SEDAR

Southeast Data, Assessment, and Review

SEDAR 38 Update

Gulf of Mexico King Mackerel

Assessment Update Report

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1. Executive Summary

- The Stock Synthesis model for Gulf of Mexico King Mackerel (SEDAR 38) was updated to fishing year 2017 incorporating five years of additional data. Three data sources were revised since SEDAR 38: charter and private landings/discards, Headboat landings/discards and shrimp fishery bycatch. All life history assumptions, including stock structure and mixing, and model configuration remained unchanged from the final decisions of SEDAR 38. The principle findings included:

- The Gulf of Mexico stock of King Mackerel was determined to be NOT OVERFISHED (SSB_{2017}/ MSST = 1.12) and the fisheries are NOT OVERFISHING (F_{2017}/ MFFT = 0.83)

- The estimate of stock status was influenced by both the updated value of the recreational catch from the Fisheries Effort Survey (FES) as well as the updated median shrimp fishery bycatch (number of fish) 1975-2017. While trends in spawning biomass were similar to those reported in SEDAR 38, estimates of virgin and current spawning stock biomass were higher and lower, respectively. Further examination revealed that the updated shrimp bycatch median was mostly responsible for the increased estimate of virgin biomass and that the Headboat CPUE was mostly responsible for the decreased estimate of current biomass

- Total spawning stock biomass estimates show a declining trend since 1990, there after it began a fluctuating, but overall increasing trend. Stock size indicators (fleet CPUEs and scientific surveys) showed varying degrees of agreement/conflicting trends with regard to the estimation of the most recent trend. Not all sources of observational were in agreement with each other.

- If exploitation rates were to immediately increase to the F_{MFMT} value the resulting retained catches (OFL) for 2021, 2022 and 2023 were projected to be 10.89, 11.05 and 11.18 million pounds, respectively. Maintaining the P* value used in SEDAR 38 (P* = 0.43), the acceptable biological catches (ABC) in 2021, 2022 and 2023 were projected to be 10.47, 10.60 and 10.71 million pounds, respectively. The landings for 2017 were 8.18 million pounds.

2. Terms of Reference

1. Update the approved SEDAR 38 Gulf of Mexico king mackerel base model with data through 2017-2018 fishing year.
2. Document any changes or corrections made to model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers, when possible.
3. Update model parameter estimates and their variances, model uncertainties, estimates of stock status and management benchmarks, and provide the probability of overfishing occurring at specified future harvest and exploitation levels.
4. To the extent practical, provide recommendations of future research to be conducted on Gulf of Mexico migratory group king mackerel, and any additional analyses which should be considered during the subsequent stock assessment.
5. Develop a stock assessment update report to address these TORS and fully document the input data and results of the stock assessment update.

3. Data Updates

The SEDAR 38U assessment is an update of the previous assessment (SEDAR 2014) base model, all data inputs and model parameters were retained unchanged unless noted. All data were summarized by fishing year (FY), defined as July 1-June 30. The following list summarizes the main data inputs and data assumptions for the assessment:

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

3.2. Removals
- Commercial Handline: 1929 to 2017 FY, measured in metric tons
- Commercial Gillnet: 1950 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

3.3. Discards
- Recreational Headboat: 1987 to 2017 FY, measured in number of fish
- Recreational Charter/ Private 1981 to 2017 FY, measured in number of fish
- Commercial and Recreational combined
- Shrimp Bycatch: 1972 to 2017 FY, measured in number of fish

3.4. Length composition of landings
- Commercial Handline: 1983 to 2017 FY
- Recreational Headboat: 1985 to 2017 FY
- Recreational Charter/ Private: 1980 to 2017 FY

3.5. Length composition of discards

- No length composition of discards were available

3.6. Age composition
- Commercial handline: 1991 to 2017 FY
- Recreational Charter/ Private: 1986 to 2017 FY
- All shrimp fishery bycatch was assumed to be age_0, based on length composition information

3.7. Abundance indices
- Fishery-dependent
  - Commercial hook and line trolling: 1998 to 2017 FY
  - Recreational Headboat: 1981 to 2017 FY
  - Recreational charter/private, 198x to 2017 FY (evaluated but not used in SS3)
- Fishery-independent
  - SEAMAP Age-0 Trawl: 1972 to 1982, 1984 to 2017 FY

3.8 Effort Series:
- Shrimp Fishery Effort 1950-2017

3.1 Life history

Stock structure and mixing assumptions from SEDAR 38 remained unchanged (**Figure 3.1**). The stock delineations and mixing zone boundary 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 3.1)**. Life history parameters with fixed input values (i.e. not estimated in SS3) included natural mortality, fecundity (in millions of hydrated eggs), and maturity-at-age. Growth was estimated as gender-specific von Bertalanffy models fitted to empirical observations of annual length-at-age within SS3. Parameter estimates from SEDAR 38 were used as starting values (**Table 3.2**).

3.2 Removals

The SS modeling platform partitions catch into two categories: (1) landings plus dead discards (i.e. removals), and (2) live discards, which are subject to a user defined release mortality. Gear specific removals and landings biomass (1000s lbs and mt) and numbers (1000s fish) are given in **Tables 3.3 – 3.6.** Directed fisheries, gear specific removals, all in biomass (mt) are shown in **Figure 3.2** Directed commercial removals in the Gulf of Mexico were predominantly from trolling and other hook and line gears (handlines), (**Table 3.3, Figure 3.3**) followed by gillnets (**Table 3.4, Figure 3.3**). Commercial removals used for SEDAR 38 and this update were nearly identical (**Figure 3.4** top panels).

Recreational removals 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 (NOAA 2019). The differences between estimated recreational removals from SEDAR 38 to the current assessment are shown in **Figure 3.4 (bottom panels)**. There was a clear increase in removals of the recreational CP/PR fleet. An observed decrease in Headboat (HB) total removals (**Figure 3.4**) 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). The change from the CHTS to the FES resulted in increased removals estimates for the charter/private (CHP) by approximately 102% per year, and decreased estimates of removals for Headboat by 30%. The effect of these changes in recreational removals were evaluated as sensitivity runs of SEDAR 38 with the recreational MRIP-CHTS series in SEDAR 38 base model replaced with the revised MRIP-FES estimates. The effect of decreased HB removals was also evaluated as a sensitivity run of SEDAR 38.

Recreational removals were measured in numbers of fish and were estimated for the period 1946 to 2017 for charter, private fisheries; and for the period 1936 to 2017 for the Headboat fishery. Recreational removals were minimal for Headboats (**Table 3.5**) and predominantly from private and charter boats (**Table 3.6**) (**Figure 3.5**).

3.2 Discards

Live discard estimation methods for directed commercial gears remain unchanged from SEDAR 38. Commercial live discards from the handline and other fisheries that target king mackerel were minimal (less than 5%) relative to landings (**Table 3.7** and **Figure 3.6)**.

Recreational (Headboat and Charter/Private) live discards were revised based on FES effort statistics (NOAA Fisheries 2019). The differences between estimated recreational live discards used in SEDAR 38 to the revised estimates are shown in **Figure 3.7,** with the revised estimates given in **Table 3.7**. The change from the CHTS to the FES resulted in decreased live discards for Headboats by 49% (median of annual differences), and an increase in CP/PR live discards by 147% (median of annual differences). The effect of these changes were evaluated by creating sensitivity runs using the SEDAR 38 model to fit (2920-2012) the original as well as the updates estimates of live discards.

Revised estimates of king mackerel recreational live discards were provided for the periods 1987 to 2017 for recreational Headboat. Headboat live discards were minimal in comparison to all other fleets. Live 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. Discard mortality assumptions remained unchanged from SEDAR 38, and were as follows: 25% discard mortality from commercial handline fisheries, 22% discard mortality for the recreational Headboat fishery, and 20% discard mortality for recreational private and charter.

For this update, estimates of shrimp bycatch were taken directly from those reported in “Shrimp Fishery Bycatch Estimates for Gulf of Mexico King Mackerel, 1972-2017”, Zhang, X. and J.

Isely. This work maintained the use of the Bayesian approach developed by Nichols for SEDAR 7 and typically used for subsequent SEDARs including the most recent assessments of red snapper (SEDAR 52) vermilion snapper (SEDAR 67) and cobia (SEDAR 28U). Discards from the shrimp fishery in the Gulf of Mexico were modeled by fitting to a median shrimp bycatch level (**Figure 3.8; Table 3.8**) and an index of shrimp fishing effort (**see Section 3.8**). Shrimp bycatch was assumed to be 100% dead discards with no landings. For shrimp discards the 'super-year' approach was utilized to avoid fitting to the noisy and uncertain yearly estimates of shrimp bycatch. The premise of a super-year is that, instead of fitting each observation directly, a measure of central tendency for the entire time series is fit. In the case of shrimp bycatch, the median has typically been utilized (i.e., the observed median is fit to the predicted median). The model predicts annual bycatch values, but does not attempt to fit the annual observations owing to the high uncertainty associated with them. The super-year covers years 1975-2017 (i.e., the median values correspond to observed and predicted bycatch values for these years), which are the years that estimates of shrimp bycatch were available.

The median value of shrimp fishery bycatch of king mackerel was revised from 708 thousand fish used in SEDAR 38 to 1.998 million fish for this update. Changes in this median value were influential on the results of this stock assessment. The increase bycatch was directly proportional to the estimate of virgin recruitment (i.e. virgin spawning stock biomass).

3.4 Length composition of landings

The annual length compositions of landed King Mackerel are shown by fishery in **Figure 3.9**. 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. As these fish are assumed to have a miniscule selectivity due to the inclusion of a retention curve, even a small number of observations below the minimum can cause the model to create extremely large recruitment events to account the extremely probability of observing undersized fish. Therefore, the assumption that all retained fish were above the legal size limit for both commercial and recreational fisheries was maintained from SEDAR 38.

3.5 Length composition of discards

There is a lack of observations of discarded, undersized fish. The lack of these observations lead to large CVs in the ascending limb of some selectivities (**Appendix 1**), which likely contributed significantly to the high convergence levels. Uninformative priors (priors with very high standard deviations) were used on a small number of parameters when the maximum likelihood estimates showed no curvature whatsoever.

3.6 Aging data

Age data were collected primarily from the commercial handline fishery, and to a lesser extent, the charter, private and Headboat. No recent age data were available for the gillnet. Age observations were summarized by year and fleet for the period FY 2013-17 (**Figure 3.10)**.

These ages were used as “conditional age at size”, which informs the model of the distribution of ages across the size bins. This data is most useful for the estimation of growth parameters.

3.7 Indices

Data standardization methods for the indices of relative abundance remained unchanged from SEDAR 38. Four of the five available CPUE indices were included in the assessment which included the commercial handline logbook index, the recreational Headboat index, SEAMAP trawl and SEAMAP plankton fishery independent survey. Indices were weighted by standardization model estimated coefficients of variation. Consistent with SEDAR 38 the Charter/Private CPUE was excluded. The updated standardized indices are provided in **Table 3.8** and plotted in **Figure 3.11**.

3.8 Effort Series

Annual estimates and associated standard errors of shrimp effort by year/season/area/depth were generated by the NMFS Galveston Lab using their SN-pooled model (Nance 2004) (**Table 3.9**). Region-specific shrimp effort was incorporated into the model as an index of shrimp bycatch fishing mortality. Essentially, a catchability parameter (q) was estimated to scale the effort series into the fishing mortality rates that produce the best agreement between the median of the annual region-specific bycatch values predicted by the assessment model and the median of the observed annual bycatch values. Using the super-year approach while fitting to a timeseries of effort allows the model the flexibility to fit the median without being forced to fit uncertain annual bycatch estimates. Yet, it constrains the model enough to maintain the bycatch estimates within feasible fishing mortality bounds and avoids overly strong year to year deviations.
The SEDAR 38 shrimp effort series and the series used in this update assessment were nearly identical (**Figure 3.12**).

Table 3.1. Life history assumptions of Gulf of Mexico 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 3.2. Estimated growth parameters for King Mackerel from SEDAR 38, used as starting parameter values in SS3.

	Gulf of Mexico	
	Female	Male
L_{inf} (mm FL)	107.21	92.57
k (year^{-1})	0.3845	0.3515
cv1	0.27	0.38
cv2	0.10	0.044

Table 3.3. Gulf of Mexico King Mackerel commercial handline removals (retained catch + dead discards) and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1927	0	0	0	0	0	0
1928	0	0	0	0	0	0
1929	0	0	0	0	0	0
1930	1249	1249	567	567	96	96
1931	666	666	302	302	51	51
1932	529	529	240	240	41	41
1933	22	22	10	10	2	2
1934	610	610	277	277	47	47
1935	22	22	10	10	2	2
1936	893	893	405	405	69	69
1937	1222	1222	554	554	94	94
1938	767	767	348	348	59	59
1939	1395	1395	633	633	107	107
1940	1751	1751	794	794	135	135
1941	22	22	10	10	2	2
1942	22	22	10	10	2	2
1943	22	22	10	10	2	2
1944	22	22	10	10	2	2
1945	1013	1013	460	460	78	78
1946	22	22	10	10	2	2
1947	22	22	10	10	2	2
1948	344	344	156	156	26	26
1949	231	231	105	105	18	18
1950	772	772	350	350	60	60
1951	821	821	373	373	63	63
1952	972	972	441	441	75	75
1953	1008	1008	457	457	77	77
1954	1006	1006	456	456	77	77
1955	1047	1047	475	475	80	80
1956	879	879	399	399	67	67
1957	1067	1067	484	484	81	81
1958	1144	1144	519	519	87	87
1959	1458	1458	661	661	111	111
1960	1490	1490	676	676	113	113
1961	1039	1039	471	471	79	79
1962	663	663	301	301	50	50
1963	365	365	166	166	28	28
1964	284	284	129	129	22	22
1965	303	303	137	137	23	23
1966	617	617	280	280	48	48
1967	685	685	311	311	54	54
1968	638	638	290	290	50	50
1969	562	562	255	255	44	44
1970	420	420	191	191	33	33

Table 3.3. **(cont)** Gulf of Mexico King Mackerel commercial handline removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1971	371	371	168	168	30	30
1972	401	401	182	182	32	32
1973	723	723	328	328	58	58
1974	798	798	362	362	66	66
1975	502	502	228	228	41	41
1976	404	404	184	184	32	32
1977	919	919	417	417	72	72
1978	826	826	375	375	64	64
1979	1695	1695	769	769	134	134
1980	1715	1715	778	778	138	138
1981	903	903	410	410	73	73
1982	1788	1788	811	811	140	140
1983	931	931	422	422	73	73
1984	1398	1398	634	634	116	116
1985	1772	1772	804	804	145	145
1986	897	897	407	407	73	73
1987	570	570	259	259	47	47
1988	1032	1032	468	468	86	86
1989	1163	1163	528	528	97	97
1990	1039	1039	471	471	92	92
1991	1105	1105	501	501	106	106
1992	2021	2021	917	917	203	203
1993	1753	1753	795	795	174	174
1994	1651	1651	749	749	163	163
1995	1383	1383	627	627	139	139
1996	1323	1323	600	600	136	136
1997	1907	1907	865	865	197	197
1998	1678	1627	761	738	168	163
1999	1947	1883	883	854	189	183
2000	1776	1724	806	782	172	167
2001	1866	1818	847	825	181	176
2002	1767	1722	802	781	174	169
2003	1702	1655	772	751	170	165
2004	1637	1594	743	723	162	157
2005	1593	1558	723	707	158	154
2006	1805	1758	819	798	175	170
2007	1785	1738	810	789	166	161
2008	1844	1803	836	818	166	162
2009	2032	1992	922	904	183	179
2010	1781	1751	808	794	154	151
2011	1868	1827	847	829	155	151
2012	2239	2198	1016	997	183	179
2013	1878	1838	852	834	154	151
2014	2359	2322	1070	1054	202	198
2015	2123	2084	963	946	192	189
2016	2353	2318	1068	1052	215	212
2017	2664	2629	1209	1193	255	252

Table 3.4. Gulf of Mexico King Mackerel commercial gillnet removals (retained catch + dead discards) and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1927	0	0	0	0	0	0
1928	0	0	0	0	0	0
1929	0	0	0	0	0	0
1930	0	0	0	0	0	0
1931	0	0	0	0	0	0
1932	0	0	0	0	0	0
1933	0	0	0	0	0	0
1934	0	0	0	0	0	0
1935	0	0	0	0	0	0
1936	0	0	0	0	0	0
1937	0	0	0	0	0	0
1938	0	0	0	0	0	0
1939	0	0	0	0	0	0
1940	0	0	0	0	0	0
1941	0	0	0	0	0	0
1942	0	0	0	0	0	0
1943	0	0	0	0	0	0
1944	0	0	0	0	0	0
1945	0	0	0	0	0	0
1946	0	0	0	0	0	0
1947	0	0	0	0	0	0
1948	0	0	0	0	0	0
1949	0	0	0	0	0	0
1950	0	0	0	0	0	0
1951	0	0	0	0	0	0
1952	0	0	0	0	0	0
1953	15	15	7	7	2	2
1954	0	0	0	0	0	0
1955	11	11	5	5	1	1
1956	5	5	2	2	1	1
1957	0	0	0	0	0	0
1958	0	0	0	0	0	0
1959	12	12	5	5	1	1
1960	56	56	25	25	6	6
1961	1181	1181	536	536	135	135
1962	2137	2137	969	969	244	244
1963	1042	1042	473	473	120	120
1964	1580	1580	717	717	183	183
1965	2260	2260	1025	1025	262	262
1966	2645	2645	1200	1200	309	309
1967	2879	2879	1306	1306	338	338
1968	2353	2353	1068	1068	277	277
1969	1757	1757	797	797	207	207
1970	2305	2305	1046	1046	272	272

Table 3.4 (cont). Gulf of Mexico King Mackerel commercial gillnet removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1971	1009	1009	458	458	119	119
1972	1636	1636	742	742	193	193
1973	4934	4934	2239	2239	588	588
1974	1896	1896	860	860	231	231
1975	2231	2231	1012	1012	266	266
1976	4275	4275	1939	1939	502	502
1977	690	690	313	313	80	80
1978	492	492	223	223	57	57
1979	933	933	423	423	110	110
1980	945	945	429	429	113	113
1981	848	848	385	385	101	101
1982	343	343	156	156	40	40
1983	539	539	245	245	63	63
1984	203	203	92	92	25	25
1985	630	630	286	286	75	75
1986	230	230	104	104	27	27
1987	12	12	5	5	1	1
1988	33	33	15	15	4	4
1989	390	390	177	177	47	47
1990	76	76	35	35	10	10
1991	344	344	156	156	45	45
1992	750	750	340	340	100	100
1993	216	216	98	98	28	28
1994	402	402	182	182	52	52
1995	518	518	235	235	68	68
1996	346	346	157	157	46	46
1997	448	448	203	203	59	59
1998	947	947	430	430	123	123
1999	331	331	150	150	43	43
2000	420	420	190	190	54	54
2001	187	187	85	85	24	24
2002	309	309	140	140	40	40
2003	445	445	202	202	58	58
2004	536	536	243	243	70	70
2005	421	421	191	191	55	55
2006	455	455	206	206	58	58
2007	579	579	263	263	72	72
2008	838	838	380	380	104	104
2009	646	646	293	293	81	81
2010	500	500	227	227	61	61
2011	433	433	196	196	51	51
2012	505	505	229	229	60	60
2013	595	595	270	270	71	71
2014	538	538	244	244	67	67
2015	535	535	243	243	69	69
2016	560	560	254	254	71	71
2017	575	575	261	261	75	75

Table 3.5. Gulf of Mexico King Mackerel recreational Headboat removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1927	0	0	0	0	0	0
1928	0	0	0	0	0	0
1929	0	0	0	0	0	0
1930	0	0	0	0	0	0
1931	0	0	0	0	0	0
1932	0	0	0	0	0	0
1933	0	0	0	0	0	0
1934	0	0	0	0	0	0
1935	0	0	0	0	0	0
1936	17	17	8	8	1	1
1937	34	34	15	15	3	3
1938	50	50	23	23	4	4
1939	67	67	30	30	6	6
1940	84	84	38	38	7	7
1941	100	100	46	46	8	8
1942	117	117	53	53	10	10
1943	134	134	61	61	11	11
1944	150	150	68	68	12	12
1945	167	167	76	76	14	14
1946	187	187	85	85	15	15
1947	207	207	94	94	17	17
1948	227	227	103	103	19	19
1949	246	246	112	112	20	20
1950	266	266	121	121	22	22
1951	286	286	130	130	24	24
1952	306	306	139	139	25	25
1953	327	327	148	148	27	27
1954	348	348	158	158	29	29
1955	368	368	167	167	30	30
1956	383	383	174	174	31	31
1957	398	398	181	181	33	33
1958	413	413	187	187	34	34
1959	429	429	194	194	35	35
1960	444	444	202	202	36	36
1961	445	445	202	202	36	36
1962	445	445	202	202	36	36
1963	442	442	201	201	36	36
1964	439	439	199	199	36	36
1965	436	436	198	198	36	36
1966	427	427	194	194	36	36
1967	417	417	189	189	35	35
1968	409	409	186	186	34	34
1969	401	401	182	182	34	34
1970	394	394	179	179	33	33

Table 3.5 (cont). Gulf of Mexico King Mackerel recreational Headboat removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish. Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1971	381	381	173	173	32	32
1972	373	373	169	169	32	32
1973	345	345	157	157	30	30
1974	343	343	156	156	30	30
1975	370	370	168	168	32	32
1976	336	336	152	152	29	29
1977	314	314	142	142	26	26
1978	290	290	131	131	24	24
1979	243	243	110	110	21	21
1980	313	313	142	142	27	27
1981	297	297	135	135	26	26
1982	210	209	95	95	18	18
1983	510	510	231	231	43	43
1984	295	295	134	134	26	26
1985	377	377	171	171	33	33
1986	107	107	48	48	9	9
1987	106	106	48	48	9	9
1988	107	107	48	48	9	9
1989	145	143	66	65	13	13
1990	107	107	49	49	10	10
1991	167	166	76	76	16	16
1992	201	200	91	91	20	20
1993	208	208	95	94	21	21
1994	217	216	98	98	22	22
1995	226	225	102	102	23	23
1996	241	240	109	109	25	25
1997	211	210	96	95	22	22
1998	152	152	69	69	16	15
1999	209	209	95	95	21	21
2000	147	144	67	65	15	14
2001	149	148	68	67	15	15
2002	223	223	101	101	22	22
2003	145	144	66	66	15	15
2004	210	210	95	95	21	21
2005	237	236	107	107	24	24
2006	225	225	102	102	22	22
2007	175	175	79	79	17	17
2008	190	189	86	86	18	18
2009	198	198	90	90	19	19
2010	172	172	78	78	16	16
2011	185	184	84	84	16	16
2012	166	166	75	75	15	15
2013	113	113	51	51	10	10
2014	150	150	68	68	14	14
2015	117	117	53	53	11	11
2016	122	121	55	55	12	12
2017	103	102	47	46	10	10

Table 3.6. Gulf of Mexico King Mackerel charter/private removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish (excluding shrimp fishery bycatch). Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1927	0	0	0	0	0	0
1928	0	0	0	0	0	0
1929	0	0	0	0	0	0
1930	0	0	0	0	0	0
1931	0	0	0	0	0	0
1932	0	0	0	0	0	0
1933	0	0	0	0	0	0
1934	0	0	0	0	0	0
1935	0	0	0	0	0	0
1936	0	0	0	0	0	0
1937	0	0	0	0	0	0
1938	0	0	0	0	0	0
1939	0	0	0	0	0	0
1940	0	0	0	0	0	0
1941	0	0	0	0	0	0
1942	0	0	0	0	0	0
1943	0	0	0	0	0	0
1944	0	0	0	0	0	0
1945	0	0	0	0	0	0
1946	48	48	22	22	4	4
1947	174	174	79	79	15	15
1948	299	299	136	136	26	26
1949	425	425	193	193	37	37
1950	551	551	250	250	48	48
1951	677	677	307	307	59	59
1952	806	806	366	366	70	70
1953	936	936	424	424	81	81
1954	1065	1065	483	483	92	92
1955	1195	1195	542	542	103	103
1956	1322	1322	600	600	114	114
1957	1449	1449	658	658	125	125
1958	1577	1577	716	716	136	136
1959	1709	1709	775	775	147	147
1960	1843	1843	836	836	158	158
1961	1910	1910	867	867	163	163
1962	1971	1971	894	894	169	169
1963	2017	2017	915	915	174	174
1964	2063	2063	936	936	180	180
1965	2112	2112	958	958	185	185
1966	2155	2155	978	978	191	191
1967	2199	2199	998	998	196	196
1968	2249	2249	1021	1021	202	202
1969	2303	2303	1045	1045	207	207
1970	2357	2357	1069	1069	213	213

Table 3.6. **(cont)** Gulf of Mexico King Mackerel charter/private removals (retained catch + dead discards), and landings (retained catch) in 1000s lbs, metric tons (mt) and 1000s of fish (excluding shrimp fishery bycatch). Removals are direct model inputs while landings are estimated within the assessment model as removals minus estimated dead discards.

