

## Appendix 4. ASAP Gulf wide projection results

### METHODS

Projections were made from each of the “unlinked” (current-shrimp) ASAP runs (SEDAR7-RW-2; SEDAR7-RW-3) to predict the outcome of various management decisions. Isopleths of projected transitional SPR (tSPR), spawning stock status (S/Smsy) 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%. For all projections, the closed season commercial discards and shrimp bycatch fleets were specified as unlinked, and changes in TAC, directed F and shrimp bycatch commenced in 2007. For the years 2004-2006, the current TAC of 9.12 million pounds was used for the projection.

Current TAC for the Gulf of Mexico red snapper stock is 9.12 million pounds. “Current” levels of directed F and shrimp bycatch were defined using the three-year average during 2001-2003. Current shrimp bycatch is equivalent to a 0% reduction. A 100% reduction implies the termination of red snapper bycatch by the shrimp fleet beginning in 2007. Bycatch reductions can result from direct management measures (e.g. effort controls, bycatch reduction devices) or from indirect factors (e.g. effort reductions caused by economic factors, gear changes).

Annual MSY estimates are not static. Instead, MSY is reestimated at each level of shrimp effort reduction. MSY estimates in 2010 and 2032 increase with reductions in shrimp effort (applied in 2007).

### RESULTS AND DISCUSSION

#### ASAP Gulf-wide 1962-2003 Projections

##### Steepness = 0.81

At steepness = 0.81,  $tSPR_{2003}$  was 0.32. It is possible to achieve  $tSPR > 0.3$  in 2010 at TACs up to 20 million pounds (Fig 1A) or 100% of current directed fishing mortality (Fig. 1C) without reducing shrimp effort. S/Smsy was 1.17 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 1B). In 2010, S/Smsy is maximal at a 0% reduction in shrimp effort because  $MSY_{2010}$  increases with reductions in shrimp effort. A yield greater than 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 1D).

In 2032,  $tSPR > 0.3$  can be achieved at TACs up to 17 million pounds (Fig 2A) and at 100% of current directed F (Fig 2C) without reducing shrimp effort. A TAC of 20 million pounds will permit  $tSPR > 0.3$  if shrimp effort is reduced by approximately 20% (Fig. 2A). At current fishing levels, projected S/Smsy in 2032 is approximately 1.9 and  $tSPR > 0.3$  (Fig. 2B). Higher levels are possible with reductions in TAC or shrimp effort. A yield in excess of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 2D).

**Steepness = 0.90**

At steepness = 0.90,  $tSPR_{2003}$  was 0.14. It is not possible to achieve  $tSPR > 0.2$  in 2010 (Figs. 3A-C).  $S/Smsy$  was 0.7 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 3B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 3D).

Transitional  $SPR > 0.3$  can be achieved and maintained through 2032 by reducing TAC to 5 million pounds (Fig 4A), by reducing directed F to about 30% of 2001-2003 levels (Fig 4C), or by reducing shrimp effort by 20-40% (Figs 4A-C). Smaller reductions in both directed fishing and shrimp effort can also allow  $tSPR > 0.3$ . Transitional  $SPR > 0.2$  can be achieved with essentially no reduction in TAC, directed F or shrimp effort (Figs 4A-C). At current fishing levels, projected  $S/Smsy$  in 2032 is approximately 1.7, and  $tSPR$  is about 0.25 (Fig. 4B). Higher levels are possible with reductions in TAC or shrimp effort. A yield of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 4D).

**Steepness = 0.95**

At steepness = 0.95,  $tSPR_{2003}$  was 0.06. It is not possible to achieve  $tSPR > 0.2$  in 2010, but levels lower than 0.1 are avoided if TAC is reduced to 5 million pounds (Fig 5A) or if directed fishing is reduced to 50% of 2001-2003 levels (Fig 5C).  $S/Smsy$  was 0.47 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 5B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 5D).

Transitional  $SPR > 0.3$  can be achieved and maintained through 2032 by eliminating the directed fishery (Fig 6A-C), or by reducing shrimp effort by  $>40\%$  (Figs 6A). Smaller reductions in both directed fishing and shrimp effort can also allow  $tSPR > 0.3$ . For example, a 25% reduction in shrimp effort and a TAC of 5 million pounds is sufficient (Fig 6A). Transitional  $SPR > 0.2$  can be achieved by reducing TAC to 7 million pounds (Fig 6A), by reducing directed fishing mortality to 40% of 2001-2003 levels, or with smaller reductions and a concurrent reduction in shrimp effort. At current fishing levels, projected  $S/Smsy$  in 2032 is approximately 1.7, but  $tSPR$  is less than 0.2 (Fig. 6B). A yield greater than 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 6D), but yields in excess of 20 million pounds are possible with moderate reductions in shrimp effort.

**ASAP Gulf-wide 1984-2003 Projections****Steepness = 0.81**

At steepness = 0.81,  $tSPR_{2003}$  was 0.23. It is not possible to achieve  $tSPR > 0.3$  in 2010, but  $tSPR > 0.2$  is possible at TACs up to 20 million pounds (Fig 7A) or 100% of current directed fishing mortality (Fig. 7C) without reducing shrimp effort.  $S/Smsy$  was 1.0 in 2003, and is maintained near that level in 2010 without reductions in TAC or shrimp effort (Fig 7B). In 2010,  $S/Smsy$  is maximal at a 0% reduction in shrimp effort because the 2010 MSY estimate increases with shrimp reduction. Yields near 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 7D).

In 2032,  $tSPR > 0.3$  can be achieved with moderate (30%) reductions in TAC (or directed F) and shrimp effort (Fig 8A-C). Transitional  $SPR > 0.2$  can be achieved without reductions. At current fishing levels, projected  $S/Smsy$  in 2032 is approximately 1.2 and  $tSPR$  is approximately 0.2 (Fig. 8B). Projected yield in 2032 is greater than 9.12 million pounds without reductions in fishing effort.

#### **Steepness = 0.90**

At steepness = 0.90,  $tSPR_{2003}$  was 0.13. It is not possible to achieve  $tSPR > 0.1$  in 2010 (Figs. 9A-C).  $S/Smsy$  was 0.77 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 9B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 9D).

