SEDAR 85 Gulf of Mexico Yellowedge Grouper Operational Assessment - Additional Projections

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1. Introduction

In preparation for the Gulf of Mexico Fishery Management Council's Scientific and Statistical Committee (SSC) review of SEDAR 85, additional projections were developed based on alternative recruitment scenarios in the late assessment period (2013-2021; where recruitment deviations were not estimated) and projection period (2022+), along with alternative Maximum Sustainable Yield (MSY) proxy values. Given the life history of Yellowedge Grouper (maximum age of 85 years) and their vulnerability to overexploitation, a higher spawner potential ratio (SPR) may be more appropriate for this hermaphroditic species. Simulations conducted by Harford et al. (2019) suggest that SPR ratios of 40% or 50% led to the highest probabilities of achieving long-term MSY for hermaphroditic stocks. They found that more conservative fishing mortality proxies were required to achieve MSY-based fishery objectives when steepness was "least certain" (i.e., uniform prior). Steepness for Gulf of Mexico Yellowedge Grouper was fixed at a biologically plausible value because it was not estimable within the SEDAR 85 OA Base Model and was highly uncertain (see SEDAR 2023 for details).

2. Alternative Recruitment Scenarios for 30% Projections

2.1. Recent Recruitment Modeling Issue

In recent assessments, the SSC has supported using the stock-recruitment relationship for determining the benchmarks but using the recent mean recruitment (e.g., last 10 years of estimated recruitment) for projections of the Overfishing Limit (OFL), particularly for stocks where recent recruitment is well below average recruitment. The SEDAR 85 OA Base Model did not estimate recruitment deviations through the terminal year of 2021 because of a lag in Yellowedge Grouper being captured by the fisheries or surveys. As a result, Stock Synthesis predicted recruitment estimates from the stock-recruit curve for 2013 to 2021 (range: 0.93 - 0.95 million Yellowedge Grouper), which were much more optimistic when compared to using recent mean recruitment (**Figure 1**). Many of the years between 2003 and 2012 (i.e., the last 10 years) were characterized by very low recruitment, and hence this scenario reflects a "worst-case" scenario. In contrast, including recruitment estimates before 2005 in the 1998-2012 average (i.e., the last 15 years) includes larger estimates in addition to the lower recruitment estimates, therefore leading to a moderate recruitment level between the worst-case scenario (recent mean recruitment from 2003-2012) and best-case scenario (using the stock-recruit curve).

When projecting with recent mean recruitment, the SEDAR 85 OA Base Model parameter estimates changed because the 2013-2021 recruitment estimates were replaced with the recent

mean, which was much lower for both the last 10 years (0.36 million Yellowedge Grouper from 2003-2012) and last 15 years (0.70 million Yellowedge Grouper from 1998-2012). Estimated parameters differed considerably, with 184 and 154 parameters (out of 247) differing by $\geq 5\%$ from the SEDAR 85 OA Base Model estimates for 2003-2012 and 1998-2012 mean recruitment, respectively. Most of these parameters were recruitment deviations, annual fleet-specific fishing mortality estimates, and selectivity parameters, some of which were identified as uncertain in the SEDAR 85 OA Base Model. Assuming lower recruitment estimates in the late years (2013-2021) based on recent mean recruitment resulted in fewer highly uncertain parameters (CV > 1) and lower negative log-likelihood estimates (**Table 1**), suggesting a better model fit to the data. In addition, a lower SSB ratio in the terminal year was achieved when assuming lower recruitment estimates in the late years of the assessment (**Table 2**; **Figure 1**).

2.2. Projection Methods

Table 3 provides a summary of projection settings. Projections were run assuming that relative *F* and selectivity associated with the last three years (2019-2021) would remain the same into the future. The terminal year of SEDAR 85 was 2021 and the first year of management advice will be 2025. Retained catch for the interim years (2022-2024) used landings estimates for 2022 and the average of the last three years of retained catches (2020-2022) for 2023 and 2024 (**Table 3**).

2.3. Recent Recruitment - Overfishing Limit and Acceptable Biological Catch Projections

Short-term forecasts were conducted to develop catch advice for two recent mean recruitment scenarios based on when recruitment was estimated: the most recent 10 years (2003-2012) and the most recent 15 years (1998-2012). The recent mean recruitment projection is not meant to revise stock status and should not be used for long-term projections for Gulf of Mexico Yellowedge Grouper. If a regime shift to lower recruitment was supported, the benchmarks would need to be recalculated (i.e., long-term SSB would be lower compared to the long-term SSB predicted using the stock-recruit curve).

2.3.1. Mean of the Last 10 Years of Estimated Recruitment (2003-2012)

OFL and ABC projection results assuming mean recruitment from the last 10 years (2003-2012) are provided in **Tables 4-5** and **Figure 2**. Compared to 2019-2021, lower landings were realized in 2022 and assumed to occur in 2023 and 2024 based on the recent average (2020-2022). Forecasts indicate that yields for the OFL projection will decline from 2025 throughout the near-term time period, although the forecasted yield in 2025 is slightly higher than the 2022 landings estimate.

2.3.2. Mean of the Last 15 Years of Estimated Recruitment (1998-2012)

OFL and ABC projection results assuming mean recruitment from the last 15 years (1998-2012) are provided in **Tables 6-7** and **Figure 3**. Forecasts indicate that the OFL yield stream will increase in 2025 to a value roughly equal to the 2020-2021 realized landings estimates, and will decline thereafter in the near-term.

3. 40% SPR Projections for the SEDAR 85 OA Base Model

3.1. Projection Methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SEDAR 85 OA Base Model. **Table 3** provides a summary of projection settings, as described in **Section 2.2**. Forecast recruitment values (including late recruitment values for 2013-2021) were derived from the model-estimated Beverton-Holt stock-recruit relationship for benchmarks and from recent mean recruitment for catch advice.

$F_{40\%SPR}$ was determined using a long-term 100-year projection assuming that equilibrium was obtained over the last 10 years (2112-2121). For the OFL projection, the $F_{40\%SPR}$ was applied to the stock starting in 2025. No fleet allocations exist for the Deepwater Grouper complex.

Using an MSY proxy of 40% SPR, the minimum stock size threshold (MSST) was determined by multiplying the reference spawning stock biomass, $SSB_{40\%SPR}$, by 0.75 and was used to determine stock status (**Table 8**). The maximum fishing mortality threshold (MFMT) was equivalent to the harvest rate ($F_{40\%SPR}$; total biomass killed all ages / total biomass age 1+) that achieved $SSB_{40\%SPR}$, and was used to assess whether overfishing was occurring in a given year (**Table 8**). A stock is considered overfished when $SSB_{Current} < MSST$ and undergoing overfishing if $F_{Current} > MFMT$, where $F_{Current}$ is defined as the geometric mean of the fishing mortality over the most recent three years (2019-2021).

Once the proxy values were calculated, 2021 stock status was used to determine whether a rebuilding plan was required (i.e., if SSB < MSST then Gulf of Mexico Yellowedge Grouper would be considered overfished and a rebuilding plan would be required).

3.2. Projection Results

Benchmarks and reference points were calculated assuming an SSB defined in terms of male and female combined SSB.

3.2.1. Biological Reference Points

The status determination criteria using an MSY proxy of 40% SPR were:

- MSY proxy = yield at $F_{40\%SPR}$ = 591,775 pounds gutted weight
- MSST = $0.75*SSB_{40\%SPR}$ = 3,632 metric tons
- MFMT = $F_{MSYproxy}$ ($F_{40\%SPR}$) = 0.044
- OY = 0.9*MSY proxy = 532,598 pounds gutted weight

3.2.2. Stock Status

Benchmarks and reference points are shown in **Table 8**. Detailed time series of derived quantities and benchmarks with SSB defined as male and female combined SSB are presented in **Table 9**. As of 2021, and assuming an SPR of 40%, the Gulf of Mexico Yellowedge Grouper stock is undergoing overfishing ($F_{Current} > MFMT$) but is not overfished ($SSB_{2021} > MSST$) according to the SEDAR 85 OA Base Model (**Table 8**). The terminal year SSB (2021) is above

$SSB_{40\%SPR}$ (**Figure 4**) at 124% of the biomass level needed to support MSY (**Table 8**). From 2019 to 2021 the estimated stock harvest rate, using the geometric mean, was 0.046, which was equivalent to 105% of $F_{40\%SPR}$ (**Table 8**).

The Kobe plot (**Figure 5**) indicates that over the time horizon of the assessment (i.e., 1975-2021), the stock has not been overfished in any year since 1975 but has experienced overfishing between 1981-1995, 1997, 1999-2000, 2003-2004, 2007, and 2019-2021 (**Table 9**).

3.2.3. Overfishing Limit and Acceptable Biological Catch Projections

OFL and ABC projection results **assuming predicted recruitment follows the stock-recruit curve** are provided in **Tables 10-11** and **Figure 6**. Forecasts indicate that yields can increase very slightly in 2025 for the OFL projection scenario presented whereas yields for the ABC projection would remain around 2022 realized landings (**Figure 6**).

3.2.3.1. Mean of the Last 10 Years of Estimated Recruitment (2003-2012)

OFL and ABC projection results assuming mean recruitment from the last 10 years (2003-2012) are provided in **Tables 12-13** and **Figure 7**. Forecasts indicate that yields for the OFL projection will decline considerably in 2025, well below the 2022 realized landings estimate, and will remain relatively low throughout the near-term time period.

3.2.3.2. Mean of the Last 15 Years of Estimated Recruitment (1998-2012)

OFL and ABC projection results assuming mean recruitment from the last 15 years (1998-2012) are provided in **Tables 14-15** and **Figure 8**. Forecasts indicate that yields for the OFL projection will decline in 2025 and remain around 2022 realized landings throughout the near-term time period.

4. 50% SPR Projections for the SEDAR 85 OA Base Model

4.1. Projection Methods

All methodology remained the same as described in Section 3.1, with the exception that an MSY proxy of 50% SPR was used.

4.2. Projection Results

Benchmarks and reference points were calculated assuming an SSB defined in terms of male and female combined SSB.

4.2.1. Biological Reference Points

The status determination criteria using an MSY proxy of 50% SPR were:

- MSY proxy = yield at $F_{50\%SPR}$ = 530,936 pounds gutted weight
- MSST = $0.75*SSB_{50\%SPR}$ = 4,672 metric tons
- MFMT = $F_{MSYproxy}$ ($F_{50\%SPR}$) = 0.032

•   OY = 0.9*MSY proxy = 477,843 pounds gutted weight

4.2.2. Stock Status

Benchmarks and reference points are shown in **Table 16**. Detailed time series of derived quantities and benchmarks with SSB defined as male and female combined SSB are presented in **Table 17**. As of 2021, and assuming an SPR of 50%, the Gulf of Mexico Yellowedge Grouper stock is undergoing overfishing ($F_{Current} > MFMT$) but is not overfished ($SSB_{2021} > MSST$) according to the SEDAR 85 OA Base Model (**Table 16**). The terminal year SSB (2021) is just below $SSB_{50\%SPR}$ (**Figure 9**) at 97% of the biomass level needed to support MSY (**Table 16**). From 2019 to 2021 the estimated stock harvest rate, using the geometric mean, was 0.046, which was equivalent to 144% of $F_{50\%SPR}$ (**Table 16**).

The Kobe plot (**Figure 10**) indicates that over the time horizon of the assessment (i.e., 1975-2021), the stock has not been overfished in any year since 1975 but has experienced overfishing throughout most of the time series with the exceptions of 1975-1980 and 2010-2011 (**Table 17**).

