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.

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 previous assessment allow ASAP to:

1. Accommodate two independent sets of age composition data for the directed component of each fleet (directly observed and modeled age comp).
2. Allow the relative F's of all fleets to be modified during projections, rather than just the non-directed fleets.
3. Accommodate total landings/discards in number or weight.
4. Allow tuning indices to be linked to spawning biomass (fecundity)
5. Allow different weight at age matrices to be used for the landings and discards of each fleet.
6. Accommodate year and fleet-specific CV's for total catch

In addition, projections now use the average estimated selectivity of the most recent three years and the parameter N_year1_devs uses natural mortality (M) in the initial year rather than total mortality (Z).

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, years selectivity was permitted to vary, etc.) used during the gulf-wide ASAP runs A-F are described in Appendix 1, runs G-L are described in Appendix 2. Parameter estimates, weightings and other model specifications are summarized in Appendix 3.

RESULTS AND DISCUSSION

PRELIMINARY RUNS

Exploratory analyses resulted in very high fishing mortality rates in the first year (1962) and very low stock size estimates for all but the youngest ages; stock sizes were then estimated to increase. These estimates were considered to be inconsistent with the magnitude of the catches taken in the 1950’s and early 1960s (Porch *et al*. 2004). A variety of changes to the index and catch weightings were explored to attempt to find model estimates more consistent with the history of the fishery. The only solution found was to assume age composition for each fishery from 1962-1971 (shrimp bycatch age composition was available from 1972).

During the initial run, raw estimates of the CVs on total catch were used (Table 1), and steepness was fixed at 0.81. The model fits to the catch series are summarized in Figure 1. The fit to the estimates of shrimp bycatch was poor. In every year 1962-2003, the predicted values were substantially less than the externally estimated values. Model runs at steepness 0.9, 0.95 and with steepness estimated also failed to fit the shrimp bycatch data to any acceptable degree.

Because of this lack of fit, all subsequent runs (Runs A-L) use re-weighted CVs on total catch (Table 2). In particular, the CVs on the shrimp bycatch (1962-2003) and the gulf-wide recreational landings (1962-2003) were reduced to yield model predicted values closer to those externally estimated.

DESCRIPTION OF RUNS AND ASSUMPTIONS ABOUT FLEETS PERTINENT TO REFERENCE POINT CALCULATIONS

Runs A-F were run using an assumption of “high” natural mortality on ages 0 and 1, M(0) = 0.98, M(1) = 0.59 and M(2-15+) = 0.1. Runs A-C 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. Runs D-F assume the shrimp fleet and the closed season 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. Runs D-F are otherwise identical to A-C. Fits to catches, indices, annual trends in F multipliers and annual trends in estimated spawning stock and recruitment are identical to the paired runs (A-C) with corresponding steepness.

Additional runs (G-L) were preformed to examine the effect of a lower estimate of natural mortality on ages 0 and 1, M(0) = 0.49, M(1) = 0.29 and M(2-15+) = 0.1. Like the “high mortality” models, runs G-I assume that all six fleets are effectively directed and jointly subject to management for the purpose of population projection, and runs J-L assume the shrimp fleet and the closed season fleets are not directed and effectively not subject to direct joint management effects for the purpose of projections. Runs G-L are otherwise identical to A-F.

RUN A (Steepness 0.81; M(1) = 0.59; No Undirected Fleets)

Run A used a steepness fixed at 0.81. The fits to the catch series are summarized in Figure 2. The fits to the shrimp bycatch and the eastern commercial handline landings are improved, but the model fits to shrimp bycatch during the years 1962-1971 are still 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 Porch and Turner (2004).

The model fits to the indices of abundance are acceptable (Fig. 3), 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.

Annual trends in the fleet specific F multipliers (the maximum age-specific value for each fleet) are summarized in Figure 4. The F multiplier associated with shrimp bycatch is considerably higher than the other fleets, and typically varies between 0.3 and 1.2. The highest values were observed during the 1970s and early 1980s and ranged from 0.6-1.2. Since 1984, F multipliers have remained below 0.6. The F multipliers of the other fleets are generally less than 0.1 , however the recreational fleet exceeded this value from the mid 1970s to the mid 1980s. A recent increase in the F multiplier of the recreational fishery is also quite notable, increasing from 0.13 in 1998 to 0.26 in 2003.

Predicted recruitment is summarized in Figure 5. 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. Run A results suggest that recruitment was higher than expected, given the stock recruitment relationship, from 1989-1996. These elevated recruitments then allowed the modeled spawning stock to rebuild during this interval. Since 2000, predicted recruitment has been substantially lower than expected. In fact, predicted recruitment in 2003 is the lowest in the time series.

Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are summarized in Figure 6. The results of Run A suggest that red snapper were already overfished, and that overfishing was occurring in 1962 ($SS_{1962}/SS_{MSY} = 0.05$; $F_{1962}/F_{MSY} = 2.9$). The population continued at low levels until 1990, when it began to recover. In 1990, spawning stock was 7% of SS_{MSY} and fishing mortality was 150% of F_{MSY}. By 2003, this model estimates spawning stock had increased to 44% of SS_{MSY} and fishing mortality still remained at around 150% of F_{MSY}. However, despite the increase in spawning stock, Run A results indicate that the red snapper stock continue under overfishing conditions in 2003. Benchmark statistics are summarized in Table 3 and indicate that MSY (yield to the commercial and recreational fisheries) was about 14 million pounds (mp), well above the current TAC of 9.8 mp.

The base projection (Fig. 7) was deterministic, and assumed a continuation of the current total allowable catch of 9.12 million pounds through 2032, and a reduction in shrimp effort of 40% in 2008. All fleets were specified as directed fisheries, and steepness was fixed at 0.81. The projection indicates that under this scenario, fishing mortality could decline to F_{MSY} levels in 2008, while spawning stock is projected to recover to SS_{MSY} in 2024. The results of this projection are also described in Table 5.

In addition, a set of projections were performed to examine the effect of various management decisions including a range of TAC from 0 to 12 million pounds concurrent with a 0% to 100% reduction in shrimp effort beginning in 2008 (Fig. 8). This model projects a constant catch just above 9.12 MP would achieve a transitional SPR of about 50% by 2032, without further reduction in shrimp effort. The projections also indicated that to achieve $SS/SS_{MSY} = 1.0$ by 2019, TAC must be reduced to five million pounds, or shrimp effort must be reduced by more than 90% (or a combination). However, the same goal can be achieved by 2032 without reducing either the TAC or shrimp effort.

Run B (Steepness 0.90; M(1) = 0.59; No Undirected Fleets)

Run B is identical to Run A, except that steepness was fixed at 0.90. The model fits to the catches are indistinguishable from those of Run A. Fits to indices are summarized in Figure 9. F multipliers by fleet are similar in trend to Run A, but all F multipliers are slightly higher (Fig. 10). Recent fishing mortalities for the shrimp bycatch are between 0.4 and 0.7, and recreational fishing mortality rises from 0.19 in 1990 to 0.46 in 2003.

The annual recruitment trend predicted by Run B is summarized in Figure 11. The results are quite similar to those of Run A. From 1989 to 1999 recruitment was higher than expected. These recruitments allowed concurrent recovery of the spawning stock. Since 2000, estimated recruitment has been substantially lower than the SRR predictions. Estimated recruitment in 2003 is the lowest in the time series.

Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are summarized in Figure 12. Run B results are similar in trend to Run A, but are less optimistic. The fishery was in poor condition in 1962 ($SS_{1962}/SS_{MSY} = 0.04$; $F_{1962}/F_{MSY} = 3.6$). The recovery that began in 1990 is also less dramatic than in Run A. In 1990, spawning stock was 3% of SS_{MSY} and fishing mortality was 300% of F_{MSY}. By 2003, spawning stock had increased to 18% of SS_{MSY} and fishing mortality had decreased to 243% of F_{MSY}. In 2003, estimated transitional SPR was approximately 11%. Run B results indicate that red snapper continues to be overfished, and overfishing is ongoing. Benchmark statistics are summarized in Table 3.

The base projection (Fig 13) was identical to Run A, except with steepness fixed at 0.90. The projection indicates that fishing mortality could decline to F_{MSY} levels in 2013, while spawning stock is projected to recover to SS_{MSY} in 2028. Transitional SPR increases from about 11% in 2003 to 55% by 2032. The results of this projection are also described in Table5.

The management scenario projections (Fig. 14) indicated that with the present TAC, a transitional SPR greater than 40% can be achieved by 2032, without reducing shrimp fleet effort. To achieve $SS/SS_{MSY} = 1.0$ by 2032, TAC must be reduced to less than nine million pounds, or shrimp effort must be reduced approximately 10% (or a combination).

Run C (Steepness 0.95; M(1) = 0.59; No Undirected Fleets)

Run C is identical to Runs A and B, except that steepness was fixed at 0.95. The model fits to the catches are nearly identical to the previous runs at steepness 0.81 and 0.9 (Fig. 2). Fits to the indices of abundance (Fig. 15) are acceptable. F multipliers by fleet are similar in trend to Runs A and B, but the F multipliers are higher yet (Fig. 16). Recent fishing mortalities for the shrimp bycatch are between 0.5 and 1.0, and recreational fishing mortality rises from 0.26 in 1990 to 0.63 in 2003.

The annual trend in recruitment predicted by Run C is similar to the previous runs (Fig 17). However, the rebuilding of the spawning stock in the 1990's is much lower than the previous runs, and is also a smaller fraction of SS_{MSY} (Fig. 18). From 1989 to 1999 recruitment was higher than expected, but due to the weak S/R relationship at steepness 0.95, the increase in spawning stock is more moderate. Like previous runs, recruitment has been lower than predicted by the SRR since 2000, and the lowest estimated recruitment occurs in 2003.

Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are the most pessimistic of these three runs (Fig. 18). Estimated stock condition in 1962 is similar to the previous runs ($SS_{1962}/SS_{MSY} = 0.04$; $F_{1962}/F_{MSY} = 4.6$), but recovery since that time has been more modest. In 1990, spawning stock was 2% of SS_{MSY} and fishing mortality was 400% of F_{MSY}. By 2003, spawning stock increased to 8% of SS_{MSY}, and fishing mortality continued to greatly exceed F_{MSY} ($F/F_{MSY} = 3.54$). Like the previous runs, Run C indicates that red snapper are overfished, and that overfishing continues. Benchmark statistics are summarized in Table 3.

The projection (Fig. 19) was identical to the previous runs, except that steepness was fixed at 0.95. The projection indicates that current harvest cannot be maintained, even if shrimp effort is reduced by 40% in 2008. Projected yield drops to zero between 2018 and 2032. Transitional SPR decreases from 3.9% in 2003 to essentially zero in 2020. The results of this projection are summarized in Table 5.

The management scenario projections (Fig. 20) indicate that, at steepness 0.95, to achieve a transitional SPR greater than 40% by 2032, a combination of TAC and shrimp effort reductions is required. For example, a TAC of approximately 7 MP with no shrimp effort reduction, but no more than 9.5 MP in combination with elimination of shrimp effort would achieve 40% SPR by 2032. To achieve $SS/SS_{MSY} = 1.0$ by 2032, TAC must be reduced to less than seven million pounds, or shrimp effort must be reduced by more than 60% (or a combination).

Run D (Steepness 0.81; M(1) = 0.59; 2 Undirected Fleets)

Runs Run D assumed a fixed steepness of 0.81. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} one of the most optimistic of any run (Fig.21). Run D indicates that the fishery was overfished in 1962, and that overfishing was occurring ($SS_{1962}/SS_{MSY} = 0.14$; $F_{1962}/F_{MSY} = 2.1$). However, according to this run, the stock is currently not overfished and not undergoing overfishing ($F_{CURRENT}$ has been less than F_{MSY} since 1989, and the spawning stock recovered to $SS/SS_{MSY} > 1.0$ in 2003 ($SS_{2003}/SS_{MSY} = 1.27$; $F_{2003}/F_{MSY} = 0.57$)). Benchmark statistics are summarized in Table 3.

The base projection (TAC = 9.12 million pounds 2004-2032, 40% reduction in shrimp effort in 2008) allows the spawning stock to increase to nearly 191% of SS_{MSY} by 2032. Transitional SPR increases from 29% in 2003 to about 47% by 2032, while $F_{2032}/F_{MSY} = 0.2$. The results of this projection are described in Table 6 and Figure 22.

The management scenario projections (Fig. 23) indicate that maintaining $SS/SS_{MSY} > 1.0$ through 2032 is possible without a reduction in current TAC or shrimp effort. But, to achieve a transitional SPR > 40% by 2032 requires a reduction of TAC to less than 5 MP or a reduction in shrimp fleet effort of about 25% (or a combination).

Run E (Steepness 0.90; M(1) = 0.59; 2 Undirected Fleets)

Run E assumed a fixed steepness of 0.90. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 24. Stock status in 1962 was poor, ($SS_{1962}/SS_{MSY} = 0.16$; $F_{1962}/F_{MSY} = 2.5$). Stock condition remained depleted through 1990 with SS_{1990}/SS_{MSY} was approximately 0.2 and $F_{1990}/F_{MSY} = 1.4$, then began to recover rapidly. In 2003, spawning stock was 79% of SS_{MSY}, and fishing mortality was 115% of F_{MSY}. Benchmark statistics are summarized in Table 3.

At steepness 0.90, the base projection indicates that fishing mortality could decline to F_{MSY} levels in 2009, while spawning stock is projected to recover to SS_{MSY} in 2022. However, transitional SPR values remain low through 2032, increasing from 11% in 2003 to about 30% in 2032. The results of this projection are described in Table 6 and Figure 25.

The management scenario projections (Fig. 26) indicate that, at steepness 0.90 transitional SPR values greater than 40% can only be achieved with substantial reductions in TAC and shrimp fleet effort. However, reaching and maintaining $SS/SS_{MSY} > 1.0$ through 2032 is possible without reducing TAC or shrimp effort.

Run F (Steepness 0.95; M(1) = 0.59; 2 Undirected Fleets)

Run F used a steepness fixed at 0.95. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are summarized in Figure 27. In 1962, spawning stock was 20% of SS_{MSY}, and F was 320% of F_{MSY}. By 1990, spawning stock had declined to 12% of SS_{MSY} despite a small reduction in F/F_{MSY}. The stock has recovered substantially since 1990. In 2003, spawning stock was 46% of SS_{MSY} though fishing mortality continued to exceed F_{MSY} ($F/F_{MSY} = 1.91$), and transitional SPR in 2003 was estimated at 3.9%. Benchmark statistics are summarized in Table 3.

At steepness 0.95, the base projection indicates that current removals will lead to a stock recovery, with shrimp effort reduction of 40% in 2008. Spawning stock is projected to be 68% of SS_{MSY} in 2032. Transitional SPR increases from 3.9% in 2003 to 11% in 2032, while F decreases to the F_{MSY} level by 2026 and continues decreasing to be only 59% of F_{MSY} by 2032. The results of this projection are described in Table 6 and Figure 28.

The management scenario projections (Fig. 29) indicate that, at steepness 0.95, it is not possible to achieve a transitional SPR greater than 40% by 2032 without reducing shrimp fleet effort by at least 50%. For example, at the present level of TAC, SPR greater than 40% can only be achieved by reducing shrimp fleet effort by more than 75% and a reduction of TAC to less than 1 MP still requires shrimp effort to be reduced to about 50%. To rebuild spawning stock to SS_{MSY} by 2032 requires to reduce TAC to less than 7 MP or shrimp fleet effort by around 70% (or a combination).

Run G (Steepness 0.81; M(1) = 0.29; No Undirected Fleets)

Run G used a steepness fixed at 0.81. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 34. According to run F, in 1962 the stock was in extremely poor condition with the spawning stock at only 2% of SS_{MSY} and F at 278% of F_{MSY}. Conditions remained poor until 1990 when a period of rapid recovery began. In 2003 spawning stock was 61% of SS_{MSY} and $F_{2003}/F_{MSY} = 1.04$. Benchmark statistics are summarized in Table 4.

At steepness 0.81, the base projection indicates that current removals will also lead to a stock recovery, with shrimp effort reduction of 40% in 2008. Spawning stock is projected to reach SS_{MSY} level in 2018 and 168% of SS_{MSY} in 2032. Transitional SPR increases from 37% in 2003 to 71% in 2032, while F decreases to the F_{MSY} level by 2004 and continues decreasing to be only 22% of F_{MSY} by 2032. The results of this projection are described in Table 7 and Figure 35.

Management projections (Fig. 36) show that achieving a transitional SPR greater than 40% and $SS/SS_{MSY} > 1$ by 2032 require no additional reduction of either TAC or shrimp fleet effort. As a matter of fact, those goals are already achieved by 2019 with initial levels of TAC and shrimp fleet effort.

Run H (Steepness 0.90; M(1) = 0.29; No Undirected Fleets)

Run H used a steepness fixed at 0.90. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 40. Like the previous run, the stock in 1962 was also in poor condition ($SS_{1962}/SS_{MSY} = 0.03$; $F_{1962}/F_{MSY} = 3.5$). Although a period of recovery started in 1990, by 2003 the stock still remained in poor condition with spawning stock at only 23% of SS_{MSY} and $F_{2003}/F_{MSY} = 1.9$. Benchmark statistics are summarized in Table 4.

The base projections indicates that $SS = SS_{MSY}$ in 2024 and by 2032 $SS_{2032}/SS_{MSY} = 1.6$, F decreases to F_{MSY} levels by 2009 and in 2032 F_{2032}/F_{MSY} is only 0.18; while transitional SPR increases from 15% in 2003 to 64% in 2032. The results of this projection are described in Table 7 and Figure 41.

Like in the previous run, a transitional SPR greater than 40% and $SS/SS_{MSY} > 1$ can be achieved by 2032 without any additional reductions in TAC and shrimp effort (Fig. 42).

Run I (Steepness 0.95; M(1) = 0.29; No Undirected Fleets)

Run I used a steepness fixed at 0.95. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 46. Similar to run H, the stock in 1962 was also in very poor condition ($SS_{1962}/SS_{MSY} = 0.03$; $F_{1962}/F_{MSY} = 4.4$). Once again, a period of recovery started in 1990, but by 2003 the stock still remained in very poor condition with spawning stock at only 8% of SS_{MSY} and $F_{2003}/F_{MSY} = 3.1$. Benchmark statistics are summarized in Table 4.

The base projections shows a recovery of the stock by year 2032 with $SS_{2032}/SS_{MSY} = 1.5$ and $F_{2032}/F_{MSY} = 0.13$, while transitional SPR increases from 5% in 2003 to 59% in 2032. The results of this projection are described in Table 7 and Figure 47.

Management projections show that a transitional SPR greater than 40% and $SS/SS_{MSY} > 1$ can be achieved by 2032 without any additional reductions in TAC and shrimp effort (Fig. 48).

Run J (Steepness 0.81; M(1) = 0.29; 2 Undirected Fleets)

Run J used a steepness fixed at 0.81. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 49. Like the previous runs, the stock in 1962 was overfished and undergoing overfishing ($SS_{1962}/SS_{MSY} = 0.11$; $F_{1962}/F_{MSY} = 1.9$). Once again, a period of recovery started in 1990, by 2003 the stock was not overfished or under overfishing conditions ($SS_{2003}/SS_{MSY} = 1.4$ and $F_{2003}/F_{MSY} = 0.25$). Benchmark statistics are summarized in Table 4.

At steepness 0.81, the base projection indicates that current removals with shrimp effort reduction of 40% in 2008 will also lead to a stock recovery. $F/F_{MSY} = 1$ by 1985 and F continues to decrease to 10% of F_{MSY} by 2032, while the recovery year for the spawning stock is 2001 and $SS_{2032}/SS_{MSY} = 2.28$. The transitional SPR showed an increase from 2003 (tSPR=0.37) to 2032 (tSPR=0.58). The results of this projection are described in Table 8 and Figure 50.

Management projections (Fig. 51) show that without reducing TAC or shrimp fleet effort, transitional SPR will be > 0.5 in 2032 and $SS_{2032}/SS_{MSY} > 2.1$.

Run K (Steepness 0.90; M(1) = 0.29; 2 Undirected Fleets)

Run K used a steepness fixed at 0.90. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 52. Once again, the red snapper stock was in poor condition in 1962 with $SS_{1962}/SS_{MSY} = 0.12$ and $F_{1962}/F_{MSY} = 2.34$. A recovery period started in 1990 and by 2003 the stock was not overfished or undergoing overfishing ($SS_{2003}/SS_{MSY} = 0.9$ and $F_{2003}/F_{MSY} = 0.64$). Benchmark statistics are summarized in Table 4.

Base projections under a fixed steepness at 0.9 and 40% shrimp effort reduction by 2008 showed that recovery year 2017 and 1991 for spawning stock and F, respectively. By 2032, SS/SS_{MSY} increases to 2.07 and F/F_{MSY} decreases to 0.15. The transitional SPR increases from 15% in 2003 to 38% in 2032. The results of this projection are described in Table 8 and Figure 53.

The management projections of run K show that to achieve a transitional SPR > 0.4 in year 2032, shrimp fleet effort has to be reduced at least by 25% if TAC is reduced to < 2 MP or up to 40% if not reduction in TAC is applied. In contrast, no reduction of TAC and shrimp fleet effort achieves $SS_{2032}/SS_{MSY} > 2.1$ (Fig. 54).

Run L (Steepness 0.95; M(1) = 0.29; 2 Undirected Fleets)

Run L used a steepness fixed at 0.95. Annual trends in yield, MSY, spawning stock (SS), SS_{MSY}, F and F_{MSY} are shown in Figure 55. Once again, the red snapper stock was in poor condition in 1962 with $SS_{1962}/SS_{MSY} = 0.15$ and $F_{1962}/F_{MSY} = 2.9$. A recovery period started in

1990 and by 2003 the stock was not overfished but still undergoing overfishing (SS_{2003}/SS_{MSY} = 0.5 and F_{2003}/F_{MSY} = 1.4). Benchmark statistics are summarized in Table 4.

Base projections under a fixed steepness at 0.95 and 40% shrimp effort reduction by 2008 show a recovery of the red snapper stock by 2032 (SS_{2032}/SS_{MSY} = 1.8 and F_{2032}/F_{MSY} = 0.2). As a matter of fact, the projections estimate recovery year for the spawning stock to be 2022 and for F 2011. The results of this projection are described in Table 8 and Figure 56.

Management projections (Fig. 57) show that $tSPR_{2032}$ can only be achieved by drastically reducing shrimp effort by more than 50% while current levels of TAC and shrimp effort will produce $SS_{2032}/SS_{MSY} > 1$.

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Table 1. Raw coefficients of variation (CVs) on total catch by fleet and year.

	CMHL-E	CMHL-W	CMLL-GW	REC-GW	CLSD-SEAS-GW	SHRIMP-GW
1962	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1963	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1964	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1965	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1966	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1967	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1968	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1969	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1970	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1971	0.1000	0.1000	0.1000	0.3770	0.1000	1.0801
1972	0.1000	0.1000	0.1000	0.3770	0.1000	0.8329
1973	0.1000	0.1000	0.1000	0.3770	0.1000	0.6120
1974	0.1000	0.1000	0.1000	0.3770	0.1000	0.3835
1975	0.1000	0.1000	0.1000	0.3770	0.1000	0.7577
1976	0.1000	0.1000	0.1000	0.3770	0.1000	0.2321
1977	0.1000	0.1000	0.1000	0.3770	0.1000	0.2463
1978	0.1000	0.1000	0.1000	0.3770	0.1000	0.3740
1979	0.1000	0.1000	0.1000	0.3770	0.1000	0.9263
1980	0.1000	0.1000	0.1000	0.3770	0.1000	0.3367
1981	0.1000	0.1000	0.1000	0.1612	0.1000	0.7797
1982	0.1000	0.1000	0.1000	0.2835	0.1000	0.8346
1983	0.1000	0.1000	0.1000	0.3305	0.1000	0.8939
1984	0.1000	0.1000	0.1000	0.3770	0.1000	0.8866
1985	0.1000	0.1000	0.1000	0.2113	0.1000	0.8740
1986	0.1000	0.1000	0.1000	0.1230	0.1000	0.8864
1987	0.1000	0.1000	0.1000	0.1466	0.1000	0.8850
1988	0.1000	0.1000	0.1000	0.1313	0.1000	0.8739
1989	0.1000	0.1000	0.1000	0.1479	0.1000	0.8571
1990	0.1000	0.1000	0.1000	0.1600	0.1000	0.8827
1991	0.1000	0.1000	0.1000	0.1952	0.5000	0.9040
1992	0.1000	0.1000	0.1000	0.1210	0.5000	0.2171
1993	0.1000	0.1000	0.1000	0.1184	0.5000	0.1329
1994	0.1000	0.1000	0.1000	0.0877	0.5000	0.1751
1995	0.1000	0.1000	0.1000	0.1410	0.5000	0.2563
1996	0.1000	0.1000	0.1000	0.1286	0.5000	0.7317
1997	0.1000	0.1000	0.1000	0.1412	0.5000	0.4177
1998	0.1000	0.1000	0.1000	0.1192	0.5000	0.4680
1999	0.1000	0.1000	0.1000	0.1142	0.5000	0.2996
2000	0.1000	0.1000	0.1000	0.1178	0.5000	0.2319
2001	0.1000	0.1000	0.1000	0.1139	0.5000	0.2603
2002	0.1000	0.1000	0.1000	0.1199	0.5000	0.1337
2003	0.1000	0.1000	0.1000	0.1147	0.5000	0.2736

Table 2. Re-weighted coefficients of variation (CVs) on total catch by fleet and year. Shaded values have been re-weighted.

	CMHL-E	CMHL-W	CMLL-GW	REC-GW	CLSD-SEAS-GW	SHRIMP-GW
1962	0.1	0.1	0.1	0.15	0.1	0.1
1963	0.1	0.1	0.1	0.15	0.1	0.1
1964	0.1	0.1	0.1	0.15	0.1	0.1
1965	0.1	0.1	0.1	0.15	0.1	0.1
1966	0.1	0.1	0.1	0.15	0.1	0.1
1967	0.1	0.1	0.1	0.15	0.1	0.1
1968	0.1	0.1	0.1	0.15	0.1	0.1
1969	0.1	0.1	0.1	0.15	0.1	0.1
1970	0.1	0.1	0.1	0.15	0.1	0.1
1971	0.1	0.1	0.1	0.15	0.1	0.1
1972	0.1	0.1	0.1	0.15	0.1	0.1
1973	0.1	0.1	0.1	0.15	0.1	0.1
1974	0.1	0.1	0.1	0.15	0.1	0.1
1975	0.1	0.1	0.1	0.15	0.1	0.1
1976	0.1	0.1	0.1	0.15	0.1	0.1
1977	0.1	0.1	0.1	0.15	0.1	0.1
1978	0.1	0.1	0.1	0.15	0.1	0.1
1979	0.1	0.1	0.1	0.15	0.1	0.1
1980	0.1	0.1	0.1	0.15	0.1	0.1
1981	0.1	0.1	0.1	0.15	0.1	0.1
1982	0.1	0.1	0.1	0.15	0.1	0.1
1983	0.1	0.1	0.1	0.15	0.1	0.1
1984	0.1	0.1	0.1	0.15	0.1	0.1
1985	0.1	0.1	0.1	0.15	0.1	0.1
1986	0.1	0.1	0.1	0.15	0.1	0.1
1987	0.1	0.1	0.1	0.15	0.1	0.1
1988	0.1	0.1	0.1	0.15	0.1	0.1
1989	0.1	0.1	0.1	0.15	0.1	0.1
1990	0.1	0.1	0.1	0.15	0.1	0.1
1991	0.1	0.1	0.1	0.15	0.1	0.1
1992	0.1	0.1	0.1	0.15	0.1	0.1
1993	0.1	0.1	0.1	0.15	0.1	0.1
1994	0.1	0.1	0.1	0.15	0.1	0.1
1995	0.1	0.1	0.1	0.15	0.1	0.1
1996	0.1	0.1	0.1	0.15	0.1	0.1
1997	0.1	0.1	0.1	0.15	0.1	0.1
1998	0.1	0.1	0.1	0.15	0.1	0.1
1999	0.1	0.1	0.1	0.15	0.1	0.1
2000	0.1	0.1	0.1	0.15	0.1	0.1
2001	0.1	0.1	0.1	0.15	0.1	0.1
2002	0.1	0.1	0.1	0.15	0.1	0.1
2003	0.1	0.1	0.1	0.15	0.1	0.1

Table 3. Benchmark Statistics for 1962-2003 gulf-wide "high" natural mortality (M1 = 0.59) ASAP treatments.

