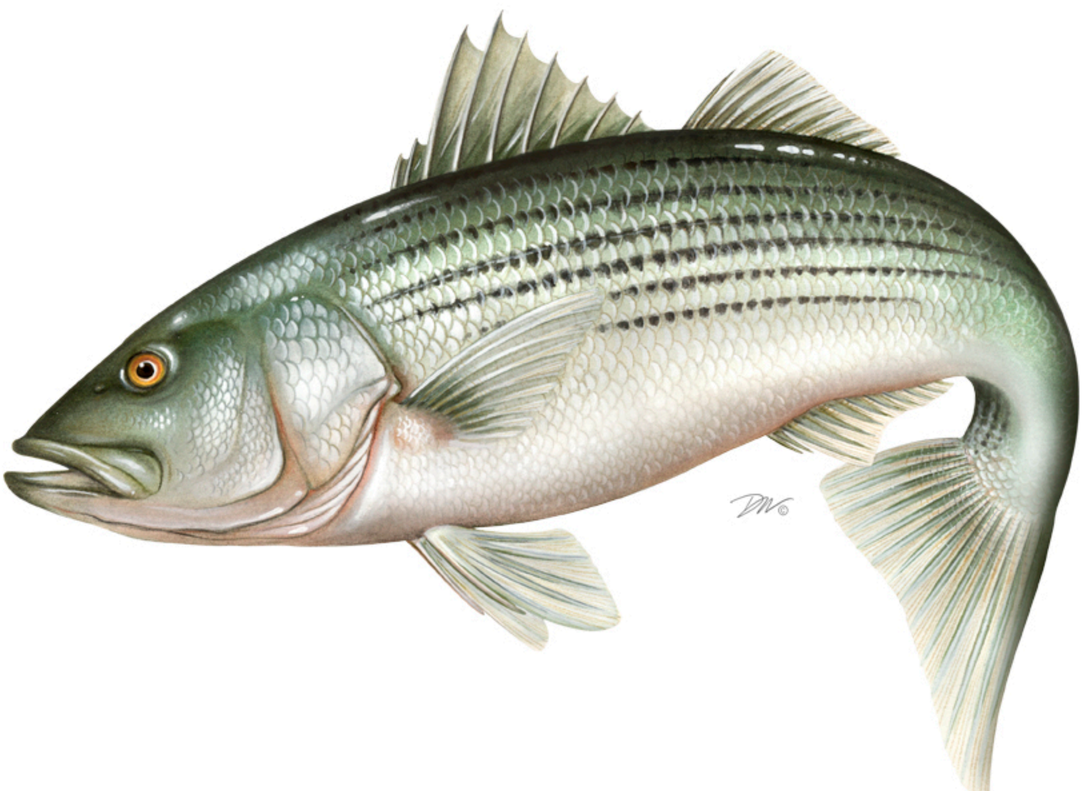
Atlantic States Marine Fisheries Commission

Summary of the 2019 Benchmark Stock Assessment for Atlantic Striped Bass



April 2019

Preface

This summary report reflects the results of the model that passed peer review by the Stock Assessment Review Committee (SARC) at the 66th Stock Assessment Workshop in November 2018. This model was approved for management use by the Atlantic Striped Bass Management Board April 29, 2019.

The complete assessment report can be found online at:
https://www.nefsc.noaa.gov/publications/crd/crd1908/

Life History
Atlantic striped bass along the eastern coast of North America can be found from the St. Lawrence River in Canada to the St. Johns River in Florida. The Atlantic coastal striped bass management unit includes the coastal and estuarine areas of all states and jurisdictions from Maine through North Carolina. Stocks which occupy coastal rivers from the Tar-Pamlico River in North Carolina south to the St. Johns River in Florida are believed primarily endemic and riverine and apparently do not presently undertake extensive Atlantic Ocean migrations as do stocks from the Roanoke River north. Coastal migratory striped bass are assessed and managed as a single stock, although the population is known to be comprised of multiple biologically distinct stocks, predominantly the Chesapeake Bay stock, the Delaware Bay stock, and the Hudson River stock.

Striped bass are a relatively long-lived species: the maximum age reported was 31 years. They exhibit sexually dimorphic growth, with females growing faster and reaching a larger maximum size than males. Estimates of maturity at age were updated for this assessment through a coastwide sampling effort. The new estimates were similar to the maturity ogive used in previous assessments, with 45% of female striped bass mature at age 6 and 100% mature by age 9.

Commercial and Recreational Landings
Commercial and recreational data from the inland and ocean waters of Maine through Virginia, and the ocean waters of North Carolina were used in this assessment. Based on tagging data, striped bass from the inland waters of North Carolina and states further south are believed to be non-migratory and are not considered part of the coastal migratory stock. Therefore, data from those regions are not included in this assessment.

Strict commercial quota monitoring is conducted by states through various state and federal dealer and fishermen reporting systems, and commercial landings are compiled annually from those sources by state biologists. Limited data on commercial discarding of striped bass was provided by Maryland and New Jersey and used, in combination with literature values and values from the previous assessment, to determine the discard mortality rates for commercial fishing gears. Recreational catch and harvest estimates for Atlantic striped bass were provided by the Marine Recreational Information Program (MRIP, formerly the Marine Recreational Fisheries Statistics Survey or MRFSS). These data include the newly calibrated MRIP estimates that were released on July 9, 2018.

Following the striped bass stock reaching an all-time low, 151,000 pounds (68.5 mt or 3,730 fish) were landed in the commercial fishery in 1986 (Table 1, Figure 1). Commercial landings for striped bass increased in the 1990’s as the stock recovered and management measures were liberalized. Between 2004 and 2014 landings were relatively stable due to the commercial quota system with average landings of 6.5 million pounds (2,948 mt) per year (943,000 fish per year). In response to the findings of the 2013 benchmark stock assessment, Addendum IV to the Atlantic Striped Bass Fishery Management Plan implemented harvest reductions starting in 2015 for both the commercial and recreational sectors. On the commercial side, this was accomplished through a quota reduction. Since implementation of Addendum IV, coastwide commercial landings for Atlantic striped bass have decreased to an average of 4.7 million pounds (2,132 mt or 608,000 fish). Although the age structure of commercial harvest varies from state to state due to size regulations, season of the fisheries, and the size classes of striped bass available to the fisheries, from 2004-2014 ages 3-9 made up 86.5% of the commercial catch in numbers. The implementation of higher size limits in 2015 in several jurisdictions reduced the proportion of age-3 fish in the catch in subsequent years.

Commercial landings have generally exceeded discards since the early 1990's with discards comprising approximately 15% of the total commercial removals from 2015-2017 (Table 1, Figure 1). The Chesapeake Bay fisheries are estimated to have a lower proportion of commercial dead discards than the fisheries in the ocean and other areas; however, the Chesapeake Bay commercial fisheries accounted for 74% of the total commercial removals by number from 2015-2017.

Recreational harvest of striped bass follows a similar trend to the commercial harvest (Table 1, Figure 1). Since 1984 when landings were at their lowest (264,000 fish), harvest has increased reaching a high of 5.4 million fish in 2010. Between 2004 and 2014, harvest remained at a steady level averaging 4.7 million fish per year. Following the implementation of size and bag limit changes in the recreational fisheries through Addendum IV, harvest decreased to an average of 3.2 million fish for 2015-2017. The number of recreational dead releases peaked in 2006 at 4.8 million fish and declined through 2011 to 1.5 million fish. Releases increased after that with an average of 2.9 million dead releases estimated for 2015-2017. The new calibrated annual estimates of recreational harvest (numbers of fish) and total catch (released + harvested fish) are on average 140% and 160% higher than prior MRIP estimates, respectively. Although the magnitude of these estimates has changed, the overall trend throughout time remains similar for both catch and harvest (Figure 2).

Indices of Abundance

Age-specific and aggregate indices of relative striped bass abundance are provided by states from fisheries-dependent and fisheries-independent sources. The Atlantic Striped Bass Stock Assessment Subcommittee (SAS) reviewed all indices used in the previous benchmark stock assessment (SAW 57) as well as several new indices. The SAS used a set of evaluation criteria to determine which indices should be considered for inclusion in the assessment. Based on their evaluation, the SAS dropped the Virginia Pound Net and the Northeast Fisheries Science Center Bottom Trawl Survey (NEFSC) as indices for this assessment. The ChesMMAP survey was introduced as a new index to replace the Virginia Pound Net as an adult index for the Chesapeake Bay. The Delaware Bay 30' Trawl survey was also introduced to provide information regarding the striped bass population in Delaware Bay. The following sources were included in the current assessment:

- MRIP Total Catch Rate Index (MRIP CPUE)
- Connecticut Long Island Sound Trawl Survey (CTLISTS)
- New York Young-of-the-Year (NYYOY)

- New York Western Long Island Beach Seine Survey (NY Age-1)
- New York Ocean Haul Seine (NYOHS)
- New Jersey Bottom Trawl Survey (NJTRL)
- New Jersey Young-of-the-Year Survey (NJYOY)
- Delaware Spawning Stock Electrofishing Survey (DESSN)
- Delaware 30' Bottom Trawl Survey (DE30)
- Maryland Spawning Stock Survey (MDSSN)
- Maryland Young-of-the-Year and Yearlings Surveys (MDYOY and MD Age-1)
- Virginia Young-of-the-Year Survey (VAYOY)
- Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP)

Although not included as an index in the assessment, the Northeast Area Monitoring & Assessment Program (NEAMAP) provided valuable biological data (e.g., age and sex data) for this assessment.

