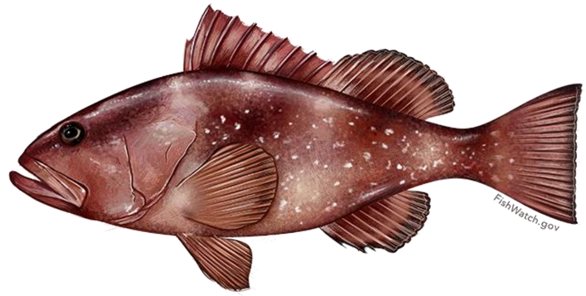

Gulf of Mexico Red Grouper

SEDAR61 Executive Summary Draft

August 2019

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Stock

This assessment reports the status of the Red Grouper (*Epinephelus morio*) resource in the Gulf of Mexico at the start of 2018. Red Grouper are modeled as separate stocks in the Gulf of Mexico and South Atlantic, divided down the center of the Florida Keys at the U.S. Highway 1 boundary. Red Grouper are most abundant in the eastern Gulf of Mexico.

Landings

Commercial landings of Red Grouper from 1986 through 2017 were obtained from the Accumulated Landings System (ALS) for Texas, Louisiana, Mississippi and Alabama; and from the Florida Trip Ticket Program for Florida due to its greater resolution in the data. Commercial landings after 1993 were adjusted by logbook data to apportion annual state landings to gear (longline, vertical line, trap, or other) and area; and landings between 2010 and 2017 were obtained from the Grouper-Tilefish Individual Fishing Quota program and were adjusted using an annual correction factor across all gear and area strata. Estimates of Red Grouper commercial landings averaged 5.09 million pounds [mp] from 1986 to 2017, with a low of 2.83 mp in 2010, and a peak of 7.45 mp in 1989 (Figure 1, Table 1).

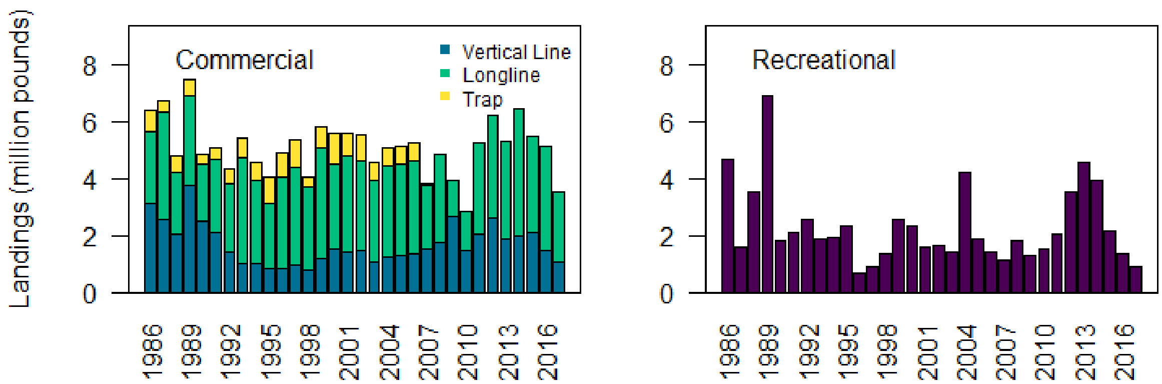

Figure 1: Final Red Grouper landings estimates from SEDAR61 assessment for commercial (left panel, by fleet) and recreational (right panel) fisheries in millions of pounds, 1986-2017.

Recreational landings of Red Grouper were obtained from the Marine Recreational Information Program (MRIP), formerly the Marine Recreational Fisheries Statistics Survey (MRFSS), and the Southeast Region Headboat Survey (SRHS). Following the three year transition period of MRIP, estimates of fishing effort for the private and shore modes were obtained from the Fishing Effort Survey and the 2013 design change in the Access Point Angler Intercept Survey was accounted for during the transition. A charter calibration analysis was conducted by the Southeast Fisheries Science Center on the newly released MRIP data to correct for the change from the Coastal Household Telephone Survey to the For-Hire Telephone Survey. Recreational landings derived from MRIP were comprised of Red Grouper landed whole and observed by interviewers ("Type A") and Red Grouper reported as killed by the fishers ("Type B1"). Estimates of Red Grouper recreational landings averaged 2.29 mp from 1986 to 2017, with a low of 0.66 mp in 1996 and a peak of 6.91 mp in 1989 (Figure 1, Table 1).

Table 1: Red Grouper estimated landings in pounds for the Commercial fleets [Vertical Line (VL), Longline (LL), Trap, and Total (Tot)], Recreational fleet, and Total landings.

