UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

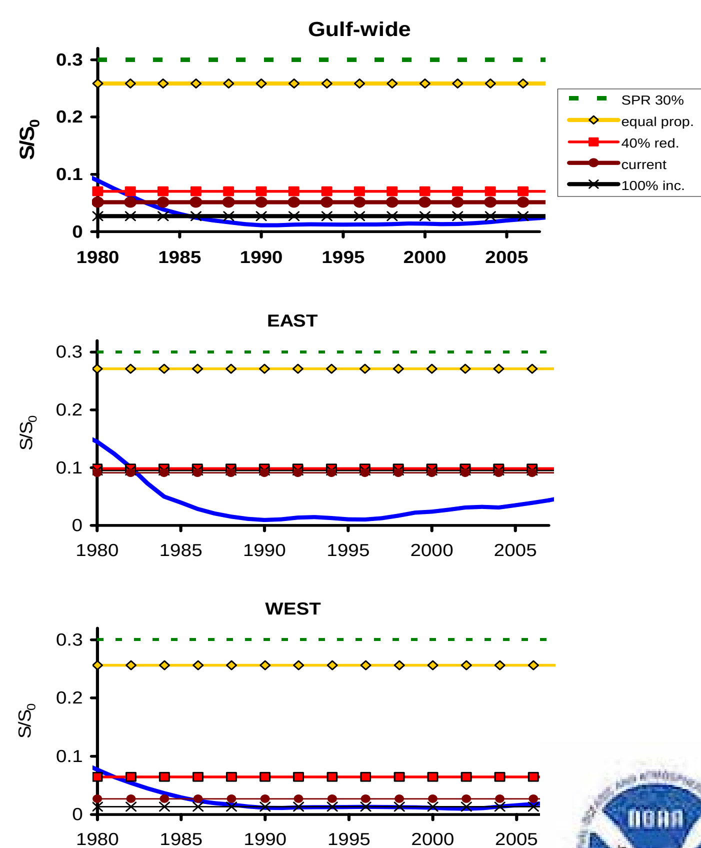
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

16 September 2005

Julie Morris, Chairwoman
Gulf of Mexico Fishery Management Council
Airport Executive Center
2203 N. Lois Avenue, Suite 1100,
Tampa, FL 33607

Dear Ms. Morris,

In response to your letter of 17 August, my staff has prepared the following materials regarding Gulf red snapper. For background and to place the requested analyses into perspective, some introductory material is provided below, followed by the requested projections.



The figure on the right shows estimated red snapper spawner abundance since 1980, expressed relative to unfished conditions (S/S_0). Also shown are various biomass reference levels related to SPR, including 30% S/S_0 (dashed horizontal), the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal prop., horizontal with yellow diamonds), the relative biomass associated with marginally maximizing yield given an additional 40% reduction in shrimp bycatch mortality rate (*i.e.* 40% red., horizontal with red squares), the relative biomass associated with marginally maximizing yield with no additional reduction in shrimp bycatch mortality rate (*i.e.* current, horizontal with brown circles), and the relative biomass associated with marginally maximizing yield after doubling current shrimp bycatch mortality rate (*i.e.* 100% inc., horizontal with black x's). This figure contrasts the estimates of current and recent red snapper spawning stock abundance relative to a range of biomass levels referred to in the projections described below.

In your letter, you note that "Council is requesting additional analyses be conducted and presented in order to evaluate TACs under several management scenarios. These scenarios should be evaluated under both a separate east and west Gulf population basis and under a Gulf-wide basis.

> For constant F scenarios: Look at yield streams from production and bycatch F's from a 10% to 60% reduction, and look at that alone and also in a linked or proportional fashion; "

The figure and tables below show projected yield and spawner index projected trajectories while fishing under the indicated constant F levels and given the indicated additional reductions in shrimp bycatch mortality rates from the base case assessment model.

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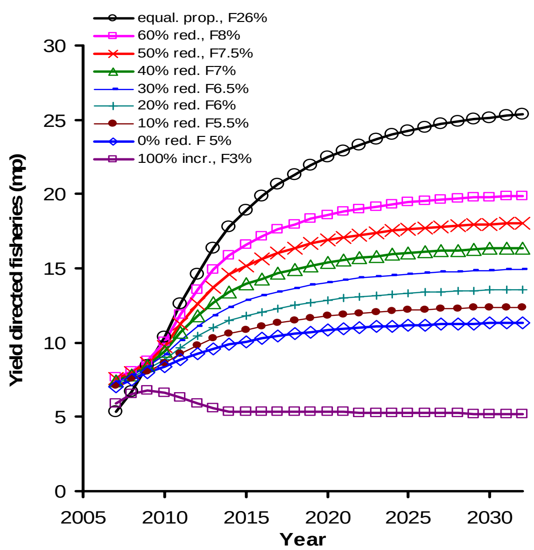


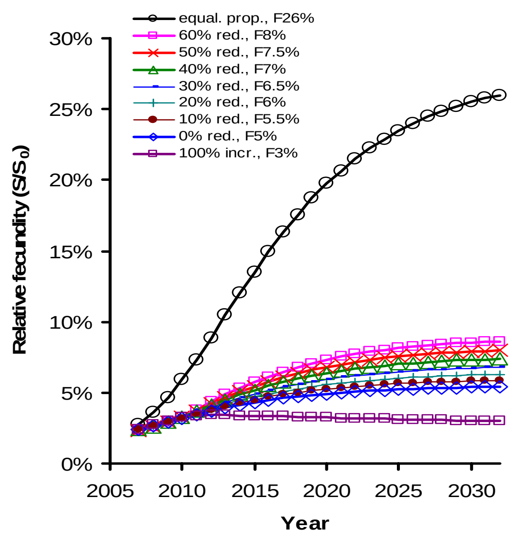


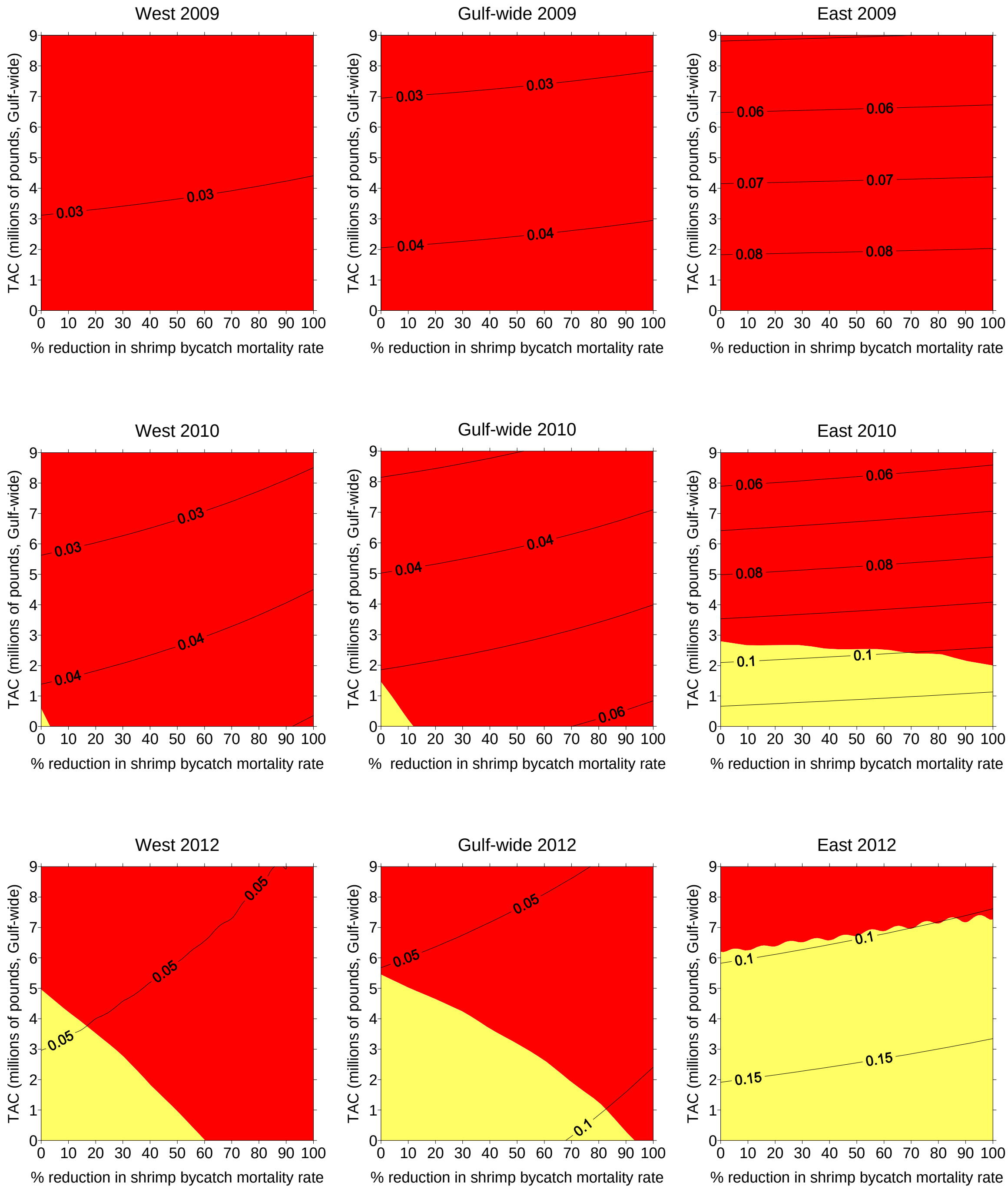
Table. Yield (mp) stream projections for F maximizing long-term yield for base age 0 model conditioned on indicated shrimp bycatch mortality rate changes and future recruitment eaual to recent average.