Indices of Age-1+ abundance were classified by what component of the striped bass population they represented: the coastal mixed population (the MRIP CPUE, and the CTLISTS, NJTRL, and NYOHS surveys), the Chesapeake Bay stock (MDSSN and ChesMMAP surveys), or the Delaware Bay stock (DESSN and DE30 surveys). The MRIP CPUE and the CTLISTS index showed similar trends for the coastal mixed stock; both were low during the 1980s and began increasing during the 1990s, but have since declined (Table 2, Figure 3). The NJTRL was low at the beginning of its time series in 1990, before jumping up in the mid-1990s; it has been mostly high and variable since then. The NYOHS showed no trend from the mid-1980s to the end of its time series in 2007.

The MDSSN survey showed a relatively stable female SSB population since the mid-1980s; the ChesMMAP survey started later, in 2002, and has been more variable as it tracks a smaller, younger component of the population and is more influenced by recruitment (Table 3, Figure 3).

The DE30 survey showed an increase from 1990 to a peak in 1995, and has been variable but generally declining since then, with the current index close to where it was at the beginning of the time series (Table 3, Figure 3). The DESSN index has been more stable, fluctuating around its long-term mean (Table 3, Figure 3).

Recruitment indices (YOY and age-1) in Chesapeake Bay were variable but declines were observed from 2004-2010, and in some years, the indices were close to low values not observed since 1990 (Table 4, Figure 4). However, strong year classes appeared in 2011 and 2015. The MDYOY, VAYOY and MD age-1 indices identified many of the same strong and weak year classes. In Delaware Bay, recruitment increased from the 1980s through the mid-1990s and remained at or above average into the early 2000s; the index became more variable after that, with more below-average year classes (Table 4, Figure 4). Recruitment in the Hudson River showed several strong year classes in the late 1980s after very low values at the beginning of the time series, and has remained variable around the long-term mean since then (Table 4, Figure 4). Strong year-classes were evident in 1993, 1996, 2001, 2003, 2011, and 2015 in Chesapeake Bay; in 1993, 1995, 1999, 2003, 2009, and 2014 in Delaware Bay; and in 1988, 1997, 1999, 2001 and 2007 in Hudson River (Table 4, Figure 4).

Stock Assessment Model

For this assessment, the statistical catch-at-age model (SCA) currently used for management was extensively modified to allow the modeling of two biologically distinct stocks. However, the SARC Panel did not endorse the use of this model to serve as a basis for fishery management advice, and instead recommended that the single-stock SCA model be used for management (see NEFSC 2019 for full details). Given this, population estimates and stock status determinations from the single-stock SCA, which was accepted at SAW/SARC 57 and updated with new data for this assessment, are presented here.

The SCA model estimated annual recruitment, annual full fishing mortality (F) by fleet, and selectivity parameters for indices and fleets in order to calculate abundance and female spawning stock biomass (SSB). Recruitment was estimated as deviations from mean recruitment. Removals were separated into two fleets, a Chesapeake Bay fleet and an ocean fleet. The ocean fleet included removals from ocean waters and other areas such as Delaware Bay and Long Island Sound.

The combined full F was 0.307 in 2017. Fishing mortality for both the Chesapeake Bay fleet and the ocean fleet has been increasing since 1990 (Table 5, Figure 5).

The stock appears to have experienced a period of low recruitment at the beginning of the time series (Table 5, Figure 6). Mean recruitment from the early 1990s to the present has been higher. The 2015 year class was strong, as was the 2011 year class, but the 2016 year class was below average. Recruitment in 2017 was estimated at 108.8 million age-1 fish, below the time series mean of 140.9 million fish (Table 5, Figure 6).

Total striped bass abundance (age-1+) increased steadily from 1982 through 1997 when it peaked around 450 million fish (Table 5, Figure 7). Total abundance fluctuated without trend through 2004 before declining to around 189 million fish in 2009, coinciding with several years of below average recruitment. There were upticks in abundance in 2012 and 2016, due to the strong 2011 and 2015 year classes. Total age-1+ abundance was 249 million fish in 2017. Abundance of age-8+ striped bass (considered the mature component of the population) increased steadily through 2004 to 16.5 million fish (Table 5, Figure 7). After 2004 age-8+ abundance oscillated and has been in decline since 2011. Age-8+ abundance in 2017 is estimated at 6.7 million fish, a value near the 30th percentile of the time-series.

Female SSB started out at low levels and increased steadily through the late-1980s and 1990s, peaking at 113,602 mt (250 million pounds) in 2003 before beginning to gradually decline; the decline became sharper in 2012 (Table 5, Figure 8). Female SSB was at 68,476 mt (151 million pounds) in 2017.

Biological Reference Points

The reference points currently used for management are based on the 1995 estimate of female SSB. The 1995 female SSB is used as the SSB threshold because many stock characteristics (such as an expanded age structure) were reached by this year and the stock was declared recovered. Estimates of female SSB_{1995} from the 2013 benchmark assessment were quite consistent across runs with different recruitment functions. The values currently used in management are $SSB_{Threshold}$ = female SSB_{1995} = 57,626 mt and SSB_{Target} = 125% female SSB_{1995} = 72,032 mt. To estimate the F threshold, population projections were made using a constant F and changing the value until the SSB threshold value was achieved. The projected F to maintain $SSB_{Threshold}$ = $F_{Threshold}$ = 0.22, and the projected F to maintain SSB_{Target} = F_{Target} = 0.18.

For this assessment the reference point definitions remained the same, but values were updated (Table 6). The SSB threshold was estimated at 91,436 mt (202 million pounds), with an SSB target of 114,295 mt (252 million pounds). The F threshold was estimated at 0.240, and the F target was estimated at 0.197.

The SAS explored alternate empirical and model-based reference points; an alternate threshold of SSB_{1993} is shown in Table 6. However, the model-based approach (e.g., SPR20%) produced SSB reference points that were unrealistically high. As a result, the SAS recommended using empirically-based reference points rather than model-based reference points.

Stock Status

Female SSB for Atlantic striped bass in 2017 was 68,476 mt, below the SSB threshold, indicating the stock is overfished (Table 6, Figure 9). F in 2017 was 0.307, above the F threshold, indicating the stock is experiencing overfishing (Table 6, Figure 9).

Projections

Six-year projections of female SSB were made by using the same population dynamics equations used in the assessment model. Four scenarios of constant catch or F were explored.

The model projection began in year 2018. A composite selectivity pattern was calculated as the geometric mean of total F-at-age for 2013-2017, scaled to the highest F. Residuals from the stock-recruitment fit were randomly re-sampled and added to the deterministic predictions of recruitment from the hockey-stick recruitment function to produce stochastic estimates of age-1 recruitment for each year of the projection. Projections were done using constant 2017 catch, F equal to F_{2017}, F equal to $F_{threshold}$, and F equal the F required to achieve the 1993 estimate of female SSB in the long term.

Under status quo F ($F=F_{2017}$), the population trajectory remained relatively flat from 2018–2023; reducing F to the F threshold resulted in an increasing trend in SSB (Figure 10). However, under all four scenarios, the probability of female SSB being below the SSB threshold in 2023 was very high, equal or close to 100% in all scenarios (Figure 11). In addition, although the probability of F being above the F threshold declined over time in the constant catch scenario, there was still a 60% chance of F being above the F threshold in 2023 (Figure 12).

Research Recommendations

The Technical Committee was able to address or make progress on several of the recommendations from the SAW/SARC 57 report, including developing maturity ogives applicable to coastal migratory stocks, evaluating the stock status definitions relative to uncertainty in biological reference points, and developing a spatially and temporally explicit catch-at-age model incorporating tag based movement information.

The Technical Committee identified several high priority research recommendations to improve the assessment. These included better characterization of commercial discards, expanded collection of sex ratio data and paired scale-otolith samples, development of an index of relative abundance for the Hudson River stock, better estimates of tag reporting rates, continued collection of mark-recapture data to better understand migration dynamics, and additional work on the impacts of *Mycobacteriosis* on striped bass population dynamics and productivity.

The Technical Committee recommends that the next benchmark stock assessment be conducted in five years in 2024, which will allow progress to be made on issues like state-specific scale-otolith conversion factors and directly incorporating tagging data into the two-stock assessment model.

Literature Cited

Northeast Fisheries Science Center (NEFSC). 2019. 66th Northeast Regional Stock Assessment Workshop (66th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 19-08; 1170 p. Available from: http://www.nefsc.noaa.gov/publications/crd/crd1908/

Table 1. Commercial and recreational removals of striped bass in numbers of fish.

