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

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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 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 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 paper documents the model structure and resulting fits to data as well as forecasts status under a number of future management options.

METHODS

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.
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 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).

RESULTS AND DISCUSSION

In order to obtain reasonable fits, the ASAP model required fixing the steepness parameter. Following the Gulf wide analysis, three steepness levels were evaluated: 0.81, 0.90 and 0.95.

Table 1 presents a summary of fishery benchmarks for each stock, East and West at the three steepness levels. In general the West red snapper stock was estimated much larger than the East GOM stock, about 5 to 6 times greater in terms of Virgin biomass. For the East stock, the virgin stock was estimated between 19.1 and 40.4 million pounds, lower estimates were obtained when higher steepness was assumed. While for the west stock, virgin biomass estimates range from 116.3 to 206.4 million pounds. Consistently, the estimates of spawning stock at MSY (SS_{MSY}) and MSY were much larger for the red snapper West stock. SS_{MSY} estimates ranged from 41.0 to 77.4 million pounds, with larger estimates also for the lowest assumed steepness (0.81), similar to the virgin

biomass. Instead, MSY ranged from 13.1 to 16.7 million pounds, with larger estimated corresponding to the higher steepness values. For the West the spawning stock at 2003 was always well below SS_{MSY}, SS_{2003}/SS_{MSY} ranged from 0.44 to 0.16. Fishing mortality reference points indicated that for the red snapper West stock, F at MSY (F_{SMY}) varied between 0.36 and 0.35 depending on the assumed steepness (Table 1). In all cases, the estimated fishing mortality in 2003 was bellow the F_{MSY}, ratios of F_{2003}/F_{MSY} varied from 0.45 to 0.94, with higher ratios for the highest steepness (0.95). Fishing mortality at percent of spawner per recruit ($F_{\%SPR}$) suggests higher fishing mortality when lower steepness was assumed (Table 1).

For the red snapper East stock estimated SS_{MSY} ranged from 5.8 to 14.2 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 0.10 to 0.18. The MSY estimates ranged from 8.6 to 9.4 million pounds, or about half of the MSY estimated for the West stock. The fishing mortality estimates in 2003 were much larger that the corresponding F_{MSY}, indeed the ratio of F_{2003}/F_{MSY} ranged from 1.8 to 3.0.

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 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), but the spawning stock was still below the SS_{MSY} reference.

Figures 1 through 5 show the different fits of the data to the ASAP model for the red snapper East stock assuming the steepness of 0.81. 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. Finally figure 5 shows the annual trajectory of yield, spawning stock and overall fishing mortality rate, with estimated reference points of MSY, SS_{MSY} , transitional SPR (tSPR), and F_{MSY}. Similar figures are presented for the assumed steepness of 0.90 (Figures 8 to 12) and 0.95 (Figure 14 to 18). 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 20 through 24. Shrimp bycatch for the West stock was consistently underestimated by all models for the period 1962 to 1973 (Fig 20 Shrimp-bycatch panel). Fishing multipliers by fleet indicated a declining trend for the commercial handline and recreational fisheries in the mid 1990's. Shrimp bycatch fishing mortality rate for the West stock was predicted to be almost twice on 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 24). Similar figures are presented for the assumed steepness of 0.90 (Figures 27 to31) and 0.95 (Figures 33 to 37).

Stock projections were carried out for both East and West groups, under the three steepness evaluated (0.80, 0.90, 0.95) and the following conditions: a) assuming roughly a 50% split of the TAC between East and West stocks (4.0 million pounds) starting in 2005 year, and b) a reduction of shrimp bycatch fishing mortality of 40% compared to 2003 beginning in 2008 year. For the 2004 year, it was assumed the same fishing mortality as the 2003. These projections are intended to evaluate the future trend of the stocks if the current status quo continues. Figure 6 shows the trajectory of the East stock of projected yield, ratio SS/SS_{MSY}, ratio F/F_{MSY}, and transitional SPR (tSPR) from 2004 to 2032, assuming the steepness of 0.81. In this case, the East stock recovers, and by 2016 the fishing mortality rate is at or below F_{MSY}, and by 2031 the spawning stock is above the corresponding SS_{MSY}. Table 2 also presents a summary of the projected stock results for a selected number of years (2019 and 2032). For the East stock with steepness of 0.90, projections indicated that the spawning stock biomass recovers under the constant quota of 4.0 million pounds by year 2030 while F mortality is below F_{MSY} by 2019 (Table 2 and Figure 13). Similar results were obtained for the East stock with steepness of 0.95, stock recovering occurred by 2027 (SS/SS_{MSY}) and 2018 (F/F_{MSY}) (Fig 19).

Projections of the West stock assuming a steepness of 0.81 are shown in Figure 25. In this case, by 2004 the stock is already exploited at a fishing mortality rate below of F_{MSY}, and by 2016 the spawning stock is above the SS_{MSY} (Table 2). Transitional SPR is at or above 50% by 2014. Similarly for the West stock steepness 0.90 (Fig 32), the spawning stock is above SS_{MSY} by 2017, and by 2018 the tSPR is above 50%. Finally for the West stock steepness of 0.95 (Fig 38), similar trends were obtained.

In addition to these projections, both the East and West red snapper stocks were projected assuming different constant quotas and different levels of shrimp bycatch fishing mortality reduction. Four constant TAC for the directed fisheries were evaluated; 0, 2, 4 and 6 million pounds over the 2005-2032 period, and six different levels of shrimp bycatch mortality reduction; 0%, 20%, 40%, 60%, 80% and 100% starting in 2008. The results of these projections are presented as plots of isopleths for transitional SPR (tSPR) at the 2019 and 2032 years. Figure 7 shows the results for the projections of the red snapper East stock, for all three steepness 0.81 (top row), 0.90 (middle row) and 0.95 (bottom row). The x-axis represents the bycatch proportion reduction (compare to 2003 value) and the y-axis represents the directed fisheries TAC (million pounds). Each contour line represents an estimated tSPR at 2019 (left column) and at 2032 (right column). For the East stock the results indicated that reductions of shrimp bycatch mortality has less effect on tSPR than the TAC, for example at a TAC of 2 million pounds, without bycatch reduction, the expected tSPR is about 48% in 2019 (steepness 0.81) and with total bycatch reduction (100%) the expected tSPR is about 52%. Instead for a bycatch reduction of 40%, a TAC of 1 million pounds will bring the East stock to about 60% tSPR in 2019, while a TAC of 4 million pounds will get the stock to 28% tSPR in year 2019 assuming a steepness of 0.81. The effect of bycatch reduction is even less at higher assumed values of steepness (0.90 and 0.95). The results also indicated that for the East stock TAC's above 5 million pounds will likely collapse the stock with high steepness. If the intend is for the stock to recover to a tSPR of 50% or above by 2032, TAC should be set at 4 million pound or less.

Figure 26 presents similar results for the projections of the red snapper West stock. Plots have the same configuration as the East stock, explained above. For the West stock it is clear that reduction of shrimp bycatch mortality will have more impact on the recovery of the stock compared to the East stock projections. In general, for the West stock TAC of up to 6 million pounds would allow the stock to recover and for an increase in tSPR. At a steepness of 0.81 a TAC of 3.75 million pound with not reduction of shrimp bycatch will bring the stock to about 60% tSPR in 2019, and 78% by 2032. However if there is a bycatch reduction of 60%, the same 60% tSPR in 2019 could be achieved with a TAC of 5.4 million pounds.

An additional set of runs was performed for the East and West red snapper stocks assuming a different vector of natural mortality (M). The differences in the natural mortality vector were only for age class 0 and 1. The runs previously described assumed an M value of 0.9833 for Age 0, 0.4833 for Age 1, and 0.10 for Ages 2 and older. The alternative runs assumed an M value of 0.5900 for Age 0, 0.2900 for Age 1, and 0.10 for Ages 2 and older. These runs were labeled low natural mortality runs. Again, ASAP model fits were carried out for East and West stocks for three assumed steepness values [0.81, 0.90, 0.95] using similar model constrains and parameter estimation methods. Because the procedure for estimating catch-at age from length frequency by fleet also uses the natural mortality vector (Turner ####), the input of catch-at age by fleet was 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 natural mortality runs and the original runs. For briefness, only figures of main differences are presented in this document.

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 assumed M on ages 0 and 1 were higher. Similarly, estimates of spawning stock at MSY were greater when assumed a low natural mortality rate was assumed (Table 3). The models estimated a slightly larger spawning biomass in 2003 (SS_{2003}), however the ratios of SS_{2003}/SS_{MSY} at low natural mortality rates were lower indicating a more depleted spawning stock for the East red snapper. In terms of fishing mortality reference points, the estimates of F_{MSY} at low natural mortality rates were slightly lower at steepness of 0.81 for the East and West stocks. But, for steepness assumptions of 0.90 or

0.95 estimates of F_{MSY} were at or just above those estimated with higher natural mortality on younger ages. Estimates of fishing mortality in 2003 were consistently lower than the higher M runs for the East and West stocks; as such the ratios of F_{2003}/F_{MSY} were slightly lower compared to those ratios of the initial runs. However, the trends were the same, and the status in 2003 of each stock was similar, i.e. the East stock was being overfished with F_{2003} greater than the F_{MSY}, while for the West stock the F_{2003} was below F_{MSY} in all steepness values evaluated.

Main differences between the initial runs and the low natural mortality runs were in the estimated spawning stock-recruitment relationships. Figure 39 shows the spawning stock and recruitment trends of the East red snapper under the low natural mortality rate assumption (steepness 0.81) which should be compared to Figure 4. Under low natural mortality, the predicted spawning stock is larger, but the number of recruits is substantially lower. Figure 40 shows the trends of yield, spawning stock and total fishing mortality (F), the trends were similar, but the magnitude changed. Similar figures are presented for the East stock under the steepness assumptions of 0.90 (Figs 41, 42) and 0.95 (Figs 43, 44), and for the West stock (Figs 46-51).

Stock projections were also carried out for the low natural mortality runs. They followed the same schema as the projections of the initial runs. Table 4 presents a summary of the SS/SS_{MSY}, F/F_{MSY} and Yield/MSY ratios for 2019 and 2032 years. For the East stock under the low natural mortality assumption, the spawning stock was able to recover to or above SS_{MSY} at all steepness values by 2021 or 2026 (Table 4). The low natural mortality projections also indicated that the fishing mortality rate (F) of the East stock would be below F_{MSY} by 2010 (steepness 0.81) to 2013 (steepness 0.90).

For the West stock projections of low natural mortality suggested that the stock would have higher ratios of SS/SS_{MSY} and lower ratios of F/F_{MSY} by 2019 and 2032 compared to the projections assuming a higher natural mortality on younger ages. Figure 45 shows the isopleths of low natural mortality projections when varying directed fishery TAC and shrimp bycatch mortality reduction of the East red snapper stock. The low natural mortality isopleths indicated that the East stock can sustained TAC's up to 6 million pounds, although the tSPR is quite low (10% or less). There is also a slightly greater effect on tSPR by reducing shrimp bycatch mortality, particularly in the long term (2032). For the West stock low natural mortality projections, the isopleths of tSPR under different levels of TAC and bycatch reduction follow the same trends as the initial runs (Fig 52).

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

Model Description	East			West		
Steepness	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{01}	0.1256	0.1044	0.1003	0.3356	0.3181	0.2825
F_{MAX}	0.1681	0.1447	0.1435	0.4308	0.4093	0.3658
$F_{30\%SPR}$	0.1817	0.1535	0.1420	0.4979	0.4702	0.4165
$F_{40\%SPR}$	0.1364	0.1136	0.1039	0.3786	0.3572	0.3157
F_{MSY}	0.1387	0.1303	0.1351	0.3668	0.3776	0.3513
F_{2003}	0.2502	0.3109	0.4099	0.1654	0.2445	0.3287
SS_{MSY}	14,225,900	9,120,590	5,850,620	77,390,600	53,962,000	41,033,900
SS_{2003}	2,512,550	1,108,860	613,967	34,152,600	15,034,300	6,484,860
MSY	9,422,340	9,520,760	8,594,900	13,123,500	14,080,600	16,670,500
Virgin Biomass	39,917,700	27,179,000	19,094,200	206,433,000	149,102,000	116,346,000
F_{2003}/F_{MSY}	1.8042	2.3862	3.0342	0.4508	0.6473	0.9356
SS_{2003}/SS_{MSY}	0.1766	0.1216	0.1049	0.4413	0.2786	0.1580

Table 2. Projection results for the East and West red snapper stocks assuming a constant quota TAC of 4 million pounds starting in 2005 and a shrimp bycatch fishing mortality reduction of 40% by 2008. Recovery year indicated the year when the ratio SS/SS_{MSY} is at or above 1, or when the F/F_{MSY} ratio is below 1.

	East			West		
Steepness	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
SS/SS_{MSY}						
1962	0.0531	0.0571	0.0661	0.0398	0.0360	0.0355
1999	0.1048	0.0646	0.0558	0.3093	0.1841	0.0992
2003	0.1763	0.1215	0.1052	0.4466	0.2832	0.1614
2019	0.4289	0.3717	0.4442	1.2752	1.2332	1.2048
2032	1.0877	1.1747	1.4048	1.9737	2.0598	2.1486
Recovery Year	**2031**	**2030**	**2027**	**2016**	**2017**	**2017**
F/F_{MSY}						
1962	3.4169	4.2443	5.0908	2.6082	3.4511	4.6518
1999	1.6703	2.5757	3.7816	1.2358	1.7484	2.4487
2003	2.0364	2.5141	2.9762	0.5182	0.7418	1.0809
2019	0.7935	0.9455	0.8905	0.1526	0.1532	0.1418
2032	0.3467	0.3322	0.3129	0.1095	0.1028	0.0883
Recovery Year	**2016**	**2019**	**2018**	**2004**	**2004**	**2004**
Yield/MSY						
1962	0.2679	0.3257	0.4161	0.0953	0.1075	0.1162
1999	0.4100	0.4355	0.4980	0.5343	0.4701	0.3754
2003	0.5440	0.5284	0.5737	0.2645	0.2513	0.2186
2019	0.3854	0.3938	0.4458	0.2177	0.2103	0.1862
2032	0.3854	0.3938	0.4458	0.2177	0.2103	0.1862

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

Model Description		**East**			**West**	
Natural Mortality Low						
Steepness	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
Benchmarks						
F_{01}	0.1142	0.0973	0.1127	0.3156	0.3213	0.3057
F_{MAX}	0.1516	0.1341	0.1610	0.4044	0.4122	0.3934
$F_{30\%SPR}$	0.1673	0.1444	0.1586	0.4746	0.4815	0.4561
$F_{40\%SPR}$	0.1257	0.1070	0.1161	0.3610	0.3661	0.3464
F_{MSY}	0.1261	0.1212	0.1515	0.3459	0.3815	0.3786
F_{2003}	0.2055	0.2810	0.4734	0.1151	0.1886	0.2961
SS_{MSY}	21,979,300	13,879,400	8,219,820	126,318,000	88,546,400	67,534,500
SS_{2003}	3,121,130	1,215,730	604,409	69,799,000	30,160,900	11,495,200
MSY	13,221,200	13,824,800	12,209,200	14,320,000	15,221,000	18,823,800
Virgin Biomass	60,808,500	40,843,300	26,938,200	333,117,000	241,014,000	188,061,000
F_{2003}/F_{MSY}	1.6292	2.3190	3.1241	0.3326	0.4945	0.7819
SS_{2003}/SS_{MSY}	0.1420	0.0876	0.0735	0.5526	0.3406	0.1702

Table 4. **Lower Natural Mortality Rate Projection** results for the East and West red snapper stocks assuming a constant quota TAC of 4 million pounds starting in 2005 and a shrimp bycatch fishing mortality reduction of 40% by 2008. Recovery year indicated the year when the ratio SS/SS_{MSY} is at or above 1, or when the F/F_{MSY} ratio is below 1.

Natural Mortality Rate Low Steepness	East			West		
	Fixed 0.81	Fixed 0.90	Fixed 0.95	Fixed 0.81	Fixed 0.90	Fixed 0.95
SS/SS_{MSY}						
1962	0.0369	0.0382	0.0447	0.0299	0.0243	0.0225
1999	0.0801	0.0438	0.0371	0.3815	0.2240	0.1054
2003	0.1417	0.0875	0.0738	0.5572	0.3446	0.1731
2019	0.5547	0.5717	0.8060	1.4216	1.3383	1.2442
2032	1.4131	1.6329	1.9942	2.0509	2.1063	2.1634
Recovery Year	**2026**	**2025**	**2021**	**2013**	**2016**	**2017**
F/F_{MSY}						
1962	3.2736	4.0180	4.8521	2.4503	3.2534	4.3138
1999	1.5692	2.6272	4.1366	0.9674	1.4636	2.2305
2003	1.8067	2.3873	2.9445	0.3699	0.5396	0.8466
2019	0.4344	0.4326	0.3529	0.1217	0.1240	0.1136
2032	0.1897	0.1643	0.1578	0.0917	0.0871	0.0726
Recovery Year	**2010**	**2013**	**2012**	**2004**	**2004**	**2004**
Yield/MSY						
1962	0.1883	0.2323	0.3117	0.0673	0.0752	0.0820
1999	0.2895	0.2997	0.3545	0.5118	0.4654	0.3516
2003	0.3903	0.3653	0.4026	0.2352	0.2234	0.1836
2019	0.2678	0.2671	0.3118	0.1898	0.1836	0.1554
2032	0.2678	0.2671	0.3118	0.1898	0.1836	0.1554

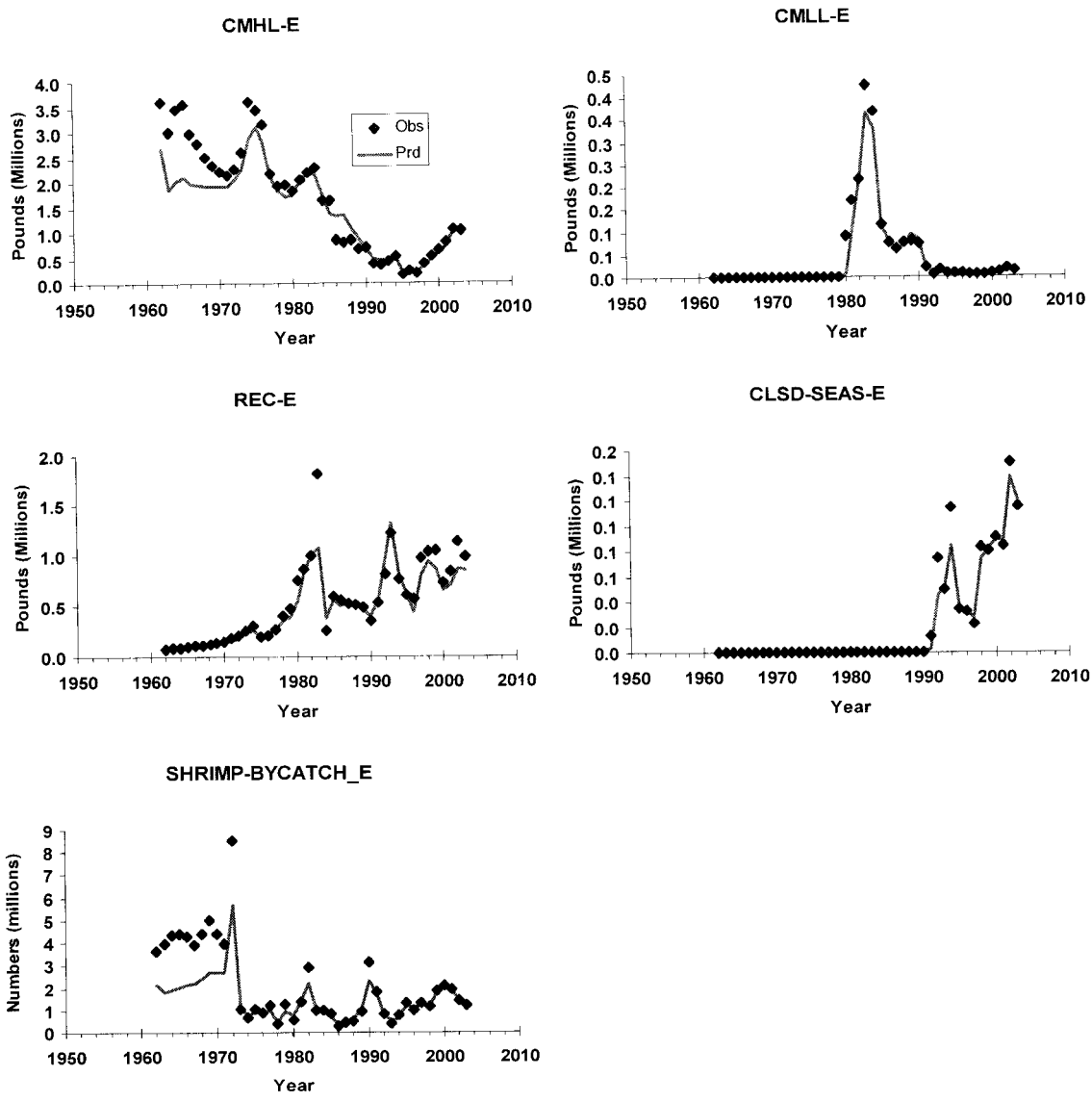

Figure 1. Fit to total catch by fleet for the East GOM (steepness 0.81)

