



Northeast Fisheries Science Center Reference Document 18-05

Butterfish 2017 Stock Assessment Update

by Charles F. Adams

February 2018

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STATE OF STOCK

This report on the butterfish (*Peprilus triacanthus*) stock is an update through 2016 of the previous benchmark assessment (NEFSC 2014). The recommended status determination is that the stock is not overfished, and overfishing is not occurring (Figs. 1-2).

The Northeast Fisheries Science Center (NEFSC) Stock Assessment Workshop (SAW) 58 (NEFSC 2014) biological references points for butterfish were recalculated based on advice from the Mid-Atlantic Fishery Management Council (MAFMC) Science and Statistical Committee (Boreman 2017). The stock assessment update was completed by adding catch and indices for 2013–2016 to data from 1989–2012 used in the previous assessment (NEFSC 2014). Estimated fishing mortality and spawning stock biomass (SSB) in 2016 was 0.05 ($CV(F_{2016}) = 0.28$) and 59,041 mt (130.2 million lb) ($CV(SSB_{2016}) = 0.25$), respectively (Figs. 1–2). The 2016 fishing mortality rate (0.05) was 94% below the revised overfishing reference point F_{MSY} proxy = 0.82. The 2016 SSB (59,041 mt) was 21% above the revised biomass reference point SSB_{MSY} proxy = 48,681 mt (107.3 million lb) ($CV = 0.25$). $SSB_{threshold}$ was one half the SSB_{MSY} proxy, or 24,341 mt (53.7 million lb).

PROJECTIONS

Projections of total catch and SSB were done with a standard forward projection methodology sampling recruitment from the entire time series (NFT 2013). It was assumed that the catch of butterfish in 2017 would equal the Domestic Annual Harvest quota (20,652 mt) and that the stock would be fished at the revised fishing mortality threshold F_{MSY} proxy = 0.82 in 2018–2020. The projected estimates are in the following table.

Overfishing Limit Catch and Spawning Stock Biomass (SSB) in metric tons

Year	Catch	SSB
2017	20,652	34,065
2018	29,155	37,242
2019	35,734	44,061
2020	37,269	45,709

CATCH

Commercial landings in 2016 were 1,182 mt (2.6 million lb), while discards were 1,636 mt (3.6 million lb). Total butterfish catch for 2016 was 2,818 mt (6.2 million lb).

Catch and Status Table: Butterfish
(weights are in 000s mt; age-0 recruitment in billions; fishing mortality for ages 2+)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Min ¹	Mean ¹	Max ¹
US landings	0.7	0.5	0.4	0.6	0.7	0.7	1.1	3.1	2.1	1.2	0.4	2.5	11.7
US discards	0.2	1.0	1.1	4.0	1.6	1.0	0.4	1.1	0.9	1.6	0.2	5.6	11.5
Foreign catch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	31.7
Total catch	0.9	1.5	1.5	4.6	2.3	1.7	1.5	4.3	3.0	2.8	0.9	11.0	39.9

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Min ²	Mean ²	Max ²
Spawning biomass	79.5	61.0	53.8	71.9	63.0	67.4	49.6	65.2	67.8	59.0	49.6	77.6	110.6
Recruit numbers	5.8	7.5	10.8	5.9	8.4	4.3	7.7	7.1	6.7	2.0	2.0	8.7	16.3
Fishing mortality	0.01	0.02	0.03	0.07	0.04	0.03	0.03	0.07	0.05	0.05	0.01	0.06	0.14

¹1965-2016 ²1989-2016

STOCK DISTRIBUTION AND IDENTIFICATION

The MAFMC Fishery Management Plan for butterfish defines the management unit as all butterfish under US jurisdiction north of Cape Hatteras, North Carolina (MAFMC 1979).

DATA AND ASSESSMENT

The butterfish stock was last assessed in 2014 during SAW 58 (NEFSC 2014).

Commercial Data

Landings and discard estimates, and commercial mean weights at age were used in this assessment update. Specifically, data for 2013–2016 were added to the data for 1989–2012 used in the previous assessment (Tables 1–4, Figs. 3–4).

Survey Data

Swept area abundances, and abundance indices (number/tow) by age from the NEFSC fall bottom trawl surveys (inshore and offshore) and the Northeast Area Monitoring and Assessment Program (NEAMAP) fall bottom trawl survey were used in this assessment update (Tables 5–8; Figs. 5–7). NEFSC data for 2013–2016 were added to the data for 1989–2012 used in the previous assessment (NEFSC 2014). NEFSC offshore data for 2009–2016 were calibrated using the coefficient (1.935) in Miller et al. (2010). NEAMAP data for 2007–2016 included revised values for 2007–2012 used in the previous assessment.

Thermal Habitat Availability Index

The time series of thermal habitat availability indices used in SAW 58 was revised with an updated and improved Regional Ocean Modeling System numerical ocean model to develop bottom water temperatures (Manderson et al. 2017). The revised values for 1989–2012, along with new estimates for 2013–2015, changed the mean thermal habitat availability index from $A = 0.68$ (used in SAW 58) to $A = 0.62$ for this assessment update (Fig. 8).

Model

The age-structured assessment program (ASAP) version 4 (Miller and Legault 2015) used in SAW 58 was used for this assessment update. Advancements in version 4 are: catchability can be fixed as the product of availability and efficiency (see Special Comments); which allows the estimation of natural mortality, and a length-based calibration performed internal to the model.

Internal model retrospective analysis for F and SSB produced Mohn's rho (Mohn 1999) values of 0.29 (Fig. 9) and -0.21 (Fig. 10), respectively. The 2016 model estimates of F and SSB adjusted for this internal retrospective error are within the model estimated 90% confidence intervals (Fig. 2). Thus, no retrospective adjustment was necessary for the terminal year estimates of F and SSB.

BIOLOGICAL REFERENCE POINTS

The revised overfishing reference point is based on Patterson (1992), i.e., $F = 2M/3 = 2 \times 1.23/3 = 0.82$ (CV = 0.05). The revised biomass reference point, using the same procedure as SAW 58 (NEFSC 2014), is $SSB_{MSY \text{ proxy}} = 48,681$ mt (107.3 million lb) (CV = 0.25). $SSB_{\text{threshold}}$ is one half the $SSB_{MSY \text{ proxy}}$, or 24,341 mt (53.7 million lb).

FISHING MORTALITY

The peak in fishing mortality rate on fully selected ages (ages 2+) was $F = 0.14$, which occurred in 1993–1994 (Table 9; Fig. 11). Fishing mortality ranged between 0.04 and 0.14 during 1995–2001, but has been ≤ 0.07 since 2002. In 2016 estimated $F = 0.05$, with a 90% confidence interval of 0.03 to 0.08.

SPAWNING STOCK BIOMASS

SSB averaged 77,621 mt (171.1 million lb) during 1989–2016 (Figs. 1 and 12–13). SSB peaked in 2000 at 110,550 mt (243.7 million lb), and has been above the $SSB_{MSY \text{ proxy}}$ for the entire time period considered in the assessment model (Table 9; Figs. 1–2). In 2016 estimated SSB = 59,041 mt (130.2 million lb), with a 90% confidence interval of 38,563 (85.0 million lb) to 88,511 mt (195.1 million lb).

RECRUITMENT

Recruitment, which can be highly variable from year to year, averaged 8.7 billion butterfish during 1989–2016 (Table 9; Figs. 12–13). The 1997 year class was the largest estimate in the time series at 16.3 billion butterfish, while the 2016 year class was the smallest estimate at 2.0 billion butterfish. A similar pattern was observed in SAW 58 when the terminal year estimate of recruitment was the lowest in the time series (Figure 14). Additional years of data have since raised the 2012 recruitment estimate, suggesting a retrospective pattern. However, internal model retrospective analysis for recruitment produced a relatively low Mohn’s rho of -0.21 (Fig. 15).

SPECIAL COMMENTS

The effect of the revised thermal habitat availability index was to scale SSB up and F down (Figure 16). Accordingly, the recalculated reference points enable internal consistency with the estimate of M from this assessment update.

The revised natural mortality from the previous assessment ($M = 1.23$) changed to $M = 1.25$ in this assessment update.

The low recruitment index appears to be related to the survey indices. Both survey indices were down in 2016 (Tables 5,7; Fig. 5), and the NEAMAP index was the lowest in the entire time series. Similarly, both survey age 0 indices were down in 2016 (Tables 6, 8) and the NEAMAP age 0 index was also the lowest in the entire time series.

