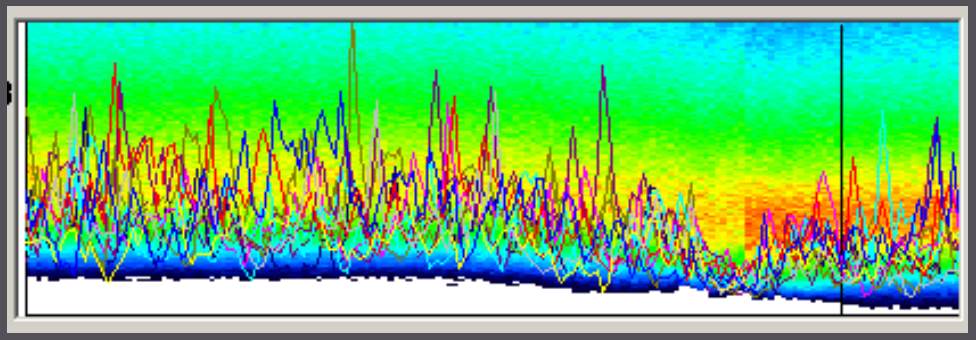
STOCHASTIC STOCK REDUCTION ANALYSIS (SRA)

Examining Probability Distribution of Stock Size Over Time under Alternative Hypotheses about Stock and Recruitment



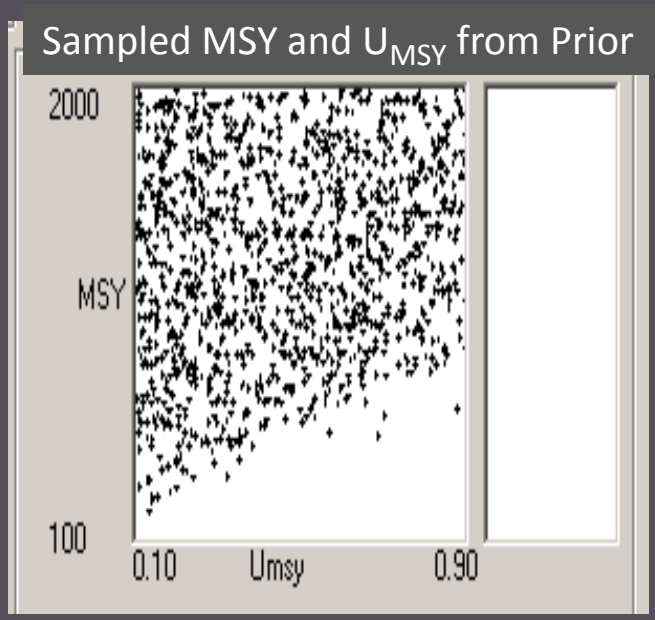
1873 2010

Outline

- Model description, formulations
- Input data/parameters/assumptions
- Model results
- Sensitivity analysis and comparison to BAM and ASPIC

SRA Model – Key Difference

- Analytical linkage between leading management parameters and recruitment
- SRA is parameterized by taking **MSY** and U_{MSY} as **leading parameters**, then calculating B&H S/R Pars, from these and from per-recruit fished and unfished eggs and exploitable biomass (Schnute and Kronlund 1996, Walters et at 2006)
- We used the stochastic version of SRA programmed in VB by Carl Walters
- In SSRA, R is assumed a lognormal annual anomalies—large simulations made with anomalies sequences chosen fro normal distribution



Model Formulations

Prior sampling

Pair of U_{MSY}, MSY, and $S=e^{-M}$ chosen from uniform priors distributions

$$recK = \frac{EPR_{F=0}}{EPR_{Fmsy}} - U_{MSY} BPR_{Fmsy} \frac{\frac{\sum_{a=1}^{a=ages} Fec_a \, dl_a/da}{EPR_{F=0}}}{\left(\frac{EPR_{F=0}}{EPR_{Fmsy}}\right)^2 (BPR_{Fmsy} + U_{MSY} \sum_{a=1}^{a=ages} W_a v_a \, dl_a/da)}$$

$EPR_{F=0}$ /EPR_{UMSY}, BPR_{UMSY} calculated from incidence funct.

$$R_0 = MSY/(U_{MSY} BPR_{Fmsy}) \left(\frac{recK - 1}{(recK - 1) EPR_{F=0}/EPR_{Fmsy}}\right)$$

$$E_0 = R_0 EPR_{F=0}$$

B/H Pars and recK, R_0 and E_0 estimated

$$R_t = \frac{recK(R_0/E_0)E_t}{1 + \frac{(recK - 1)}{E_0} E_t}$$

Initial population age structure $R_t * e^{w_t}$

Forward computation

Calculate Likelihood of data for each trajectory

Repeated many times (e.g., 10,000 prior runs)

MCMC sampling

Posterior Dist. for MSY, U_{MSY}, U_{2010}/U_{MSY}, E_{2010}/E_0

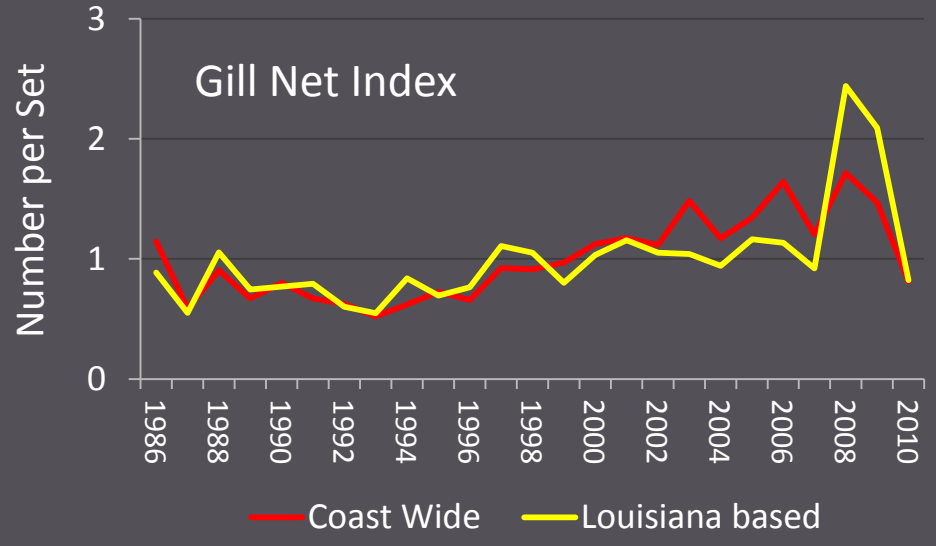
MCMC random walk in parameter space (MYS, U_{MSY}, S, σ)

