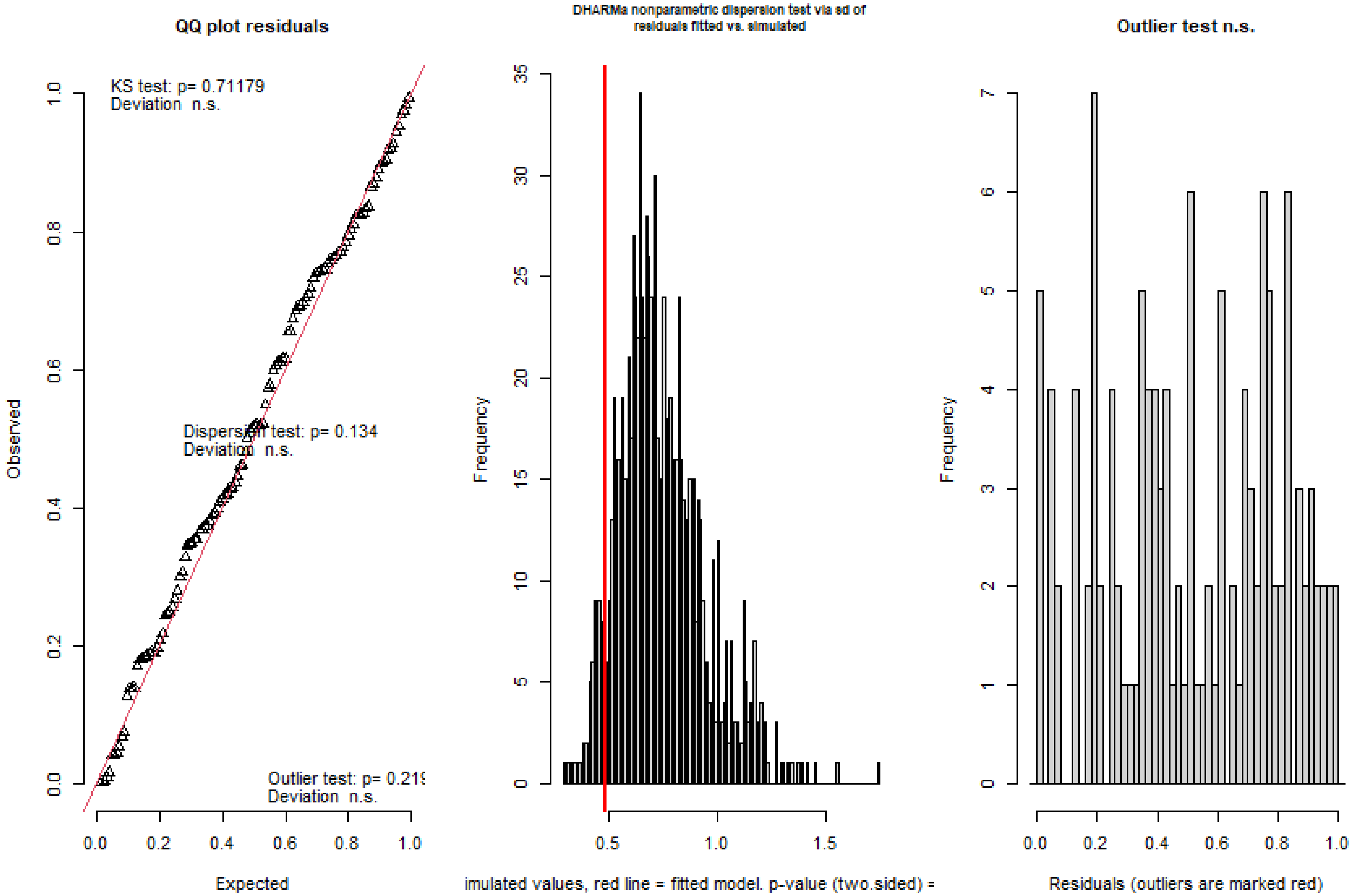


Figure 3.17 Results of tests related to residuals distribution, dispersion, and outliers for the best fit stop net survey index.

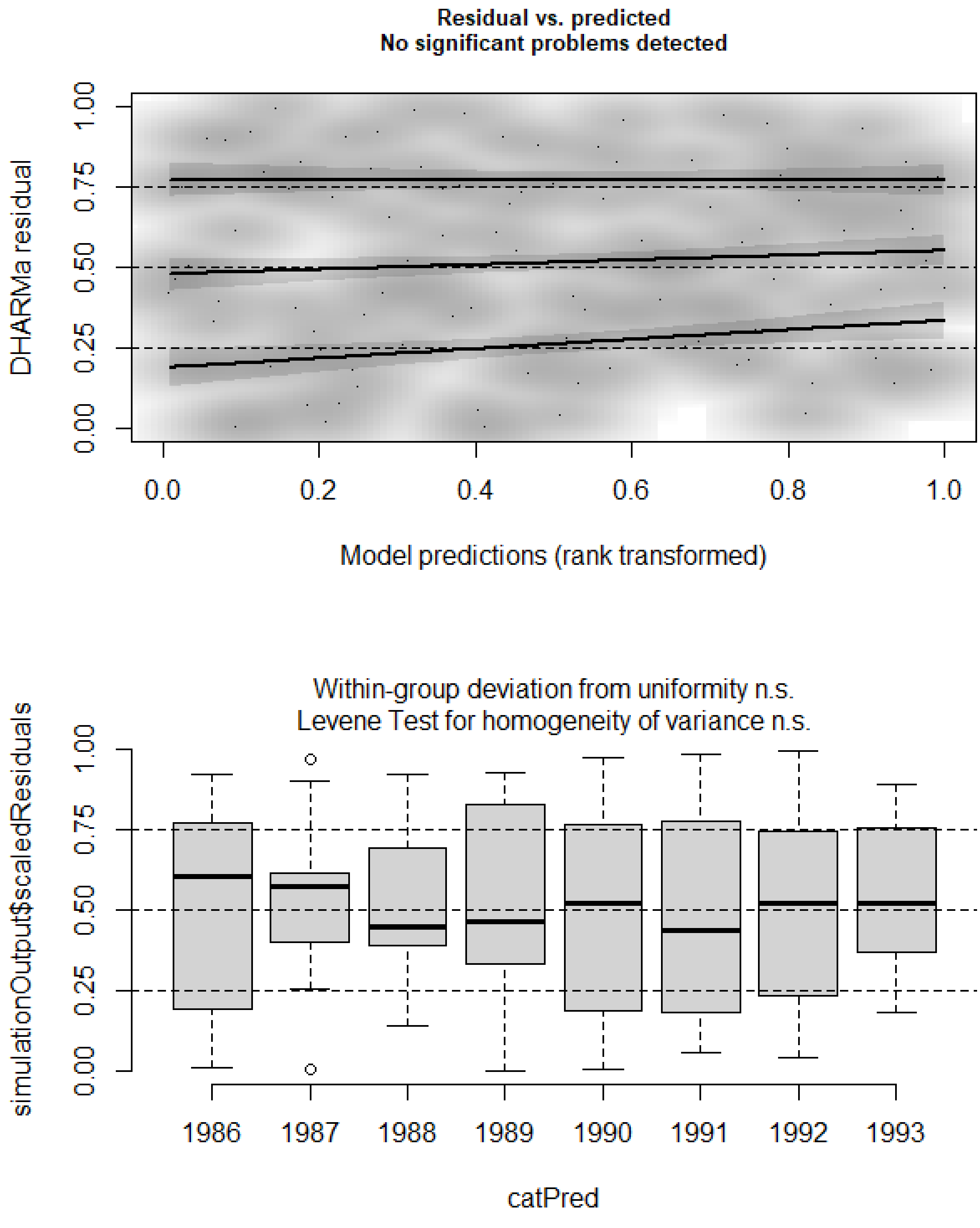


Figure 3.18 Residuals versus predicted values (top panel) and fishing year (bottom panel) for the best fit model for the SC stop net survey.

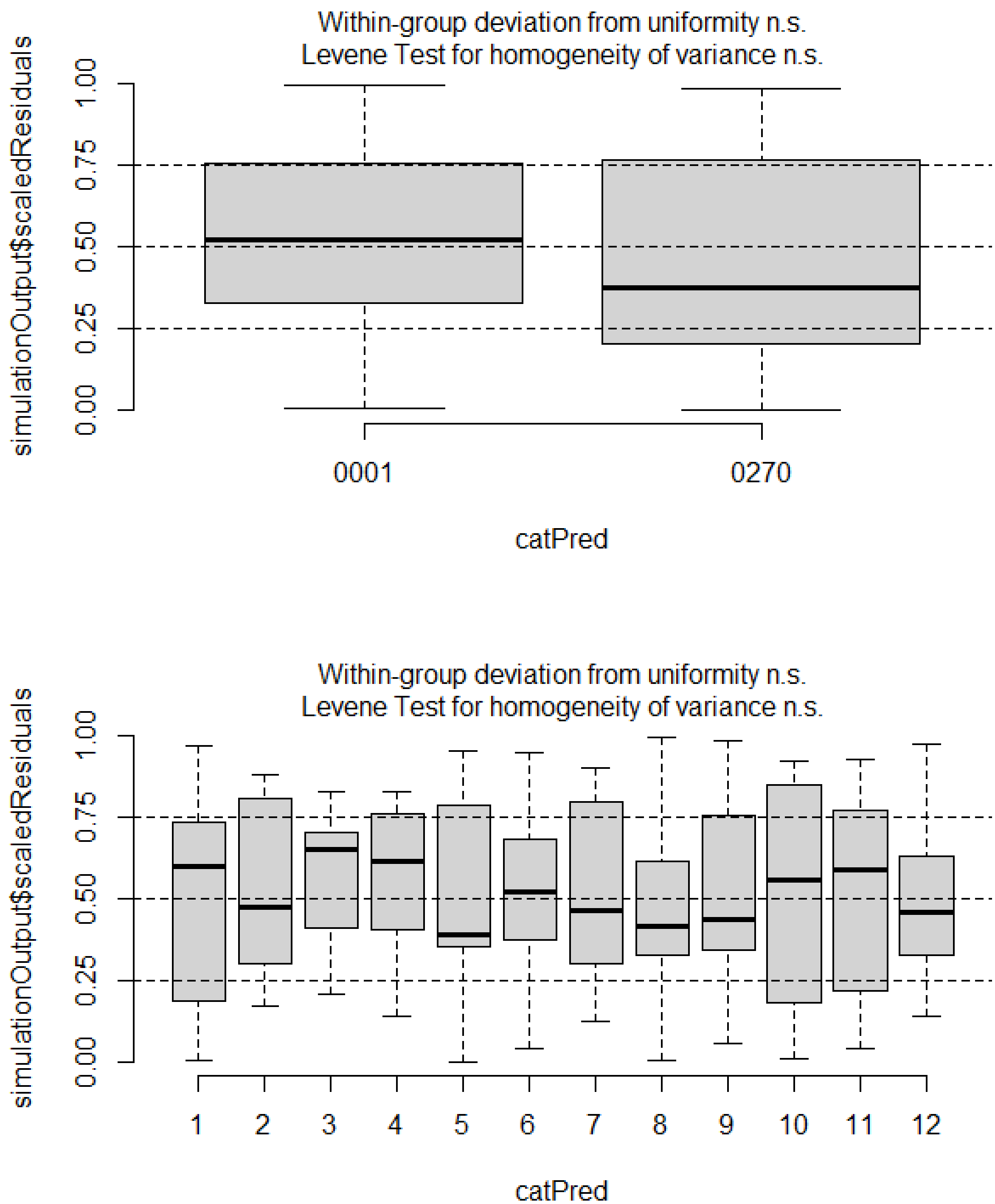


Figure 3.19 Residuals versus station (top panel) and month (bottom panel) for the best fit model for the SC stop net survey.

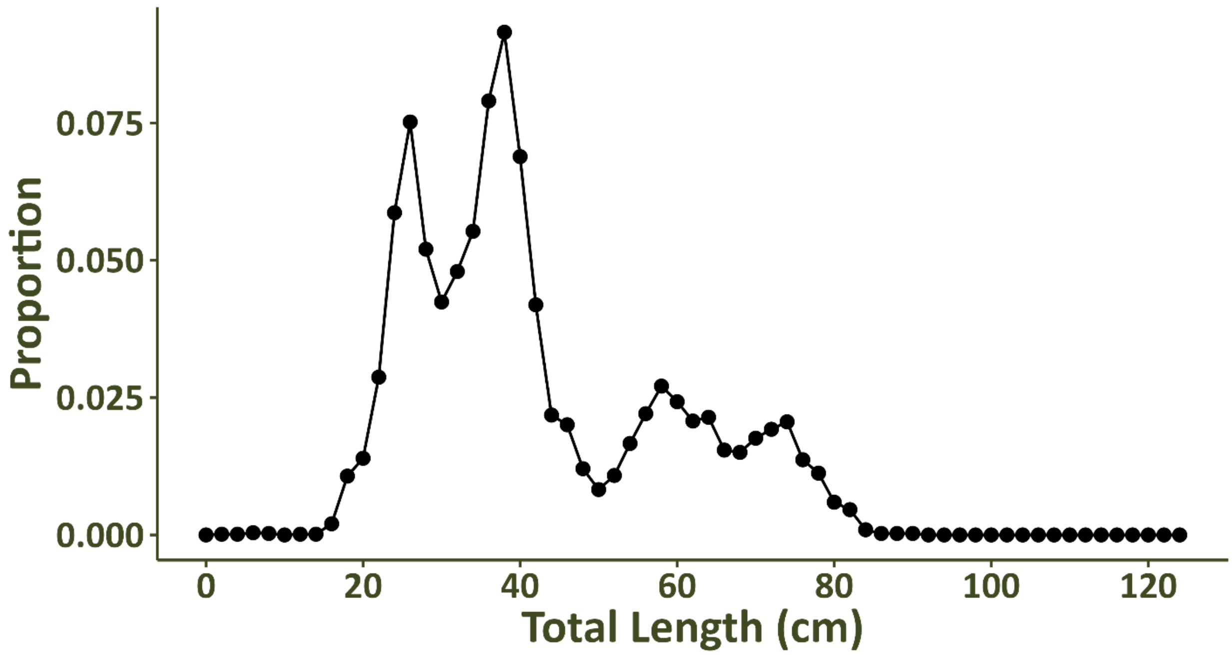


Figure 3.20 Length composition of Red Drum encountered by the stop net survey when pooled across years.

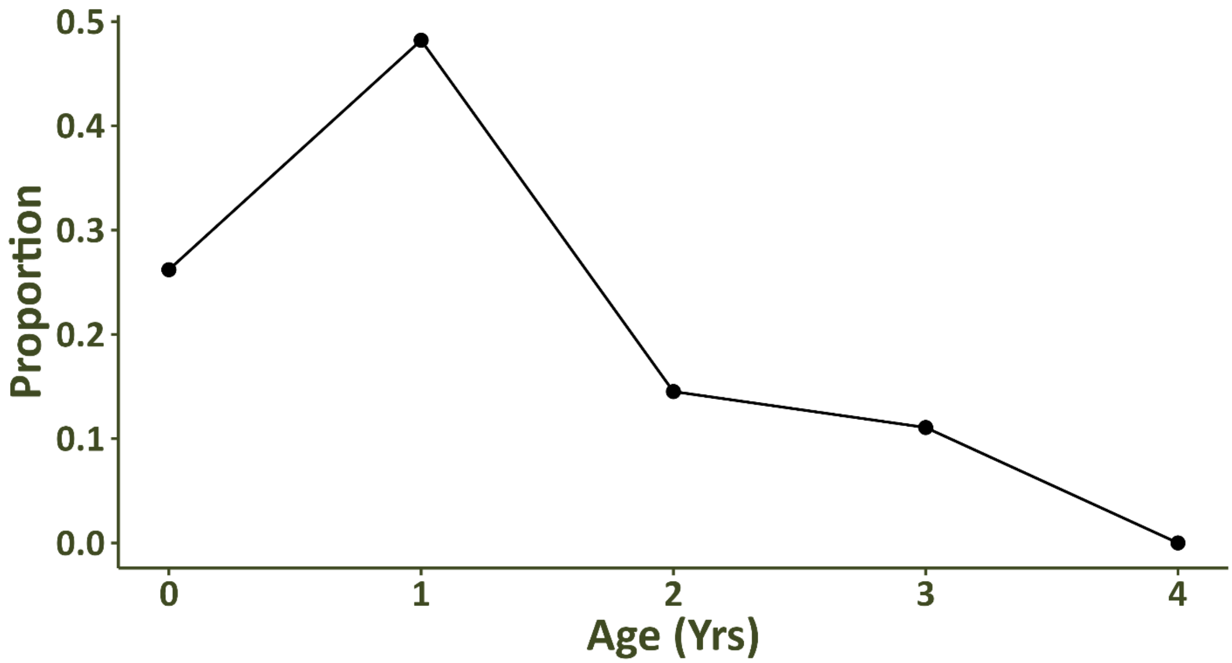


Figure 3.21 Age composition of Red Drum encountered by the stop net survey when pooled across years (1986-1993). Age-4 represents an age-4+ group.

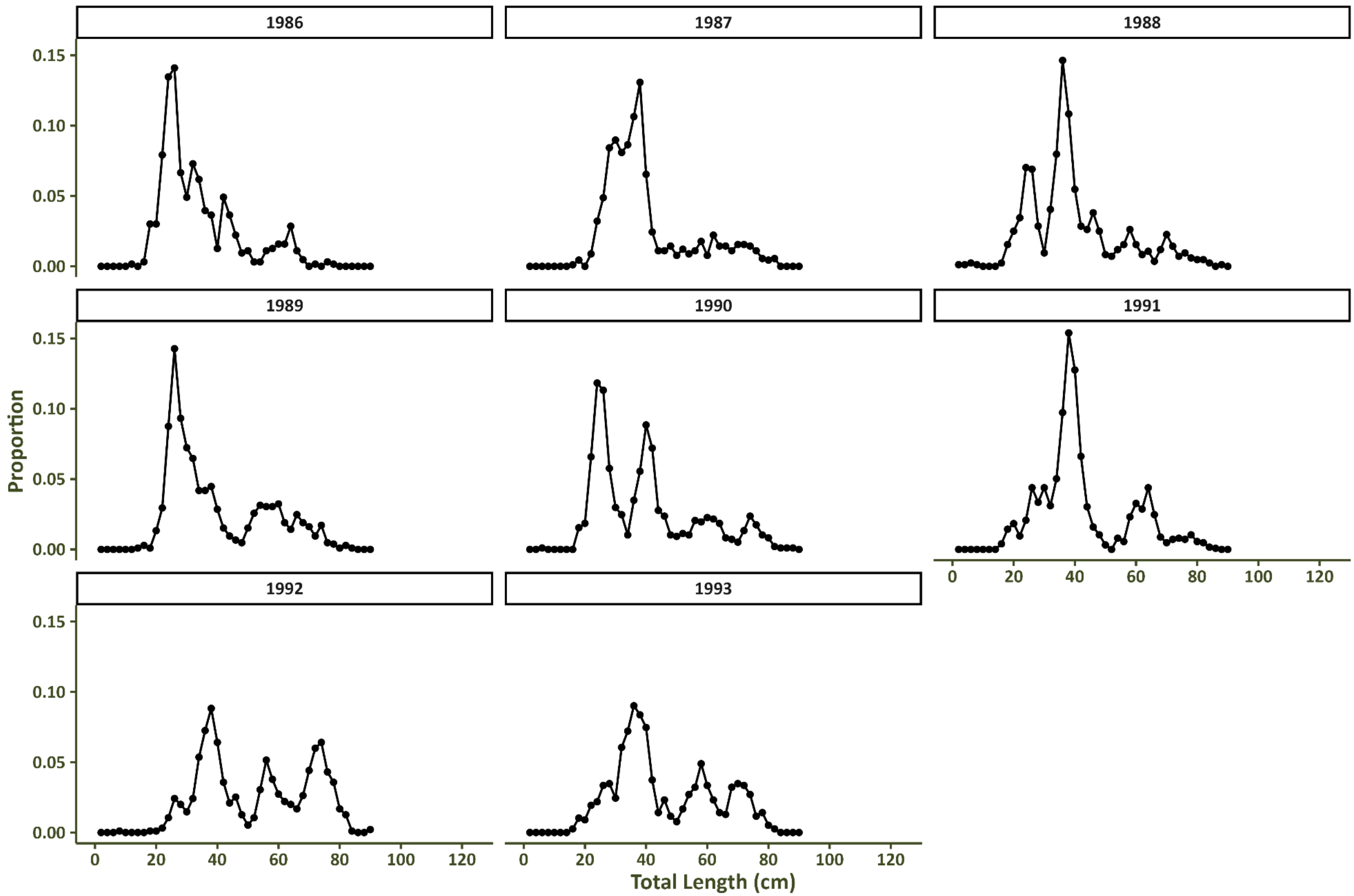


Figure 3.22 Annual length compositions developed for the stop net survey.

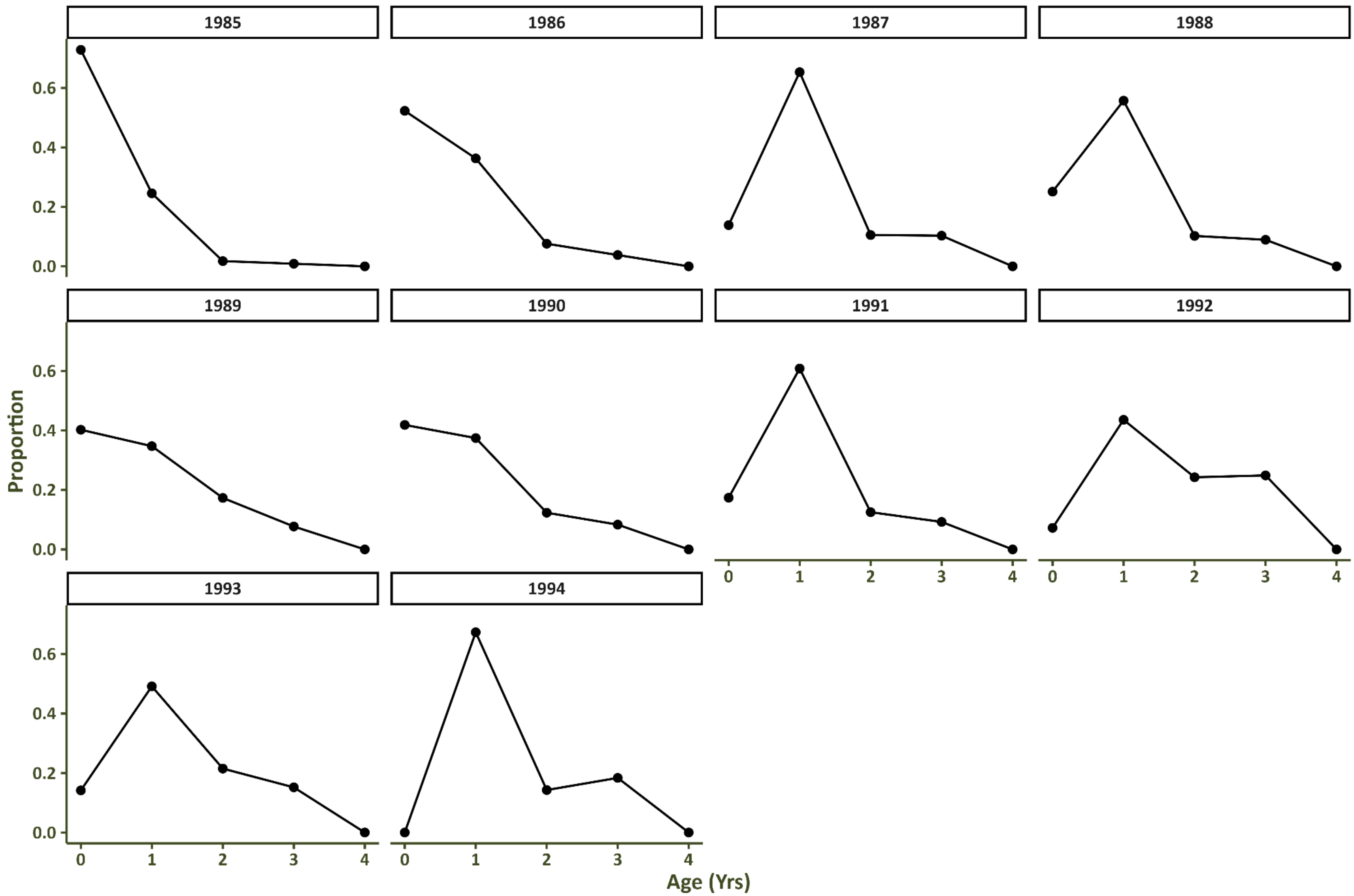


Figure 3.23 Annual age compositions developed for the stop net survey.

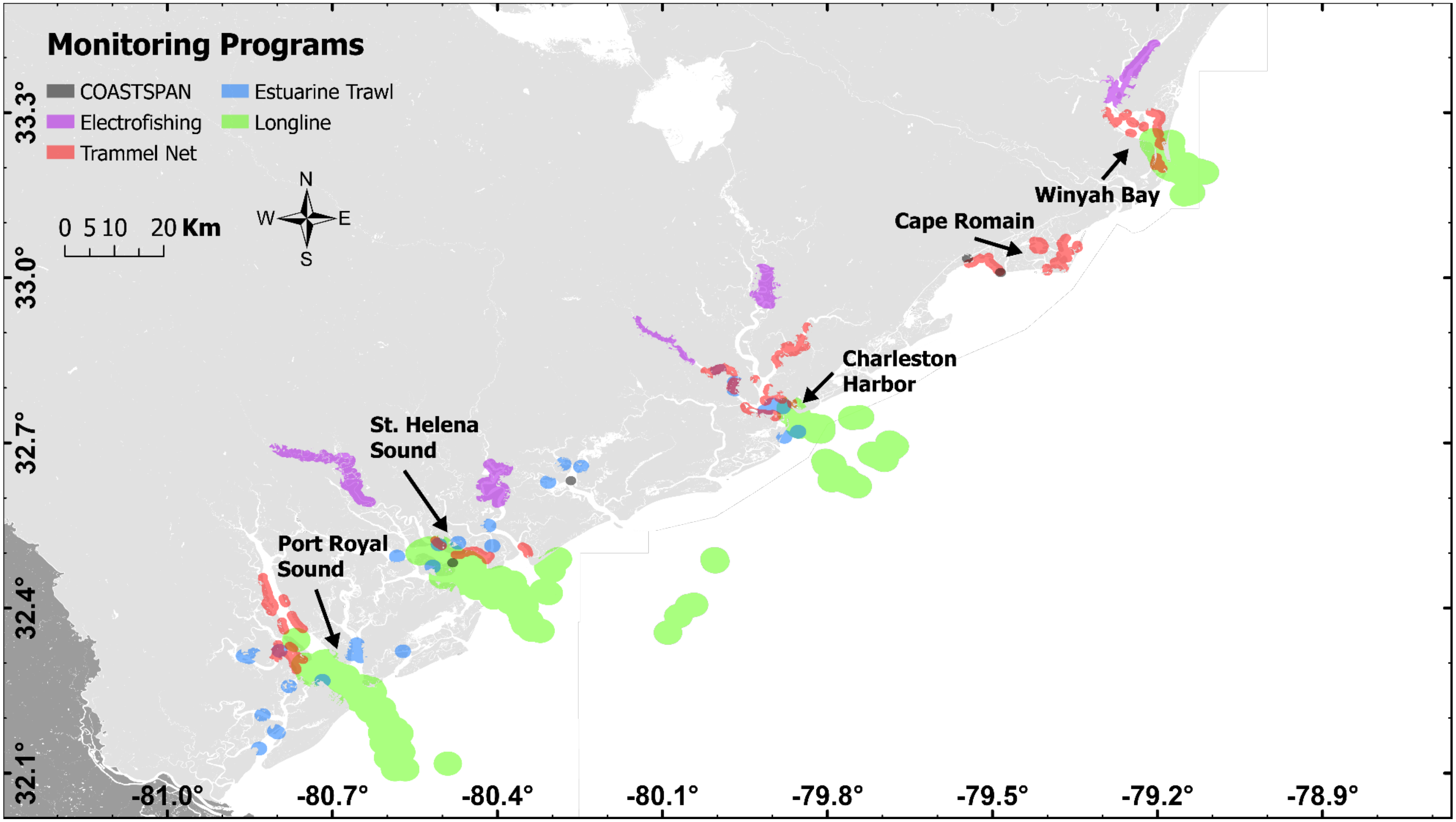


Figure 3.24 Sampling distribution of the contemporary trammel net (red shaded areas), electrofishing (purple shaded areas) and adult Red Drum and shark longline (green shaded areas) surveys. Also identified are two additional contemporary fishery-independent finfish surveys that do not regularly encounter Red Drum, SCDNR's COASTSPAN (gray shaded areas) and estuarine trawl (blue shaded areas) surveys. Identified are the five major SC estuaries, from Port Royal Sound in the south to Winyah Bay in the north.

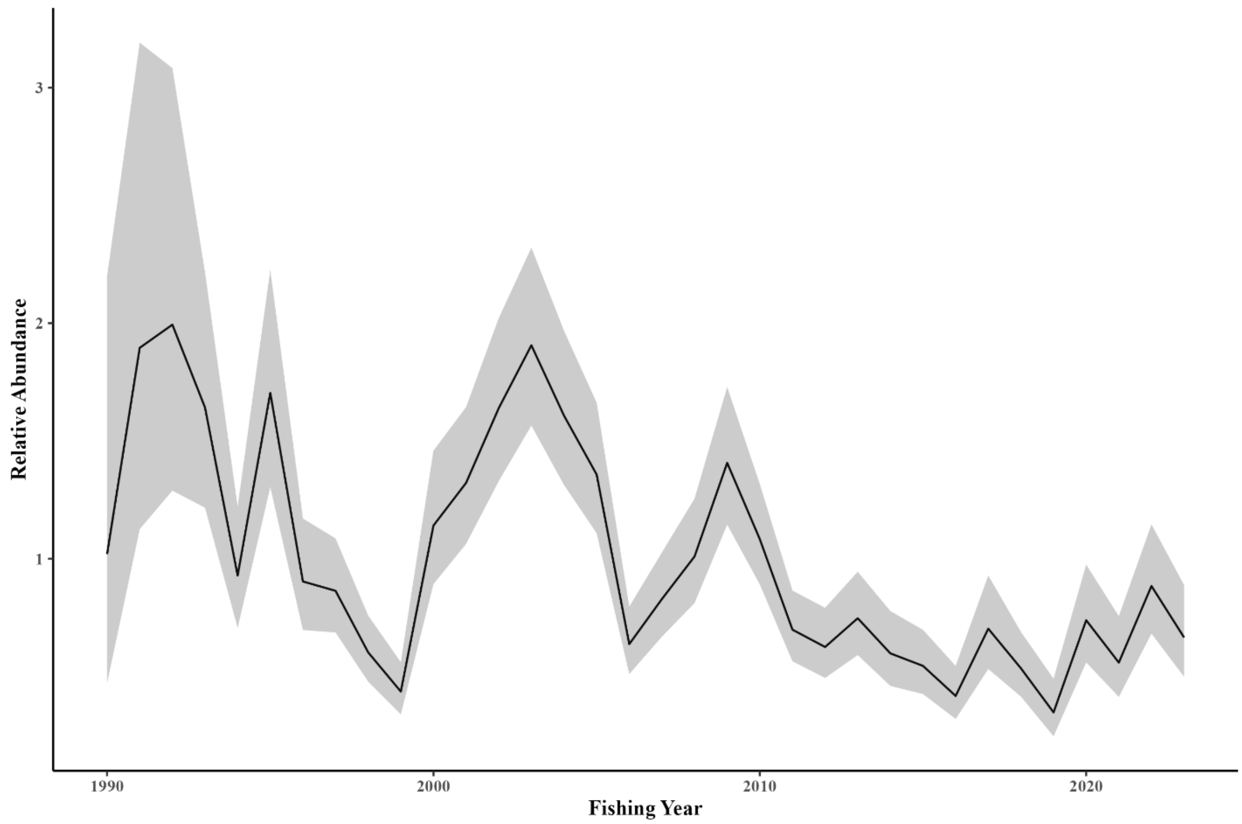


Figure 3.25 SC trammel net survey standardized relative abundance index (solid line) with 95% confidence interval (shaded region) from 1990-2023.