4.2.3. Overfishing Limit and Acceptable Biological Catch Projections

OFL and ABC projection results **assuming predicted recruitment follows the stock-recruit curve** are provided in **Tables 18-19** and **Figure 11**. Forecasts indicate that yields would remain around 2022 realized landings for the OFL projection scenario presented whereas yields for the ABC projection would remain well below 2022 realized landings (**Figure 11**).

4.2.3.1. Mean of the Last 10 Years of Estimated Recruitment (2003-2012)

OFL and ABC projection results assuming mean recruitment from the last 10 years (2003-2012) are provided in **Tables 20-21** and **Figure 12**. Forecasts indicate that yields for the OFL projection will decline considerably in 2025 to nearly half of realized landings in 2022, and remain very low throughout the near-term time period.

4.2.3.2. Mean of the Last 15 Years of Estimated Recruitment (1998-2012)

OFL and ABC projection results assuming mean recruitment from the last 15 years (1998-2012) are provided in **Tables 22-23** and **Figure 13**. Forecasts indicate that yields for the OFL projection will decline considerably in 2025 and remain well below 2022 realized landings throughout the near-term time period.

5. Maximum Sustainable Yield Projections for the SEDAR 85 OA Base Model

In addition to SPR projections, an MSY projection using the model-derived stock-recruit curve was run to compare the estimated SPR when MSY was achieved with the reference points under consideration by the SSC.

5.1. Results

Overfishing Limit (OFL) projection results assuming predicted recruitment follows the stock-recruit curve are provided in **Table 24**. The MSY projections resulted in an SPR of 28%.

6. References

Harford WJ, SR Sagarese and M Karnauskas. 2019. Coping with information gaps in stock productivity for rebuilding and achieving maximum sustainable yield for grouper–snapper fisheries. Fish and Fisheries 20(2):303-321. doi: *https://doi.org/10.1111/faf.12344*

Southeast Data Assessment and Review (SEDAR). 2023. SEDAR85: Gulf of Mexico Yellowedge Grouper Operational Assessment. SEDAR, North Charleston, SC. 293 pp. Available at: *https://sedarweb.org/assessments/sedar-85/*.

7. Tables

Table 1. Comparison of convergence diagnostics (NLL = negative log-likelihood; CV = coefficient of variation) for the sensitivity runs assuming late recruitment (2013-2021; where recruitment deviations were not estimated) is equal to mean recruitment over the last 10 years where estimated (2003-2012) or the last 15 years where estimated (1998-2012) for the SEDAR 85 OA Base Model for Gulf of Mexico Yellowedge Grouper. Late recruitment (2013-2021) was obtained from the stock-recruit curve in the SEDAR 85 OA Base Model.

Description	NLL	Gradient	Estimated Parameters (Bounded)	Parameters with CV>1
SEDAR 85 OA Base Model	21,035.6	0.00095	247 (0)	23
Late recruitment (2013-2021) from 2003-2012 Average	20,975.5	0.00983	247 (0)	20
Late recruitment (2013-2021) from 1998-2012 Average	21,014.4	0.00189	247 (0)	22

Table 2. Comparison of key estimates and derived quantities for the sensitivity runs assuming late recruitment (2013-2021; where recruitment deviations were not estimated) is equal to mean recruitment over the last 10 years where estimated (2003-2012) or the last 15 years where estimated (1998-2012) for the SEDAR 85 OA Base Model for Gulf of Mexico Yellowedge Grouper. R0 = virgin recruitment (log-scale), SSB defined as male and female combined SSB in metric tons (mt), Recr = recruitment. SSB ratio was calculated as annual SSB divided by SSB_0. Late recruitment (2013-2021) was obtained from the stock-recruit curve in the SEDAR 85 OA Base Model.

Description	Steepness	Sigma R	Ln (R0)	Virgin SSB (mt)	Virgin Recr (1,000s)	SSB ratio Start Yr	SSB ratio End Yr
SEDAR 85 OA Base Model	0.827	0.5	6.89	13,197	985.4	1	0.46
Late recruitment (2013-2021) from 2003-2012 Average	0.827	0.5	6.84	12,655	936.4	1	0.34
Late recruitment (2013-2021) from 1998-2012 Average	0.827	0.5	6.88	13,036	971.7	1	0.38

Table 3. Settings used for Gulf of Mexico Yellowedge Grouper projections and alternative scenarios for recruitment in the late years of the assessment (2013-2021; where recruitment deviations were not estimated) and the projection period (2022+). Late recruitment (2013-2021) was obtained from the stock-recruit curve in the SEDAR 85 OA Base Model.

Parameter	Value	Comment
Relative F	Average from 2019-2021	Average relative fishing mortality (apical F) over terminal three years of model
Selectivity	Average from 2019-2021	Fleet specific selectivity estimated over terminal three years of model
Recruitment (benchmarks)	Beverton-Holt stock-recruitment relationship	Derived from the model estimated Beverton-Holt stock-recruitment relationship
Recruitment (catch advice, last 10 years)	Average from 2003-2012	Recent average recruitment
Recruitment (catch advice, last 15 years)	Average from 1998-2012	Recent average recruitment
Interim Landings (2022-2024)	9.04/9.78 metric tons (Commercial Vertical Line - East); 12.53/8.86 metric tons (Commercial Vertical Line - West); 161.73/206.42 metric tons (Commercial Longline - East); 34.38/60.01 metric tons (Commercial Longline - West)	Landings provided for 2022; For 2023 and 2024, used 3-year average of landings (2020-2022)
Allocation Ratio	None	

Table 4. Results of the OFL projection (fishing set at $F_{30\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio	OFL
2025	360	0.06	1	3,358	2.297	3.062	0.265	0.514
2026	360	0.06	1	3,176	2.172	2.896	0.251	0.490
2027	360	0.06	1	3,009	2.058	2.744	0.238	0.468
2028	360	0.06	1	2,858	1.954	2.606	0.226	0.448
2029	360	0.06	1	2,719	1.860	2.479	0.215	0.429
2030	360	0.06	1	2,593	1.774	2.365	0.205	0.413

Table 5. Results of the ABC projection (directed $F = 0.75 *$ Directed F at $F_{30\%SPR}$ (0.06)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio	Yield
2025	360	0.045	0.75	3,358	2.297	3.062	0.265	0.386
2026	360	0.045	0.75	3,227	2.207	2.943	0.255	0.373
2027	360	0.045	0.75	3,107	2.125	2.833	0.246	0.362
2028	360	0.045	0.75	2,997	2.050	2.733	0.237	0.351
2029	360	0.045	0.75	2,896	1.981	2.641	0.229	0.341
2030	360	0.045	0.75	2,804	1.917	2.557	0.222	0.332

Table 6. Results of the OFL projection (fishing set at $F_{30\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio	OFL
2025	698	0.061	1	4,197	1.493	1.990	0.322	0.689
2026	698	0.061	1	4,038	1.436	1.915	0.310	0.669
2027	698	0.061	1	3,899	1.387	1.849	0.299	0.651
2028	698	0.061	1	3,778	1.343	1.791	0.290	0.636
2029	698	0.061	1	3,671	1.305	1.741	0.282	0.621
2030	698	0.061	1	3,577	1.272	1.696	0.274	0.609

Table 7. Results of the ABC projection (directed $F = 0.75 *$ Directed F at $F_{30\%SPR}$ (0.061)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F30%SPR	SSB	SSB/SSB30%SPR	SSB/MSST	SSB ratio	Yield
2025	698	0.045	0.75	4,197	1.493	1.990	0.322	0.517
2026	698	0.045	0.75	4,104	1.460	1.946	0.315	0.509
2027	698	0.045	0.75	4,028	1.432	1.910	0.309	0.503
2028	698	0.045	0.75	3,964	1.410	1.880	0.304	0.497
2029	698	0.045	0.75	3,911	1.391	1.854	0.300	0.492
2030	698	0.045	0.75	3,866	1.375	1.833	0.297	0.488

Table 8. Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 85 Gulf of Mexico Yellowedge Grouper Operational Assessment using 40% spawner potential ratio (SPR) as a proxy for maximum sustainable yield. Spawning Stock Biomass (SSB) is in metric tons (male and female combined SSB), whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 1+). Late recruitment (2013-2021; where recruitment deviations were not estimated) was obtained from the stock-recruit curve in the SEDAR 85 OA Base Model.

Criteria	Definition	Value
Base M	Target M for fully selected ages in the Lorenzen (2000) scaling	0.073
Steepness	Steepness of the Beverton-Holt stock-recruit relationship (fixed)	0.827
Unfished Recruitment (R0)	Unfished recruitment (1,000s)	985
Generation Time	Fecundity-weighted mean age	18.17
Unfished SSB (SSB0)	Unfished spawning stock biomass (mt)	13,197
Mortality Rate Criteria		
FMSYproxy	Equilibrium F that achieves SPR40%	0.044
MFMT	FMSYproxy	0.044
Fcurrent	Geometric mean of the last 3 years of the assessment (F2019-2021)	0.047
Fcurrent/MFMT	Current stock status based on MFMT	1.08
Biomass Criteria		
SSBMSYproxy	Equilibrium SSB at FSPR 40 %	4,842
MSST	0.75 * SSBSPR40%	3,632
SSBcurrent	SSB in 2021	6,017
SSBcurrent/SSBFMSYproxy	Current stock status based on SSBSPR40% (Equil)	1.24
SSBcurrent/MSST	Current stock status based on MSST	1.66
SSBcurrent/SSBunfished	SSB ratio in 2021	0.46

Table 9. Time series of fishing mortality (F) and SSB relative to associated biological reference points **assuming late recruitment (2013-2021; where recruitment deviations were not estimated) and projected recruitment (2022+) was obtained from the stock-recruit curve**. SSB is in metric tons (male and female combined SSB), whereas F is a harvest rate (total biomass killed all ages / total biomass age 1+). Reference points include $F_{40\%SPR} = 0.044$, $SSB_{F40\%SPR} = 4{,}842$ metric tons, and $MSST_{F40\%SPR} = 3{,}632$ metric tons which was calculated as $(0.75) * SSB_{F40\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons. Red indicates overfishing and/or overfished states if present.

Year	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio
1975	0.014	0.330	13,197	2.725	3.634	1.000
1976	0.011	0.249	12,994	2.683	3.578	0.985
1977	0.011	0.244	12,843	2.652	3.536	0.973
1978	0.010	0.239	12,697	2.622	3.496	0.962
1979	0.015	0.338	12,557	2.593	3.457	0.952
1980	0.028	0.642	12,362	2.553	3.404	0.937
1981	0.088	2.024	12,016	2.481	3.309	0.911
1982	0.131	3.011	10,937	2.259	3.011	0.829
1983	0.083	1.913	9,515	1.965	2.620	0.721
1984	0.070	1.615	8,839	1.825	2.434	0.670
1985	0.100	2.298	8,378	1.730	2.307	0.635
1986	0.063	1.443	7,692	1.588	2.118	0.583
1987	0.060	1.375	7,433	1.535	2.047	0.563
1988	0.092	2.121	7,245	1.496	1.995	0.549
1989	0.049	1.124	6,818	1.408	1.877	0.517
1990	0.050	1.151	6,744	1.393	1.857	0.511
1991	0.047	1.080	6,654	1.374	1.832	0.504
1992	0.061	1.394	6,587	1.360	1.814	0.499
1993	0.045	1.027	6,437	1.329	1.772	0.488
1994	0.065	1.481	6,426	1.327	1.769	0.487
1995	0.050	1.149	6,289	1.299	1.732	0.477
1996	0.033	0.763	6,251	1.291	1.721	0.474
1997	0.045	1.036	6,321	1.305	1.741	0.479
1998	0.040	0.912	6,295	1.300	1.733	0.477
1999	0.058	1.340	6,299	1.301	1.734	0.477

Table 9 Continued. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points **assuming late recruitment (2013-2021; where recruitment deviations were not estimated) and projected recruitment (2022+) was obtained from the stock-recruit curve**. SSB is in metric tons (male and female combined SSB), whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 1+). Reference points include $F_{40\%SPR} = 0.044$, $SSB_{F40\%SPR} = 4{,}842$ metric tons, and $MSST_{F40\%SPR} = 3{,}632$ metric tons which was calculated as $(0.75) * SSB_{F40\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons. Red indicates overfishing and/or overfished states if present.