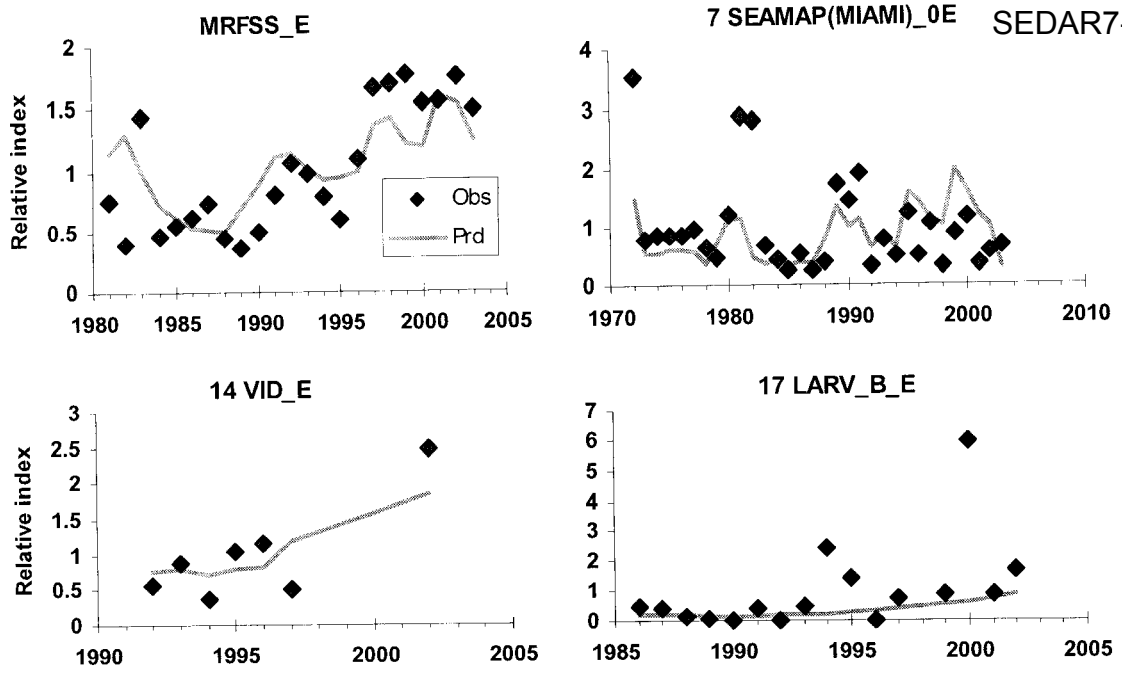

Figure 2. Fit to indices of abundance for the East GOM red snapper (Steepness 0.81)

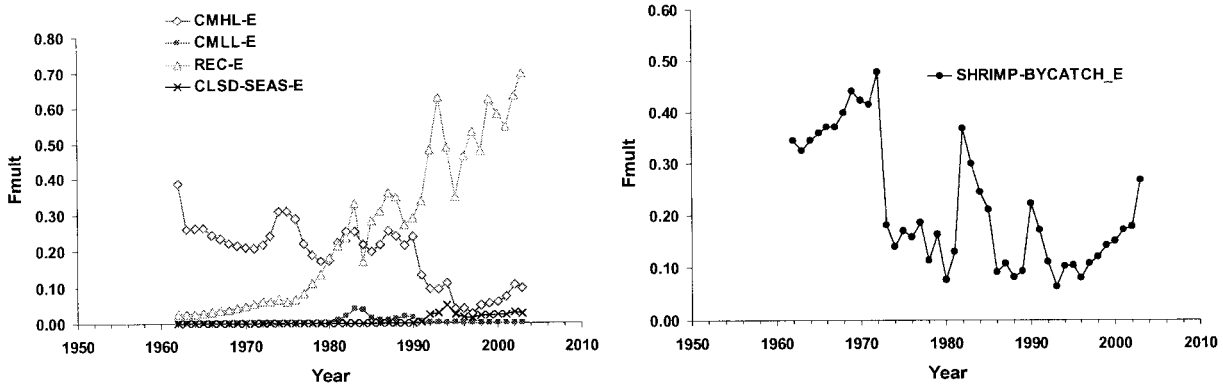

Figure 3. F multipliers by fleet for the East GOM red snapper (steepness 0.81)

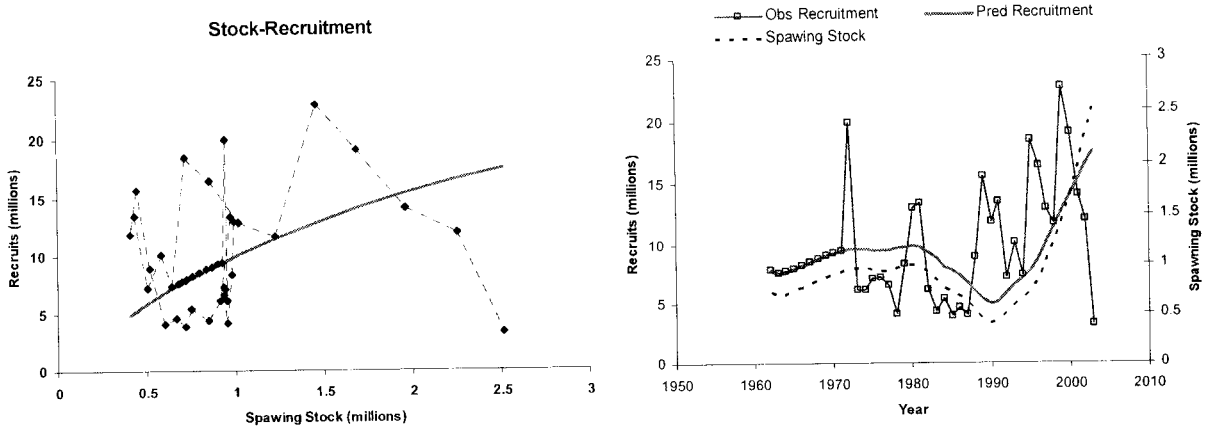

Figure 4. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.81)

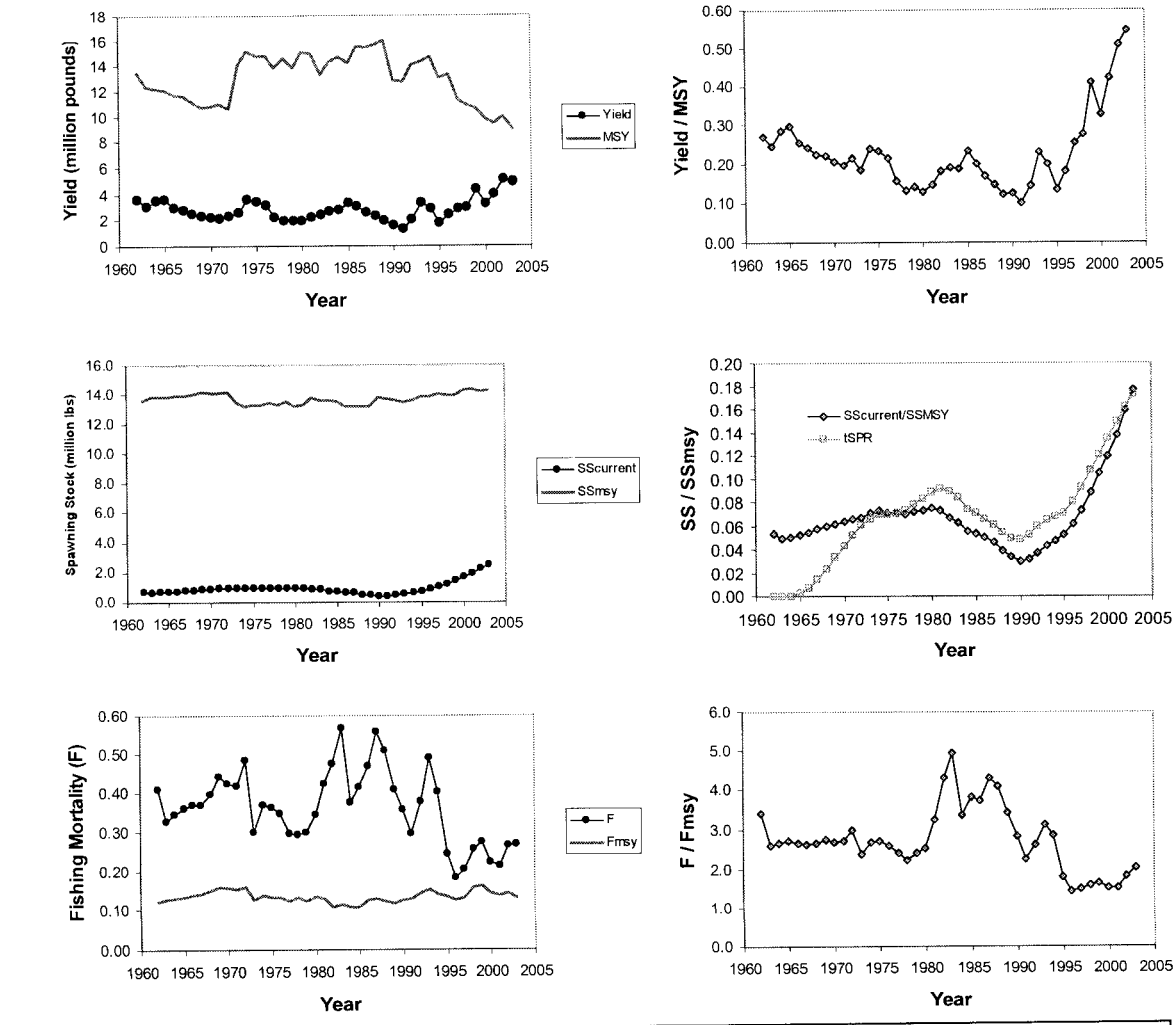

Figure 5 Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of East GOM red snapper (steepness 0.81)

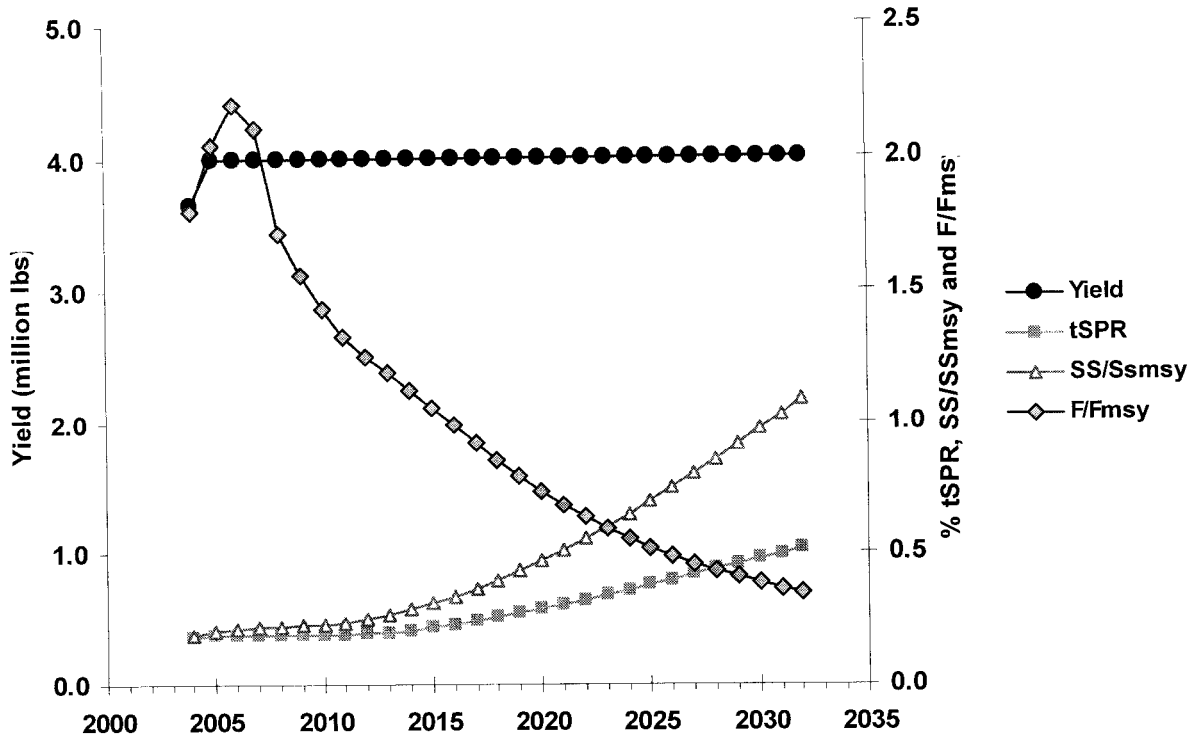

Figure 6. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for East GOM red snapper (steepness 0.81). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

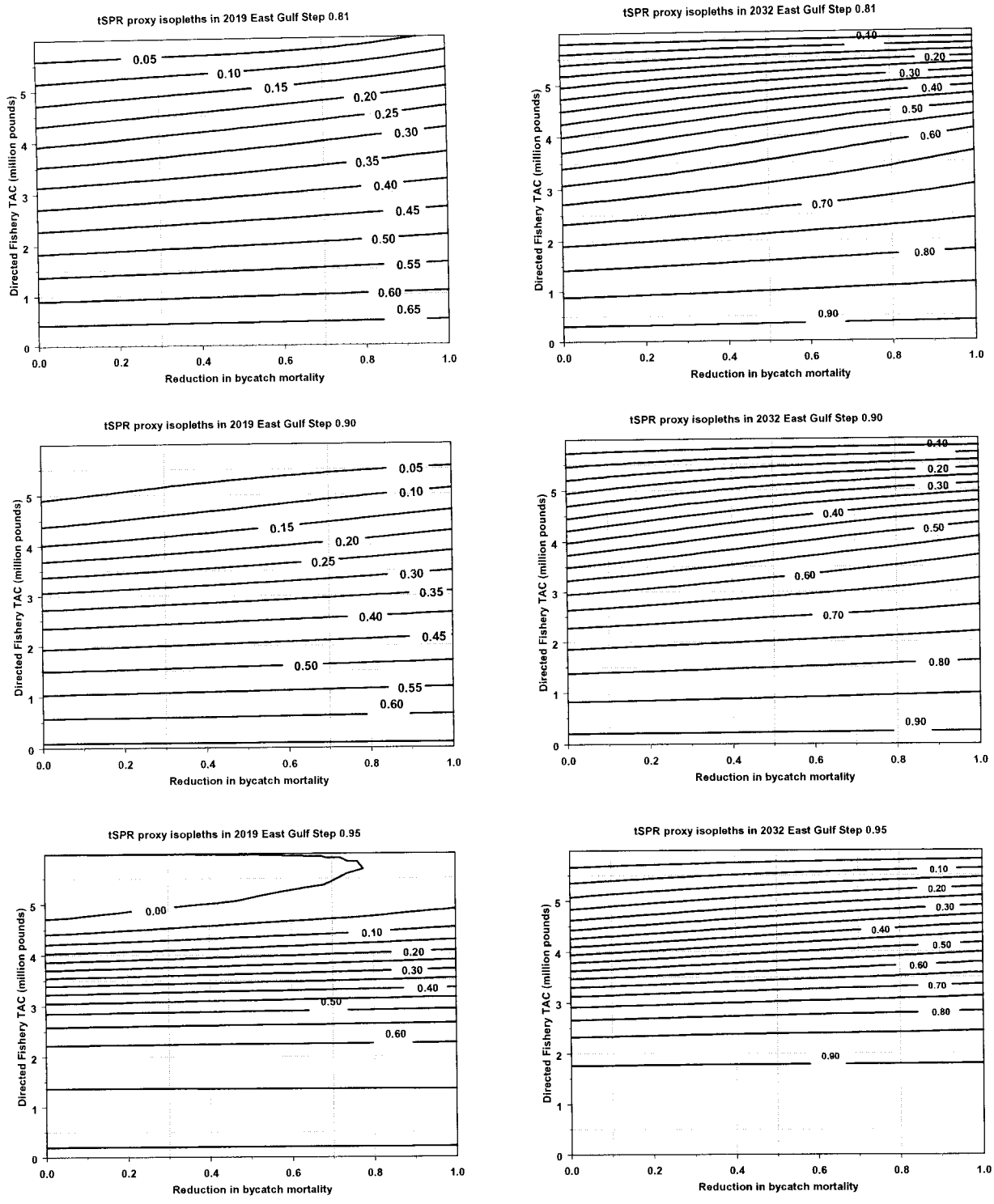

Figure 7. Isopleths of transition SPR projections at 2019 and 2032 of East GOM red snapper using a TAC of 0 to 6 million pounds and reductions of shrimp bycatch mortality of 0 to 100% beginning in 2008, for 0.81, 0.90 and 0.95 fixed steepness.

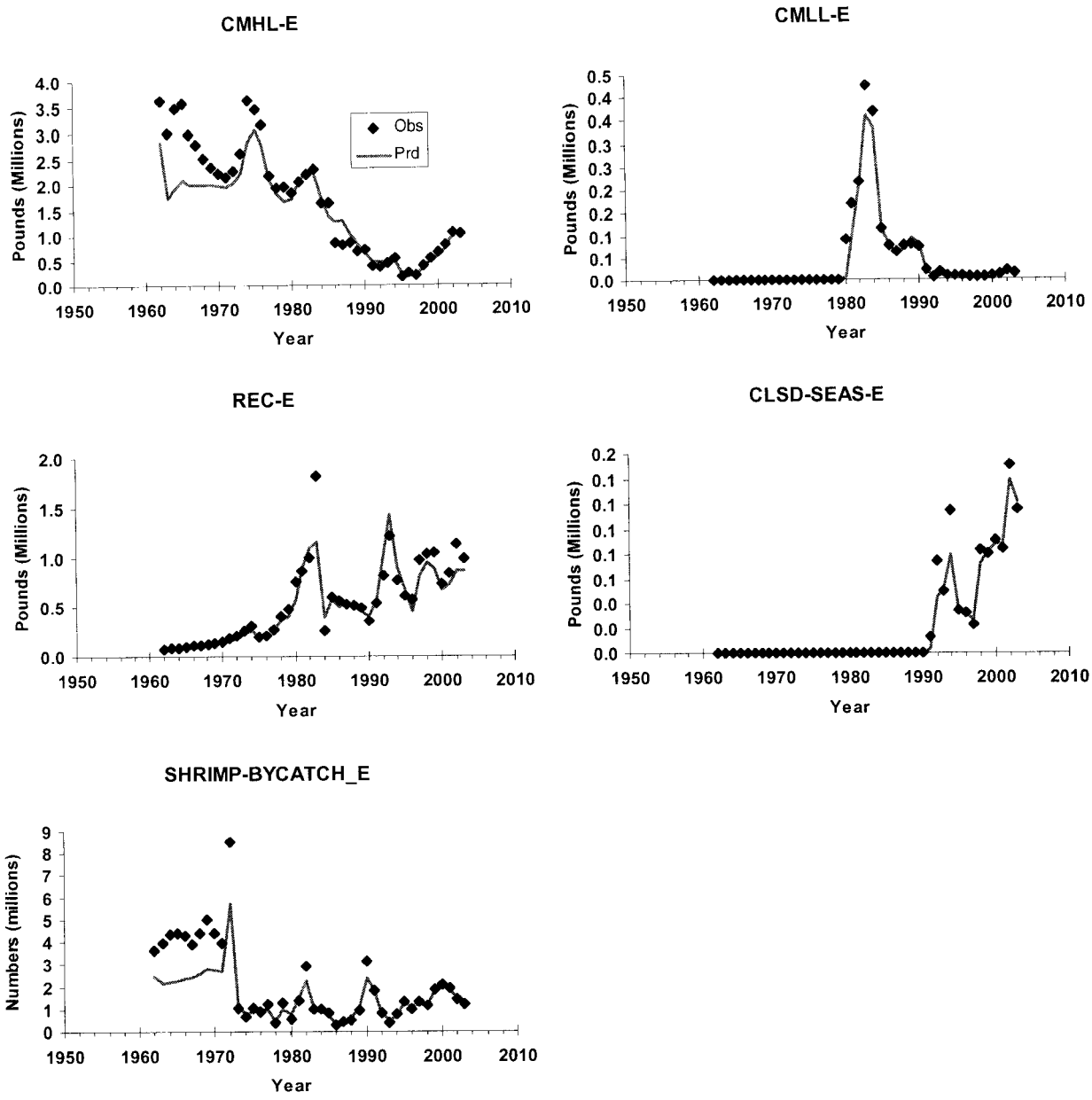

Figure 8. Fit to total catch by fleet for the East GOM (steepness 0.90)