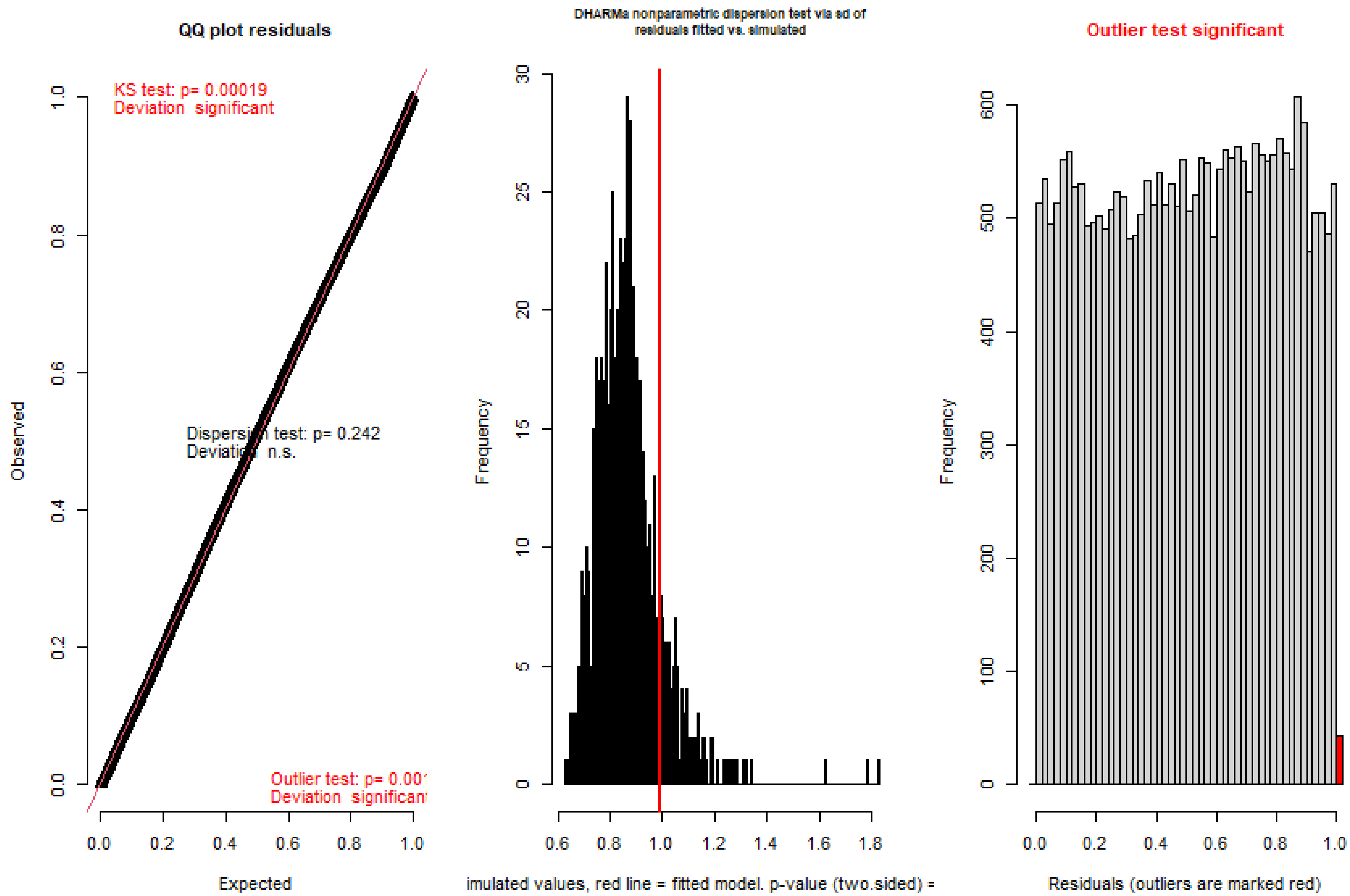


Figure 3.26 Results of tests related to residuals distribution, dispersion, and outliers for the best fit trammel net survey index.

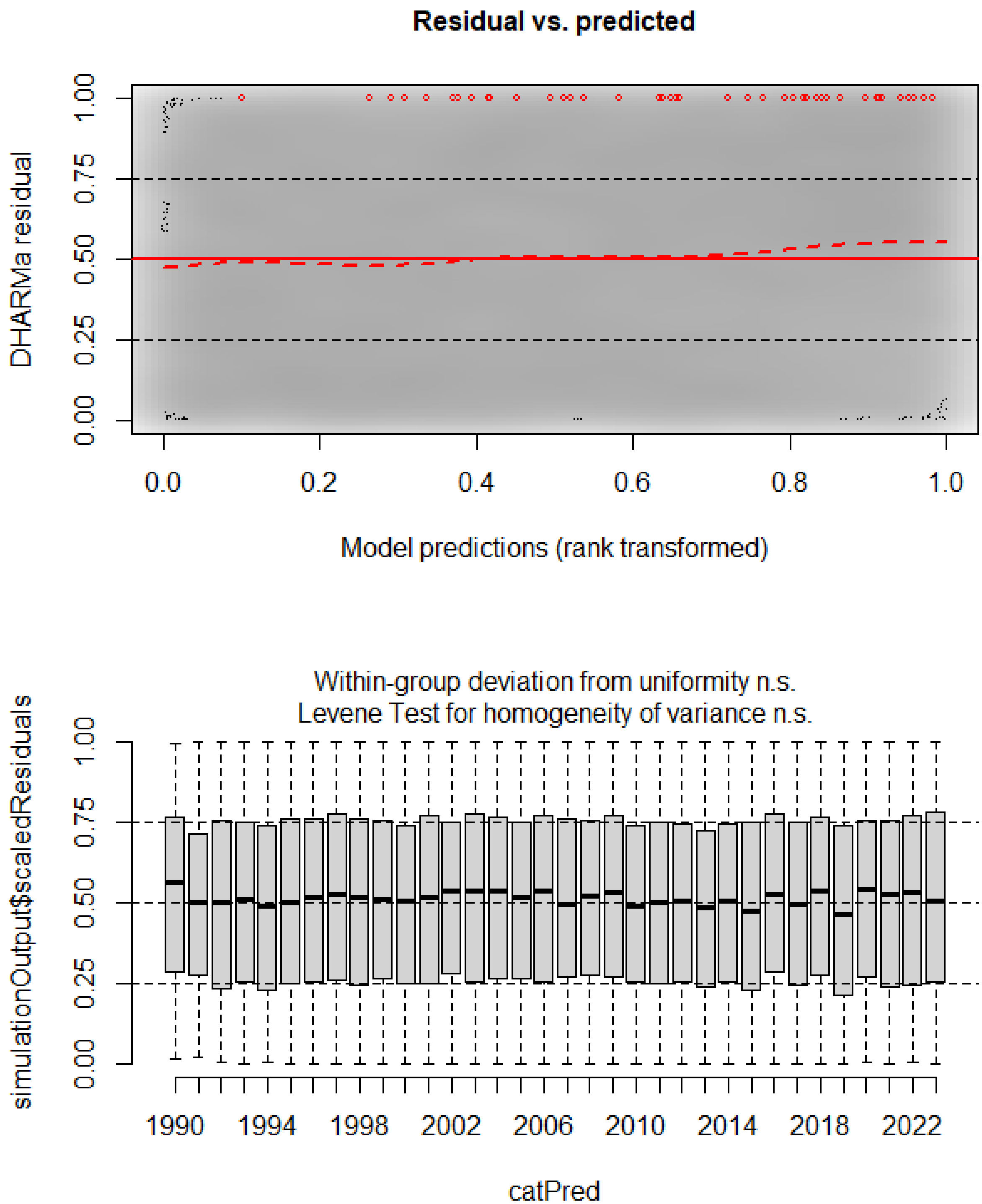
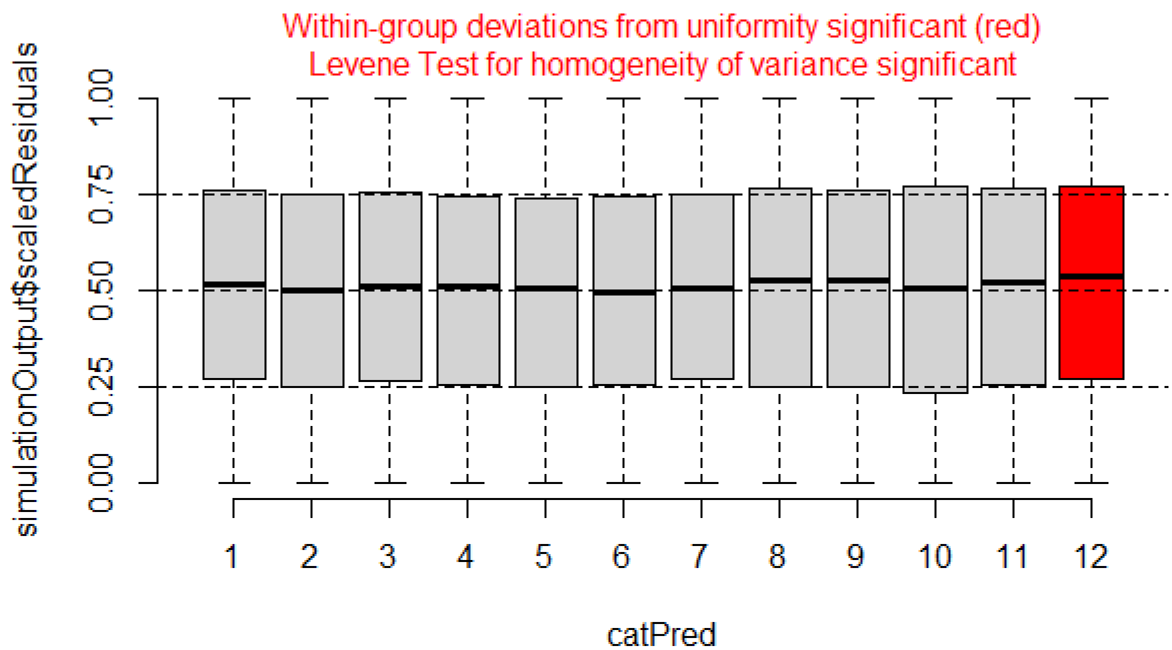


Figure 3.27 Residuals versus predicted values (top panel) and fishing year (bottom panel) for the best fit model for the SC trammel net survey.



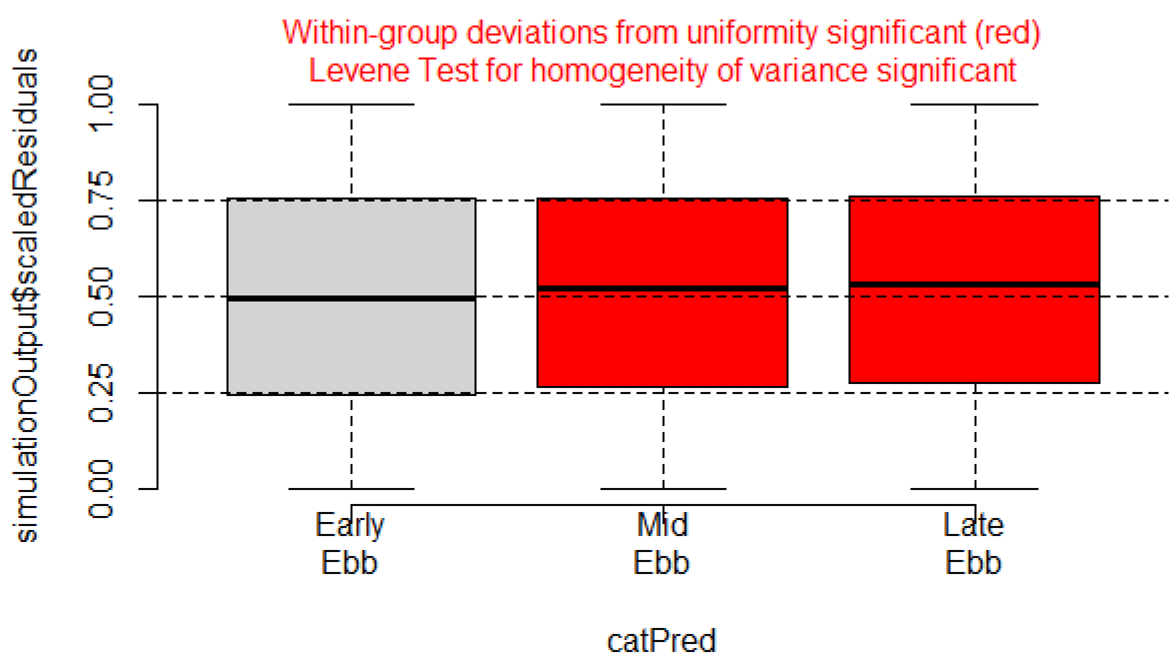


Figure 3.28 Residuals versus month (top panel) and tidal (bottom panel) for the best fit model for the SC trammel net survey.

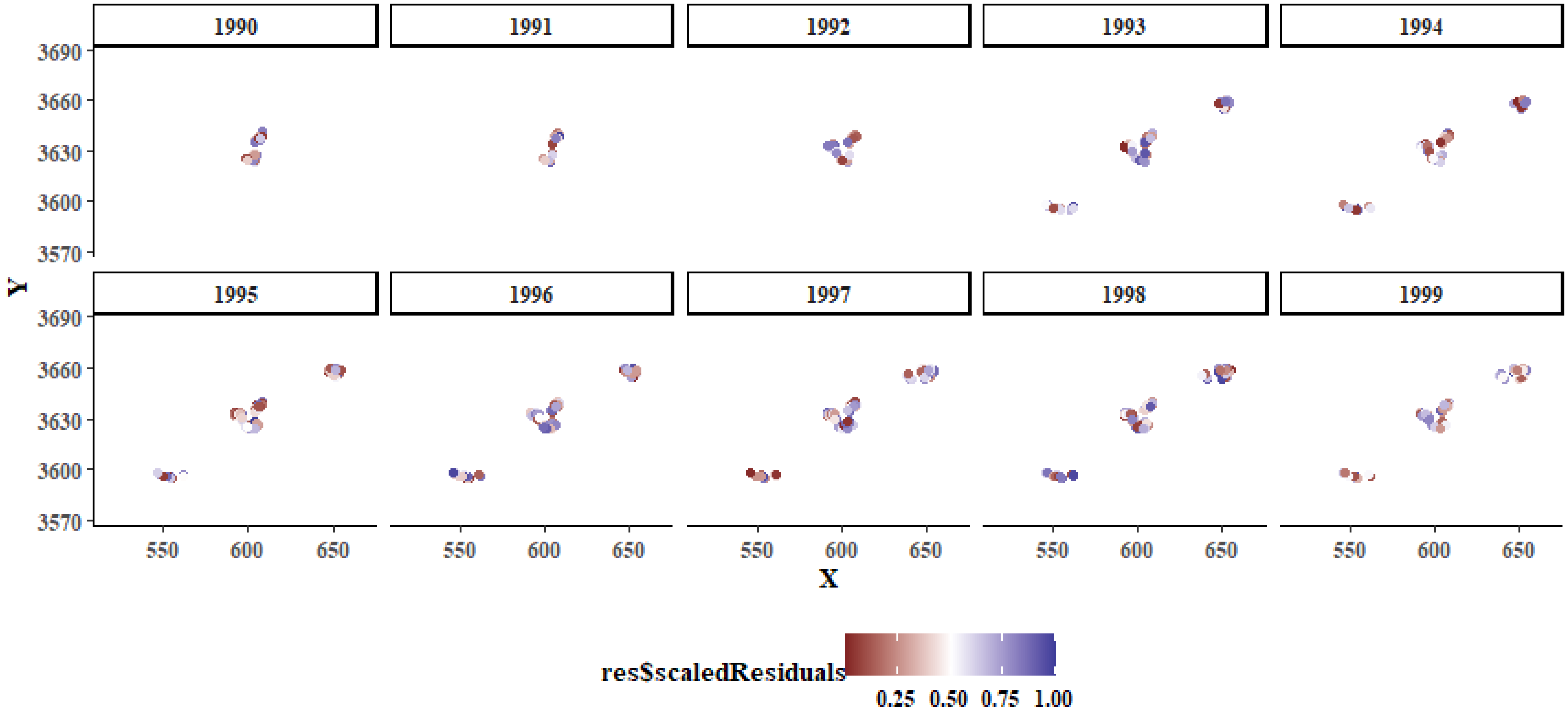


Figure 3.29 Residuals versus location and time for the trammel net survey.

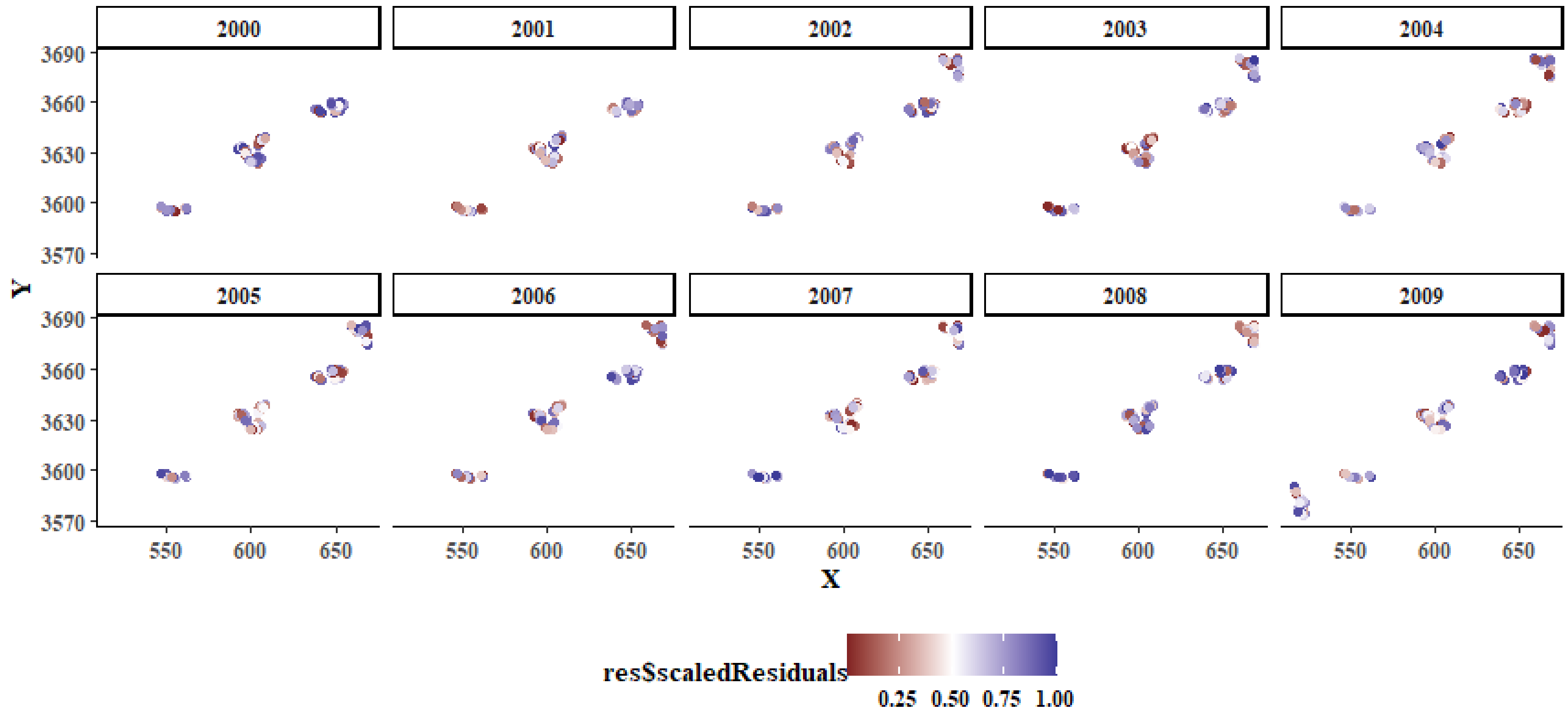


Figure 3.29 *cont.*

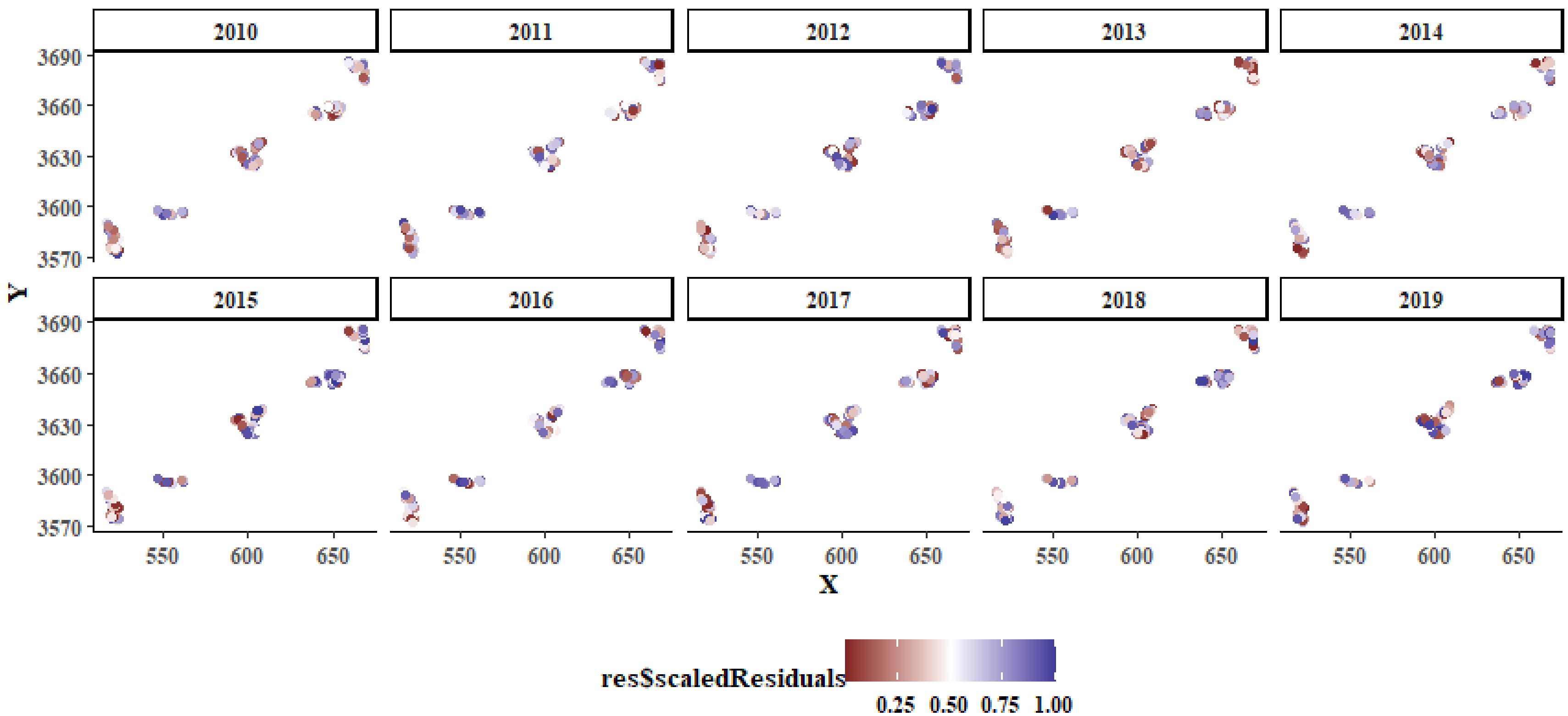


Figure 3.29 *cont.*

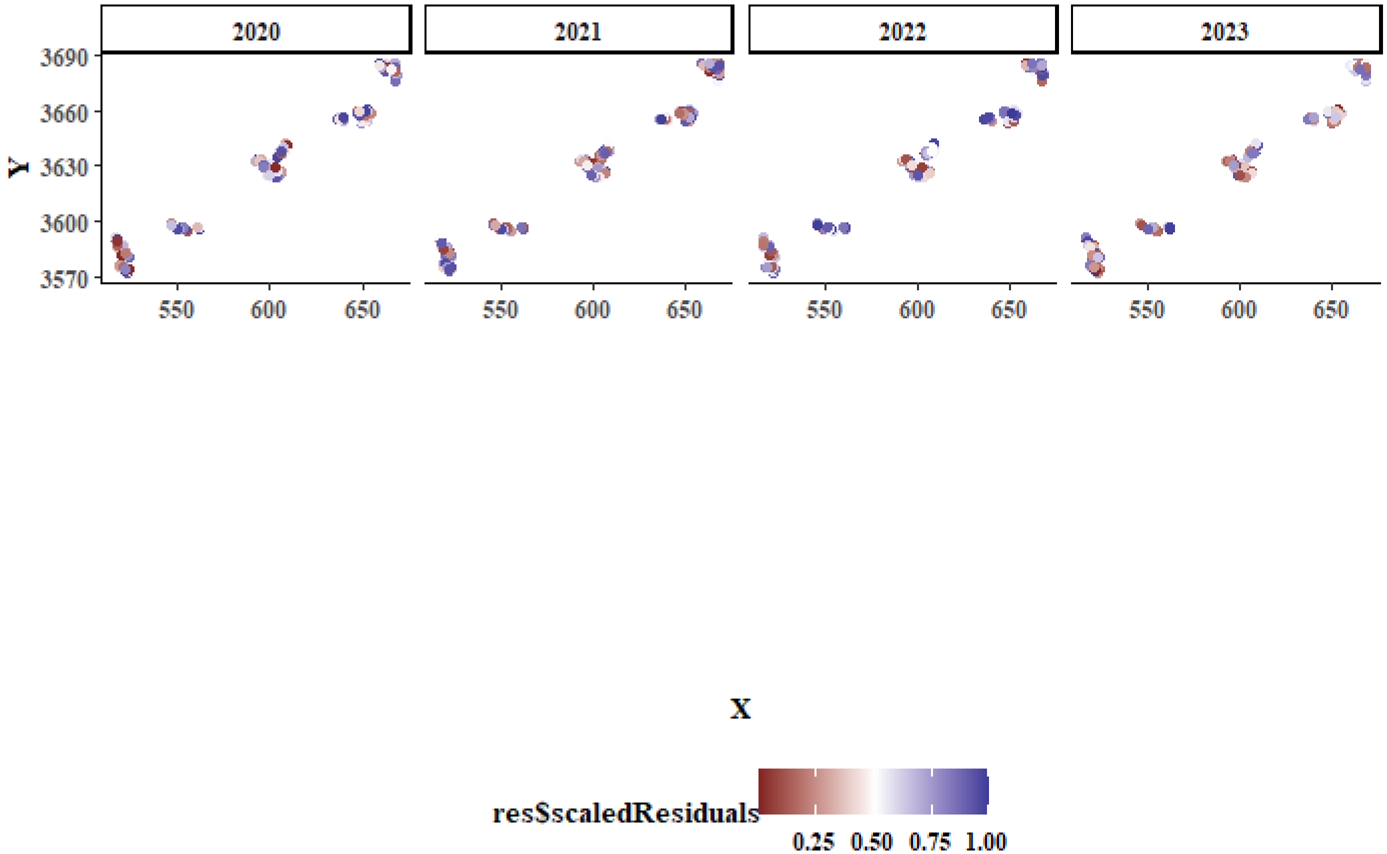


Figure 3.29 *cont.*

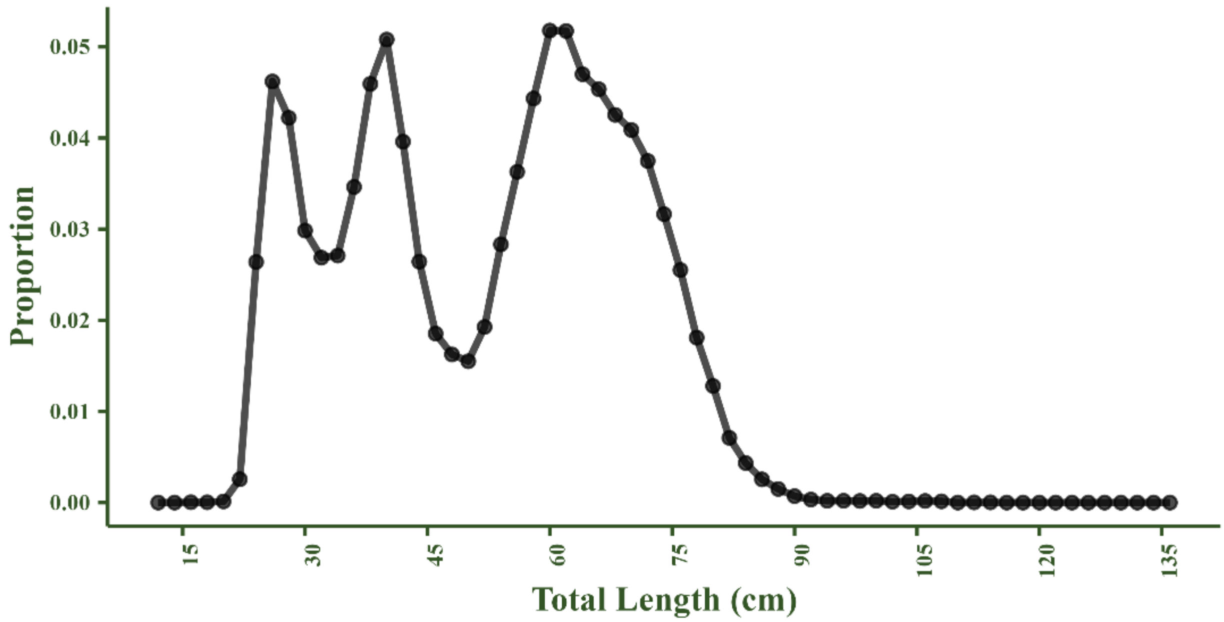


Figure 3.30 Length composition of Red Drum encountered by the trammel net survey when pooled across all years.

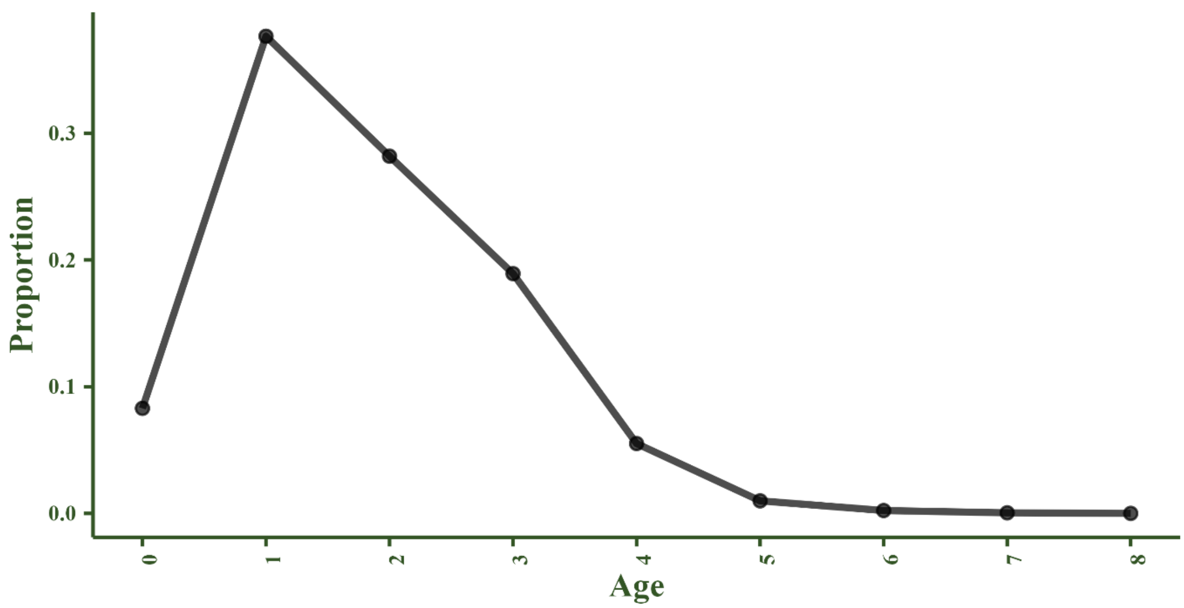


Figure 3.31 Age composition of Red Drum encountered by the trammel net survey when pooled across all years. Age-8 represents an age-8+ group.