Year	Commercial				Recreational	Total
	VL	LL	Trap	Tot		
1986	3,133,011	2,504,650	721,348	6,359,009	4,676,997	11,036,006
1987	2,537,410	3,758,330	447,757	6,743,497	1,579,248	8,322,746
1988	2,043,147	2,183,317	539,425	4,765,889	3,547,855	8,313,744
1989	3,775,350	3,087,243	591,194	7,453,787	6,907,369	14,361,156

Year	Commercial				Recreational	Total
	VL	LL	Trap	Tot		
1990	2,469,221	2,026,853	334,955	4,831,029	1,782,876	6,613,905
1991	2,075,282	2,561,904	411,019	5,048,204	2,083,653	7,131,857
1992	1,424,826	2,371,557	528,973	4,325,355	2,550,947	6,876,302
1993	1,001,121	3,724,886	707,455	5,433,462	1,884,944	7,318,406
1994	1,026,514	2,903,003	641,849	4,571,367	1,941,832	6,513,198
1995	843,594	2,266,021	909,812	4,019,428	2,298,187	6,317,615
1996	837,805	3,226,399	836,304	4,900,508	660,869	5,561,377
1997	933,435	3,440,688	962,970	5,337,094	916,213	6,253,306
1998	778,452	2,943,414	287,335	4,009,201	1,334,853	5,344,054
1999	1,174,147	3,917,107	704,258	5,795,512	2,548,896	8,344,408
2000	1,499,370	3,008,671	1,061,616	5,569,657	2,320,453	7,890,111
2001	1,403,240	3,397,676	772,980	5,573,897	1,576,490	7,150,387
2002	1,470,920	3,116,785	908,232	5,495,937	1,617,362	7,113,299
2003	1,049,740	2,855,956	648,867	4,554,563	1,428,269	5,982,832
2004	1,230,528	3,221,703	615,220	5,067,451	4,211,976	9,279,426
2005	1,318,369	3,191,919	635,602	5,145,889	1,853,680	6,999,569
2006	1,361,551	3,235,570	649,246	5,246,367	1,434,912	6,681,279
2007	1,521,677	2,237,912	24,477	3,784,066	1,114,476	4,898,542
2008	1,728,517	3,099,236	0	4,827,753	1,799,609	6,627,362
2009	2,658,554	1,249,366	0	3,907,921	1,290,079	5,198,000
2010	1,490,378	1,337,465	0	2,827,843	1,495,781	4,323,624
2011	2,043,875	3,163,589	15	5,207,479	2,042,623	7,250,102
2012	2,582,715	3,606,211	0	6,188,927	3,520,408	9,709,334
2013	1,840,218	3,440,115	0	5,280,334	4,535,769	9,816,102
2014	1,990,313	4,439,581	0	6,429,894	3,946,715	10,376,610
2015	2,107,070	3,329,708	0	5,436,778	2,140,314	7,577,092
2016	1,479,044	3,633,527	0	5,112,571	1,360,960	6,473,530
2017	1,047,923	2,460,469	0	3,508,392	872,583	4,380,975

Discards

Commercial discards of Red Grouper for the vertical line and longline fleets were estimated using a CPUE expansion approach that used the coastal observer program (2007-2017) in conjunction with total fishing effort from the commercial reef logbook program (1993-2017). Discard mortality rates of 41.5% for the commercial longline fleet and 19.0% for the commercial vertical line fleet were applied following updated estimates obtained from the NMFS Observer data through 2017 using the SEDAR42 recommended methodology. The trap fishery estimated discards and discard mortality rate of 10.0% remained unchanged from SEDAR42. Red Grouper commercial dead discards were estimated beginning in 1990 with the implementation of federal minimum size limits. Commercial longline fleet discards averaged 0.45 mp from 1990-2017, with a low of 0.08 mp in 2009 and a peak of 0.85 mp in 1993. Commercial vertical line fleet discards averaged 0.08 mp from 1990-2017, with a low of 0.02 mp in 2016 and a peak of 0.21 mp in 1990. Commercial trap fleet discards averaged 0.04 mp from 1990-2006, with a low of 0.01 mp in 1998 and a peak of 0.05 mp in 1995 (Figure 2).

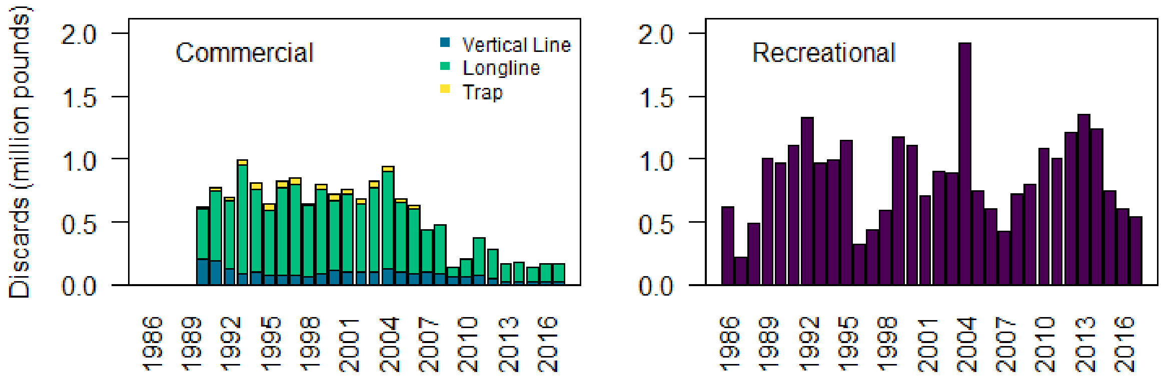

Figure 2: Final Red Grouper dead discard estimates from SEDAR61 assessment for commercial (left panel, by fleet) and recreational (right panel) fisheries in millions of pounds, 1986-2017.