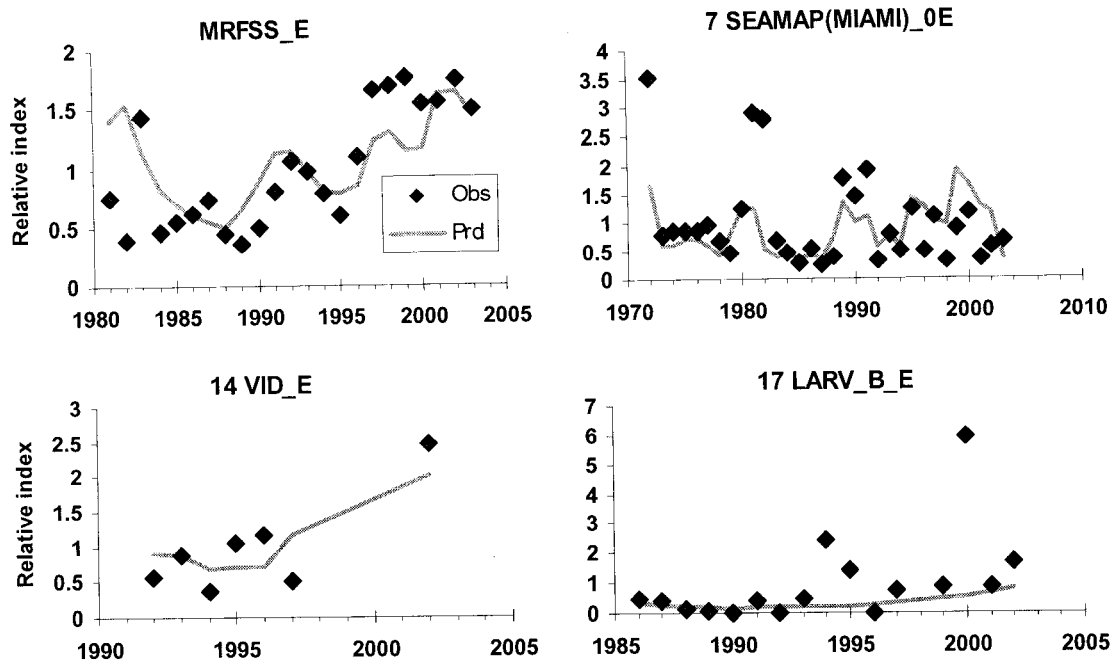

Figure 9. Fit to indices of abundance for the East GOM red snapper (Steepness 0.90)

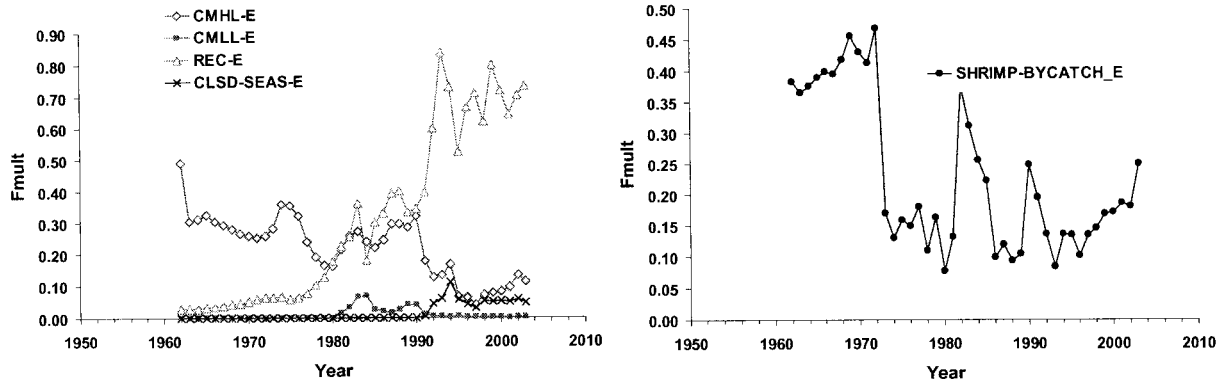

Figure 10. F multipliers by fleet for the East GOM red snapper (steepness 0.90)

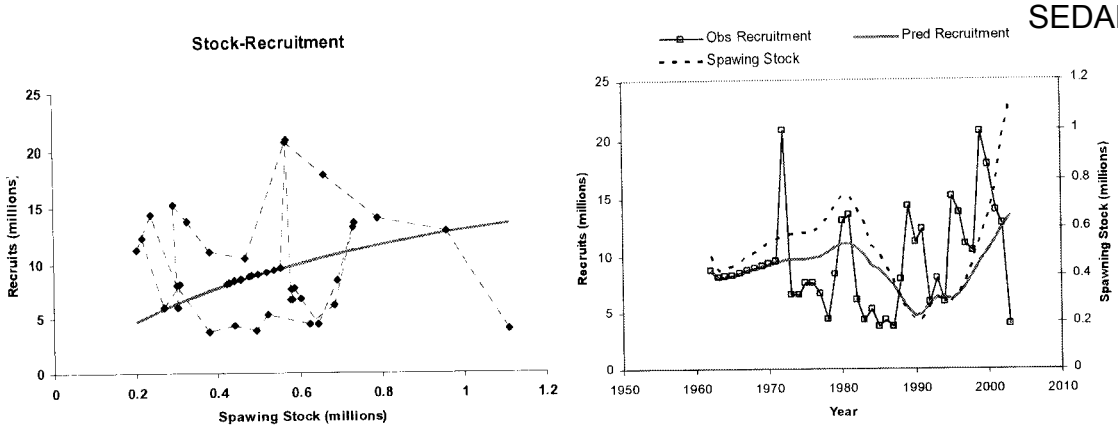

Figure 11. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.90)

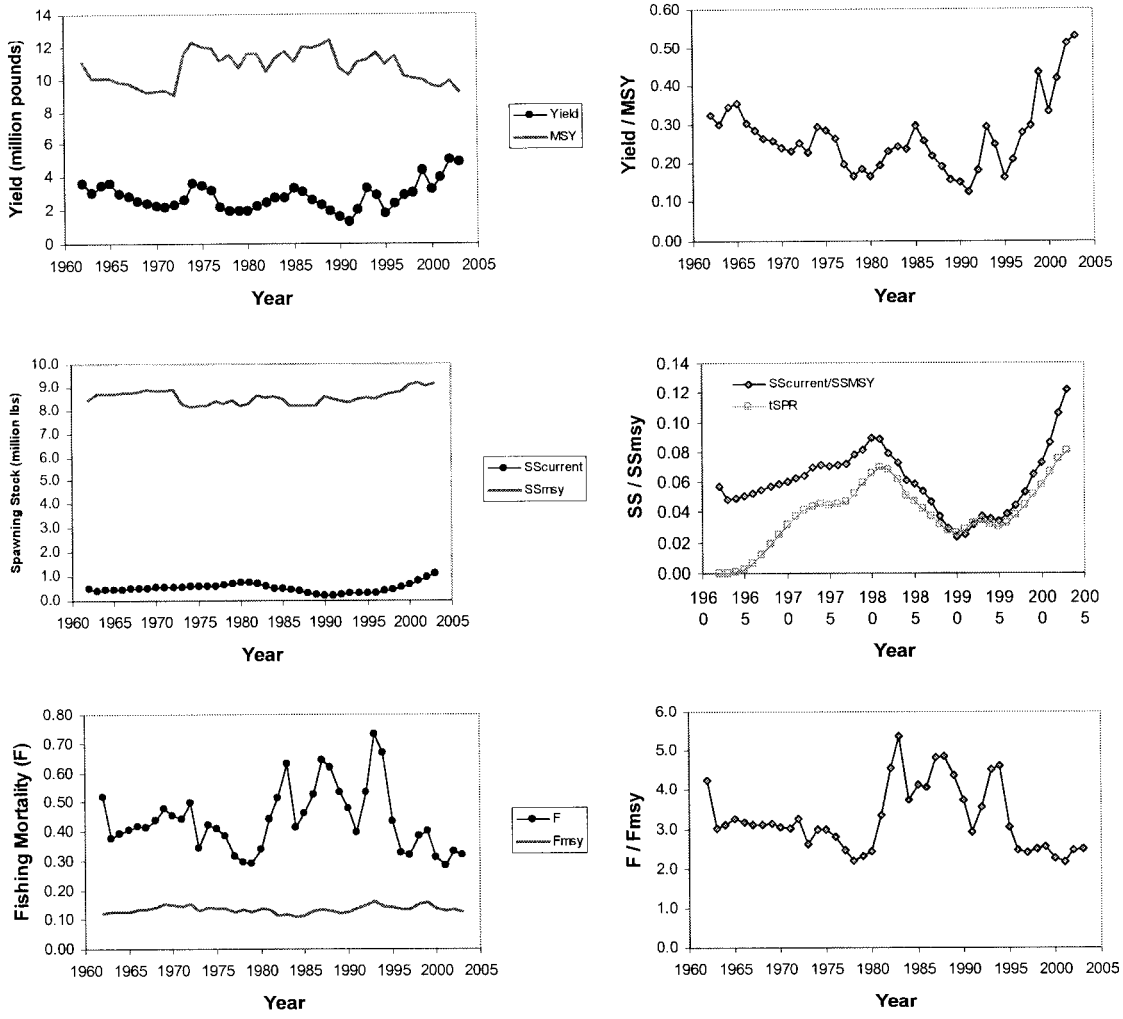

Figure 12. Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of East GOM red snapper (steepness 0.90)

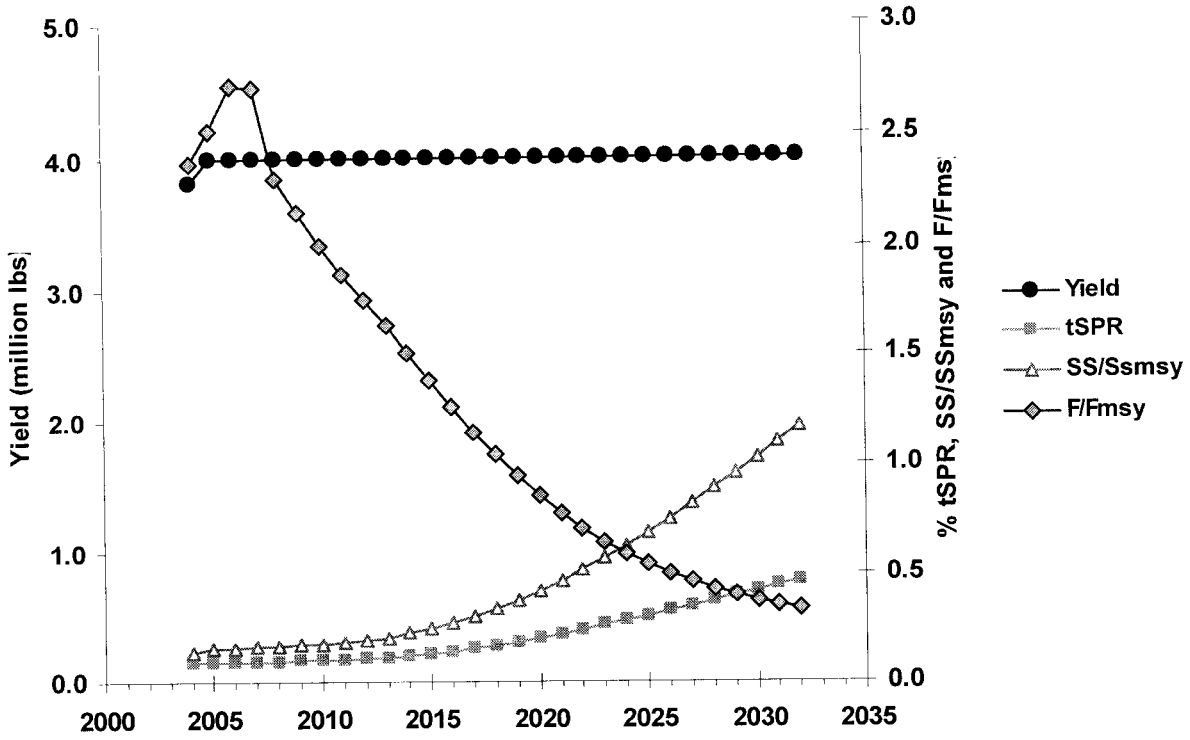

Figure 13. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for East GOM red snapper (steepness 0.90). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

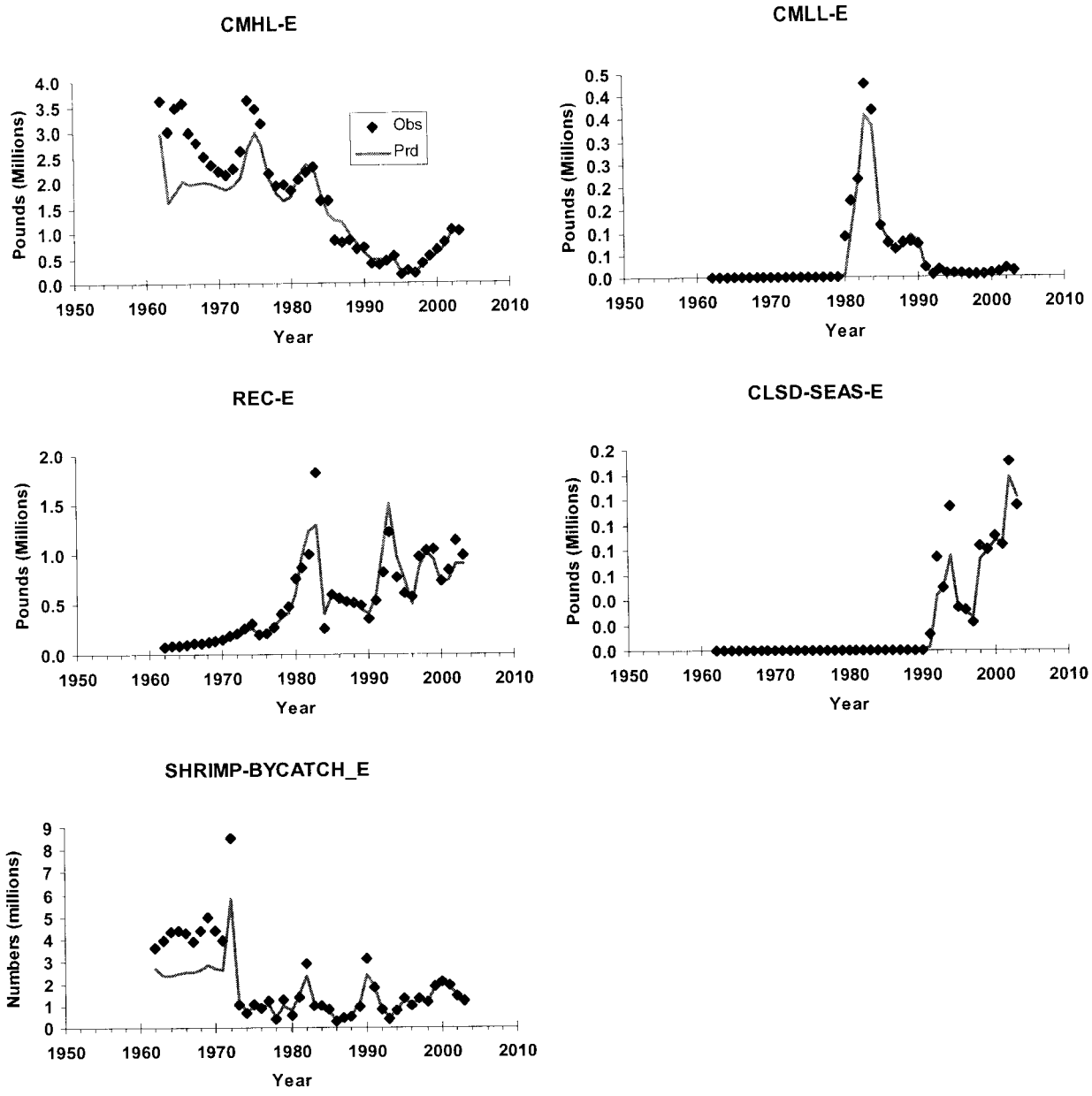

Figure 14. Fit to total catch by fleet for the East GOM (steepness 0.95)

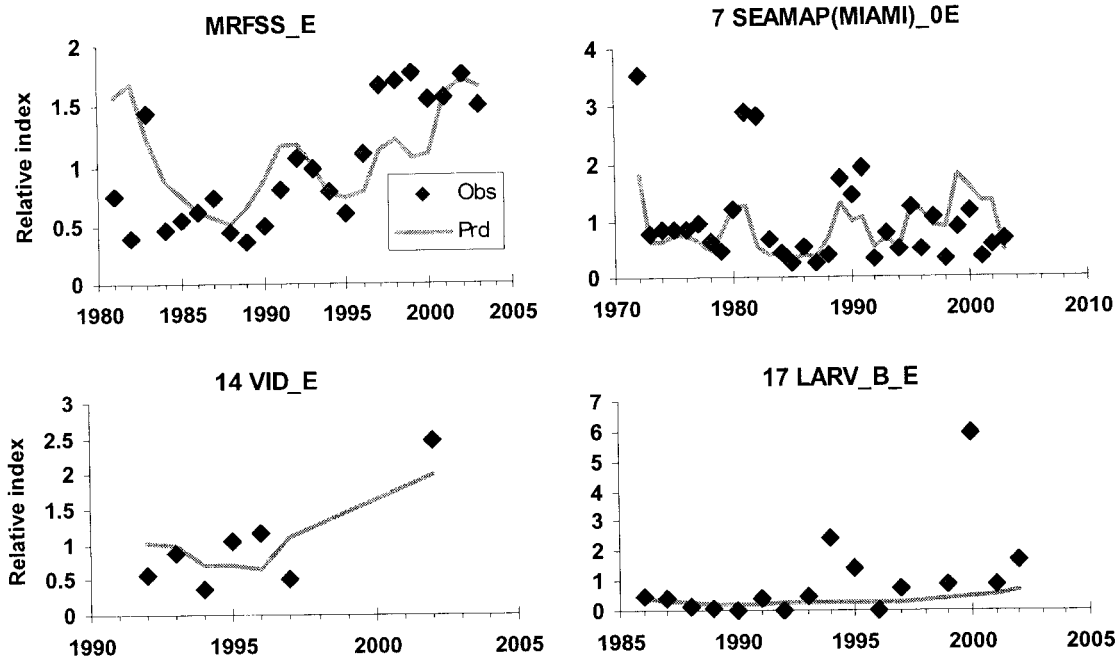

Figure 15. Fit to indices of abundance for the East GOM red snapper (Steepness 0.95)

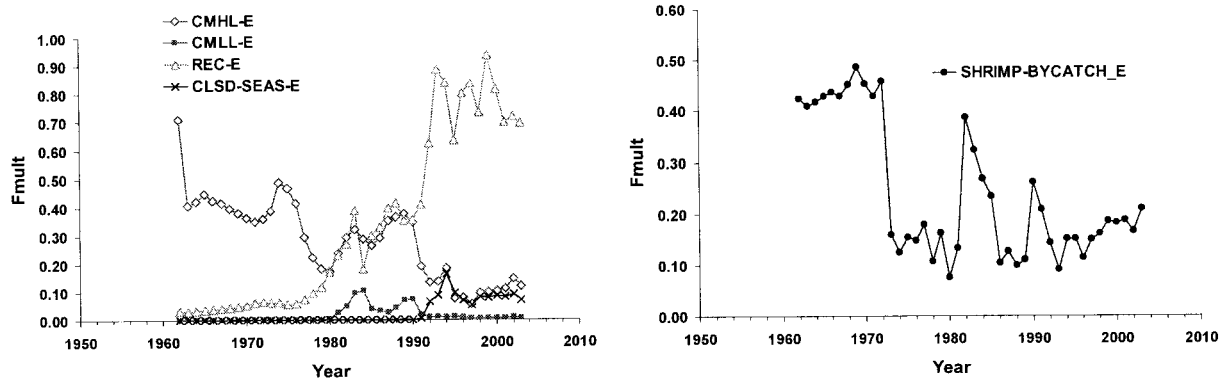

Figure 16. F multipliers by fleet for the East GOM red snapper (steepness 0.95)

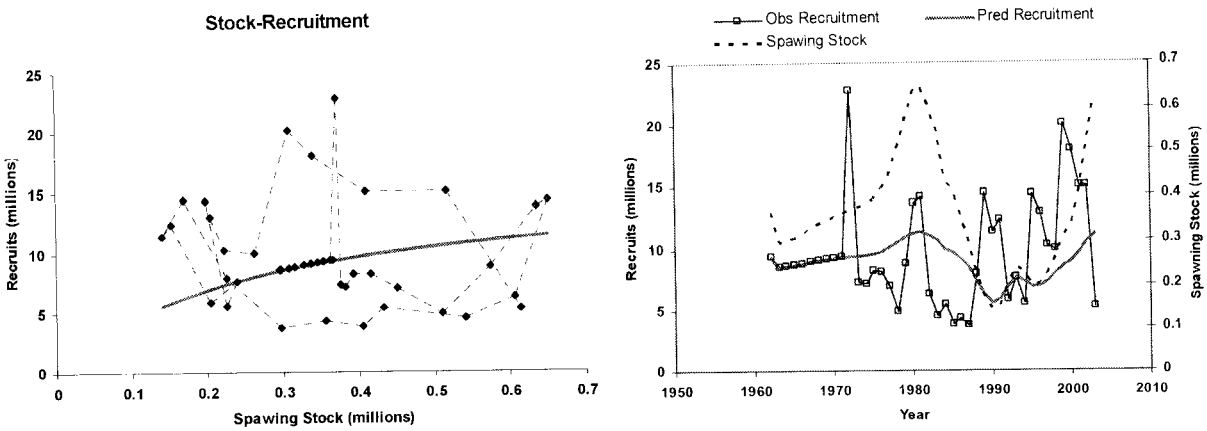

Figure 17. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.95)

