THE IMPACT OF A REDUCTION IN SHRIMP EFFORT THRESHOLDS ON SEDAR 52 GULF OF MEXICO RED SNAPPER CATCH LIMIT PROJECTIONS

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Executive summary

The Gulf of Mexico Fishery Management Council requested an evaluation of the impact of potential increases in shrimp effort (or shrimp days) on the red snapper resource. Results from new projections of the SEDAR 52 assessment indicate that increasing gulfwide shrimp effort by 8% (i.e., reducing the shrimp effort threshold to 60% of 2001 – 2003 average levels) would be unlikely to substantially impact ABCs for Gulf of Mexico red snapper. Further increases in effort were also evaluated to determine at what threshold value a substantial impact would occur. Overall, moderate increases in shrimp effort are unlikely to alter rebuilding schedules or ABCs, while allowing effort to return to 2001 – 2003 levels would cause substantial declines in ABCs.

1. Introduction

In a memo dated April 16, 2018, the Gulf of Mexico Fishery Management Council (GMFMC) requested the Southeast Fishery Science Center (SEFSC) to perform a series of alternate projections to demonstrate the impact of an increase in shrimp effort (analogous to shrimp days) on acceptable biological catches (ABCs) for the Gulf of Mexico red snapper fishery. Due to bycatch of juvenile red snapper in the shrimp fishery, Amendment 14 to the Shrimp Fishery Management Plan required a reduction of shrimp effort in areas where red snapper bycatch was high (i.e., 10-30 fathom depth zones in statistical areas 10-21 in the Gulf of Mexico). Effort reductions of 74% from the 2001-2003 average were initially required and updated in 2011 to 67% with a long-term target of 60% by 2032 (i.e., the target rebuilding date for red snapper). Although red snapper is still in a rebuilding plan (due to its being below the SSB_{MSY} proxy of SPR 26%), it is no longer considered overfished, because it is above the minimum stock size threshold (MSST) of 0.5 * $SSB_{SPR26\%}$ (SSB_{2016} / MSST = 1.41). Therefore, the GMFMC is interested in lowering the target shrimp effort reduction thresholds in the Gulf of Mexico. Based on the request to investigate the impact of increasing shrimp effort on Gulf of Mexico red snapper rebuilding schedules and ABCs, the SEFSC performed a series of alternate ABC projections where shrimp bycatch levels were increased by various proportions compared to the 2001 – 2003 baseline levels.

2. Methods

Deterministic projections were run using the final SEDAR 52 Stock Synthesis 3 (SS3; Methot 2015; Methot and Wetzel 2013) base model accepted by the Gulf of Mexico SSC (SEDAR 2018a). Projection settings followed the methods outlines in the SEDAR 52 projections document as described in the OFL and ABC section therein (SEDAR 2018b). Projections began in 2017 using the same parameter values and population dynamics as the base model. A full description of the model settings can be found in **Table 1**. Because the base model assumes a fixed steepness of essentially 1.0, the projections assumed that forecasted recruitment would continue at recent average levels (i.e., projected recruitment was near the ‘virgin’ recruitment level for the recent productivity regime, 1984 – 2016, of 163 million fish) and historical average recruitment apportionment levels were assumed (i.e., 34% to the east and 66% to the west). For all years of the projections it was assumed that recent fishery dynamics would continue indefinitely including maintaining a 51% to 49% allocation of commercial to recreational catch. The selectivity for each fleet was taken from the terminal timeblock and relative harvest rates for the directed fisheries were assumed to stay in proportion to the terminal three year average (2013 – 2016) values. Similarly, discarding and retention practices were assumed to continue as they had in the three most recent years (2013 - 2016). The projected fishing mortality levels for the six bycatch fleets (shrimp bycatch, recreational closed season, and commercial closed season/no-IFQ) were assumed to be the same as in 2016 (i.e., fixed at their associated 2016 values; see **Figure 1** for terminal year relative fishing mortality rates by fleet) in the Base projections, but the fishing mortality for the shrimp bycatch fleets were varied depending on the scenario (as outlined below and in **Table 2**).