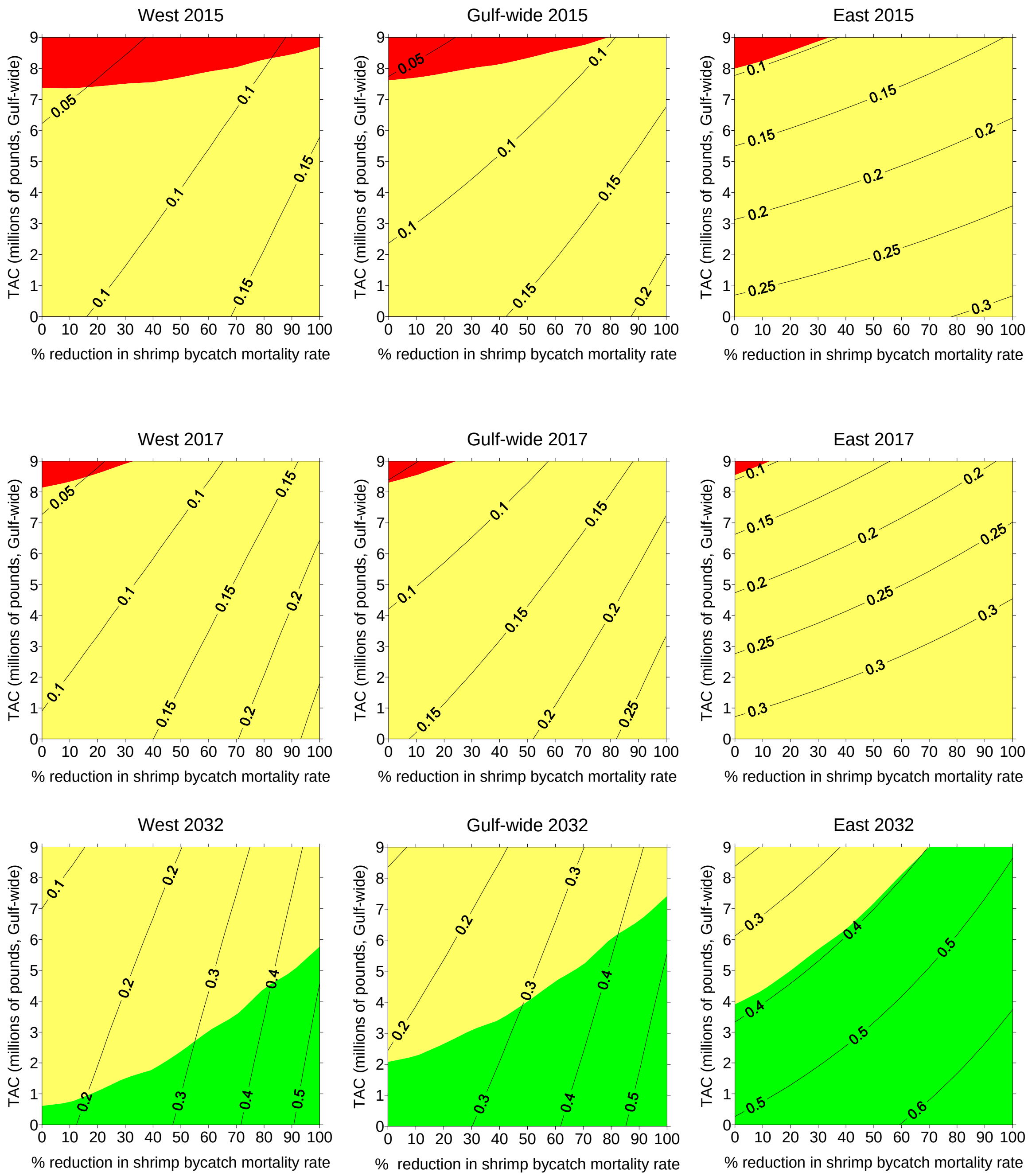
	% change in shrimp bycatch mortality rate								
Year	0	-10	-20	-30	-40	-50	-60	+100	Equal Proportional Reduction
2007	7.0	7.1	7.2	7.4	7.4	7.5	7.7	5.9	5.3
2008	7.5	7.6	7.7	7.8	7.8	8.0	8.1	6.5	6.7
2009	8.0	8.1	8.2	8.4	8.5	8.6	8.8	6.8	8.4
2010	8.4	8.6	8.9	9.2	9.4	9.7	10.1	6.7	10.4
2011	8.9	9.3	9.7	10.2	10.7	11.2	11.9	6.3	12.6
2012	9.3	9.8	10.4	11.1	11.8	12.6	13.5	5.9	14.6
2013	9.6	10.3	11.0	11.8	12.7	13.7	14.9	5.6	16.4
2014	9.9	10.6	11.5	12.4	13.4	14.6	15.9	5.4	17.8
2015	10.1	10.9	11.8	12.8	13.9	15.2	16.6	5.3	18.9
2016	10.3	11.1	12.1	13.1	14.3	15.7	17.2	5.3	19.9
2017	10.5	11.3	12.3	13.4	14.6	16.0	17.6	5.3	20.6
2018	10.6	11.5	12.5	13.7	14.9	16.4	18.0	5.3	21.3
2019	10.7	11.6	12.7	13.9	15.2	16.7	18.3	5.3	21.9
2020	10.8	11.8	12.8	14.0	15.4	16.9	18.6	5.3	22.5
2021	10.9	11.9	13.0	14.2	15.6	17.1	18.8	5.3	22.9
2022	11.0	12.0	13.1	14.3	15.7	17.3	19.0	5.3	23.3
2023	11.1	12.1	13.2	14.4	15.8	17.4	19.2	5.3	23.7
2024	11.1	12.1	13.3	14.5	15.9	17.5	19.3	5.3	24.0
2025	11.2	12.2	13.3	14.6	16.0	17.6	19.4	5.3	24.3
2026	11.2	12.2	13.4	14.7	16.1	17.7	19.5	5.3	24.5
2027	11.2	12.3	13.4	14.7	16.2	17.8	19.6	5.2	24.7
2028	11.3	12.3	13.5	14.8	16.2	17.9	19.7	5.2	24.9
2029	11.3	12.3	13.5	14.8	16.3	17.9	19.8	5.2	25.0
2030	11.3	12.4	13.5	14.9	16.3	18.0	19.8	5.2	25.2
2031	11.3	12.4	13.6	14.9	16.4	18.0	19.9	5.2	25.3
2032	11.3	12.4	13.6	14.9	16.4	18.0	19.9	5.2	25.4
Maximum Long-term Yield:	11.3	12.4	13.6	15.0	16.5	18.1	20.0	5.0	25.4
SPR in 2032	5%	6%	6%	7%	7%	8%	9%	3%	26%