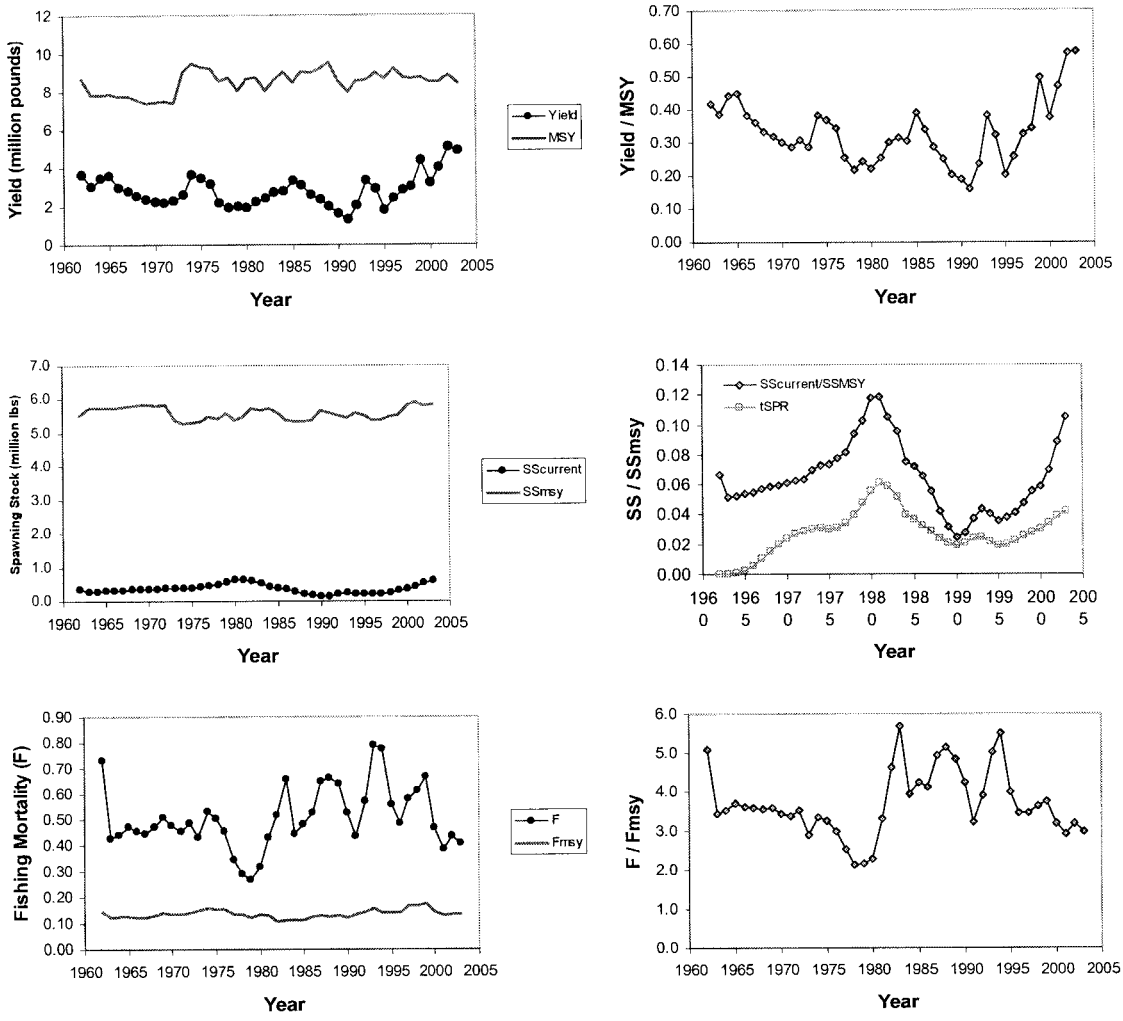

Figure 18. Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of East GOM red snapper (steepness 0.95)

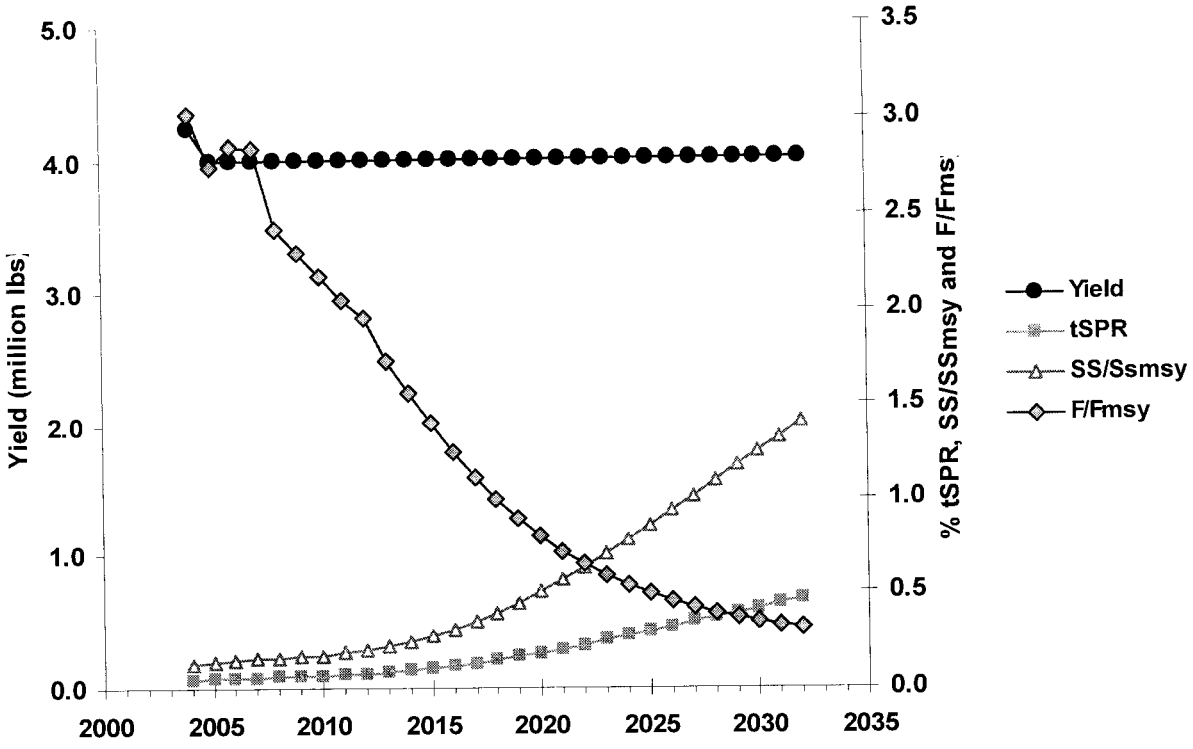

Figure 19. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for East GOM red snapper (steepness 0.95). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

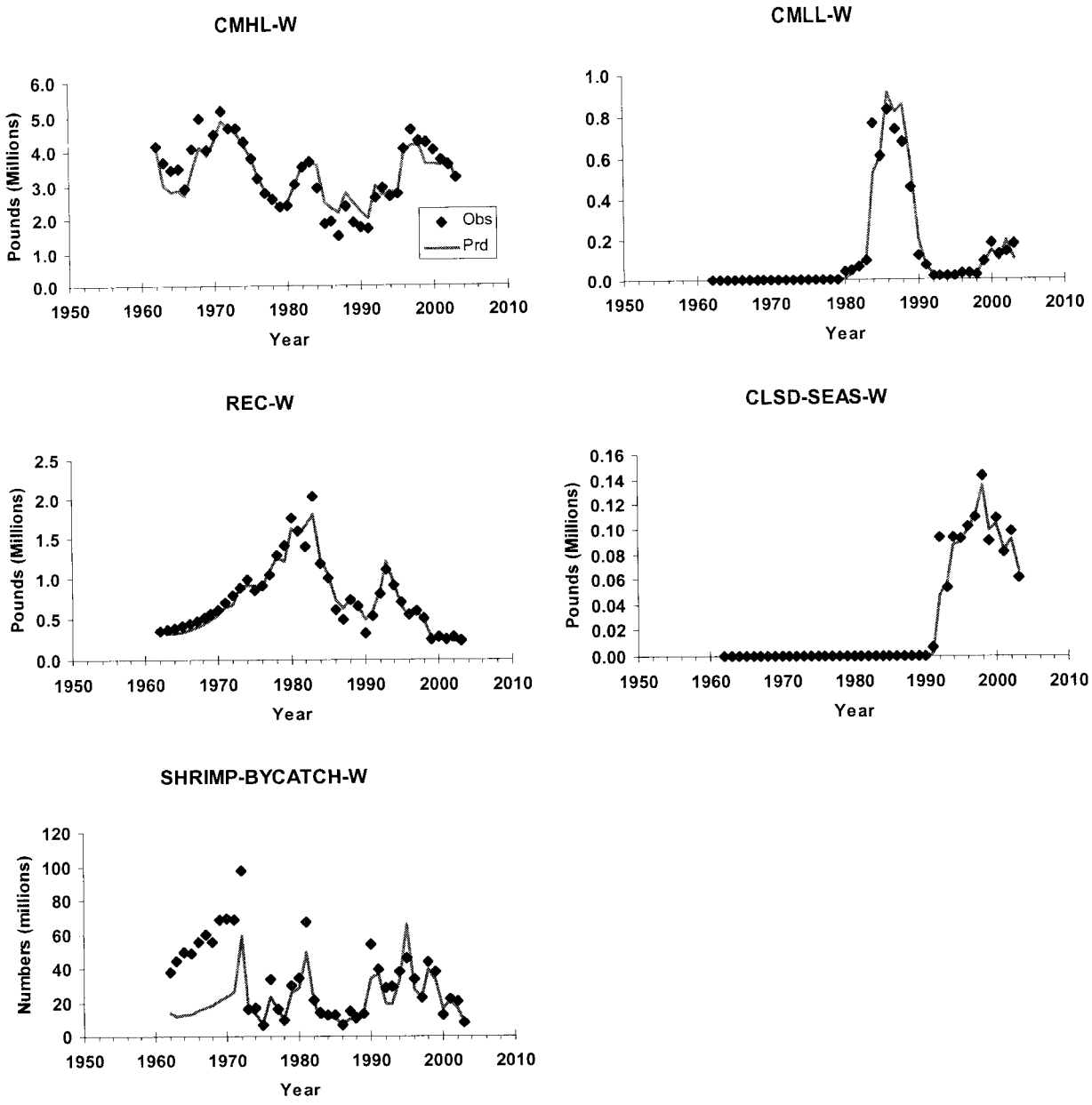

Figure 20. Fit to total catch by fleet for the West GOM (steepness 0.81)

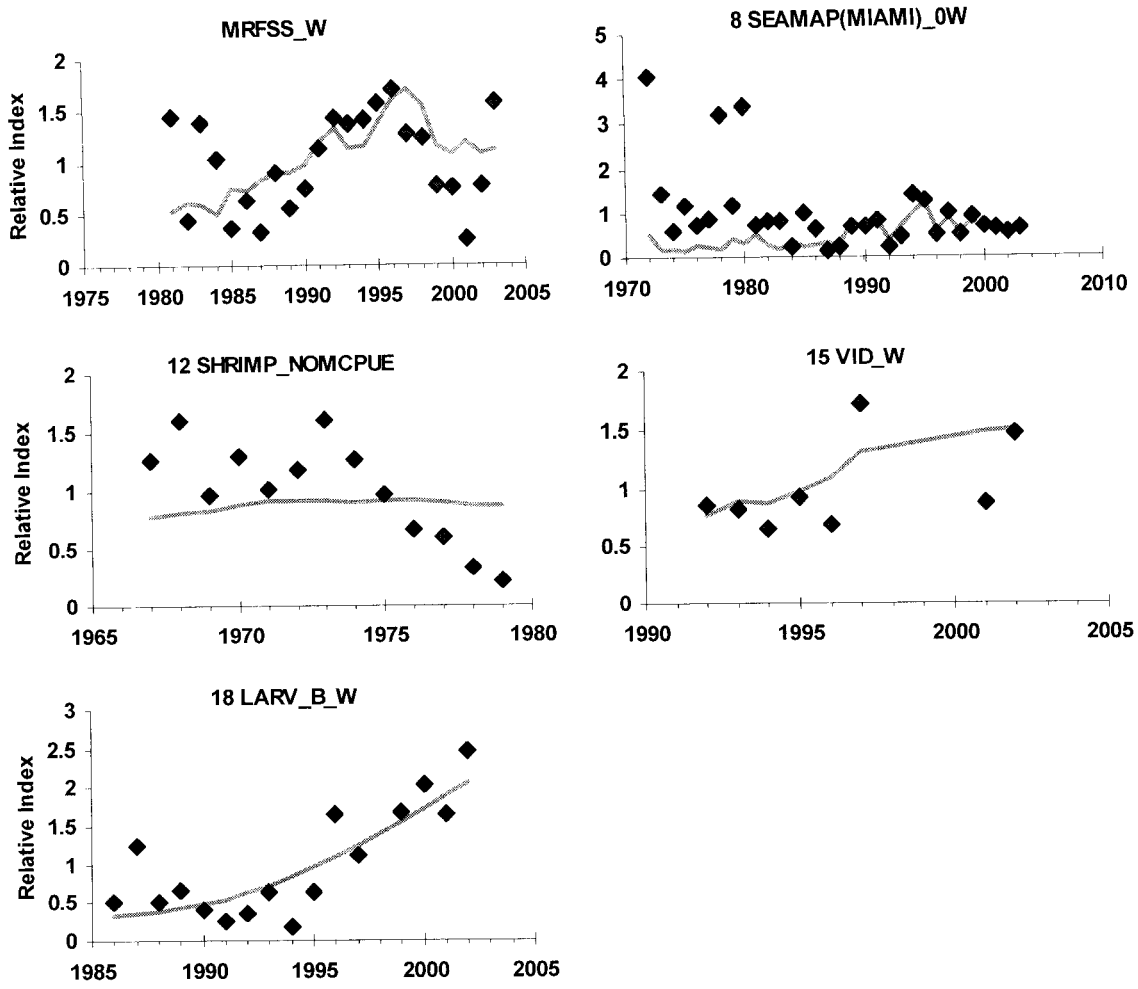

Figure 21. Fit to indices of abundance for the West GOM red snapper (Steepness 0.81)

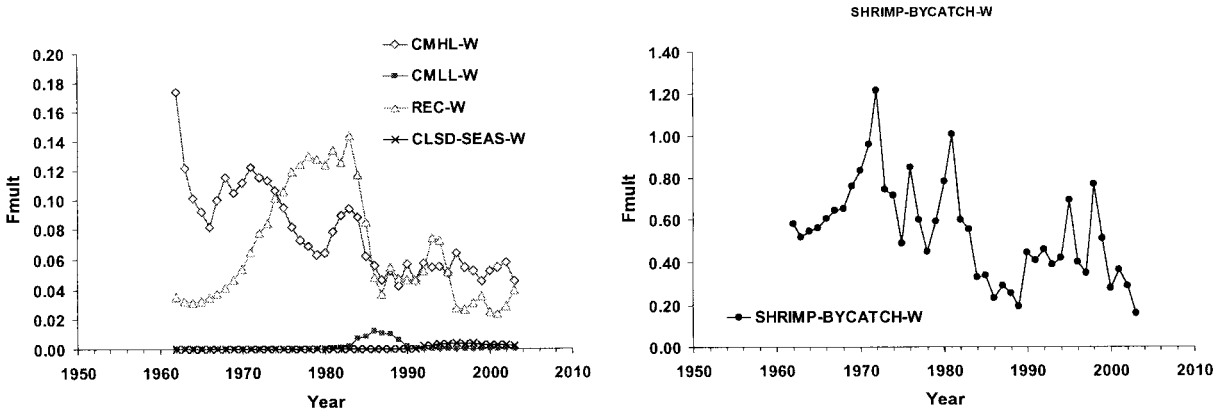

Figure 22. F multipliers by fleet for the West GOM red snapper (steepness 0.81)

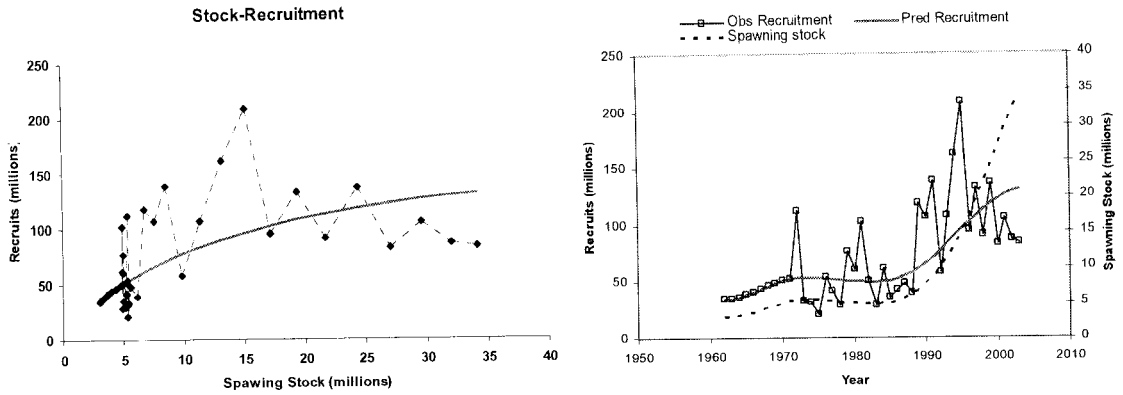

Figure 23. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.81)

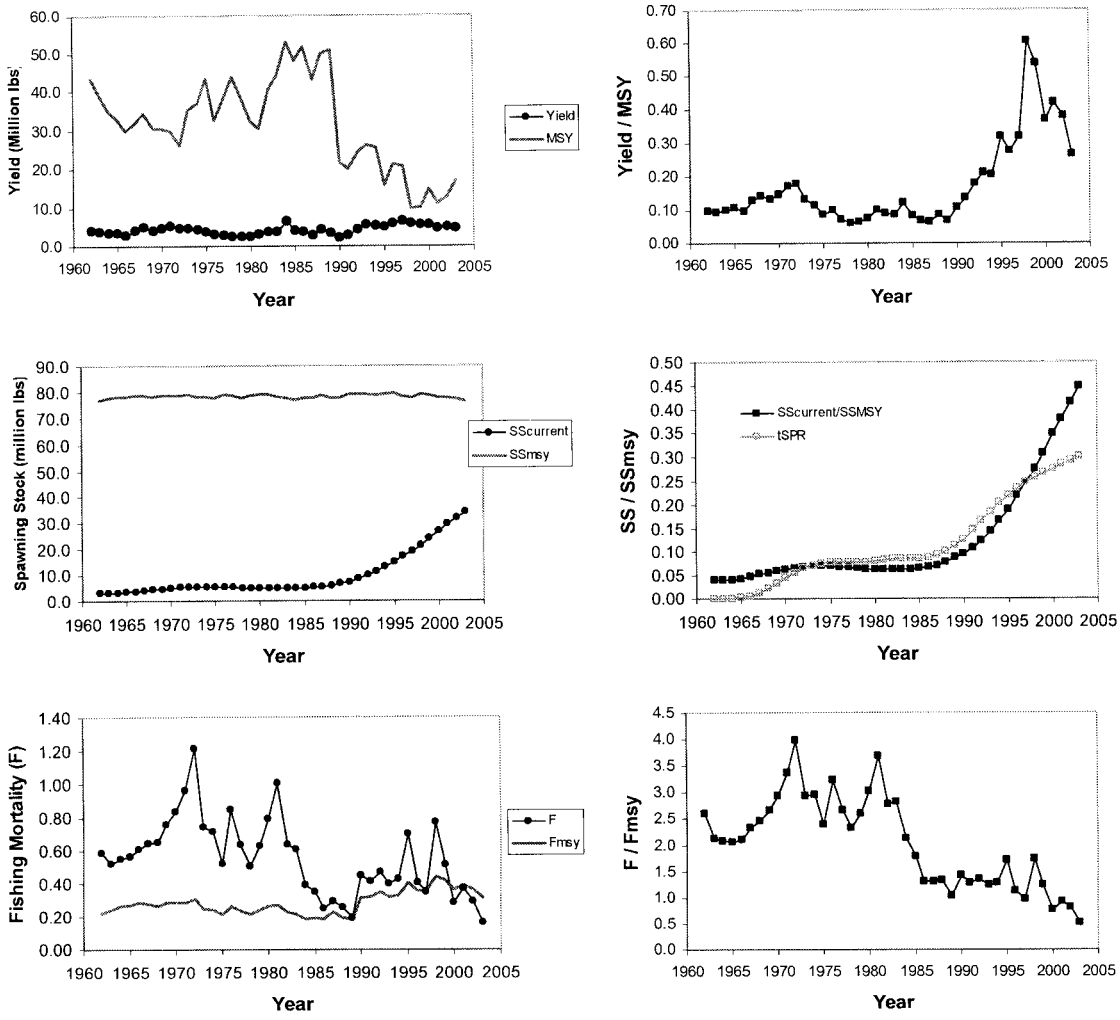

Figure 24. Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of West GOM red snapper (steepness 0.81)