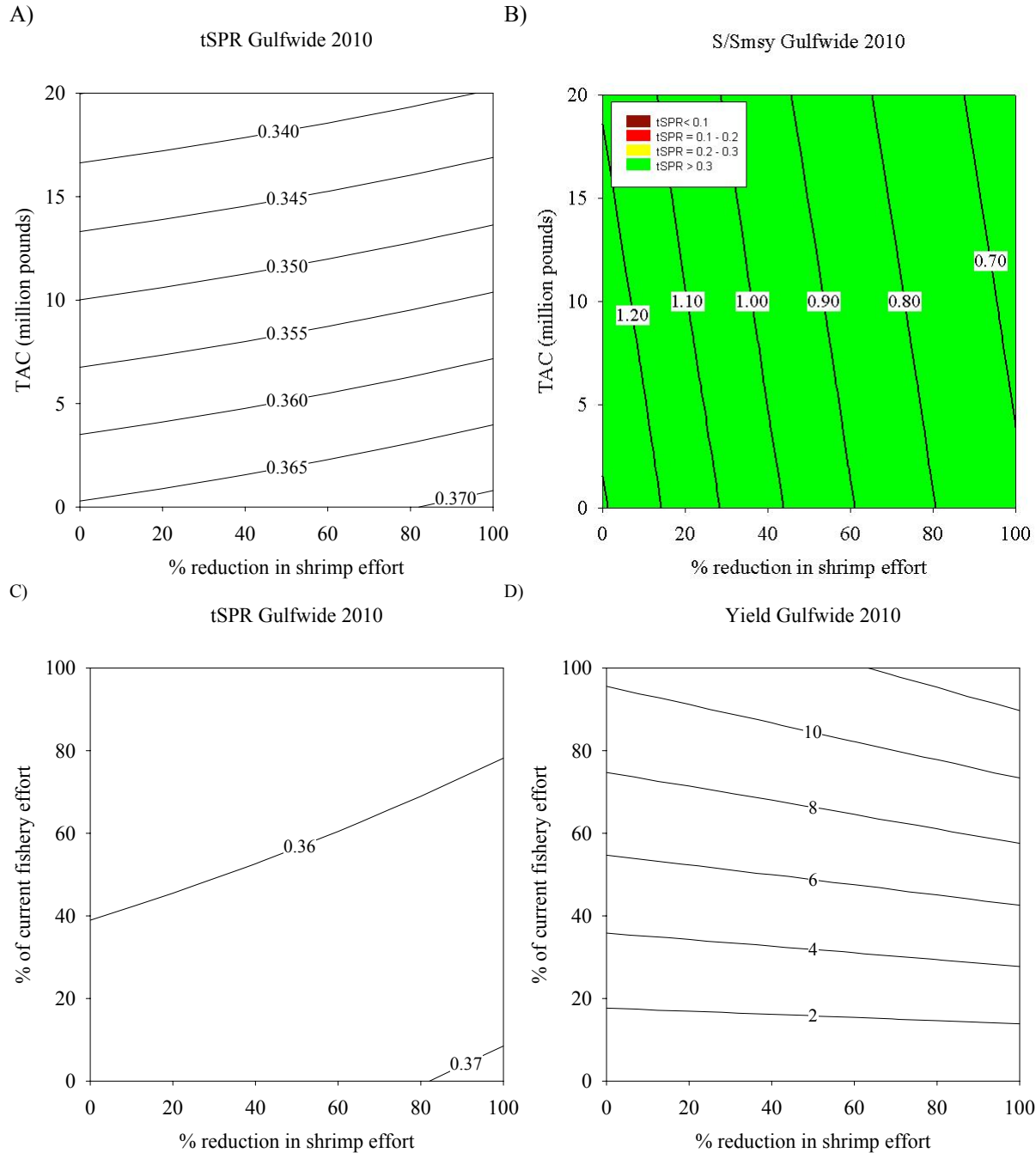
Transitional  $SPR > 0.3$  cannot be achieved in 2032 without moderate (30%) reductions in TAC (or directed F) and shrimp effort (Fig. 10A-C). Transitional  $SPR > 0.2$  can be achieved with minimal reductions (10-30%) in TAC, directed F or shrimp effort (Figs 10A-C). At current fishing levels, projected  $S/Smsy$  in 2032 is approximately 1.5, and  $tSPR$  is about 0.19 (Fig. 10B). A yield of 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort, but higher yields are possible with modest reductions in shrimp effort (Fig 10D).

#### **Steepness = 0.95**

At steepness = 0.95,  $tSPR_{2003}$  was 0.07. It is not possible to achieve  $tSPR > 0.2$  in 2010, but levels lower than 0.1 are avoided if TAC is reduced to 6.5 million pounds (Fig 11A) or if directed fishing is reduced to 70% of 2001-2003 levels (Fig 11C).  $S/Smsy$  was 0.65 in 2003, and is maintained at that level in 2010 without reductions in TAC or shrimp effort (Fig 11B). A yield of 9.12 million pounds can be achieved in 2010 without reducing directed F or shrimp effort (Fig 11D).

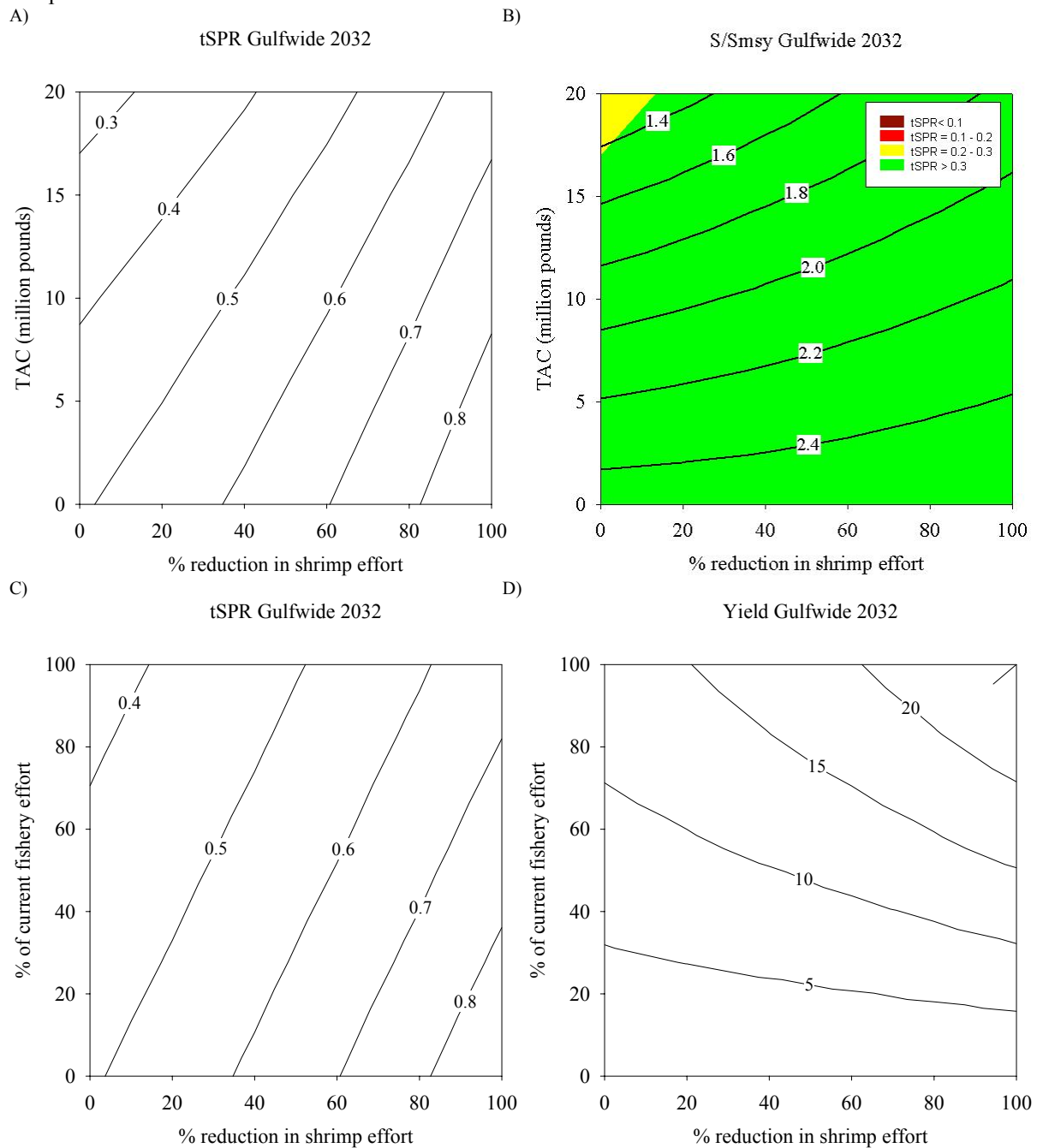
Transitional  $SPR > 0.3$  can be achieved and maintained through 2032 by eliminating the directed fishery (Fig 12A-C), or by reducing shrimp effort by >40% (Figs 12A). Smaller reductions in both directed fishing and shrimp effort can also allow  $tSPR > 0.3$ . For example, a 30% reduction in shrimp effort and a TAC of 5 million pounds is sufficient (Fig 12A). Transitional  $SPR > 0.2$  can be achieved by reducing TAC to 6 million pounds (Fig 12A), by reducing directed fishing mortality to 35% of 2001-2003 levels (Fig 12C), or with smaller reductions and a concurrent reduction in shrimp effort. At current fishing levels, projected  $S/Smsy$  in 2032 is approximately 1.25, but  $tSPR$  is less than 0.2 (Fig. 12B). A yield greater than 9.12 million pounds can be achieved in 2032 without reducing directed F or shrimp effort (Fig 12D), but yields in excess of 20 million pounds are possible with moderate reductions in shrimp effort.

