SEDAR7-RW-4

ASSESSMENTS OF RED SNAPPER STOCKS IN THE EASTERN AND WESTERN GULF OF MEXICO USING AN AGE-STRUCTURED-ASSESSMENT-PROCEDURE (ASAP)

Revised and Updated Analyses of Results Presented in the SEDAR7-AW-64 Document.

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INTRODUCTION

Recent studies of red snapper life history characteristics and otolith microchemistry suggest that there is a significant demarcation between populations found east and west of the delta of the Mississippi river (Cowan et al., 2003). Therefore, the SEDAR panel recommended that assessments consider a gulf wide stock (Anonymous 2004) and eastern and western stocks separated by the delta of the Mississippi River.

Based on decisions made at the SEDAR data (April 2004) and assessment workshops (August 2004), a range of ASAP model runs fit to fleet-specific catch and effort data spanning 1962-2003 were made to provide guidance on the status of the red snapper resource in eastern and western Gulf of Mexico. This document revised and update the ASAP model results, previously presented in the SEDAR7-AW-64 document.

METHODS

The results presented in this document are both from updates to the ASAP program algorithms and from their implementation of the model with reference in particular to the assumed conditions of the stock at the beginning of the time series (1962). Changes in the ASAP algorithms included the expansion of deviations in the age-structure composition of the initial stock (1962 year), such as the stock could be start from an exploited status at 1962, instead of an assumed un-exploited (i.e. virgin) status as in previous applications. In the implementation, the assumed coefficients of variation (CV) were increase from 0.2 to 0.9 for the numbers-at-age for year one (1962), allowing the model to greatly deviate from the input stock virgin size. These changes resulted in a better and more stable fit of the data, with lower likelihood function values and more realistic estimates of benchmark parameters for the stocks evaluated.

As in previous analyses, for eastern and western runs, 5 regionally explicit fleets were specified: Commercial handline (CMHL), commercial longline (CMLL), recreational (REC), commercial handline and longline discards during the closed season (CLSD-SEAS), and shrimp bycatch (SHRIMP-BYCATCH). Modeled ages were Age 0 to the plus group Age 15+. Five regionally explicit indices were used for tuning, the MRFSS index, the SEAMAP Age0 trawl index developed the Miami Laboratory (SEAMAP (MIAMI)_0), the video index (VIDEO) and the SEAMAP ichthyoplankton index (LARV_B); additionally the nominal shrimp bycatch CPUE series (Shrimp_NomCPUE, presented by Goodyear 1992, 1995) was used for the west analyses. Overall, the indices were weighted equally. However, annual variability within each index was modeled using rescaled input CVs. In every case, the model parameter representing the log virgin stock size was estimated freely, however greater deviations from the input value were allowed in the present results, CV of numbers-at-age for year one were 0.9. The ASAP model used the catch at age for each fleet as estimated from length-frequency analysis (Turner et al., 2004). For years when no length-frequency samples were available from any given fishery, the catch-at-age composition of the first year available was assumed for all prior years.

In general, geographic delimitation between East and West red snapper stock corresponded to the Mississippi river delta (Cowan et al., 2002). For catch statistics, statistical areas 1 through 12 were assigned to the East stock, and statistical areas 13 to 21 to the West stock, which for fisheries-statistics purposes coincide with the state boundary of Louisiana and Mississippi. Thus the East stock comprises catches from Florida West coast to Mississippi, and the West stock comprises catches from Louisiana and Texas. Estimates of bycatch and discards from commercial and recreational fisheries were broken down by region, following the geographical areas defined before (Scott N. 2004, Sladek 2004, Scott G. 2004). Indices of abundance for each region were estimated following similar protocols as for the Gulf wide cases, with data restriction to the specific geographic region (Cass-Calay 2004, McCarty and Cass-Calay 2004, Scott 2004). Estimates of shrimp bycatch prior to 1972 (1962 to 1971) by region were given by SEDAR-AW-(Porch and Turner 2004).

As in previous analyses, the ASAP model fixed the steepness parameter. Following the Gulf wide analyses, three steepness levels were evaluated: 0.81, 0.90 and 0.95. If allowed, the ASAP model would converge to a solution estimating steepness, however in all cases the steepness estimated was 1.0. The results present several MSY and SPR-based benchmarks. However, it is important to identify that MSY based benchmarks depend on the selectivity patterns within and among fisheries, and how MSY-benchmarks are constructed. Differences in MSY based benchmarks are due primarily to how the non-directed fisheries, mainly shrimp bycatch is considered within the calculations. If ONLY directed fisheries are considered to be manageable (i.e. effective fishing mortality can be reduce or increase through management), while non-directed (shrimp bycatch and discards from closed seasons) will continue at current levels (i.e. effective fishing mortality will be as in the last year of assessment). Hereafter the yield associated with this long-term strategy is referred to as $MSY_{current\text{-}shrimp.}$ This case was also referred in prior documents as the Un-link (unlinked) case. Alternative, MSY based benchmarks can be constructed assuming that ALL fisheries can be managed, therefore fishing mortality can be change simultaneously for directed and non-directed fisheries. Hereafter this should refer to as MSY_{linked}. A disadvantage of MSY based reference points is that the corresponding biomass targets change with changes in the vulnerability (or selectivity) patterns. A more stable and potentially risk averse policy is to maintaining a given spawning potential ratio (SPR) of the stock. While the fishing mortality rate associated with a given SPR ($F_{\%SPR}$) depends on the current vulnerability pattern, the corresponding long-term spawning biomass ($SS_{\%SPR}$) does not.

Sensitivity analyses were considered for the East and West stocks assuming a different natural mortality vector. The so-called “low mortality” vector assumed an M value of 0.49 for Age 0, 0.29 for Age 1, and 0.1 for Ages 2 and older.

RESULTS AND DISCUSSION

Table 1 presents a summary of fishery benchmarks for each stock, East and West at the three steepness levels for the two types of MSY-based benchmarks; linked (top table) and current shrimp (unlinked, bottom table). In general the West red snapper stock was estimated much larger than the East GOM stock, about 6 to 7 times greater in terms of Virgin biomass. For the East stock, the virgin stock was estimated between 19.7 and 33.6 million pounds, lower estimates were obtained when higher steepness was assumed. While for the West stock, virgin biomass estimates range from 144.2 to 220.3 million pounds. Consistently, the estimates of spawning stock at MSY_{link} ($SS_{MSYlink}$) and MSY_{link} were much larger for the red snapper West stock. $SS_{MSYlink}$ estimates ranged from 52.7 to 83.6 million pounds, with larger estimates also for the lowest assumed steepness (0.81), similar to the virgin biomass. Instead, MSY ranged from 16.4 to 25.4 million pounds, with larger estimates corresponding to the higher steepness values. For the West stock the spawning stock at 2003 was always well below SS_{MSY}, SS_{2003}/SS_{MSY} ranged from 0.52 to 0.18. Fishing mortality reference points indicated that for the red snapper West stock, F at MSY (F_{SMY}) varied between 0.33 and 0.36 depending on the assumed steepness (Table 1). At low steepness, the estimated fishing mortality in 2003 was below the F_{MSY}, ratios of F_{2003}/F_{MSY} varied from 0.63 to 1.2, with higher ratios for the highest steepness (0.95).

For the red snapper East stock estimated $SS_{MSYlink}$ ranged from 5.9 to 12.5 million pounds with higher estimates under the assumption of lower steepness (0.81). In all cases, the model predicted a low spawning stock in 2003, the ratio of SS_{2003}/SS_{MSY} ranged from 0.12 to 0.45. The MSY_{link} estimates ranged from 8.8 to 10.7 million pounds, or about half of the MSY_{link} estimated for the West stock. The fishing mortality estimates in 2003 were larger that the corresponding $F_{MSYlink}$ the ratio of F_{2003}/F_{MSY} ranged from 1.23 to 3.4.

In summary the red snapper East stock is much smaller than the West stock, approximately 20% of the West stock virgin biomass, and with an estimated MSY_{link} of about half of the West stock. Also, the East stock supports lower fishing mortality rates, comparing all the F reference points against the West stock. More important the East stock was assessed in a worst condition compared to the West stock. In the East, both overfishing and overfished conditions were present in 2003. While for the West stock, the fishing mortality in 2003 was below the F at MSY (i.e. no overfishing), except at the higher steepness. However, the spawning stock was still below the SS_{MSY} levels (Table 2).

Figures 1 through 4 show the different fits of the data to the ASAP model for the red snapper East stock assuming the steepness of 0.81 and a high mortality vector. Figure 1 shows the fit of total catch to the five fleets and figure 2 shows the observed and predicted indices of abundances used for the East stock. Estimated fishing mortality rates by fleet are presented in Figure 3, for the East stock the recreational fishery shows an increasing trend since mid 1980's, reaching peak values in the latest years. Stock recruitment relationship and annual trends are shown in figure 4. The predicted recruitment for the East stock shows an increase since the early 1990's, with a corresponding increase of the spawning stock during the same period. Similar figures are presented for steepness of 0.90 (Figures 5 to 8) and 0.95 (Figure 9 to 12). In general the fit of total catch by fleet and the fit of indices of abundance are very similar among the three steepness evaluated. Differences show between the trends and estimates of fishing mortality for each fleet, and annual trends of spawning stock and predicted recruits.

For the red snapper West stock assuming the steepness of 0.81 catch by fleet and indices fit are shown in Figures 13 through 16. Shrimp bycatch for the West stock was consistently underestimated by all models for the period 1962 to 1973 (Fig 13 Shrimp-bycatch panel). Fishing multipliers by fleet indicated a declining trend for the commercial hand-line and recreational fisheries in the mid 1990's. Shrimp bycatch fishing mortality rate for the West stock was predicted to be almost twice that of the East stock, but it shows a reducing trend in the latest years. Overall predicted spawning West stock and recruits show an increasing trend since the mid 1990's, and the 2003 predicted spawning stock is the largest been since 1962 (Fig 16). Similar figures are presented for the assumed steepness of 0.90 (Figures 17 to 20) and 0.95 (Figures 21 to 24).

Sensitivity runs were performed for the East and West red snapper stocks assuming a lower vector of natural mortality for ages 0 and 1. These sensitivity runs assumed an M value of 0.59 for Age 0, 0.29 for Age 1, and 0.10 for Ages 2 and older. These runs are labeled "low mortality". Because the procedure for estimating catch-at age from the length frequency data by fleet also uses the natural mortality vector (Turner et al, 2004 SEDAR7-AW-24), the input of catch-at age by fleet and discards by fleet were also different in the low natural mortality runs. Other input data such as indices of abundance, fecundity vector, and weight at age vectors were similar between the two sets of runs.

Overall, the model fits to catch at age by fleet and indices of abundance were similar between the low mortality and the high mortality runs. Table 3 summarizes the benchmarks indicators for the East and West stocks low natural mortality rates, for the three steepness levels evaluated. In general, assuming a lower natural mortality at younger ages implied larger stocks in both the East and West regions. The estimates of virgin biomass were larger for the East and West stocks at any given assumed steepness, roughly 1.4 to 1.6 times greater than the estimates when the assuming high natural mortality. Similarly, estimates of spawning stock at MSY were greater when assumed a low mortality rate was assumed (Table 3). For the East red snapper, the ratios of SS_{2003}/SS_{MSY} at low natural mortality rates also indicated an overfished stock in 2003, with exception of the high steepness (0.95) and current-shrimp type benchmark estimates. In terms of fishing mortality reference points, the estimates of F_{MSY} were similar between low and high natural mortality rates, with exception of the East stock high steepness (0.95), in both link and current shrimp (unlink) benchmarks. Estimates of fishing mortality in 2003 were also similar between low and high natural mortality runs for the East and West stocks. The trends were the same, and the status in 2003 of each stock was similar, i.e. the East stock was overfished and overfishing was going on, with exception of the case of high steepness (0.95). For the West stock trends and stock status was the same between low and high natural mortality runs.

Projections of the East and West Gulf of Mexico red snapper stocks were carried out for the ASAP model current-shrimp (i.e. unlinked) evaluations. Two main groups of projections were performed: a) projections under a constant catch quota (TAC) with different levels of shrimp bycatch fishing mortality reduction, and b) projections under a constant fishing mortality of the directed fisheries with different levels of shrimp bycatch F reduction.

The projections began in 2004 and were continued through 2032. For the period of 2004 through 2006, a Gulf-wide directed fishery TAC of 9.12 million pounds was equally split between East and West fisheries, while the current fishing mortality rates (averaged over the last three years of the assessment 2001-03) were applied for the non-directed fisheries (shrimp bycatch and closed season). Beginning in year 2007 the different projection scenarios were then implemented. The mortality rates associated with closed season discarding in the recreational and commercial fishing sectors were held at the current levels throughout the projection period, as it is unclear what future scenarios would result under different management regimes. Projections were done for the three levels of steepness in the stock-recruitment relationship for both eastern and western stock (0.81, 0.90, and 0.95), and assuming a high natural mortality vector (Age 0 = 0.98, Age 1 = 0.59, Age 2+ = 0.1). It is important to note that these projections as in the ASAP assessments, treat the East and West Gulf of Mexico red snapper as completely independent stocks, with not relation between them at all.

For the East stock, projections of constant harvest were implemented for TACs of 0, 2, 4, 6, and 8 million pounds, with reductions of shrimp bycatch of 0, 20, 40, 60, 80 and 100% compared to the average of the most recent 3-year (2001-2003) estimated levels. Because the stock evaluations indicated higher overall productivity in the West, for the West stock, projections of constant harvest were implemented for TACs of 0, 2, 4, 6, 8, 10, 12, 14 and 18 MP, with reductions of shrimp bycatch from 0, 20, 40, 60, 80 and 100%. For both stocks, projections of directed fishery mortality rates were also conducted over the range of status quo levels to 0. The results of these projections were then contoured to provide a basis for interpolating projection outcomes over the range of catch, directed effort, and bycatch reduction levels specified.

Projection results are grouped by the assumed steepness (0.81, 0.90, 0.95) and by year 2010 and 2032 (Figures 25 to 30). In general, reduction of shrimp bycatch has a larger effect in the West compared to the East stock. The slopes of the tSPR isopleths in the West are much higher than in the East, particularly at 2032. Assumed steepness has also an impact in the current status and projections of the East and West stocks. The East stock, at the lower steepness (0.81, 0.90) show higher tSPR values in 2010 and 2032 compared to the high steepness (0.95) projections. For the East stock Spawning stock would reach SS_{MSY} levels in 2032 with a 4 MP TAC and no bycatch reduction, or 5 MP TAC and 100% reduction of bycatch, at the 0.95 assumed steepness (Fig 30), however at this levels, still tSPR would be below 20%. Yield isopleths indicated that greater catches will be likely at about 70% of current directed fishing rates and complete reduction of shrimp bycatch (Fig 30). Under the lower steepness assumption (0.90 and 0.81), the East stock could reach SSMSY levels in 2032 with TAC between 4.5 and 5.8 MP and no bycatch reduction. However in these cases, tSPR is higher, above 20%.