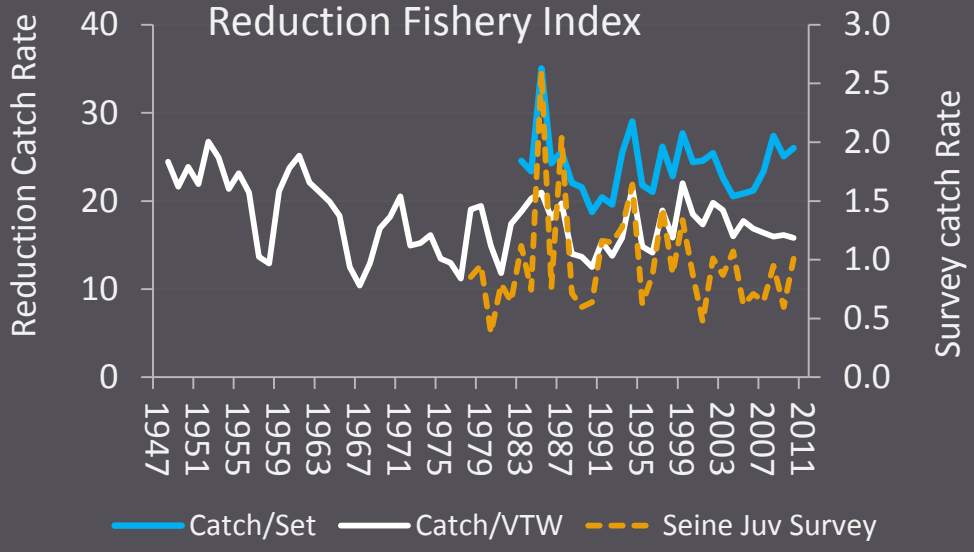
Starting parameters estimates and distributions

Walters et al (2006)

Gulf Menhaden SRA Modeling Approach

- **Alternate-1 Model** based on the coast wide gill net survey index
- **Alternate-2 Model** based on the commercial reduction fishery CPUE (C/VTW) index
- Given uncertainty about *U*, for each alternate model run **Four simulation scenarios with current U set at 0.3, 0.4, 0.5, 0.6**





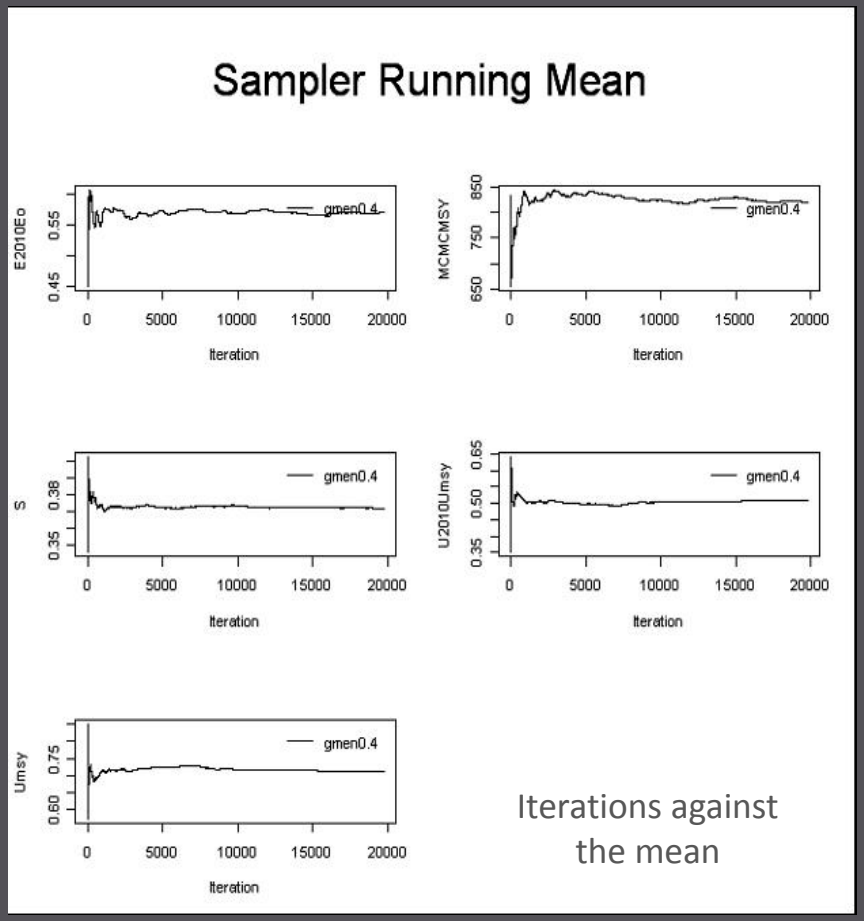
Input Data/Parameters

- Historical annual landings: (*metric tons, 1873-2010)*
- Vulnerability at age: obtained from *BAM for three periods (*1873-1979, 1980-1993 and 1994-2010)
- SD Recruitment=0.5 (log normal anomolies e^{w}) (Sd=0.25 and Sd=0.75)
- Index variance (lognormal obs. error, defaulted to 0.04, SD=0.2)
- Current estimate of exploitation rate *(U): Given uncertainty, four scenarios with U=0.3-0.6 for each alternate model (range from historical tagging and assessment)*
- Life history parameters: *growth parameters (K=0.44, Linf=23.7cm, t_0=-0.808), maximum weight (0.27kg), length maturity (18.3cm)*
- Leading parameters priors: MSY (100,000 - 2,000,000 mt); *U_{MSY} (0.1 - 0.9); natural mortality rate (M=0.8-1.1, $S = e^{-M}$ = 0.3-0.45)— assumed uniform probability distribution for MSY , U_{MSY} , and S*
- *Number of prior runs for MCMC sampling=100,000*