Red Grouper recreational discards were derived from MRIP estimates of live released fish (B2) between 1986 and 2017 and self-reported discards in the SRHS logbook since 2007. Red Grouper discards from headboats for years prior to 2007 in Florida were estimated using the MRIP Charter:SRHS discard ratio as a proxy. The discard mortality for the recreational discards remained unchanged from SEDAR42 at 11.6%. Red Grouper recreational dead discard estimates averaged 0.87 mp from 1986 to 2017, with a low of 0.22 mp in 1987 and a peak of 1.92 mp in 2004 (Figure 2).

Data and Assessment

The assessment model used for the SEDAR61 Gulf of Mexico Red Grouper stock assessment was Stock Synthesis version 3.30. Stock Synthesis is an integrated statistical catch-at-age model, which projects forward from initial conditions using age-structured population dynamics equations. This flexible framework uses all available data in the least processed form possible in order to maintain consistency in error structure across data analysis and modeling assumptions.

For Gulf of Mexico Red Grouper, a model of moderate complexity was implemented. The model includes three commercial fishing fleets (vertical line, longline, and trap) and one recreational fishing fleet, with associated data inputs including landings, discards, age compositions, and discard length compositions where available. A pseudo-fishing fleet is included to represent episodic natural mortality due to severe red tide events. Four fishery-dependent catch-per-unit-effort indices and four fishery-independent surveys (including indices of relative abundance and length compositions) are included. Nearly all indices of relative abundance show clear declines in abundance over the last few years (Figure 3).

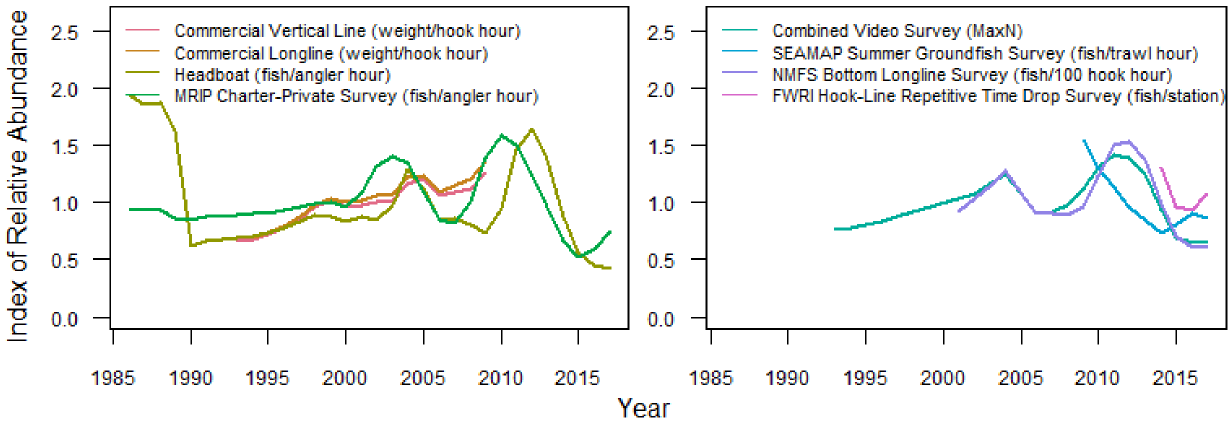

Figure 3: Final Red Grouper index estimates from SEDAR61 assessment by fishery (left panel) and survey (right panel), 1986-2017.

Life history equations and parameters used in SEDAR61 are reported in Table 2. A fixed length-weight relationship was used to convert body length (cm) to body weight (kg) in Stock Synthesis. Growth was modeled externally using a single size-modified von Bertalanffy growth curve for both sexes combined which takes into account the non-random sampling due to minimum size restrictions. An age-specific vector of natural mortality (M) was obtained using the Lorenzen (2005) estimator and a target M of 0.144 year^{-1} determined from the Hoenig (1983) teleost regression. Total fecundity-at-age was modeled as a function of proportion female, proportion mature, and batch fecundity. This approach accounts for a decrease in fecundity as females transition and become males. Spawning Stock Biomass (SSB) was defined as the number of eggs in the assessment model (relative number rather than an absolute number due to the derivation of fecundity-at-age). The Beverton-Holt stock-recruitment model was used in this assessment, and following the recommendation of SEDAR42, steepness (the fraction of virgin recruits produced at 20% of the equilibrium SSB) was fixed at 0.99.

Table 2: Overview of life history equations and recommended parameters used in SEDAR61. All Lengths (L) reported in the table were in Fork Length (FL).

Definition	Equation	Parameters
Total to Fork	FL = a + b * TL	a= 5.35 mm , b= 0.95
Length to Weight	$W(t) = a * L(t)^b$	a= 5.99E-06 kg*cm^{-b} , b= 3.25
Age to Length	$L(t)=L_{inf}*[1-e^{-K(t-t0)}]$	L_{inf}= 79.99 cm , K= 0.131 yr^{-1} , t_0= -0.87 yr
Target M	$M=\exp[1.46 - 1.01 * \ln(t_{max})]$	t_{max}= 29 yr
Age-specific M	See Sec. 2.2.3. Natural Mortality	
Maturity	$P_f(t) = \exp(-\exp[-(f_0+f_1* t)])$	f_0= -2.55 yr , f_1= 1.05

