SEDAR

Southeast Data, Assessment, and Review

SEDAR 38 Update

South Atlantic King Mackerel

Stock Assessment Report

Apr 2020

SEDAR
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Table of Contents

1. Executive Summary

- The Stock Synthesis model for South Atlantic King Mackerel (SEDAR 38) was updated to fishing year 2017 (Mar 2017-Feb 2018), incorporating five years of additional data. All life history assumptions, including stock structure and mixing, and model configuration remained unchanged from the final decisions of SEDAR 38. The principal findings included:

- The South Atlantic stock of King Mackerel was determined to be NOT OVERFISHED and the fisheries are NOT OVERFISHING.

- Stock and fishery status determinations were consistent across model sensitivities and diagnostic runs. Primarily, the status determinations did not change under alternative assumptions of steepness that ranged 0.4 to 1.0, and unfished age-0 recruitment levels that ranged 8 million to 12 million fish. For reference, the peak number of fish caught by the recreational fleets was 1.4 million fish in 2007.

- Total biomass and spawning stock biomass estimates increased steadily since 2013. All fishery indicators (fleet CPUEs and scientific survey) showed positive trends since SEDAR 38.

- Stock Synthesis estimated a recent period (2013 to 2016) of above average age-0 recruitments, contrasting the period prior (2008 to 2012) of below average recruitments first detected during SEDAR 38. Two particularly high recruitment years were estimated for 2015 and 2016, supported by the juvenile survey observations in 2016 (SEAMAP trawl survey), as well as fleet length compositions.

- Observations by stakeholders may help validate the model predictions, given the distinct change in signal from five-years of low recruitment up to SEDAR 38 to four years of recent high recruitment. The fish would have entered the fisheries beginning in fishing year 2015, with relatively high abundance beginning in fishing year 2017, particularly of fish between 24 and 36 inches fork length.

- The projected yield estimates (in millions of lbs) of South Atlantic King Mackerel by fishing year were:

Fishing Year	p*=0.1	p*=0.2	p*=0.3	p*=0.4	OFL
2021	27.7	30.0	31.6	33.0	34.3
2022	22.9	25.2	26.8	28.2	29.5
2023	19.8	22.1	23.7	25.1	26.3
2024	17.8	20.0	21.6	22.9	24.2
2025	16.3	18.5	20.1	21.5	22.7

  - The equilibrium yield at the biomass reference point (SPR=30% Unfished) was 18.3 million pounds
  - The optimum yield ($F=0.75*F_{SPR30}$) estimate was 16.7 million pounds
  - For reference, the average yield between 2016 and 2017 was 9.6 million pounds

2. Data Updates

All data were summarized by fishing year (FY), defined as March 1st of the current year to February 28th of the following year (29th during leap years). For example, the 2020 FY is March 1, 2020 to February 28, 2021. The following list summarizes the main data inputs and data assumptions for the assessment:

2.1. Life history
- The life history assumptions of SEDAR 38 remain unchanged.

2.2. Landings
- Commercial Handline: 1929 to 2017 FY, measured in metric tons
- Commercial Gillnet: 1949 to 2017 FY, measured in metric tons
- Recreational Headboat: 1936 to 2017 FY, measured in number of fish
- Recreational Charter/ Private: 1946 to 2017 FY, measured in number of fish
- Recreational Tournament: 1946 to 2017 FY, measured in number of fish

2.3. Discards
- Commercial Combined: 1998 to 2017 FY, measured in number of fish
- Recreational Headboat: 1987 to 2017 FY, measured in number of fish
- Recreational Charter/ Private 1981 to 2017 FY, measured in number of fish
- Recreational Tournament: 1981 to 2017 FY, measured in number of fish
- Shrimp Bycatch: 1978 to 2017 FY, measured in number of fish

2.4. Length composition of landings
- Commercial Handline: 1984 to 2017 FY
- Recreational Headboat: 1984 to 2017 FY
- Recreational Charter/ Private: 1984 to 2017 FY
- Recreational Tournament: 1984 to 2017 FY

2.5. Length composition of discards
- Discards for all fleets were assumed to be age zero based on a review of available observer information.

2.6. Age composition
- Commercial handline: 1991 to 2017 FY
- Recreational Charter/ Private: 1986 to 2017 FY
- Recreational Tournament: 1986 to 2017 FY

2.7. Abundance indices
- Fishery-dependent
  - Commercial hook and line trolling: 1998 to 2017 FY
  - Recreational headboat: 1980 to 2017 FY
  - Recreational charter/private, 1981 to 2017 FY (evaluated but not used in SS3)

- Fishery-independent
    - SEAMAP Age-0 Trawl: 1981 to 1982, 1984 to 2017 FY

Detailed descriptions of the datasets were provided in the SEDAR 38 Stock Assessment Report (https://sedarweb.org/docs/sar/SEDAR_38_SA_SAR.pdf, Section II). CPUE index and survey standardization methods remained unchanged.

2.1 Life history

Stock structure and mixing assumptions remained unchanged from SEDAR 38 (https://sedarweb.org/docs/sar/SEDAR_38_SA_SAR.pdf, SECTION II, Subsection 2.3). The stock delineations and mixing zone boundaries (**Figure 2.1**) were defined to be:

(1) South Atlantic King Mackerel stock ranges from North Carolina to Florida at the Monroe-Dade counties line during November 1st to March 31st, and North Carolina to Florida including Monroe County south of the Florida Keys during April 1st to October 31st,
(2) the Gulf of Mexico King Mackerel stock ranges from Texas to Florida including Monroe County north of the Florida Keys during all months of the year, and
(3) the winter mixing zone is defined to be Monroe County, Florida, south of the Keys during November 1st to March 31st.

King Mackerel natural mortality, fecundity, and maturity assumptions remain unchanged from SEDAR 38 (**Table 2.1)**. Life history parameters with fixed input values (i.e. not estimated in SS3) included natural mortality-, fecundity-, and maturity-at-age. Growth was estimated as gender-specific von Bertalanffy models fitted to empirical observations of annual length-at-age within SS3. Final growth parameter estimates from SEDAR 38 were used as starting values (**Table 2.2**).

2.2 Landings

Commercial landings in the South Atlantic were predominantly from trolling and other hook and line gears (handlines), followed by gillnets (**Table 2.3, Figure 2.2**). Landings (in metric tons) were estimated from 1929 to 2017 for handlines, and from 1949 to 2017 for gillnets.

Recreational landings were predominantly from private and charter boats, followed by headboats, and tournaments (**Table 2.3, Figure 2.3**). Recreational landings were measured in numbers of fish and total landings were estimated for the period 1946 to 2017 for charter and private fisheries; and for the period 1936 to 2017 for the headboat fishery. No direct estimates of tournament landings were available. Tournament landings started in 1980, ramped up to be 3% of recreational private landings to 1990, and assumed 3% of charter/private recreational landings for the duration of the time series. Relative landings by fleet, estimated in metric tons (numbers of fish were converted to biomass using SS3), are compared in **Figure 2.4**.

Recreational landings estimation methods for charter/private (CP/PR) vessels were based on fishing effort statistics from the FES, a notable change in methodology from SEDAR 38. The differences between estimated recreational landings from SEDAR 38 to the current assessment are shown in **Figure 2.5**. There was a clear increase in landings of the recreational CP/PR fleet. An observed decrease in headboat (HB) total removals (**Figure 2.5**) was due to fewer estimated dead discards (based on the ratio of HB to CP/PR landings, so when CP/PR increased the HB ratio decreased). Tournament catches were approximated as 3% of CP/PR and the change in estimated landings follows the CP/PR fleet (**Figure 2.5**). The effect of these changes in recreational landings were evaluated as sensitivity runs of SEDAR 38 with the recreational charter and private landings and discards time series in SEDAR 38 base model replaced with the revised estimates. The effect of decreased HB removals was also evaluated as a sensitivity run of SEDAR 38.

2.3 Discards

Discard estimation methods for commercial gears, including shrimp discards, remain unchanged from SEDAR 38 (https://sedarweb.org/docs/sar/SEDAR_38_SA_SAR.pdf, Section III, subsections 3.5 and 4.4). Commercial discards from the handline and other fisheries that target King Mackerel were minimal (less than 5%) relative to landings (**Table 2.4, Figure 2.6**).

Recreational discard estimates were revised from SEDAR 38, based on FES effort statistics. Estimates of King Mackerel recreational discards were provided for the periods 1987 to 2017 for recreational headboats, and 1981 to 2017 for recreational charter and private fisheries. Headboat discards were minimal in comparison to all other fleets. Discards of King Mackerel from recreational fisheries are predominantly from the private and charter boat fisheries, believed to be a result of size and bag limit regulations. The change to FES resulted in an increase in CP/PR discards, and decrease in HB discards (**Figure 2.7**). These revised estimates were included in the sensitivity analysis of the SEDAR 38 model.

Discard mortality assumptions remained unchanged from SEDAR 38, and were as follows: 20% discard mortality from commercial handline fisheries, 100% discard mortality for the gillnet and shrimp trawl fishery, 22% discard mortality for the recreational headboat fishery, and 20% discard mortality for recreational private, charter, and tournament fisheries.

2.4 Length composition of landings

The annual length compositions of landed King Mackerel during fishing years 2013 to 2017 are shown by fishery in **Figure 2.8**. Length composition from the period prior remain unchanged from SEDAR 38. Length observations were binned across 5cm groups with a minimum size of 20cm and a maximum size of 160cm. Due to defined size limit regulations, length observations below the size limits were excluded from length compositions under the assumption that the harvest of sublegal fish is negligible compared to documented landings and estimated discards. In practice, even small numbers of fish below defined fleet retention limits can create substantial modeling instability or bias. Therefore, the assumption that all retained fish were above the legal size limit for both commercial and recreational fisheries was maintained from SEDAR 38.

2.5 Length composition of discards

The size of discarded fish from commercial and recreational fisheries remained unchanged from SEDAR 38. Fish were assumed to be all age-0, undersized individuals (< 50cm fork length) for all fleets except recreational tournaments. The sizes of fish released during tournaments followed a retention function adopted during SEDAR 38 (Idhe et al 2014, Miller et al 2014).

2.6 Aging data

Age data were collected primarily from the commercial handline fishery, and to a lesser extent, the charter, private, and tournament fisheries. No recent age data were available for the gillnet or headboat fleets. Age observations were summarized by year and fleet for the period FY 2013-17 (**Figure 2.9)**. The distributions of observed sizes-at-age of males and females (**Figure 2.10**), aggregated across time, provided validation of gender-specific growth patterns, a key population dynamic modeled in SEDAR 38.

2.7 Indices

Data standardization methods for the indices of relative abundance remained unchanged from SEDAR 38. Three CPUE indices were included in the assessment that included the commercial trolling handline index, the recreational headboat index, and the SEAMAP trawl fishery independent survey. The updated standardized indices are provided in **Table 2.5** and plotted in **Figure 2.11**. The recreational charter/private index is shown for comparative purposes, but was not modeled in SS3.

2.8 Tables

Table 2.1. Life history assumptions of South Atlantic King Mackerel input as fixed parameters in SS3.

	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6	Age-7	Age-8	Age-9	Age-10	Age-11+
Nat. Mort.	0.657	0.247	0.224	0.208	0.195	0.186	0.178	0.172	0.167	0.163	0.160	0.157
Maturity	Maturity= 1/(1 + exp(-0.36886*(58.113)))											
Fecundity	Eggs = 0.0000073141*Length^ 3.0087053											

Table 2.2. Estimated growth parameters of King Mackerel from SEDAR 38, used as starting parameter values in SS3.

	Atlantic	
	Female	Male
L_{inf} (mm FL)	116.7	96.8
k (year^{-1})	0.316	0.398
cv1	0.25	0.26
cv2	0.079	0.063

Table 2.3. Commercial and recreational landings of South Atlantic King Mackerel by fleet.

Fishing_Year	Com_Handline (metric tons, whole wt)	Com_Gillnet (metric tons, whole wt)	Rec_Headboat (thousands of fish)	Rec_Charter_Private (thousands of fish)	Rec_Tournament (thousands of fish)
1929	1189	0	0	0	0
1930	1107	0	0	0	0
1931	1250	0	0	0	0
1932	1258	0	0	0	0
1933	1094	0	0	0	0
1934	931	0	0	0	0
1935	1158	0	0	0	0
1936	1386	0	0.6	0	0
1937	969	0	1	0	0
1938	1316	0	2	0	0
1939	1188	0	2	0	0
1940	783	0	3	0	0
1941	0	0	4	0	0
1942	0	0	4	0	0
1943	0	0	5	0	0
1944	0	0	5	0	0
1945	1318	0	6	0	0
1946	879	0	8	26	0
1947	440	0	9	47	0
1948	0	0	11	68	0
1949	154	0.6	13	89	0
1950	692	11	15	110	0
1951	881	17	17	131	0
1952	730	7	18	152	0
1953	566	59	20	173	0
1954	437	88	22	194	0
1955	771	69	24	215	0
1956	1037	117	26	236	0
1957	1073	53	27	257	0
1958	941	20	29	278	0
1959	1047	10	31	299	0
1960	958	28	33	320	0
1961	1003	33	34	349	0
1962	906	120	36	378	0
1963	816	200	38	407	0
1964	814	250	40	436	0
1965	744	403	42	465	0
1966	522	510	41	468	0
1967	529	703	40	470	0
1968	539	769	40	473	0
1969	642	941	39	476	0
1970	821	977	39	478	0
1971	707	687	36	526	0
1972	1055	616	35	573	0
1973	1211	685	27	620	0
1974	1219	692	31	668	0

Fishing_Year	Com_Handline (metric tons, whole wt)	Com_Gillnet (metric tons, whole wt)	Rec_Headboat (thousands of fish)	Rec_Charter_Private (thousands of fish)	Rec_Tournament (thousands of fish)
1975	1238	740	43	715	0
1976	1368	964	39	723	0
1977	1588	599	40	731	0
1978	1228	484	41	739	0
1979	1158	401	36	747	0
1980	1980	681	35	755	0
1981	1958	776	85	759	2
1982	1918	806	55	764	3
1983	1281	445	68	655	6
1984	1188	370	42	610	7
1985	1330	267	36	692	12
1986	1460	31	52	811	14
1987	1671	36	44	517	11
1988	1477	54	26	626	15
1989	1279	37	39	489	11
1990	1410	38	46	1279	15
1991	1408	36	58	837	25
1992	1332	60	39	848	25
1993	1171	36	37	595	18
1994	1312	57	37	616	18
1995	1190	43	30	606	18
1996	1538	129	51	571	17
1997	1522	199	36	678	20
1998	1693	57	28	787	24
1999	1352	52	31	668	20
2000	1281	83	30	882	26
2001	1273	58	17	552	17
2002	1247	73	16	1011	30
2003	1219	46	14	905	27
2004	1615	90	26	666	20
2005	1312	135	36	681	20
2006	1672	107	28	1023	31
2007	1715	92	32	1310	39
2008	1869	105	17	798	24
2009	2108	63	19	836	25
2010	2003	52	18	464	14
2011	1444	31	10	307	9
2012	1024	34	6	263	8
2013	854	30	6	247	7
2014	958	49	11	333	10
2015	1088	36	11	302	9
2016	1228	43	10	545	16
2017	1261	32	9	628	19

Table 2.4. Estimated commercial and recreational discards (in thousands of fish) of South Atlantic King Mackerel.

Fishing_Year	Commercial Discards	Rec_Headboat Discards	Rec_Charter Private Discards	Shrimp Bycatch
1978	0	0	0	
1979	0	0	0	
1980	0	0	0	
1981	0	0.3	6	
1982	0	0.03	1	
1983	0	0.06	0.1	
1984	0	0.09	0.5	
1985	0	2	62	
1986	0	1.1	29	
1987	0	0.5	115	
1988	0	1.3	79	
1989	0	0.9	25	85
1990	0	0.5	76	593
1991	0	3.1	133	71
1992	0	2.3	126	105
1993	0	1.7	74	69
1994	0	2	89	131
1995	0	2.2	203	218
1996	0	3.6	180	349
1997	0	1.9	222	83
1998	38	1.9	151	281
1999	31	2.6	267	146
2000	33	1.9	171	62
2001	33	1.3	130	28
2002	29	1.5	468	28
2003	30	2.1	391	83
2004	25	1.8	429	100
2005	24	2.6	346	127
2006	28	2.5	509	49
2007	31	1.6	487	86
2008	33	3	287	49
2009	35	1.7	162	29
2010	32	2.6	157	16
2011	28	1.6	112	86
2012	26	0.8	104	38
2013	26	0.9	118	45
2014	29	1.4	157	55
2015	30	1.6	153	395
2016	31	2	132	141
2017	29	1	320	91

Table 2.5. South Atlantic King Mackerel standardized indices of relative abundance and coefficients of variation.

Fishing_Year	Com_Handline	Handline CV	Rec Headboat	Headboat CV	SEAMAP Trawl	SEAMAP CV
1980			1.33	0.17		
1981			1.31	0.16		
1982			0.87	0.18		
1983			0.84	0.17		
1984			0.97	0.17		
1985			0.54	0.18		
1986			0.66	0.16		
1987			0.86	0.17		
1988			0.45	0.19		
1989			0.87	0.19		
1990			0.83	0.18	2.83	0.17
1991			1.09	0.17	0.55	0.21
1992			0.94	0.15	0.85	0.24
1993			0.93	0.15	0.52	0.23
1994			0.73	0.16	0.66	0.22
1995			0.67	0.16	1.33	0.21
1996			0.78	0.18	2.01	0.19
1997			1.47	0.15	0.59	0.24
1998	0.90	0.05	1.29	0.17	1.93	0.23
1999	0.83	0.05	0.79	0.18	1.26	0.19
2000	0.80	0.05	1.22	0.17	0.84	0.24
2001	0.80	0.05	0.98	0.18	0.45	0.24
2002	0.89	0.05	0.66	0.20	0.53	0.19
2003	0.97	0.05	0.89	0.21	0.84	0.20
2004	1.11	0.05	1.43	0.21	1.19	0.22
2005	1.08	0.05	1.76	0.21	1.50	0.20
2006	1.15	0.05	1.61	0.20	1.07	0.22
2007	1.15	0.05	1.66	0.19	1.28	0.18
2008	1.14	0.05	1.24	0.16	1.12	0.21
2009	1.11	0.05	1.36	0.16	0.56	0.22
2010	1.07	0.05	1.04	0.18	0.31	0.23
2011	1.10	0.05	0.51	0.18	0.53	0.26
2012	0.89	0.06	0.40	0.18	0.29	0.22
2013	0.86	0.06	0.31	0.19	0.33	0.20
2014	1.10	0.06	0.31	0.19	0.61	0.23
2015	1.02	0.06	0.35	0.19	0.56	0.19
2016	1.00	0.06	0.45	0.19	1.54	0.20
2017	1.10	0.06	1.07	0.19	0.82	0.17

2.9 Figures

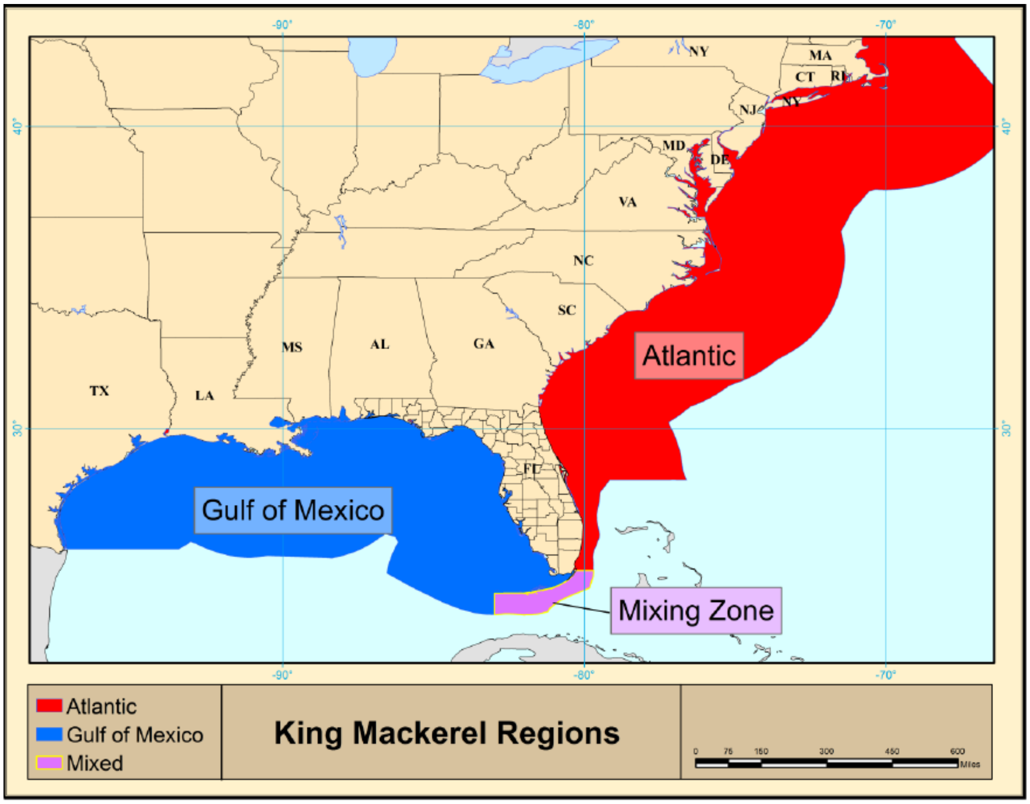

Figure 2.1. Regional stock boundaries used to aggregate landings for the stock assessments of South Atlantic and Gulf of Mexico King Mackerel.

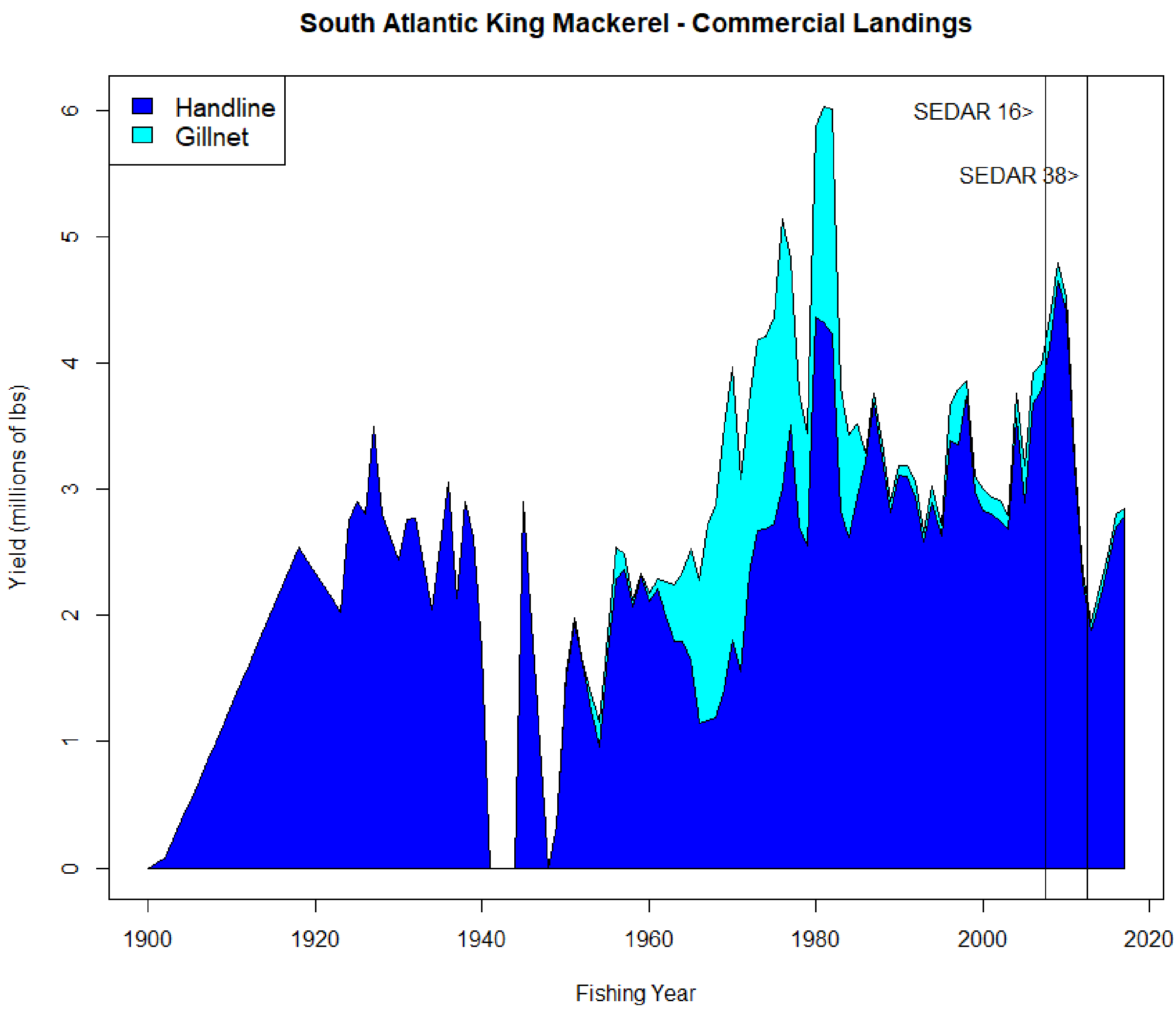

Figure 2.2. Estimated commercial landings of South Atlantic King Mackerel from directed fleets (measured in metric tons whole weight).