Gulfwide ASAP 1962-2003; High Mortality ( $M_1 = 0.59$ )  
 Steepness = 0.81



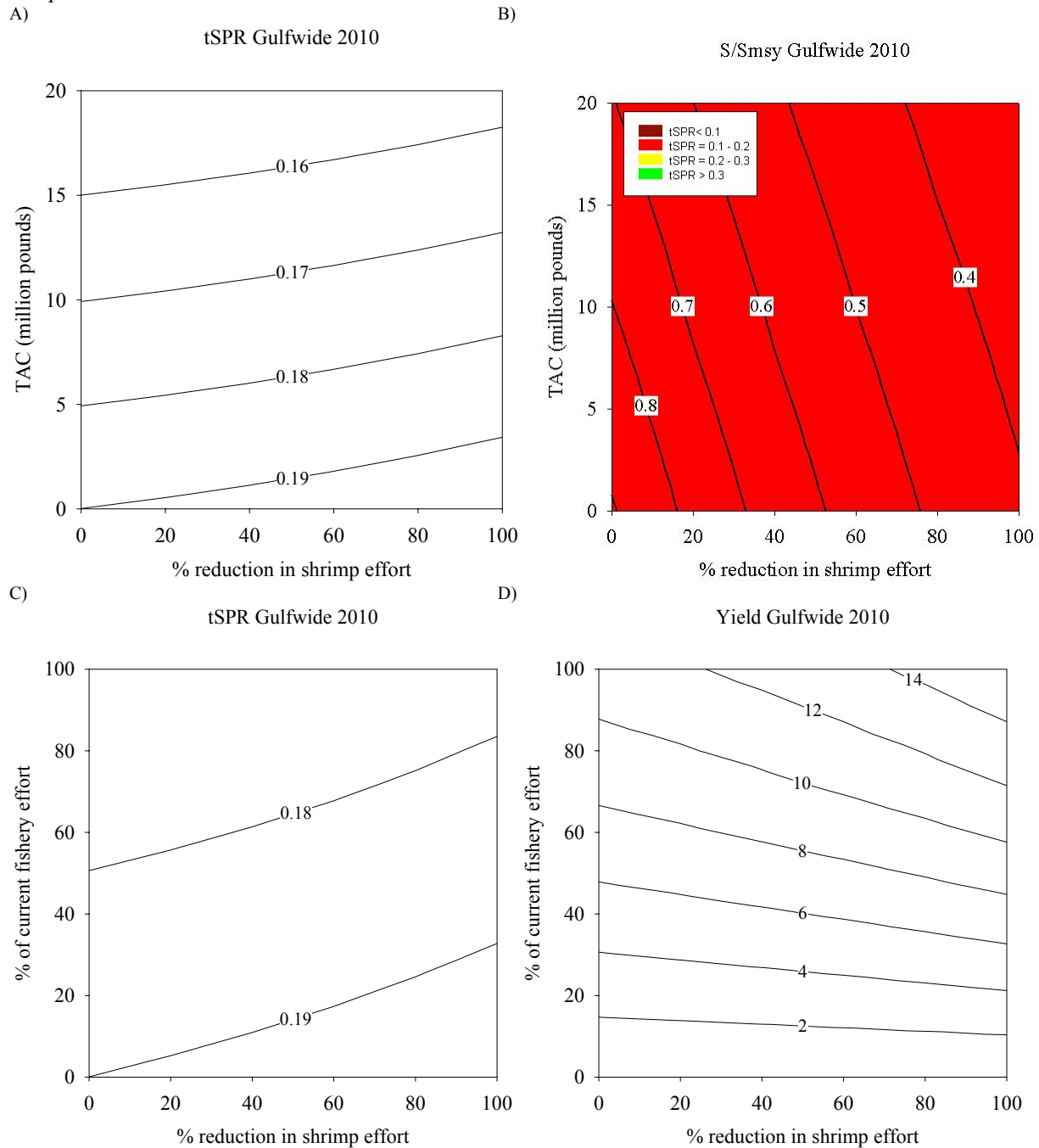
**Figure 1.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.81. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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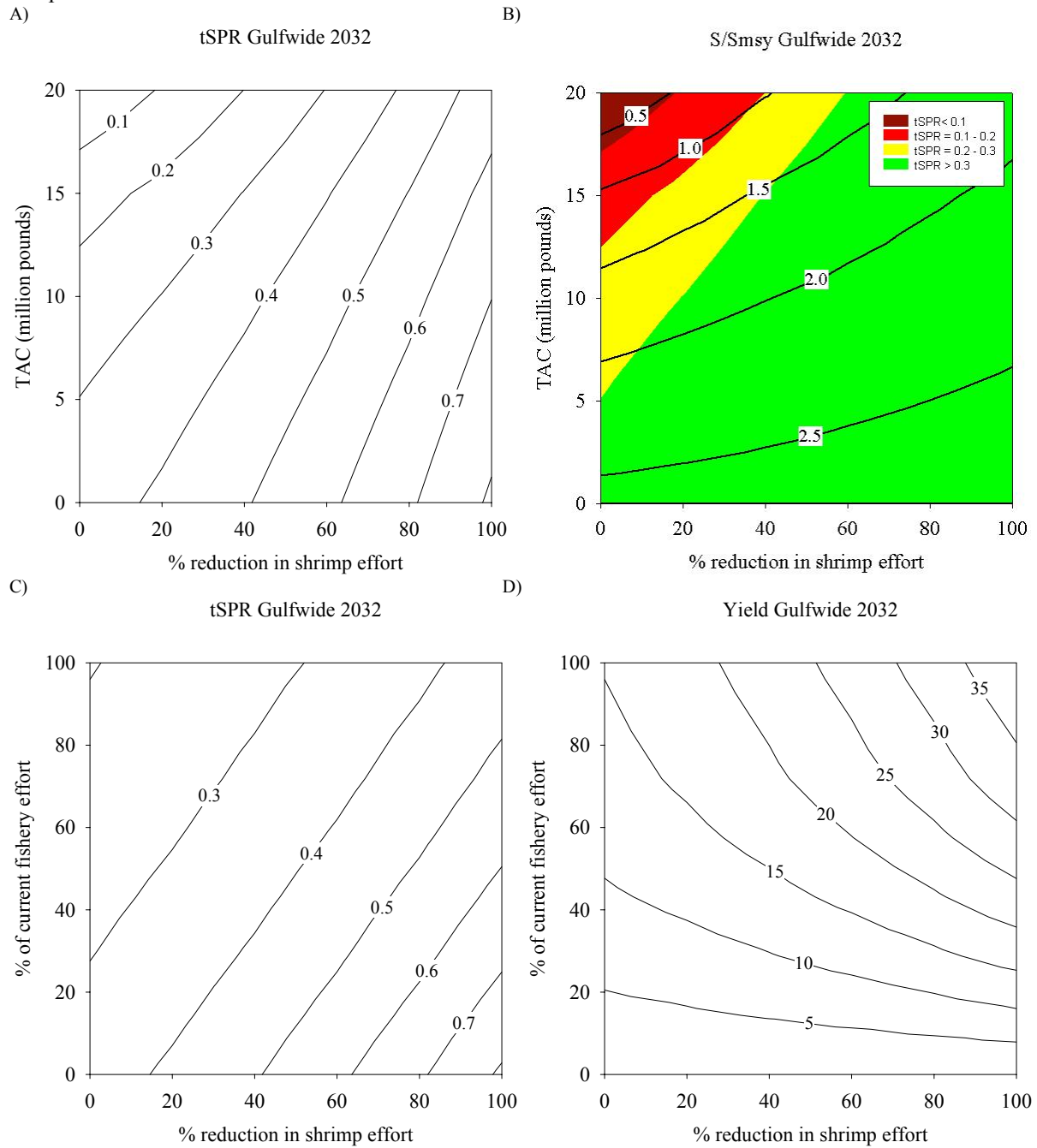
**Figure 2.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.81. