REVISED ASSESSMENTS OF GULF OF MEXICO RED SNAPPER DURING 1962-2003 USING A GULFWIDE IMPLEMENTATION OF AN AGE-STRUCTURED-ASSESSMENT-PROGRAM (ASAP)

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INTRODUCTION

Based on decisions taken at the August, 2004, red snapper assessment discussions, a range of ASAP model fits to fleet-specific catch and effort data spanning 1962-2003 were made to provide guidance on the status of the Gulf-wide red snapper resource. This paper documents the model structure and resulting fits to data as well as forecast status under a number of future management options.

Following the December 2004 Assessment Workshop (Miami, FL), this paper was substantially revised due to two important changes to the ASAP code.

1. The model was modified to allow the number of fish in the plus group during the initial year (1962) to deviate from virgin condition.
2. Boundaries were expanded to permit estimates of number-at-age (all ages 0-15+) in the initial year (1962) to deviate more substantially from virgin condition.

These modifications resulted in substantial differences in the estimates of population status, maximum sustainable yield (MSY) and other management benchmarks, necessitating the resubmittal of this manuscript to the Review Workshop.

METHODS

All assessment model runs were made using ASAP, an AD-Model builder implementation of a forward-projection, age-structured assessment program described in detail by Legault and Restrepo (1998). An earlier version of this program was used in previous assessments of red snapper (Schirripa and Legault, 1999). Modifications to ASAP since the 1999 assessment include:

1. Accommodation of two independent sets of age composition data for the directed component of each fleet (directly observed and modeled age comp).
2. During projections, the relative F's of each fleet can be modified, rather than just the non-directed fleets.
3. Accommodation of total landings and discards expressed in number or weight.
4. Tuning indices can now be linked to spawning biomass (fecundity)
5. Unique weight at age matrices can now be used for the landings and discards of each fleet.
6. Year and fleet-specific CV's on total catch are permitted.
7. Projections use the average estimated selectivity of the most recent three years
8. The parameter N_year1_devs uses natural mortality (M) in the initial year rather than total mortality (Z).

Model Specifications

For each gulf-wide ASAP run, 6 fleets were specified: Commercial handline east (CMHL-E), commercial handline west (CMHL-W), commercial longline gulf-wide (CMLL-GW), recreational gulf-wide (REC-GW), commercial handline and longline discards during the closed season (CLSD-SEAS-GW), and shrimp bycatch gulf-wide (SHRIMP-BYCATCH). Modeled ages were Age 0 to the plus group Age 15+. Six indices were used for tuning, the gulf-wide MRFSS index (MRFSS-GW), the SEAMAP Age0 trawl index (SEAMAP(SN)-0GW) developed by Scott Nichols (NOAA, Pascagoula), the SEAMAP Age1 trawl index (SEAMAP(MIAMI)-1GW) developed by the Miami Laboratory, the nominal shrimp bycatch CPUE series (SHRIMP_NOMCPUE) used by Schirripa and Legault (1999), the gulf-wide video index (VIDEO_GW) and the gulf-wide SEAMAP ichthyoplankton index (LARV_B_GW). Overall, the indices were weighted equally. However, annual variability was modeled using CVs rescaled to the average for each index. In every case, the model parameter representing the log virgin stock size was estimated freely.

Data (catch series, indices, fleet and index specifications etc.) used during the gulf-wide ASAP runs are summarized in Appendix 9 of the SEDAR7 Stock Assessment Workshop Report (SEDAR7-SAR1-SectIII).

To obtain biologically feasible results, it was necessary to apply assumed age composition for each fleet during 1962-1971 if total landings were non-zero. The assumed age composition was estimated using the five-year average of the earliest available data. Revisions to the ASAP code did not eliminate this requirement.

Projections

As per the request of the Assessment Workshop, projections were made from each of the “Current Shrimp (Unlinked), High M” runs to examine the outcome of various management decisions. Isopleths of projected transitional SPR (tSPR), spawning stock status

(SS/SS_{MSY}) and yield during 2010 and 2032 were constructed using total allowable catches (TAC) ranging from 0 to 20 million pounds and shrimp effort reductions ranging from 0 to 100%. Similar isopleth diagrams were constructed using % current directed F and shrimp effort reductions both ranging from 0 to 100%. The methods are described in detail in Appendix 4 of the SEDAR7 Stock Assessment Workshop Report (SEDAR7-SAR1-SectIII).

RESULTS AND DISCUSSION

Current Shrimp "Unlinked" Models

Current Shrimp "Unlinked" models assume that the shrimp bycatch and closed season discard fleets are not directed and effectively not subject to direct joint management effects for the purpose of projections. Within the ASAP framework, this leads to MSY reference point calculations which treat the bycatch and closed season fleet selectivity as unmodifiable from the standpoint of reference point calculations. Current Shrimp "unlinked" models were run at steepness 0.81, 0.90 and 0.95, and at "High" and "Low" natural mortality. ("High M": M(0) = 0.98, M(1) = 0.49 and M(2-15+) = 0.1; "Low M": M(0) = 0.49, M(1) = 0.29 and M(2-15+) = 0.1).

Model fits to the total catch series are summarized in Figs. 1 and 2. In general, the fits were good, as was expected given the small CVs (0.15 for REC_GW, 0.1 for all others). However, the model fits to shrimp bycatch during the years 1962-1971 are consistently lower than the "observed" values. It is important to note, however, that during 1962-1971, direct observations of shrimp bycatch were not available. Instead, these catches were estimated using the procedure described by SEDAR7-AW-23. Changes in steepness and natural mortality did not appreciably alter model fits to the total catch series (Figs. 1-2).

The model fits to the indices of abundance are acceptable (Figs. 3-4), with the exception of the poor fit to the early years of the SEAMAP Age 1 index. In this case, the predicted index values are less than the observations. This behavior is due to the large CVs (and hence low weighting to the observations) associated with the SEAMAP index values prior to 1982. Before 1982, raw CVs average 0.98. During 1982-2003, the CVs average 0.11. Changes in natural mortality did not appreciably alter model fits to the indices (Figs. 3-4). However, variations in steepness did cause modest fluctuations in the fits to the indices. In general, model runs at steepness = 0.95 resulted in fits that most resembled the observed index values.

Annual trends in the fleet specific F-multipliers are summarized in Figs. 5-6. F-multipliers are dependant on the assumed steepness. The lowest F-multipliers result when steepness is fixed at 0.81, the highest F-multipliers are found at steepness = 0.95 (Figs. 5-6). The effect of natural mortality is modest. F-multipliers for the directed fleets are higher for the "High M" runs, while the shrimp bycatch fleet shows the opposite result (Figs. 5-6).

The F multiplier associated with shrimp bycatch is considerably higher than the other fleets, and typically varies between 0.2 and 1.7. The highest values were observed during the

1970s and early 1980s and ranged from 0.6-1.7. Since 1984, the shrimp fleet F multipliers have decreased somewhat, and have remained below 1.0. F-multipliers for the commercial handline fleets were highest before 1984. Recent values are lower, particularly in the eastern Gulf (Figs. 5-6). The commercial longline fleet commenced during the early 1980s. the F-multiplier rapidly increased until 1988, and then declined dramatically during the early 1990s. Recent F-multipliers are near zero (Fig 5-6). The recreational fishery was quite modest in the 1960s but began to increase during the 1970s. Historic F-multipliers were highest from 1978-1983, then decreased through 1989. A second maximum occurred during 1992-1994. Since 1996, recreational fishing mortality has increased markedly, approaching (or exceeded) the highest values recorded. Closed season discards began in 1991. The associated F-multiplier increased precipitously though the early 1980s, then quickly declined to current levels less than 0.05 (Figs. 5-6).

Annual estimates of recruitment and spawning stock are summarized in Figs. 7-8. During the initial years (1962-1971), no recruitment indices are available. Therefore, the model is forced to use the stock recruitment relationship to predicted recruitment. Model results suggest that recruitment was higher than expected, given the stock recruitment relationship, during 1972, 1979-1981 and from 1989-1995. However, since 2000, predicted recruitment has been substantially lower than expected. In fact, predicted recruitment in 2003 is the lowest in the time series. A dramatic increase in estimated spawning stock begins in 1990 as higher than expected recruitments occur. However, this increase will end, or reverse in the future if recent lower than expected recruitments persist.