Model Description	**Run A**	**Run B**	**Run C**	**Run D**	**Run E**	**Run F**
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Shrimp bycatch and closed season discards directed?	Directed	Directed	Directed	Undirected	Undirected	Undirected
Benchmark Statistic						
$F_{0.1}$	0.264	0.213	0.165	0.234	0.211	0.180
F_{MAX}	0.339	0.276	0.217	0.315	0.287	0.248
$F_{30\%SPR}$	0.386	0.311	0.241	0.101	0.011	0.000
$F_{40\%SPR}$	0.294	0.236	0.182	0.034	0.000	0.000
F_{MSY}	0.299	0.266	0.218	0.187	0.194	0.188
F_{2003}	0.460	0.645	0.772	0.106	0.223	0.360
SS_{MSY}	8.67E+07	6.25E+07	4.80E+07	3.01E+07	1.44E+07	8.14E+06
SS_{2003}	3.83E+07	1.14E+07	3.72E+06	3.83E+07	1.14E+07	3.72E+06
MSY	1.39E+07	1.95E+07	2.78E+07	1.31E+07	9.13E+06	8.28E+06
virgin	2.33E+08	1.75E+08	1.39E+08	2.33E+08	1.75E+08	1.39E+08
F_{2003}/F_{MSY}	1.540	2.429	3.537	0.565	1.150	1.912
SS_{2003}/SS_{MSY}	0.442	0.183	0.078	1.275	0.792	0.457
tSPR 2003	0.286	0.112	0.039	0.286	0.112	0.039
tSPR @ SS_{MSY}	0.409	0.376	0.356	0.202	0.126	0.082
Current Yield	9.69E+06	9.69E+06	9.69E+06	9.69E+06	9.69E+06	9.69E+06

Table 4. Benchmark Statistics for 1962-2003 gulf-wide "low" natural mortality (M1 = 0.29) treatments.

Model Description	**Run G**	**Run H**	**Run I**	**Run J**	**Run K**	**Run L**
Steepness	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95	Fixed = 0.81	Fixed = 0.90	Fixed = 0.95
Shrimp bycatch and closed season discards directed?	Directed	Directed	Directed	Undirected	Undirected	Undirected
Benchmark Statistic						
$F_{0.1}$	0.351	0.286	0.208	0.233	0.219	0.190
F_{MAX}	0.450	0.368	0.270	0.313	0.295	0.260
$F_{30\%SPR}$	0.523	0.423	0.308	0.134	0.023	0.000
$F_{40\%SPR}$	0.398	0.322	0.233	0.067	0.000	0.000
F_{MSY}	0.388	0.345	0.269	0.203	0.208	0.195
F_{2003}	0.405	0.644	0.826	0.052	0.133	0.268
SS_{MSY}	1.40E+08	1.01E+08	7.90E+07	6.02E+07	2.62E+07	1.22E+07
SS_{2003}	8.49E+07	2.35E+07	6.42E+06	8.49E+07	2.35E+07	6.42E+06
MSY	1.50E+07	2.04E+07	3.18E+07	2.68E+07	1.52E+07	1.05E+07
virgin	3.71E+08	2.77E+08	2.24E+08	3.71E+08	2.77E+08	2.24E+08
F_{2003}/F_{MSY}	1.043	1.869	3.072	0.255	0.640	1.376
SS_{2003}/SS_{MSY}	0.609	0.234	0.081	1.412	0.898	0.524
tSPR 2003	0.368	0.150	0.047	0.368	0.150	0.047
tSPR @ SS_{MSY}	0.414	0.382	0.364	0.223	0.131	0.077
Current Yield	9.66E+06	9.66E+06	9.66E+06	9.66E+06	9.66E+06	9.66E+06

Table 5. Projection results for Runs A-C (all fleets specified as directed fisheries, High M).

	Run A	Run B	Run C
SScurrent/SSmsy			
1962	0.045	0.042	0.041
2003	0.442	0.183	0.078
2032	1.44	1.35	0.00
Recovery Year	**2024**	**2028**	**N/A**
Fcurrent/Fmsy			
1962	2.91	3.61	4.58
2003	1.54	2.43	3.54
2032	0.278	0.232	20.0
Recovery Year	**2008**	**2013**	**N/A**
Y/MSY			
1962	0.136	0.154	0.166
2003	0.700	0.498	0.348
2032	0.422	0.329	0.00
tSPR			
1980	0.069	0.040	0.028
2003	0.286	0.112	0.039
2032	0.626	0.548	0.000

Table 6. Projection results for Runs D-F (closed season discards and shrimp bycatch specified as non-directed, High M).

	Run D	Run E	Run F
SScurrent/SSmsy			
1962	0.142	0.163	0.201
2003	1.275	0.792	0.457
2032	1.91	1.64	0.677
Recovery Year	**2003**	**2022**	**N/A**
Fcurrent/Fmsy			
1962	2.10	2.55	3.20
2003	0.565	1.15	1.91
2032	0.199	0.275	0.595
Recovery Year	**1989**	**2009**	**2026**
Y/MSY			
1962	0.290	0.396	0.529
2003	0.742	1.06	1.17
2032	0.358	0.439	0.484
tSPR			
1980	0.069	0.040	0.028
2003	0.286	0.112	0.039
2032	0.470	0.298	0.108

Table 7. Projection results for Runs G-I (all fleets specified as directed fisheries, Low M).

	Run G	Run H	Run I
SScurrent/SSmsy			
1962	0.033	0.028	0.026
2003	0.609	0.234	0.081
2032	1.68	1.60	1.55
Recovery Year	**2018**	**2024**	**2026**
Fcurrent/Fmsy			
1962	2.77	3.51	4.43
2003	1.04	1.87	3.07
2032	0.223	0.182	0.132
Recovery Year	**2004**	**2009**	**2013**
Y/MSY			
1962	0.095	0.107	0.115
2003	0.643	0.474	0.304
2032	0.385	0.301	0.207
tSPR			
1980	0.075	0.036	0.023
2003	0.368	0.150	0.047
2032	0.708	0.639	0.593

Table 8. Projection results for Runs J-L (closed season discards and shrimp bycatch specified as non-directed, Low M).

	Run J	Run K	Run L
SScurrent/SSmsy			
1962	0.113	0.125	0.154
2003	1.41	0.898	0.524
2032	2.28	2.07	1.83
Recovery Year	**2001**	**2017**	**2022**
Fcurrent/Fmsy			
1962	1.86	2.34	2.92
2003	0.255	0.640	1.38
2032	0.103	0.154	0.202
Recovery Year	**1985**	**1991**	**2011**
Y/MSY			
1962	0.205	0..297	0.418
2003	0.361	0.634	0.924
2032	0.214	0.297	0.354
tSPR			
1980	0.075	0.036	0.023
2003	0.368	0.150	0.047
2032	0.581	0.379	0.235

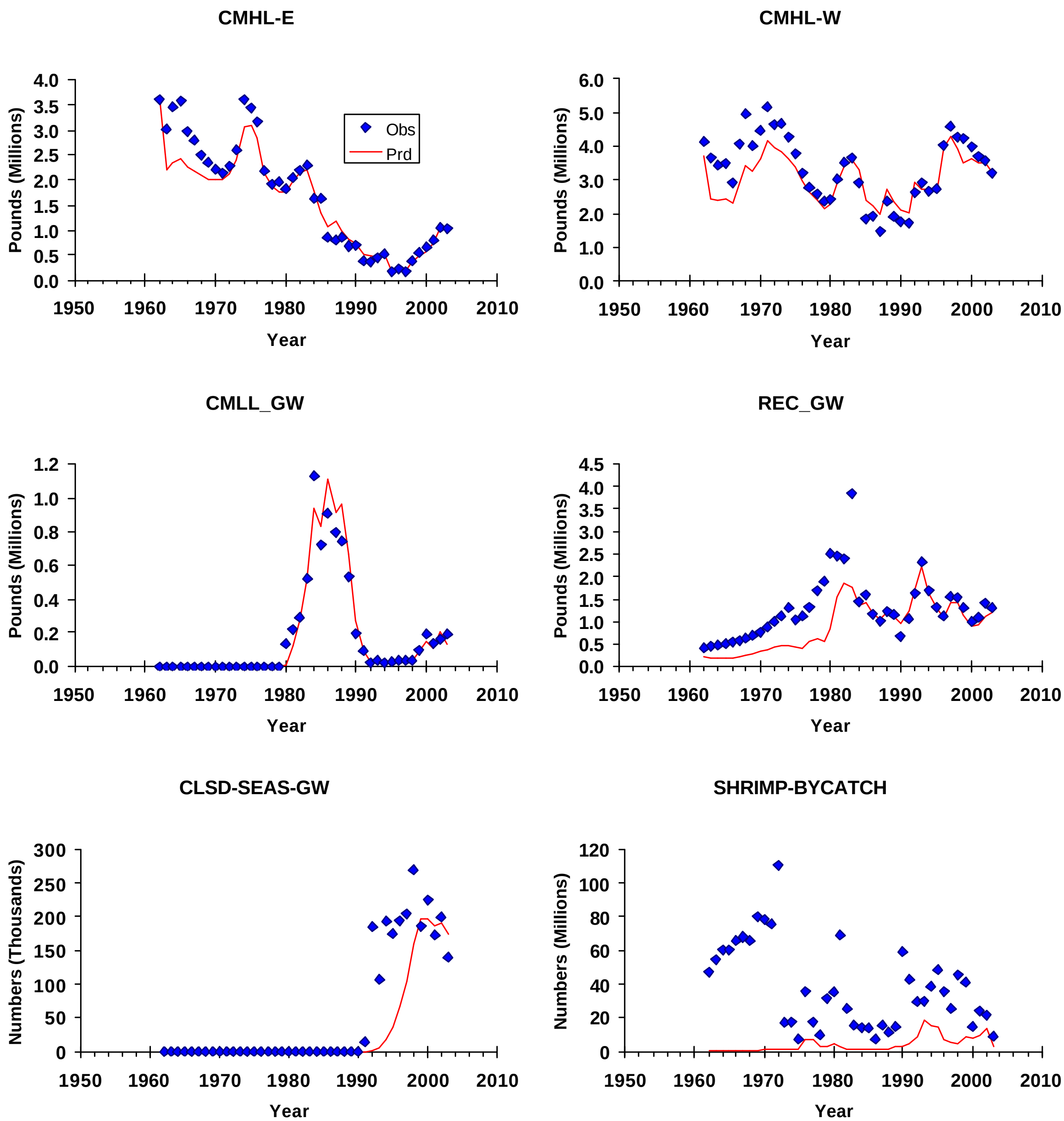


Figure 1. Fits to total catch by fleet for the preliminary run using raw CVs on total catch.

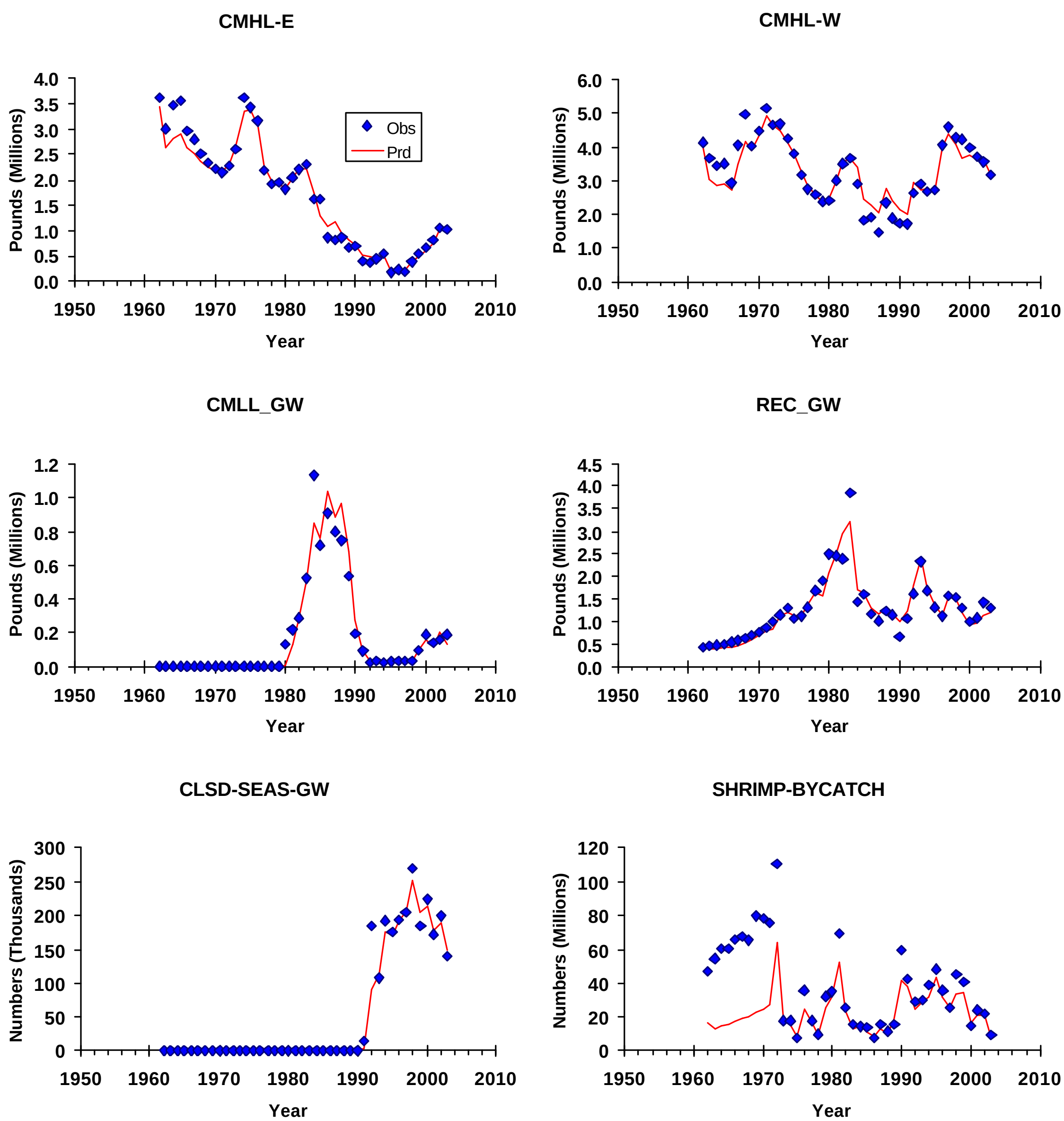


Figure 2. Fits to total catch by fleet for Runs A through F ("high" natural mortality runs).

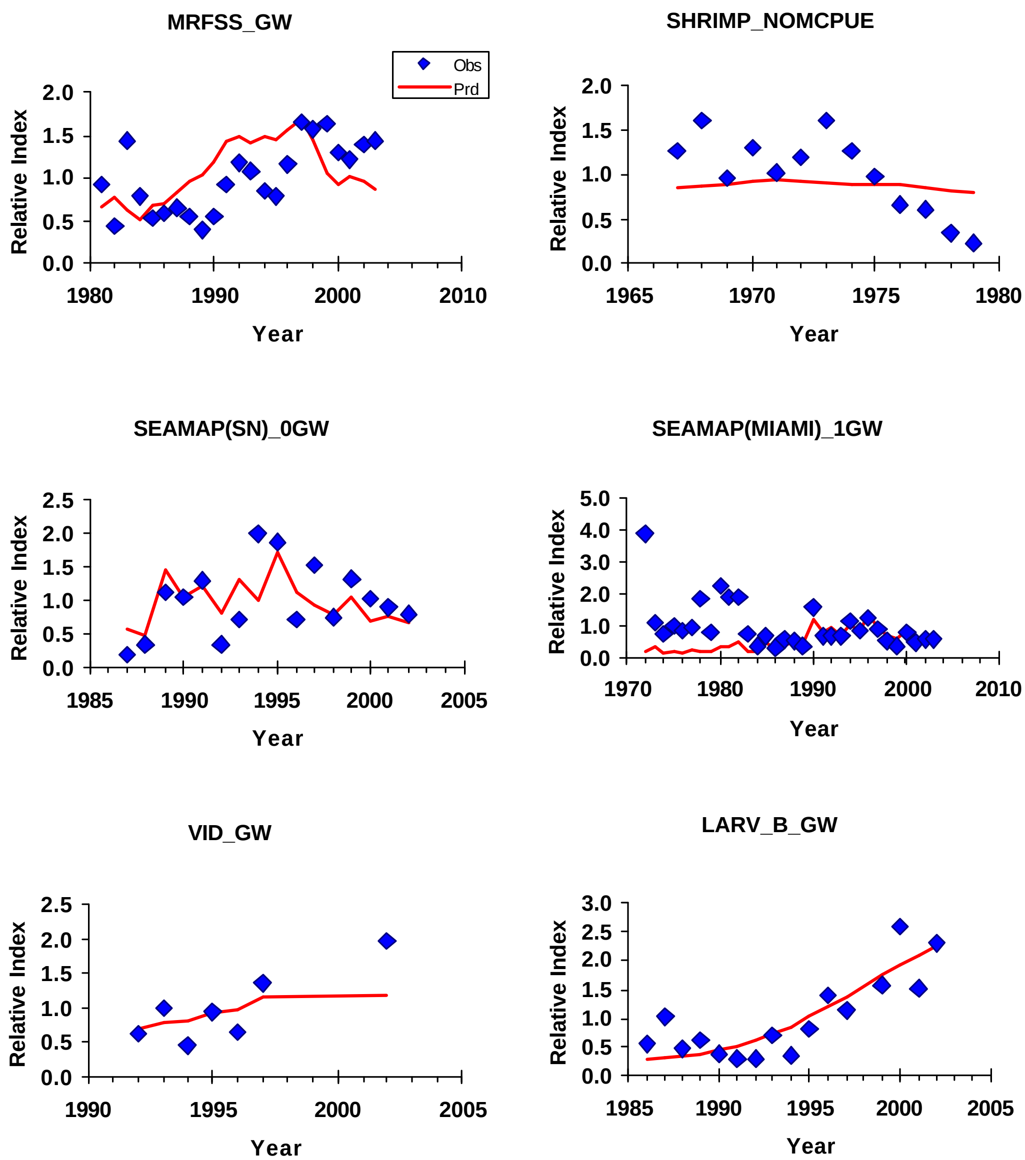


Figure 3. Fits to indices of abundance for Runs A and D.

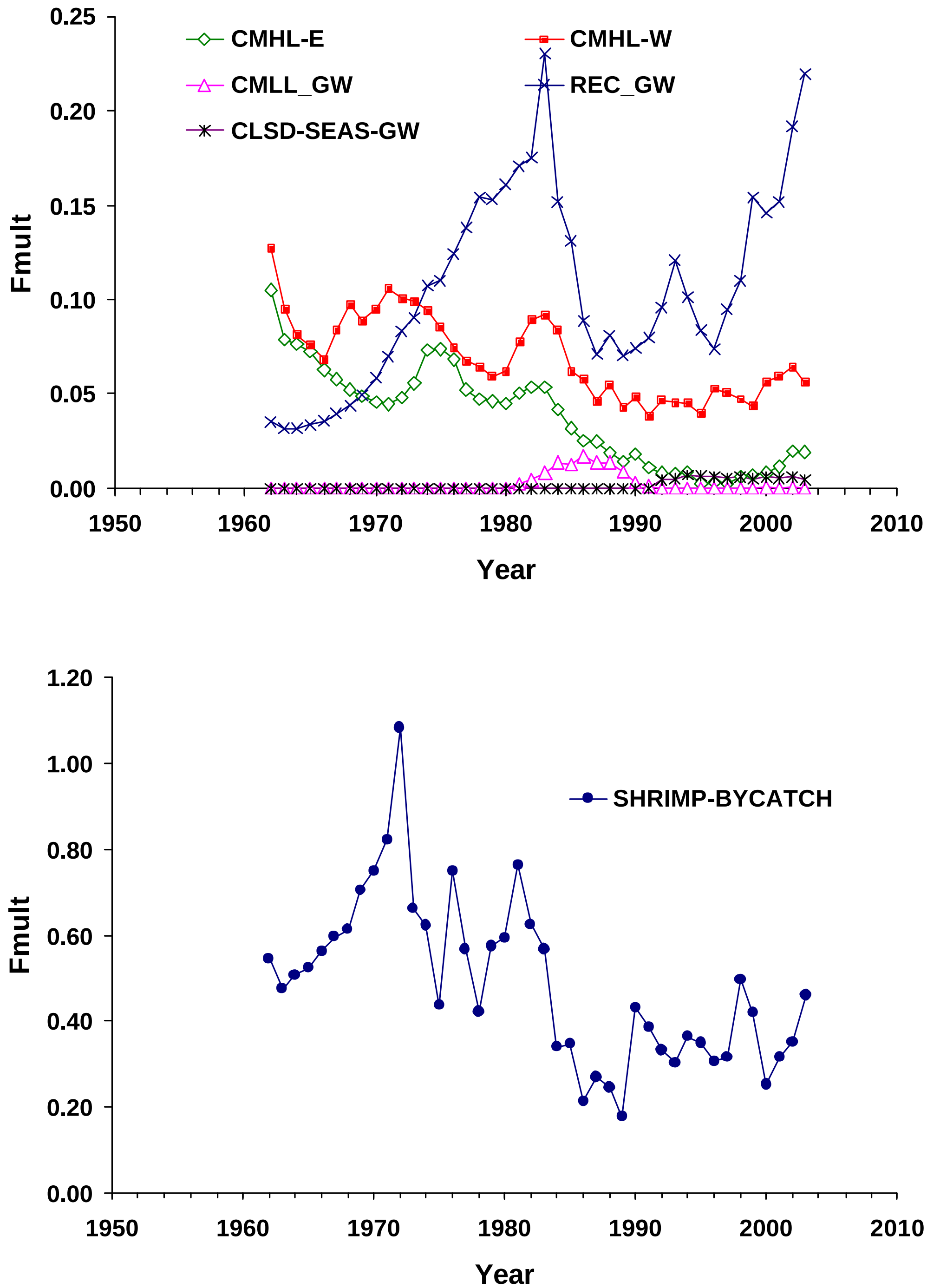


Figure 4. F multipliers by fleet for Runs A and D.

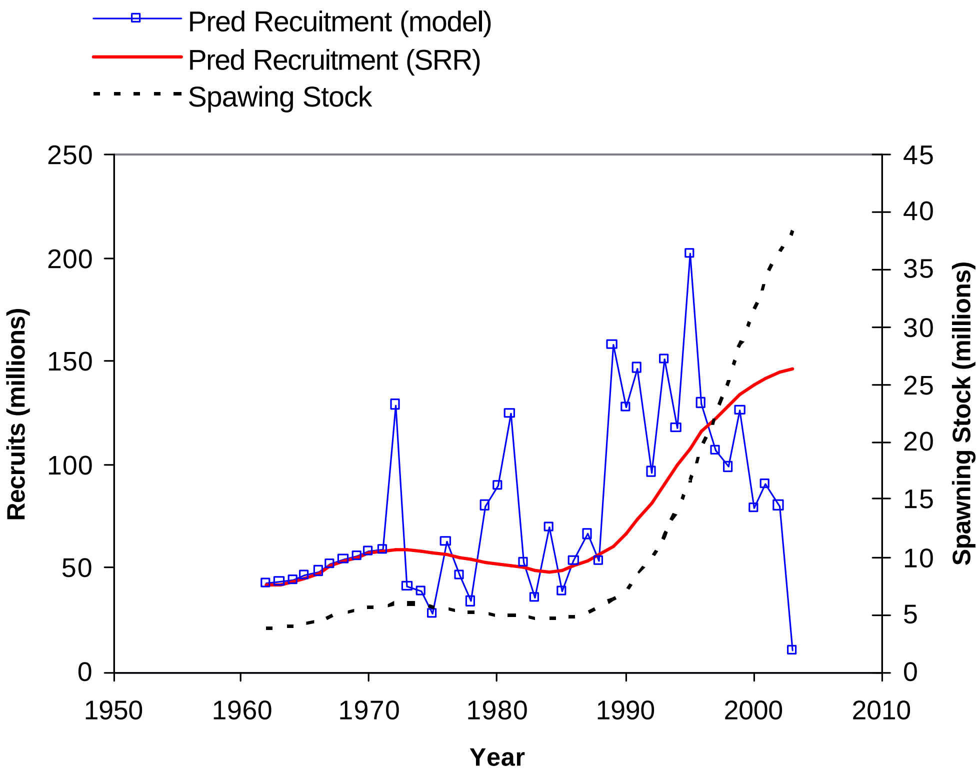


Figure 5. Spawning stock and recruitment estimates for Runs A and D.

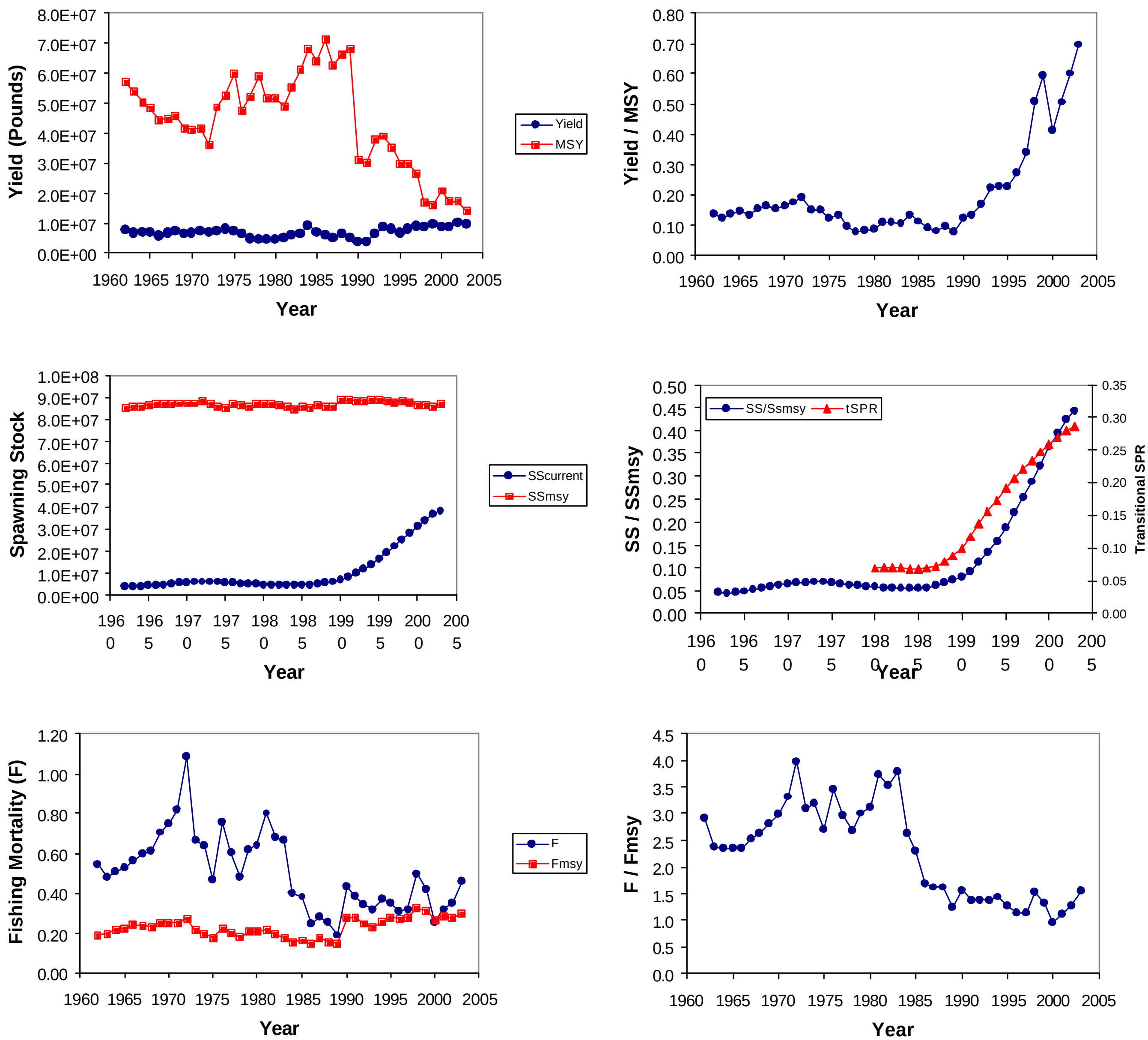


Figure 6. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run A.