Definition	Equation	Parameters
	$P_f(t) = 0.50$	t_{50}= 2.8 yr , L_{50}= 29.2 cm
Sexual Transition	$P_m(t) = \exp(-\exp[-(m_0+m_1 * t)])$	m_0= 2.14 yr , m_1= -0.16
	$P_m(t) = 0.50$	t_{50}= 11.2 yr , L_{50}= 70.7 cm
Batch Fecundity	$BF(t) = a * L(t)^b$	a= 4.47E-05 eggs*cm^{-3*b} , b= 5.48
Age to Fecundity	$Fec(t) = P_f(t) * P_m(t) * BF(t)$	relative eggs
Recruitment	$R_{yr}=[4hR_0SSB_{yr}]*[SSB_0(1-h)+SSB_{yr}(5h-1)]^{-1}$	h=0.99, R_0= 20.44 million recruits

Stock Biomass

The estimated virgin spawning stock biomass was much larger than any of the estimates in the modeled time series of 1986 to 2017 (Figure 4). Spawning stock biomass declined from 1986 to 1990 and remained relatively low until 1995, a period where the stock was undergoing overfishing. Spawning stock biomass gradually increased until 2005 as the 1998 cohort moved through the population but declined considerably in 2006 following a severe red tide event that killed roughly 29.5% of the population. Spawning stock biomass increased from 2006 and peaked in 2012, likely due to the 2005 cohort moving through the population in combination with management measures (e.g., a reduction in the commercial size limit in 2009, the implementation of the commercial IFQ program in 2010). Spawning stock biomass declined sharply between 2014 and 2015, due in part to a severe red tide event that killed roughly 21.3% of the population. Spawning stock biomass has declined in the last three years, with the lowest estimate occurring in 2017 (Figure 4).

The estimate of relative spawning biomass in 2017 (i.e., depletion defined as the spawning biomass in 2017 divided by that at unfished equilibrium) is 0.246, with 95% asymptotic confidence intervals ranging between 0.198 and 0.294 (Figure 4). This is the lowest estimate in the time series modeled in the assessment. Relative spawning biomass was below the 30% management target from 1990 through 1996 and from 2015 through 2017. The two largest relative spawning biomass estimates of 0.538 (95%CI: 0.474-0.603) and 0.518 (95%CI: 0.446-0.589) occurred in 2012 and 2013, respectively, which were the last two years of data in the previous SEDAR42 stock assessment. The Gulf of Mexico Red Grouper relative spawning biomass has been decreasing since 2012, reaching a low of 0.246 in 2017 (Table 3).

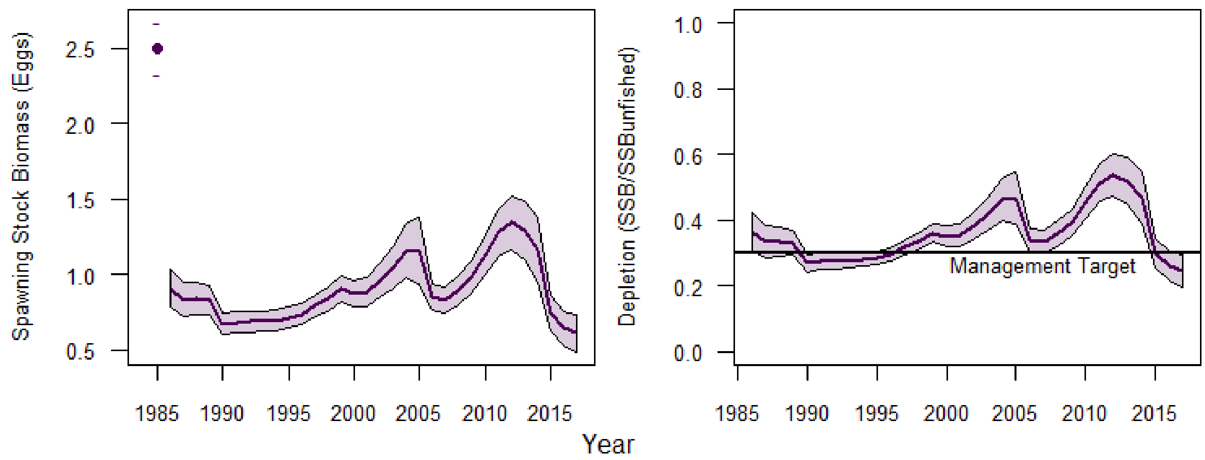

Figure 4: Spawning stock biomass (relative number of eggs) and stock depletion (SSB/SSB unfished) for Gulf of Mexico Red Grouper with 95% asymptotic confidence intervals (shaded region). The point in the left panel represents the estimated unfished equilibrium SSB with 95% asymptotic confidence intervals (lines).

Table 3: Recent trend in spawning stock biomass (spawning output in relative number of eggs) and relative spawning biomass (depletion) for the Gulf of Mexico Red Grouper with 95% confidence intervals (CI).

Year	Spawning Stock Biomass	95% CI	Relative Spawning Biomass	95% CI
2008	0.897	(0.799-0.995)	0.360	(0.322-0.398)
2009	0.982	(0.872-1.092)	0.394	(0.352-0.435)
2010	1.129	(0.998-1.260)	0.453	(0.404-0.501)
2011	1.280	(1.126-1.434)	0.513	(0.457-0.57)
2012	1.342	(1.166-1.518)	0.538	(0.474-0.603)
2013	1.291	(1.095-1.488)	0.518	(0.446-0.589)
2014	1.165	(0.946-1.384)	0.467	(0.387-0.547)
2015	0.745	(0.632-0.858)	0.299	(0.254-0.344)
2016	0.647	(0.534-0.761)	0.259	(0.215-0.304)
2017	0.614	(0.490-0.737)	0.246	(0.198-0.294)

Recruitment

Gulf of Mexico Red Grouper have low recruitment with occasional large year-classes (Figure 5). Very large year classes (>35 million age-0 Red Grouper) in 1995, 1998, 2001, 2005, and 2013 supported many of the fisheries catches, as evident by clear cohorts moving through the composition data used in the assessment. The lowest recruitment estimate occurred in 1997, with only 5.22 million recruits in comparison to the 120.01 million recruits estimated in 2005. Recent recruitment is lower on average than the mean recruitment throughout the time series. With the exception of a relatively high recruitment event in 2013, recent recruitment has generally remained below the average recruitment since 2007.