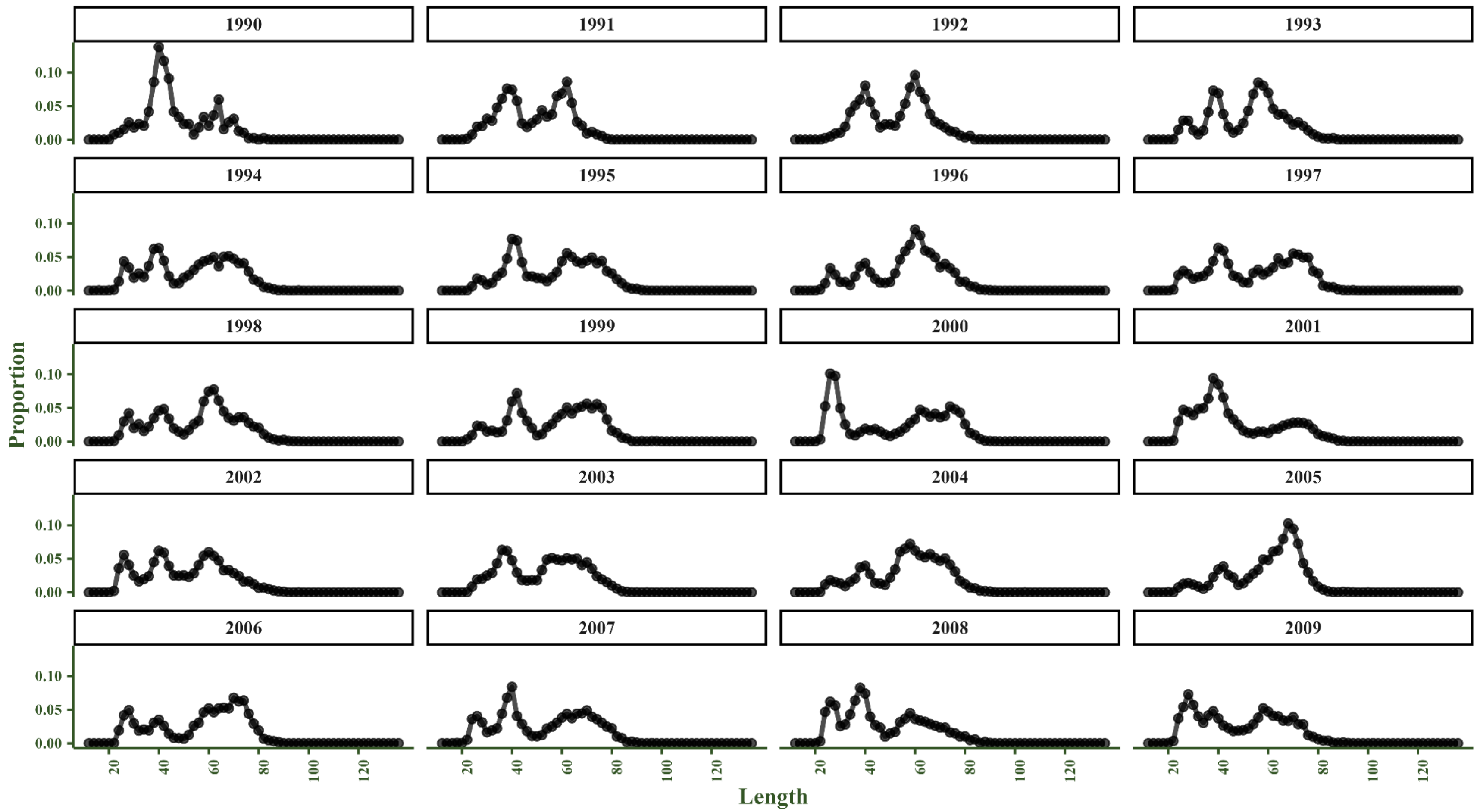


Figure 3.32 Annual length composition of Red Drum encountered by the trammel net survey from 1991-2010.

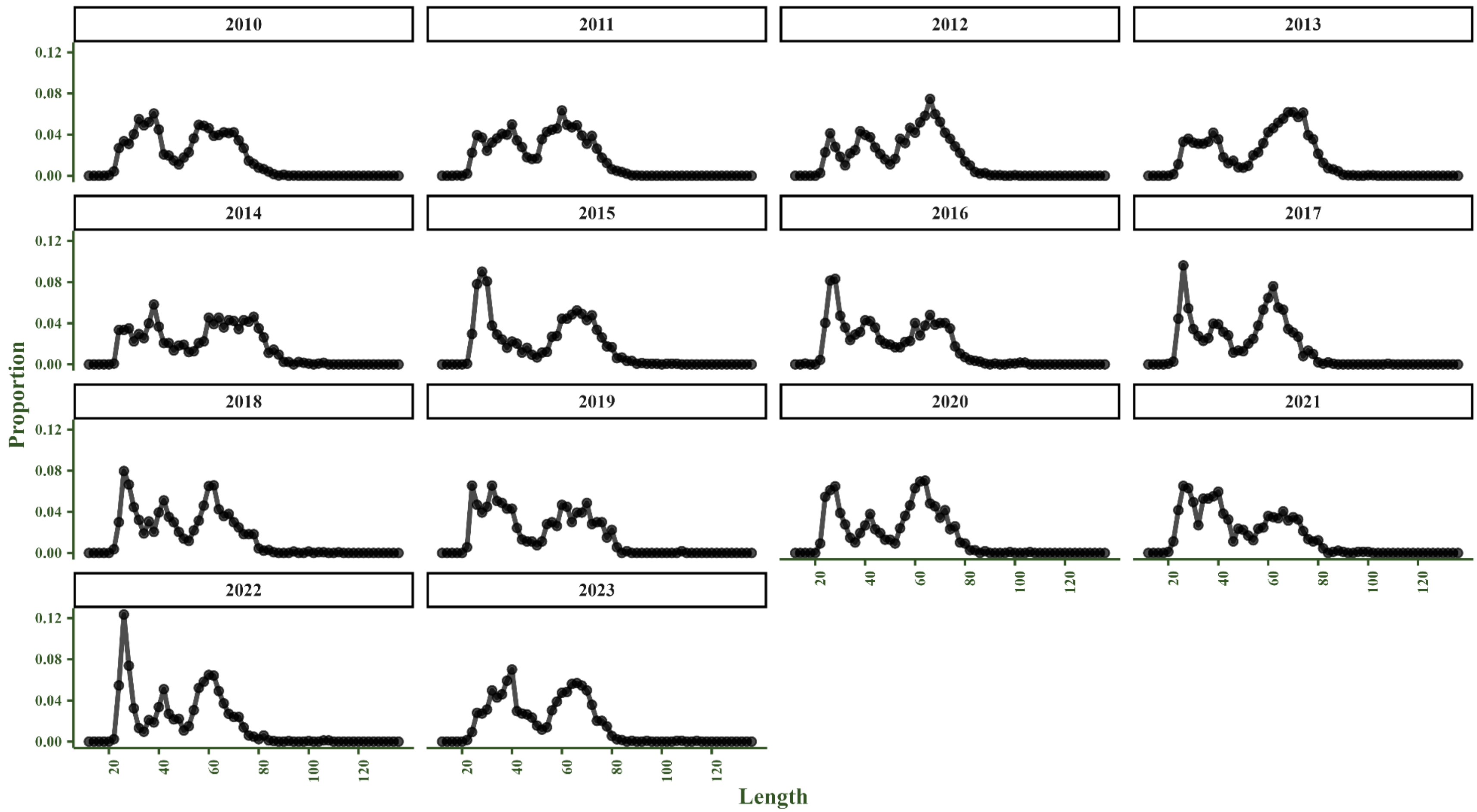


Figure 3.33 Annual length composition of Red Drum encountered by the trammel net survey from 2011-2023.

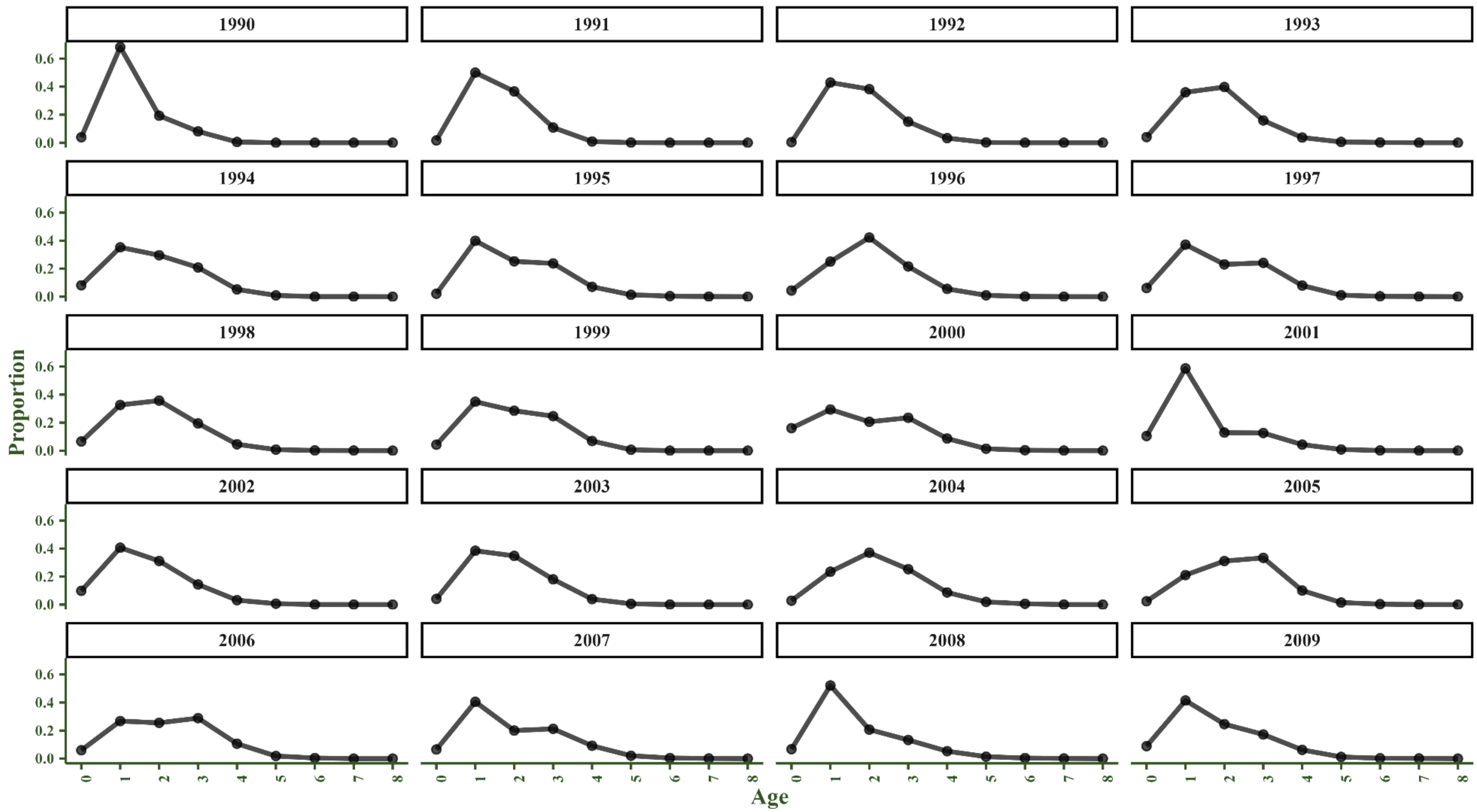


Figure 3.34 Annual age composition of Red Drum encountered by the trammel net survey from 1990-2009.

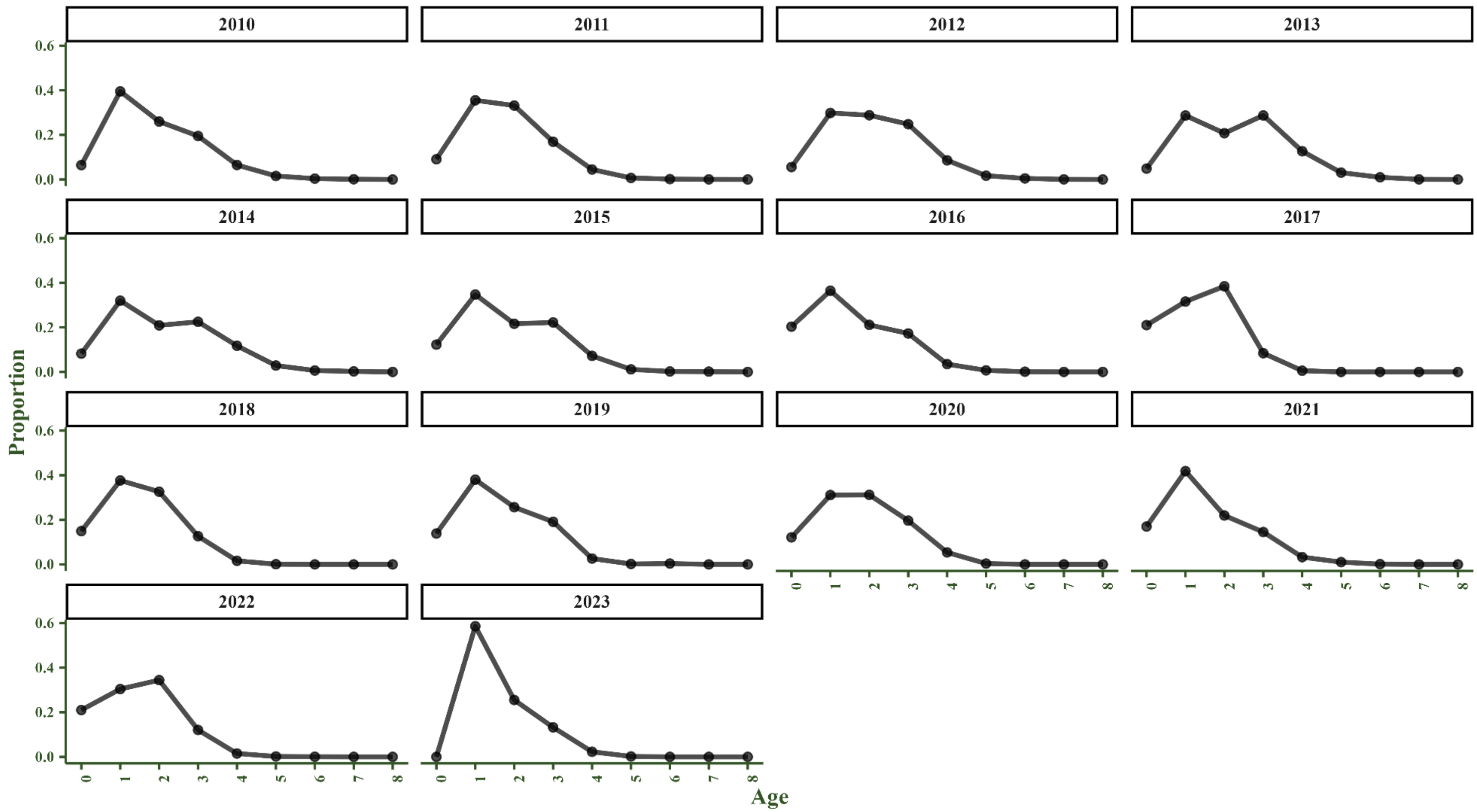


Figure 3.35 Annual age composition of Red Drum encountered by the trammel net survey from 2010-2023.

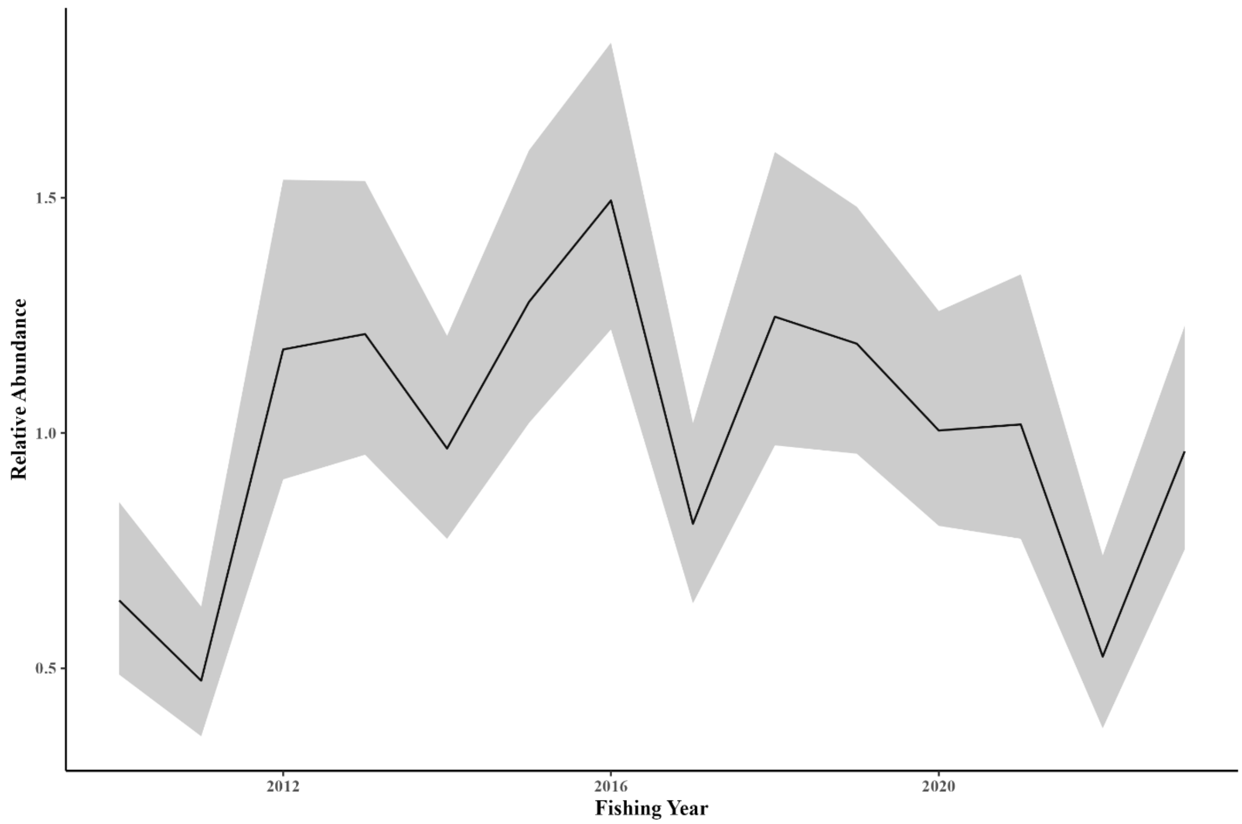


Figure 3.36 SC longline survey standardized relative abundance index (solid line) with 95% confidence interval (shaded region) from 2010-2023.

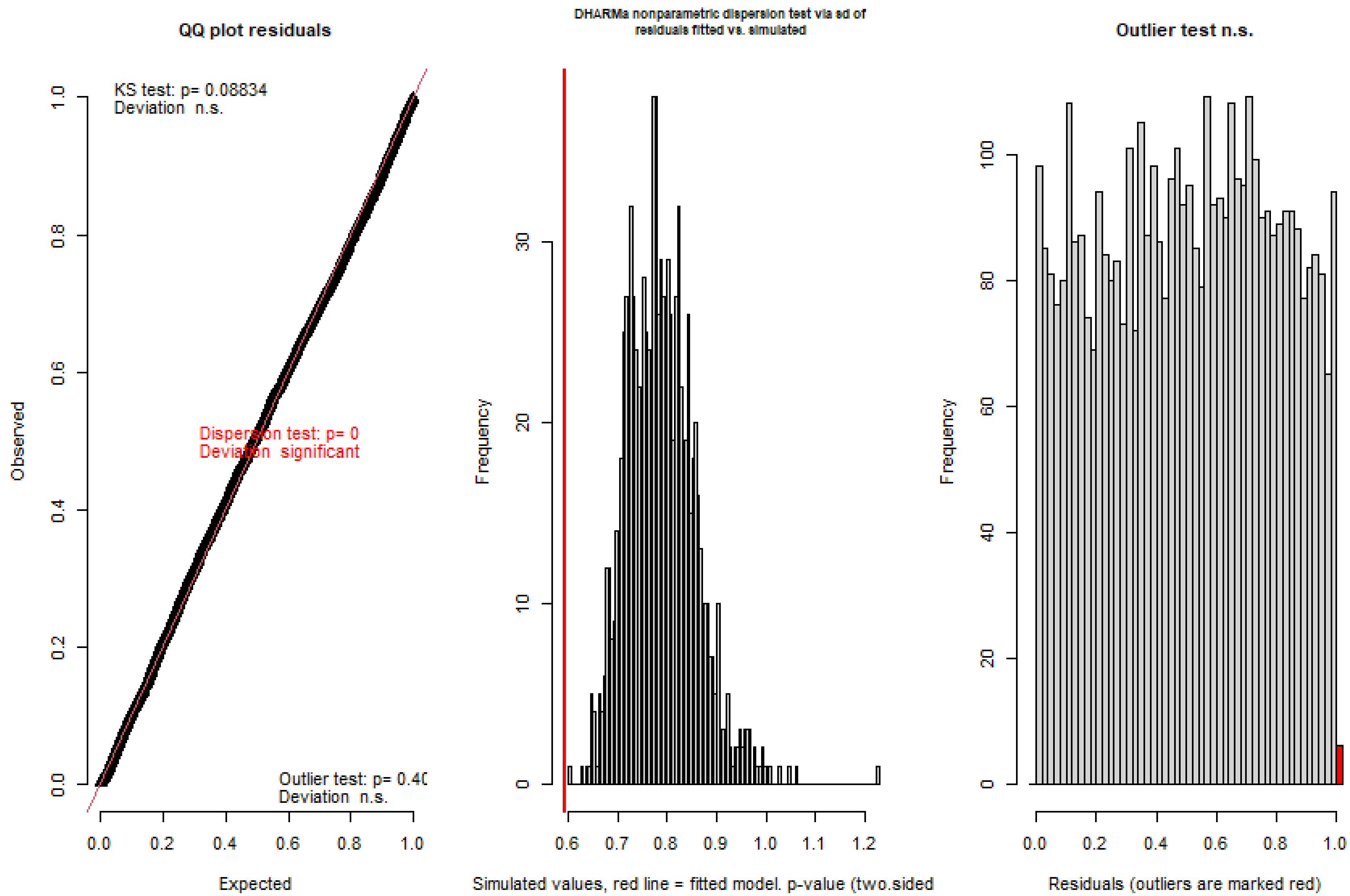


Figure 3.37 Results of tests related to residuals distribution, dispersion, and outliers for the best fit longline survey index.

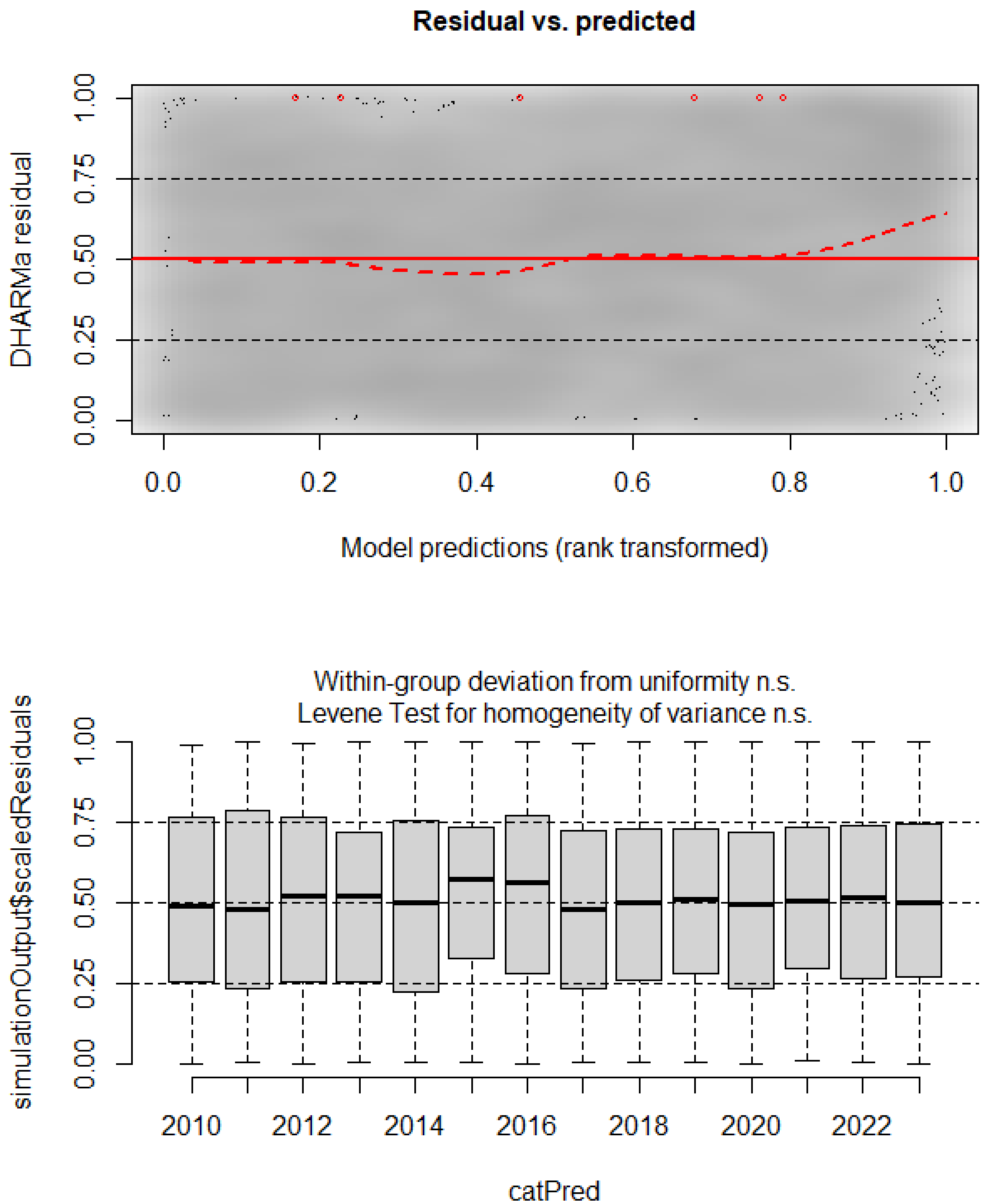


Figure 3.38 Residuals versus predicted values (top panel) and fishing year (bottom panel) for the best fit model for the SC longline survey.

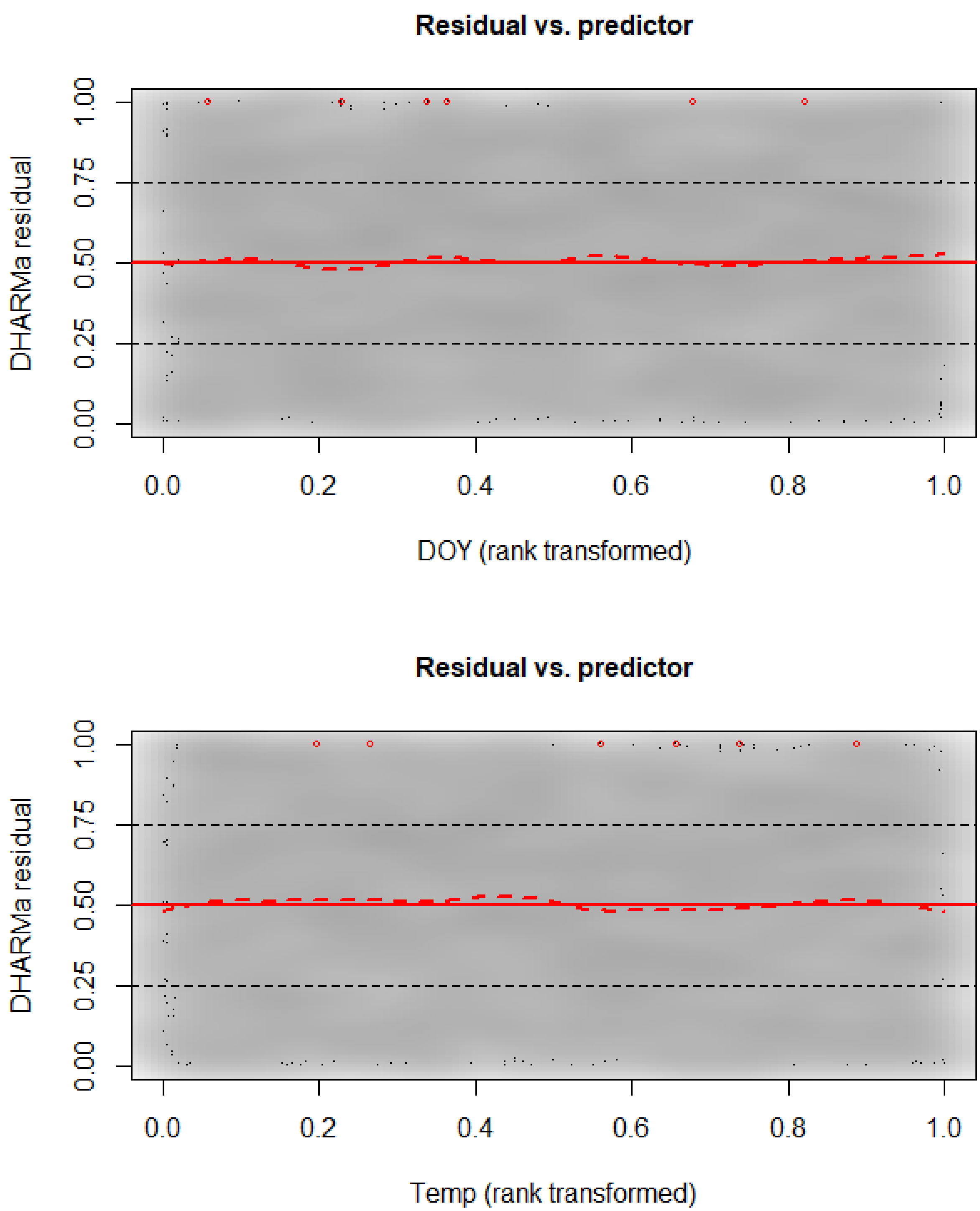


Figure 3.39 Residuals versus day of year (top panel) and water temperature (bottom panel) for the best fit model for the SC longline survey.

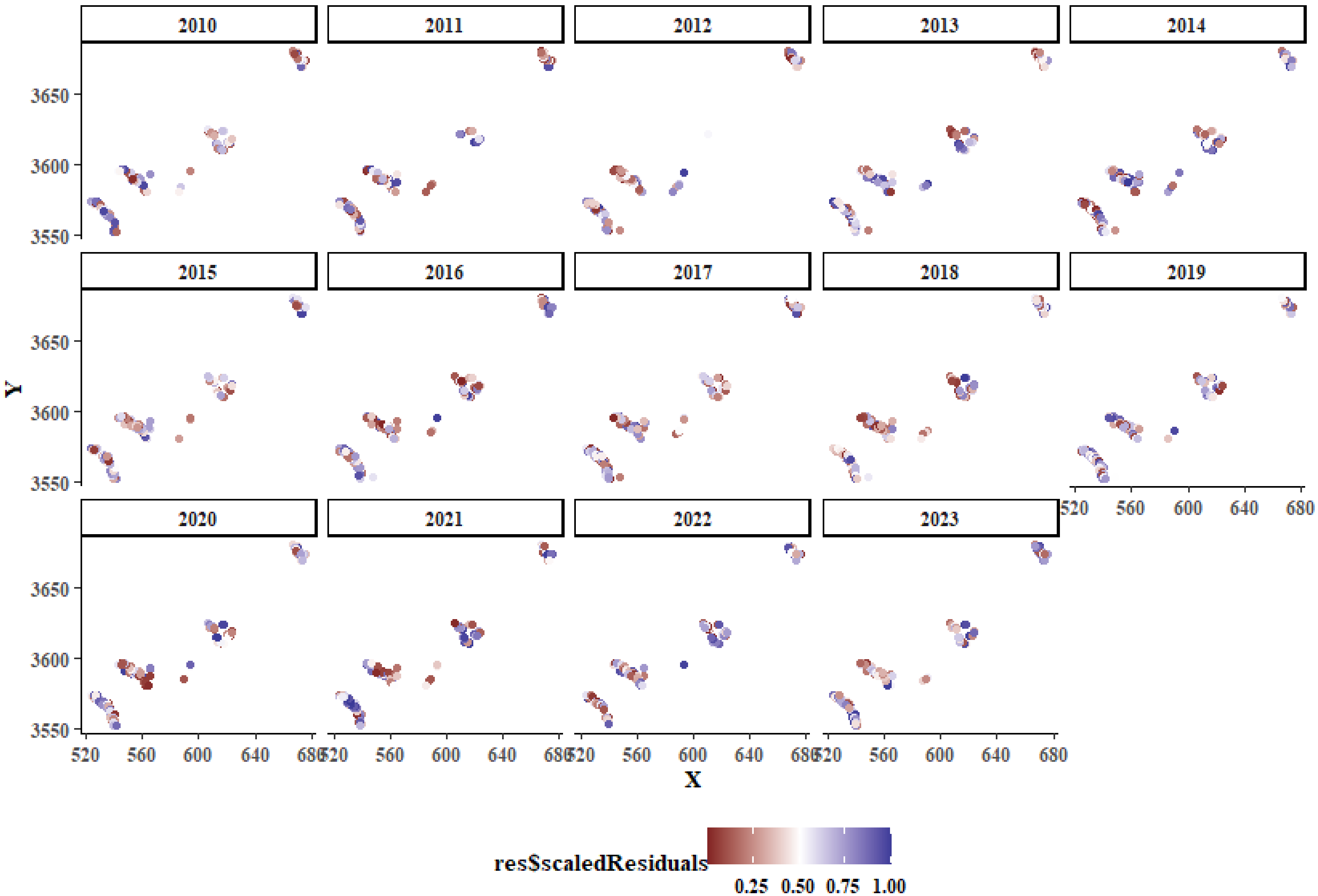


Figure 3.40 Residuals versus location and time for the longline survey.