Year	Commercial Harvest	Commercial Discards	Recreational Harvest*	Recreational Release Mortalities†	Total
1982	359,979	33,214	318,872	193,486	905,551
1983	271,958	47,984	615,844	111,924	1,047,711
1984	467,158	24,850	264,002	79,663	835,673
1985	69,288	29,555	732,002	94,682	925,527
1986	6,352	40,888	268,724	124,475	440,439
1987	3,727	29,785	114,351	145,471	293,334
1988	27,601	54,801	127,827	244,914	455,143
1989	3,908	87,813	161,791	406,866	660,378
1990	93,887	46,630	578,897	442,811	1,162,225
1991	114,170	90,439	798,260	715,552	1,718,422
1992	232,983	197,240	869,781	937,611	2,237,615
1993	314,522	116,921	789,037	812,488	2,032,966
1994	322,574	160,198	1,058,811	1,361,143	2,902,725
1995	537,342	187,185	2,287,578	2,010,689	5,022,794
1996	853,147	261,022	2,544,837	2,609,169	6,268,175
1997	1,076,561	331,383	3,001,559	2,978,716	7,388,220
1998	1,217,047	348,852	3,077,870	3,270,354	7,914,123
1999	1,223,372	332,101	3,330,322	3,161,882	8,047,676
2000	1,216,826	203,084	3,901,584	3,055,801	8,377,295
2001	929,394	174,926	4,212,411	2,454,617	7,771,349
2002	920,628	191,099	4,283,019	2,795,880	8,190,626
2003	862,381	129,813	5,021,287	2,852,116	8,865,597
2004	879,233	160,196	4,809,192	3,677,938	9,526,558
2005	969,808	145,094	4,551,590	3,444,770	9,111,262
2006	1,047,645	158,260	5,054,694	4,813,025	11,073,624
2007	1,014,707	166,397	4,177,242	2,944,764	8,303,111
2008	1,027,387	108,962	4,695,177	2,391,299	8,222,826
2009	1,053,530	128,191	4,901,115	1,943,488	8,026,323
2010	1,031,544	133,064	5,444,331	1,761,624	8,370,563
2011	944,669	87,924	5,048,912	1,482,139	7,563,643
2012	870,365	191,577	4,171,793	1,848,537	7,082,272
2013	784,379	112,097	5,215,393	2,393,952	8,505,821
2014	750,263	121,253	4,033,746	2,172,532	7,077,795
2015	622,079	101,343	3,085,724	2,307,133	6,116,279
2016	609,847	105,119	3,504,611	2,985,523	7,205,099
2017	592,576	108,475	2,934,292	3,423,544	7,058,888

* Includes estimates of Wave 1 harvest for VA and NC from tag releases for years with no MRIP sampling

† 9% release mortality applied to fish released alive

Table 2. Indices of age 1+ abundance and associated CVs for the mixed ocean population of striped bass.

Year	MRIP	CV	CT Trawl	CV	NY OHS	CV	NJ Trawl	CV
1982	0.16	0.67						
1983	0.38	0.93						
1984	0.44	1.50						
1985	0.12	0.72						
1986	0.27	0.84						
1987	0.46	1.02	0.053	0.32	3.83	0.11		
1988	0.47	0.68	0.036	0.44	3.6	0.10		
1989	0.44	0.72	0.063	0.30	2.58	0.13		
1990	0.64	0.68	0.162	0.27	3.5	0.18	2.20	0.42
1991	0.79	0.64	0.146	0.25	3.28	0.19	2.72	0.35
1992	1.91	0.57	0.22	0.26	3	0.19	1.49	0.37
1993	1.78	0.49	0.273	0.18	3.32	0.11	1.60	0.38
1994	2.53	0.44	0.296	0.18	2.9	0.15	2.01	0.20
1995	3.63	0.49	0.594	0.14	2.84	0.18	13.94	0.11
1996	4.08	0.45	0.635	0.14	5.11	0.10	17.10	0.11
1997	4.59	0.45	0.855	0.12	4.84	0.14	17.08	0.11
1998	4.77	0.42	0.972	0.13	5.01	0.15	15.78	0.05
1999	4.58	0.42	1.105	0.11	3.46	0.16	9.57	0.06
2000	4.22	0.46	0.84	0.12	4.36	0.11	10.87	0.06
2001	3.44	0.41	0.607	0.15	3.47	0.15	3.91	0.16
2002	3.17	0.45	1.304	0.10	3.23	0.20	10.13	0.13
2003	2.97	0.46	0.871	0.11	4.24	0.19	14.36	0.04
2004	2.06	0.40	0.556	0.14	4.88	0.09	10.00	0.07
2005	2.60	0.42	1.172	0.12	3.91	0.14	28.06	0.10
2006	2.84	0.41	0.612	0.16	4.37	0.14	8.87	0.20
2007	1.92	0.40	1.02	0.12			14.14	0.12
2008	1.75	0.40	0.568	0.14			3.68	0.17
2009	1.61	0.38	0.598	0.18			12.76	0.12
2010	1.48	0.37	0.397	0.22			3.54	0.26
2011	1.16	0.38	0.476	0.21			7.16	0.09
2012	1.22	0.45	0.433	0.17			16.65	0.24
2013	2.21	0.36	0.674	0.13			8.84	0.20
2014	1.66	0.40	0.408	0.20			8.29	0.35
2015	1.62	0.42	0.197	0.24			0.77	0.35
2016	1.63	0.37	0.482	0.16			2.01	0.18
2017	2.96	0.39	0.340	0.25			18.25	0.12

Table 3. Indices of age-1+ abundance of striped bass in Delaware and Chesapeake Bays.

Year	DE SSN	CV	DE 30	CV	MD SSN	CV	ChesMMAP	CV
1982								
1983								
1984								
1985					4.88	0.25		
1986					10.07	0.25		
1987					7.15	0.25		
1988					3.27	0.25		
1989					3.96	0.25		
1990			2.38	1.32	5.04	0.25		
1991			0.32	0.24	4.61	0.25		
1992			1.72	0.55	6.29	0.25		
1993			2.93	1.17	6.25	0.25		
1994			6.36	3.56	5.13	0.25		
1995			16.47	5.20	4.62	0.25		
1996	1.81	0.30	9.64	2.39	7.59	0.25		
1997	2.16	0.32	4.32	1.92	3.83	0.25		
1998	2.12	0.38	2.23	0.82	4.79	0.25		
1999	1.47	0.26	12.48	4.09	4.02	0.25		
2000	1.66	0.32	6.43	2.42	3.54	0.25		
2001	1.88	0.39	3.48	1.19	2.87	0.25		
2002	1.60	0.35	7.75	2.77	4.1	0.25	31.94	0.24
2003	3.21	0.42	2.53	0.99	4.5	0.25	77.74	0.16
2004	2.81	0.51	1.08	0.45	6.05	0.25	86.76	0.13
2005	1.77	0.31	2.60	1.07	4.96	0.25	146.19	0.16
2006	2.22	0.45	4.04	1.68	4.92	0.25	84.48	0.18
2007	1.78	0.72	1.98	0.76	2.14	0.25	71.86	0.18
2008	1.72	0.30	2.39	0.89	4.37	0.25	50.62	0.15
2009	1.25	0.24	1.22	0.42	5.7	0.25	20.89	0.24
2010	2.69	0.63	2.25	1.01	4.53	0.25	20.13	0.28
2011	3.25	0.78	1.15	0.46	4.58	0.25	27.31	0.17
2012	1.94	0.41	1.74	0.44	2.65	0.25	109.14	0.27
2013	2.10	0.42	1.44	0.45	4.42	0.25	74.21	0.2
2014	2.43	0.39	1.92	1.14	5.57	0.25	43.74	0.27
2015	0.86	0.18	2.93	1.45	7.34	0.25	55.26	0.29
2016	0.49	0.13	1.45	1.51	3.96	0.25	139.43	0.21
2017	1.75	0.42	1.66	0.78	5.46	0.25	148.2	0.27

Table 4. Indices of recruitment for striped bass

Year	NY YOY	CV	NY Age 1	CV	NJ YOY	CV	MDVA YOY	CV	MD Age 1	CV
1982							52.77	0.430	0.02	0.510
1983					1.09	0.543	84.82	0.322	0.02	0.580
1984					1.34	0.669	64.35	0.385	0.32	0.200
1985			0.96	0.237	0.52	0.258	82.97	0.321	0.01	1.000
1986	2.20	0.136	0.61	0.377	1.97	0.984	65.11	0.367	0.16	0.250
1987	4.65	0.129	0.30	0.293	0.42	0.209	88.10	0.311	0.03	0.470
1988	28.36	0.169	0.21	0.310	0.31	0.157	204.03	0.294	0.06	0.460
1989	49.28	0.106	0.81	0.277	0.31	0.155	104.21	0.305	0.07	0.290
1990	35.37	0.127	1.78	0.237	0.18	0.088	110.92	0.266	0.19	0.240
1991	35.53	0.132	0.37	0.250	0.16	0.081	70.90	0.339	0.33	0.210
1992	6.00	0.150	1.26	0.217	0.18	0.090	69.92	0.339	0.20	0.220
1993	16.93	0.106	1.34	0.219	0.11	0.053	83.63	0.304	0.15	0.260
1994	21.99	0.141	0.75	0.217	0.09	0.044	233.65	0.263	0.19	0.250
1995	23.61	0.106	1.43	0.247	0.13	0.063	129.02	0.262	0.78	0.180
1996	19.03	0.100	1.29	0.225	0.09	0.043	107.18	0.307	0.12	0.280
1997	12.12	0.116	1.54	0.250	0.09	0.044	292.20	0.253	0.08	0.390
1998	27.11	0.144	1.00	0.274	0.12	0.060	107.68	0.266	0.26	0.230
1999	16.10	0.124	2.10	0.276	0.12	0.058	149.71	0.236	0.17	0.250
2000	30.67	0.111	2.05	0.203	0.08	0.041	127.57	0.327	0.37	0.180
2001	6.88	0.160	1.56	0.242	0.10	0.048	169.70	0.233	0.26	0.200
2002	28.90	0.159	2.16	0.209	0.11	0.053	221.79	0.279	0.32	0.180
2003	14.72	0.102	2.53	0.182	0.19	0.097	70.64	0.337	0.79	0.160
2004	29.78	0.148	1.19	0.176	0.07	0.036	231.43	0.213	0.07	0.330
2005	8.73	0.103	2.41	0.186	0.13	0.064	149.39	0.239	0.74	0.180
2006	11.28	0.160	0.64	0.274	0.10	0.052	154.67	0.242	0.28	0.220
2007	5.83	0.120	2.02	0.215	0.15	0.075	89.06	0.301	0.28	0.210
2008	42.65	0.120	0.58	0.242	0.09	0.044	135.30	0.247	0.07	0.300
2009	19.04	0.110	1.24	0.214	0.11	0.054	82.86	0.313	0.31	0.200
2010	13.92	0.136	0.33	0.237	0.09	0.043	103.97	0.278	0.12	0.270
2011	25.62	0.133	0.45	0.232	0.10	0.048	111.14	0.271	0.17	0.223
2012	12.16	0.156	2.00	0.221	0.11	0.057	274.26	0.209	0.02	0.510
2013	9.85	0.142	0.90	0.195	0.24	0.119	49.85	0.434	0.35	0.170
2014	5.07	0.118	0.56	0.206	0.13	0.067	116.33	0.261	0.05	0.370
2015	24.60	0.106	0.82	0.198	0.08	0.041	133.22	0.248	0.12	0.285
2016	21.68	0.125	3.16	0.194	0.13	0.064	183.47	0.302	0.23	0.130
2017	10.93	0.137	2.00	0.194	0.10	0.050	74.87	0.327	0.42	0.260

Table 5. Spawning stock biomass, recruitment, abundance, and full F estimates from the non-migration SCA model.