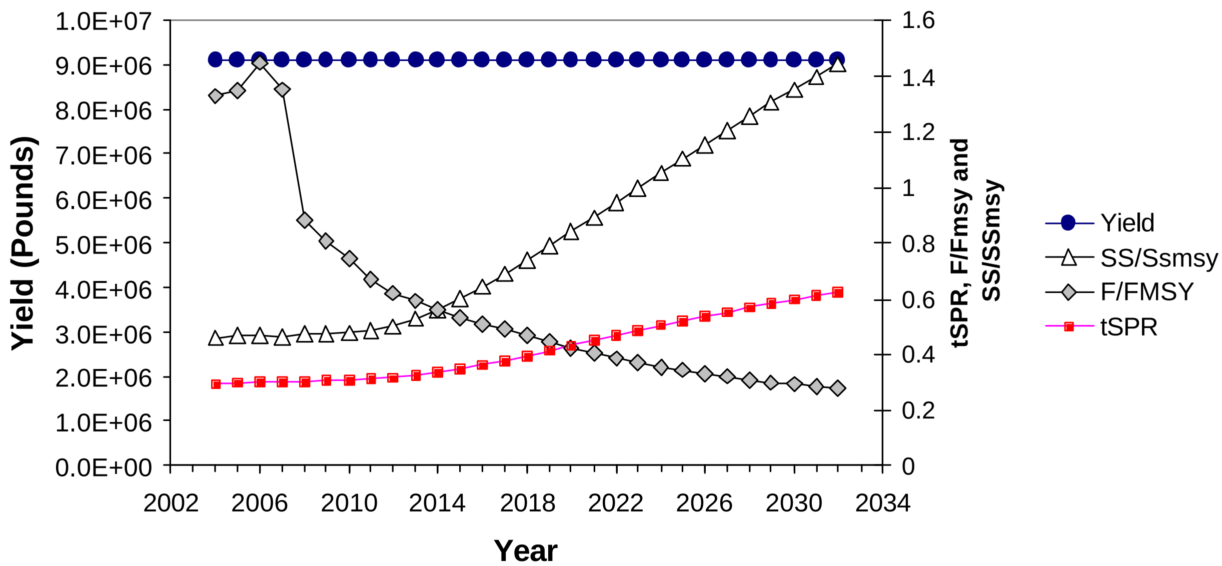


Figure 7. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run A. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

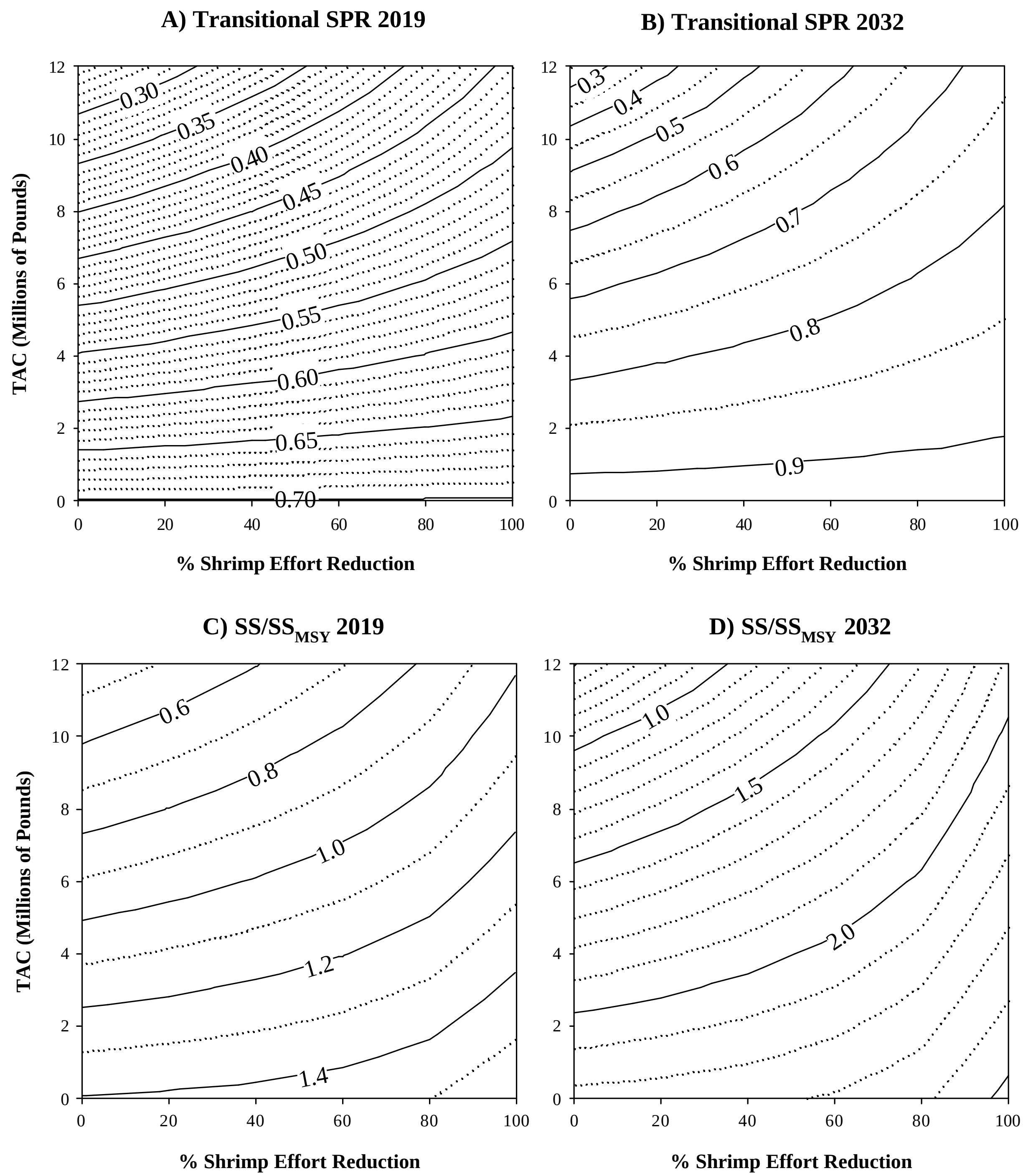


Figure 8. Run A projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

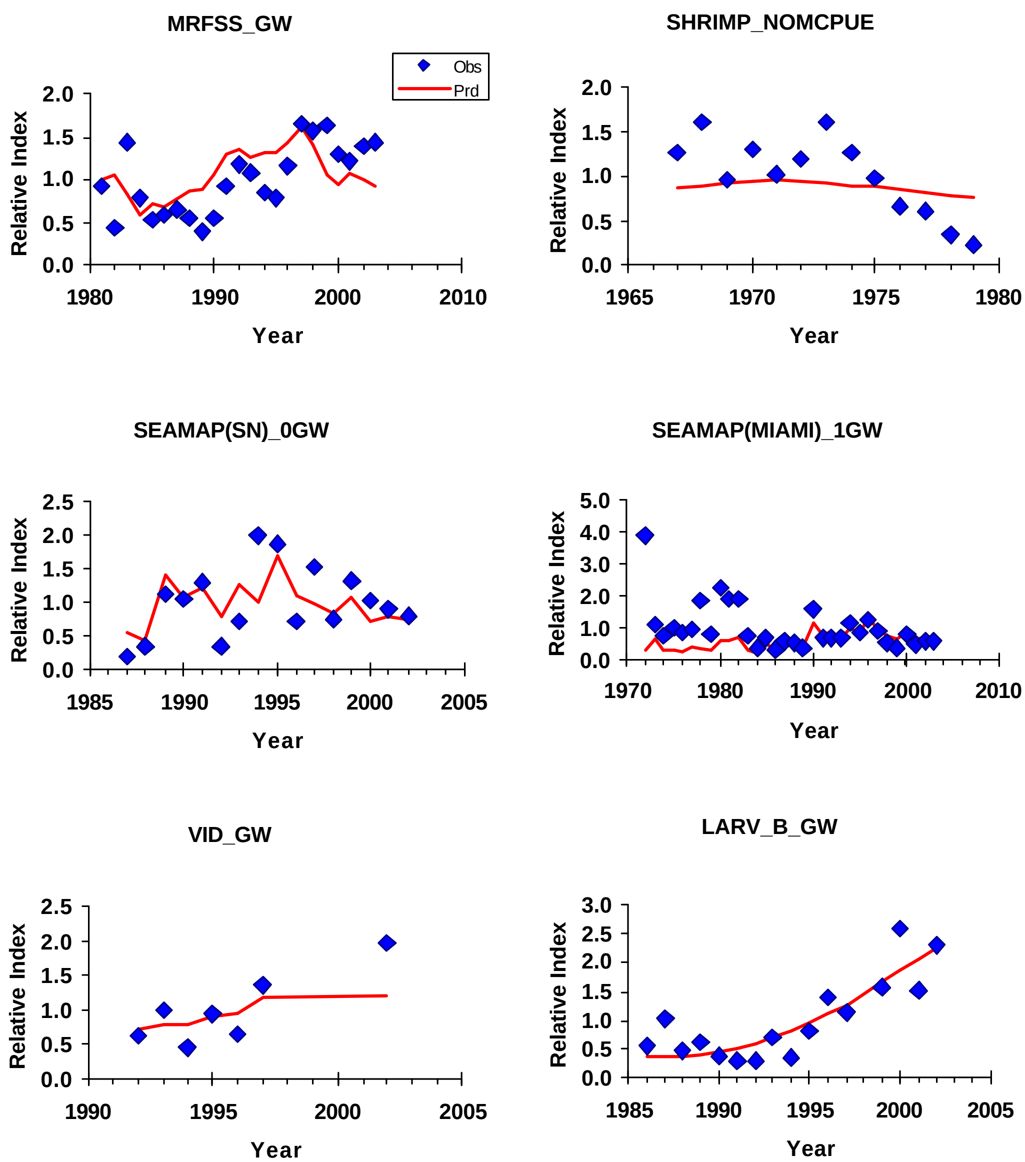


Figure 9 Fits to indices of abundance for Runs B and E.

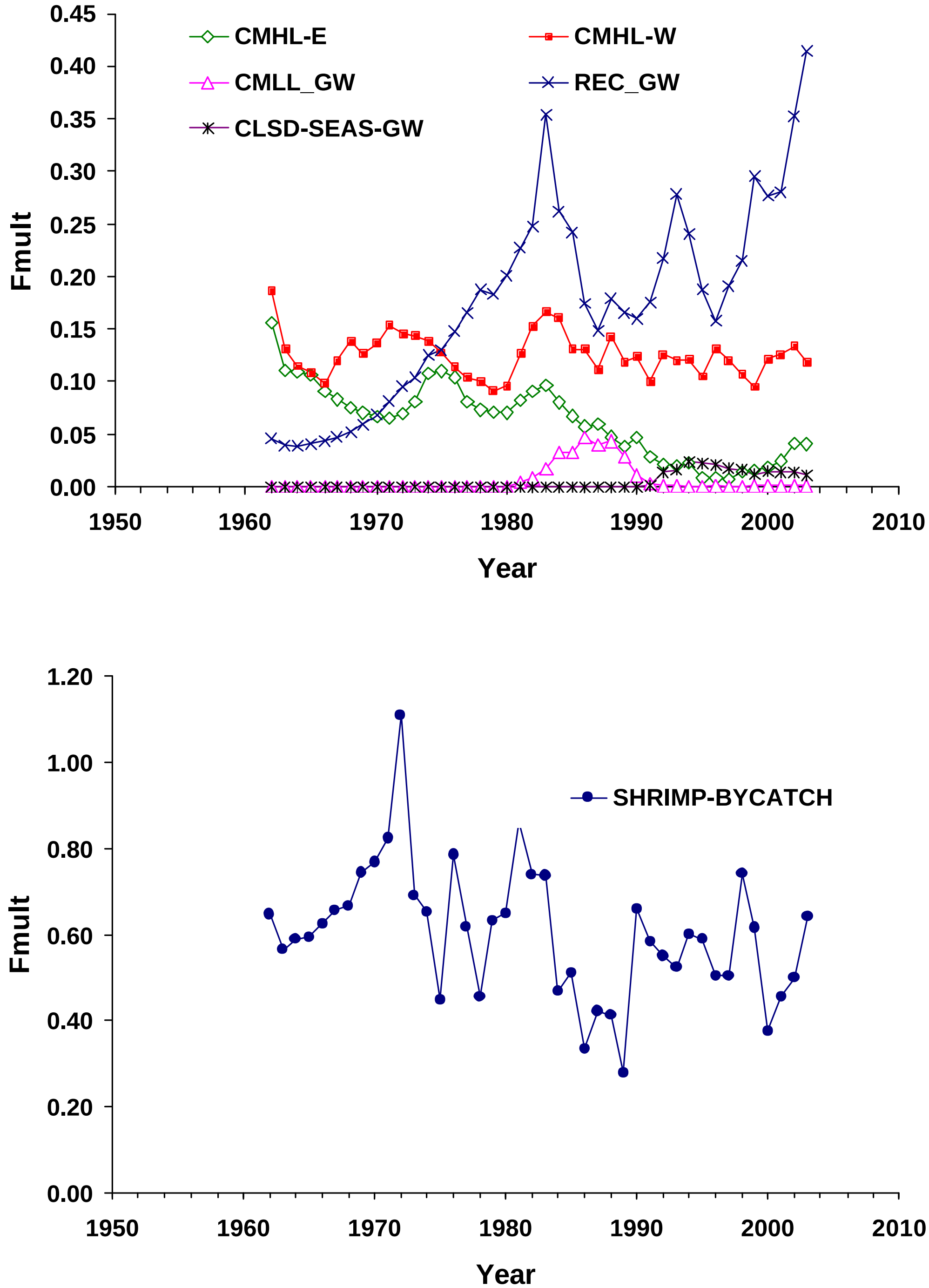


Figure 10. F multipliers by fleet for Runs B and E.

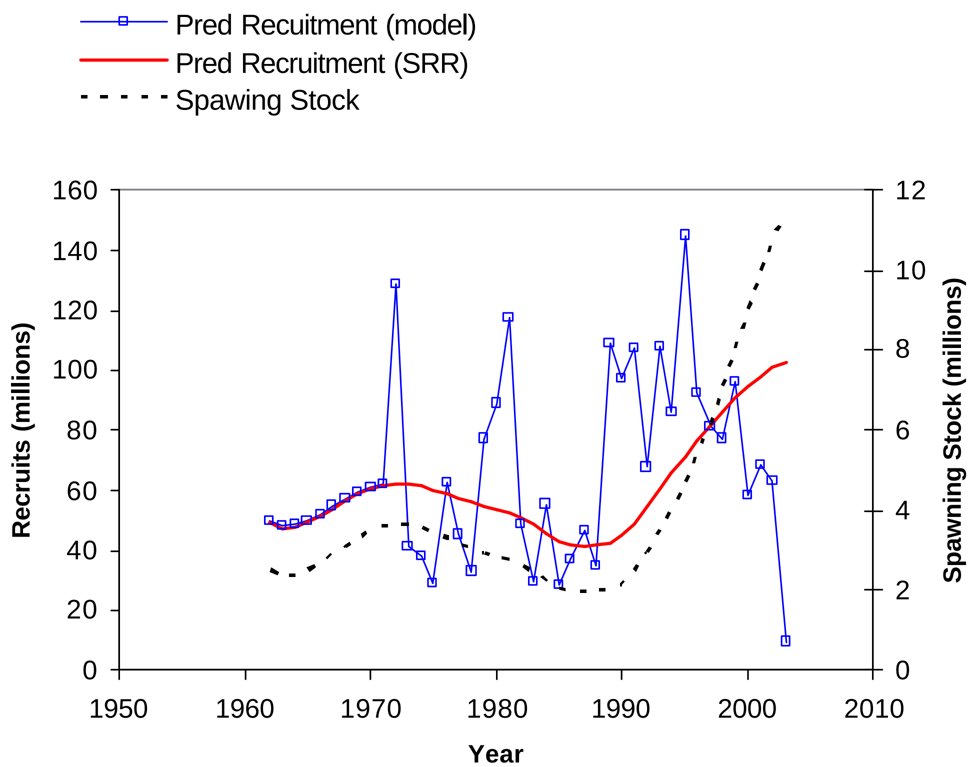


Figure 11. Spawning stock and recruitment estimates for Runs B and E.

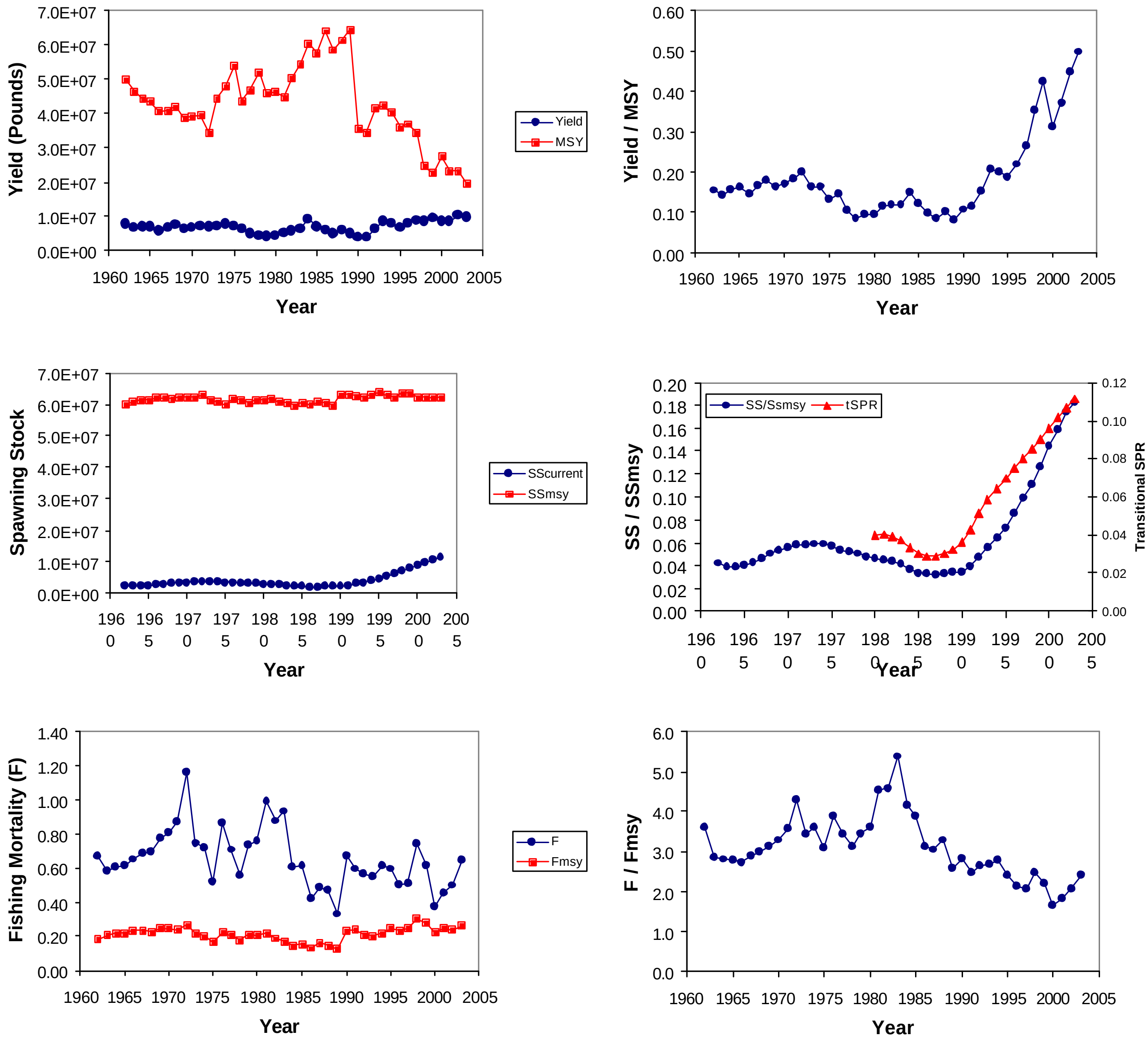


Figure 12. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run B.

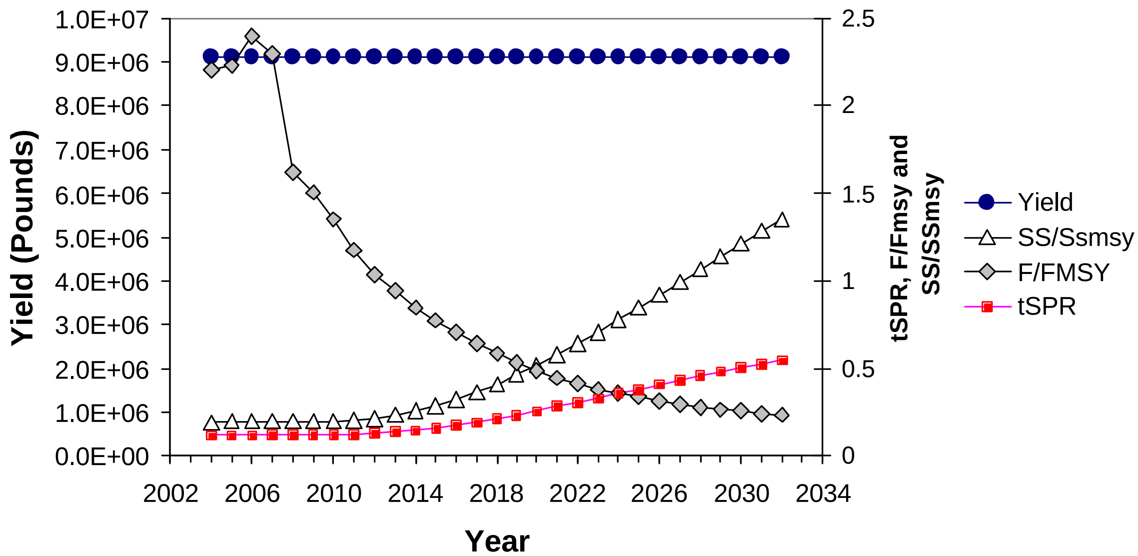


Figure 13. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run B. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

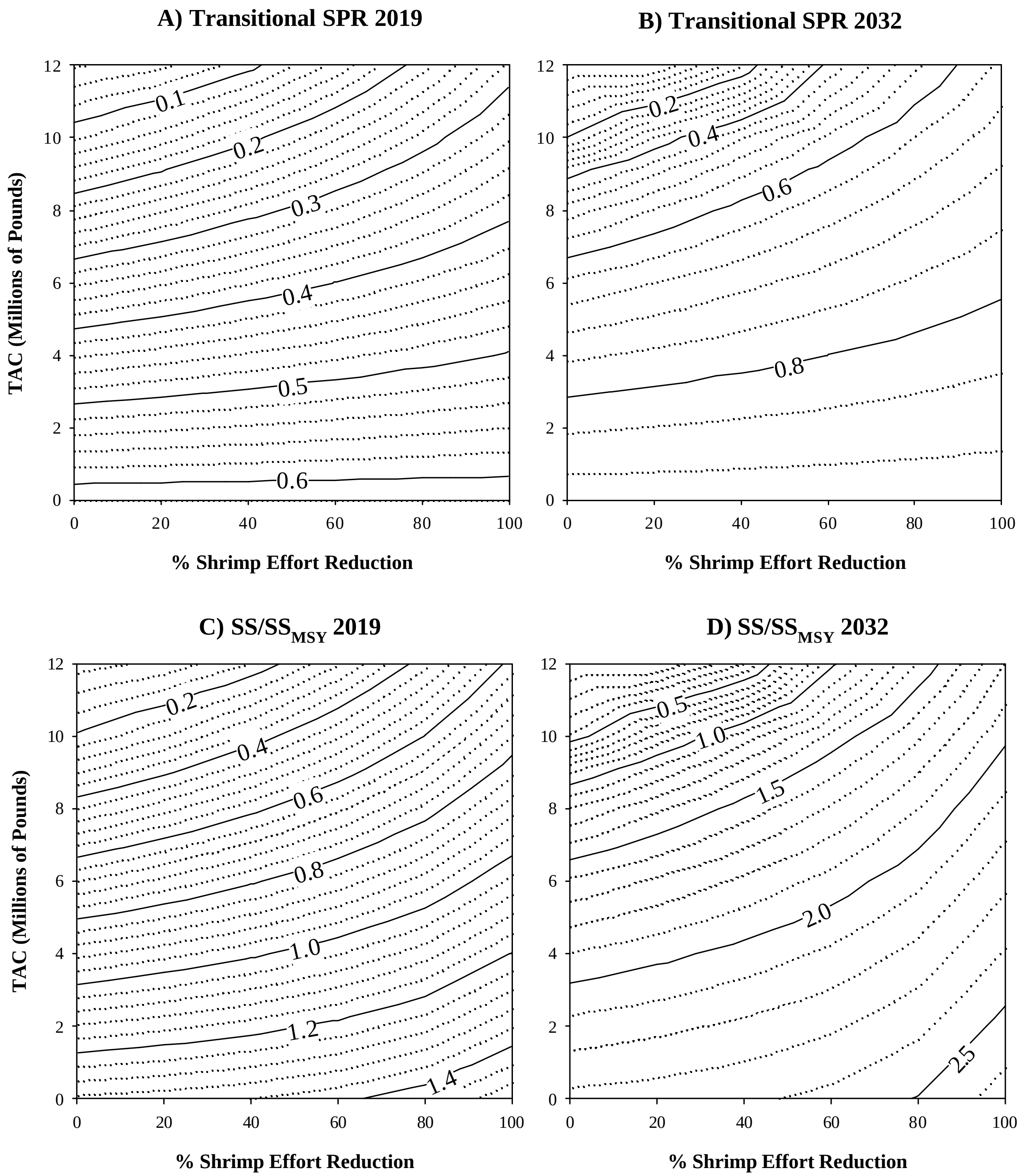


Figure 14. Run B projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

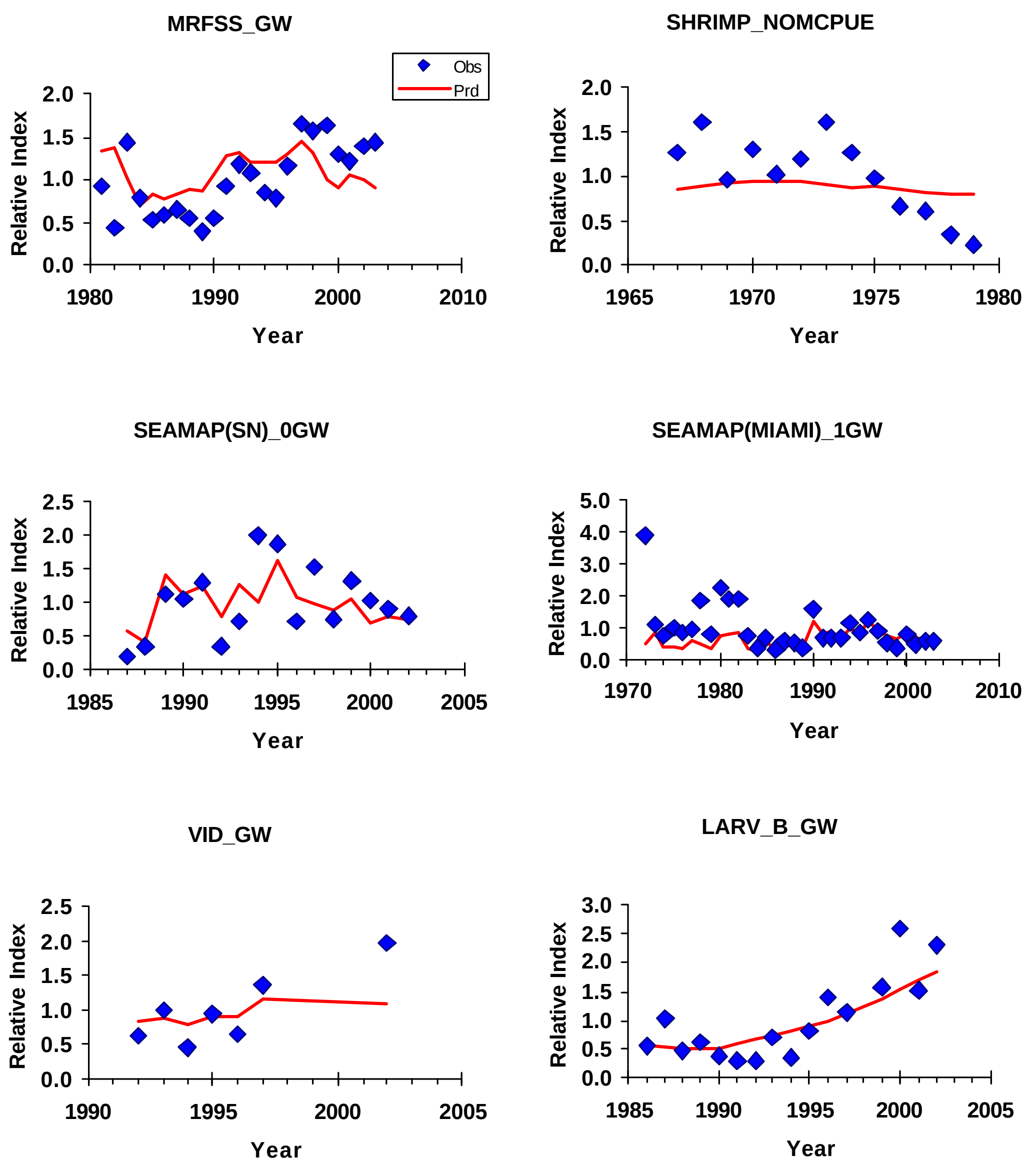


Figure 15. Fits to indices of abundance for Runs C and F.