Fishing Year	Removals Bio (x1k lbs)	Landings Bio (x1k lbs)	Removals Bio (mt)	Landings Bio (mt)	Removals N (1000s fish)	Landings N (1000s fish)
1971	2563	2563	1163	1163	232	232
1972	2776	2776	1259	1259	252	252
1973	2936	2936	1332	1332	272	272
1974	3078	3078	1397	1397	291	291
1975	3361	3361	1525	1525	311	311
1976	3456	3456	1568	1568	313	313
1977	3550	3550	1611	1611	314	314
1978	3574	3574	1622	1622	314	314
1979	3471	3471	1575	1575	313	313
1980	3395	3395	1541	1541	312	312
1981	3451	3413	1566	1548	316	312
1982	5609	5488	2545	2490	494	483
1983	4790	4790	2173	2173	431	431
1984	4699	4656	2132	2113	447	443
1985	3429	3366	1556	1527	318	312
1986	6143	5964	2787	2706	566	550
1987	3786	3519	1718	1597	358	333
1988	3185	3019	1445	1370	302	286
1989	6270	5582	2845	2533	600	534
1990	5789	5343	2626	2424	597	551
1991	6968	6472	3162	2937	778	722
1992	4884	4695	2216	2130	561	539
1993	7529	7098	3416	3221	850	801
1994	9065	8328	4113	3778	1023	940
1995	8236	8235	3737	3736	946	946
1996	11479	11478	5208	5208	1344	1343
1997	8843	8418	4012	3820	1034	984
1998	13487	13075	6119	5932	1520	1473
1999	9075	8715	4117	3954	995	952
2000	11540	10787	5236	4894	1263	1176
2001	14601	14586	6625	6618	1597	1590
2002	6077	5622	2757	2551	680	626
2003	5483	5476	2488	2485	620	617
2004	7488	6267	3397	2843	838	697
2005	6003	5101	2724	2315	671	567
2006	6129	6124	2781	2779	669	666
2007	5286	5282	2398	2397	552	550
2008	5421	4894	2460	2220	554	498
2009	4920	4412	2232	2002	502	449
2010	4516	4100	2049	1860	439	398
2011	5580	5153	2532	2338	520	479
2012	7923	7289	3595	3307	732	671
2013	4621	4618	2097	2095	431	429
2014	6758	6749	3066	3062	666	662
2015	5645	4863	2561	2206	585	502
2016	5268	5260	2390	2386	553	550
2017	5521	4871	2505	2210	603	530

Table 3.7. Estimated live discards by fleet and year for Gulf of Mexico king mackerel.

YEAR	Com H&L	Headboat	CHT/PRI
1980		0.004	
1981		0.019	17.3
1982		0.113	53.3
1983		0.055	0.1
1984		0.002	20.4
1985		0.007	29.1
1986		0.009	83.8
1987		0.016	132.4
1988		0.063	81.0
1989		0.429	409.9
1990		0.016	269.4
1991		0.207	297.1
1992		0.195	110.6
1993		0.325	243.5
1994		0.789	406.7
1995		0.461	376.3
1996		0.466	309.3
1997		0.325	230.8
1998	23.6	0.195	215.3
1999	26.6	0.238	199.7
2000	21.3	1.674	393.3
2001	20.7	0.553	1006.3
2002	21.0	0.427	263.5
2003	20.0	0.312	364.5
2004	17.6	0.095	696.1
2005	14.6	0.344	540.9
2006	18.0	0.459	456.1
2007	16.8	0.061	455.9
2008	14.8	0.484	328.2
2009	14.7	0.194	397.1
2010	10.8	0.105	234.3
2011	13.8	0.176	215.7
2012	14.6	0.157	311.7
2013	13.8	0.129	237.3
2014	14.6	0.115	359.6
2015	15.2	0.096	451.1
2016	15.6	0.259	369.9
2017	15.1	0.317	369.5

Table 3.8. Indices of abundance used in this assessment, Gulf of Mexico king mackerel.

FYear	Handline CPUE	Handline CV	Headboat CPUE	HeadboatCV	SEAMAP Trawl	SEAMAP CV	SEAMAP Plankton	SEAMAP CV
1972					3.26	0.43		
1973								
1974					1.26	0.68		
1975								
1976					0.07	1.29		
1977								
1978					0.79	0.79		
1979					1.07	0.57		
1980			0.68	0.19	0.06	1.29		
1981			0.67	0.18	0.20	0.95		
1982			0.84	0.21	0.10	1.29		
			0.75	0.20				
1983								
1984			0.52	0.18	0.84	0.69		
1985			1.26	0.16	0.27	0.63		
1986			1.30	0.16	0.38	0.94	0.12	0.47
1987			0.89	0.16	0.06	1.29	0.38	0.28
1988			1.23	0.14	0.58	0.44	0.59	0.38
1989			1.31	0.14	0.34	0.68	0.80	0.29
1990			1.43	0.15	1.34	0.31	0.66	0.29
1991			1.23	0.15	0.18	0.52	0.71	0.28
1992			1.06	0.15	0.26	0.56	0.64	0.21
1993			0.99	0.19	2.02	0.27	1.23	0.18
1994			0.83	0.16	0.76	0.42	1.02	0.2
1995			0.57	0.17	0.52	0.52	1.96	0.17
1996			0.69	0.16	0.54	0.44	0.75	0.23
1997			0.98	0.16	0.97	0.36	1.31	0.18
1998	1.12	0.09	0.64	0.17	0.91	0.35	1.31	0.18
1999	0.89	0.08	0.93	0.17	0.86	0.35	0.92	0.19
2000	0.84	0.08	1.24	0.15	0.43	0.49	0.92	0.24
2001	0.85	0.08	1.21	0.15	1.15	0.34	1.55	0.18
2002	0.88	0.08	1.09	0.18	1.16	0.37	1.43	0.19
2003	0.86	0.08	1.70	0.14	2.90	0.24	1.07	0.19
2004	0.88	0.09	0.95	0.18	1.86	0.27	1.46	0.18
2005	0.96	0.10	1.08	0.15	2.30	0.25	1.46	0.18
2006	0.92	0.10	0.91	0.14	1.63	0.31	1.16	0.22
2007	1.04	0.09	0.51	0.16	2.63	0.24	1.41	0.19
2008	1.01	0.10	0.57	0.17	0.20	0.68	1.41	0.19
2009	1.16	0.09	0.58	0.17	1.51	0.27	0.83	0.21
2010	1.33	0.11	0.61	0.17	1.04	0.33	1.11	0.22
2011	1.08	0.12	0.77	0.16	0.31	0.78	1.27	0.22
2012	1.20	0.11	0.68	0.19	0.76	0.52	0.87	0.23
2013	1.02	0.12	0.67	0.18	2.60	0.44	0.90	0.2
2014	0.99	0.11	0.84	0.21	0.61	0.49	0.96	0.23
2015	1.03	0.12	0.75	0.20	1.32	0.40	0.96	0.23
2016	1.20	0.12	0.52	0.18	0.97	0.49	0.99	0.20
2017	1.23	0.06	1.07	0.16				

Table 3.9. Statistics of marginal posterior densities of annual estimates king mackerel as bycatch (millions of fish) in the Gulf of Mexico shrimp fishery (fishing year). January 1-June 30 portion 2018 of 2017 fishing year estimates are not complete but use an average for the last three years for the missing months. Shrimp discards are assumed 100% dead.

Fishing Year	Mean	SD	MC error	2.50%	Median	97.50%
1972	27.130	97.390	1.730	1.045	9.173	161.200
1973	2.389	7.921	0.139	0.278	1.228	10.590
1974	2.778	6.263	0.117	0.349	1.449	13.220
1975	1.157	4.560	0.076	0.111	0.477	5.275
1976	1.565	3.110	0.050	0.254	0.895	7.029
1977	0.983	2.304	0.035	0.162	0.567	4.261
1978	14.090	37.470	0.635	1.325	6.389	66.270
1979	25.770	81.650	1.468	0.912	8.325	153.700
1980	0.499	1.061	0.015	0.109	0.323	1.800
1981	2.430	7.943	0.124	0.260	1.076	12.490
1982	2.956	9.926	0.174	0.229	1.213	15.070
1983	4.189	11.310	0.183	0.355	1.998	20.010
1984	10.090	51.360	0.736	0.673	4.078	47.670
1985	7.168	19.410	0.292	0.572	3.269	35.030
1986	12.480	41.350	0.567	0.917	5.552	64.250
1987	15.940	45.990	0.684	1.109	6.705	83.610
1988	17.330	42.640	0.593	1.445	8.443	81.480
1989	27.800	82.360	1.262	1.945	12.290	143.000
1990	28.380	78.270	1.210	2.142	12.370	148.300
1991	20.210	70.410	0.978	1.035	7.325	109.200
1992	1.575	4.120	0.053	0.511	1.064	4.986
1993	7.476	10.490	0.169	2.164	5.060	27.640
1994	7.679	14.130	0.228	1.582	4.623	33.480
1995	9.662	25.030	0.365	1.529	5.169	43.730
1996	8.833	24.850	0.360	0.859	4.217	41.810
1997	13.010	39.140	0.555	0.944	5.260	71.100
1998	6.297	13.730	0.219	0.576	3.132	30.320
1999	12.000	36.670	0.588	1.021	5.561	58.250
2000	10.730	41.590	0.647	0.589	3.863	58.130
2001	0.563	1.007	0.016	0.141	0.328	2.442
2002	0.614	0.857	0.014	0.185	0.429	2.075
2003	5.578	7.115	0.107	1.950	4.129	17.690
2004	5.710	13.300	0.173	2.072	4.028	17.570
2005	4.195	7.784	0.114	0.988	2.688	16.260
2006	4.692	28.550	0.391	0.457	1.943	22.330
2007	0.920	1.659	0.030	0.421	0.694	2.341
2008	0.287	0.091	0.001	0.203	0.274	0.431
2009	0.313	0.115	0.002	0.173	0.289	0.610
2010	0.605	1.305	0.017	0.211	0.400	2.143
2011	0.123	0.051	0.001	0.081	0.114	0.218
2012	0.324	0.070	0.001	0.235	0.313	0.469
2013	0.502	0.097	0.002	0.362	0.489	0.713
2014	0.251	0.097	0.002	0.144	0.234	0.457
2015	0.605	0.245	0.004	0.394	0.561	1.057
2016	0.399	0.115	0.002	0.254	0.377	0.670
2017	0.492	0.167	0.003	0.323	0.460	0.838

Table 3.10. Gulf of Mexico shrimp fishery effort and coefficient of variation by fishing year.

Fyear	Effort	CV	Fyear	Effort	CV
1950	20	0.13	1984	108	0.13
1951	25	0.13	1985	111	0.13
1952	30	0.13	1986	122	0.13
1953	30	0.13	1987	116	0.13
1954	40	0.13	1988	116	0.13
1955	38	0.13	1989	110	0.13
1956	49	0.13	1990	116	0.13
1957	58	0.13	1991	115	0.13
1958	77	0.13	1992	114	0.13
1959	83	0.13	1993	106	0.13
1960	83	0.13	1994	101	0.13
1961	64	0.13	1995	93	0.13
1962	64	0.13	1996	104	0.13
1963	75	0.13	1997	112	0.13
1964	59	0.13	1998	114	0.13
1965	58	0.13	1999	101	0.13
1966	65	0.13	2000	101	0.13
1967	75	0.13	2001	105	0.13
1968	79	0.13	2002	101	0.13
1969	73	0.13	2003	86	0.13
1970	74	0.13	2004	70	0.13
1971	99	0.13	2005	52	0.13
1972	83	0.13	2006	44	0.13
1973	82	0.13	2007	39	0.13
1974	69	0.13	2008	37	0.13
1975	75	0.13	2009	37	0.13
1976	80	0.13	2010	33	0.13
1977	92	0.13	2011	35	0.13
1978	113	0.13	2012	36	0.13
1979	88	0.13	2013	36	0.13
1980	89	0.13	2014	37	0.13
1981	93	0.13	2015	38	0.13
1982	92	0.13	2016	40	0.13
1983	93	0.13	2017	36	0.13

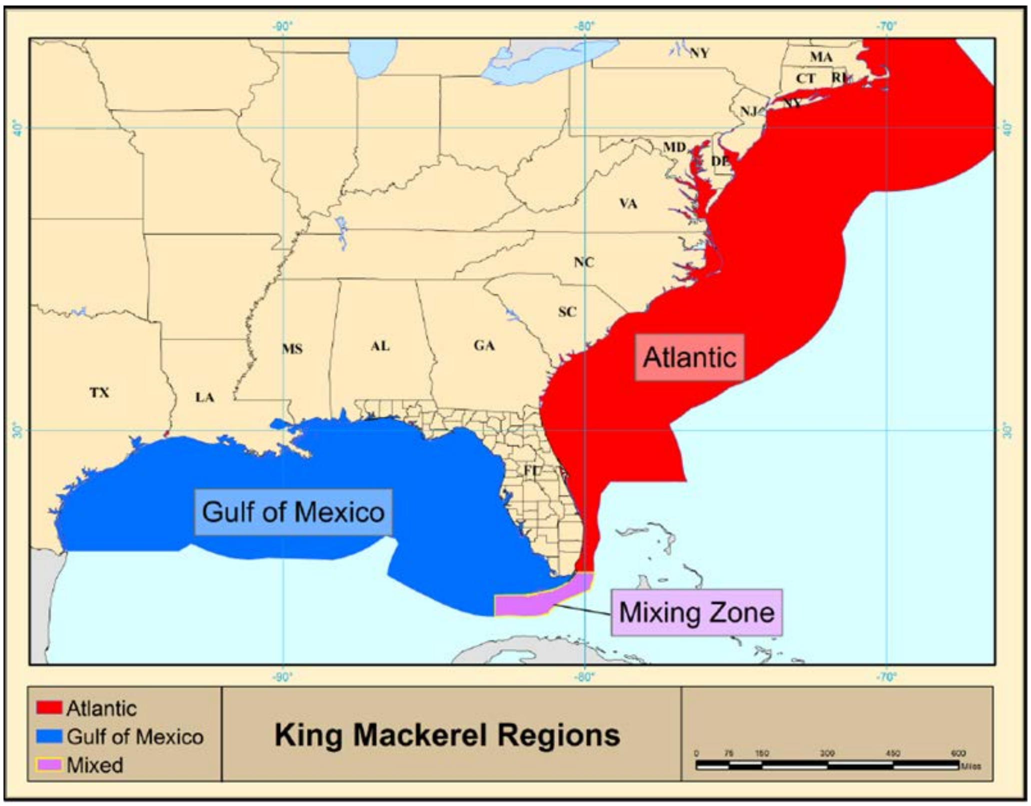

Figure 3.1. Regional stock boundaries used to aggregate landings for the stock assessments of South Atlantic and Gulf of Mexico King Mackerel.

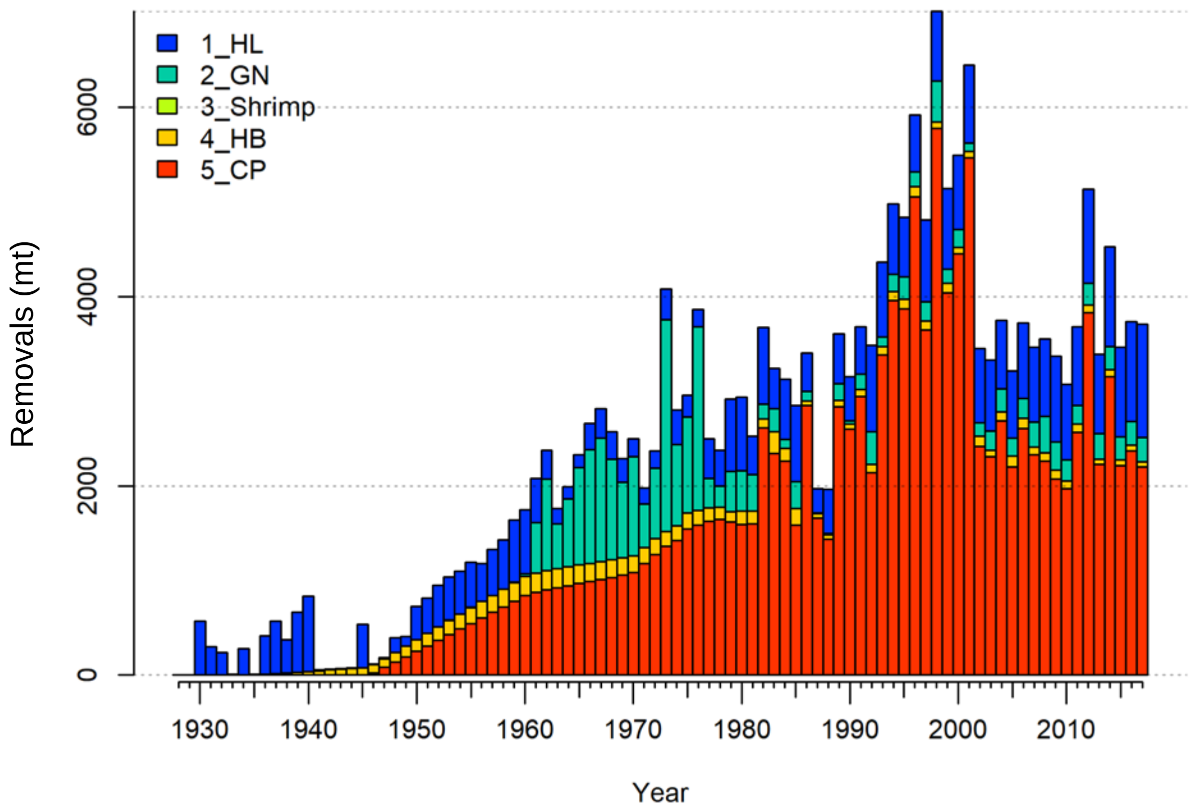

Figure 3.2. Total estimated removals (retained catch and dead discards) of Gulf of Mexico King Mackerel in metric tons.

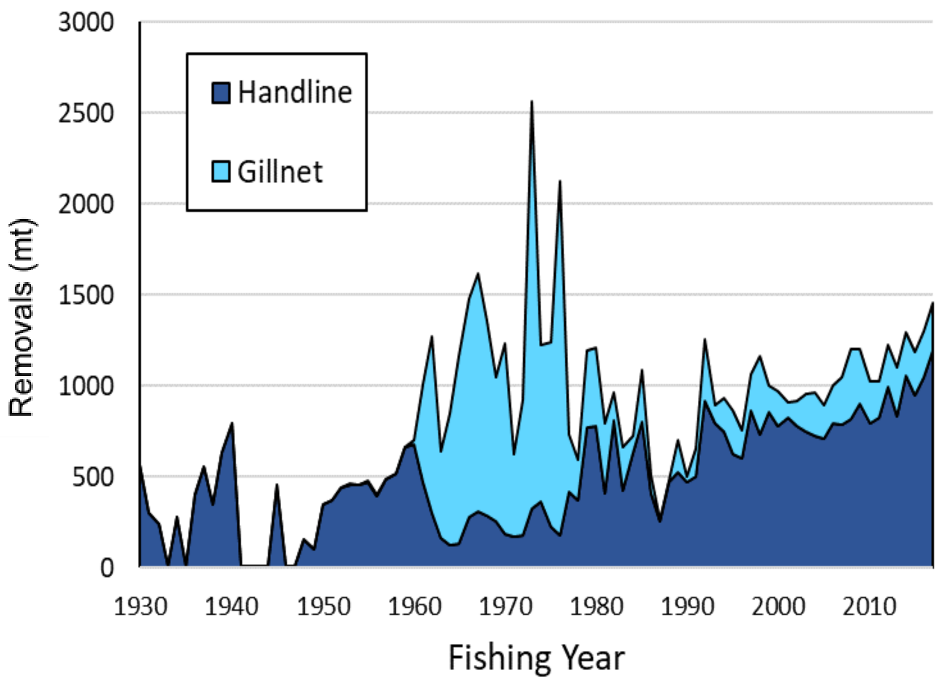

Figure 3.3. Estimated commercial removals of Gulf of Mexico King Mackerel from directed fleets (measured in metric tons whole weight).