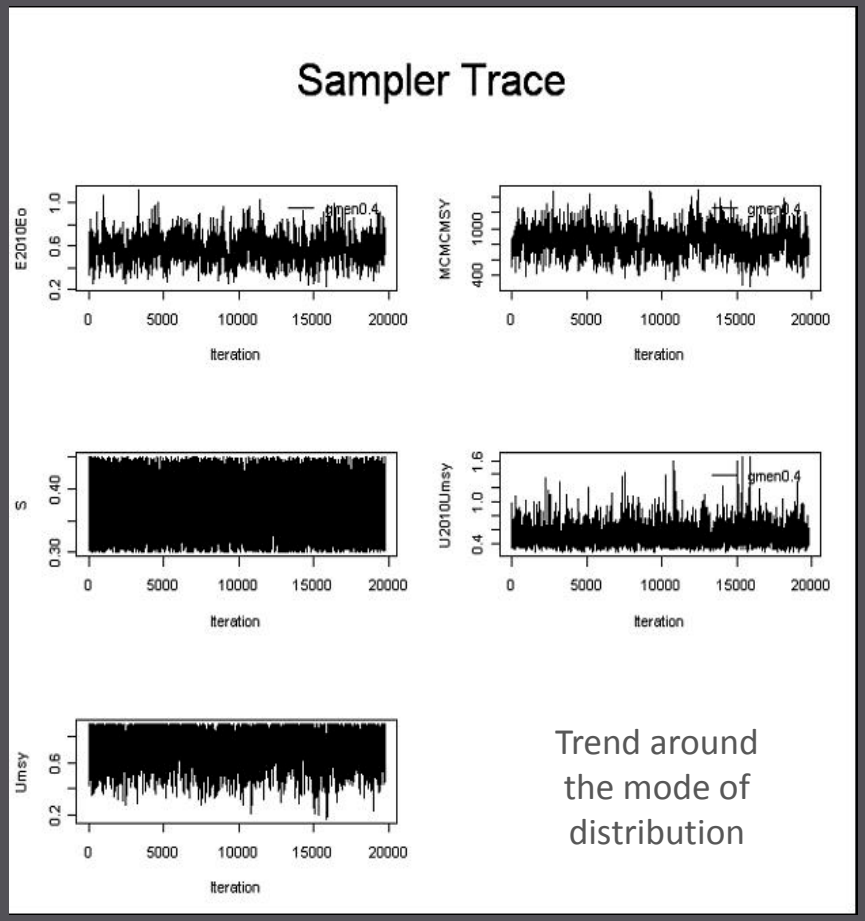
Gulf menhaden stochasticSRA Results

- MCMC convergence diagnostics, model fits
- Exploitable biomass and exploitation rate trajectories
- Posterior distributions of U_{MSY} and MSY and
- Posterior distributions of U_{2010}/U_{MSY} *and* current stock status
- Sensitivity runs
- Compare to BAM and ASPIC

MCMC sampling: Convergence Diagnostics (boa-R)



Iterations against the mean

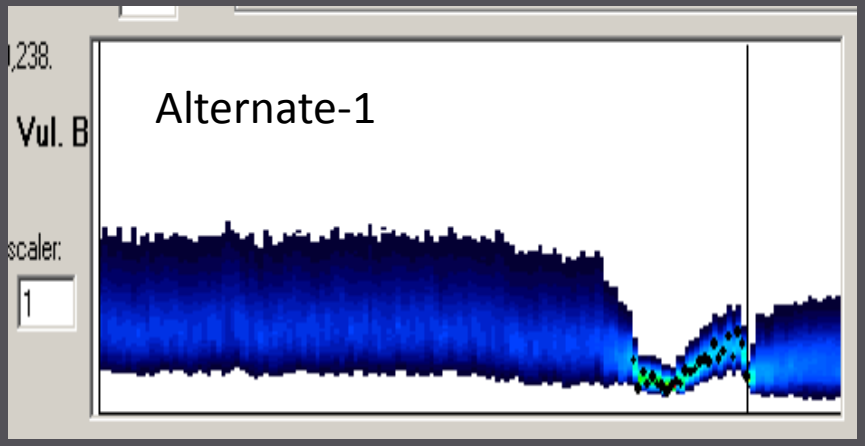


Trend around the mode of distribution

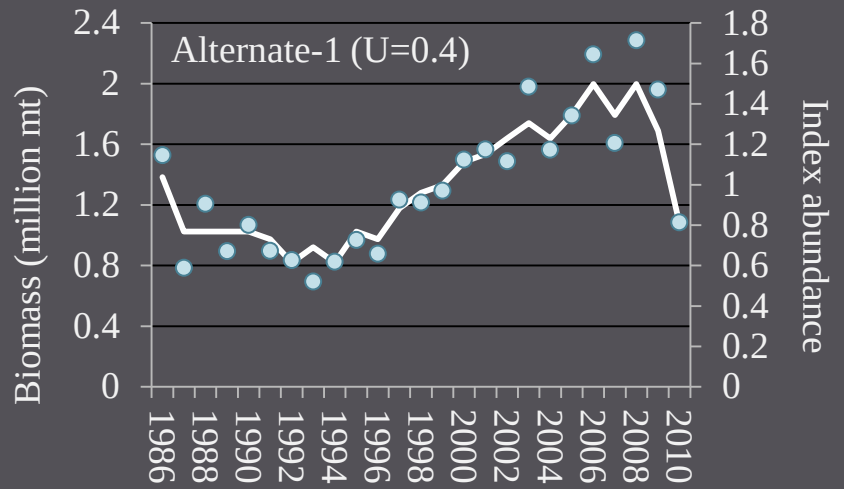
- no evidence that parameter estimates did not converge
- Sampling from a stable distribution

SRA Results: MCMC Alternate-1 and 2 Model fits

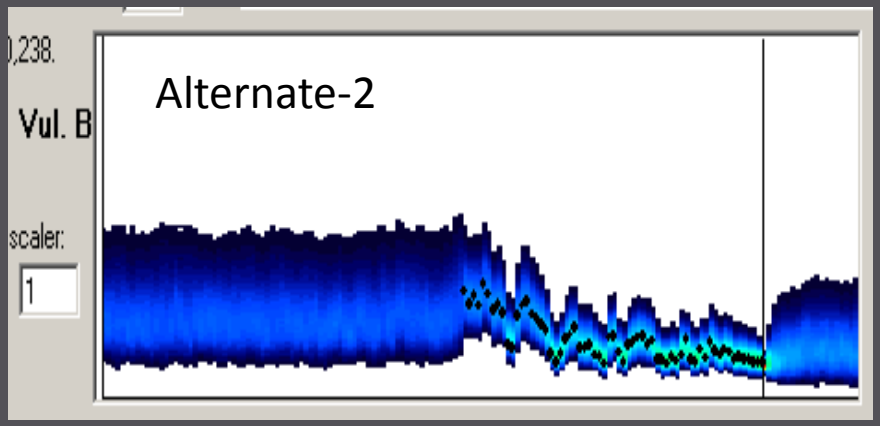
MCMC Prob. Dist. *vul-B* vs gillnet Index