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TABLES

Table 1. Butterfish USA landings (mt), historic USA discards (mt), estimated USA discards (mt), foreign catch (mt), and total catch (mt), 1965–2016. See NEFSC (2014) for further details of historic data.

Year	USA Landings	Historic USA Discards	USA Discards	Foreign Catch	Total catch
1965	2944		11474	749	15167
1966	2461		10997	3865	17323
1967	2245		10174	2316	14735
1968	1585		9856	5437	16878
1969	2198		9421	15378	26997
1970	1731		8760	12450	22941
1971	1566		7977	8913	18456
1972	704		6653	12221	19578
1973	1521		6696	31679	39896
1974	1778		6197	15465	23440
1975	1973		5658	12764	20395
1976	1376	152	6193	14437	22006
1977	1296	152	7255	3312	11863
1978	3615	61	8675	1699	13989
1979	2646	185	9193	1107	12946
1980	5172	184	9956	1392	16520
1981	4855	0	9531	1400	15786
1982	8837	68	11098	1578	21513
1983	4743	162	10911	630	16284
1984	11715	257	10257	429	22401
1985	4633	106	8328	804	13765
1986	4418		7936	164	12518
1987	4578		7351		11929
1988	2107		7352		9459
1989	3216		4480		7696
1990	2298		533		2831
1991	2189		4887		7076
1992	2754		5025		7779
1993	4608		7577		12185
1994	3634		6694		10328
1995	2067		6353		8420
1996	3555		1049		4604
1997	2794		1134		3928
1998	1966		6412		8378
1999	2110		8867		10977
2000	1449		7044		8493
2001	4404		4969		9373
2002	872		2350		3222
2003	536		2088		2624
2004	497		1323		1820
2005	428		647		1075
2006	555		856		1411
2007	679		239		918
2008	452		1029		1481

Table 1, continued. Butterfish USA landings (mt), historic USA discards (mt), estimated USA discards (mt), foreign catch (mt), and total catch (mt), 1965–2016. See NEFSC (2014) for further details of historic data.

Year	USA Landings	Historic USA Discards	USA Discards	Foreign Catch	Total catch
2009	435		1079		1514
2010	576		4017		4593
2011	664		1612		2276
2012	671		1040		1711
2013	1081		444		1525
2014	3135		1144		4279
2015	2131		895		3026
2016	1182		1636		2818

Table 2. Estimated USA Butterfish discards (mt) and total catch (mt) from Table 1, and respective coefficients of variation (CV), 1989–2016.

Year	USA Discards	CV	Year	USA Catch	CV
1989	4480	0.85	1989	7696	0.49
1990	533	0.37	1990	2831	0.07
1991	4887	0.99	1991	7076	0.68
1992	5025	0.54	1992	7779	0.35
1993	7577	0.32	1993	12185	0.20
1994	6694	0.41	1994	10328	0.26
1995	6353	0.49	1995	8420	0.37
1996	1049	0.71	1996	4604	0.16
1997	1134	0.84	1997	3928	0.24
1998	6412	1.87	1998	8378	1.43
1999	8867	0.36	1999	10977	0.29
2000	7044	0.23	2000	8493	0.19
2001	4969	0.54	2001	9373	0.29
2002	2350	1.25	2002	3222	0.91
2003	2088	1.38	2003	2624	1.10
2004	1323	0.28	2004	1820	0.20
2005	647	0.21	2005	1075	0.13
2006	856	0.71	2006	1411	0.43
2007	239	0.60	2007	918	0.16
2008	1029	0.64	2008	1481	0.44
2009	1079	0.30	2009	1514	0.22
2010	4017	0.33	2010	4593	0.29
2011	1612	0.15	2011	2276	0.10
2012	1040	0.36	2012	1711	0.22
2013	444	0.22	2013	1525	0.06
2014	1144	0.19	2014	4279	0.05
2015	895	0.18	2015	3026	0.05
2016	1636	0.17	2016	2818	0.10

Table 3. Butterfish total catch mean weight at age (kg), 1989–2016. Italicized values were originally missing; thus they were interpolated as the age 3 value plus the average difference between age 3 and age 4 for the entire time series.

Year	Age 0	Age 1	Age 2	Age 3	Age 4+
1989	0.02	0.04	0.06	0.09	0.21
1990	0.04	0.06	0.09	0.10	0.12
1991	0.03	0.04	0.09	0.10	0.17
1992	0.03	0.05	0.08	0.12	0.16
1993	0.04	0.06	0.09	0.12	<i>0.16</i>
1994	0.04	0.04	0.08	0.10	0.18
1995	0.02	0.04	0.07	0.11	<i>0.15</i>
1996	0.04	0.06	0.08	0.09	0.10
1997	0.03	0.07	0.09	0.11	<i>0.16</i>
1998	0.04	0.05	0.07	0.12	<i>0.17</i>
1999	0.03	0.04	0.08	0.09	<i>0.14</i>
2000	0.02	0.05	0.08	0.10	0.17
2001	0.03	0.04	0.08	0.13	<i>0.17</i>
2002	0.02	0.05	0.07	0.10	<i>0.14</i>
2003	0.04	0.05	0.08	0.10	0.13
2004	0.04	0.05	0.08	0.11	0.17
2005	0.05	0.04	0.06	0.10	0.12
2006	0.04	0.05	0.08	0.10	0.16
2007	0.05	0.06	0.08	0.12	0.19
2008	0.03	0.05	0.07	0.12	<i>0.16</i>
2009	0.04	0.04	0.07	0.09	0.17
2010	0.03	0.05	0.07	0.09	0.10
2011	0.03	0.05	0.07	0.09	0.11
2012	0.04	0.05	0.08	0.10	0.12
2013	0.04	0.05	0.07	0.07	0.11
2014	0.04	0.06	0.09	0.11	0.12
2015	0.04	0.06	0.08	0.11	0.15
2016	0.04	0.05	0.08	0.09	0.13

Table 4. Butterfish total catch proportion weight at age, 1989–2016.

Year	Age 0	Age 1	Age 2	Age 3	Age 4+
1989	0.14	0.38	0.34	0.14	0.01
1990	0.08	0.43	0.37	0.11	0.01
1991	0.23	0.44	0.22	0.10	0.01
1992	0.13	0.37	0.43	0.07	0
1993	0.12	0.37	0.31	0.20	0
1994	0.14	0.36	0.31	0.13	0.05
1995	0.21	0.36	0.36	0.08	0
1996	0.07	0.18	0.48	0.24	0.03
1997	0.08	0.56	0.28	0.07	0.01
1998	0.10	0.44	0.42	0.05	0
1999	0.15	0.45	0.25	0.06	0.09
2000	0.22	0.37	0.24	0.07	0.10
2001	0.16	0.18	0.55	0.08	0.03
2002	0.14	0.39	0.29	0.11	0.07
2003	0.23	0.24	0.20	0.25	0.08
2004	0.13	0.42	0.26	0.12	0.07
2005	0.10	0.24	0.32	0.23	0.12
2006	0.24	0.40	0.20	0.10	0.07
2007	0.05	0.35	0.40	0.17	0.04
2008	0.22	0.32	0.32	0.11	0.02
2009	0.19	0.39	0.26	0.10	0.06
2010	0.16	0.42	0.28	0.13	0.01
2011	0.19	0.34	0.27	0.11	0.09
2012	0.09	0.49	0.25	0.13	0.05
2013	0.23	0.44	0.24	0.08	0.02
2014	0.12	0.37	0.29	0.18	0.03
2015	0.10	0.31	0.44	0.12	0.02
2016	0.11	0.49	0.29	0.11	0.01

Table 5. Butterfish stratified mean number per tow from Northeast Fisheries Science Center fall surveys, and corresponding coefficients of variation (CV), for data collected in offshore strata 1989–2016 and inshore strata 1989–2008.