For the West stock, projections indicated that it can support greater yields in the order of 20 to 30 MP depending on the assumed steepness. Higher yield would be expected with higher shrimp bycatch reductions. West spawning stock biomass in 2032 would be above SS_{MSY} levels at any steepness, with TACs below 18 MP and no bycatch reduction, and tSPR levels would also be above 30%. Estimates of MSY do change with shrimp bycatch reduction, the estimated MSY increases as shrimp bycatch decreases. Thus, also estimates of SS_{MSY} and the corresponding fishing mortality benchmarks. Because in the projections, implementation of TAC and shrimp bycatch take place in 2007 year, the results at 2010 three years only after, reflect transitional effects of the stock. For example the 2010 SS/SS_{MSY} isopleths show a different trend compared to the 2032 SS/SS_{MSY} isopleths. The 2010 plots indicate that higher SS/SS_{MSY} ratios are achieved by lowering TAC and maintaining current shrimp bycatch levels. While in 2032 plots indicate that higher SS/SS_{MSY} ratios are achieved by lower TACs and reducing shrimp bycatch effort. What happened in 2010 plots, is that the SS_{2010} is relatively similar among the different shrimp bycatch reduction projection scenarios, (only three years after the scenario is implemented) while the target value, in this case SS_{MSY} is different among scenarios with lower SS_{MSY} at current levels of bycatch, and greater SS_{MSY} at minimum bycatch. Therefore the ratio SS_{2010}/SS_{MSY} is greater for high bycatch levels simply because the denominator is smaller. When the stock has passed several years, so that the dynamic equilibrium is reached (2032), then the trends of the isopleths reflect the true effects of bycatch reduction and constant catch projections.

Stock assessment and projection results of East and West stocks with the current ASAP program are sensitive to initial conditions and user settings regarding relative weighting factors, as indicated in the manual (Legault and Restrepo 1998).

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Table 1. Benchmark statistics for 1962-2003 East & West GOM red snapper ASAP runs.

Model Description	East			West		
ASAP - Linked	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{MSY}	0.1179	0.1117	0.3462	0.3484	0.3563	0.3325
$F_{current}$	0.1689	0.1342	1.1751	12.6302	19.9349	30.5799
$F_{30\%SPR}$	0.1630	0.1427	0.3598	0.4791	0.4537	0.4094
$F_{40\%SPR}$	0.1212	0.1047	0.2572	0.3640	0.3441	0.3090
$F_{0.1}$	0.1036	0.0874	0.2470	0.3171	0.2983	0.2648
F_{max}	0.1407	0.1221	0.3686	0.4075	0.3850	0.3453
MSY_{link}	9,180,200	8,886,590	10,713,500	16,400,400	19,948,300	25,415,500
SS_{MSY}	12,516,600	9,061,670	5,955,000	83,622,200	64,854,400	52,714,900
Virgin	33,617,000	25,092,800	19,723,100	220,306,000	175,370,000	144,240,000
steepness	0.81	0.90	0.95	0.81	0.90	0.95
SPR_{MSY}	41.0%	38.1%	31.2%	90.1%	88.8%	88.2%
$SSB_{30\%spr}$	8,233,960	6,999,300	5,617,360	56,601,600	46,609,600	39,842,200

Model Description	East			West		
ASAP – current shrimp unlink	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{MSY}	0.1956	0.2165	0.3567	0.1844	0.1936	0.1875
$F_{current}$	0.1519	0.1259	0.5388	0.0297	0.0491	0.0732
$F_{30\%SPR}$	0.1429	0.1395	0.0000	0.1596	0.1161	0.0722
$F_{40\%SPR}$	0.0775	0.0780	0.0000	0.1015	0.0623	0.0246
$F_{0.1}$	0.2098	0.1921	0.3105	0.1923	0.1755	0.1544
F_{max}	0.2845	0.2623	0.4367	0.2599	0.2386	0.2125
$MSY_{current\ shrimp}$	5,124,480	5,363,590	4,587,300	30,850,700	26,756,300	23,872,800
SS_{MSY}	6,431,380	4,739,810	1,656,850	48,454,000	31,121,300	20,776,500
Virgin	33,617,000	25,092,800	19,723,100	220,306,000	175,370,000	144,240,000
Steepness	0.81	0.9	0.95	0.81	0.9	0.95
SPR_{MSY}	24.2%	21.4%	9.7%	27.4%	20.3%	15.7%
$SSB_{30\%spr}$	8,237,250	6,998,180	4,974,930	55,539,400	46,485,600	39,842,400

Table 2. Stock status indicators for the East and West red snapper from the ASAP 1962-2003 models. Ratios of Spawning Stock biomass (SSB/SS_{MSY}) and fishing mortality (F/F_{MSY}) over corresponding values at MSY estimated assuming control on all fisheries (linked) and control only in directed fisheries (current shrimp / unlinked). Ratios of spawning stock biomass ($SSB/SSB_{SPR30\%}$) and fishing mortality ($F/F_{SPR30\%}$) over corresponding values at Spawing Potential Ratio (SPR) of 30%, and estimated transitional SPR values.

EAST			**SSB/SSBmsy**				**SSB / SSB_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1999**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	high	0.81	0.061	0.053	0.170	0.359	0.087	0.077	0.256	0.545
linked	high	0.90	0.054	0.057	0.173	0.453	0.062	0.067	0.220	0.587
linked	high	0.95	0.054	0.063	0.064	0.127	0.057	0.069	0.064	0.135
Currrent shrimp	high	0.81	0.139	0.087	0.332	0.698	0.087	0.077	0.256	0.545
Currrent shrimp	high	0.90	0.127	0.095	0.374	0.867	0.062	0.067	0.220	0.587
Currrent shrimp	high	0.95	0.138	0.111	0.200	0.457	0.064	0.077	0.072	0.152
			F/Fmsy				**F / F_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1998**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	high	0.81	3.931	3.119	1.433	1.500	3.065	2.079	1.019	1.085
linked	high	0.90	5.256	3.531	1.496	1.238	4.738	2.654	1.238	0.969
linked	high	0.95	6.923	4.376	4.507	3.395	2.583	1.323	4.612	3.266
Currrent shrimp	high	0.81	3.542	2.722	0.750	0.776	3.498	2.373	1.128	1.063
Currrent shrimp	high	0.90	4.676	2.997	0.698	0.582	4.847	2.715	1.223	0.903
Currrent shrimp	high	0.95	6.082	3.697	2.545	1.510	N/A	N/A	N/A	N/A
							SPR (transitional)			
Type	**M case**	**steepness**					**1962**	**1984**	**1998**	**2003**
linked	high	0.81						0.063	0.155	0.247
linked	high	0.90						0.046	0.115	0.213
linked	high	0.95						0.035	0.030	0.047
Currrent shrimp	high	0.81						0.063	0.155	0.247
Currrent shrimp	high	0.90						0.046	0.115	0.213
Currrent shrimp	high	0.95						0.035	0.030	0.047

WEST			**SSB/SSBmsy**				**SSB / SSB_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1999**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	high	0.81	0.044	0.049	0.303	0.523	0.065	0.072	0.457	0.772
linked	high	0.90	0.030	0.026	0.159	0.307	0.041	0.035	0.227	0.428
linked	high	0.95	0.022	0.018	0.083	0.180	0.027	0.023	0.112	0.239
Currrent shrimp	high	0.81	0.212	0.099	1.017	0.902	0.066	0.073	0.465	0.787
Currrent shrimp	high	0.90	0.167	0.071	0.870	0.640	0.041	0.035	0.227	0.429
Currrent shrimp	high	0.95	0.138	0.063	0.777	0.458	0.027	0.023	0.112	0.239
			F/Fmsy				**F / F_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1998**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	high	0.81	3.058	2.030	1.440	0.631	1.631	0.864	1.256	0.459
linked	high	0.90	3.784	3.454	2.081	0.889	2.069	1.449	1.988	0.699
linked	high	0.95	5.060	4.754	2.987	1.237	2.621	2.038	2.896	1.005
Currrent shrimp	high	0.81	2.041	1.362	0.244	0.161	1.352	1.070	0.185	0.186
Currrent shrimp	high	0.90	2.529	2.526	0.437	0.254	3.070	3.077	0.518	0.423
Currrent shrimp	high	0.95	3.537	3.511	0.738	0.390	7.691	7.131	1.579	1.013
							SPR (transitional)			
Type	**M case**	**steepness**					**1962**	**1984**	**1998**	**2003**
linked	high	0.81						0.061	0.270	0.333
linked	high	0.90						0.026	0.139	0.186
linked	high	0.95						0.015	0.063	0.095
Currrent shrimp	high	0.81						0.061	0.270	0.333
Currrent shrimp	high	0.90						0.026	0.139	0.186
Currrent shrimp	high	0.95						0.015	0.063	0.095

Table 3. Benchmark statistics for 1962-2003 East & West GOM red snapper ASAP runs assuming a **Lower Natural Mortality rate**.

Model Description	East			West		
ASAP - Linked	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{MSY}	0.1321	0.1149	0.1179	0.3452	0.3614	0.3557
$F_{current}$	0.1769	0.1280	0.1000	0.1805	0.2662	0.4017
$F_{30\%SPR}$	0.1835	0.1482	0.1456	0.4764	0.4614	0.4381
$F_{40\%SPR}$	0.1371	0.1092	0.1071	0.3623	0.3507	0.3322
$F_{0.1}$	0.1168	0.0908	0.0888	0.3143	0.3036	0.2858
F_{max}	0.1566	0.1252	0.1229	0.4029	0.3899	0.3690
MSY_{link}	9,966,420	10,138,800	8,411,800	15,470,800	18,091,900	25,394,100
SS_{MSY}	15,596,600	11,396,500	8,827,300	121,387,000	93,884,000	78,400,900
Virgin	41,481,600	31,166,300	24,512,500	318,295,000	252,708,000	213,686,000
steepness	0.81	0.9	0.95	0.81	0.9	0.95
SPR_{MSY}	41.3%	38.5%	37.2%	42.8%	38.8%	36.7%
$SSB_{30\%spr}$	10,154,300	11,227,500	7,242,660	85,719,600	68,563,000	58,346,100

Model Description	East			West		
ASAP – current shrimp unlink	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{MSY}	0.1919	0.2122	0.2250	0.1903	0.2038	0.1985
$F_{current}$	0.1290	0.1070	0.0832	0.0179	0.0305	0.0552
$F_{30\%SPR}$	0.1382	0.1382	0.1536	0.1698	0.1285	0.0726
$F_{40\%SPR}$	0.0737	0.0776	0.0944	0.1107	0.0726	0.0224
$F_{0.1}$	0.2061	0.1877	0.1792	0.1978	0.1849	0.1654
F_{max}	0.2790	0.2562	0.2454	0.2666	0.2503	0.2261
$MSY_{current\ shrimp}$	5,912,150	6,455,560	6,057,560	43,252,000	36,109,900	30,420,600
SS_{MSY}	7,861,600	5,944,650	4,998,550	72,029,200	46,098,300	29,765,200
Virgin	41,481,600	31,166,300	24,512,500	318,295,000	252,708,000	213,686,000
Steepness	0.81	0.9	0.95	0.81	0.9	0.95
SPR_{MSY}	24.1%	21.6%	21.8%	28.3%	21.0%	15.2%
$SSB_{30\%spr}$	10,150,100	8,690,240	7,252,750	83,039,100	68,002,800	58,367,700

Table 4. **Lower Natural Mortality Rate** Stock status indicators for the East and West red snapper from the ASAP 1962-2003 models. Ratios of Spawning Stock biomass (SSB/SS_{MSY}) and fishing mortality (F/F_{MSY}) over corresponding values at MSY estimated assuming control on all fisheries (linked) and control only in directed fisheries (current shrimp / unlinked). Ratios of spawning stock biomass ($SSB/SSB_{SPR30\%}$) and fishing mortality ($F/F_{SPR30\%}$) over corresponding values at Spawing Potential Ratio (SPR) of 30%, and estimated transitional SPR values.

EAST			**SSB/SSBmsy**				**SSB / SSB_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1999**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	low	0.81	0.060	0.046	0.167	0.358	0.086	0.068	0.255	0.550
linked	low	0.90	0.051	0.046	0.163	0.438	0.046	0.043	0.162	0.445
linked	low	0.95	0.047	0.057	0.231	0.698	0.050	0.063	0.275	0.851
current shrimp	low	0.81	0.154	0.090	0.326	0.710	0.086	0.068	0.255	0.550
current shrimp	low	0.90	0.137	0.093	0.354	0.840	0.060	0.056	0.210	0.575
current shrimp	low	0.95	0.135	0.116	0.482	1.233	0.050	0.062	0.275	0.850
			F/Fmsy				**F / F_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1998**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	low	0.81	3.741	3.191	1.320	1.338	2.539	1.919	0.779	0.964
linked	low	0.90	4.789	3.638	1.398	1.139	5.356	3.289	1.339	1.139
linked	low	0.95	6.316	3.804	1.160	0.865	5.503	2.620	0.905	0.701
current shrimp	low	0.81	3.264	2.692	0.656	0.672	3.253	2.349	1.005	0.933
current shrimp	low	0.90	4.096	2.958	0.619	0.504	4.454	2.735	1.076	0.774
current shrimp	low	0.95	5.358	2.973	0.489	0.370	5.215	2.477	0.828	0.542
							SPR (transitional)			
Type	**M case**	**steepness**					**1962**	**1984**	**1998**	**2003**
linked	low	0.81						0.058	0.162	0.261
linked	low	0.90						0.041	0.118	0.223
linked	low	0.95						0.037	0.120	0.242
current shrimp	low	0.81						0.058	0.162	0.261
current shrimp	low	0.90						0.041	0.118	0.223
current shrimp	low	0.95						0.037	0.120	0.242
WEST			**SSB/SSBmsy**				**SSB / SSB_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1999**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	low	0.81	0.042	0.056	0.387	0.658	0.060	0.079	0.555	0.932
linked	low	0.90	0.028	0.026	0.213	0.400	0.037	0.035	0.296	0.548
linked	low	0.95	0.019	0.014	0.089	0.191	0.024	0.018	0.122	0.257
current shrimp	low	0.81	0.228	0.112	1.188	1.109	0.062	0.082	0.573	0.962
current shrimp	low	0.90	0.179	0.077	1.067	0.815	0.037	0.036	0.299	0.552
current shrimp	low	0.95	0.145	0.059	0.864	0.504	0.024	0.018	0.122	0.257
			F/Fmsy				**F / F_SPR30%**			
Type	**M case**	**steepness**	**1962**	**1984**	**1998**	**2003**	**1962**	**1984**	**1999**	**2003**
linked	low	0.81	2.855	1.541	1.249	0.523	1.692	0.793	1.035	0.379
linked	low	0.90	3.651	2.890	1.806	0.737	2.161	1.436	1.745	0.577
linked	low	0.95	4.756	4.656	2.747	1.129	2.629	2.140	2.697	0.917
current shrimp	low	0.81	1.657	0.847	0.136	0.094	0.964	0.619	0.102	0.105
current shrimp	low	0.90	2.258	1.862	0.246	0.150	2.339	2.016	0.268	0.238
current shrimp	low	0.95	3.095	3.281	0.524	0.278	6.831	6.709	1.087	0.760
							SPR (transitional)			
Type	**M case**	**steepness**					**1962**	**1984**	**1998**	**2003**
linked	low	0.81						0.066	0.315	0.386
linked	low	0.90						0.026	0.176	0.233
linked	low	0.95						0.012	0.073	0.109
current shrimp	low	0.81						0.066	0.315	0.386
current shrimp	low	0.90						0.026	0.176	0.233
current shrimp	low	0.95						0.012	0.073	0.109