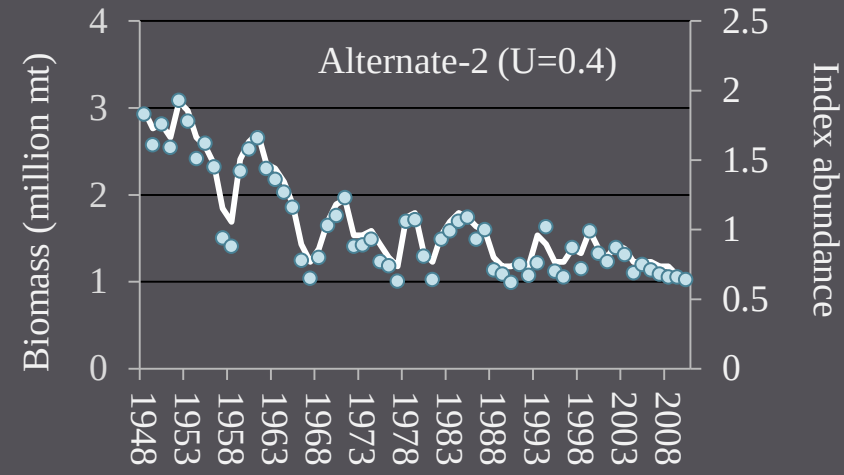
MCMC *vul-B* mode vs Gillnet Index



MCMC Prob. Dist. *vul-B* vs Reduction Index



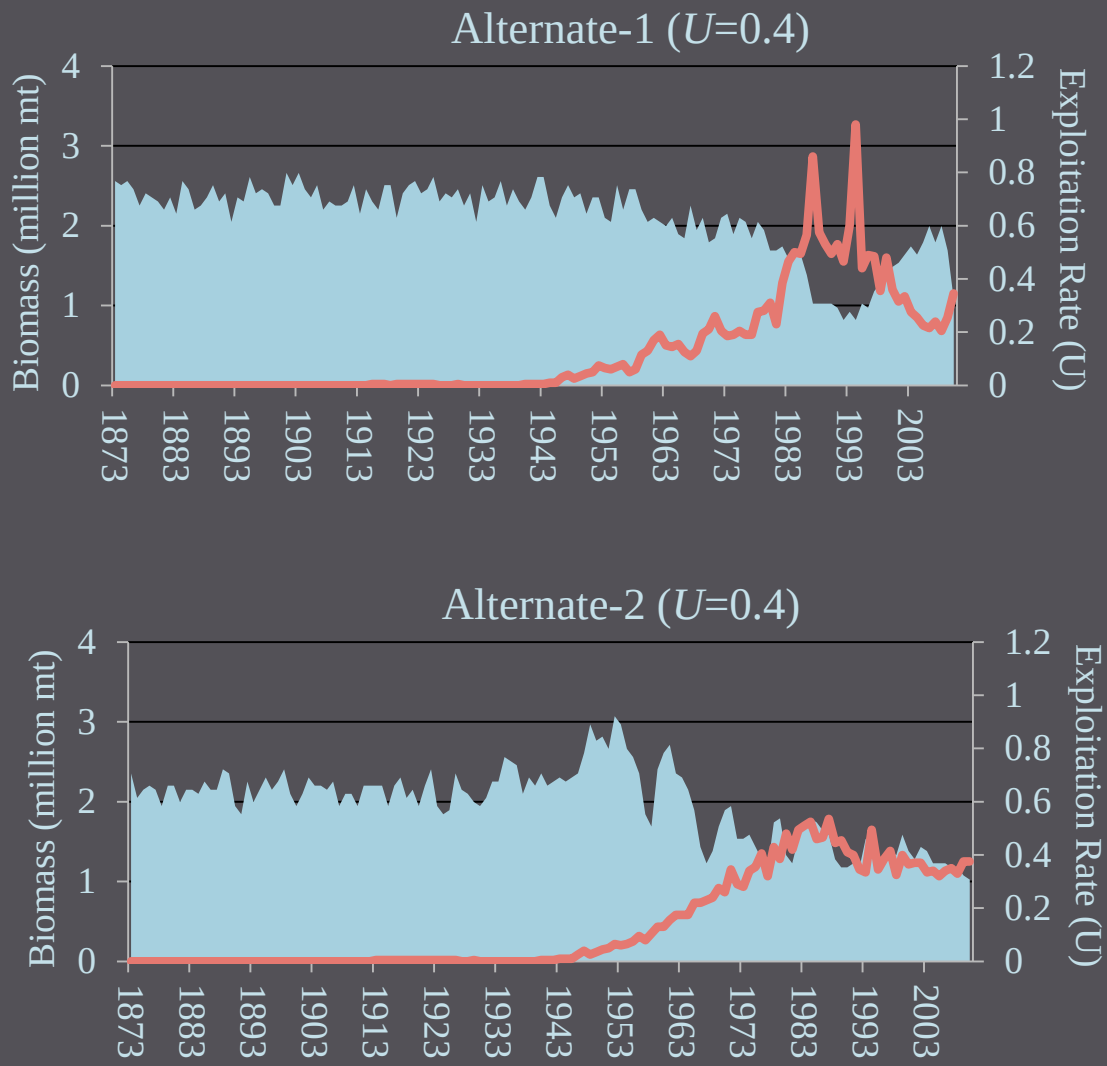
MCMC *vul-B* mode vs Reduction Index



SRA Results:

Trends in Exploitable Biomass Exploitation Rate

- MCMC modes show different patterns for exploitable *B* in recent years for a selected *U*=0.4
- Both models show rapid increase in *U* and decline in *B* during mid-1980's through 1990's
- Following by sharp decline in *U* and increase in *B* after the mid-1990's in the alt-1 model runs and slight decline in *U* but no increase in *B* in the Alt-2 model runs



SRA Results:

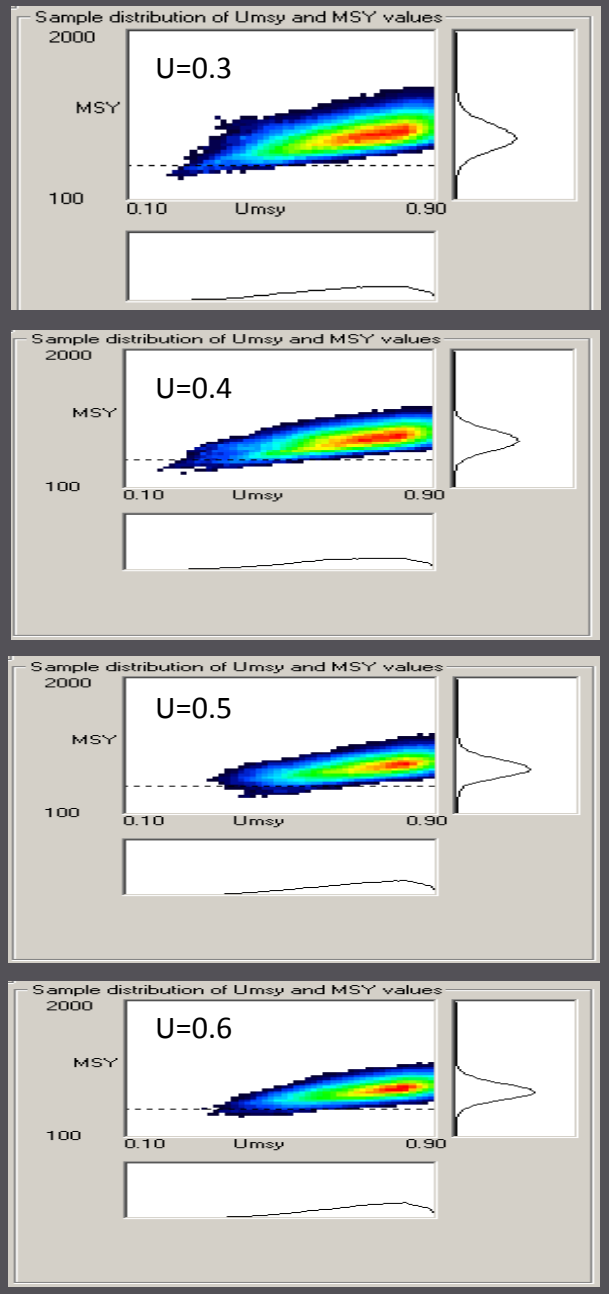
MCMC posterior distributions and density for U_{MSY}