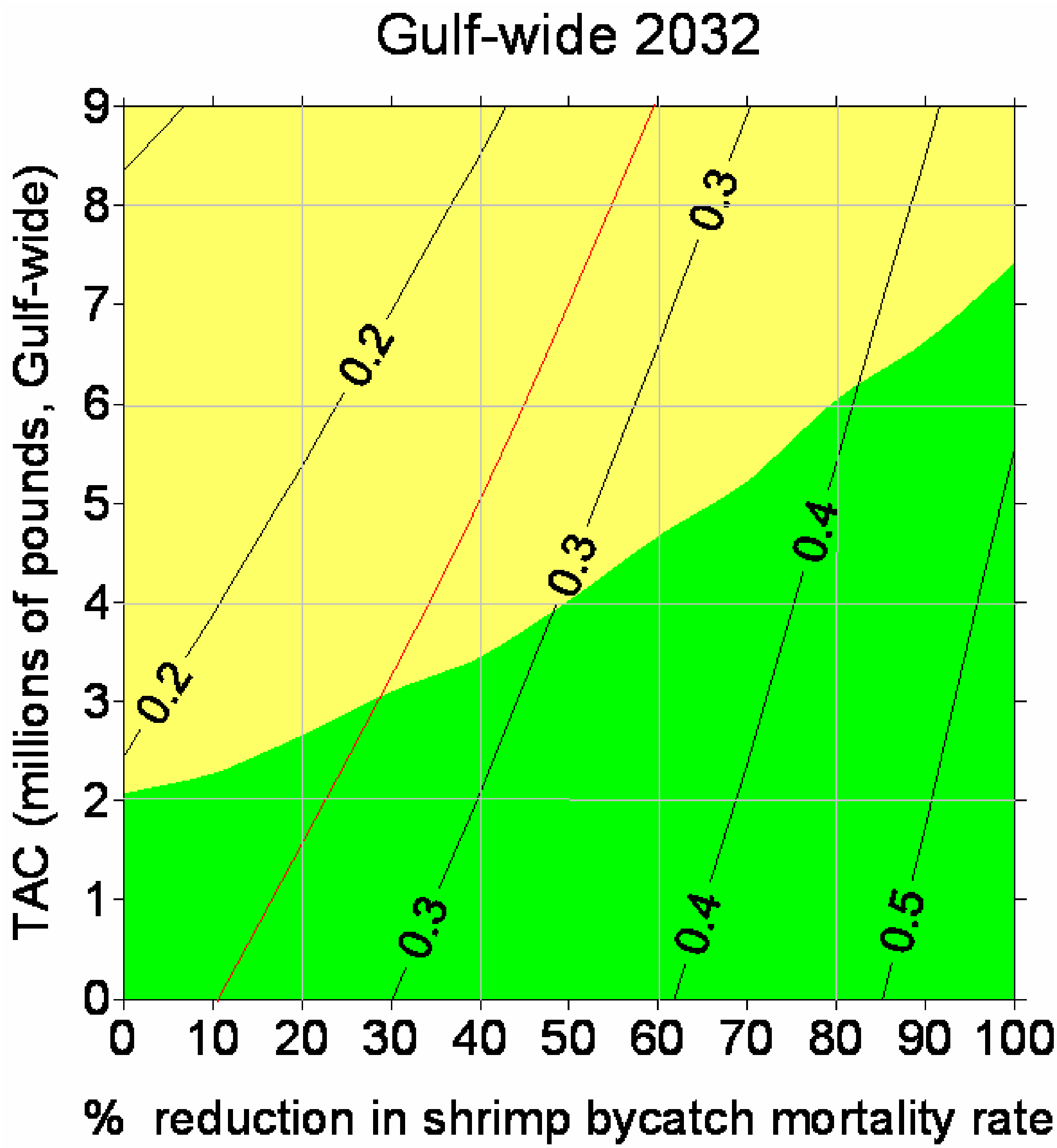
Table. Spawner abundance index (S/S0) projections for F maximizing long-term yield for base age 0 model conditioned on indicated shrimp bycatch mortality rate changes and future recruitment equal to recent average									
	% change in shrimp bycatch mortality rate								
Year	0	-10	-20	-30	-40	-50	-60	+100	Equal Proportional Reduction
2007	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.8%
2008	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.6%	2.7%	3.6%
2009	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	3.0%	4.6%
2010	3.2%	3.2%	3.2%	3.2%	3.3%	3.3%	3.3%	3.3%	5.9%
2011	3.5%	3.5%	3.6%	3.6%	3.7%	3.7%	3.8%	3.4%	7.3%
2012	3.7%	3.8%	3.9%	4.0%	4.1%	4.2%	4.3%	3.4%	8.9%
2013	3.9%	4.1%	4.2%	4.3%	4.5%	4.7%	4.9%	3.4%	10.5%
2014	4.1%	4.3%	4.5%	4.6%	4.9%	5.1%	5.3%	3.4%	12.0%
2015	4.3%	4.5%	4.7%	4.9%	5.2%	5.5%	5.8%	3.4%	13.5%
2016	4.5%	4.7%	4.9%	5.2%	5.5%	5.8%	6.1%	3.4%	15.0%
2017	4.6%	4.9%	5.1%	5.4%	5.7%	6.1%	6.5%	3.3%	16.3%
2018	4.7%	5.0%	5.3%	5.6%	6.0%	6.4%	6.8%	3.3%	17.6%
2019	4.8%	5.1%	5.4%	5.8%	6.2%	6.6%	7.1%	3.3%	18.7%
2020	4.9%	5.2%	5.6%	5.9%	6.4%	6.8%	7.3%	3.2%	19.7%
2021	5.0%	5.3%	5.7%	6.1%	6.5%	7.0%	7.5%	3.2%	20.7%
2022	5.1%	5.4%	5.8%	6.2%	6.7%	7.2%	7.7%	3.2%	21.5%
2023	5.1%	5.5%	5.9%	6.3%	6.8%	7.3%	7.9%	3.2%	22.2%
2024	5.2%	5.6%	6.0%	6.4%	6.9%	7.4%	8.0%	3.1%	22.9%
2025	5.2%	5.6%	6.0%	6.5%	7.0%	7.5%	8.1%	3.1%	23.5%
2026	5.3%	5.7%	6.1%	6.5%	7.1%	7.6%	8.2%	3.1%	24.0%
2027	5.3%	5.7%	6.1%	6.6%	7.2%	7.7%	8.3%	3.1%	24.5%
2028	5.3%	5.8%	6.2%	6.6%	7.2%	7.8%	8.4%	3.1%	24.9%
2029	5.4%	5.8%	6.2%	6.7%	7.3%	7.8%	8.5%	3.1%	25.2%
2030	5.4%	5.8%	6.2%	6.7%	7.3%	7.9%	8.5%	3.0%	25.5%
2031	5.4%	5.8%	6.3%	6.8%	7.3%	7.9%	8.6%	3.0%	25.7%
2032	5.4%	5.9%	6.3%	6.8%	7.4%	8.0%	8.6%	3.0%	26.0%
SPR @Fref	5%	6%	6%	6%	7%	8%	8%	3%	26%

You also requested a number of constant catch scenarios (3, 6, 9 million pounds), and also, "what level of TAC (or TAC yield streams) and shrimp trawl bycatch mortality reduction is needed to reach the rebuilding goals of either $B_{30\%SPR}$ or B_{MSY} on or before 2032?" Note that the equal proportional reduction case represents one time trajectory leading to rebuilding to the estimated MSY biomass level given the assumed stock-recruitment relationship and based upon the entire human-induced mortality selectivity vector. Intermediate year target SPR levels can be obtained from the graphs below to examine the range of constant catch and additional shrimp bycatch reduction scenarios which could lead to a rebuilt stock in 2032. Those combinations are shown in the 2032 isopleth diagram below.

The isopleth figures below show constant catch and TAC combinations that permit achieving a wide range of SPR levels in different years are shown in the following figures. These show the progression of projected S/S_0 for constant TACs indicated over a range of further reductions in shrimp bycatch mortality rate starting in year 2007 for years 2009, 2010, 2012, 2015, 2017, and 2032. In these figures, red shading indicates SPR levels lower than the relative biomass associated with marginally maximizing yield given the additional reduction in shrimp bycatch mortality rate indicated on the x-axis. Yellow shades indicate SPR levels from 1 to 4 times those levels, and green shades indicate levels >4 times those levels. In all cases number labels for the isopleths represent SPR values in the indicated year for the corresponding TAC and percentage additional reduction in shrimp bycatch mortality rate.


West 2009
Gulf-wide 2009
East 2009
West 2010
Gulf-wide 2010
East 2010
West 2012
Gulf-wide 2012
East 2012
TAC (millions of pounds, Gulf-wide)
% reduction in shrimp bycatch mortality rate
0.03
0.04
0.05
0.06
0.07
0.08
0.1
0.15

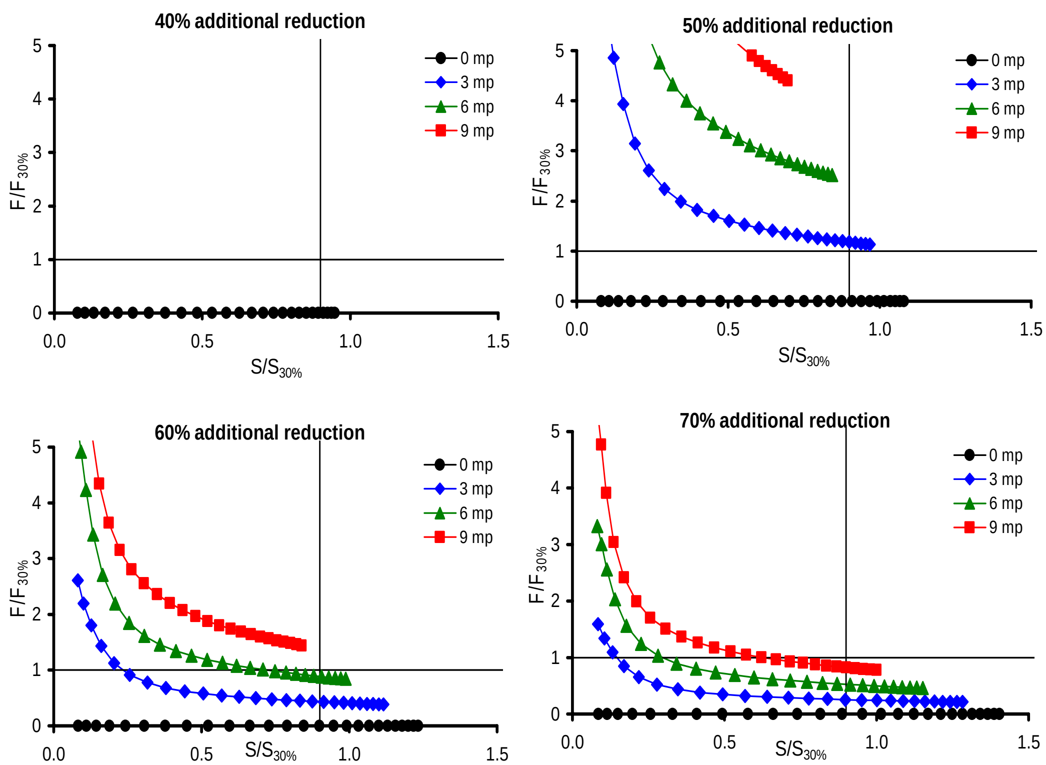

West 2015
Gulf-wide 2015
East 2015
West 2017
Gulf-wide 2017
East 2017
West 2032
Gulf-wide 2032
East 2032
TAC (millions of pounds, Gulf-wide)
% reduction in shrimp bycatch mortality rate



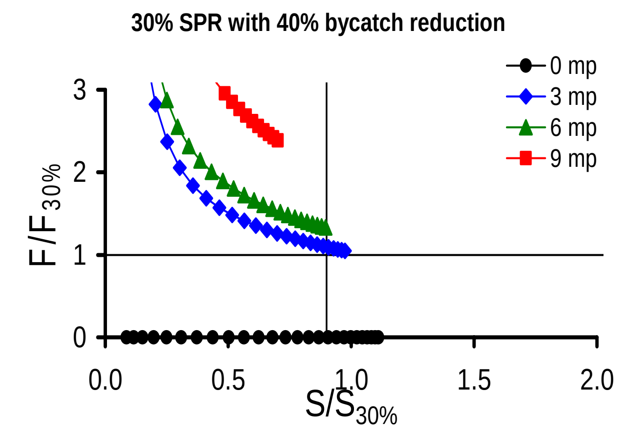
As shown in the above figure, there are a large number of TAC and shrimp reduction scenario combinations that could result in $B_{30\%SPR}$ by 2032 for the Gulf-wide case. $B_{30\%SPR}$ is not projected to be achievable Gulf-wide with less than an additional 30% reduction in shrimp bycatch mortality rate. At that level of bycatch mortality rate reduction, there would be no directed fishery TAC. Assuming additional shrimp bycatch mortality rate reductions from 40-60% starting in 2007, TAC could range from about 2-6.5mp annually, respectively. In order to rebuild to the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal % reduction scenario, 26% SPR solid red isopleth above), with additional shrimp bycatch mortality rate reductions from 40-60%, TAC could range from about 5.2-9mp annually, respectively. Achieving lower SPR levels such as those associated with marginally maximizing yield given an additional 40%-60%

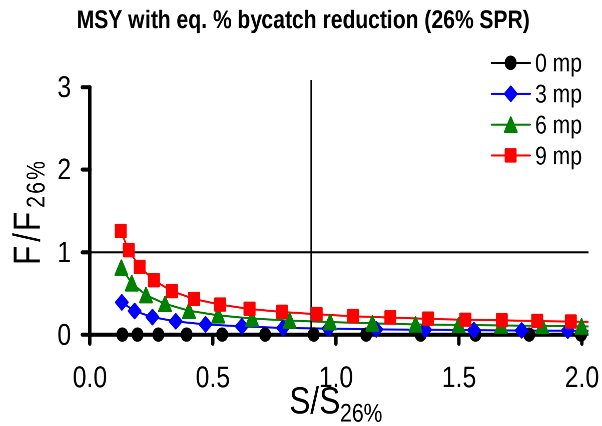
reduction in shrimp bycatch mortality rate would be possible with higher annual TACs because the SPR levels to which rebuilding would proceed would be lower.