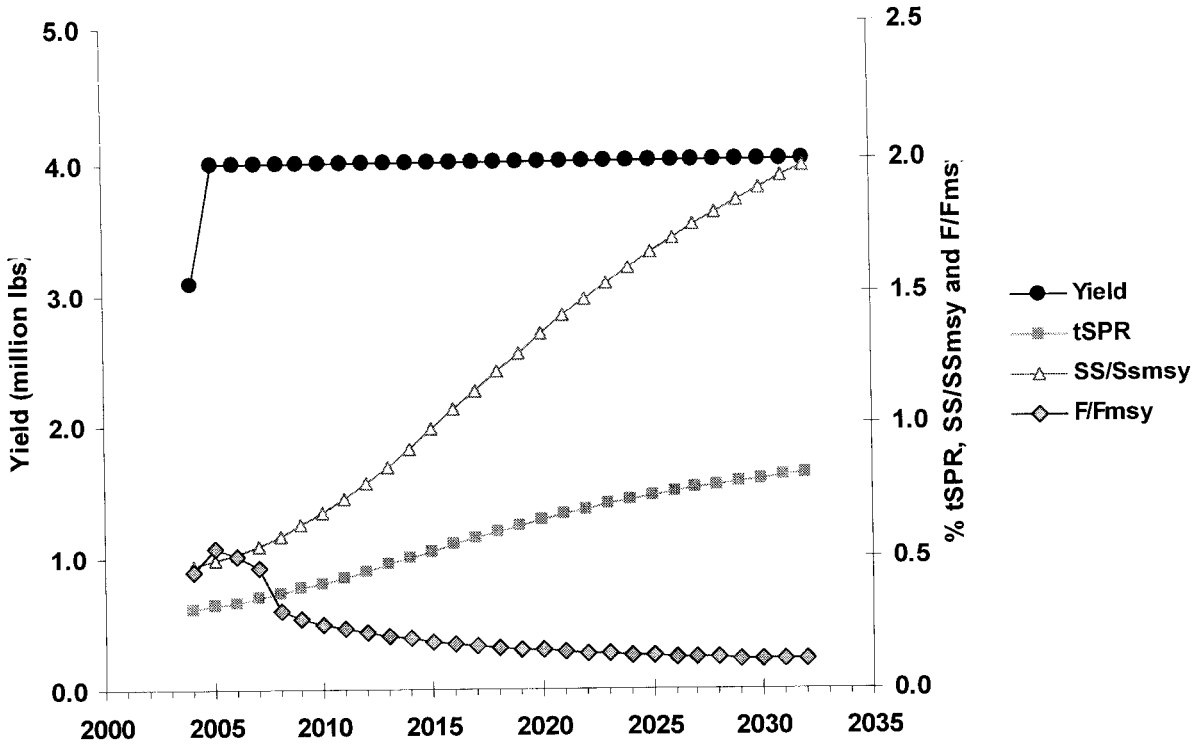

Figure 25. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for West GOM red snapper (steepness 0.81). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

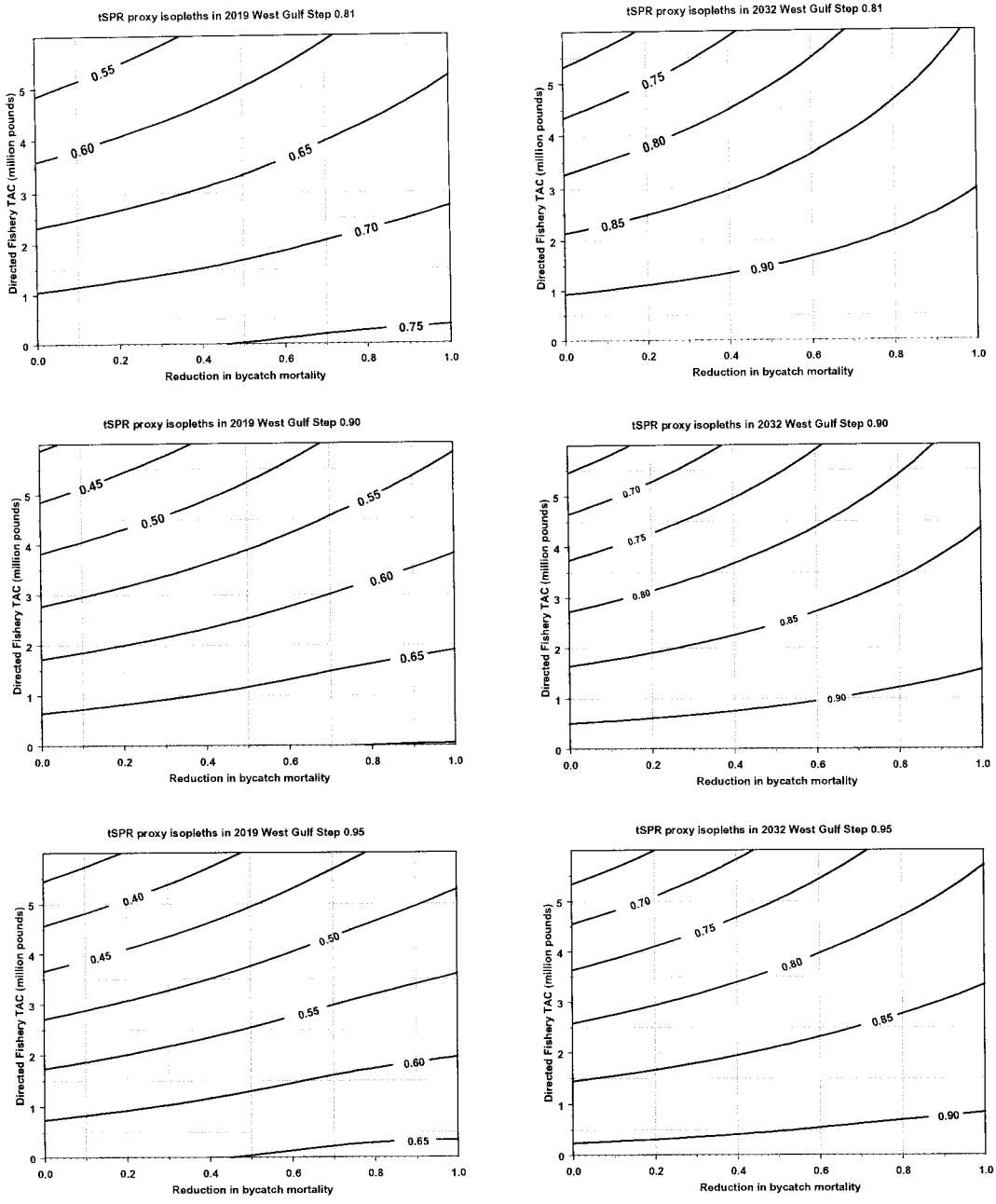

Figure 26. Isopleths of transition SPR projections at 2019 and 2032 of West GOM red snapper using a TAC of 0 to 6 million pounds and reductions of shrimp bycatch mortality of 0 to 100% beginning in 2008, for 0.81, 0.90 and 0.95 fixed steepness.

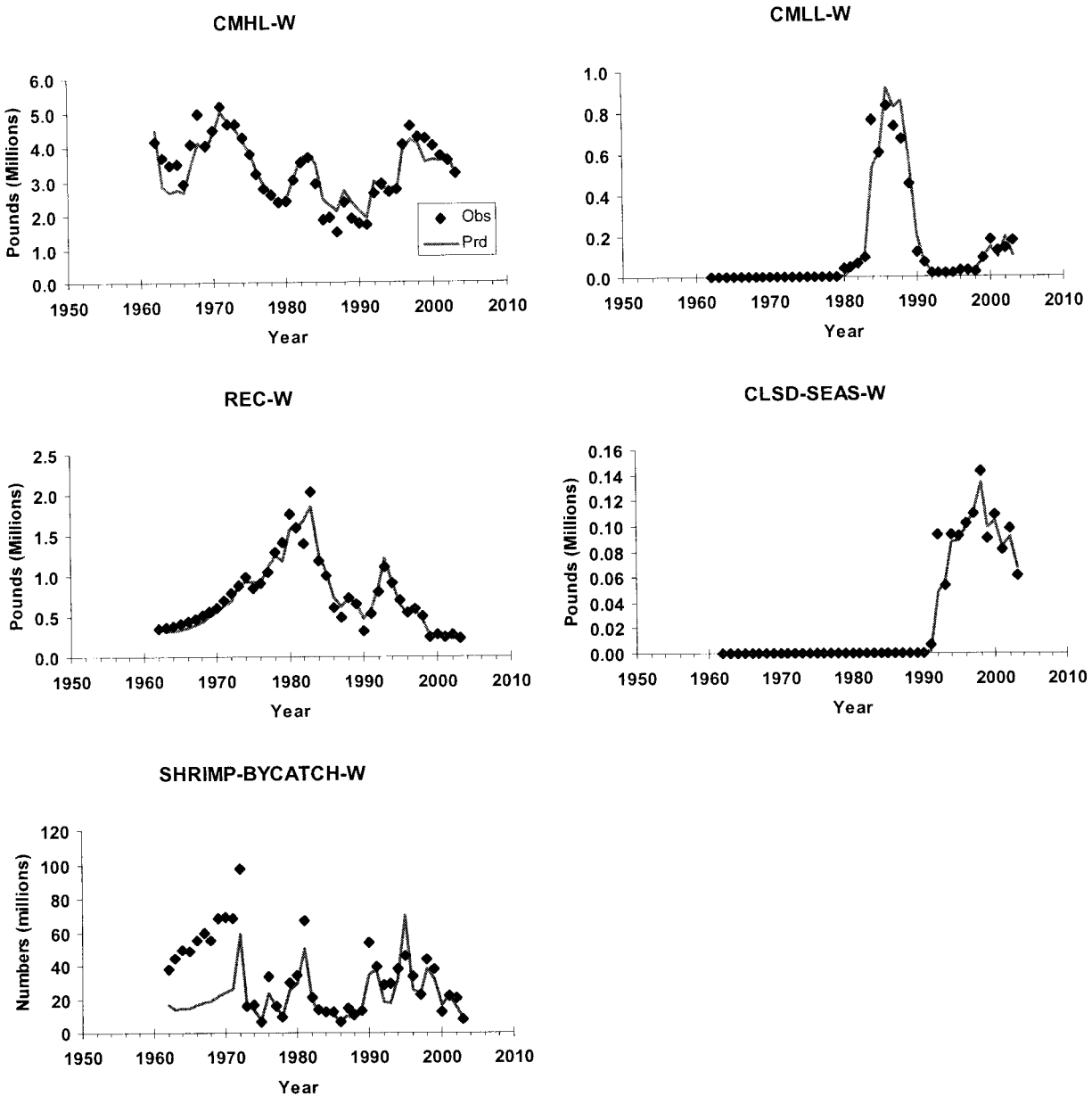

Figure 27. Fit to total catch by fleet for the West GOM (steepness 0.90)

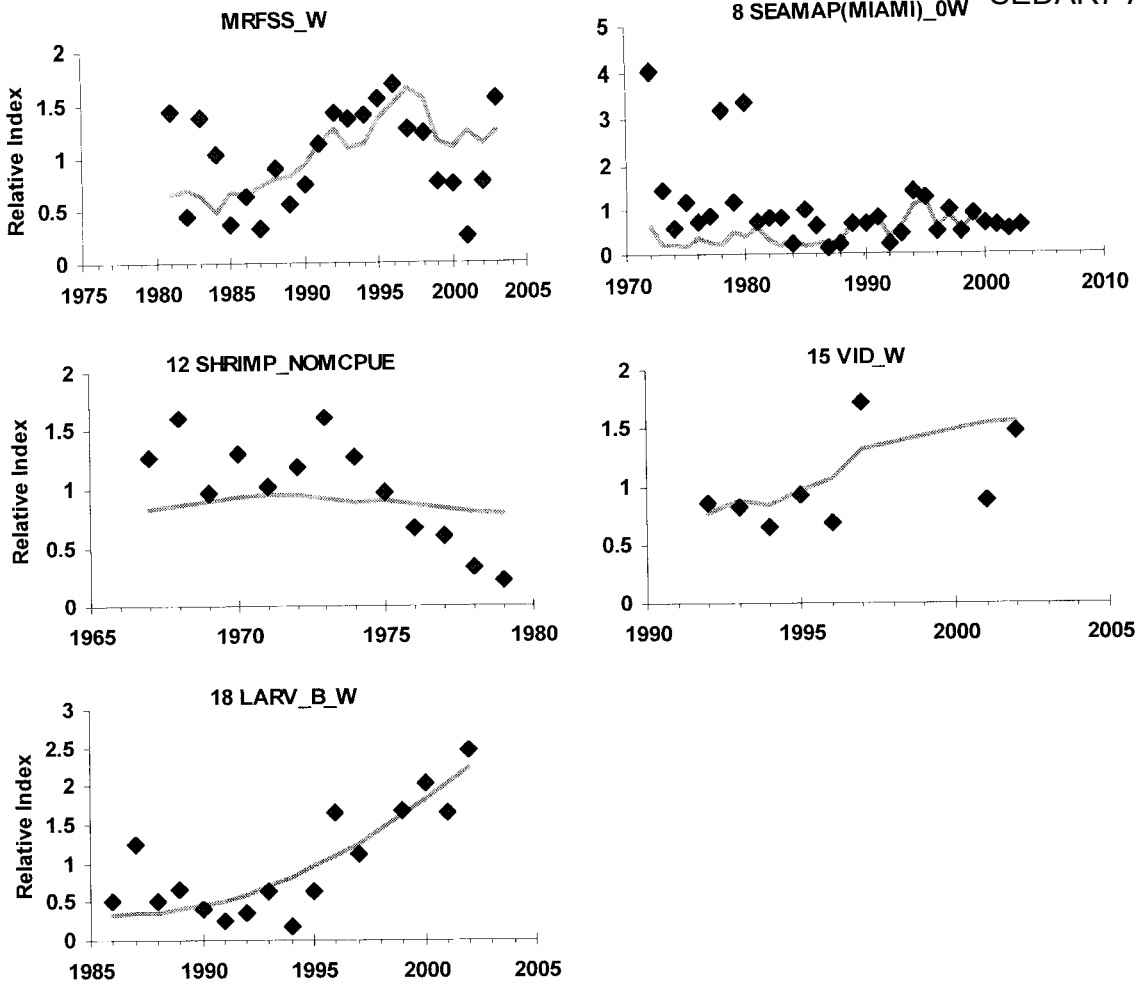

Figure 28. Fit to indices of abundance for the West GOM red snapper (Steepness 0.90)

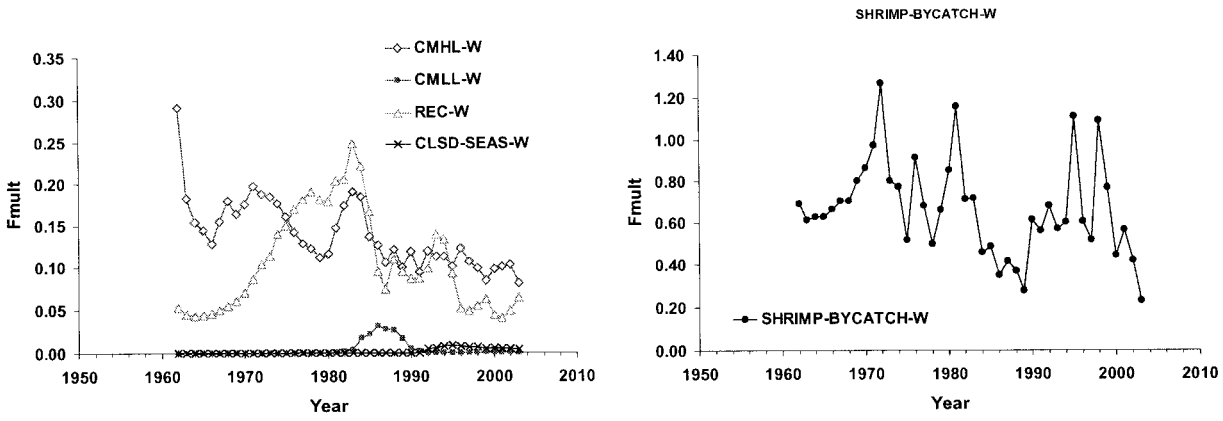

Figure 29. F multipliers by fleet for the West GOM red snapper (steepness 0.90)

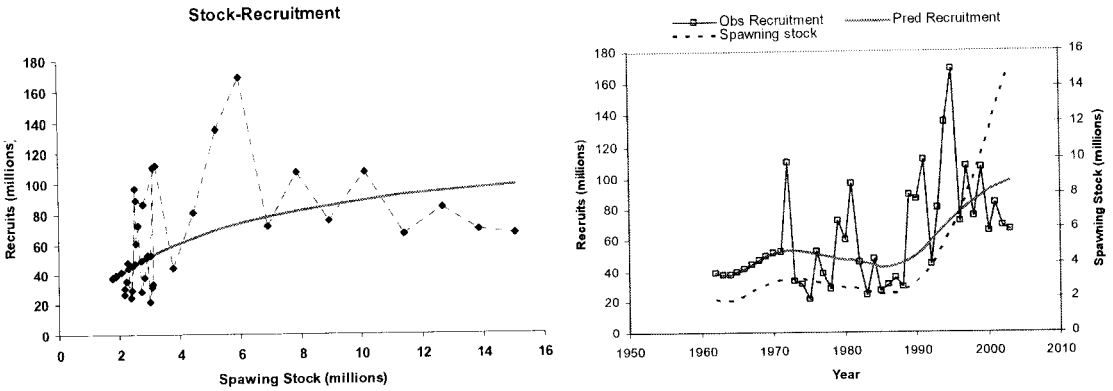

Figure 30. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.90)

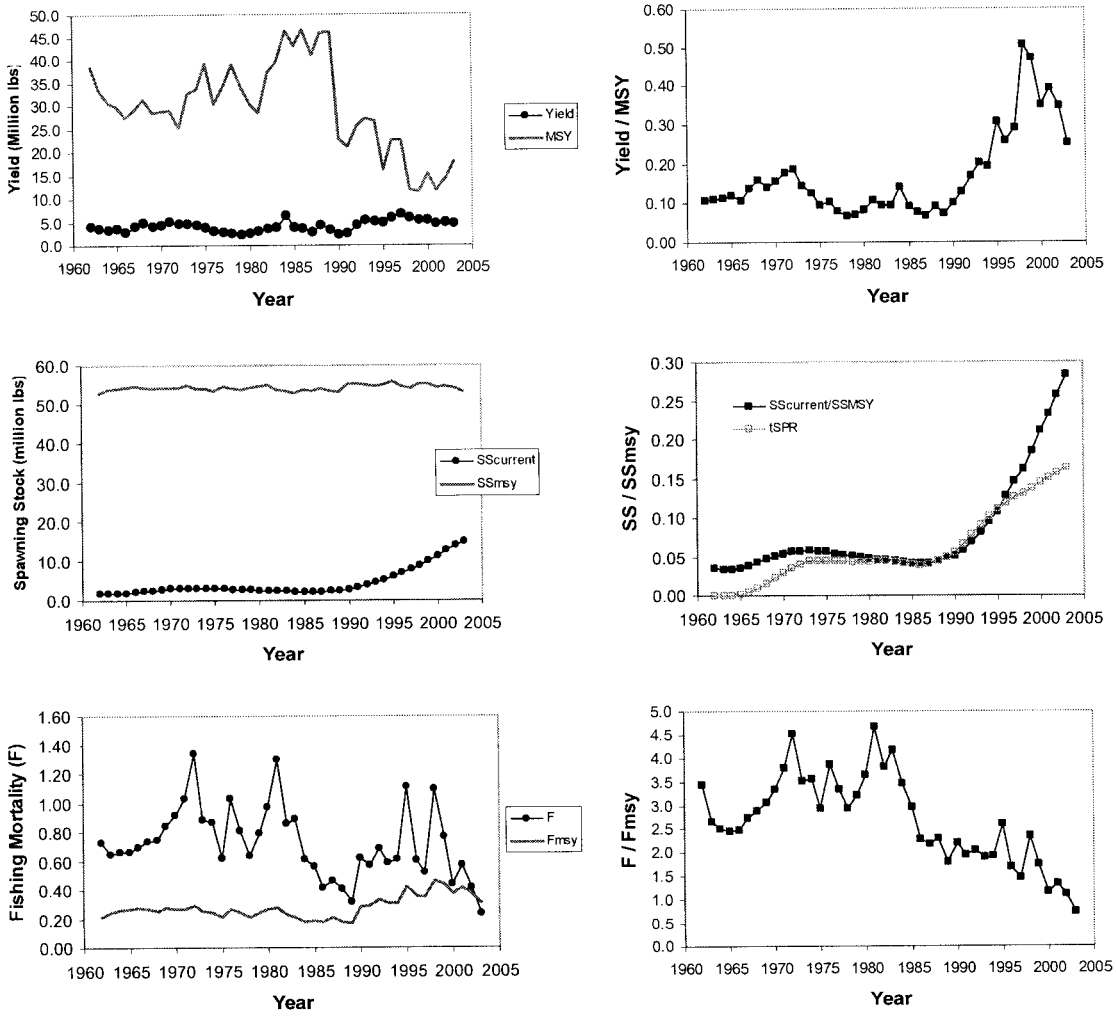

Figure 31. Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of West GOM red snapper (steepness 0.90)