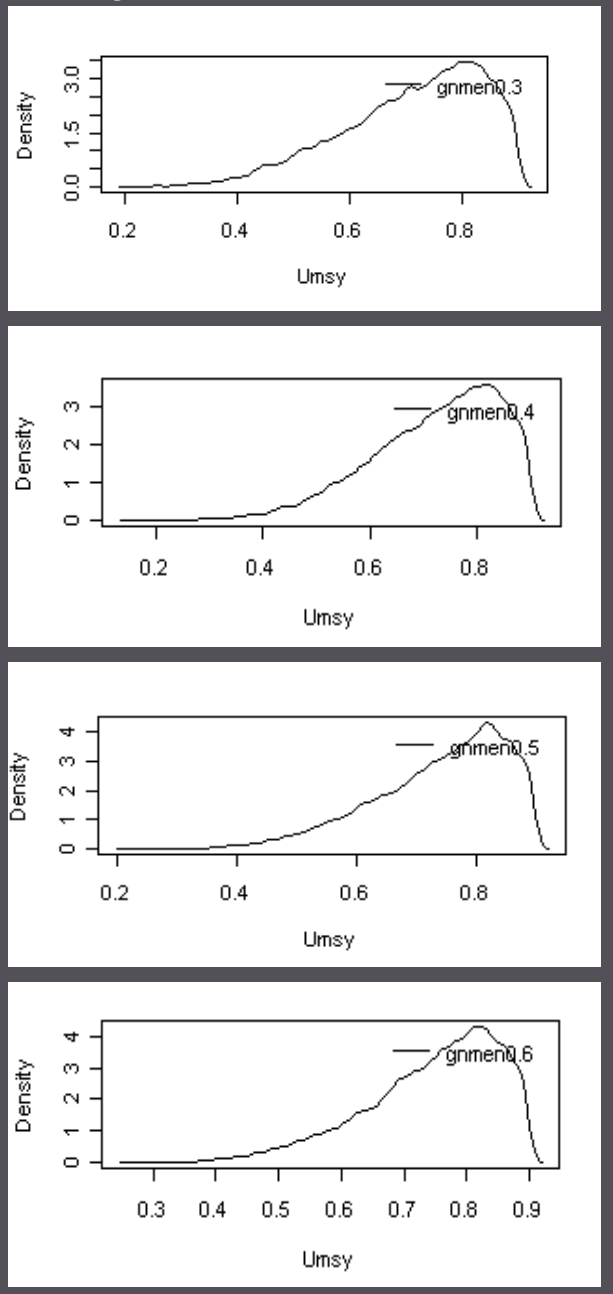
Alternate-1 Model Runs

- Uncertainty larger for runs with lower current *U* input
- Posterior Density show U_{MSY} skewed toward high values, 0.71 - 0.75

Posterior Distribution

U_{MSY} Posterior Density





SRA Results:

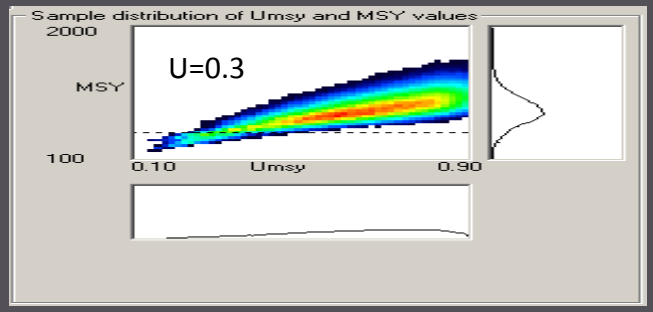
MCMC posterior distributions and density for U_{MSY}