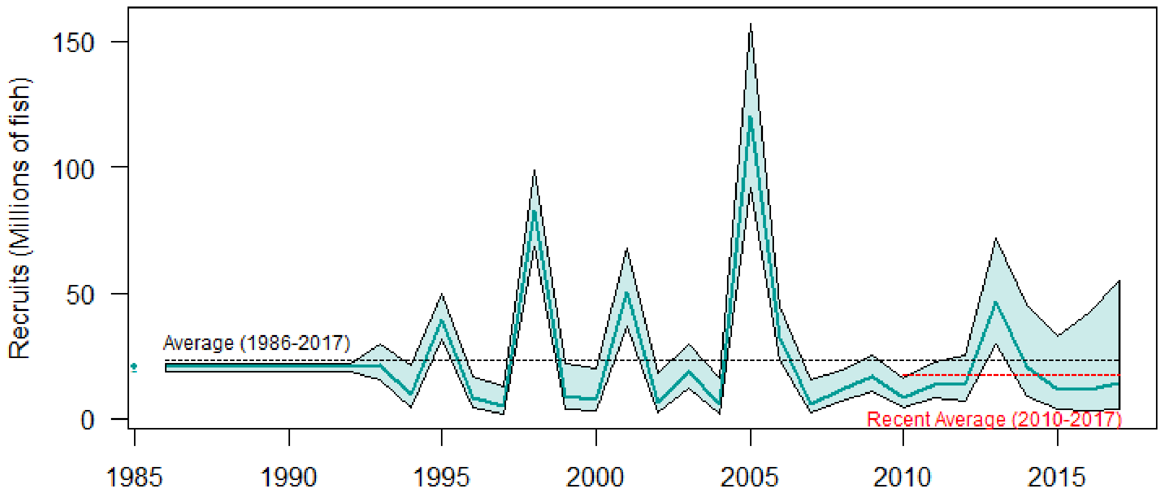

Figure 5: Estimated recruitment (millions of fish) for Gulf of Mexico Red Grouper with 95% asymptotic confidence intervals (shaded region). Thin dashed lines represent average recruitment during the entire time series (upper line) and the recent period (2010-2017; lower line).

Table 4: Recent trends in recruitment and recruitment deviations for the Gulf of Mexico Red Grouper with 95% confidence intervals (CI).

Year	Recruitment (millions)	95% CI	Recruitment Deviations	95% CI
2008	11.80	(7.14-19.50)	-0.27	(-0.79-0.25)
2009	16.63	(11.04-25.04)	0.07	(-0.35-0.49)
2010	8.42	(4.39-16.16)	-0.61	(-1.26-0.04)
2011	13.55	(8.21-22.36)	-0.14	(-0.65-0.38)
2012	13.40	(7.08-25.35)	-0.15	(-0.78-0.49)
2013	46.22	(29.82-71.65)	1.09	(0.65-1.53)
2014	20.31	(9.08-45.43)	0.25	(-0.58-1.08)
2015	11.44	(4.00-32.74)	-0.41	(-1.52-0.70)
2016	11.72	(3.25-42.21)	-0.48	(-1.90-0.94)
2017	14.23	(3.69-54.90)	-0.35	(-1.88-1.17)

Exploitation Status

Based on current definitions of Minimum Stock Size Threshold, $MSST_{new} = 0.5SPR_{30\%}$, and Maximum Fishing Mortality Threshold, $MFMT = F_{SPR30\%}$, the SEDAR61 Base Assessment Model indicated that the Gulf of Mexico Red Grouper stock is not overfished (SSB / $MSST_{new}$ > 1) and overfishing is not occurring (F / MFMT < 1) [SSB_{2017} / $MSST_{new}$ = 1.64; F_{2017} / MFMT = 0.783] (Table 5). Under the previous definition $MSST_{old} = (1-M)*SPR_{30\%}$, the Red Grouper resource would be considered overfished in 2017 [SSB_{2017} / $MSST_{old}$ = 0.958]. According to the new definition for MSST, the Red Grouper stock has not been overfished at any point in the time series 1986-2017 (Figure 6). The stock was undergoing overfishing in the early portion of the time series (Figure 6).

Table 5: Summary of MSRA benchmarks and reference points for the SEDAR61 Gulf of Mexico Red Grouper stock assessment. Stock status is provided relative to both the current ($0.5B_{MSY(proxy)}$) and old ($[1-M]*B_{MSY(proxy)}$) definitions of MSST. SSB is in relative number of eggs, whereas F is a harvest rate (total biomass killed / total biomass).