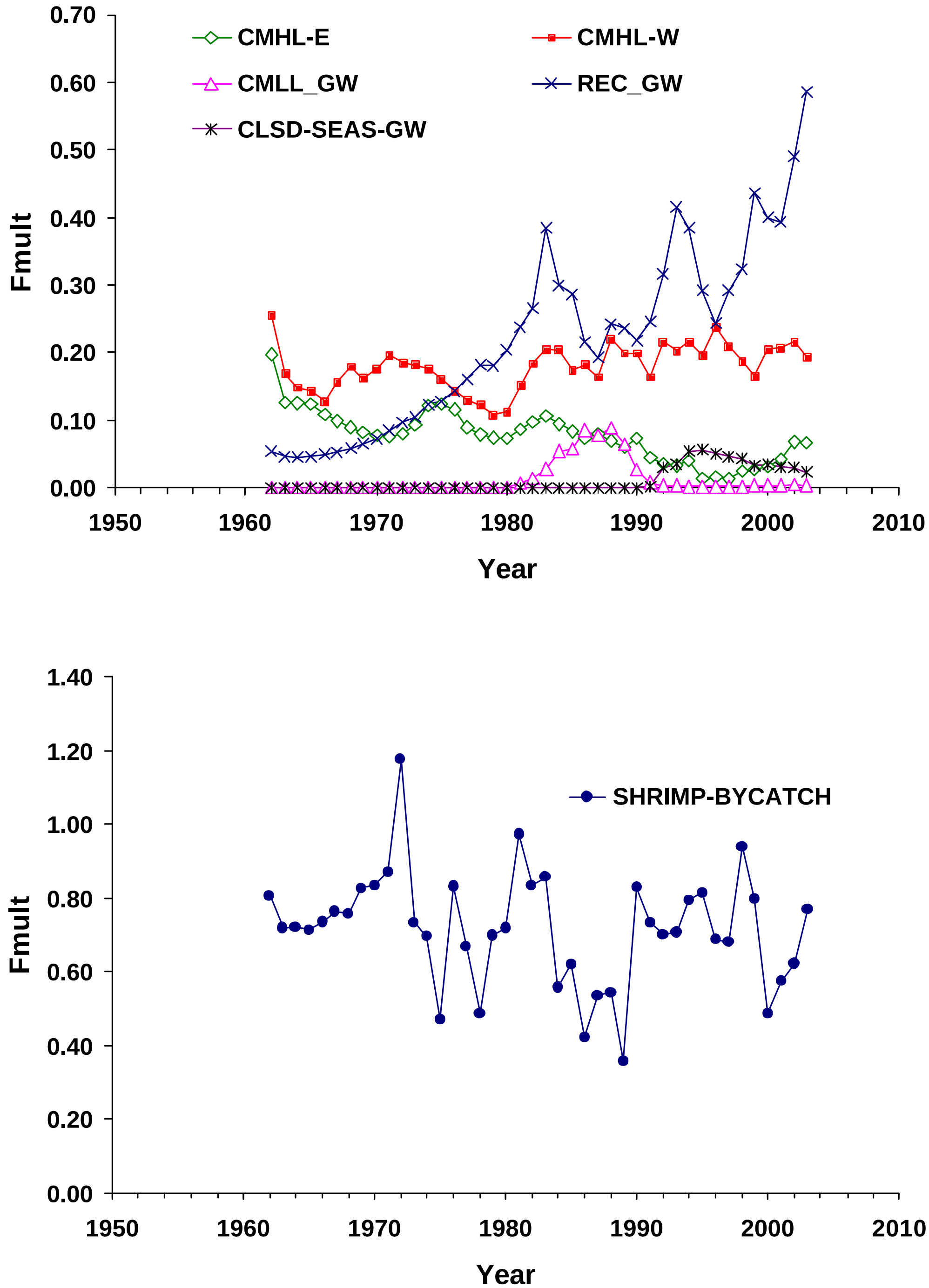


Figure 16. F multipliers by fleet for Runs C and F.

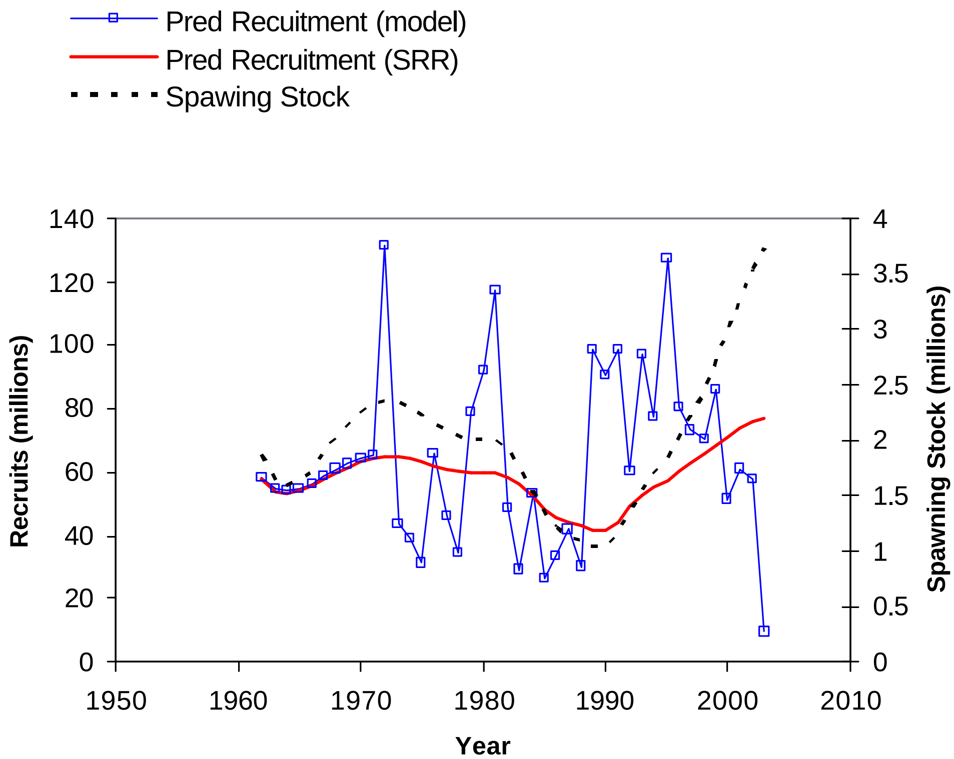


Figure 17. Spawning stock and recruitment estimates for Runs C and F.

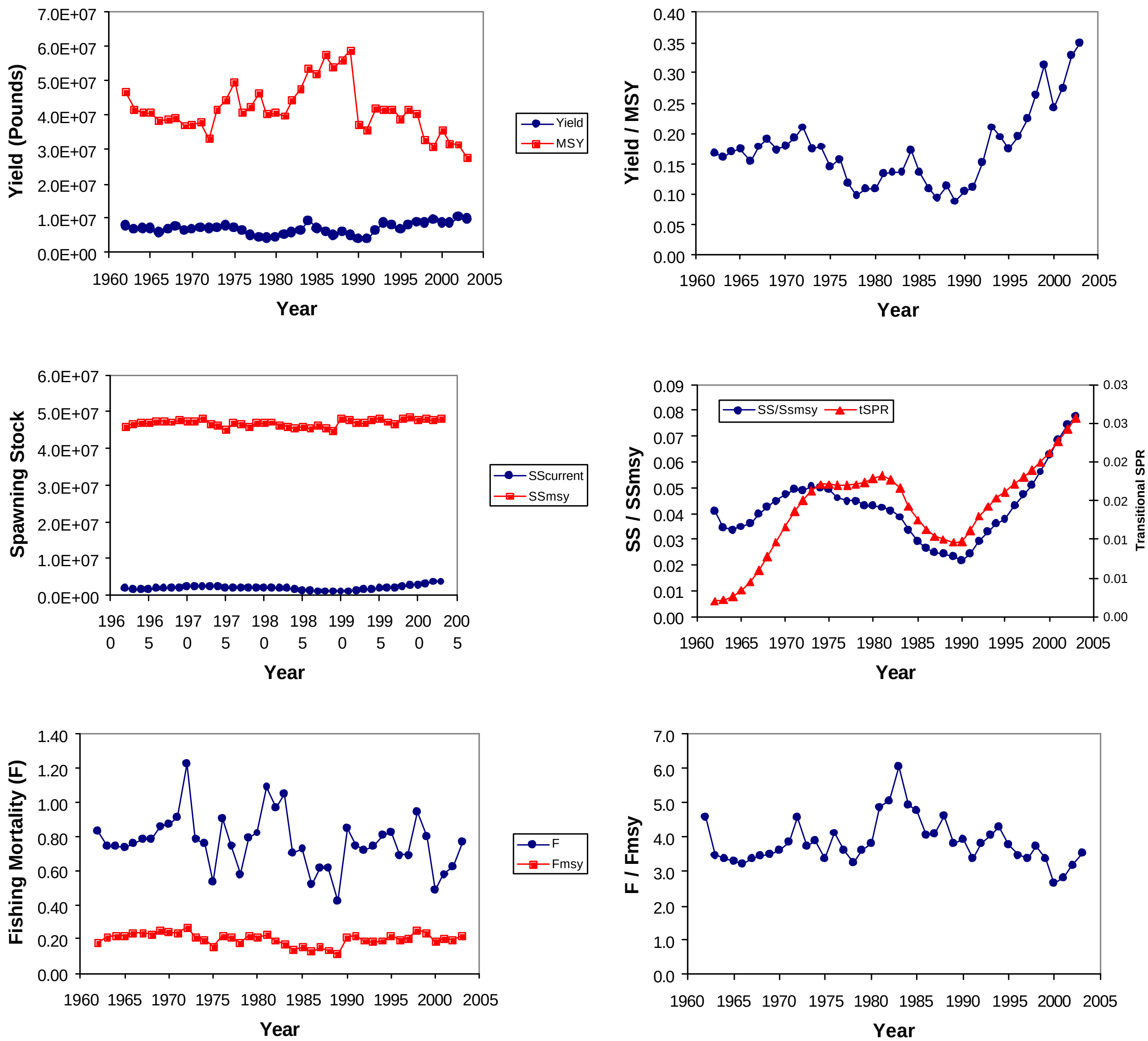
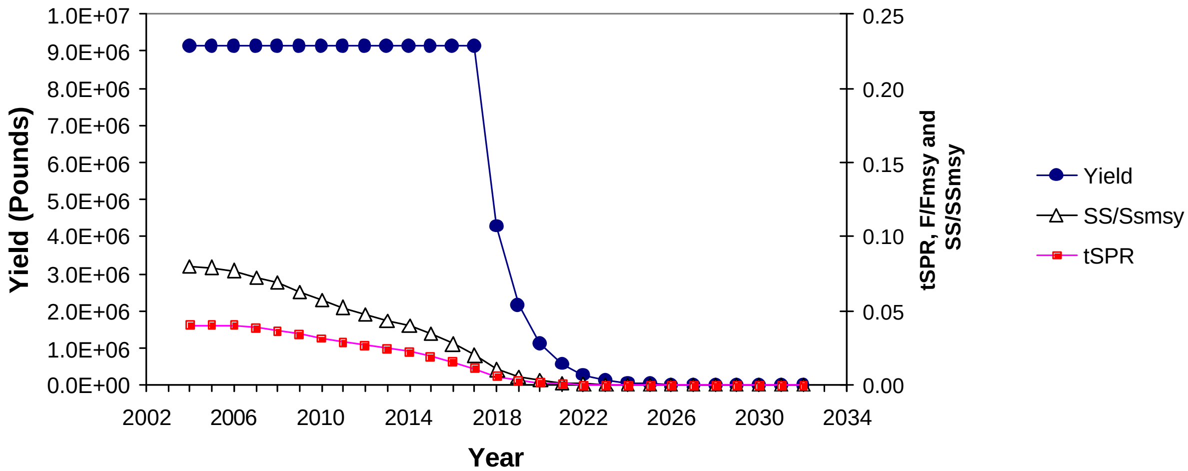


Figure 18. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run C.



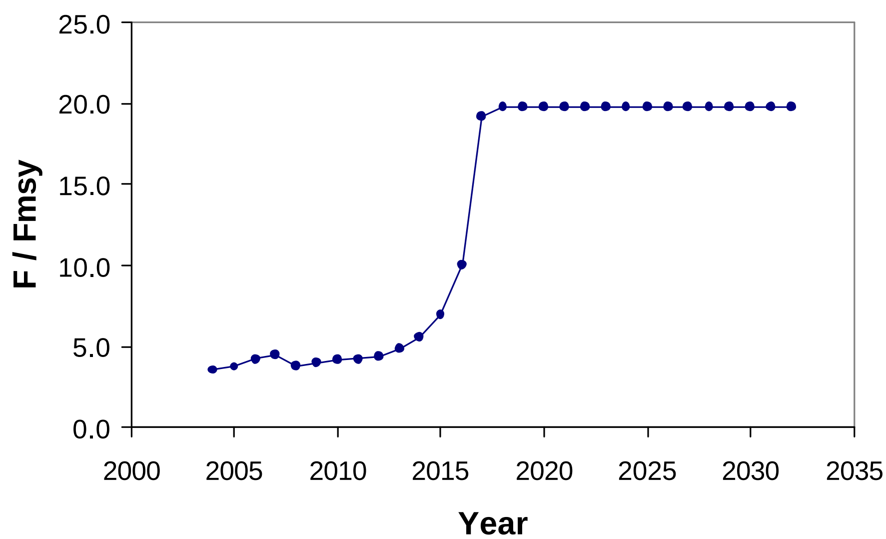


Figure 19. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run C. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

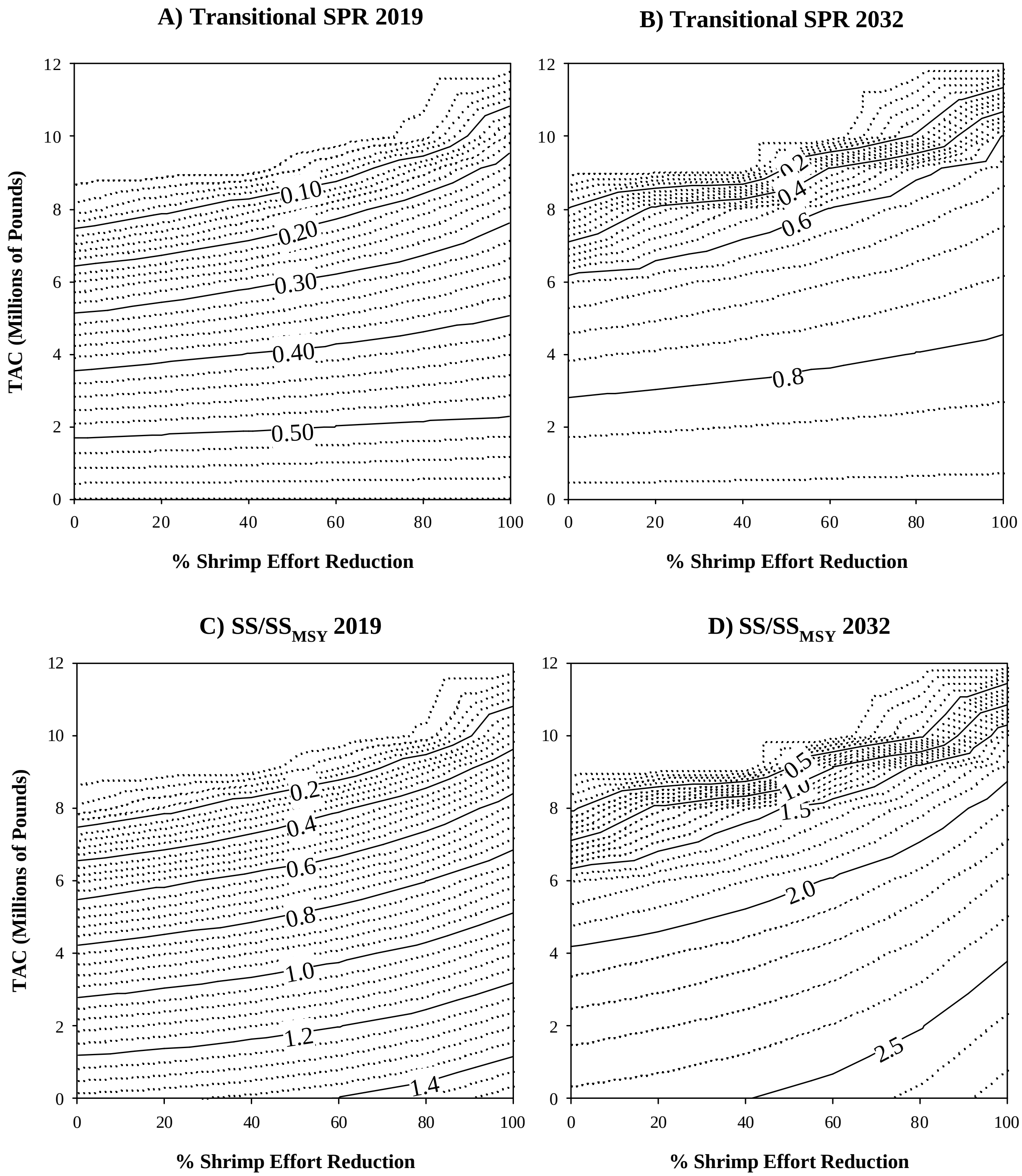


Figure 20. Run C projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

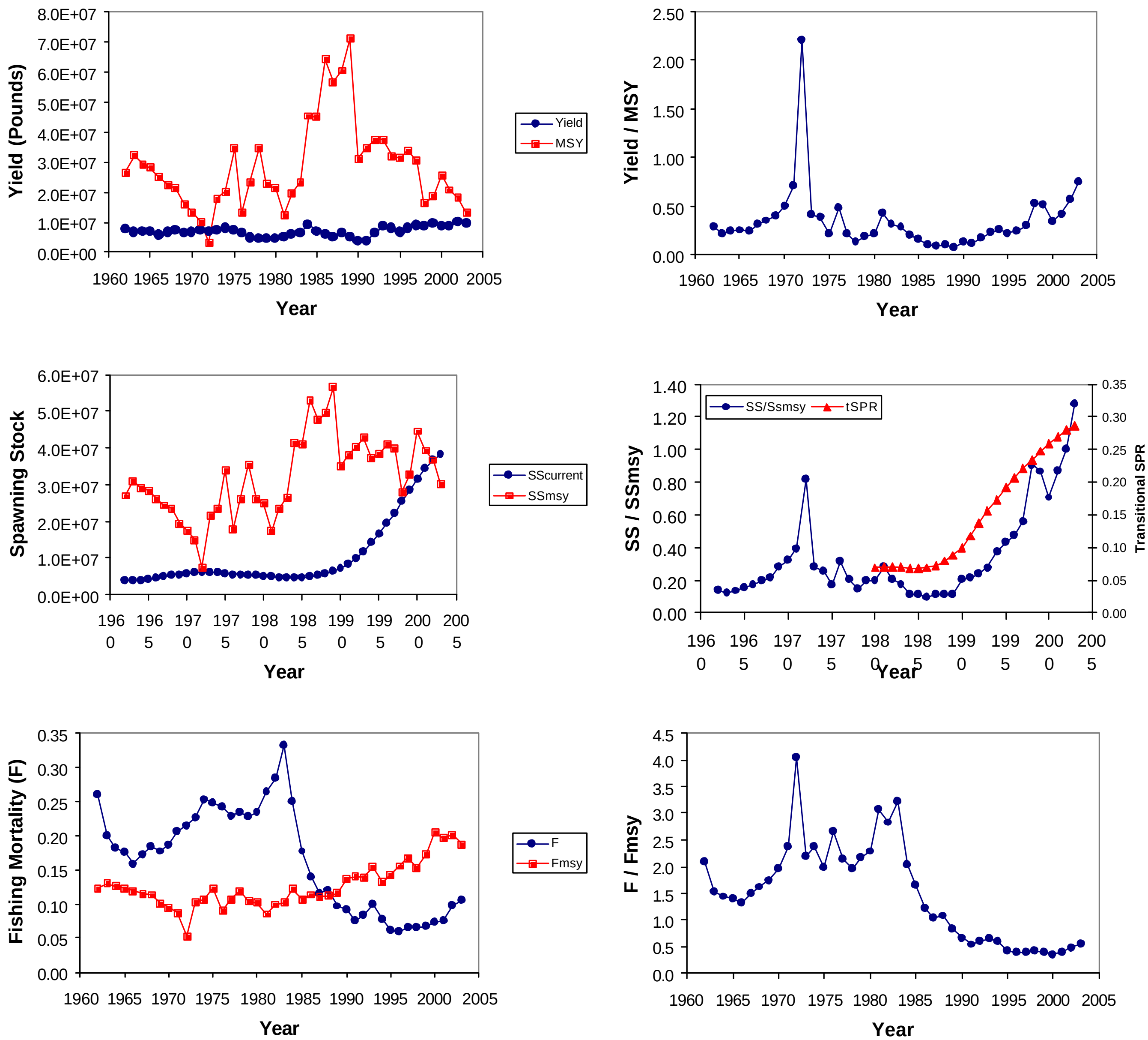


Figure 21. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run D.

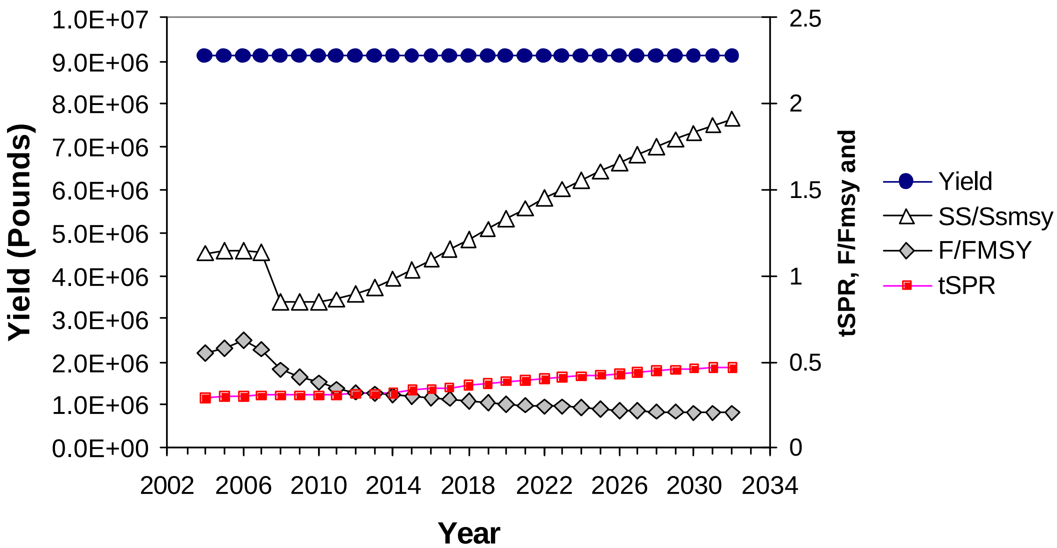


Figure 22. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run D. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