Offshore			Inshore		
Year	Number	CV	Year	Number	CV
1989	377.34	0.38	1989	594.95	0.52
1990	379.94	0.23	1990	63.71	0.32
1991	187.87	0.43	1991	172.60	0.24
1992	246.05	0.27	1992	107.53	0.12
1993	248.98	0.25	1993	292.31	0.25
1994	510.35	0.47	1994	303.32	0.12
1995	116.57	0.26	1995	39.52	0.35
1996	78.85	0.22	1996	157.52	0.32
1997	220.26	0.13	1997	632.94	0.10
1998	214.49	0.33	1998	112.32	0.37
1999	247.81	0.38	1999	185.17	0.30
2000	202.92	0.28	2000	312.86	0.27
2001	63.62	0.31	2001	368.50	0.24
2002	92.61	0.21	2002	225.53	0.34
2003	187.75	0.15	2003	267.15	0.19
2004	75.50	0.29	2004	317.13	0.29
2005	39.19	0.30	2005	228.52	0.07
2006	179.31	0.24	2006	202.04	0.23
2007	41.21	0.23	2007	220.95	0.14
2008	131.93	0.23	2008	131.67	0.14
2009	182.45	0.25			
2010	128.16	0.24			
2011	250.38	0.28			
2012	66.59	0.31			
2013	63.92	0.22			
2014	96.78	0.20			
2015	290.70	0.33			
2016	114.34	0.37			

Table 6. Butterfish stratified mean number per tow at age from Northeast Fisheries Science Center fall surveys for data collected 1989–2016 in offshore strata.

Year	Age 0	Age 1	Age 2	Age 3	Age 4+
1989	325.84	39.43	11.45	0.62	0
1990	343.42	32.55	3.15	0.82	0
1991	167.26	18.37	2.21	0.02	0
1992	232.64	9.93	3.43	0.05	0
1993	195.92	46.58	6.07	0.42	0
1994	475.76	23.85	9.38	1.33	0.03
1995	41.44	48.16	26.91	0.07	0
1996	59.40	15.01	4.21	0.24	0
1997	204.14	13.81	2.14	0.19	0
1998	164.99	41.97	6.84	0.69	0
1999	241.17	4.92	1.72	0	0
2000	151.05	45.85	5.73	0.29	0
2001	38.53	15.20	9.66	0.22	0
2002	80.45	9.27	2.84	0.05	0
2003	175.45	10.38	1.69	0.11	0.12
2004	57.31	12.75	4.81	0.22	0.41
2005	33.92	3.17	1.52	0.58	0
2006	155.83	17.51	5.17	0.74	0.06
2007	26.03	13.65	1.51	0.02	0
2008	124.81	6.17	0.94	0.02	0
2009	158.32	20.06	3.88	0.17	0.01
2010	84.10	35.90	6.90	1.25	0
2011	218.27	26.86	4.76	0.42	0.06
2012	27.15	28.83	9.91	0.62	0.07
2013	57.07	5.28	1.39	0.17	0.01
2014	75.71	17.54	2.95	0.59	0
2015	246.89	35.59	7.88	0.31	0.02
2016	76.18	28.54	7.87	1.60	0.15

Table 7. Butterfish arithmetic mean number per tow from Northeast Area Monitoring and Assessment Program fall surveys, and corresponding coefficients of variation (CV), for data collected 2007–2016.

Year	Number	CV
2007	1052.53	0.36
2008	1028.89	0.17
2009	3597.7	0.14
2010	1071.53	0.12
2011	1647.62	0.16
2012	625.29	0.21
2013	3547.04	0.43
2014	3762.92	0.27
2015	1110.78	0.22
2016	417.85	0.19

Table 8. Butterfish stratified mean number per tow at age from Northeast Area Monitoring and Assessment Program fall surveys for data collected 2007–2016.

Year	Age 0	Age 1	Age 2	Age 3	Age 4+
2007	960.60	69.75	18.98	2.89	0.31
2008	976.77	46.73	4.45	0.86	0.09
2009	3547.90	43.95	5.12	0.68	0.06
2010	844.99	171.41	46.07	8.21	0.85
2011	1466.73	143.57	32.29	4.50	0.53
2012	500.43	86.28	31.51	6.36	0.71
2013	3308.74	188.07	43.97	5.67	0.57
2014	3484.71	243.64	27.60	6.31	0.65
2015	906.52	156.43	38.88	8.11	0.84
2016	258.51	104.37	45.88	8.33	0.76

Table 9. Model estimates of spawning stock biomass (mt), recruitment (millions), fully selected fishing mortality F (age 2+), and respective coefficients of variation (CV).

Year	Spawning Biomass	CV	Recruitment	CV	F	CV
1989	69,402	0.31	9,293	0.27	0.12	0.56
1990	96,272	0.27	10,088	0.23	0.03	0.28
1991	81,532	0.23	8,377	0.23	0.10	0.71
1992	80,812	0.21	7,868	0.21	0.10	0.40
1993	81,560	0.19	11,491	0.21	0.14	0.28
1994	72,284	0.19	12,685	0.20	0.14	0.32
1995	81,524	0.18	5,486	0.24	0.11	0.40
1996	77,515	0.19	10,326	0.21	0.06	0.25
1997	97,372	0.18	16,289	0.17	0.04	0.31
1998	107,060	0.16	9,797	0.23	0.07	0.99
1999	92,925	0.17	15,052	0.22	0.11	0.35
2000	110,550	0.18	11,678	0.22	0.08	0.27
2001	103,890	0.19	8,727	0.22	0.09	0.34
2002	87,550	0.19	8,838	0.21	0.04	0.78
2003	82,649	0.18	9,981	0.19	0.03	0.88
2004	87,397	0.17	5,561	0.22	0.02	0.27
2005	56,859	0.17	8,151	0.18	0.02	0.22
2006	68,156	0.16	7,796	0.20	0.02	0.45
2007	79,453	0.16	5,783	0.19	0.01	0.23
2008	60,973	0.17	7,452	0.19	0.02	0.46
2009	53,786	0.17	10,803	0.21	0.03	0.28
2010	71,873	0.18	5,912	0.22	0.07	0.35
2011	63,005	0.20	8,360	0.22	0.04	0.23
2012	67,370	0.21	4,300	0.24	0.03	0.31
2013	49,576	0.22	7,717	0.24	0.03	0.24
2014	65,215	0.23	7,131	0.24	0.07	0.25
2015	67,786	0.24	6,717	0.26	0.05	0.25
2016	59,041	0.25	1,992	0.32	0.05	0.28

FIGURES

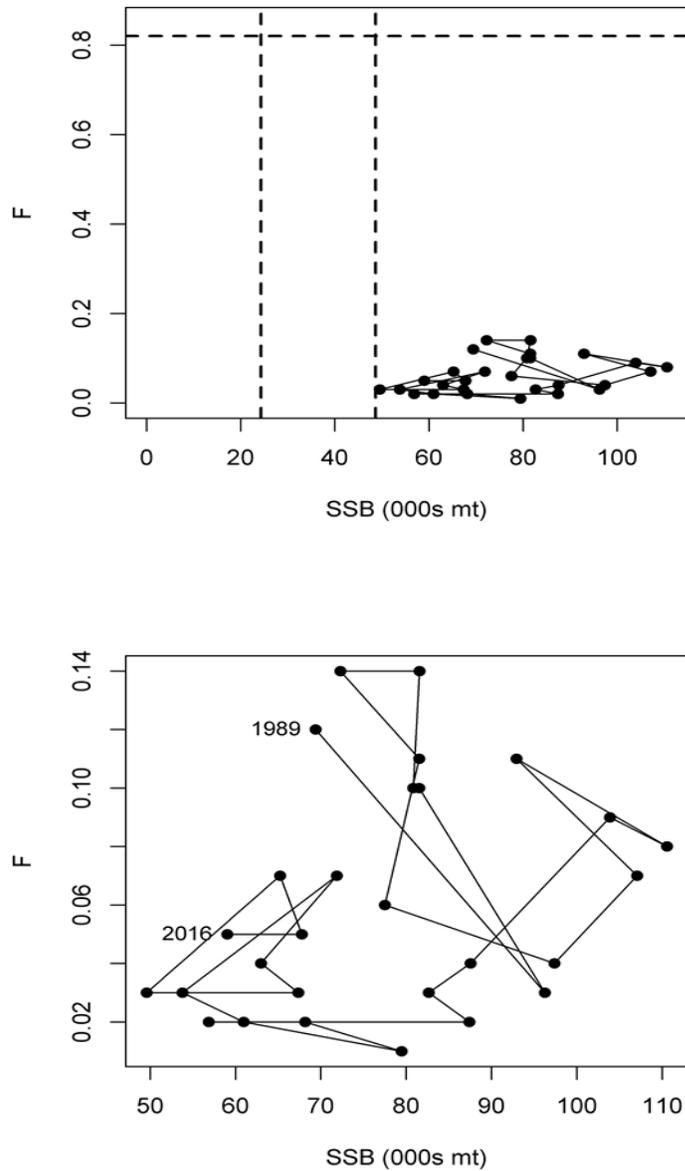


Figure 1. Butterfish stock status, 1989–2016, relative to the revised biological reference points $SSB_{\text{threshold}} = 24,341$ mt, $SSB_{\text{MSY proxy}} = 48,681$ mt, and $F_{\text{MSY proxy}} = 0.82$. The tight grouping of points is expanded in the lower panel for clarity.