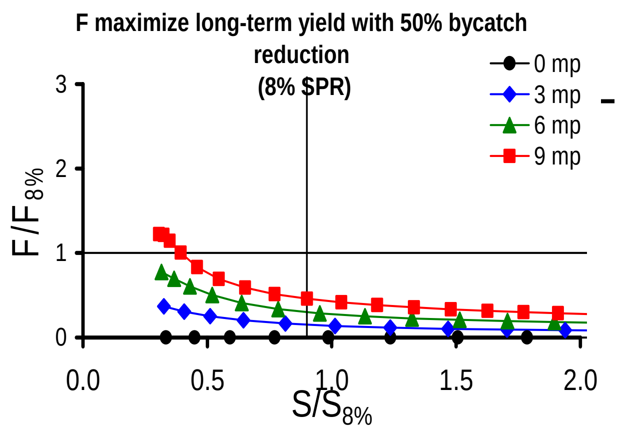
Under constant catch projections, the fishing mortality rate declines as stock abundance increases. For constant catch levels of 3, 6, and 9 million pounds, the progression of F relative to $F_{30\%}$ and S relative to $S_{30\%}$ under several constant TAC and several different levels of additional bycatch mortality rate reduction is shown below.

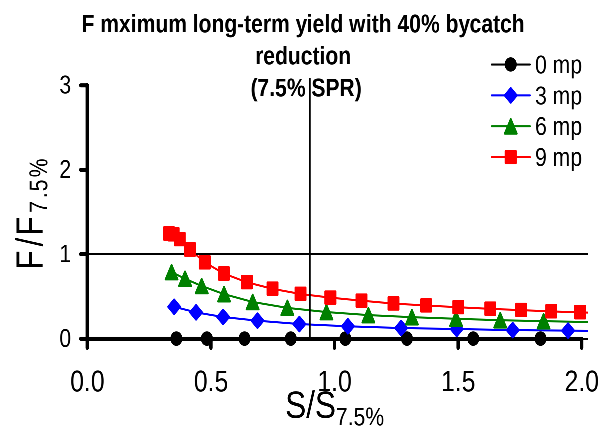


For comparison, the progression of F and S relative to different benchmarks under several constant TAC and several different levels of additional bycatch mortality rate reduction is shown below. From these figures it is clear that with lower standards, there is a quicker approach to those standards with higher TAC and lower shrimp bycatch mortality rate reductions.