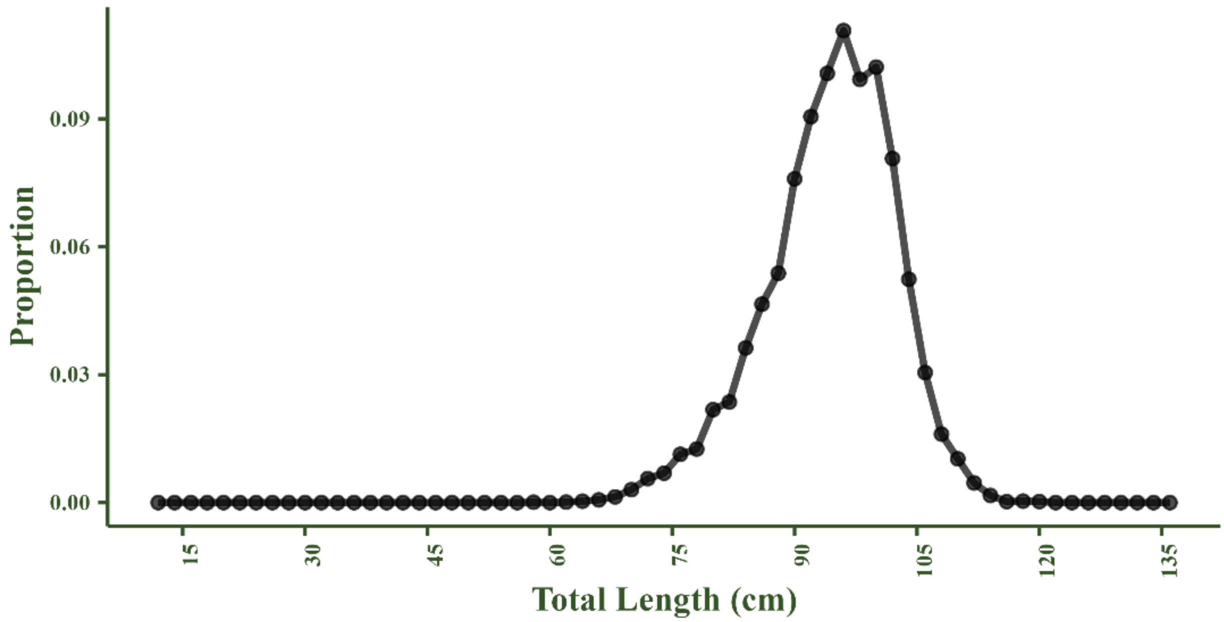


Figure 3.41 Length composition of Red Drum encountered by the longline survey when pooled across all years.

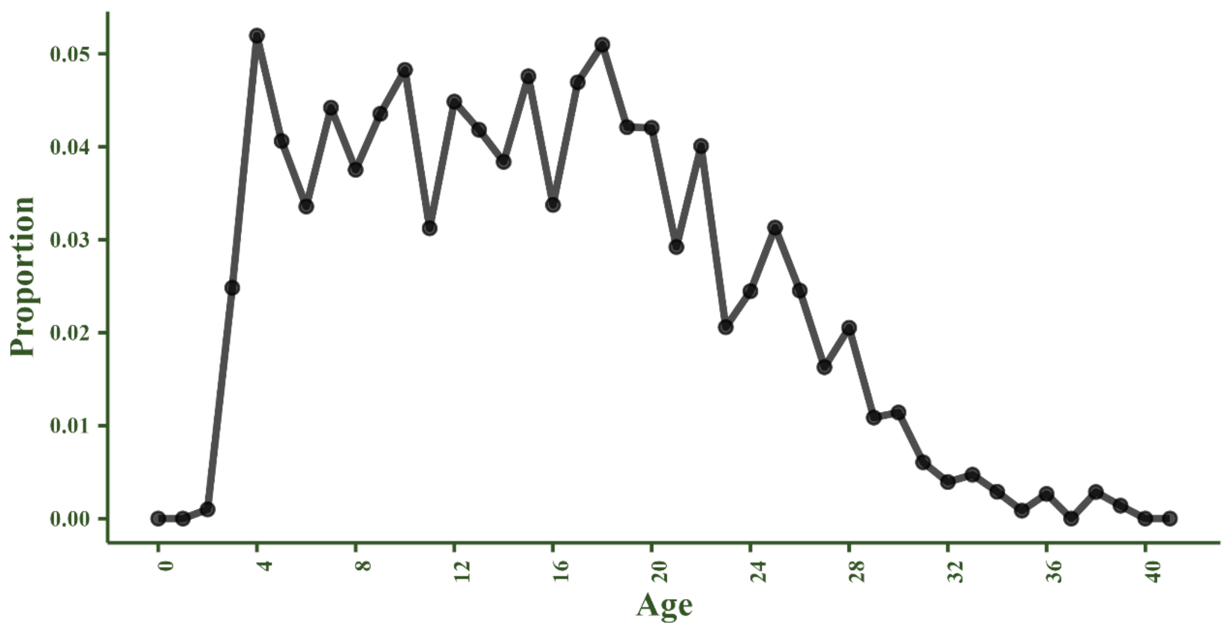


Figure 3.42 Age composition of Red Drum encountered by the longline survey when pooled across all years.

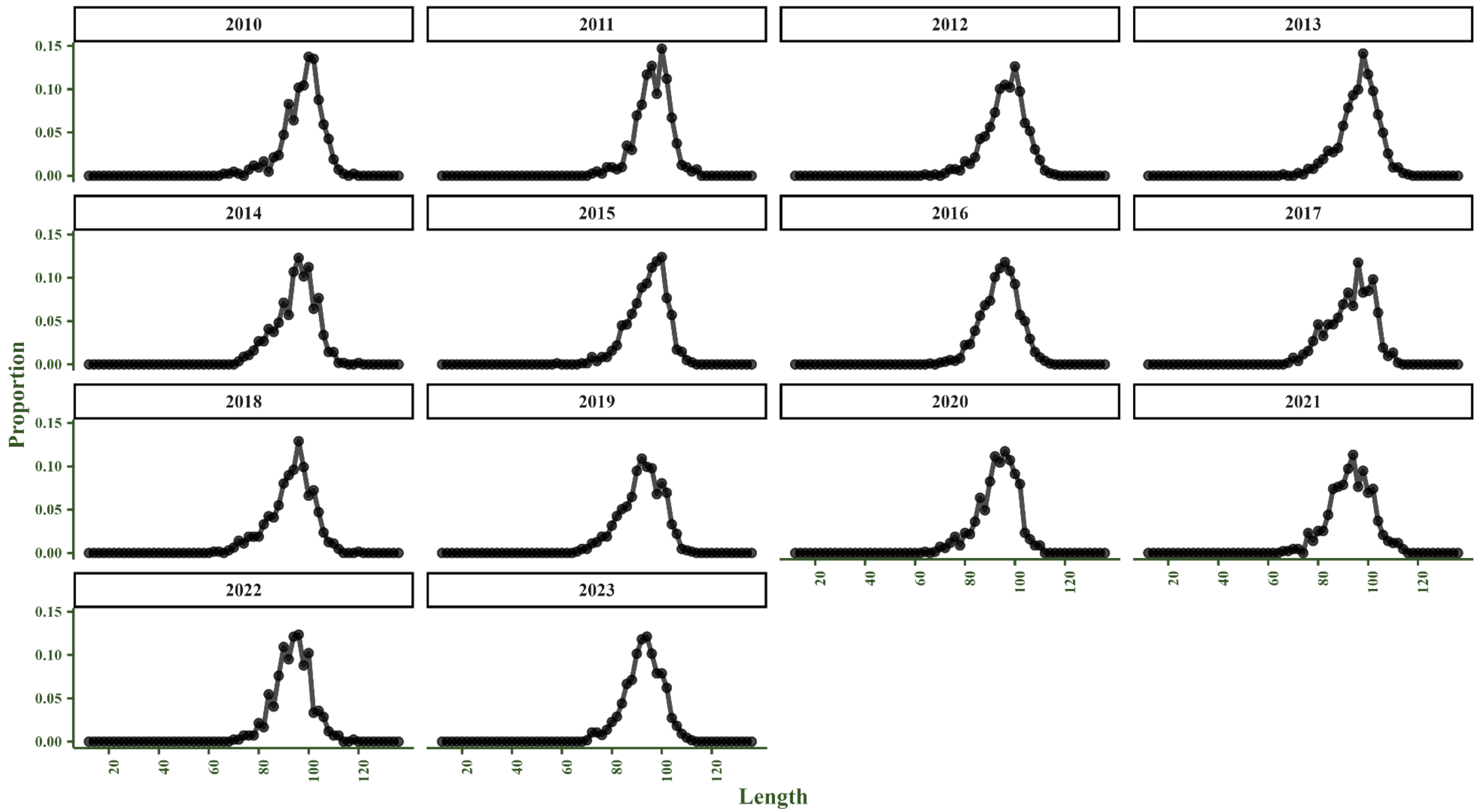


Figure 3.43 Annual length compositions developed for the longline survey from 2010-2023.

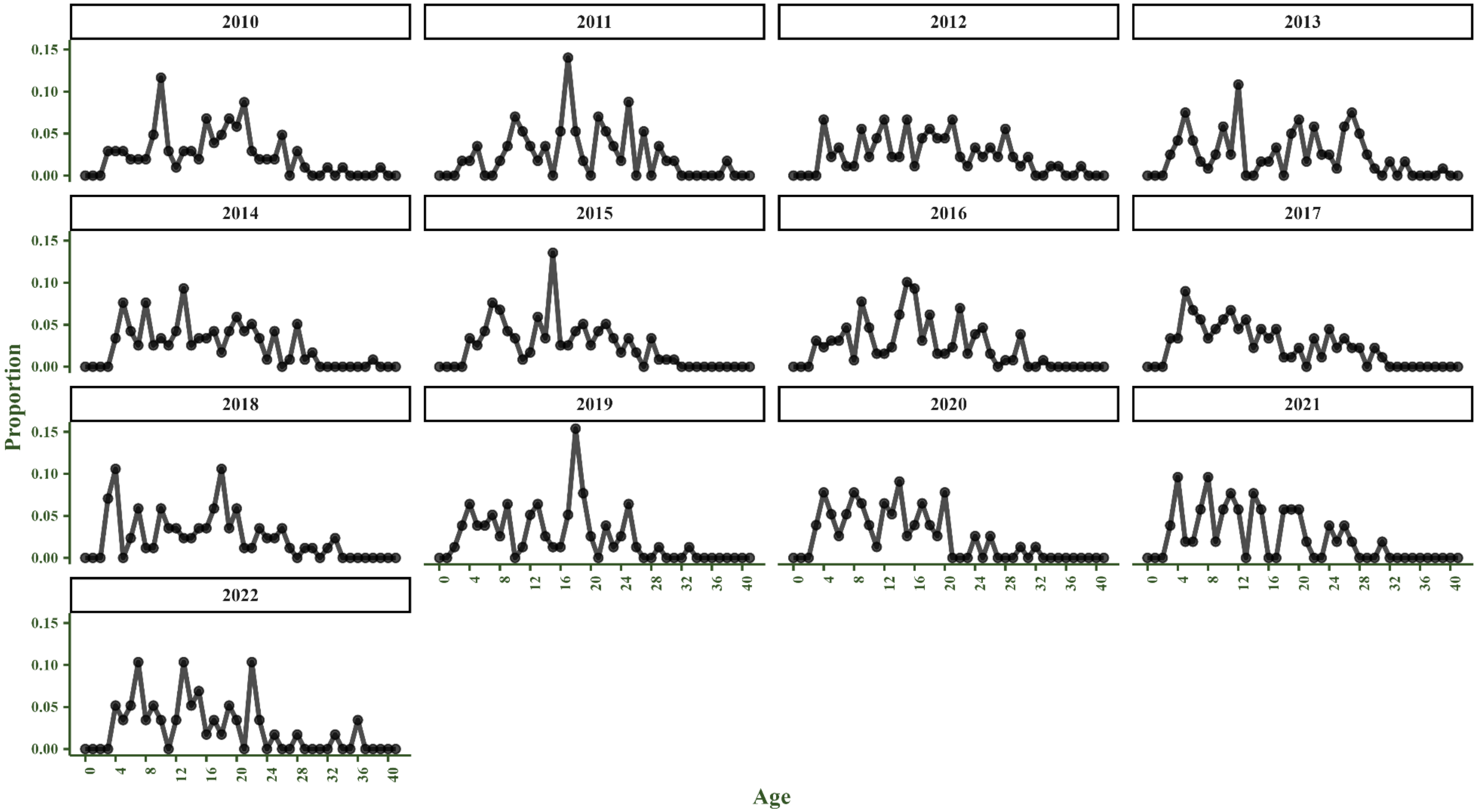


Figure 3.44 Annual age compositions developed for the longline survey from 2010-2022. Note, age composition data for 2023 samples was not available for the assessment.

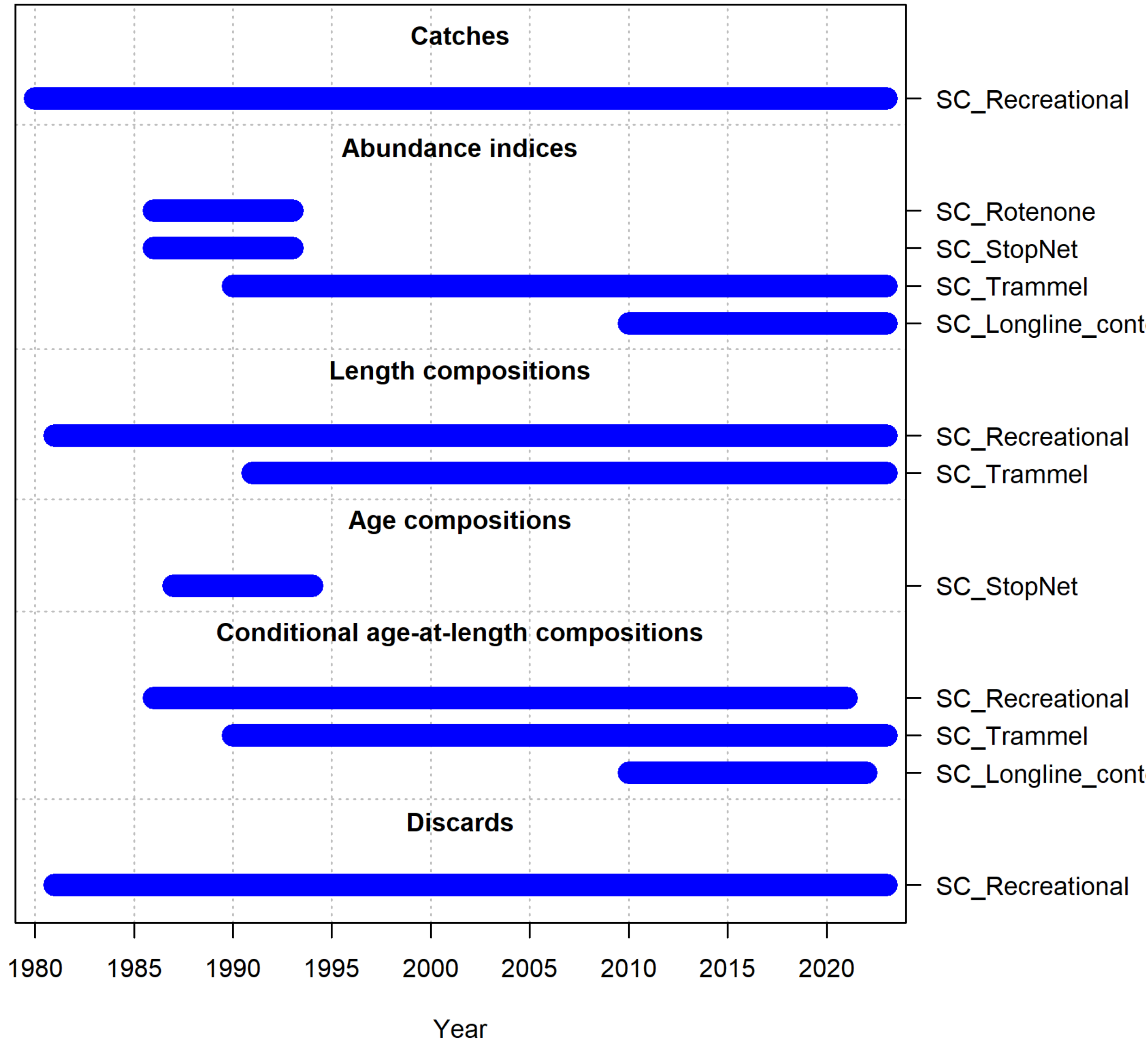


Figure 4.1 Data time series used in SS base model for the SC sub-stock.

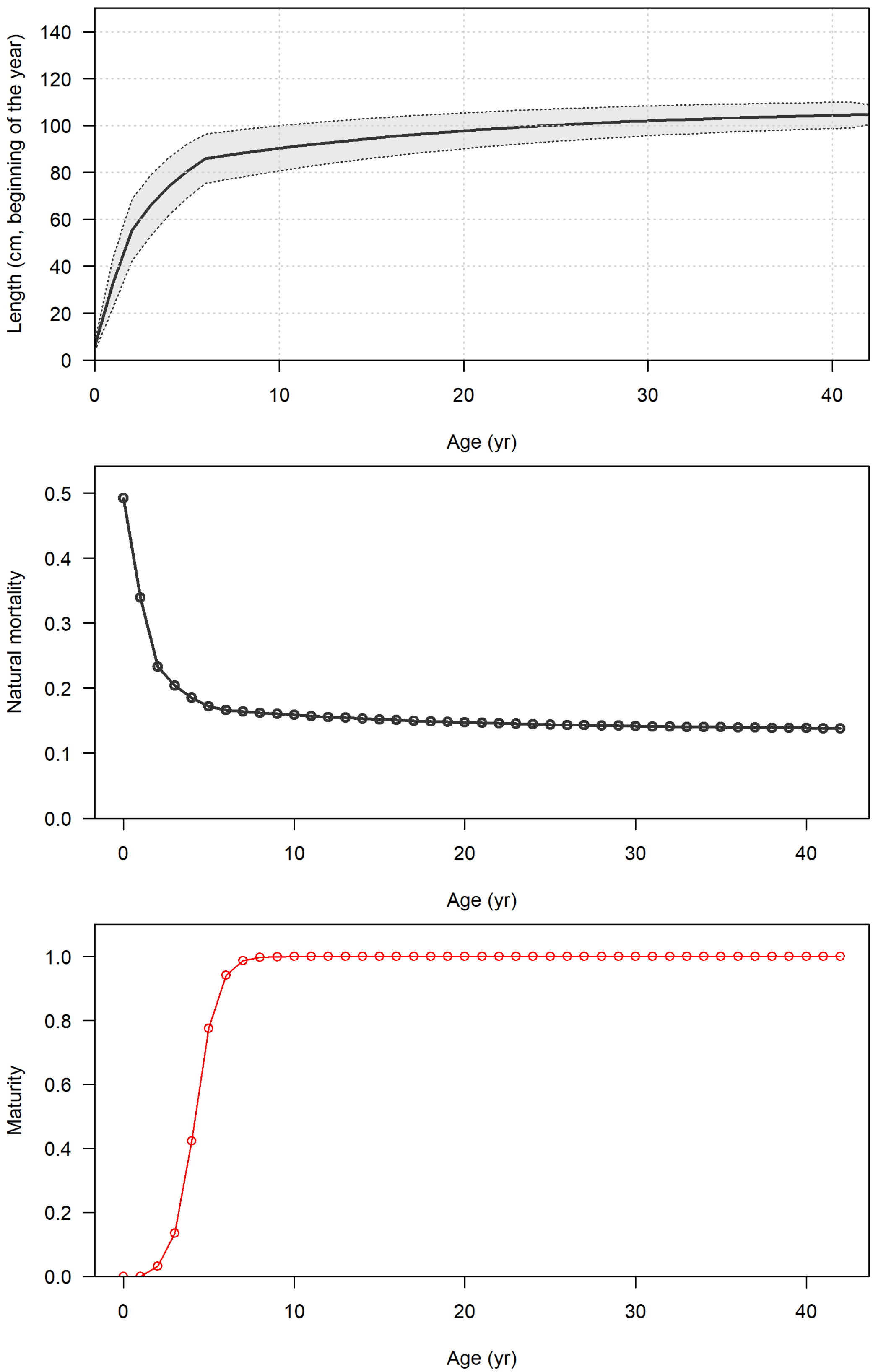
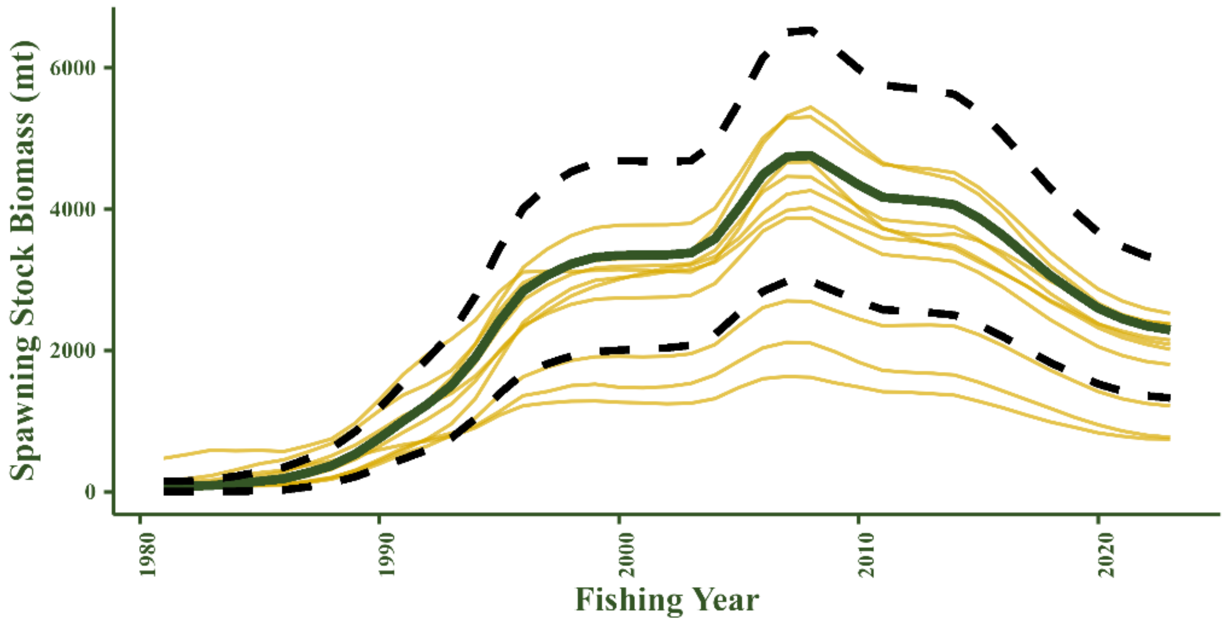


Figure 4.2 Model fit to the life history parameters for growth (top panel), natural mortality (*M* middle panel), and maturity (bottom panel) in the SS base model.



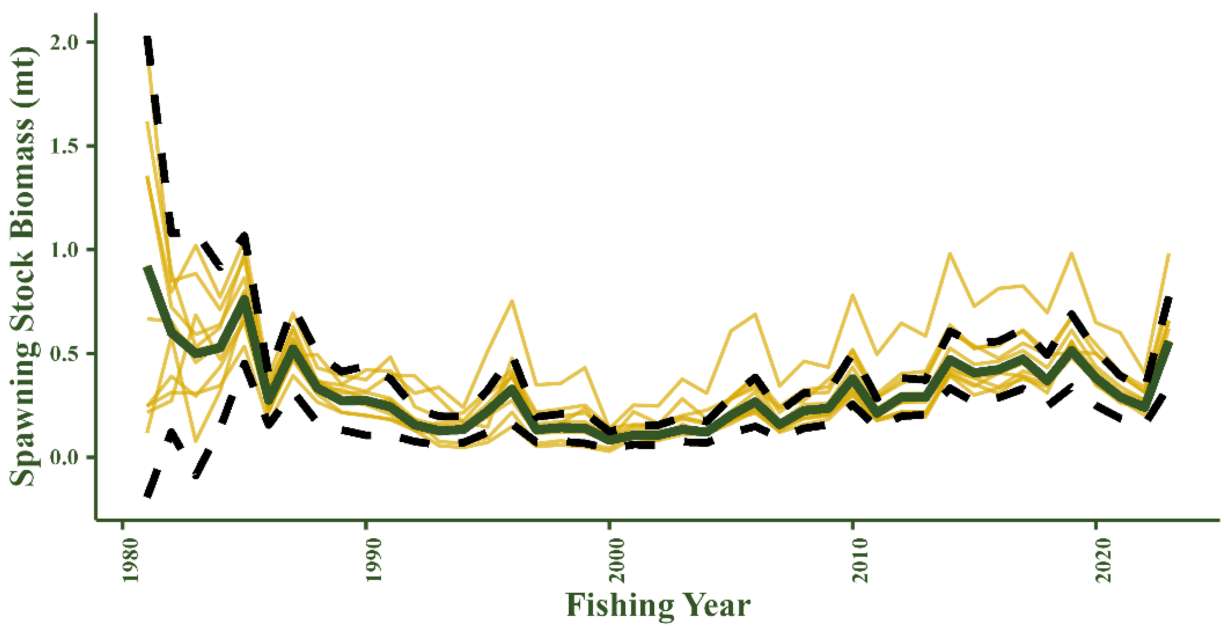


Figure 4.3 Predicted SSB (top) and Age-2 *F* (bottom) from 200 runs (think yellow lines) using the jitter analysis (10%) applied to the SC sub-stock base run of the stock assessment model for Red Drum. The base model (thick green line) and 95% confidence intervals (dashed black lines) are provided for comparison.

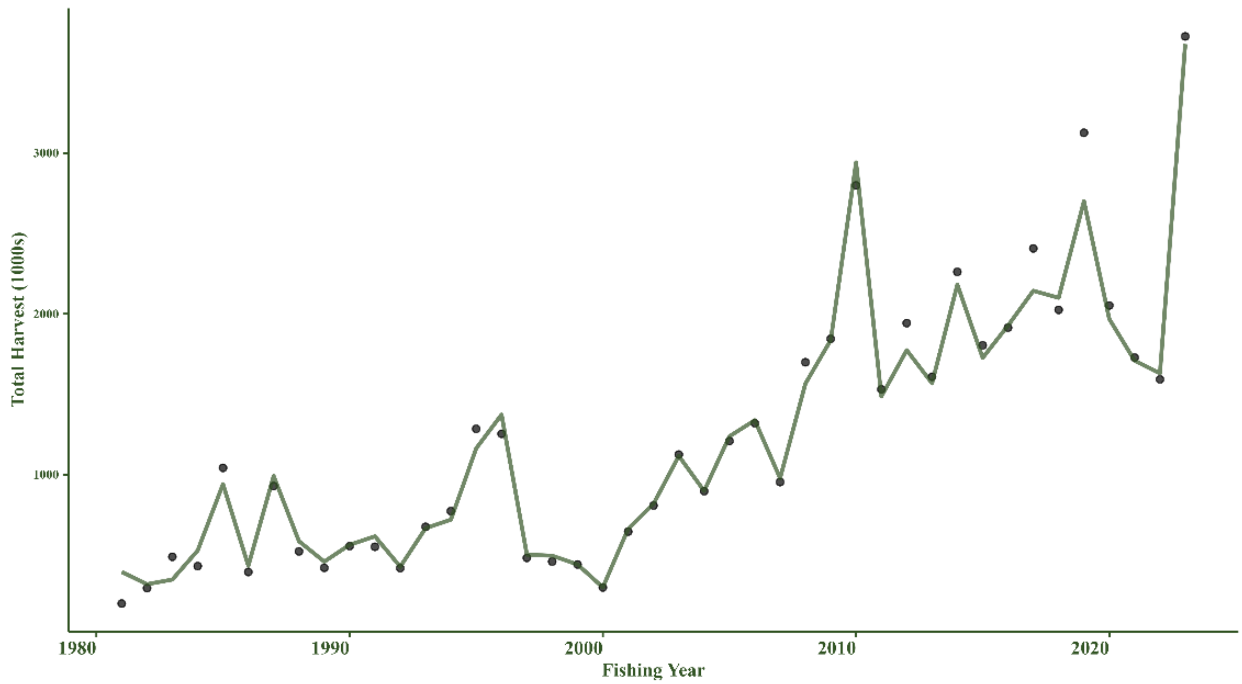


Figure 4.4 Observed (black dots) and estimated catches (green line) for the SC recreational fleet for the SC sub-stock model.

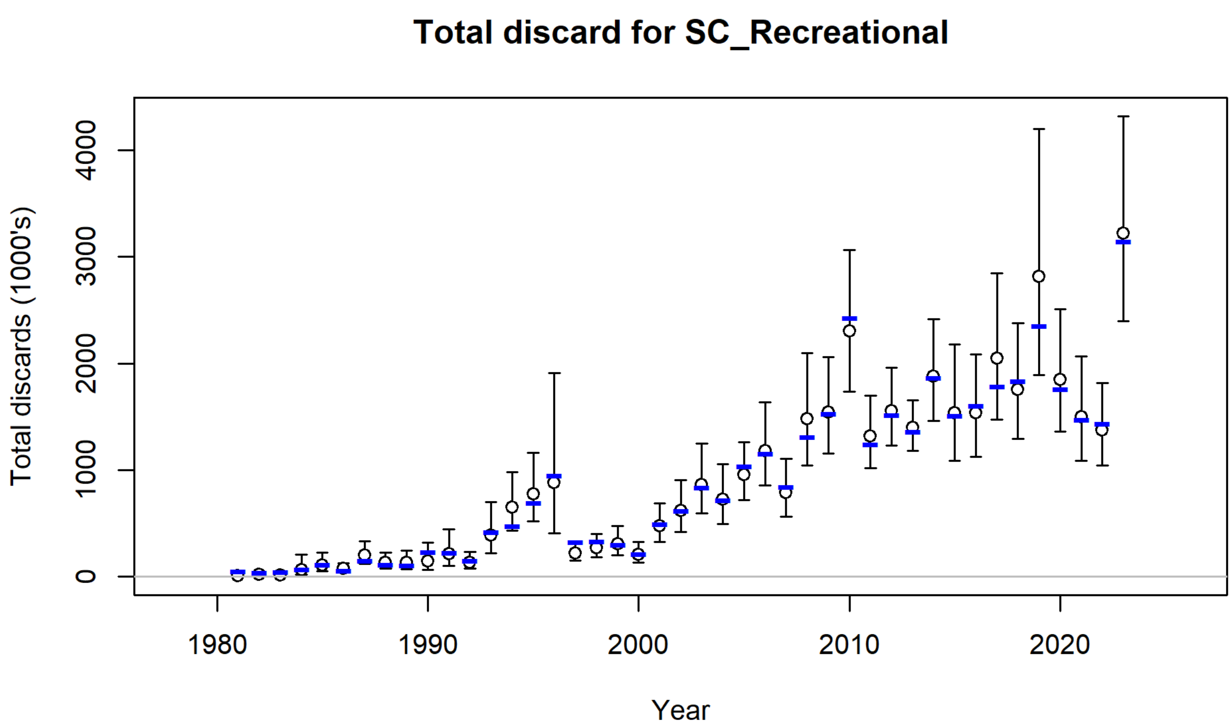


Figure 4.5 Observed and estimated discards (in 1000's of fish) for the SC sub-stock model.