Recruitment and spawning stock estimates are dependant on assumptions regarding steepness and natural mortality (Figs 7-8). Annual spawning stock estimates decrease as steepness and/or natural mortality increase. Annual recruitment estimates are highest at “High” natural mortality, but the relationship with steepness is more complex. Before 1984 and in 2003, recruitment estimates change very little with changes in steepness. Between 1984 and 2002, recruitment estimates are highest at steepness = 0.81.

Stock status (SS/SS_{MSY}, F/F_{MSY}, tSPR) and management benchmarks (F_{MSY}, $F_{30\%SPR}$, MSY etc.) for “Current Shrimp (Unlinked)” runs are summarized in Tables 1 and 2, respectively. Population trajectories are shown in Figs 9-10. Population trajectories and management benchmarks are sensitive to the assumed steepness and natural mortality vector. However, in all cases, “Current Shrimp (Unlinked)” runs indicate that red snapper were already overfished, and that overfishing was occurring in 1962 ($F_{1962}/F_{MSY} > 2.0$; $SS_{1962}/SS_{MSY} < 0.2$; Figs 9-10 and Table 1). All runs indicate that a recovery began in the mid 1980s. The speed of the recovery is dependant on steepness, and to a lesser extent on natural mortality. At steepness = 0.81, overfishing ended in the mid 1980s and the population reached SS_{MSY} during 2001 or 2002. At steepness = 0.90, overfishing ended in the mid 1990s but the population remained slightly below SS_{MSY} through 2003. At steepness = 0.95, F/F_{MSY} was close to, or just below 1.0 after 1995, but the stock status remained well below 1.0 through 2003. As expected, “Low M” runs were more optimistic than “High M” runs, but the difference was very modest. (Figs. 9-10, Table 1).

“Linked” Models

Linked models assume that all six fleets are effectively directed and jointly subject to management for the purpose of population projection. This assumption within the ASAP framework, results in calculations of MSY reference points (F and biomass) on the basis of the joint selectivity of all fleets simultaneously. “Linked” models were run at steepness 0.81, 0.90 and 0.95, and at “High” and “Low” natural mortality. (“High M”: M(0) = 0.98, M(1) = 0.49 and M(2-15+) = 0.1; “Low M”: M(0) = 0.49, M(1) = 0.29 and M(2-15+) = 0.1).

Model results unrelated to MSY do not vary when fleets are specified as “linked” rather than “unlinked”. Therefore, fits to the total catch series (Figs. 1-2) and indices of abundance (Figs. 3-4) are identical to those described in the section “Current Shrimp Unlinked Runs”. Likewise, annual trends in the fleet specific F-multipliers (Figs 5-6) and spawning stock and recruitment estimates (Figs. 7-8) are also identical those described in the section “Current Shrimp Unlinked Runs”.

Stock status (SS/SS_{MSY}, F/F_{MSY}, tSPR) and management benchmarks (F_{MSY}, $F_{30\%SPR}$, MSY etc.) for “Linked” runs are summarized in Tables 3 and 4, respectively. Population trajectories are shown in Figs 11-12. In terms of F/F_{MSY} and SS/SS_{MSY}, “Linked” runs are less optimistic then the “Current Shrimp (Unlinked)” cases. “Linked” runs suggest that red snapper were gravely overfished, and that overfishing was occurring in 1962 ($F_{1962}/F_{MSY} > 2.9$; $SS_{1962}/SS_{MSY} < 0.05$; Figs 11-12 and Table 3). A slow decrease in F began in the mid 1980s, but in most cases F/F_{MSY} remained above 1.0 through 2003 (Figs 11-12). The single exception is at “Low M” and steepness 0.81 (Fig. 12). Using these assumptions, F/F_{MSY} decreased to levels near, but generally below 1.0 after 1995. No linked run indicated that SS/SS_{MSY} had reached 1.0 by 2003. As expected, runs that assumed lower steepness were more optimistic than runs at higher steepness and “Low M” runs were slightly more optimistic than “High M” runs (Tables 3-4).

Projections

The projection results are described in detail in Appendix 4 of the SEDAR7 Stock Assessment Workshop Report (SEDAR7-SAR1-SectIII).

LITERATURE CITED

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Schirripa, M. J., and C. M. Legault. 1999. Status of red snapper in U.S. waters of the Gulf of Mexico updated through 1998. Report SFD-99/00-75, Sustainable Fisheries Division, Miami Laboratory, National Marine Fisheries Service, Miami, FL.

Table 1. Stock status during specific reference years for 1962-2003 gulfwide "Current Shrimp (Unlinked)" ASAP runs.

Model Description	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**
Shrimp bycatch and closed season discards directed?	Unlinked	Unlinked	Unlinked	Unlinked	Unlinked	Unlinked
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Natural Mortality	High	High	High	Low	Low	Low
SS/SSmsy						
1962	0.186	0.161	0.146	0.198	0.173	0.153
1984	0.079	0.061	0.062	0.103	0.073	0.065
1998	0.938	0.666	0.605	1.237	0.882	0.678
Current (2001-2003)	1.173	0.697	0.469	1.557	0.997	0.582
F/Fmsy						
1962	2.288	2.580	3.284	1.954	2.370	2.960
1984	1.922	3.301	3.937	1.143	2.602	3.677
1998	0.326	0.687	1.119	0.182	0.402	0.874
Current (2001-2003)	0.365	0.666	0.947	0.208	0.408	0.765
tSPR						
1984	0.048	0.022	0.015	0.059	0.022	0.012
1999	0.250	0.099	0.041	0.309	0.137	0.047
2003	0.318	0.140	0.061	0.383	0.189	0.070

Table 2. Benchmark statistics for 1962-2003 gulfwide "Current Shrimp (Unlinked)" ASAP runs.

Model Description	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**	**Current Shrimp**
Shrimp bycatch and closed season discards directed?	Unlinked	Unlinked	Unlinked	Unlinked	Unlinked	Unlinked
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Natural Mortality	High	High	High	Low	Low	Low
Benchmark Statistic						
$F_{0.1}$	0.228	0.208	0.189	0.230	0.215	0.195
F_{MAX}	0.307	0.282	0.258	0.308	0.290	0.265
$F_{30\%SPR}$	0.118	0.043	0.000	0.130	0.048	0.000
$F_{40\%SPR}$	0.051	0.000	0.000	0.063	0.000	0.000
F_{MSY}	0.198	0.209	0.213	0.202	0.216	0.213
F_{2003}	0.072	0.139	0.201	0.042	0.088	0.163
SS_{MSY} (Millions)	41.6	23.7	14.9	60.3	33.0	18.6
$SS_{Current}$ (Mlillons)	48.8	16.6	7.0	93.8	32.9	10.8
MSY (Million Pounds)	21.0	17.8	17.1	28.7	21.4	17.7
R0 (Millions)	207.5	166.0	135.0	128.7	102.3	86.3
F_{2003}/F_{MSY}	0.365	0.666	0.947	0.208	0.408	0.765
SS_{2003}/SS_{MSY}	1.173	0.697	0.469	1.557	0.997	0.582
tSPR 2003	0.318	0.140	0.061	0.383	0.189	0.070
tSPR @ MSY	0.215	0.143	0.103	0.222	0.144	0.092

Table 3. Stock status during specific reference years for 1962-2003 gulfwide "Linked" ASAP runs.

Model Description	**Linked**	**Linked**	**Linked**	**Linked**	**Linked**	**Linked**
Shrimp bycatch and closed season discards directed?	Linked	Linked	Linked	Linked	Linked	Linked
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Natural Mortality	High	High	High	Low	Low	Low
SS/SSmsy						
1962	0.044	0.033	0.026	0.042	0.030	0.022
1984	0.039	0.023	0.020	0.050	0.024	0.016
1998	0.312	0.121	0.062	0.445	0.178	0.065
Current (2001-2003)	0.512	0.223	0.118	0.706	0.320	0.127
F/Fmsy						
1962	3.166	3.747	4.777	2.985	3.661	4.577
1984	2.536	4.128	5.073	1.843	3.596	4.987
1998	1.409	2.391	3.665	1.187	1.961	3.314
Current (2001-2003)	1.142	1.737	2.357	0.942	1.459	2.246
tSPR						
1984	0.048	0.022	0.015	0.059	0.022	0.012
1999	0.250	0.099	0.041	0.309	0.137	0.047
2003	0.318	0.140	0.061	0.383	0.189	0.070

Table 4. Benchmark statistics for 1962-2003 gulfwide "Linked" ASAP runs.