Year	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio
2000	0.059	1.356	6,191	1.279	1.705	0.469
2001	0.040	0.926	6,131	1.266	1.688	0.465
2002	0.039	0.905	6,272	1.295	1.727	0.475
2003	0.055	1.271	6,455	1.333	1.777	0.489
2004	0.045	1.037	6,523	1.347	1.796	0.494
2005	0.043	0.992	6,640	1.371	1.828	0.503
2006	0.036	0.823	6,742	1.392	1.856	0.511
2007	0.044	1.013	6,894	1.424	1.898	0.522
2008	0.041	0.949	6,991	1.444	1.925	0.530
2009	0.042	0.970	7,113	1.469	1.958	0.539
2010	0.023	0.527	7,217	1.490	1.987	0.547
2011	0.029	0.671	7,440	1.536	2.049	0.564
2012	0.035	0.794	7,574	1.564	2.085	0.574
2013	0.036	0.819	7,614	1.572	2.096	0.577
2014	0.042	0.975	7,583	1.566	2.088	0.575
2015	0.041	0.944	7,448	1.538	2.051	0.564
2016	0.040	0.926	7,273	1.502	2.003	0.551
2017	0.040	0.907	7,070	1.460	1.947	0.536
2018	0.042	0.973	6,850	1.415	1.886	0.519
2019	0.053	1.210	6,598	1.363	1.817	0.500
2020	0.044	1.010	6,268	1.294	1.726	0.475
2021	0.045	1.031	6,017	1.243	1.657	0.456

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Table 10. Results of the OFL projection (fishing set at $F_{40\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) were obtained from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight. Reference points include $F_{40\%SPR} = 0.044$, $SSB_{F40\%SPR} = 4{,}842$ metric tons, and $MSST_{F40\%SPR} = 3{,}632$ metric tons which was calculated as $(0.75) * SSB_{F40\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	OFL
2025	917	0.044	1	5,443	1.124	1.499	0.412	0.649
2026	915	0.044	1	5,349	1.105	1.473	0.405	0.641
2027	913	0.044	1	5,275	1.089	1.452	0.400	0.635
2028	912	0.044	1	5,217	1.077	1.436	0.395	0.630
2029	911	0.044	1	5,169	1.068	1.423	0.392	0.626
2030	910	0.044	1	5,132	1.060	1.413	0.389	0.622

Table 11. Results of the ABC projection (directed $F = 0.75 *$ Directed F at $F_{40\%SPR}$ (0.044)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) were obtained from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight. Reference points include $F_{40\%SPR} = 0.044$, $SSB_{F40\%SPR} = 4{,}842$ metric tons, and $MSST_{F40\%SPR} = 3{,}632$ metric tons which was calculated as $(0.75) * SSB_{F40\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	Yield
2025	917	0.033	0.75	5,443	1.124	1.499	0.412	0.486
2026	916	0.033	0.75	5,413	1.118	1.490	0.410	0.486
2027	916	0.033	0.75	5,399	1.115	1.487	0.409	0.486
2028	916	0.033	0.75	5,399	1.115	1.487	0.409	0.487
2029	916	0.033	0.75	5,408	1.117	1.489	0.410	0.488
2030	916	0.033	0.75	5,424	1.120	1.494	0.411	0.489

Table 12. Results of the OFL projection (fishing set at $F_{40\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	OFL
2025	360	0.043	1	3,358	1.724	2.298	0.265	0.369
2026	360	0.043	1	3,234	1.660	2.213	0.256	0.358
2027	360	0.043	1	3,120	1.601	2.135	0.247	0.348
2028	360	0.043	1	3,015	1.547	2.063	0.238	0.338
2029	360	0.043	1	2,919	1.498	1.998	0.231	0.329
2030	360	0.043	1	2,832	1.453	1.938	0.224	0.321

Table 13. Results of the ABC projection (directed $F = 0.75$ * Directed F at $F_{40\%SPR}$ (0.043)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	Yield
2025	360	0.033	0.75	3,358	1.724	2.298	0.265	0.277
2026	360	0.033	0.75	3,271	1.679	2.238	0.258	0.271
2027	360	0.033	0.75	3,191	1.638	2.184	0.252	0.266
2028	360	0.033	0.75	3,118	1.601	2.134	0.246	0.261
2029	360	0.033	0.75	3,052	1.567	2.089	0.241	0.257
2030	360	0.033	0.75	2,993	1.536	2.048	0.236	0.253

Table 14. Results of the OFL projection (fishing set at $F_{40\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	OFL
2025	698	0.043	1	4,197	1.120	1.493	0.322	0.495
2026	698	0.043	1	4,113	1.098	1.463	0.316	0.489
2027	698	0.043	1	4,044	1.079	1.439	0.310	0.483
2028	698	0.043	1	3,988	1.064	1.419	0.306	0.478
2029	698	0.043	1	3,942	1.052	1.403	0.302	0.475
2030	698	0.043	1	3,905	1.042	1.389	0.300	0.471

Table 15. Results of the ABC projection (directed F = 0.75 * Directed F at $F_{40\%SPR}$ (0.043)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F40%SPR	SSB	SSB/SSB40%SPR	SSB/MSST	SSB ratio	Yield
2025	698	0.033	0.75	4,197	1.120	1.493	0.322	0.371
2026	698	0.033	0.75	4,161	1.110	1.480	0.319	0.370
2027	698	0.033	0.75	4,138	1.104	1.472	0.317	0.370
2028	698	0.033	0.75	4,127	1.101	1.468	0.317	0.370
2029	698	0.033	0.75	4,123	1.100	1.467	0.316	0.370
2030	698	0.033	0.75	4,126	1.101	1.468	0.317	0.371

Table 16. Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 85 Gulf of Mexico Yellowedge Grouper Operational Assessment using 50% spawner potential ratio (SPR) as a proxy for maximum sustainable yield. Spawning Stock Biomass (SSB) is in metric tons (male and female combined SSB), whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 1+). Late recruitment (2013-2021) was obtained from the stock-recruit curve in the SEDAR 85 OA Base Model.

Criteria	Definition	Value
Base M	Target M for fully selected ages in the Lorenzen (2000) scaling	0.073
Steepness	Steepness of the Beverton-Holt stock-recruit relationship (fixed)	0.827
Unfished Recruitment (R0)	Unfished recruitment (1,000s)	985
Generation Time	Fecundity-weighted mean age	18.17
Unfished SSB (SSB0)	Unfished spawning stock biomass (mt)	13,197
Mortality Rate Criteria		
FMSYproxy	Equilibrium F that achieves SPR50%	0.032
MFMT	FMSYproxy	0.032
Fcurrent	Geometric mean of the last 3 years of the assessment (F2019-2021)	0.047
Fcurrent/MFMT	Current stock status based on MFMT	1.489
Biomass Criteria		
SSBMSYproxy	Equilibrium SSB at FSPR 50 %	6,230
MSST	0.75 * SSBSPR50%	4,672
SSBcurrent	SSB in 2021	6,017
SSBcurrent/SSBFMSYproxy	Current stock status based on SSBSPR50% (Equil)	0.97
SSBcurrent/MSST	Current stock status based on MSST	1.29
SSBcurrent/SSBunfished	SSB ratio in 2021	0.46

Table 17. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points **assuming late recruitment (2013-2021; where recruitment deviations were not estimated) and projected recruitment (2022+) was obtained from the stock-recruit curve**. SSB is in metric tons (male and female combined SSB), whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 1+). Reference points include $F_{50\%SPR} = 0.032$, $SSB_{F50\%SPR} = 6{,}230$ metric tons, and $MSST_{F50\%SPR} = 4{,}672$ metric tons which was calculated as $(0.75) * SSB_{F50\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons. Red indicates overfishing and/or overfished states if present.

Year	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio
1975	0.014	0.454	13,197	2.118	2.824	1.000
1976	0.011	0.344	12,994	2.086	2.781	0.985
1977	0.011	0.337	12,843	2.062	2.749	0.973
1978	0.010	0.329	12,697	2.038	2.718	0.962
1979	0.015	0.466	12,557	2.016	2.688	0.952
1980	0.028	0.885	12,362	1.984	2.646	0.937
1981	0.088	2.791	12,016	1.929	2.572	0.911
1982	0.131	4.152	10,937	1.756	2.341	0.829
1983	0.083	2.638	9,515	1.527	2.036	0.721
1984	0.070	2.227	8,839	1.419	1.892	0.670
1985	0.100	3.169	8,378	1.345	1.793	0.635
1986	0.063	1.990	7,692	1.235	1.646	0.583
1987	0.060	1.896	7,433	1.193	1.591	0.563
1988	0.092	2.925	7,245	1.163	1.551	0.549
1989	0.049	1.550	6,818	1.094	1.459	0.517
1990	0.050	1.587	6,744	1.083	1.443	0.511
1991	0.047	1.489	6,654	1.068	1.424	0.504
1992	0.061	1.922	6,587	1.057	1.410	0.499
1993	0.045	1.416	6,437	1.033	1.378	0.488
1994	0.065	2.041	6,426	1.032	1.375	0.487
1995	0.050	1.584	6,289	1.009	1.346	0.477
1996	0.033	1.052	6,251	1.003	1.338	0.474
1997	0.045	1.428	6,321	1.015	1.353	0.479
1998	0.040	1.258	6,295	1.010	1.347	0.477
1999	0.058	1.848	6,299	1.011	1.348	0.477

Table 17 Continued. Time series of fishing mortality (*F*) and SSB relative to associated biological reference points **assuming late recruitment (2013-2021; where recruitment deviations were not estimated) and projected recruitment (2022+) was obtained from the stock-recruit curve**. SSB is in metric tons (male and female combined SSB), whereas *F* is a harvest rate (total biomass killed all ages / total biomass age 1+). Reference points include $F_{50\%SPR} = 0.032$, $SSB_{F50\%SPR} = 6{,}230$ metric tons, and $MSST_{F50\%SPR} = 4{,}672$ metric tons which was calculated as $(0.75) * SSB_{F50\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons. Red indicates overfishing and/or overfished states if present.