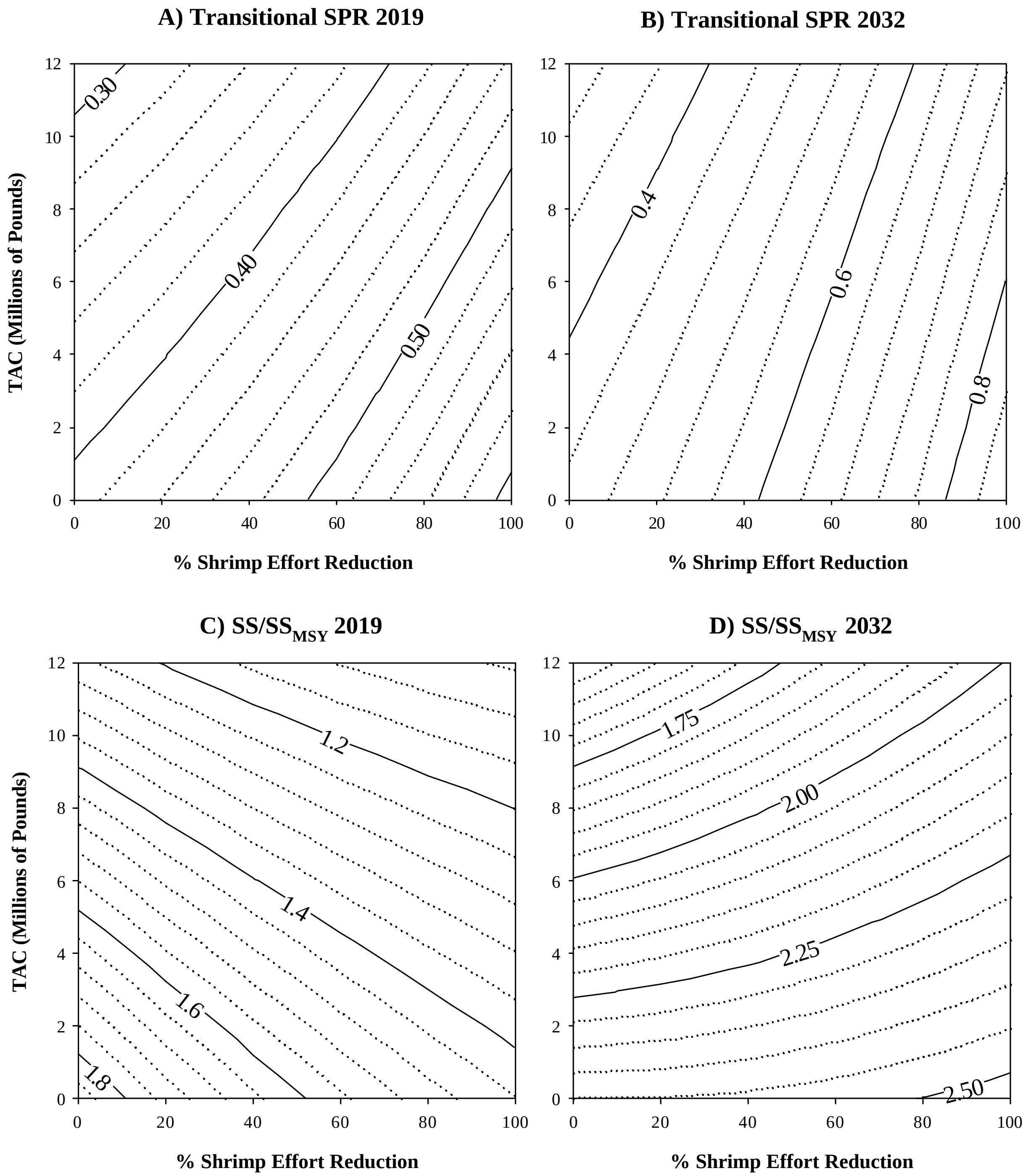


Figure 23. Run D projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

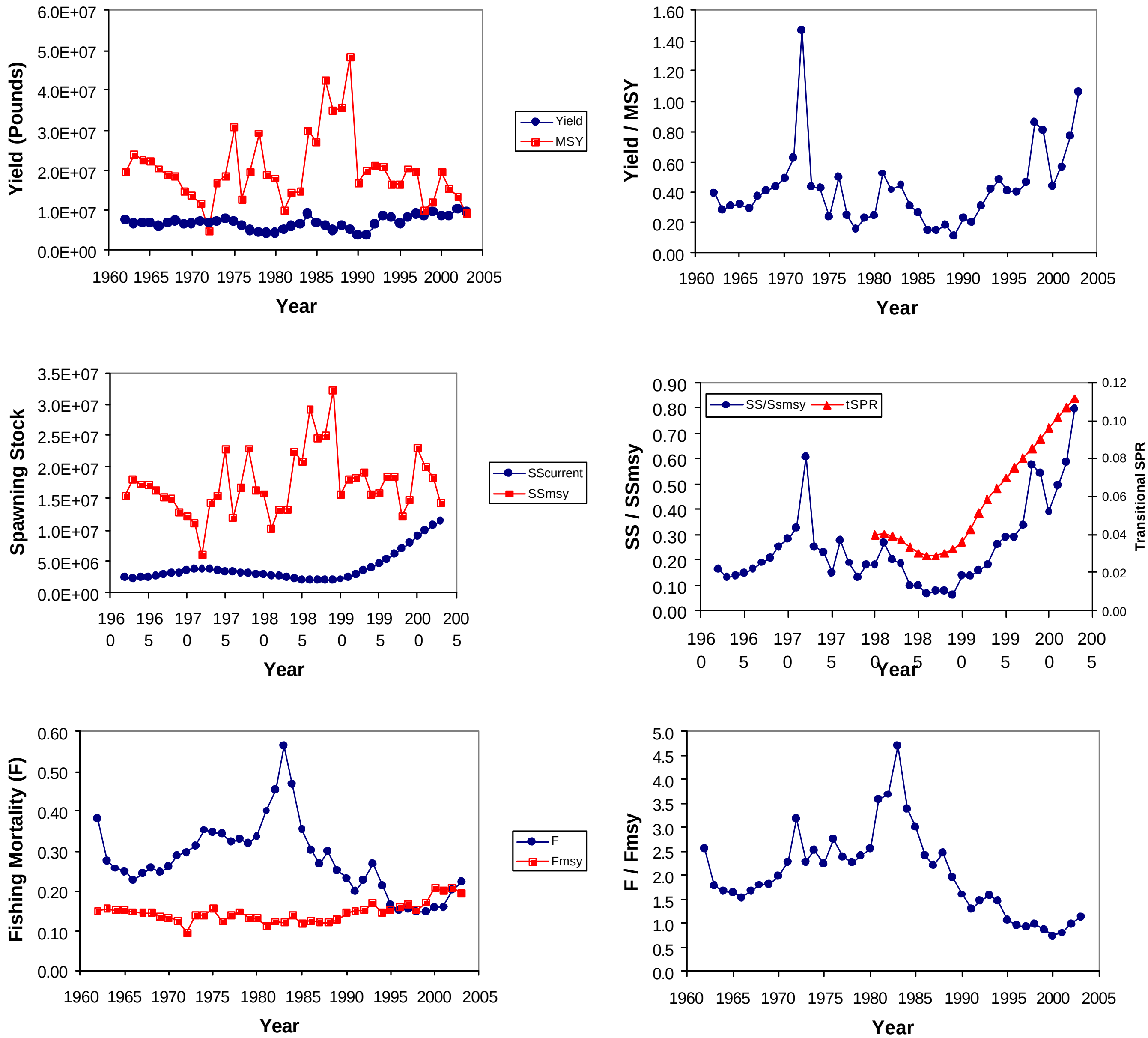


Figure 24. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run E .

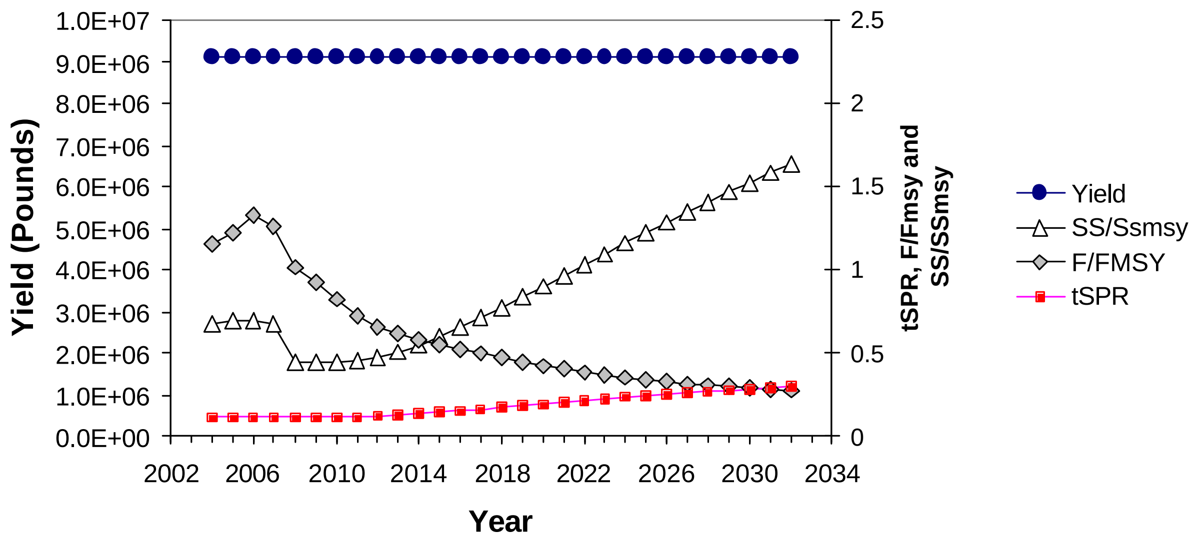


Figure 25. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run E. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

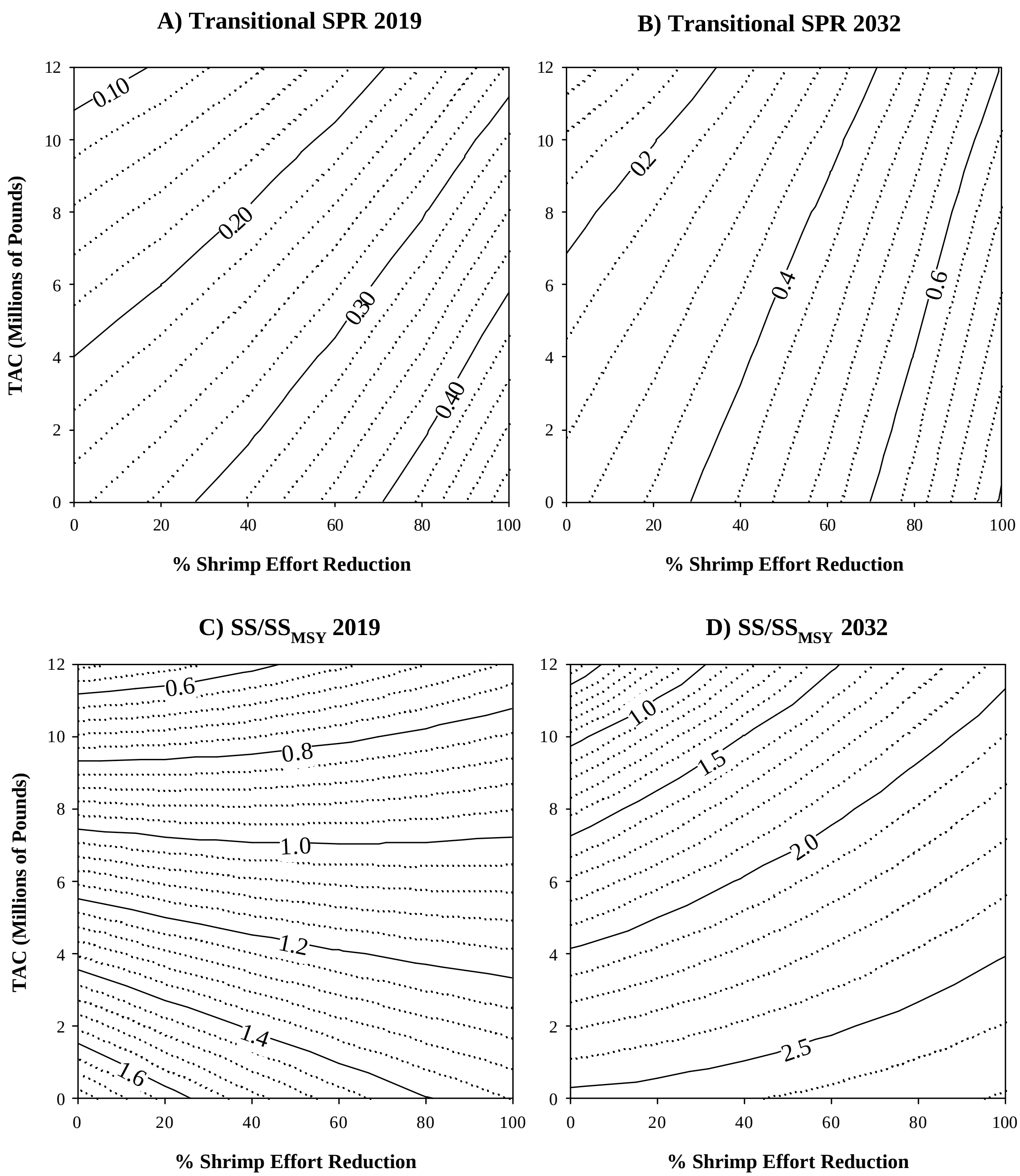


Figure 26. Run E projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

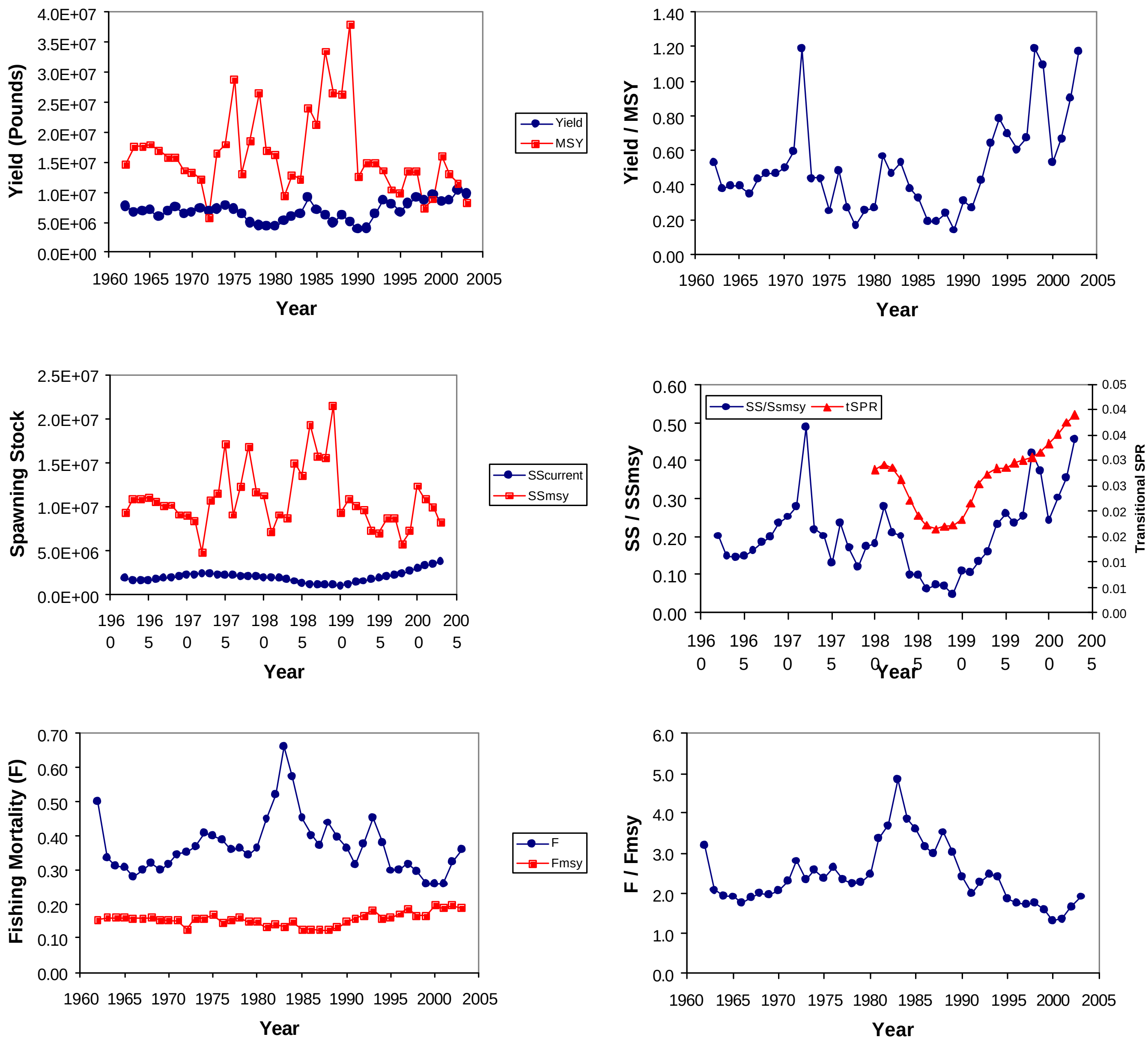


Figure 27. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run F.

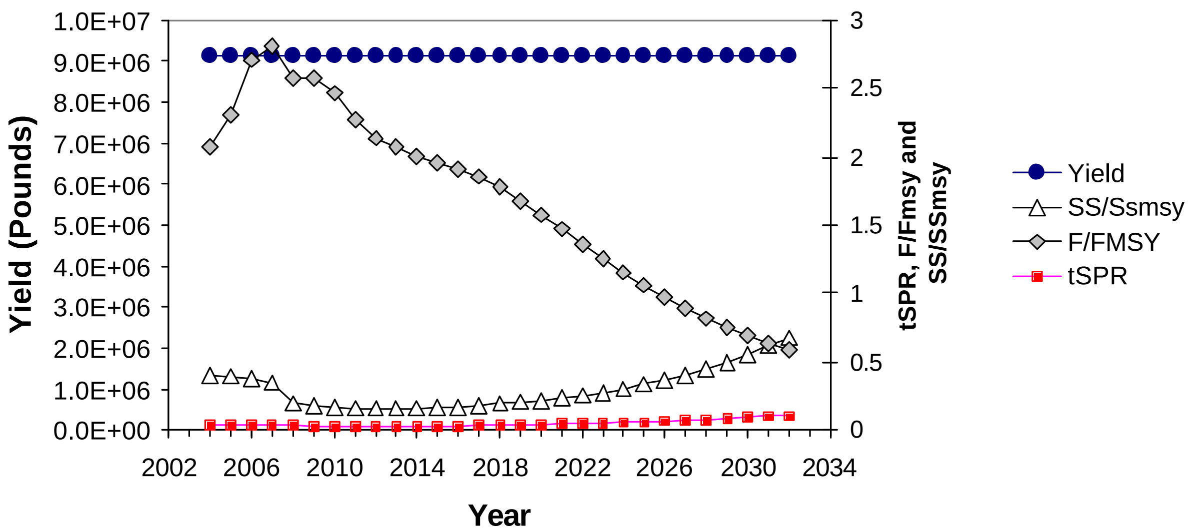


Figure 28. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run F. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

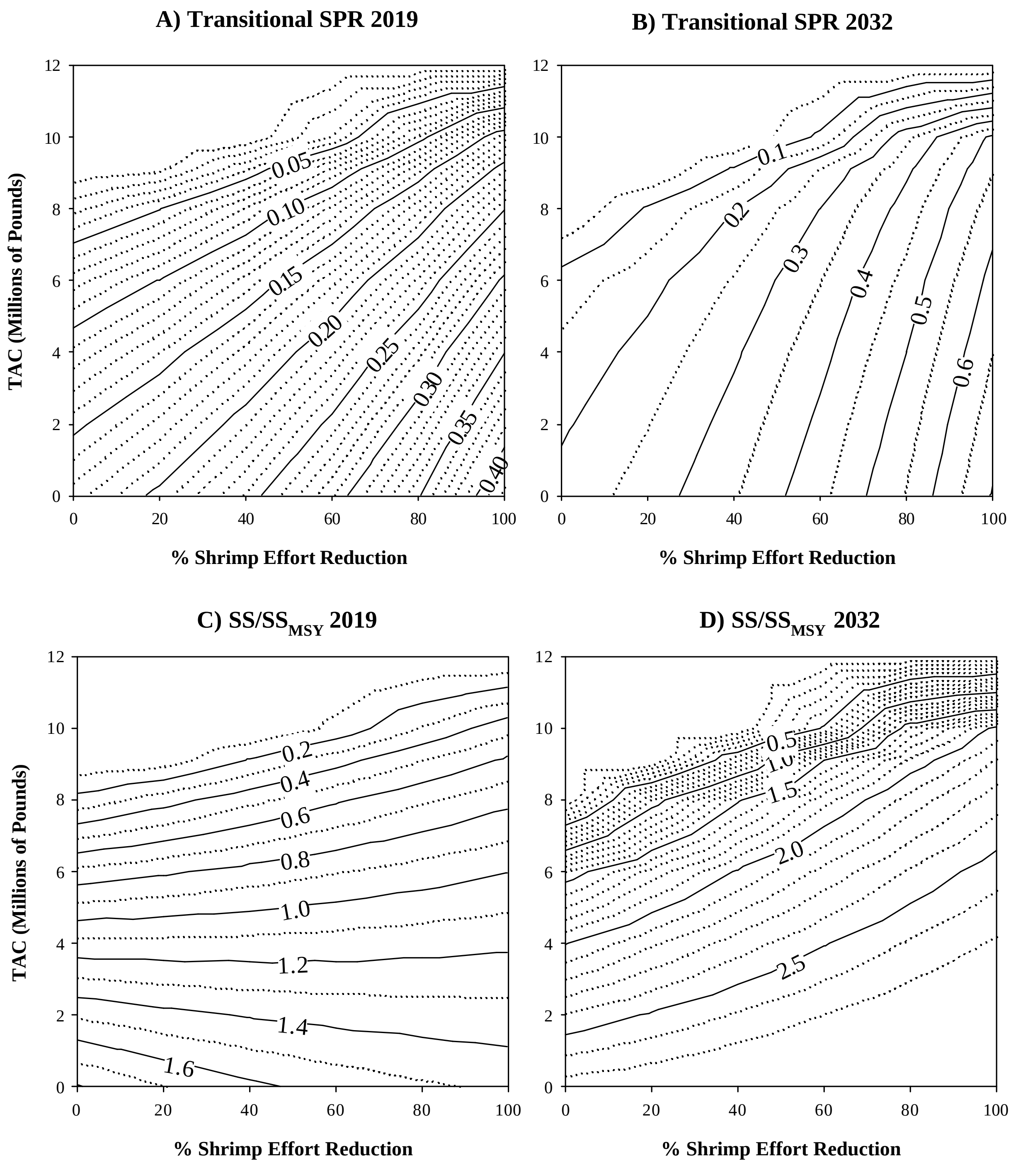


Figure 29. Run F projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS_{MSY} in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008

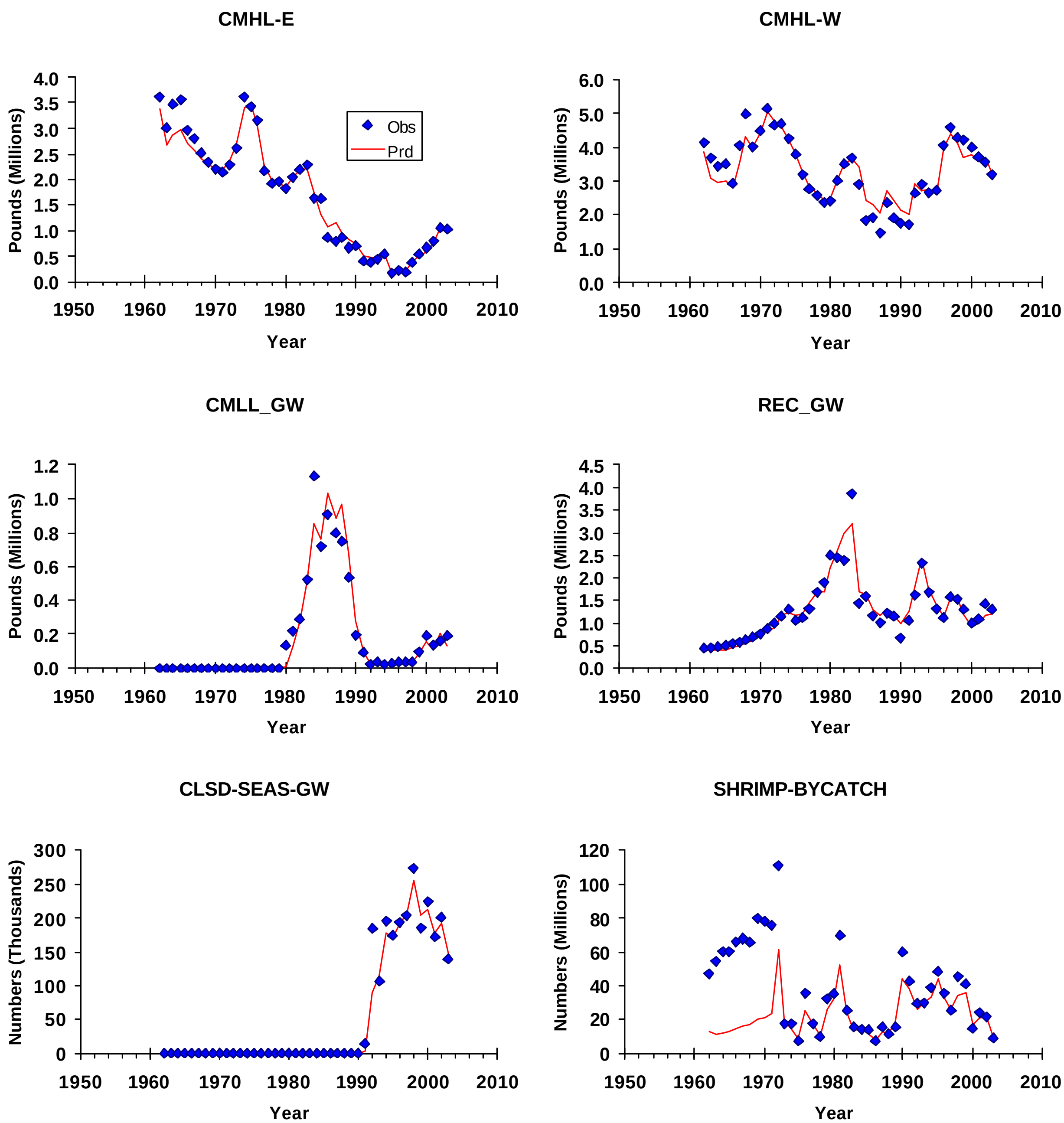


Figure 30. Fits total catches by fleet for Runs G to L.

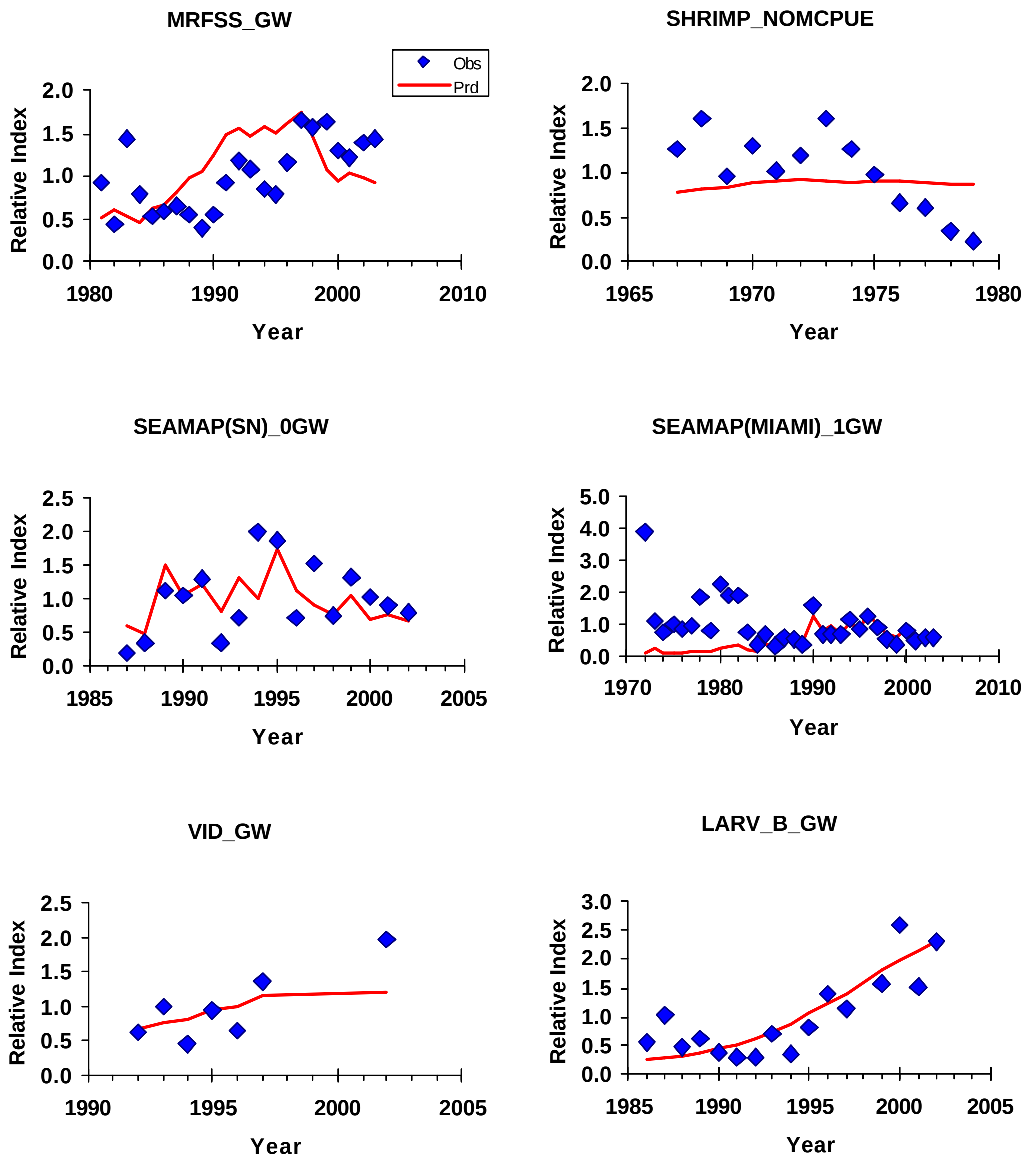


Figure 31. Fits to indices of abundance for Runs G and J.