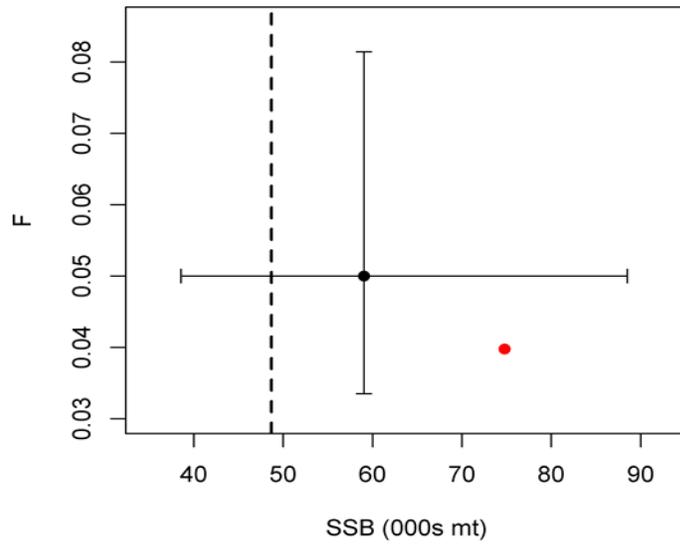
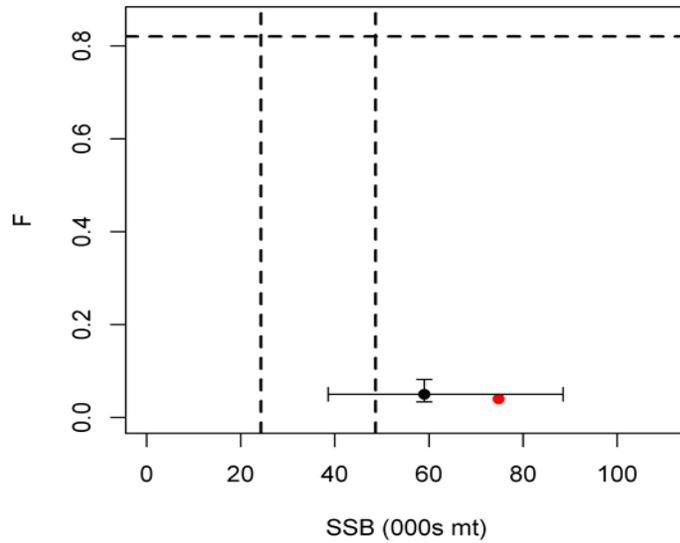


Figure 2. Butterfish stock status in 2016 relative to the revised biological reference points $SSB_{\text{threshold}} = 24,341$ mt, $SSB_{\text{MSY proxy}} = 48,681$ mt, and $F_{\text{MSY proxy}} = 0.82$. The black circle is the model estimate and the error bars are 90% confidence intervals; the red circle is the model estimate adjusted for internal model retrospective error. The plot is expanded in the lower panel to clarify that the retrospective adjustment is within the 90% confidence bounds.

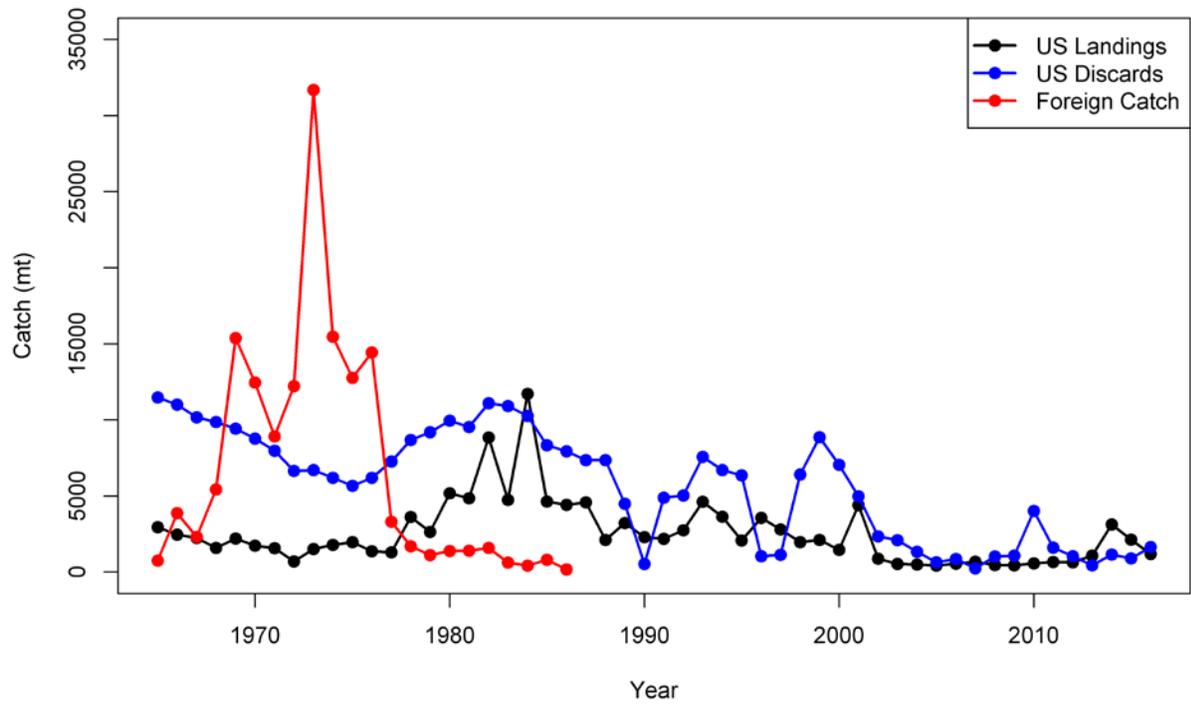


Figure 3. US landings, US discards, and foreign catch of butterfish, 1965–2016.

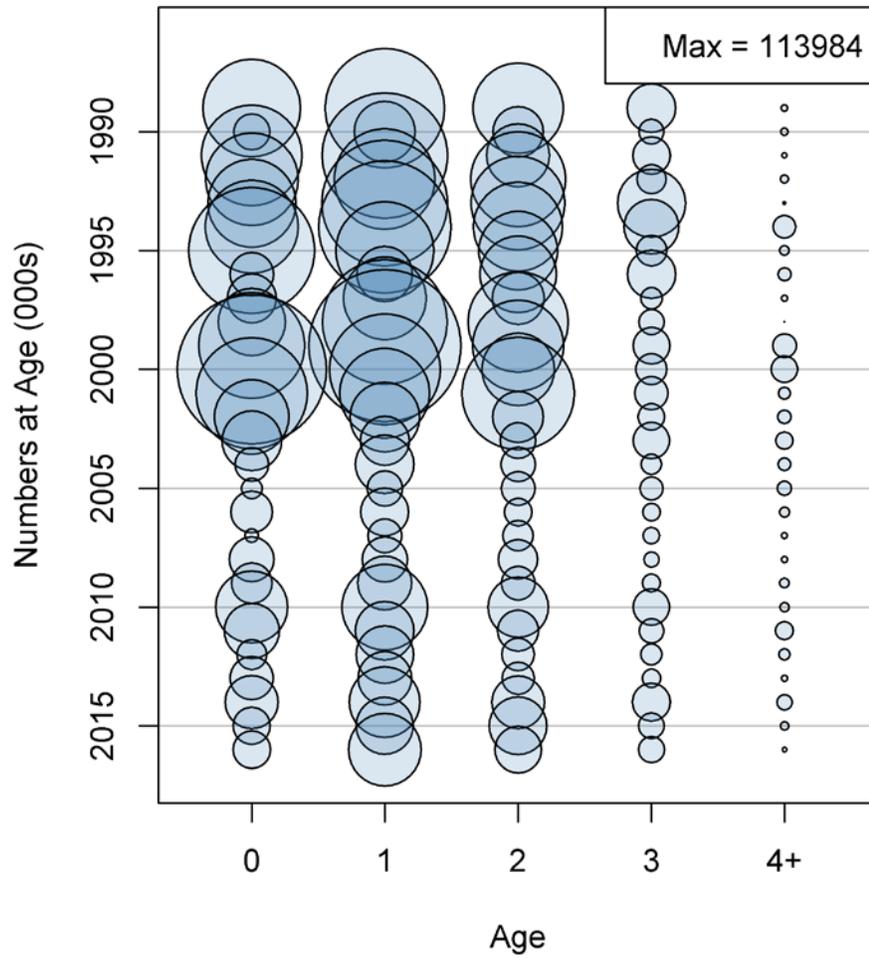


Figure 4. Butterfish commercial catch numbers (000s) at age, 1989–2016.