Model Description	**Linked**	**Linked**	**Linked**	**Linked**	**Linked**	**Linked**
Shrimp bycatch and closed season discards directed?	Linked	Linked	Linked	Linked	Linked	Linked
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Natural Mortality	High	High	High	Low	Low	Low
Benchmark Statistic						
$F_{0.1}$	0.269	0.216	0.175	0.360	0.299	0.217
F_{MAX}	0.346	0.280	0.232	0.462	0.384	0.283
$F_{30\%SPR}$	0.403	0.327	0.272	0.543	0.452	0.334
$F_{40\%SPR}$	0.306	0.247	0.204	0.413	0.343	0.253
F_{MSY}	0.295	0.258	0.223	0.395	0.356	0.272
F_{2003}	0.337	0.449	0.526	0.372	0.519	0.612
SS_{MSY} (Millions)	95.5	74.3	59.4	132.8	102.6	85.4
$SS_{Current}$ (Mlillons)	48.8	16.6	7.0	93.8	32.9	10.8
MSY (Million Pounds)	18.9	28.1	38.7	16.5	23.3	38.0
R0 (Millions)	207.5	166.0	135.0	128.7	102.3	86.3
F_{2003}/F_{MSY}	1.142	1.737	2.357	0.942	1.459	2.246
SS_{2003}/SS_{MSY}	0.512	0.223	0.118	0.706	0.320	0.127
tSPR 2003	0.318	0.140	0.061	0.383	0.189	0.070
tSPR @ MSY	0.415	0.387	0.372	0.417	0.389	0.376

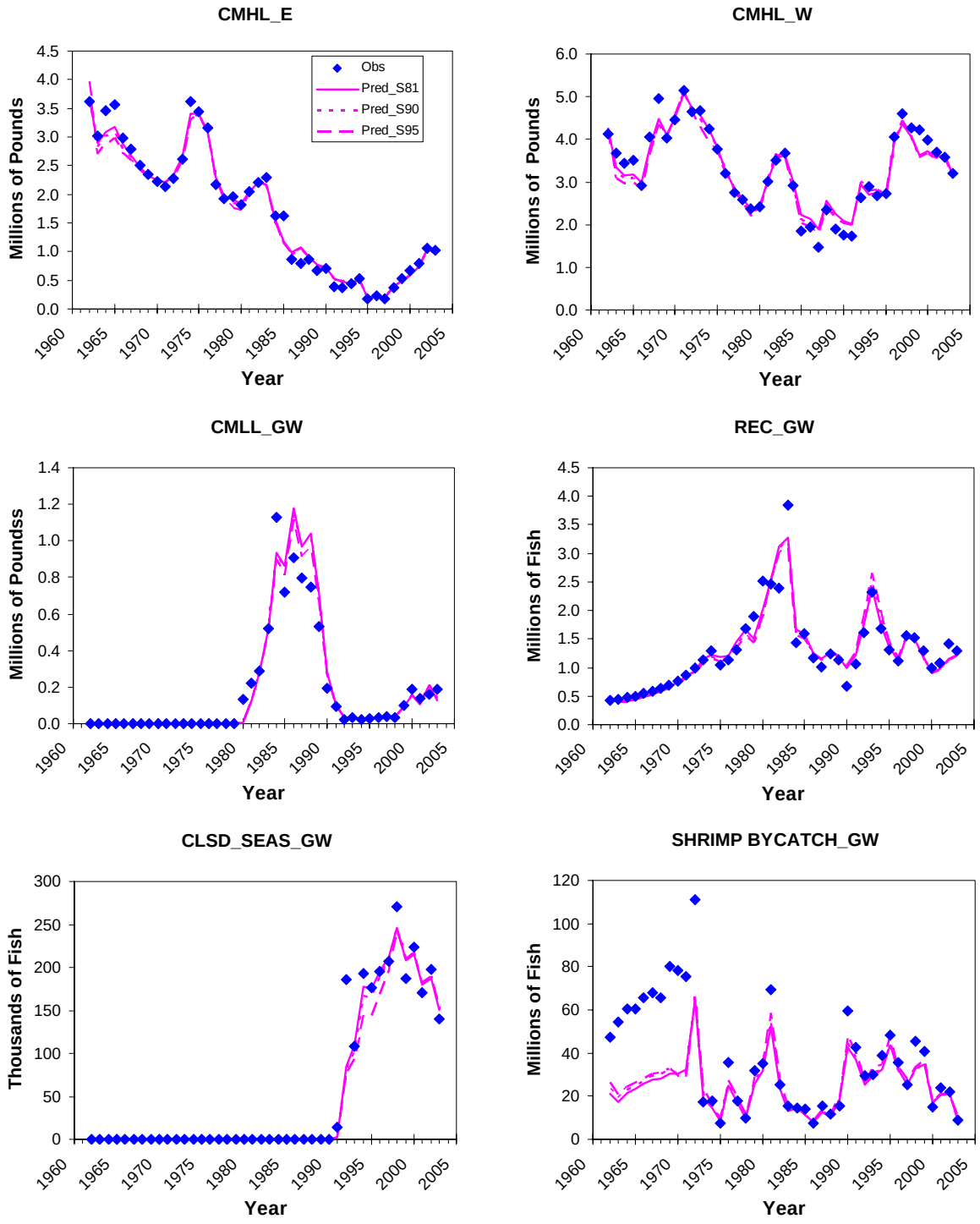

Figure 1. Fits to total catch by fleet for Current Shrimp, Unlinked, High Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line). Observed values are indicated with filled diamonds.