Variable	Value
Reference Point Criteria	
Base M	0.144
Steepness	0.99
Virgin Recruitment	20,443
SSB Unfished	2,494,130
Generation Time	11.17
Mortality Rate Criteria	
F_{MSY}	Not Estimable
$F_{MSY(proxy)}$	0.259
MFMT	0.259
F_{OY}	0.194
$F_{current}$(2015-2017 Average)	0.203
$F_{current}$ / MFMT	0.784
Overfishing	No
Biomass Criteria	
$SSB_{MSY(proxy)}$	748,241
$MSST_{old}$	640,494
$MSST_{new}$ (Amendment 44)	374,120
SSB_{2017}	613,517
SPR Proxy Target	0.300
SPR $MSST_{old}$	0.257
SPR $MSST_{new}$	0.150

Variable	Value
SSB_{2017} / $SSB_{FMSY(proxy)}$	0.82
SSB_{2017} / $MSST_{old}$	0.96
$MSST_{old}$ Overfished?	Yes
SSB_{2017} / $MSST_{new}$ (Amendment 44)	1.64
$MSST_{new}$ Overfished?	No
SSB_{2017} / $SSB_{Unfished}$	0.25

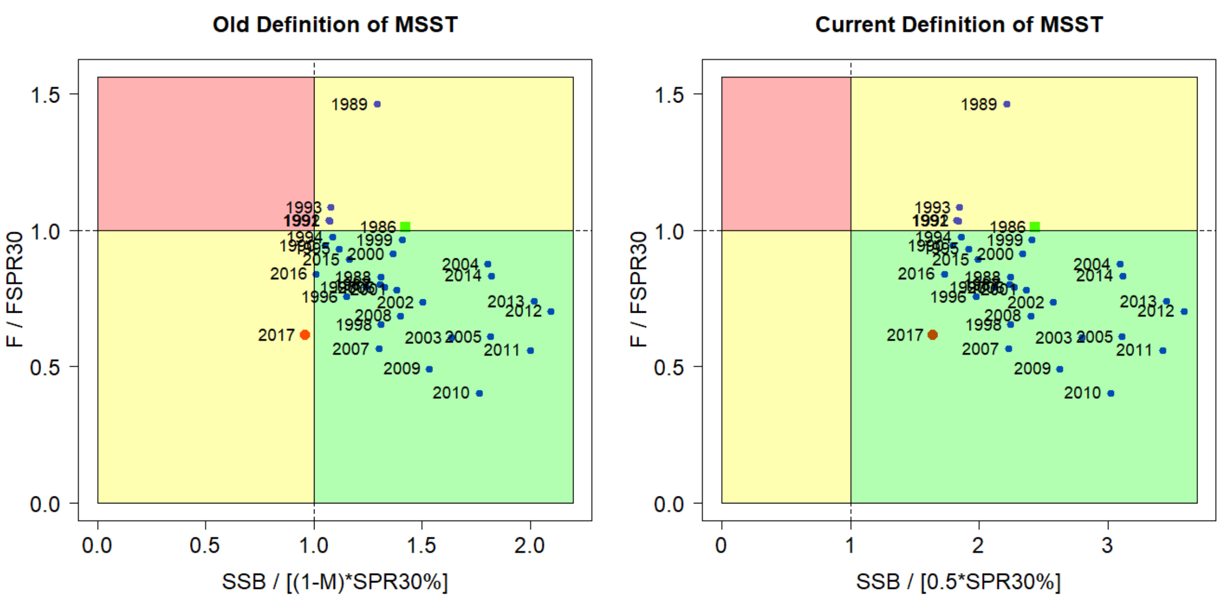

Figure 6: Kobe plot of stock status for Gulf of Mexico Red Grouper based on the old definition of MSST ([1-M]$B_{MSY(proxy)}$; left panel) and the current definition of MSST (0.5$B_{MSY(proxy)}$; right panel).

Ecosystem Considerations

Impacts of red tide blooms, *Karenina brevis*, have been an increasing cause of concern for fisheries management on the West Florida Shelf. Anecdotal evidence from 1971 described a notable red tide event that resulted in the mass death of shallow-water groupers (Smith 1975). More recently, the most severe red tide event affecting Red Grouper occurred in 2005, followed by another fish kill less than a decade later in 2014. While this assessment only included data through 2017, there has been growing evidence that a severe red tide event occurred in 2018. These added sources of mortality have a significant impact on the population size of Red Grouper.

Red tide mortality has been considered in the Red Grouper assessment model since the SEDAR12 Update. Initially, an extra mortality term was included in 2005 to account for elevated mortality following observations by fishermen who attended the meeting. During SEDAR42, a red tide pseudo-fishing fleet was used to drive mortality and was based on a binary index where red tide events were depicted as present (= 1, solely in 2005) or absent (= 0) between 1998 and 2010 based on the predicted probability of a severe red tide bloom. In contrast to SEDAR42 where only a single red tide event was included, two red tide events (2005, 2014) were incorporated into the SEDAR61 assessment model. The assessment model used information from data sources already in the model to scale red tide removals in 2005 and 2014. Selectivity of the red tide fishing fleet was assumed constant at age (i.e. = 1) due to the lack of data on size-specific red tide mortality .

Given the overwhelming amount of anecdotal evidence provided by fishermen and stakeholders describing a severe red tide event in 2018, the subsequent Management Advice section includes projections assuming a range of scenarios from no red tide mortality to double the 2005 red tide mortality rate. An important point to note is that despite increasing frequency of red tide events, we currently lack the ability to predict red tide events, and all Management Advice projections assume no red tide events in future years beyond 2018.