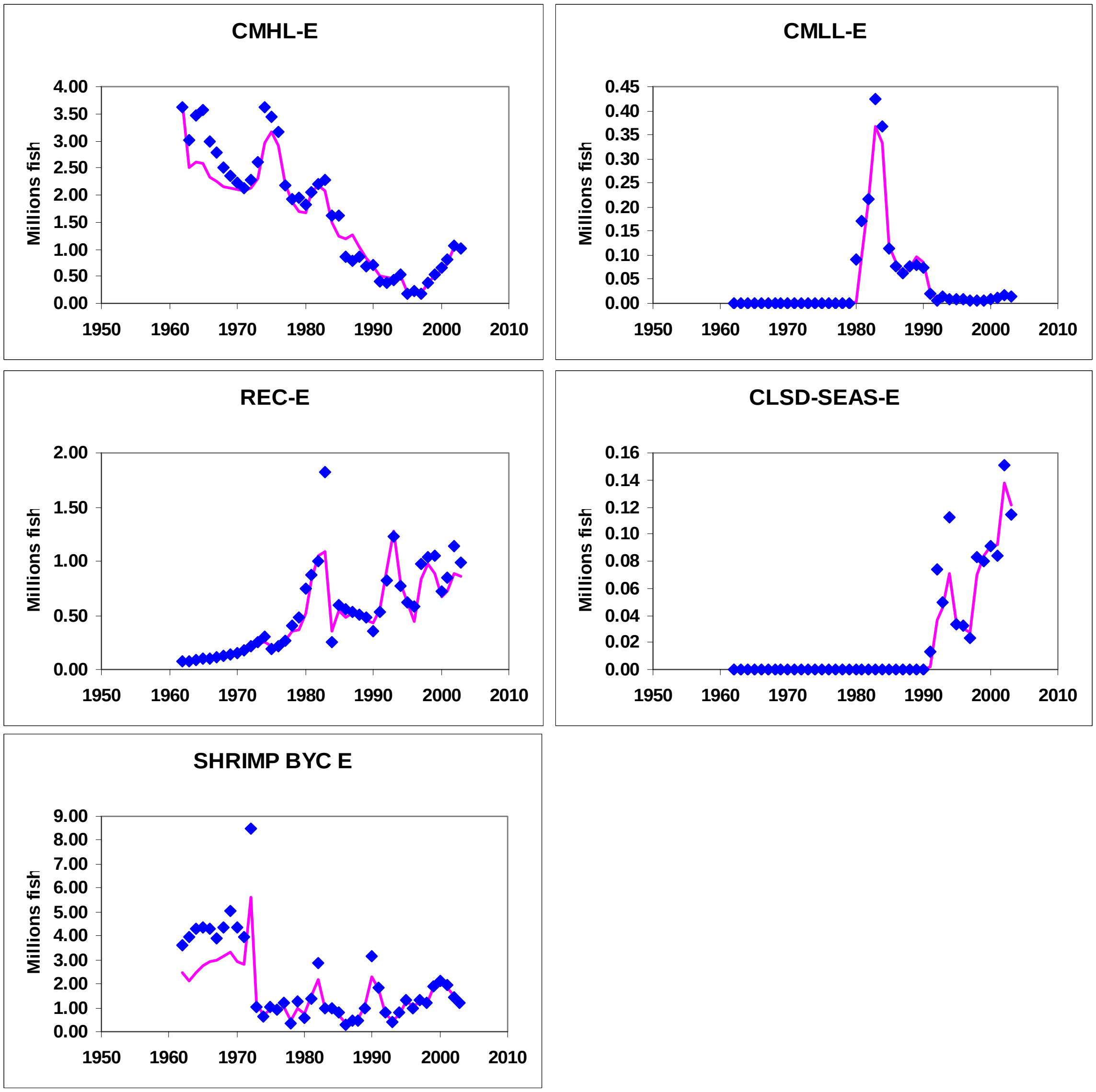


Figure 1. Fit to total catch by fleet for the East GOM (steepness 0.81)

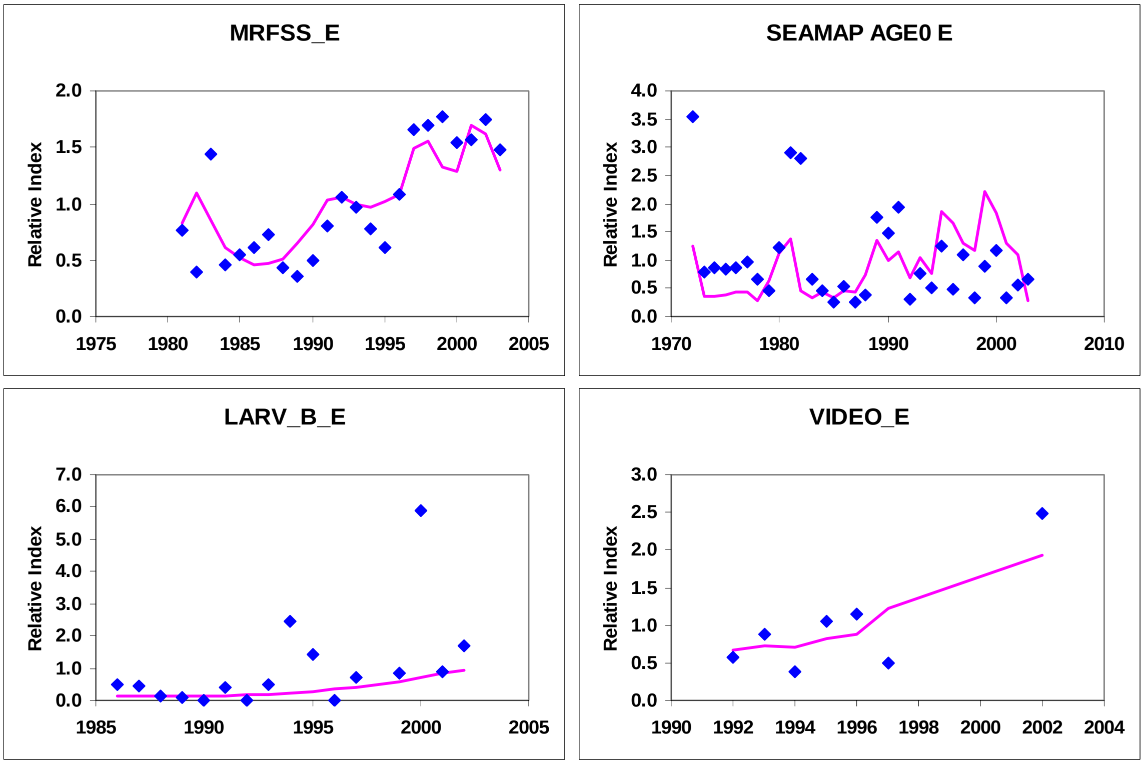


Figure 2. Fit to indices of abundance for the East GOM red snapper (Steepness 0.81)

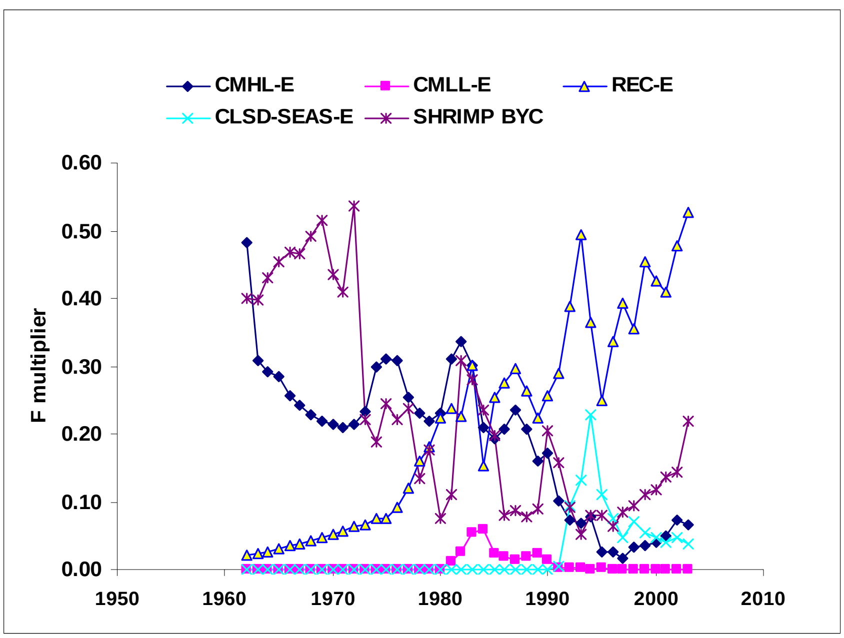


Figure 3. F multipliers by fleet for the East GOM red snapper (steepness 0.81)

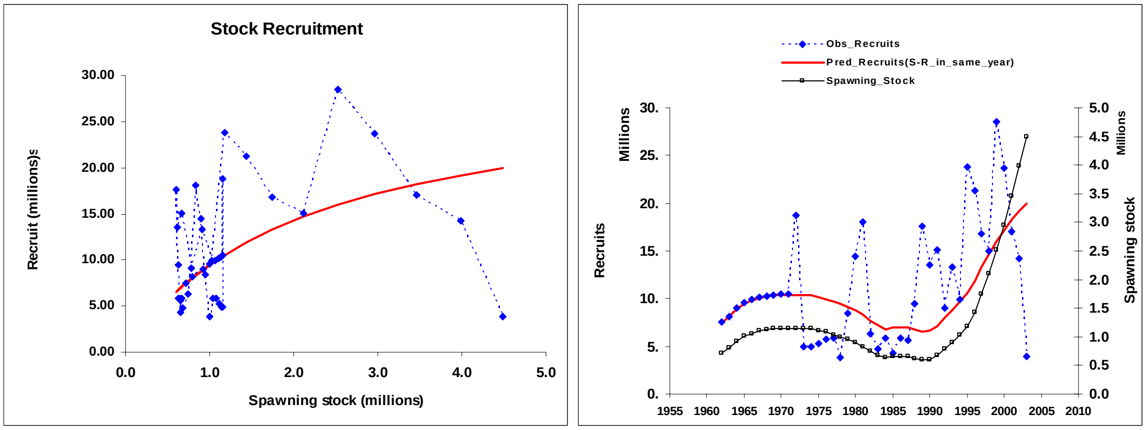


Figure 4. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.81)

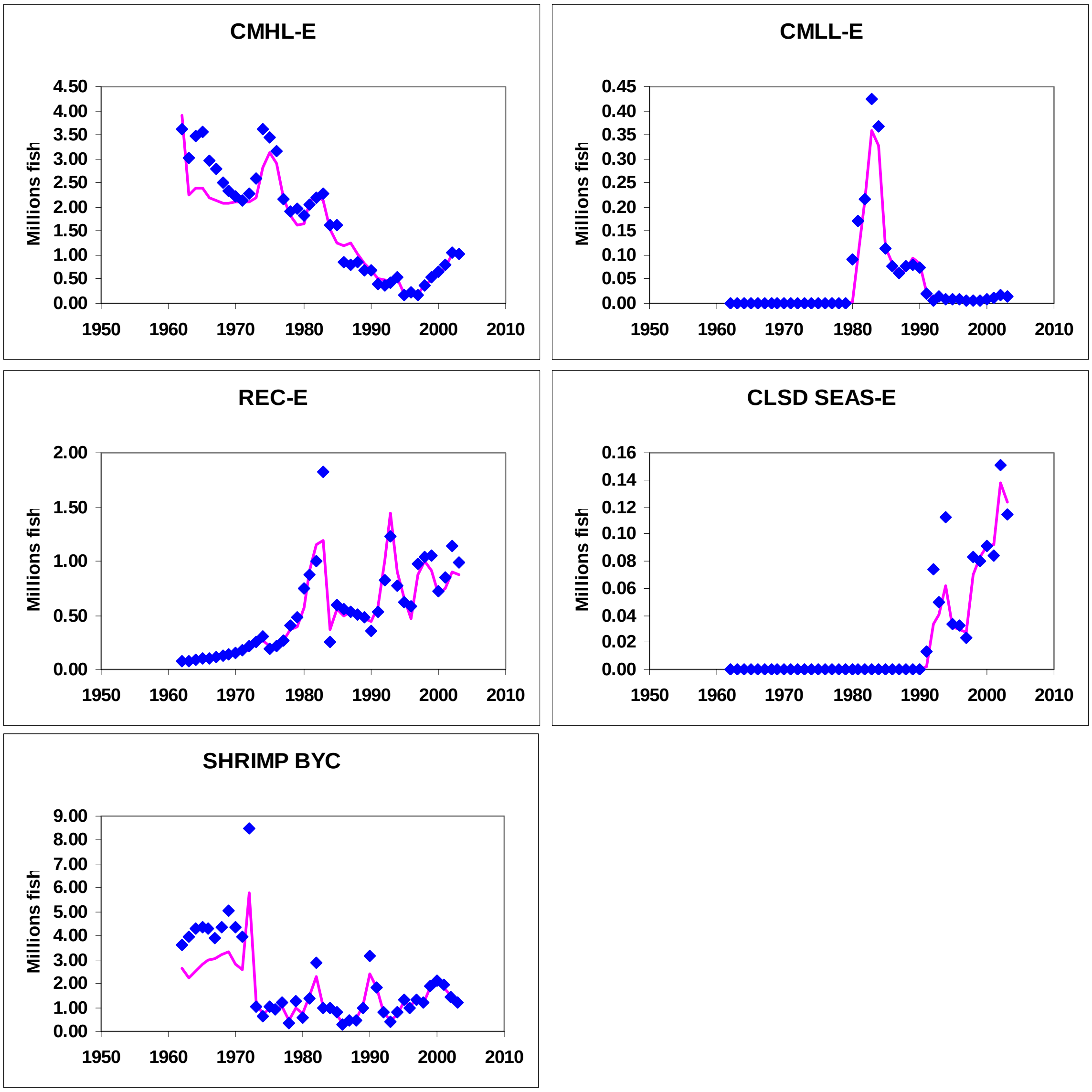


Figure 5. Fit to total catch by fleet for the East GOM (steepness 0.90)