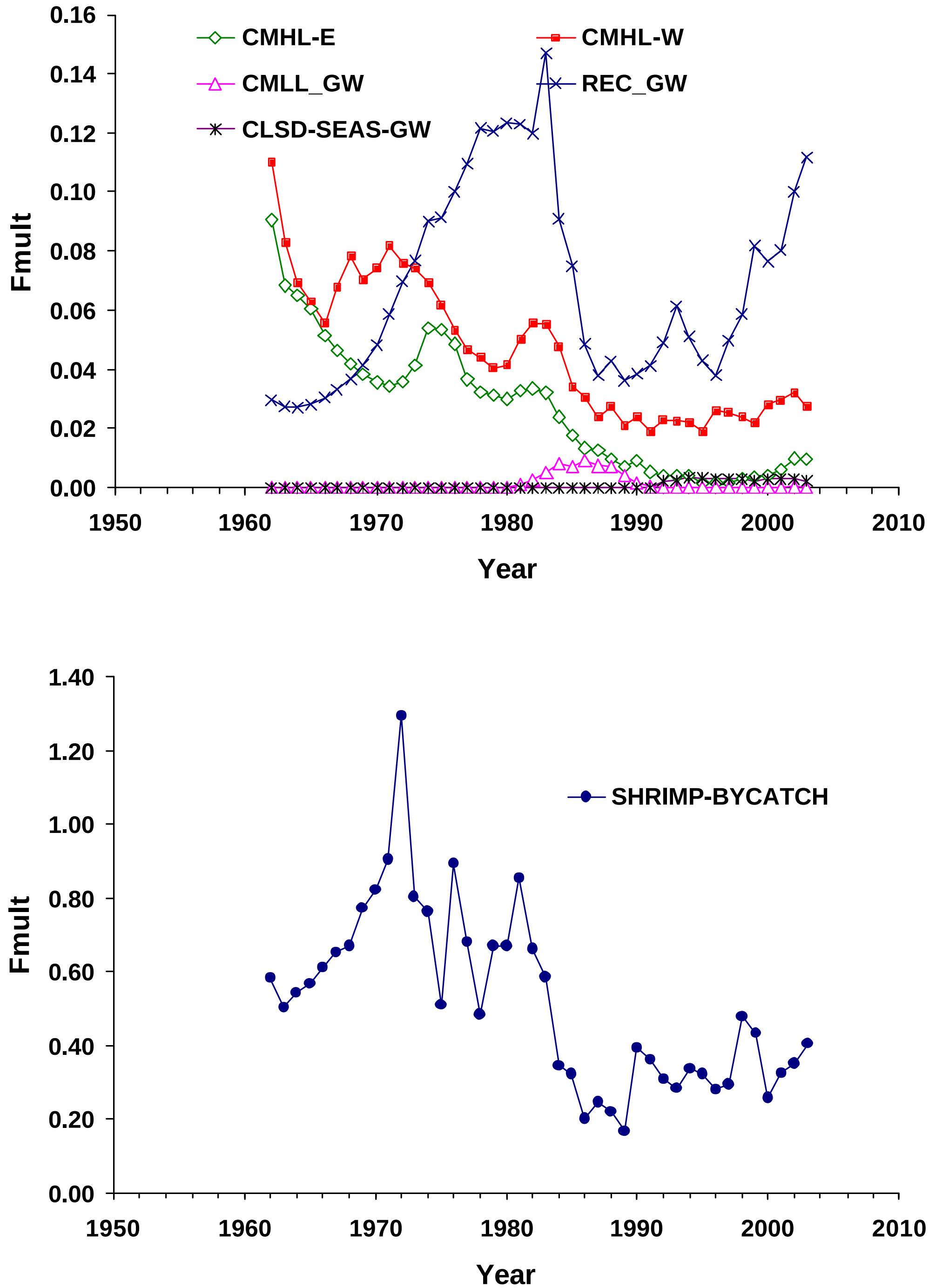


Figure 32. F multipliers by fleet for Runs G and J.

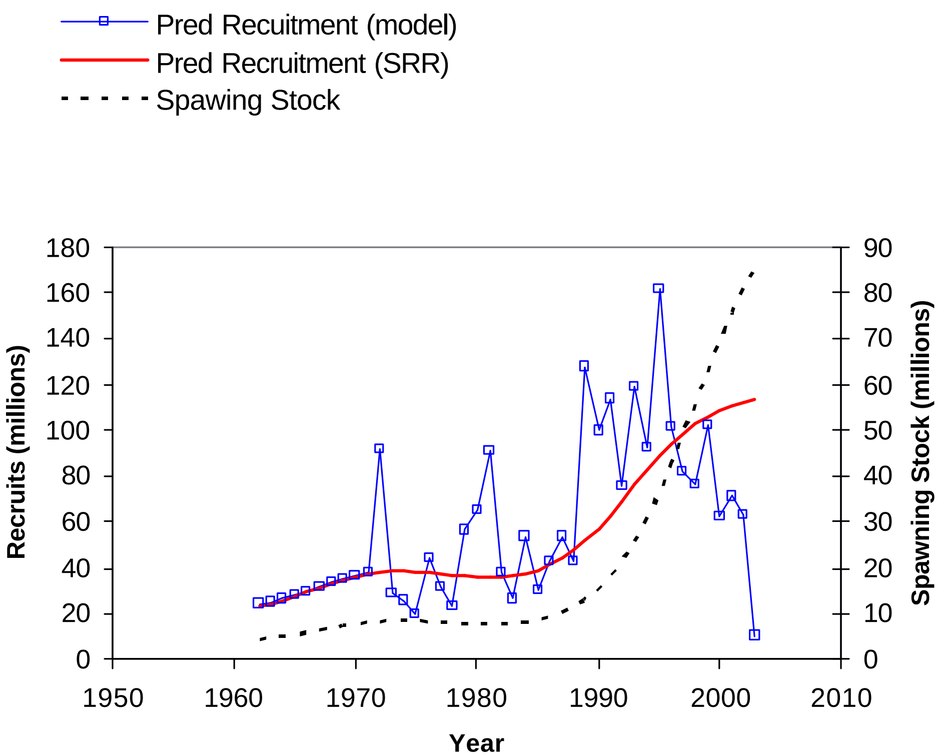


Figure 33. Spawning stock and recruitment estimates for Runs G and J.

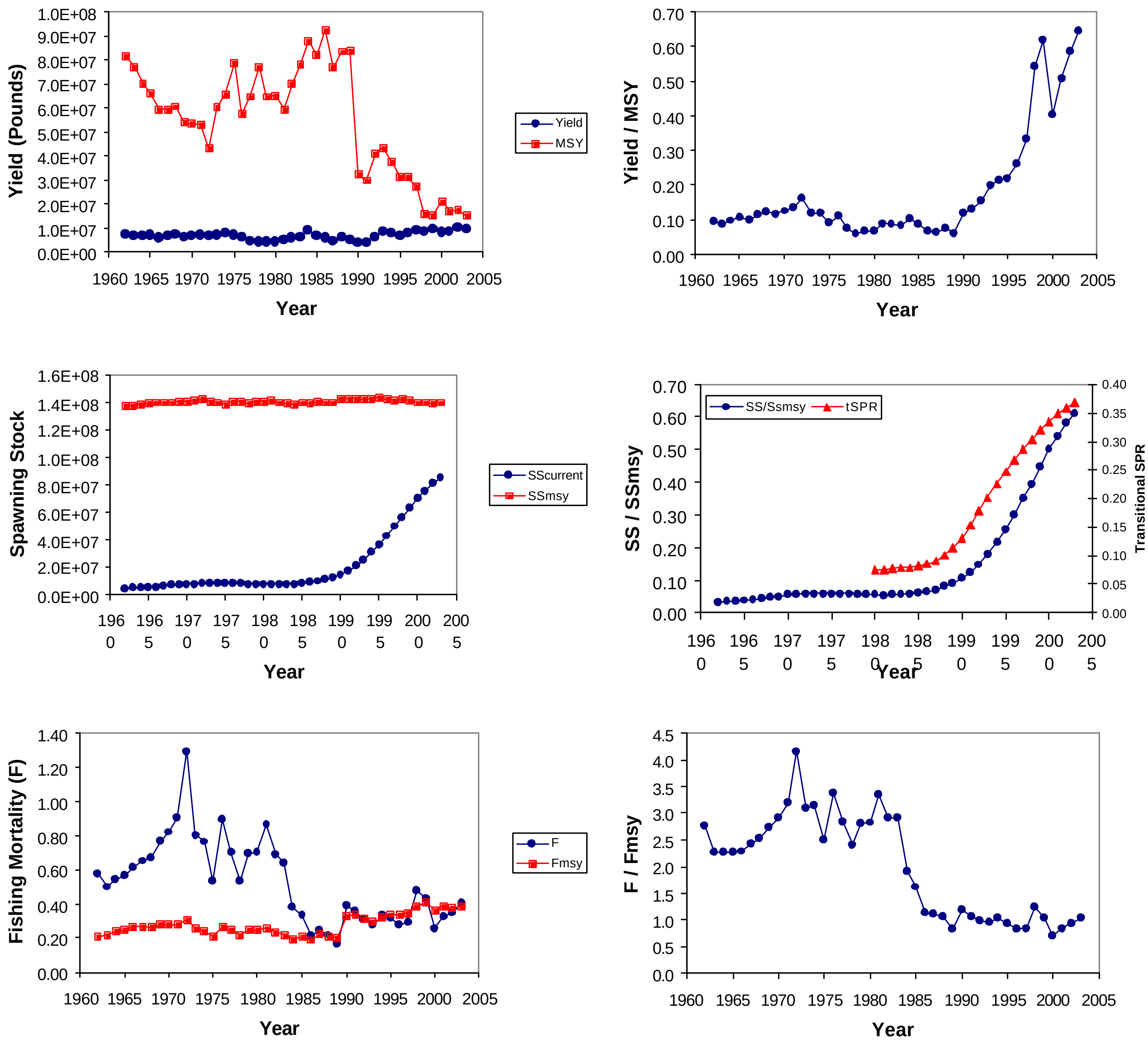


Figure 34. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run G.

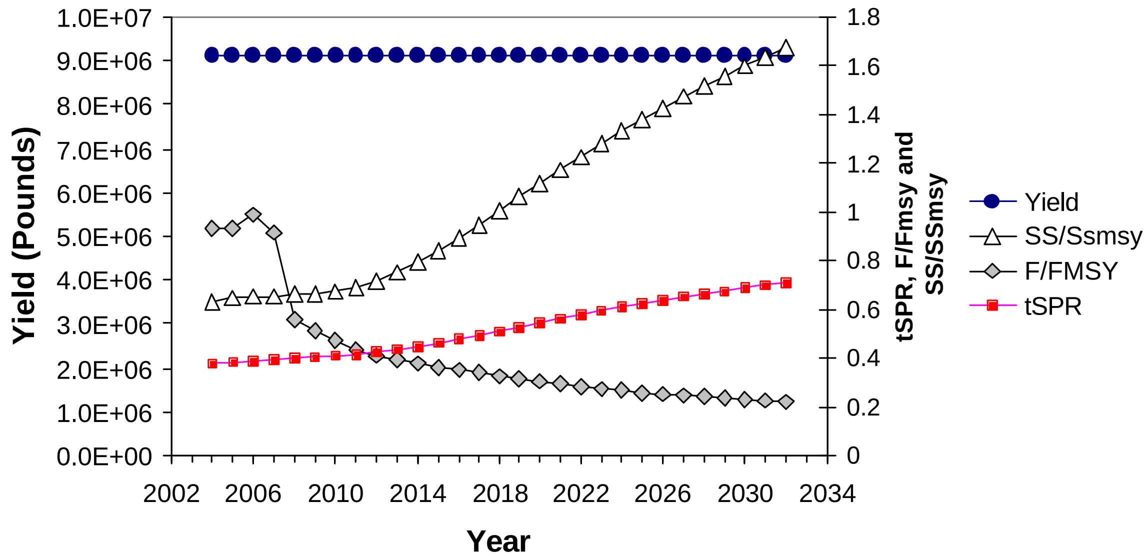


Figure 35. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run G . The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

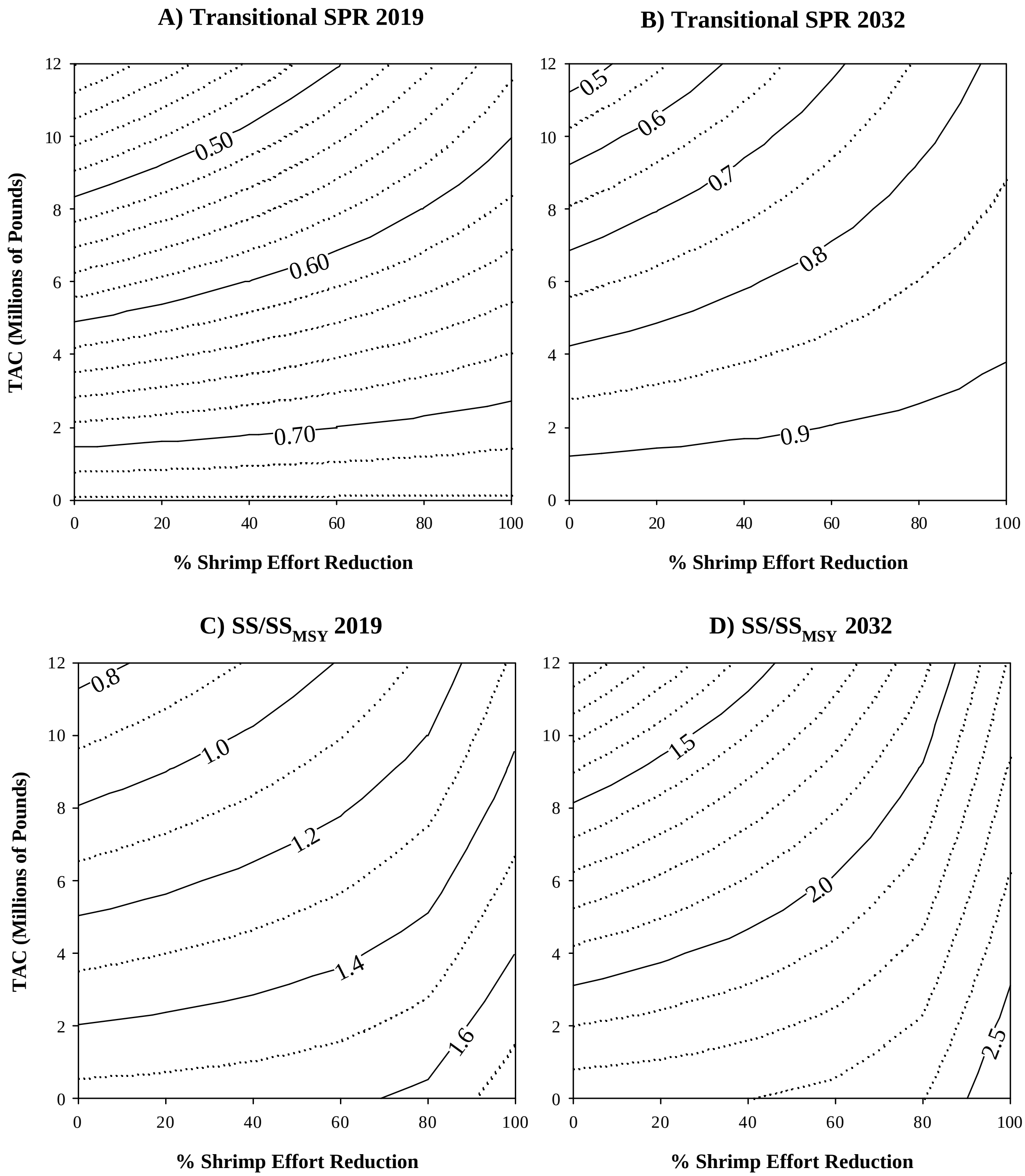


Figure 36. Run G projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

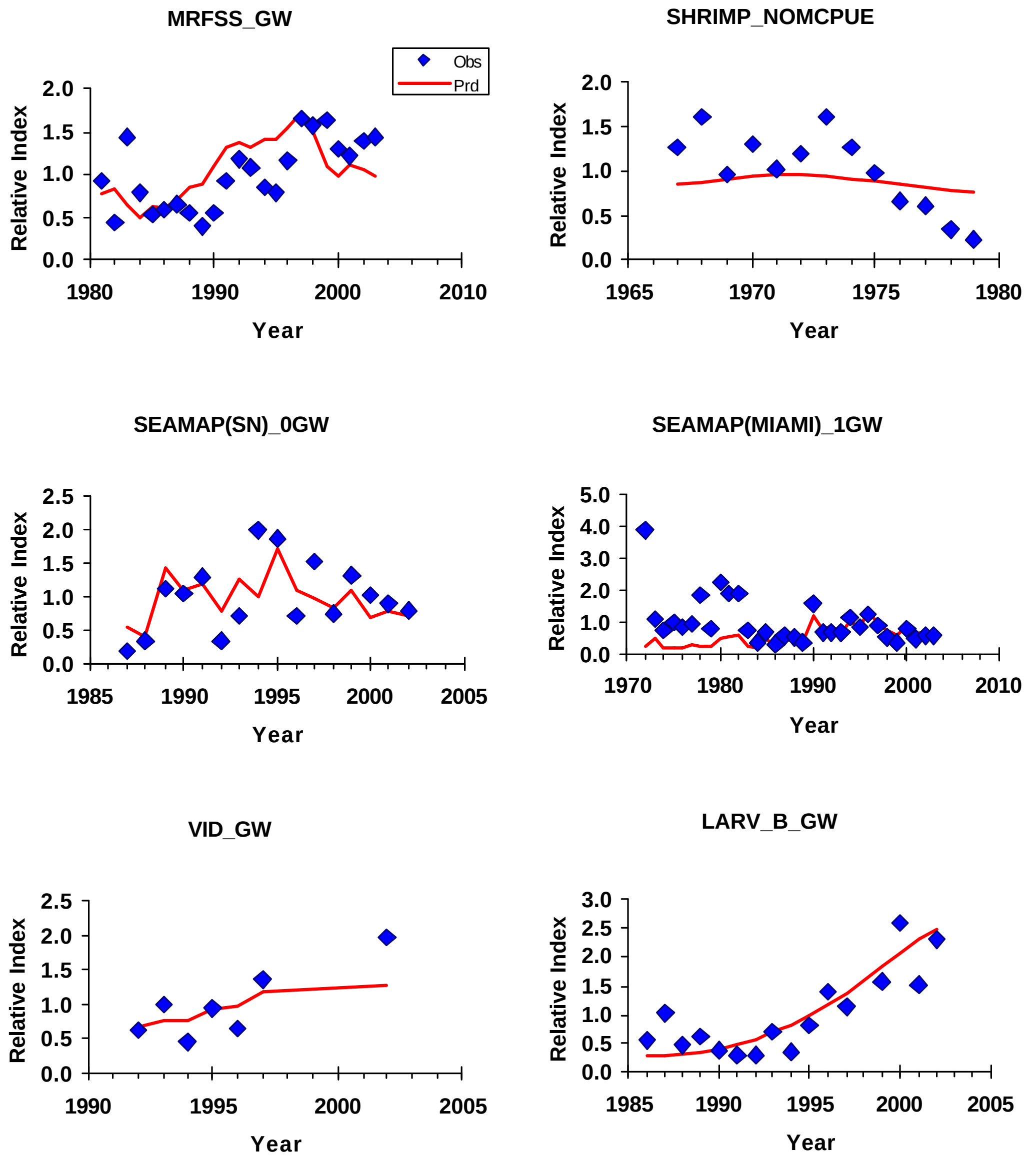


Figure 37. Fits to indices of abundance for Runs H and K.

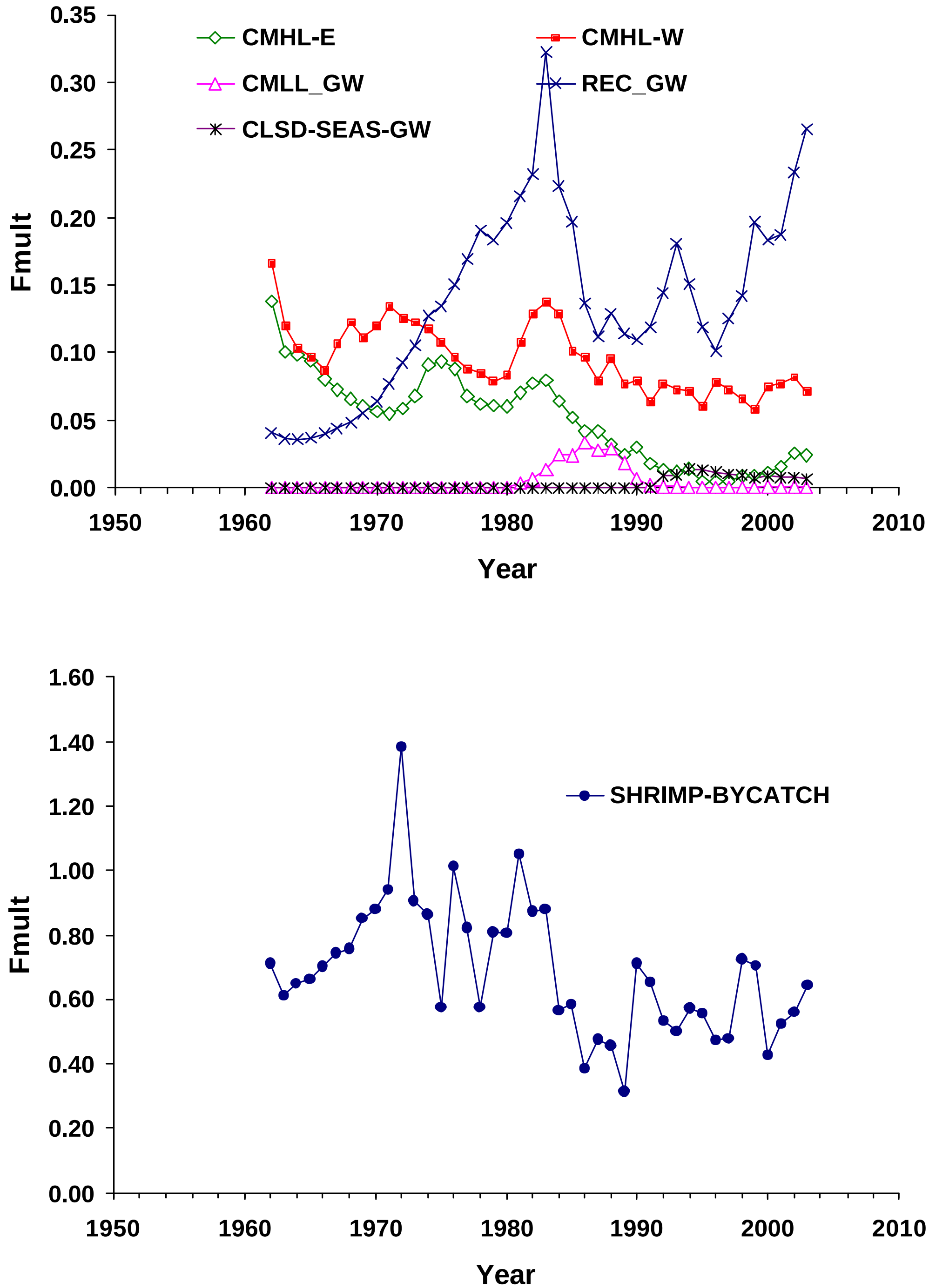


Figure 38. F multipliers by fleet for Runs H and K.

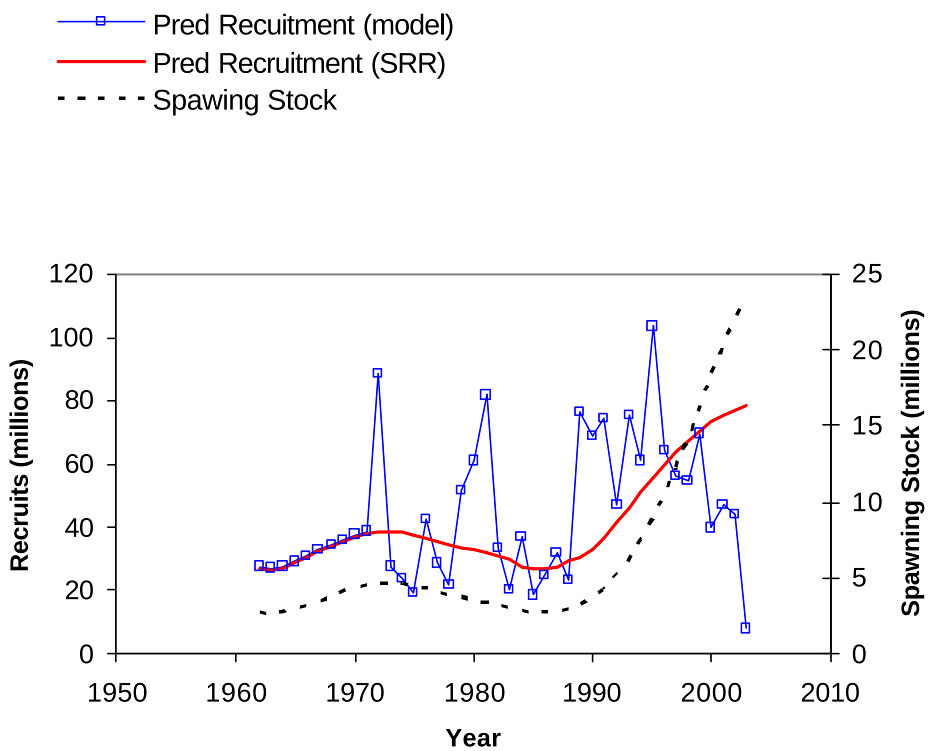


Figure 39. Spawning stock and recruitment estimates for Runs H and K.

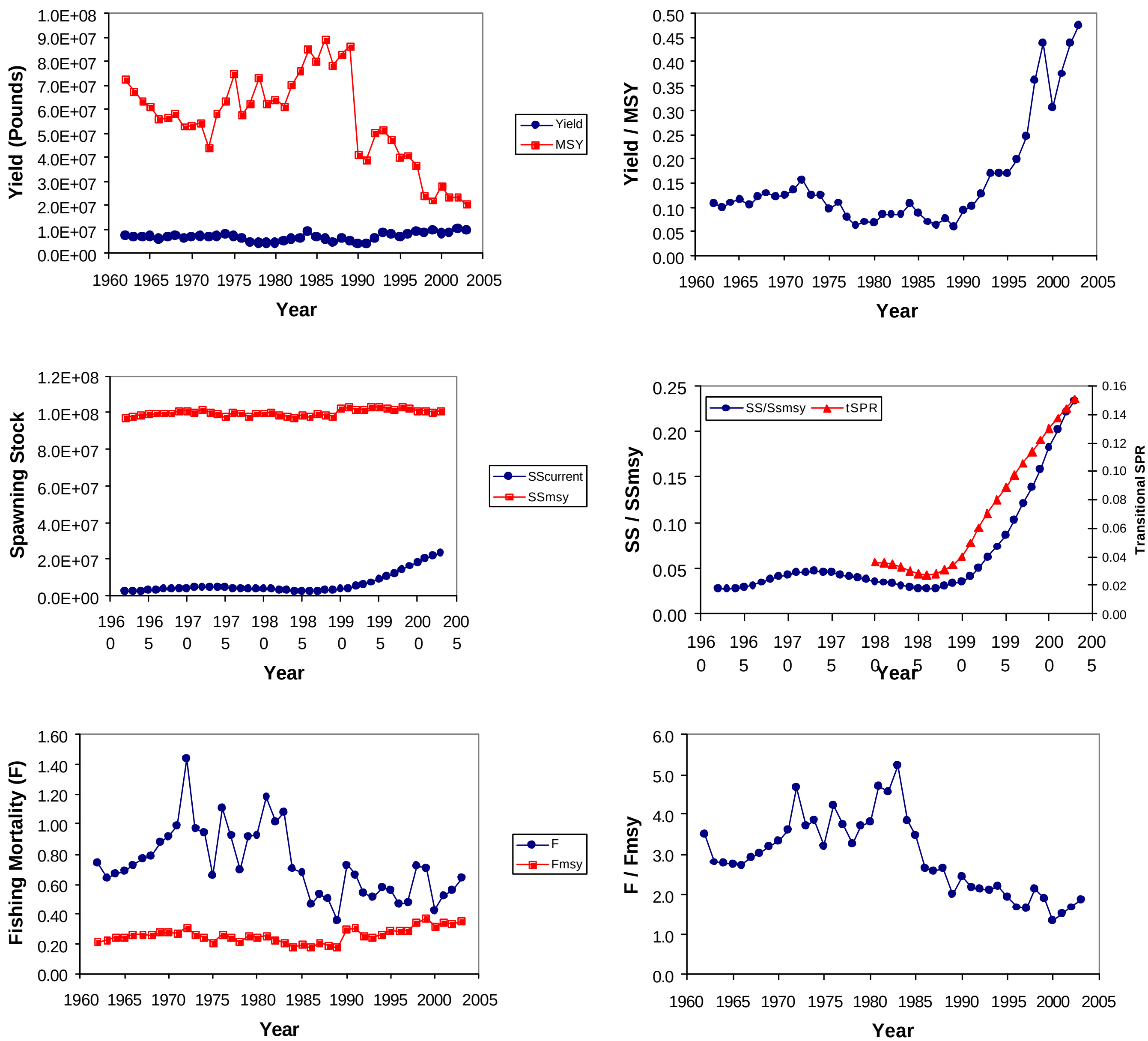


Figure 40. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run H.