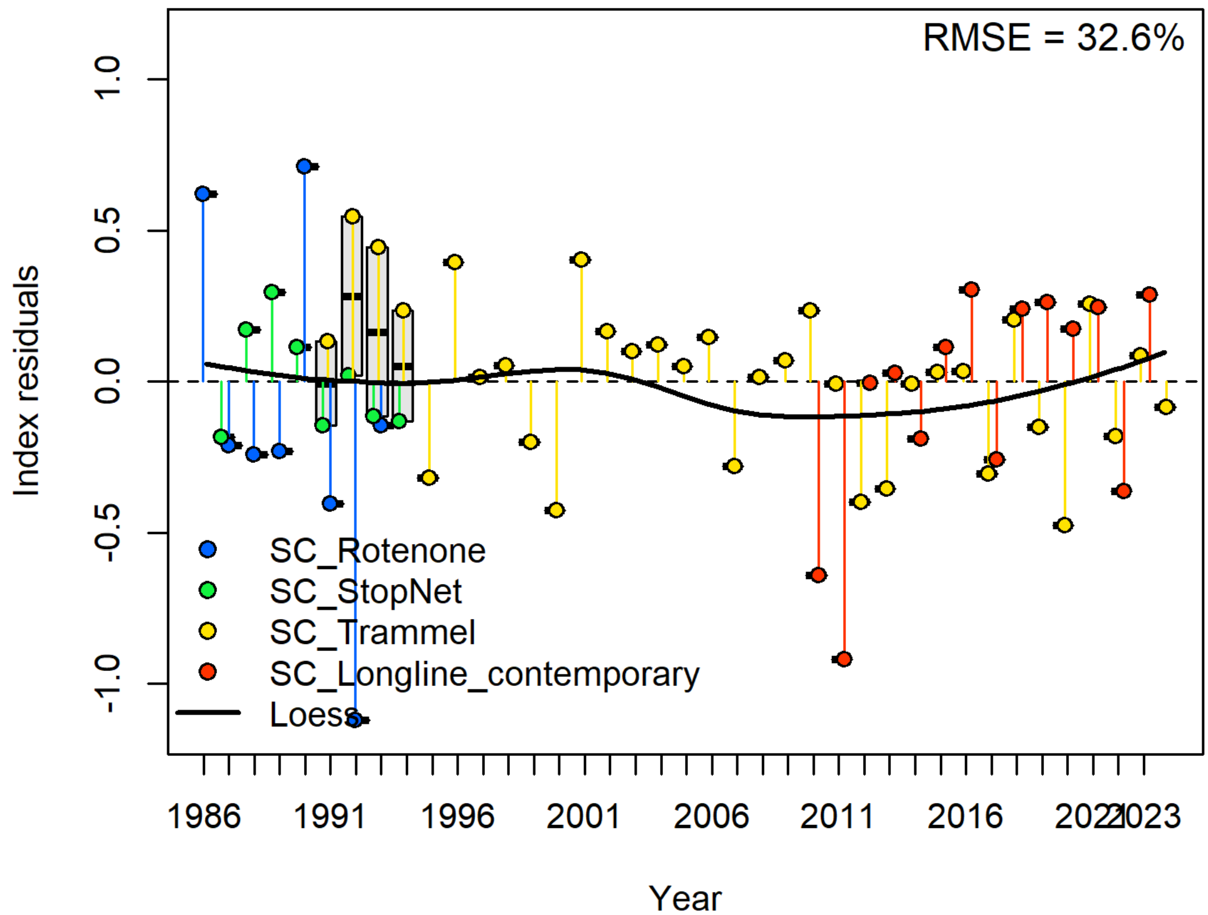


Figure 4.6 Joint residual plot for all fishery-independent surveys from the SC sub-stock model color-coded by index. Each point with lines indicates the residual from that survey in that given year, with boxplots showing the median and quartiles when multiple surveys occur in the same year. The black line is a loess smoother through the residuals and root-mean squared error (RMSE) is provided in the upper right corner.

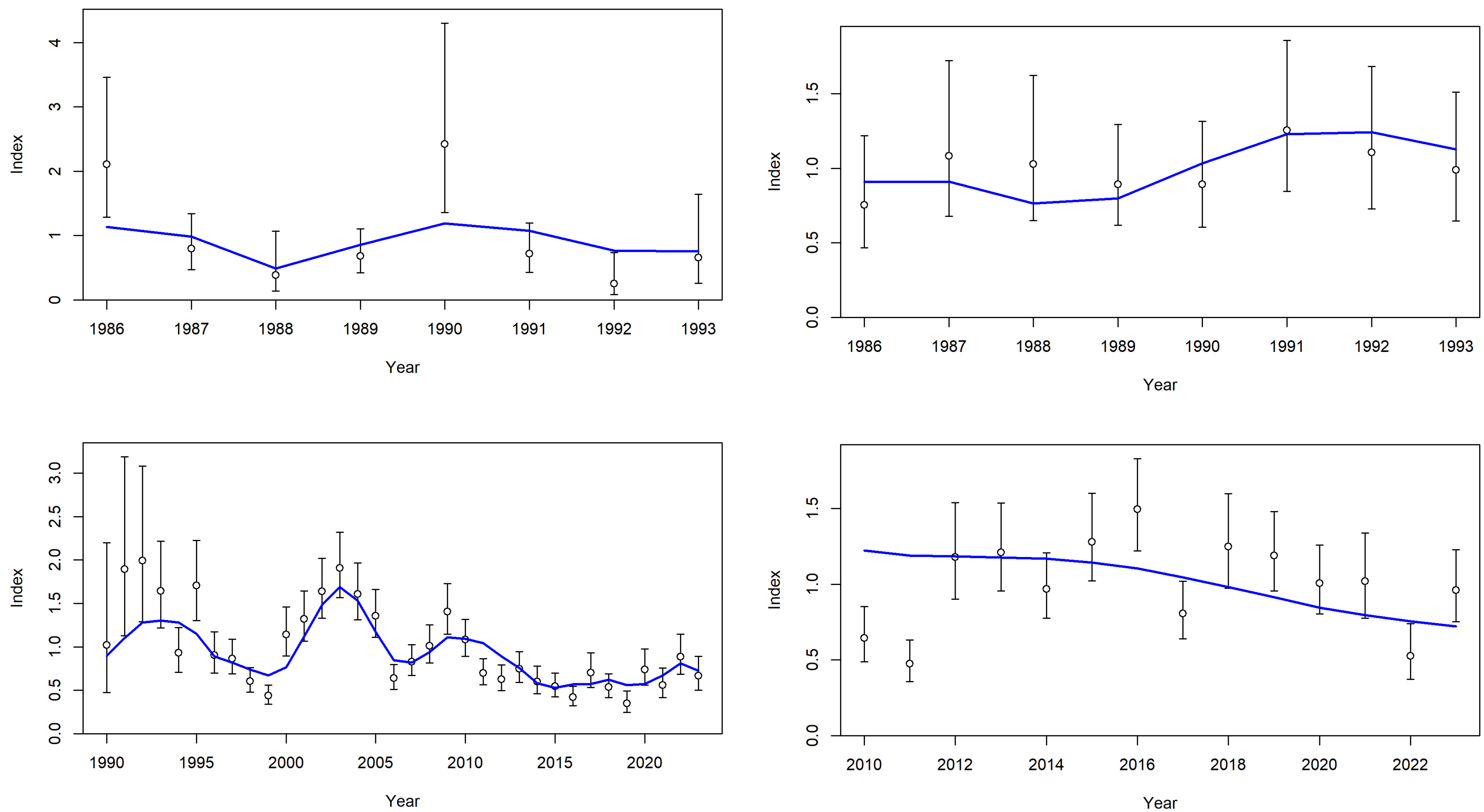


Figure 4.7 Observed (black circles with bars indicating confidence intervals) and estimated index values (blue lines) for the rotenone age-0 recruitment survey (top left panel), stop net sub-adult survey (top right panel), trammel net sub-adult survey (bottom left panel), and longline adult survey (bottom right panel) for the SC sub-stock model.

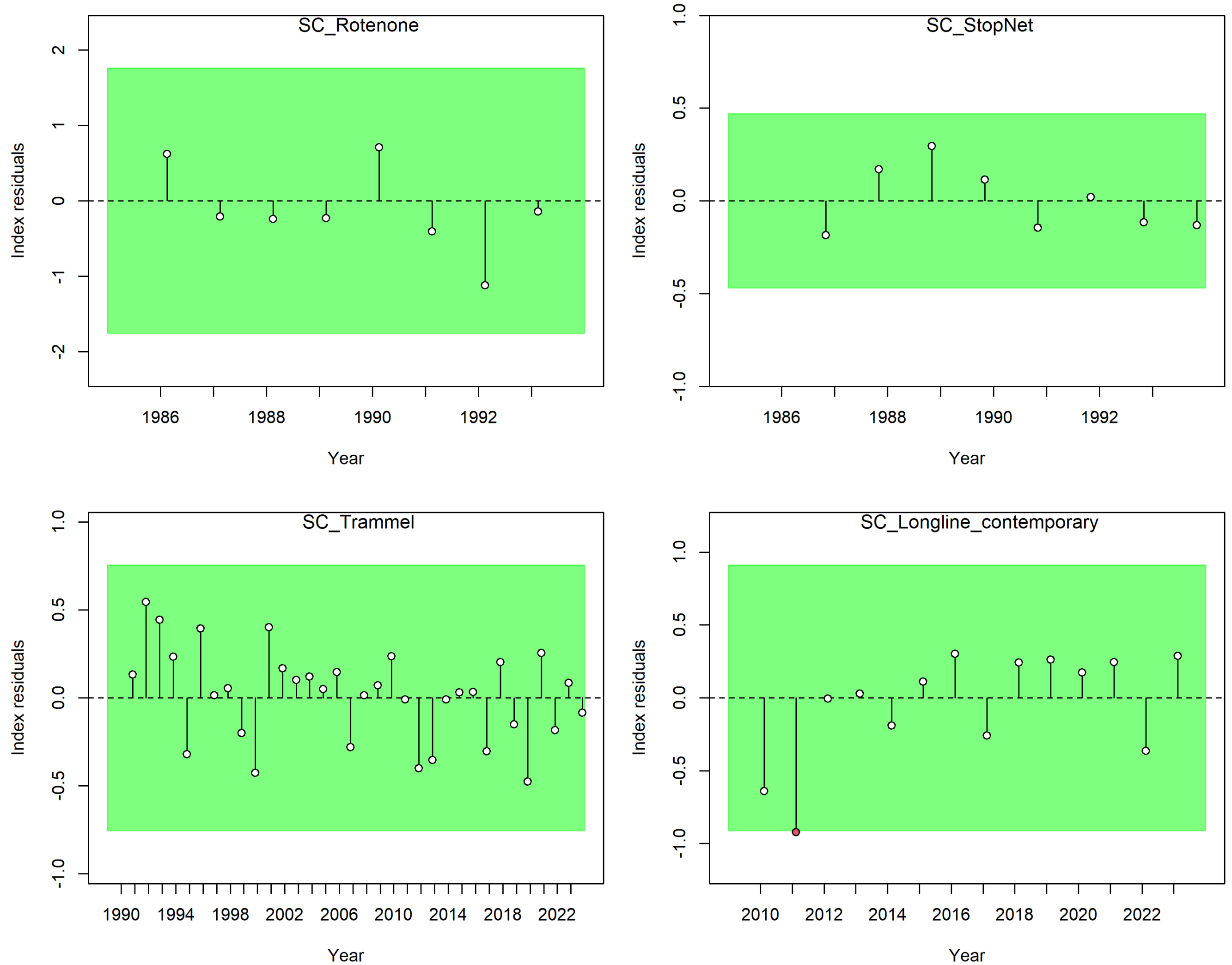


Figure 4.8 Standardized residuals on a runs test plot for the rotenone age-0 recruitment survey (top left panel), stop net sub-adult survey (top right panel), trammel net sub-adult survey (bottom left panel), and longline adult survey (bottom right panel). Green shading indicates no evidence (α > 0.05) to reject the hypothesis of a randomly distributed time series of residuals. The shaded (green) area spans three residual standard deviations to either side from zero.

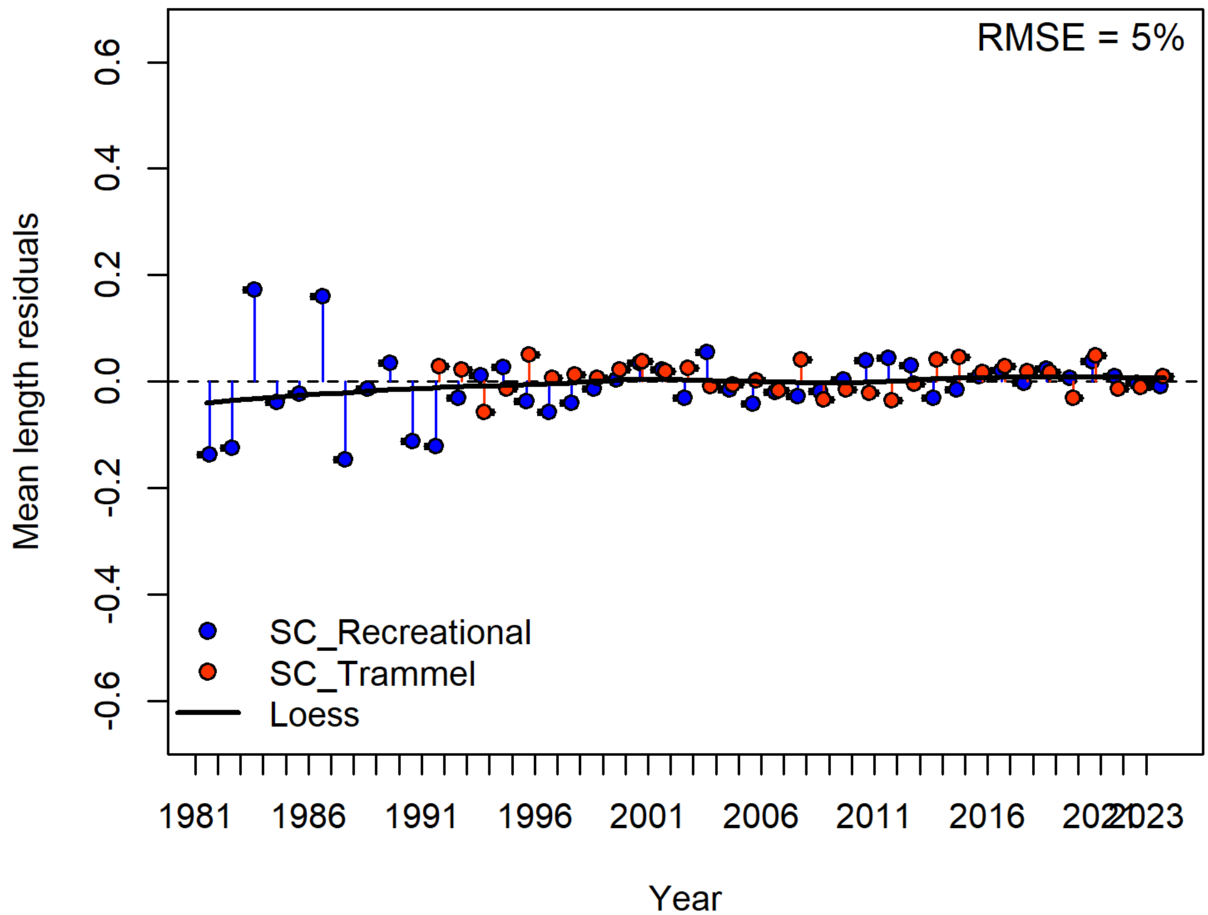


Figure 4.9 Joint residual plot for recreational fleet and trammel net sub-adult survey length compositions color-coded by index. Each point with lines indicates the residuals from that survey in that given year. The black line is a loess smoother through the residuals and root-mean squared error (RMSE) is provided in the upper right corner.

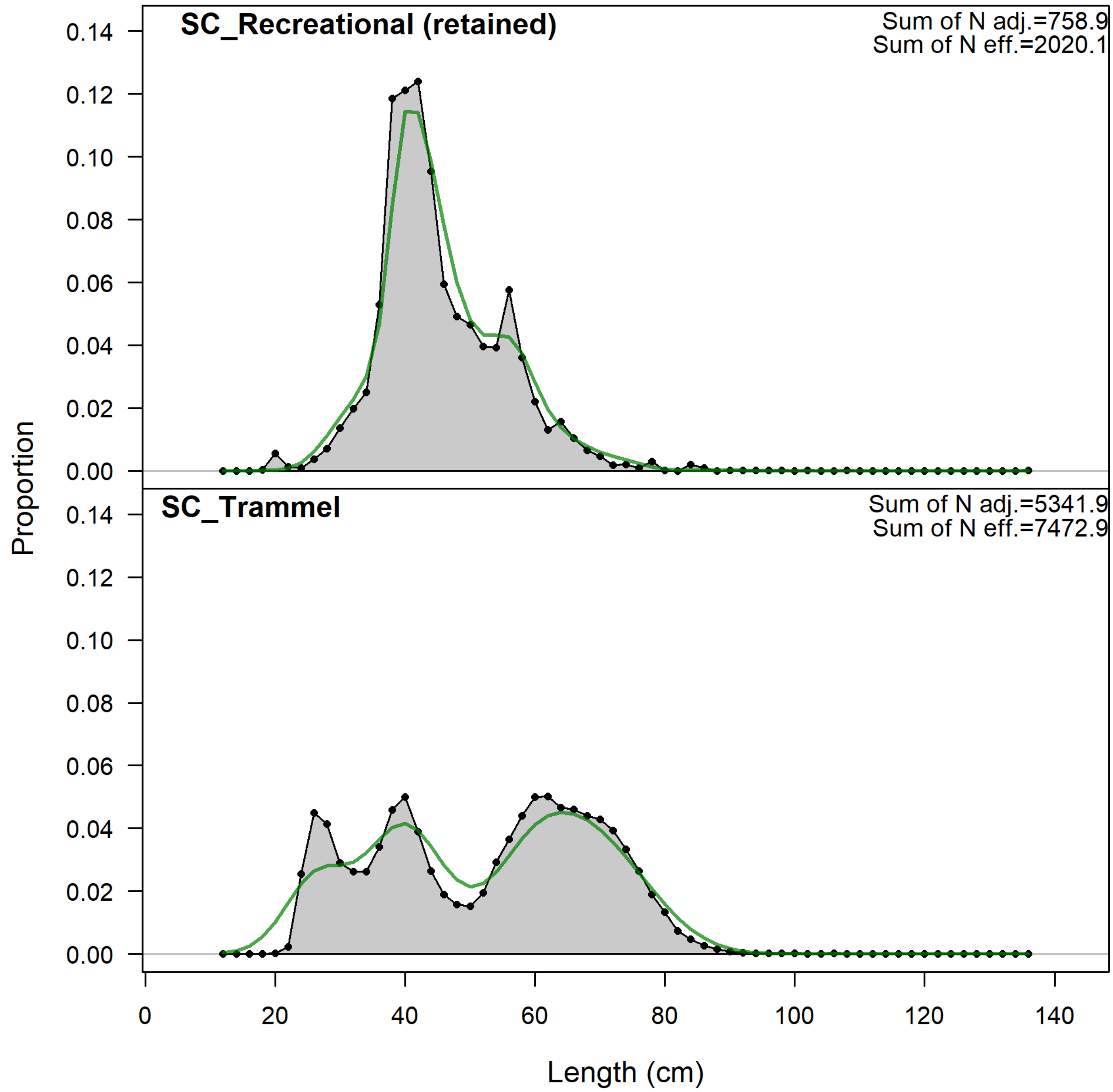


Figure 4.10 Length compositions (observed – gray shaded and black line/dots; predicted – green line), aggregated across time by fleet/survey.

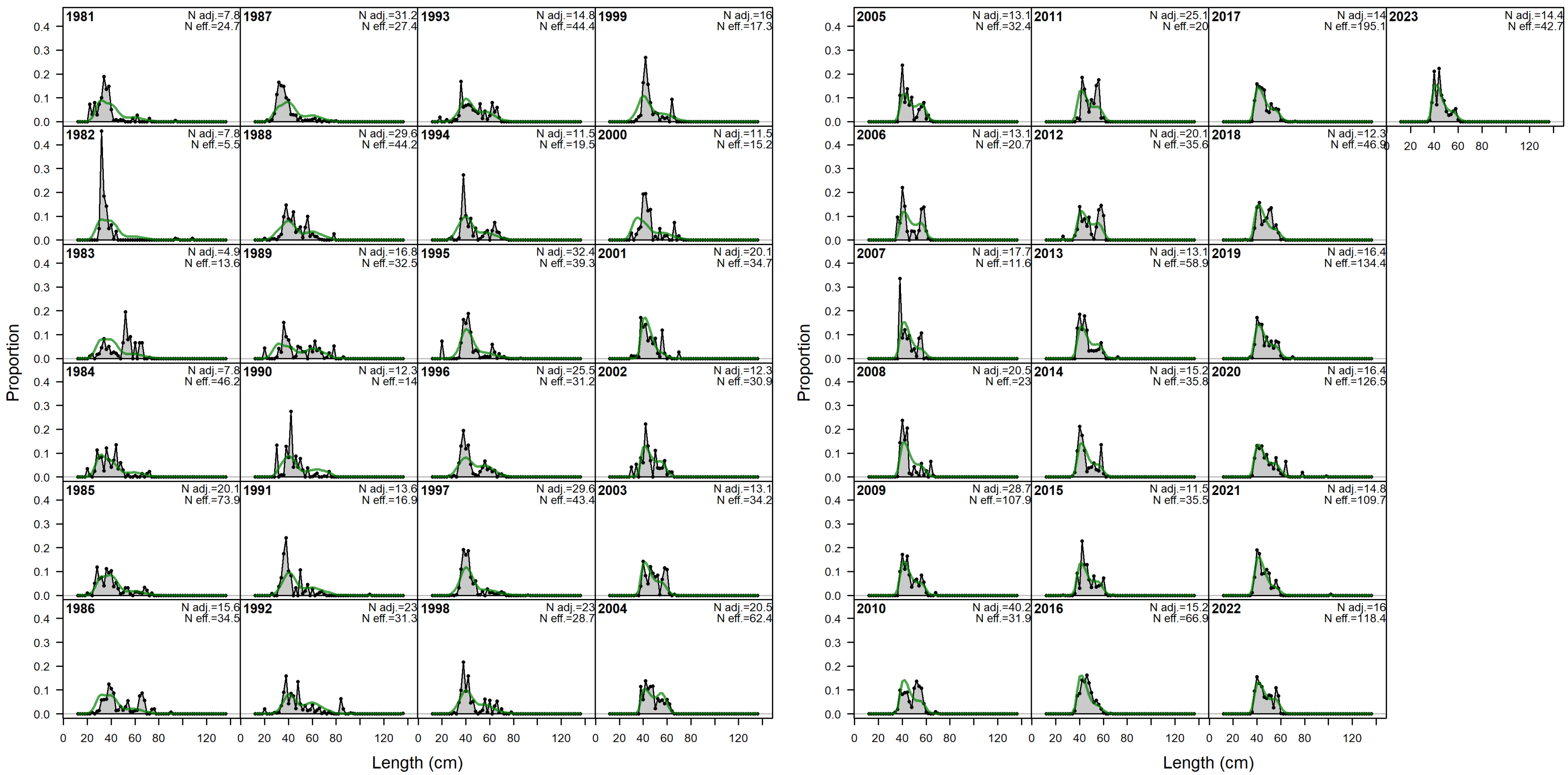


Figure 4.11 Observed (gray shaded & black line/dots) and predicted (green line) length compositions for the recreational fleet retained catch. N. adi. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size after Francis re-weighting.

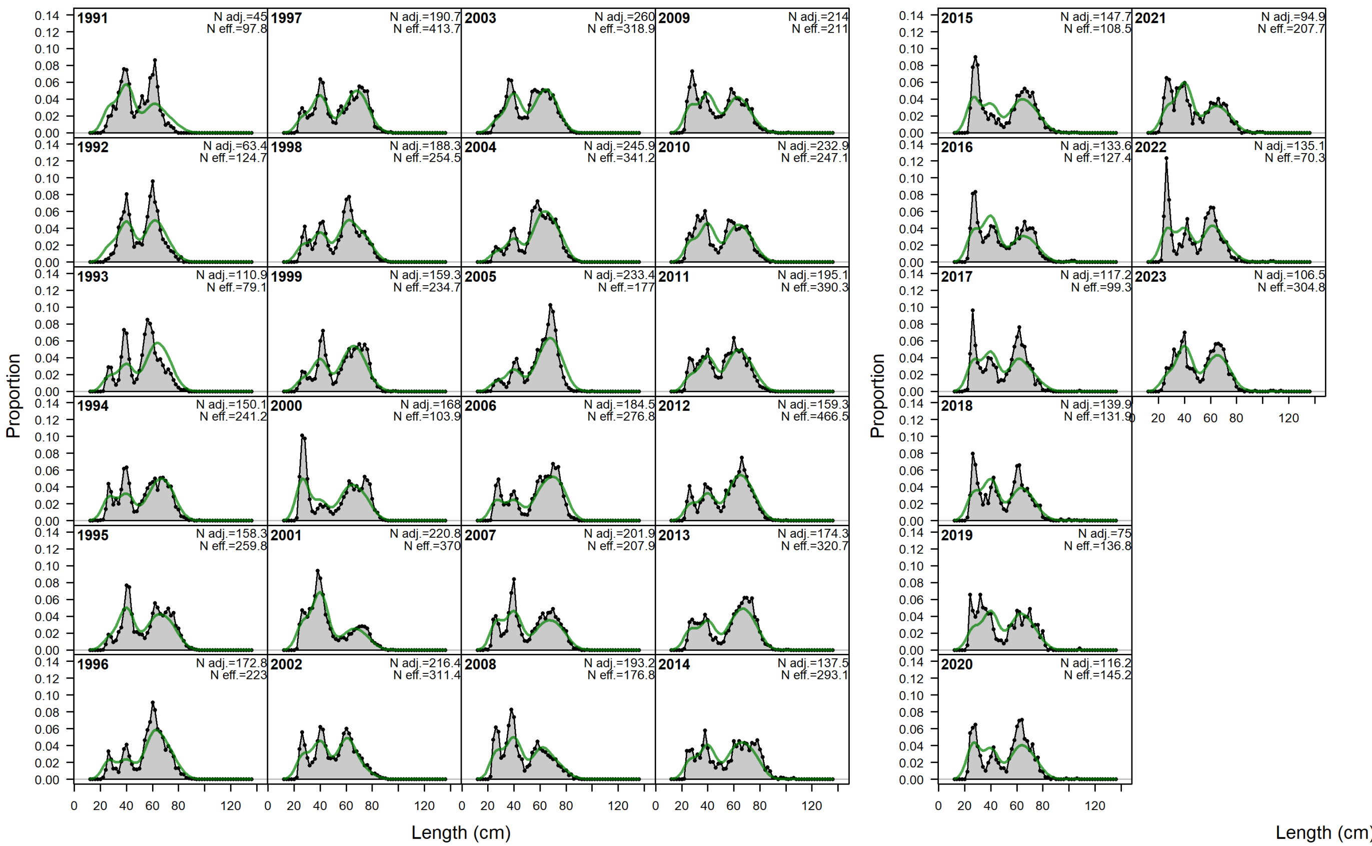


Figure 4.12 Observed (gray shaded & black line/dots) and predicted (green line) length compositions for the trammel net sub-adult survey. N. adi. represents the input effective sample size (number of trips sampled) and N eff. represents the model estimate of effective sample size after Francis re-weighting.

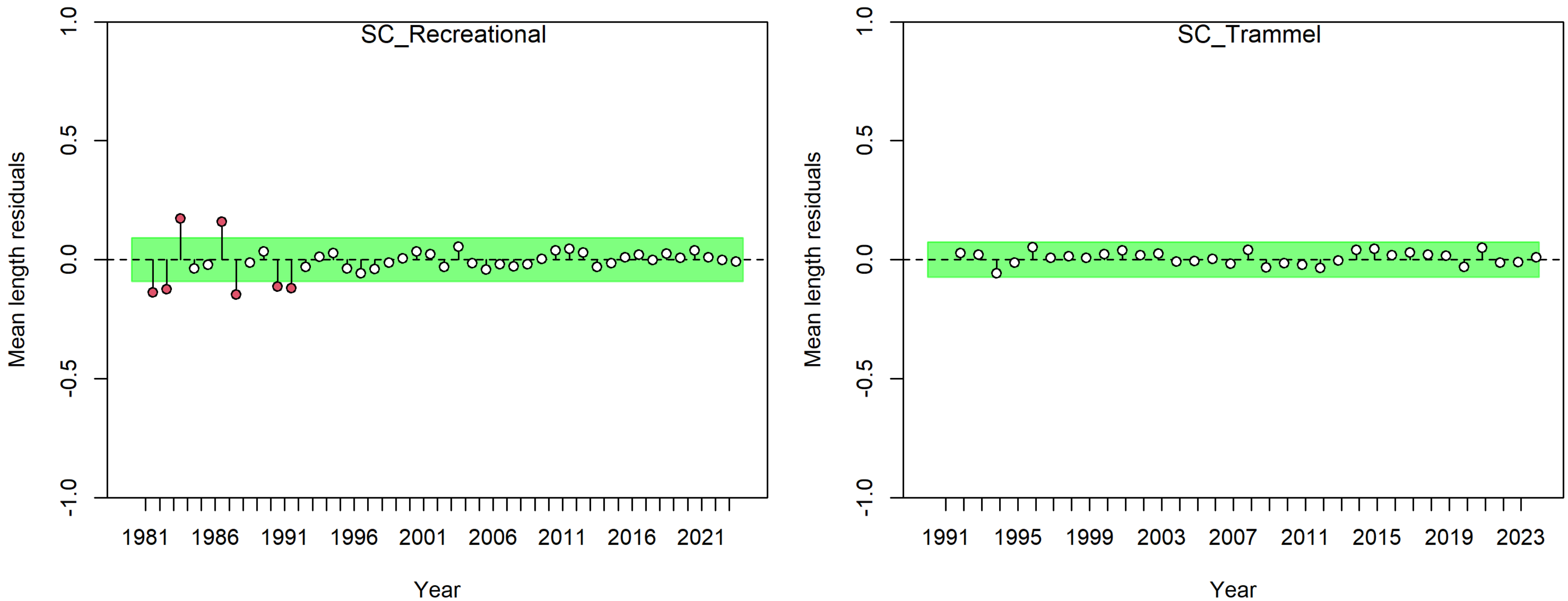


Figure 4.13 The standardized residuals on a runs test plot for the recreational fleet length composition (top panel) and trammel net sub-adult survey length composition (bottom panel). Green shading indicates no evidence (α > 0.05) to reject the hypothesis of a randomly distributed time series of residuals. The shaded (green) area spans three residual standard deviations to either side from zero and the red points outside the shading violate the 'three-sigma limit' for that series.

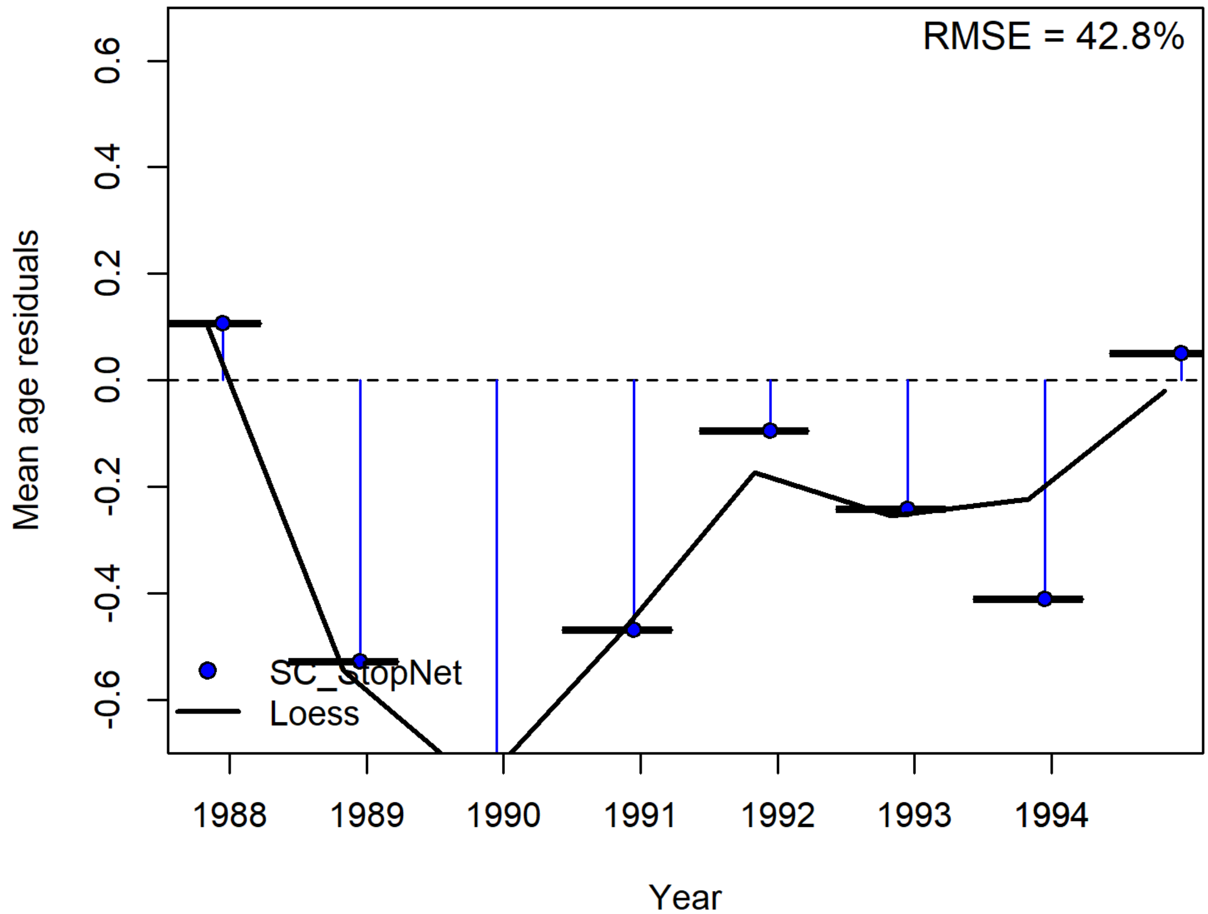


Figure 4.14 Joint residual plot for stop net sub-adult survey age compositions. Each point with lines indicates the residuals from that survey in that given year. The black line is a loess smoother through the residuals and root-mean squared error (RMSE) is provided in the upper right corner.