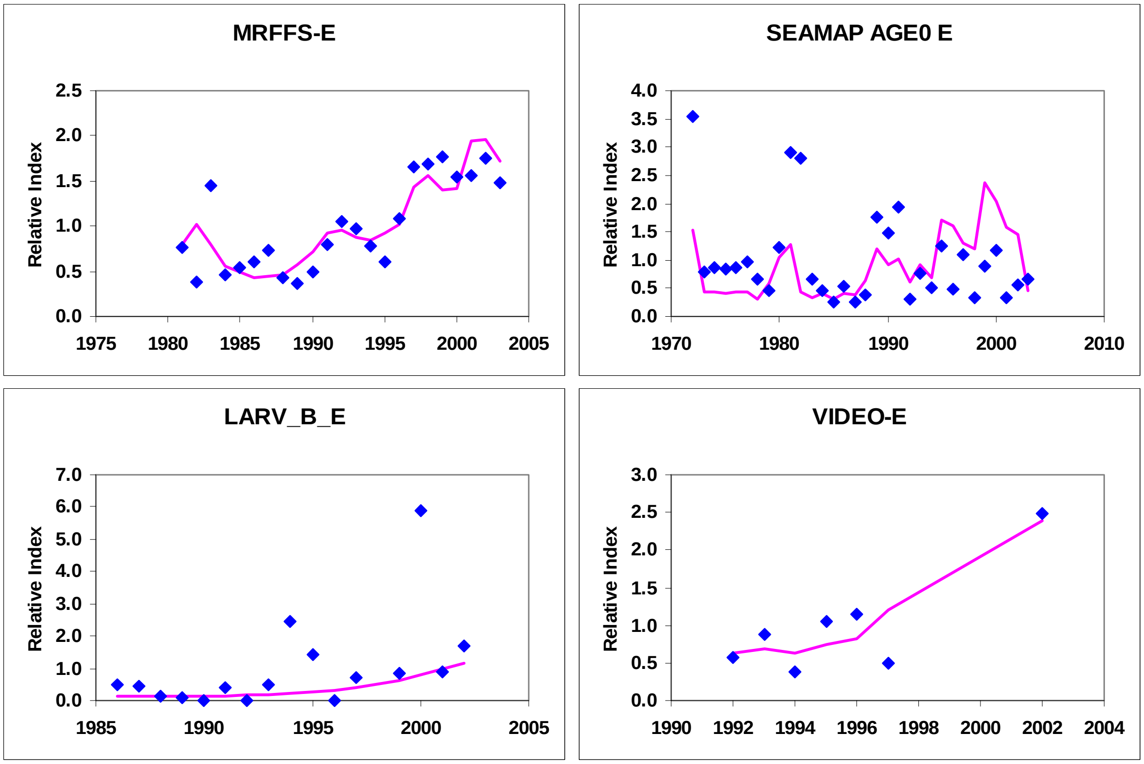


Figure 6. Fit to indices of abundance for the East GOM red snapper (Steepness 0.90)

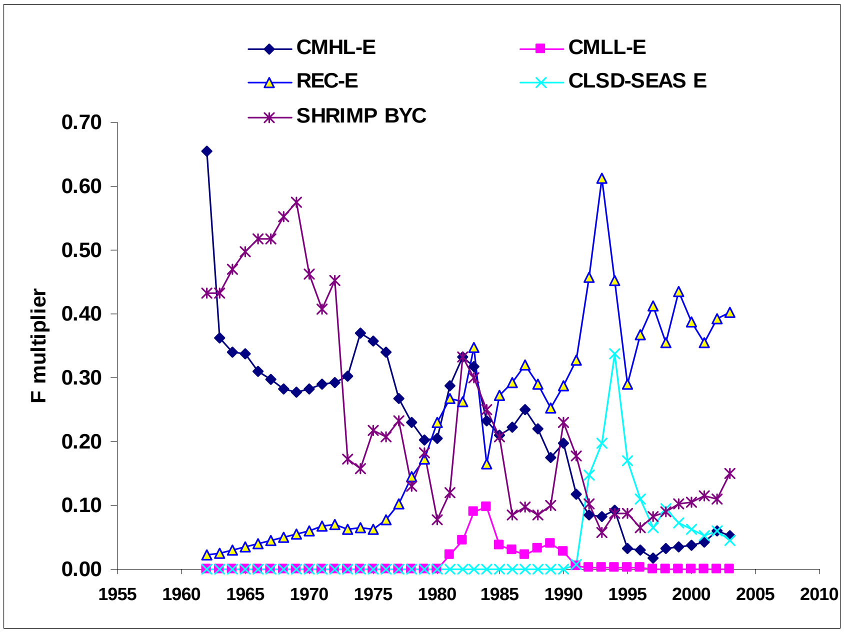


Figure 7. F multipliers by fleet for the East GOM red snapper (steepness 0.90)

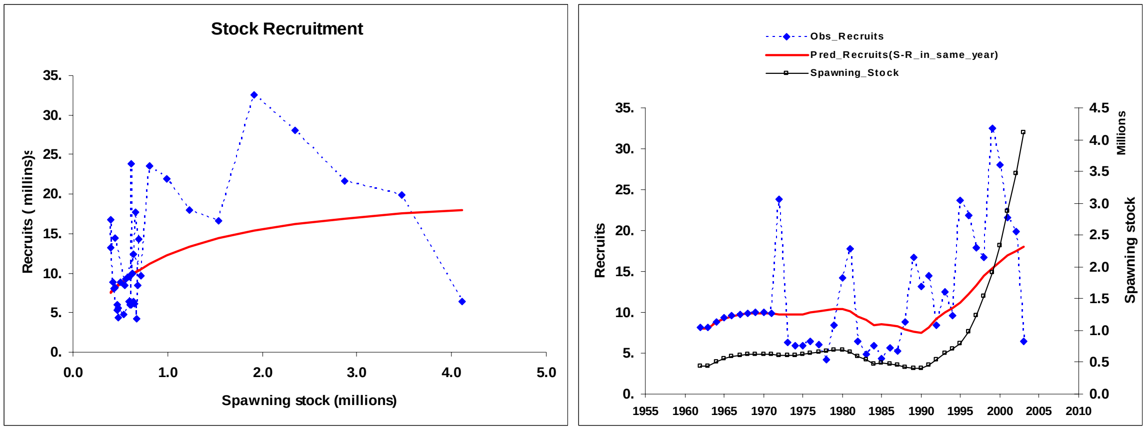


Figure 8. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.90)

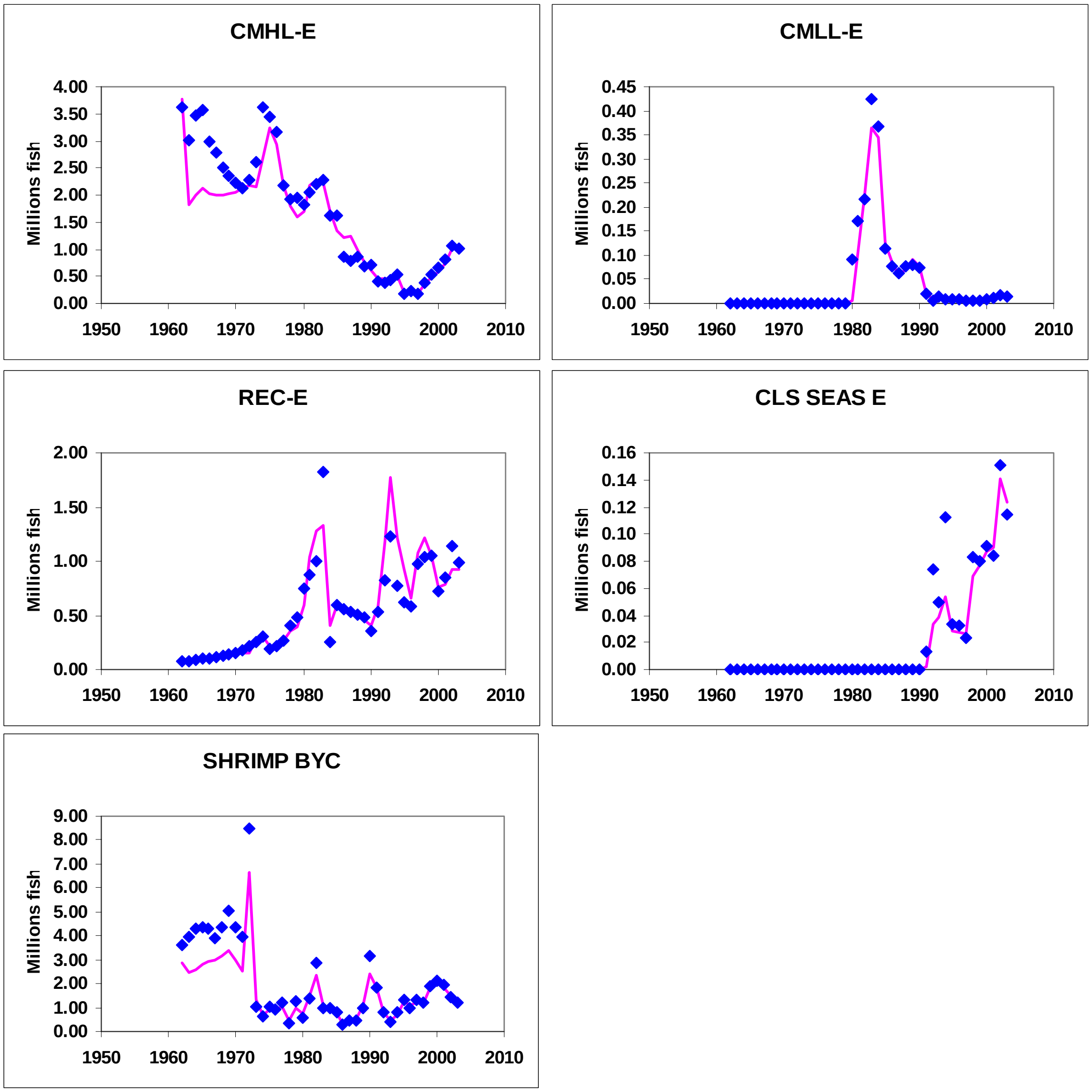


Figure 9. Fit to total catch by fleet for the East GOM (steepness 0.95)

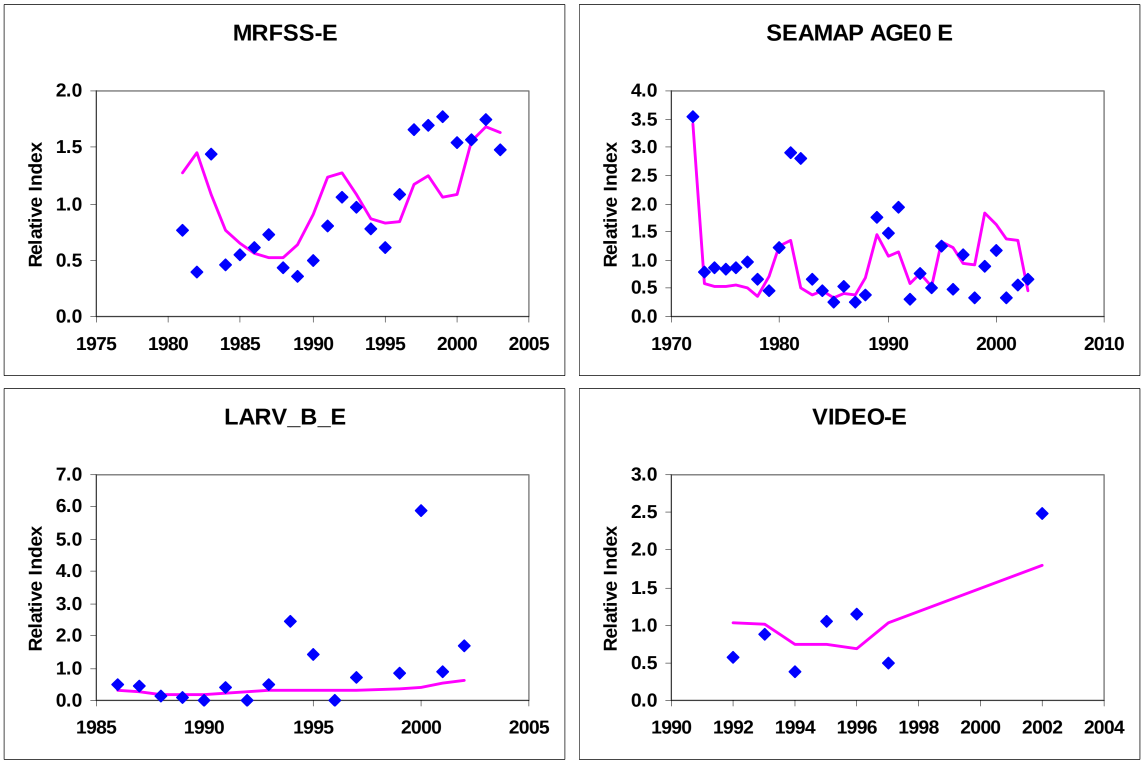


Figure 10. Fit to indices of abundance for the East GOM red snapper (Steepness 0.95)

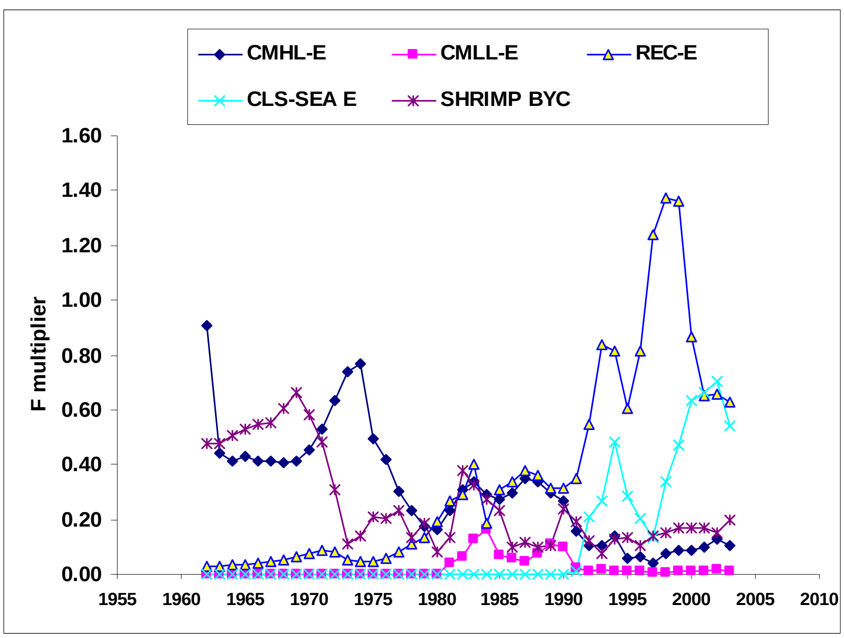


Figure 11. F multipliers by fleet for the East GOM red snapper (steepness 0.95)