Year	Female SSB (mt)	Recruitment (Millions of age-1 fish)	Total Age 1+ Abundance (Millions of fish)	Total Age 8+ Abundance (Millions of fish)	Full F
1982	19,112	37.9	56.5	1.8	0.171
1983	16,090	75.4	98.4	1.5	0.141
1984	16,211	65.6	103.1	1.3	0.066
1985	16,866	72.6	114.9	1.5	0.192
1986	15,369	69.9	118	1.7	0.051
1987	18,962	72.1	123.7	2.2	0.030
1988	25,288	97	152.3	2.6	0.035
1989	38,239	108	174.2	3.5	0.046
1990	44,866	126.3	202.3	5.7	0.061
1991	52,912	100.8	188.5	7	0.087
1992	67,439	108	194.1	8.2	0.105
1993	75,906	132.4	221	8.7	0.083
1994	85,180	283.5	382.1	9.3	0.109
1995	91,436	182.5	334.9	10.4	0.200
1996	101,396	232.2	378.3	10.7	0.263
1997	95,812	257.9	419.4	10.7	0.217
1998	87,835	144.3	322.2	10.1	0.227
1999	86,218	149.7	300.3	9.6	0.212
2000	97,695	127	267.5	10	0.211
2001	100,859	195.5	322.6	13.8	0.209
2002	112,163	224.7	366.7	14.1	0.225
2003	113,602	138.3	295.7	15.4	0.241
2004	109,072	312.2	449	16.5	0.267
2005	107,971	162.3	345.1	14.3	0.262
2006	101,869	136.4	293.2	12.9	0.309
2007	100,065	92.7	228.9	10.9	0.228
2008	106,656	129.2	242.3	11.7	0.241
2009	106,094	77.5	189.6	12.9	0.233
2010	106,261	104.9	198	11.9	0.273
2011	99,768	147.9	238.7	14.7	0.276
2012	98,798	214.4	316.4	13.2	0.272
2013	88,864	65.4	193.7	11.6	0.368
2014	78,999	92.6	184.9	8.8	0.283
2015	70,858	186.9	272.2	8.2	0.243
2016	73,924	239.6	351.3	7.1	0.278
2017	68,476	108.8	249.2	6.7	0.307

Table 6. Reference points derived from the non-migration model for selected annual SSB levels for Atlantic striped bass, 2017 estimates of F and SSB, and the probability that the stock is overfished and overfishing is occurring.

Threshold definition	SSB ref (SE)	2017 SSB (SE)	Overfished Probability $p(SSB_{2017} < SSB_{ref})$
SSB 1993	75,906 (5,025)	68,476 (7,630)	84%
SSB 1995	91,436 (5,499)		100%

Threshold definition	F ref (CV)	2017 F (SE)	Overfishing Probability $p(F_{2017} > F_{ref})$
SSB 1993	0.278 (0.077)	0.307 (0.034)	76%
SSB 1995	0.240 (0.087)		95%

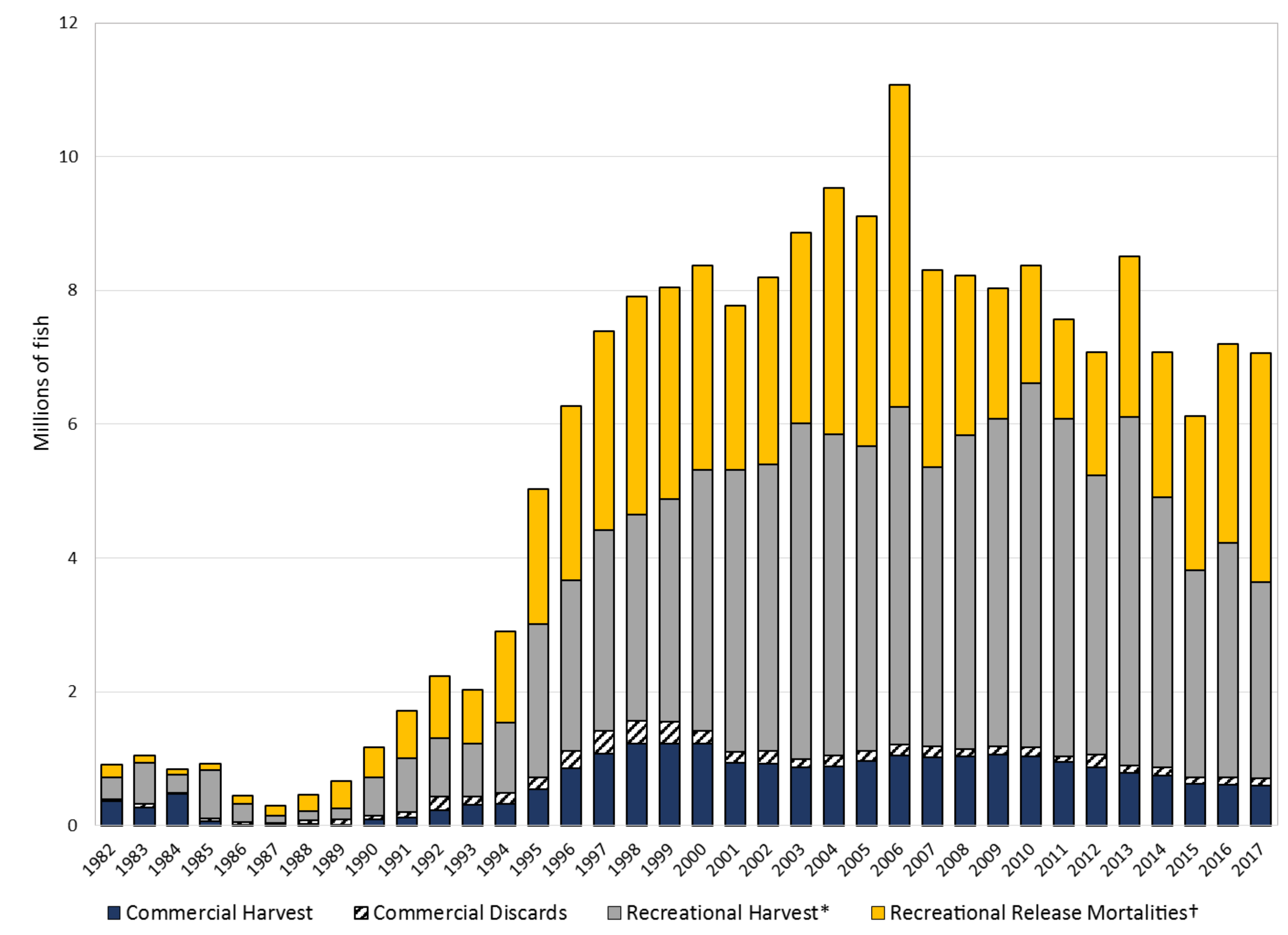


Figure 1. Total striped bass removals by sector in numbers of fish. *Recreational harvest includes ASMFC estimates of Wave-1 harvest for North Carolina and Virginia. † Release mortality of 9% applied to live releases.