Year	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio
2000	0.059	1.869	6,191	0.994	1.325	0.469
2001	0.040	1.276	6,131	0.984	1.312	0.465
2002	0.039	1.248	6,272	1.007	1.342	0.475
2003	0.055	1.753	6,455	1.036	1.382	0.489
2004	0.045	1.430	6,523	1.047	1.396	0.494
2005	0.043	1.368	6,640	1.066	1.421	0.503
2006	0.036	1.135	6,742	1.082	1.443	0.511
2007	0.044	1.397	6,894	1.107	1.476	0.522
2008	0.041	1.309	6,991	1.122	1.496	0.530
2009	0.042	1.337	7,113	1.142	1.522	0.539
2010	0.023	0.726	7,217	1.159	1.545	0.547
2011	0.029	0.925	7,440	1.194	1.592	0.564
2012	0.035	1.095	7,574	1.216	1.621	0.574
2013	0.036	1.129	7,614	1.222	1.630	0.577
2014	0.042	1.344	7,583	1.217	1.623	0.575
2015	0.041	1.302	7,448	1.196	1.594	0.564
2016	0.040	1.277	7,273	1.167	1.557	0.551
2017	0.040	1.251	7,070	1.135	1.513	0.536
2018	0.042	1.342	6,850	1.100	1.466	0.519
2019	0.053	1.669	6,598	1.059	1.412	0.500
2020	0.044	1.392	6,268	1.006	1.342	0.475
2021	0.045	1.421	6,017	0.966	1.288	0.456

Table 18. Results of the OFL projection (fishing set at $F_{50\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) were obtained from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight. Reference points include $F_{50\%SPR} = 0.032$, $SSB_{F50\%SPR} = 6,230$ metric tons, and $MSST_{F50\%SPR} = 4,672$ metric tons which was calculated as $(0.75) * SSB_{F50\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13,197$ metric tons.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	OFL
2025	917	0.032	1	5,443	0.874	1.165	0.412	0.470
2026	916	0.032	1	5,419	0.870	1.160	0.411	0.471
2027	916	0.032	1	5,411	0.869	1.158	0.410	0.471
2028	916	0.032	1	5,418	0.870	1.160	0.411	0.472
2029	916	0.032	1	5,432	0.872	1.163	0.412	0.474
2030	917	0.032	1	5,454	0.875	1.167	0.413	0.475

Table 19. Results of the ABC projection (directed $F = 0.75 *$ Directed F at $F_{50\%SPR}$ (0.032)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) were obtained from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight. Reference points include $F_{50\%SPR} = 0.032$, $SSB_{F50\%SPR} = 6,230$ metric tons, and $MSST_{F50\%SPR} = 4,672$ metric tons which was calculated as $(0.75) * SSB_{F50\%SPR}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13,197$ metric tons.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	Yield
2025	917	0.024	0.75	5,443	0.874	1.165	0.412	0.353
2026	917	0.024	0.75	5,465	0.877	1.170	0.414	0.355
2027	918	0.024	0.75	5,503	0.883	1.178	0.417	0.358
2028	919	0.024	0.75	5,553	0.891	1.189	0.421	0.362
2029	920	0.024	0.75	5,611	0.901	1.201	0.425	0.365
2030	921	0.024	0.75	5,676	0.911	1.215	0.430	0.369

Table 20. Results of the OFL projection (fishing set at $F_{50\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	OFL
2025	360	0.032	1	3,358	1.380	1.840	0.265	0.269
2026	360	0.032	1	3,274	1.346	1.794	0.259	0.263
2027	360	0.032	1	3,198	1.314	1.752	0.253	0.258
2028	360	0.032	1	3,128	1.285	1.714	0.247	0.254
2029	360	0.032	1	3,065	1.260	1.679	0.242	0.250
2030	360	0.032	1	3,008	1.236	1.648	0.238	0.246

Table 21. Results of the ABC projection (directed $F = 0.75 *$ Directed F at $F_{50\%SPR}$ (0.032)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 10 years where estimated (2003-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	Yield
2025	360	0.024	0.75	3,358	1.380	1.840	0.265	0.201
2026	360	0.024	0.75	3,301	1.357	1.809	0.261	0.199
2027	360	0.024	0.75	3,250	1.336	1.781	0.257	0.197
2028	360	0.024	0.75	3,205	1.317	1.756	0.253	0.195
2029	360	0.024	0.75	3,165	1.301	1.734	0.250	0.193
2030	360	0.024	0.75	3,130	1.286	1.715	0.247	0.191

Table 22. Results of the OFL projection (fishing set at $F_{50\%SPR}$) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and OFL is the overfishing limit in millions of pounds gutted weight.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	OFL
2025	698	0.032	1	4,197	0.896	1.195	0.322	0.359
2026	698	0.032	1	4,166	0.890	1.186	0.320	0.359
2027	698	0.032	1	4,147	0.886	1.181	0.318	0.359
2028	698	0.032	1	4,140	0.884	1.179	0.318	0.359
2029	698	0.032	1	4,141	0.884	1.179	0.318	0.360
2030	698	0.032	1	4,148	0.886	1.181	0.318	0.360

Table 23. Results of the ABC projection (directed $F = 0.75$ * Directed F at $F_{50\%SPR}$ (0.032)) for Gulf of Mexico Yellowedge Grouper **assuming late recruitment (2013-2021) and projected recruitment (2022+) are equal to mean recruitment over the last 15 years where estimated (1998-2012)**. Recruitment (Recr) is in 1,000s of age-0 fish, F is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight.

Year	Recr	F	F/F50%SPR	SSB	SSB/SSB50%SPR	SSB/MSST	SSB ratio	Yield
2025	698	0.024	0.75	4,197	0.896	1.195	0.322	0.270
2026	698	0.024	0.75	4,200	0.897	1.196	0.322	0.271
2027	698	0.024	0.75	4,216	0.901	1.201	0.323	0.273
2028	698	0.024	0.75	4,243	0.906	1.208	0.325	0.275
2029	698	0.024	0.75	4,276	0.913	1.218	0.328	0.277
2030	698	0.024	0.75	4,316	0.922	1.229	0.331	0.280

Table 24. Results of the maximum sustainable yield (MSY) projection for Gulf of Mexico Yellowedge Grouper **assuming predicted recruitment from the stock-recruit curve**. Recruitment (Recr) is in 1,000s of age-0 fish, *F* is a harvest rate (total biomass killed all ages / total biomass age 1+), SSB is in metric tons (male and female combined SSB), and yield in millions of pounds gutted weight. Reference points include $F_{MSY} = 0.065$, $SSB_{MSY} = 3{,}170$ metric tons, and $MSST_{MSY} = 2{,}377$ metric tons which was calculated as $(0.75) * SSB_{MSY}$. SSB ratio was calculated as annual SSB divided by SSB_0 where $SSB_0 = 13{,}197$ metric tons.

Year	Recr	F	F/FMSY	SSB	SSB/SSBMSY	SSB/MSST	SSB ratio	OFL
2025	917	0.065	1	5,443	1.717	2.290	0.412	0.970
2026	912	0.065	1	5,224	1.648	2.198	0.396	0.940
2027	908	0.065	1	5,034	1.588	2.117	0.381	0.912
2028	904	0.065	1	4,868	1.536	2.048	0.369	0.888
2029	900	0.065	1	4,720	1.489	1.986	0.358	0.866
2030	897	0.065	1	4,589	1.448	1.930	0.348	0.846