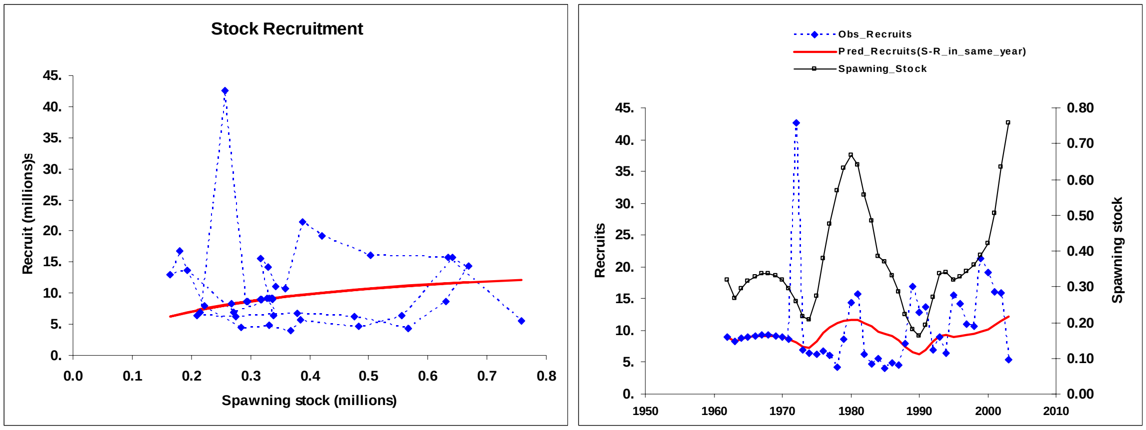


Figure 12. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.95)

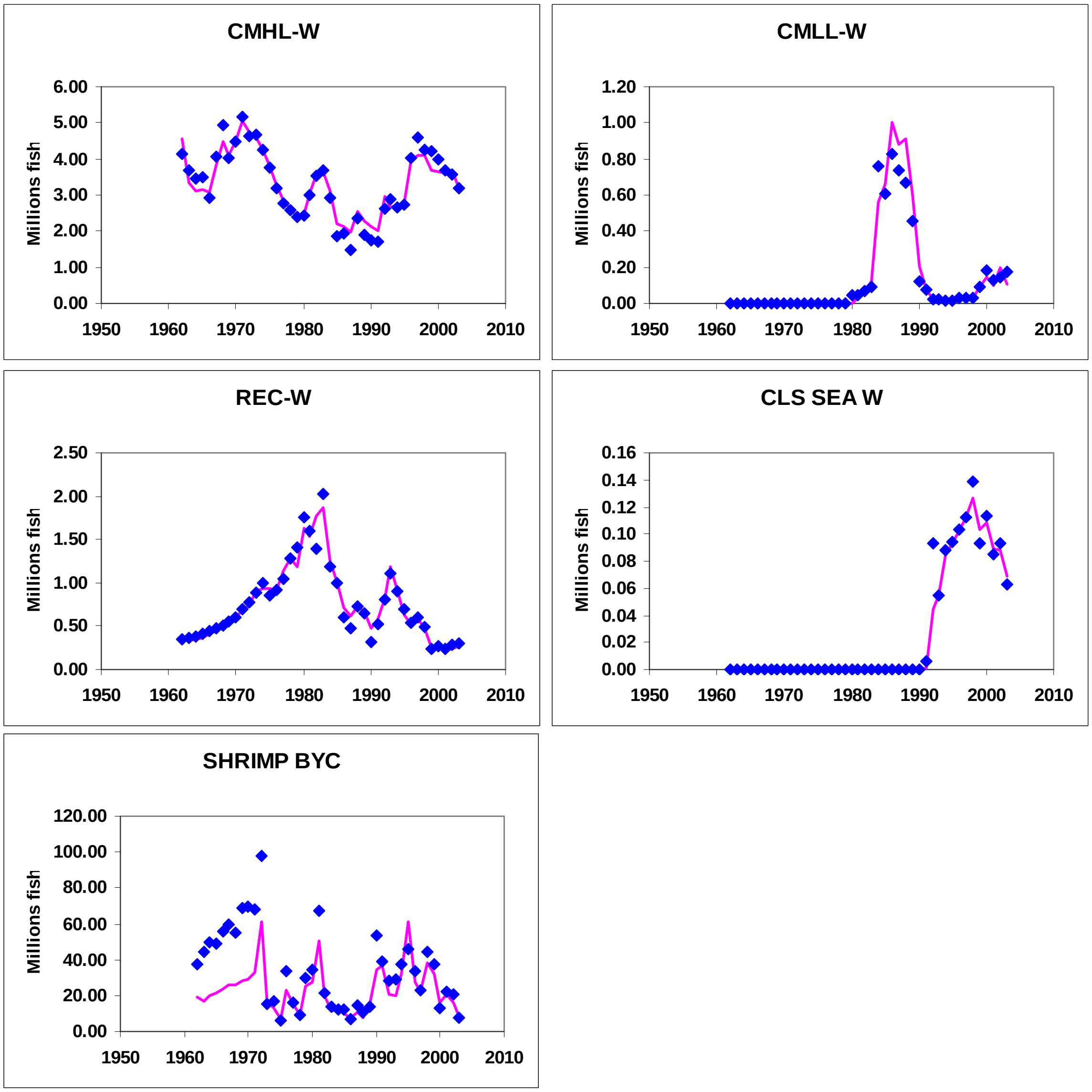


Figure 13. Fit to total catch by fleet for the West GOM (steepness 0.81)

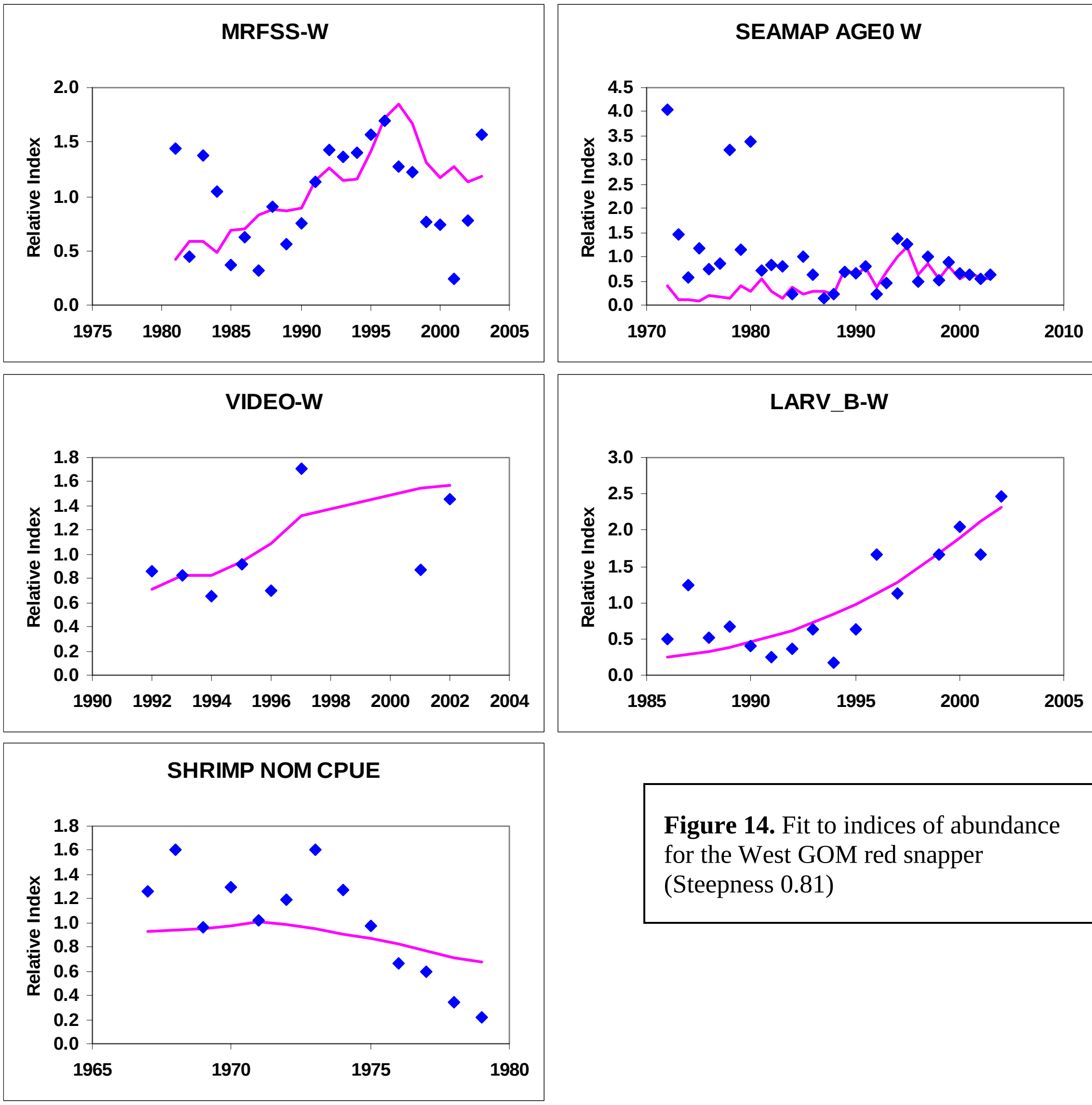


Figure 14. Fit to indices of abundance for the West GOM red snapper (Steepness 0.81)

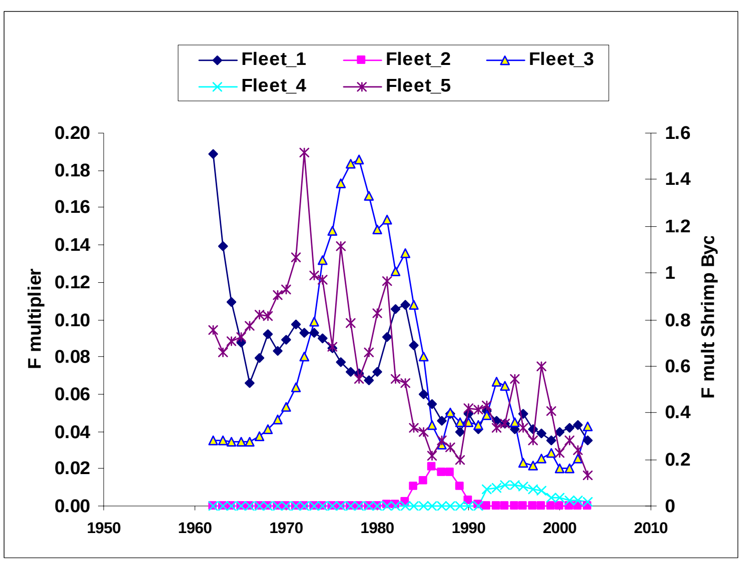


Figure 15. F multipliers by fleet for the West GOM red snapper (steepness 0.81)

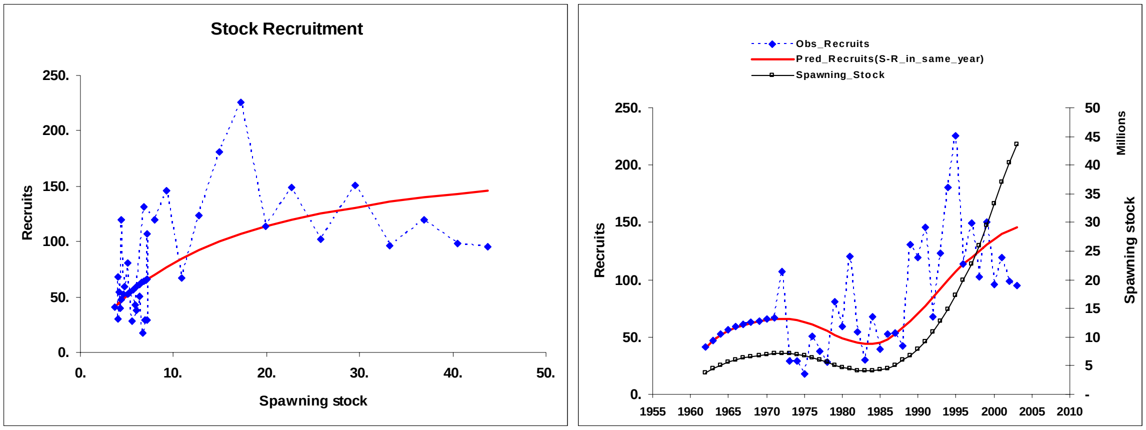


Figure 16. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.81)