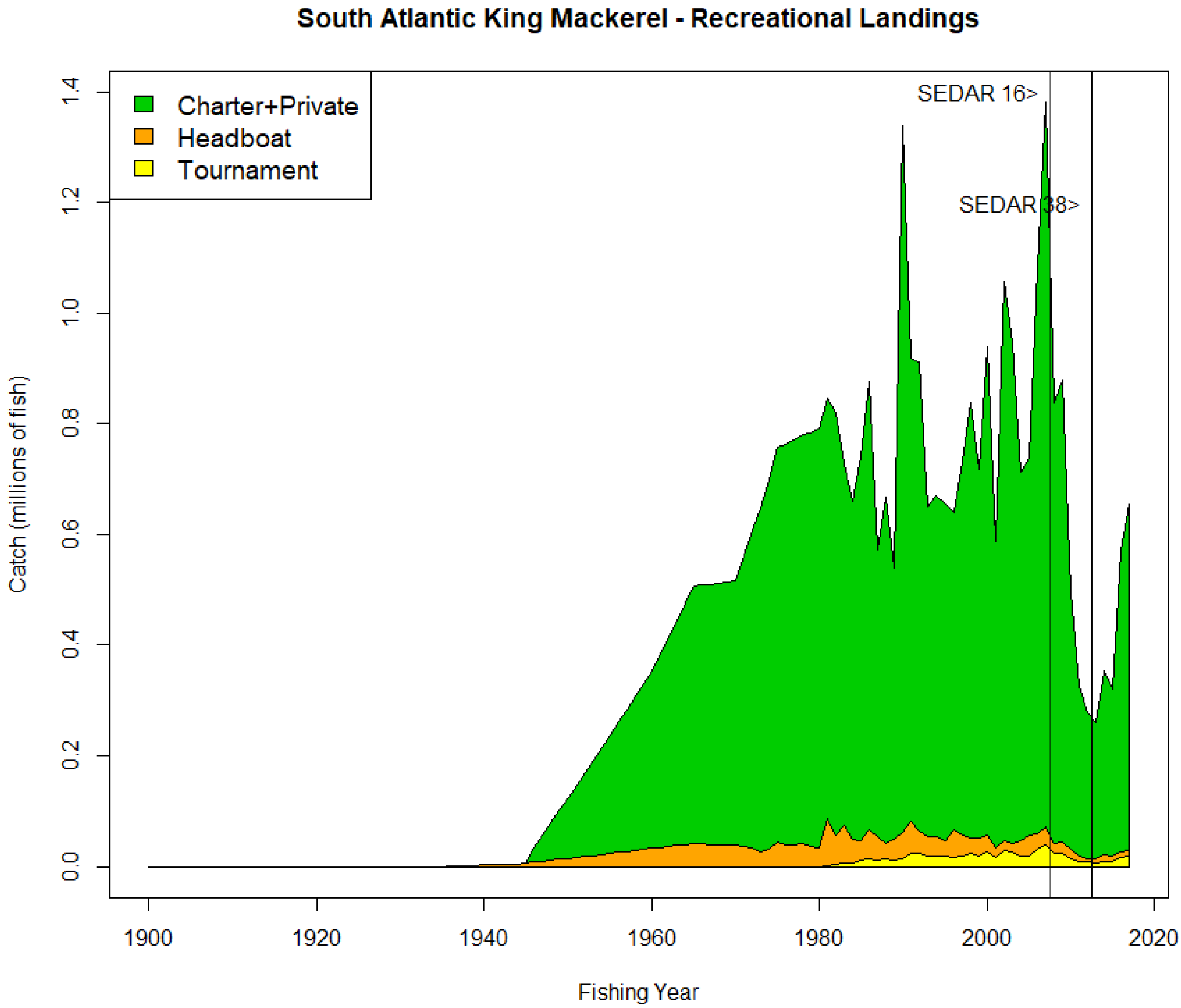

Figure 2.3 Estimated recreational landings of South Atlantic King Mackerel.

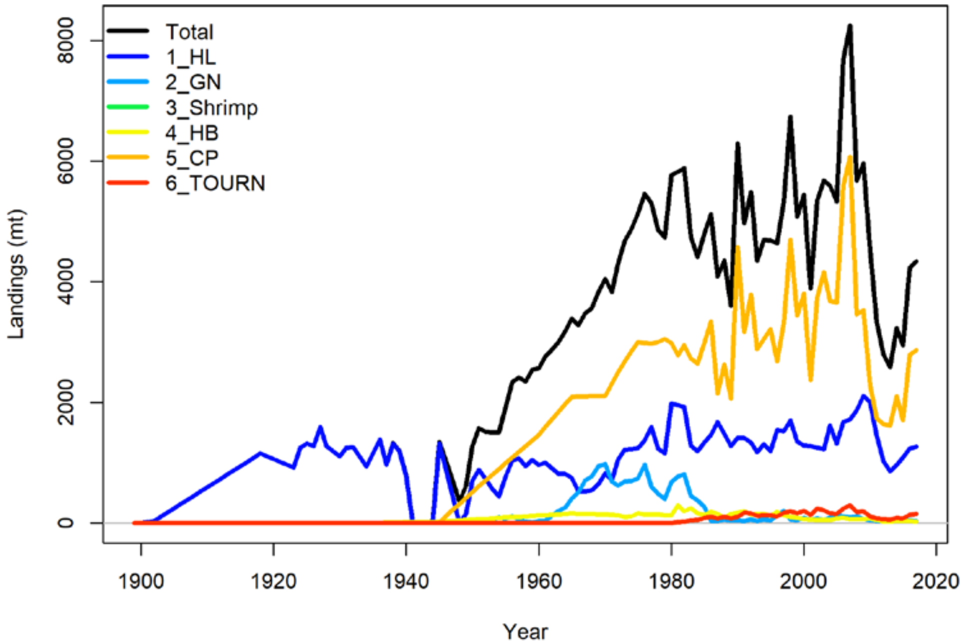

Figure 2.4. Total estimated landings of South Atlantic King Mackerel in metric tons.

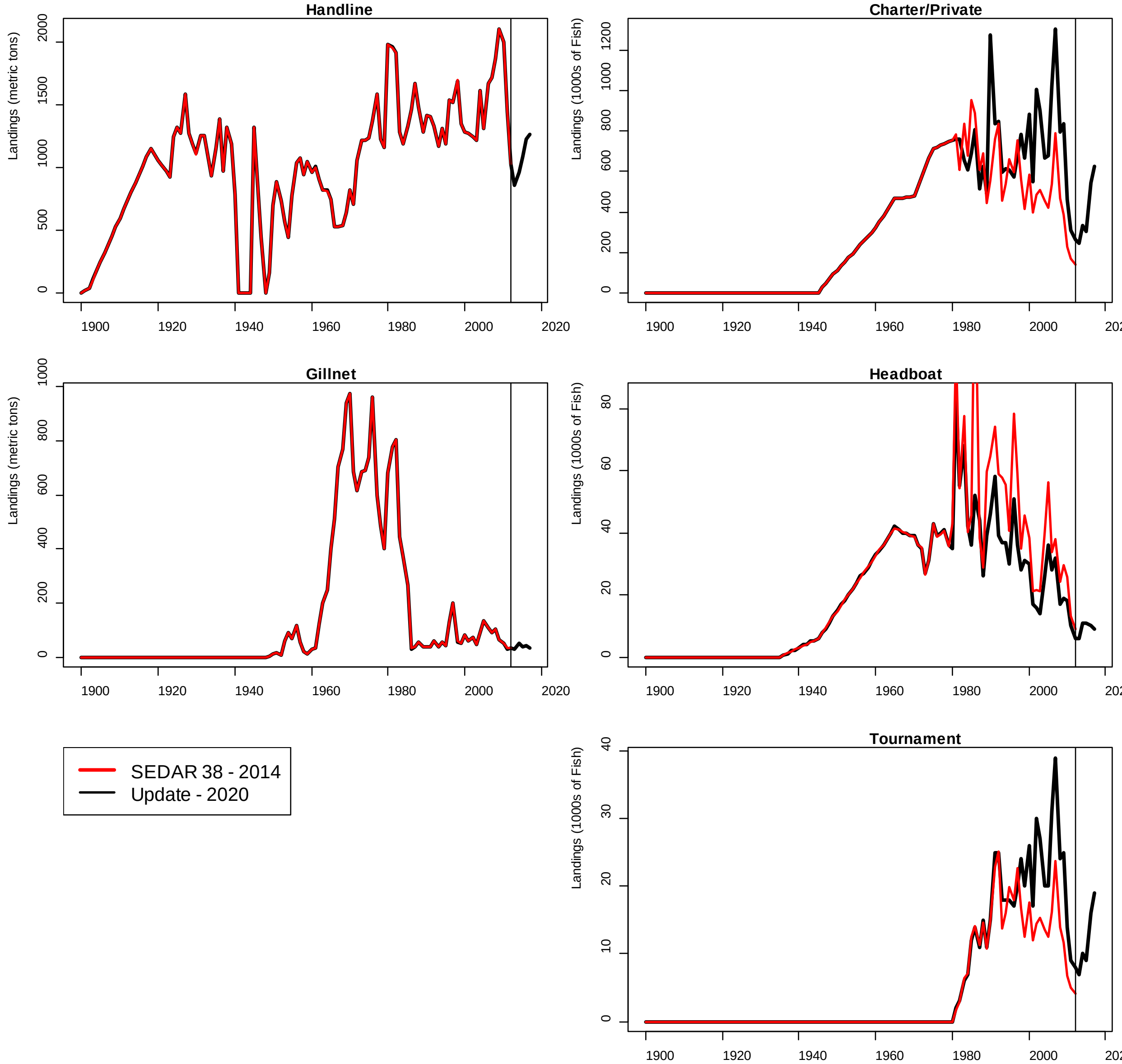

Figure 2.5. Comparison of removal estimates (landings plus dead discards) between SEDAR 38 (red lines) and the 2020 updated assessment (bold black lines). The vertical line indicates the terminal year of data from SEDAR 38. The change in recreational landings estimates was attributed to different methodologies for estimating recreational effort from the MRIP Coastal Household Telephone Survey to the Fishing Effort Survey. There was a notable increase in the estimates of fishing landings and discards of the recreational charter/private (CP/PR) fleet. The decrease in headboat (HB) total removals is due to fewer estimated dead discards (based on the ratio of HB to CP/PR landings, so when CP/PR increased the HB ratio decreased). Tournament catches were approximated as 3% of CP/PR and the change in estimated landings follows the CP/PR fleet.

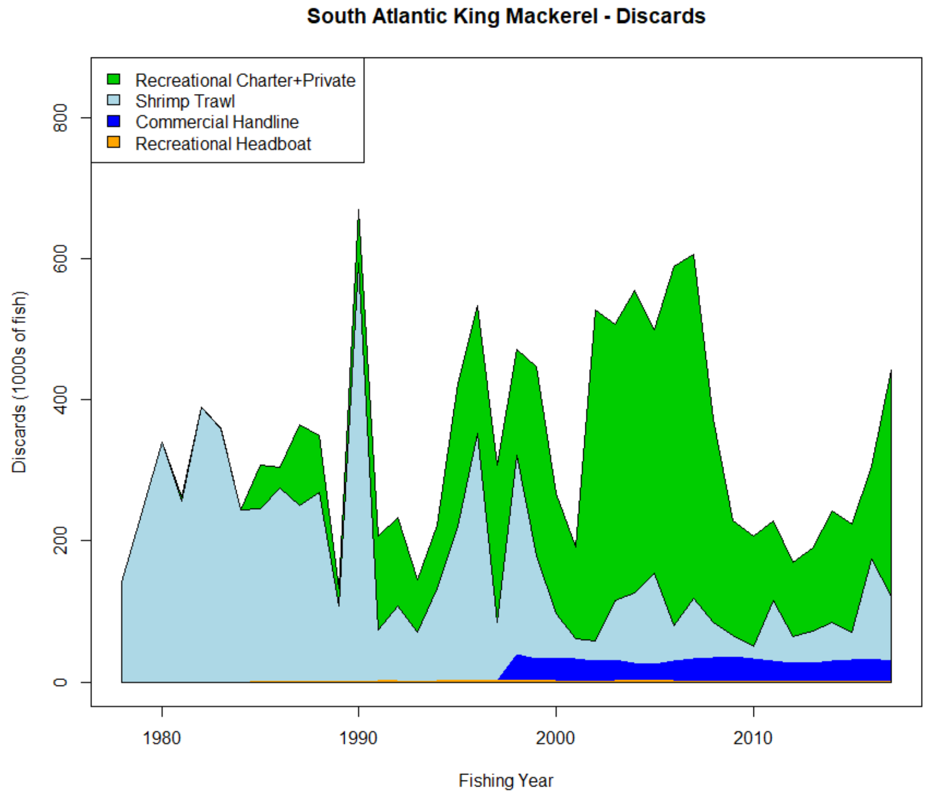

Figure 2.6. Estimated discards of South Atlantic King Mackerel in numbers of fish (1000s).

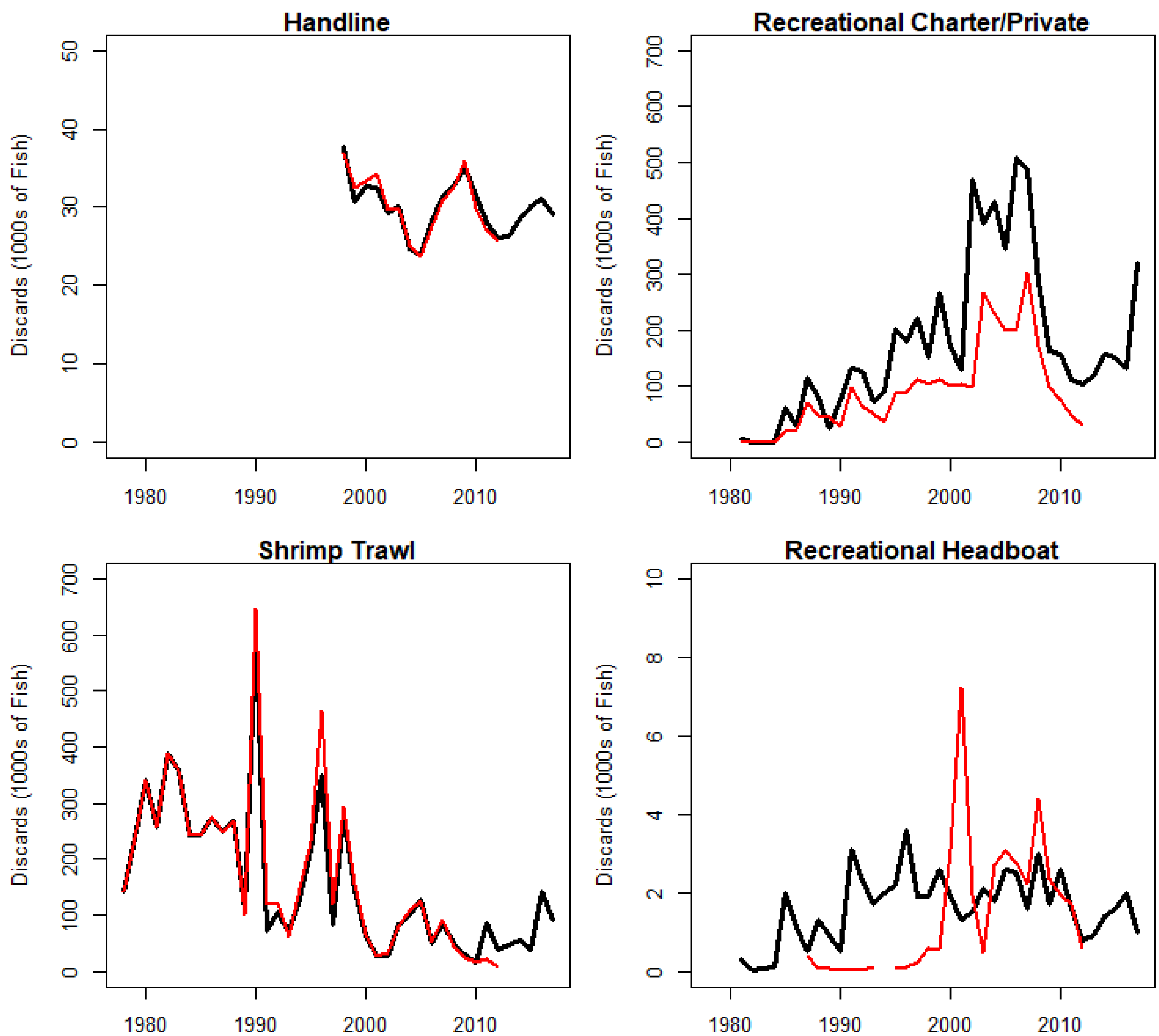

Figure 2.7. Comparison of estimated discards of South Atlantic King Mackerel between SEDAR 38 (red lines) and the 2020 update (black lines).

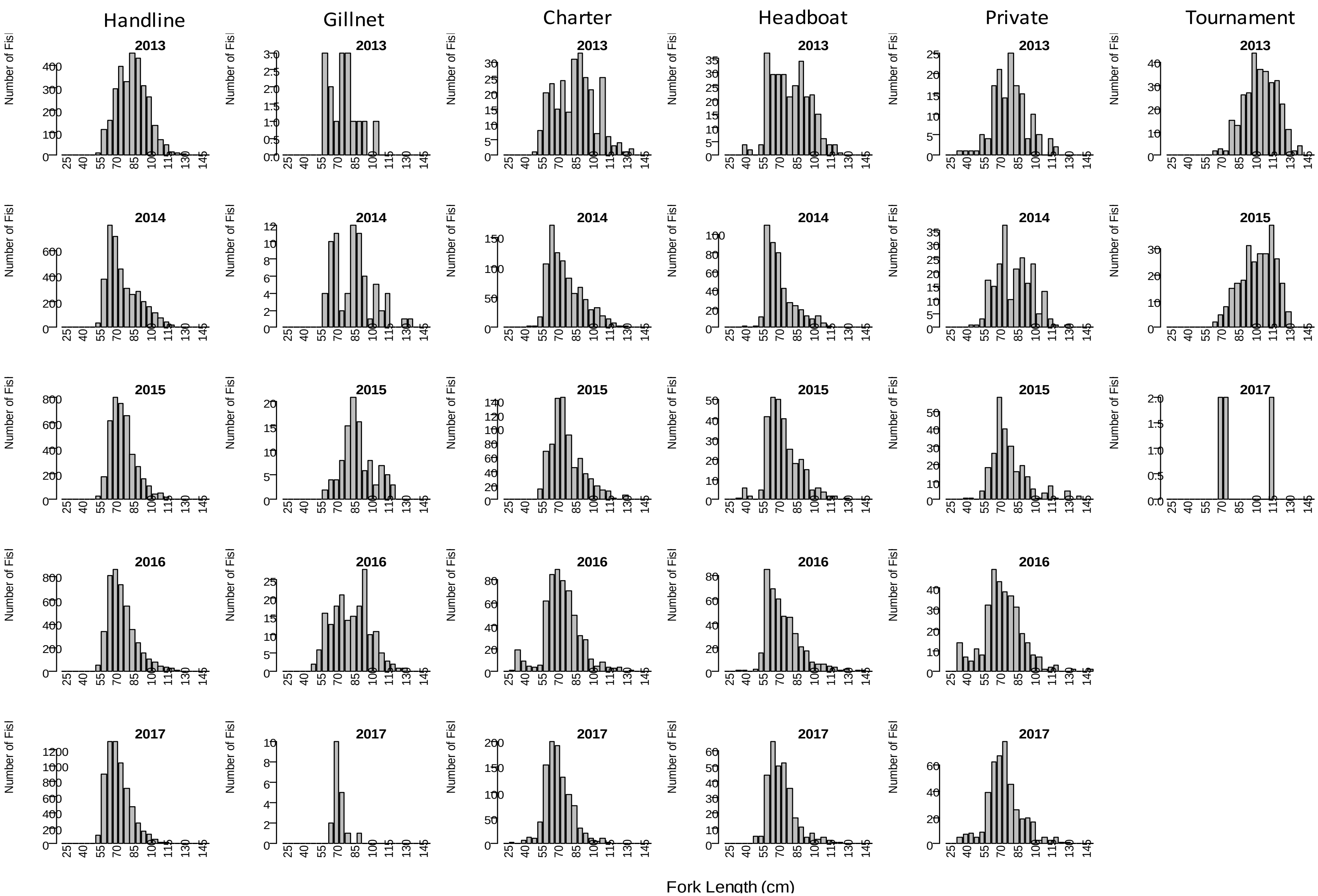

Figure 2.8. Annual length composition of King Mackerel landed in the South Atlantic by fishery. Length measurements are fork length in cm, shown on the x-axis, and the frequency of observations is shown on the y-axis.

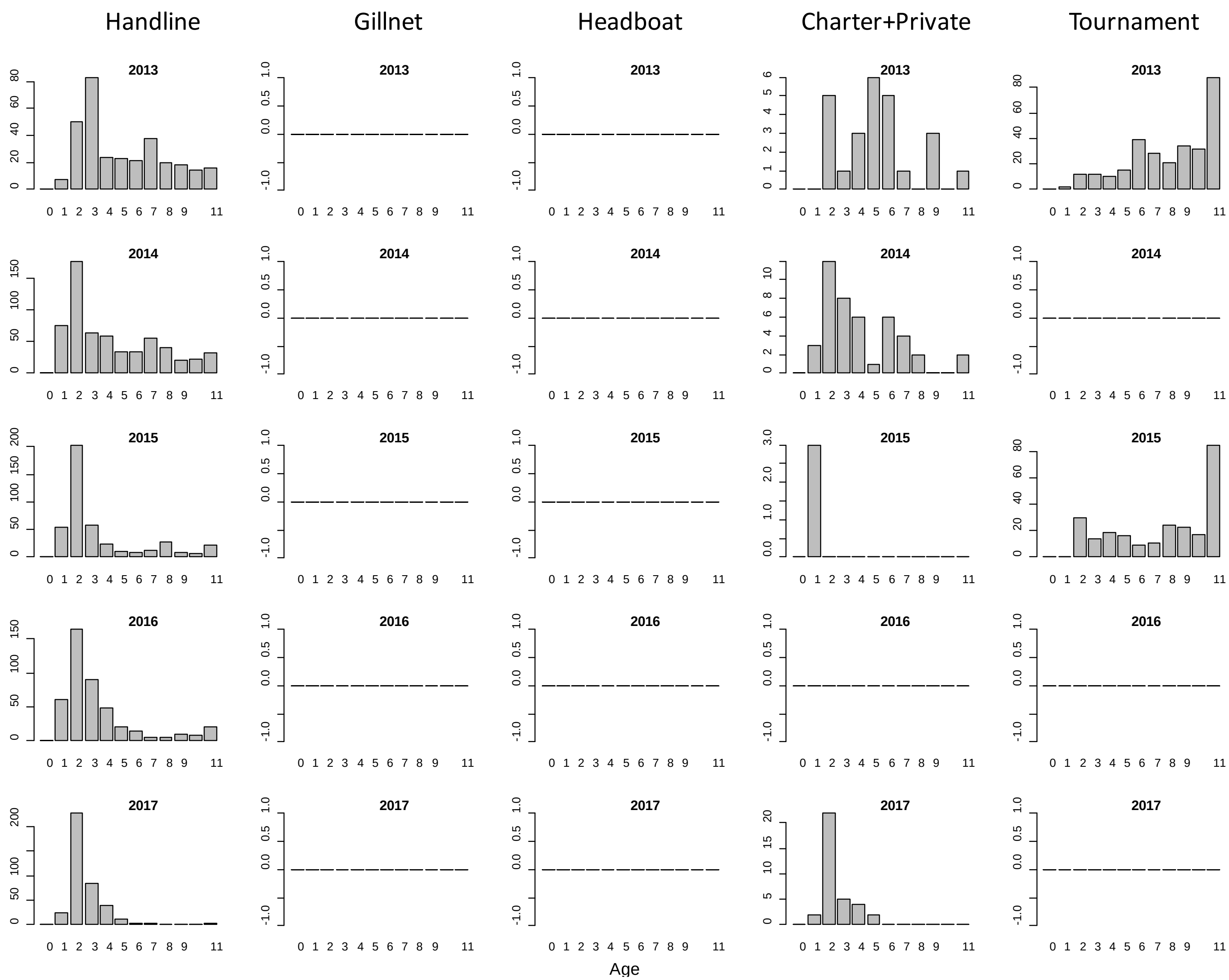

Figure 2.9. Age estimates of King Mackerel landed in the South Atlantic by fishery. Estimated ageclass is shown on the x-axis (age 11 is a plusgroup including fish 11 years and older), and the count of observations is shown on the y-axis.