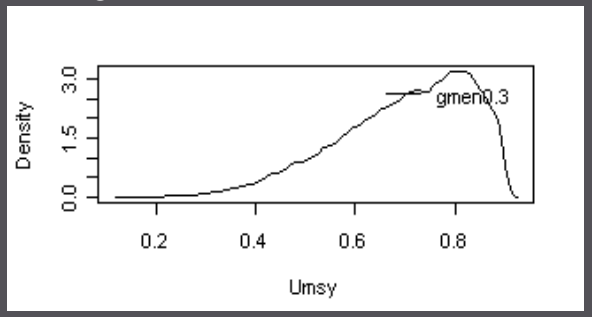
Alternate-2 Model Runs

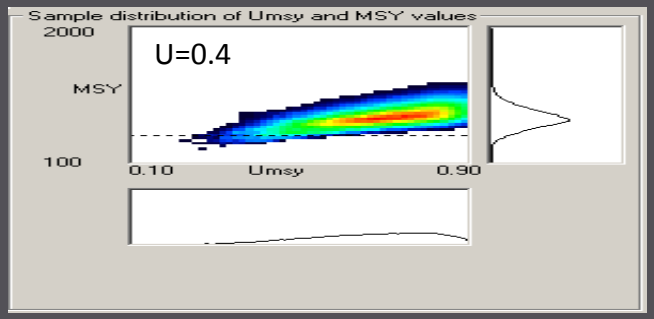
- U_{MSY} estimated high 0.7 - 0.76

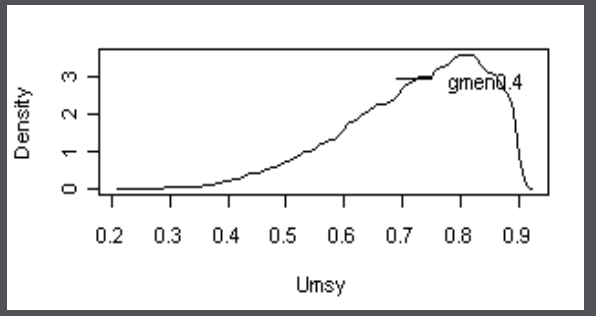
Posterior Distribution

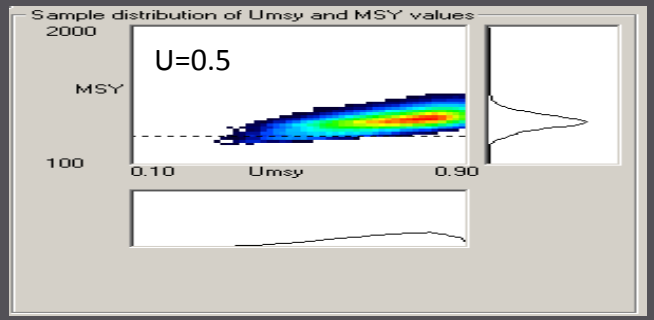
U_{MSY} Posterior Density

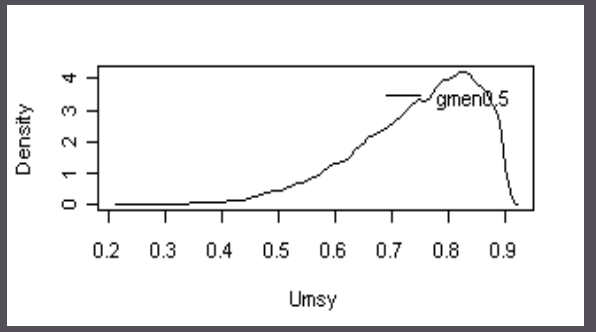


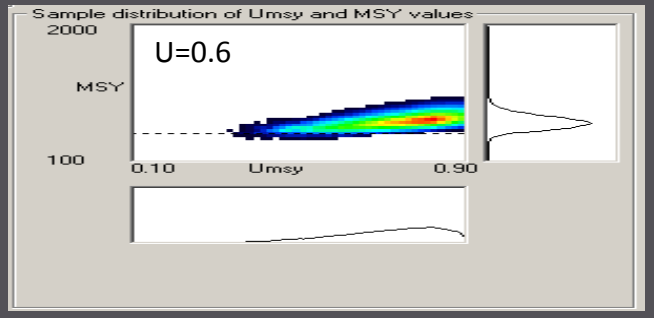


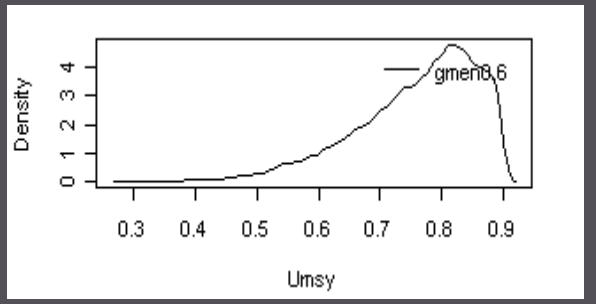












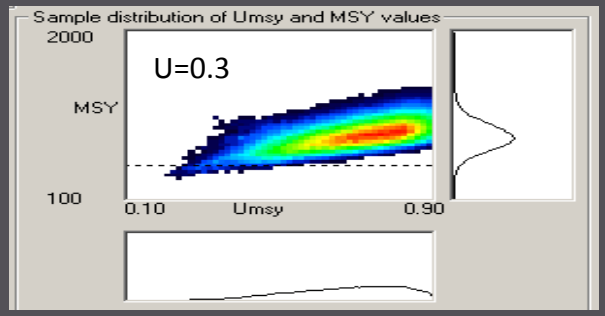
SRA Results:

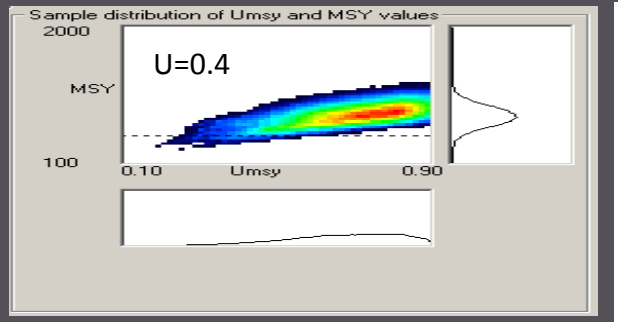
MCMC Posterior distributions and density for MSY

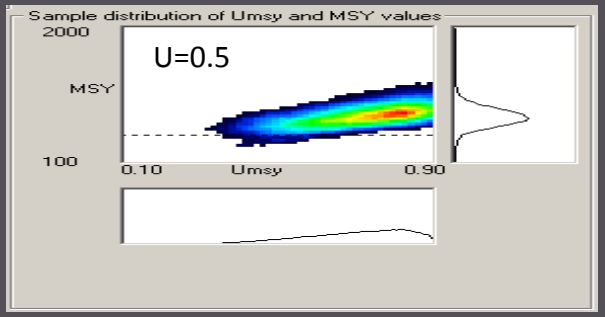
Alternate-1 Model Runs

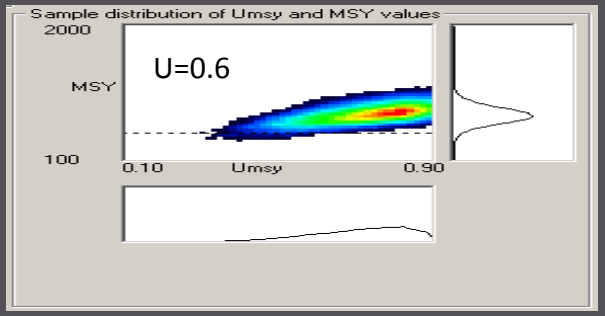
- Posterior density plots show no major shift in MSY probability distribution
- High probability for MSY between 800,000 and 900,000 mt
- Recent landings (dotted lines) below MSY estimates