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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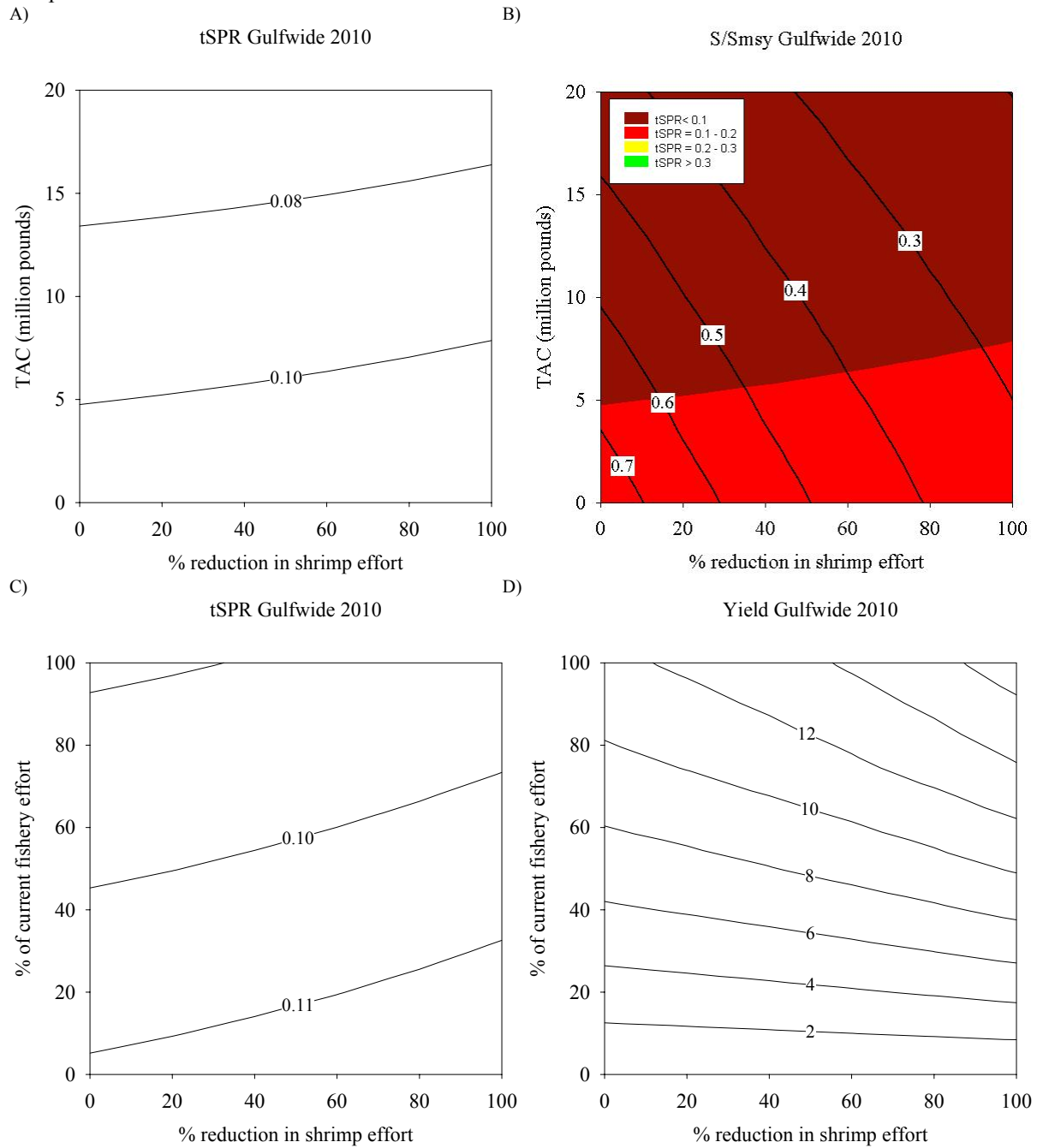
**Figure 3.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.90. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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**Figure 4.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.90. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