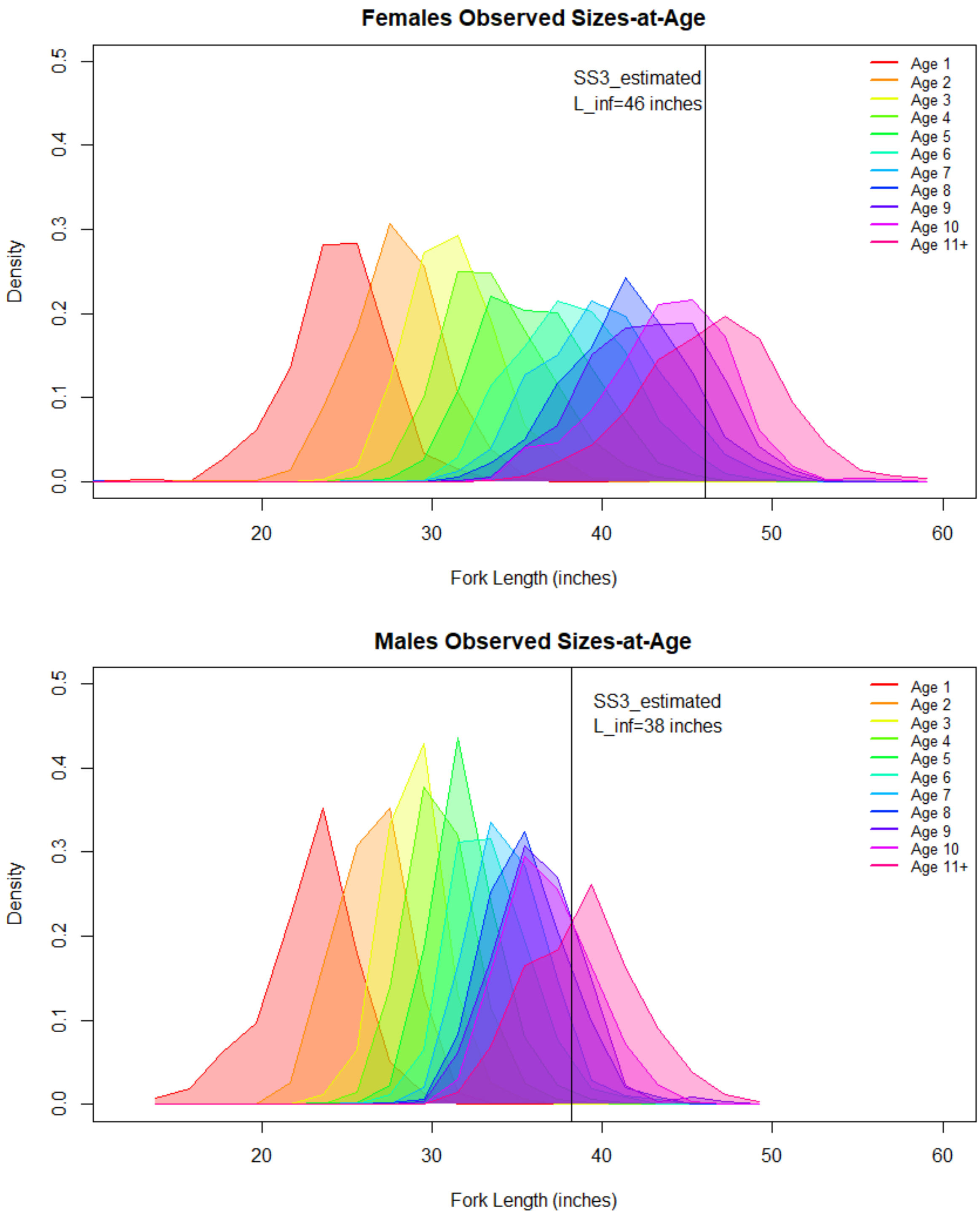

Figure 2.10. Observed sizes-at-age of South Atlantic King Mackerel. The SS3 estimated asymptotic mean lengths (L_inf) for each gender are shown as black vertical lines.

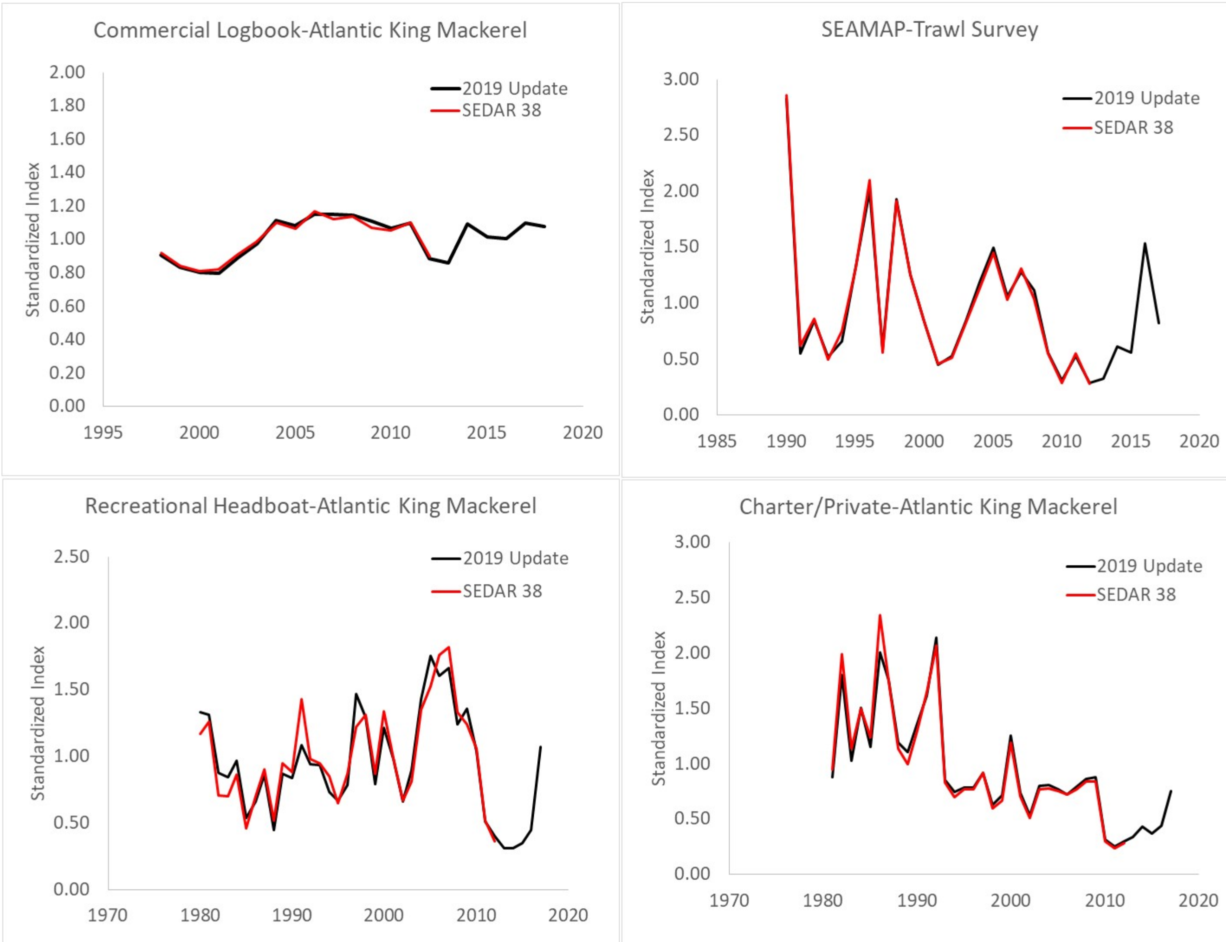

Figure 2.11. Standardized indices of abundance of King Mackerel in the South Atlantic. Note the Charter/Private fleet CPUE series is shown for comparative purposes, but was not modeled in SS3.

3. Stock Assessment Methods

The assessment model in SEDAR 38 was Stock Synthesis (Methot 2013) version 3.24s (SS3). Stock Synthesis has been widely used and tested for population assessment, and is the predominant modeling platform for most current SEDAR assessments. Descriptions of SS3 algorithms and capabilities are available in the SS user's manual (https://www.st.nmfs.noaa.gov/Assets/science_program/SS_User_Manual_3.24s.pdf) and Methot and Wetzel (2013).

SS3 is an integrated statistical catch-at-age model that incorporates many of the important processes (mortality, fishery selectivity, growth, reproduction, etc.) that operate in conjunction to predict annual size-at-age, total removals (landed as well as discarded), fleet length compositions, age compositions, and fleet catches-per-unit-effort. Many of these processes are interrelated, and therefore the associated model parameters are correlated. SS3 provides a statistical platform to integrate these different metrics into an overall objective function, and in turn, account for the joint uncertainty of biological processes and fishery dynamics. SS3 is comprised of three subcomponents: 1) a population subcomponent that recreates an estimate of the numbers/biomass at age using estimates of natural mortality, growth, fecundity, etc.; 2) an observational sub-component that consists of observed (measured) quantities such as CPUE or proportion at length/age; and 3) a statistical sub-component that uses likelihoods to quantify the fit of the observations to the recreated population.

Prior to integrating the updated data series into the South Atlantic King Mackerel assessment, two sensitivity runs of the SEDAR 38 SS3 base model were completed to directly estimate the effects on the stock assessment resulting from the change in recreational fishing effort statistics from the MRIP Coastal Household Telephone Survey to the Fishing Effort Survey (FES). This approach provided an efficient method of evaluating the model effects of changes in recreational landings and discards associated with the FES.

Once the analyses of FES effects on the assessment were completed, the model was updated with all revised data series. Biological assumptions and SS3 configurations remain unchanged from SEDAR 38, and a detailed description of the model can be found here: https://sedarweb.org/docs/sar/SEDAR_38_SA_SAR.pdf. Data series timeframes and overlap are shown in **Figure 3.1**. A brief overview of model parameterization follows.

- **Growth** was modeled in SS3 as a three-parameter von Bertalanffy model (Lmin, Lmax, and K) with separate curves (growth morphs) estimated for males versus females.
- **Spawning output** was a function of individual weight under fixed assumptions of maturity-at-age and weight-based fecundity (**Figure 3.2**).
- **Natural mortality** was estimated externally from SS3 assuming a Lorenzen (1996) function based on mean size-at-age, and scaled to an average M value of 0.16, inferred from the maximum observed age of 26 (Hoenig 1983). The Lorenzen natural mortality values were input into SS3 as fixed parameters (**Table 2.1**).

- **Stock-recruitment** assumed a Beverton-Holt relationship with two estimated parameters, the log of unexploited equilibrium recruitment (R0) and standard deviation in recruitment deviations (σR). Steepness (h) was fixed at 0.99.
- **Recruitment deviations** were estimated for the period 1981-2017 during which length composition data exist, as well as aging estimates post-1990.
- **Starting state** assumed unfished conditions at the model start year (1900) when fishing mortalities for all fleets were assumed equal to 0. Historical landings were reconstructed back to the initiation of the fishery during SEDAR 38, and these estimates remained unchanged.
- **Fishing fleets** represented six different commercial and recreational sectors with separate selectivity patterns, including commercial handline, commercial gillnet, shrimp trawl bycatch, recreational headboat, charter/private, and tournament.
- **Indices of relative abundance** included two fishery-dependent indices (commercial handline- trolling only and recreational headboat) and one fishery independent survey (SEAMAP South Atlantic trawl survey). Indices were weighted by standardization model estimated coefficients of variation.
- **Aging data** were input as annual conditional-age-at-length, the count of aged fish by 5 cm length bins, input separately for males and females for the commercial handline and recreational charter/private, and recreational tournament.
- **Length compositions** were input as fork length measurements in 5cm bins ranging from 20 to 160 cm, input separately by gender when known (or as unknown gender when not sexed) and fleet.
- **Fleet selectivities** were estimated as gender-specific, length-based double normal (handline, gillnet, headboat, charter/private) or logistic (tournament) functions for all fisheries except the SEAMAP survey and the shrimp bycatch which were assumed to catch age-0 fish. Due to changes in tournament dynamics from aggregate catch awards to single trophy fish prizes, a time block on selectivity was imposed beginning in 1997 when the change occurred.
- **Time-varying retentions** were defined to account for minimum size limit regulations, which have changed multiple times. The breaks on these time blocks were 1989, 1990, 1992, 1999 and each coincide with a change in the size or retention limit. Retention was modeled as a knife-edged step function of size, with the probability of being retained based on the minimum size regulations, below which, all fish were assumed to be discarded, and above which fish were assumed to be retained.
- **Estimated parameters** included annual fleet-specific fishing mortalities, annual recruitment deviations beginning in1980, fleet selectivity parameters, sex-specific growth parameters, Beverton-Holt stock recruitment parameter (R0) and the catchability coefficient of the shrimp trawl. Steepness was fixed at 0.99 in the base model, and profiled across a range from 0.4 to 1.0 to evaluate estimate robustness to alternative stock productivity assumptions.

- **Model convergence criteria** included successful variance-covariance matrix (Hessian) inversion, the scale of the maximum gradient component (lower is better), and jitter of starting values across a range of plus/minus 20% initial values to validate model convergence to a global solution (maximum likelihood estimate).
- **Model fit diagnostics** included likelihood profiling of key stock productivity parameters including unfished mean recruitment and steepness, evaluation of fits to abundance indices, residuals fits to fleet length compositions, and retrospective analysis removing the most recent one up to five years of data.
- **Benchmarks and fishing reference points** for stock status estimates were based on spawning potential ratio (SPR) of 0.3 of unfished levels. Fishing mortality reference points for all fleets were based on the geometric mean of the Fs for the past three years (FY2015-17). The fishing mortality benchmark was the fishing mortality rate that results in an equilibrium SPR of 30%. The optimal yield fishing mortality was set at 75% of F_{SPR30}, for consistency with SEDAR 38. The allowable biological catches associated with a range of p-star values of 0.1, 0.2, 0.3, 0.4, and 0.5 (overfishing limit) were tabulated for fishing years 2021 to 2025.
- **Forecast assumptions** included (1) fixed selectivity, discard rate, and retention at size equal to the average of the terminal two years of the assessment (FY2016-17), (2) catches in FY 2018, 2019, and 2020 were assumed to be equal to FY2017, (3) fleet catch allocations were assumed equal to the averages of the terminal two years, (4) future recruitments were predicted from the Beverton-Holt stock recruitment curve with a fixed steepness equal to 0.99, (5) stock status probabilities were approximated from a normal distribution with mean equal to parameter maximum likelihood estimates and standard deviation based on the Hessian matrix.

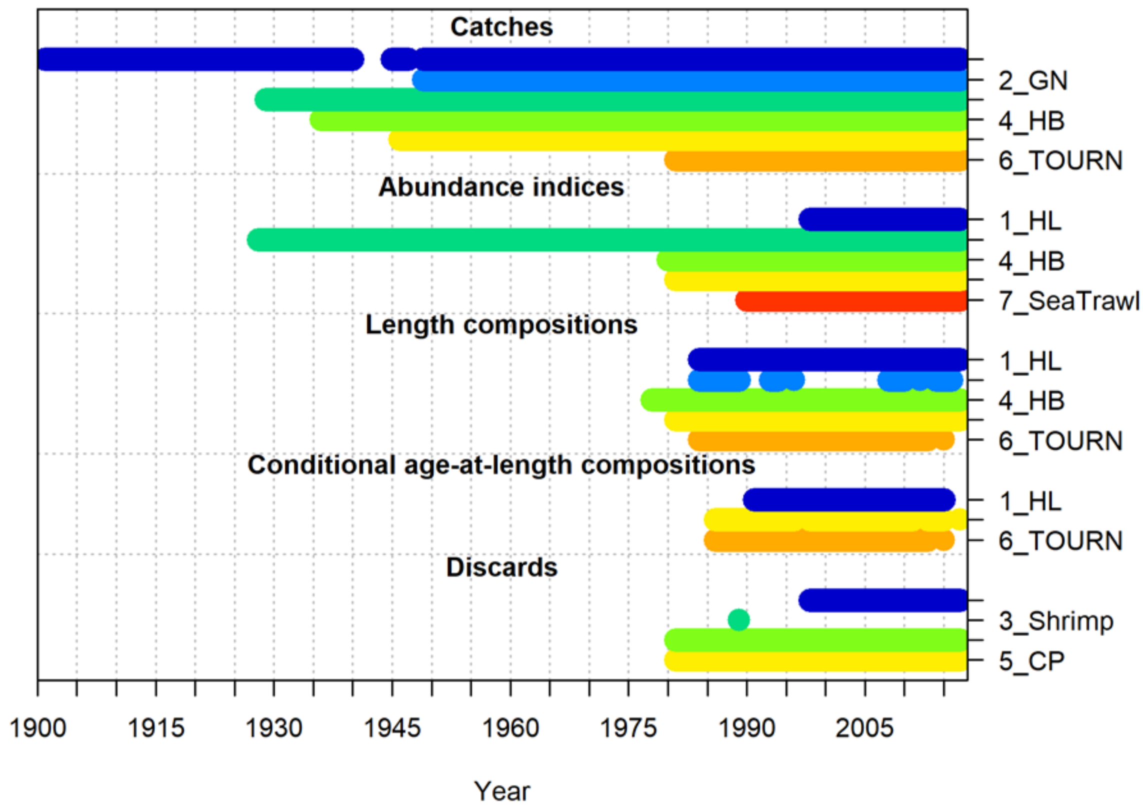

Figure 3.1. South Atlantic King Mackerel data series SS3 inputs.

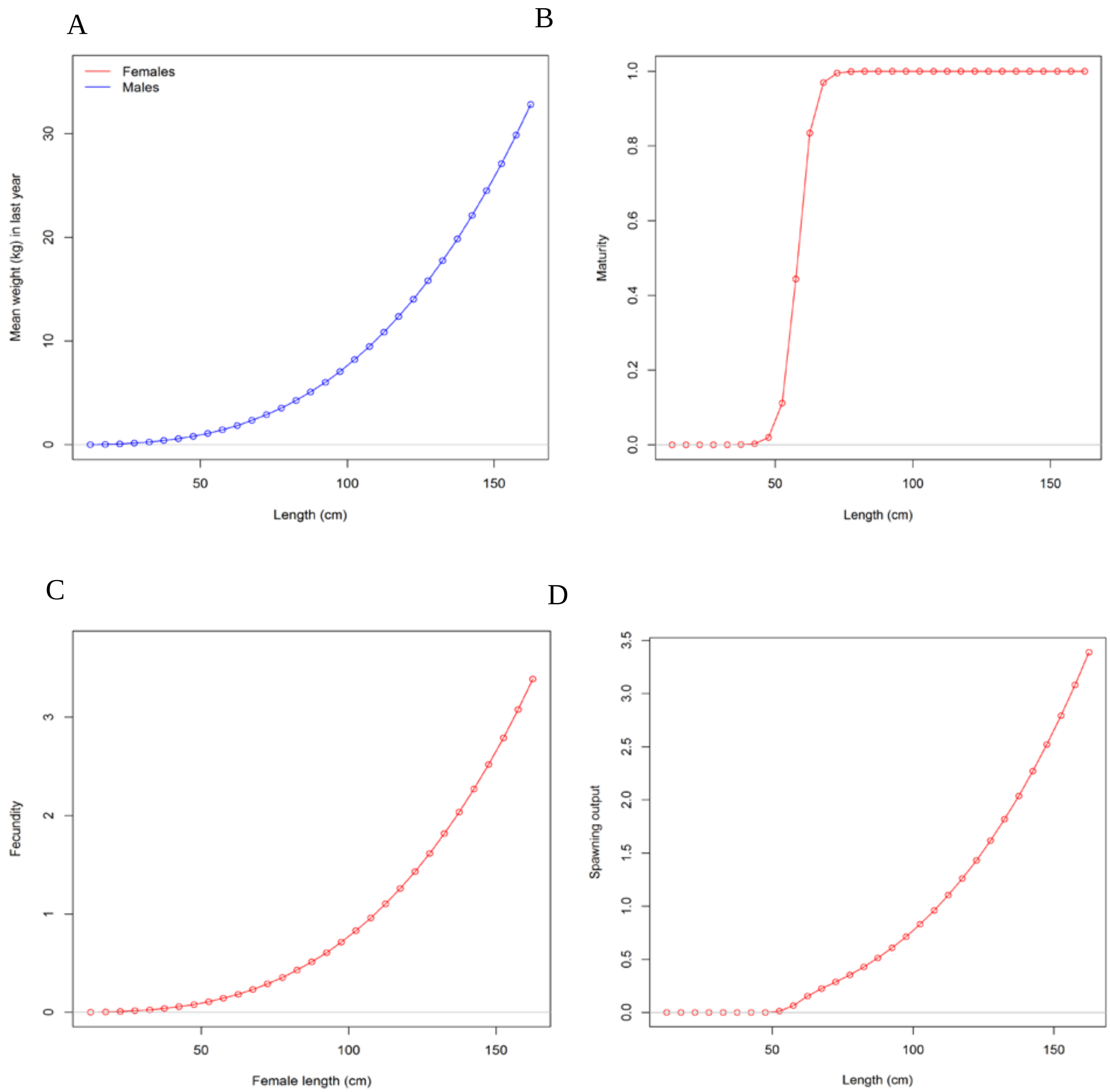

Figure 3.2. King Mackerel reproductive life history assumptions. A. length-weight relationship, B. maturity as a function of length, C. fecundity as function of length and D. Spawning output as a function of length (product of maturity and fecundity).

4. Stock Assessment Results

4.1 Sensitivity of SEDAR 38 to the Recreational Fishing Effort Survey

The change from the CHTS to the FES resulted in increased catch and dead discard estimates of the charter/private (CP/PR) fleet by roughly 38% per year on average, and to a lesser magnitude, decreased headboat (HB) discard estimates by approximately 25% on average. The effects on the SEDAR 38 assessment of these changes was straightforward. Increased CP/PR landings resulted in higher mean recruitment estimates (i.e. more fish were created to account for increased removals), and in turn higher biomass and yield estimates (**Figure 4.1, Table 4.1**). The change in HB estimates had minimal effect on SEDAR 38 recruitment or biomass estimates (**Figure 4.1**), since the magnitude of the HB discards are negligible compared to landings and other fleet discards. **Table 4.1** shows the effect of both revisions to SEDAR 38 benchmarks. Notably, the target fishing rate at the 30% spawning potential ratio was similar across the sensitivities.