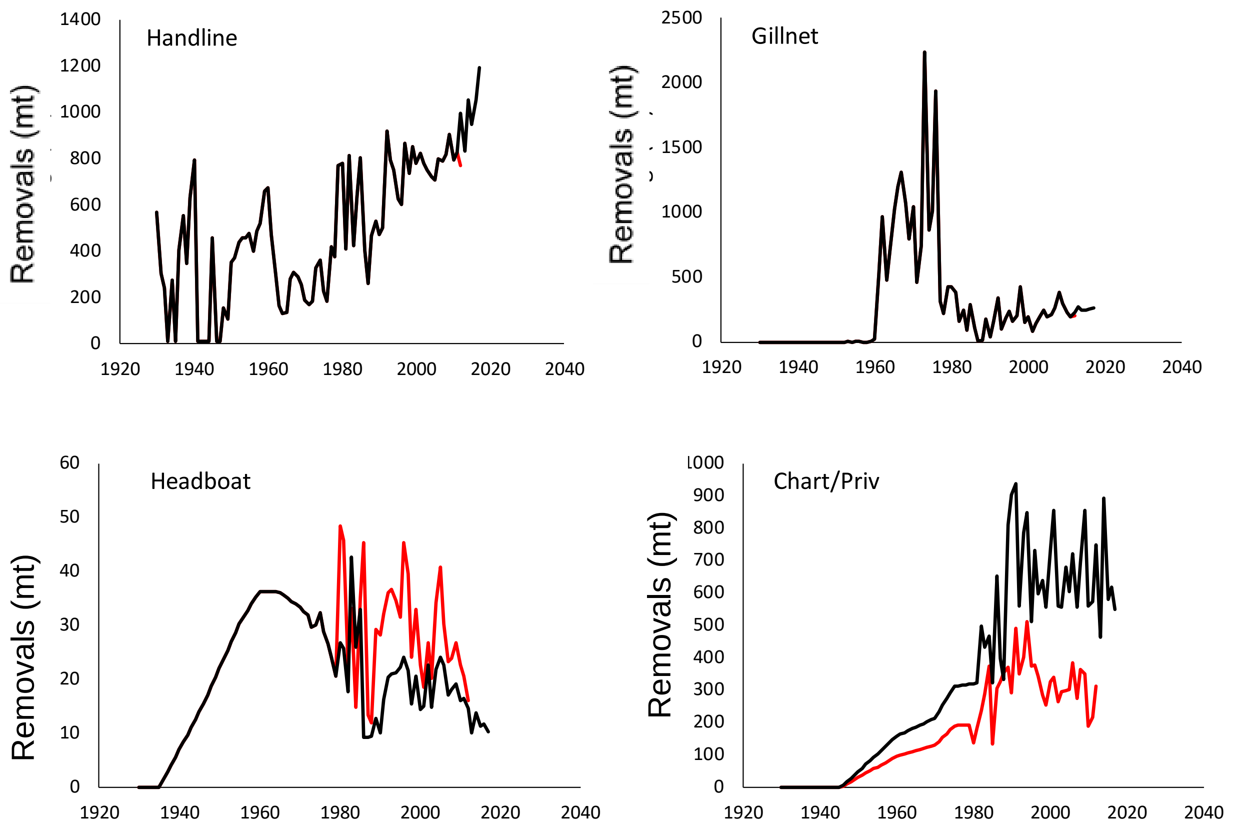

Figure 3.4. Comparison of removal estimates (landings plus dead discards) between SEDAR 38 (red lines) and the 2020 updated assessment (bold black lines). The change in recreational landings estimates was attributed to different methodologies for estimating recreational effort from the MRIP Coastal Household 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).

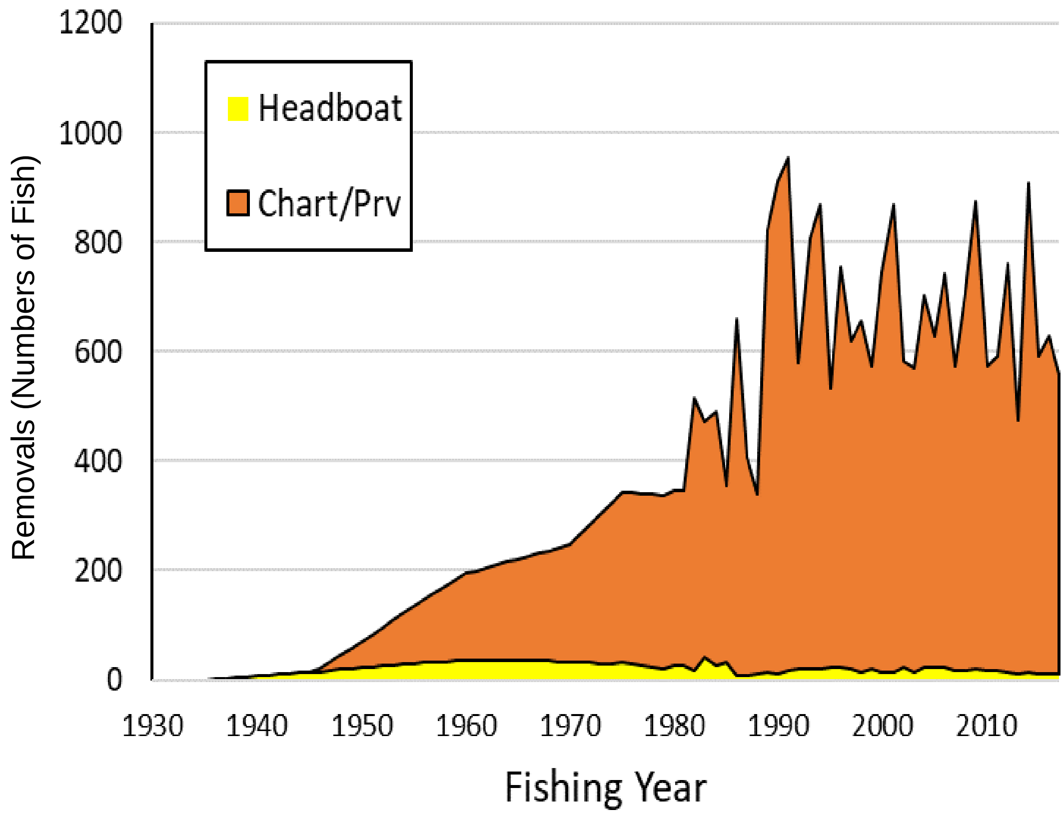

Figure 3.5 Estimated recreational removals of Gulf of Mexico King Mackerel.

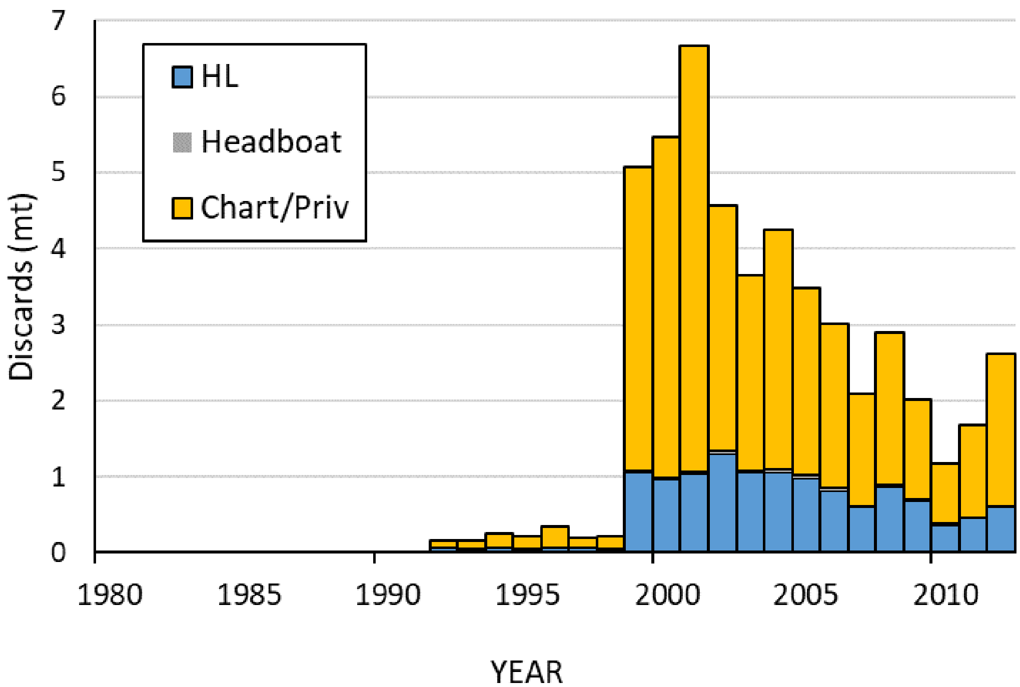

Figure 3.6. Estimated discards of Gulf of Mexico King Mackerel in weight (mt).

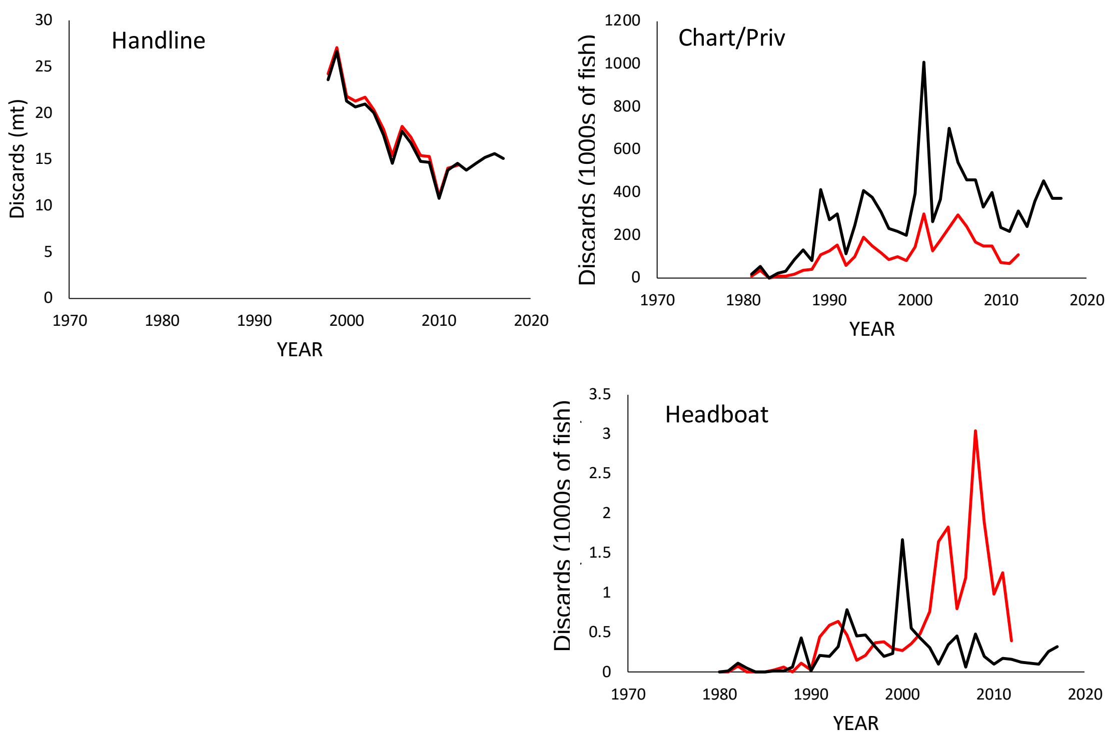

Figure 3.7. Comparison of estimated discards (1000s of fish) of Gulf Mexico King Mackerel between SEDAR 38 (red lines) and the 2020 update (black lines).

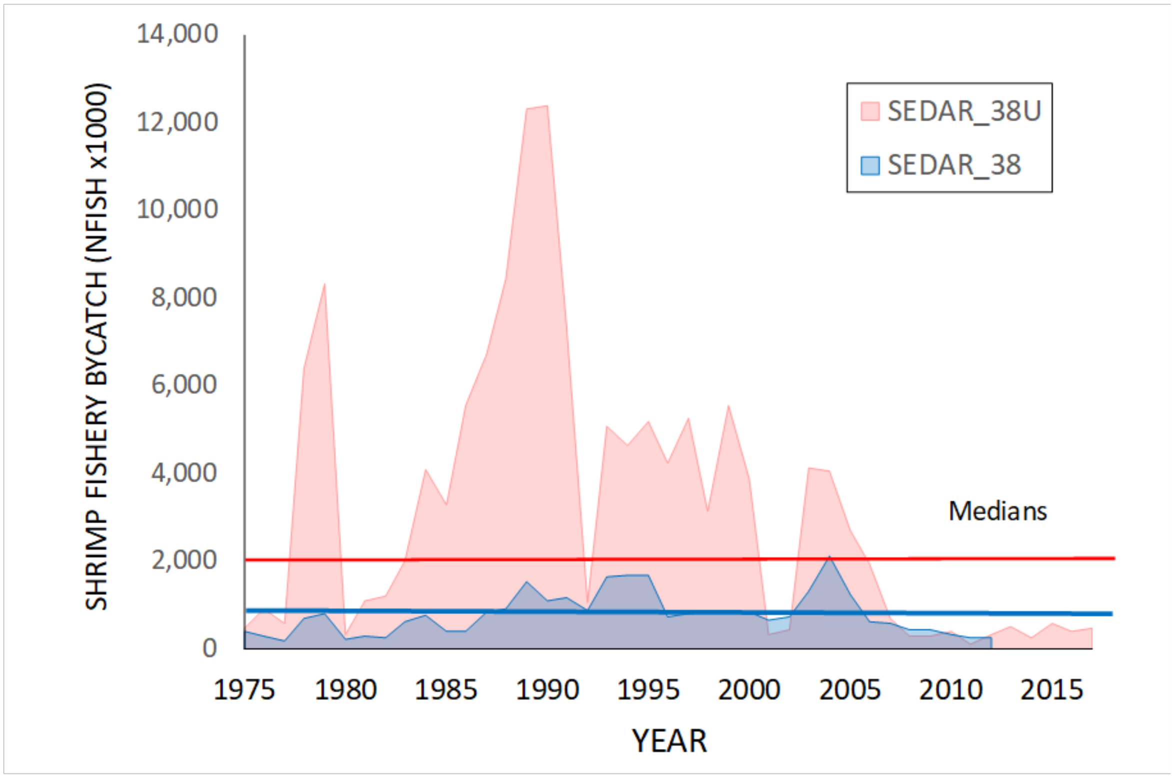

Figure 3.8. Comparison of estimated shrimp fishery discards of Gulf Mexico King Mackerel between SEDAR 38 (red lines) and the 2020 update (blue lines).

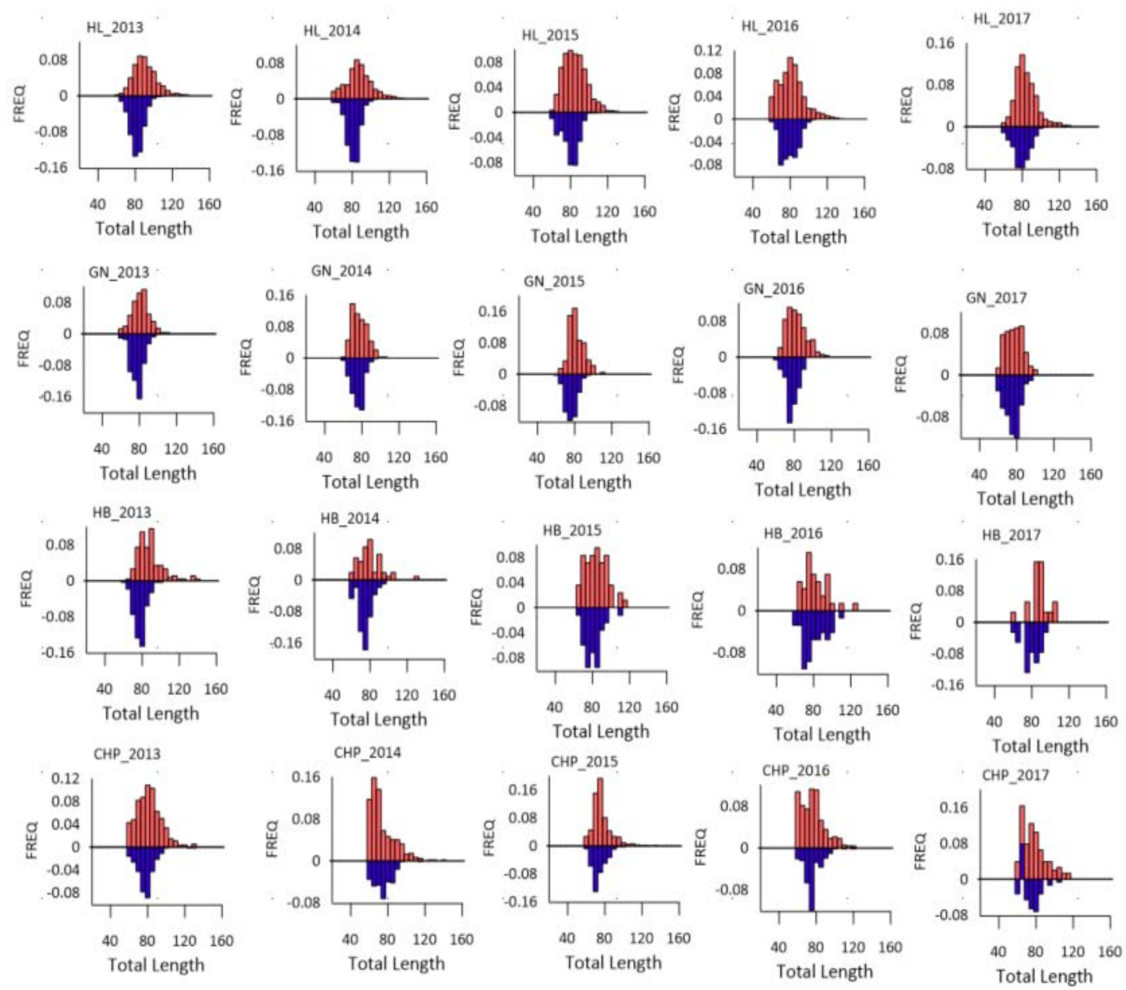

Figure 3.9. Relative frequency of annual length (fork length in cm) composition of king mackerel landed in the Gulf of Mexico by fishery and sex (red is female, blue males).

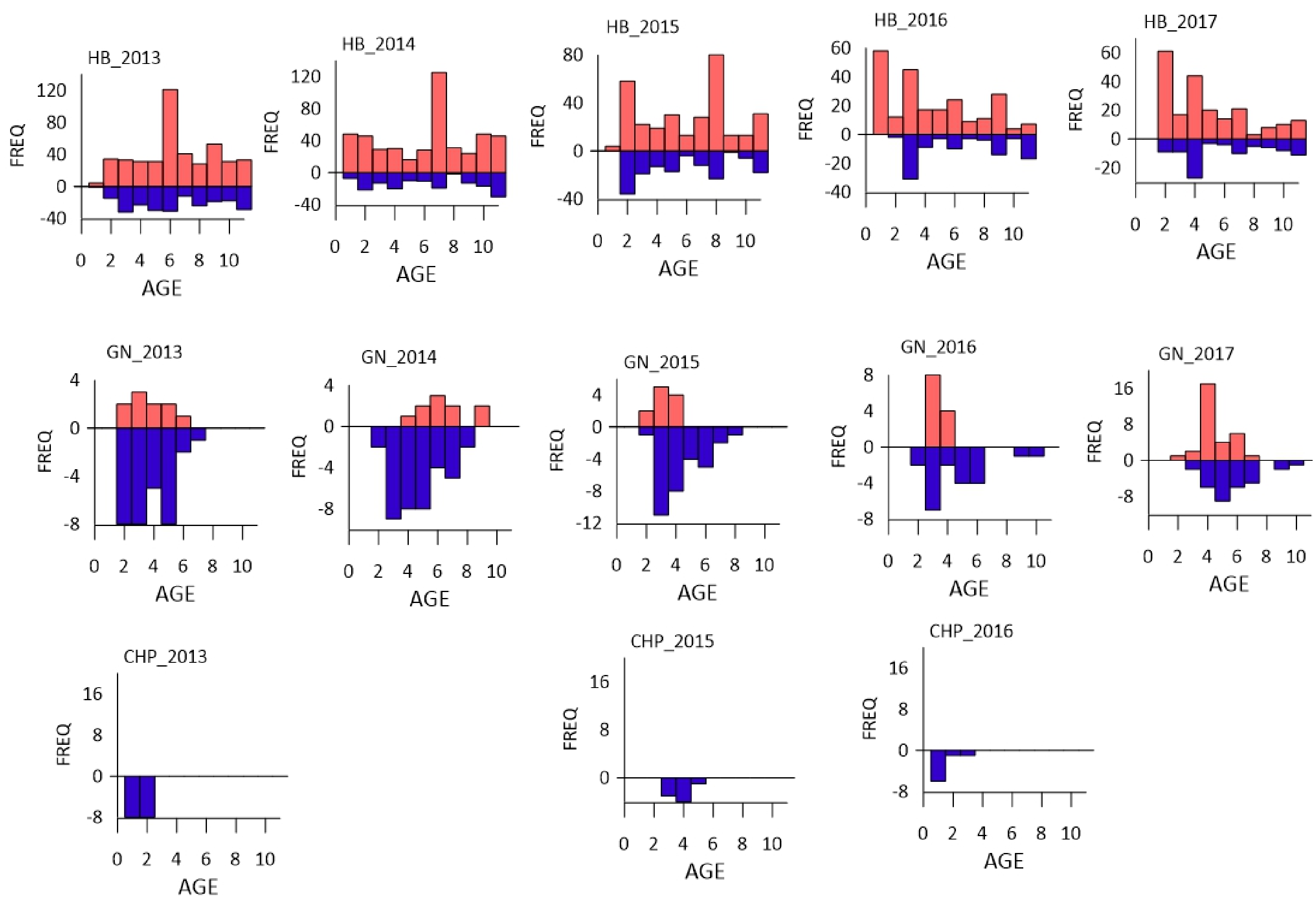

Figure 3.10. Relative frequency of annual age composition of king mackerel landed in the Gulf of Mexico by fishery and sex (red is female, blue males). Age in years is shown on the x-axis, and the relative frequency of observations is shown on the y-axis.

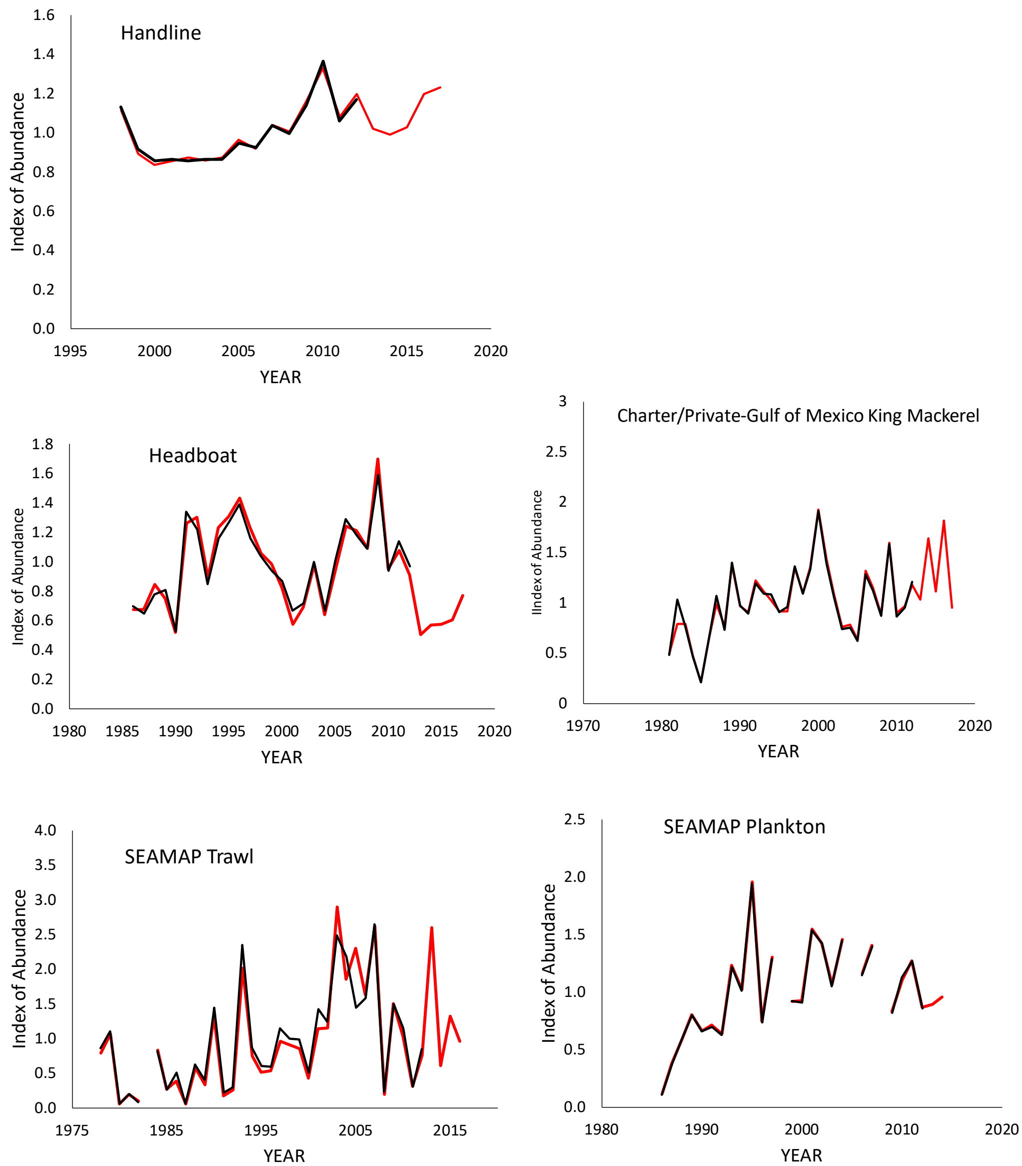

Figure 3.11. Indices of abundance used in SEDAR 38 (black) and this update (red) for Gulf of Mexico king mackerel.