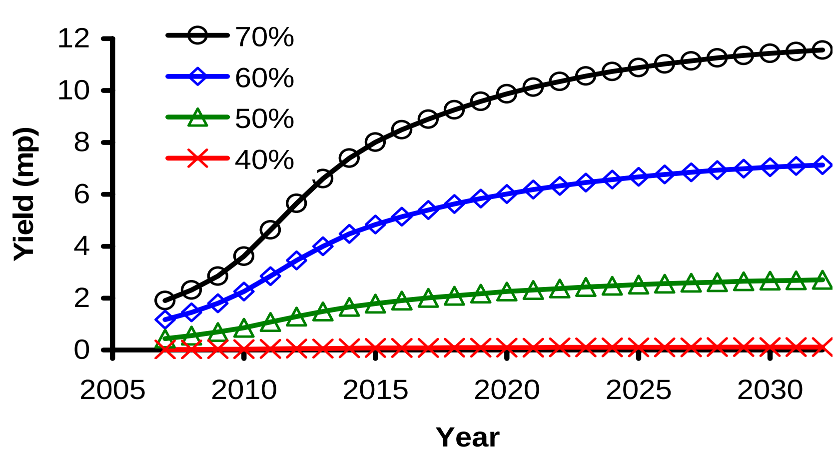




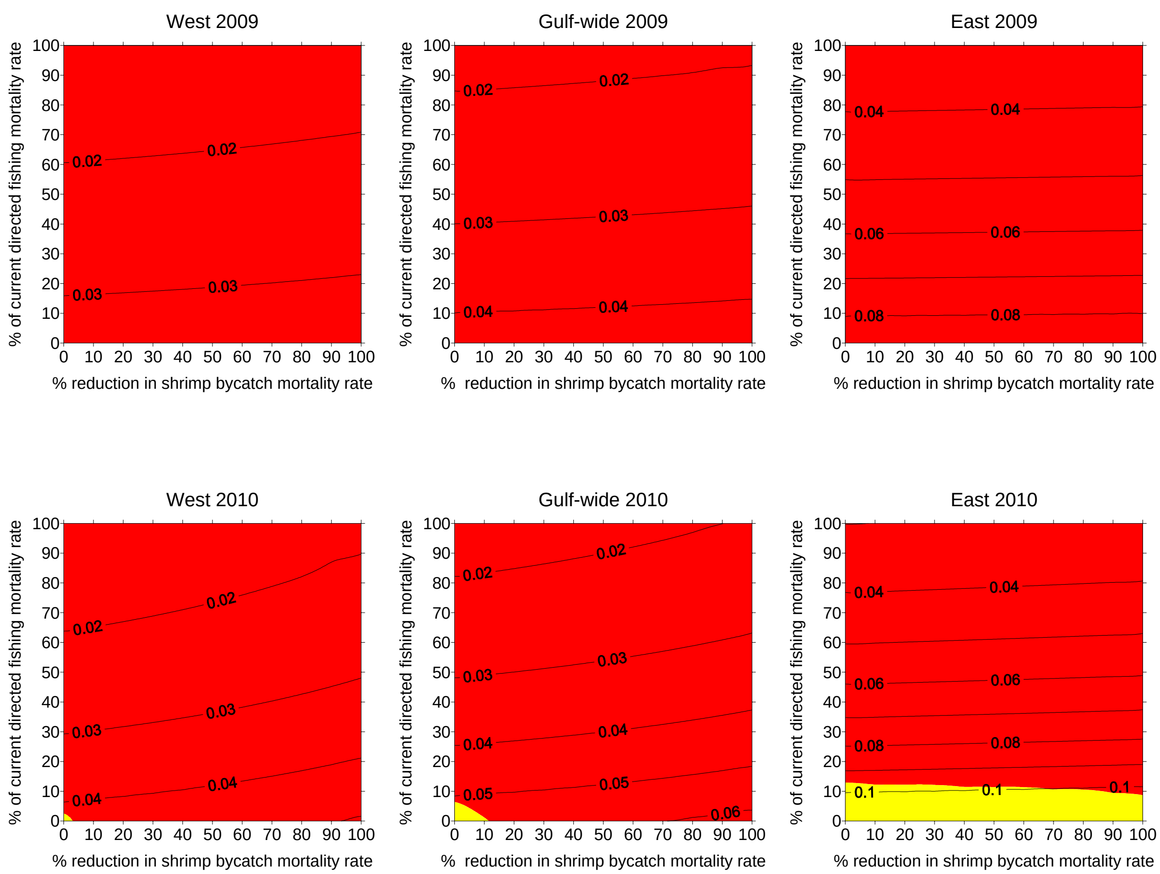


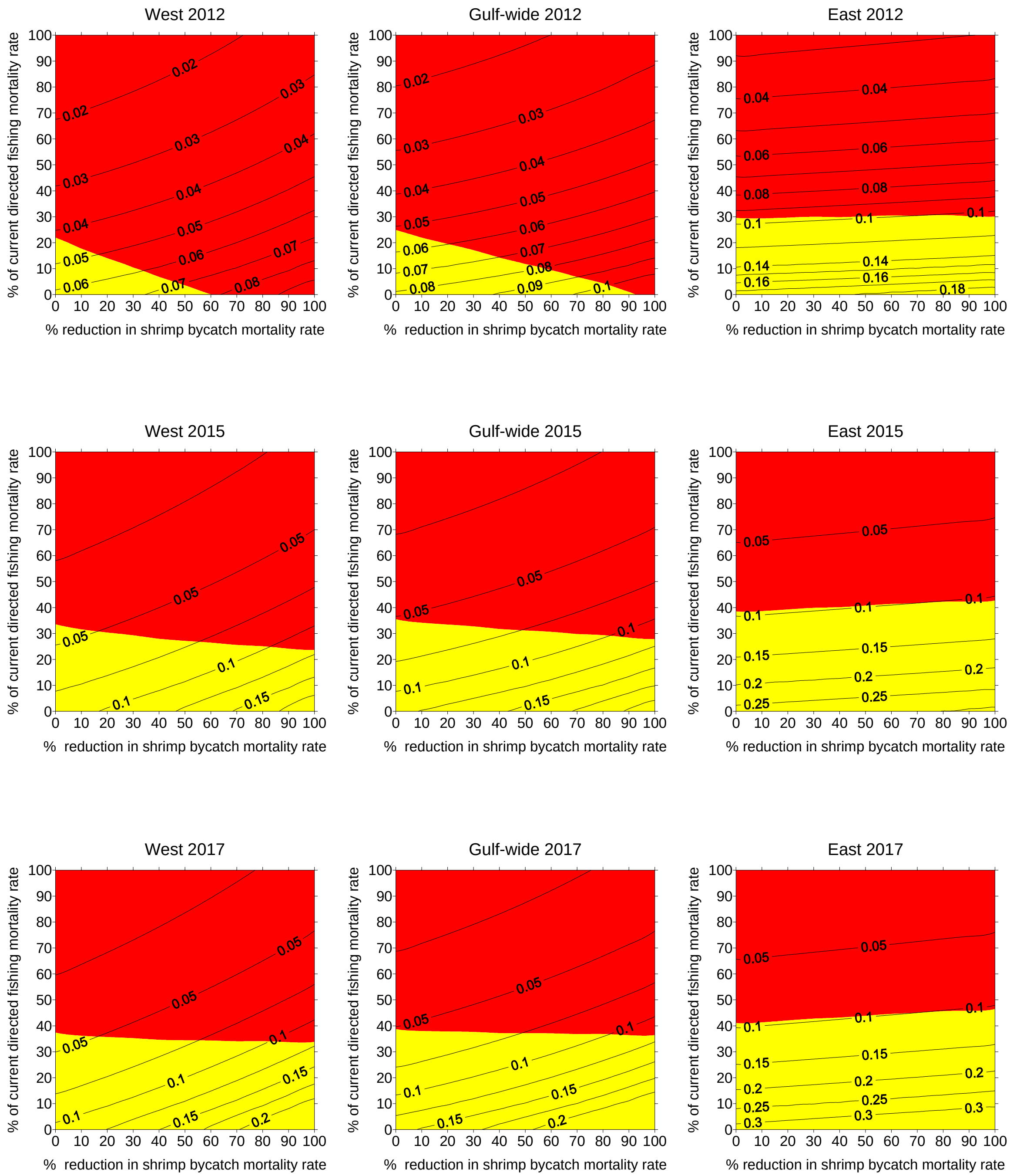


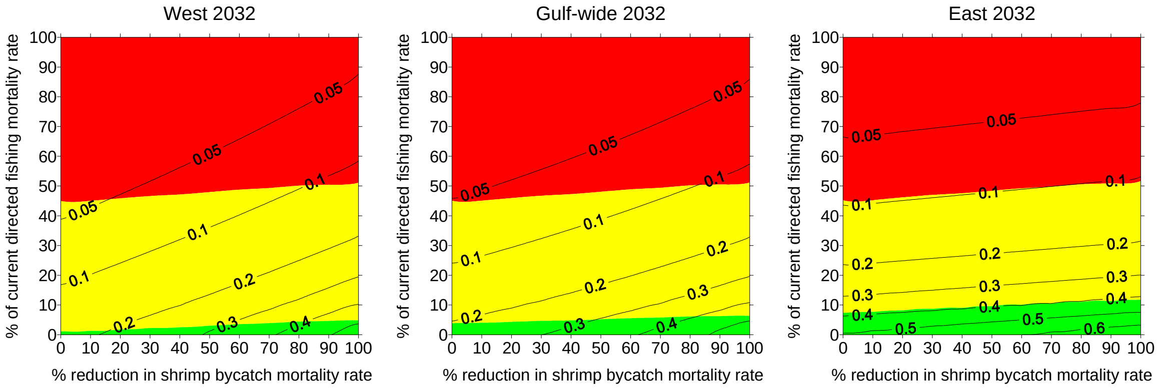
You also noted "Council also discussed the objective of ending overfishing over a one or two year period. Overfishing means fishing at a rate above MFMT, which is currently defined as $F_{30\%\ SPR}$" and asked "What actions would be necessary (in both the bycatch and directed fisheries) to end overfishing after one year, and after two years? Would these actions be consistent with the rebuilding scenarios described above?" Constant F projections have the quality of permitting yield to increase with abundance while fishing mortality rate remains the same. The time trends in expected TAC under a directed fishery $F_{30\%SPR}$ harvest strategy, which would end overfishing in 2007 and lead to rebuilding, conditioned given the indicated additional reduction in shrimp bycatch mortality rate, is shown in the following figure.



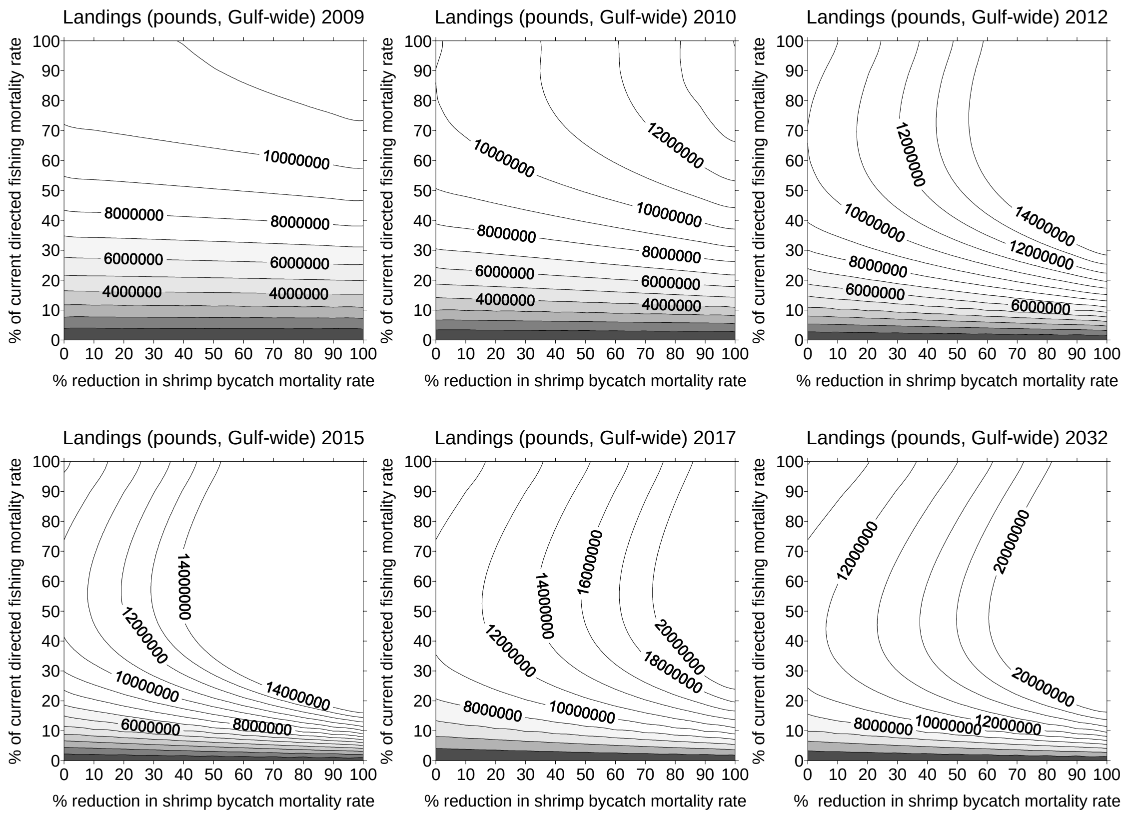
The isopleths below show the progression of projected S/S_0 for constant finfish fishing mortality rates expressed as a percentage of current fleet-wide fishing mortality rate over a range of further reductions in shrimp bycatch mortality rate starting in year 2007 for the years indicated.As before, red shading indicates SPR levels lower than the relative biomass associated with marginally maximizing yield given the additional reduction in shrimp bycatch mortality rate indicated on the x-axis. Yellow shades indicate SPR levels from 1 to 4 times those levels, and green shades indicate levels >4 times those levels.