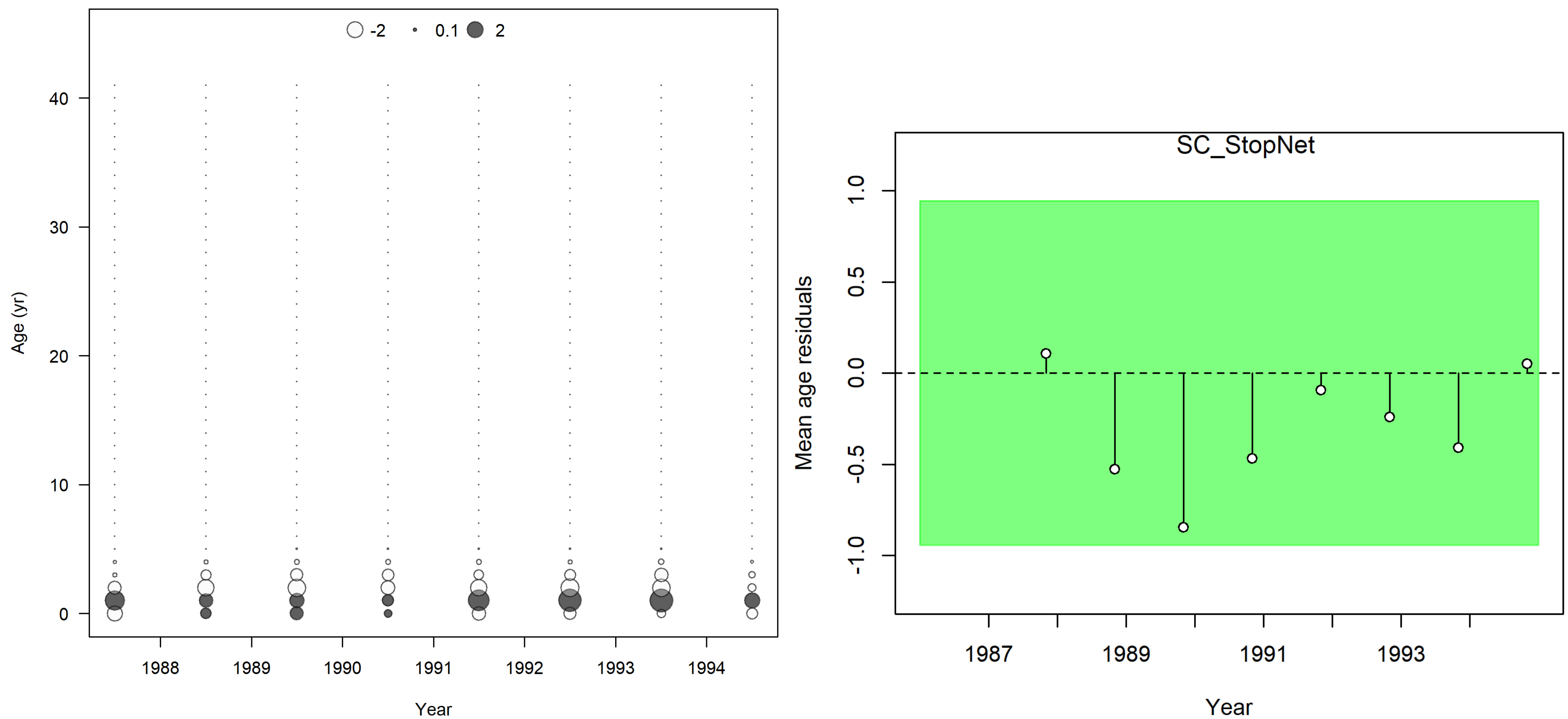


Figure 4.15 Pearson residuals from the fit to the stop net sub-adult age composition data (left panel) and the standardized residuals on a runs test plot (right panel). Closed bubbles represent positive Pearson residuals (observed>expected) and open bubbles represent negative residuals (observed<expected). Green shading indicates no evidence (α > 0.05) to reject the hypothesis of a randomly distributed time series of residuals. The shaded (green) area spans three residual standard deviations to either side from zero and the red points outside the shading violate the 'three-sigma limit' for that series.

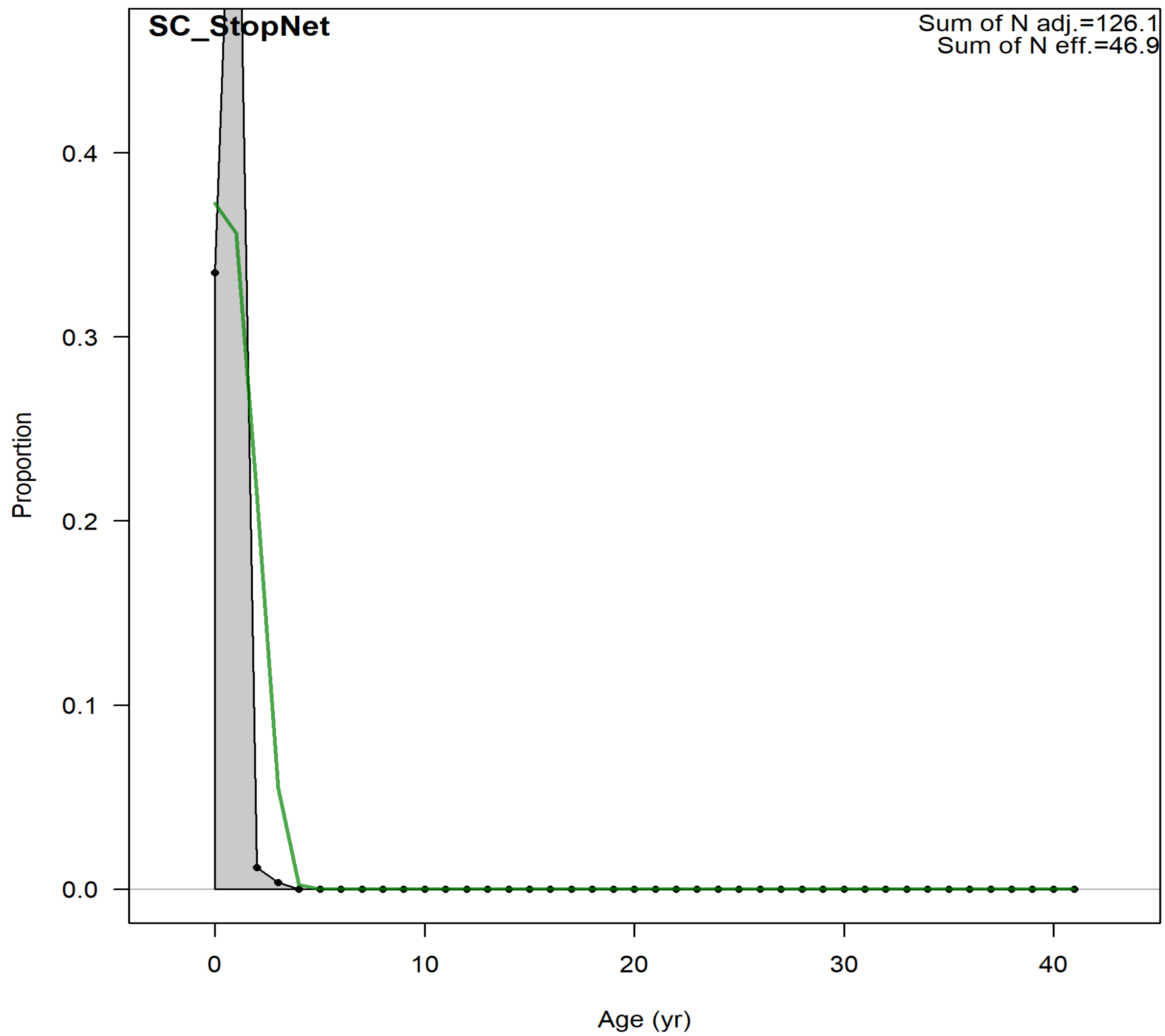


Figure 4.16 Age composition, aggregated across time for the stop net survey.

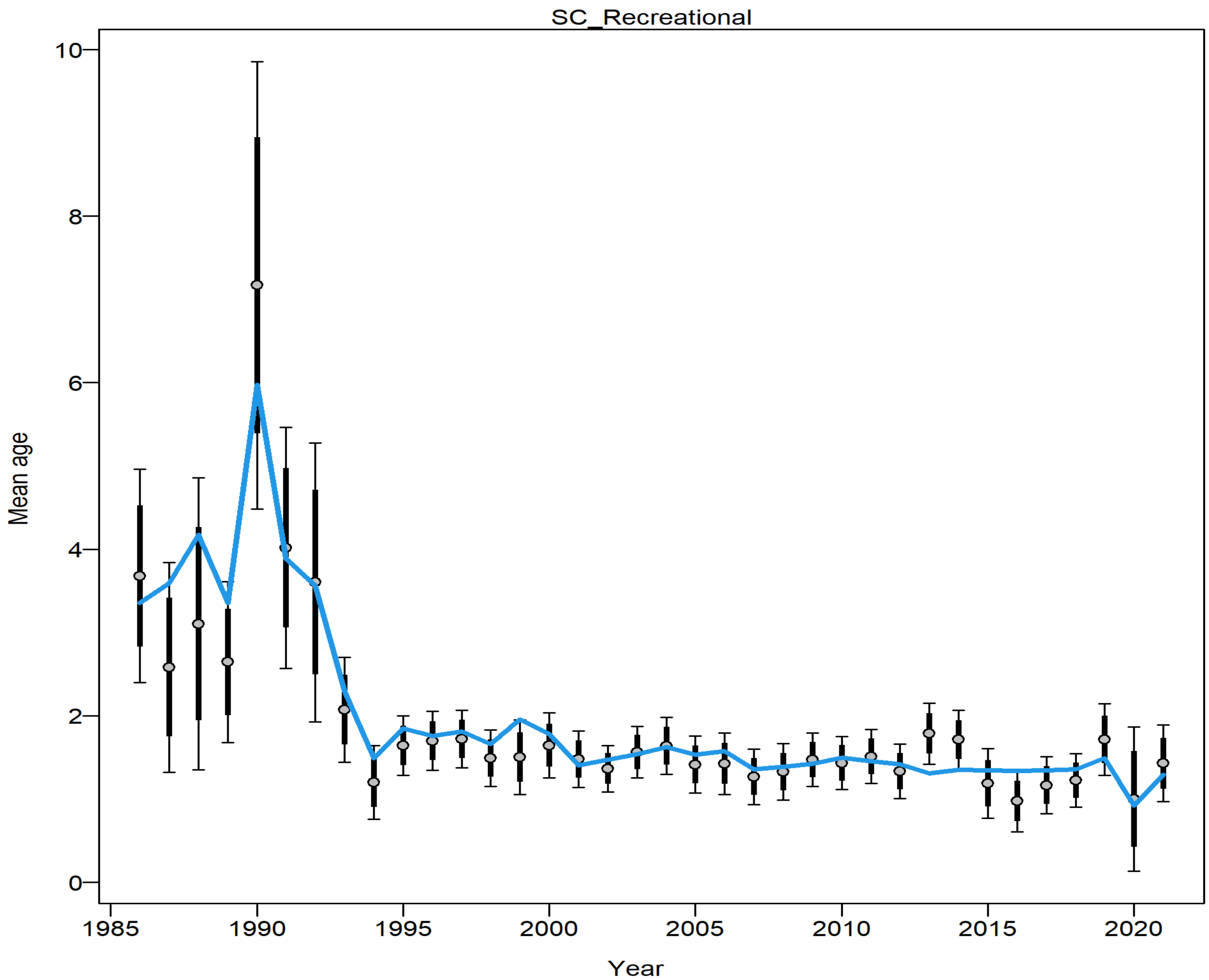


Figure 4.17 Observed (black dots; 95% CI error bars) and model estimated (blue line) mean age from the recreational fleet conditional age-at-length data.

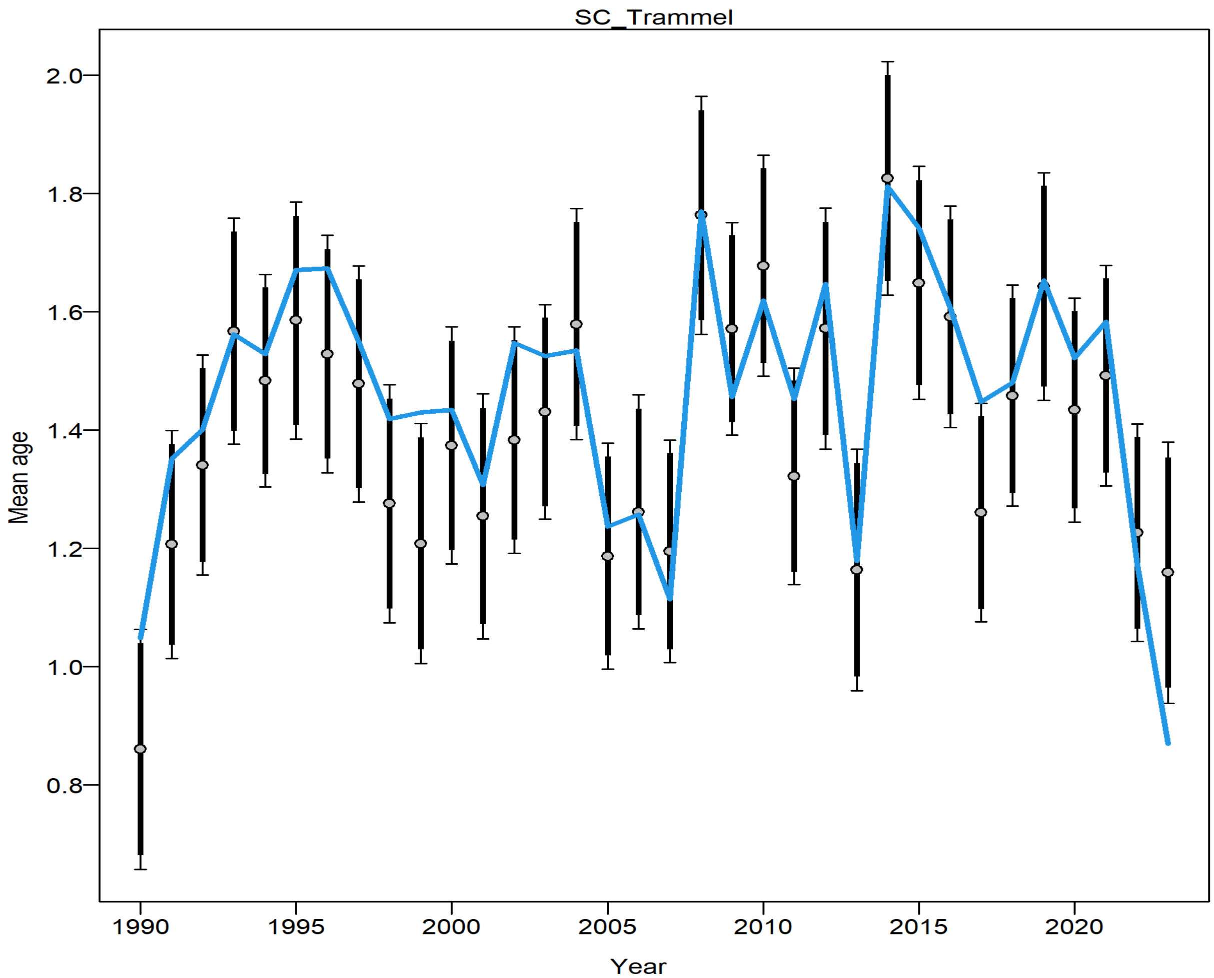


Figure 4.18 Observed (black dots; 95% CI error bars) and model estimated (blue line) mean age from the conditional age-at-length data for the trammel net sub-adult survey.

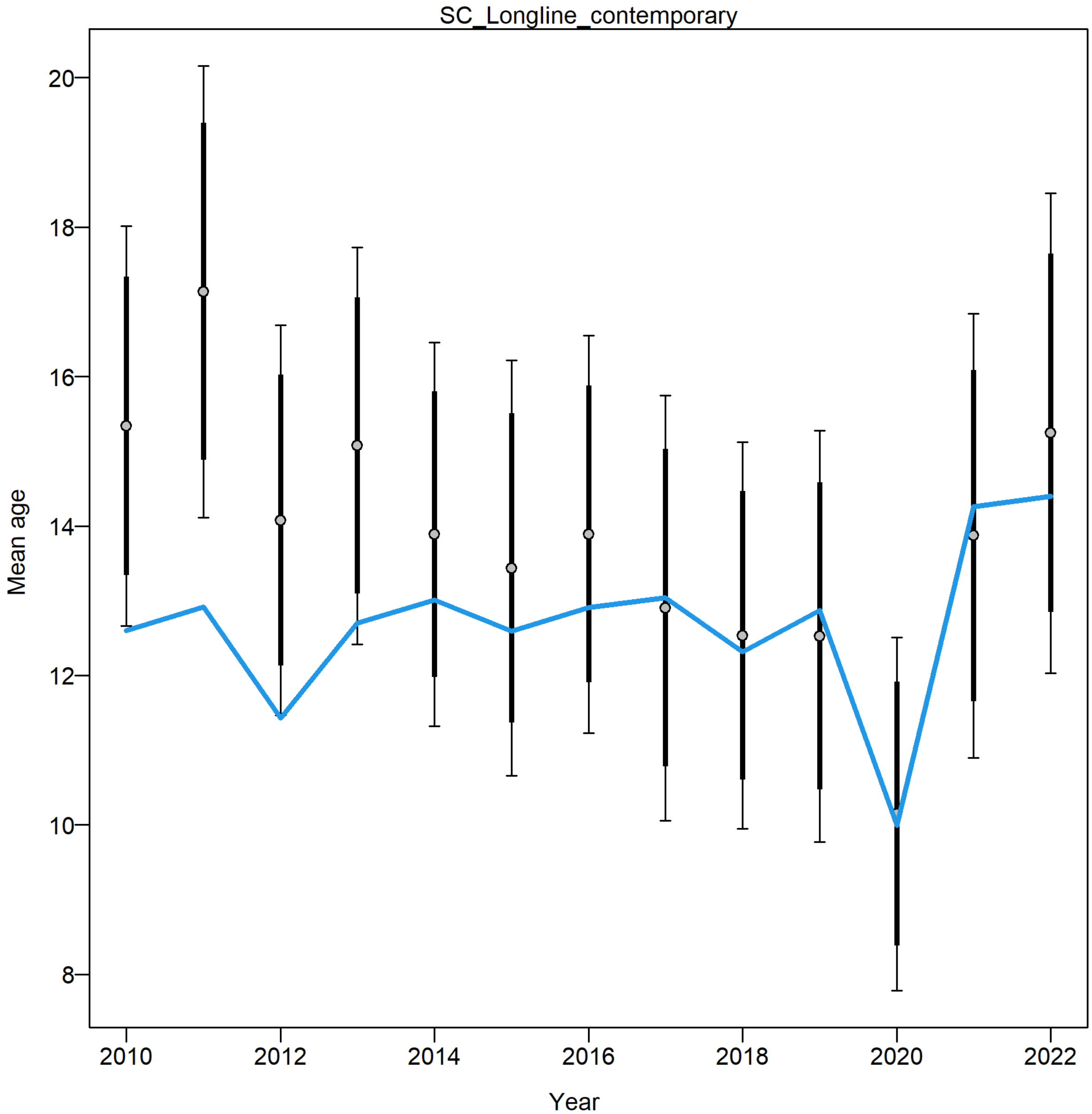


Figure 4.19 Observed (black dots; 95% CI error bars) and model estimated (blue line) mean age from the conditional age-at-length data for the longline adult survey.

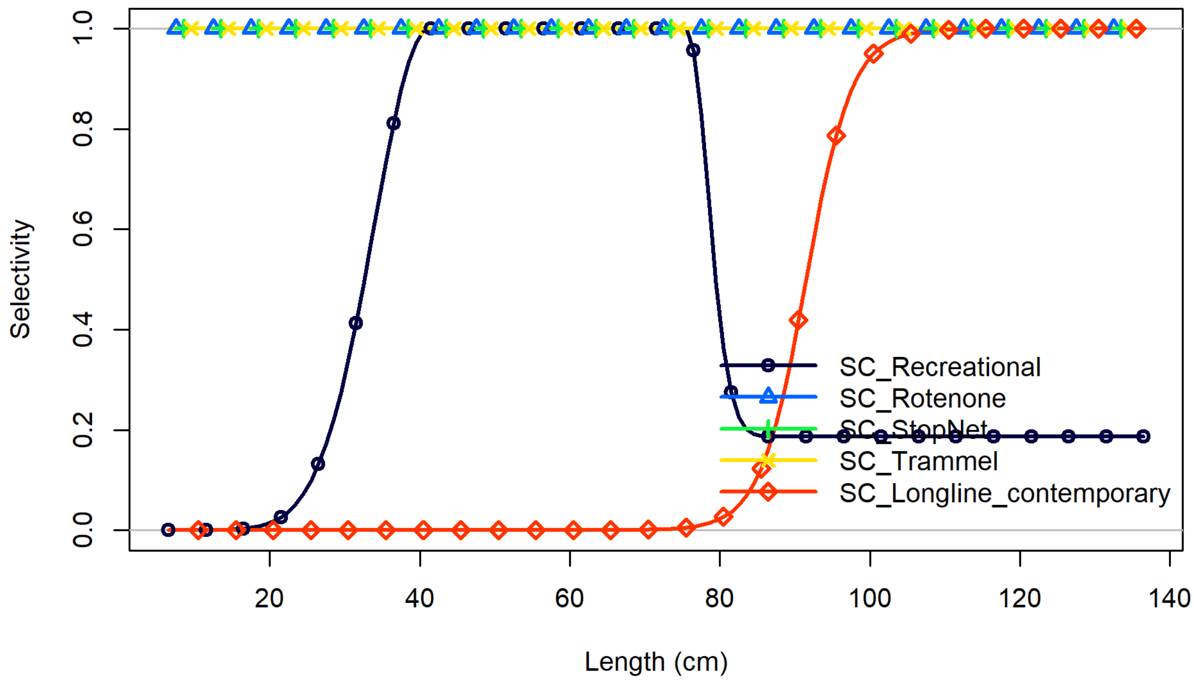


Figure 4.20 Length based selectivities for the SC sub-stock model. The longline adult survey selectivity was fixed.

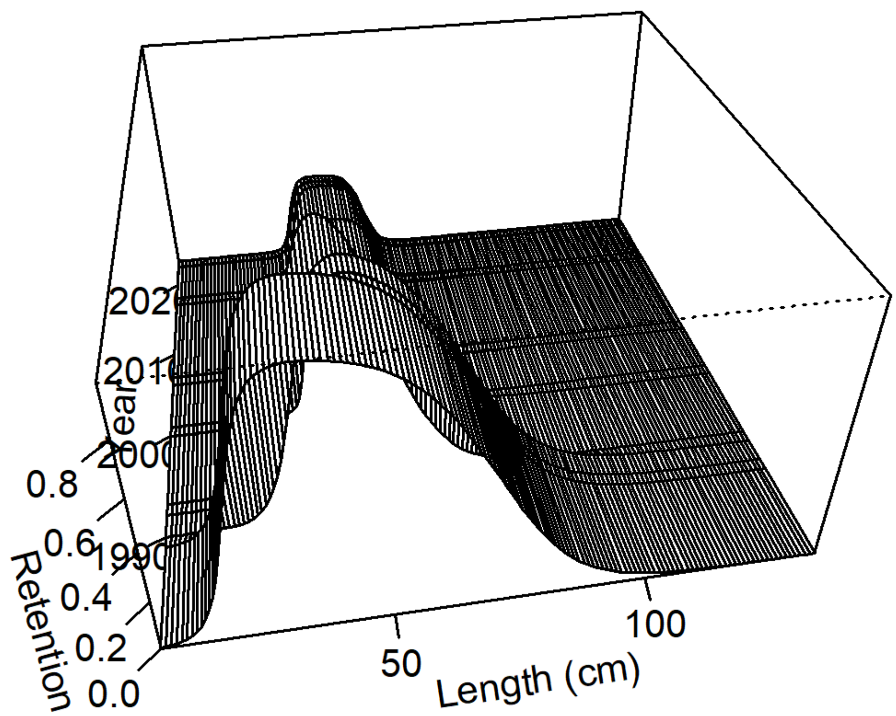


Figure 4.21 Retention estimates, by regulatory period, for the recreational fleet.

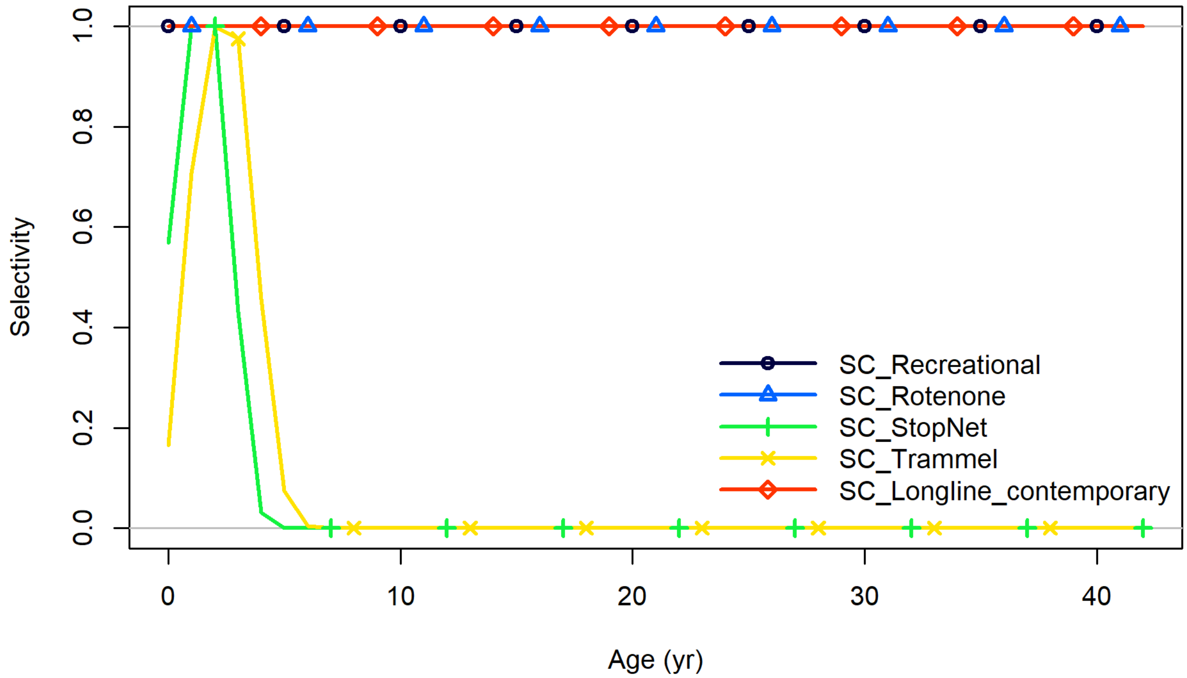


Figure 4.22 Age based selectivities estimated for the stop net and trammel net sub-adult surveys.

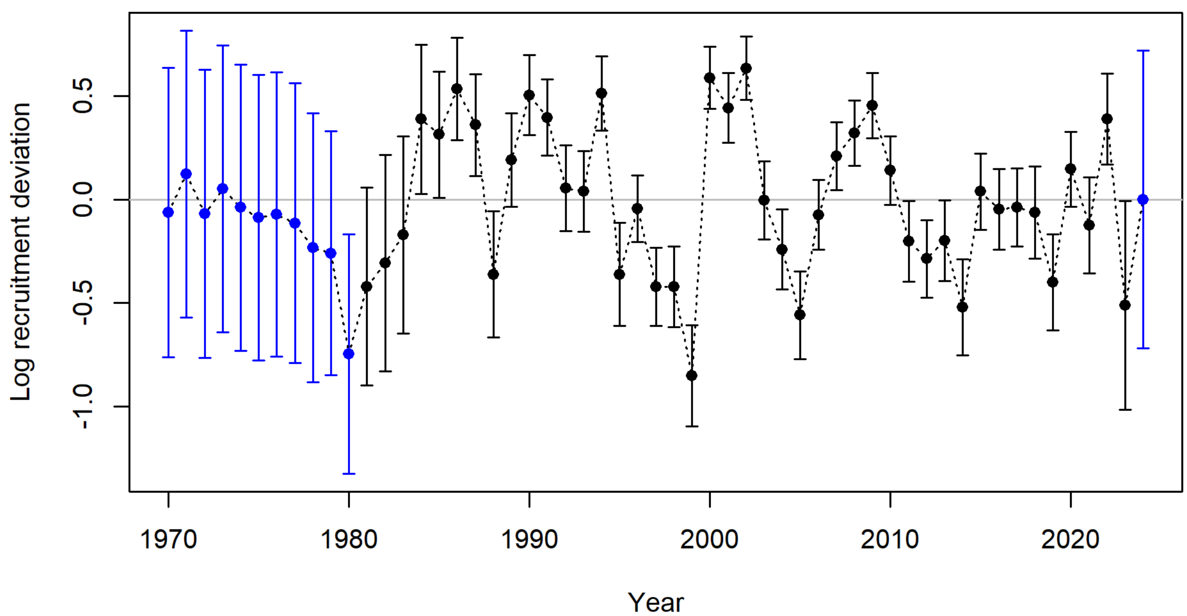


Figure 4.23 Recruitment deviations, with 95% confidence intervals from asymptotic standard errors.

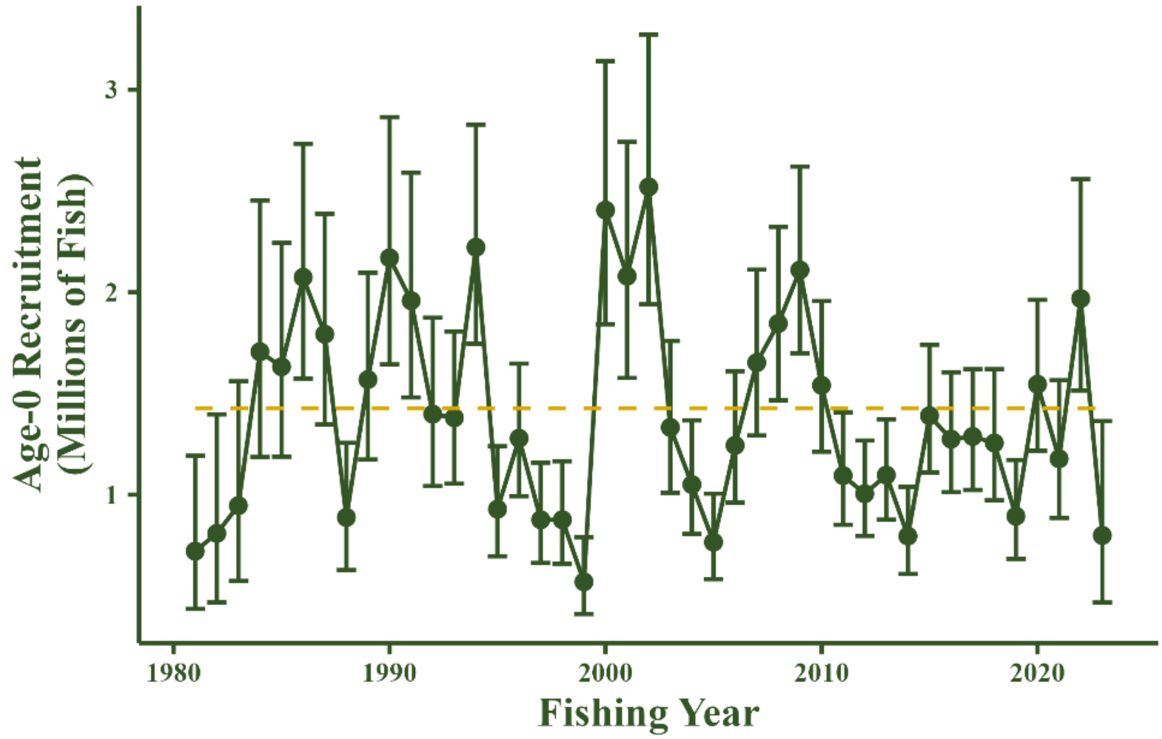


Figure 4.24 Estimated recruitment (in millions of age-0 fish). Error bars are 95% confidence intervals based on asymptotic standard errors.