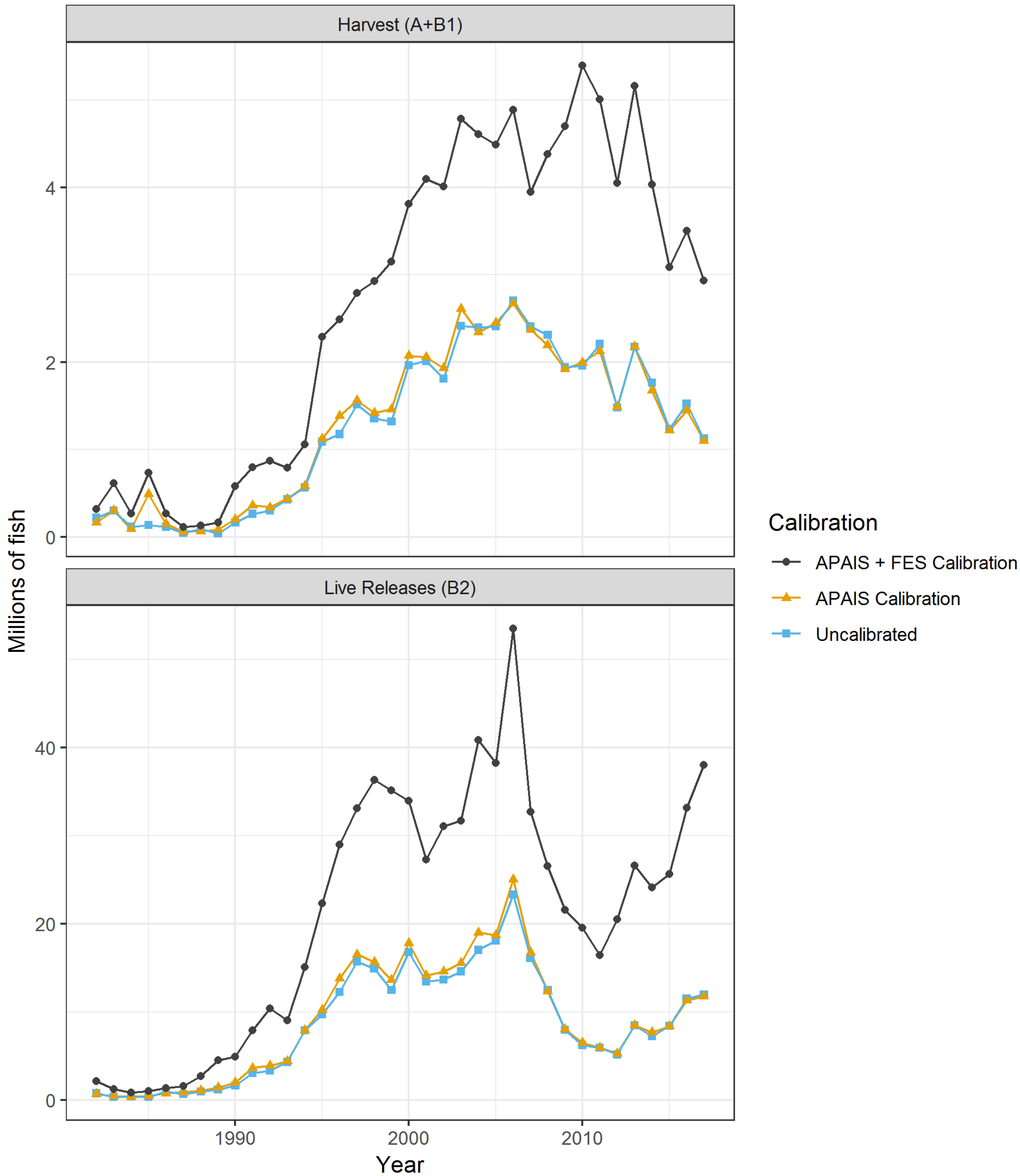


Figure 2. Comparison of calibrated and uncalibrated MRIP estimates of harvest (top) and live releases (bottom) of striped bass. Uncalibrated = old, uncalibrated MRIP estimates; APAIS calibration = estimates calibrated to take into account changes to the Access Point Intercept Survey only; APAIS + FES calibration = estimates calibrated to take into account changes to the both the Access Point Intercept Survey and the Fishing Effort Survey.

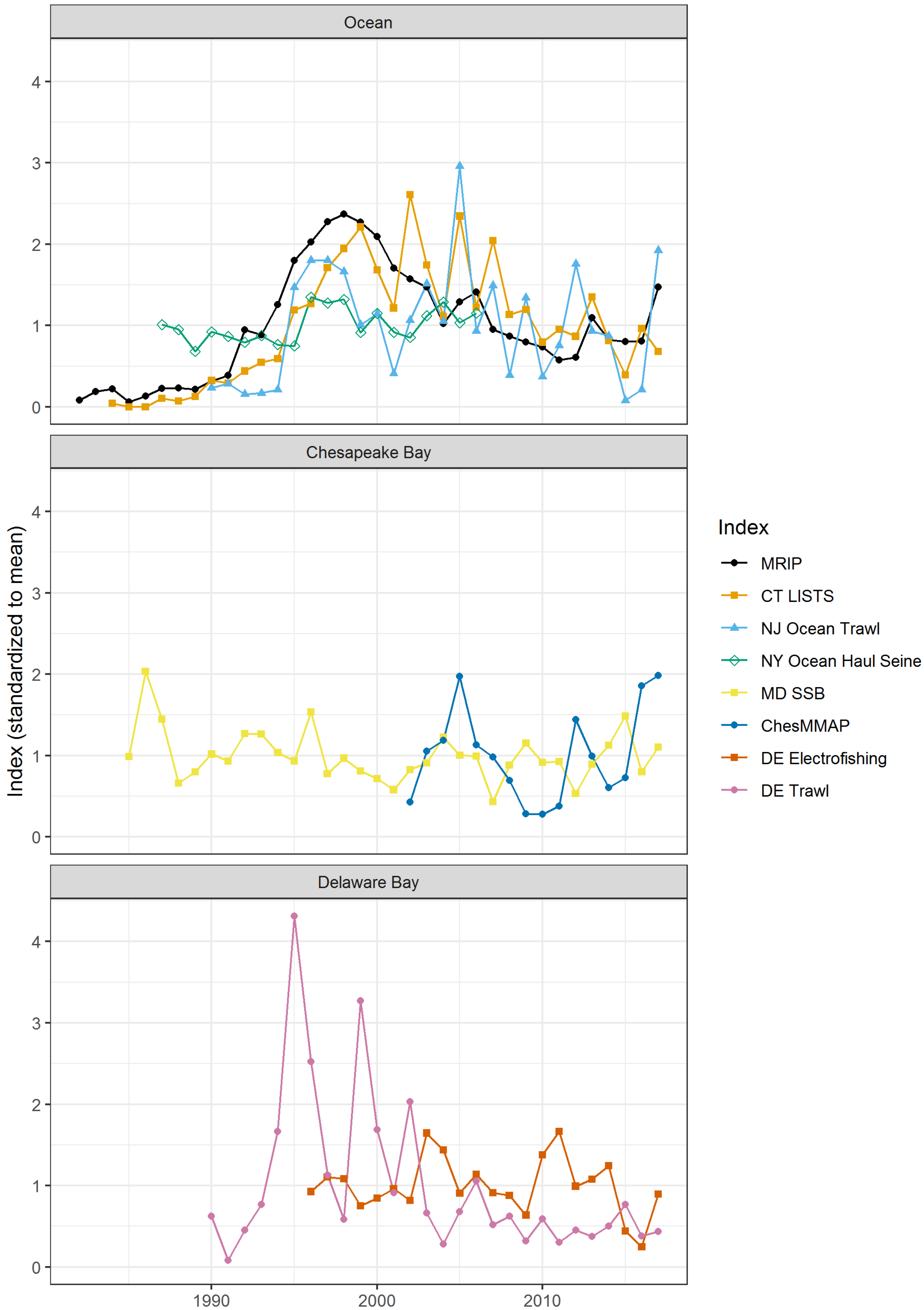


Figure 3. Age 1+ indices of abundance for striped bass by region.

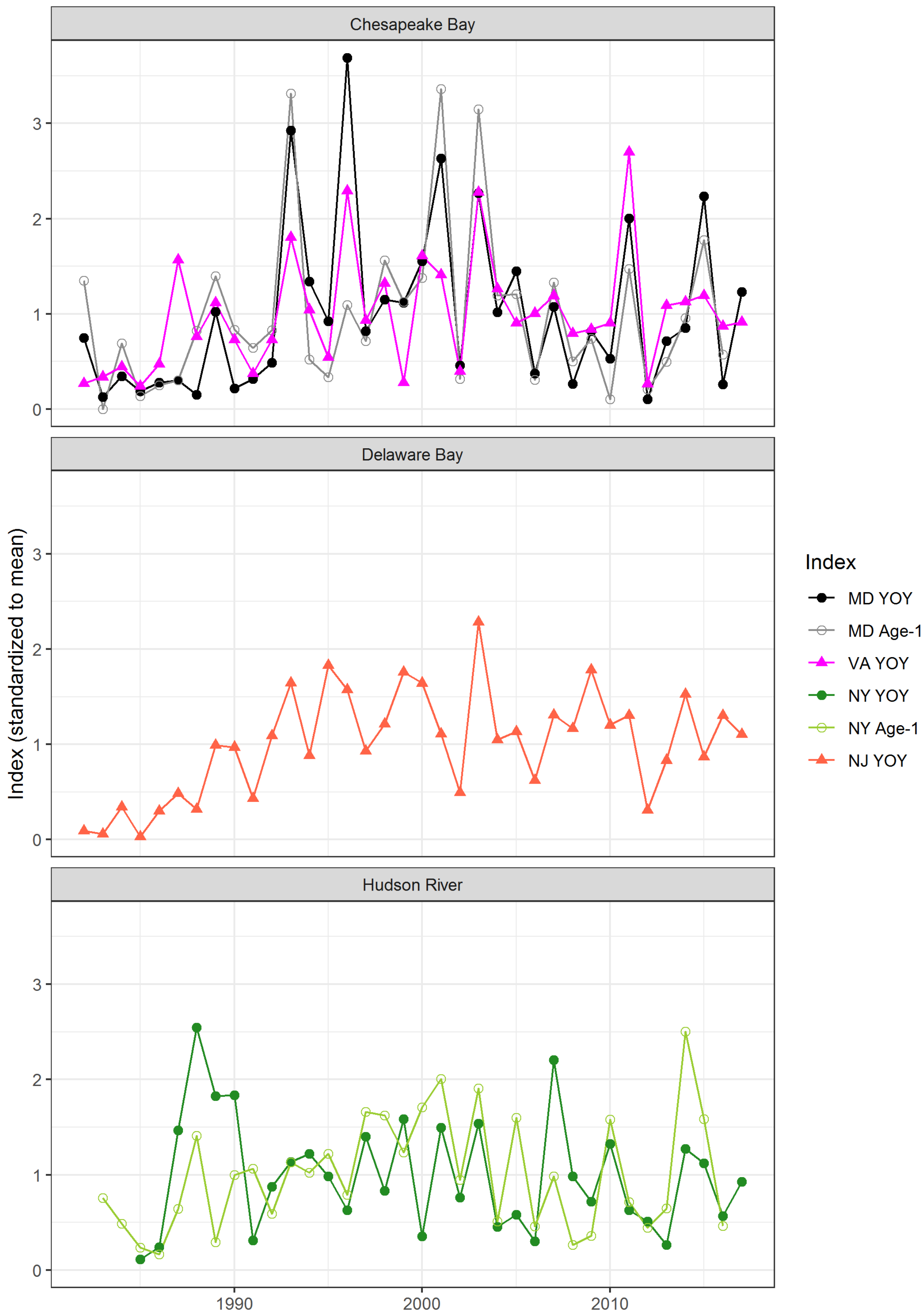


Figure 4. Recruitment indices for striped bass by region. Age-1 indices have been lagged back one year for easier comparison with YOY indices.