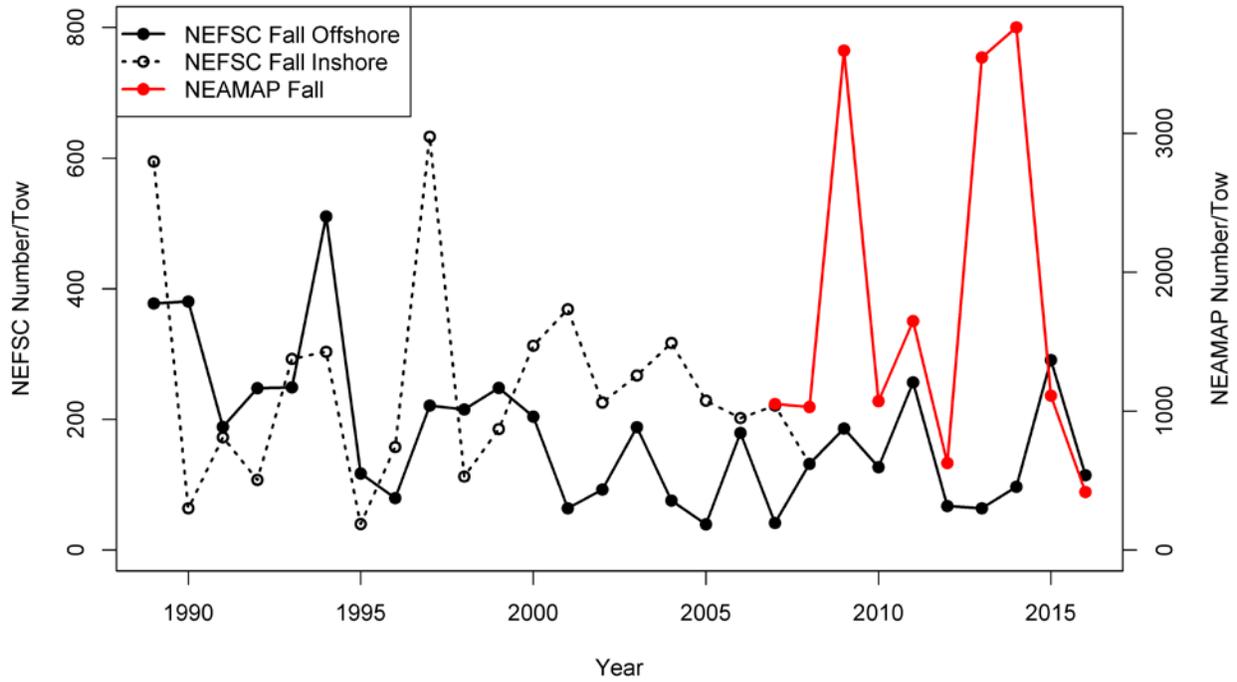


Figure 5. Northeast Fisheries Science Center (NEFSC) fall offshore and inshore survey stratified mean number per tow for butterfish; and Northeast Area Monitoring and Assessment Program (NEAMAP) fall survey arithmetic mean number per tow for butterfish.

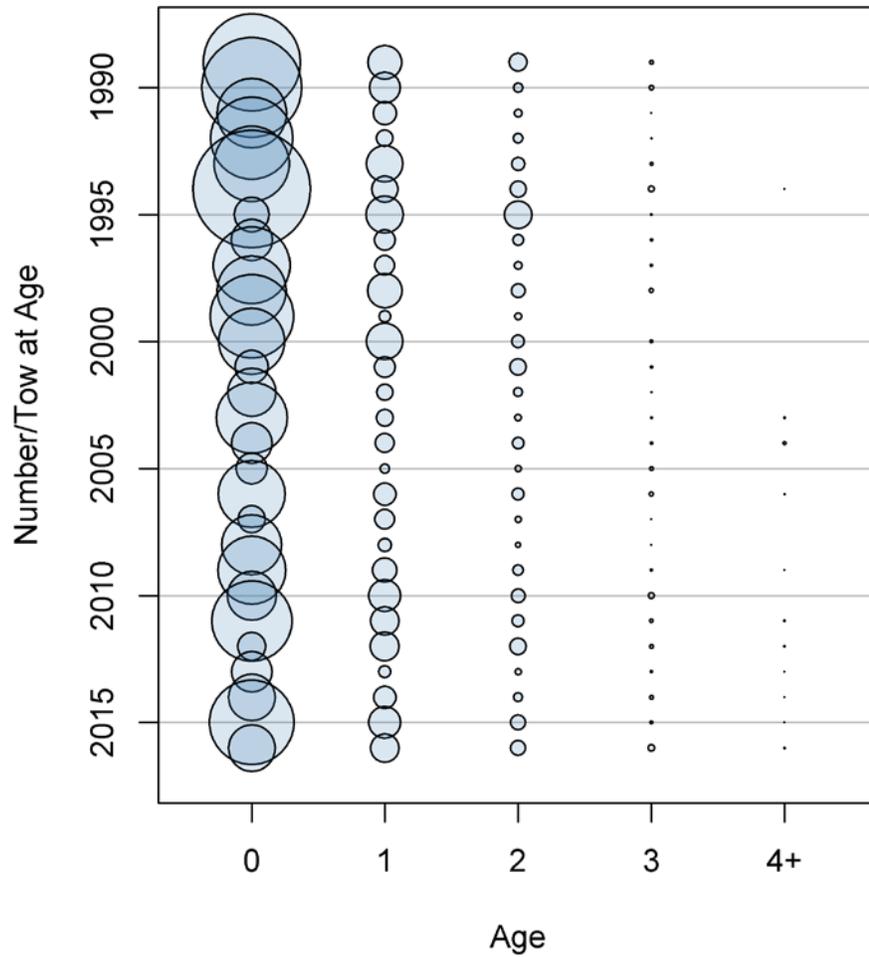


Figure 6. Butterfish stratified mean number per tow at age from Northeast Fisheries Science Center fall surveys for data collected 1989–2016 in offshore strata.

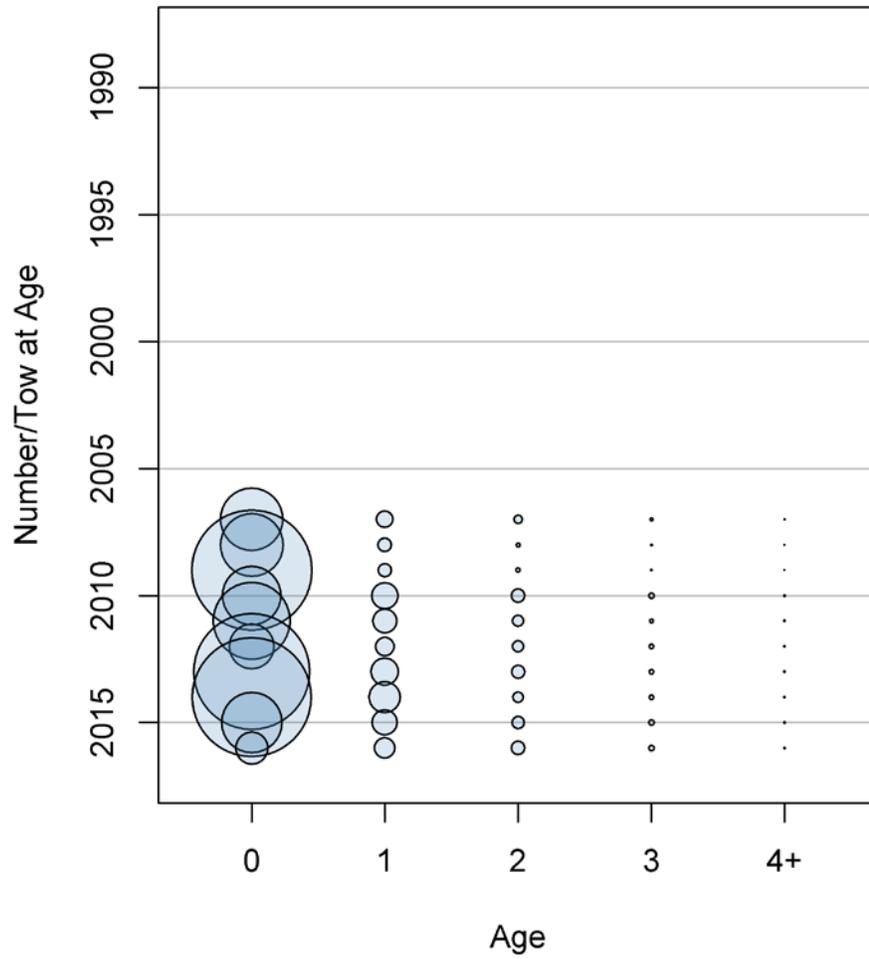


Figure 7. Butterfish stratified mean number per tow at age from Northeast Area Monitoring and Assessment Program fall surveys for data collected 2007–2016.