For SPR-based analyses, the harvest rate (total number killed / total abundance) that led to a gulfwide SPR of 26% (i.e., $SPR = \frac{\frac{SSB}{R}}{\frac{SSB_0}{R_0}} = 0.26$, which is equivalent to $\frac{SSB}{SSB_0}$ when steepness = 1.0 and recruitment is constant) was obtained by iteratively adjusting yield streams. Basically, the fishing mortality rates exerted by the directed fleets were scaled up or down by the same proportional amount (with the fishing mortality rates exerted by the bycatch and discard fleets held constant) until the fishing mortality that achieved a SPR of 26% was obtained.

Overfishing limits (OFLs) were calculated as the median (50th percentile) of the probability density function (PDF) of retained yield (millions of pounds) using the projection of $F_{SPR26\%}$ (i.e., the yields that achieved a SPR of 26% in equilibrium). ABCs were obtained through rebuilding projections based on a $F_{Rebuild}$ that achieved a SPR of 26% by 2032, where the ABC was calculated assuming a probability of overfishing (P*) of 0.40 (i.e., the 40th percentile of the PDF of the landings in retained yield from $F_{Rebuild}$). All projections included 2017 provisional landings (15.36 million pounds) and a fully utilized 2018 ACL (13.74 million pounds). Uncertainty in derived quantities (including retained yield) was carried through the projections from the parameter estimation phase in the stock assessment model and represented the approximate variance from the inversion of the Hessian matrix. The probability density function (PDF) and 95% confidence intervals are calculated assuming a normal distribution of the derived quantity.

A total of five sensitivity runs were carried out. Each examined different increases in the level of shrimp bycatch fishing mortality (as a proxy for an increase in effort). Runs were compared to the base model runs used for setting ABCs and OFLs through projected yield streams and associated SPR values from 2019 (the first year of catch advice set using the SEDAR 52 projections) to 2032 (the rebuilding date for Gulf of Mexico red snapper).

Although the initial GMFMC request asked for 1% decrements from the current 67% reduction in shrimp effort to 60%, initial explorations indicated that the maximum decrement in shrimp effort threshold requested (i.e., 60%) resulted in mostly negligible reductions in ABCs.

Therefore, it was determined that a more informative analysis would be to perform a handful of sensitivity runs with more extreme increases in shrimp effort ranging from the maximum reduction threshold requested (i.e., a 60% reduction from the 2001 – 2003 average effort) to a 0% reduction (including intermediate values representing 56% and 40% reductions from the 2001 – 2003 average).

A number of assumptions needed to be made to translate percent increases in shrimp effort to percent increases in associated shrimp bycatch fishing mortality (i.e., the fixed fishing mortality values used in the projections). The major assumption was that fishing mortality was directly proportional to fishing effort and that a percent increase in effort (or shrimp days) represented a matching percent increase in fishing mortality rates. Secondly, it was assumed that a percent increase in total effort corresponded to an equal increase in effort in both regions. Because the assessment model includes two regions, east and west Gulf of Mexico, each with its own shrimp bycatch fleet, it was necessary to scale the fishing mortality in each region. Unfortunately, the shrimp effort increases outlined in Amendment 14 were associated with statistical areas 10-21, which intersected the statistical areas assumed for the eastern and western Gulf of Mexico in the SEDAR 52 assessment model (i.e., east corresponded to areas 1-12 and west corresponded to areas 13-21). Therefore, without further guidance as to the relative increases in effort by area, it was necessary to assume an equal proportional increase in each area. Additionally, because of the mismatch in statistical areas for officially calculating the relative decrease in effort from the 2001 – 2003 levels compared to the effort values used in the SEDAR 52 assessment, the relative reductions varied slightly between methods. Based on statistical zones 10 – 21 (i.e., those used in Amendment 14), there has been a 69% reduction in effort. However, using areas 1-21 (i.e., the total effort used in the SEDAR 52 assessment), there has only been a 63% reduction in effort compared to the 2001 -2003 average levels.

It is important to understand that the relationship between the percent change in the threshold effort level and the change in effort needed to achieve that threshold is not linear, because the distribution of effort between regions varies among the two time periods (i.e., the eastern gulf represents 15% of the shrimp effort in 2016, whereas it represented 24% during the 2001 – 2003 baseline period). Thus, because effort changes are assumed proportional among regions, the relationship between the percent change from baseline levels (i.e., the threshold value) and the percent change in effort required to achieve those threshold values is not directly proportional (i.e., to move from a 63% threshold to a 60% threshold requires an 8% increase in gulfwide effort).