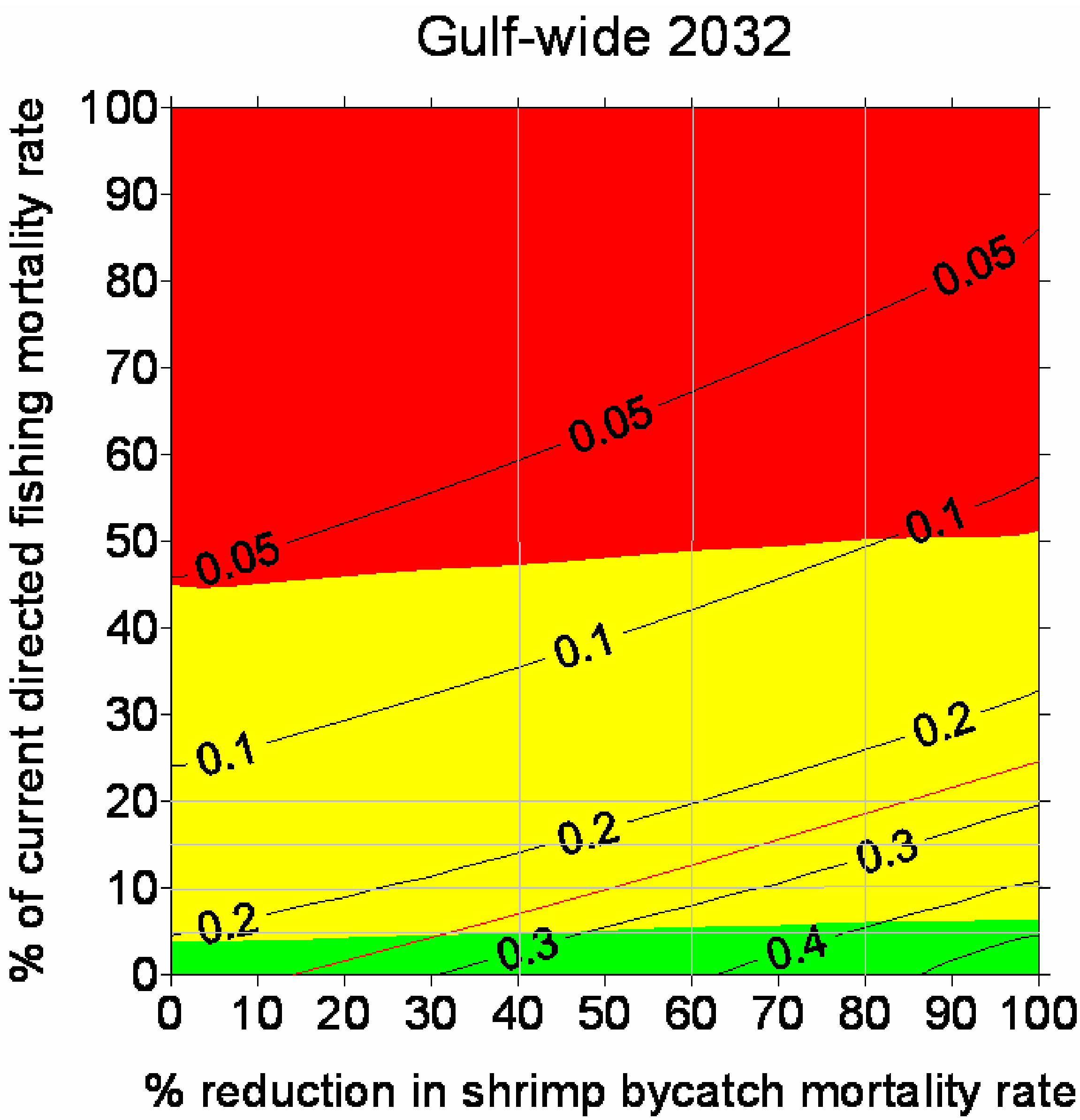

West 2012
Gulf-wide 2012
East 2012
West 2015
Gulf-wide 2015
East 2015
West 2017
Gulf-wide 2017
East 2017
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate

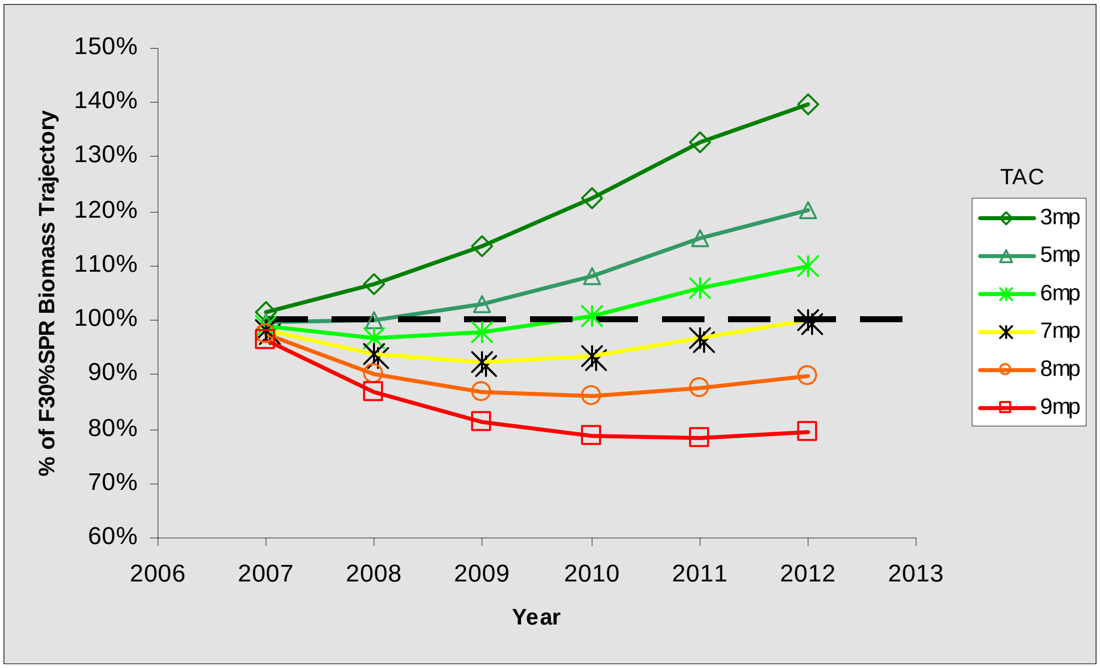

West 2032
Gulf-wide 2032
East 2032
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate
0.05
0.1
0.2
0.3
0.4
0.5
0.6

The progression of expected landed catch in the indicated year for constant F (expressed as a percentage of current directed fishing mortality rate) projections for the Gulf over a range of additional reductions in shrimp bycatch mortality rate starting in 2007 is shown below.



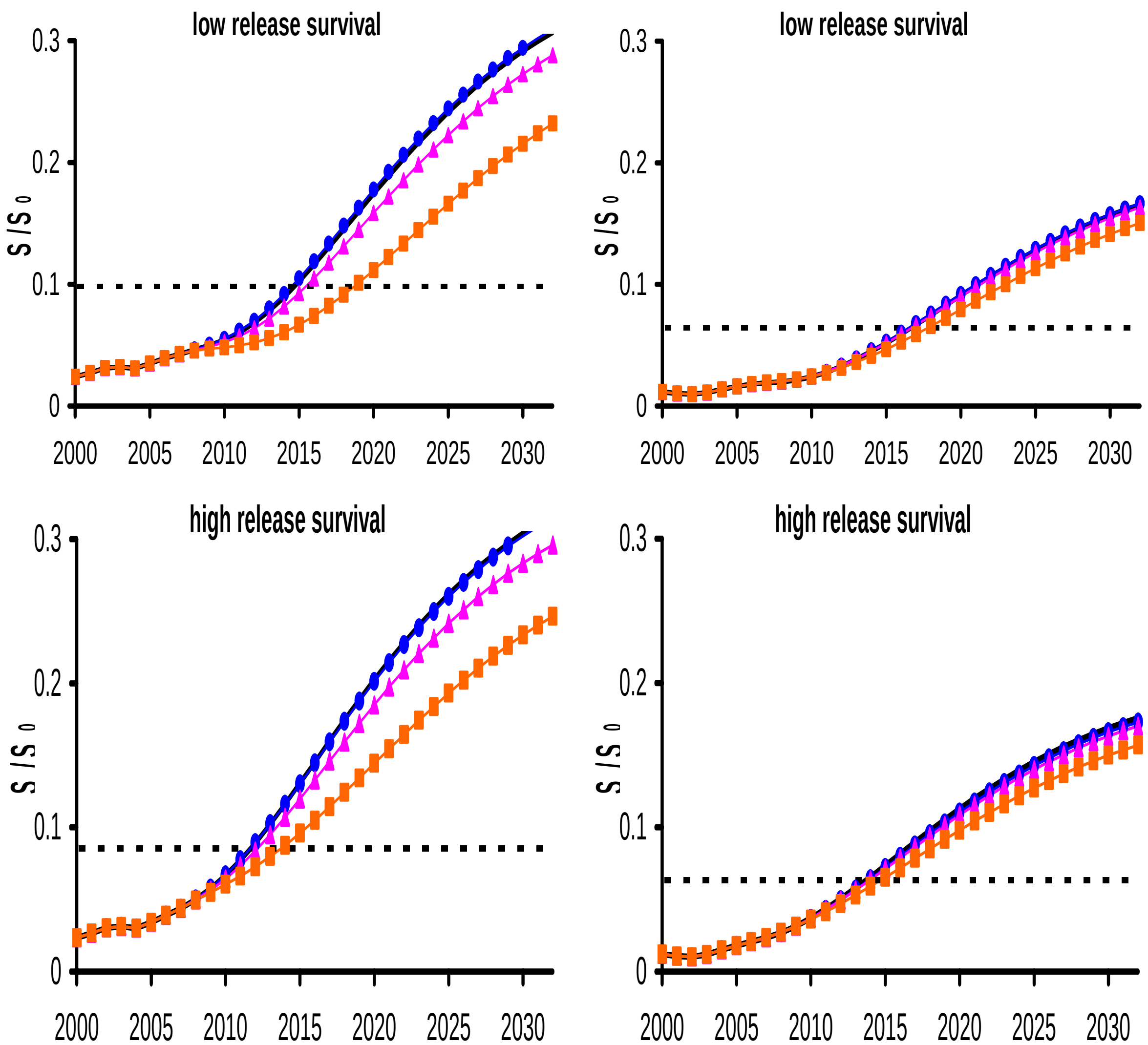
As with the constant catch projections, there are a relatively broad range of combinations of shrimp bycatch mortality rate reductions and reductions in directed fishery F that could result in $B_{30\%SPR}$ by 2032 for the Gulf-wide case and immediately (in 2007) end overfishing. This level of stock rebuilding would not be expected by 2032 with less than an 80% reduction in directed fishery F levels. Rebuilding to the estimated MSY biomass level from the assumed stock-recruitment relationship based upon the entire human-induced mortality selectivity vector (*i.e.* equal % reduction scenario, 26% SPR solid red isopleth below), would not be expected with less than a 75% reduction in directed fishing mortality rate.