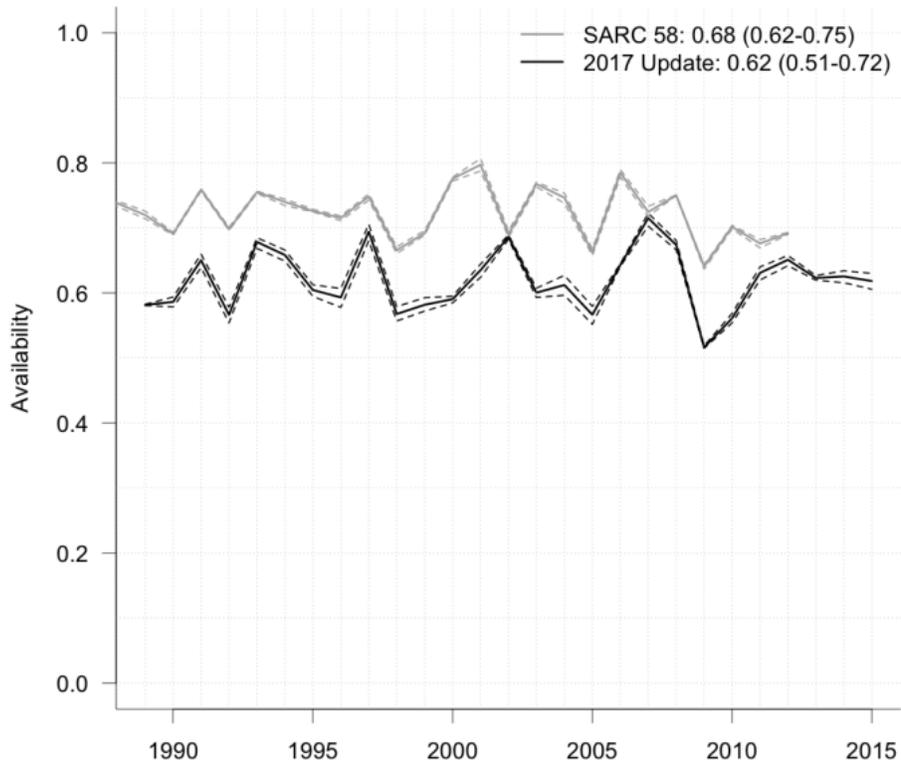


Figure 8. Availability of butterflyfish to the Northeast Fisheries Science Center offshore survey, 1989–2015. Solid lines indicates availability A , while dashed lines show the respective 95% confidence intervals.

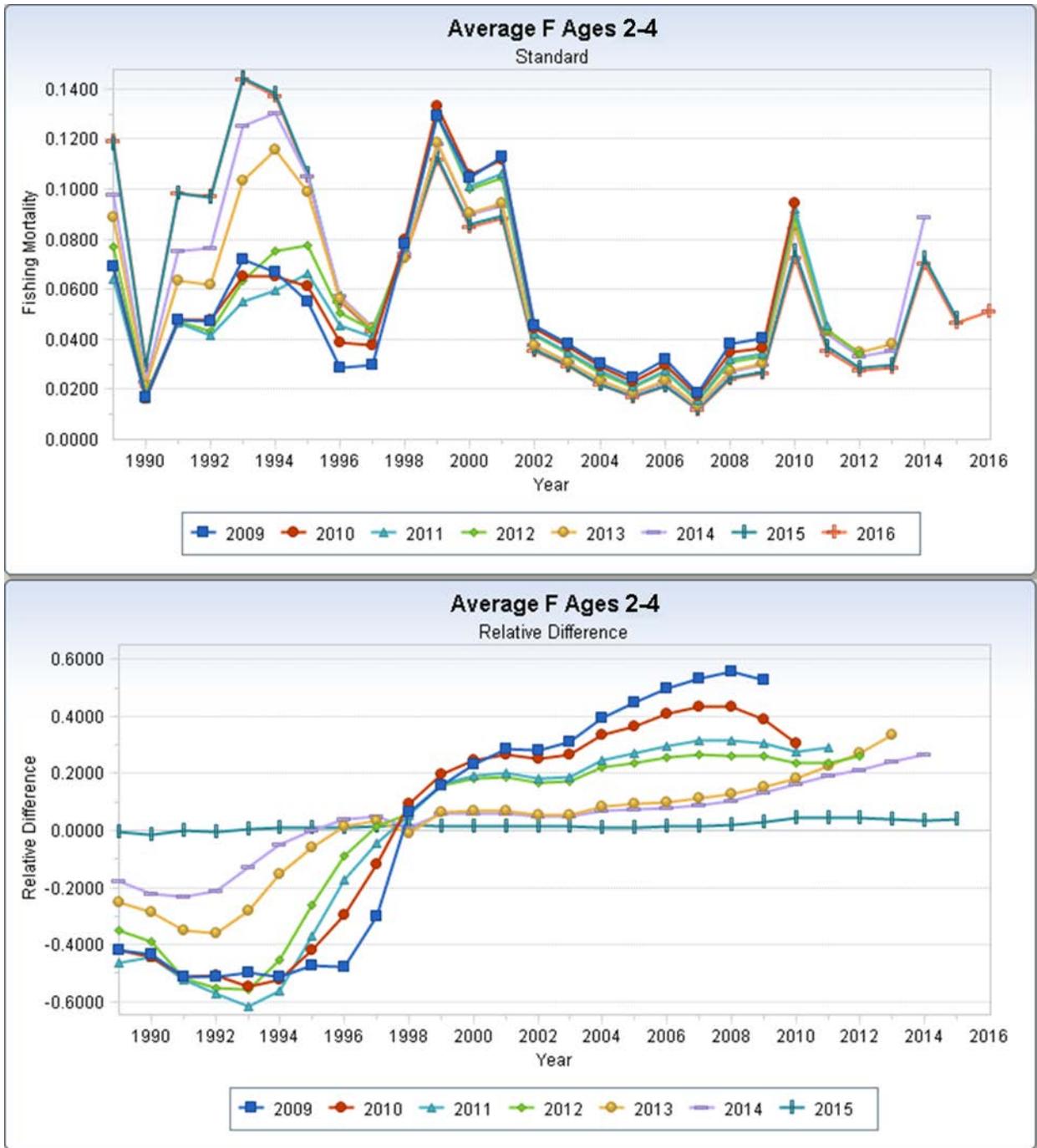


Figure 9. Results of internal model retrospective analysis for fully recruited F. Mohn's rho = 0.29