4.2 SEDAR 38 Update

4.2.1 SS3 model convergence and fit diagnostics

SS3 converged to a stable solution, with a negative log-likelihood consistent across the jittered parameter starting values (**Figure 4.2**). Therefore, the final model solution was considered to be at parameter maximum likelihood estimates. Parameter standard deviations were estimated from the inverse of the Hessian matrix, a key diagnostic of successful model convergence (i.e. estimates of covariance across parameters were obtained). The model gradient was 0.015, higher than a target of 0.001 (lower is better), but was considered acceptable for model convergence since the solution was stable.

Likelihood profiles for steepness (**Figure 4.3**) showed a minimum profile value of 0.55, indicating steepness was, technically, estimable parameter in the model. However, the stock recruitment relationship showed little evidence of a strong relationship leading the SEDAR 38 expert review panel to recommend that it be fixed at 0.99. That parameterization was retained in this update. Similar in pattern to SEDAR 38 analyses, the length composition data dominates the total likelihood, and the age data are in direct conflict with the other information. Given the base model assumption of a fixed steepness at 0.99, evaluating the sensitivity of alternative values across the range of biologically plausibility value provided a dimension of uncertainty of stock trend and status to alternative productivity assumptions. The stock depletion level was determined to be above the target value (i.e. stock was not depleted) across all steepness sensitivity runs (**Figure 4.4**).

Unfished recruitment was well determined in the model (**Figure 4.5**); however, similar to observations of steepness, there is a conflict between the length composition and the age data, which would tend towards higher values. As was found during SEDAR 38, the information taken as a whole provides a defined best estimate for average unfished recruitment near 9.8 million age-0 fish.

The model showed a general good fit to fleet relative abundance inter-annual trends (**Figure 4.6**), but often missed the magnitude of change in some years. For example, the recent period headboat decline and rebound were captured in the model predicted trend but not magnitude (**Figure 4.6**). Given the multiple fleet dynamics incorporated in the model, and the agreement in recent trend between indices (all increased relatively steadily since SEDAR 38), the overall model performance on index fits was considered acceptable. Fits to the SEAMAP trawl fishery independent survey showed a possible offset in the recent period, which might be explained by the series input as an age-0 index, but the data comprised of age-0 plus age-1 fish. An evaluation of alternative reference ages for the SEAMAP index, or modified index that references age-0 and age-1 fish separately is recommended for future research assessments.

Fits to the length composition (**Figure 4.7**) and associated model residuals (**Figure 4.8**) provided a primary diagnostic of model performance. As observed during SEDAR 38, the model demonstrated acceptable fit to the length composition data for both commercial and recreational fleets. Fits to the population size structure appeared adequate for the recreational headboat and charter and private fleets; however, fits to the sex specific length data were less accurate across years. Predicted tournament length composition showed good fit to the population and female data, but predicted lengths of males showed a consistent positive bias. Pearson residuals also demonstrated acceptable model fit across the range of the data, but showed a lack-of-fit to some data sources near the extreme upper and lower tails of the size distributions where few observations were available. In general, the fleet length composition fits for the period 1980 to 2017 and estimates of fleet selectivities (**Figures 4.9 and 4.10**) matched those from SEDAR 38 with great similarity, indicating stable model performance with the addition of five years of data.

One of the major advantages of SS3 in SEDAR 38 was the ability to model gender-specific growth patterns, a known population dynamic for King Mackerel; females grow more rapidly and to larger sizes than males. Estimates of male and female growth patterns were very consistent in the updated model compared to SEDAR 38 **(Figure 4.11**). Since much of SS3 programmed population dynamics are dependent on growth assumptions, the data plotted in **Figure 2.10** in the previous section provides a validation of the modeled asymptotic growth. This agreement between observed size distributions of males and females at the maximum ageclass and the estimated mean asymptotic lengths is an important confirmation that growth was appropriately specified in the model.

Model parameters are presented in **Table 4.2,** including whether the parameter was fixed or estimated, maximum likelihood estimates, associated asymptotic standard errors, initial values, minimum and maximum values, and priors. Overall, parameter estimates were relatively precise; SS3 estimated low standard errors for the majority of parameters with a few exceptions. Standard errors were high for the most recent recruitment deviations and for several of the selectivity parameters. We discuss the selectivity parameters below in more detail in the following section. The standard errors for the two most recent recruitment deviations (2016 and 2017) are much higher (~0.2) than in earlier years likely due to the more limited signal from age and length information compared to when the fish enter the fisheries at older ages.

4.2.2 Fishery Selectivity

Fleet selectivity estimates were very consistent with SEDAR 38 (**Figures 4.9 and 4.10**). Length-based selectivity for all sexes and fleets other than tournaments was strongly dome-shaped. Most selectivity parameters were estimated with good precision; however, a few showed high CVs and were poorly estimated (**Table 4.2**). For the Handline, Gillnet and Charter/private the width of plateau of the dome (parameter 2, SizeSel_1P_2_1_HL, SizeSel_2P_2_2_GN, SizeSel_5P_2_5_CP) had CVs greater than 100% indicating that these were very not well informed by the data, or potentially correlated with other parameters. In addition, the female offset to the first parameter defining the location of peak selectivity was also poorly estimated (SzSel_1Fem_Ascend_1_HL). For the tournament fishery, the logistic selectivities estimated fish at or above 100 cm were fully selected, which contrasts with the other fleets in which fish above 100cm are less vulnerable to capture than smaller sizes. Both the SEAMAP survey and the Shrimp fishery selectivities were fixed to only age-0 fish.

4.2.3 Fishing Mortality

Fishing mortality rates (estimated as exploitation rate in number) have remained relatively constant since SEDAR 38, with 4-5% (0.04-0.05) of the stock (in numbers) removed by fishing activities (landed and discarded dead) annually during 2011 to 2017 (**Table 4.3, Figure 4.12**). Peak fishing mortality occurred during the 1990s, when 8 to 11% (exploitation rate of 0.08 to 0.11) of the stock was removed by fishing each year. Since that time, fishing mortality has generally declined. Overall, recent harvest rates were at the lowest levels since the early 1970s (**Table 4.3**). Similar to the findings of SEDAR 38, the recreational charter/private and the commercial handline fleets are the predominant sources of fishing mortality. In comparison, gillnets, shrimp bycatch, headboats, and tournaments exert considerably lower mortality.

4.2.4 Recruitment

One of the major assumptions of SEDAR 38 was that recruitment to the population is independent across the range of estimated spawning stock biomass, that is the steepness parameter (h) of the Beverton-Holt curve was fixed at 0.99 (**Figure 4.13**). Under this assumption, the main productivity parameter estimated in SS3 was the average level of age-0 recruitment at unfished equilibrium spawning biomass (R0). Similar to SEDAR 38, the likelihood profile indicated a maximum likelihood estimate of steepness was lower than 0.99; however, there was notable conflict between data sources on the best estimate. Further, the log-likelihood profile analysis of steepness indicated that stock trends (e.g. SSB) and status determinations (e.g. SSB/SSB_{SPR30}) were largely consistent across alternative steepness sensitivities, as discussed in Section 4.2.1.

Annual recruitment deviations highlighted the variability in year-to-year recruitments, with a general cyclical pattern of periods of high and low signals (**Figure 4.14**). SS3 estimated many below average cohorts during 1981 to 1995, several above average cohorts during 1995 to 2007, below average recruitment during 2008 to 2012 and most recently, a period of above average recruitments from 2013 to 2016 (**Table 4.4**). Two of the highest recruitments on record were estimated to have occurred in 2015 and 2016 (**Table 4.4**, **Figure 4.15**).

A detailed inquiry was undertaken to assess the evidence for recent high recruitment. A high recruitment signal was detected in the SEAMAP fishery independent juvenile survey in 2016, which showed one of the highest catch rates in the time series; however, less evidence was seen in the index for the 2015 cohort. Leave-one-out analyses and single-information source sensitivities by data type (indices, discards, length composition, age data) showed evidence that handline fleet age data, and multiple fleet length compositions supported the high recent recruitments. However, there was a notable lack of coverage in the age data in the most recent years, particularly from the North Carolina fisheries. Some of the lack of coverage may have reflected challenge in sampling after Hurricane Matthew in 2016. North Carolina fisheries in the past have caught some of the largest and oldest fish, so the loss of data would have required re-partitioning the fleets in the model to avoid a false signal in annual age-at-length data. Hence, the most straightforward option for the update assessment was to remove the age data from the commercial handline fleet in 2016 and 2017.

In general, the model showed consistency in high and low recruitment signals from the data sources. For example, SEDAR 38 detected a period of low recruitments in the terminal years, and the trends were similar in the updated model (five additional years of data). If current recruitment estimates are accurate, the fishers should have noticed an increased abundance of mackerel in recent years compared to prior to 2014. That is, the model estimated a low recruitment period up to SEDAR 38 (2008 to 2012), with a notable decline in commercial and recreational landings. In contrast, the period after (2013 to 2016) showed a series of above average recruitments. Discussions with stakeholders could be a method to validate the model predictions with observations on the water.

4.2.5 Stock Biomass

Estimates of total stock biomass and spawning biomass were consistent between SEDAR 38 and the updated assessment, with exception to the increased magnitude associated with the Fishing Effort Survey described in Section 4.1. Similar to SEDAR 38, estimates of SSB were fairly well determined as evidenced by the 95% intervals (**Figure 4.16**). Stock recruitment and biomass trends did not change between assessments, highlighting model stability in historic estimates. Biomass was estimated to be near unfished levels prior to the 1950s, followed by a period of decline between 1980 and the late 1990s (**Figure 4.16**). Stock biomass reached its lowest point in 1998, after which there was a steady biomass increase up to 2010. Since 2010, the stock has shown a more cyclical pattern associated with the estimated periods of high and low recruitment. Stock biomass increased steadily over the last four years since SEDAR 38 (**Table 4.5**, **Figure 4.16**).

4.2.6 Benchmarks/Reference points

A spawning potential ratio of 30% unfished equilibrium levels (SPR30) marked the target stock biomass and fishing mortality reference points, consistent with the adopted advice framework of SEDAR 38. The reference point estimates of South Atlantic King Mackerel were:

- Unfished equilibrium recruitment, R0 = 9,815,000 age-0 fish
- Spawning Biomass at SPR30, SSB_{SPR30} = 2,439 millions of eggs produced

- Fishing Mortality at SPR30, F_{SPR30} = 0.145 annual exploitation rate in numbers
- Equilibrium Yield at SPR30 = 18.3 million pounds
- Optimum Yield ($F=75\%F_{SPR30}$) = 16.7 million pounds
- For reference, the average yield between 2016 and 2017 was 9.6 million pounds

Time series of fishery mortality relative to the SPR30 reference point (F/F_{SPR30}) followed the period of increasing fishing pressure from 1950 to 1990, and peak fishing mortality occurred during 1998 when the estimated harvest rate was roughly 80% the SPR30 target rate (**Table 4.5, Figure 4.17**). Current fishing mortality rates (ranging 0.04 to 0.05) were markedly lower than the reference point (F_{SPR30}=0.145). The fisheries were determined to be NOT OVERFISHING.

Spawning biomass in 2017 was estimated at 4,232 (millions of eggs), above the SPR30 reference point of 2,439 (**Table 4.6, Figure 4.17**). The stock status was determined to be NOT OVERFISHED.

A summary of stock reference points, fishery status, and stock status is available in **Table 4.7**, and time series trends relative to the benchmarks are plotted in **Figure 4.18**. The estimates of current stock status and fishery status relative to the reference points were:

- SSB_{2017}/SSB_{SPR30} = 1.7
- F_{2017}/F_{SPR30} = 0.29

A probabilistic estimation of biological reference point uncertainty was conducted based on the stock status and benchmark estimate variances. Normal probability density functions provided the 95% quantiles of stock and fishery status. The confidence intervals and probability estimates of current stock and fishery status are summarized here:

- The 95% confidence interval of current stock status (SSB_{2017}/SSB_{SPR30}) = 1.6 to 1.8
- The 95% confidence interval of current fishery status (F_{2017}/F_{SPR30}) = 0.19 to 0.39
- The estimated probability the stock is overfished is less than 1%
- The estimated probability that overfishing is occurring is less than 1%

We conducted a retrospective analysis to evaluate how terminal trends diverge when additional information is added to the model. Overall, there were no severe patterns or systematic bias revealed from the retrospective runs (**Figure 4.19**). All bias diagnostic statistics (Mohn's rho) were below the target threshold (i.e. less than 0.2). There was some evidence for caution in reliability of estimates of the terminal years' recruitments, likely due to the change in information from age-0 survey only to length and age data added in following years.

4.3 Projections

Future catches at the benchmark exploitation rate (F_{SPR30}=0.145) for fishing years 2021 to 2025 were notably higher than recent catches (**Table 4.8**). This was due to the shift in estimated recruitment from a 5-year period (2008-12) of below average recruitment, to a recent four-year period of above average recruitment (2013-16). In general, the catch projection was highest for fishing year 2021, and declined toward to an equilibrium yield of 18.3 million pounds at constant recruitment of 9.8 million fish. The allowable biological catches associated with a range of p-star values from 0.1 to 0.5 are listed in **Table 4.8**, and the probability density distributions around projected yields at F_{SPR30} are plotted in **Figure 4.20**. The allowable biological catches at different p-star values are also highlighted in **Figure 4.20**. **Table 4.9** contains the projected recruitment, spawning biomass, and stock status under constant exploitation at F_{SPR30}.

The distinct cyclical shift in recruitment from the low period occurring up to SEDAR 38 to the recent high recruitment period may provide an opportunity to evaluate how well the assessment model estimates align with observations by stakeholders over the last decade. Particularly, stakeholder comments during SEDAR 38 provided evidence of a recent large cohort of juveniles in the Atlantic. SS3 estimated above average recruitment in 2013 and 2014, and two of the largest cohorts in the time series in 2015 and 2016. These fish would have entered the fisheries beginning in fishing year 2015, with predicted higher abundance beginning in fishing year 2017, particularly of fish between 20 to 36 inches fork length. Conversations with stakeholders may provide additional evidence for these high recruitment events that are expected to result in significantly increased catches at the target exploitation rate over the next five years.

Projected yields and stock spawning biomass trends under four fishing scenarios were compared to highlight the trade-offs between alternative constant exploitation strategies (**Figure 4.21**). The fishing scenarios included zero exploitation (constant F equal to 0), exploitation at the OFL (constant F equal to $F_{SPR30} = 0.14$), exploitation at the constant F equal to 75% of F_{SPR30} (F=0.11), and exploitation at current fishing mortality rates (constant F = 0.05). Fishing at the OFL would result in a three-fold increase over current fishing mortality. In general, fishing at current exploitation levels results in a relatively steady stock biomass near current levels, while fishing at OFL resulted in a rapid decline in spawning biomass toward to SPR target. Lastly, a low future recruitment sensitivity was parameterized to determine the difference in 2021-25 OFLs in the case that recruitment cycles back to a low period, similar to the period 2008 to 2012. This sensitivity fixed the future recruitment deviations from 2018 to 2025 to mimic the low period observed prior to SEDAR 38 (**Figure 4.22**). The results indicated a period of low recruitment beginning in 2018 would result in an approximately 15% to 30% reduction in OFL compared to the average recruitment base projections (**Table 4.10**).

4.4 Summary and Conclusions

Overall, the SS3 model for South Atlantic King Mackerel demonstrated good convergence, acceptable fits to the data sources, and stable performance in terms of solving to a consistent solution, as well as estimating similar growth, selectivity, biomass, and recruitment trends as the previous assessment. The stock was determined to be NOT OVERFISHED and the fisheries are NOT OVERFISHING. In general, all fishery indicators and resulting stock status estimates showed positive trends since SEDAR 38. Comparison of model results between SEDAR 38 and this update highlighted a consistency in stock estimates, particularly the long-term biomass trends and recruitment signals. Recent above average recruitment estimates (2013 to 2016) contrasted the period prior (2008 to 2012) of below average recruitments first detected during SEDAR 38. Two high recruitment years were estimated for 2015 and 2016, supported by the juvenile survey observations in 2016 (SEAMAP trawl survey), as well as fleet length compositions. The distinct shift in recruitment trends would have resulted in an increased abundance of fish available to the fisheries in recent years. Discussions with stakeholders may help validate the model, as the stock abundance was estimated to be at its highest level in over 40 years, with coincident increasing catches and catch rates, and the lowest exploitation rate since the 1970s.

4.5 Research recommendations

In addition to the research recommendations documented during SEDAR 38, additional recommendation were noted during the update assessment. Research aimed at improving the documentation of data series formatting, including index standardization, for SS3 would improve modeling efficiency. This includes statistical coding for consistent database querying and data processing. An evaluation of alternative age references, or age-specific time series, for the SEAMAP fishery independent survey was recommended by the data providers and noted by the analyst for future assessments. An analysis of the effect of excluding sublegal fish size observations on the assessment should be undertaken. Information on the age-composition of discarded fish from all fleets is needed to validate the assumption of exclusively age-0 discards. The conditional age-at-length data had a significant influence on recent recruitment estimates. Future research assessments should evaluate model sensitivity to the age-data and explore alternative parameterizations (such as inverse age-length key), as the fleet coverage was suboptimal with zero information available for several fleets and years.

4.6 Acknowledgements

Many people at various state and federal agencies assisted with assembling the data sources included in this stock assessment. We thank the data providers, assessment analysts, and technical reviewers for all of their efforts.

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4.8 Tables

Table 4.1. Sensitivity analyses of SEDAR 38 demonstrating the effect of the Fishing Effort Survey recreational landings estimates on stock benchmarks. Spawning biomass is in millions of eggs, total biomass is in metric tons, recruitment is in thousands of age-0 fish, SPR30% is the spawning potential (egg production) at 30% at unfished equilibrium spawning, and F is the exploitation rate by numbers.

	SEDAR 38	Increased CP/PR Landings	Decreased HB Landings
Spawning Biomass Unfished	7973	8389	7929
Total Biomass Unfished	134213	141173	133479
Recruitment Unfished	9719	10239	9671
SPR target	0.30	0.30	0.30
Spawning Biomass at SPR30	2378	2502	2365
F at SPR30	0.15	0.15	0.15
Total Yield at SPR30%	17.7 mil lbs	18.9 mil lbs	17.6 mil lbs

Table 4.2. List of Non-F SS parameters for South Atlantic King Mackerel, that includes the initial parameter starting values, estimated parameter values and their associated standard errors, and probability density functions assigned as priors. Parameters that were held constant to their input values are labeled as fixed.

Num	Label	Estimation	Init	PR_type	Prior	Prior_SD	Estimate	StDev
1	L_at_Amin_Fem_GP_1	fixed	21	Normal	21	0.051	21	_
2	L_at_Amax_Fem_GP_1	estimated	116.767	none			116.755	0.335
3	VonBert_K_Fem_GP_1	estimated	0.31596	none			0.314031	0.003
4	CV_young_Fem_GP_1	estimated	0.252128	none			0.244399	0.004
5	CV_old_Fem_GP_1	estimated	0.078575	none			0.0791088	0.001
6	L_at_Amin_Mal_GP_1	fixed	21	Normal	21	0.0235	21	_
7	L_at_Amax_Mal_GP_1	estimated	96.7974	none			96.814	0.249
8	VonBert_K_Mal_GP_1	estimated	0.397624	none			0.393502	0.005
9	CV_young_Mal_GP_1	estimated	0.260586	none			0.261901	0.005
10	CV_old_Mal_GP_1	estimated	0.0627828	none			0.0627139	9E-04
11	Wtlen_1_Fem	fixed	7.31E-06	Normal	7.31E-06	0.8	7.31E-06	_
12	Wtlen_2_Fem	fixed	3.00871	Normal	3.00871	0.8	3.00871	_
13	Mat50%_Fem	fixed	58.113	Normal	58.113	0.8	58.113	_
14	Mat_slope_Fem	fixed	-0.36886	Normal	-0.36886	0.8	-0.36886	_
15	Eggs_scalar_Fem	fixed	6.08E-07	Normal	6.08E-07	0.8	6.08E-07	_
16	Eggs_exp_len_Fem	fixed	3.0512	Normal	3.0512	0.8	3.0512	_
17	Wtlen_1_Mal	fixed	7.31E-06	Normal	7.31E-06	0.8	7.31E-06	_
18	Wtlen_2_Mal	fixed	3.00871	Normal	3.00871	0.8	3.00871	_
19	RecrDist_GP_1	fixed	0	none			0	_
20	RecrDist_Area_1	fixed	0	none			0	_
21	RecrDist_Seas_1	fixed	0	none			0	_
22	CohortGrowDev	fixed	0	none			0	_
23	SR_LN(R0)	estimated	9.18813	none			9.19166	0.034
24	SR_BH_steep	fixed	0.99	none			0.99	_
25	SR_sigmaR	estimated	0.69286	none			0.674025	0.049
26	SR_envlink	fixed	0	none			0	_
27	SR_R1_offset	fixed	0	none			0	_
28	SR_autocorr	fixed	0	none			0	_
29	Main_RecrDev_1981	estimated	_	dev			0.0579527	0.077
30	Main_RecrDev_1982	estimated	_	dev			-0.285574	0.08
31	Main_RecrDev_1983	estimated	_	dev			-0.301403	0.071
32	Main_RecrDev_1984	estimated	_	dev			0.00843779	0.054
33	Main_RecrDev_1985	estimated	_	dev			0.166194	0.047
34	Main_RecrDev_1986	estimated	_	dev			-0.108454	0.049
35	Main_RecrDev_1987	estimated	_	dev			-0.669886	0.06
36	Main_RecrDev_1988	estimated	_	dev			-0.436249	0.056
37	Main_RecrDev_1989	estimated	_	dev			0.35079	0.041
38	Main_RecrDev_1990	estimated	_	dev			0.017164	0.044
39	Main_RecrDev_1991	estimated	_	dev			-0.656804	0.056
40	Main_RecrDev_1992	estimated	_	dev			-0.414249	0.053
41	Main_RecrDev_1993	estimated	_	dev			-0.396108	0.053
42	Main_RecrDev_1994	estimated	_	dev			0.0929785	0.045
43	Main_RecrDev_1995	estimated	_	dev			0.361549	0.043