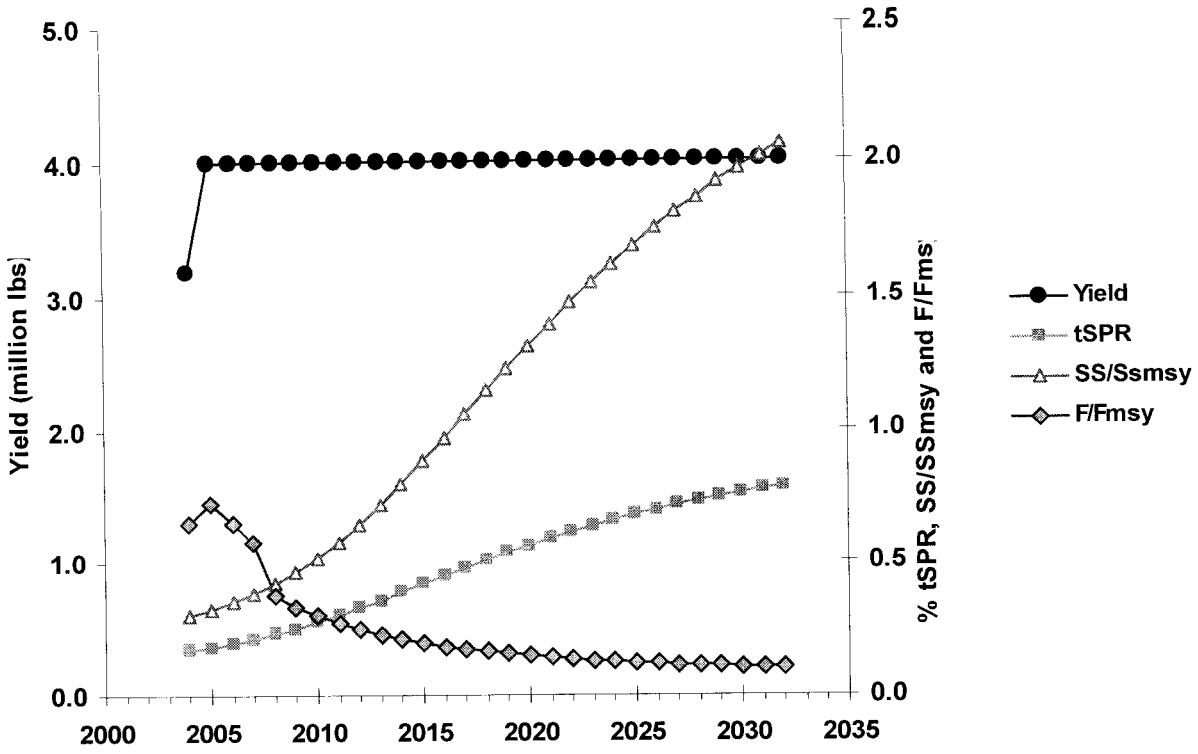

Figure 32. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for West GOM red snapper (steepness 0.90). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

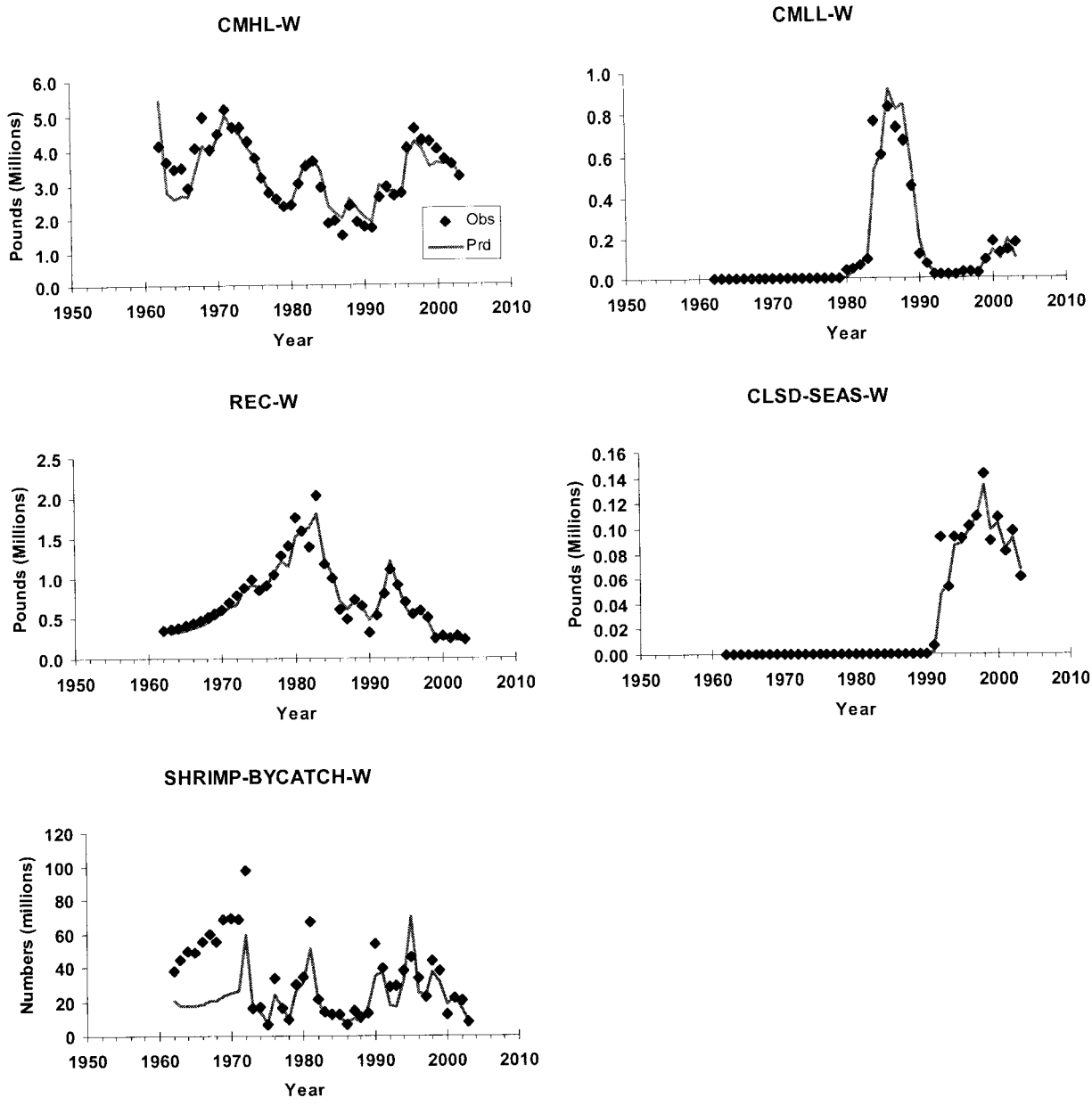

Figure 33. Fit to total catch by fleet for the West GOM (steepness 0.95)

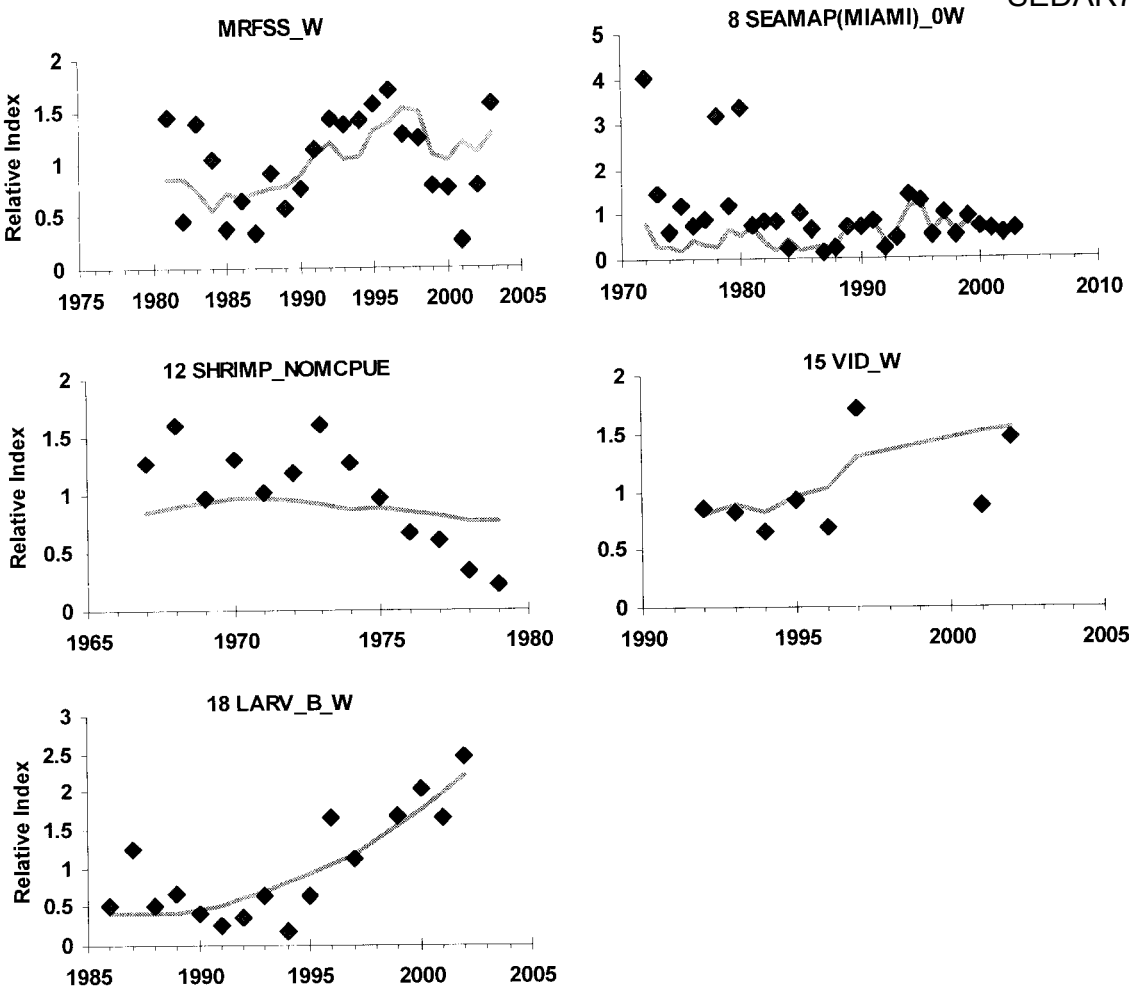

Figure 34. Fit to indices of abundance for the West GOM red snapper (Steepness 0.95)

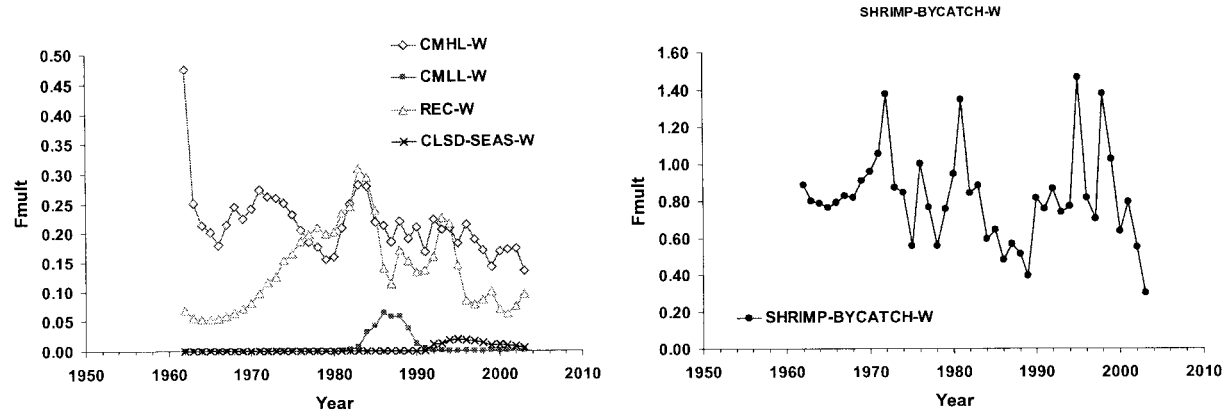

Figure 35. F multipliers by fleet for the West GOM red snapper (steepness 0.95)

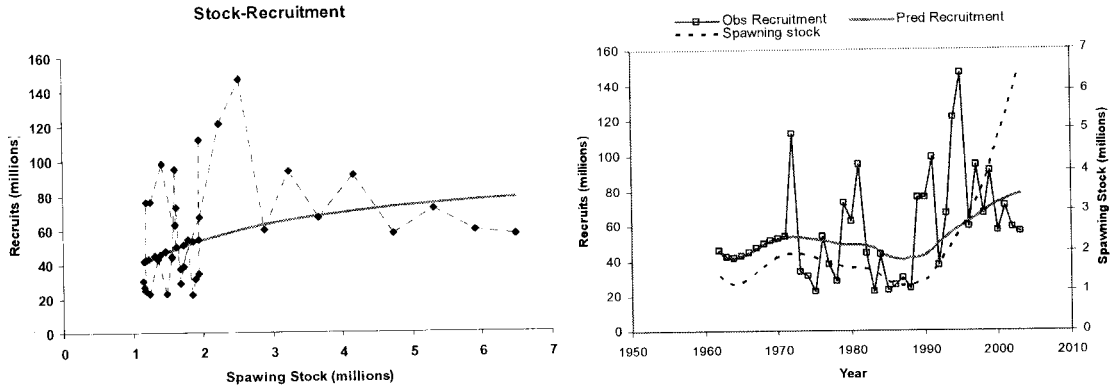

Figure 36. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.95)

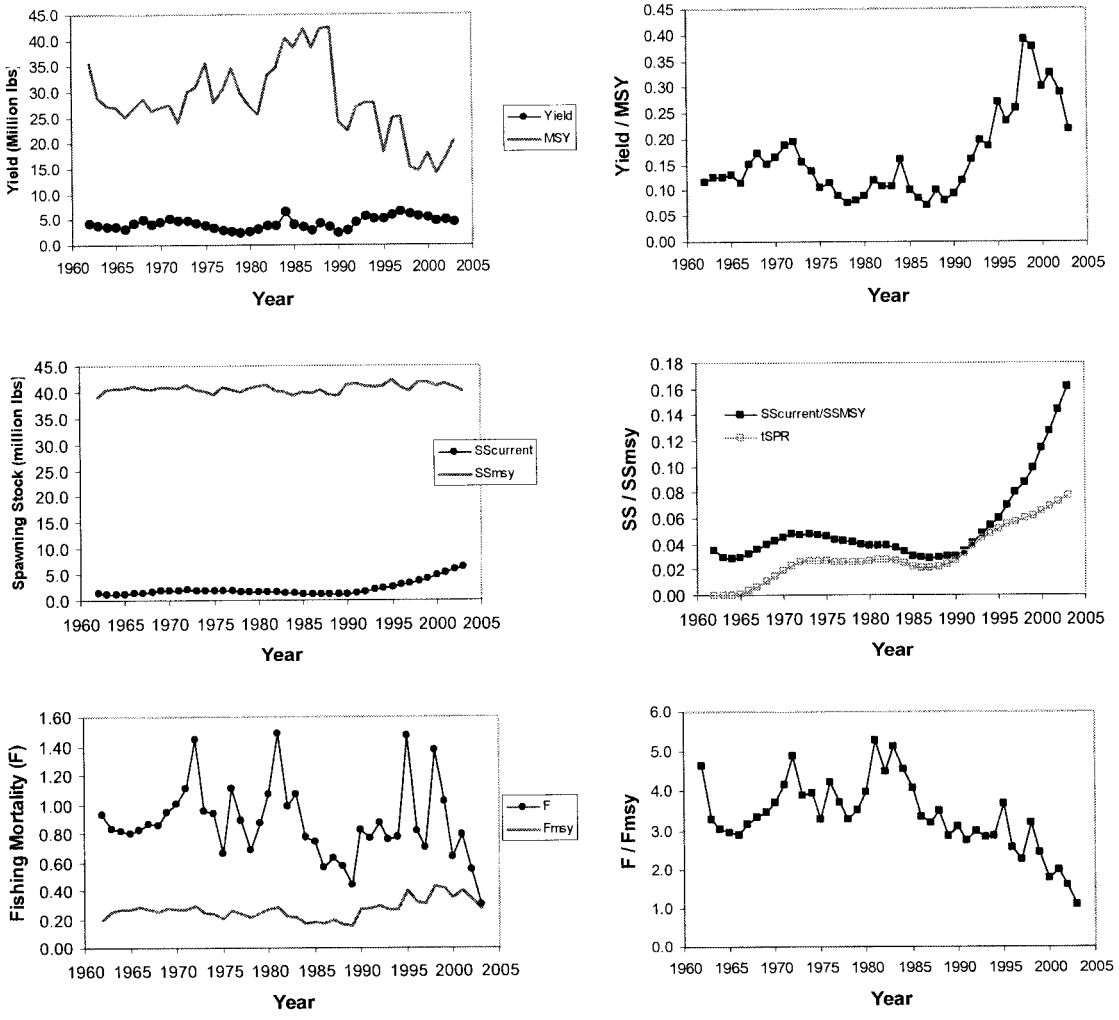

Figure 37. Trajectories of Yield, F, spawning stock, MSY, F_{MSY}, and SS_{MSY} of West GOM red snapper (steepness 0.95).

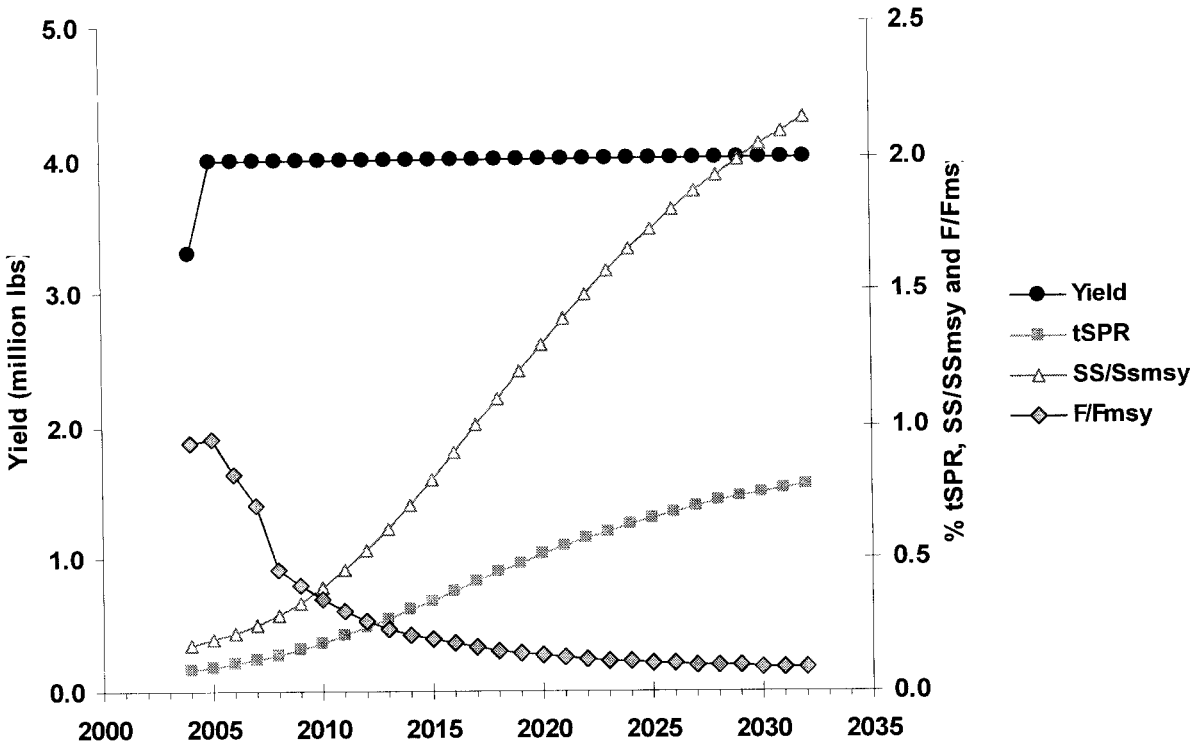

Figure 38. Projection of yield, % tSPR, SS/SS_{MSY} and F/F_{MSY} for West GOM red snapper (steepness 0.95). Projection assumes a constant TAC of 4.0 million lbs and a 40% reduction of bycatch mortality by 2008.