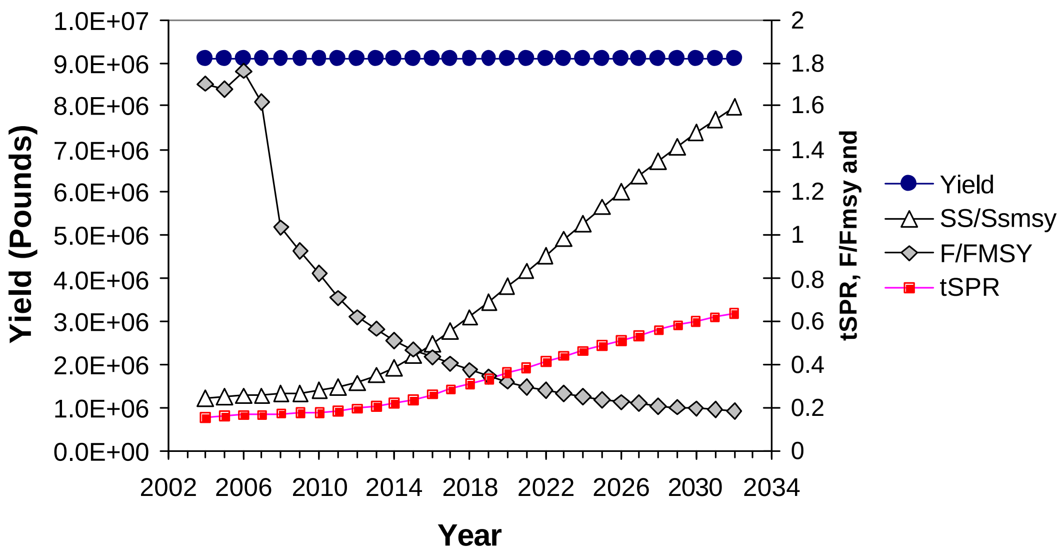


Figure 41. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run H. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

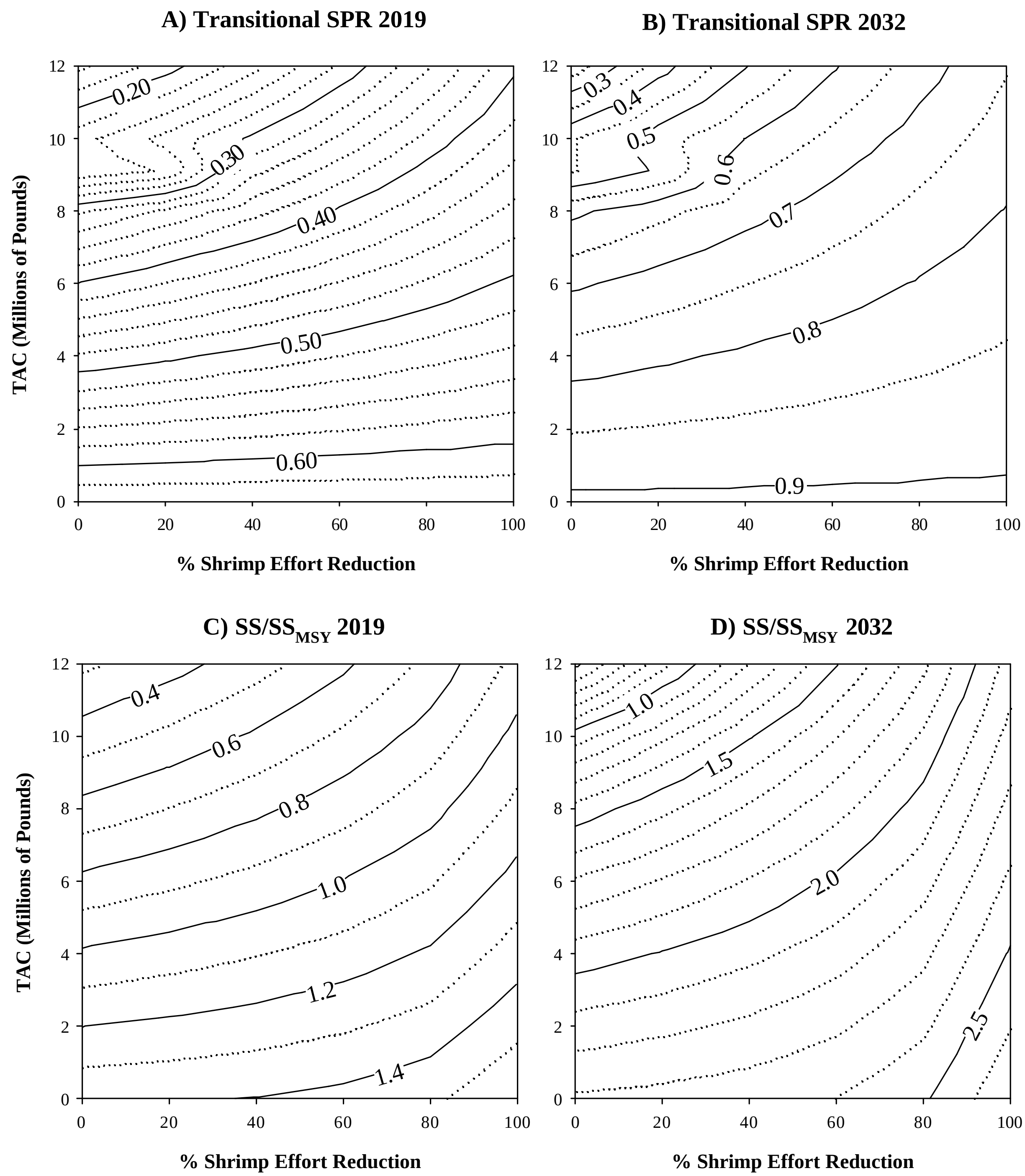


Figure 42. Run H projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS_{MSY} in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

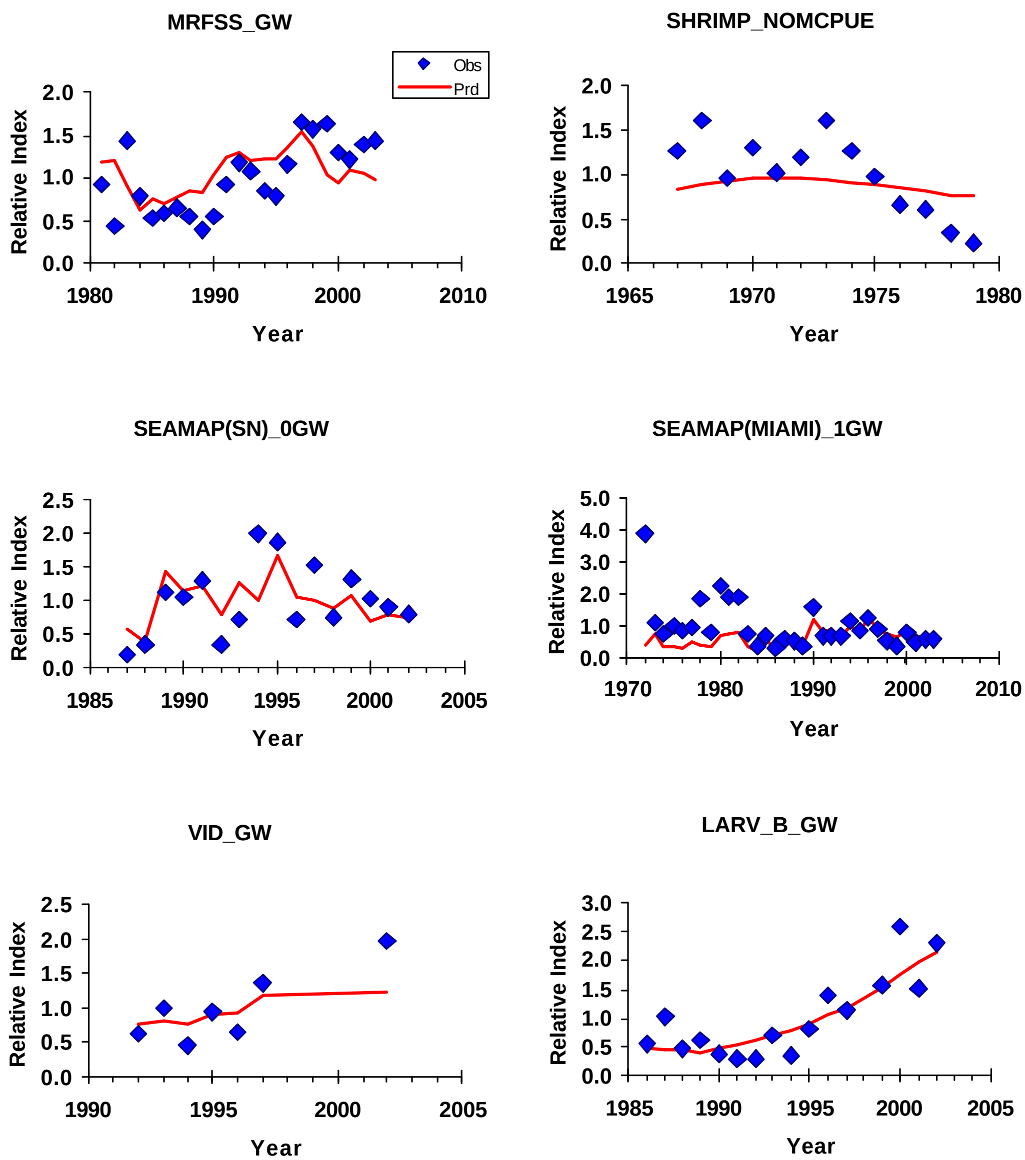


Figure 43. Fits to indices of abundance for Runs I and L.

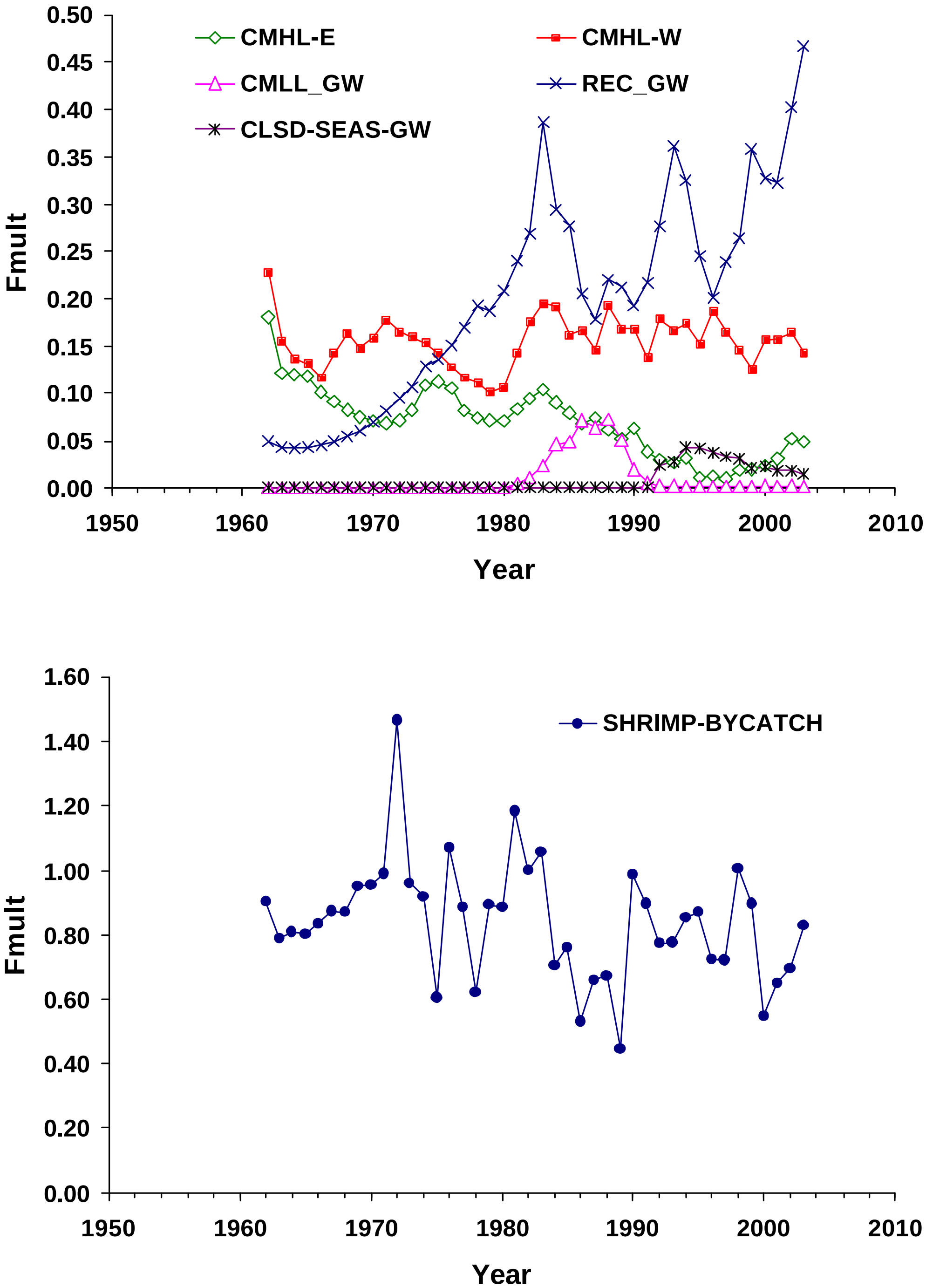


Figure 44. F multipliers by fleet for Runs I and L .

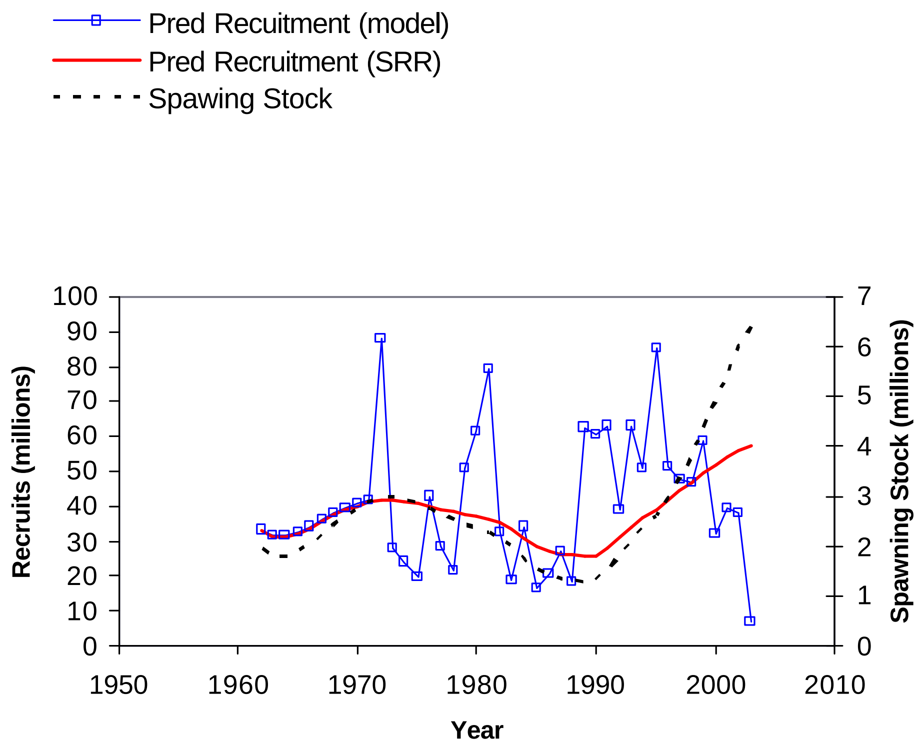


Figure 45. Spawning stock and recruitment estimates for Runs I and L.

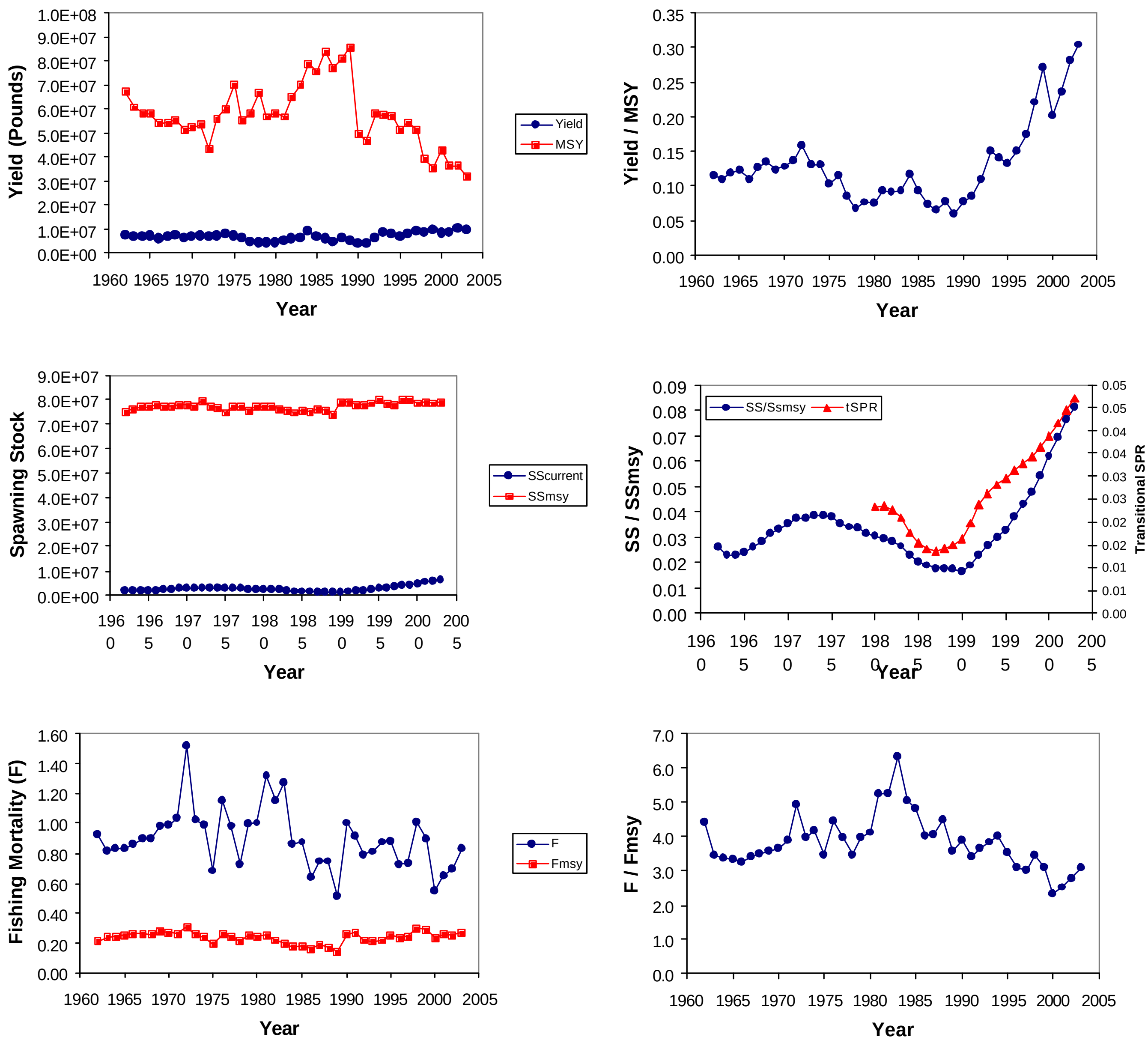


Figure 46. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run I.

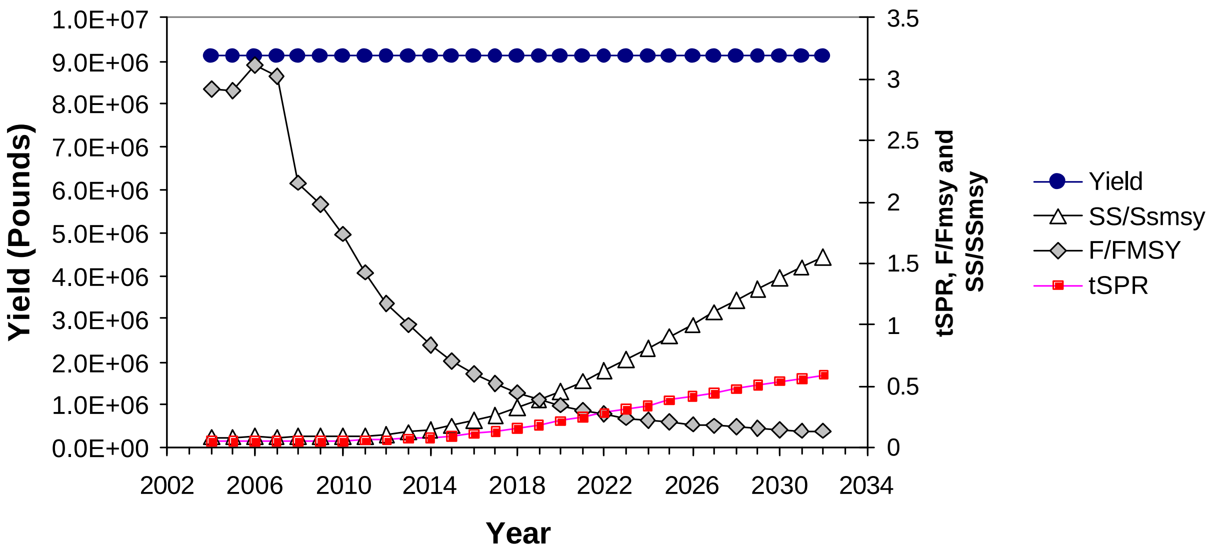


Figure 47. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run I. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

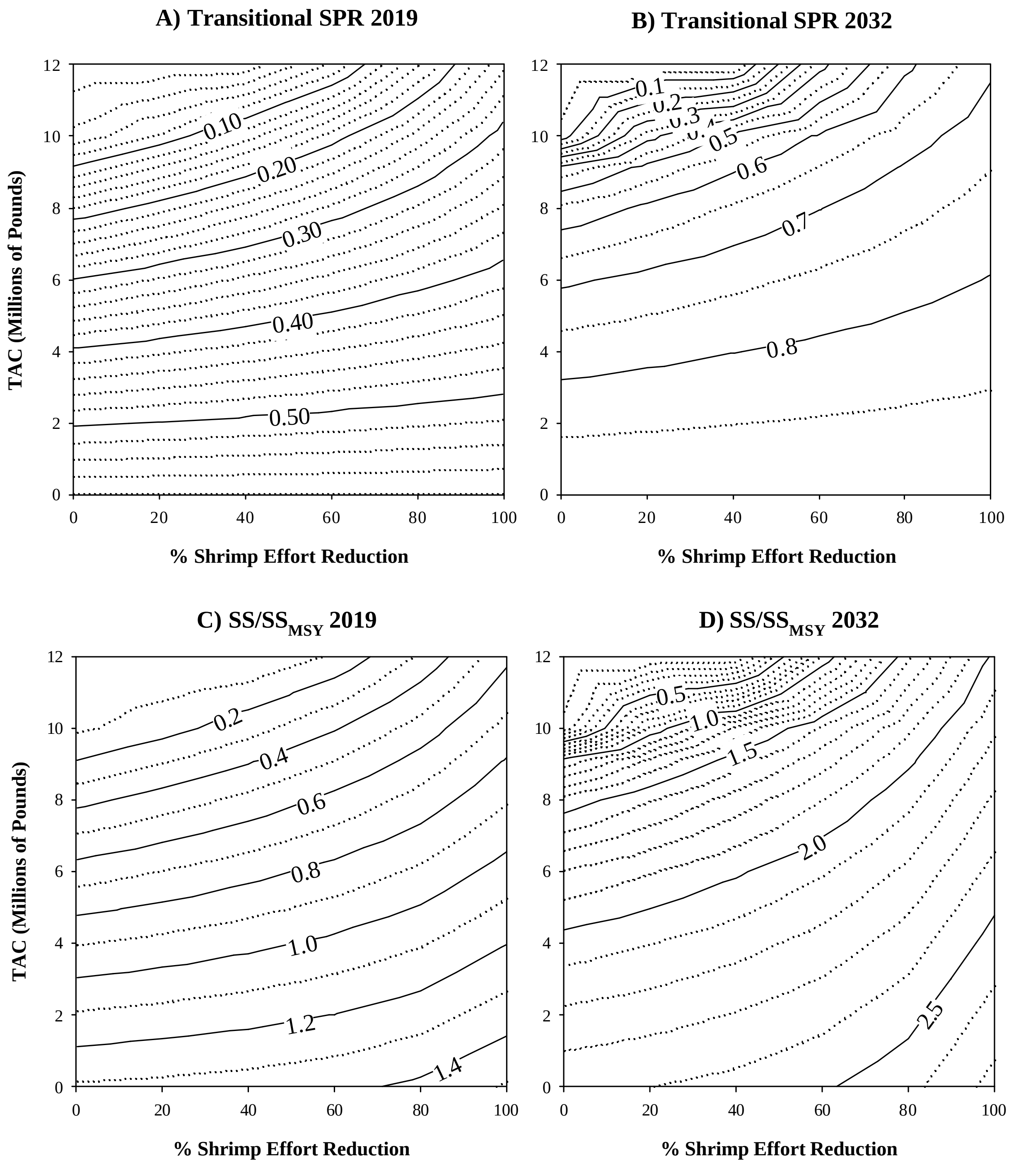


Figure 48. Run I projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

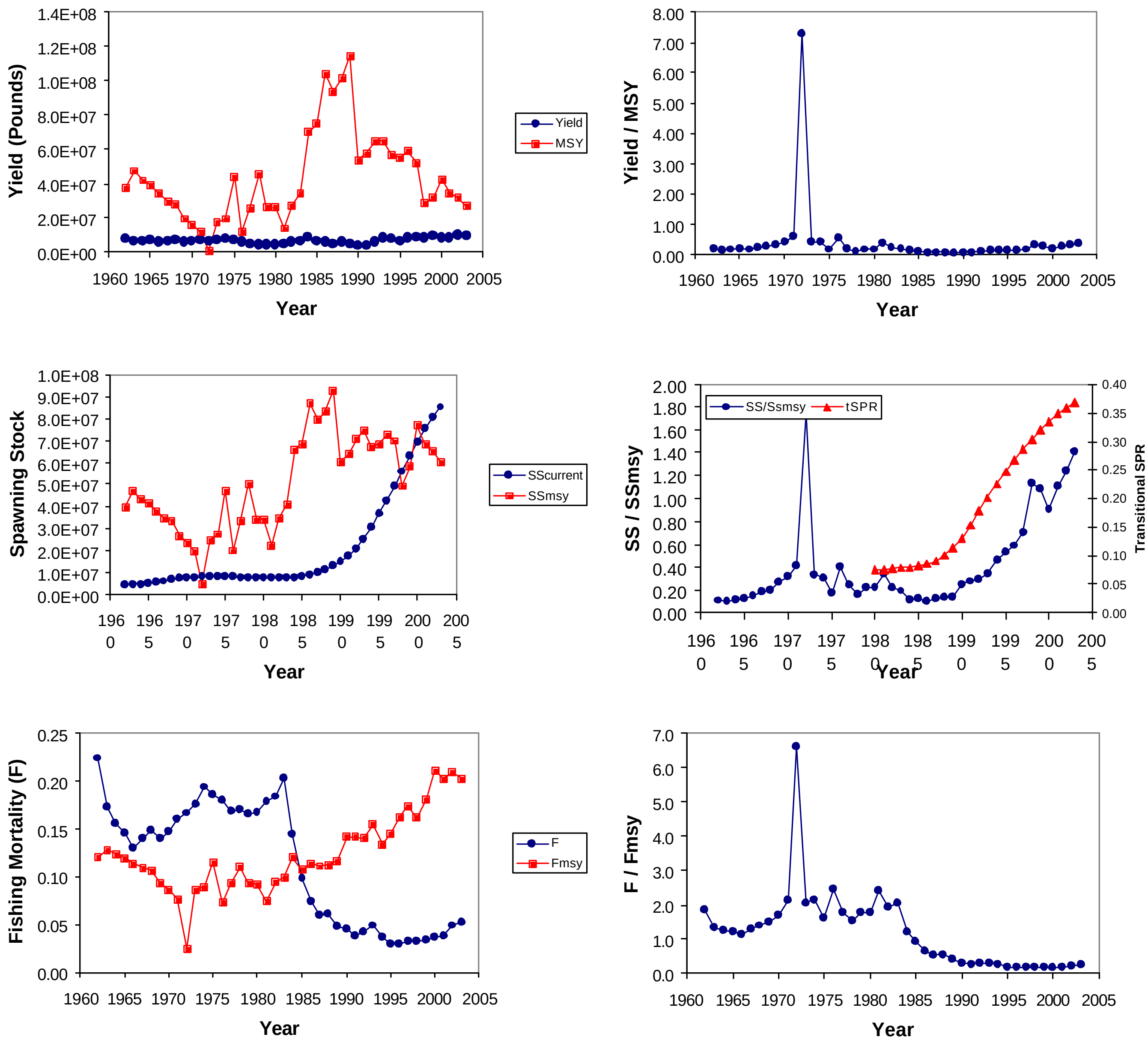


Figure 49. Trajectories of Yield, F, Spawning stock (SS), MSY, $F_{MSY,}$ SS_{MSY} and tSPR for Run J.