Fits to Catch Series for Current Shrimp, "Unlinked", Low M Runs

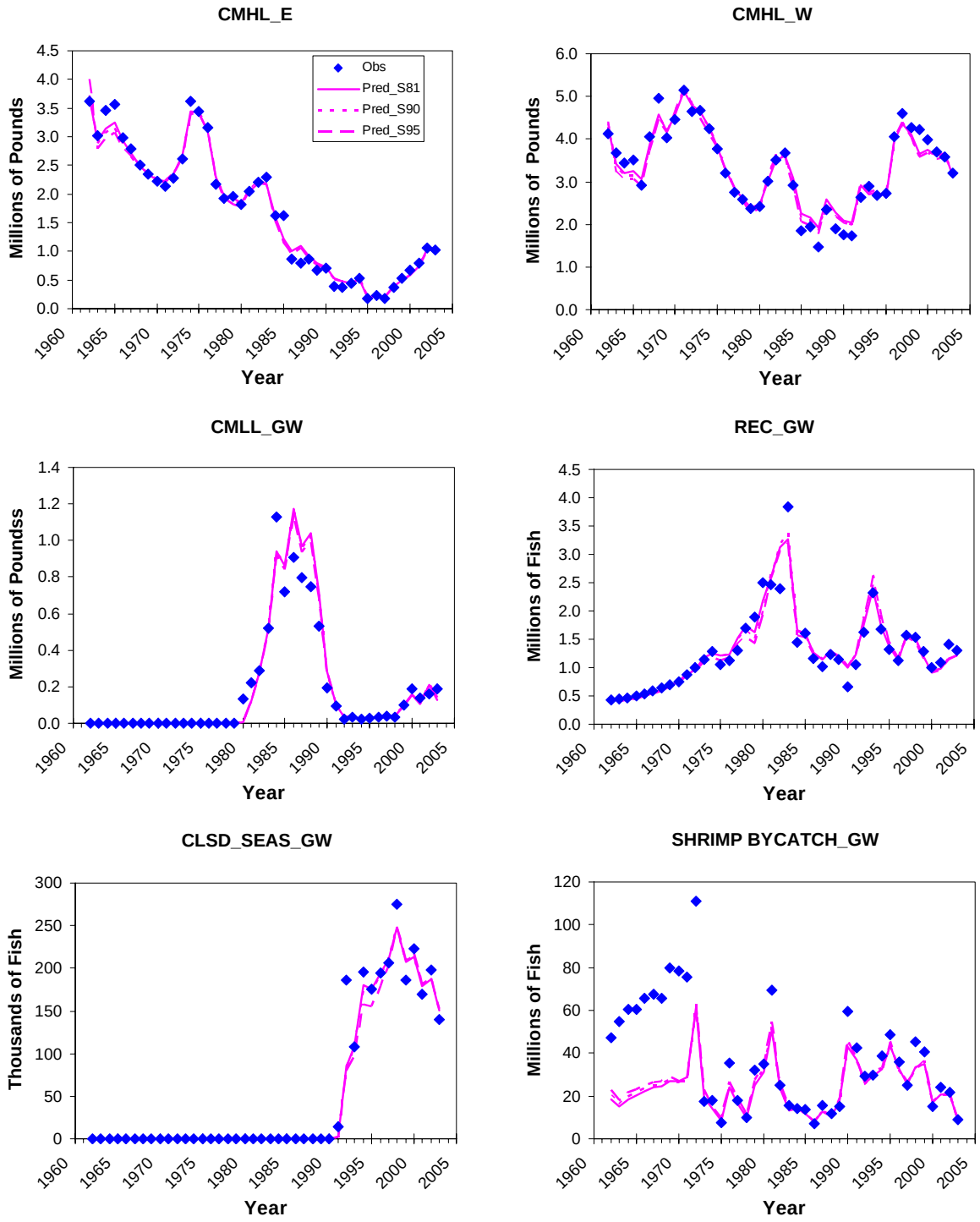

Figure 2. Fits to total catch by fleet for Current Shrimp, Unlinked, Low Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line). Observed values are indicated with filled diamonds.

Fits to Indices for Current Shrimp, "Unlinked", High M Runs

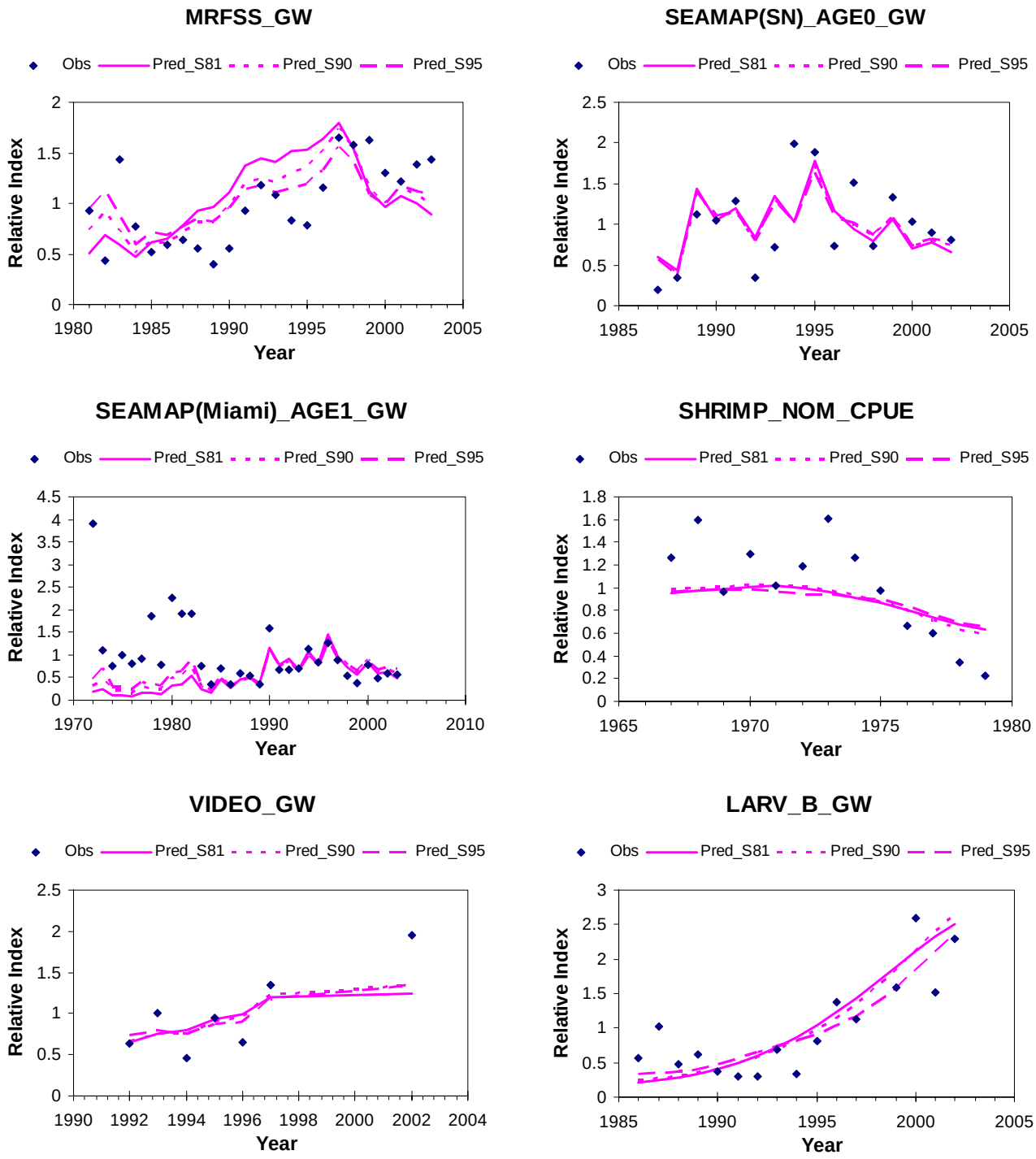

Figure 3. Fits to indices of abundance for Current Shrimp, Unlinked, High Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line). Observed values are indicated with filled diamonds.