8. Figures
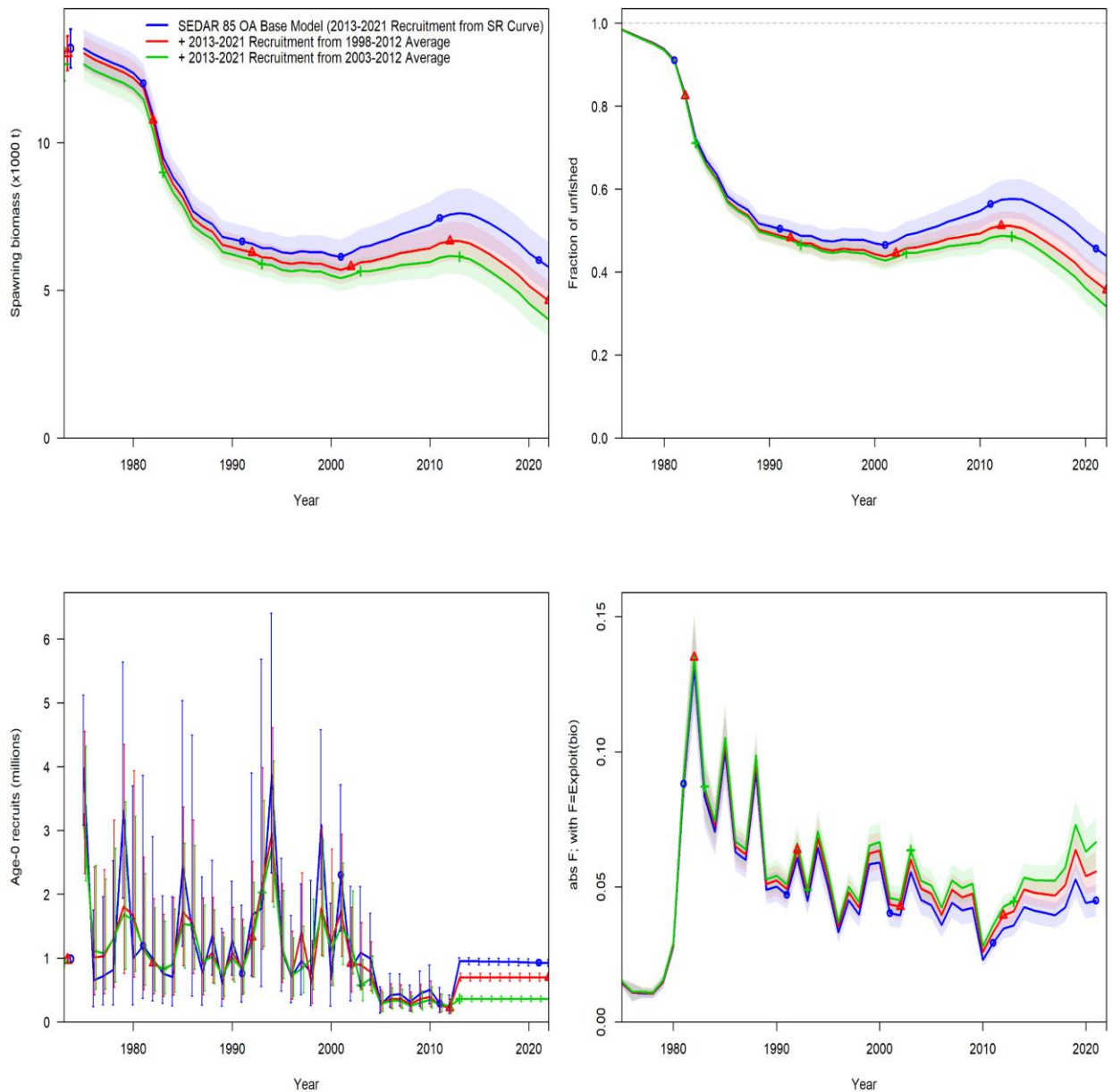
Figure 1. Estimates of spawning stock biomass (male and female combined SSB in 1,000s of metric tons; top left panel), the ratio of SSB to virgin SSB (top right panel), recruitment (millions of fish; bottom left panel), and fishing mortality (total biomass killed all ages / total biomass age 1+; bottom right panel) for the sensitivity runs assuming late recruitment (2013-2021; where recruitment deviations were not estimated) is equal to mean recruitment over the last 10 years where estimated (2003-2012) or the last 15 years where estimated (1998-2012) for the SEDAR 85 OA Base Model for Gulf of Mexico Yellowedge Grouper.
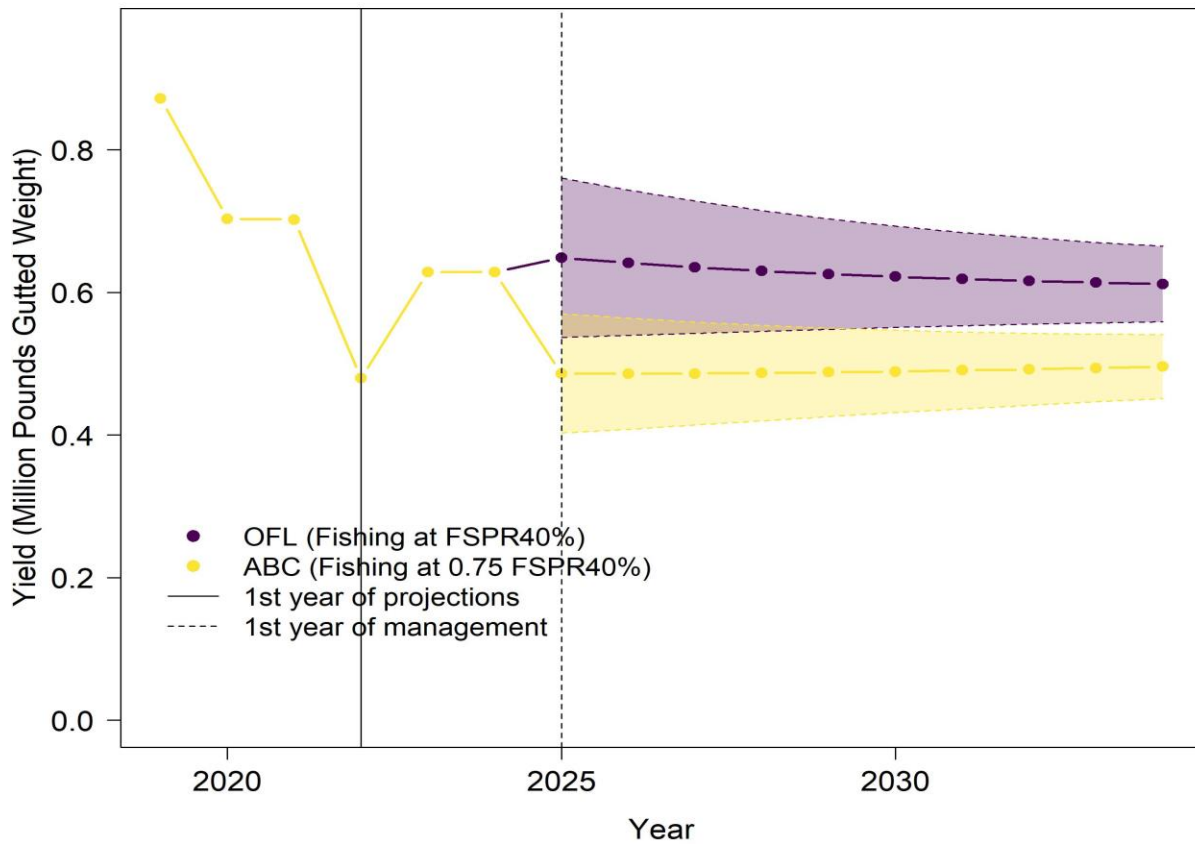
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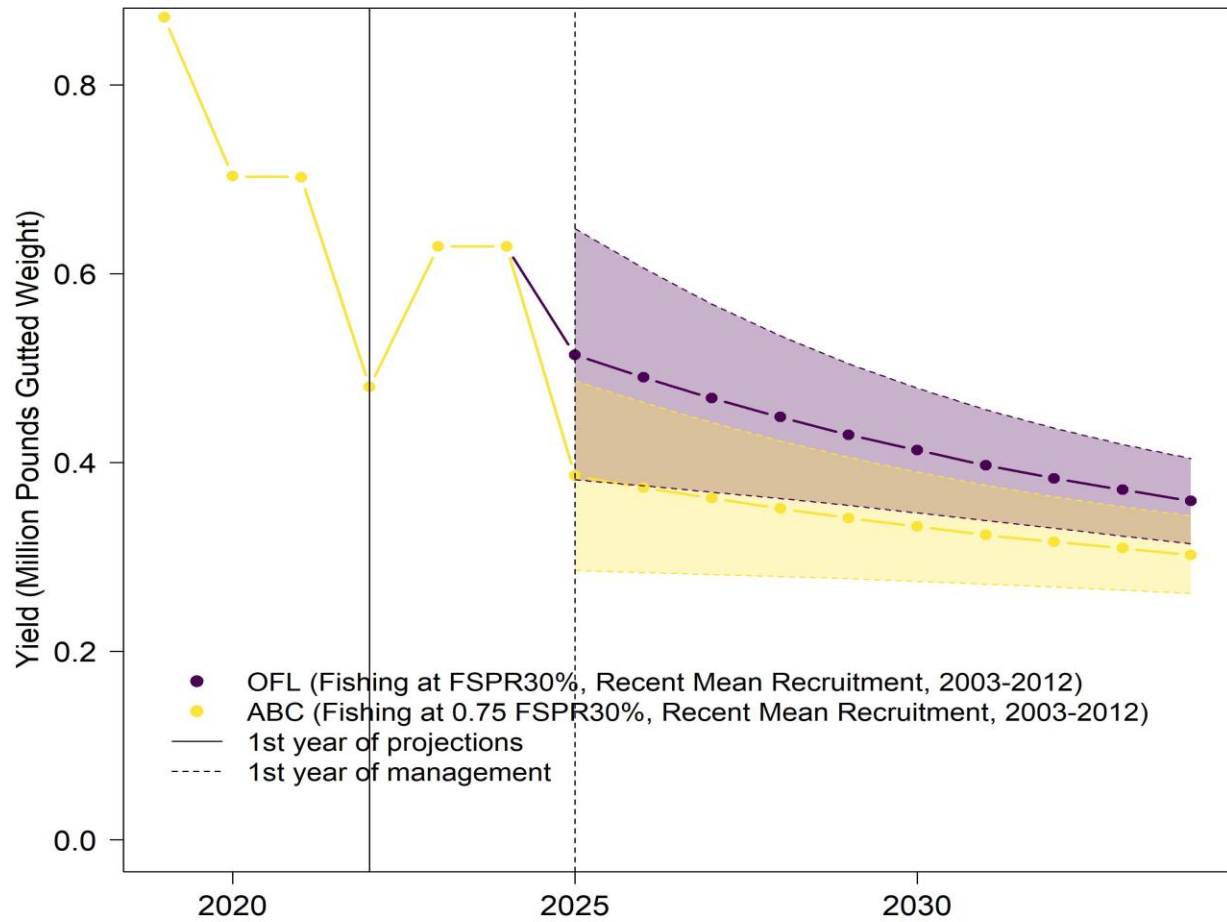
*Figure 2. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{30\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{30\%SPR}$ (0.06)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 10 years where estimated (2003-2012)**.*