44	Main_RecrDev_1996	estimated	_	dev			0.470857	0.04
45	Main_RecrDev_1997	estimated	_	dev			-0.226298	0.047
46	Main_RecrDev_1998	estimated	_	dev			0.530071	0.036
47	Main_RecrDev_1999	estimated	_	dev			-0.15686	0.045
48	Main_RecrDev_2000	estimated	_	dev			-0.528002	0.055
49	Main_RecrDev_2001	estimated	_	dev			0.485121	0.041
50	Main_RecrDev_2002	estimated	_	dev			0.0198679	0.053
51	Main_RecrDev_2003	estimated	_	dev			0.819503	0.04
52	Main_RecrDev_2004	estimated	_	dev			0.514756	0.045
53	Main_RecrDev_2005	estimated	_	dev			0.236734	0.045
54	Main_RecrDev_2006	estimated	_	dev			0.356658	0.041
55	Main_RecrDev_2007	estimated	_	dev			0.302064	0.041
56	Main_RecrDev_2008	estimated	_	dev			-0.523541	0.06
57	Main_RecrDev_2009	estimated	_	dev			-0.93442	0.075
58	Main_RecrDev_2010	estimated	_	dev			-0.523423	0.061
59	Main_RecrDev_2011	estimated	_	dev			-0.836257	0.073
60	Main_RecrDev_2012	estimated	_	dev			-0.15894	0.062
61	Main_RecrDev_2013	estimated	_	dev			0.444997	0.059
62	Main_RecrDev_2014	estimated	_	dev			0.326737	0.095
63	Main_RecrDev_2015	estimated	_	dev			0.698656	0.116
64	Main_RecrDev_2016	estimated	_	dev			0.832308	0.183
65	Main_RecrDev_2017	estimated	_	dev			0.0630716	0.165
780	LnQ_base_3_3_Shrimp	estimated	5.40276	none			5.4439	0.123
781	SizeSel_1P_1_1_HL	estimated	72.4583	none			72.3552	0.61
782	SizeSel_1P_2_1_HL	estimated	-12.0821	Normal	-12.0821	2	-12.082	1.999
783	SizeSel_1P_3_1_HL	estimated	5.11995	none			5.11673	0.077
784	SizeSel_1P_4_1_HL	estimated	4.78641	none			4.80104	0.16
785	SizeSel_1P_5_1_HL	fixed	-15	none			-15	_
786	SizeSel_1P_6_1_HL	estimated	-1.48095	none			-1.49017	0.156
787	Retain_1P_1_1_HL	fixed	29	none			29	_
788	Retain_1P_2_1_HL	fixed	1	none			1	_
789	Retain_1P_3_1_HL	fixed	1	none			1	_
790	Retain_1P_4_1_HL	fixed	0	none			0	_
791	DiscMort_1P_1_1_HL	fixed	10	none			10	_
792	DiscMort_1P_2_1_HL	fixed	1	none			1	_
793	DiscMort_1P_3_1_HL	fixed	0.25	none			0.25	_
794	DiscMort_1P_4_1_HL	fixed	0	none			0	_
795	SzSel_1Fem_Peak_1_HL	estimated	3.00552	none			2.96935	0.634
796	SzSel_1Fem_Ascend_1_HL	fixed	0	none			0	_
797	SzSel_1Fem_Descend_1_HL	estimated	0.914334	none			0.913998	0.158
798	SzSel_1Fem_Final_1_HL	estimated	-0.77228	none			-0.76493	0.195
799	SzSel_1Fem_Scale_1_HL	fixed	1	none			1	_
800	SizeSel_2P_1_2_GN	estimated	73.3709	none			73.4617	1.025
801	SizeSel_2P_2_2_GN	estimated	-12.7197	Normal	-12.7197	2	-12.7197	1.998
802	SizeSel_2P_3_2_GN	estimated	4.27117	Normal	4.78044	2	4.29863	0.203
803	SizeSel_2P_4_2_GN	estimated	6.85985	none			6.87479	0.099
804	SizeSel_2P_5_2_GN	fixed	-999	none			-999	_
805	SizeSel_2P_6_2_GN	fixed	-999	none			-999	_
806	SizeSel_4P_1_4_HB	estimated	66.5652	none			66.423	0.63
807	SizeSel_4P_2_4_HB	estimated	-3.24408	none			-3.26174	0.4
808	SizeSel_4P_3_4_HB	estimated	4.88427	none			4.86567	0.099
809	SizeSel_4P_4_4_HB	estimated	5.27189	none			5.2897	0.127
810	SizeSel_4P_5_4_HB	fixed	-15	none			-15	_
811	SizeSel_4P_6_4_HB	estimated	-2.42102	none			-2.41149	0.097
812	Retain_4P_1_4_HB	fixed	29	none			29	_

813	Retain_4P_2_4_HB	fixed	1	none			1	_	
814	Retain_4P_3_4_HB	fixed	1	none			1	_	
815	Retain_4P_4_4_HB	fixed	0	none			0	_	
816	DiscMort_4P_1_4_HB	fixed	10	none			10	_	
817	DiscMort_4P_2_4_HB	fixed	1	none			1	_	
818	DiscMort_4P_3_4_HB	fixed	0.22	none			0.22	_	
819	DiscMort_4P_4_4_HB	fixed	0	none			0	_	
820	SizeSel_5P_1_5_CP	estimated	73.4696	none			73.3946		0.585
821	SizeSel_5P_2_5_CP	estimated	-13.0702	Normal	-13.0702	2	-13.0701		1.997
822	SizeSel_5P_3_5_CP	estimated	5.77602	none			5.77968		0.081
823	SizeSel_5P_4_5_CP	estimated	4.4313	none			4.42989		0.161
824	SizeSel_5P_5_5_CP	fixed	-15	none			-15	_	
825	SizeSel_5P_6_5_CP	estimated	-1.03479	none			-1.01713		0.066
826	Retain_5P_1_5_CP	fixed	29	none			29	_	
827	Retain_5P_2_5_CP	fixed	1	none			1	_	
828	Retain_5P_3_5_CP	fixed	1	none			1	_	
829	Retain_5P_4_5_CP	fixed	0	none			0	_	
830	DiscMort_5P_1_5_CP	fixed	10	none			10	_	
831	DiscMort_5P_2_5_CP	fixed	1	none			1	_	
832	DiscMort_5P_3_5_CP	fixed	0.2	none			0.2	_	
833	DiscMort_5P_4_5_CP	fixed	0	none			0	_	
834	SizeSel_6P_1_6_TOURN	estimated	87.5994	none			87.6669		0.881
835	SizeSel_6P_2_6_TOURN	fixed	-6.07561	none			-6.07561	_	
836	SizeSel_6P_3_6_TOURN	estimated	5.62842	none			5.6245		0.097
837	SizeSel_6P_4_6_TOURN	fixed	4.21396	none			4.21396	_	
838	SizeSel_6P_5_6_TOURN	fixed	-15	none			-15	_	
839	SizeSel_6P_6_6_TOURN	fixed	15	none			15	_	
840	SzSel_6Fem_Peak_6_TOURN	fixed	-10	none			-10	_	
841	SzSel_6Fem_Ascend_6_TOURN	estimated	-0.03933	Normal	-0.03934	0.03	-0.04071		0.026
842	SzSel_6Fem_Descend_6_TOURN	fixed	-10	none			-10	_	
843	SzSel_6Fem_Final_6_TOURN	fixed	-10	none			-10	_	
844	SzSel_6Fem_Scale_6_TOURN	fixed	1	none			1	_	
845	AgeSel_3P_1_3_Shrimp	fixed	0	none			0	_	
846	AgeSel_3P_2_3_Shrimp	fixed	0	none			0	_	
847	AgeSel_7P_1_7_SeaTrawl	fixed	0	none			0	_	
848	AgeSel_7P_2_7_SeaTrawl	fixed	0	none			0	_	
849	Retain_1P_1_1_HL_BLK1repl_1990	fixed	35	Normal	51	10	30	_	
850	Retain_1P_1_1_HL_BLK1repl_1992	fixed	51	Normal	61	10	51	_	
851	Retain_1P_1_1_HL_BLK1repl_1999	fixed	61	Normal	61	10	61	_	
852	Retain_4P_1_4_HB_BLK1repl_1990	fixed	35	Normal	51	10	30	_	
853	Retain_4P_1_4_HB_BLK1repl_1992	fixed	51	Normal	61	10	51	_	
854	Retain_4P_1_4_HB_BLK1repl_1999	fixed	61	Normal	61	10	61	_	
855	Retain_5P_1_5_CP_BLK1repl_1990	fixed	35	Normal	51	10	30	_	
856	Retain_5P_1_5_CP_BLK1repl_1992	fixed	51	Normal	61	10	51	_	
857	Retain_5P_1_5_CP_BLK1repl_1999	fixed	61	Normal	61	10	61	_	
858	SizeSel_6P_1_6_TOURN_BLK2repl_1997	estimated	114.524	none			114.932		1.835
859	SizeSel_6P_3_6_TOURN_BLK2repl_1997	estimated	6.39607	none			6.40724		0.101

Table 4.3. Estimated annual exploitation rate (by number) of South Atlantic King Mackerel.

Fishing Year	F	Fishing Year	F	Fishing Year	F
1901	0.000	1951	0.014	2001	0.066
1902	0.000	1952	0.013	2002	0.069
1903	0.001	1953	0.014	2003	0.083
1904	0.001	1954	0.014	2004	0.064
1905	0.002	1955	0.017	2005	0.060
1906	0.002	1956	0.021	2006	0.086
1907	0.003	1957	0.022	2007	0.089
1908	0.003	1958	0.022	2008	0.062
1909	0.004	1959	0.024	2009	0.073
1910	0.005	1960	0.025	2010	0.063
1911	0.005	1961	0.027	2011	0.047
1912	0.006	1962	0.028	2012	0.044
1913	0.006	1963	0.030	2013	0.040
1914	0.007	1964	0.031	2014	0.042
1915	0.007	1965	0.033	2015	0.040
1916	0.008	1966	0.033	2016	0.049
1917	0.009	1967	0.034	2017	0.042
1918	0.009	1968	0.035		
1919	0.009	1969	0.038		
1920	0.008	1970	0.040		
1921	0.008	1971	0.039		
1922	0.008	1972	0.044		
1923	0.007	1973	0.048		
1924	0.010	1974	0.050		
1925	0.011	1975	0.053		
1926	0.010	1976	0.057		
1927	0.013	1977	0.057		
1928	0.010	1978	0.053		
1929	0.010	1979	0.054		
1930	0.009	1980	0.067		
1931	0.010	1981	0.066		
1932	0.010	1982	0.070		
1933	0.009	1983	0.063		
1934	0.008	1984	0.061		
1935	0.010	1985	0.066		
1936	0.012	1986	0.070		
1937	0.008	1987	0.058		
1938	0.011	1988	0.069		
1939	0.010	1989	0.067		
1940	0.006	1990	0.092		
1941	0.000	1991	0.078		
1942	0.000	1992	0.095		
1943	0.000	1993	0.079		
1944	0.000	1994	0.092		
1945	0.011	1995	0.089		
1946	0.009	1996	0.082		
1947	0.006	1997	0.081		
1948	0.004	1998	0.115		
1949	0.006	1999	0.070		
1950	0.011	2000	0.079		

Table 4.4. Atlantic King Mackerel estimated spawning stock biomass (SSB in millions of eggs) and recruitment (in thousands fish).

Fishing Year	SSB	Rec	Fishing Year	SSB	Rec	Fishing Year	SSB	Rec
1901	8130	9815	1951	7696	9813	2001	3501	12661
1902	8129	9815	1952	7645	9813	2002	3556	7952
1903	8127	9815	1953	7598	9813	2003	3564	17690
1904	8121	9815	1954	7555	9813	2004	3628	13045
1905	8111	9815	1955	7515	9813	2005	3838	9881
1906	8097	9815	1956	7455	9813	2006	4218	11146
1907	8080	9815	1957	7374	9812	2007	4383	10556
1908	8060	9815	1958	7293	9812	2008	4415	4623
1909	8038	9815	1959	7222	9812	2009	4560	3066
1910	8013	9815	1960	7146	9811	2010	4534	4624
1911	7986	9814	1961	7075	9811	2011	4369	3381
1912	7957	9814	1962	6999	9811	2012	4171	6655
1913	7926	9814	1963	6923	9811	2013	3956	12171
1914	7895	9814	1964	6847	9810	2014	3789	10811
1915	7862	9814	1965	6767	9810	2015	3772	15682
1916	7828	9814	1966	6684	9810	2016	3953	17928
1917	7793	9814	1967	6615	9809	2017	4232	8310
1918	7757	9814	1968	6543	9809			
1919	7721	9814	1969	6475	9809			
1920	7691	9813	1970	6398	9808			
1921	7667	9813	1971	6316	9808			
1922	7649	9813	1972	6253	9807			
1923	7637	9813	1973	6169	9807			
1924	7630	9813	1974	6070	9806			
1925	7606	9813	1975	5965	9806			
1926	7579	9813	1976	5854	9805			
1927	7556	9813	1977	5733	9805			
1928	7517	9813	1978	5628	9804			
1929	7499	9813	1979	5558	9803			
1930	7489	9813	1980	5505	9803			
1931	7485	9813	1981	5400	8277			
1932	7476	9813	1982	5296	5870			
1933	7466	9813	1983	5162	5777			
1934	7468	9813	1984	5011	7874			
1935	7479	9813	1985	4798	9218			
1936	7478	9813	1986	4569	7003			
1937	7464	9813	1987	4400	3994			
1938	7473	9813	1988	4316	5044			
1939	7462	9813	1989	4140	11080			
1940	7459	9813	1990	3941	7935			
1941	7479	9813	1991	3703	4043			
1942	7545	9813	1992	3645	5152			
1943	7610	9813	1993	3486	5245			
1944	7673	9813	1994	3317	8551			
1945	7730	9814	1995	3124	11181			
1946	7706	9814	1996	3005	12470			
1947	7693	9813	1997	3042	6210			
1948	7698	9813	1998	3191	13236			
1949	7721	9814	1999	3233	6660			
1950	7728	9814	2000	3374	4596			

Table 4.5. Fishery status of Atlantic King Mackerel, measured as fishing mortality relative to fishing mortality rate that achieves a spawning potential of 30% unfished equilibrium.

Fishing Year	F/FSPR30	Fishing Year	F/FSPR30	Fishing Year	F/FSPR30
1901	0.001	1951	0.094	2001	0.454
1902	0.002	1952	0.092	2002	0.478
1903	0.005	1953	0.093	2003	0.568
1904	0.009	1954	0.094	2004	0.440
1905	0.013	1955	0.119	2005	0.411
1906	0.016	1956	0.144	2006	0.592
1907	0.020	1957	0.151	2007	0.615
1908	0.024	1958	0.151	2008	0.424
1909	0.028	1959	0.166	2009	0.500
1910	0.031	1960	0.173	2010	0.433
1911	0.035	1961	0.186	2011	0.323
1912	0.039	1962	0.195	2012	0.302
1913	0.043	1963	0.204	2013	0.274
1914	0.047	1964	0.216	2014	0.289
1915	0.051	1965	0.230	2015	0.277
1916	0.054	1966	0.224	2016	0.334
1917	0.058	1967	0.236	2017	0.290
1918	0.062	1968	0.243		
1919	0.060	1969	0.260		
1920	0.058	1970	0.276		
1921	0.055	1971	0.268		
1922	0.053	1972	0.300		
1923	0.051	1973	0.327		
1924	0.069	1974	0.345		
1925	0.073	1975	0.367		
1926	0.070	1976	0.392		
1927	0.088	1977	0.393		
1928	0.071	1978	0.363		
1929	0.067	1979	0.373		
1930	0.062	1980	0.463		
1931	0.070	1981	0.454		
1932	0.071	1982	0.481		
1933	0.062	1983	0.430		
1934	0.053	1984	0.418		
1935	0.066	1985	0.456		
1936	0.079	1986	0.481		
1937	0.056	1987	0.401		
1938	0.076	1988	0.475		
1939	0.069	1989	0.463		
1940	0.045	1990	0.632		
1941	0.001	1991	0.537		
1942	0.001	1992	0.652		
1943	0.001	1993	0.545		
1944	0.002	1994	0.632		
1945	0.076	1995	0.615		
1946	0.061	1996	0.560		
1947	0.043	1997	0.557		
1948	0.026	1998	0.787		
1949	0.040	1999	0.481		
1950	0.077	2000	0.545		

Table 4.6. Stock status estimates of Atlantic King Mackerel, measured as spawning biomass (millions of eggs) relative to spawning biomass at 30% of unfished spawning potential (SSB_{SPR30}).

Fishing	SSB/SSBSPR3	Fishing	SSB/SSBSPR3	Fishing	SSB/SSBSPR3
1901	3.33	1951	3.16	2001	1.44
1902	3.33	1952	3.13	2002	1.46
1903	3.33	1953	3.12	2003	1.46
1904	3.33	1954	3.10	2004	1.49
1905	3.33	1955	3.08	2005	1.57
1906	3.32	1956	3.06	2006	1.73
1907	3.31	1957	3.02	2007	1.80
1908	3.30	1958	2.99	2008	1.81
1909	3.30	1959	2.96	2009	1.87
1910	3.29	1960	2.93	2010	1.86
1911	3.27	1961	2.90	2011	1.79
1912	3.26	1962	2.87	2012	1.71
1913	3.25	1963	2.84	2013	1.62
1914	3.24	1964	2.81	2014	1.55
1915	3.22	1965	2.77	2015	1.55
1916	3.21	1966	2.74	2016	1.62
1917	3.20	1967	2.71	2017	1.73
1918	3.18	1968	2.68		
1919	3.17	1969	2.65		
1920	3.15	1970	2.62		
1921	3.14	1971	2.59		
1922	3.14	1972	2.56		
1923	3.13	1973	2.53		
1924	3.13	1974	2.49		
1925	3.12	1975	2.45		
1926	3.11	1976	2.40		
1927	3.10	1977	2.35		
1928	3.08	1978	2.31		
1929	3.07	1979	2.28		
1930	3.07	1980	2.26		
1931	3.07	1981	2.21		
1932	3.07	1982	2.17		
1933	3.06	1983	2.12		
1934	3.06	1984	2.05		
1935	3.07	1985	1.97		
1936	3.07	1986	1.87		
1937	3.06	1987	1.80		
1938	3.06	1988	1.77		
1939	3.06	1989	1.70		
1940	3.06	1990	1.62		
1941	3.07	1991	1.52		
1942	3.09	1992	1.49		
1943	3.12	1993	1.43		
1944	3.15	1994	1.36		
1945	3.17	1995	1.28		
1946	3.16	1996	1.23		
1947	3.15	1997	1.25		
1948	3.16	1998	1.31		
1949	3.17	1999	1.33		
1950	3.17	2000	1.38		

Table 4.7. Summary of benchmarks and stock status of South Atlantic King Mackerel. Fishing mortality is exploitation rate in numbers, spawning stock biomass is in millions of eggs, and recruitment is in thousands of age 0 fish.

Metric	Value/Determination
Assessment Year	2020
Data Range in Fishing Years (Mar 1-Feb 28)	1901 to 2017
Fishing $mortality_{2017}$	0.04
Fishing $mortality_{SPR30}$	0.14
F_{2017}/F_{SPR30}	0.29
95% Confidence Interval of F_{2017}/F_{SPR30}	0.19 to 0.39
$Recruitment_{Unfished}$	9,815,000
$Recruitment_{2017}$	8,310,000
Spawning Stock $Biomass_{Unfished}$	8,130
Spawning Stock $Biomass_{SPR\ target}$	2,439
Spawning Stock $Biomass_{2017}$	4,232
SSB_{2017}/SSB_{SPR30}	1.7
95% Confidence Interval of SSB_{2017}/SSB_{MSY}	1.6 to 1.8
$Yield_{2017}$	9.5 million lbs
$Yield_{SPR\ target}$	18.3 million lbs
Optimum $Yield_{SPR\ target}$	16.7 million lbs
Stock Status	Not Overfished
Fishery Status	Not Overfishing

Table 4.8. Projected catch limits of South Atlantic King Mackerel (in millions of pounds) under constant exploitation rate = F_{SPR30}. The allowable biological catches associated with a range of p-star (p*) values from 0.1 to 0.5 are listed for the next five fishing years. The overfishing limit (OFL) is the median projected retained catch at F_{SPR30}.

Fishing Year	p*=0.1	p*=0.2	p*=0.3	p*=0.4	OFL
2021	27.7	30.0	31.6	33.0	34.3
2022	22.9	25.2	26.8	28.2	29.5
2023	19.8	22.1	23.7	25.1	26.3
2024	17.8	20.0	21.6	22.9	24.2
2025	16.3	18.5	20.1	21.5	22.7

Table 4.9. Projected recruitment (1000s of fish), spawning stock biomass (millions of eggs), and stock status estimates (relative to SSB at 30%SPR) under constant exploitation at $F=F_{SPR30}$.

Fishing Year	Recruitment	SSB	SSB/SSB_{SPR30}
2018	9797	4712	1.94
2019	9801	5160	2.12
2020	9802	5411	2.23
2021	9803	5565	2.29
2022	9799	4995	2.06
2023	9795	4503	1.85
2024	9790	4091	1.68
2025	9786	3749	1.54

Table 4.10. Sensitivity analysis of projected overfishing limits under two alternative future recruitment scenarios, which included average recruitment (base advice) and a low recruitment scenario.

Fishing Year	OFL_average recruitment	OFL_Low recruitment	Difference
2021	34.3	29.3	-0.15
2022	29.5	22.4	-0.24
2023	26.3	18.2	-0.31
2024	24.2	17.2	-0.29
2025	22.7	17.8	-0.21

4.9 Figures

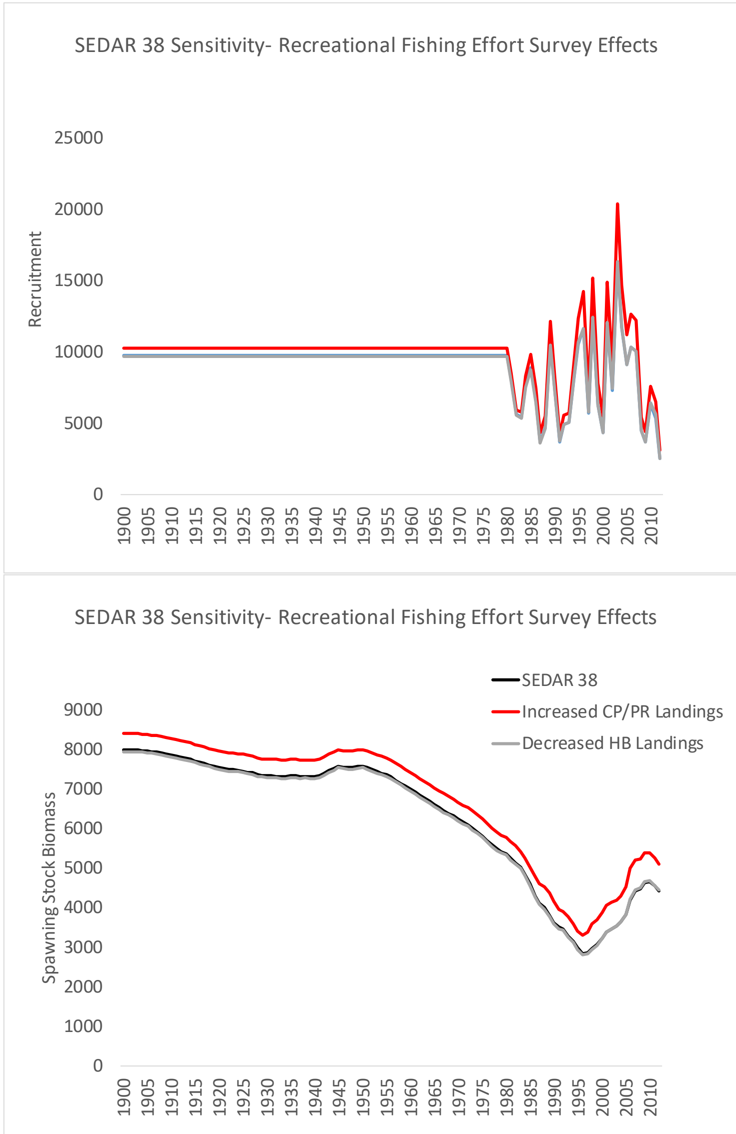


Figure 4.1. Sensitivity analysis of SEDAR 38 demonstrating the effect of revised landings estimates from the recreational Fishing Effort Survey on estimates of recruitment and spawning stock biomass of South Atlantic King Mackerel. Note that SEDAR 38 estimates were based on the MRIP Household Telephone Survey.