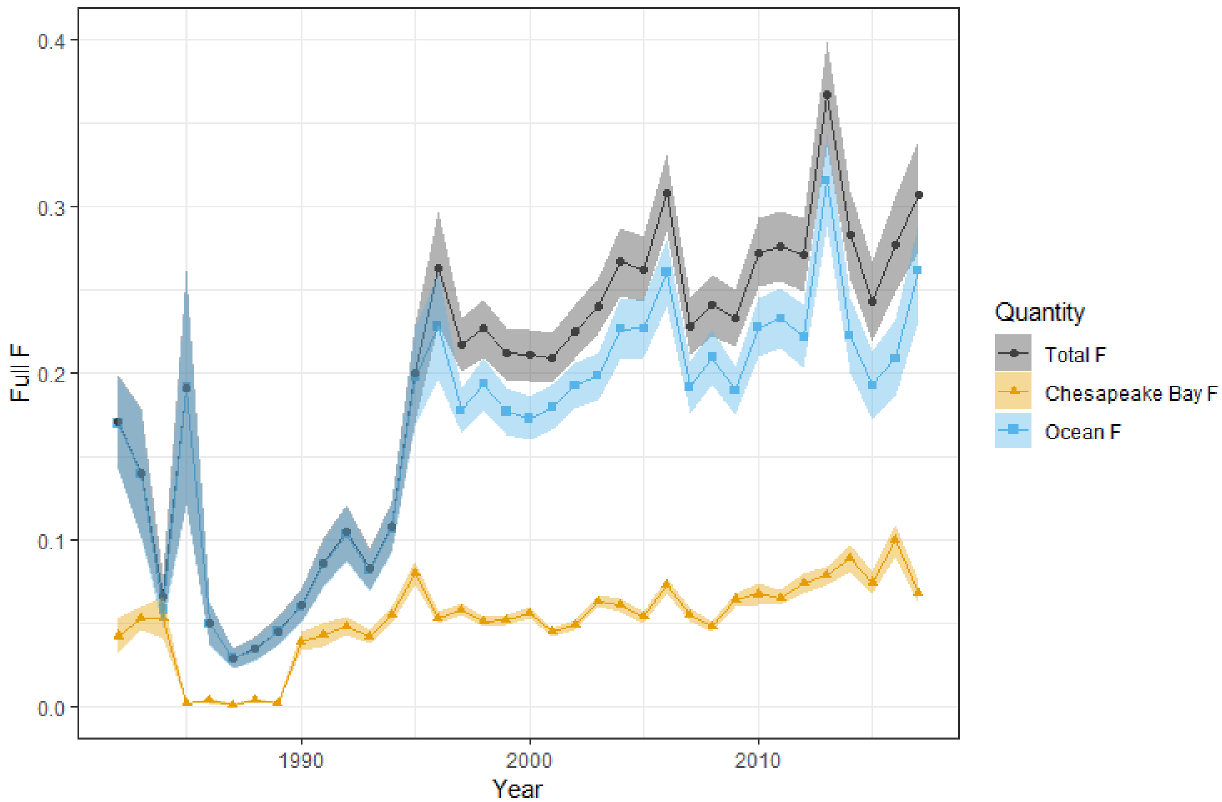


Figure 5. Full F for the Chesapeake Bay and Ocean fleets, and the full total F for both fleets combined. Shaded area indicates ±one standard deviation.

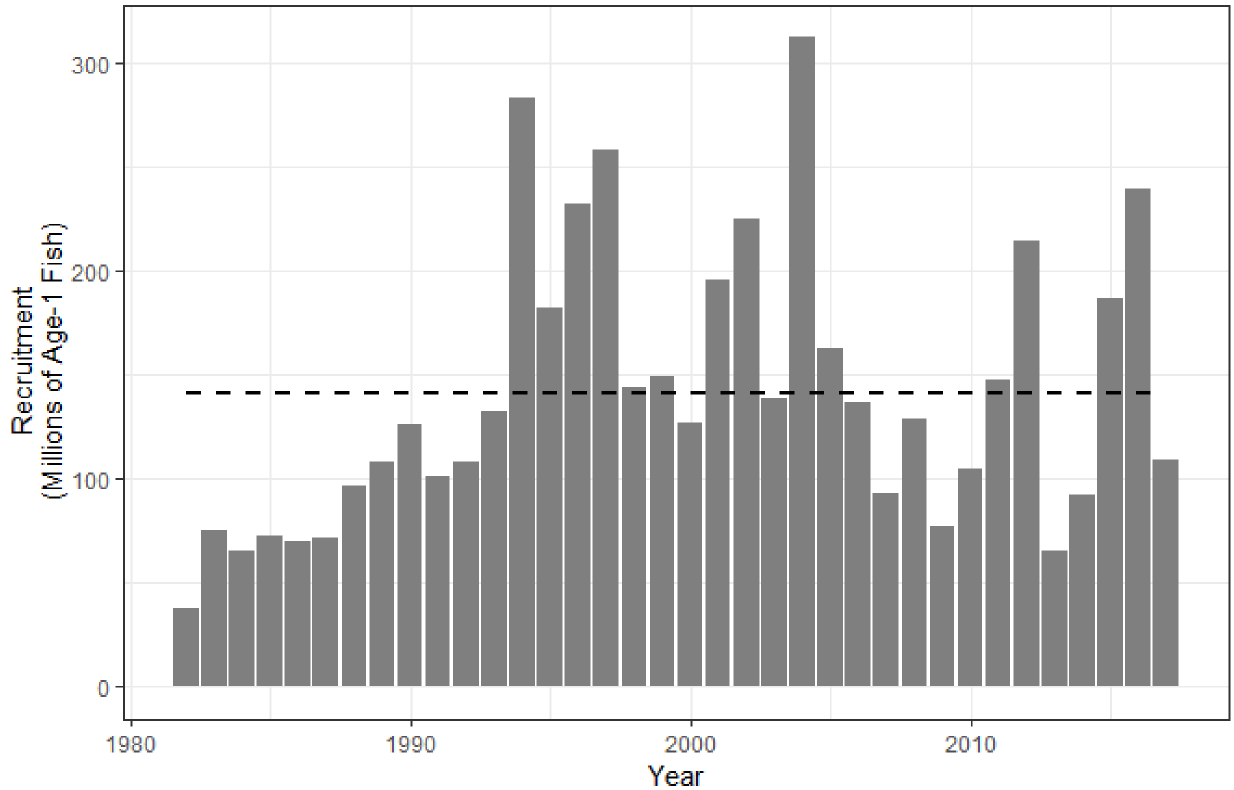


Figure 6. Estimates of recruitment for Atlantic striped bass. Dashed black line indicates time-series average for the stock.

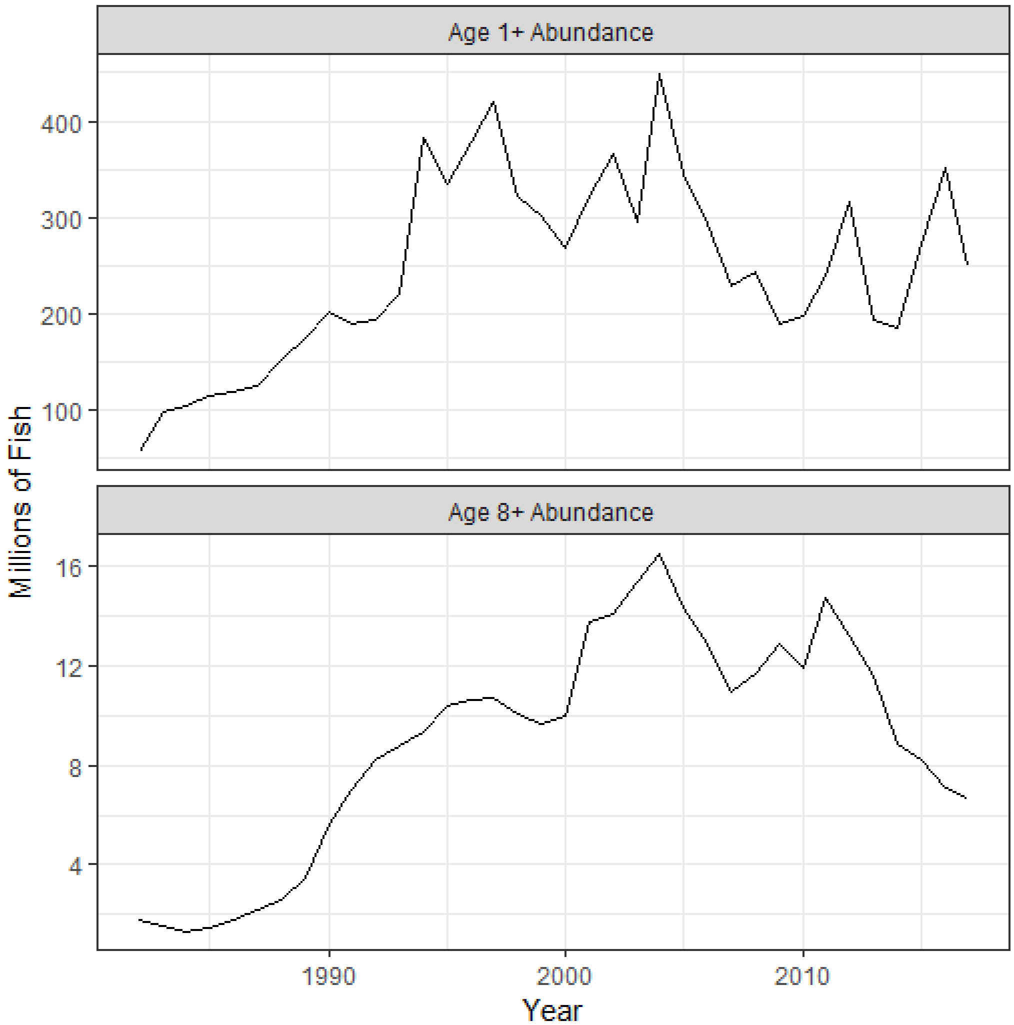


Figure 7. Total abundance of Age 1+ (top) and Age 8+ (bottom) striped bass.