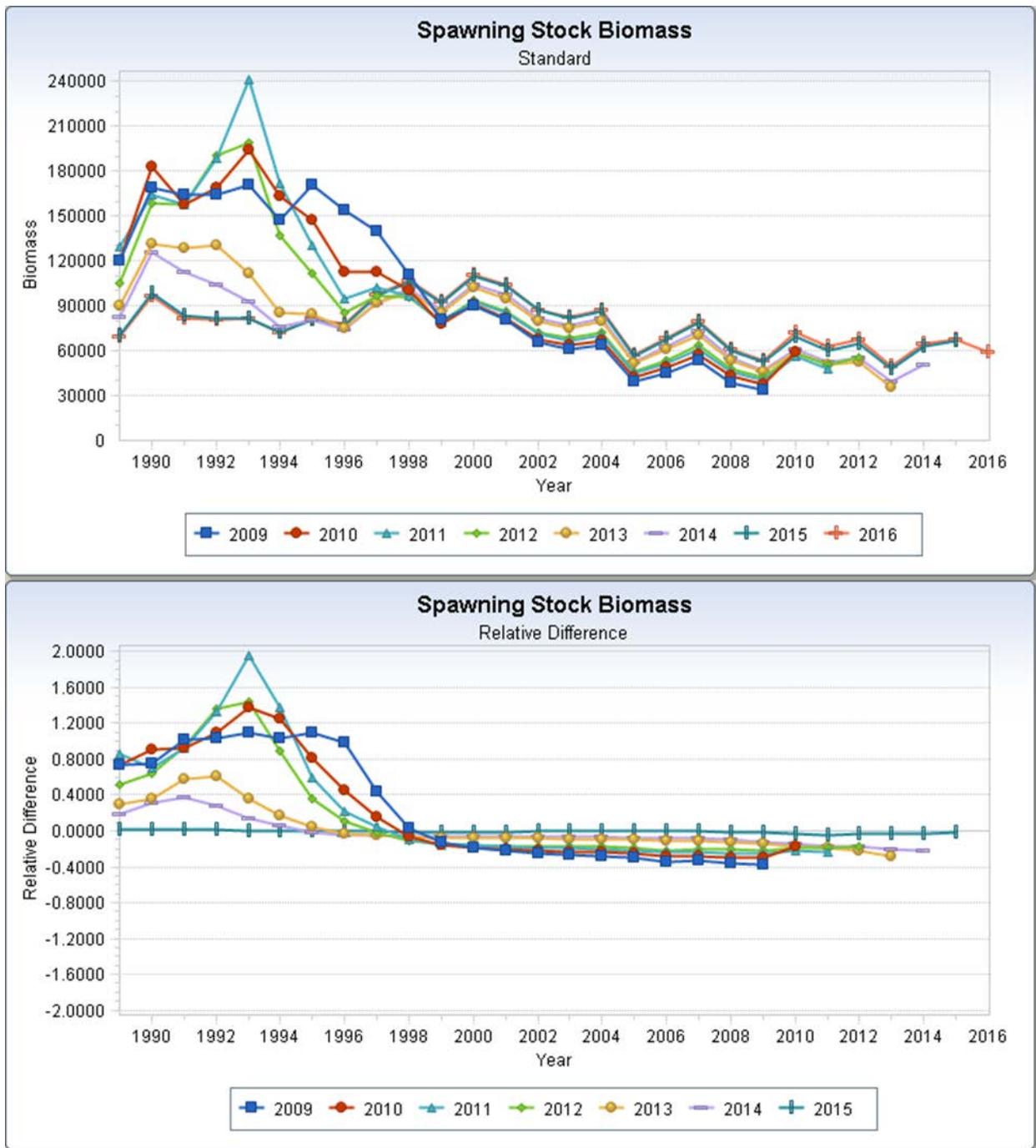


Figure 10. Results of internal model retrospective analysis for spawning stock biomass. Mohn's rho = -0.21.

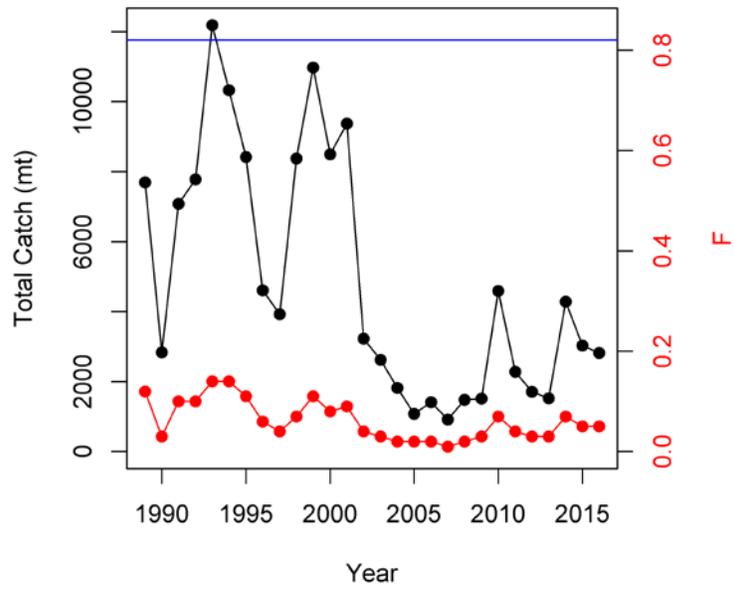


Figure 11. Butterfish total catch (black) and fully recruited fishing mortality (red). The blue line is the revised F_{MSY} proxy.

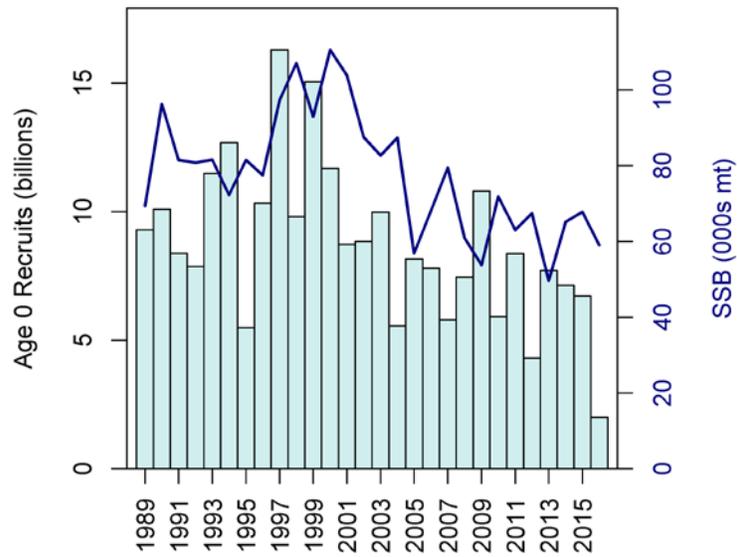


Figure 12. Butterfish recruitment (vertical bars), and the spawning stock biomass (blue line) that produced the corresponding recruitment. Year refers to spawning year.

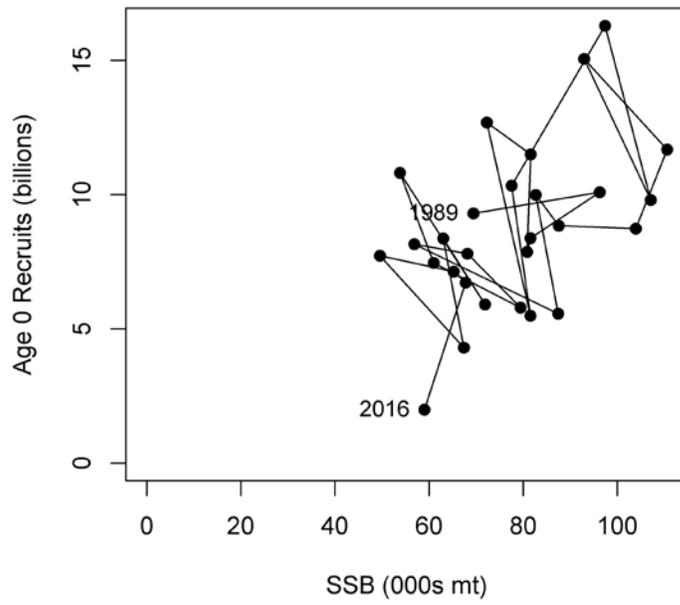


Figure 13. Butterfish stock-recruitment scatter plot.