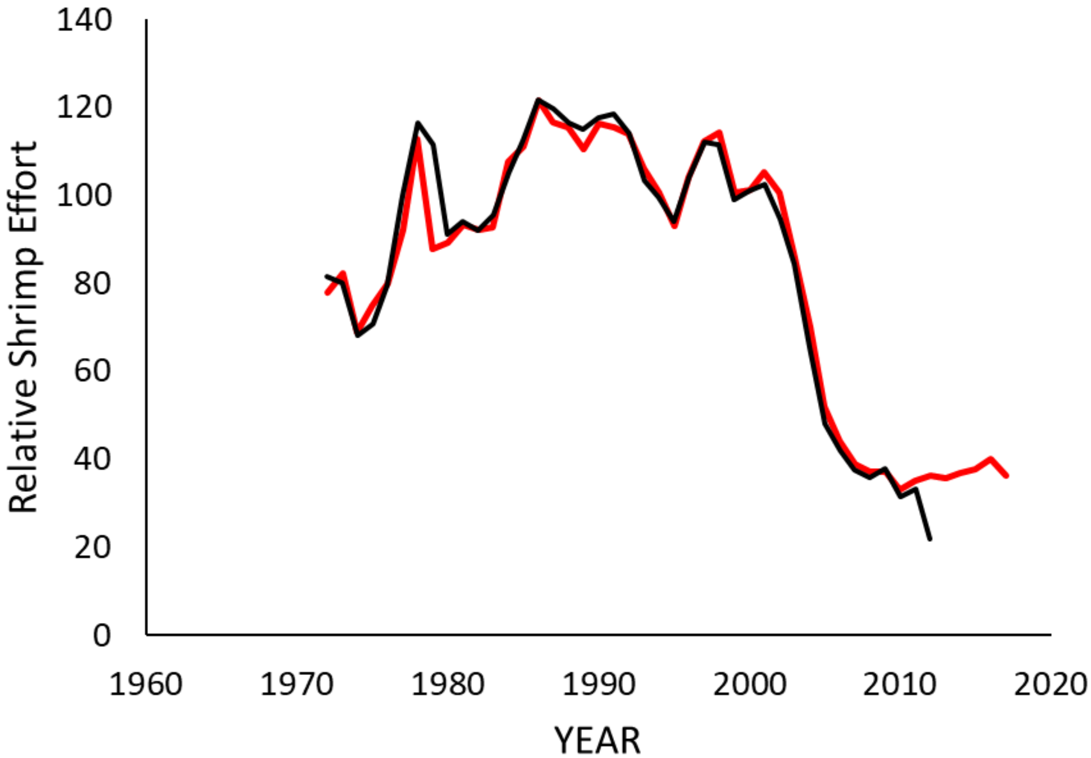

Figure 3.12. Shrimp effort series used in SEDAR 38 (black) and this update (red) for Gulf of Mexico king mackerel.

4. Stock Assessment Methods

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

SS 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. SS 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 in the assessment a "model building" exercise was conducted using the SEDAR 38 model up to 2012. The three data sets that had shown the most change due to revision of the data were replaced one at a time, and in a cumulative manner: (1) the change in recreational fishing effort from the MRIP Coastal Household Telephone Survey to the Fishing Effort Survey (FES); (2) changes in the manner in which shrimp fishery bycatch was estimated, and (3) slight changes in the indices of abundance.

Once the analyses of model building exercise were completed, the updated 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 4.1**. 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 measured in millions of hydrated eggs fixed assumptions of maturity-at-age and weight-based fecundity (**Figure 4.2**).
- **Natural mortality** was estimated externally from SS3 assuming a Lorenzen function based on mean size-at-age, and input into SS3 as fixed parameters.
- **Stock-recruitment** assumed a Beverton-Holt relationship with two parameters, the log of unexploited equilibrium recruitment (R0) and steepness (h) which was fixed at 0.99. A third parameter representing the standard deviation in recruitment (σR) was fixed at 0.6.

- **Recruitment deviations** were estimated for the period 1981-2017 during which length composition data exist, as well as age compositions 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 removals 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 two fishery independent survey (SEAMAP Gulf of Mexico trawl survey, and SEAMAP Gulf of Mexico plankton survey). Annual index values were weighted by standardization model estimated coefficients of variation for that year.
- **Aging data** were input as conditional-age-at-length, the count of aged fish by 5 cm length bins, input separately for males and females for the commercial handline, 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 trawl survey and the shrimp bycatch which were assumed to catch age-0 fish. The SEAMAP plankton survey was assumed to reference spawning stock biomass.
- **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 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.
- **Benchmarks and fishing reference points.** . For this assessment status was defined by the following definitions: The minimum stock size threshold (MSST) = (1-M)*SSB_{SPR30} where M = 0.174. When SSB current/MSST is less than 1.0, the stock is considered

overfished . The Maximum Fishing Mortality Threshold (MFMT) = F_{SPR30}. When F/MFMT is greater than 1.0 the stock is undergoing overfishing. Consistent with SEDAR 38, $SSB_{Current}$ is the terminal year.

- **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 initial values to validate model convergence to a global solution (maximum likelihood estimate).
- **Model fit diagnostics** included likelihood profiling of key estimated stock productivity parameters including unfished mean recruitment, 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.
- **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) removals in FY 2018, 2019, and 2020 were assumed to be equal to FY2017, (3) directed fleet allocations were assumed equal to the averages of the terminal two years, (4) shrimp bycatch mortality was assumed to continue at 2017 levels, (5) future recruitments were predicted from the Beverton-Holt stock recruitment curve, and (6) stock status probabilities were approximated from the standard deviations from the resulting Hessian, as normal bivariate distribution between unfished recruitment level and steepness.

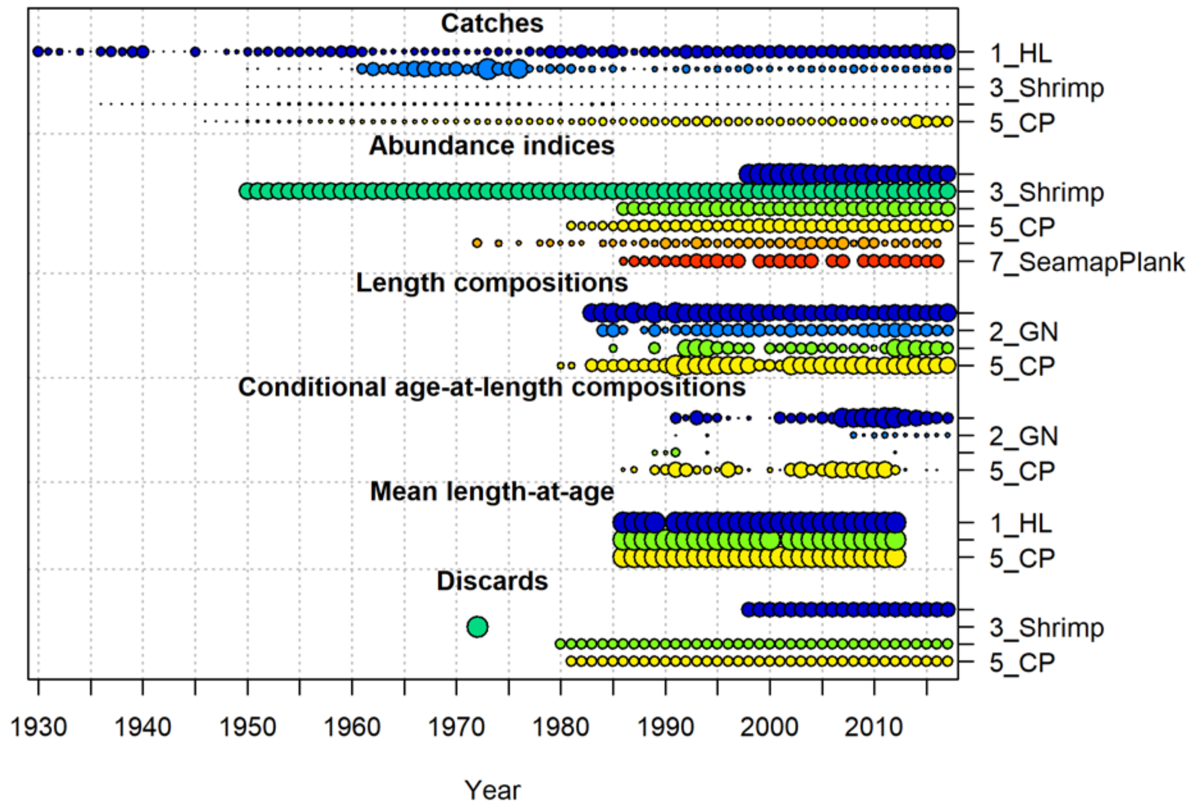

Figure 4.1. Gulf of Mexico King Mackerel data series SS3 inputs. The size of the dots is relative to sample variance.

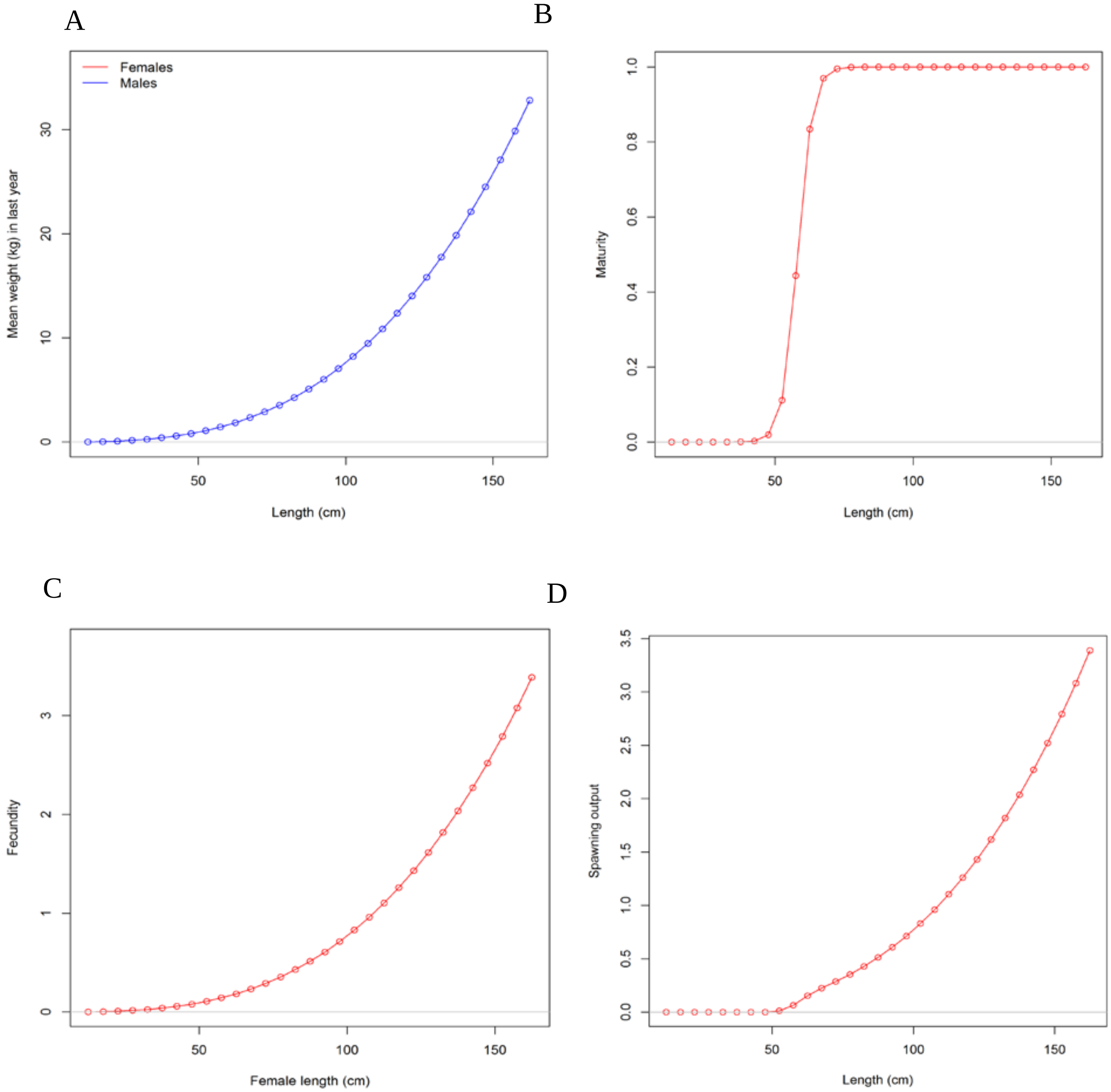

Figure 4.2. Gulf of Mexico king mackerel reproductive life history assumptions. A. Length-Weight relationship, B. maturity as a function of length, C. fecundity as function of length and D. Spawning output as a function of length (product of maturity and fecundity).

5. Stock Assessment Results

5.1 Sensitivity of SEDAR 38 to Updated Data Inputs

There were substantial revisions to three key data sources between the SEDAR 38 stock assessment and this update including recreational landings and discards, the shrimp bycatch, and the Headboat index. To examine the effects of these data updates, the SEDAR 38 base model was refit changing one, and only one updated data series at a time. The effects of this exercise are shown in **Figure 5.1**. Note: because NOAA no longer supports the MRIP-CHTS estimates and the program has been discontinued, no MRIP-CHTS estimates were provided 2013-2017. Therefore, these comparisons were made using the SEDAR 38 base model fit only up to year 2012 with both the original (CHTS) and updated (FES) data sets.

Changing only the MRIP-CHTS data to the MRIP-FES data (**Figure 5.1; 1_FES**) had the effect of increasing the estimate of virgin spawning stock biomass as well as annual estimates of spawning stock biomass compared to the SEDAR 38 base model (**Figure 5.1; 0_2013**). This result was expected because in order for the modeled population to support the increased harvest estimated from the FES data, the estimated population size needed to be increased. Conversely, changing only the decreased Headboat removals (landings and discards; **Figure 5.1; 2_HB**)) led to an estimate of lower virgin spawning stock biomass and estimated population size. Changing only the median of the shrimp fishery bycatch (**Figure 5.1; 3_Shrimp**) from 708 to 1,998 million fish led to increased estimates of virgin spawning stock biomass. Since the natural mortality of age_0 fish remained unchanged, the increased shrimp bycatch mortality on age 0 fish forced the model to increase the estimate of unfished recruitment (and thus, unfished biomass).

The second step was to examine the accumulated effects of the data updates on the SEDAR 38 base model, starting with the FES data, then the Headboat data, and finally the shrimp bycatch data. The resulting estimated trends in spawning stock biomass are shown in **Figure 5.2**. Of course, adding the FES data (**Figure 5.2; 1_FES**) was a duplication of the previous examination. Adding the updated Headboat data (**Figure 5.2; 2_FES+HB**) had very little effect except to slightly increase the overall scale of the spawning stock biomass. However, adding in the updated shrimp bycatch data (**Figure 5.3; 3_FES+HB+Shrimp**) increased the estimate of virgin spawning stock biomass considerably. Even so, the estimate of spawning stock biomass from approximately 1990-2012 were only slightly higher than those estimated with the original SEDAR 38 data.

Step three of this comparison was to compare the SEDAR 38 base model (**Figure 5.3; 0_2013**) to the SEDAR 38U base model (**Figure 5.3; 2017_BASE**) fit to all updated data, As was demonstrated in the parts one and two, the addition of the updated data increased the estimated virgin spawning stock biomass. However, unlike the parts one and two, the estimates of the most recent spawning stock biomass were considerably lower. To try to isolate the cause of this the S38U model was then fit using the SEDAR 38 shrimp median of 708 thousand fish (**Figure 5.3; bottom panel, Shrimp_708**). While this fit resulted in a closer match between the estimated virgin spawning stock biomass, the differences in the estimates of current biomass remained. Therefore, it was apparent that the updated shrimp bycatch estimates were not responsible for the decreased estimates of spawning stock biomass from 1999-2017.

For the fourth and final step, a jack-knife procedure was carried out by removing one CPUE time series at a time and comparing trends in estimated spawning stock biomass (**Figure 5.4, top**). Further inspection of the trends reveals that removal of the Headboat index had the largest influence on the estimates of 1999-2017 spawning stock biomass. This lead to the preliminary conclusion that the updated shrimp bycatch estimate and the most recent CPUE's from the Headboat index were having the most influence on the observed differences. To verify this conclusion, the S38U was fit using the SEDAR 38 shrimp bycatch estimate and removing the entire Headboat index. This produced a trend in estimated spawning stock biomass that was much more similar to the S38 base case (**Figure 5.4; bottom**). This verifies that the most influential updated data inputs were the shrimp fishery bycatch and the most recent five years of the Headboat index of abundance.

5.2 SEDAR 38 Update

5.2.1 Assessment model convergence and fit diagnostics

Using a jitter analysis the assessment model convergence shown to arrive at a somewhat stable solution; however, some model instability and sensitivity to starting parameter values was evident (**Figure 5.5 top**). Despite this, the resulting trends in SSB, recruitment and harvest rate remained very stable through the fits (**Figure 5.5 bottom**). 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 0.105, higher than a target of 0.001 (lower is better) indicating some model instability, likely due to conflicting signals in the data (see profile analysis below). Improvements to the model convergence level should be a primary objective of future assessments.

Unfished recruitment was seemingly well determined in the model (**Figure 5.6**); however, there were obvious conflicts with the length composition and survey data fitting best at low values and the age data fitting best at high values. The information taken as a whole provides a defined best estimate for average unfished recruitment near 7.5 million age-0 fish. However, since this value lies at the intersection of the opposing data it should be viewed with caution.

Although not estimated for the assessment model, a profile analysis was performed on the steepness parameter. Overall, the observational data fit best at increasing high values. Furthermore, it was the discard data was contributing the most to the changes (**Figure 5.7**). Closer examination reveals that it is the shrimp fishery bycatch that accounted for essentially the entire change in likelihoods due to all discards. Converse to the profiling on R0, the length information fit best at high steepness and the survey data low. Given the negative correlation between R0 and steepness, this would be expected.

The model showed mixed degrees of agreement to the interannual trends in relative abundance (**Figure 5.8**), often missing the magnitude of change in some years. For example, the model fit to the recent period Headboat decline and rebound were captured in the model predicted trend but not magnitude. 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 if the series was input as an age-0 index, but the data were comprised of age-0 and age-1 fish. An evaluation of alternative references ages via examination of seasonal length compositions for the SEAMAP index, or modified index that references age-0 and age-1 fish separately is recommended in future research assessments.

Fits to the length composition (**Figure 5.9**) 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.

Retrospective analysis was conducted over a five-year period, 2012-2017. Results indicated only small differences in the same year estimates of spawning stock biomass; however, no systematic patterns emerged (**Figure 5.10**). Each "peel" of a year resulted in a Mohn's rho was well within the acceptable limits (-0.15 to 0.20).

5.2.2 Fishery Selectivity

Fleet selectivity estimates were very consistent with SEDAR 38 (**Figures 5.11**). In general, the fleet length composition fits for the period 1980 to 2017 and estimates of fleet selectivities matched those from SEDAR 38 with great similarity, indicating stable model performance with the addition of five years of data. Length-based selectivity for all sexes and fleets was strongly dome-shaped. Most selectivity parameters were estimated with good precision; however, a few showed very high CVs and were poorly estimated (**Appendix 1**). Possible reasons for these high CVs are correlation among some of the parameters and/or size of the size bin increment. Selectivity parameters that had the highest CV's were those associated with time varying retention, likely due to a lack of adequate observations of released fish (those under the legal size limit). Both the SEAMAP trawl survey and the Shrimp fishery selectivities were fixed to only age-0 fish.

5.2.3 Fishing Mortality

Annual estimates of fishing mortality, recruitment, stock biomass, and catch are given in **Table 5.1**. Fishing mortality rates (estimated as exploitation rate in number) have remained relatively constant since SEDAR 38, with the last 5 years (2013-2017) averaging 17% of the stock (in biomass) removed by fishing activities (landed and discarded dead) annually (**Table 5.1, Figure 5.12**). Peak fishing mortality occurred during the 1990s, averaging 40% stock removal 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 5.1**).

5.2.4 Recruitment

One of the limitations of the SEDAR 38 assessment was that the shape and parameterization of the spawner-recruitment relationship could not be estimated with available data. Therefore, a major assumption of the model was that recruitment would continue at recent levels during a short-term projection. Therefore, the steepness parameter (h) of the Beverton-Holt curve was

fixed at 0.99 (**Figure 5.13, top**). Under this assumption, the main parameter driving estimated productivity was the average level of age-0 recruitment at unfished equilibrium spawning biomass (virgin recruitment, *R0*). However, there was notable conflict between data sources on the best estimate of virgin recruitment. 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 5.2.1**.
Annual recruitment deviations highlighted the variability in year-to-year recruitments, with a general cyclical pattern of periods of high and low signals (**Figure 5.13, bottom**).

Estimated recruitment was generally below average from1973 to 1988 (but with two above average cohorts in 1972 and 1982), above average recruitment during 1989 to 2004, returning to mostly below average during 2005-2012. From 2013 until 2016 recruitments fluctuated around the R0 value. (**Figure 5.14, Table 5.1**).