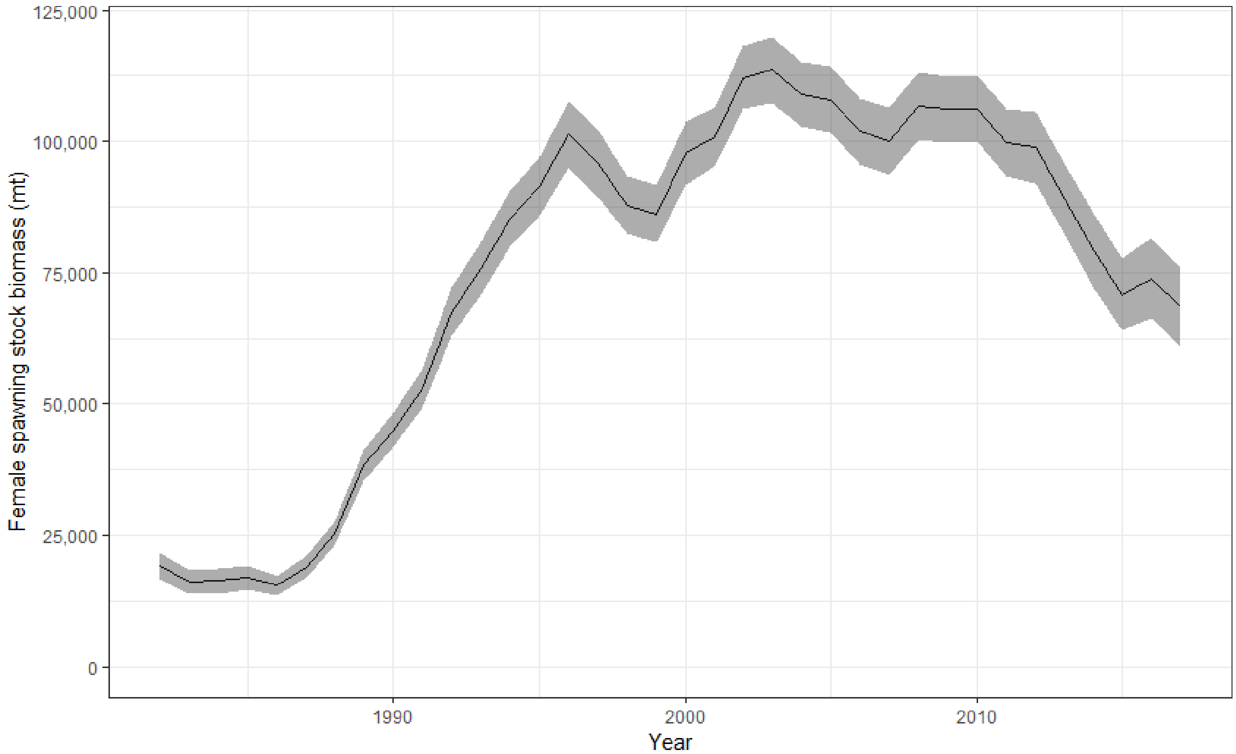


Figure 8. Female spawning stock biomass of striped bass. Shaded area indicates ±one standard deviation.

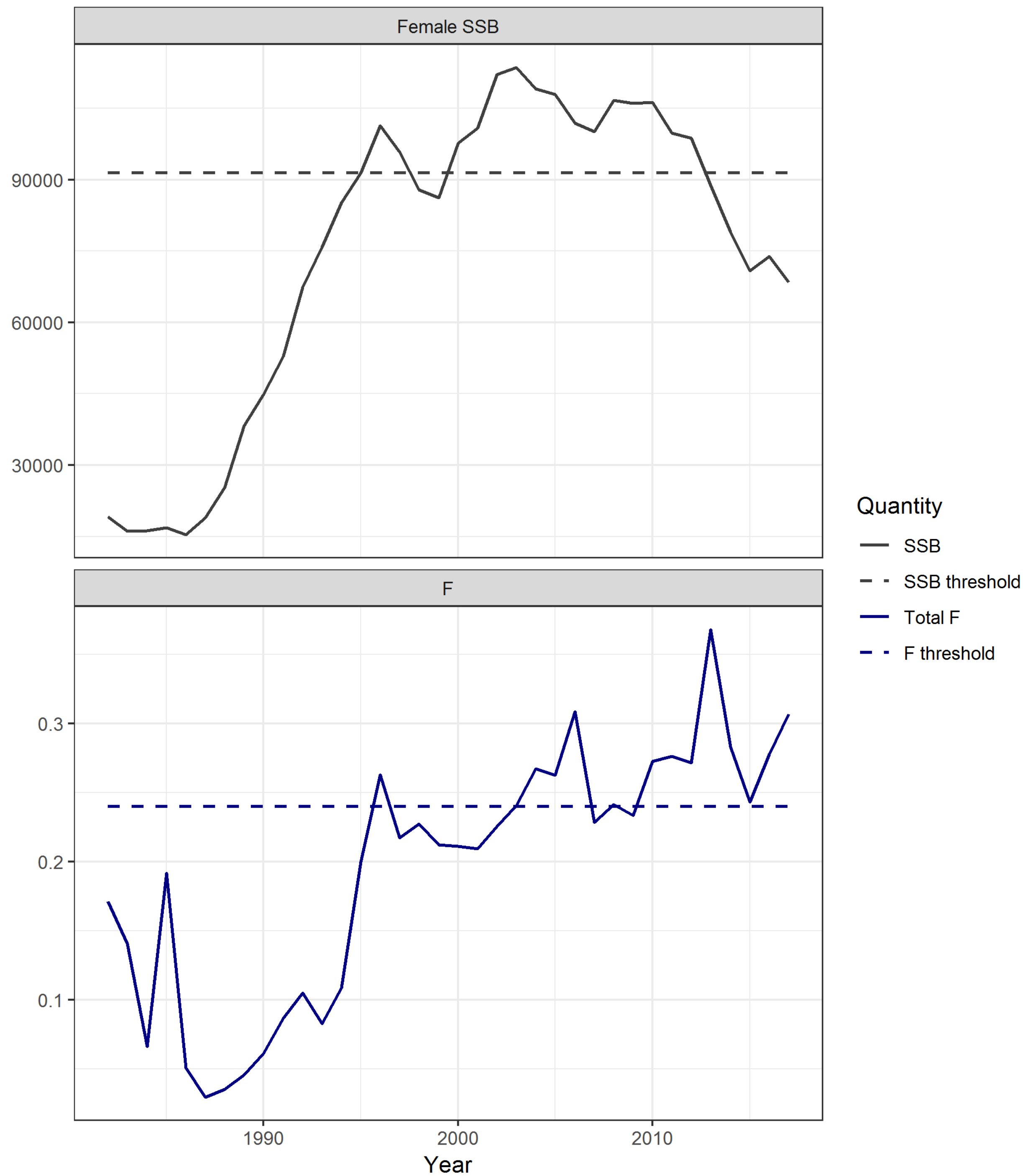


Figure 9. Estimates of striped bass female SSB plotted with the SSB threshold (top) and full F plotted with the F threshold (bottom).