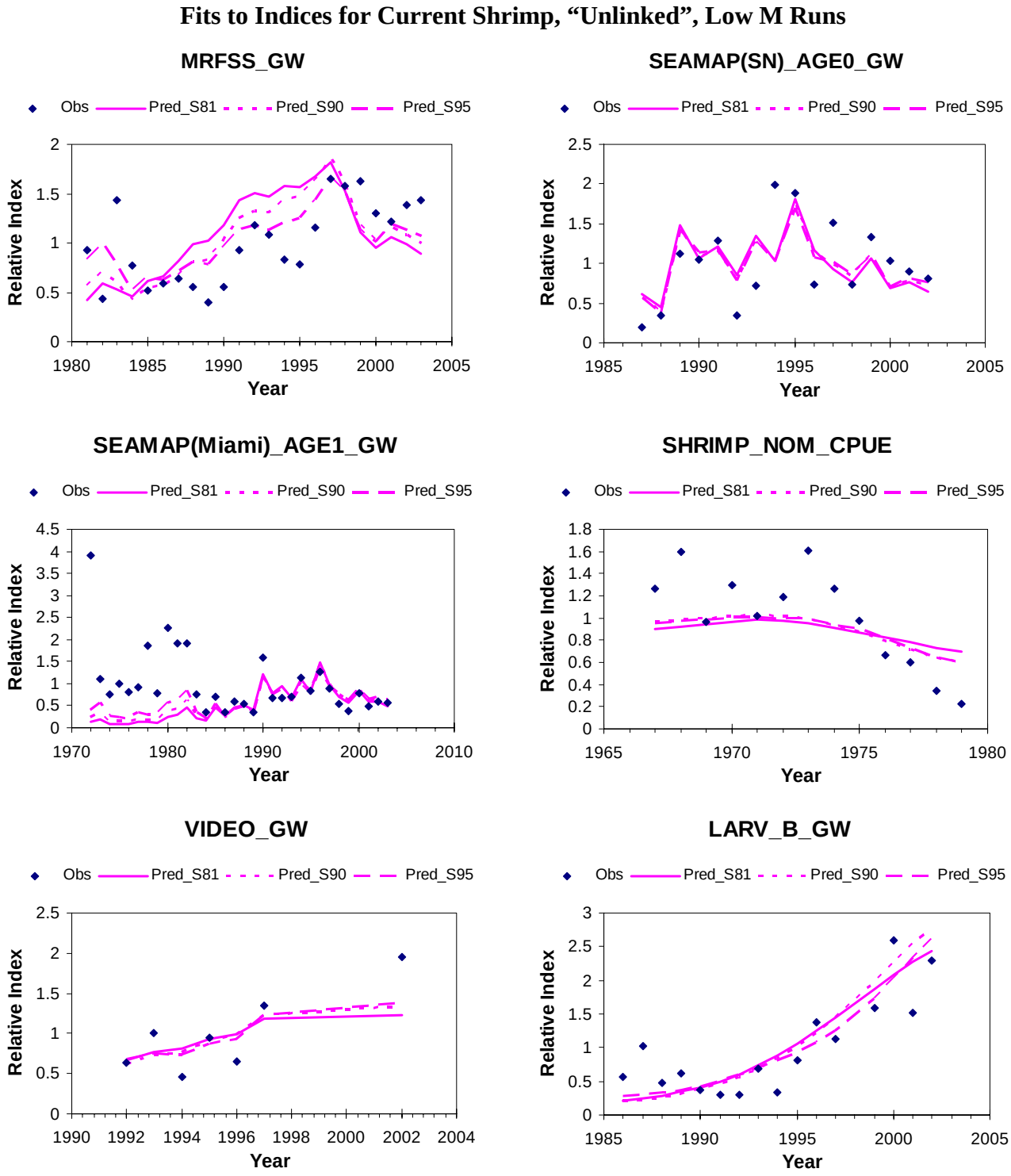

Figure 4. Fits to indices of abundance for Current Shrimp, Unlinked, Low Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line). Observed values are indicated with filled diamonds.

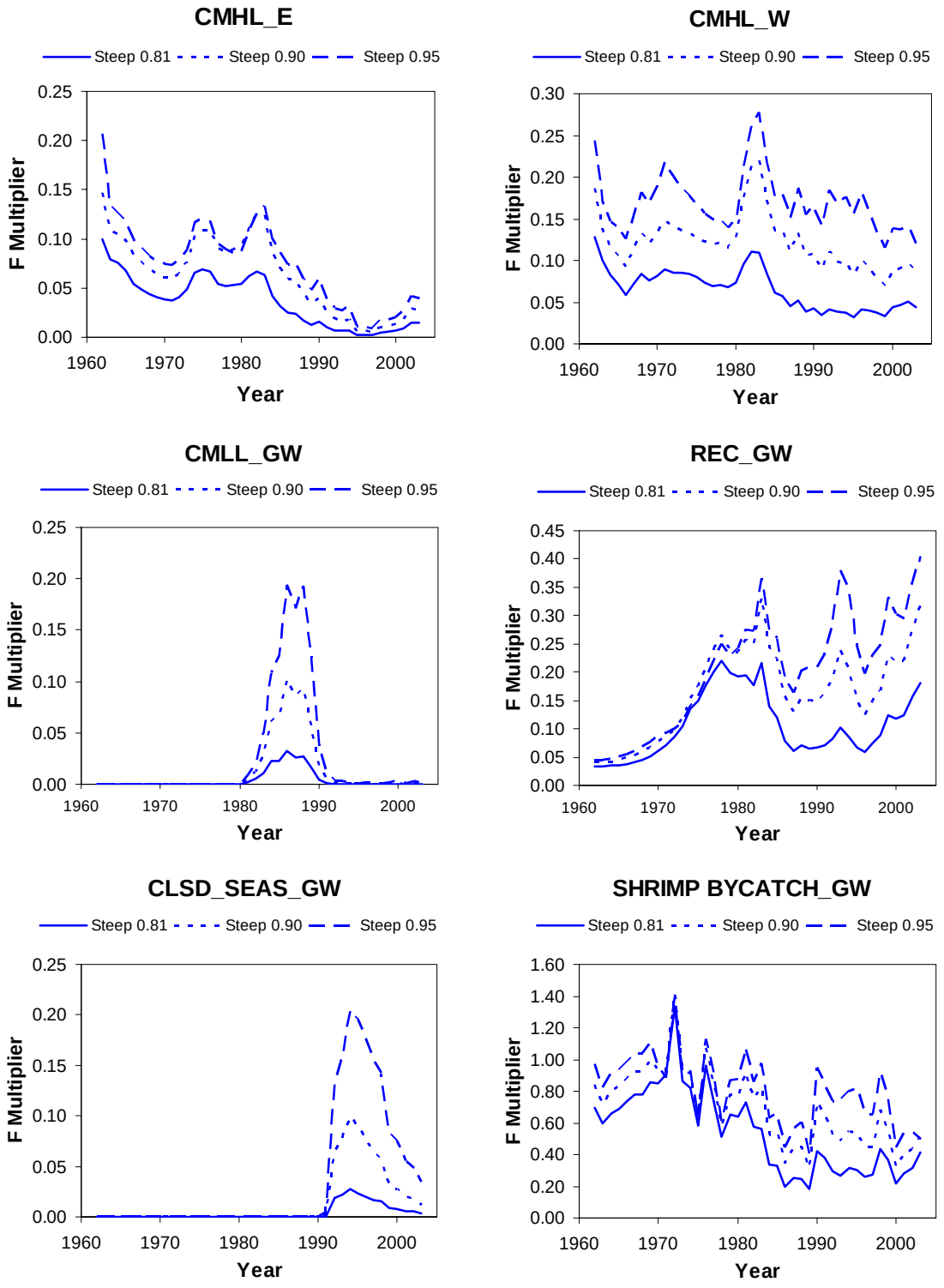

Figure 5. F-Multipliers by fleet for Current Shrimp, Unlinked, High Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line).