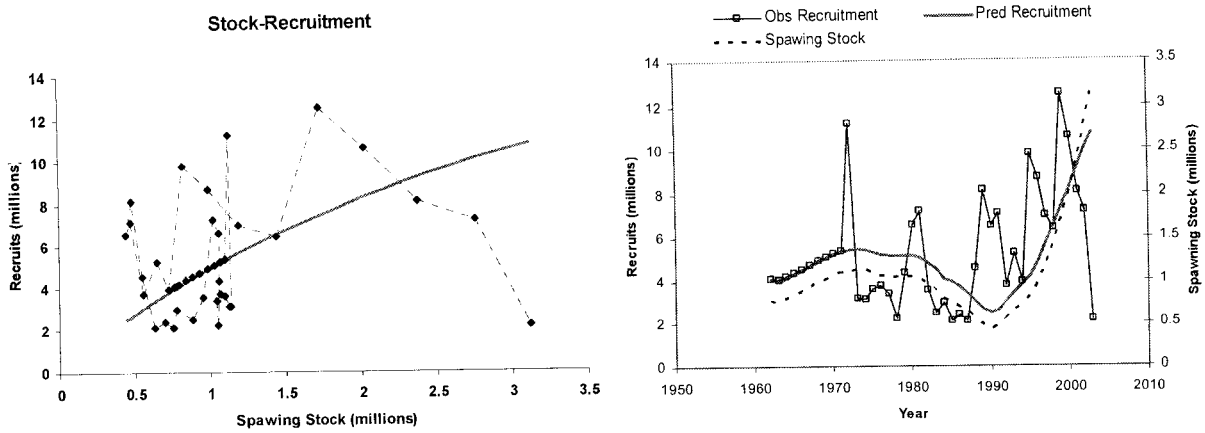

Figure 39. Low natural mortality run. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.81)

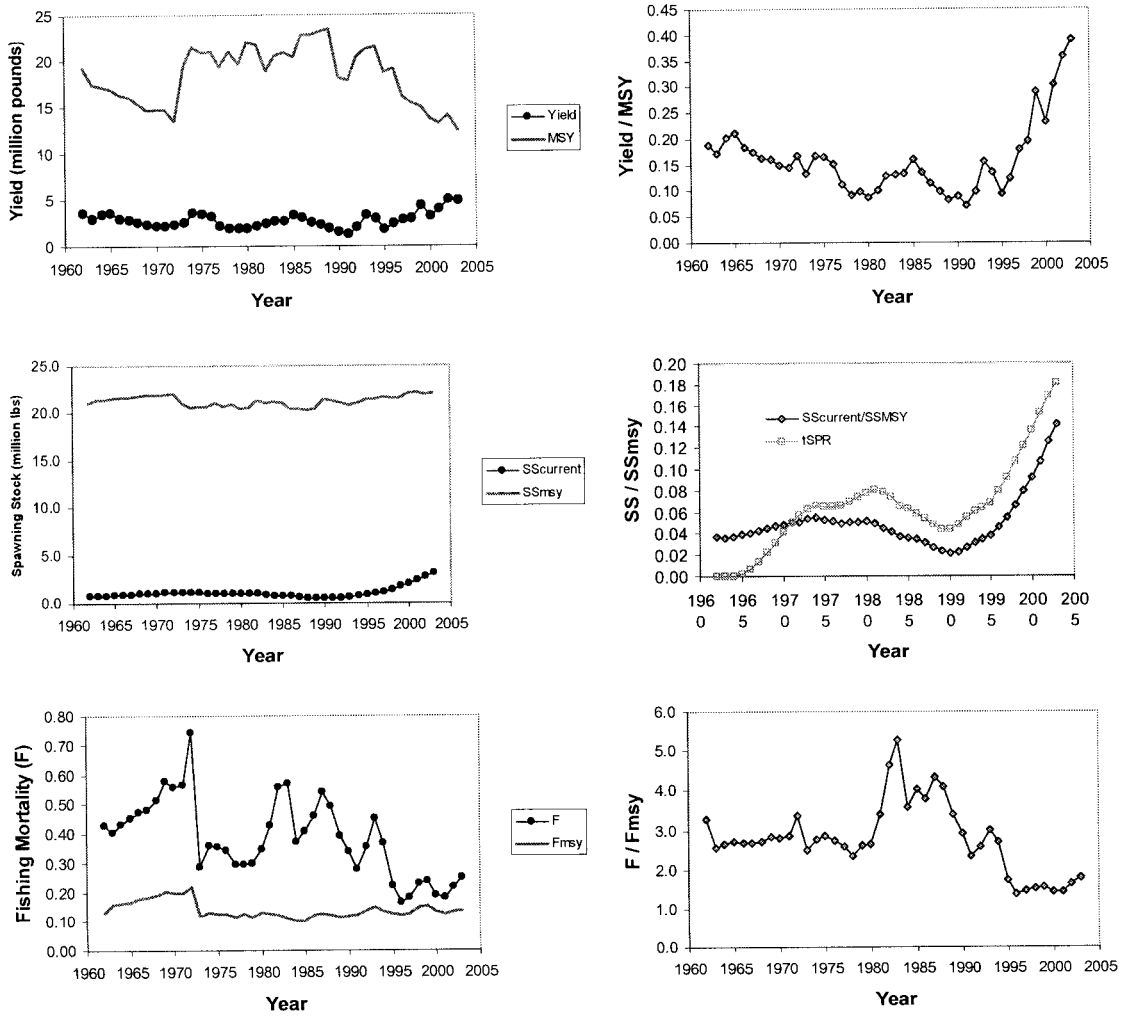

Figure 40. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY, tSPR and SSMSY of East GOM red snapper (steepness 0.81)

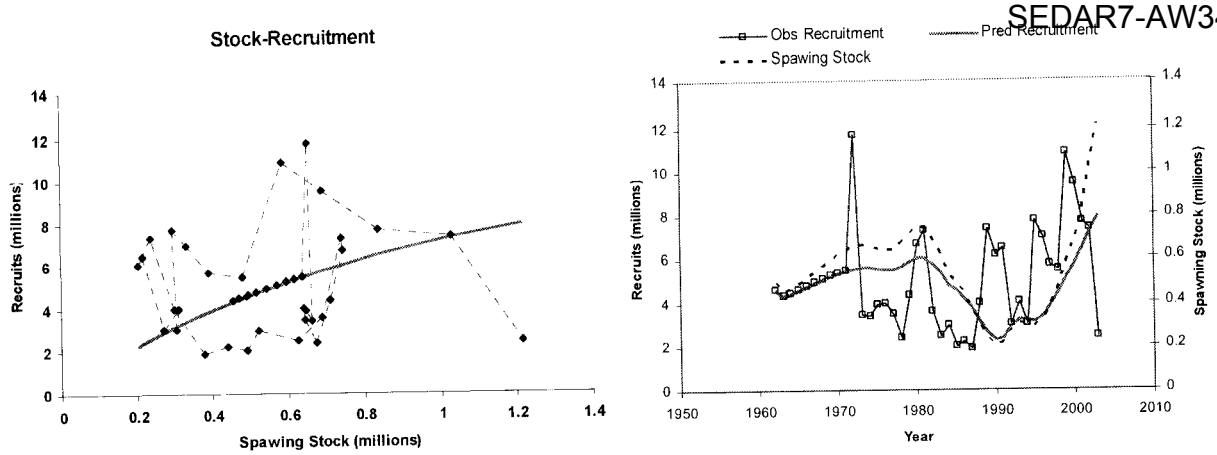

Figure 41. Low natural mortality run. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.90)

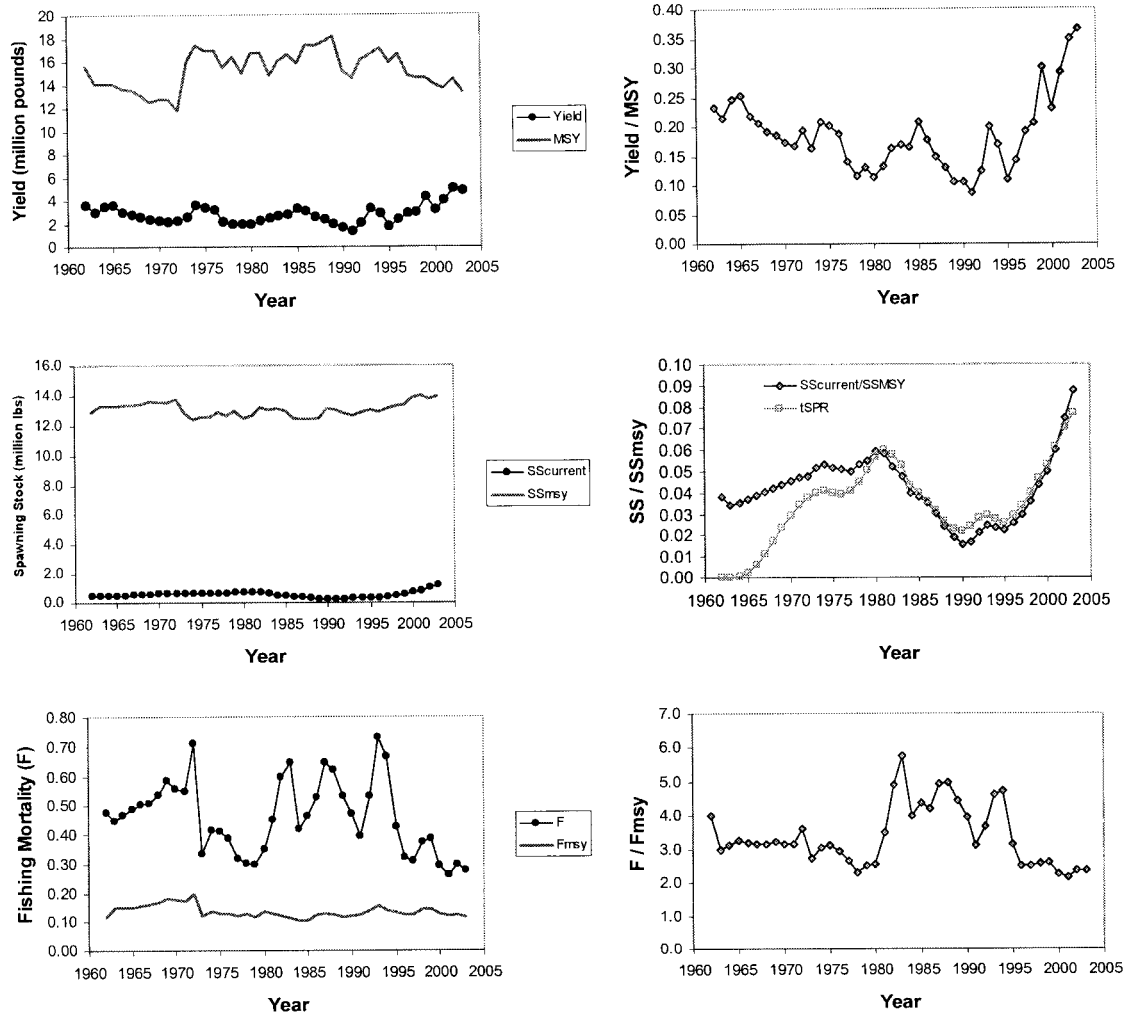

Figure 42. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY, tSPR and SSMSY of East GOM red snapper (steepness 0.90)

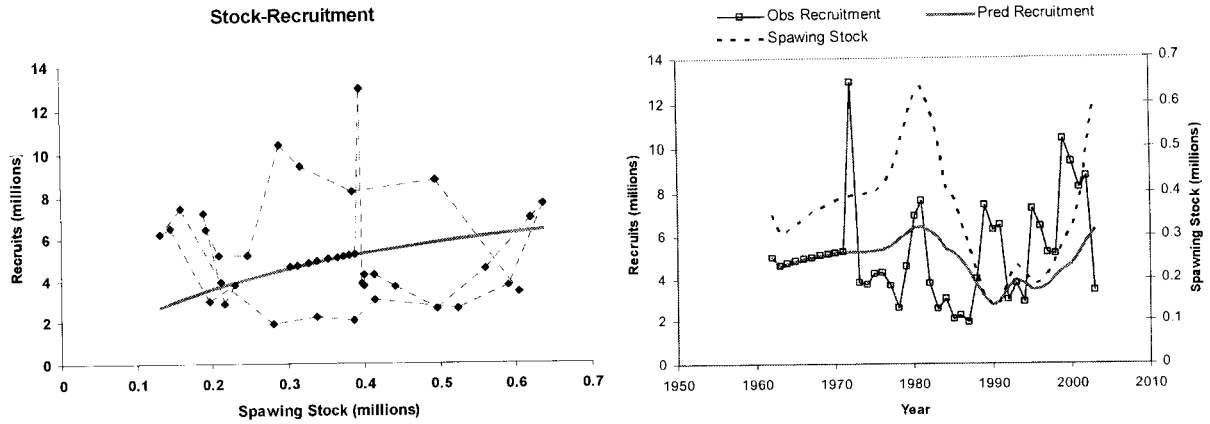

Figure 43. Low natural mortality run. Spawning stock and recruitment estimates East GOM red snapper (steepness 0.95)

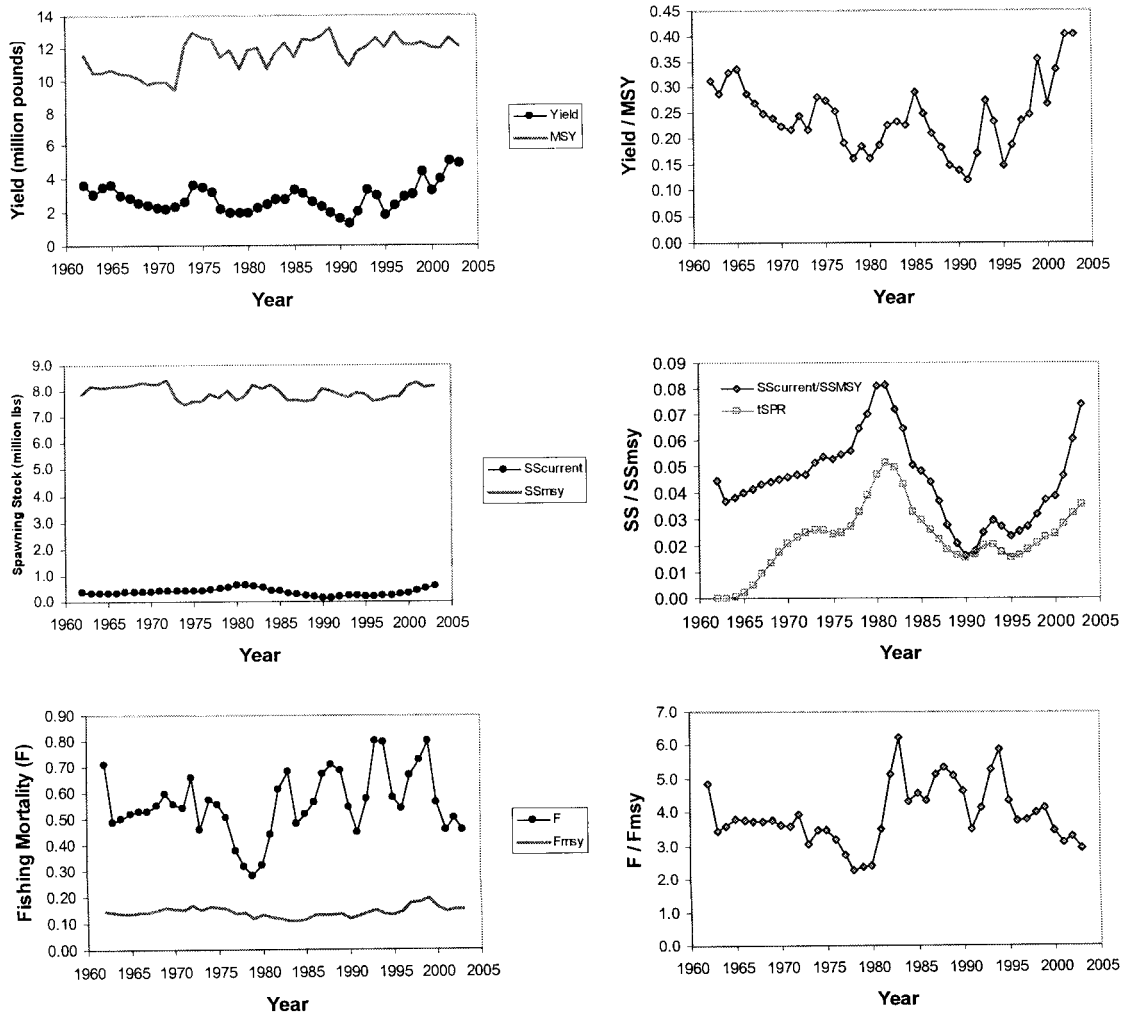

Figure 44. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY, tSPR and SSMSY of East GOM red snapper (steepness 0.95)

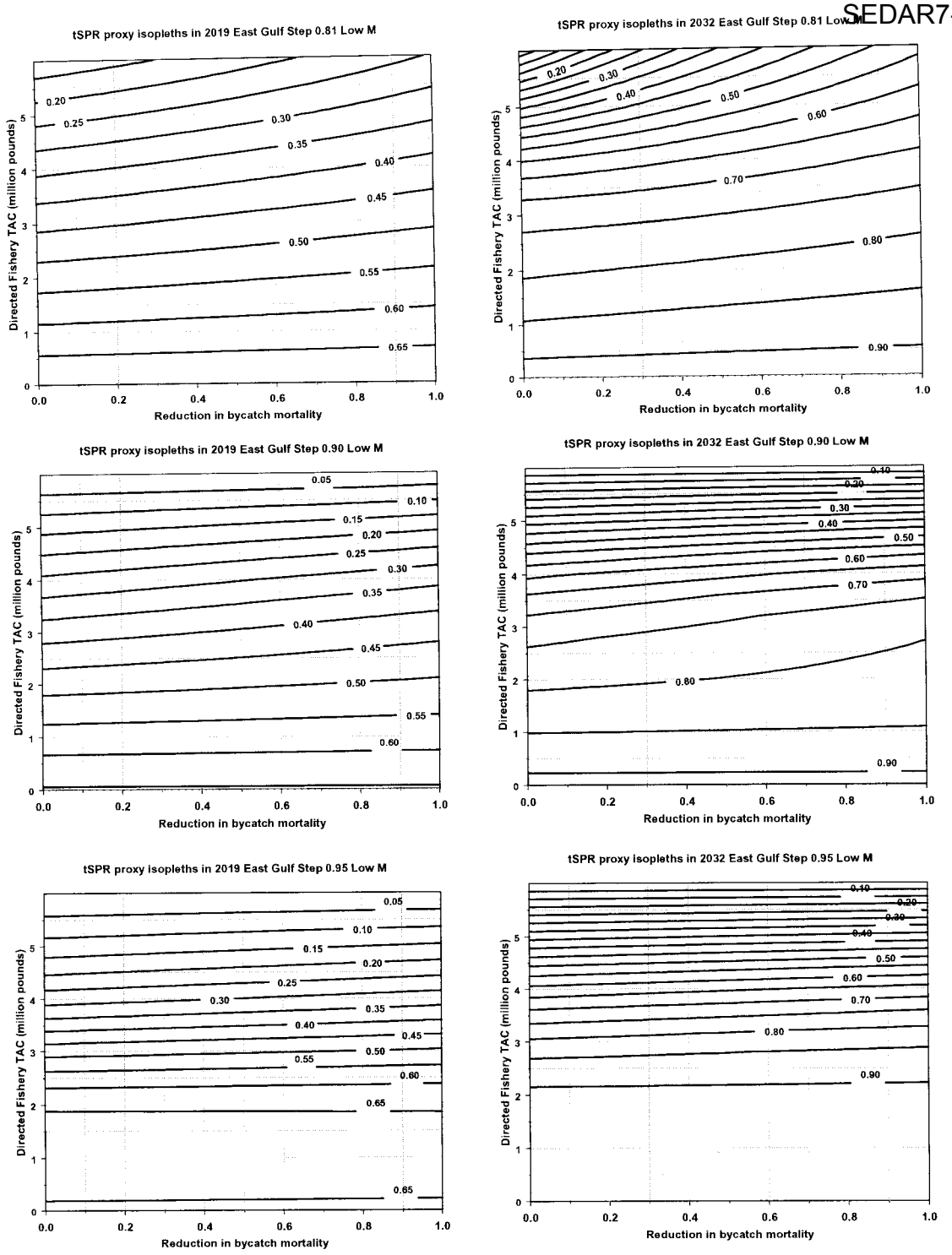

Figure 45. Low natural mortality run. Isopleths of transition SPR projections at 2019 and 2032 of East GOM red snapper using a TAC of 0 to 6 million pounds and reductions of shrimp bycatch mortality of 0 to 100% beginning in 2008, for fixed steepness 0.81, 0.90 and 0.95.