5.2.5 Stock Biomass

Estimates of spawning biomass were not entirely consistent with those of SEDAR 38. The updated data resulted in a fit that increased the virgin spawning stock biomass, agreement starting in approximately 1977, and then a divergence after approximately 1999 (**Figure 5.15**). Similar to SEDAR 38, the 95% confidence intervals around the estimate of spawning stock biomass where deceptively low. This is in part due to natural mortality and the steepness parameters being fixed, leaving only R0 and sigma_r (recruitment standard deviation) to be estimated. In such a situation, the values that R0 and sigma_r can take on are limited. Since the low in 1990, stock biomass has been on a generally increasing trend, but fluctuations are evident from variability in annual recruitment.

5.2.6 Benchmarks/Reference points

The definitions of overfished and overfishing used in this update were as follows:

Overfished: $SSB_{Current}$ < MSST; where MSST = (1-M)*SSB_{MSY} (or proxy), and M = 0.174
Overfishing: $F_{Current}$ > MFMT; where MFMT = F_{MSY} or proxy

The proxy for SSB_{MSY} is SSB_{SPR30} and the F_{MSY} proxy is F_{SPR30}.

The reference point estimates of Gulf of Mexico king mackerel were:

- MSST = (1-0.174)*SSB_{SPR30} = 1,416 billons of eggs
- MFMT = F_{SPR30} = 0.17 annual exploitation in biomass
- Equilibrium Retained Yield (landings) at F_{SPR30} = 11.51 million pounds
- Equilibrium Optimum Yield (landings) at 85% F_{SPR30} = 10.83 million pounds

5.2.7 Stock Status

The time series of SSB/SSB_{MSST} F/F_{MFMT} and are given in **Table 5.2** and shown in **Figure 5.16**. Time series of fishery mortality relative to the F_{MFMT} followed the period of increasing fishing pressure from 1950 to 1990, and peak fishing mortality occurred during 1992 when the estimated F/MFMT was roughly 2.5. From that year forward, the estimates of F/MFMT began a downward trend as retained catch restrictions were applied.

A comparison of selected benchmarks between SEDAR 38 and SEDAR 38 Update are given in **Table 5.3**. When making comparison between benchmarks from the two SEDAR assessments, it needs to be kept in mind that three of the four historic catch streams have changed. Additionally, since the same assessment model configuration was used for the two SEDARs, the differences between the two SEDARs is due to changes in data rather than changes in modeling approaches. Values for the update are generally higher due to the recreational landings and shrimp bycatch being revised upward. A summary of the benchmark values for the SEDAR 38 Update are given in **Table 5.4**.

The spawning stock biomass in 2017 was estimated to be 1,580 (mt), above the MSST reference point of 1,416 (SSB/MSST = 1.12) (**Table 5.4, Figure 5.16**). The stock status was determined to be NOT OVERFISHED.

The fishing mortality rates in 2017 was estimated to be 0.14, lower than the MFMT reference point of 0.17 (F/MFMT = 0.83) (**Table 5.4, Figure 5.16**). The fisheries were determined to be NOT OVERFISHING.

A summary of stock reference points, fishery status, and stock status is available in **Table 5.4**, 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 85% quantiles of stock and fishery status. The estimates of current stock status and fishery status relative to the reference points (with 80% confidence intervals) were:

- SSB_{2017} / MSST = 1.12 (0.98 – 1.26)
- The estimated probability the stock is not overfished is 85%
- F_{2017} / MFMT = 0.83 (0.68 – 0.98)
- The estimated probability that overfishing is not occurring is 92%

5.3 Projections

Projections of retained yield (in millions of pounds) for constant F projections at $F_{Current}$, F_{MFMT} and F_{OY} (85% of F_{SPR30}) are given in **Table 5.5** and **Figure 5.17**. Note that these projections do not use the P* for adjustment. Projected retained yield for constant F projections at F_{MFMT} (OFL) and adjusted for a P* = 0.43 values (ABC) and probabilities of overfishing are given in **Table 5.6**. The retained yield for 2017 was 8.18 million pounds. At the P* used in SEDAR 38 stock assessment (P* = 0.43) the ABC in 2021-2023 was predicted to be 10.47, 10.60 and 10.71 million lbs., respectively.

5.4 Results and Conclusions

This update to the SEDAR 38 assessment found the stock to be not overfished and not experiencing overfishing. Three of the five catch/discard series were changed between the benchmark and the update, limiting direct comparisons between the two assessments. The relative effects of these changes on the resulting trends were in line with expectations, which would be an increase in the overall stock size as well as an increase in virgin recruitment.

As in SEDAR 38 the fit of the assessment model to the data was found somewhat lacking with regard to the degree of convergence and stability. Model diagnostics suggest this is due to conflicting signals between major data components sources, which should be further evaluated during the next operational/research track assessment. However, although convergence may have been an issue, resulting trends and management quantities remained consistent. Even with the reweighting the various sources of observation data convergence was not improved. The Independent Review conduct for the SEDAR 38 assessment found the model suitable for management advice. Having applied the management advice provided by that assessment and finding either stable or increasing indices of abundance and stable landings adds reassurance of the efficacy of that advice.

5.5 Research recommendations

- The assessment should be moved to the most updated version of SS, which, among other improvements, has the means to explicitly model a bycatch-only fishery.
- The reasons for the conflicting signals in the data requires further investigation.
- The assessment should take full advantage of the upcoming shrimp bycatch estimation workshop and any results or recommendation resulting from it.
- The number of samples of lengths of discarded, undersized fish needs to be increased. This should add stability to model as well as increase the accounting of dead discards.
- Assurances should be made that there is an appropriate match between the sampling design of the biological data (i.e. ages, lengths, etc.) and the assumptions of its use in the assessment model.

Acknowledgements

Many people at various state and federal agencies assisted with assembling the data sources included in this stock assessment.

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Table 5.1. Estimated annual recruitment (1,000 of fish), spawning stock biomass (billions of eggs), fishing mortality is exploitation rate in biomass and landings (millions of pounds retained) of Gulf of Mexico king mackerel.

FY	Recruits	SSB	F	Landings	FY	Recruits	SSB	F	Landings
1930	7679	5644	0.006	1.249	1975	5189	2956	0.061	6.464
1931	7678	5610	0.003	0.666	1976	3543	2845	0.082	8.472
1932	7678	5595	0.003	0.529	1977	8066	2638	0.061	5.473
1933	7678	5585	0.000	0.022	1978	7201	2469	0.061	5.181
1934	7678	5590	0.003	0.610	1979	6715	2348	0.076	6.342
1935	7678	5580	0.000	0.022	1980	2236	2243	0.077	6.368
1936	7678	5587	0.004	0.909	1981	2355	2156	0.070	5.461
1937	7678	5569	0.006	1.255	1982	11401	2035	0.114	7.829
1938	7678	5543	0.004	0.817	1983	1731	1777	0.100	6.770
1939	7678	5531	0.007	1.462	1984	3449	1679	0.105	6.552
1940	7678	5504	0.009	1.834	1985	5636	1593	0.109	6.146
1941	7678	5469	0.001	0.122	1986	5339	1453	0.138	7.198
1942	7678	5485	0.001	0.139	1987	2646	1296	0.091	4.206
1943	7678	5500	0.001	0.156	1988	7233	1254	0.099	4.190
1944	7678	5513	0.001	0.172	1989	9233	1194	0.181	7.279
1945	7678	5526	0.006	1.180	1990	12314	1066	0.177	6.565
1946	7678	5509	0.001	0.257	1991	9009	1063	0.201	8.088
1947	7678	5518	0.002	0.403	1992	8184	1125	0.174	7.666
1948	7678	5522	0.004	0.870	1993	12283	1233	0.202	9.274
1949	7678	5512	0.005	0.903	1994	11069	1252	0.224	10.595
1950	7678	5501	0.008	1.589	1995	15415	1267	0.204	10.361
1951	7678	5472	0.010	1.784	1996	9226	1355	0.234	13.387
1952	7678	5423	0.011	2.084	1997	9129	1439	0.192	10.983
1953	7677	5347	0.013	2.286	1998	10913	1549	0.260	15.801
1954	7677	5253	0.014	2.419	1999	9196	1435	0.197	11.138
1955	7677	5151	0.015	2.621	2000	8820	1434	0.235	13.074
1956	7676	5040	0.015	2.589	2001	13433	1368	0.301	16.738
1957	7676	4930	0.018	2.915	2002	9271	1205	0.166	7.875
1958	7675	4811	0.020	3.134	2003	12450	1333	0.144	7.721
1959	7675	4682	0.023	3.607	2004	10900	1497	0.160	8.607
1960	7674	4528	0.025	3.833	2005	6520	1626	0.122	7.316
1961	7673	4360	0.031	4.575	2006	5135	1828	0.116	8.561
1962	7672	4173	0.036	5.216	2007	10451	1950	0.103	7.774
1963	7671	3988	0.029	3.866	2008	3568	1989	0.104	7.723
1964	7670	3869	0.033	4.366	2009	2571	2057	0.096	7.247
1965	7669	3751	0.039	5.110	2010	4592	2085	0.088	6.523
1966	7668	3631	0.046	5.844	2011	3753	1999	0.106	7.597
1967	7667	3512	0.050	6.181	2012	4971	1848	0.152	10.157
1968	7666	3398	0.048	5.649	2013	9894	1621	0.116	7.164
1969	7665	3303	0.044	5.023	2014	2277	1527	0.158	9.758
1970	7664	3228	0.049	5.475	2015	13670	1494	0.145	7.600
1971	7663	3148	0.041	4.324	2016	3300	1475	0.136	8.259
1972	14029	3109	0.051	5.186	2017	7935	1580	0.139	8.178
1973	4830	3042	0.080	8.937					
1974	5880	2973	0.057	6.116					

Table 5.2. Time series of SSB/MSST, SSB/$SSB_{SPR30\%}$, SSB/SSB_0 ,and F/MFMT for Gulf of Mexico King Mackerel, fishing year 1930-2017.

FY	SSB/MSST	SSB/$SSB_{SPR30\%}$	SSB/SSB_0	F/MFMT	FY	SSB/MSST	SSB/$SSB_{SPR30\%}$	SSB/SSB_0	F/MFMT
1930	3.99	3.29	1.00	0.04	1974	2.10	1.73	0.53	0.34
1931	3.96	3.27	0.99	0.02	1975	2.09	1.72	0.52	0.37
1932	3.95	3.26	0.99	0.02	1976	2.01	1.66	0.50	0.49
1933	3.94	3.26	0.99	0.00	1977	1.86	1.54	0.47	0.37
1934	3.95	3.26	0.99	0.02	1978	1.74	1.44	0.44	0.37
1935	3.94	3.25	0.99	0.00	1979	1.66	1.37	0.42	0.45
1936	3.94	3.26	0.99	0.03	1980	1.58	1.31	0.40	0.46
1937	3.93	3.25	0.99	0.04	1981	1.52	1.26	0.38	0.42
1938	3.91	3.23	0.98	0.02	1982	1.44	1.19	0.36	0.68
1939	3.91	3.23	0.98	0.04	1983	1.25	1.04	0.31	0.60
1940	3.89	3.21	0.98	0.05	1984	1.19	0.98	0.30	0.63
1941	3.86	3.19	0.97	0.00	1985	1.12	0.93	0.28	0.65
1942	3.87	3.20	0.97	0.00	1986	1.03	0.85	0.26	0.83
1943	3.88	3.21	0.97	0.00	1987	0.92	0.76	0.23	0.55
1944	3.89	3.22	0.98	0.01	1988	0.89	0.73	0.22	0.59
1945	3.90	3.22	0.98	0.04	1989	0.84	0.70	0.21	1.09
1946	3.89	3.21	0.98	0.01	1990	0.75	0.62	0.19	1.06
1947	3.90	3.22	0.98	0.01	1991	0.75	0.62	0.19	1.20
1948	3.90	3.22	0.98	0.03	1992	0.79	0.66	0.20	1.04
1949	3.89	3.21	0.98	0.03	1993	0.87	0.72	0.22	1.21
1950	3.88	3.21	0.97	0.05	1994	0.88	0.73	0.22	1.34
1951	3.86	3.19	0.97	0.06	1995	0.89	0.74	0.22	1.22
1952	3.83	3.16	0.96	0.07	1996	0.96	0.79	0.24	1.40
1953	3.78	3.12	0.95	0.08	1997	1.02	0.84	0.25	1.15
1954	3.71	3.06	0.93	0.08	1998	1.09	0.90	0.27	1.56
1955	3.64	3.00	0.91	0.09	1999	1.01	0.84	0.25	1.18
1956	3.56	2.94	0.89	0.09	2000	1.01	0.84	0.25	1.41
1957	3.48	2.88	0.87	0.11	2001	0.97	0.80	0.24	1.80
1958	3.40	2.81	0.85	0.12	2002	0.85	0.70	0.21	0.99
1959	3.31	2.73	0.83	0.14	2003	0.94	0.78	0.24	0.86
1960	3.20	2.64	0.80	0.15	2004	1.06	0.87	0.27	0.96
1961	3.08	2.54	0.77	0.18	2005	1.15	0.95	0.29	0.73
1962	2.95	2.43	0.74	0.22	2006	1.29	1.07	0.32	0.70
1963	2.82	2.33	0.71	0.17	2007	1.38	1.14	0.35	0.62
1964	2.73	2.26	0.69	0.20	2008	1.40	1.16	0.35	0.62
1965	2.65	2.19	0.66	0.23	2009	1.45	1.20	0.36	0.58
1966	2.56	2.12	0.64	0.28	2010	1.47	1.22	0.37	0.53
1967	2.48	2.05	0.62	0.30	2011	1.41	1.17	0.35	0.63
1968	2.40	1.98	0.60	0.29	2012	1.31	1.08	0.33	0.91
1969	2.33	1.93	0.59	0.26	2013	1.14	0.95	0.29	0.70
1970	2.28	1.88	0.57	0.29	2014	1.08	0.89	0.27	0.95
1971	2.22	1.84	0.56	0.24	2015	1.05	0.87	0.26	0.87
1972	2.20	1.81	0.55	0.31	2016	1.04	0.86	0.26	0.81
1973	2.15	1.77	0.54	0.48	2017	1.12	0.92	0.28	0.83

Table 5.3. Comparison of selected benchmarks and metrics from SEDAR 38 to SEDAR 38 Update for Gulf of Mexico king mackerel.

Metric	SEDAR 38	SEDAR 38U
Spawning Stock Biomass Unfished (bil. eggs)	4,130	5,644
Total Biomass Unfished (mil. lbs.)	147	205
Recruitment (age 0 fish) unfished (1000s)	5,069	7,679
Spawning Stock Biomass at SPR30% (bil. eggs)	1,224	1,714
MSST ((1-M)*SSB at SPR30%)	1,011	1,416
Fishing Mortality at SPR30%	0.16	0.17
Retained Yield (landings) at SPR30% (mil. lbs.)	8.09	11.51

Table 5.4. Summary of benchmarks and stock status of Gulf of Mexico king mackerel. Fishing mortality is exploitation rate in biomass, spawning stock biomass is in billions of eggs, and recruitment is in thousands of age 0 fish. Yield values are in millions of pounds.

Metric	Value/Determination
Assessment Year	2020
Data Range in Fishing Years (July 1-June 30)	1930 to 2017
Fishing mortality$_{2017}$	0.14
Fishing mortality$_{MFMT}$	0.17
F_{2017}/MFMT	0.83
80% Confidence Interval of F_{2017}/F_{MFMT}	0.68 to 0.98
Recruitment$_{Unfished}$	7,678,550
Recruitment$_{2017}$	7,934,500
Spawning Stock Biomass$_{Unfished}$	5,644
Spawning Stock Biomass at SPR30%	1,714
Spawning Stock Biomass$_{MSST}$	1,416
Spawning Stock Biomass$_{2017}$	1,580
SSB_{2017}/MSST	1.12
80% Confidence Interval of SSB_{2017}/MSST	0.98 to 1.26
Yield 2017 (mil lbs)	8.18
Retained Yield @ F_{MFMT} (mil lbs)	11.51
Optimum Yield @ 85% of F_{MFMT} (mil lbs)	10.82
Stock Status	Not Overfished
Fishery Status	Not Overfishing

Table 5.5. Landings (retained catch) and SSB/MSST by year when fishing at $F_{Current}$ and F_{MFMT} , and F_{OY}, where F_{OY} is 85% of F_{MFMT} with a P* = 0.5. Equilibrium are landings when fishing at each level.

	Fcurrent		FMFMT		FOY	
Fish. Year	**Landings**	**SSB/MSST**	**Landings**	**SSB/MSST**	**Landings**	**SSB/MSST**
2021	11.34	1.14	10.89	1.14	9.37	1.14
2022	11.43	1.14	11.05	1.15	9.72	1.18
2023	11.50	1.15	11.18	1.17	9.99	1.22
2024	11.55	1.15	11.27	1.18	10.20	1.25
2025	11.59	1.15	11.33	1.19	10.35	1.28
2026	11.61	1.16	11.38	1.19	10.47	1.30
2027	11.63	1.16	11.41	1.20	10.56	1.32
2028	11.64	1.16	11.44	1.20	10.62	1.33
2029	11.65	1.16	11.46	1.20	10.67	1.34
2030	11.66	1.16	11.47	1.21	10.71	1.34
Equilibrium	11.68	1.16	11.51	1.21	10.83	1.36

Table 5.6. Projected retained yield (mt) with 80% confidence intervals, ABC (mt), OFL (million lbs) and ABC (million lbs) for fishing at $F_{SPR30\%}$ and P* = 0.43 for Gulf of Mexico King Mackerel.

P* = 0.43 YEAR	LCI	Retained Yield (mt)	UCI	ABC in MT	OFL (million lbs)	ABC (million lbs)
2018		**5196**				
2019		**5096**				
2020		**5104**				
2021	3559	4941	6323	4751	10.89	10.47
2022	3523	5014	6504	4809	11.05	10.60
2023	3524	5070	6617	4857	11.18	10.71
2024	3535	5111	6687	4894	11.27	10.79
2025	3548	5141	6733	4921	11.33	10.85
2026	3560	5162	6765	4942	11.38	10.89
2027	3569	5178	6786	4956	11.41	10.93
2028	3577	5189	6801	4967	11.44	10.95
2029	3584	5198	6812	4976	11.46	10.97
2030	3589	5204	6820	4982	11.47	10.98

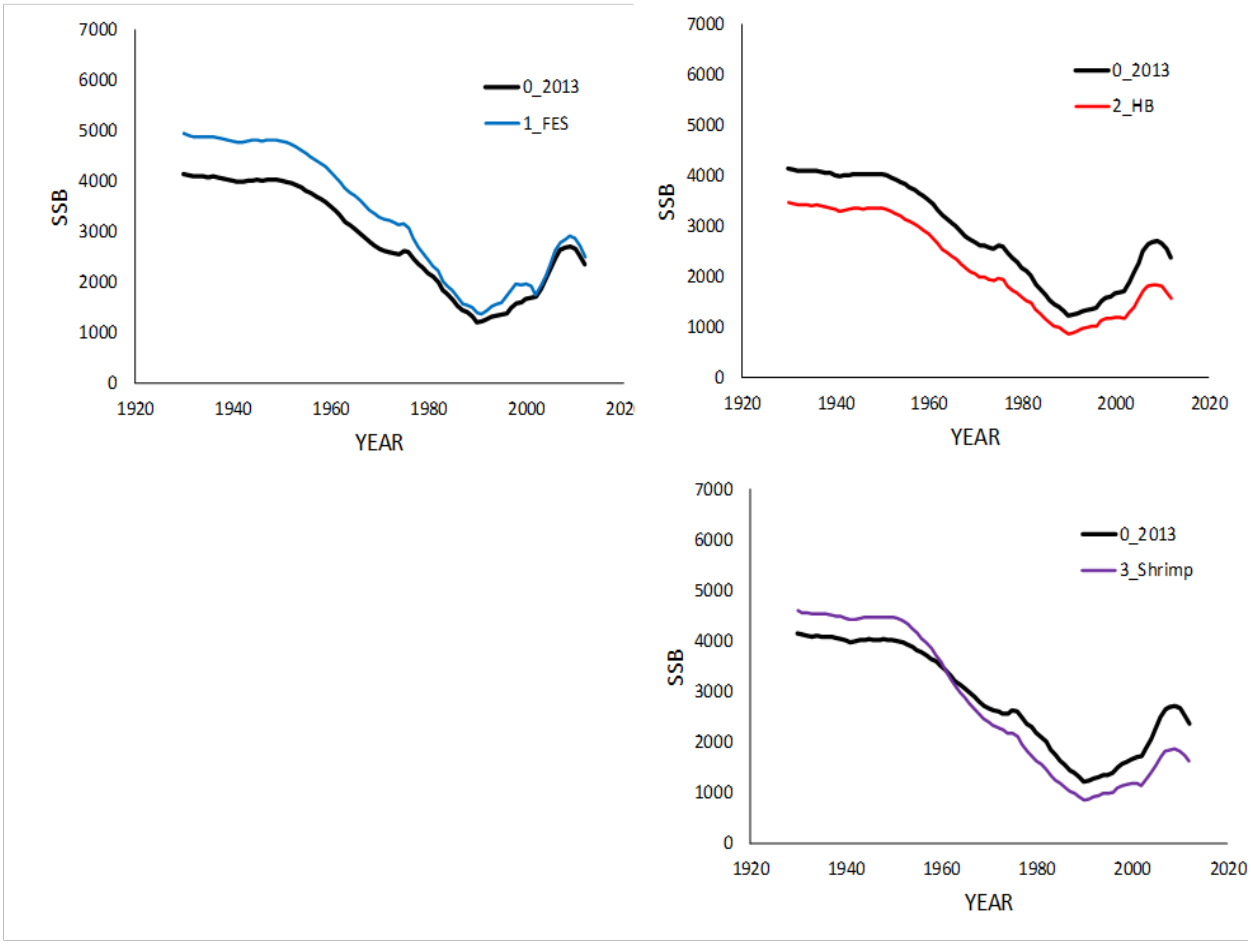

Figure 5.1. Effect of swopping out the updated observational data in isolation of each other. Each data set, and only that one data set, were replaced one at a time to examine the effects of each set had on the trend in spawning stock biomass (measured in billions of eggs). All fits used an ending year of 2012. Black line represents the trend from SEDAR 38.