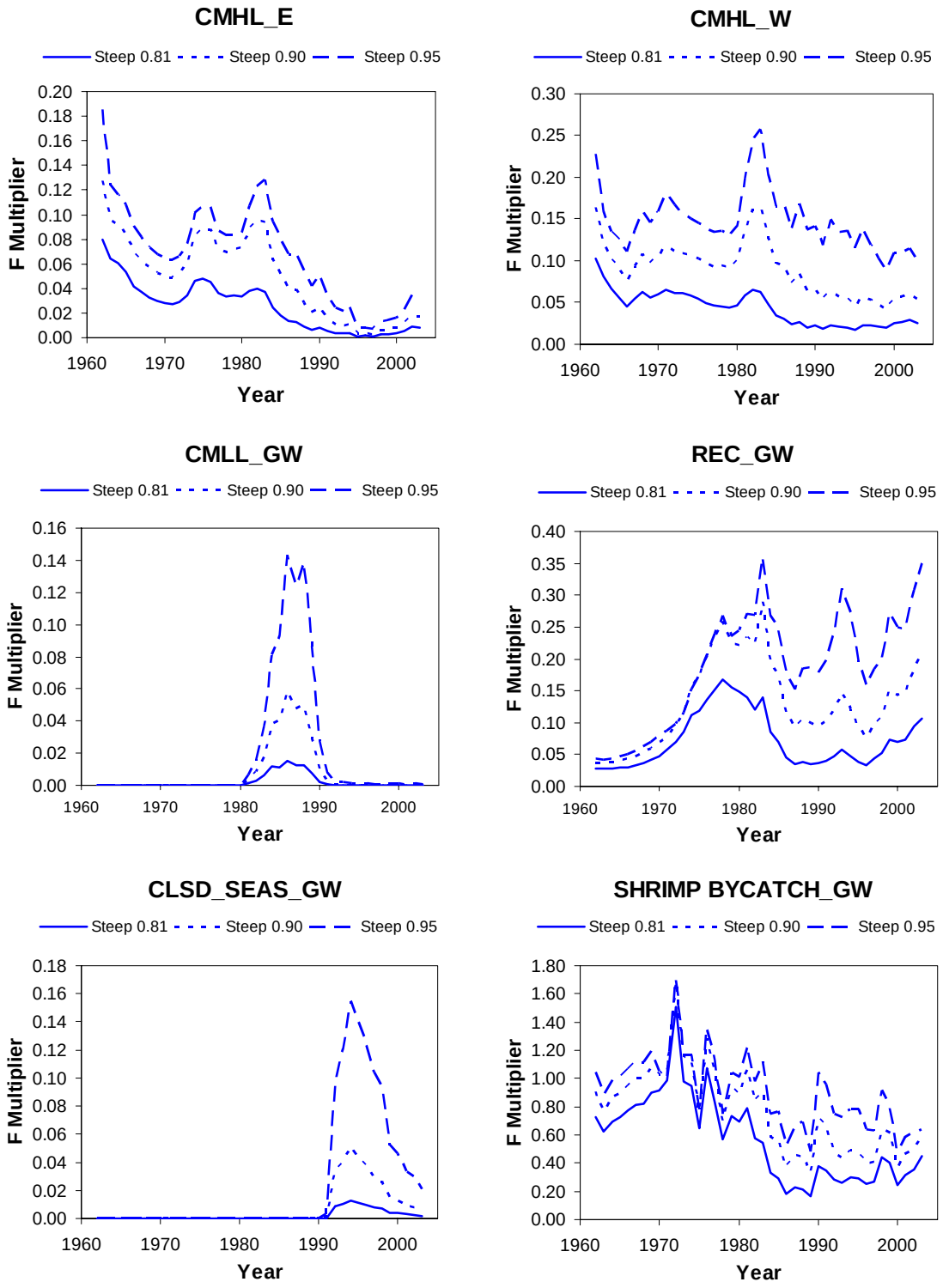

Figure 6. F-Multipliers by fleet for Current Shrimp, Unlinked, Low Natural Mortality runs at steepness 0.81 (solid line), 0.90 (dotted line) and 0.95 (dashed line).

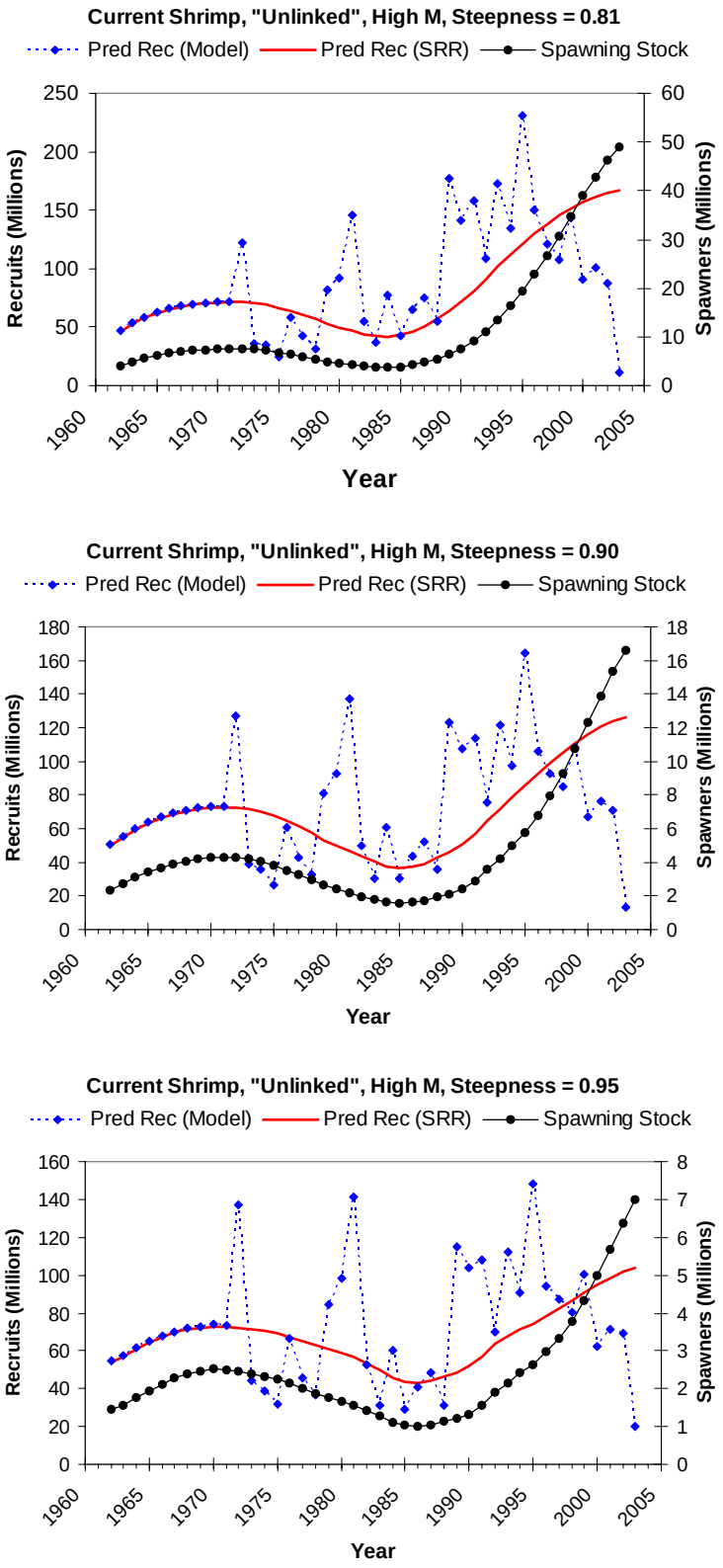

Figure 7. Spawning stock (black line with circles) and recruitment estimates for Current Shrimp, Unlinked, High Mortality runs at steepness = 0.81, 0.90 and 0.95. Recruitment estimates from the model are indicated with a blue dotted line and blue diamonds; Recruitment estimates from the spawner recruit relationship (SRR) are indicated with a red solid line.

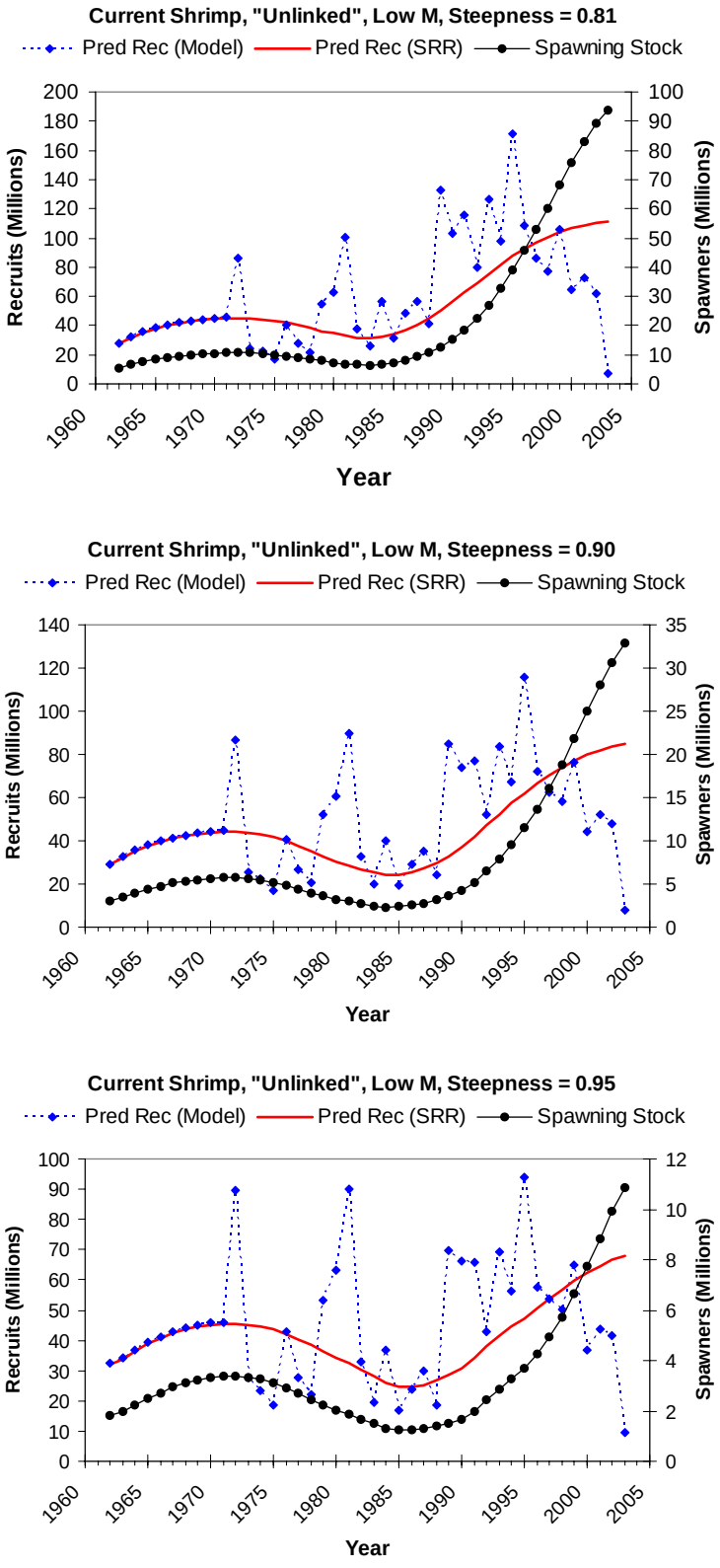

Figure 8. Spawning stock (black line with circles) and recruitment estimates for Current Shrimp, Unlinked, Low Mortality runs at steepness = 0.81, 0.90 and 0.95. Recruitment estimates from the model are indicated with a blue dotted line and blue diamonds; Recruitment estimates from the spawner recruit relationship (SRR) are indicated with a red solid line.