Gulf-wide 2032
% of current directed fishing mortality rate
% reduction in shrimp bycatch mortality rate
0
10
20
30
40
50
60
70
80
90
100
0.05
0.1
0.2
0.3
0.4



The accumulation of SPR during the rebuilding projections occurs more quickly as new recruits grow into the spawning population; a lag of several years. Much of the initial rebuilding potential is due to recent high recruitment estimates. Because of this feature, in the short-run, SPR trajectories are relatively insensitive to the future decreases in shrimp bycatch mortality rates. The figure above contrasts the deviations from a projected $F_{30\%SPR}$ biomass rebuilding trajectory (dashed line) compared to the expected trajectories of SPR under constant catch scenarios from 3-9 million pounds per year for the projection period of 2007-2011. Constant catches from 2007-2011 greater than 7 million pounds are not projected to permit the Gulf-wide stock to attain the expected $F_{30\%SPR}$ trajectory by 2012. A 5-year constant catch of 5 million or less pounds would permit the stock to rebuild at a rate greater than expected under an $F_{30\% SPR}$ harvest strategy.

Lastly, you note "Bycatch mortality in the directed red snapper fishery has been an ongoing cause of concern, and it is even more so in the current red snapper assessment. The current size limits of 15 inches total length for the commercial fishery and 16 inches total length for the recreational fishery were adopted under assumed release mortalities of 33% commercial and 20% recreational. The current stock assessment uses recreational release mortality rates of 15% (eastern Gulf) and 40% (western Gulf), and commercial release mortality rates of 71% (eastern Gulf) and 82% (western Gulf) (Table 6.5 in the SEDAR 7 Red Snapper Data Workshop Report). The Council therefore requests that a range of size limits be analyzed for their potential effects on TAC and on bycatch mortality reduction. Specifically, a no size limit and a 13-inch total length size limit should be included in the analyses." In response, please find an attached manuscript by Dr. Clay Porch on the implications of changing the current minimum size on red snapper rebuilding prospects.



The figure above shows projected trends in spawning potential relative to unfished levels (S/S_0) for East (left panels) and West (right panels) Gulf red snapper based on the age-0 model with future recruitment set at 1984-2003 average levels, constant harvest of 9 mp and an additional 40% reduction in shrimp bycatch mortality rate. The top panels refer to the current base case, which has relatively low discard survival rates, and the bottom panels refer to the same model run with the relatively higher discard survival rates used during the 1999 assessment. The four scenarios run are status-quo (heavy black line), no commercial limit (blue circles, which is generally very close to and sometimes obscures the status-quo projection), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). The dashed line in this case is the equilibrium spawning potential at marginal long-term maximum yield assuming an additional 40% reduction in shrimp bycatch mortality rate.

In summary, the results of this analysis indicate that if the survival rates of discarded red snapper are within the range examined, then the current 15 inch commercial limit offers little, if any, additional protection to the stock because the released fish mostly die rather than contribute towards filling the quota. The 16 inch recreational limit, on the other hand, would afford some protection because a larger fraction of the recreational discards survive to spawn or contribute later towards filling the quota as heavier animals.

Sincerely,

Nancy B. Thompson, PhD
Director
Southeast Fisheries Science Center

Attachment: Porch MS.

Cc: F/SER – Crabtree; F/SEC – Chester, Scott, Porch, Turner; Gulf Council – Swingle, Atran

PROJECTED EFFECTS OF CHANGES IN MINIMUM SIZE REGULATIONS ON THE FUTURE STATUS OF THE RED SNAPPER (*LUTJANUS CAMPECHANUS*) FISHERY IN THE U.S. GULF OF MEXICO

Clay E. Porch

September, 2005

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Sustainable Fisheries Division
75 Virginia Beach Drive
Miami, FL 33149-1099

Sustainable Fisheries Division Contribution No. SFD-2005-009

Introduction

This paper projects various future size limit scenarios put forward by the participants of the 2004 SEDAR stock assessment workshop for Gulf of Mexico red snapper (SEDAR 7 AW) and at the August 8-12, 2005 Gulf of Mexico Fishery Management Council meeting in Fort Myers Beach.

Methods

Model equations

The basic population structures in the model are discussed thoroughly in Porch (2004) and will not be reviewed here. Instead the focus will be placed on the main point of interest here, which is the modeling of discards attributable to the minimum size limit. For clarity the subscripts relating to stock and habitat (region) have been omitted.

The equation for the total catch (landings plus discards) for each fleet is

$$(1) \qquad C_{i,s\{c,a\},y\{c,a\}} = \frac{F_{iasy}}{\xi_{iay} Z_{asy}} \tilde{N}_{ca}(1 - e^{-Z_{asy}})$$

where season s and year y are inferred from cohort c and age-class a. The instantaneous mortality rate Z is modeled as the sum of coefficients reflecting natural (M) and fishing-related (F) causes:

$$(2) \qquad Z_{asy} = M_a + \sum_i F_{iasy}$$

where i indexes a particular source of fishing mortality, hereafter referred to as a fleet. The fishing mortality rate parameters are further decomposed into separable age-dependent and time-dependent effects:

$$(3) \qquad F_{iasy} = q_{iy} v_{ia} f_{iy} \xi_{iay}$$

where q represents the catchability of the most vulnerable age-class, v_a represents the relative vulnerability of the remaining age-classes, f is the total effort exerted by the fleet, and ξ is the probability that a fish will die once it is caught (landed or released but died later).

Under the presumption that discarded fish are mostly below the size limit L ,

$$(4) \qquad \xi_{iay} = 1 - (1 - d_{ias}) G_{L|a}$$

where d is the fraction of released fish that die and $G_{L|a}$ is the probability that a captured fish will be smaller than the size limit given that it is age a. Estimates of the number landed (harvest H) and number discarded (D) are therefore

$$(5a) \qquad H_{iasy} = (1 - G_{L|a}) C_{iasy}$$

$$(5b) \qquad D_{iasy} = G_{L|a} C_{iasy}$$

The corresponding number discarded dead (*DD*) and total number killed (*K*) are

$$(5c) \quad DD_{iasy} = d_{ias} D_{iasy}$$

$$(5d) \quad K_{iasy} = H_{iasy} + DD_{iasy}$$

Projections of the effects of any suite of future minimum size limits are easily accomplished by simply applying the equations above with assumed levels of effort, catchability and vulnerability (typically averages of the last few years). The effect of the size limit is reflected in the probability *G*, which we assume to be zero-truncated normal with a constant CV of 0.16 (see Diaz et al., 2004).

Application to red snapper

The SEDAR Assessment Workshop (AW) participants requested projections of the base-case model assuming:

a. Status quo; total allowed landings (TAC) of 9.12 million lbs, shrimp bycatch and closed season discards at current effort levels (average of last three years), and minimum size limits of 15 inches for the commercial fleets and 16 inches for the recreational fleets.
b. Status quo, except 13 inch limit on both sectors
c. Status quo, except no size limit on either sector
d. Status quo, except no commercial size limit

It was noted by some workshop participants that red snapper below 12 inches are not considered marketable and would not be retained commercially. Accordingly, it was assumed that, in the absence of size limit regulations (cases c and d), the effective size limit for the commercial fishery was 12 inches. Some recreational anglers would likely keep red snapper smaller than 12 inches if retention were allowed, but few would catch and keep fish under six inches. Therefore the effective minimum size for the recreational fishery in case (c) was set to six inches. For these projections, changes in the minimum size limits were assumed to begin in 2007.

The base model selected by the SEDAR Assessment Workshop (AW, December 2004) participants expressed the recruitment of 1 year-old fish to the population as a Beverton-Holt function of the spawning potential during the previous year (See Porch 2004 for details). Forecasts were based on a scenario where future recruitment varied with projected spawning potential according to the estimated ‘historical’ Beverton-Holt relationship. Subsequently, SEDAR Review Workshop (RW, April 2005) participants favored a reformulation of that model which expressed the recruitment of age 0 as

Beverton-Holt function of the spawning potential during the same year and incorporated estimates of the bycatch of age 0 animals by offshore shrimp trawlers. The RW also recommended conducting forecasts where the future recruitment followed more recent trends (see SEDAR 2005 for details). Accordingly, the impact of changing the minimum size limits was evaluated under four scenarios: (a) age 1 model, historical recruitment trends; (b) age 1 model, recent recruitment trends; (c) age 0 model, historical recruitment trends; (d) age 1 model, recent recruitment trends.

In some cases the current TAC of 9.12 million lbs was not sustainable over the time period of the projections (to the year 2032). The routine used finds the scenario with the time series of landings that comes the closest to the time series of TACs. This approach allows the stock to be driven to very low levels, but avoids the unlikely scenario of abruptly driving it to extinction. Finally, a 40% reduction in offshore shrimp trawl effort was assumed beginning in 2007, in accordance with the recommendations of the RW, which were based on the economic forecasts of Travis and Griffin (2004).

Results and discussion

The projected trends in S/S_0 under each minimum size scenario are shown for the four combinations of model type (age-0 versus age-1) and future recruitment (historical versus recent R_0) in Figure 1. In no case did the western stock recover to a level of spawning potential commensurate with an SPR of 30%. This would require a reduction in shrimp effort in the west of more than 40% relative to current levels (see SEDAR 2005). However, it was possible in some cases to recover to the spawning potential associated with the marginal long-term maximum yield conditional on the presumed 40% reduction in offshore shrimp trawling effort, S_{LTMY}\{40% reduced shrimp\}. If future recruitments remain at current high levels, then both the eastern and western stocks are projected to recover to S_{LTMY}\{40% reduced shrimp\} before 2032, regardless of the size limits imposed (although the recovery is markedly slower without size limits). The forecasts are less optimistic when future recruitments follow more historical trends. In the case of the age-1 model, neither stock was projected to recover regardless of the size limits imposed. In the case of the age-0 model, both stocks were projected to recover by 2032 except when no size limit was in place for either fishery.