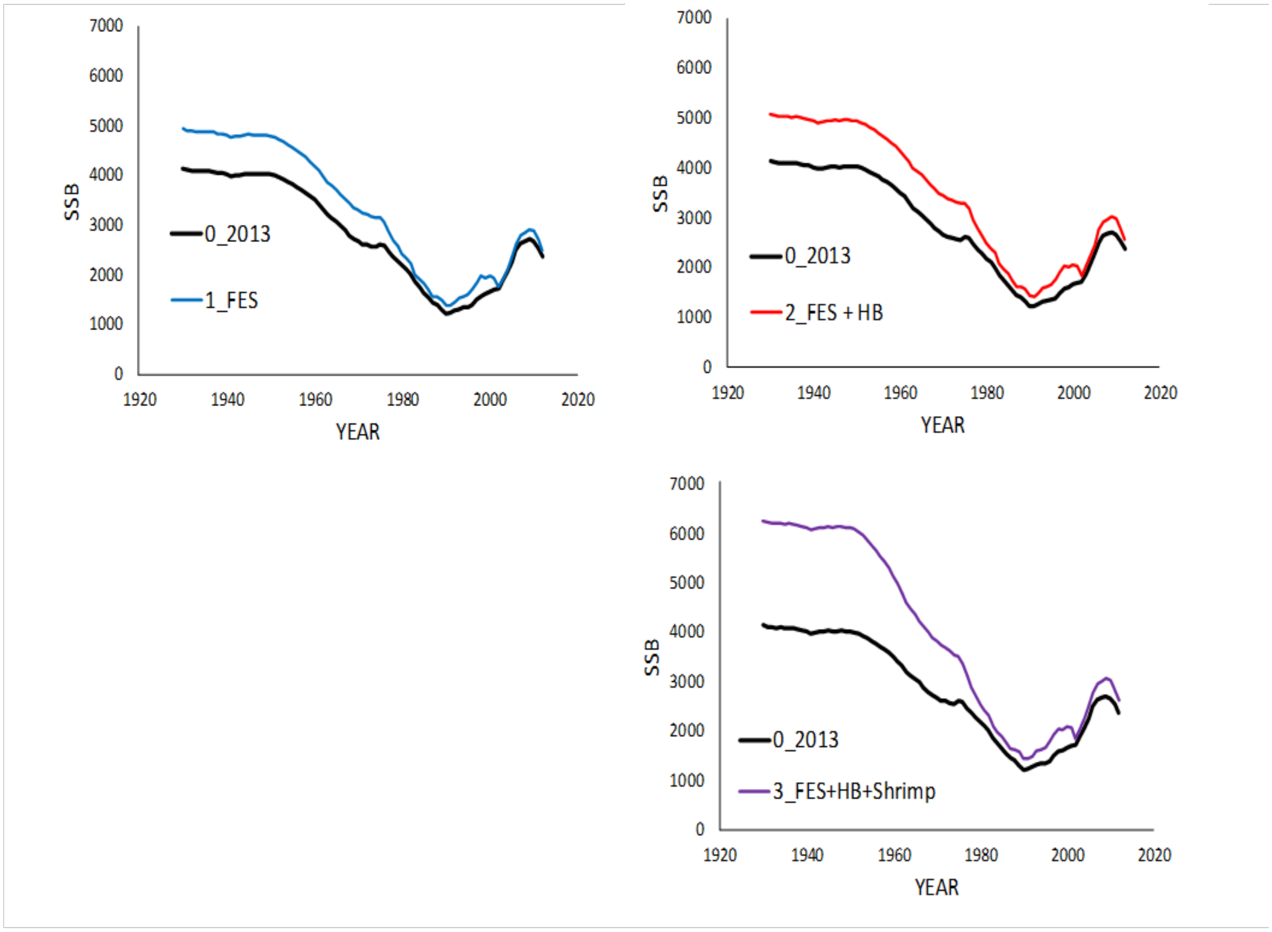

Figure 5.2. Effect of the cumulative adding the updated observational data in isolation of each other. Each data set, and only that one data set, were replaced one at a time to examine the effects of each set had on the trend in spawning stock biomass, measured in billions of eggs. All fits used an ending year of 2012.

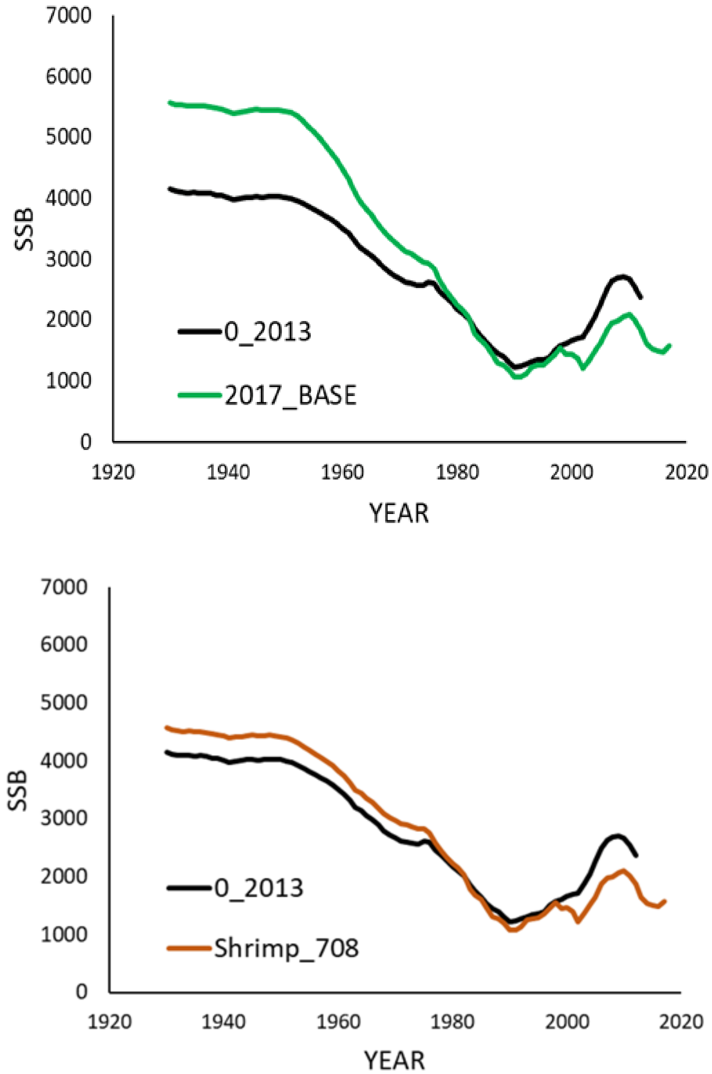

Figure 5.3. Trend in spawning stock biomass from SEDAR 38 (black line) and base model from this update (green line) (top). Trend in spawning stock biomass (measured in billions of eggs) from SEDAR 38 and the base model from this update using the SEDAR 38 median shrimp bycatch estimate (708 thousand age 0 fish, orange line).

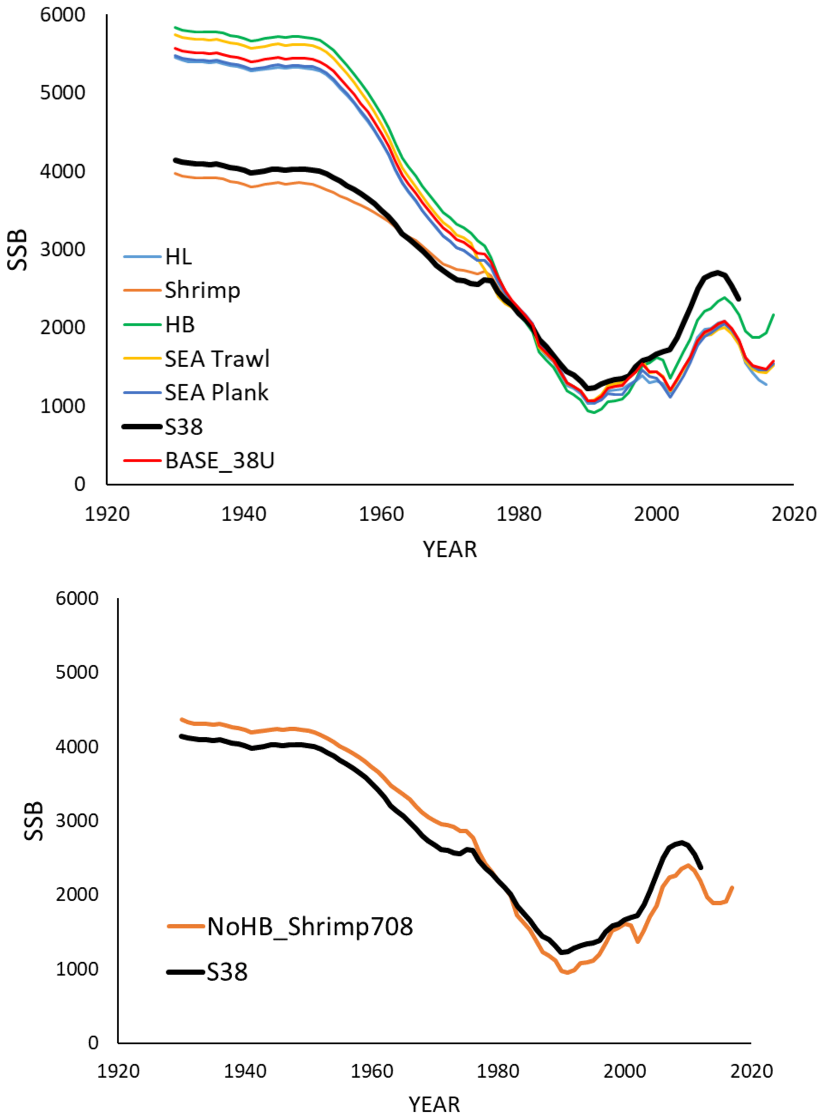

Figure 5.4. Jack-knife analysis of SEDAR 38 update by removing one index of abundance at a time. Trend in spawning stock biomass (measured in billions of eggs) from SEDAR 38 (black line) and base model from this update (red line) (top). Trend in spawning stock biomass from SEDAR 38 and the base model from this update using the SEDAR 38 shrimp median and excluding the headboat index of abundance (NoHB_Shrimp708).

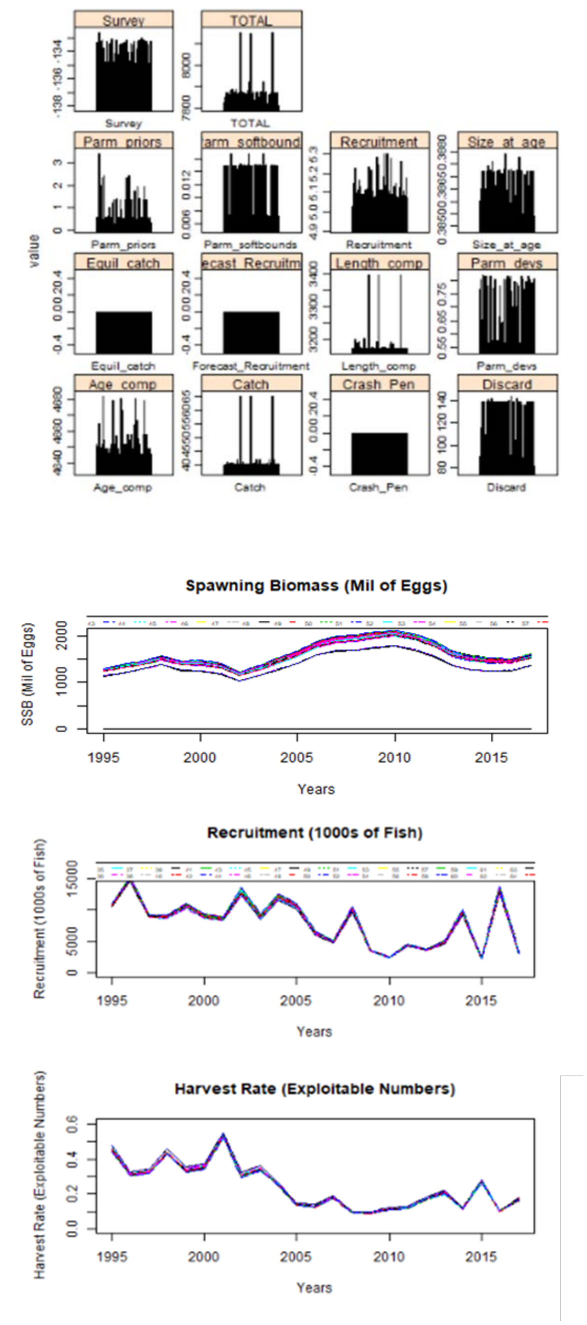

Figure 5.5. Distribution of jitter analysis by parameter (top); trends in spawning stock biomass, recruitment and exploitation from jitter analysis (bottom) Gulf of Mexico king mackerel.

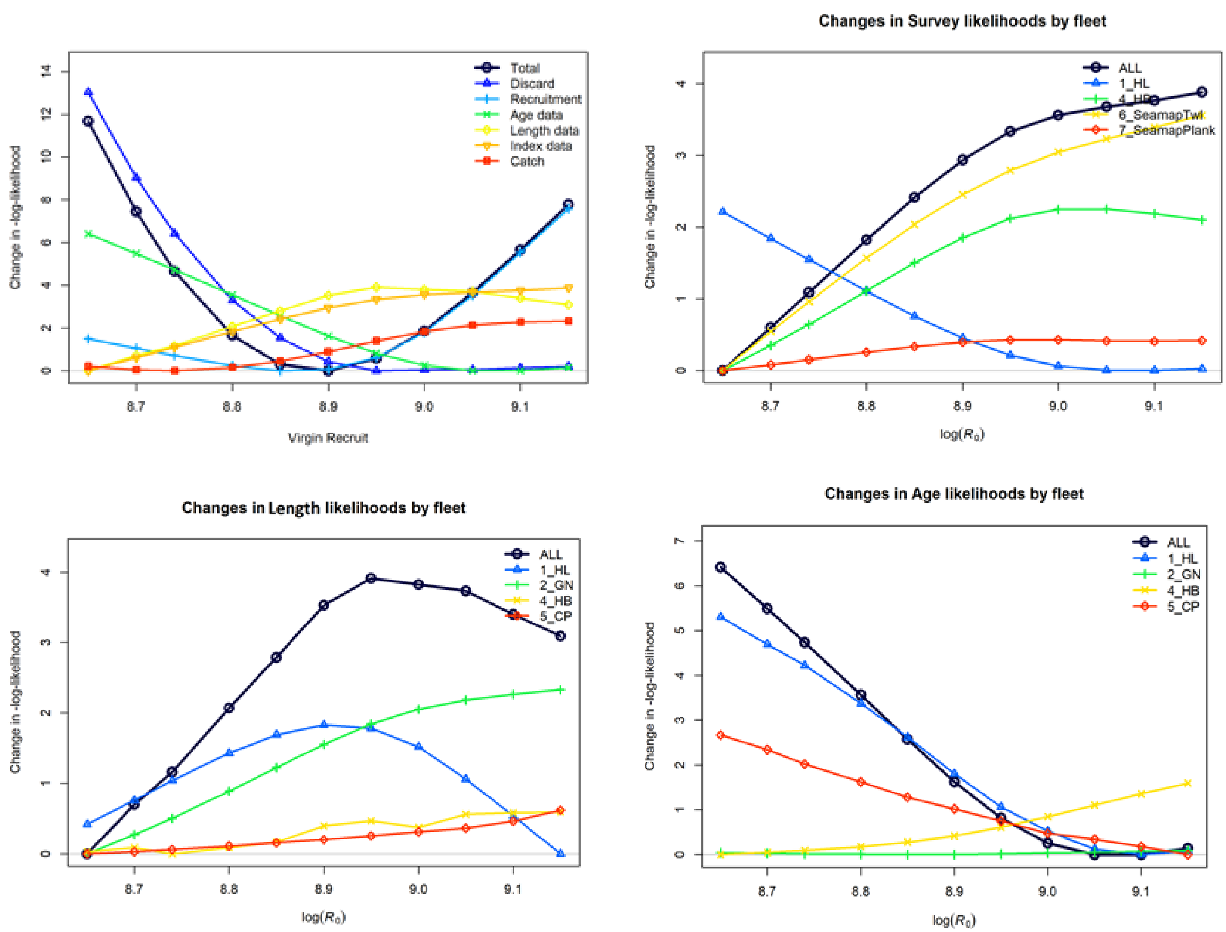

Figure 5.6. Profile analysis on virgin recruitment (R0). Total likelihood (upper left); by individual survey (upper right); by fleets length composition (lower left); and by ages data (lower right) for Gulf of Mexico king mackerel.

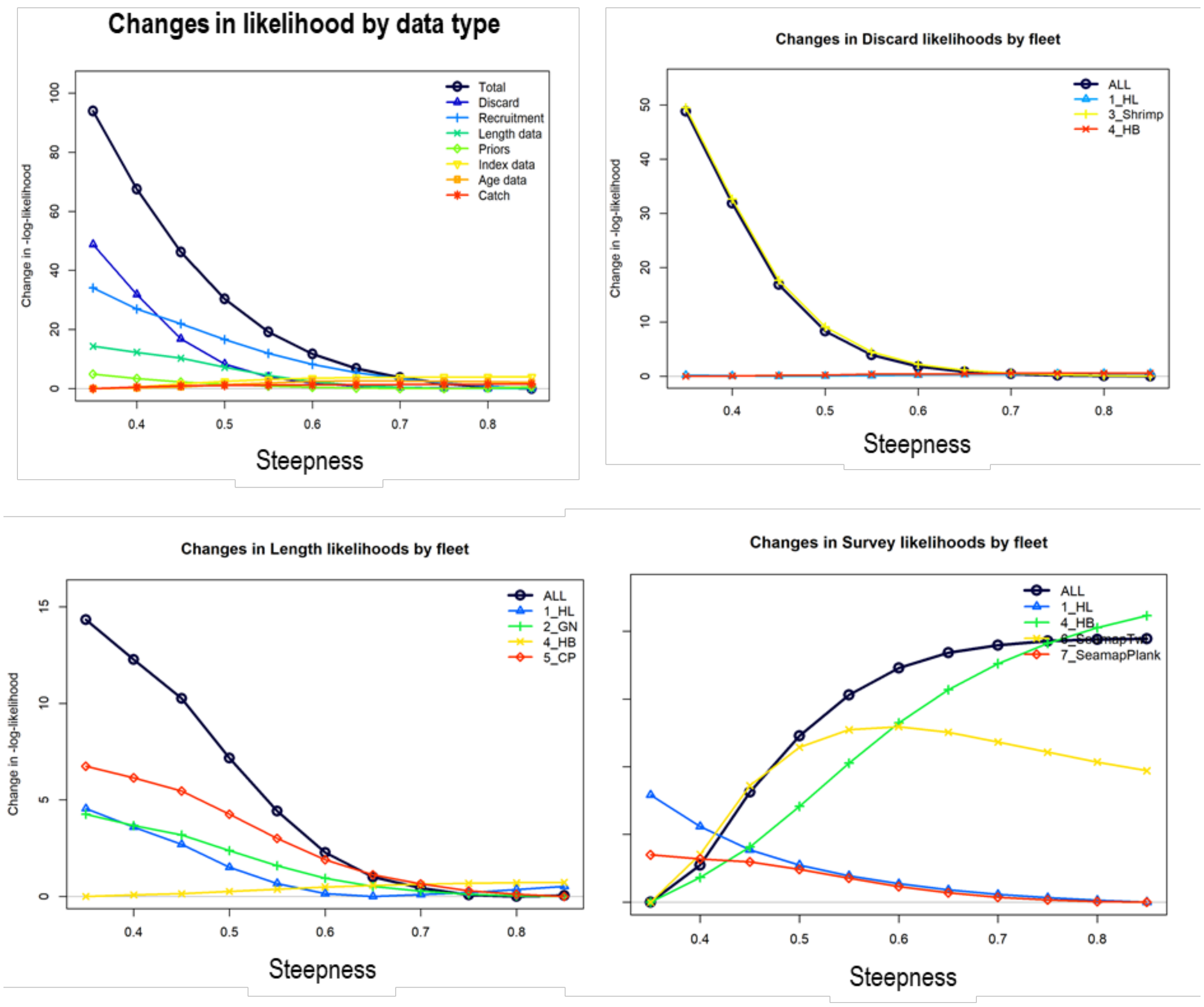

Figure 5.7. Profile analysis on steepness. Total likelihood (upper left); by individual discards (upper right); by fleets length composition (lower left); and by ages data (lower right) for Gulf of Mexico king mackerel.

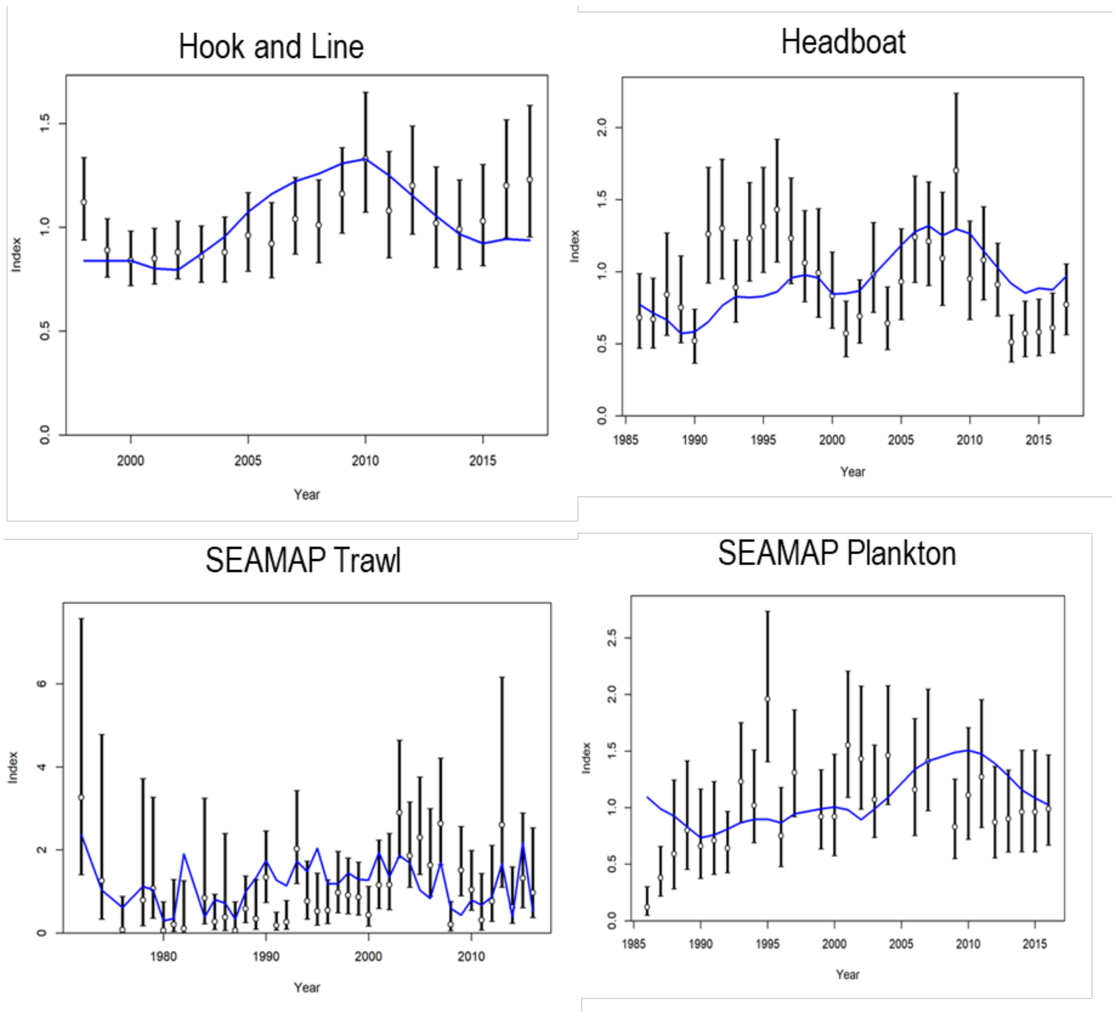

Figure 5.8. Fit indices of abundance used for the updated assessment of Gulf of Mexico king mackerel