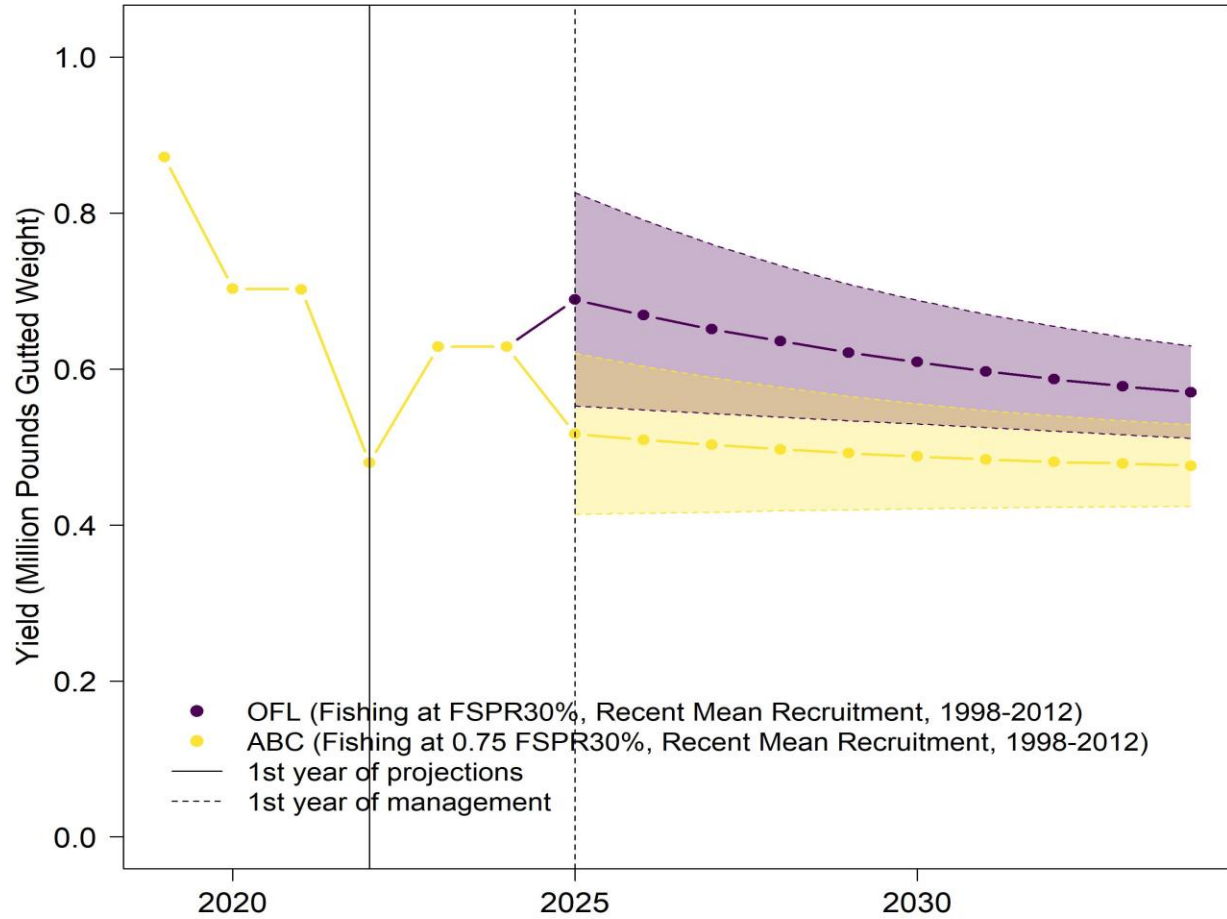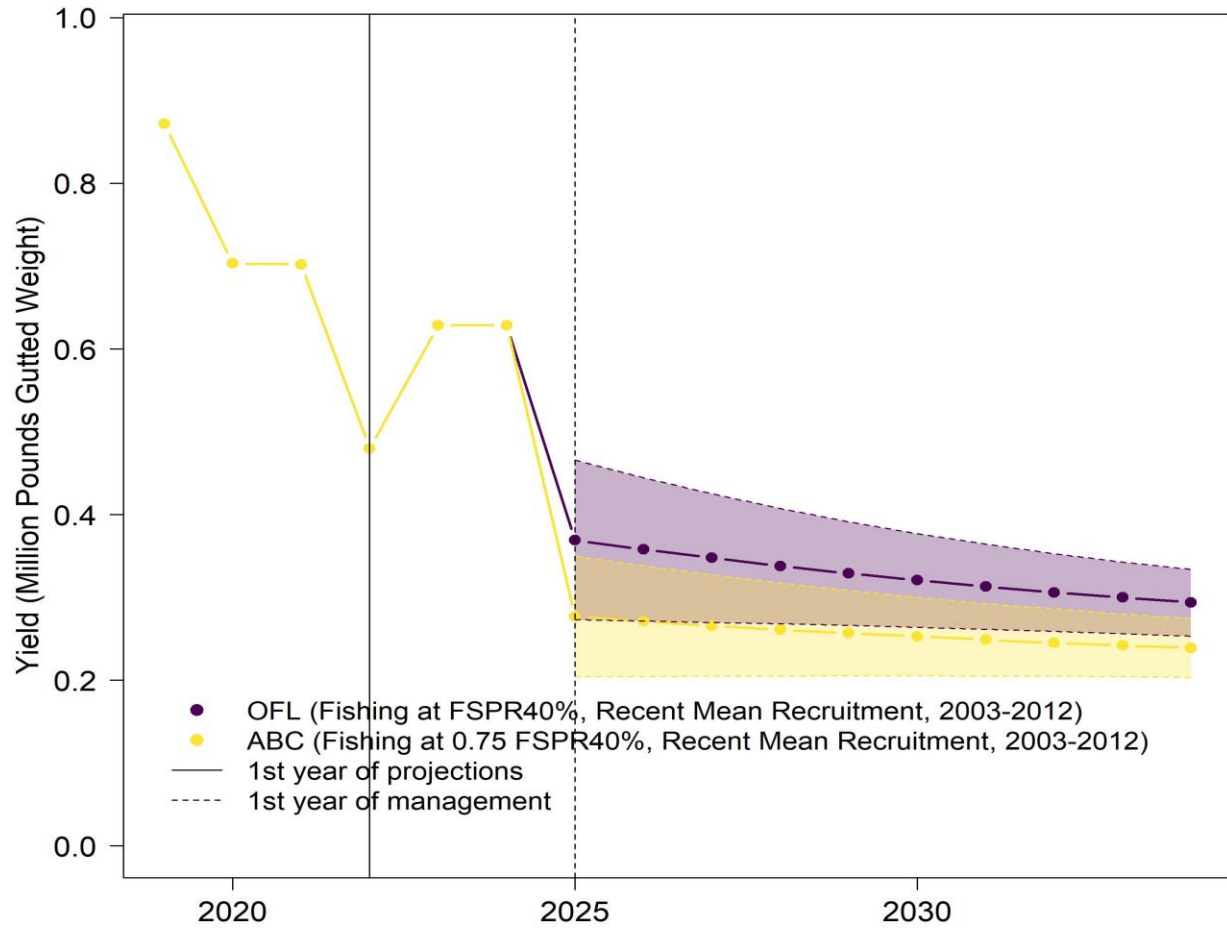
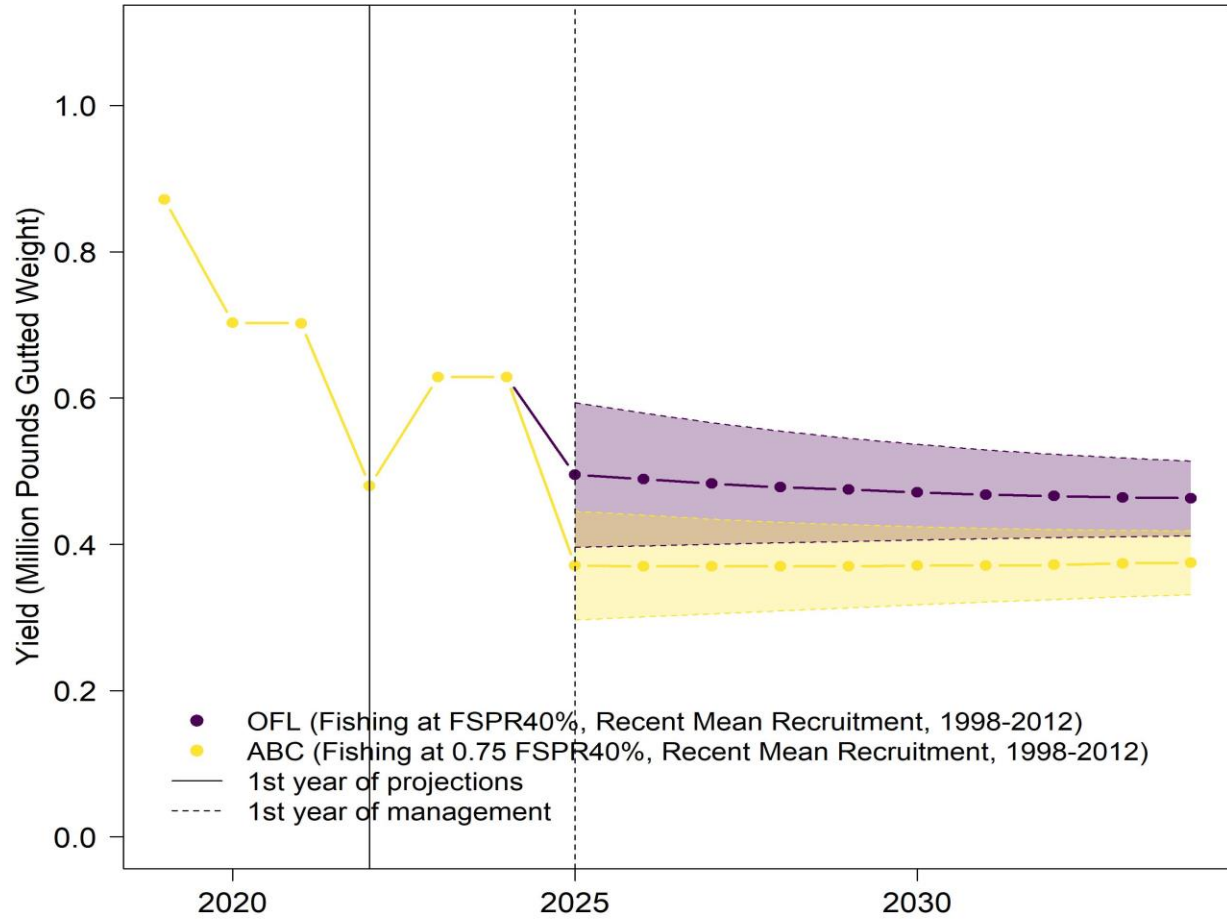*Figure 3. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{30\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{30\%SPR}$ (0.061)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 15 years where estimated (1998-2012)**.*
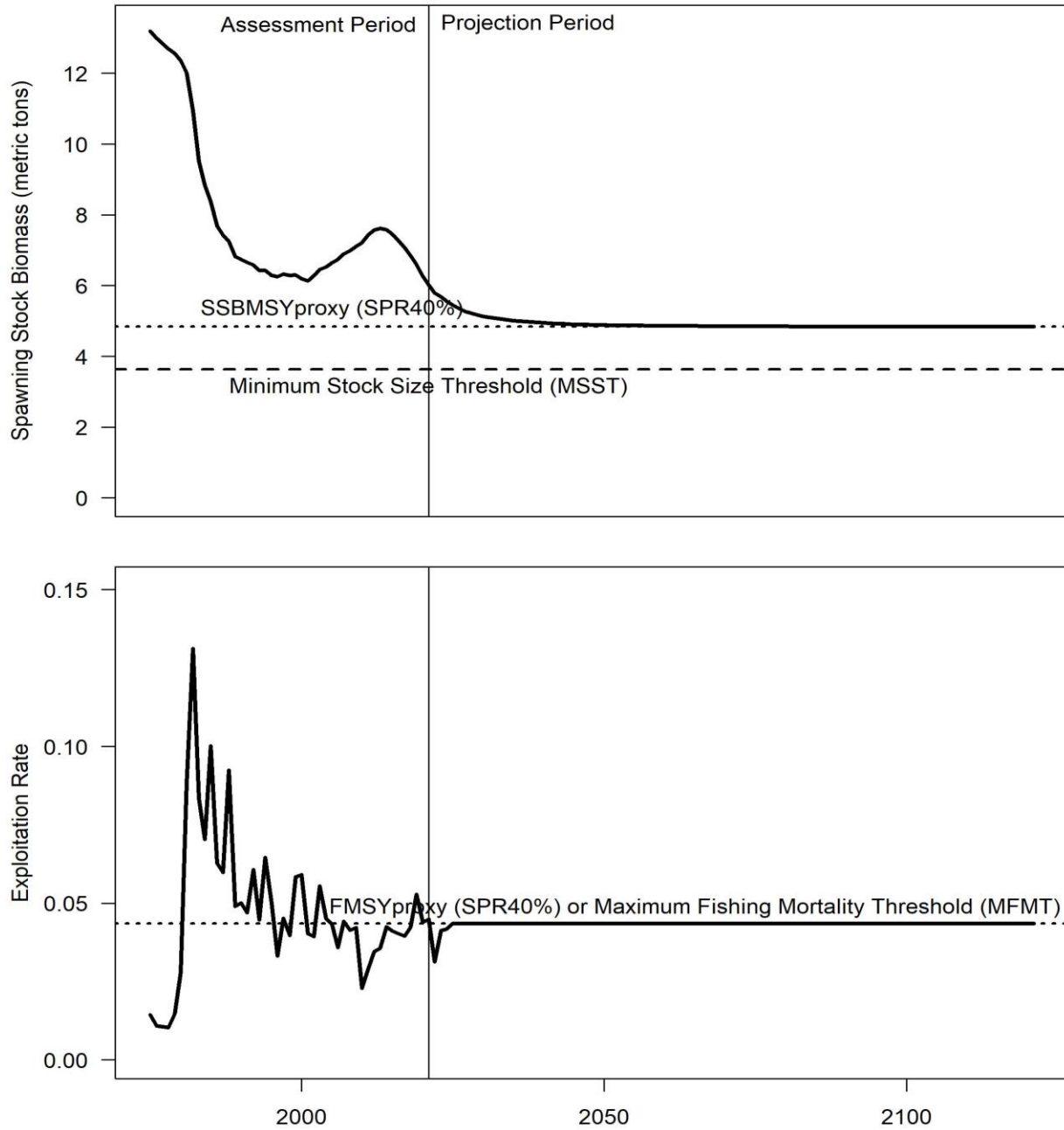
Figure 4. Time series of SSB (male and female combined SSB) and exploitation rate (total biomass killed all ages / total biomass age 1+) with respect to status determination criteria for the SEDAR 85 Gulf of Mexico Yellowedge Grouper Operational Assessment. Results are shown for an MSY$_{proxy}$ of 40% SPR.
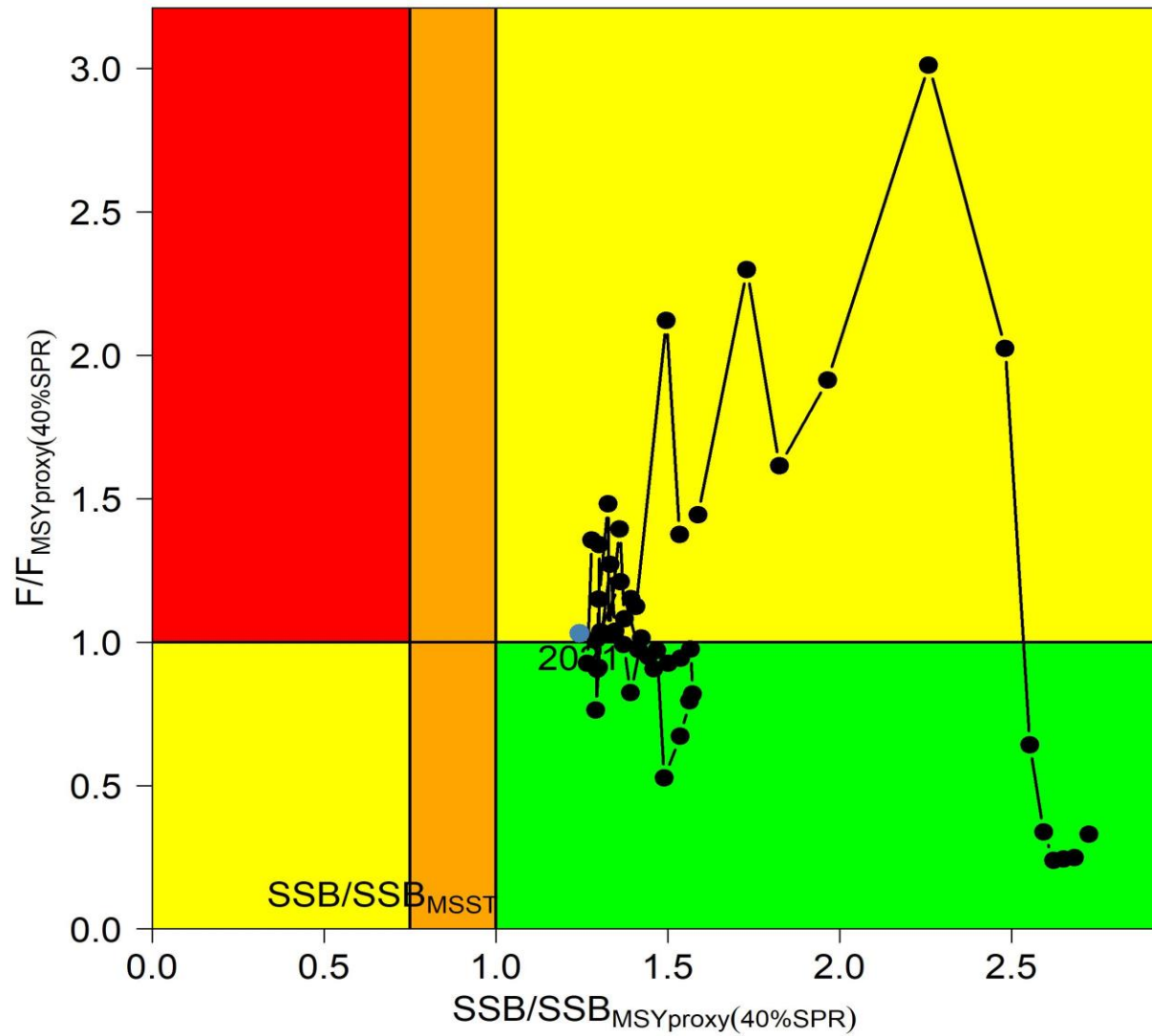
*Figure 5. Kobe plot illustrating the trajectory of stock status for Gulf of Mexico Yellowedge Grouper. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST = 0.75 x SSB$_{40\%SPR}$). The 2021 terminal year stock status is indicated by the gray dot. See **Table 9** for values. SSB defined as male and female combined SSB. Results are shown for an MSY$_{proxy}$ of 40% SPR.*