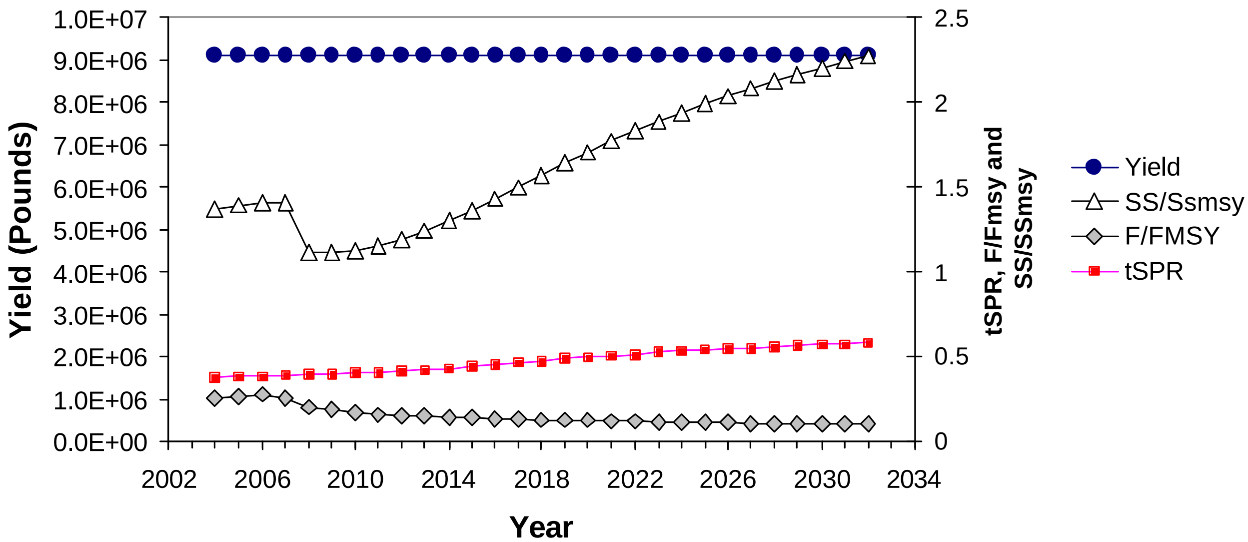


Figure 50. Projection of yield, transitional SPR, SS/SS$_{MSY}$ and F/F$_{MSY}$ for Run J. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

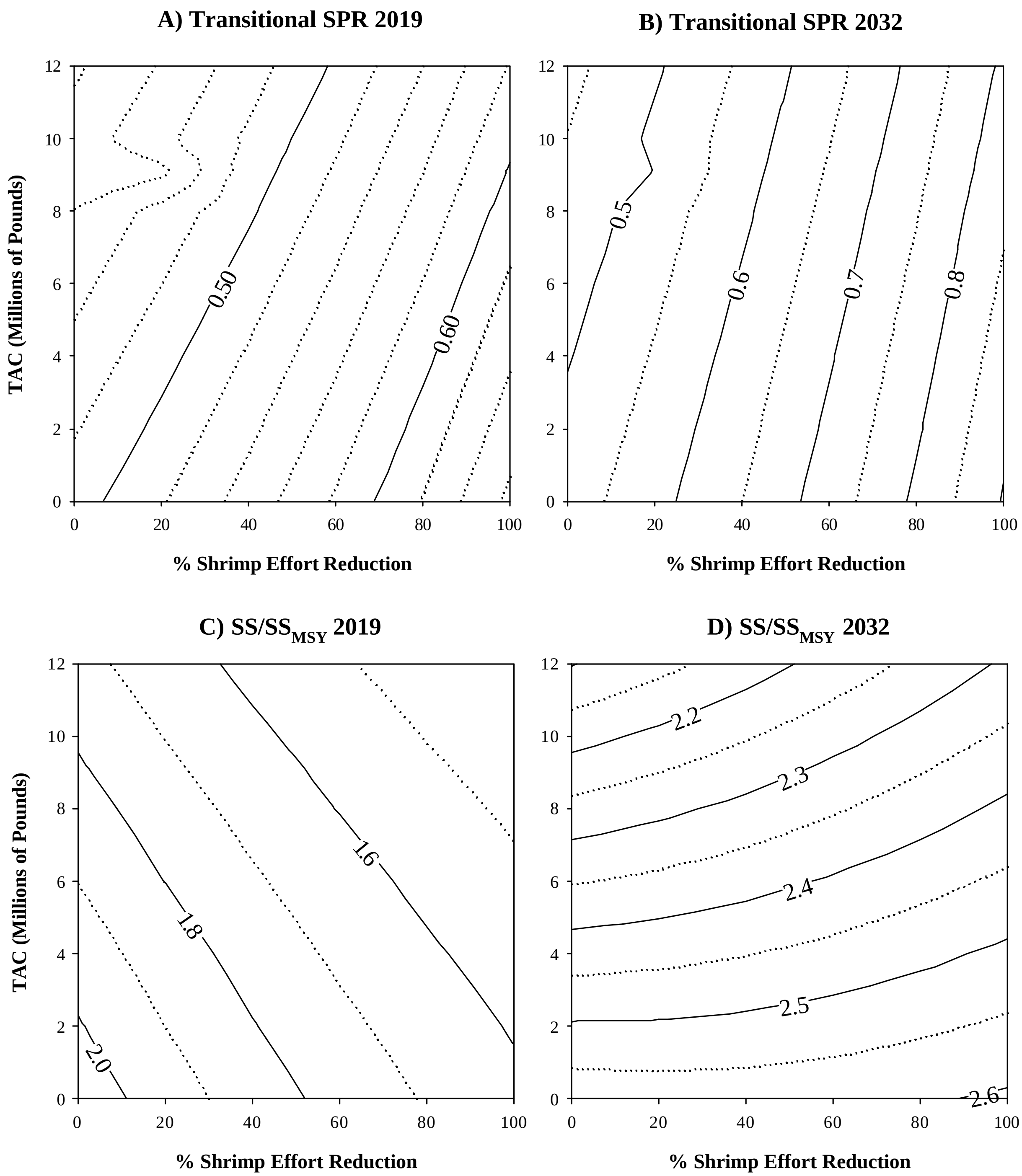


Figure 51. Run J projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

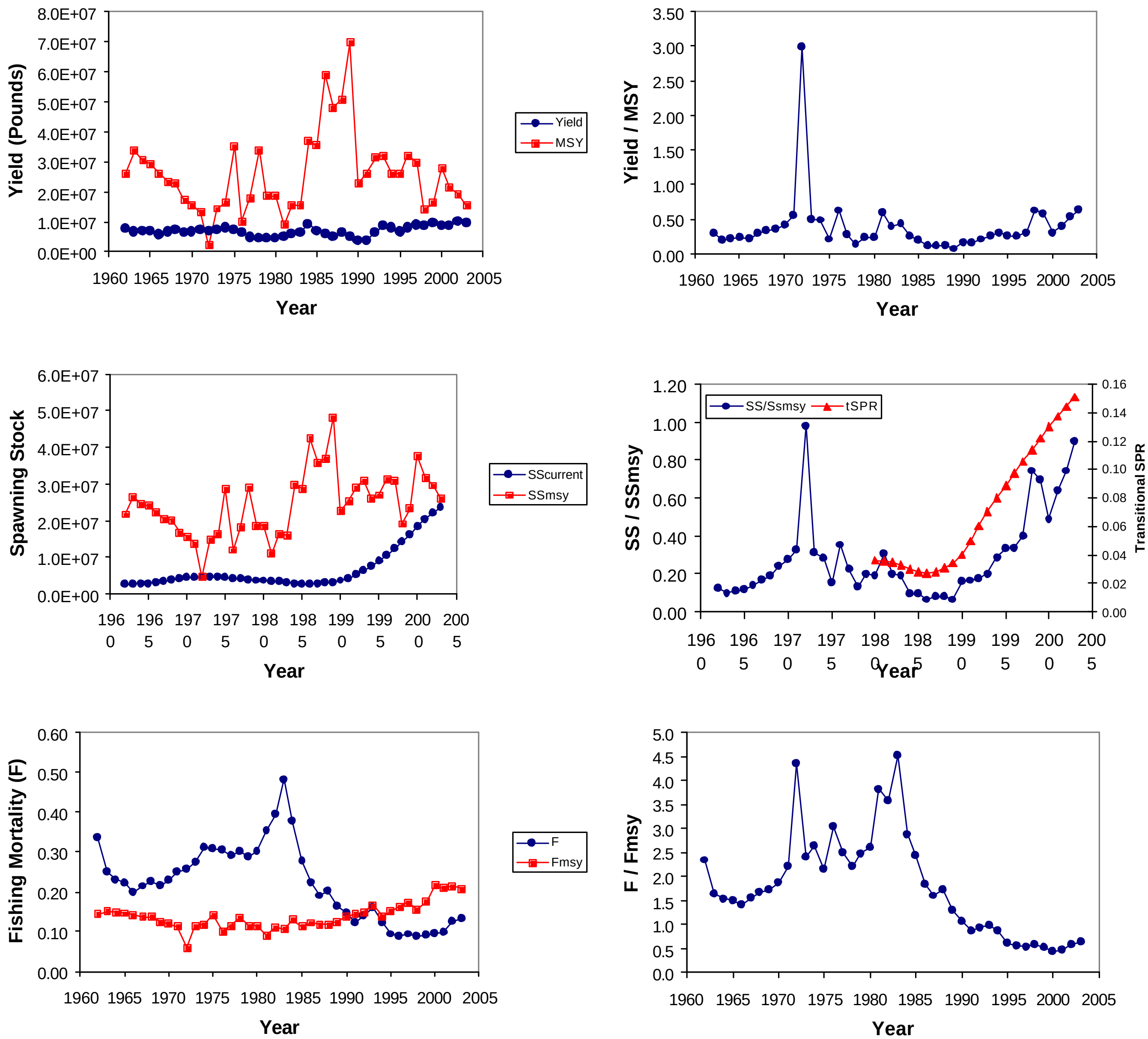


Figure 52. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run K.

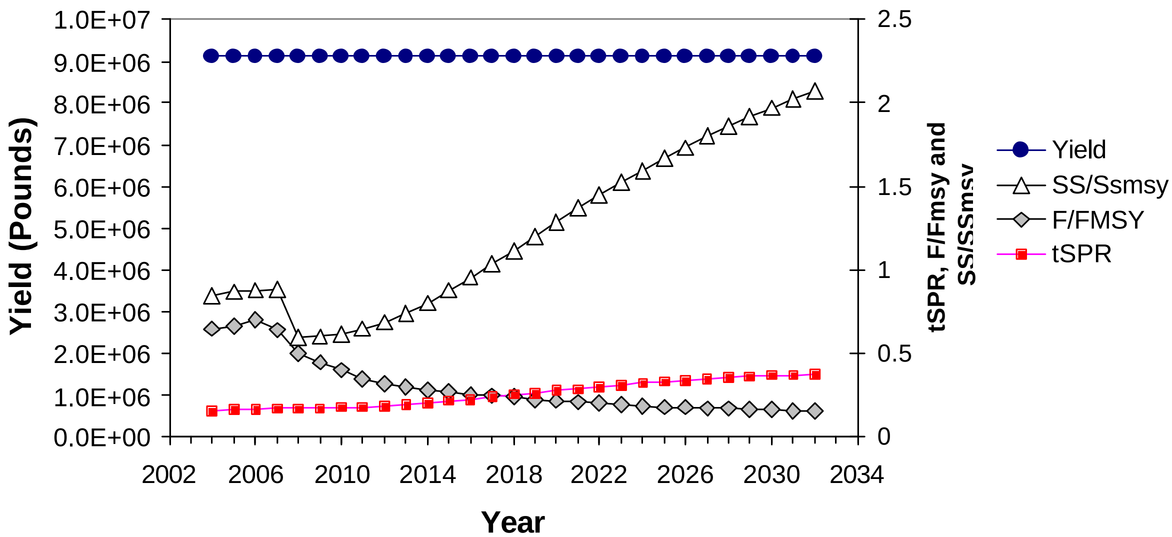


Figure 53. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run K. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

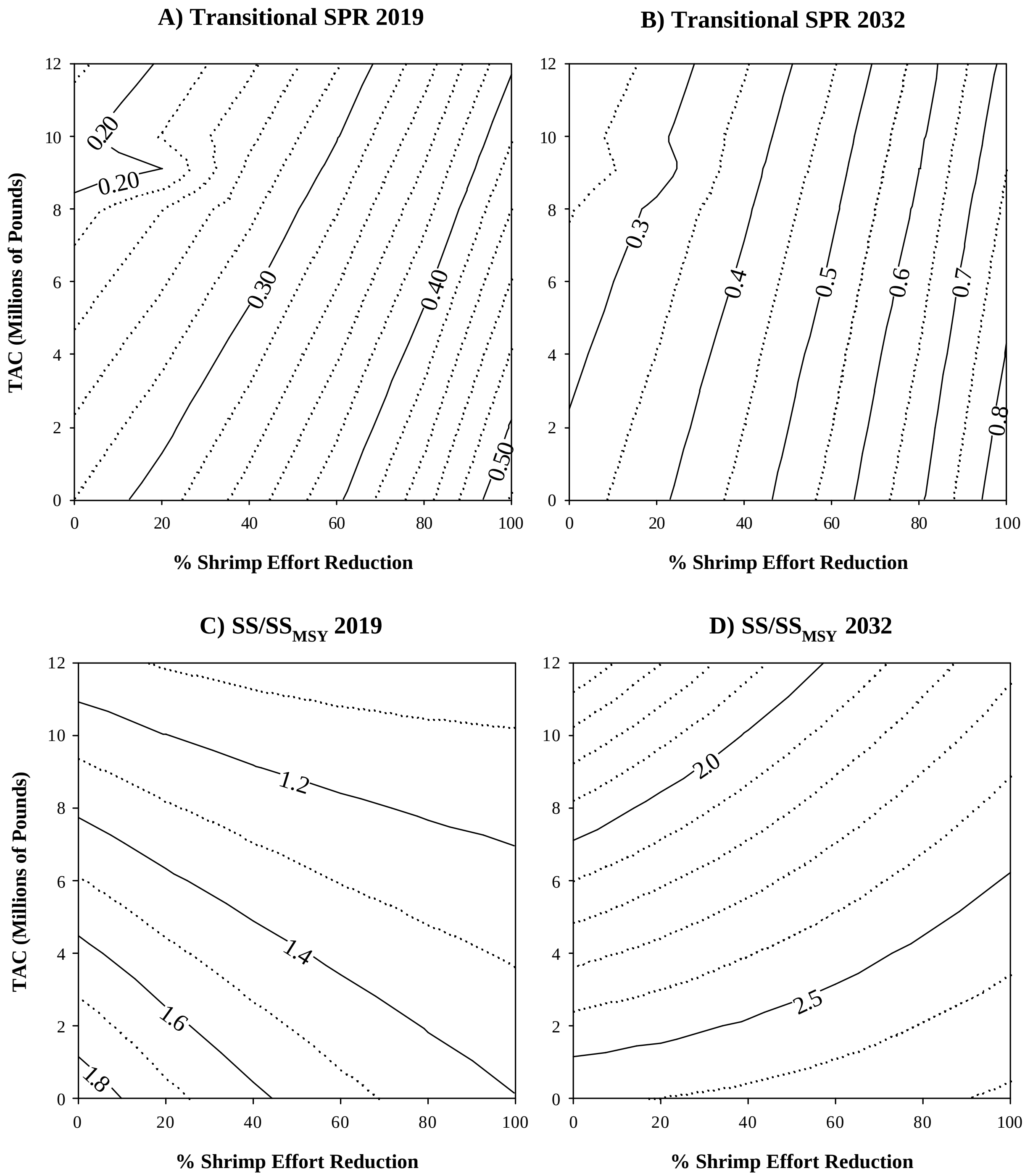


Figure 54. Run K projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS$_{MSY}$ in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.

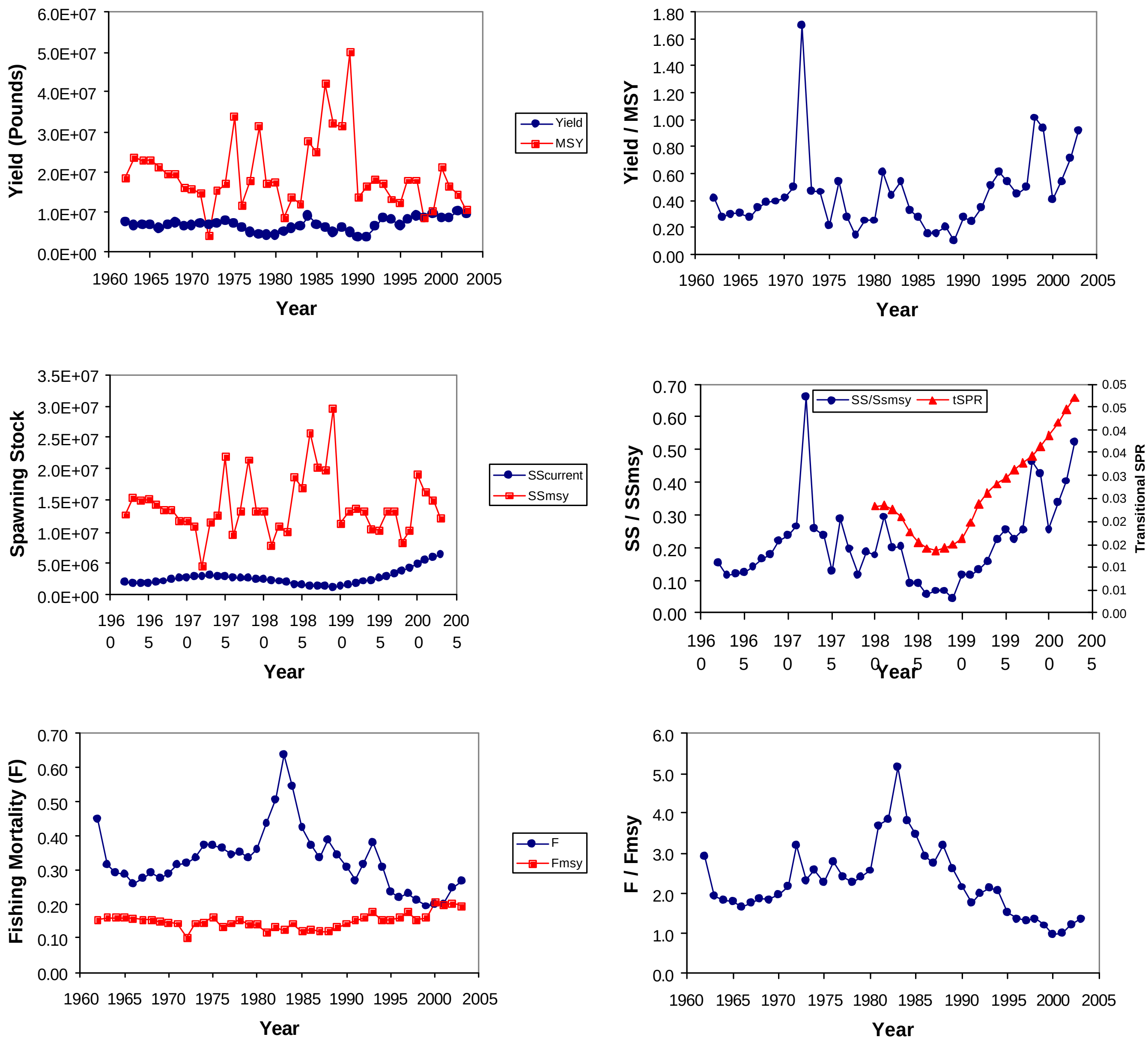


Figure 55. Trajectories of Yield, F, Spawning stock (SS), MSY, F_{MSY}, SS_{MSY} and tSPR for Run L.

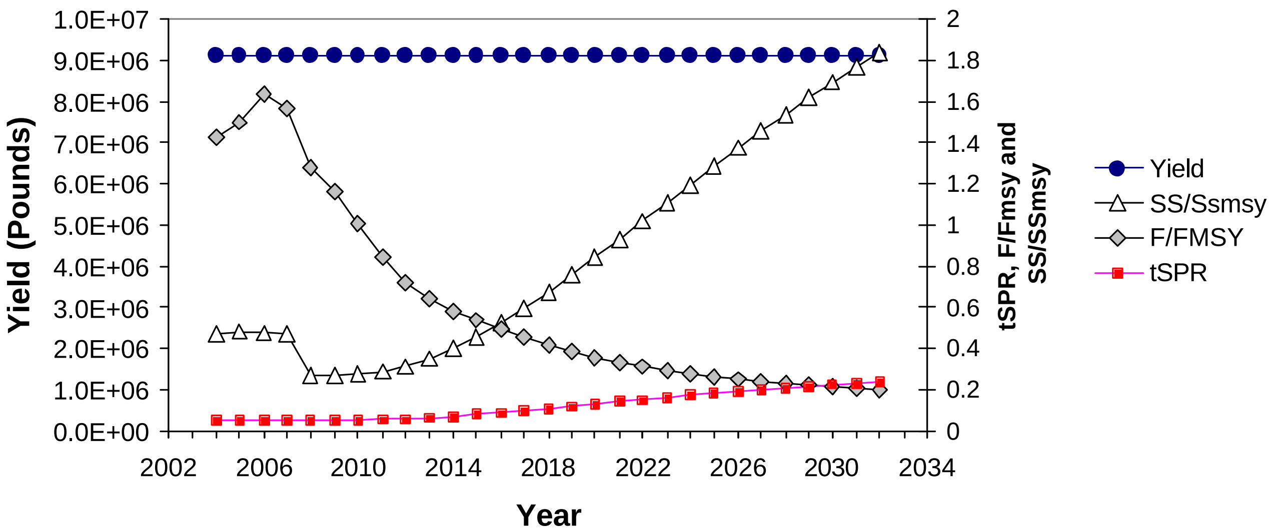


Figure 56. Projection of yield, transitional SPR, SS/SS_{MSY} and F/F_{MSY} for Run L. The projection assumes a constant TAC of 9.12 million pounds 2004-2032, and a 40% reduction in the effort of the shrimp fleet in 2008.

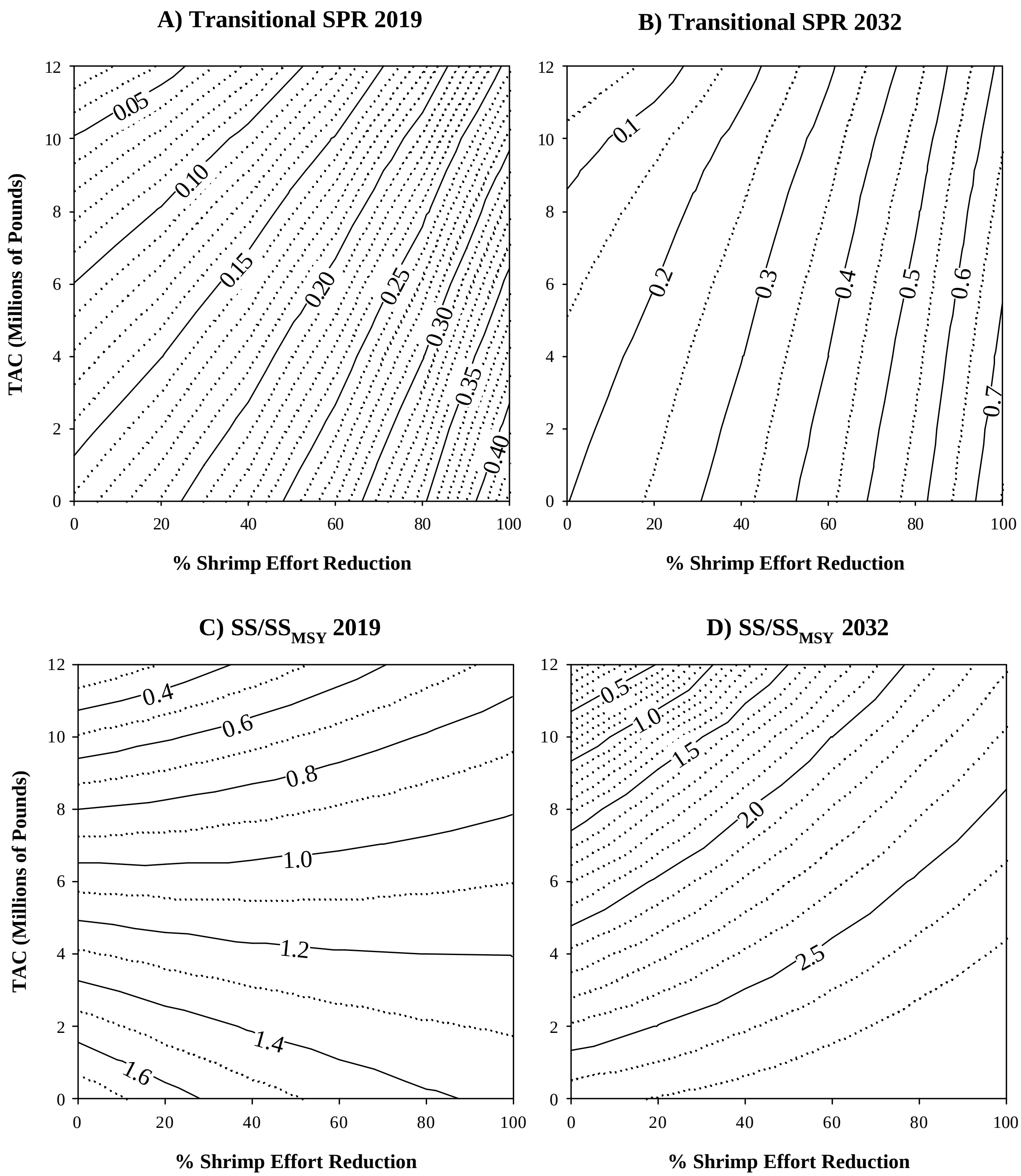


Figure 57. Run L projections of transitional SPR in 2019 (**A**) and 2032 (**B**) and SS/SS_{MSY} in 2019 (**C**) and 2032 (**D**) using a TAC of 0 to 12 million pounds and a concurrent reduction in shrimp fleet effort of 0 to 100% beginning in 2008.