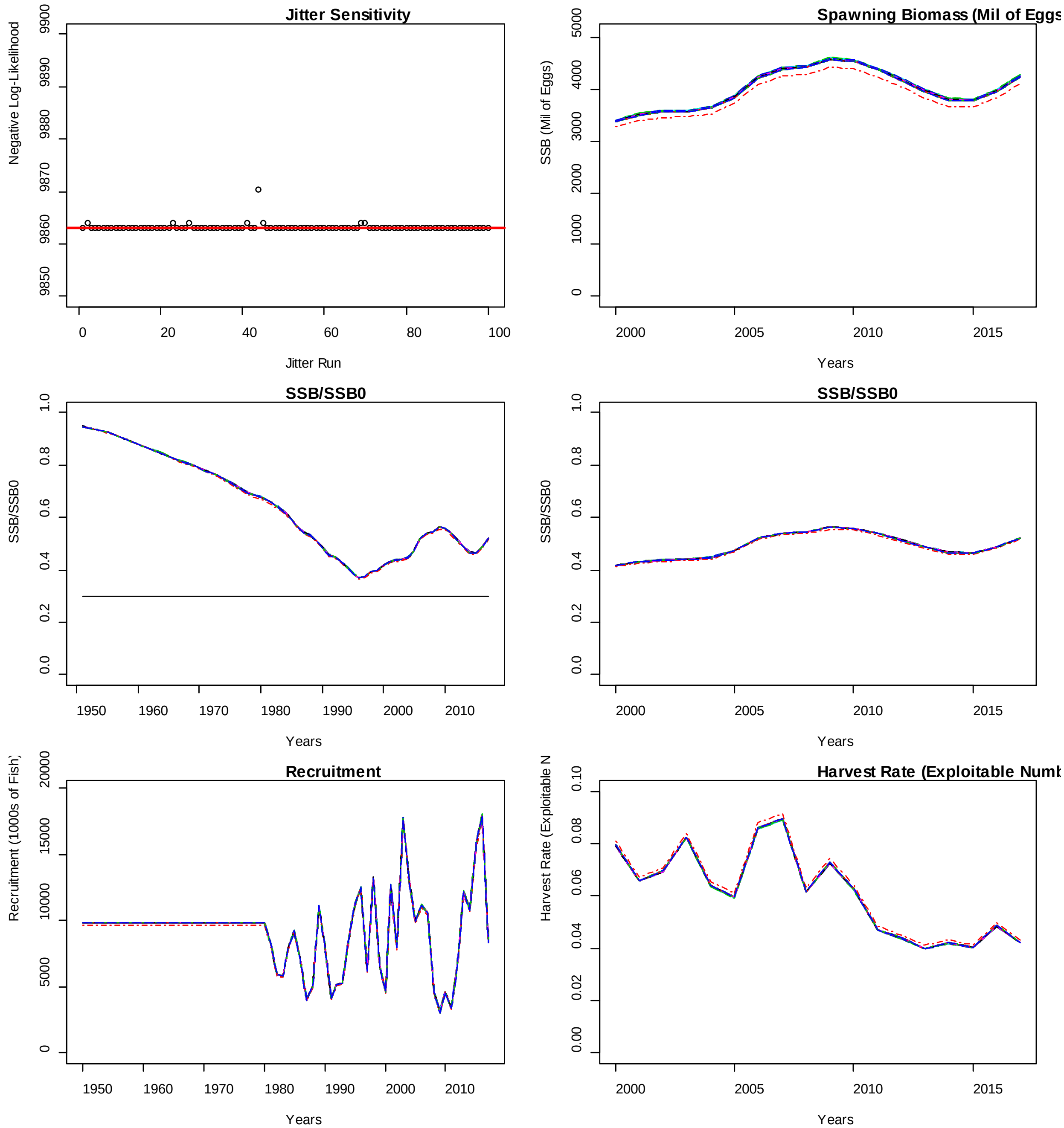


Figure 4.2. Comparison of SS3 runs across jittered starting parameter values (+ or - 10%). Red line in the upper left panel shows the objective function value of the base model.

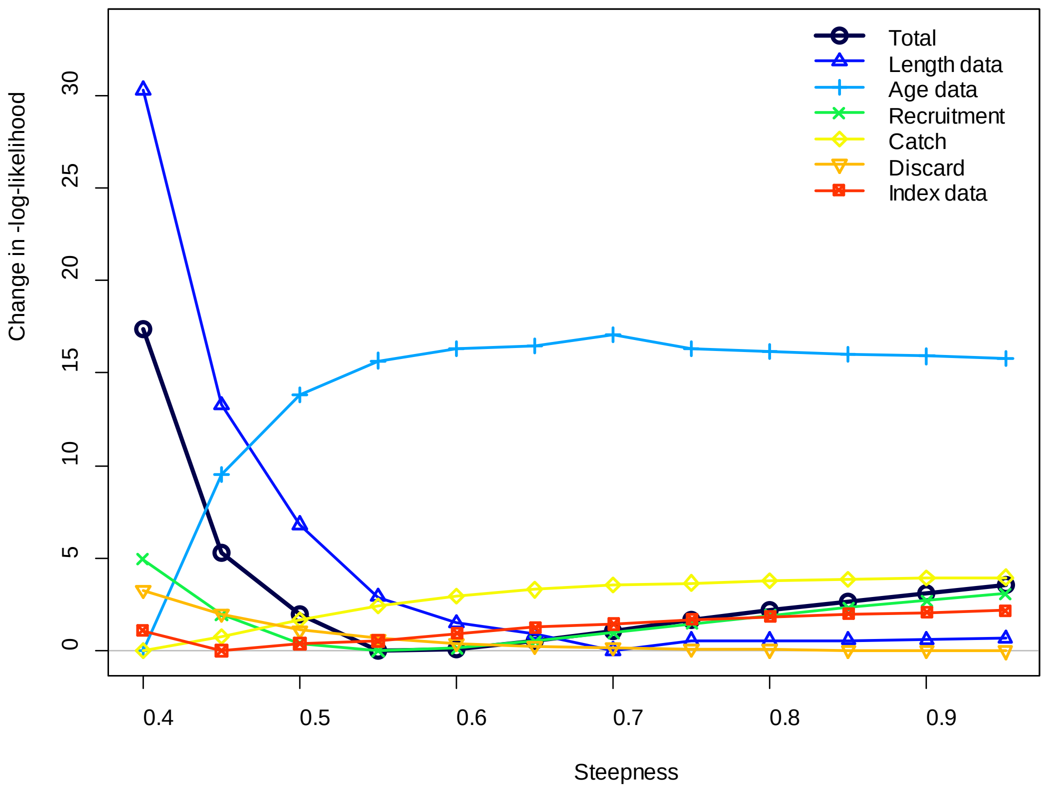


Figure 4.3. Likelihood profile of the Beverton-Holt steepness parameter. The y-values represent the change in negative log-likelihood, by data component.

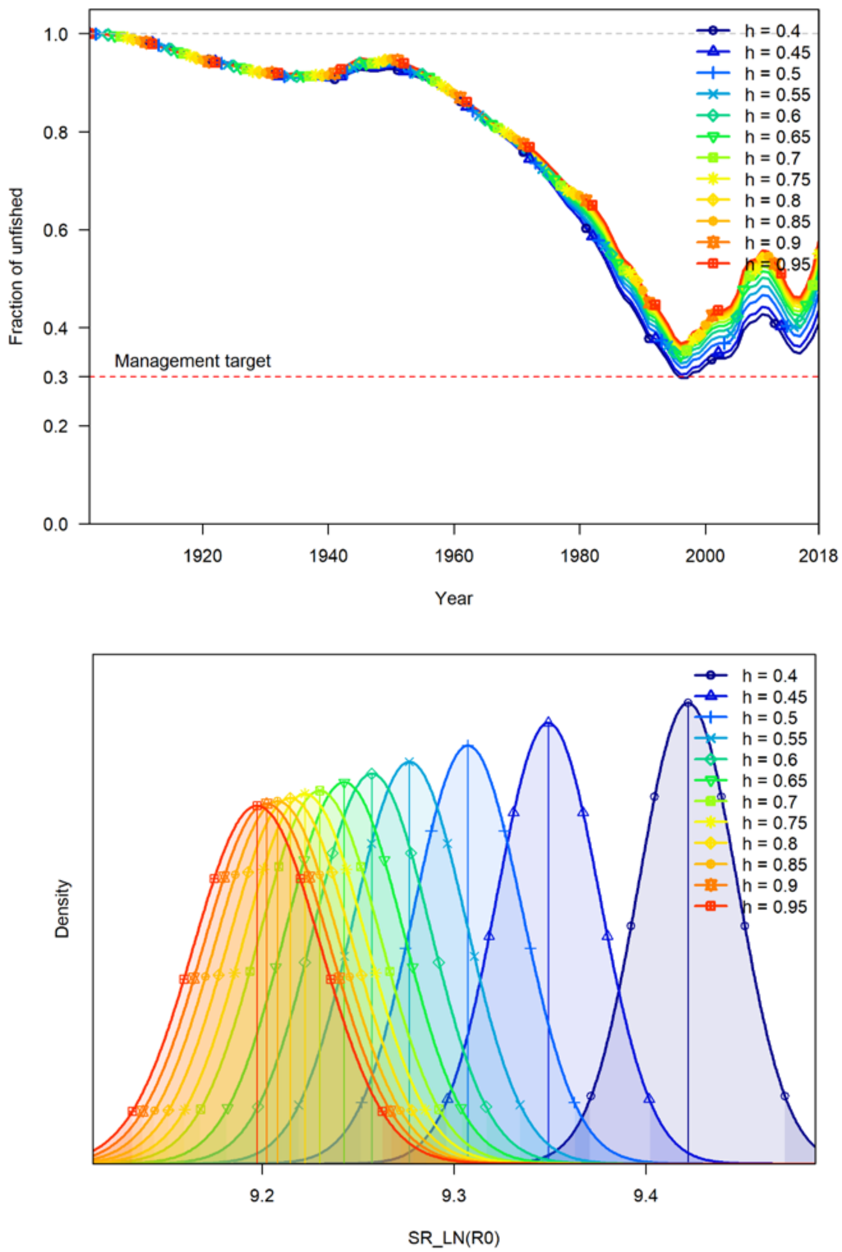


Figure 4.4. Stock status sensitivity of South Atlantic King Mackerel to alternative assumptions of steepness. Upper panel shows the stock depletion ratio relative to the defined management target in SEDAR 38 (SPR30). The lower panel shows the estimate of unfished equilibrium recruitment (R0) associated with alternative steepness assumptions.

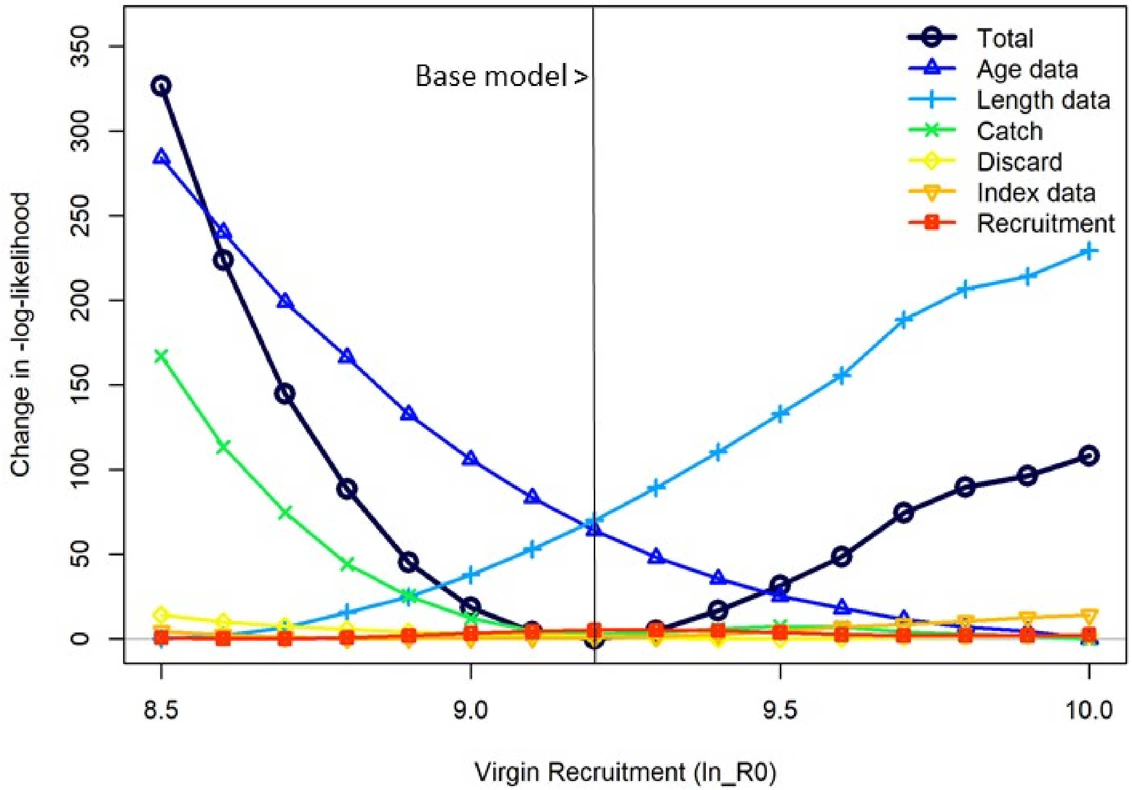


Figure 4.5. Likelihood profile of unfished recruitment (R0) estimates. The dotted line represents the point estimate from the base model. The values represent the change in negative log-likelihood, by component.

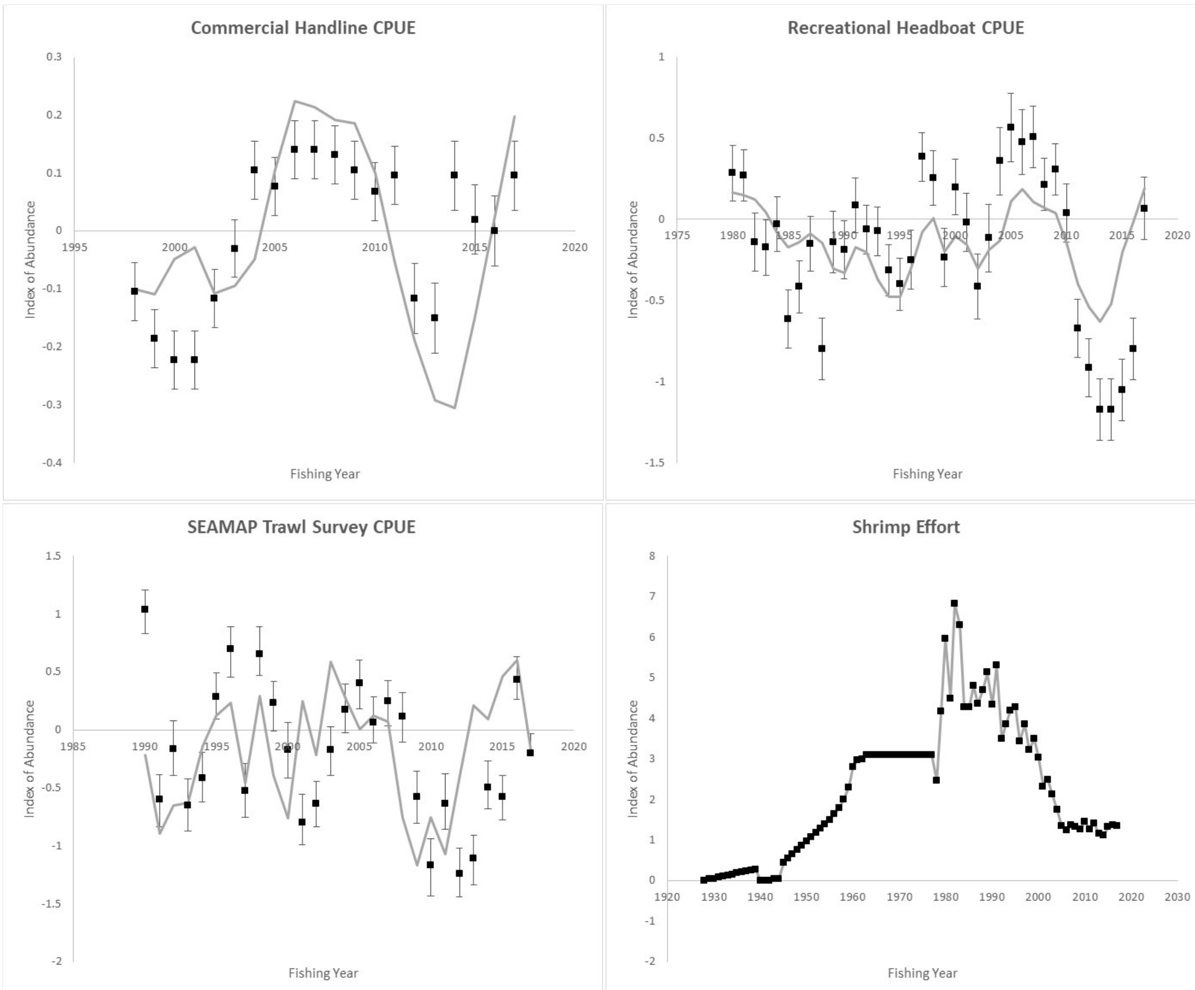


Figure 4.6. Model fit (gray line) to the indices of abundance (shown on the log-e scale as black squares with standard error).

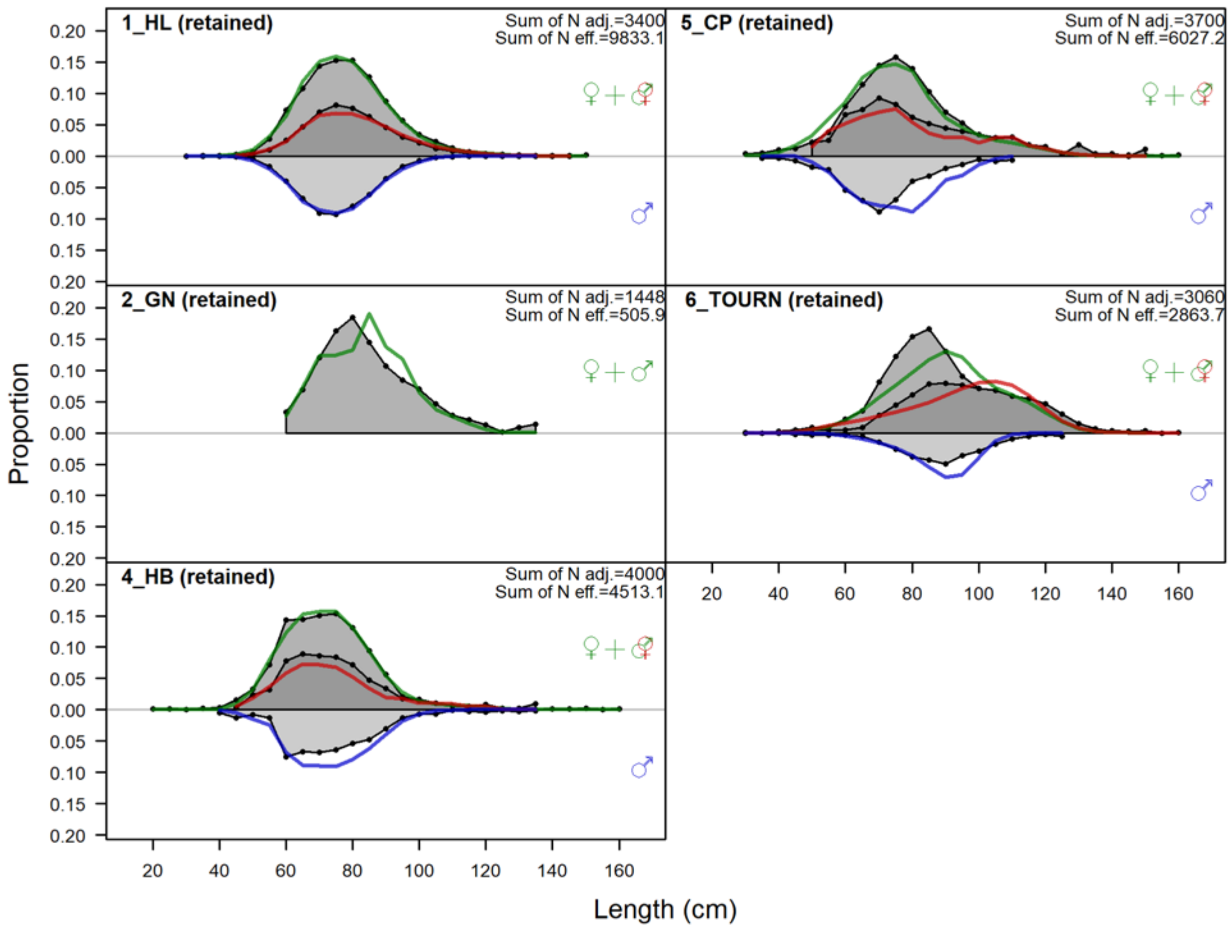


Figure 4.7. Time-aggregated fits to fleet length compositions. The red distribution is the length composition of females, the blue is males, and the green is undetermined gender.

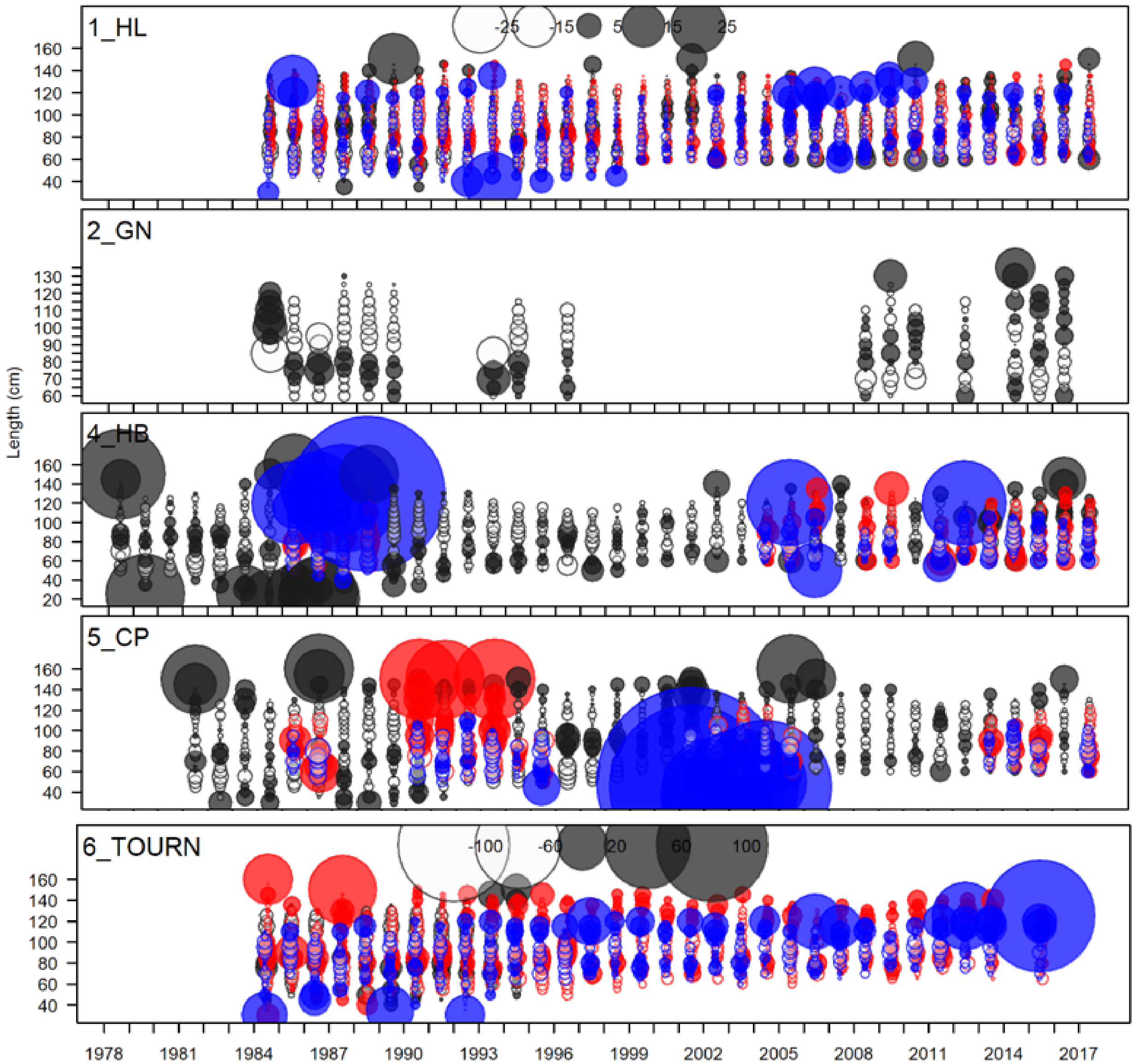


Figure 4.8. SS3 residual fits to fleet length compositions. Filled circles are positive residuals, open are negative. Blue circles are the residual fits to male length measurements, red are to female lengths, and gray are to lengths of fish with unknown gender.