Posterior Distribution

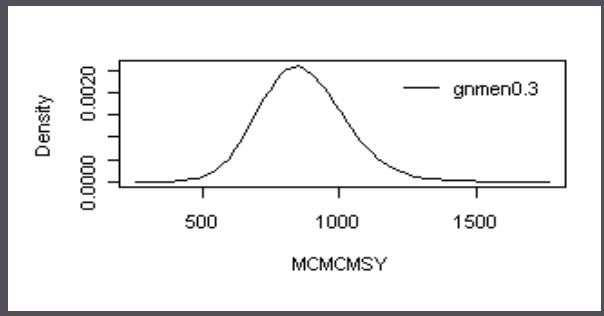


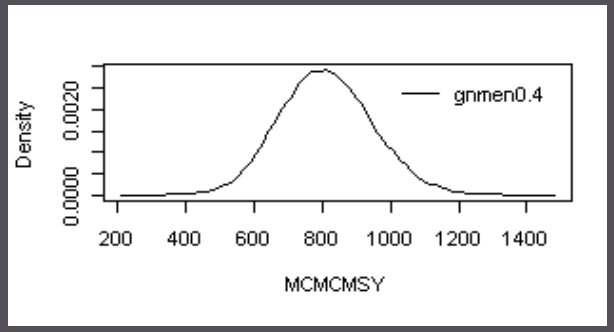


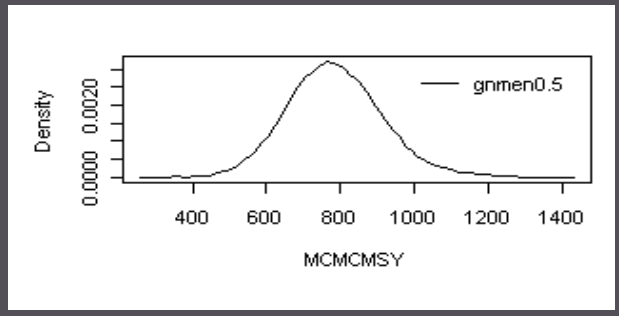


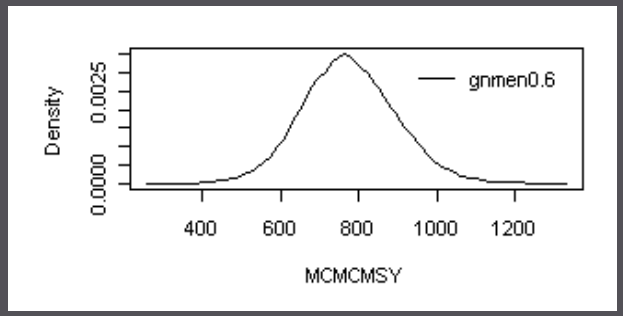


MSY Posterior Density









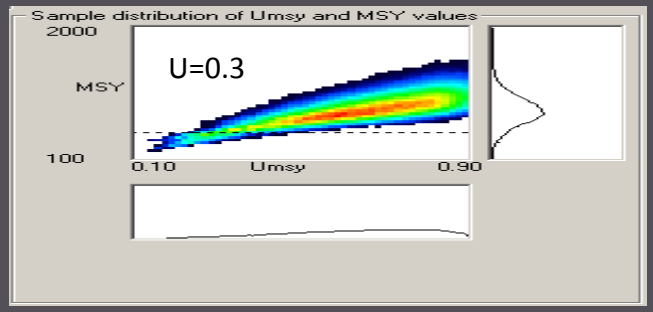
SRA Results:

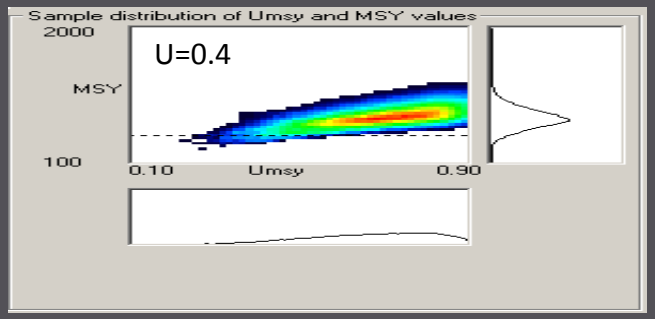
MCMC Posterior distributions and density for MSY

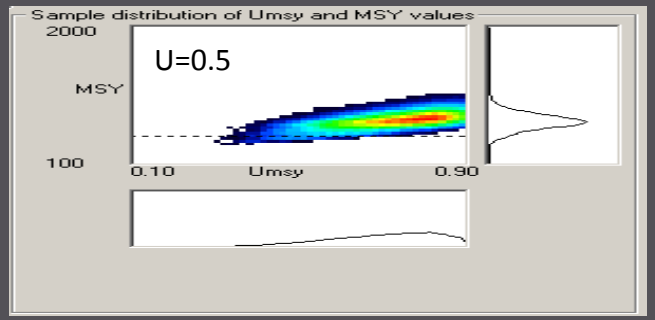
Alternate-2 Model Runs

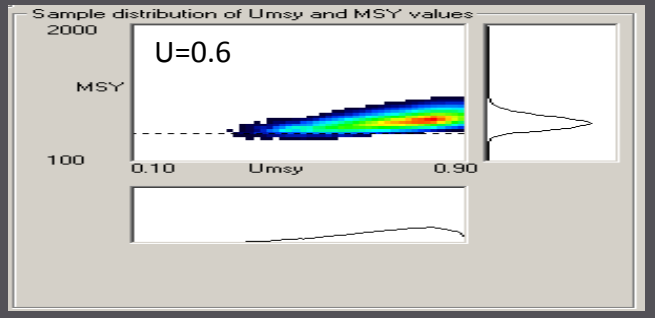
- No major shift among model runs
- High probability MSY varied between 700,000 and 900,000 mt
- Recent landings (dotted lines) below MSY estimates