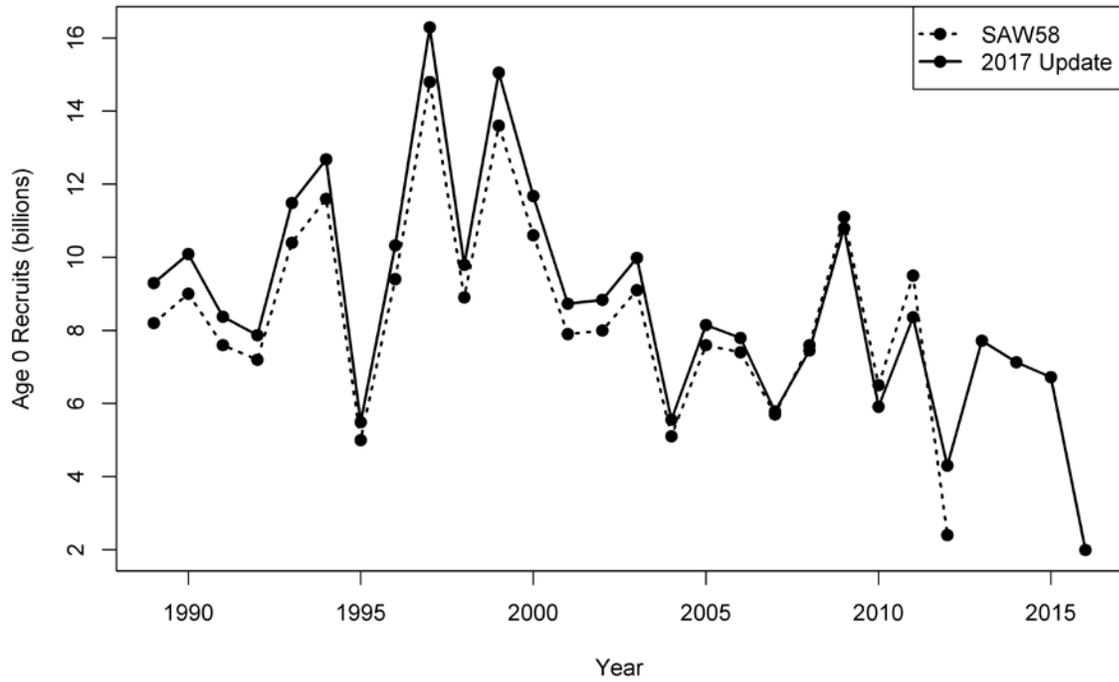


Figure 14. Comparison of the recruitment index from SAW 58 (NEFSC 2014) and this stock assessment update.

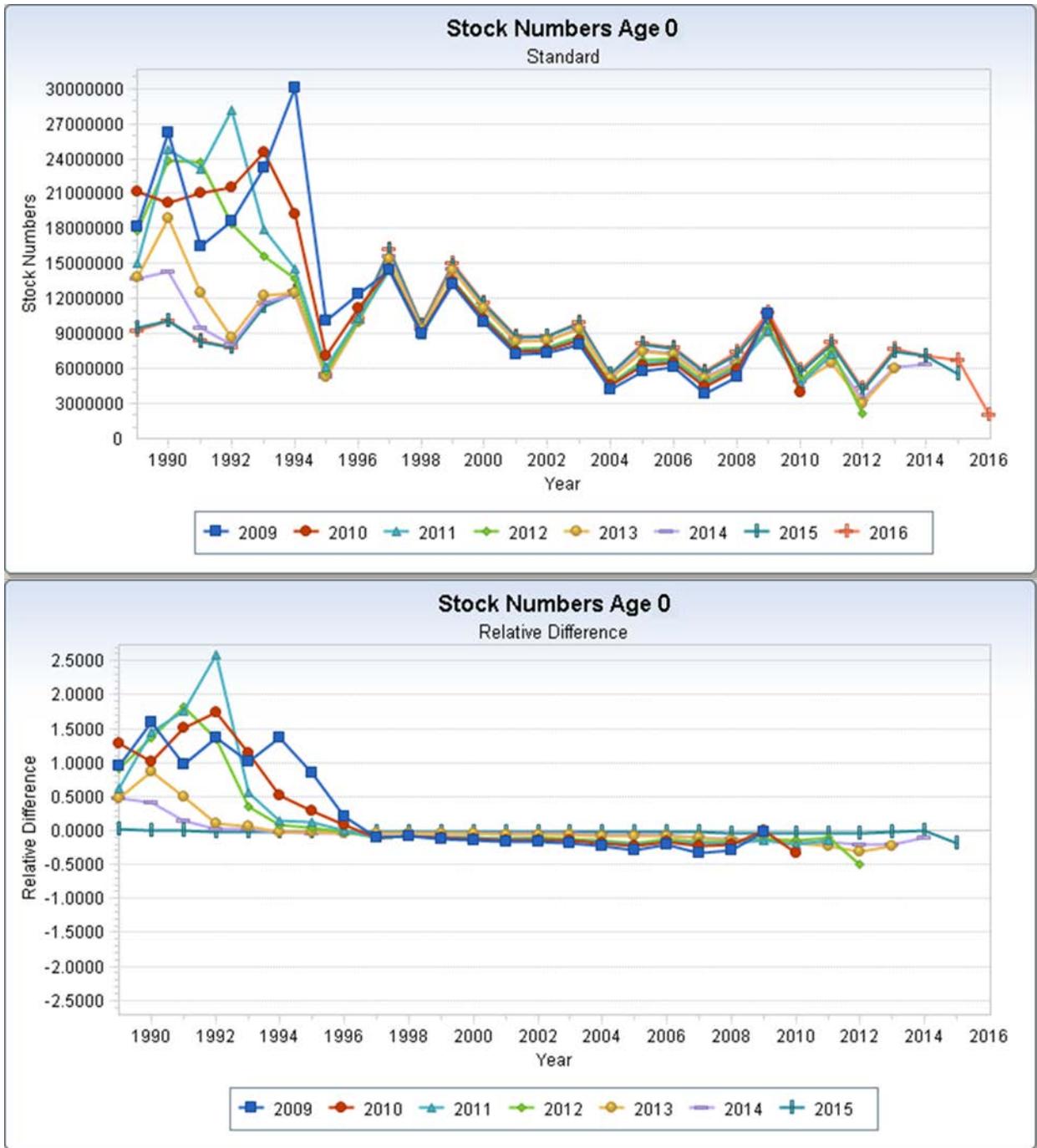


Figure 15. Results of internal model retrospective analysis for recruitment. Mohn's rho = -0.21

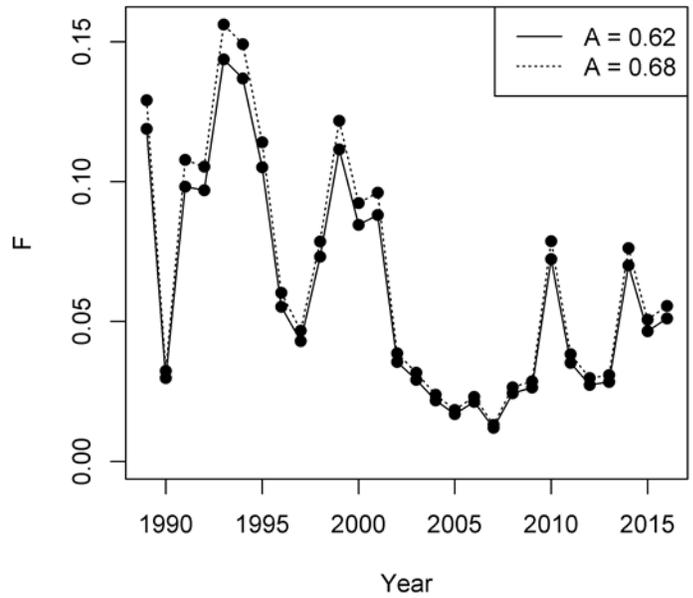
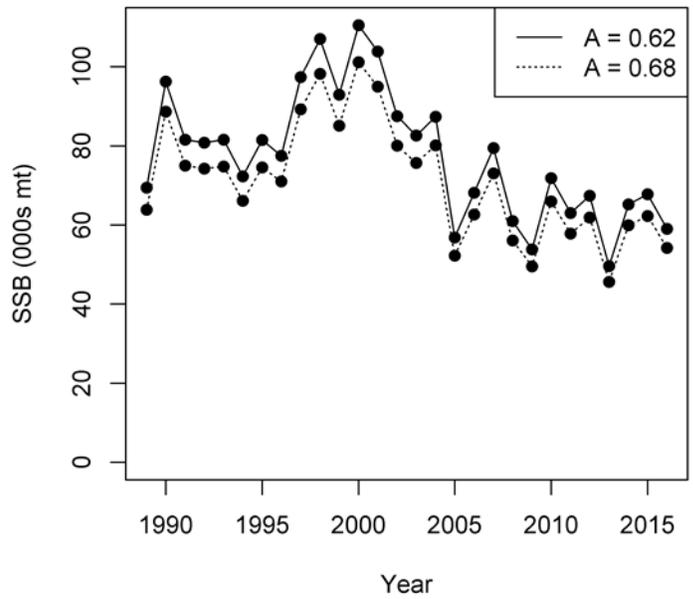


Figure 16. Effect of revised thermal habitat availability index ($A = 0.62$) on model estimates of spawning stock biomass (upper) and fishing mortality (lower). $A = 0.68$ was used in SAW 58 (NEFSC 2014).

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