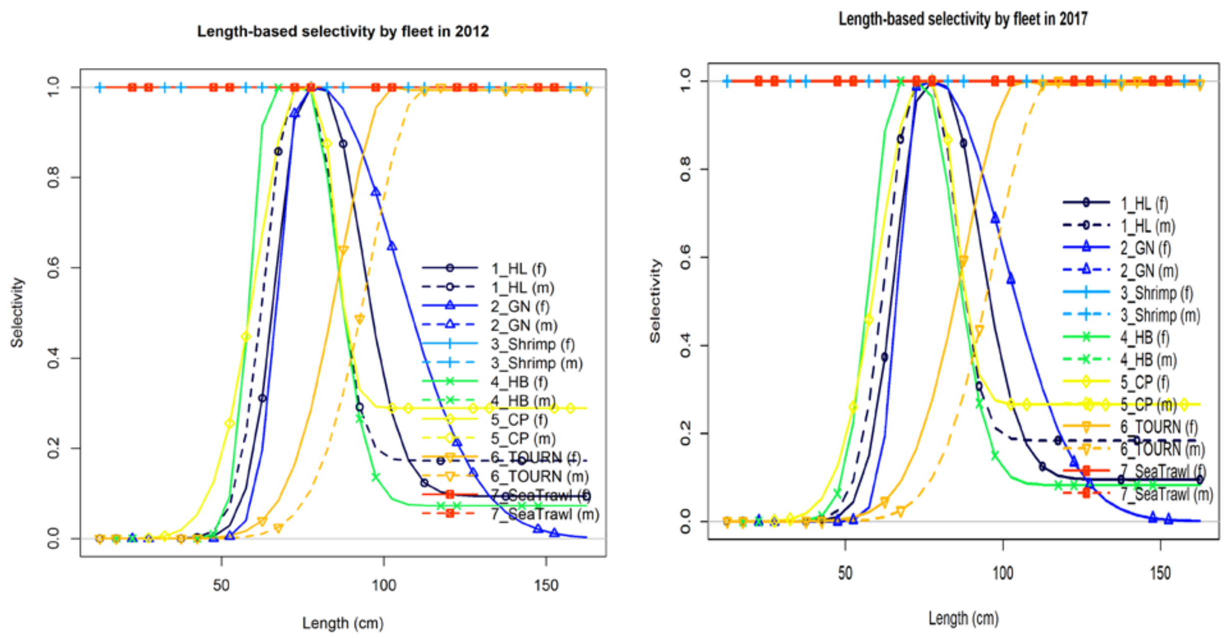


Figure 4.9. Estimated fleet selectivities-at-length by fleet and sex. Left panel shows the estimated selectivities from SEDAR 38, and the right panel are the estimated selectivities of the update model.

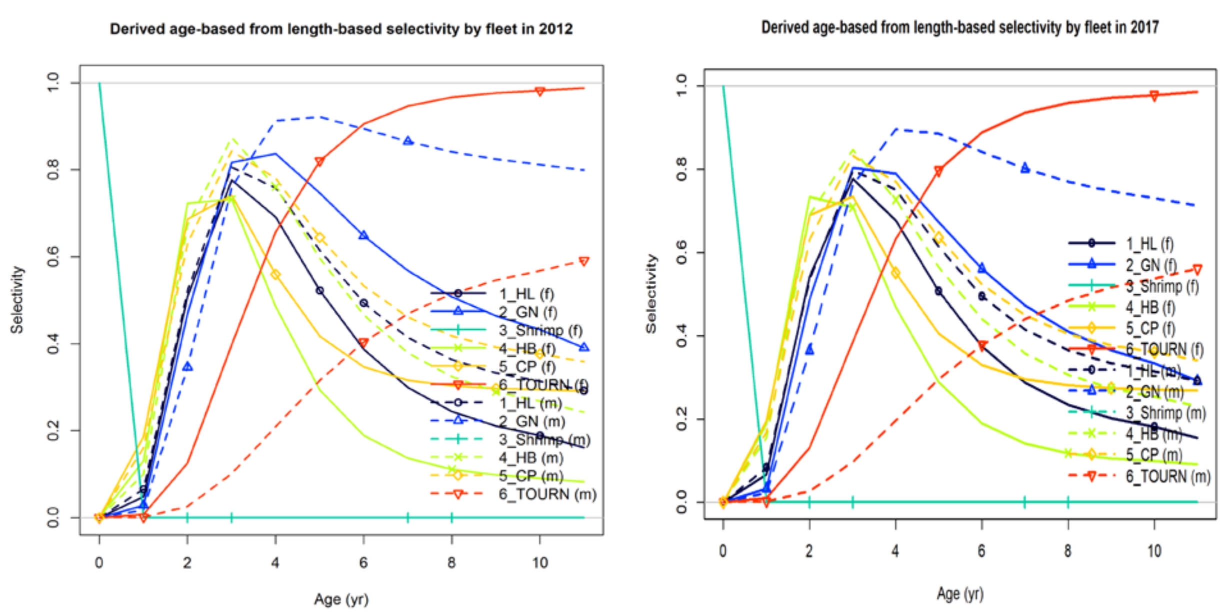


Figure 4.10. Derived age-based selectivities from estimated length-based selectivity by fleet and sex. Left panel shows the estimated selectivities from SEDAR 38, and the right panel are the estimated selectivities of the updated model.

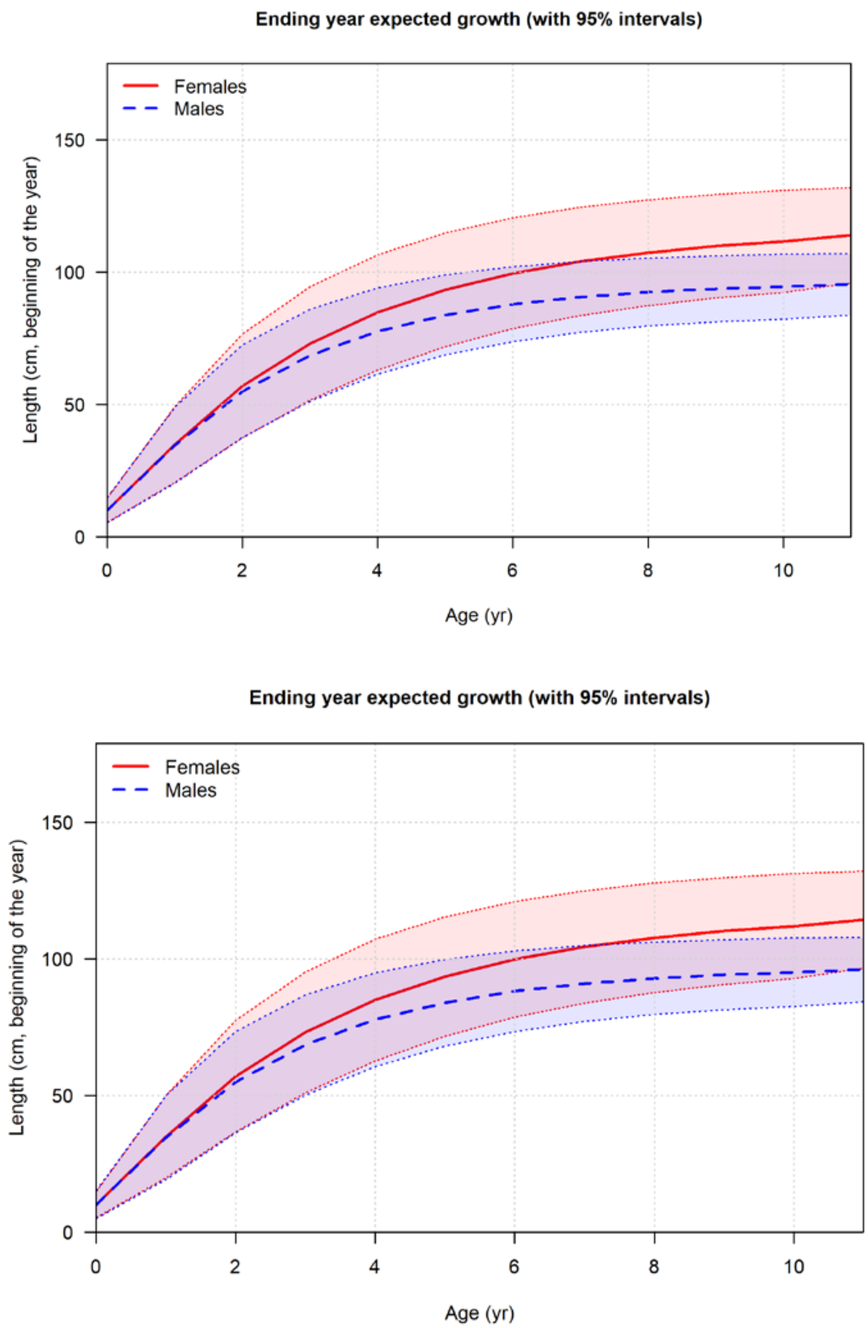


Figure 4.11. Growth relationship and 95% intervals for males (blue line) and females (red line) estimated in SS3. Upper panel is the estimated growth curves from SEDAR 38 and the lower panel is the 2020 update.

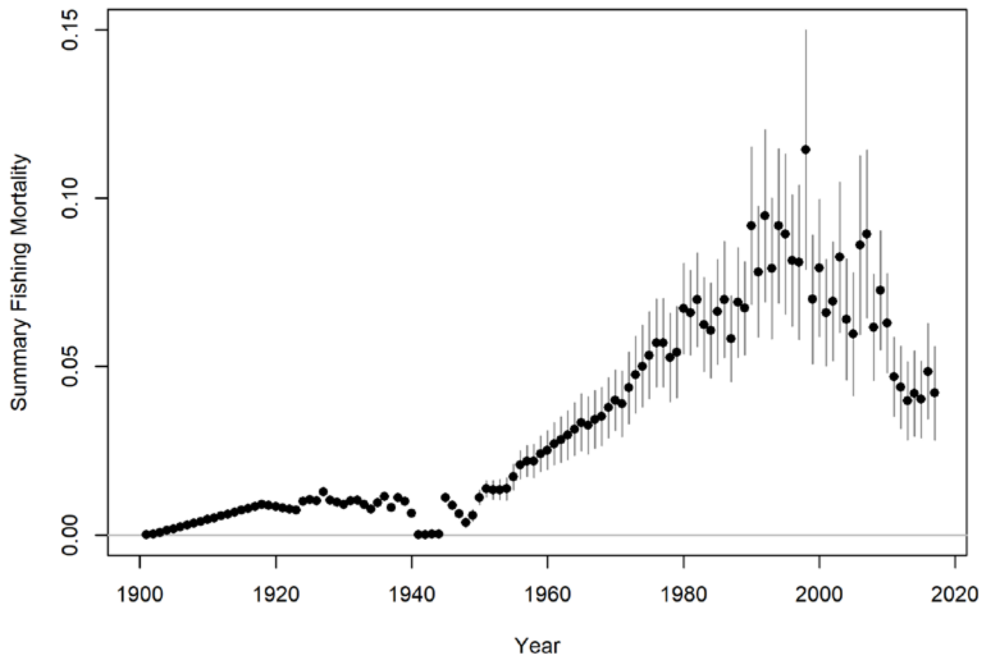


Figure 4.12. Estimated fishing mortality rates (exploitation rate in number) of South Atlantic King Mackerel.

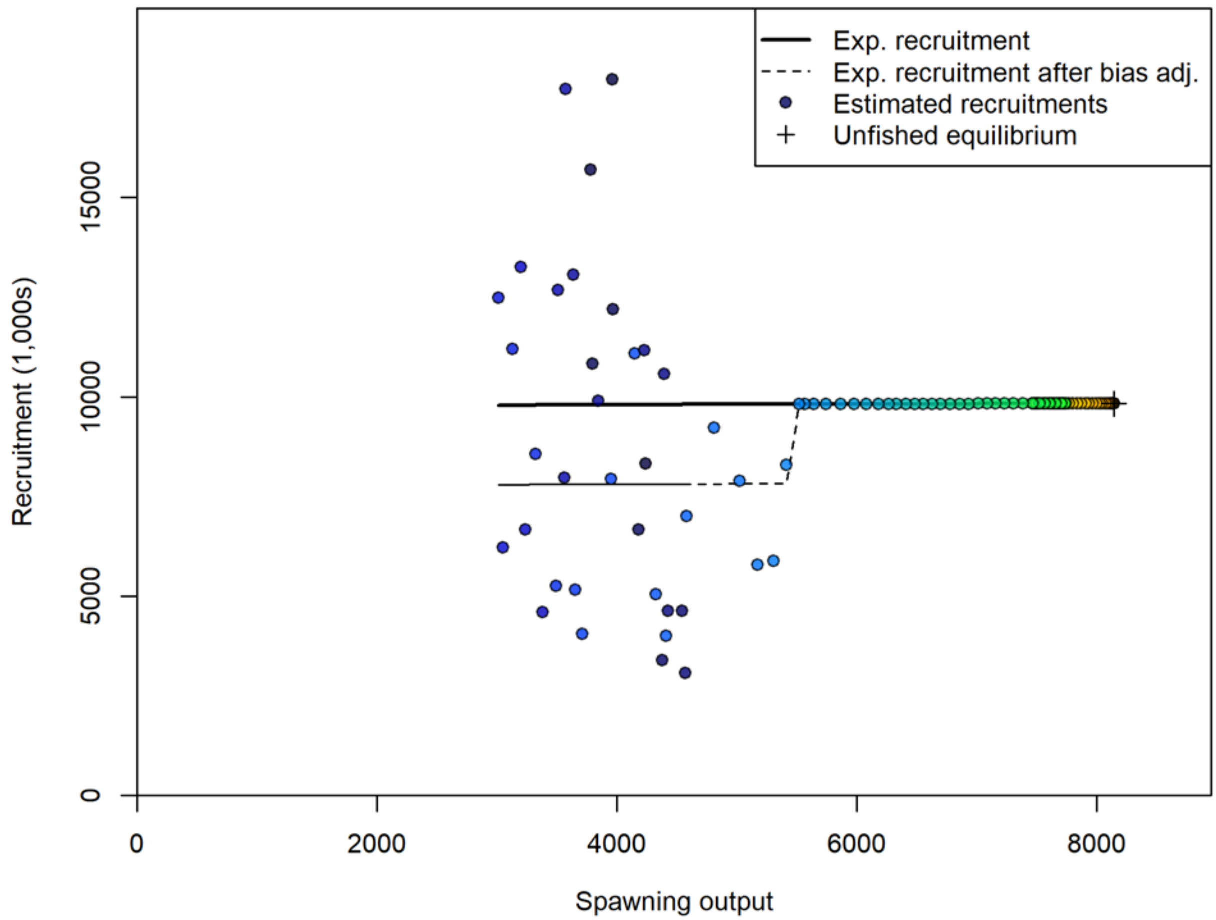


Figure 4.13. Stock-recruitment relationship for South Atlantic King Mackerel with a fixed steepness equal to 0.99. Plotted are predicted annual recruitments from SS (circles), and expected recruitment from the stock-recruit relationship (black line).

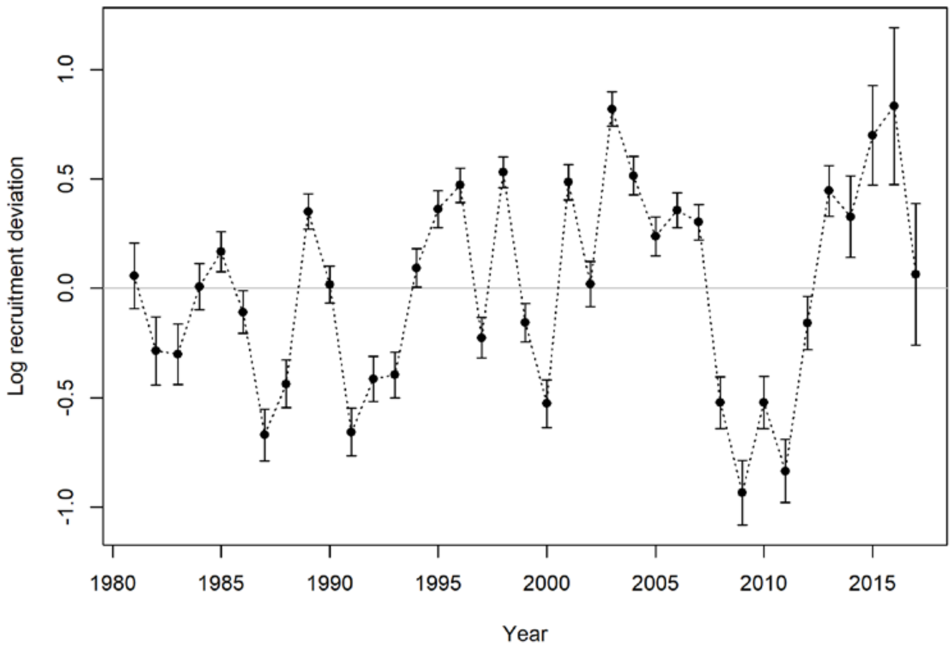


Figure 4.14. Predicted log recruitment deviations with associated 95% asymptotic intervals.

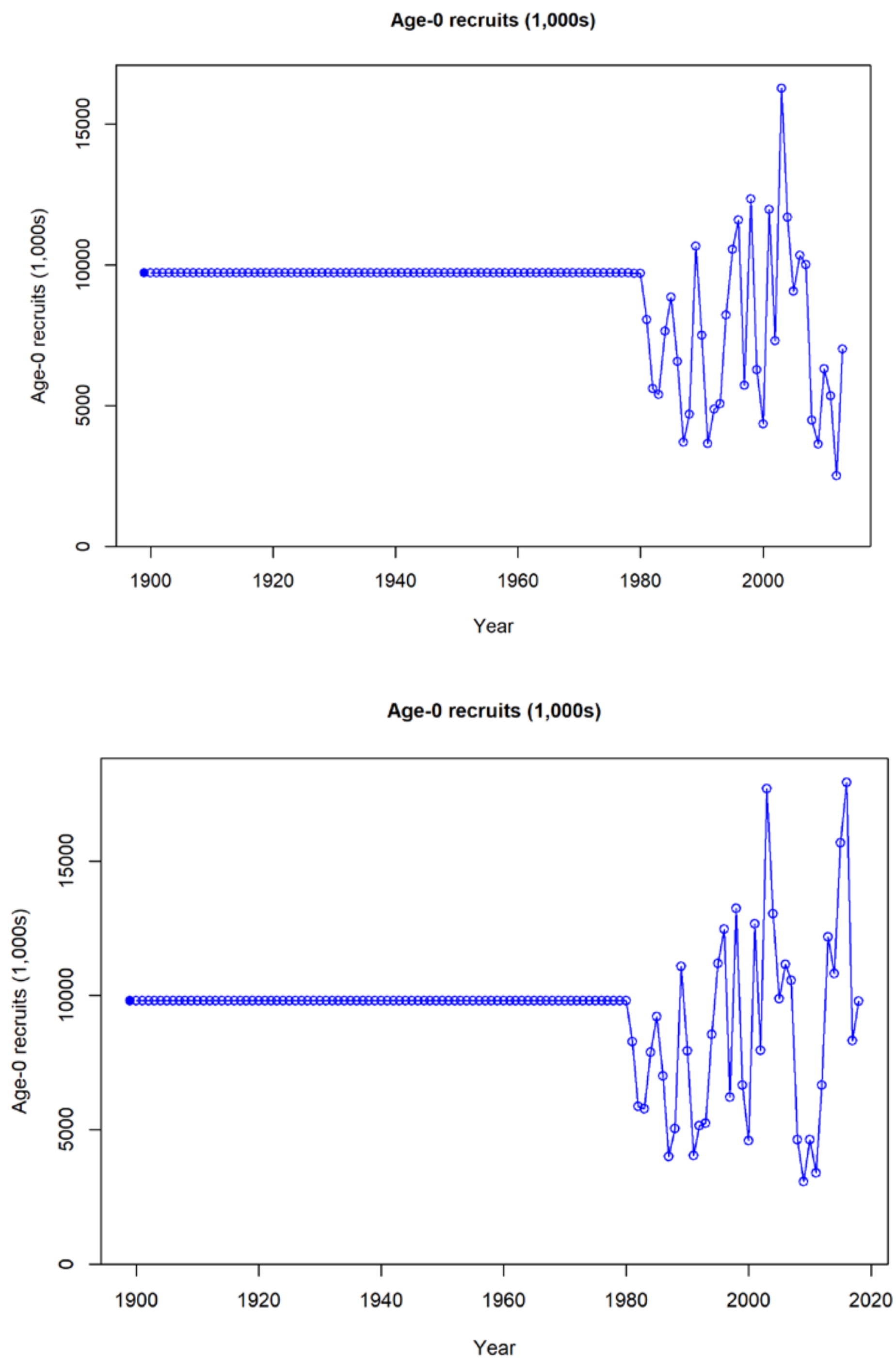


Figure 4.15. SS3 predicted age-0 recruits of South Atlantic King Mackerel. The upper panel shows the estimated recruits from SEDAR 38 and the lower panel shows the 2020 updated model estimates.

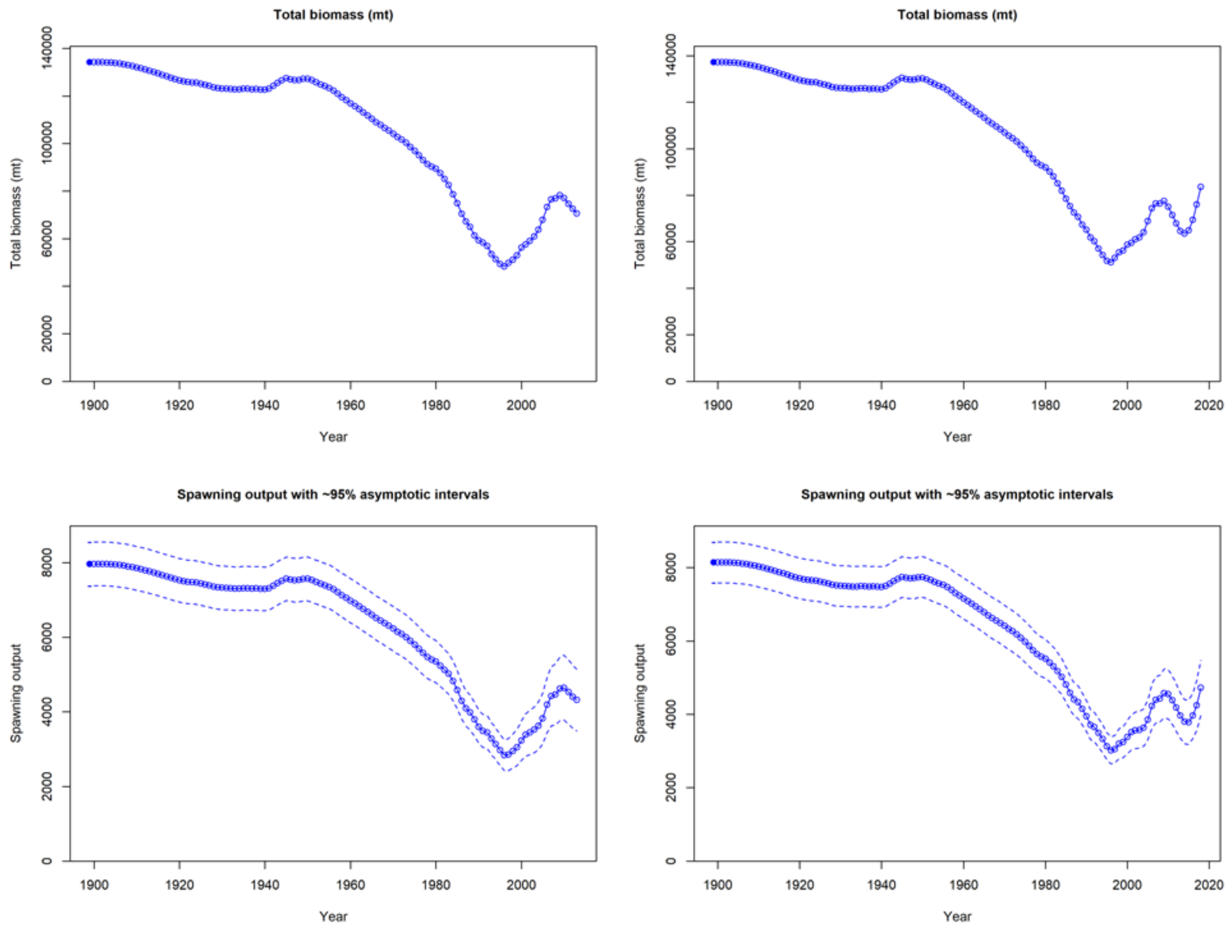
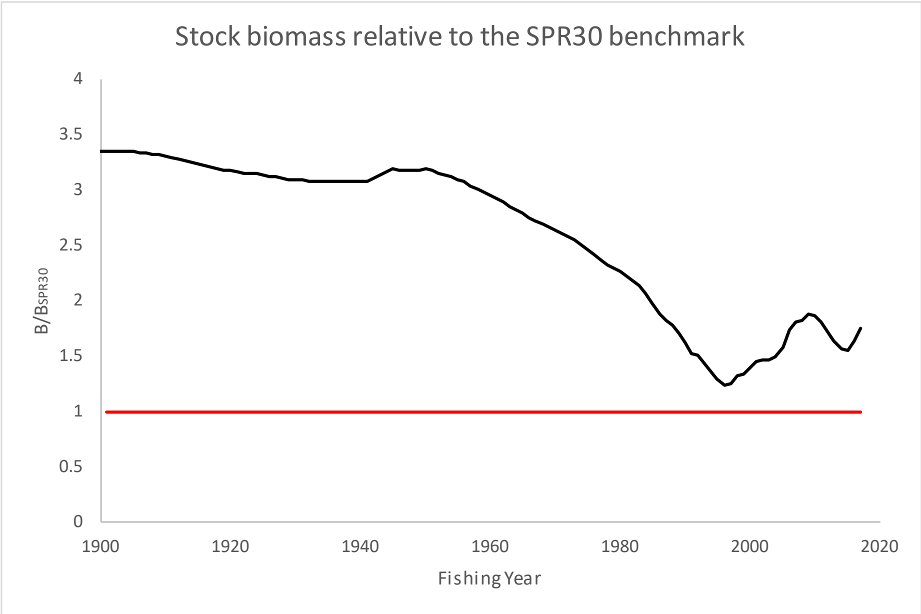


Figure 4.16. Estimated total biomass in whole metric tons and spawning biomass (egg production in millions) with 95% CI. The left panels show the estimated biomasses from SEDAR 38 and the right panels show the estimates from the 2020 updated model.