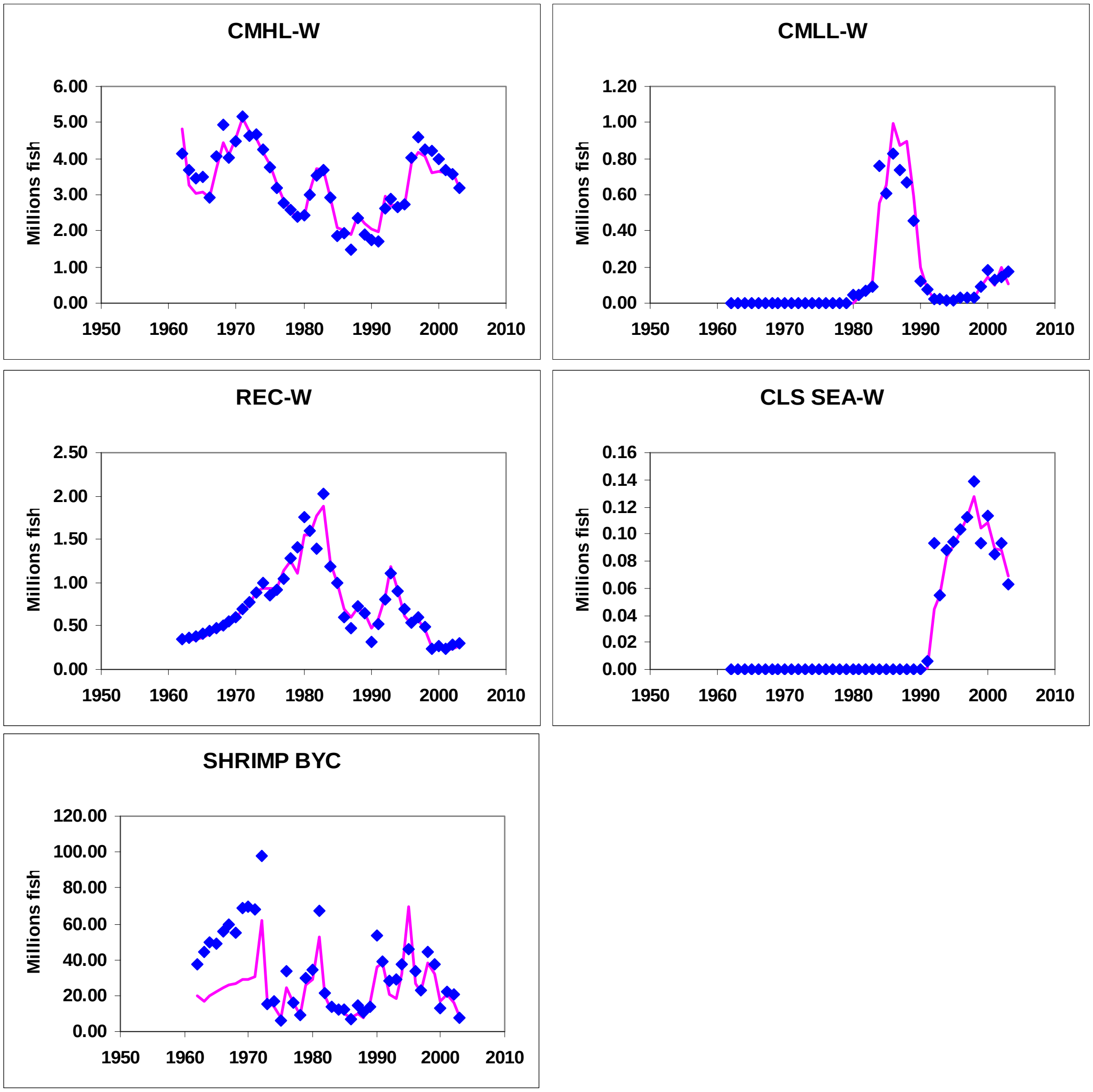


Figure 17. Fit to total catch by fleet for the West GOM (steepness 0.90)

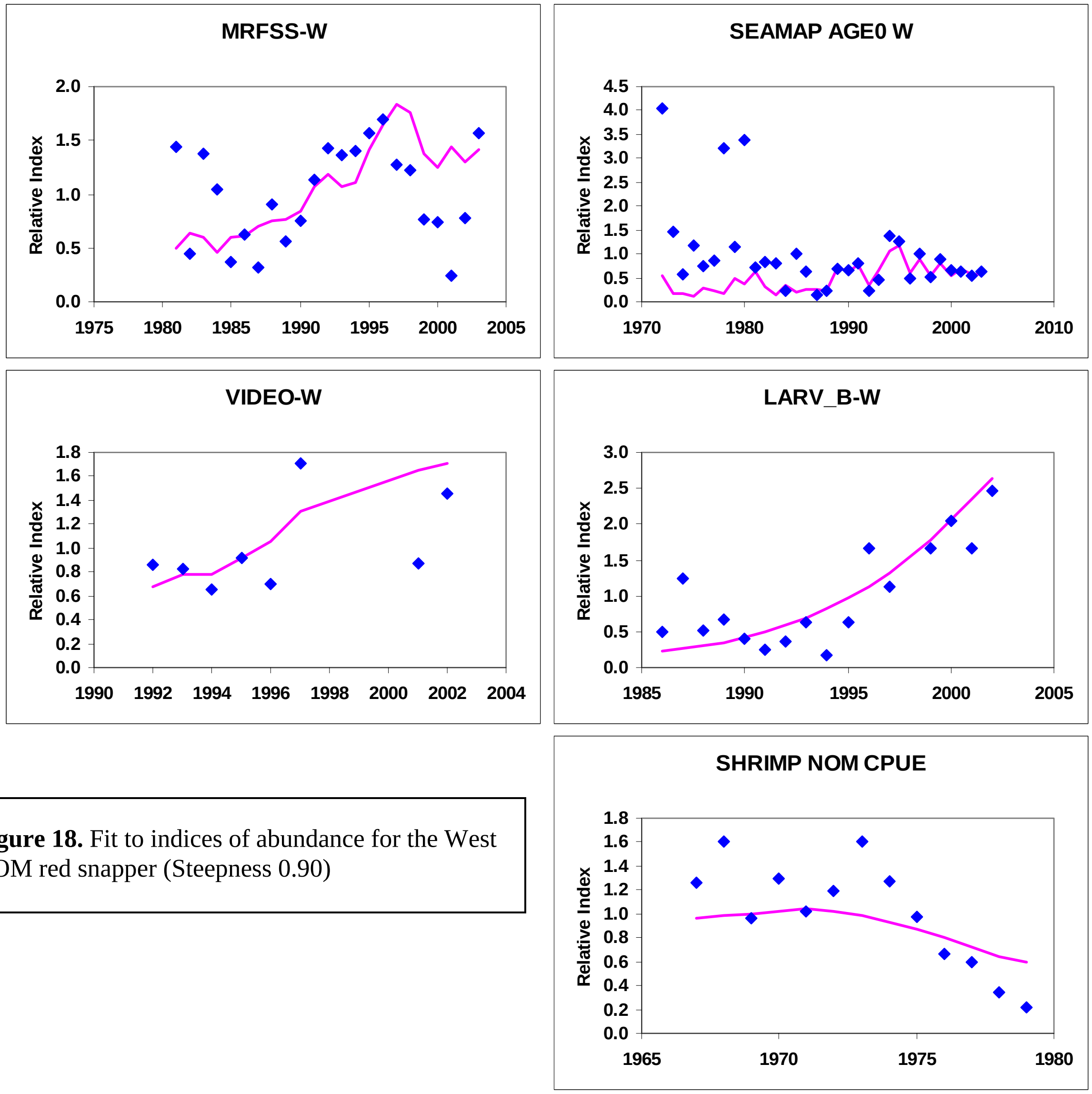


Figure 18. Fit to indices of abundance for the West GOM red snapper (Steepness 0.90)

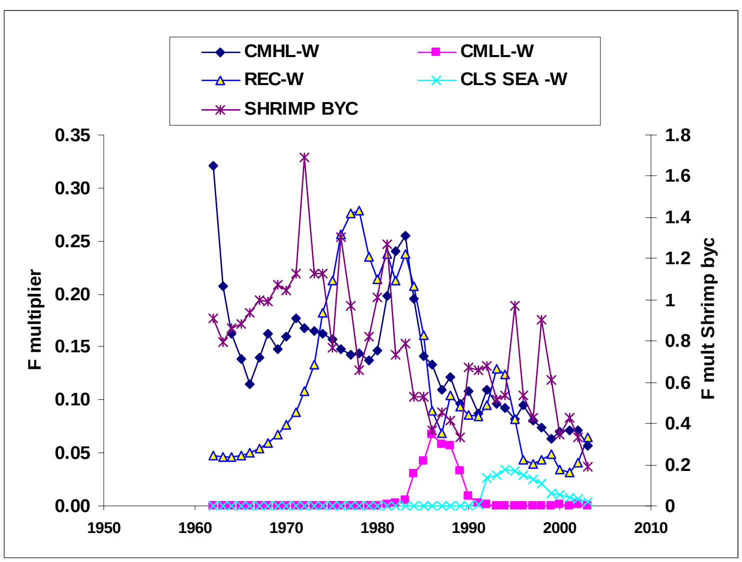


Figure 19. F multipliers by fleet for the West GOM red snapper (steepness 0.90)

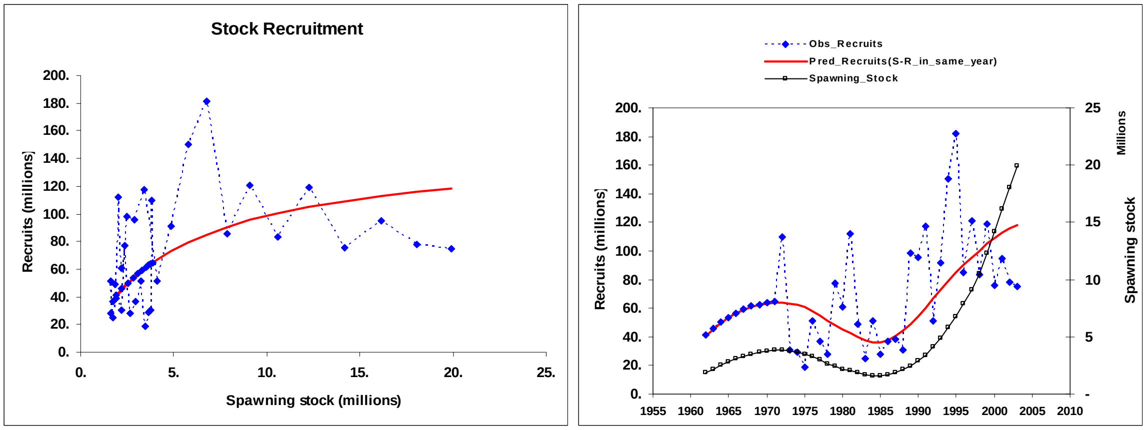


Figure 20. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.90)

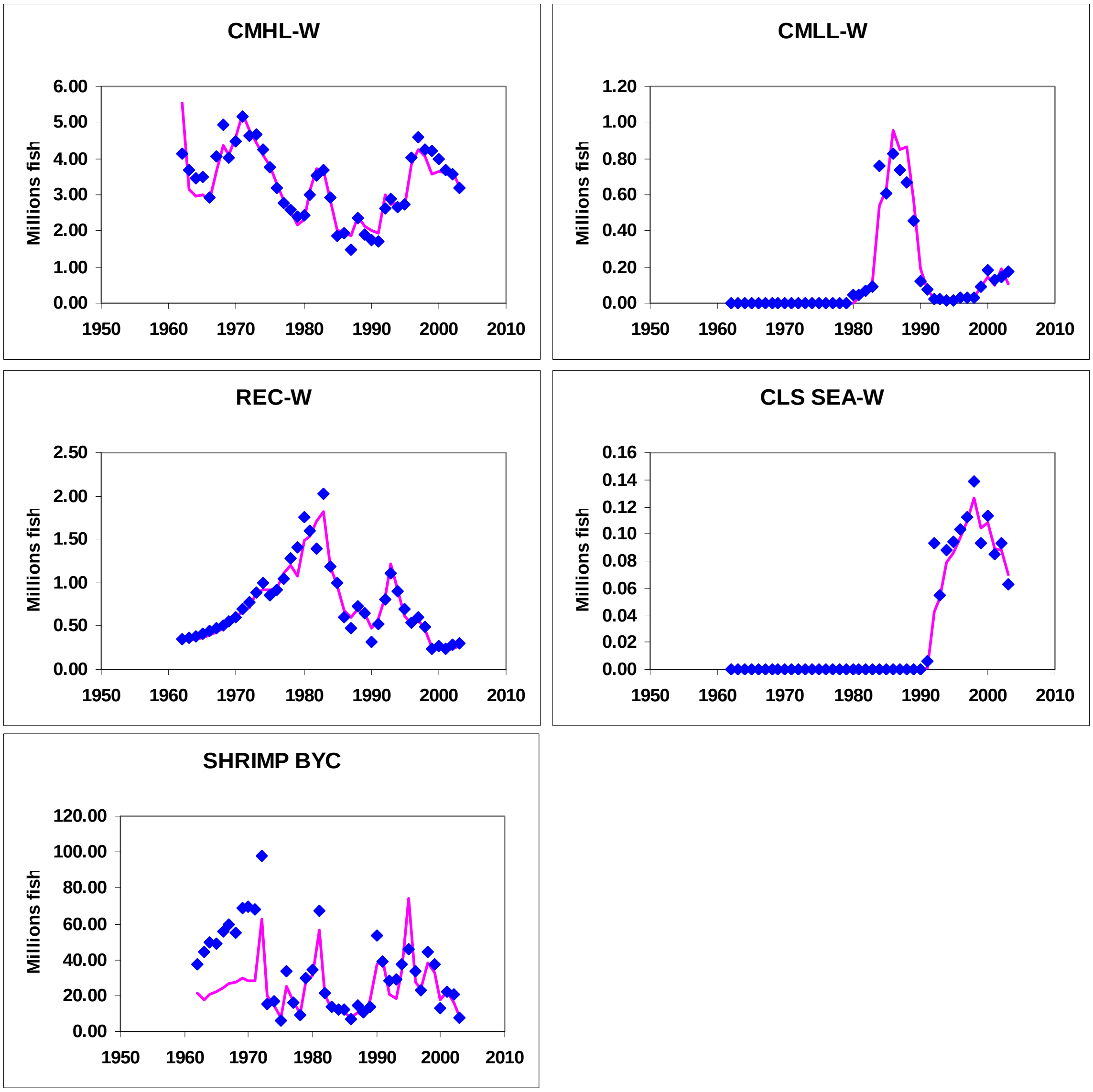
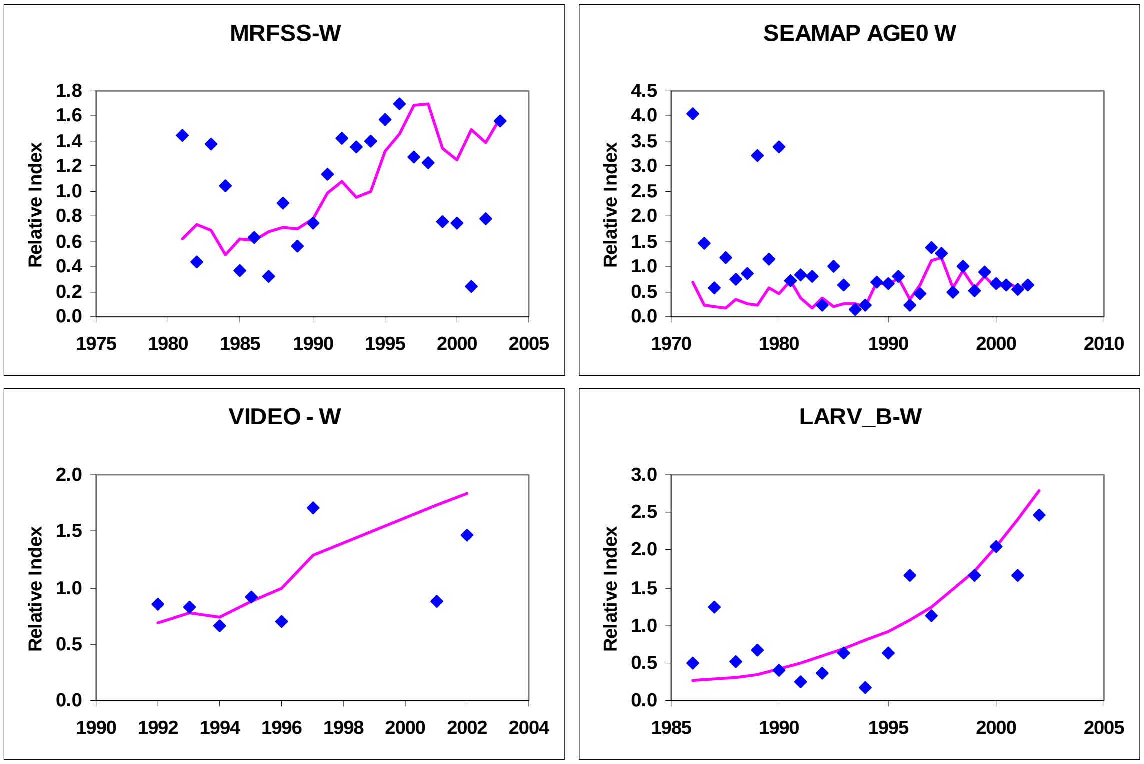