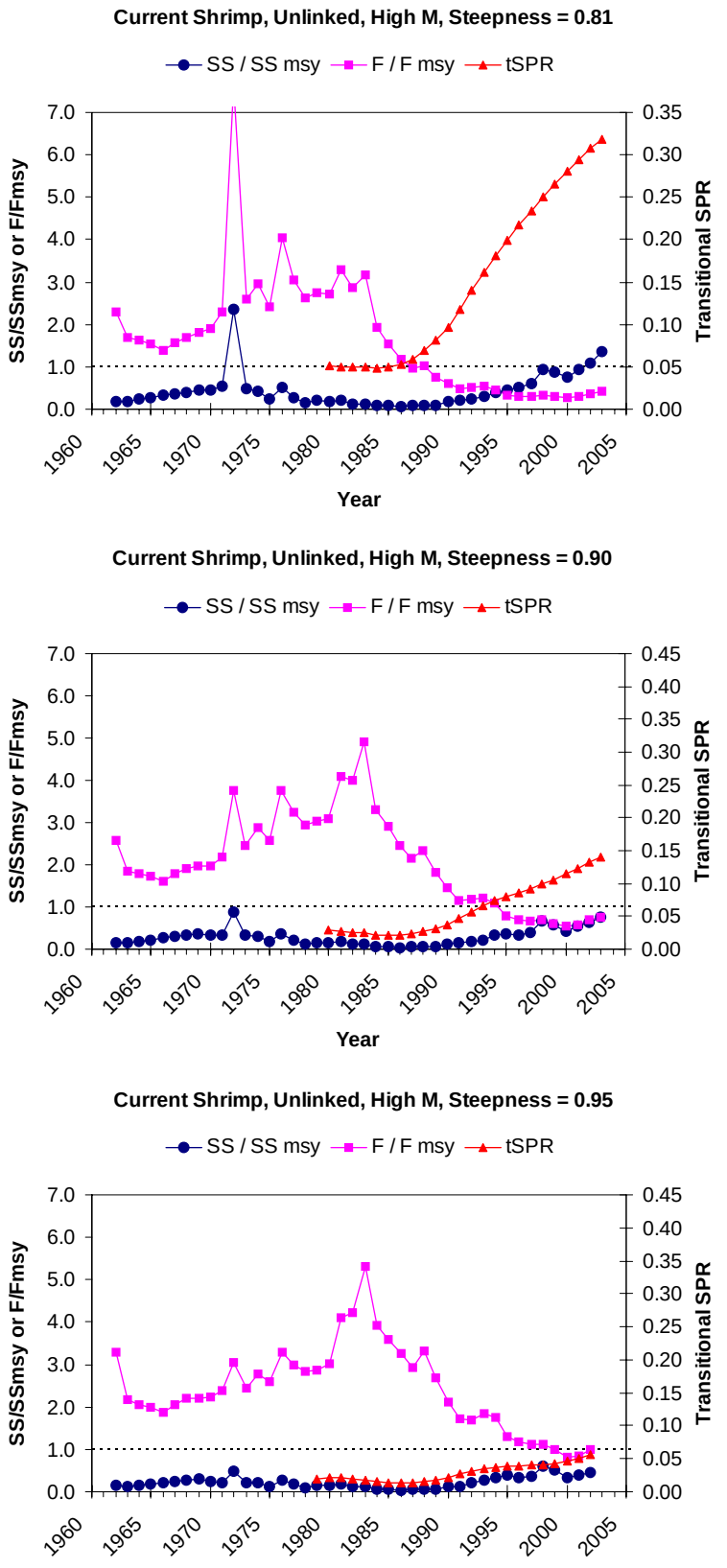

Figure 9. Trajectories of transitional spawning potential ratio (tSPR) and spawning stock (SS) and fishing mortality (F) as a fraction of SS_{MSY} and F_{MSY} for Current Shrimp, Unlinked, High M runs at steepness = 0.81, 0.90 and 0.95.

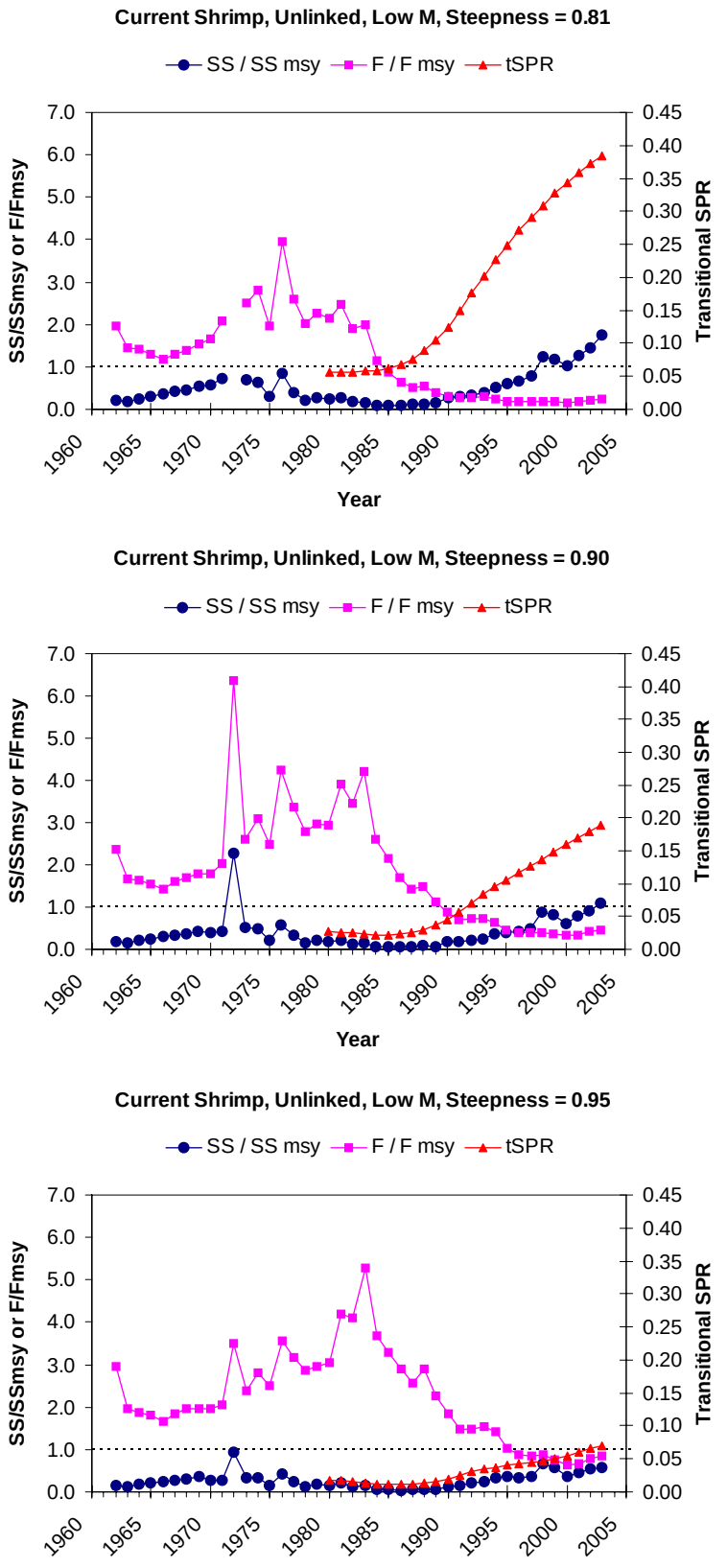

Figure 10. Trajectories of transitional spawning potential ratio (tSPR) and spawning stock (SS) and fishing mortality (F) as a fraction of SS_{MSY} and F_{MSY} for Current Shrimp, Unlinked, Low M runs at steepness = 0.81, 0.90 and 0.95.