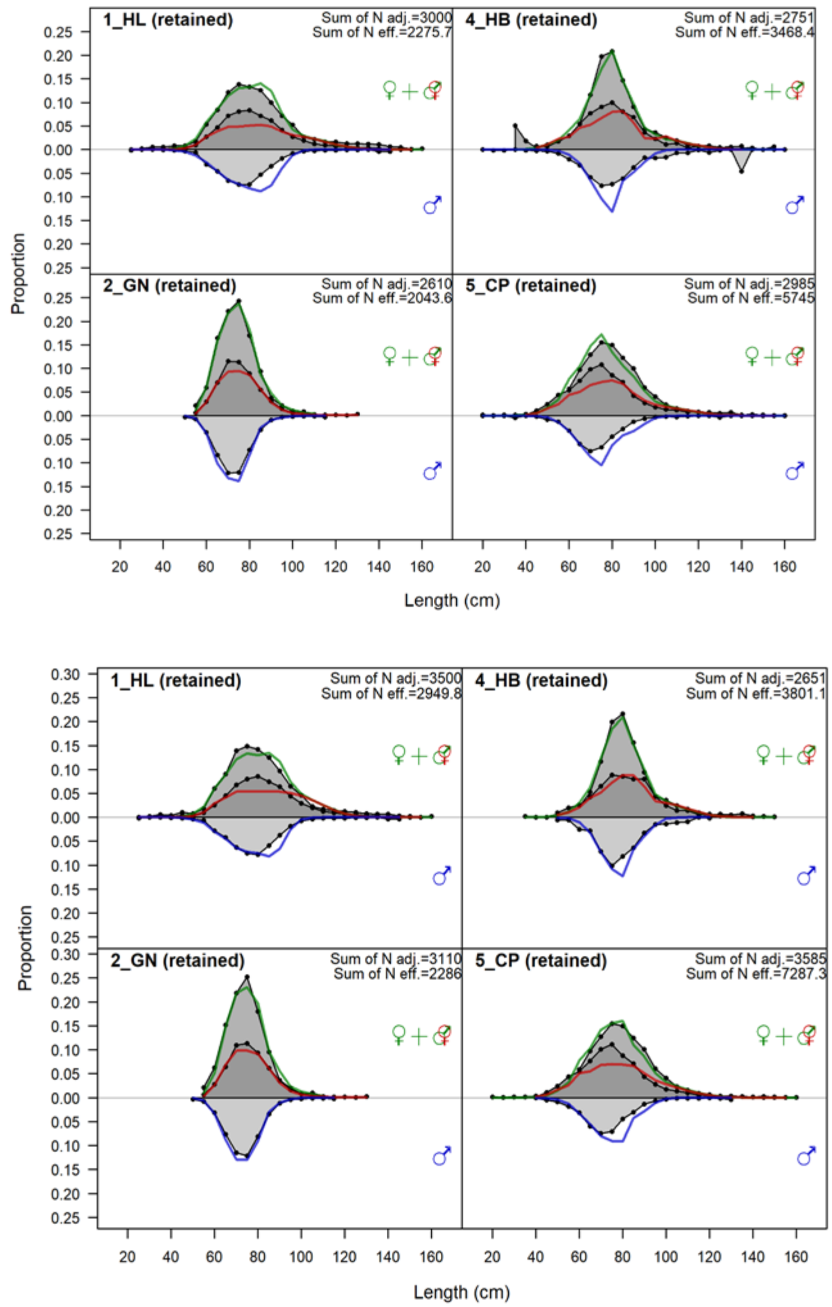

Figure 5.9. Fit length compositions from S38 (top) and S38U (bottom) for Gulf of Mexico king mackerel males (blue) and females (red).

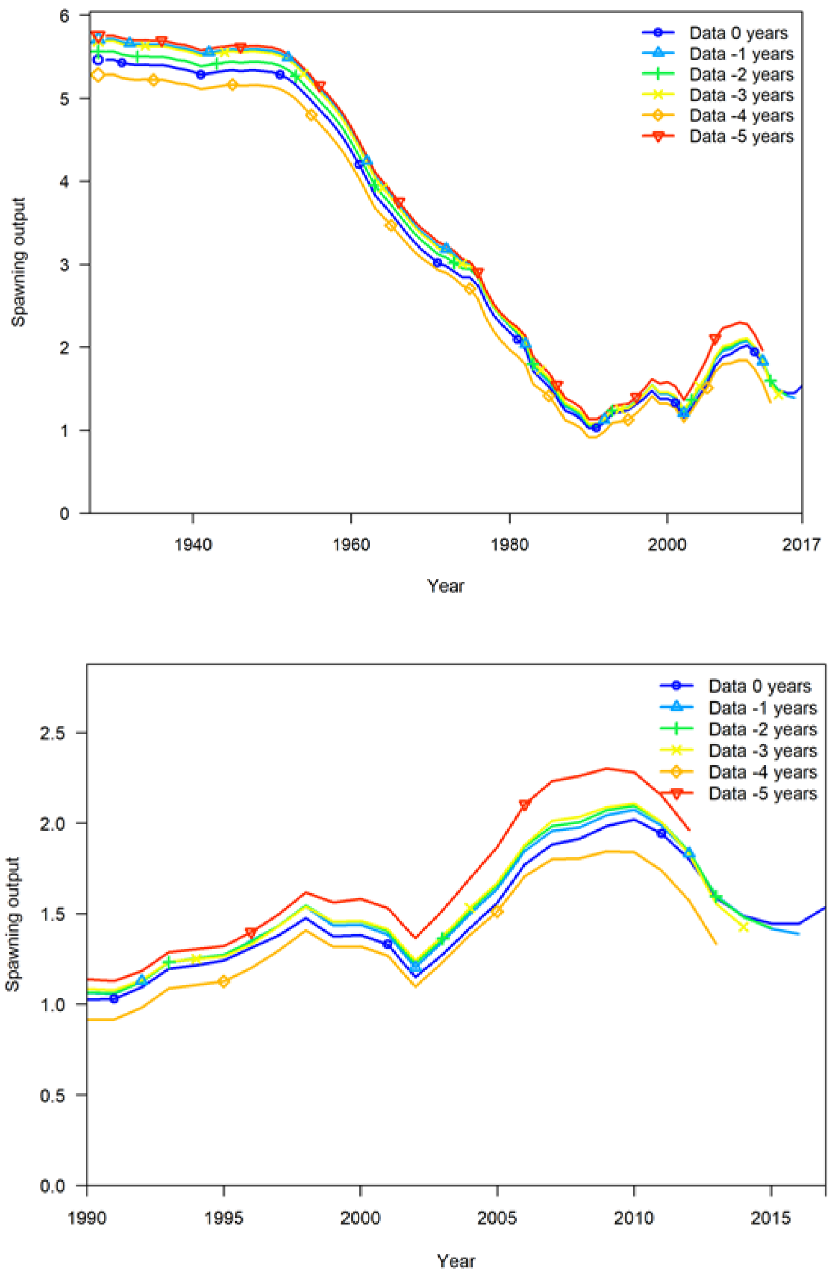

Figure 5.10. Spawning output (billions of eggs) from retrospective analysis using a 5-year retrospect for the years 1930-2017 (top) and a zoom in on the same information for the last 17 years (1990-2017) for Gulf of Mexico king mackerel.

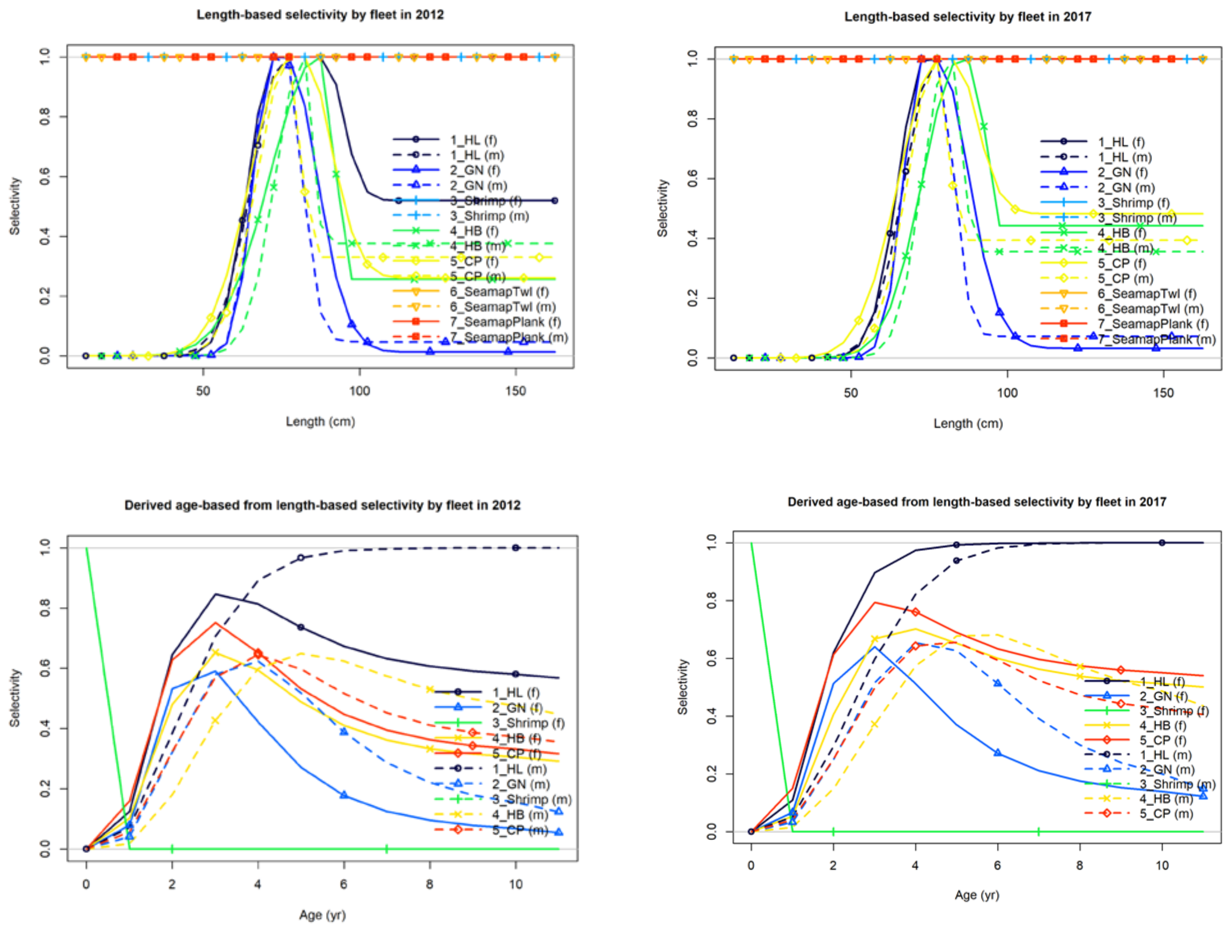

Figure 5.11. Estimated length based selectivity by gear and sex from S38 (top, left) and S38U (top right); derived age based selectivity by gear and sex from S38 (bottom, left) and S38U (bottom right) for Gulf of Mexico king mackerel.

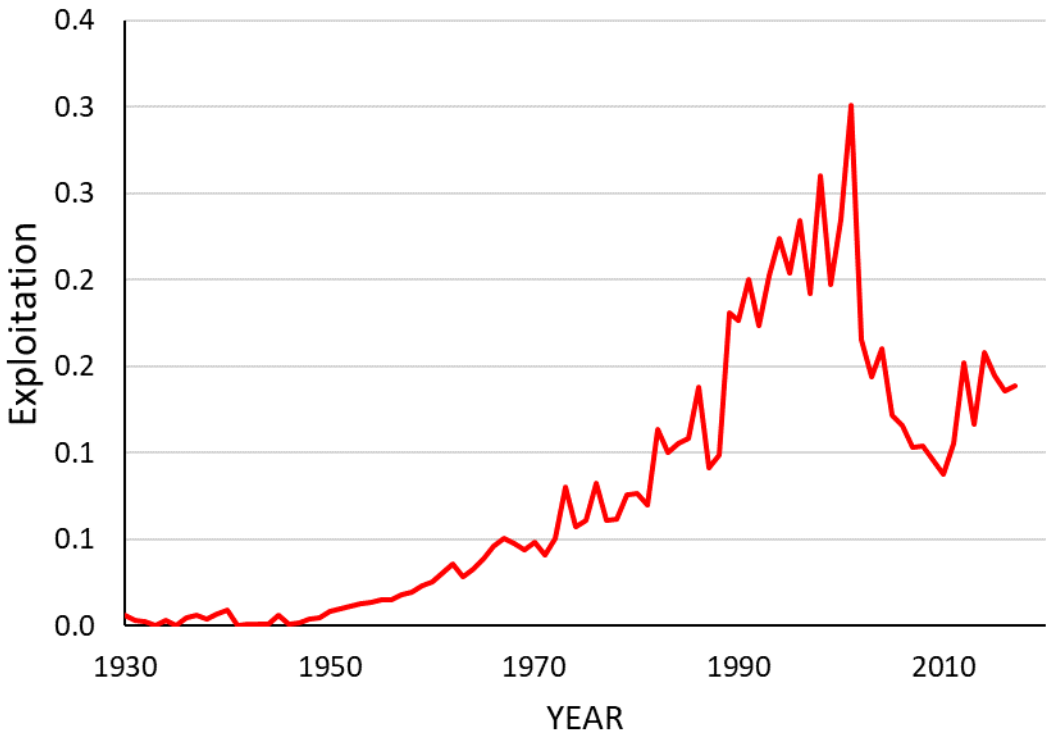

Figure 5.12. Estimated exploitation rate Gulf of Mexico king mackerel.

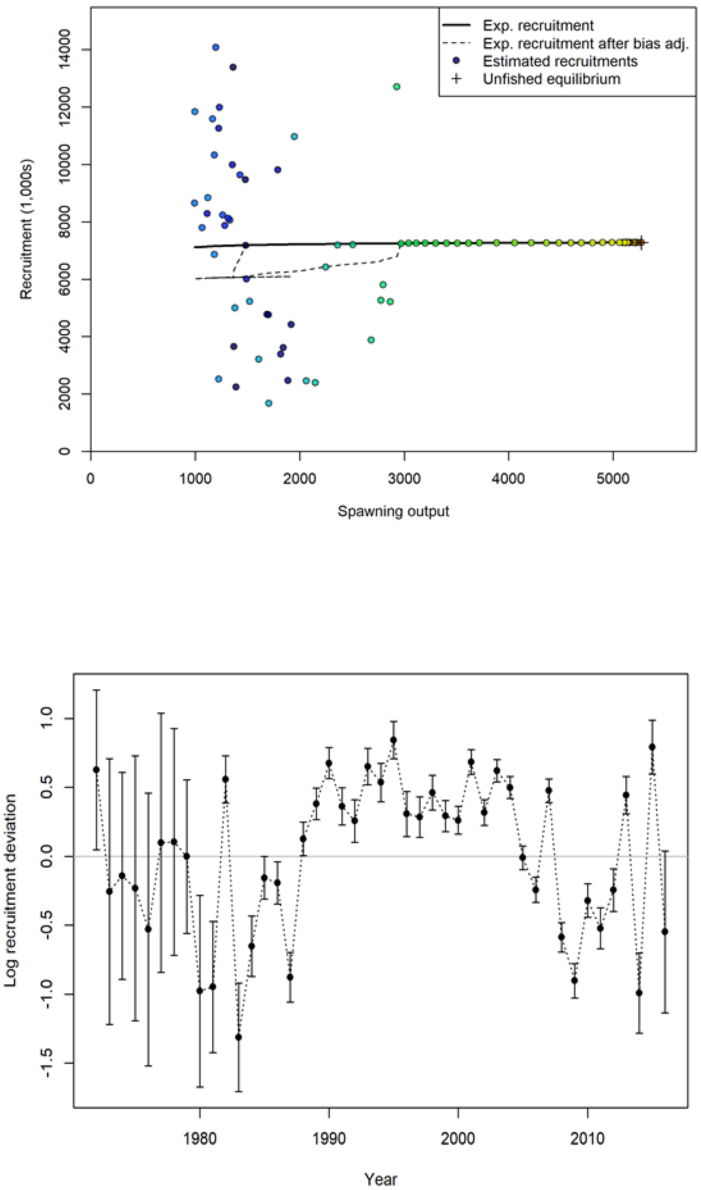

Figure 5.13. Estimated spawning stock/recruitment points and assumed relation (top); annual recruitment deviations and approximate 95% confidence intervals (bottom) for Gulf of Mexico king mackerel.

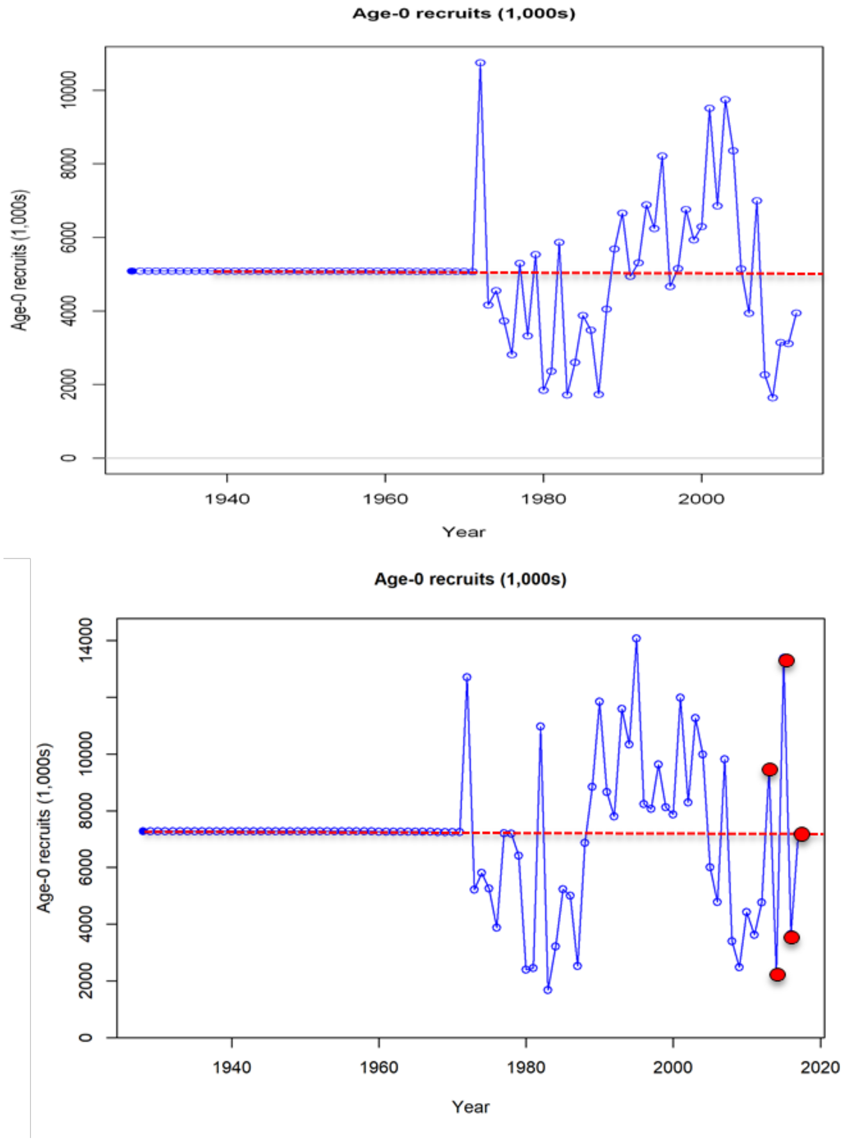

Figure 5.14. Estimated recruitment (age_0) fish from SEDAR 38 (top) and this SEDAR38 update for Gulf of Mexico king mackerel. Larger terminal markers are the recruitment estimates since SEDAR 38.

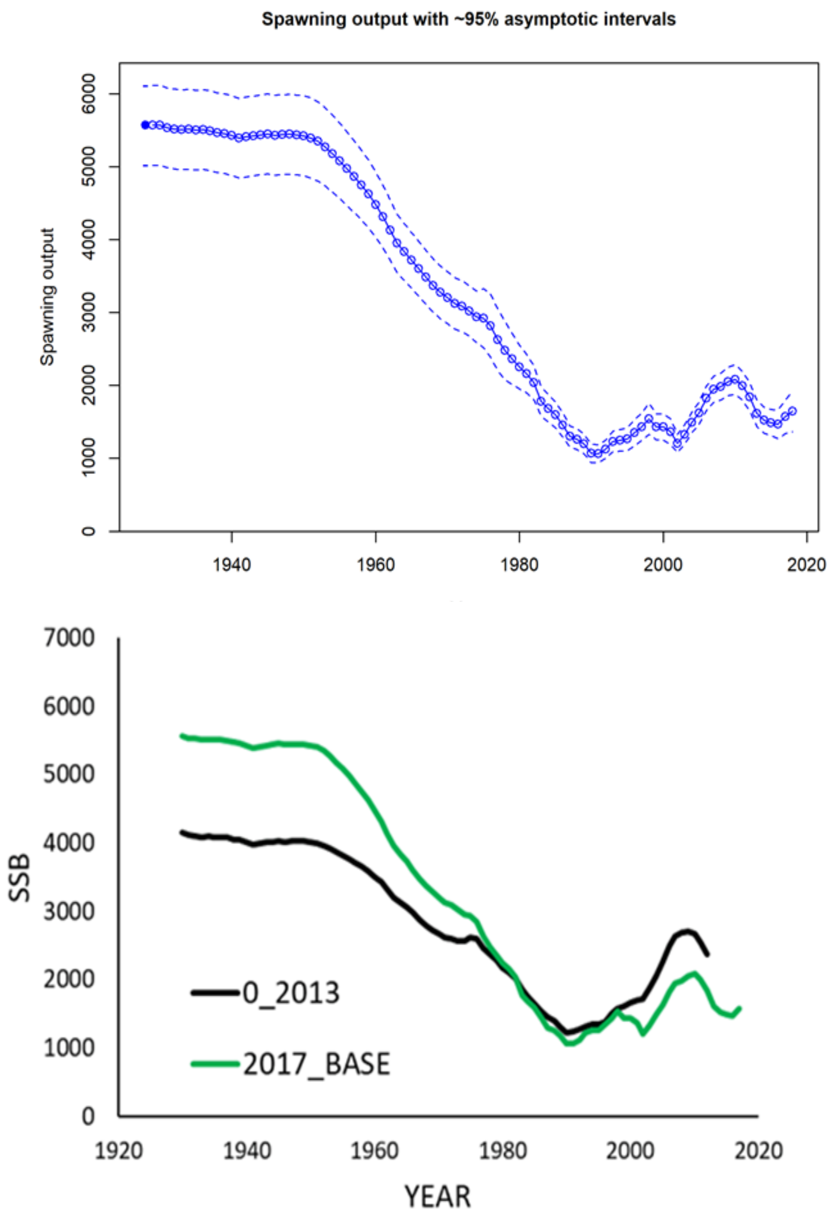

Figure 5.15. Estimated spawning output (mt) from SEDAR 38 (top) and this SEDAR38 update for Gulf of Mexico king mackerel. Note that black horizontal line is only an arbitrary reference point to aid between graph comparisons only and have no management implications.