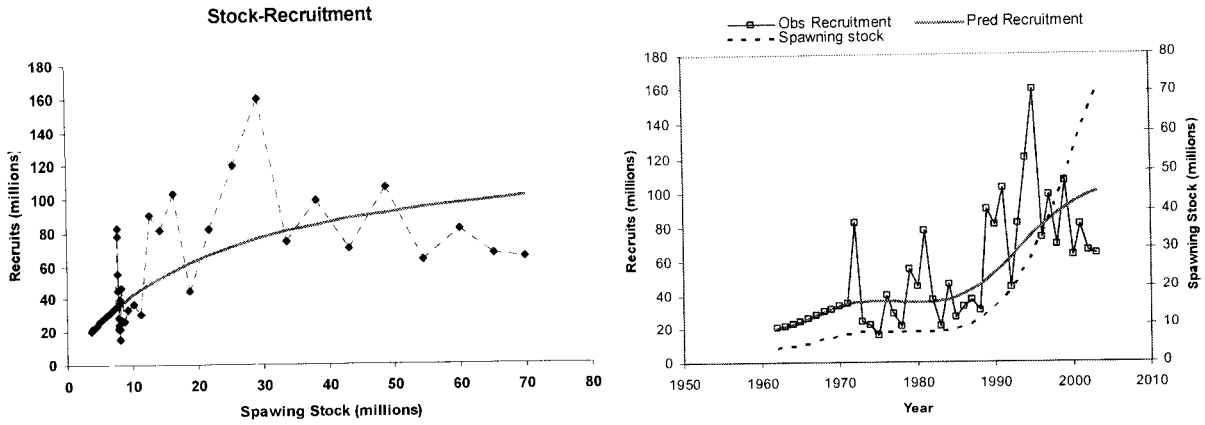

Figure 46. Low natural mortality run. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.81)

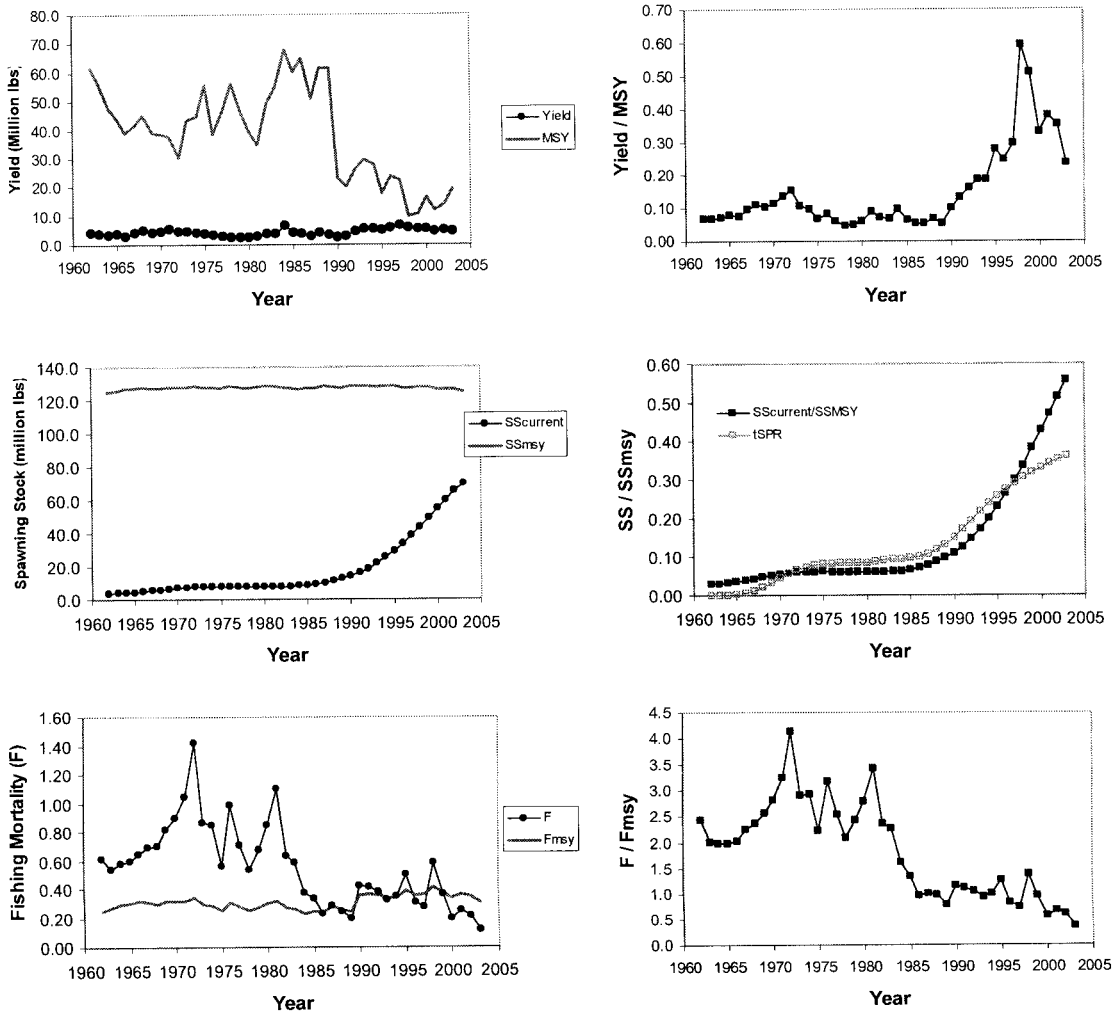

Figure 47. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY, tSPR and SSMSY of West GOM red snapper (steepness 0.81)

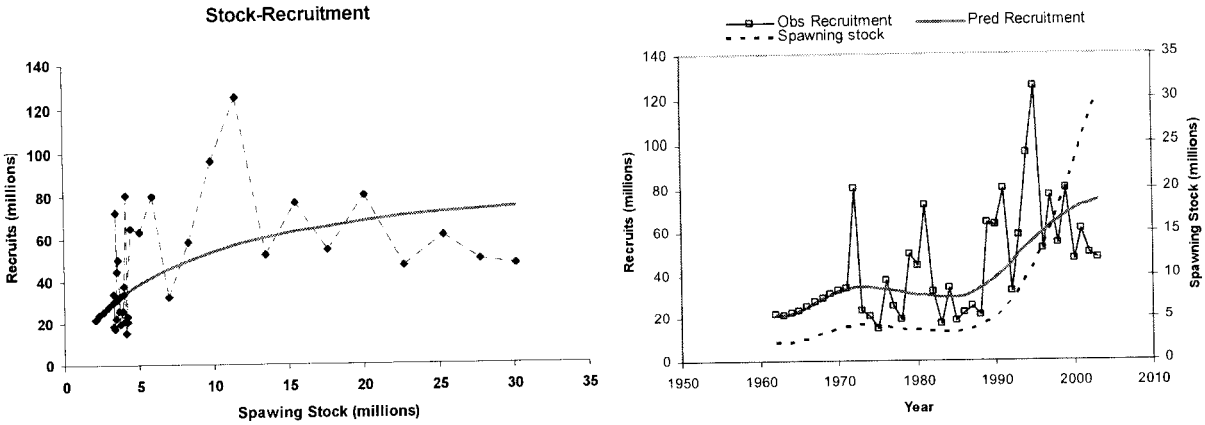

Figure 48. Low natural mortality run. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.90)

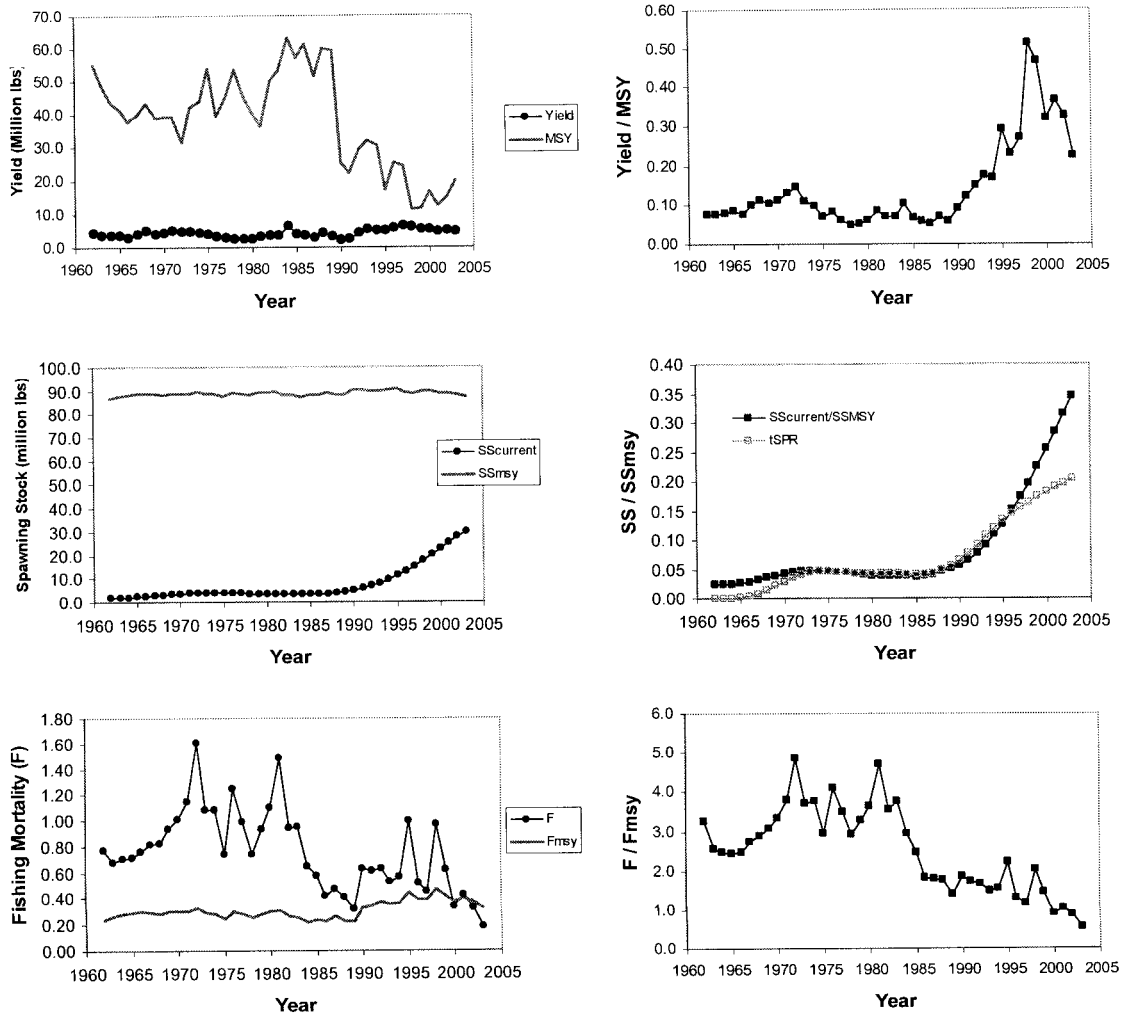

Figure 49. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY and SSMSY of West GOM red snapper (steepness 0.90)

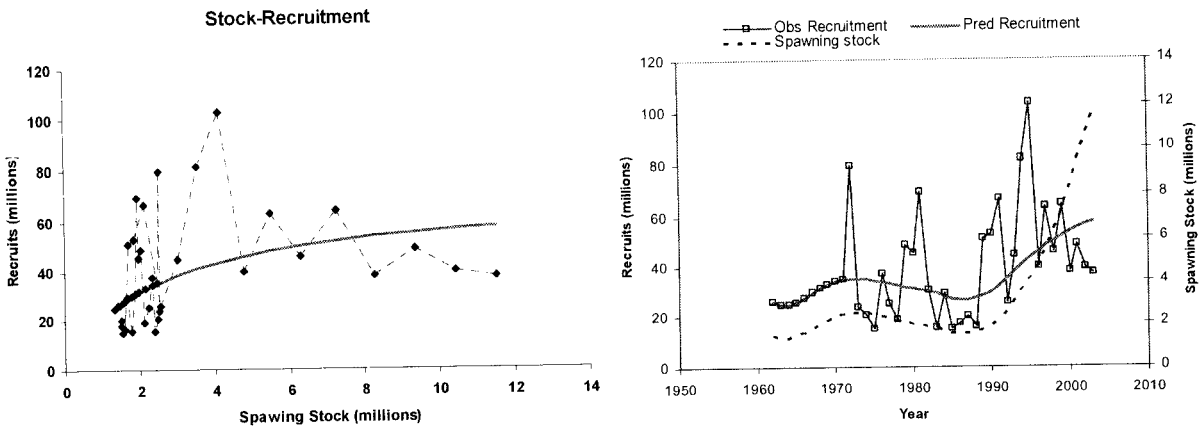

Figure 50. Low natural mortality run. Spawning stock and recruitment estimates West GOM red snapper (steepness 0.95)

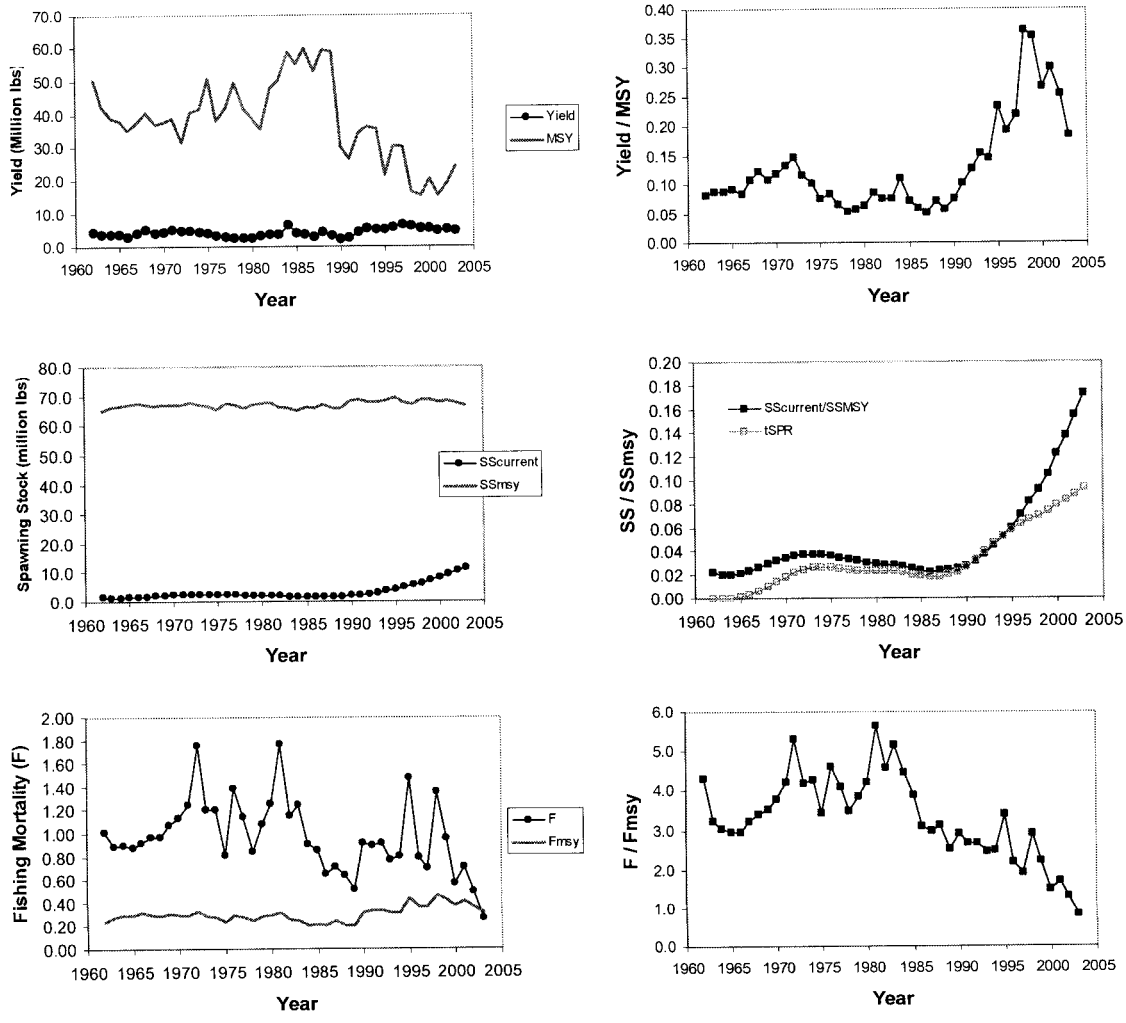

Figure 51. Low natural mortality run. Trajectories of yield, F, spawning stock, MSY, FMSY, tSPR and SSMSY of West GOM red snapper (steepness 0.95)

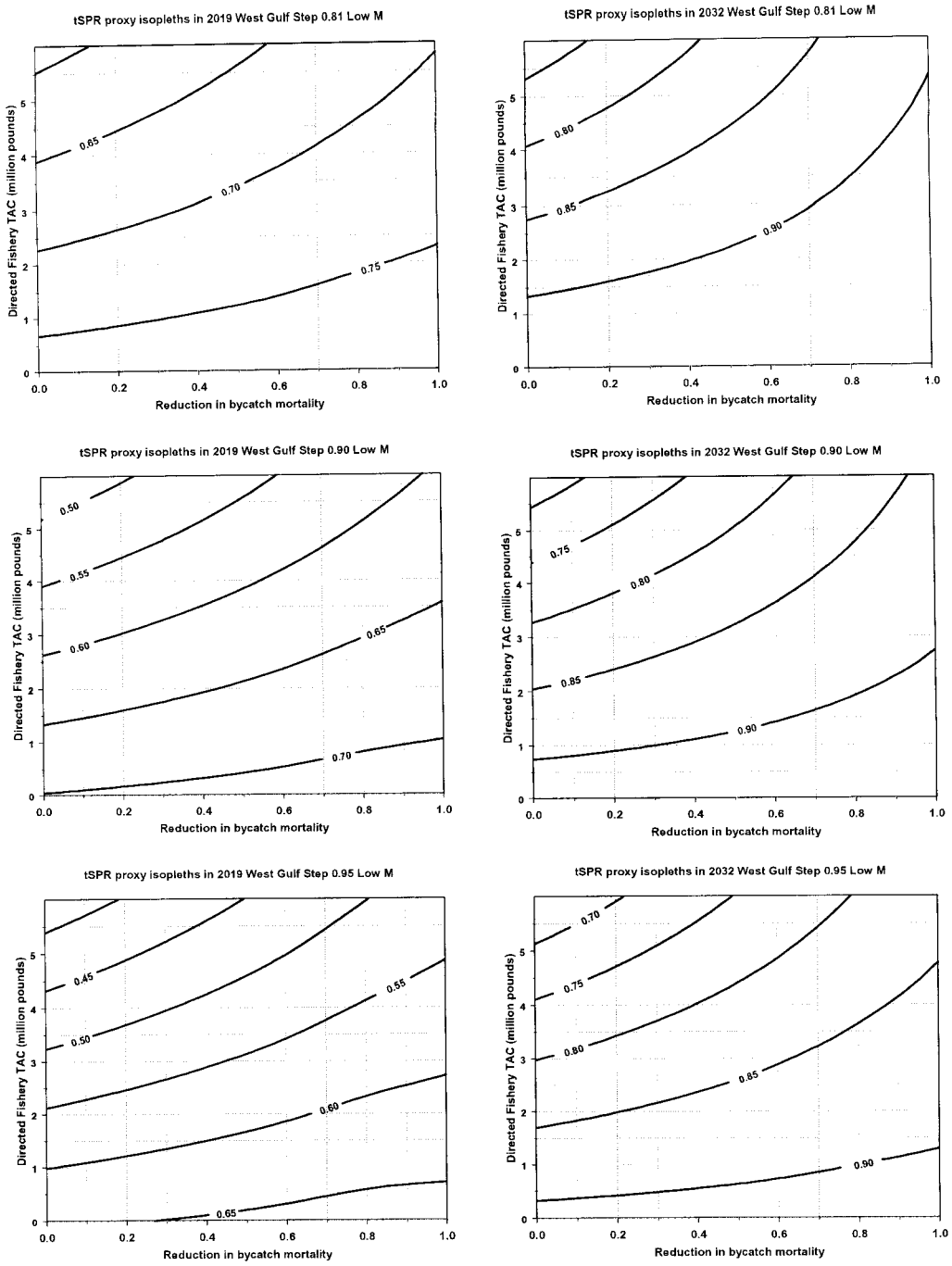

Figure 52. Low natural mortality run. Isopleths of transition SPR projections at 2019 and 2032 of West GOM red snapper using a TAC of 0 to 6 million pounds and reductions of shrimp bycatch mortality of 0 to 100% beginning in 2008, for fixed steepness 0.81, 0.90 and 0.95.