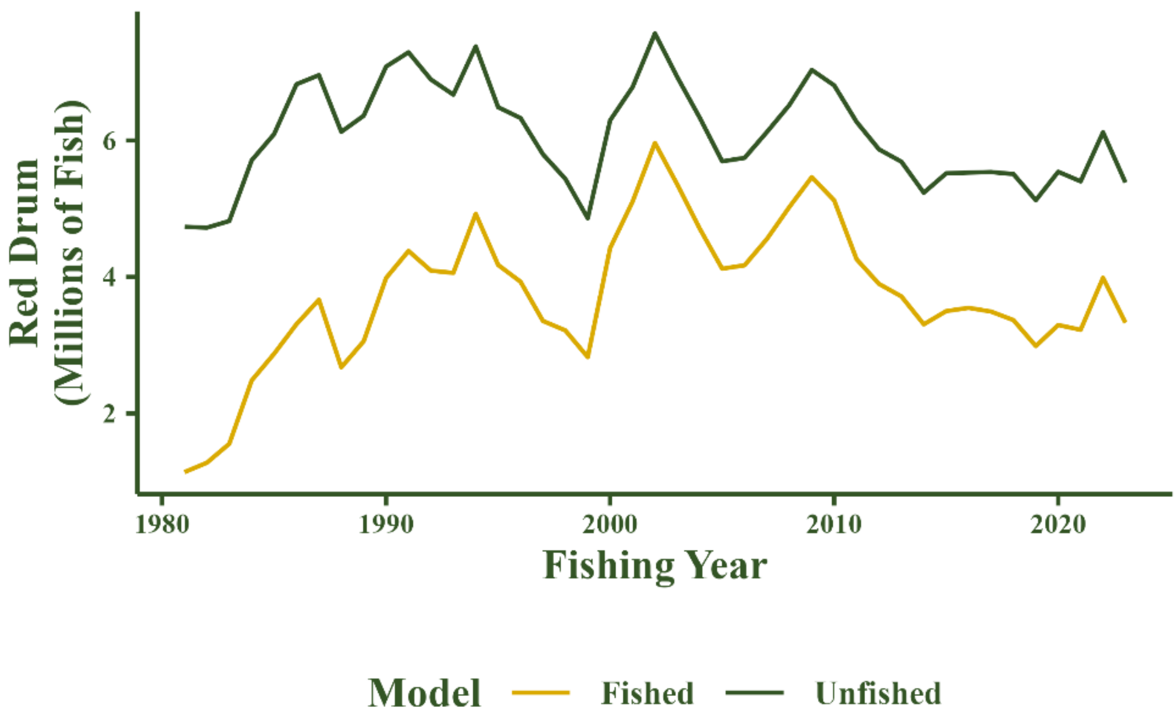


Figure 4.25 Estimated population abundance (in millions of fish) for both unfished (yellow) and fished (yellow) conditions based on estimated recruitment.

Figure 4.26 Estimated female SSB relative to the estimated $SSB_{30\%}$ threshold. Error bars are 95% confidence intervals based on asymptotic standard errors.

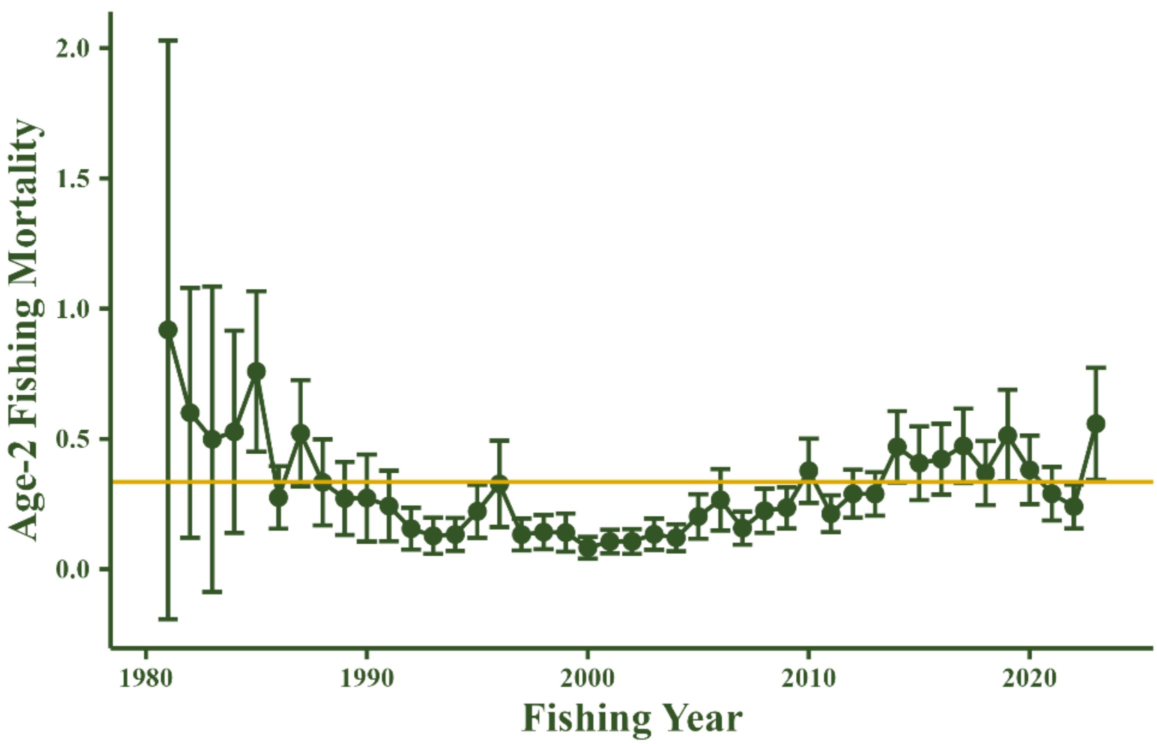


Figure 4.27 Total age-2 fishing mortality (*F*). Error bars are 95% confidence intervals based on asymptotic standard errors.

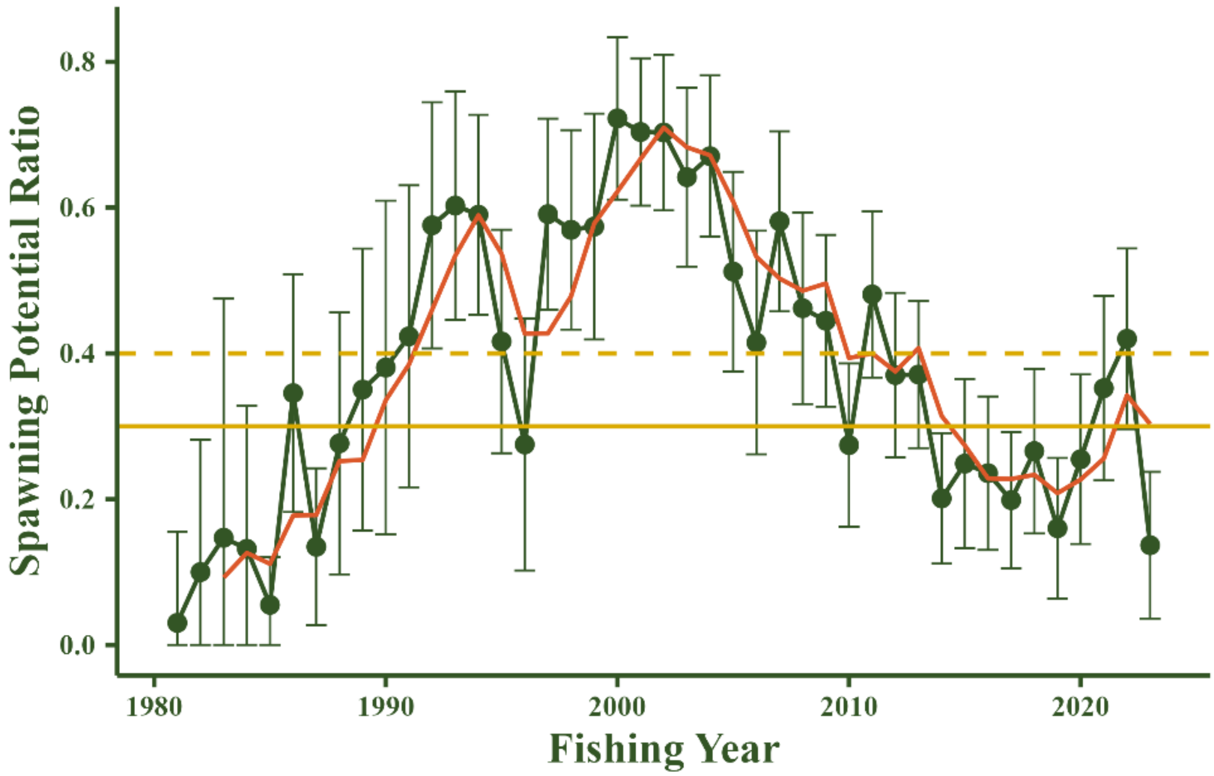


Figure 4.28 Annual (green line/dot) and 3-yr average (orange line) SPR estimates. Horizontal lines denote target ($SPR_{40\%}$; dashed line) and threshold ($SPR_{30\%}$) fishing mortality status reference points.

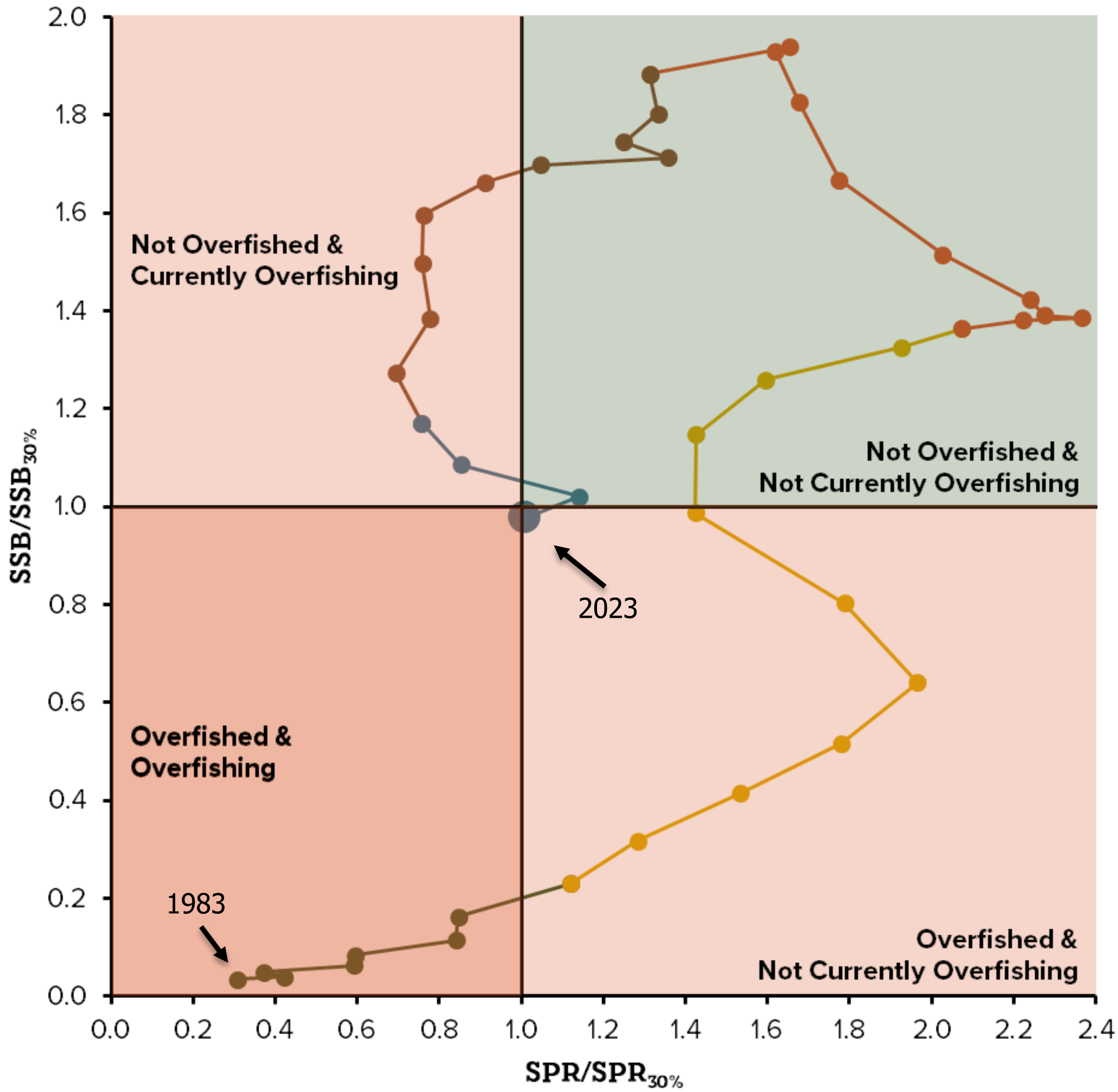


Figure 4.29 3-year average SSB relative to $SSB_{threshold}$ ($SSB_{30\%}$; y-axis) and $SPR_{threshold}$ ($SPR_{30\%}$, x-axis) as a function of fishing year (multi-color line; dots each year). Decades are represented by different line segments, with the 3-yr average 1983 and 2023 values identified.

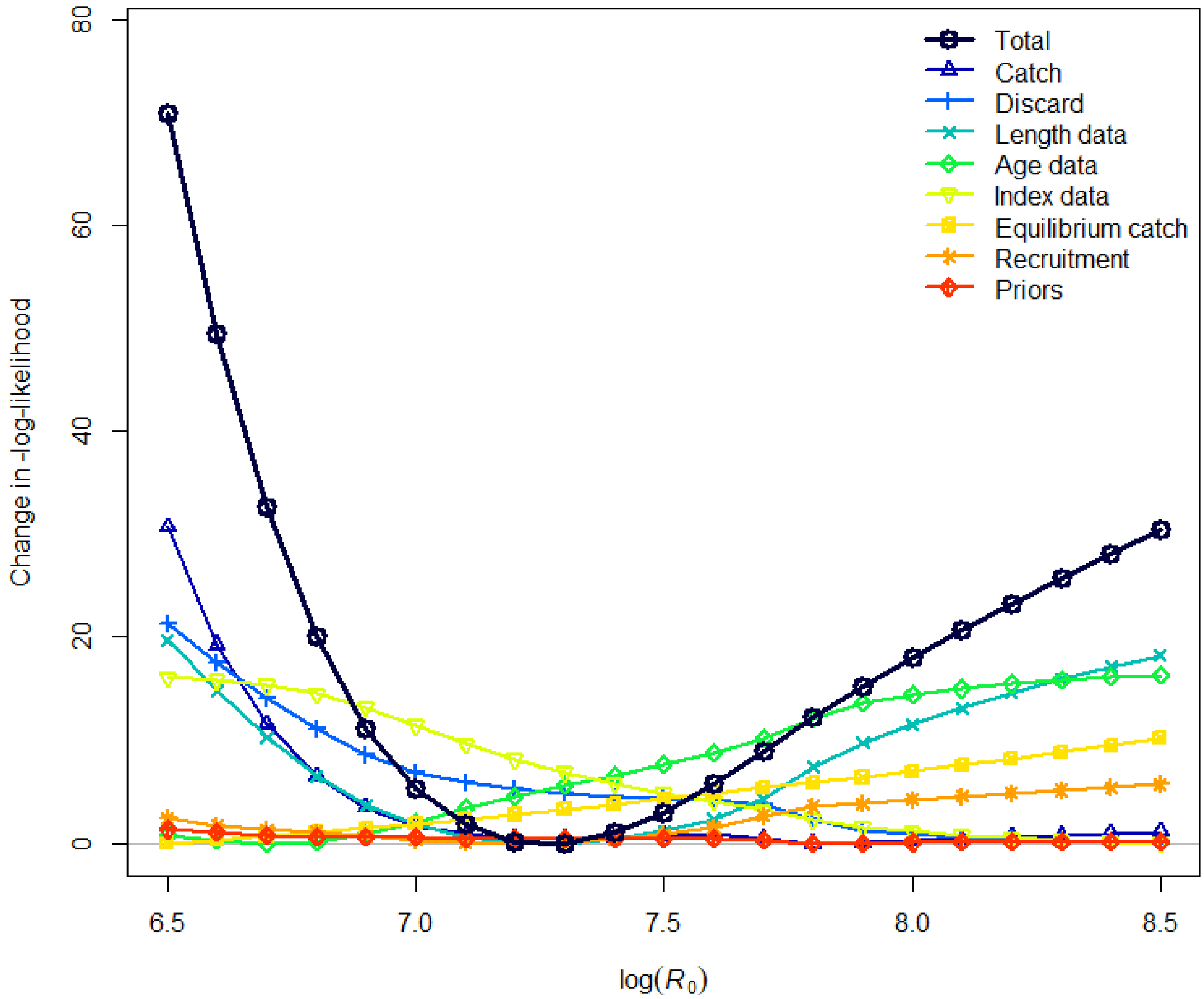


Figure 4.30 Likelihood profile plot for unfished recruitment (R_0) parameter (on the log scale).

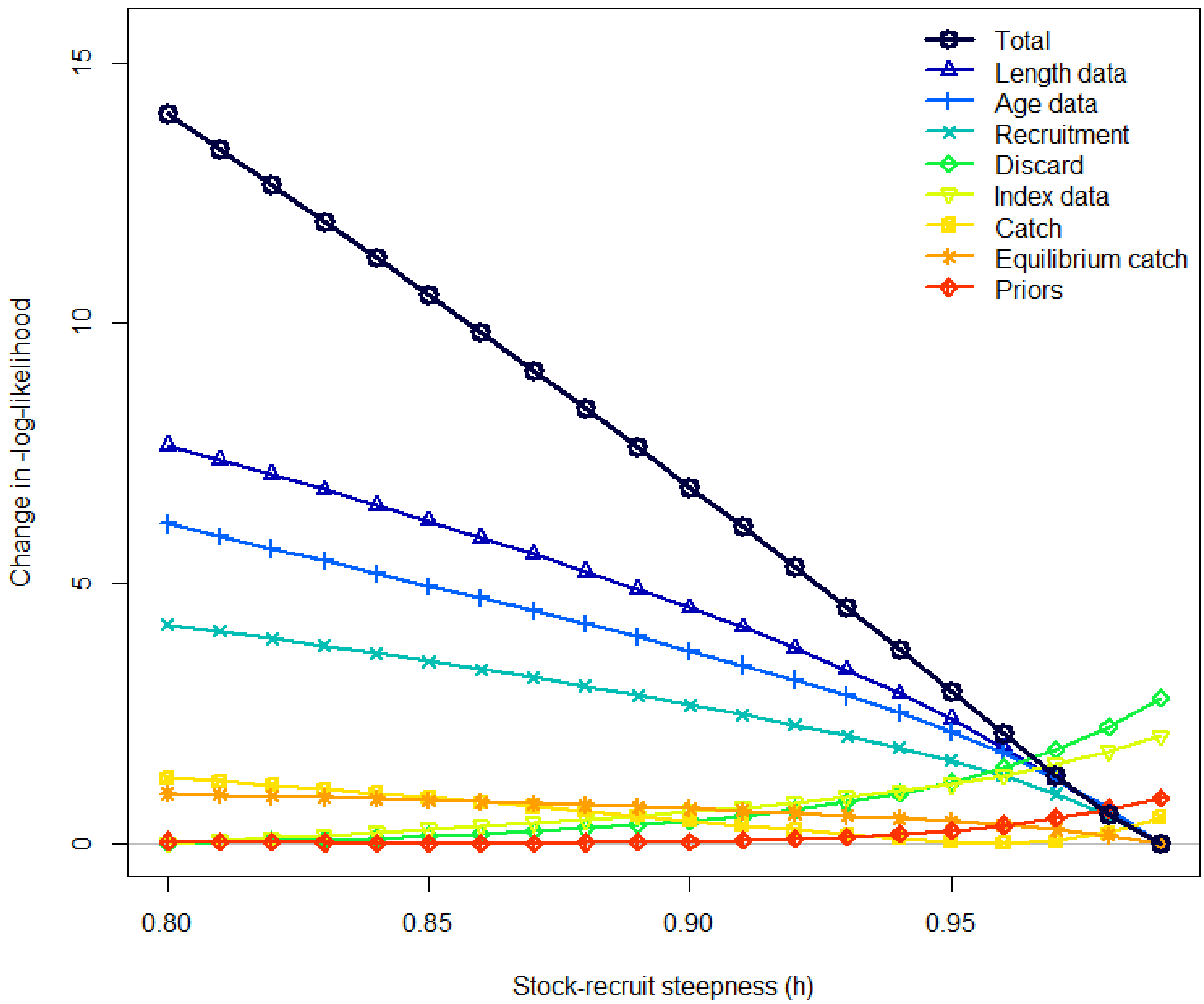


Figure 4.31 Likelihood profile plot for unfished steepness parameter (on the log scale).

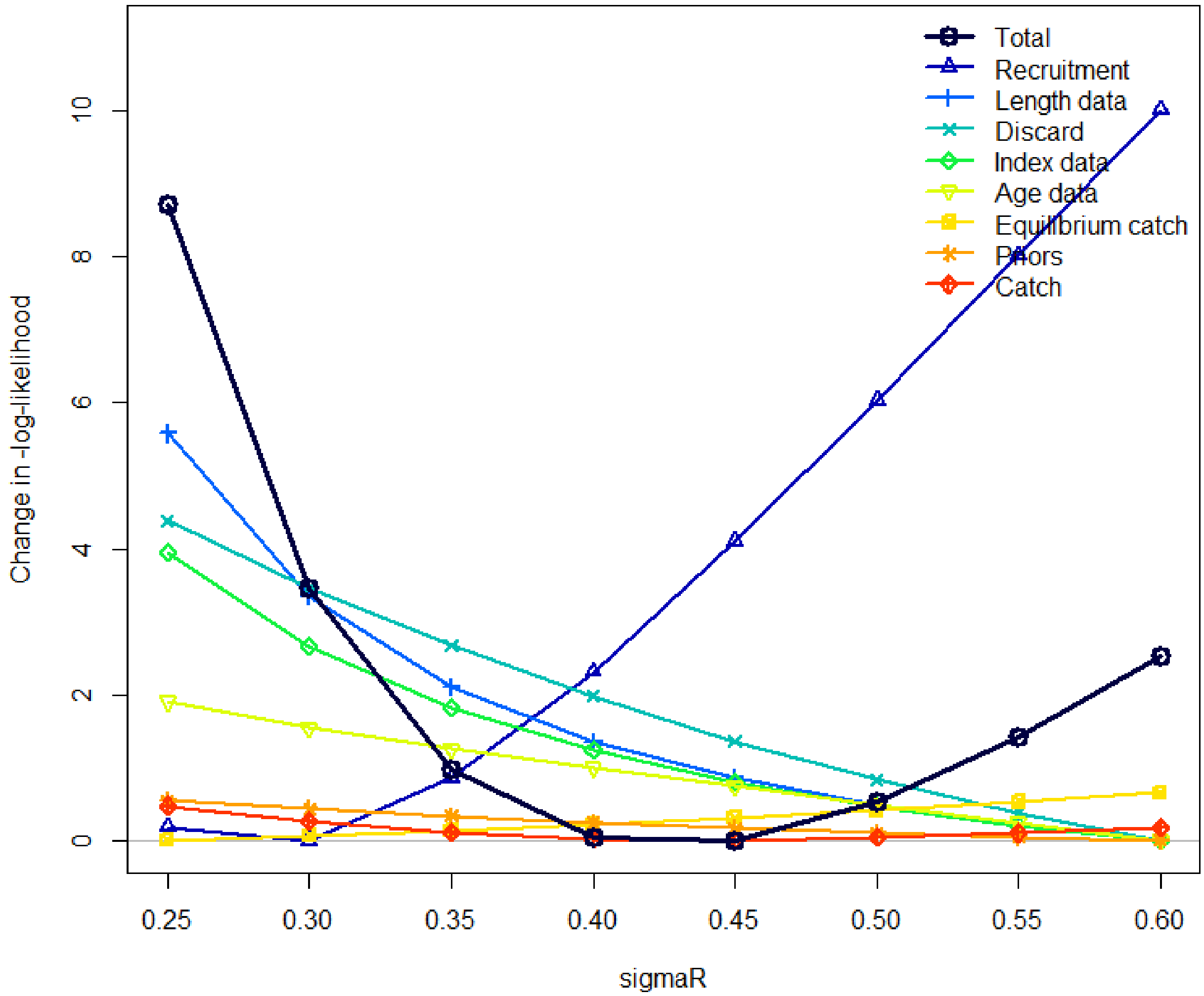
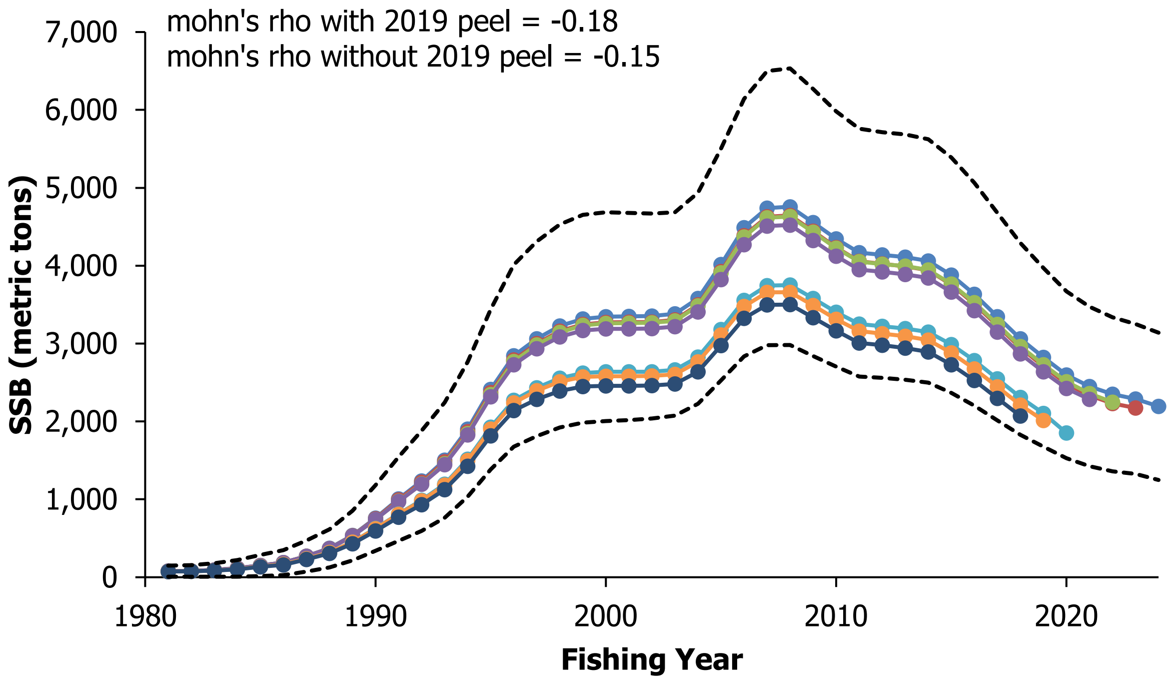


Figure 4.32 Likelihood profile plot for unfished σ_R (on the log scale).



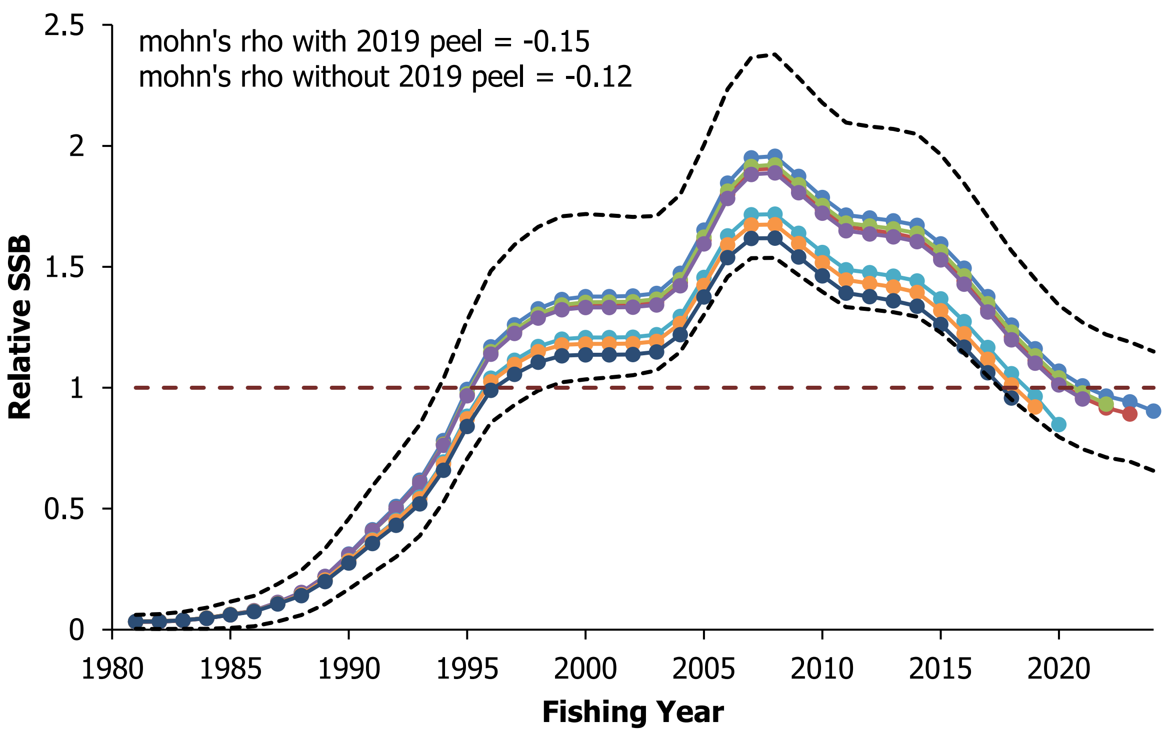


Figure 4.33 Spawning stock biomass and relative spawning stock biomass estimates from retrospective analysis. Black dashed lines are 95% confidence intervals based on asymptotic standard errors. For the relative SSB, the dashed red horizontal line is the relative $SSB_{threshold}$.

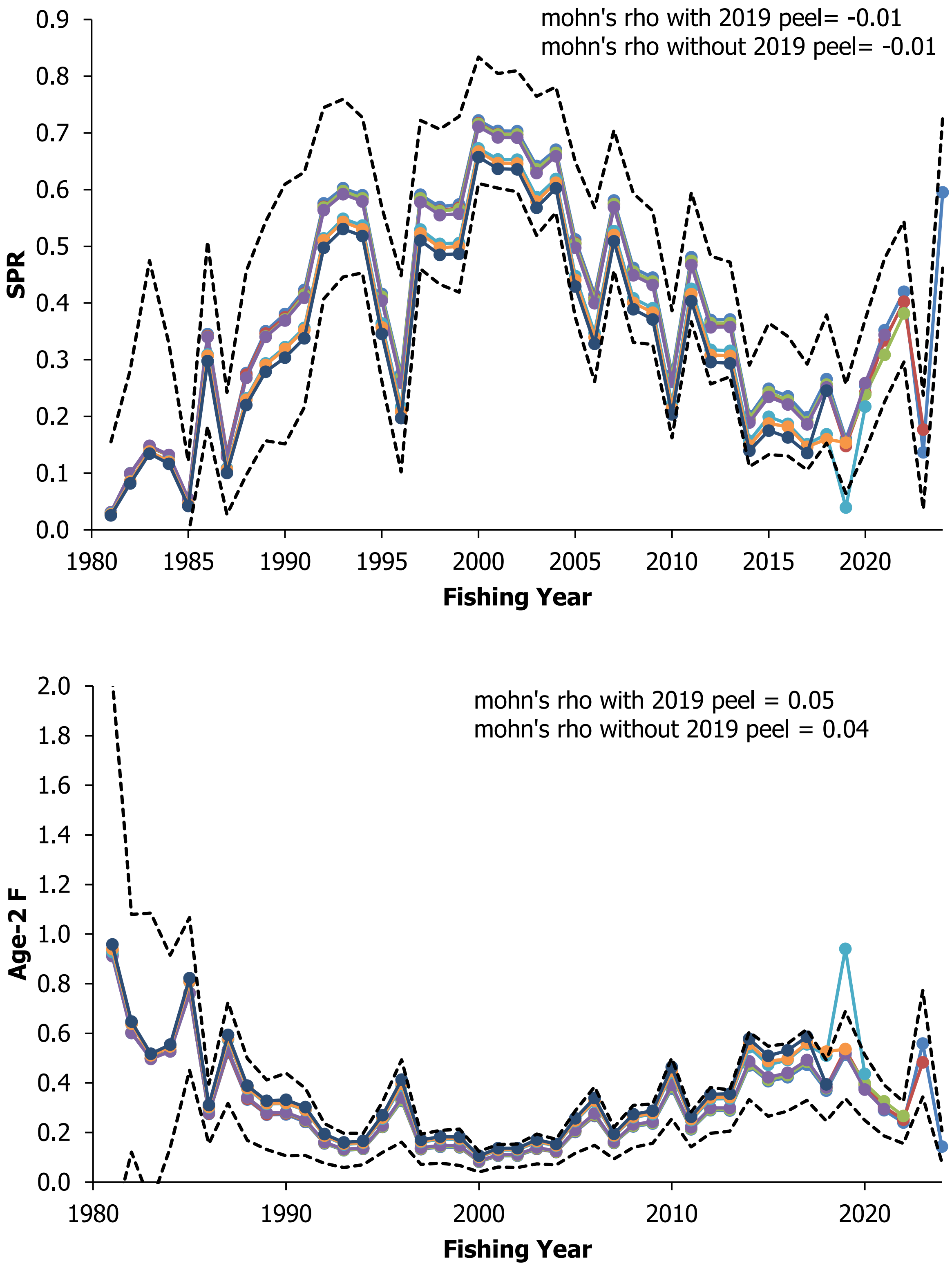
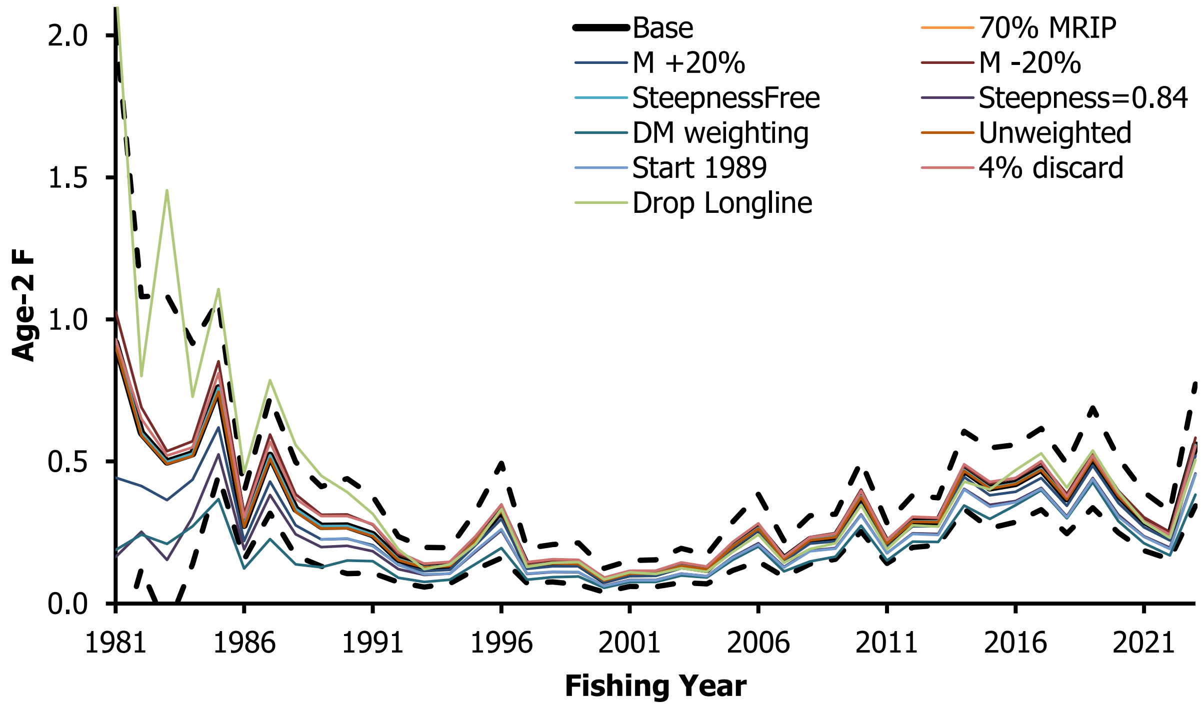


Figure 4.34 Spawning potential ratio (top) and age-2 fishing mortality (bottom) estimates from retrospective analysis. Black dashed lines are 95% confidence intervals based on asymptotic standard errors for based model estimates.