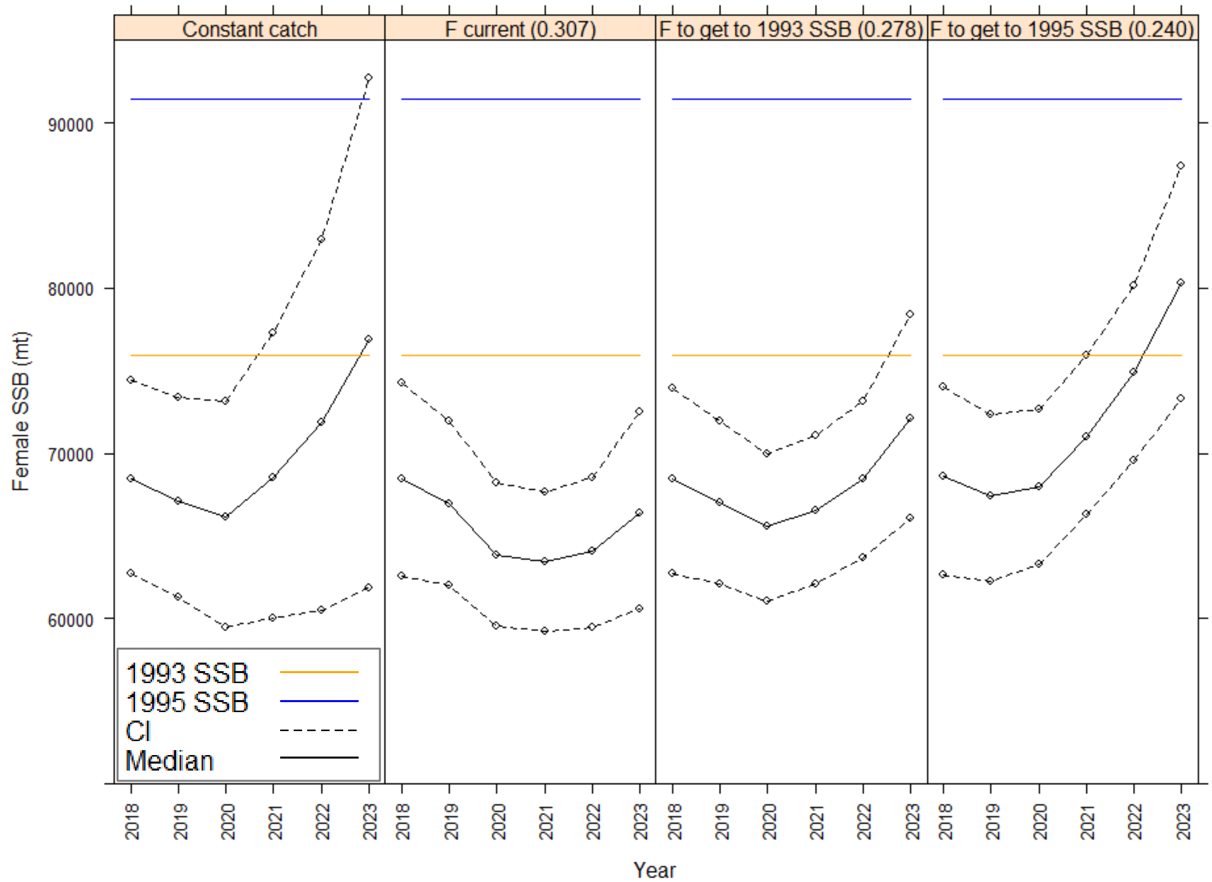


Figure 10. Trajectories of female spawning stock biomass (SSB) with 95% confidence intervals under different harvest scenarios

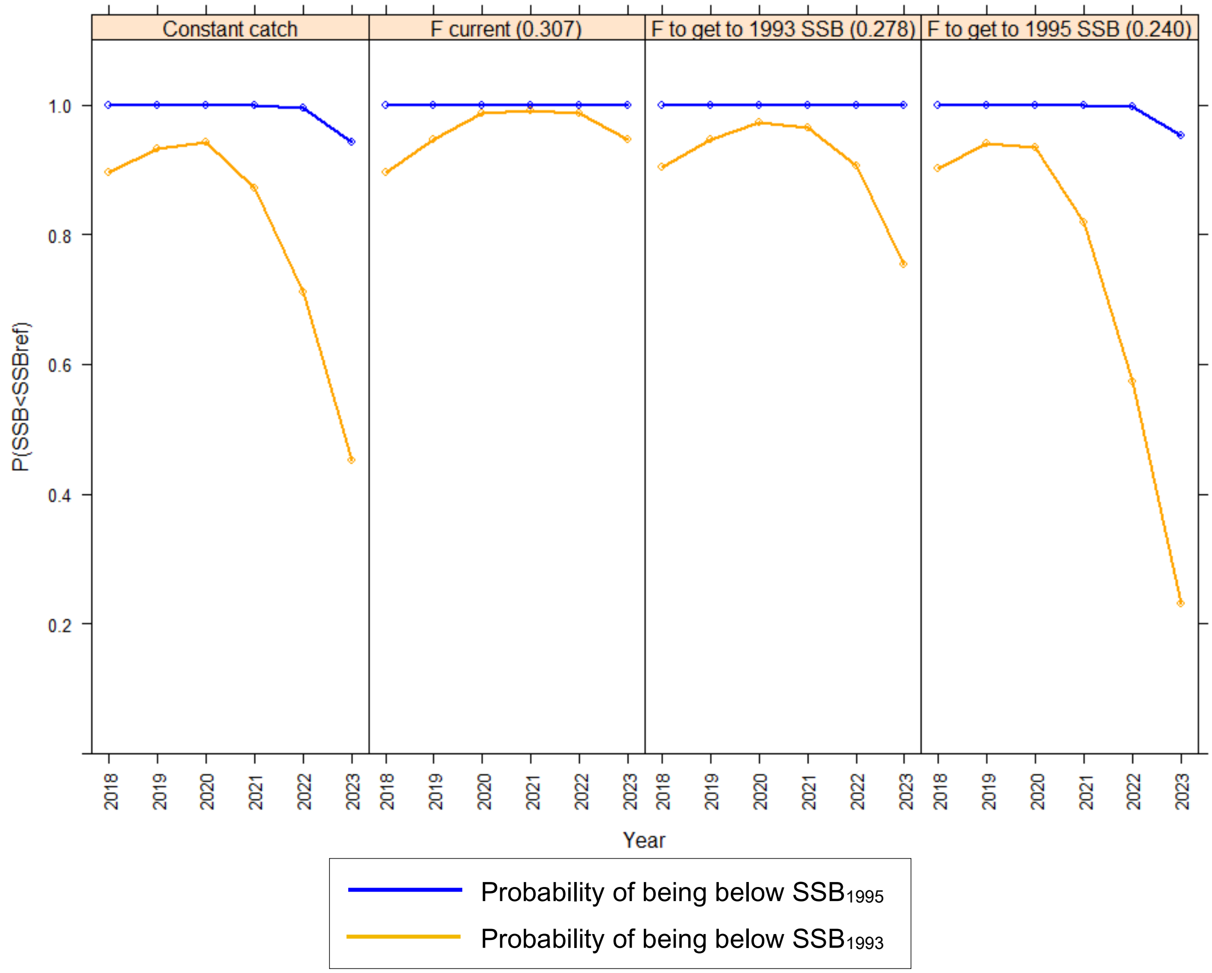


Figure 11. Probability of female spawning stock biomass (SSB) being below the SSB threshold under different harvest scenarios.

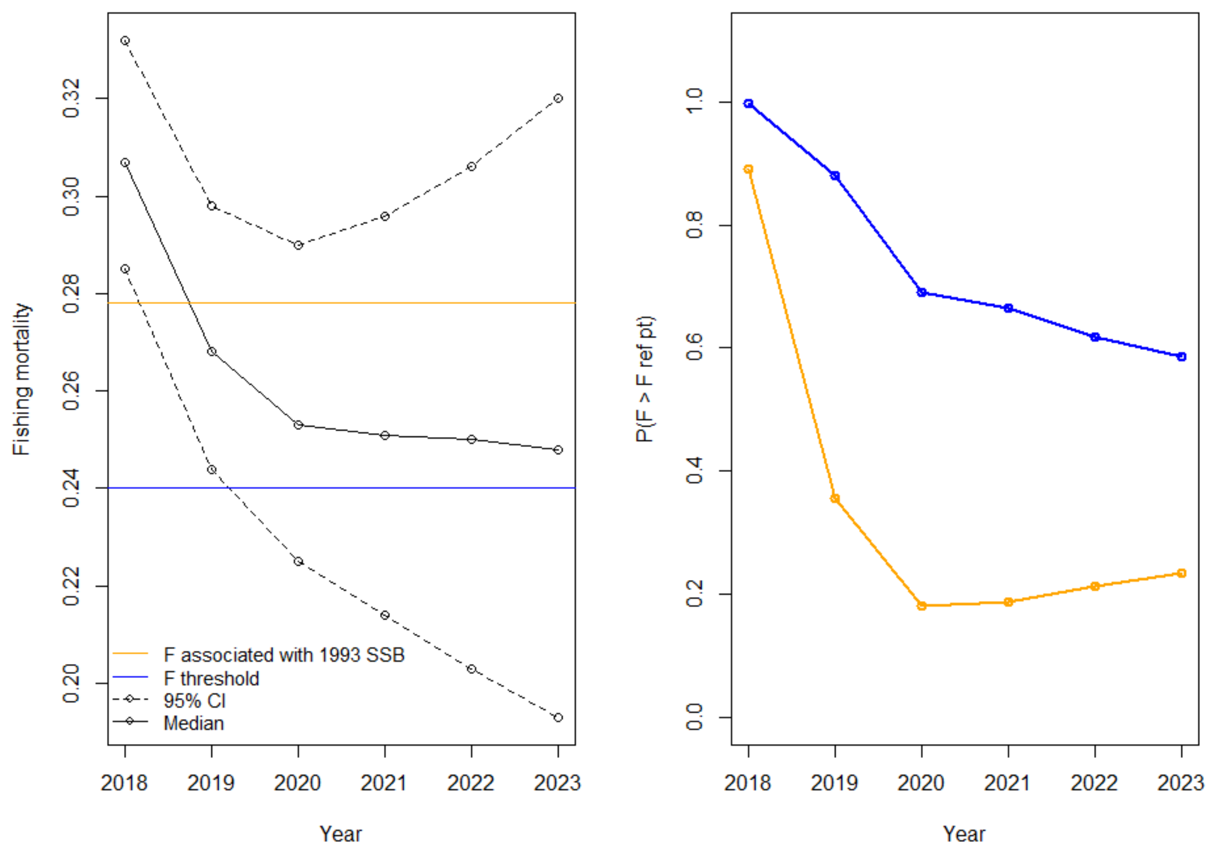


Figure 12. Trajectory of combined full fishing morality (F) for striped bass (left) and the probability of F being above F threshold (right) under the constant 2017 catch scenario.