Figure 21. Fit to total catch by fleet for the West GOM (steepness 0.95)



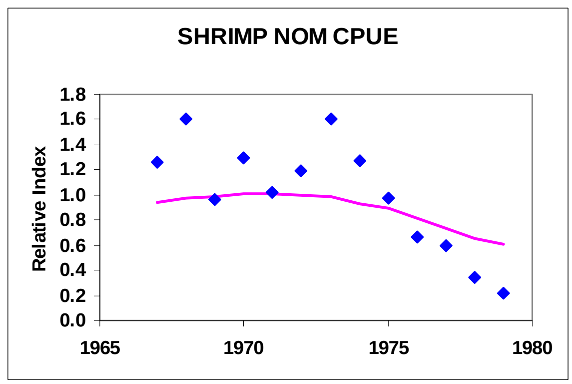


Figure 22. Fit to indices of abundance for the West GOM red snapper (Steepness 0.95)

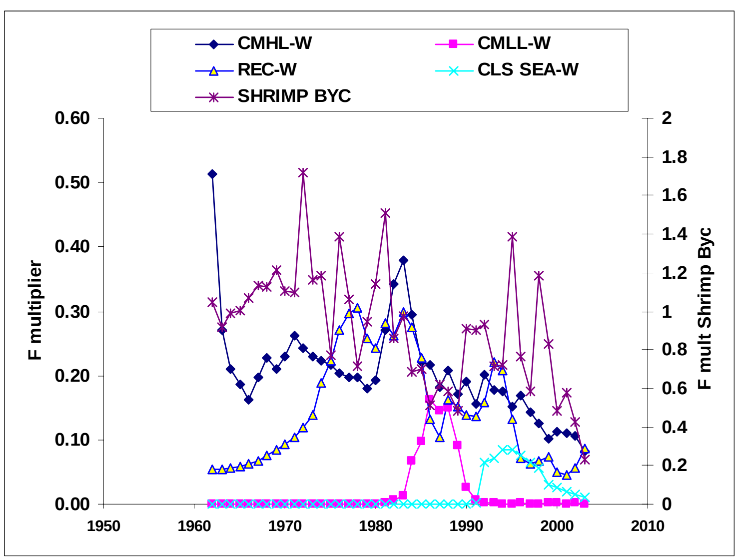


Figure 23. F multipliers by fleet for the West GOM red snapper (steepness 0.95)

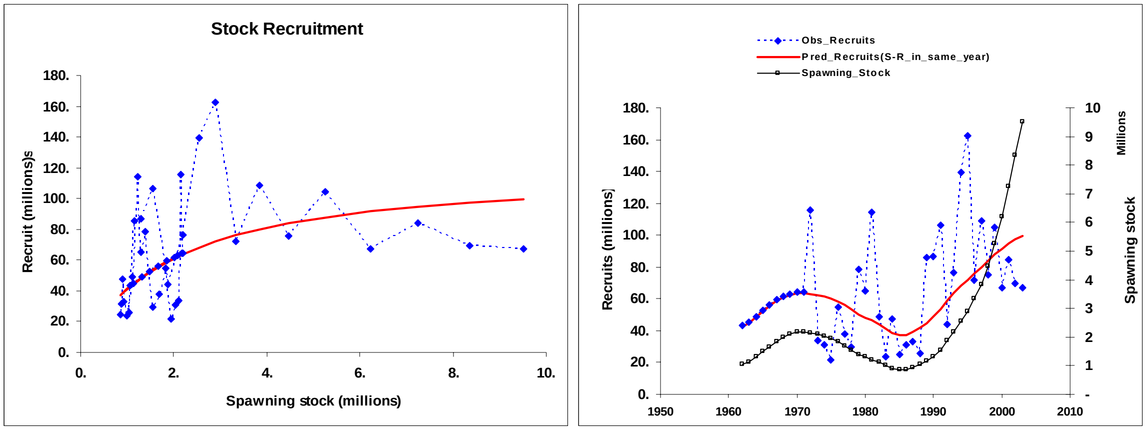


Figure 24. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.95)

Steepness 0.81 2010

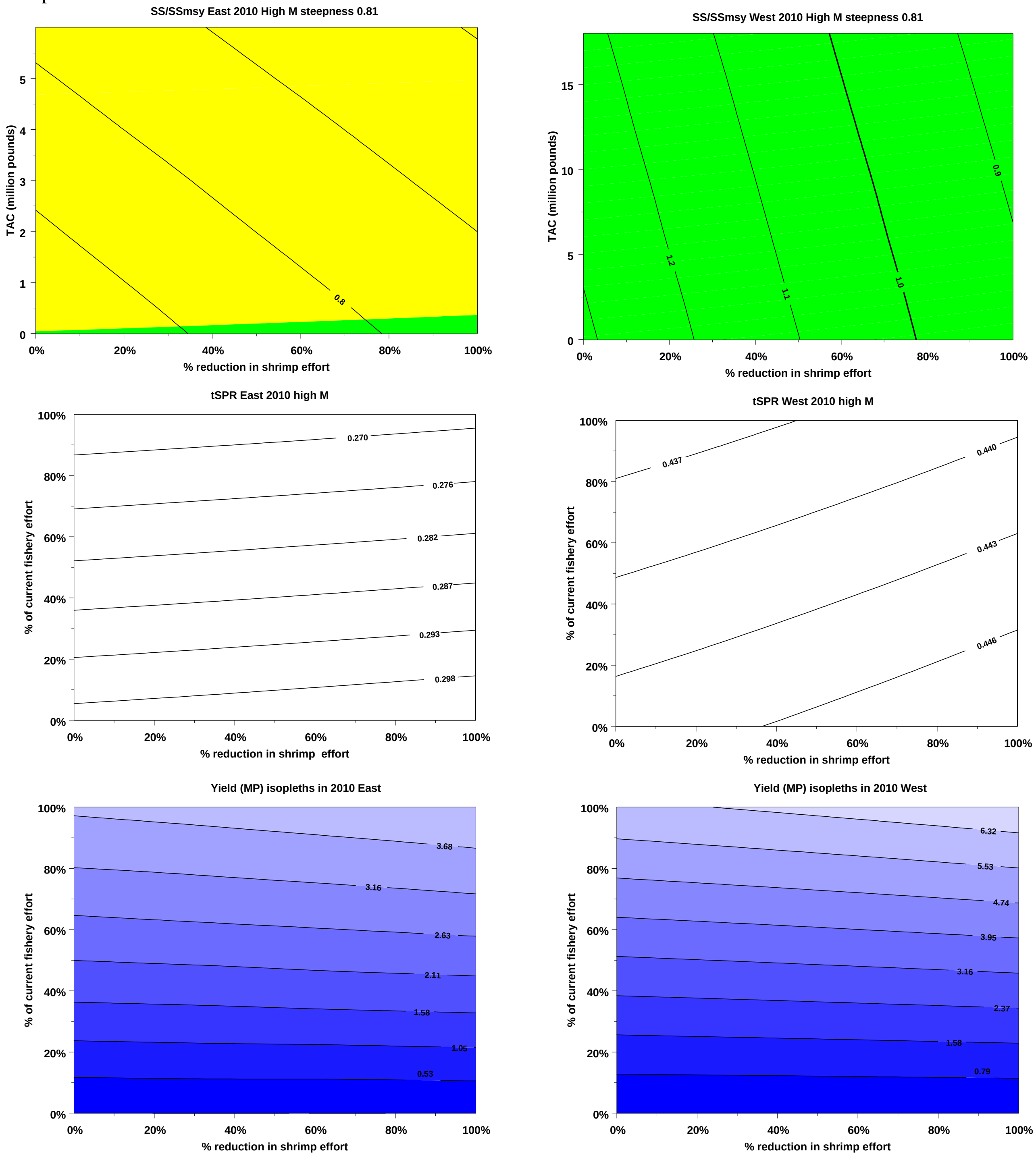


Figure 25. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.81.

Steepness 0.81 2032

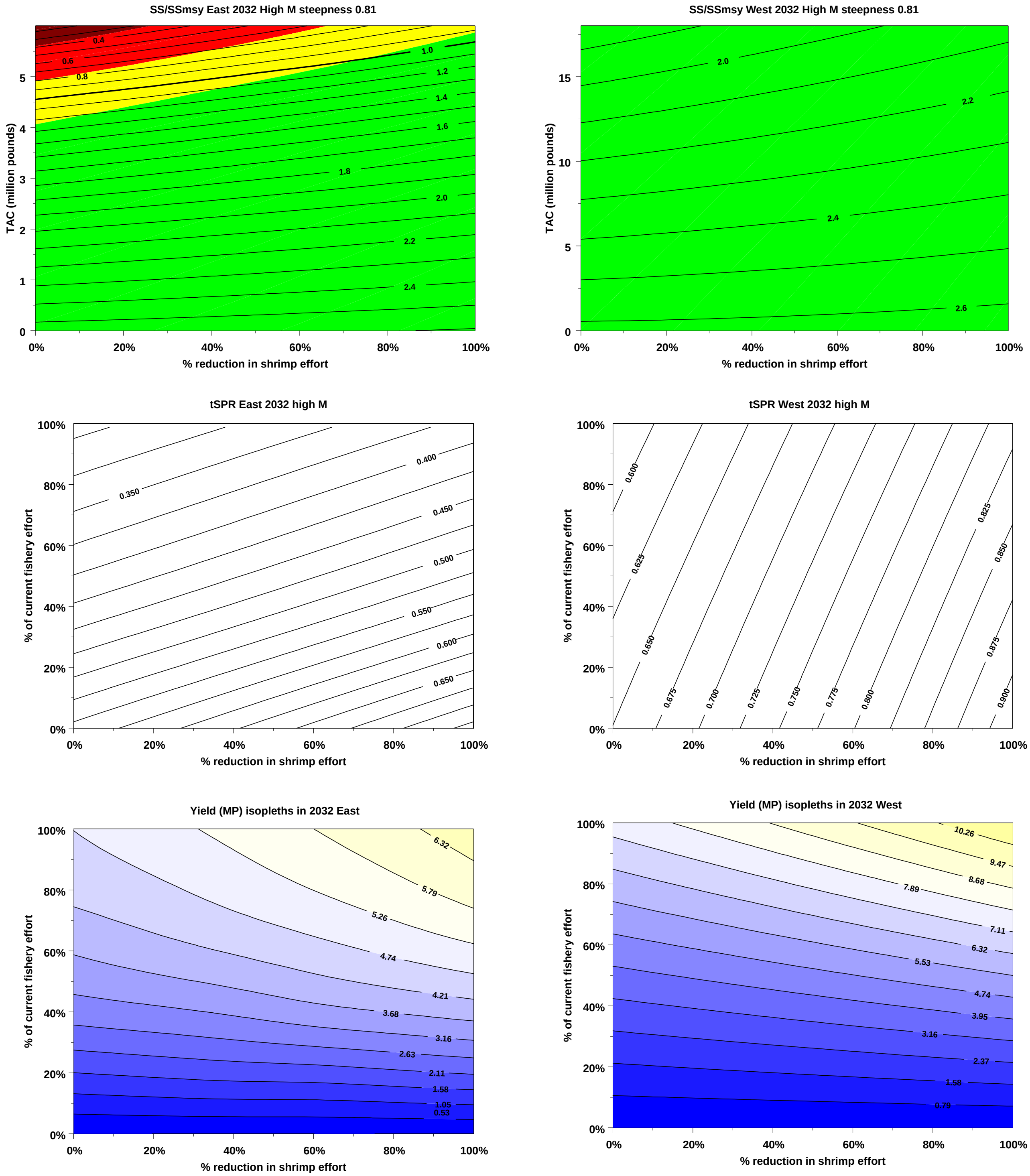


Figure 26. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.81.