Runs were carried out representing a 60% reduction compared to the SEDAR 52 total effort levels from 2001 – 2003 (i.e., matching the maximum threshold reduction and maximum percentage increase in effort of 8% requested by the GMFMC; *Reduce_60*), a 56% reduction from the SEDAR 52 total effort levels from 2001 -2003 (*Reduce_56*), a 40% reduction from the SEDAR 52 total effort levels from 2001 -2003 (*Reduce_40*), and a 0% reduction (i.e., effort equivalent to that in 2001 – 2003, *Reduce_0*; see **Table 2** for a list of scenarios and associated fishing mortality values). Given the assumptions required to translate effort (shrimp day) increases into associated fishing mortality increases (i.e., that they are proportional), a 0% reduction does not result in fishing mortality values for the shrimp bycatch fleets that match the 2001 -2003 average estimated shrimp bycatch fishing mortalities from the SEDAR 52 assessment. An additional scenario (*Asses_F_2001_2003*) was thus carried out that utilized the estimated average shrimp bycatch fishing mortality rates for 2001 to 2003 from the SEDAR 52 assessment as an alternate approach to projecting the dynamics of the shrimp fleets during the baseline period (i.e., 2001 – 2003).

3. Results

Increasing shrimp bycatch effort within the limits proposed in the GMFMC memo (i.e., reducing the threshold to 60% or increasing effort by 8%) has relatively minimal impacts on ABCs. The *Reduce_60* and *Reduce_56* scenarios decreased catches by approximately 100,000 and 200,000 pounds per year, respectively, over the course of the red snapper rebuilding period (**Table 3**) and had almost no impact on the resulting SPR values (**Table 4**). Intermediate increases in shrimp effort (e.g., the *Reduce_40* scenario) had a stronger influence and resulted in a loss of about a million pounds per year in the ABC over the rebuilding period. Both the *Reduce_0* and the *Asses_F_2001_2003* scenarios demonstrated similar results with losses in ABC of about 2.5 million pounds per year, but with a maximum of 3 million pounds in 2019 (the first year of catch advice).

4. Discussion

Results indicate that increasing shrimp effort (or shrimp days) by the amounts proposed in the GMFMC memo would be unlikely to substantially impact ABCs for Gulf of Mexico red snapper. Allowing shrimp effort to increase back to the baseline levels from 2001 – 2003 would cause strong declines in ABC levels. Overall, moderate changes in shrimp bycatch levels are unlikely to alter rebuilding schedules or ABCs.

As described in the methods, bycatch and discard fleets are treated in a similar manner as natural mortality in the projections. This implies that retained yield by the directed fleets is maximized following the removals due to the bycatch/discard fleets. Given the way that bycatch and discard fleets are handled, resultant ABCs will typically increase when bycatch/discards decrease and vice versa. The reason for this is that total dead removals which achieve a desired SPR rebuilding target are relatively invariant, and the model can trade removals between bycatch/discard or directed fleets. In the current projections, as bycatch increased the resulting retained yield (ABCs) had to decrease to maintain the same level of dead removals in order to achieve the rebuilding target.

Although shrimp bycatch still represents one of the larger sources of mortality for red snapper (particularly in the western region), mortality due to discards from the recreational fleets during closed seasons (especially in the eastern region) is now much higher (**Figure 1**). The increase in recreational closed season discards over the last decade has acted to diminish the impact of shrimp bycatch levels on ABCs and rebuilding schedules. Additionally, compared to previous assessments and associated projections (e.g., prior to SEDAR 31), the relatively high natural mortality values assumed for age-0 and 1 fish (i.e., those ages primarily caught as bycatch in shrimp trawls) likely acts to additionally reduce the impact of shrimp bycatch on rebuilding schedules. Because a higher proportion of these juvenile fish are assumed to die from natural causes, shrimp bycatch has a lesser impact on the resource, and moderate increases in shrimping effort is unlikely to greatly impact ABCs.

There are a number of important caveats for these projections. First, these calculations do not account for the highly variable nature of recruitment events nor the fundamental relation between adult spawners and subsequent recruits. Projections are completely deterministic and based on the assumption that future recruitment will remain constant at recent averages (i.e., steepness is approximately 1.0). The constant recruitment assumption is appropriate for short-term projections where SSB is not likely to decrease rapidly, but can lead to inappropriate long-term or equilibrium projections. Additionally, the multiple assumptions required to translate increases in shrimp effort into associated increases in shrimp bycatch fishing mortality (i.e., that they are directly proportional) along with the slight differences in how effort is tallied between the assessment model and Amendment 14 imply that these results should only be used for informational purposes. The resultant ABCs should not be used for setting management advice without more detailed analyses.