Management Advice

The retained yield and associated depletion were projected through 2117 (shown through 2035) for each 2018 red tide scenario under (1) maintaining 2017 landings and (2) achieving 30% SPR in equilibrium (Figure 7). Five red tide scenarios were simulated ranging from no mortality to double the 2005 red tide mortality: (a) no red tide mortality in 2018, (b) half 2014 magnitude (0.1285), (c) same as 2014 (0.257), (d) same as 2005 (0.339), and (e) double 2005 magnitude (0.678). If the worst case red tide severity occurred in 2018, fishing to maintain 2017 landings leads to an overfished state over the 2020–2024 interval (Figure 7, right panel, yellow solid line). Conversely, targeting 30% SPR in equilibrium allowed much higher landings, and an overfished state was also only observed under the most severe red tide magnitude for the current definition of $MSST_{new}$ (Figure 7, right panel, yellow dashed line).

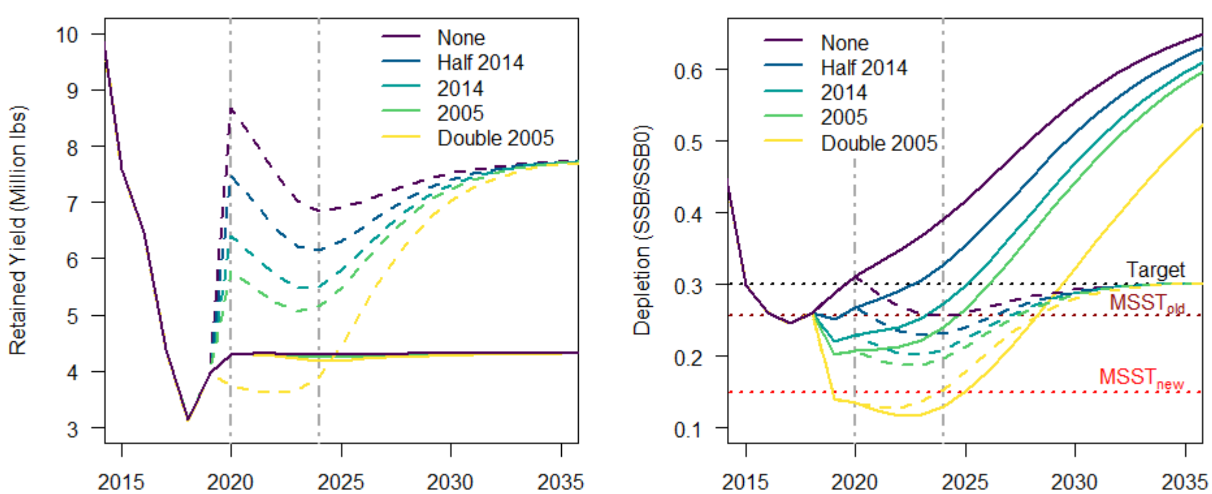

Figure 7: Overfishing limit (retained yield; left panel) and resulting Depletion (right panel) for projections with landings fixed at 2017 levels (solid lines) and fishing at $F_{SPR30\%}$ (dashed lines),

both assuming recent average recruitment. Red tide scenarios include 2018 red tide event magnitude assumed: (1) none; (2) half of 2014 (0.1285); (3) same as 2014 (0.257), (4) same as 2005 (0.339), and (5) double 2005 (0.678). The upcoming 2020-2024 interval is marked with gray vertical lines. The Target Depletion ($SPR_{30\%}$), previously defined Minimum Stock Size Threshold ($MSST_{old}$), and currently defined Minimum Stock Size Threshold ($MSST_{new}$) are marked with horizontal dotted lines.

The probability of overfishing in 2020–2024 was determined by comparing the probability density function (PDF) of retained yield (millions of pounds) using the "no 2018 red tide" scenario to the PDF of retained yield under each red tide scenario. The corresponding overfishing limits (OFLs) were calculated as the median (50th percentile, or a 50% probability of overfishing occuring). Maintaining landings observed in 2017 resulted in a low probability of overfishing in 2020–2024 under all red tide scenarios with the exception of the most severe simulation of double the 2005 red tide mortality, which had an 83% chance of overfishing (Table 6). The projections that achieve 30% SPR in equilibrium ($F_{SPR30\%}$) resulted in a relatively high probability of overfishing for all simulated scenarios that included red tide mortality in 2018.

Table 6: Estimated probability of overfishing in 2020–2024 for the Gulf of Mexico Red Grouper base models under projections that achieve $SPR_{30\%}$ in equilibrium and maintain 2017 catch levels. Five 2018 red tide scenarios of varying magnitudes include: (1) no red tide mortality in 2018; (2) half of 2014 (0.1285); (3) same as 2014 (0.257), (4) same as 2005 (0.339), and (5) double 2005 (0.678).