Steepness 0.90 2010

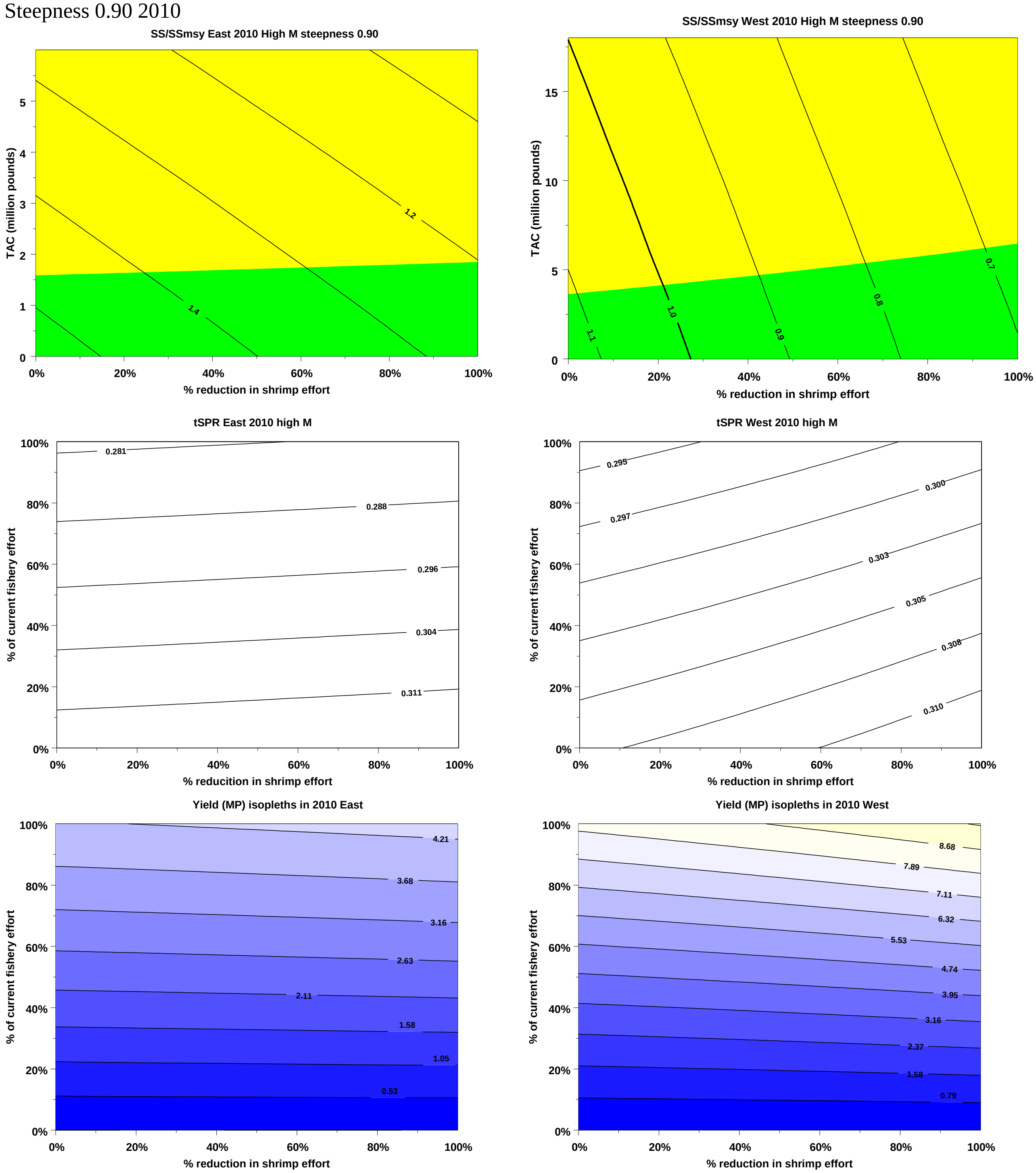


Figure 27. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.90.

Steepness 0.90 2032

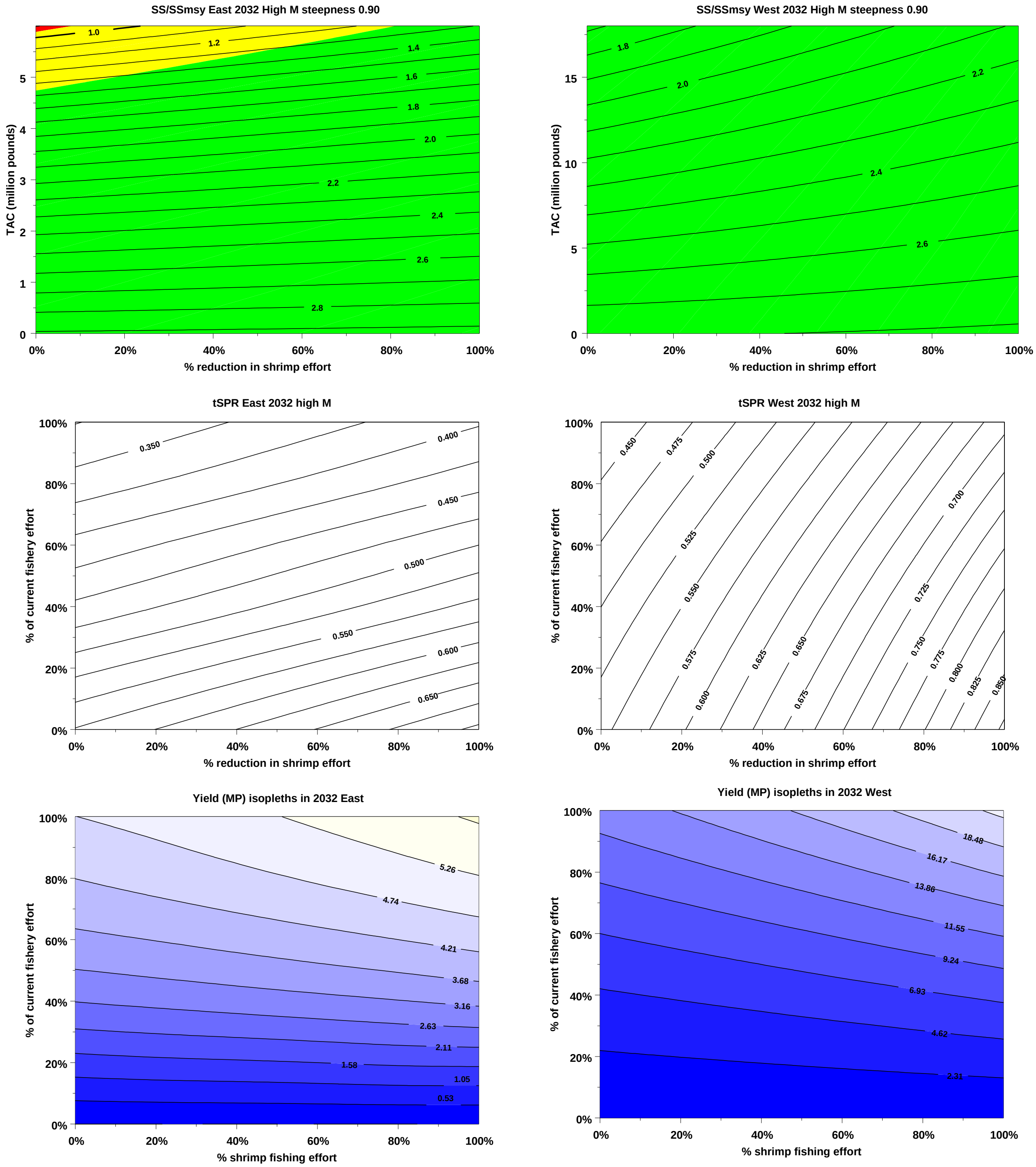


Figure 28. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.90.

Steepness 0.95 2010

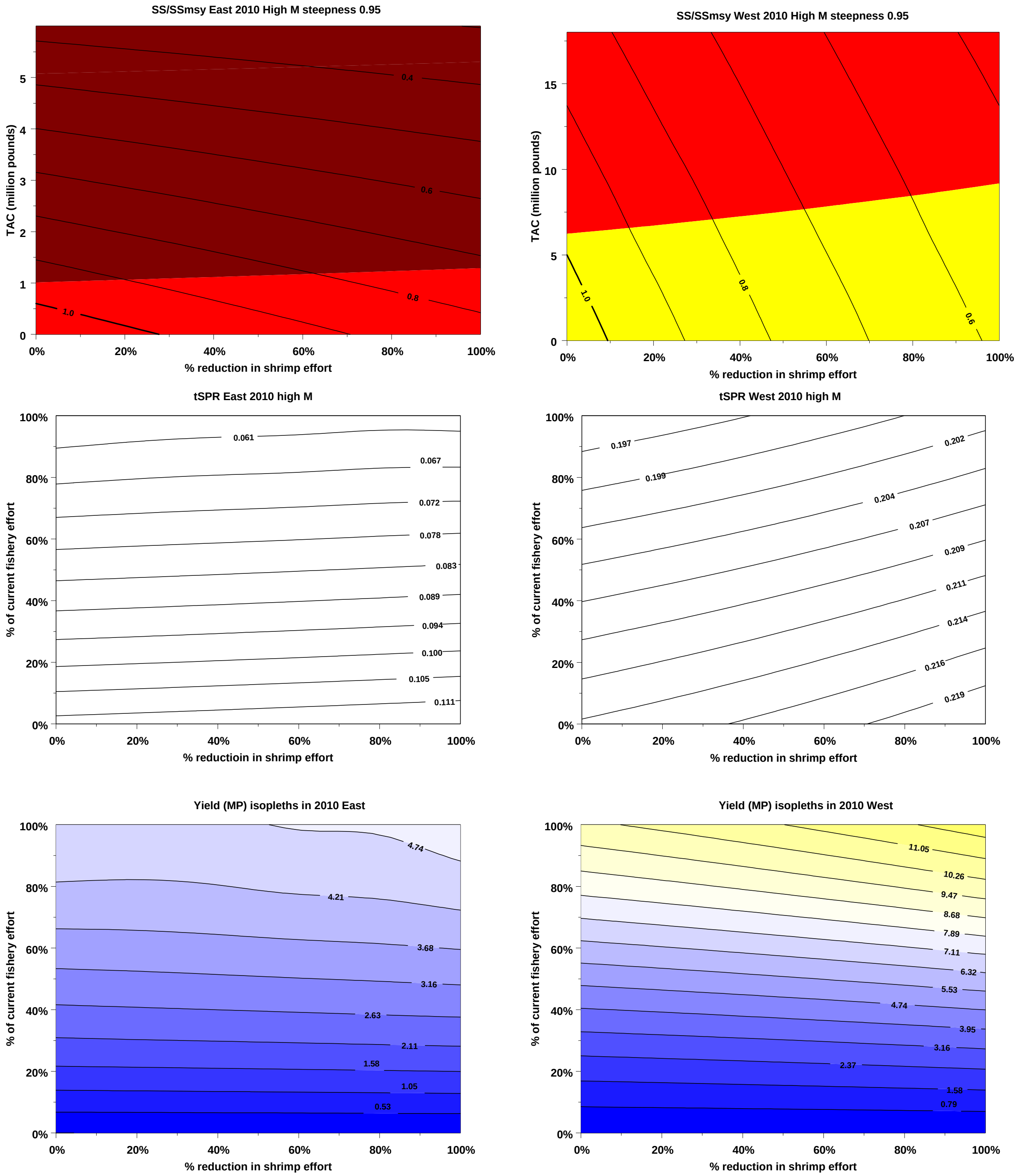


Figure 29. Top row: Isopleths of number of spawners in 2010 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.95.

Steepness 0.95 2032

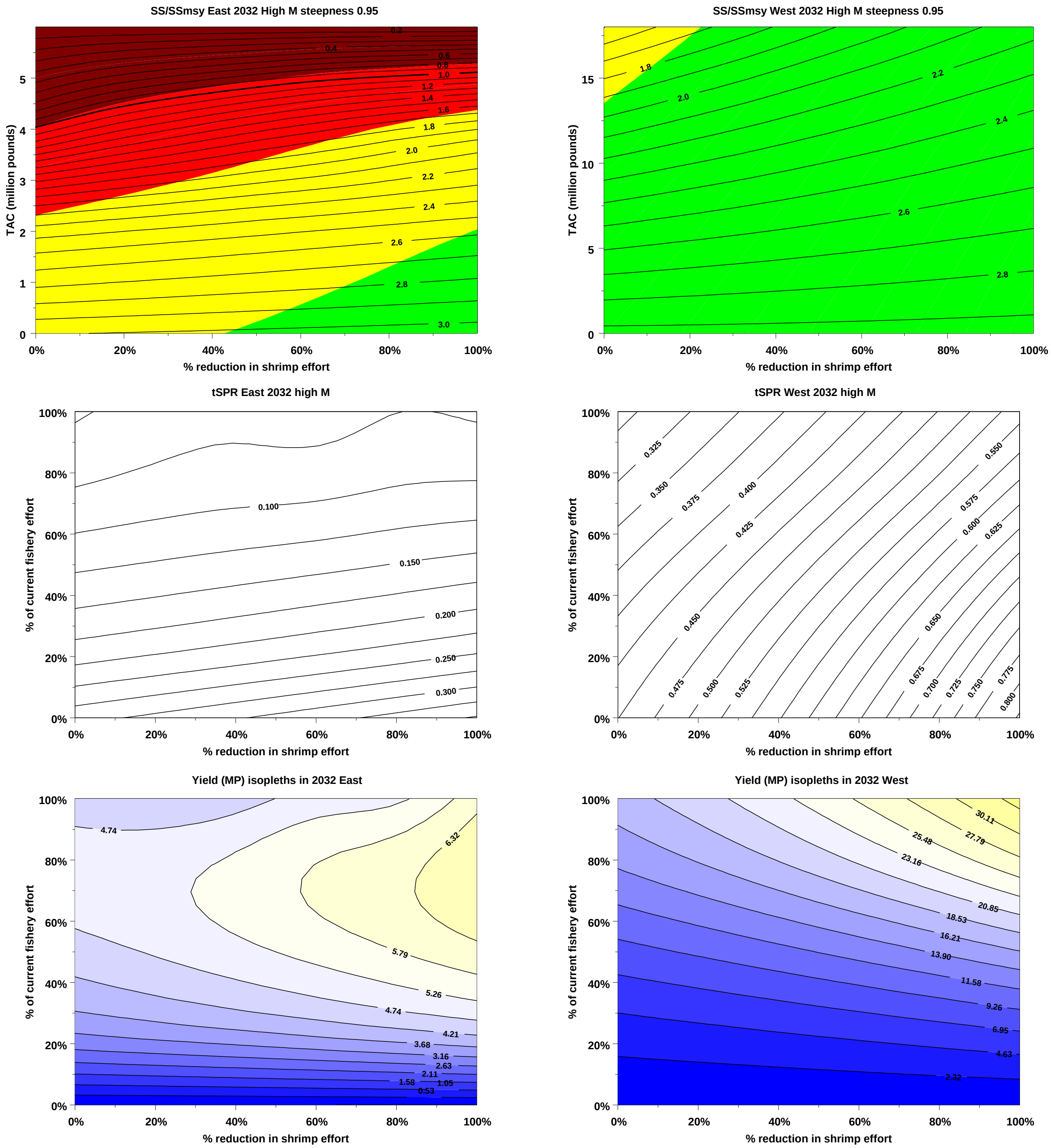


Figure 30. Top row: Isopleths of number of spawners in 2032 relative to MSY levels (SS/SSMSY), where MSY is conditioned on the projected percent reduction in effective offshore shrimp effort (horizontal axis). The vertical axis refers to the projected TAC for the directed fisheries. The shaded color backgrounds represent four regions of corresponding projected transitional SPR isopleths: a) 0% - 10% dark-red, b) 10% - 20% red, c)20%- 30% yellow, and d) >30% green. Middle row: Isopleths of tSPR as a function of percent of current directed fisheries fishing mortality. Bottom row: Isopleths of yield (landings in million pounds) as a function of percent of current F and shrimp bycatch reduction. Results from East (right) and West (left) independent ASAP projections with high mortality vector and steepness of 0.95.