5. Acknowledgements

The SEDAR 52 assessment would not have been possible without the efforts of the numerous SEFSC, SERO, and GMFMC staff along with the many academic and research partners involved throughout the Gulf of Mexico. In particular, those who helped compile the documents and input data sets including: Julie Neer (SEDAR Coordinator); Ryan Rindone (Management History); Refik Orhun and Beth Wrege (Commercial Catch); Vivian Matter and Kelly Fitzpatrick (Recreational Catch and Discards); Kevin McCarthy (Commercial discards); Adyan Rios and Skyler Sagarese (Recreational CPUE); Robert Allman, Gary Fitzhugh, and Linda Lombardi-Carlson (Life History); Adam Pollack, Walter Ingram, Kevin Thompson, Matt Campbell, David Hanisko, Sean Powers, John Walter, and Mandy Karnauskas (Fishery Independent Indices); Rick Hart and Jeff Isely (Shrimp bycatch); Ching-Ping Chih (Size and Age composition); Matthew Campbell and Beverly Sauls (Discard mortality); Dominique Lazarre (Headboat Discard Length Frequency); and Elizabeth Scott-Denton (Shrimp Bycatch Length Frequency).

6. References

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Methot, R., and Wetzel, C. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research, 142: 86-99.

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SEDAR. 2018b. SEDAR 52 Stock Assessment Report: Gulf of Mexico Red Snapper. SEDAR, North Charleston, SC. 434p. Available online at: http://sedarweb.org/docs/sar/S52_Final_SAR_v2.pdf.

7. Tables

Table 1. Summary of projection settings and equations. Citations to Tables and Figures refer to those in the SEDAR 52 stock assessment report (SEDAR 2018a,b).

Derived quantity	Equation	Parameter values
Recruitment (R)	$R_{Reg,Year} = P_{Area}\dfrac{4hR_0 SSB_{Year}}{SSB_0(1-h)+SSB_{Year}(5h-1)}$	P_{East} = 0.23, P_{West} = 0.77, h = 0.99, R_0 = 163 million fish
Growth Curve	$L(t) = L_\infty\left[1-e^{-k(t-t_0)}\right]$	L_∞ = 85.64cm, k = 0.19yr^{-1}, t_0 = -0.39, See **Figure 2.4**
Weight-Length Relationship	$Weight = aL^b$	a = 1.7E-5, b = 3, See **Figure 2.5**
Fecundity-at-Age (Fec)	Input	See **Table 2.3**
Selectivity (S)	Input	See **Figure 4.9**
Retention (Ret)	Input	See **Figure 4.13**
Discard Mortality (DM)	Input	See **Table 2.2**
Natural Mortality (M)	Input	See **Table 2.1**
Directed Fishing Mortality (F_{Dir}) by Fleet	$F^{Fleet}_{Dir,Reg,Age,Year} = S^{Fleet}_{Dir,Reg,Age}F^{Fleet}_{Dir\_Mult,Reg,year}Ret^{Fleet}_{Dir,Reg,Age}$	Directed Fleets are HL, LL, HBT, and MRIP
Directed Discard Fishing Mortality (F_{Disc}) by Fleet	$F^{Fleet}_{Disc,Reg,Age,Year} = F^{Fleet}_{Dir\_Mult,Reg,year}(1-Ret^{Fleet}_{Dir,Reg,Age})\,DM^{Fleet}_{Dir}$	Fishing mortality due to open season discards for a directed fleet
Total Directed Fishing Mortality (F_{Tot_Dir}) by Fleet	$F^{Fleet}_{Tot\_Dir,Reg,Age,Year} = F^{Fleet}_{Dir,Reg,Age,Year} + F^{Fleet}_{Disc,Reg,Age,Year}$	Total fishing mortality for a directed fleet
Bycatch/Closed Season Discard Fishing Mortality (F_{Byc}) by Fleet	$F^{Fleet}_{Byc,Reg,Age,Year} = S^{Fleet}_{Byc,Reg,Age}F^{Fleet}_{Byc\_Mult,Reg,year}$	Bycatch and Closed Season Discard Fleets are C_No_IFQ, R_Closed, and SHR
Total Fishing Mortality (F_{Tot})	$F_{Tot,Reg,Age,Year} = \sum_{Fleet} F^{Fleet}_{Tot\_Dir,Reg,Age,Year} + F^{Fleet}_{Byc,Reg,Age,Year}$	Total Fishing Mortality Summed Across All Fleets
Total Mortality (Z)	$Z_{Reg,Age,Year} = F_{Tot,Reg,Age,Year} + M_{Age}$	Total Mortality Summed Across All Fleets
Abundance-at-Age (N)	$N_{Reg,Age+1,Year+1} = N_{Reg,Age,Year}e^{-Z_{Reg,Age,Year}}$	Total Abundance by Region
Spawning Stock Biomass (SSB)	$SSB_{Year} = \sum_{Reg}\sum_{Age=0}^{20}(Fec_{Age}N_{Reg,Age,Year}e^{-0.5Z_{Reg,Age,Year}})$	Note that Mortality is Discounted for Midyear Spawning
Retained Catch-at-Age (C) by Fleet	$C^{Fleet}_{Dir,Reg,Age,Year} = N_{Reg,Age,Year}(1-e^{-Z_{Reg,Age,Year}})\dfrac{F^{Fleet}_{Dir,Reg,Age,Year}}{Z_{Reg,Age,Year}}$	Retained Catch for a Directed Fleet
Retained Yield (Y) by Fleet	$Y^{Fleet}_{Dir,Reg,Year} = \sum_{Age=0}^{20}\overline{W^{Fleet}_{Age}}C^{Fleet}_{Dir,Reg,Age,Year}$	See SS3 Manual (Methot 2015) for a Complete Description of the Length Integrated Fleet-Specific Weight-at-Age (W)
Spawning Potential Ratio (SPR)	$SPR = \dfrac{\frac{SSB}{R}}{\frac{SSB_0}{R_0}}$	SSB_0 = 4.72E+15 eggs