Figure 6. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{40\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{40\%SPR}$ (0.044)) projections for Gulf of Mexico Yellowedge Grouper with recruitment predicted by the stock-recruit curve and an MSY_{proxy} of 40% SPR.

*Figure 7. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{40\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{40\%SPR}$ (0.043)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 10 years where estimated (2003-2012)**. Results are shown for an MSY_{proxy} of 40% SPR.*

*Figure 8. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{40\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{40\%SPR}$ (0.043)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 15 years where estimated (1998-2012)**. Results are shown for an MSY_{proxy} of 40% SPR.*
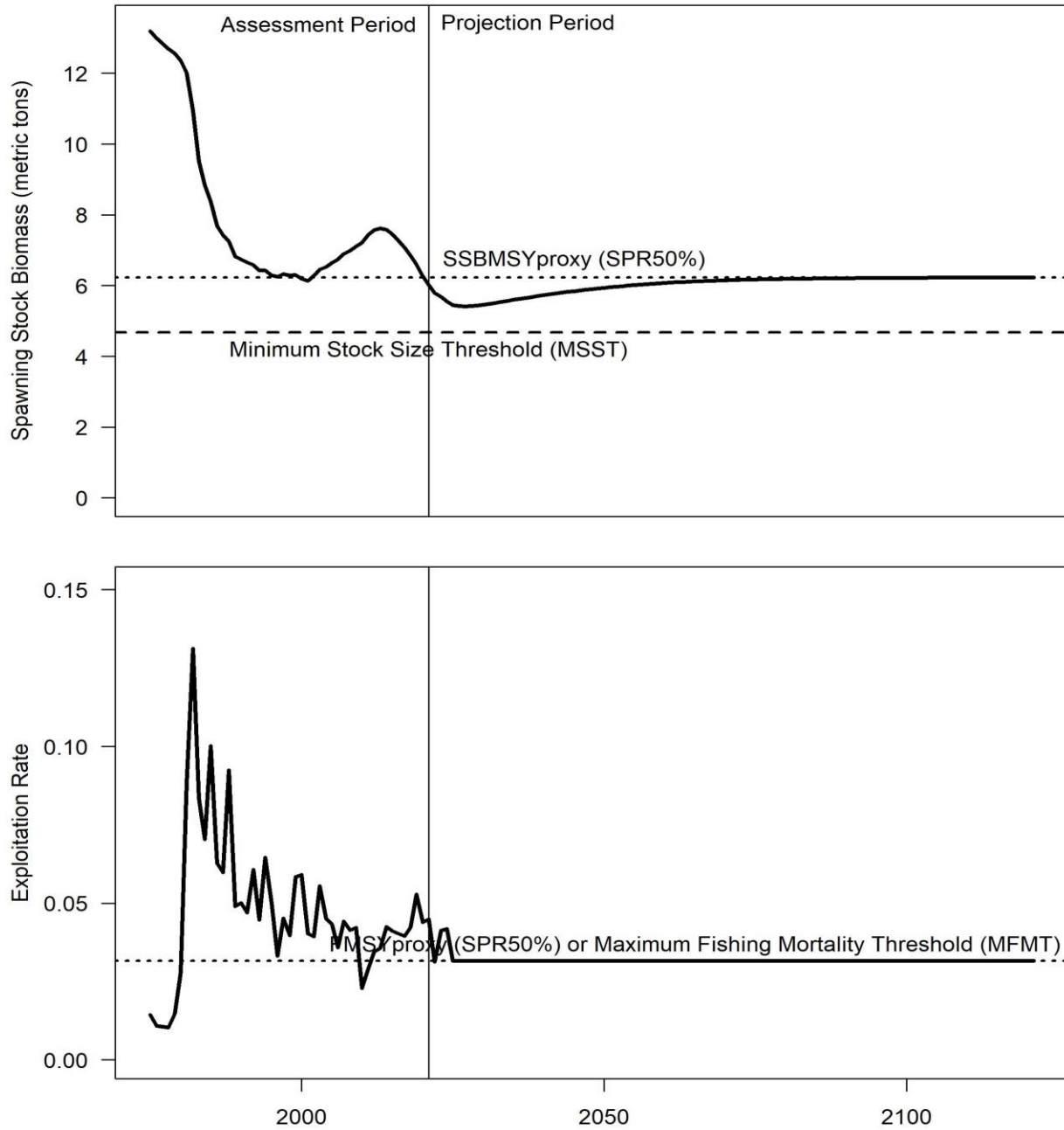
Figure 9. Time series of SSB (male and female combined SSB) and exploitation rate (total biomass killed all ages / total biomass age 1+) with respect to status determination criteria for the SEDAR 85 Gulf of Mexico Yellowedge Grouper Operational Assessment. Results are shown for an MSY$_{proxy}$ of 50% SPR.
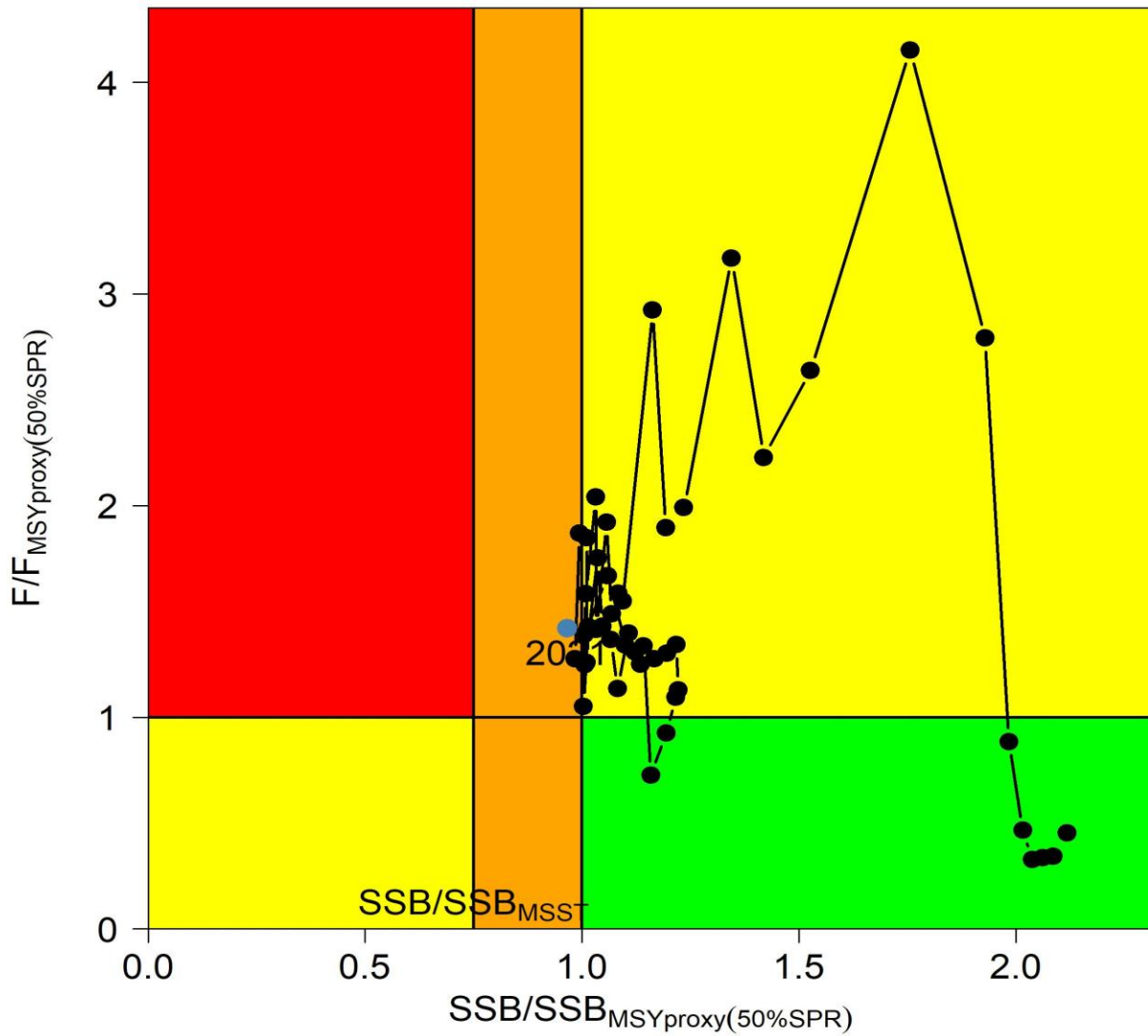