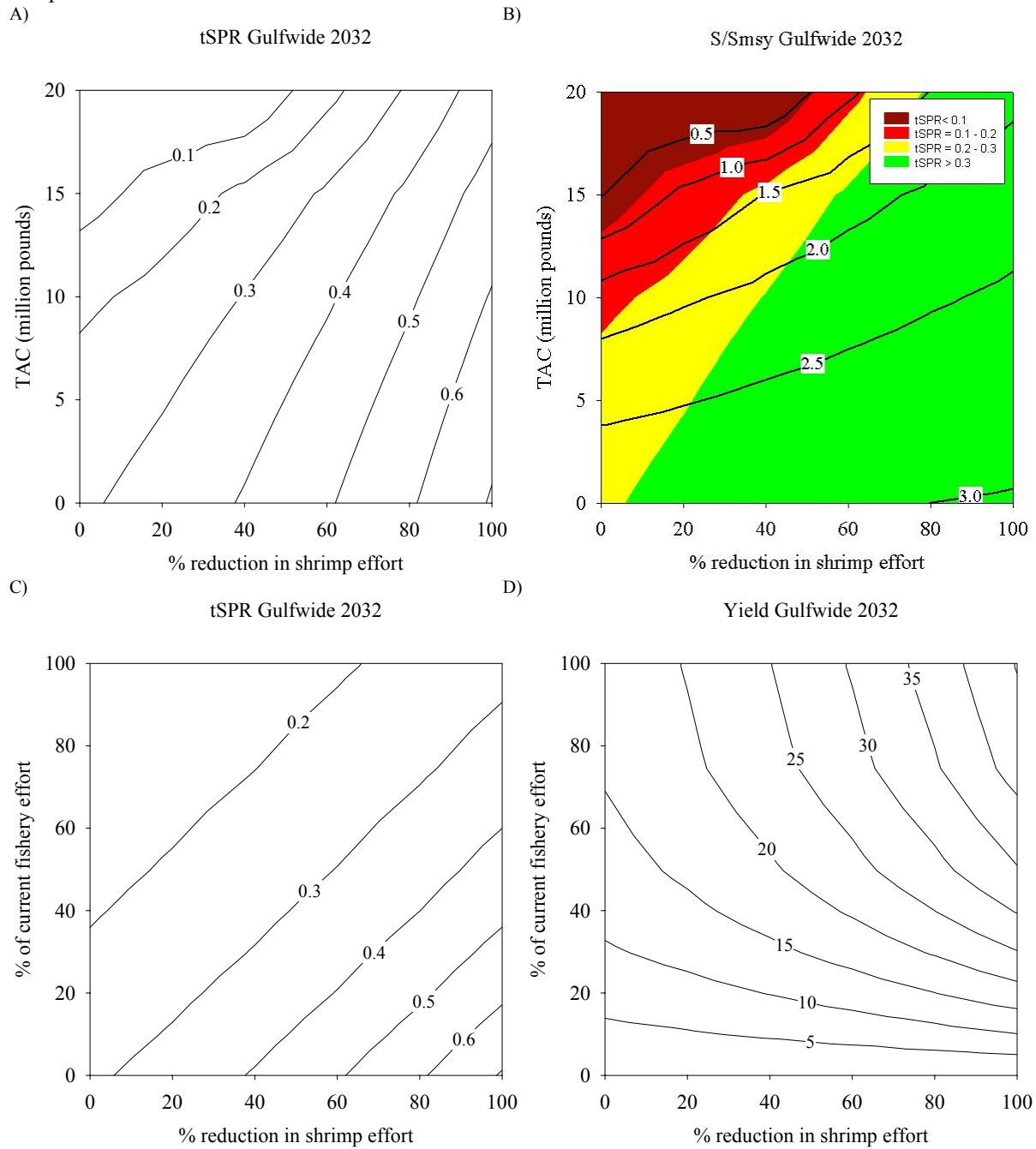
Gulfwide ASAP 1962-2003; High Mortality ( $M_1 = 0.59$ )  
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**Figure 5.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.95. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