Table 2. Scenarios and associated fishing mortality rates. The *Asses_F_2001_2003* scenario uses the estimated average shrimp bycatch fishing mortality rates for 2001 to 2003 from the SEDAR 52 assessment as an alternate approach to projecting the dynamics of the shrimp fleets during the baseline period. Therefore, the percent change is not in shrimp days, but the change in actual fishing mortality rates from the assessment model.

Scenario Run	SEDAR 52 Base	Reduce_60	Reduce_56	Reduce_40	Reduce_0	Assess_F_2001_2003
% Reduction In Gulfwide Shrimp Days Compared to 2001-2003 Average	63%	60%	56%	40%	0%	--
% Increase in Shrimp Days Compared to Base Model	--	8%	20%	63%	270%	447% east*, 247% west*
East Shrimp Bycatch F	0.0069	0.0075	0.0083	0.0113	0.0187	0.0310
West Shimp Bycatch F	0.1537	0.1660	0.1844	0.2505	0.4150	0.3797

*These values represent changes in fishing mortality rates not shrimp days.

Table 3. ABCs (in millions of pounds whole weight) for each of the scenarios.

	ABC					
Year	**SEDAR 52 Base**	**Reduce_60**	**Reduce_56**	**Reduce_40**	**Reduce_0**	**Assess_F_2001_2003**
2019	16.0	16.0	16.0	14.7	13.1	13.3
2020	15.0	15.0	15.0	13.9	12.5	12.7
2021	14.3	14.3	14.2	13.3	12.0	12.2
2022	13.8	13.7	13.7	12.8	11.5	11.7
2023	13.4	13.3	13.3	12.4	11.1	11.2
2024	13.2	13.1	13.0	12.2	10.7	10.9
2025	13.1	13.0	12.9	12.0	10.6	10.7
2026	13.0	13.0	12.8	12.0	10.5	10.7
2027	13.0	12.9	12.8	12.0	10.5	10.6
2028	13.0	12.9	12.8	11.9	10.5	10.6
2029	13.0	12.9	12.8	11.9	10.5	10.6
2030	13.0	12.9	12.8	11.9	10.4	10.6
2031	13.0	12.9	12.8	11.9	10.4	10.6
2032	13.0	12.9	12.8	11.9	10.4	10.6

Table 4. SPR values for each of the scenarios.