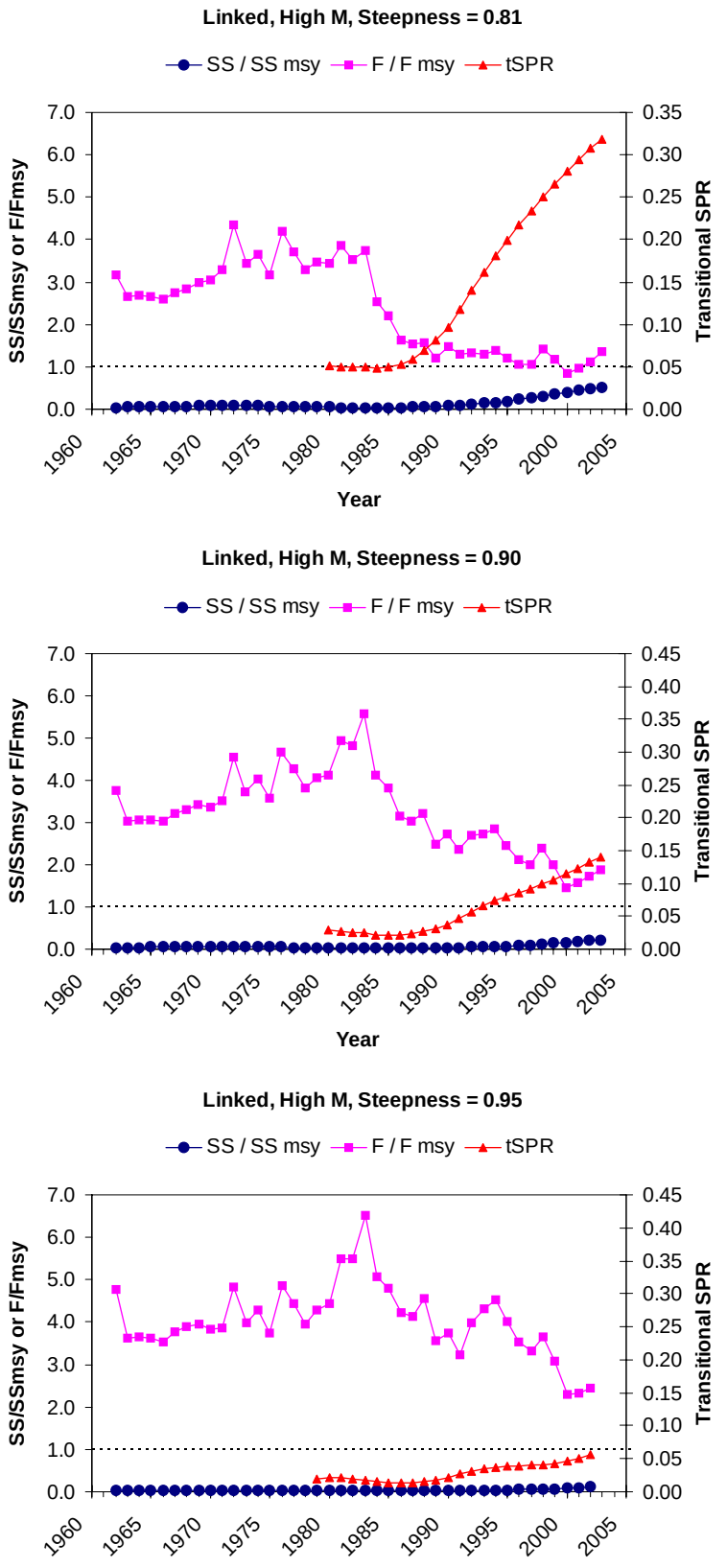

Figure 11. Trajectories of transitional spawning potential ratio (tSPR) and spawning stock (SS) and fishing mortality (F) as a fraction of SS_{MSY} and F_{MSY} for Linked, High M runs at steepness = 0.81, 0.90 and 0.95.

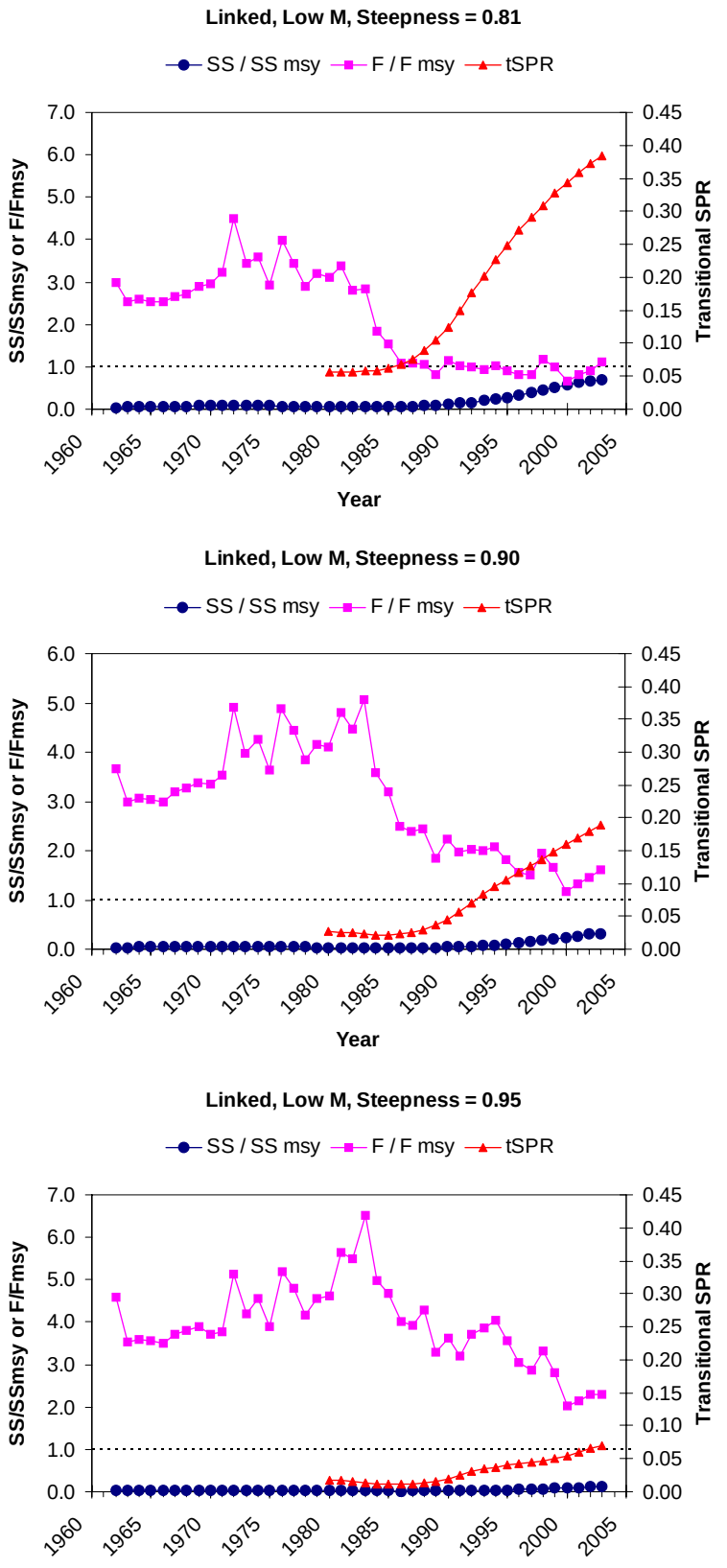

Figure 12. Trajectories of transitional spawning potential ratio (tSPR) and spawning stock (SS) and fishing mortality (F) as a fraction of SS_{MSY} and F_{MSY} for Linked, Low M runs at steepness = 0.81, 0.90 and 0.95.