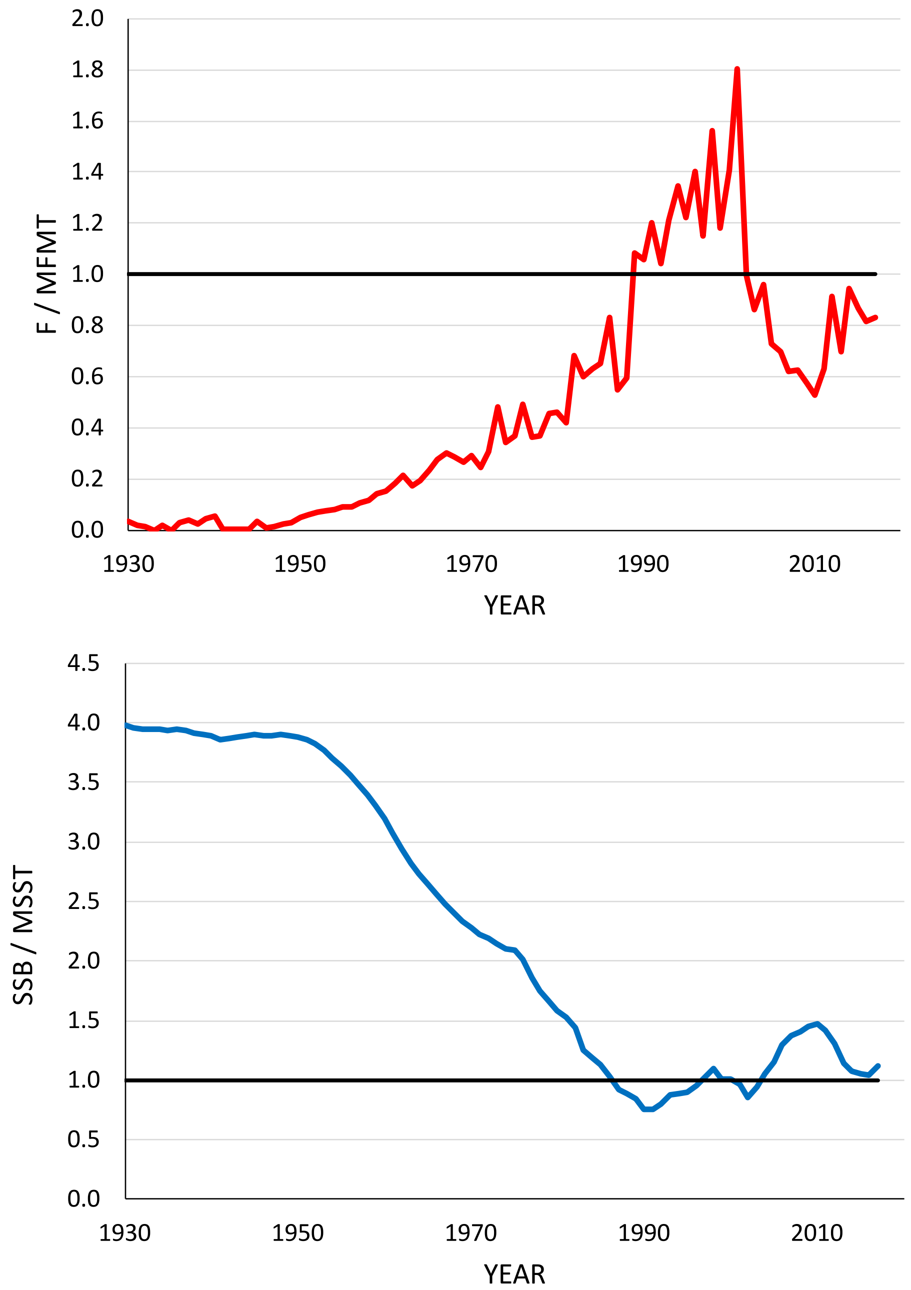

Figure 5.16 Estimated trends F/F_{MFMT} (top) and SSB/MSST (bottom) for Gulf of Mexico king mackerel, 1930-2017 measured as spawning output (in billions of eggs) relative to the Minimum Spawning Stock Threshold ((1-M)*SSB at SPR30%) and F relative to MFMT (F at SPR30%).

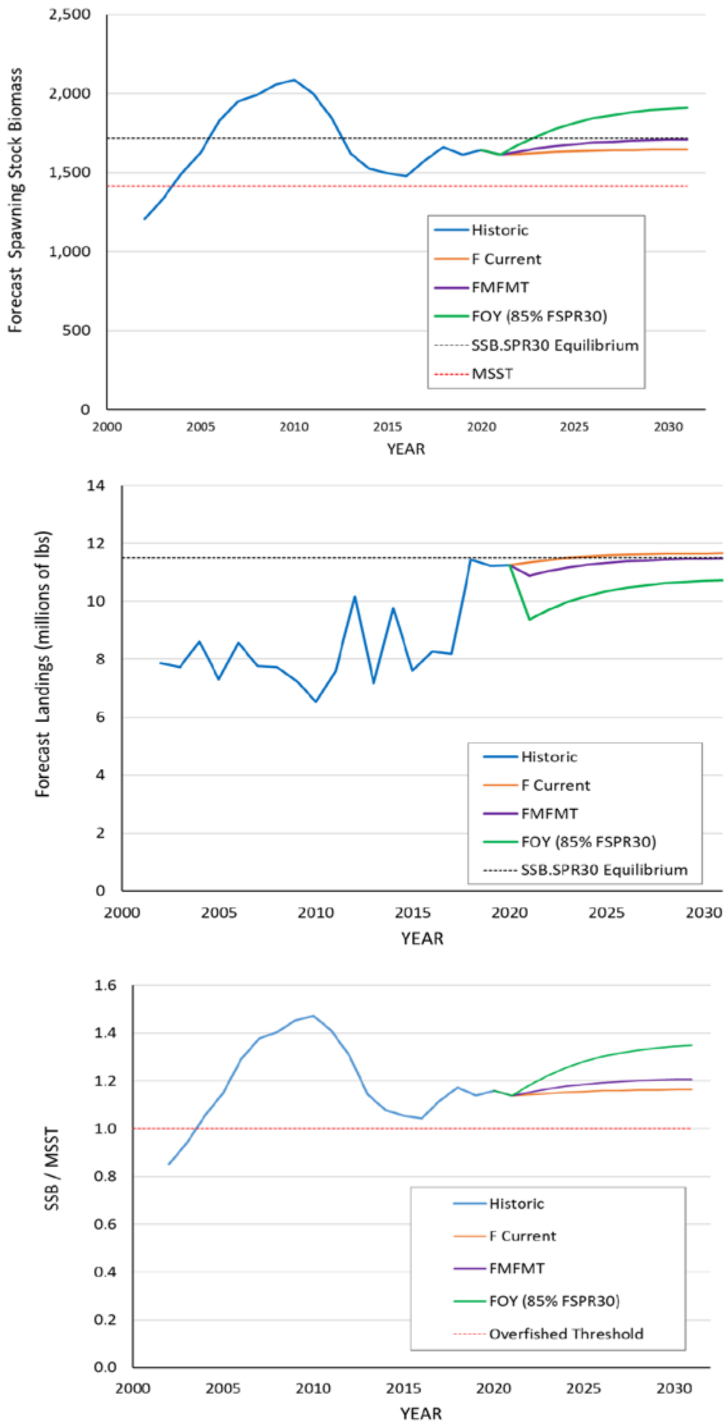

Figure 5.17. Forecasts of spawning stock biomass (in billions of eggs) (top), landings (middle) and SSB/MFFT under $F_{Current}$, F_{MFMT}, and F_{OY} (85% of F_{MFMT}). Black dotted line is equilibrium spawning stock biomass at F_{MFMT} , red line is MSST (top); black line is equilibrium yield at SPR30 (middle); red line is MFMT (bottom). Forecasts of landings (bottom) under $F_{Current}$, F_{MFMT}, and F_{OY} (85% of F_{SPR30}). All forecasts are made assuming fishing at each of the respective the Overfishing Limit (OFL).

APPENDIX I

Parameter value definitions, estimates, standard deviations and CV's for base model

Label	Value	Phase	Min	Max	Init	Status	Parm_SDv	Parm_CV
L_at_Amin_Fem_GP_1	21.000	-3	10.00	80.00	21.00	NA	_	_
L_at_Amax_Fem_GP_1	107.357	3	100.00	150.00	112.03	OK	0.416	0.004
VonBert_K_Fem_GP_1	0.383	4	0.10	0.50	0.37	OK	0.005	0.013
CV_young_Fem_GP_1	0.268	6	0.01	0.30	0.27	OK	0.005	0.019
CV_old_Fem_GP_1	0.100	6	0.01	0.30	0.10	OK	0.002	0.016
L_at_Amin_Mal_GP_1	21.000	-3	10.00	80.00	21.00	NA	_	_
L_at_Amax_Mal_GP_1	92.435	3	70.00	120.00	93.11	OK	0.238	0.003
VonBert_K_Mal_GP_1	0.356	4	0.10	0.70	0.38	OK	0.005	0.013
CV_young_Mal_GP_1	0.375	6	0.01	0.50	0.35	OK	0.007	0.018
CV_old_Mal_GP_1	0.045	6	0.01	0.30	0.06	OK	0.001	0.028
Wtlen_1_Fem	0.000	-2	0.00	1.00	0.00	NA	_	_
Wtlen_2_Fem	3.008	-2	0.00	4.00	3.01	NA	_	_
Mat50%_Fem	58.114	-3	0.00	0.00	58.11	NA	_	_
Mat_slope_Fem	-0.369	-3	-3.00	3.00	-0.37	NA	_	_
Eggs_scalar_Fem	0.000	-3	-3.00	3.00	0.00	NA	_	_
Eggs_exp_len_Fem	3.051	-3	-3.00	3.00	3.05	NA	_	_
Wtlen_1_Mal	0.000	-2	0.00	1.00	0.00	NA	_	_
Wtlen_2_Mal	3.008	-2	0.00	4.00	3.01	NA	_	_
RecrDist_GP_1	0.000	-4	0.00	0.00	0.00	NA	_	_
RecrDist_Area_1	0.000	-4	0.00	0.00	0.00	NA	_	_
RecrDist_Seas_1	0.000	-4	0.00	0.00	0.00	NA	_	_
CohortGrowDev	0.000	-4	0.00	0.00	0.00	NA	_	_
SR_LN(R0)	8.933	1	3.00	20.00	8.61	OK	0.053	0.006
SR_BH_steep	0.990	-2	0.20	1.00	0.99	NA	_	_
SR_sigmaR	0.676	4	0.00	2.00	0.60	OK	0.089	0.132
SR_envlink	0.000	-3	-5.00	5.00	0.00	NA	_	_
SR_R1_offset	0.000	-4	-5.00	5.00	0.00	NA	_	_
SR_autocorr	0.000	-99	0.00	0.00	0.00	NA	_	_
Main_RecrDev_1972	0.690	_	_	_	_	act	0.304	0.441
Main_RecrDev_1973	-0.328	_	_	_	_	act	0.560	1.709
Main_RecrDev_1974	-0.141	_	_	_	_	act	0.412	2.930
Main_RecrDev_1975	-0.282	_	_	_	_	act	0.562	1.992
Main_RecrDev_1976	-0.653	_	_	_	_	act	0.579	0.887
Main_RecrDev_1977	0.169	_	_	_	_	act	0.528	3.129
Main_RecrDev_1978	0.068	_	_	_	_	act	0.463	6.778
Main_RecrDev_1979	0.006	_	_	_	_	act	0.289	45.224
Main_RecrDev_1980	-1.083	_	_	_	_	act	0.386	0.357
Main_RecrDev_1981	-1.026	_	_	_	_	act	0.253	0.246

Main_RecrDev_1982	0.557	_	_	_	_	act	0.088	0.158
Main_RecrDev_1983	-1.319	_	_	_	_	act	0.206	0.156
Main_RecrDev_1984	-0.625	_	_	_	_	act	0.112	0.179
Main_RecrDev_1985	-0.127	_	_	_	_	act	0.079	0.618
Main_RecrDev_1986	-0.175	_	_	_	_	act	0.078	0.447
Main_RecrDev_1987	-0.868	_	_	_	_	act	0.093	0.107
Main_RecrDev_1988	0.142	_	_	_	_	act	0.063	0.444
Main_RecrDev_1989	0.388	_	_	_	_	act	0.060	0.154
Main_RecrDev_1990	0.676	_	_	_	_	act	0.059	0.087
Main_RecrDev_1991	0.364	_	_	_	_	act	0.070	0.193
Main_RecrDev_1992	0.267	_	_	_	_	act	0.080	0.301
Main_RecrDev_1993	0.673	_	_	_	_	act	0.068	0.102
Main_RecrDev_1994	0.570	_	_	_	_	act	0.073	0.127
Main_RecrDev_1995	0.902	_	_	_	_	act	0.070	0.078
Main_RecrDev_1996	0.386	_	_	_	_	act	0.085	0.220
Main_RecrDev_1997	0.374	_	_	_	_	act	0.077	0.206
Main_RecrDev_1998	0.551	_	_	_	_	act	0.068	0.123
Main_RecrDev_1999	0.383	_	_	_	_	act	0.062	0.161
Main_RecrDev_2000	0.341	_	_	_	_	act	0.054	0.159
Main_RecrDev_2001	0.762	_	_	_	_	act	0.049	0.064
Main_RecrDev_2002	0.393	_	_	_	_	act	0.051	0.129
Main_RecrDev_2003	0.689	_	_	_	_	act	0.045	0.065
Main_RecrDev_2004	0.557	_	_	_	_	act	0.044	0.079
Main_RecrDev_2005	0.045	_	_	_	_	act	0.047	1.050
Main_RecrDev_2006	-0.194	_	_	_	_	act	0.049	0.253
Main_RecrDev_2007	0.517	_	_	_	_	act	0.046	0.089
Main_RecrDev_2008	-0.558	_	_	_	_	act	0.056	0.101
Main_RecrDev_2009	-0.886	_	_	_	_	act	0.065	0.073
Main_RecrDev_2010	-0.331	_	_	_	_	act	0.062	0.187
Main_RecrDev_2011	-0.561	_	_	_	_	act	0.076	0.135
Main_RecrDev_2012	-0.308	_	_	_	_	act	0.078	0.255
Main_RecrDev_2013	0.353	_	_	_	_	act	0.069	0.195
Main_RecrDev_2014	-1.144	_	_	_	_	act	0.154	0.135
Main_RecrDev_2015	0.619	_	_	_	_	act	0.101	0.162
Main_RecrDev_2016	-0.833	_	_	_	_	act	0.309	0.370
Late_RecrDev_2017	0.000	_	_	_	_	act	0.676	0.537
InitF_11_HL	0.000	-1	0	1	0	NA	_	_
InitF_22_GN	0.000	-1	0	1	0	NA	_	_
InitF_33_Shrimp	0.000	-1	0	1	0	NA	_	_
InitF_44_HB	0.000	-1	0	1	0	NA	_	_
InitF_55_CP	0.000	-1	0	1	0	NA	_	_
LnQ_base_3_3_Shrimp	5.448	1	-10	20	2	OK	0.093	0.017
SizeSel_1P_1_1_HL	77.233	3	40	80	70.52	OK	1.112	0.014
SizeSel_1P_2_1_HL	-5.981	3	-15	3	-7	OK	203.072	33.950

SizeSel_1P_3_1_HL	5.299	3	-5	15	5.26321	OK	0.145	0.027
SizeSel_1P_4_1_HL	5.474	3	-5	15	5.47408	OK	1.000	0.183
SizeSel_1P_5_1_HL	-15.000	-1	-15	5	-15	NA	_	_
SizeSel_1P_6_1_HL	15.000	-6	-5	5	15	NA	_	_
Retain_1P_1_1_HL	27.500	-2	27.5	150	27.5	NA	_	_
Retain_1P_2_1_HL	1.000	-4	-1	40	1	NA	_	_
Retain_1P_3_1_HL	1.000	-2	0	1	1	NA	_	_
Retain_1P_4_1_HL	0.000	-4	-1	2	0	NA	_	_
DiscMort_1P_1_1_HL	10.000	-2	-1	29	10	NA	_	_
DiscMort_1P_2_1_HL	1.000	-4	-1	2	1	NA	_	_
DiscMort_1P_3_1_HL	0.250	-2	-1	2	0.25	NA	_	_
DiscMort_1P_4_1_HL	0.000	-4	-1	2	0	NA	_	_
SzSel_1Fem_Peak_1_HL	-3.798	2	-10	10	0	OK	1.547	0.407
SzSel_1Fem_Ascend_1_HL	-0.386	2	-10	10	0	OK	0.245	0.636
SzSel_1Fem_Descend_1_HL	-0.168	2	-10	10	0	OK	102.717	610.397
SzSel_1Fem_Final_1_HL	-1.256	2	-20	10	-1.25585	OK	0.240	0.191
SzSel_1Fem_Scale_1_HL	1.000	-2	-10	10	1	NA	_	_
SizeSel_2P_1_2_GN	72.796	3	28	157	71.2182	OK	0.500	0.007
SizeSel_2P_2_2_GN	-13.207	3	-15	3	-13.2079	OK	2.594	0.196
SizeSel_2P_3_2_GN	4.260	3	-9	25	4.07651	OK	0.104	0.024
SizeSel_2P_4_2_GN	3.841	3	-2	15	4.78102	OK	0.162	0.042
SizeSel_2P_5_2_GN	-15.000	-1	-15	5	-15	NA	_	_
SizeSel_2P_6_2_GN	-2.564	6	-15	15	-3.93653	OK	0.205	0.080
SzSel_2Fem_Peak_2_GN	0.012	2	-10	10	0	OK	0.776	64.590
SzSel_2Fem_Ascend_2_GN	0.001	2	-10	10	0	OK	0.166	138.615
SzSel_2Fem_Descend_2_GN	1.379	2	-10	10	0	OK	0.190	0.138
SzSel_2Fem_Final_2_GN	-0.837	2	-10	10	0	OK	0.332	0.397
SzSel_2Fem_Scale_2_GN	1.000	-2	-10	10	1	NA	_	_
SizeSel_4P_1_4_HB	80.899	3	28	150	84.1332	OK	1.037	0.013
SizeSel_4P_2_4_HB	-3.873	3	-18	3	-10.7928	OK	0.692	0.179
SizeSel_4P_3_4_HB	4.864	3	-9	25	5.76107	OK	0.145	0.030
SizeSel_4P_4_4_HB	-6.669	3	-18	15	-7.88214	OK	2.243	0.336
SizeSel_4P_5_4_HB	-15.000	-1	-15	5	-15	NA	_	_
SizeSel_4P_6_4_HB	-0.601	6	-15	15	-1.26776	OK	0.187	0.311
Retain_4P_1_4_HB	27.500	-2	27.5	150	27.5	NA	_	_
Retain_4P_2_4_HB	1.000	-4	-1	40	1	NA	_	_
Retain_4P_3_4_HB	1.000	-2	0	1	1	NA	_	_
Retain_4P_4_4_HB	0.000	-4	-1	2	0	NA	_	_
DiscMort_4P_1_4_HB	10.000	-2	-1	29	10	NA	_	_
DiscMort_4P_2_4_HB	1.000	-4	-1	2	1	NA	_	_
DiscMort_4P_3_4_HB	0.220	-2	-1	2	0.22	NA	_	_
DiscMort_4P_4_4_HB	0.000	-4	-1	2	0	NA	_	_
SzSel_4Fem_Peak_4_HB	3.985	2	-10	10	4.67109	OK	2.174	0.546
SzSel_4Fem_Ascend_4_HB	0.772	2	-10	10	1.08998	OK	0.241	0.312

SzSel_4Fem_Descend_4_HB	7.633	2	-10	10	6.68725	OK	1.885	0.247
SzSel_4Fem_Final_4_HB	0.360	2	-10	10	-0.561632	OK	0.211	0.585
SzSel_4Fem_Scale_4_HB	1.000	-2	-10	10	1	NA	_	_
SizeSel_5P_1_5_CP	77.501	3	28	150	74.9726	OK	0.001	0.000
SizeSel_5P_2_5_CP	-13.028	3	-15	3	-13.0305	OK	2.798	0.215
SizeSel_5P_3_5_CP	5.178	3	-9	25	5.33871	OK	0.051	0.010
SizeSel_5P_4_5_CP	-14.992	3	-15	5	4.83827	LO	0.257	0.017
SizeSel_5P_5_5_CP	-15.000	-1	-15	5	-15	NA	_	_
SizeSel_5P_6_5_CP	-0.474	6	-15	15	-1.22629	OK	0.111	0.235
Retain_5P_1_5_CP	27.500	-2	27.5	150	27.5	NA	_	_
Retain_5P_2_5_CP	1.000	-4	-1	40	1	NA	_	_
Retain_5P_3_5_CP	1.000	-2	0	1	1	NA	_	_
Retain_5P_4_5_CP	0.000	-4	-1	2	0	NA	_	_
DiscMort_5P_1_5_CP	10.000	-2	-1	29	10	NA	_	_
DiscMort_5P_2_5_CP	1.000	-4	-1	2	1	NA	_	_
DiscMort_5P_3_5_CP	0.200	-2	-1	2	0.2	NA	_	_
DiscMort_5P_4_5_CP	0.000	-4	-1	2	0	NA	_	_
SzSel_5Fem_Peak_5_CP	0.154	2	-10	10	0	OK	0.950	6.164
SzSel_5Fem_Ascend_5_CP	0.549	2	-10	10	0	OK	0.119	0.217
SzSel_5Fem_Descend_5_CP	19.797	2	-10	20	0	OK	0.372	0.019
SzSel_5Fem_Final_5_CP	0.442	2	-10	10	0	OK	0.143	0.324
SzSel_5Fem_Scale_5_CP	1.000	-2	-10	10	1	NA	_	_
AgeSel_1P_1_1_HL	1.000	-1	0	11	1	NA	_	_
AgeSel_1P_2_1_HL	11.000	-1	0	11	11	NA	_	_
AgeSel_2P_1_2_GN	1.000	-1	0	11	1	NA	_	_
AgeSel_2P_2_2_GN	11.000	-1	0	11	11	NA	_	_
AgeSel_3P_1_3_Shrimp	0.000	-1	0	11	0	NA	_	_
AgeSel_3P_2_3_Shrimp	0.000	-1	0	11	0	NA	_	_
AgeSel_4P_1_4_HB	1.000	-1	0	11	1	NA	_	_
AgeSel_4P_2_4_HB	11.000	-1	0	11	11	NA	_	_
AgeSel_5P_1_5_CP	1.000	-1	0	11	1	NA	_	_
AgeSel_5P_2_5_CP	11.000	-1	0	11	11	NA	_	_
AgeSel_6P_1_6_SeamapTwl	0.000	-1	0	11	0	NA	_	_
AgeSel_6P_2_6_SeamapTwl	0.000	-1	0	11	0	NA	_	_
AgeSel_7P_1_7_SeamapPlank	1.000	-1	0	11	1	NA	_	_
AgeSel_7P_2_7_SeamapPlank	11.000	-1	0	11	11	NA	_	_