	SPR					
Year	SEDAR 52 Base	Reduce_60	Reduce_56	Reduce_40	Reduce_0	Assess_F_2001_2003
2019	0.22	0.22	0.22	0.22	0.22	0.22
2020	0.23	0.23	0.23	0.23	0.23	0.23
2021	0.24	0.24	0.24	0.24	0.24	0.24
2022	0.24	0.24	0.24	0.25	0.25	0.25
2023	0.25	0.25	0.25	0.25	0.25	0.25
2024	0.25	0.25	0.25	0.25	0.26	0.26
2025	0.25	0.25	0.25	0.25	0.26	0.26
2026	0.25	0.25	0.25	0.26	0.26	0.26
2027	0.26	0.25	0.25	0.26	0.26	0.26
2028	0.26	0.26	0.25	0.26	0.26	0.26
2029	0.26	0.26	0.25	0.26	0.26	0.26
2030	0.26	0.26	0.26	0.26	0.26	0.26
2031	0.26	0.26	0.26	0.26	0.26	0.26
2032	0.26	0.26	0.26	0.26	0.26	0.26

8. Figures

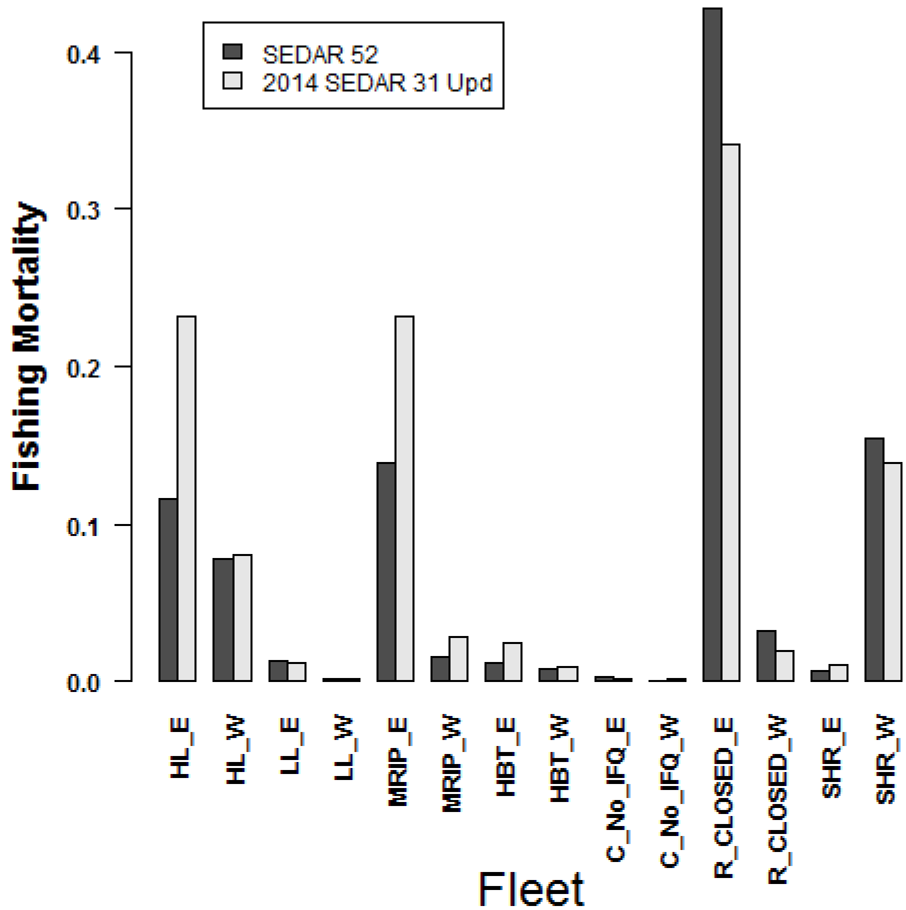

Figure 1. The terminal year fishing mortalities used in the projections for the SEDAR 52 Base Model (black bars) and the 2014 SEDAR 31 Update Assessment (grey bars). The directed fleet fishing mortalities represent three year averages from the terminal three years of the associated assessment model. The projections assume the directed fleet fishing mortalities are held in a constant proportion based on these values, whereas the bycatch and discard fleet fishing mortalties are fixed at the levels shown here for every year of the projection (except as altered for each scenario; see text and **Table 2** for scenarios and new fishing mortality rates used in each).