Scenario	**2018 Red Tide Magnitude**				
	None	Half 2014	2014	2005	Double 2005
2017 Landings	**0.00**	**0.01**	**0.05**	**0.11**	**0.83**
$F_{SPR30\%}$	**0.50**	**0.82**	**0.98**	**1.00**	**1.00**

The definition of $MSST_{old}$ (overfished status) appears to more closely agree with the reported probabilities of overfishing, where red tide scenarios with a high probability of undergoing overfishing 2020–2024 (Table 6, $F_{SPR30\%}$) result in an overfished state over the same interval (Figure 7). The implications of redefining MSST was shown relative to the entire Depletion time series alongside projections of red tide impacts (Figure 8). These scenarios are projecting impacts from varying red tide severities for the 2018 event and no subsequent red tide events 2019–2035. Given the increasing frequency of documented red tide events affecting Red Grouper (e.g. 2005, 2014, 2018), these results should be interpreted with caution.

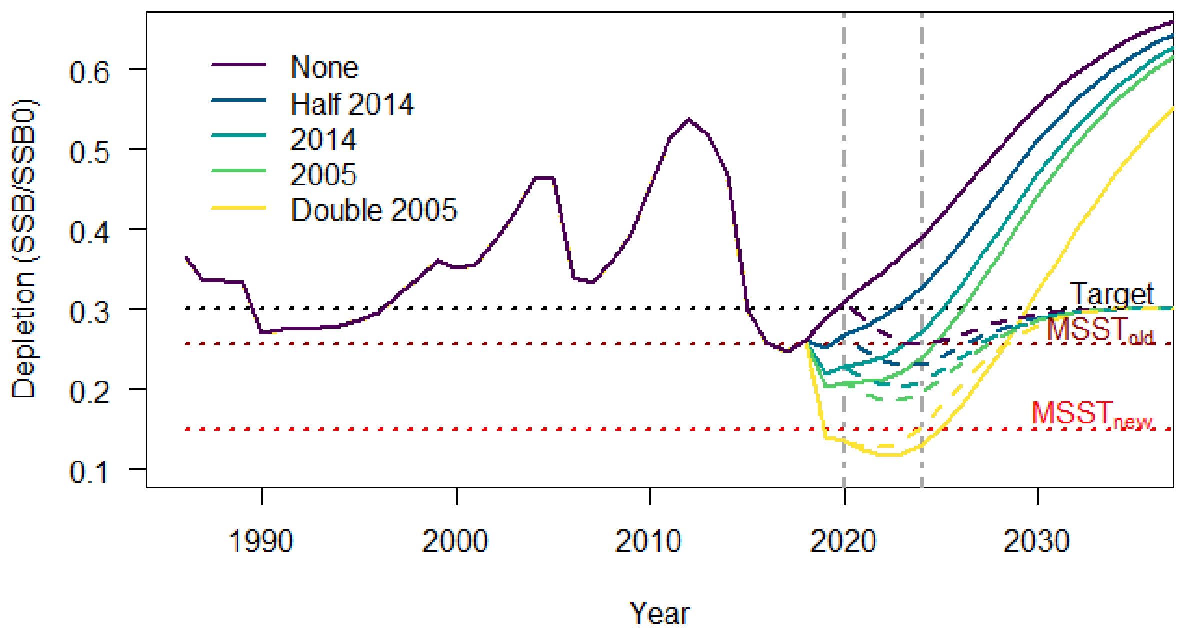

Figure 8: Entire time series of Depletion with projections of landings fixed at 2017 levels (solid lines) and fishing at $F_{SPR30\%}$ (dashed lines), both assuming recent average recruitment. Red tide scenarios include 2018 red tide event magnitude assumed: (1) none; (2) half of 2014 (0.1285); (3) same as 2014 (0.257), (4) same as 2005 (0.339), and (5) double 2005 (0.678). The upcoming 2020-2024 interval is marked with gray vertical lines. The Target Depletion ($SPR_{30\%}$), previously defined Minimum Stock Size Threshold ($MSST_{old}$), and currently defined Minimum Stock Size Threshold ($MSST_{new}$) are marked with horizontal dotted lines.

Unresolved Problems and Major Uncertainties

Measures of uncertainty in the base model underestimate the total uncertainty in the current stock status and projections because they do not account for possible alternative structural models for Red Grouper population dynamics and fishery processes (e.g., selectivity). To address such structural uncertainties, including those related to red tide mortality, we performed sensitivity analyses and alternative projection scenarios (2018 red tide severity) to investigate a range of alternative assumptions, and present the key ones in the main document.

Future Red Grouper assessments should focus on refining approaches to calculate historical landings to unfished conditions which would help alleviate concerns over approximating initial conditions (e.g., initial fishing mortality rates). Other major sources of uncertainty for the Gulf of Mexico Red Grouper stock assessment are how past red tides have impacted age classes and how future red tides will impact the population (e.g., mortality only, movement + mortality) and steepness.

Research Recommendations

There are many research projects that could improve the stock assessment for Gulf of Mexico Red Grouper and lead to improved biological understanding and decision-making.

- Investigate methods to better collect age structure samples and continue research on enhancing ageing procedures
- Continue data collection of discards (size composition, mortality) from observer programs
- Explore appropriate measures of reproductive potential for protogynous groupers, including Red Grouper, such as combined male/female SSB
- Re-evaluate historical landings (with uncertainty) in light of the new MRIP estimates
- Investigate alternative analyses for developing catch-per-unit effort indices of relative abundance for commercial fleets (post-IFQ)
- Continue research aimed at addressing red tide issues such as elucidating ecosystem impacts, investigating a species' response (i.e., movement, mortality), obtaining species composition/size of fishes killed, refining existing indices of red tide severity/mortality and cooperative research with fishermen for data collection