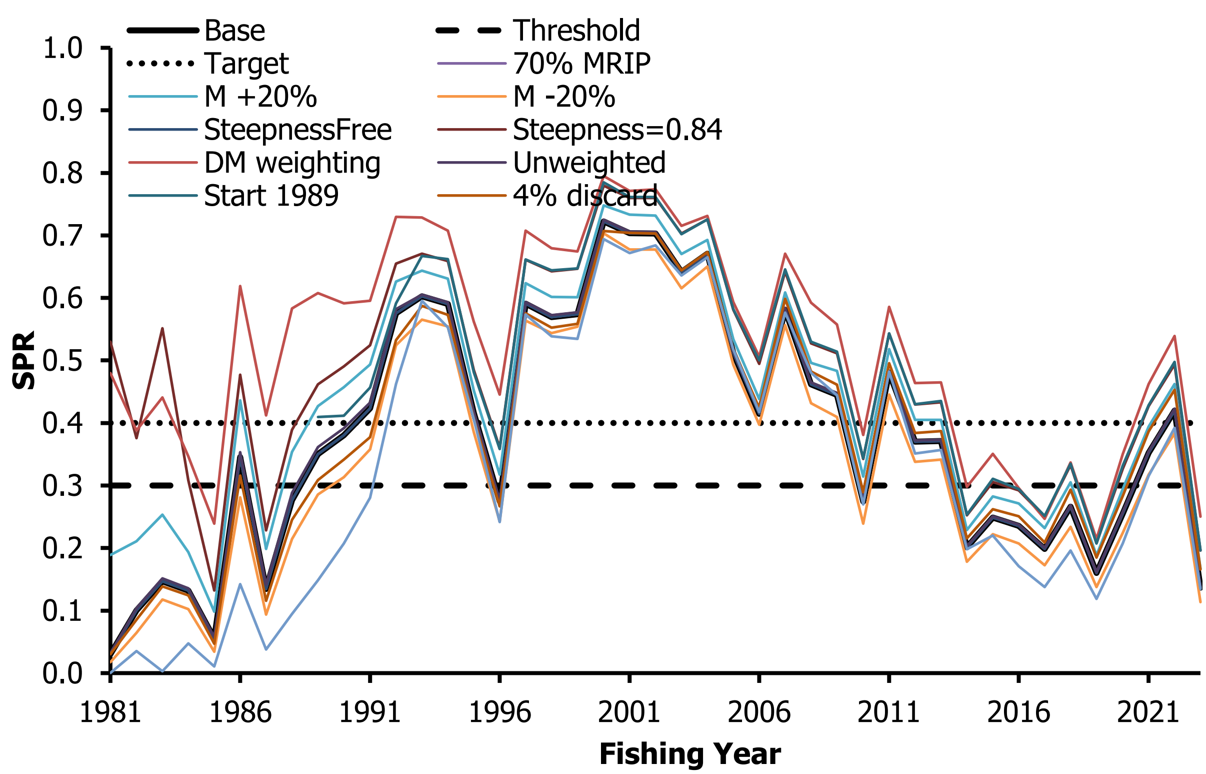


Figure 4.35 Age-2 fishing mortality (top) and spawning potential ratio (bottom) estimates from sensitivity analysis. For Age-2 *F*, the black dashed lines are 95% confidence intervals based on asymptotic standard errors for base model estimates. For SPR, the black dashed horizontal line is the $SPR_{threshold}$ and the dotted black horizontal line is the SPR_{target}.

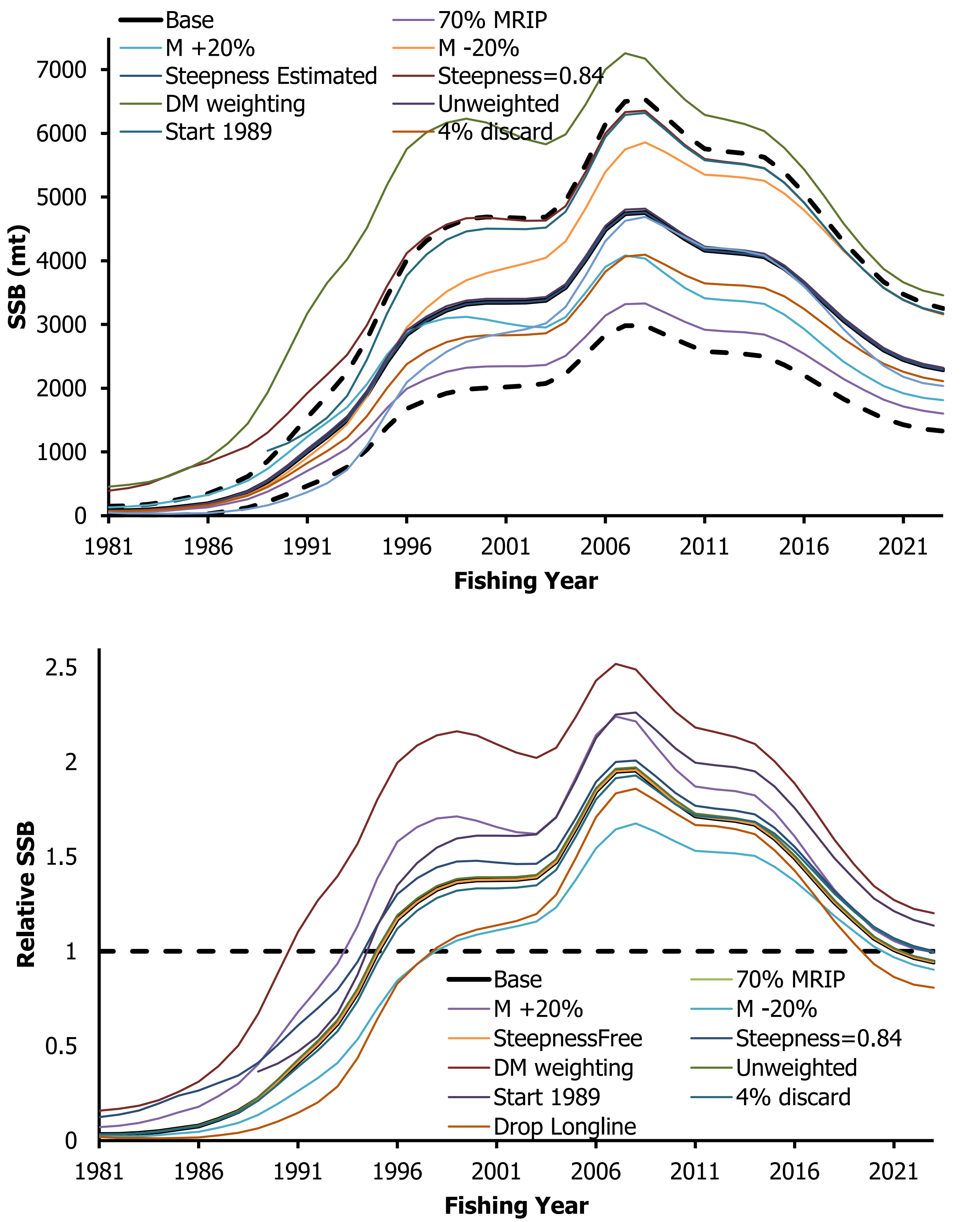


Figure 4.36 Spawning stock biomass (top) and relative spawning stock biomass (bottom) estimates from sensitivity analysis. For the SSB, the black dashed lines are 95% confidence intervals based on asymptotic standard errors. For the relative SSB, the dashed black horizontal line is the relative $SSB_{threshold}$.

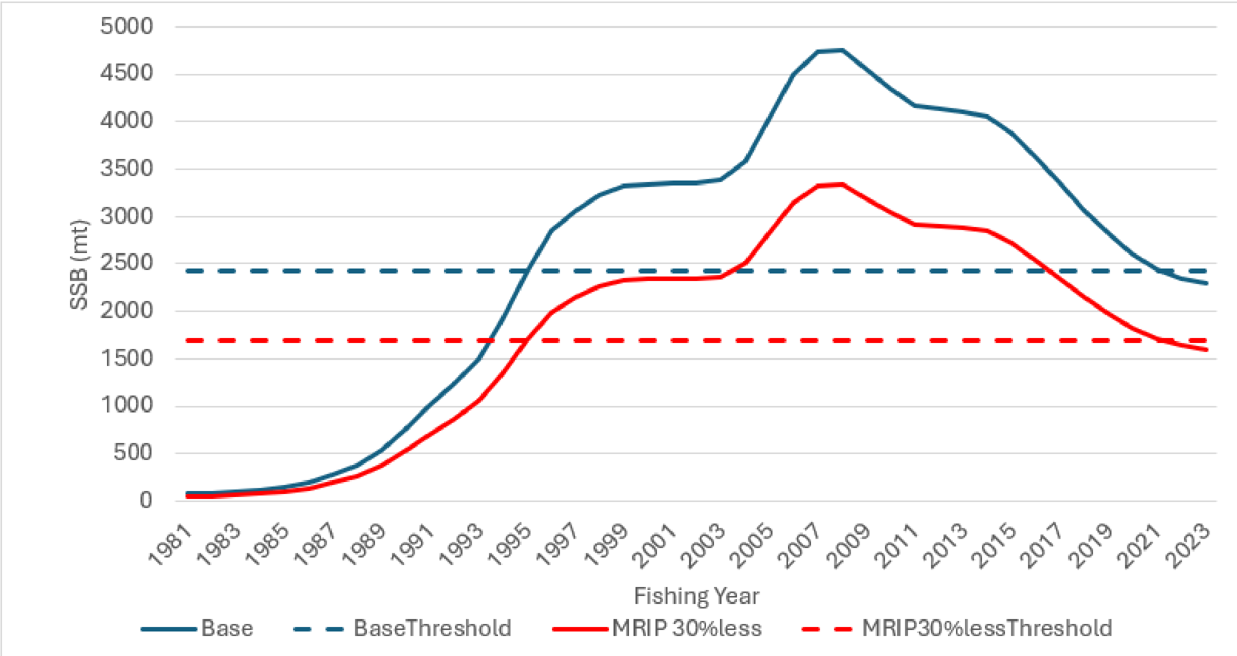


Figure 4.37 Spawning stock biomass estimates from the base SC sub-population model and 70% MRIP sensitivity analysis with corresponding threshold for each run. The dotted horizontal line is the relative $SSB_{threshold}$ for each model run (Base versus MRIP 30% less).

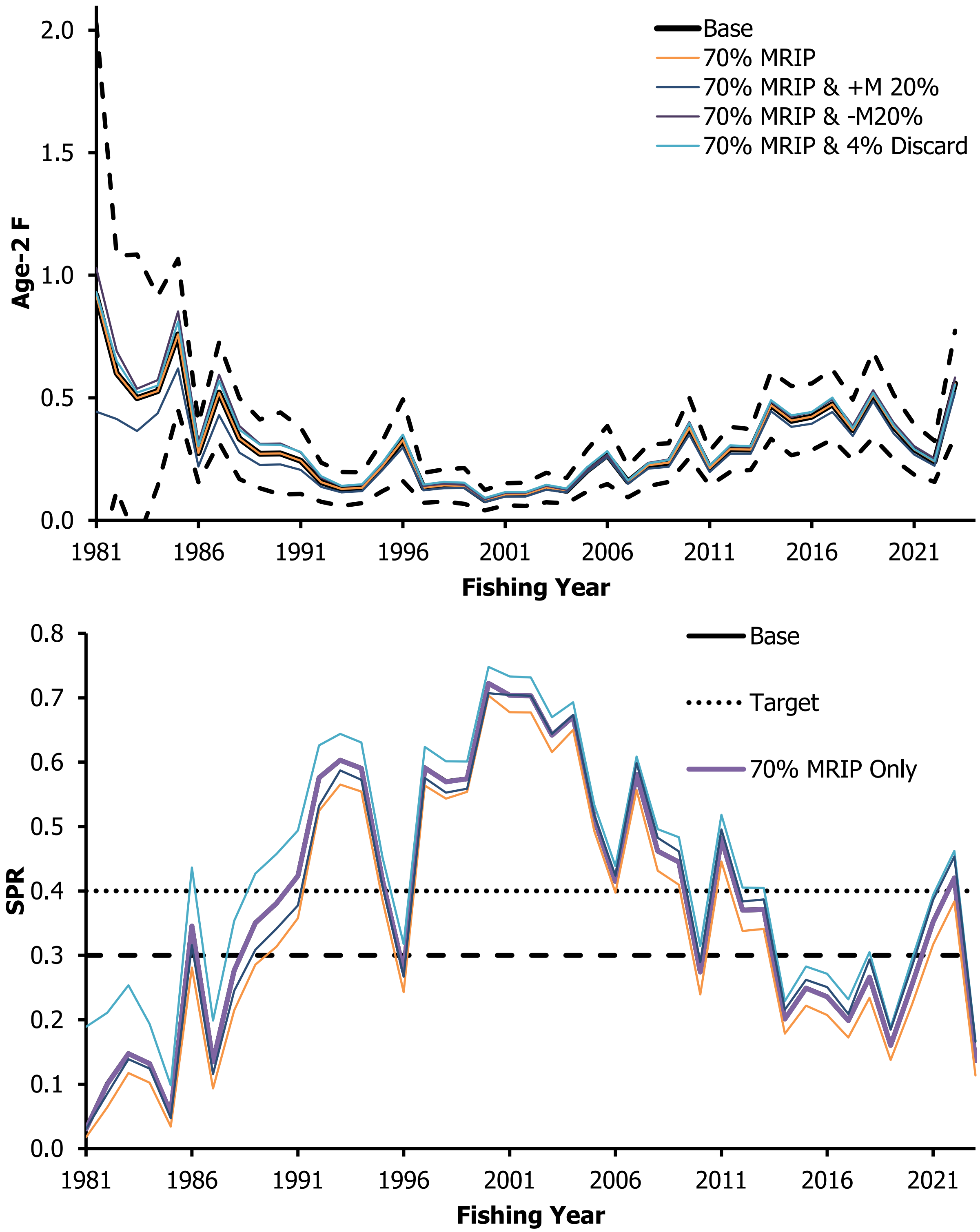


Figure 4.38 Age-2 fishing mortality (top) and spawning potential ratio (bottom) estimates from combining mortality sensitivity analyses. Black dashed lines are 95% confidence intervals based on asymptotic standard errors for base model estimates. The dashed and dotted black horizontal line is the $SPR_{threshold}$ and SPR_{target}.

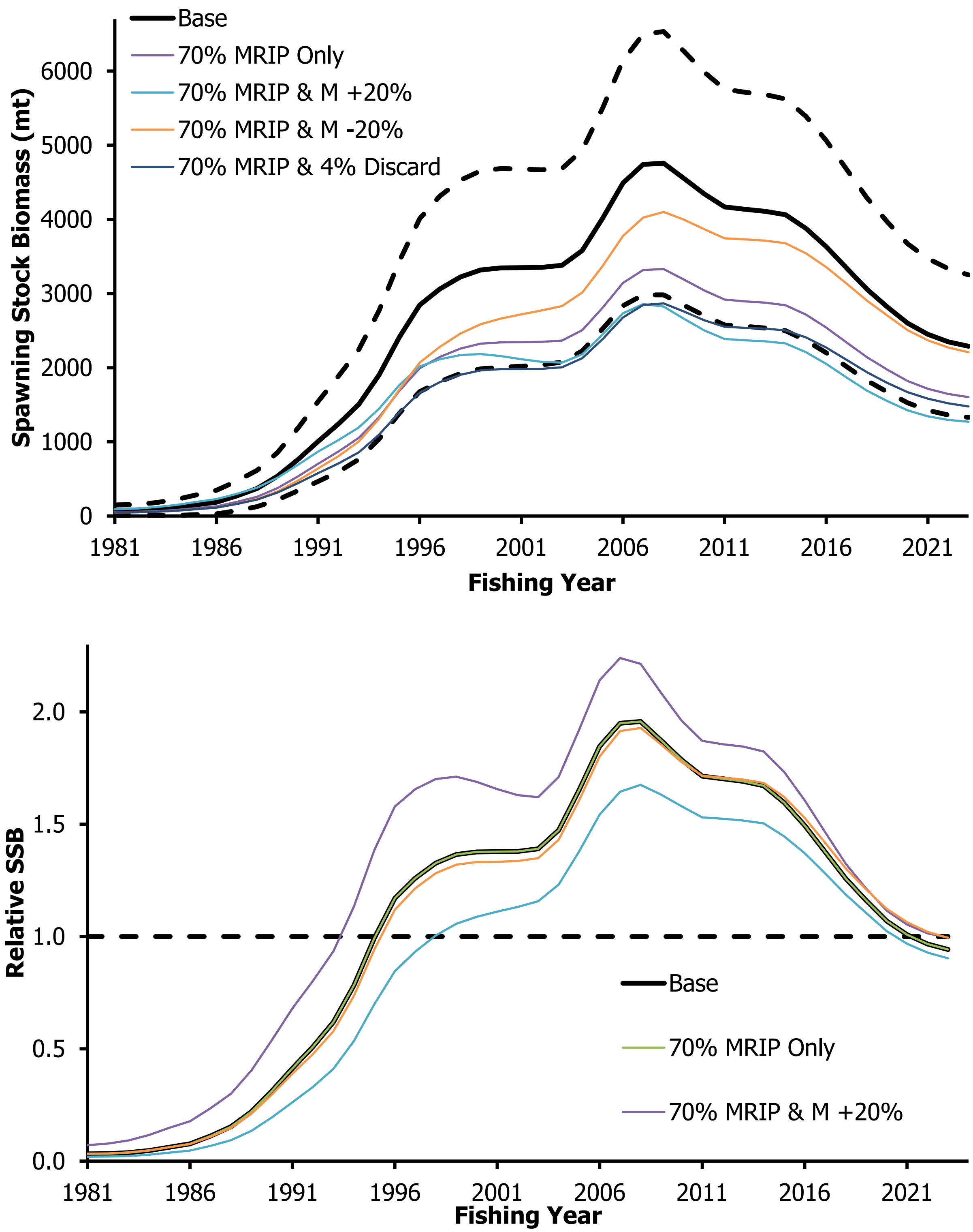
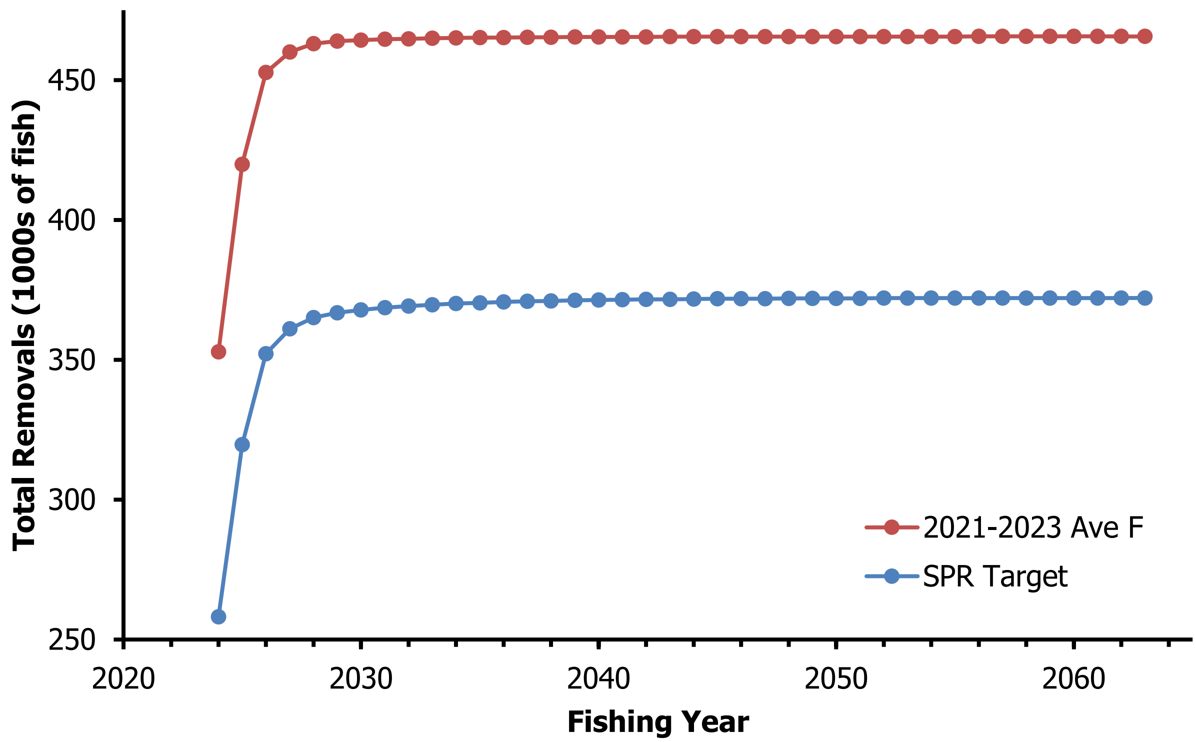


Figure 4.39 Spawning stock biomass (top) and relative spawning stock biomass (bottom) estimates from combining mortality sensitivity analysis. Top - black dashed lines are 95% confidence intervals based on asymptotic standard errors for base model estimates. Bottom - the dotted black line is the relative $SSB_{threshold}$.



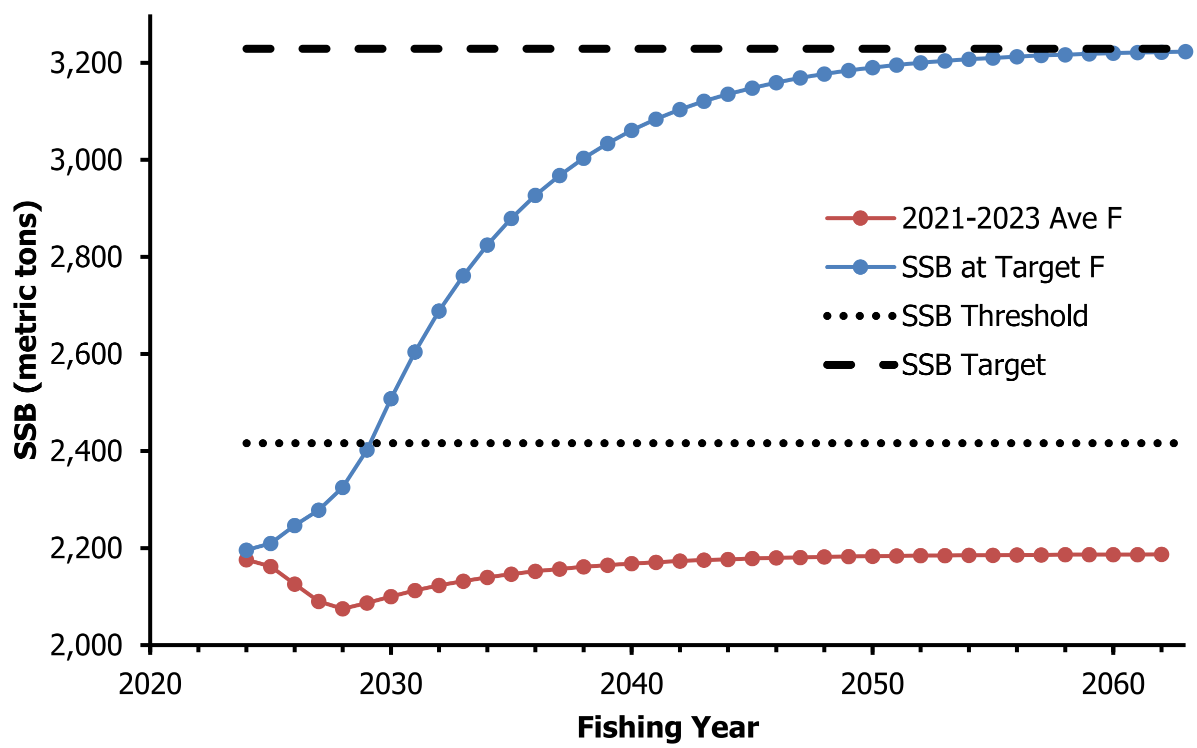


Figure 6.1 The potential future spawning potential ratio (top) and spawning stock biomass (bottom) under current *F* conditions (red line), as well as under target *F* (blue line).

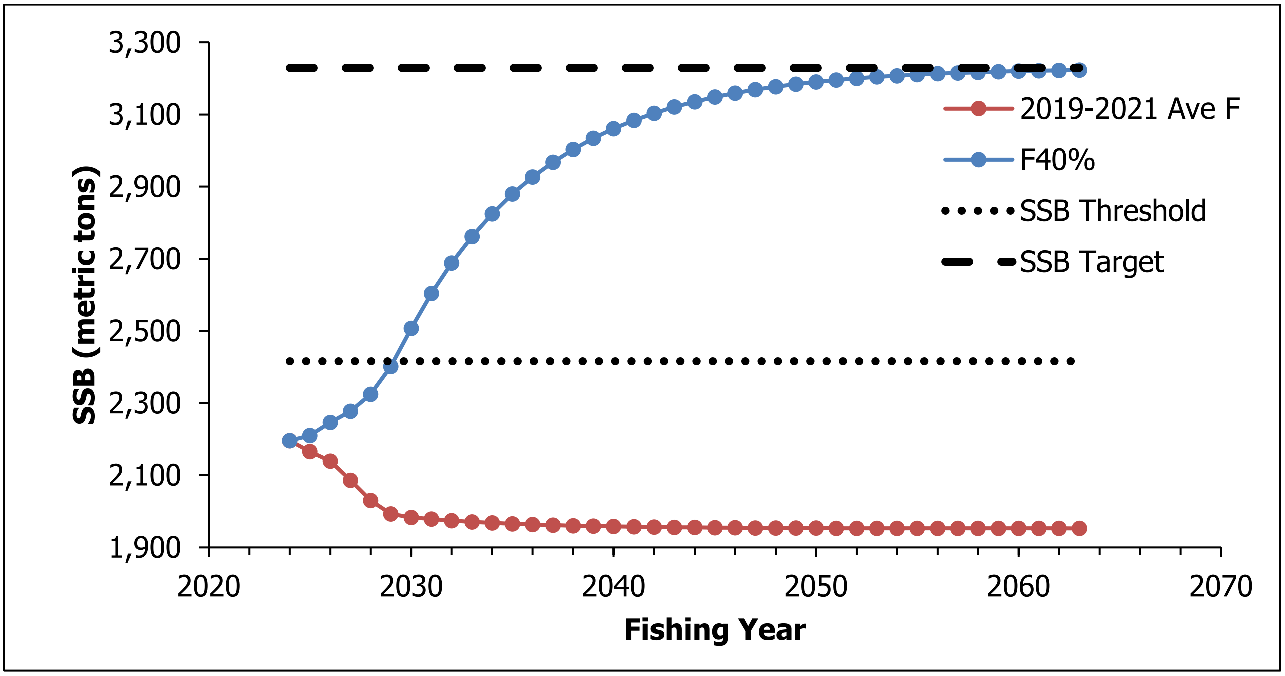


Figure 6.2 The potential future spawning potential ratio (top) and spawning stock biomass (bottom) under current *F* conditions (red line), as well as under target *F* (blue line).

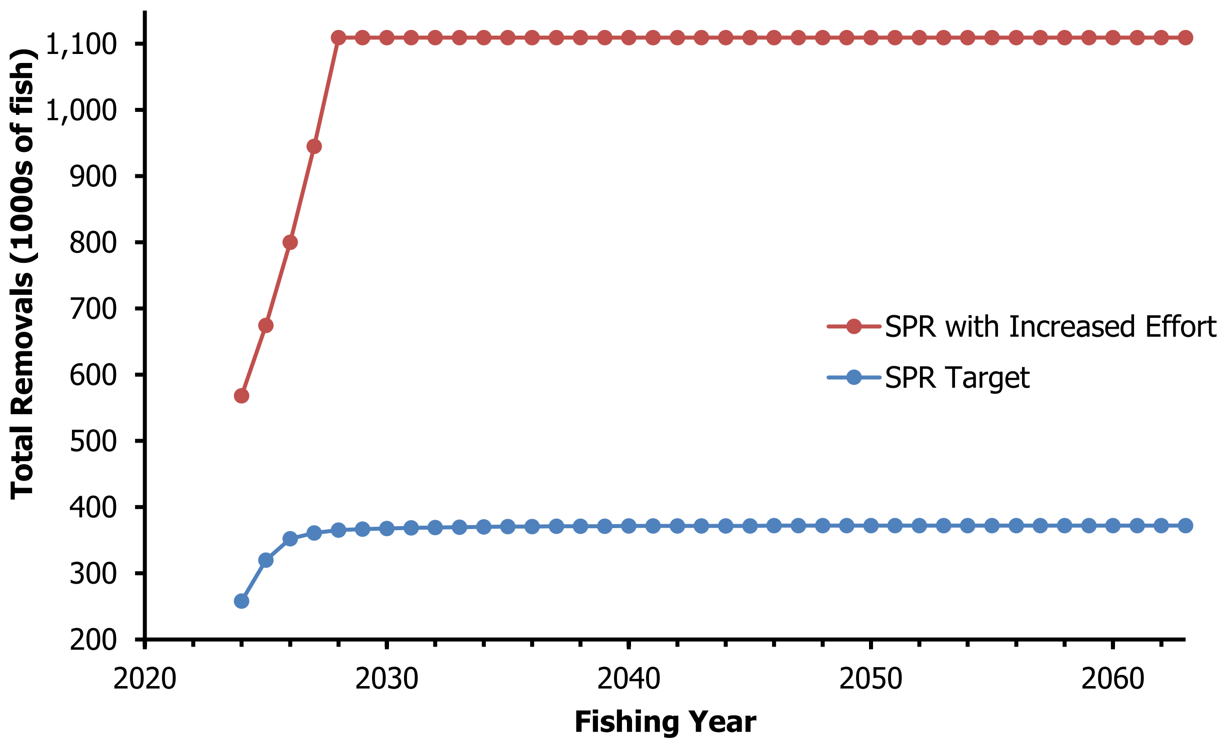


Figure 6.3 The potential future spawning potential ratio underestimated *F* conditions with a five year increase in effort (red line), as well as under sustainable *F* (blue line).