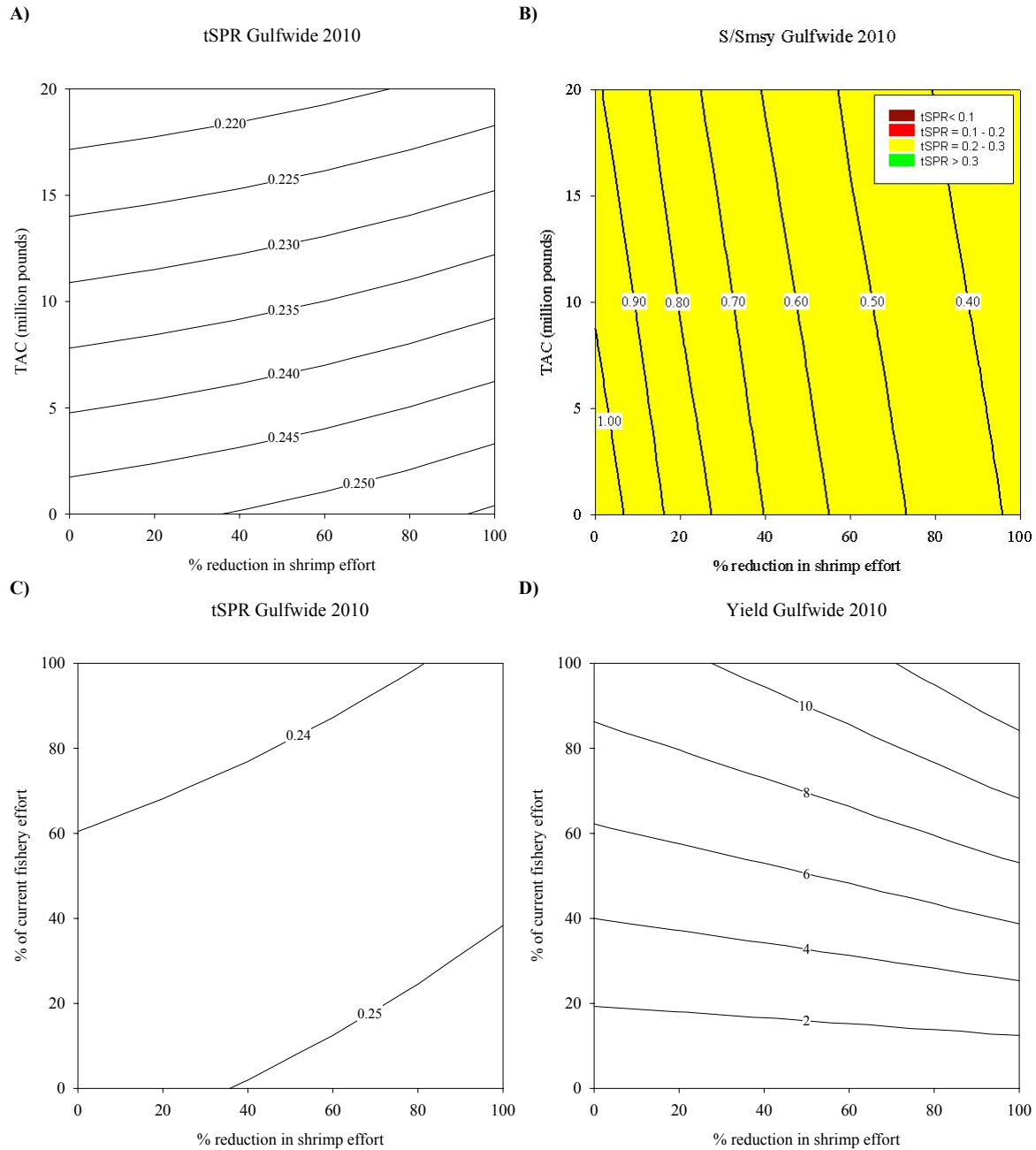


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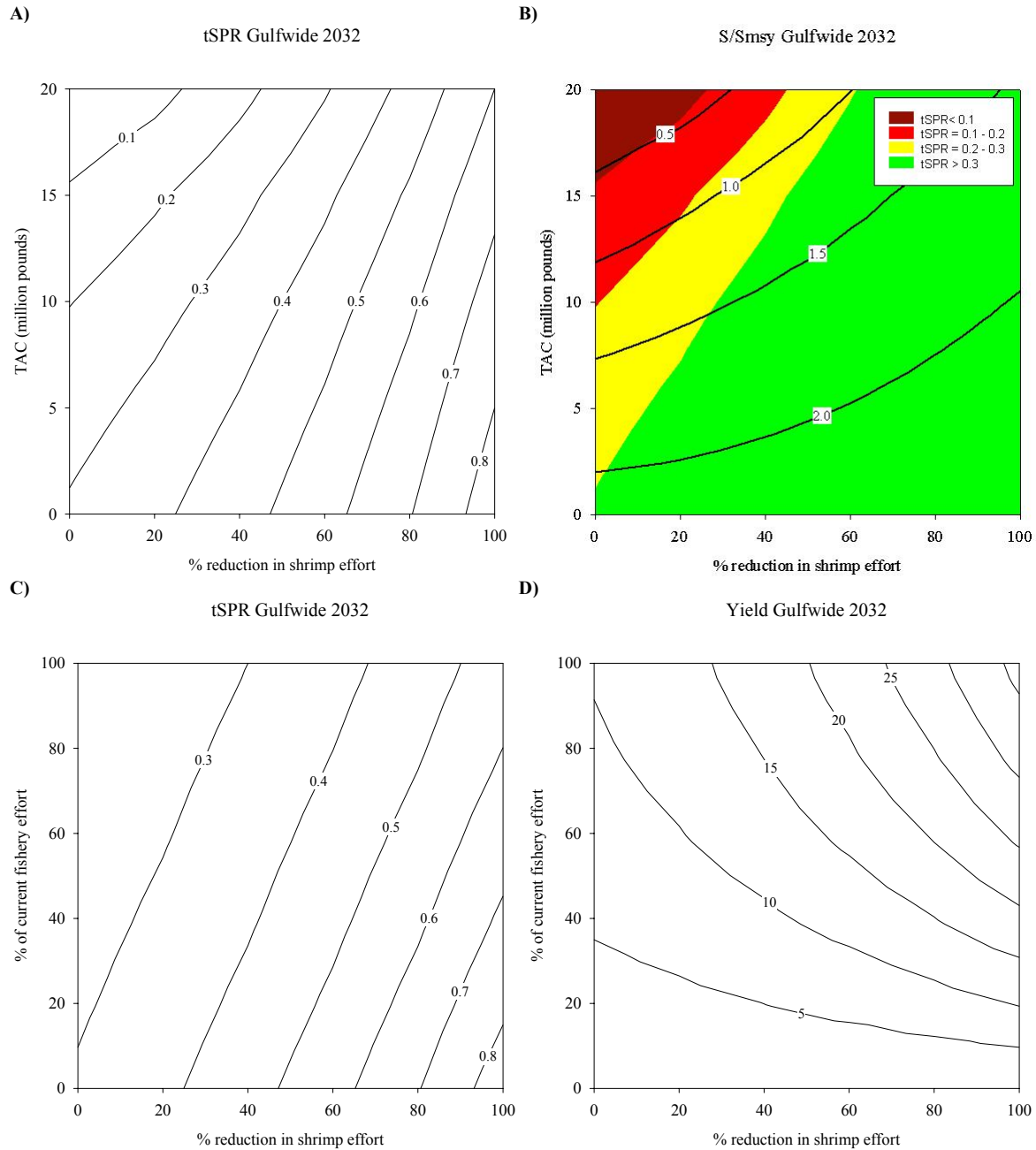
**Figure 6.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.95. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates  $tSPR < 0.1$ , red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates  $tSPR > 0.3$ . Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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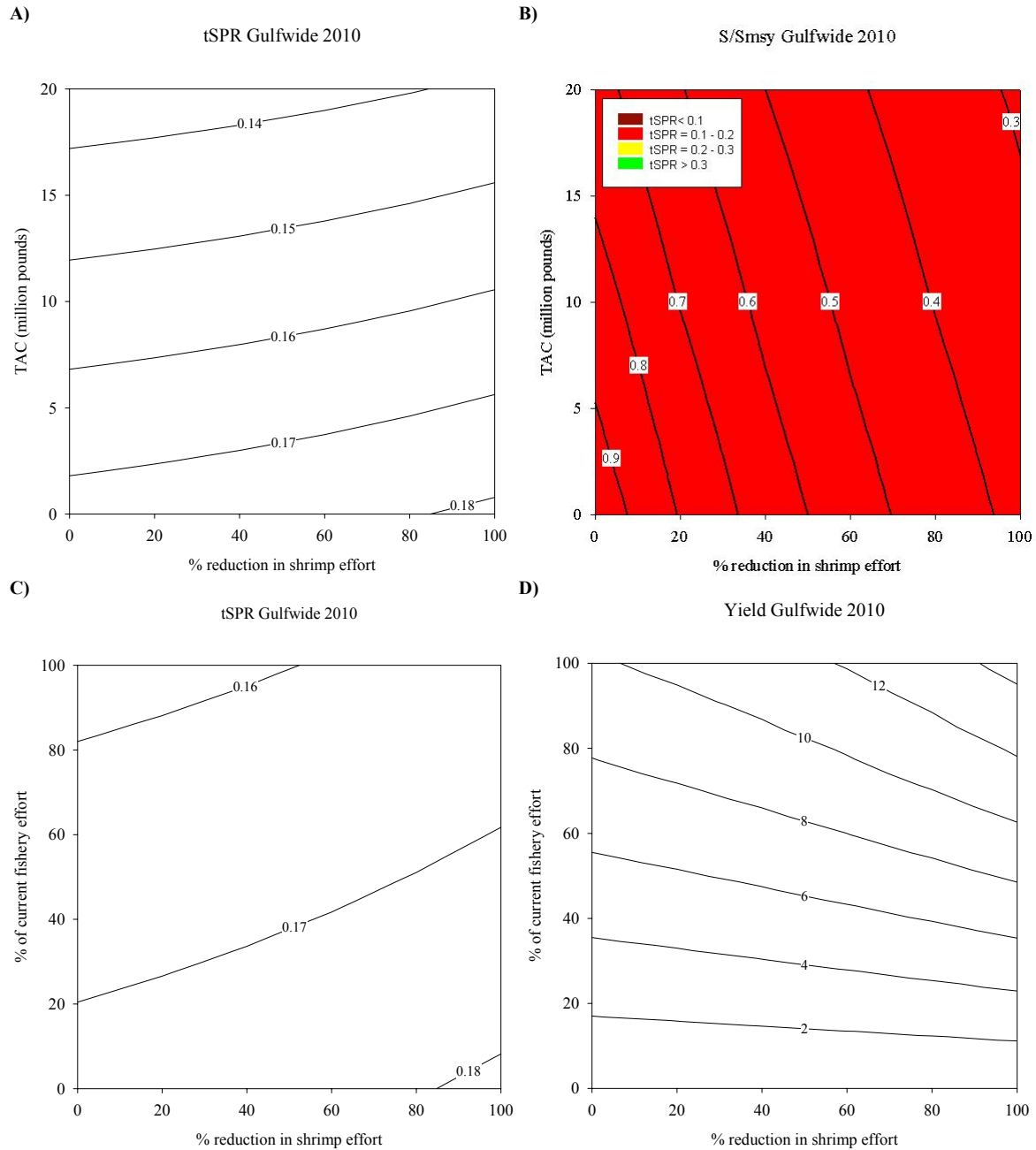
**Figure 7.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.81. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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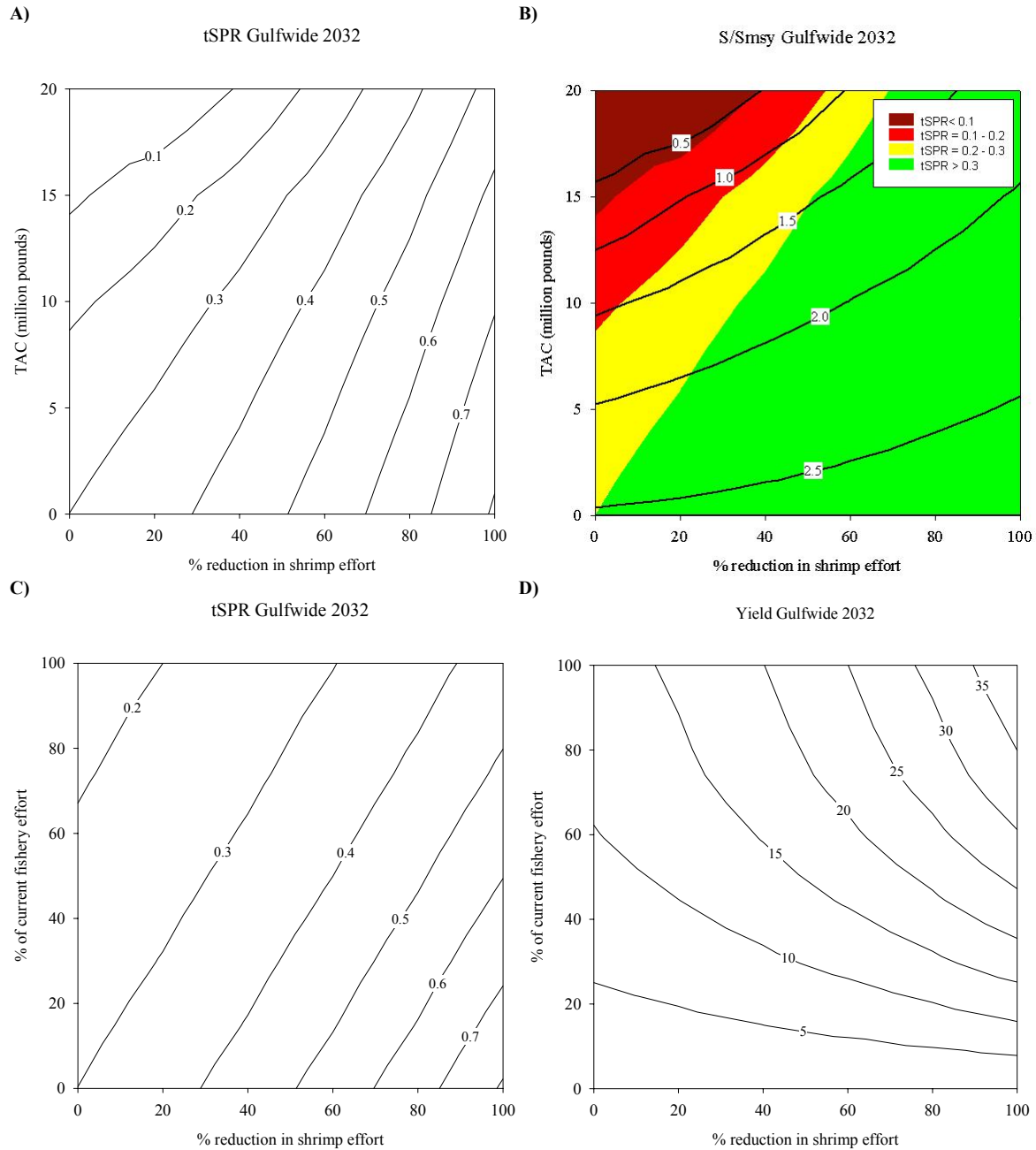
**Figure 8.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.81. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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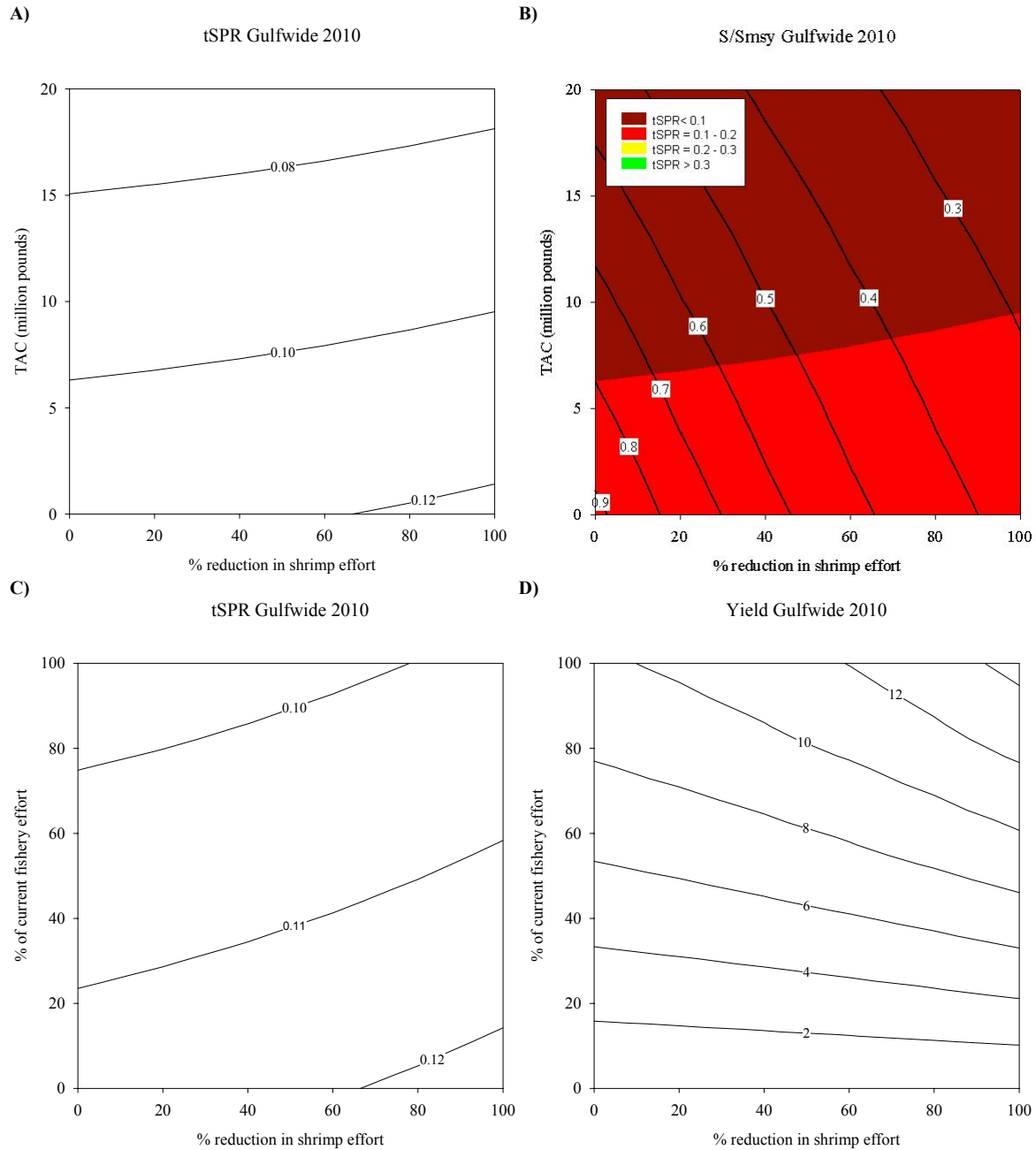
**Figure 9.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.90. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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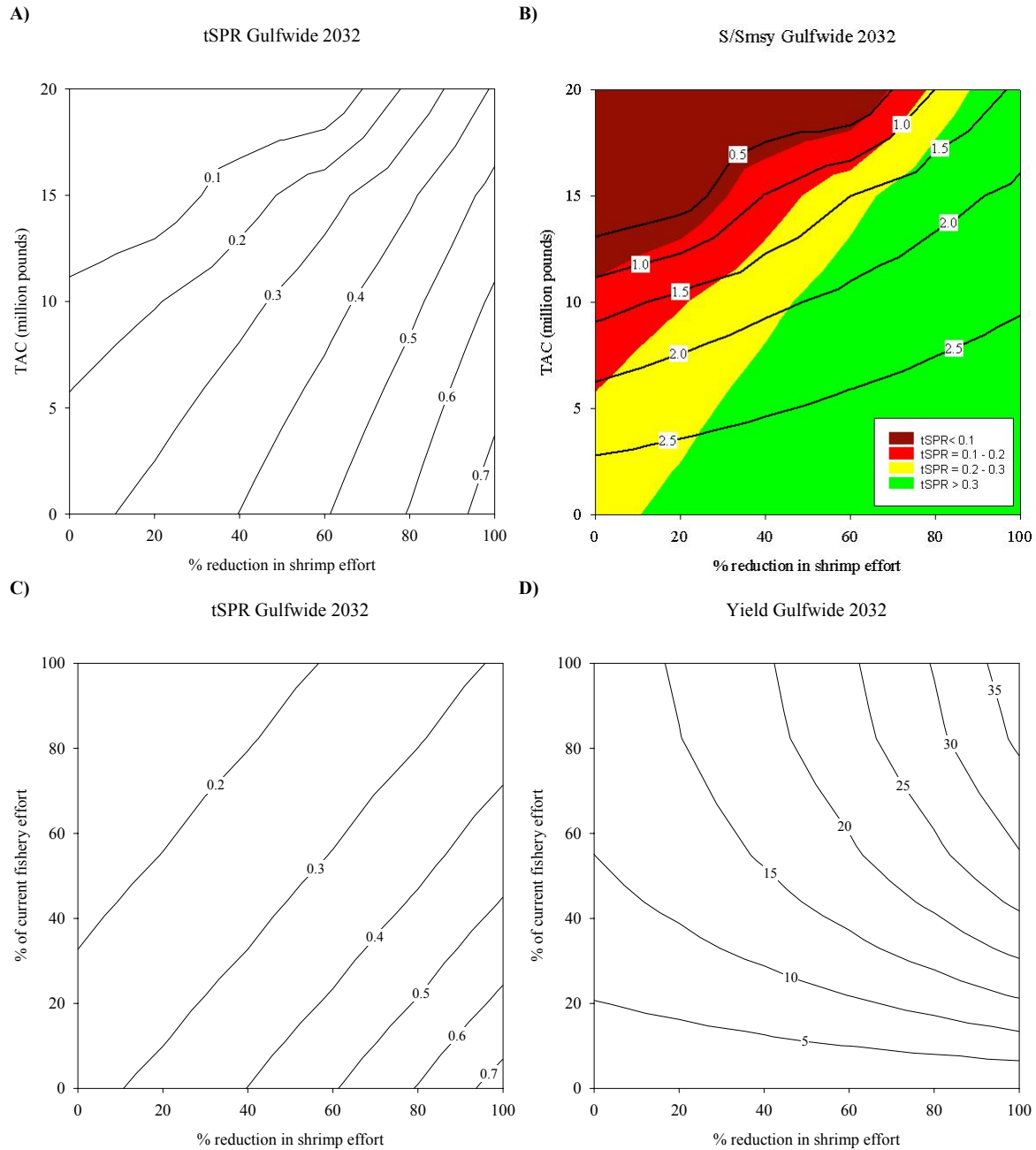
**Figure 10.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.90. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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**Figure 11.** Projected isopleths of tSPR,  $SS_{2010}/SS_{MSY}$  and yield in the year 2010 assuming steepness = 0.95. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2010}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2010}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.

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**Figure 12.** Projected isopleths of tSPR,  $SS_{2032}/SS_{MSY}$  and yield in the year 2032 assuming steepness = 0.95. **Panels A and B:** Isopleths of tSPR (A) and  $SS_{2032}/SS_{MSY}$  with tSPR overlaid (B) as a function of projected total allowable catch (TAC) and percent reduction in offshore shrimp effort. The color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR > 0.3. Annual MSY estimates are not static. Instead, MSY is recalculated for each shrimp effort reduction. Estimated  $MSY_{2032}$  increases with shrimp effort reduction. **Panels C and D:** Isopleths of tSPR (C) and yield in millions of pounds (D) as a function of the projected directed fishing mortality (expressed as a % of 2001-2003 levels) and projected percent reduction in offshore fishing effort.