*Figure 10. Kobe plot illustrating the trajectory of stock status for Gulf of Mexico Yellowedge Grouper. The orange coloring indicates regions where the stock is below the biomass target but above the biomass threshold (MSST = 0.75 x SSB$_{50\%SPR}$). The 2021 terminal year stock status is indicated by the gray dot. See **Table 17** for values. SSB defined as male and female combined SSB. Results are shown for an MSY$_{proxy}$ of 50% SPR.*
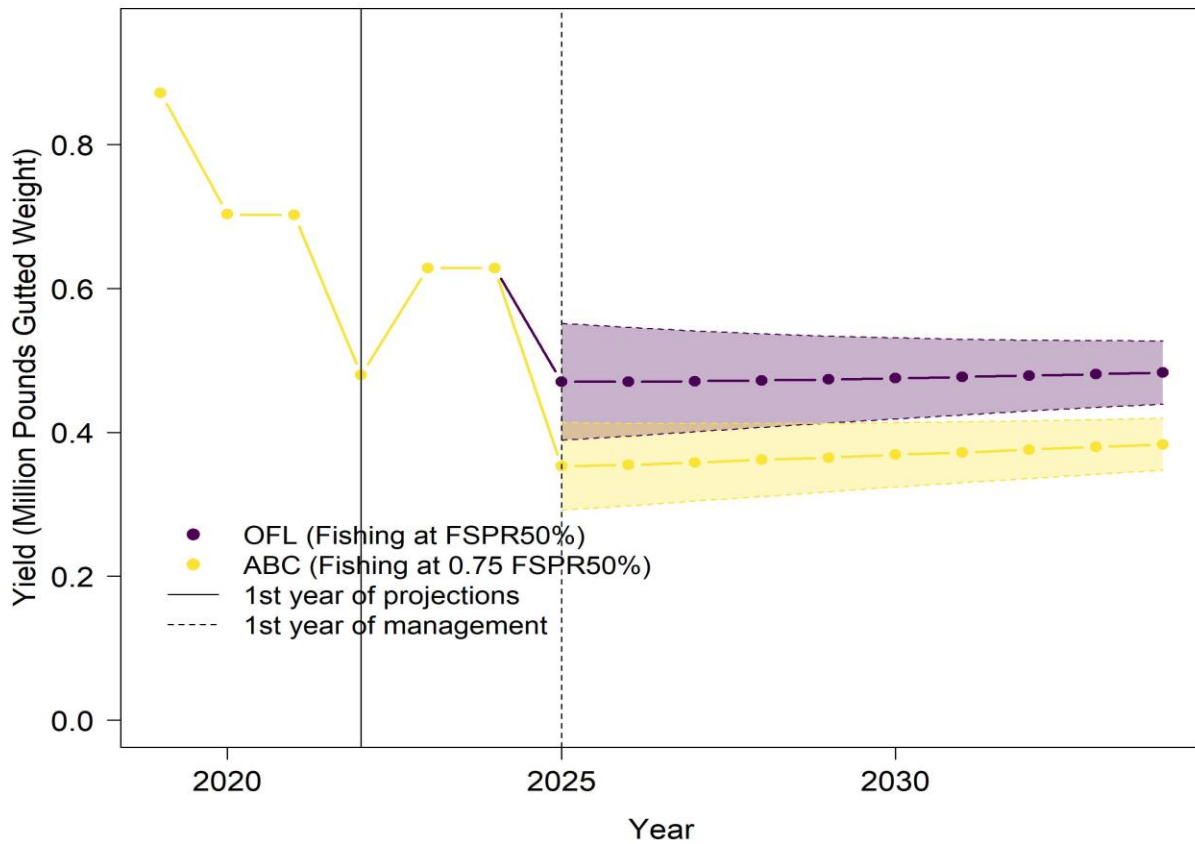
Figure 11. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{50\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{50\%SPR}$ (0.032)) projections for Gulf of Mexico Yellowedge Grouper with recruitment predicted by the stock-recruit curve and an MSY_{proxy} of 50% SPR.
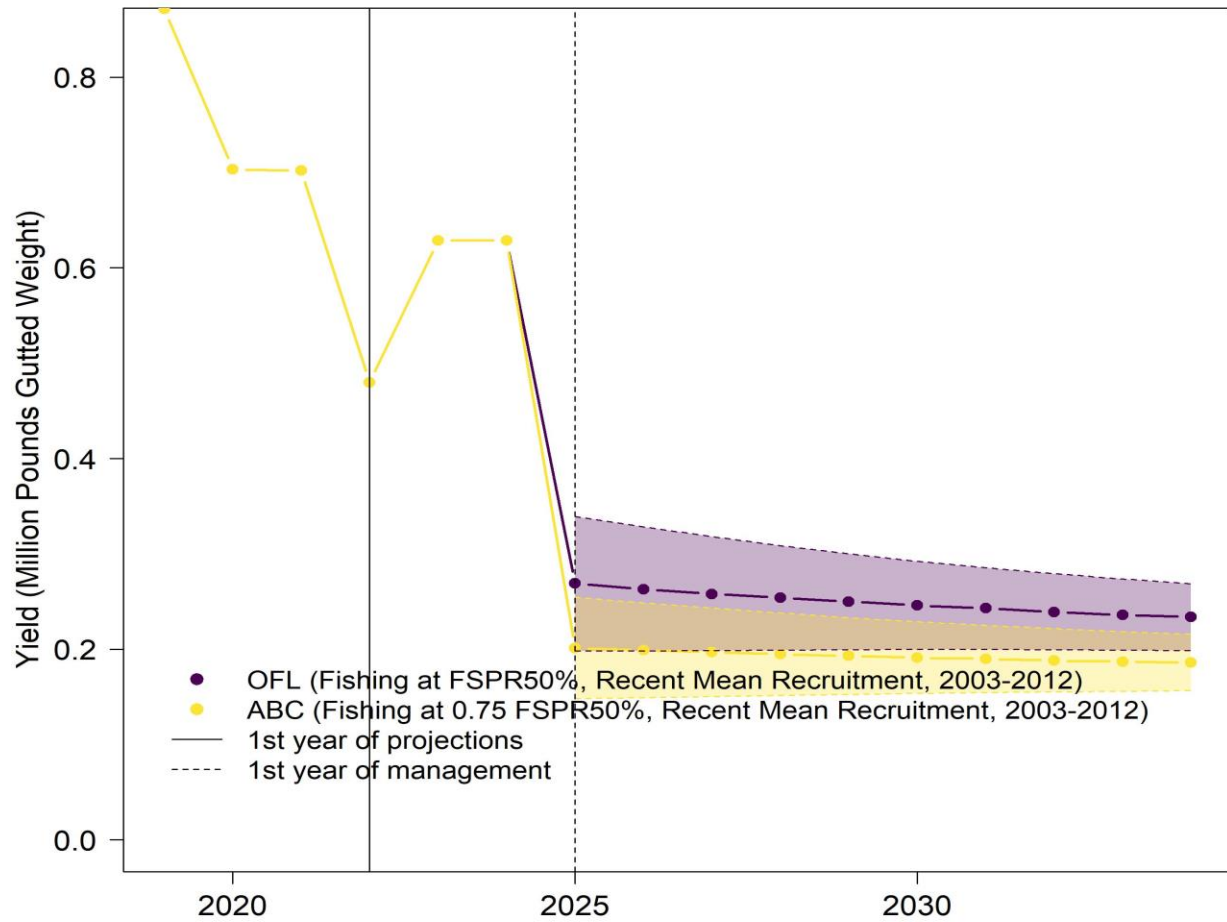
*Figure 12. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{50\%SPR}$) and ABC (directed F = 0.75 x Directed F at $F_{50\%SPR}$ (0.032)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 10 years where estimated (2003-2012)**. Results are shown for an MSY_{proxy} of 50% SPR.*
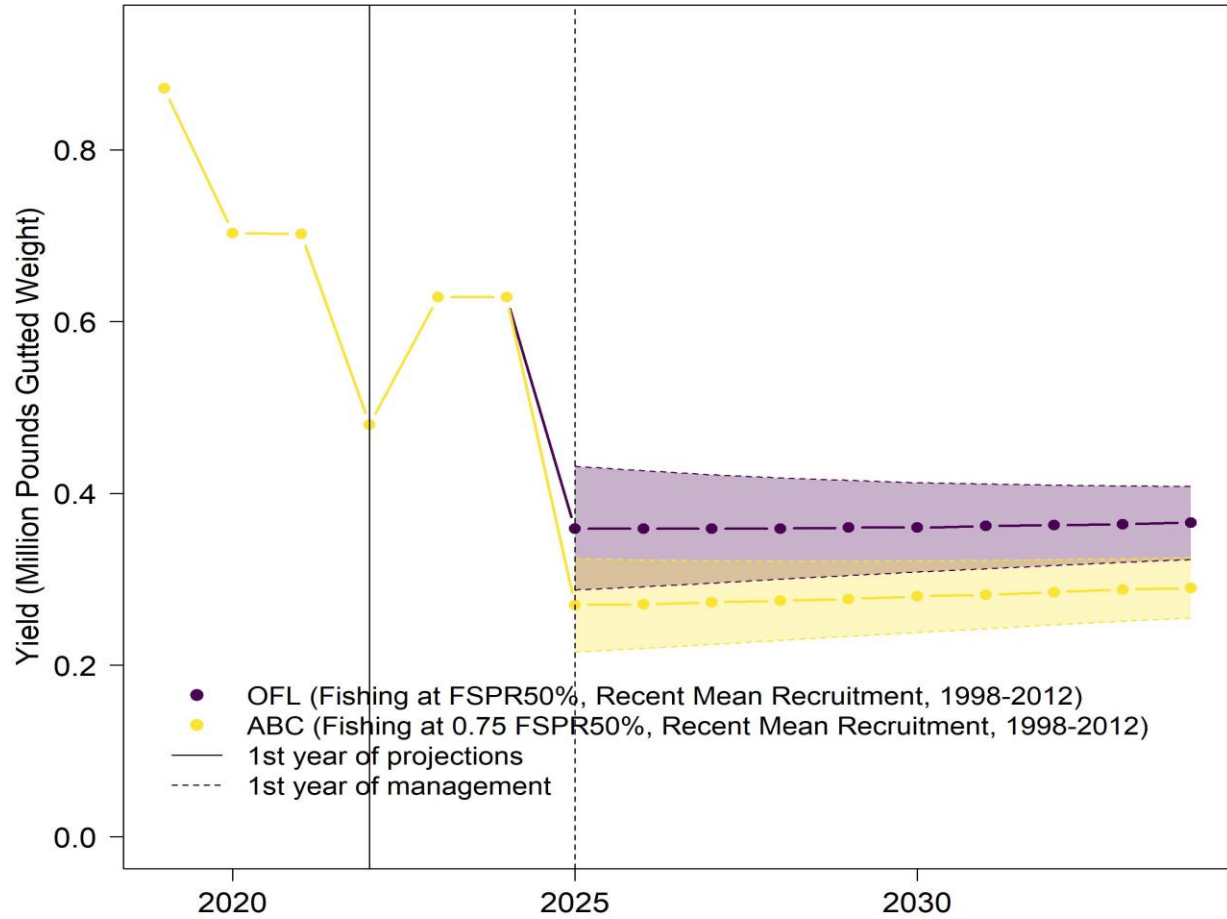
*Figure 13. Historic (2019-2021), interim (2022-2024) and forecasted yields (2025+) for the OFL (fishing set at $F_{50\%SPR}$) and ABC (directed $F = 0.75$ x Directed F at $F_{50\%SPR}$ (0.032)) projections for Gulf of Mexico Yellowedge Grouper with **late (2013-2021) and projected (2022+) recruitment derived from mean recruitment over the last 15 years where estimated (1998-2012)**. Results are shown for an MSY_{proxy} of 50% SPR.*