The projected recovery rate was slightly faster without the commercial size limit, but increasingly slowed by smaller recreational limits. The recreational limit is estimated to be more effective than the commercial limit owing largely to the ***assumption*** that red snapper discarded by recreational anglers have a much higher survival rate (85% in the eastern Gulf and 60% in the western Gulf) than those discarded by commercial fishers (29% in the eastern Gulf and 18% in the western Gulf). The discard survival rates assumed during the prior assessment were higher and not so disparate between sectors (67% commercial, 80% recreational). When these higher survival values are used (in both the assessment and associated projections), the projected recovery rate was slightly slower without the commercial size limit (Figure 2). However, as before, the recovery rate was affected more by decreasing the recreational size limit than by decreasing the commercial limit. This is true partly because the commercial discard-survival rate used, although higher than before, was still somewhat lower than the recreational rate. Moreover, the relative change from current limits to no limit was less for the commercial

fishery than for the recreational fishery because the commercial fishery had a one inch lower size limit (15 versus 16 inches) and a six inch higher implicit size limit (12 versus 6 inches).

If the survival rates of discarded red snapper are within the range examined here, then the current 15 inch commercial limit offers little, if any, additional protection to the stock because the released fish mostly die rather than contribute towards filling the quota and thereby shortening the open season. The 16 inch recreational limit, on the other hand, would afford some protection because a larger fraction of the recreational discards survive to spawn or contribute later towards the quota as heavier animals. Future analyses should probably focus on determining the true magnitude of the discard survival rates rather than simulating the effects of a range of the minimum size limits.

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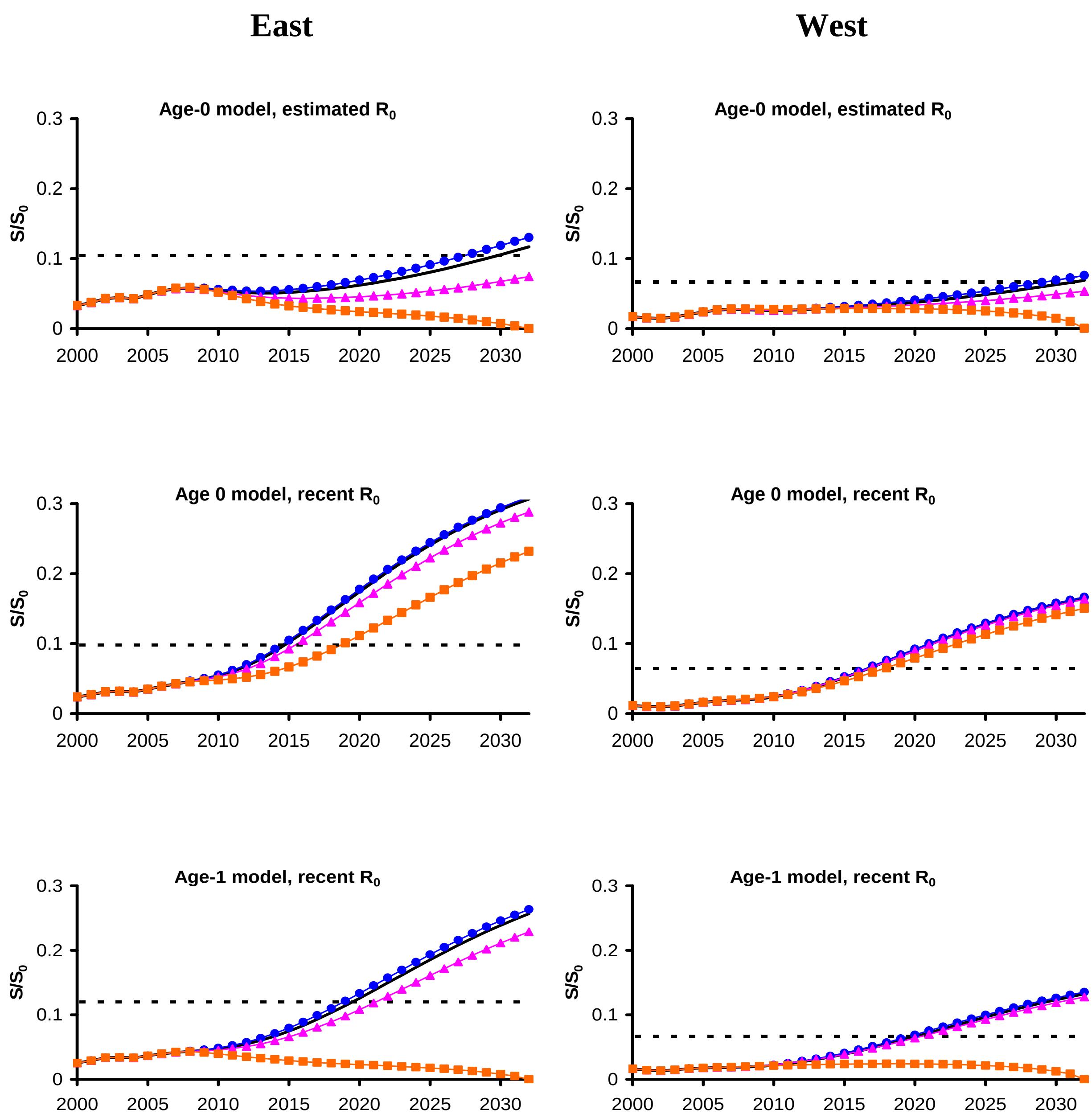

Figure 1. Projected trends in spawning potential relative to unfished levels (S/S_0) based on the age-0 and age-1 models when future recruitment is dictated by the 'historical' spawner-recruit relationship (estimated R0) or the 1984-2003 average levels (recent R0). The four scenarios are status-quo (heavy black line), no commercial limit (blue circles), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). Dashed line is the equilibrium spawning potential at marginal long-term maximum yield relative to unfished levels (S_{LTMY}/S_0).

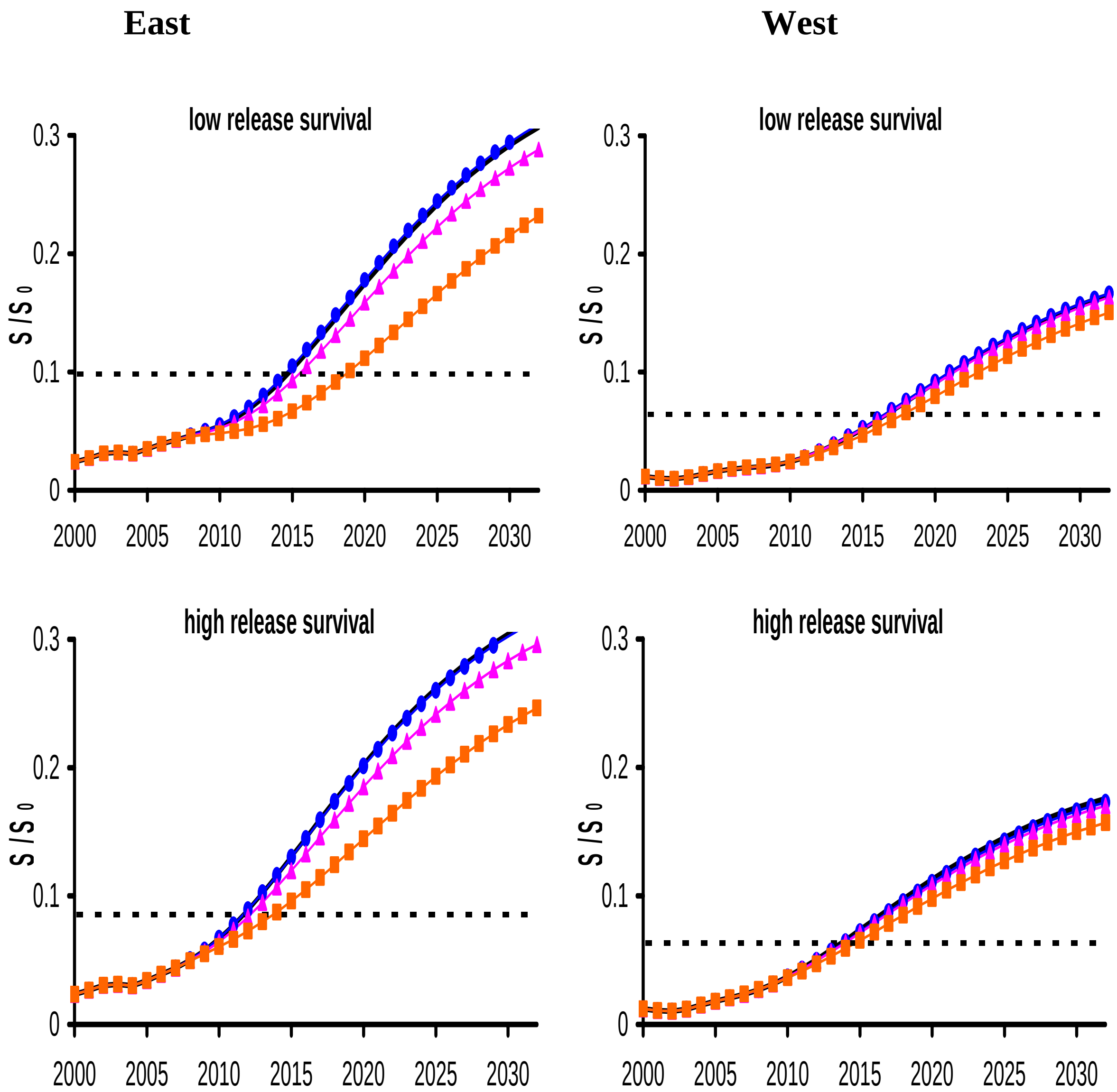

Figure 2. Projected trends in spawning potential relative to unfished levels (S/S_0) based on the age-0 model with future recruitment dictated by the 1984-2003 average levels (recent R0). The top panels refer to the current base case, which has relatively low discard survival rates, and the bottom panels refer to the same model run with the relatively higher discard survival rates used during the 1999 assessment. The four scenarios are status-quo (heavy black line), no commercial limit (blue circles), 13 inch commercial and recreational limit (pink triangles) and no limit for commercial or recreational (orange squares). Dashed line is the equilibrium spawning potential at marginal long-term maximum yield relative to unfished levels (S_{LTMY}/S_0).