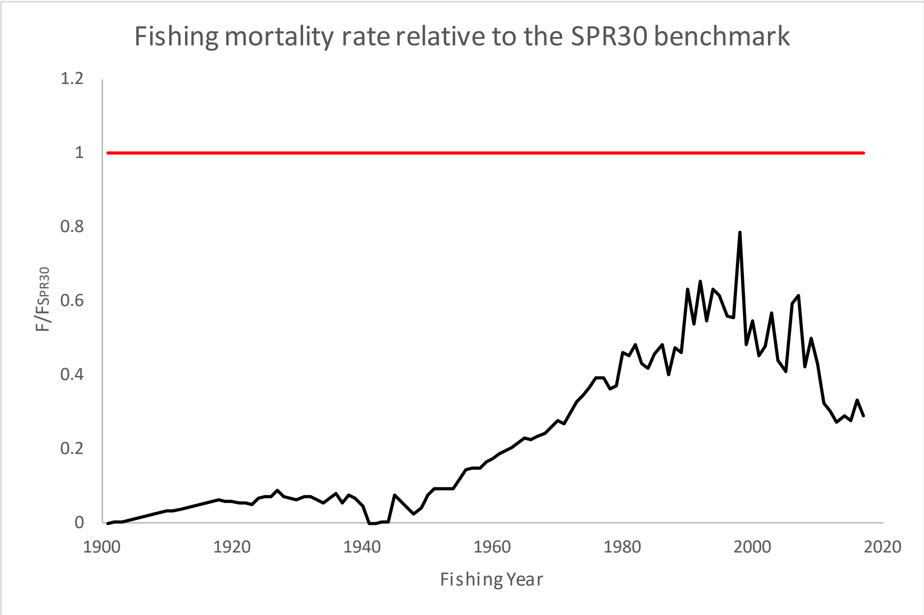


Figure 4.17. Stock and fishery status trends for Atlantic King Mackerel, measured as spawning output relative to 30% of unfished levels (SPR30) and fishing mortality (F) relative to the target fishing mortality rate that produces the target depletion level (F_{SPR30}). The red line shows the benchmark target.

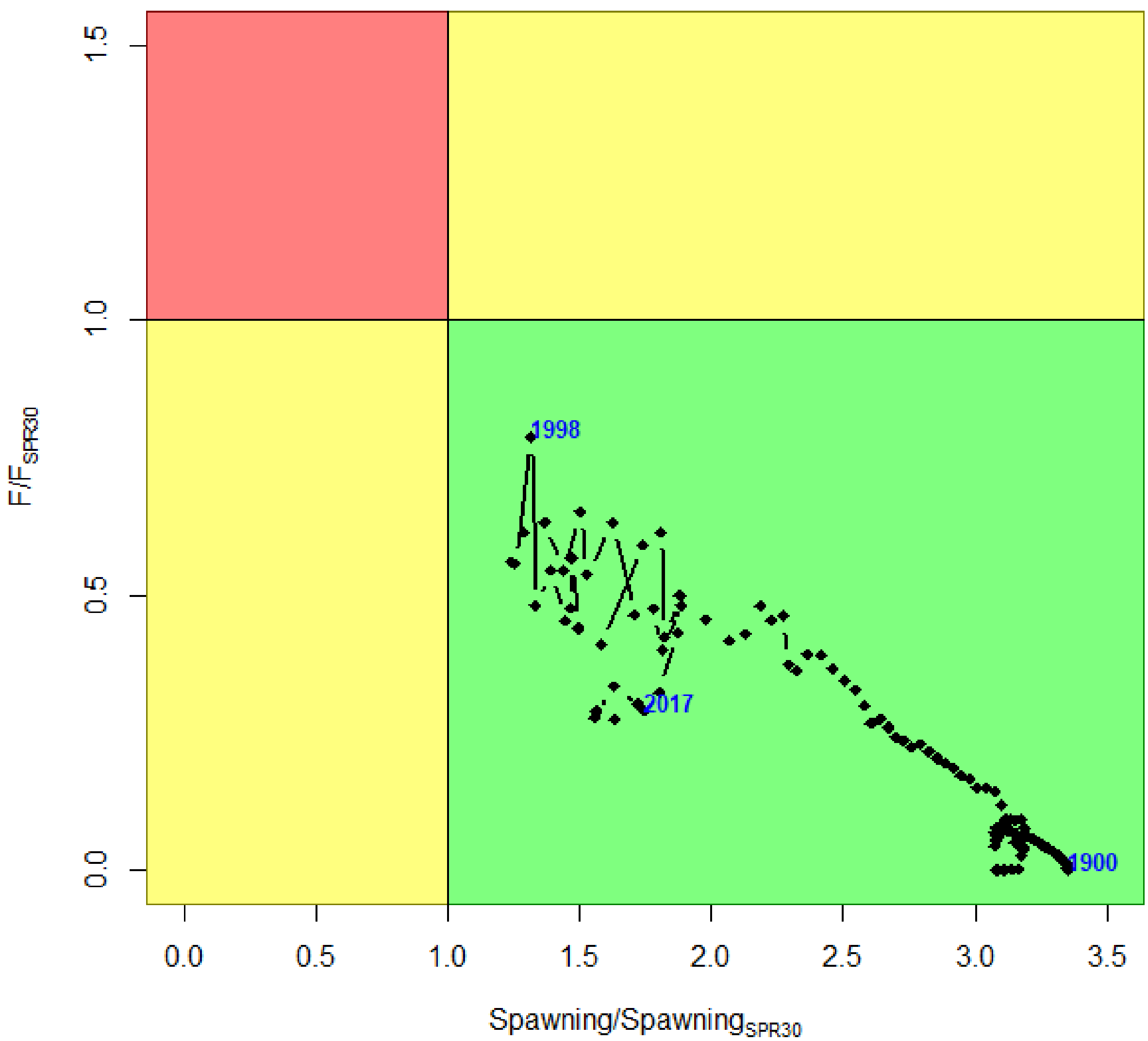


Figure 4.18. Kobe plot showing the combined stock status and fishery status trajectory. Green quadrant (lower right) represents a status of not overfished and not undergoing overfishing. The red quadrant (upper left) represents a status of overfished and undergoing overfishing. The yellow quadrants represent statuses of not overfished but undergoing overfishing (upper left), or overfished but not undergoing overfishing (lower left).

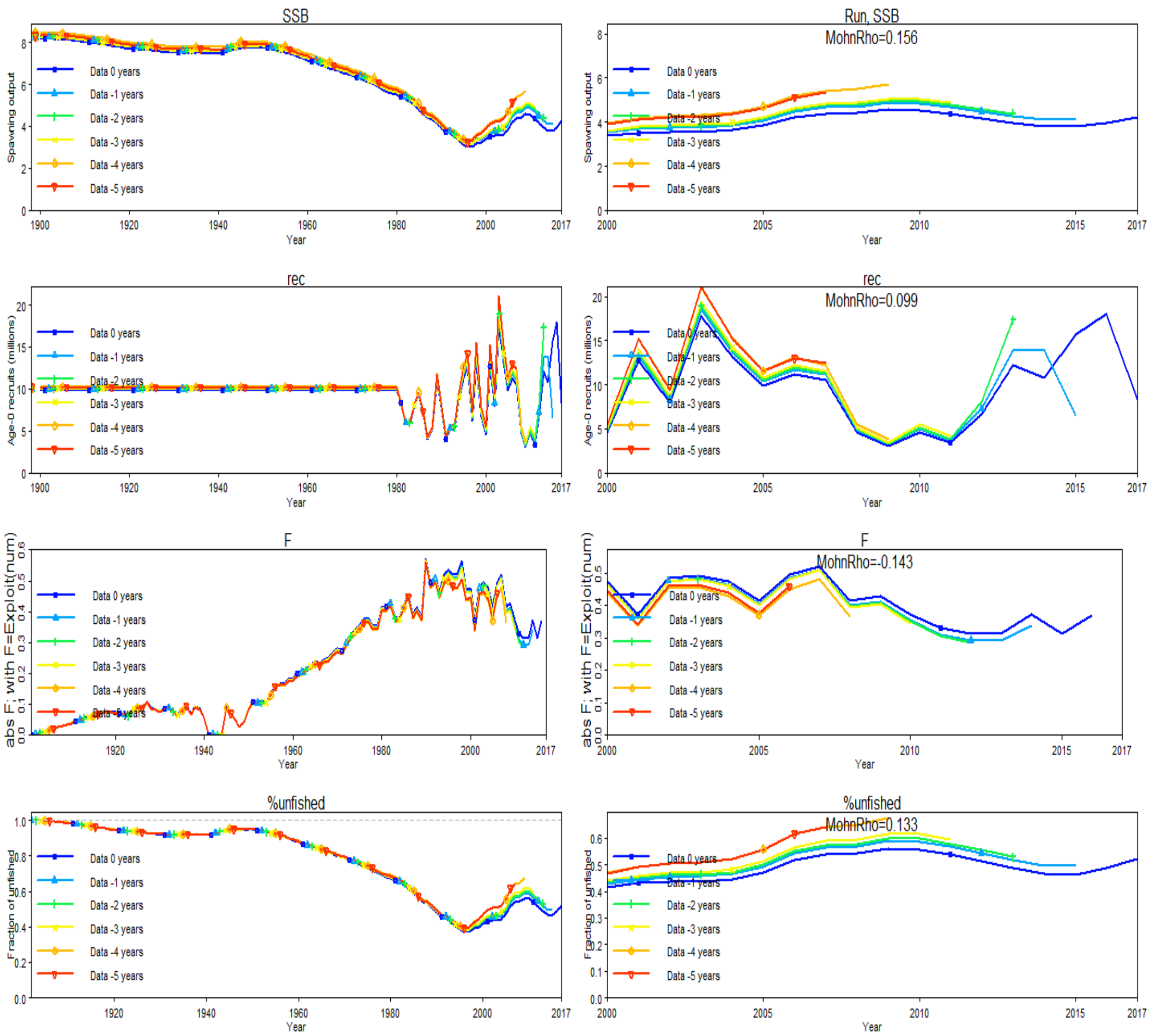


Figure 4.19. Predicted age-0 recruitment, spawning stock biomass (female SSB) and fishing mortality (exploitation rate in numbers) from the retrospective analysis for the entire time series and expanded to1980-2012.

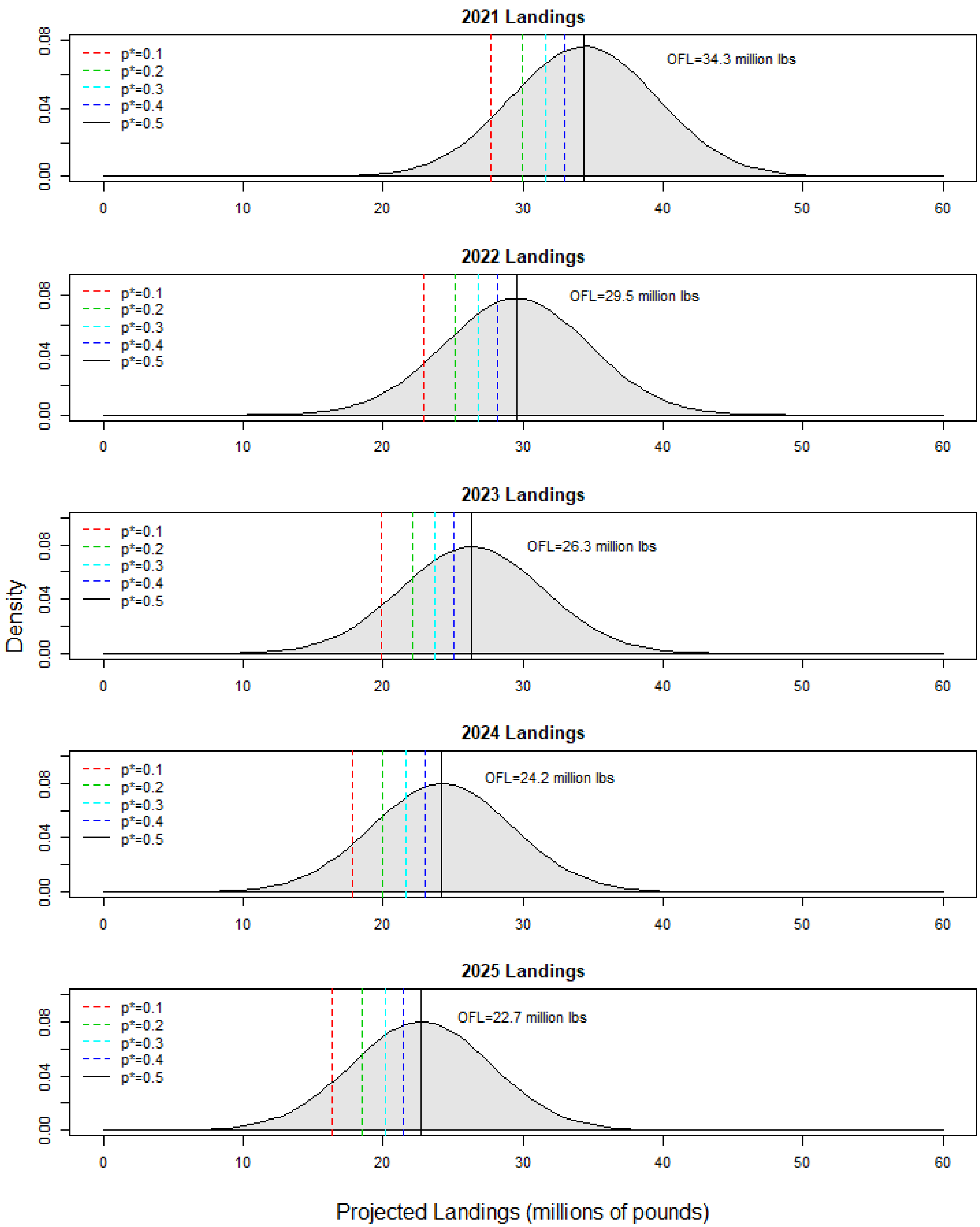


Figure 4.20. Projected catch limits of South Atlantic King Mackerel. The grey shaded areas are the density distributions of forecasted retained yields during fishing years 2021 to 2015. The solid, vertical, black lines show the overfishing limits (OFL, p-star=0.5). The red, green, cyan, and blue dashed lines show the allowable biological catch limits associated with p-stars of 0.1, 0.2, 0.3, and 0.4, respectively.

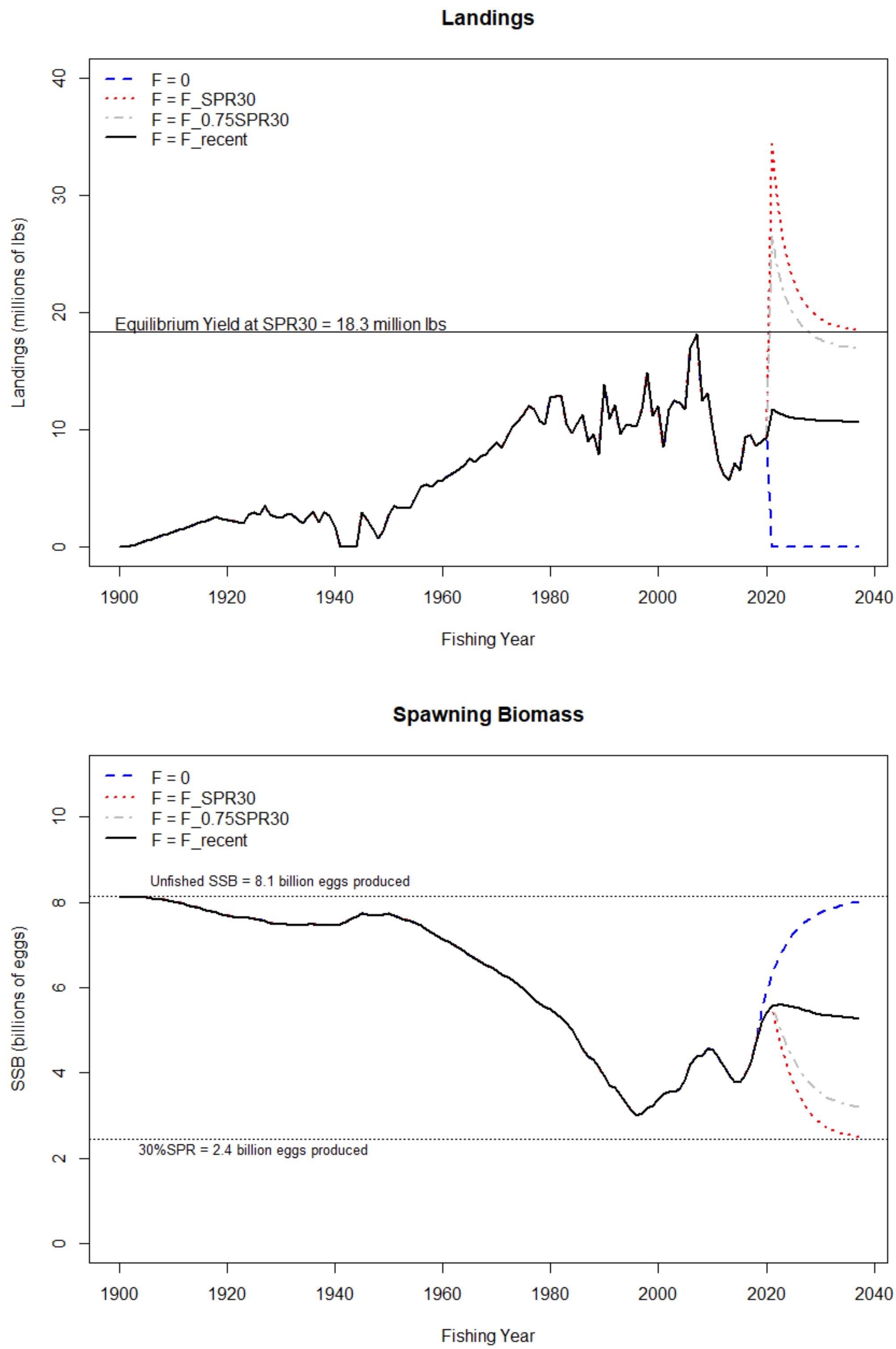


Figure 4.21. Projected landings (upper panel) and spawning biomass (lower panel) under alternative constant exploitation rate scenarios, including no fishing (F=0), fishing at the overfishing limit (F_{SPR30}=0.14), fishing at 75% of F_{SPR30} (F=0.11), and fishing at the recent average exploitation rate (F= 0.05).

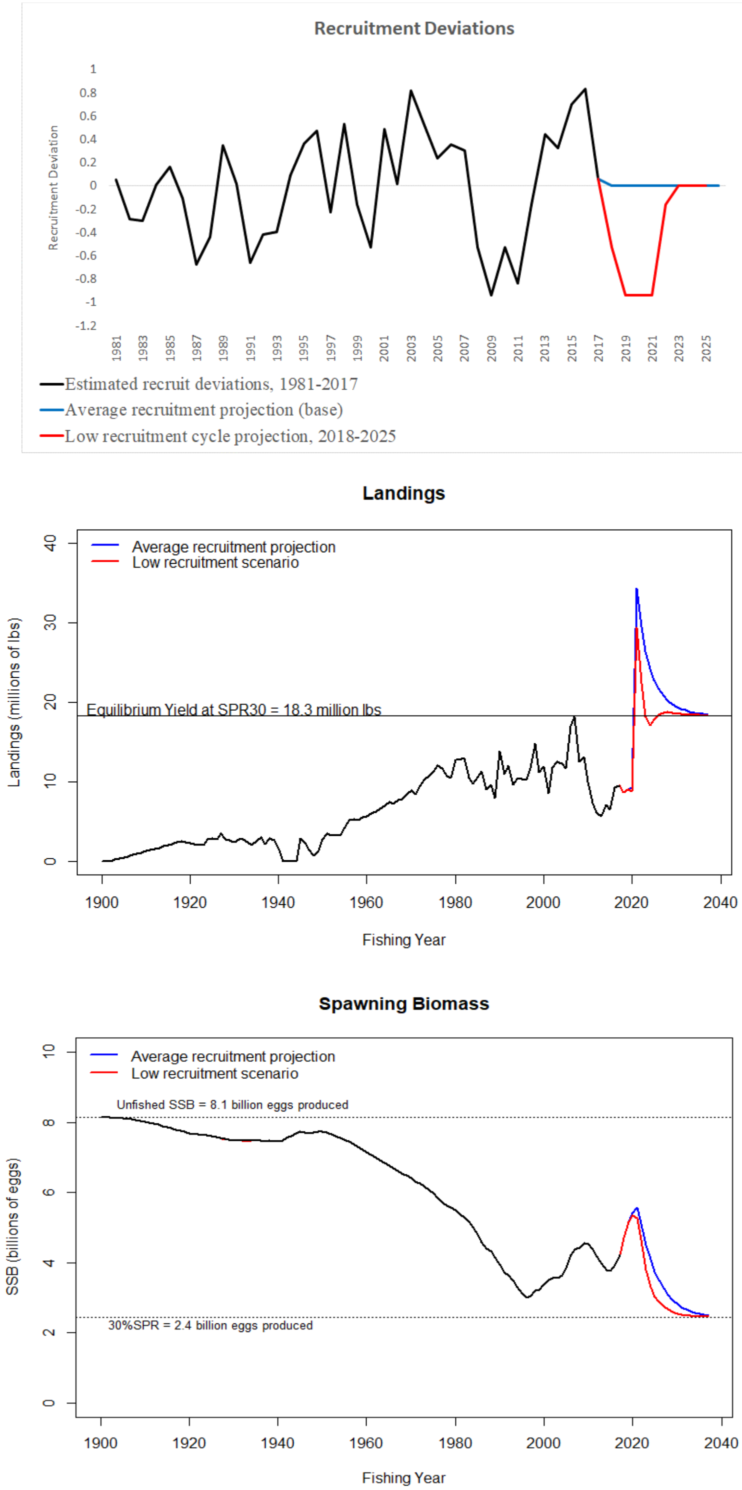


Figure 4.22. Low recruitment projection sensitivity analysis at fixed exploitation ($F=F_{SPR30}$). The upper panel shows the estimated recruitment deviations (1981-2017, black line), the average recruitment projection base parameterization (blue line), and the "what-if" low recruitment sensitivity parameterization that mimicked a low recruitment similar to 2008 to 2012 (red line). The middle panel shows the projected landings, and the lower plot compares the spawning biomass predictions between the two scenarios.