Posterior Distribution

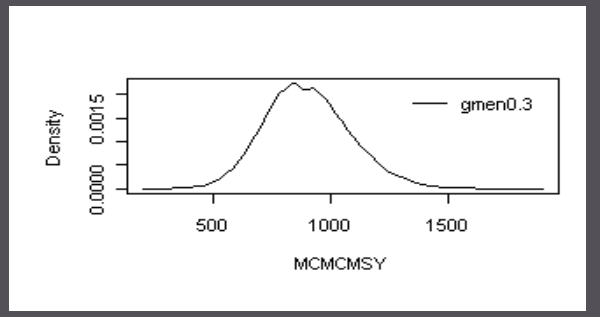


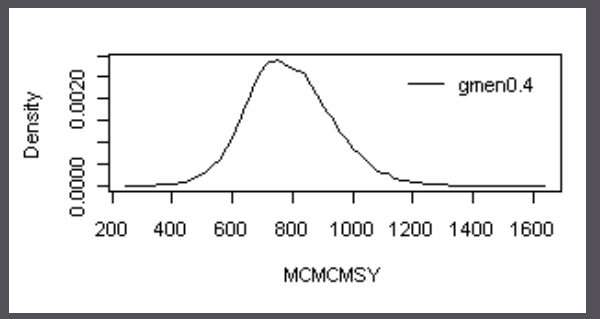


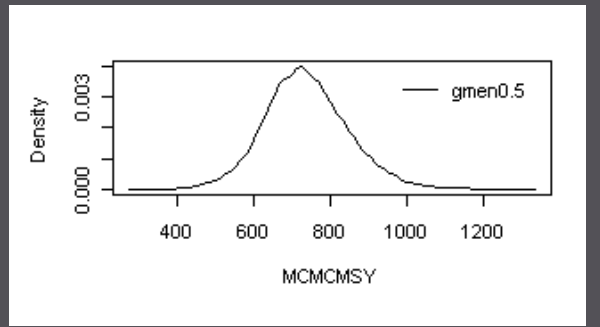


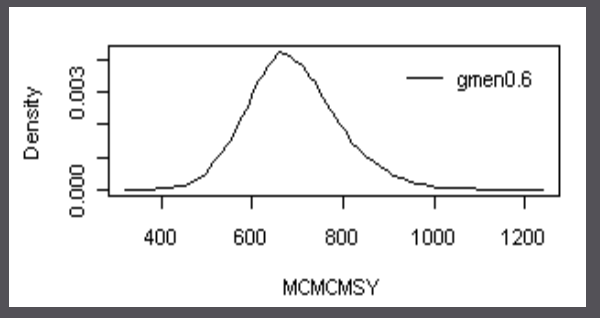


MSY Posterior Density





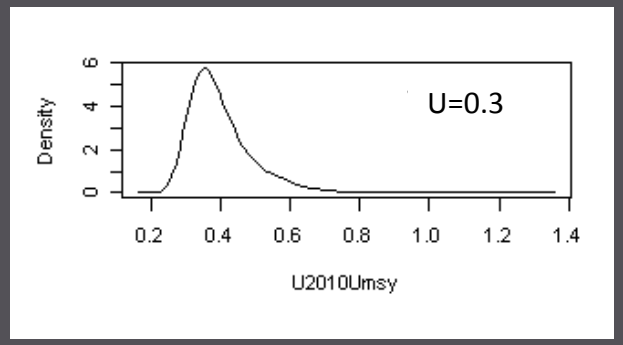


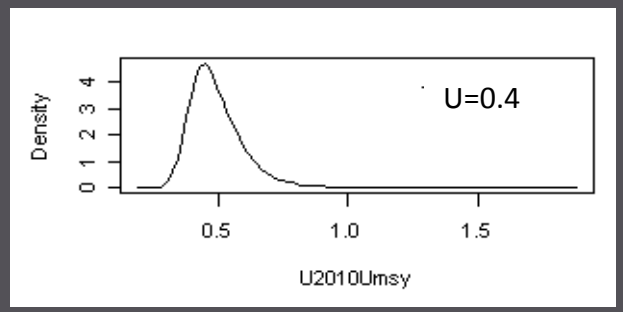


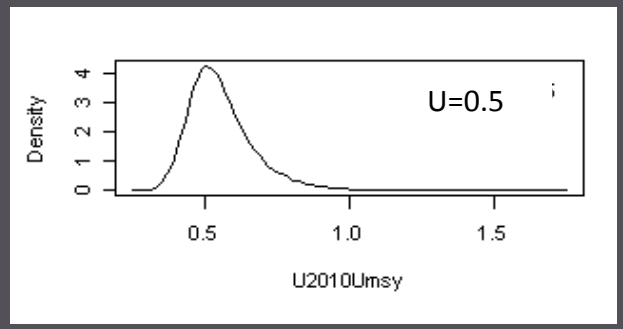
SRA Results:
Stock Status

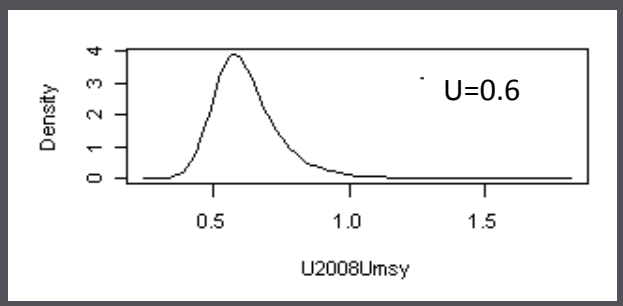
- MCMC posterior density for U_{2010}/U_{MSY} from the alternate-1 model runs (left panels) and alternate-2 model runs (right panels)
- U_{2010}/U_{MSY} varied between 0.40 and 0.63 for the alternate-1 model runs
- U_{2010}/U_{MSY} varied between 0.42 and 0.66 for the alternate-2 model runs

Alternate-1 Model Runs

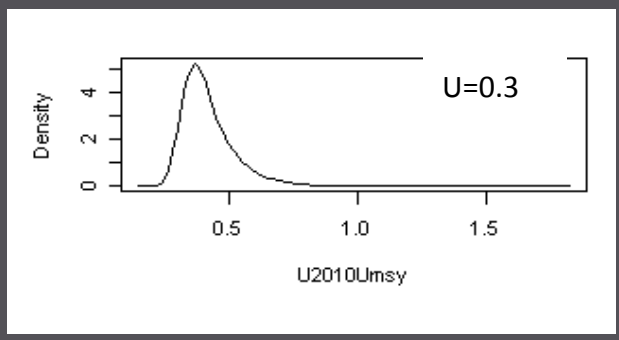


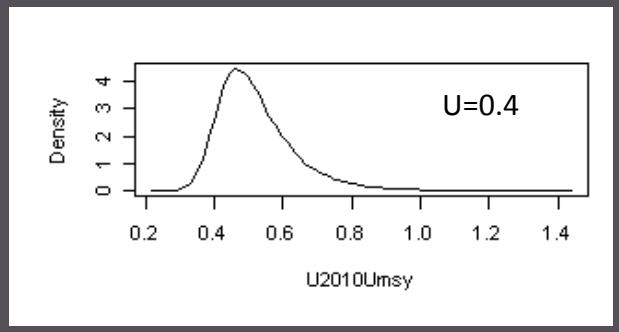


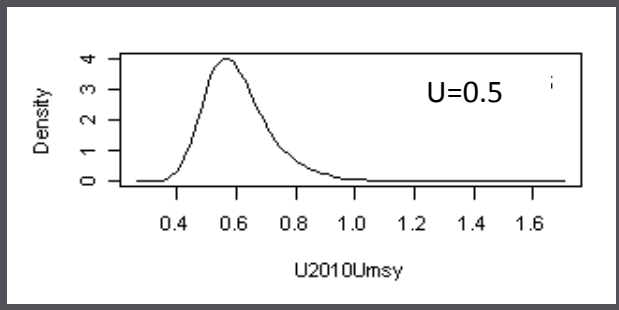


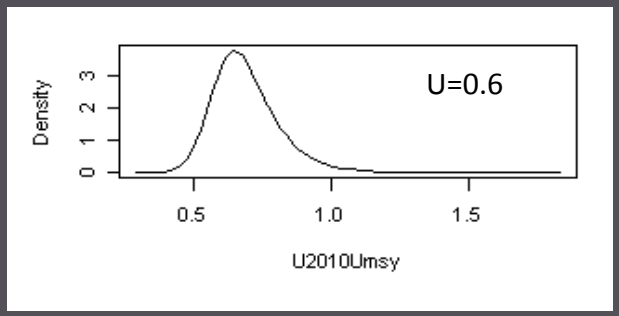


Alternate-2 Model Runs









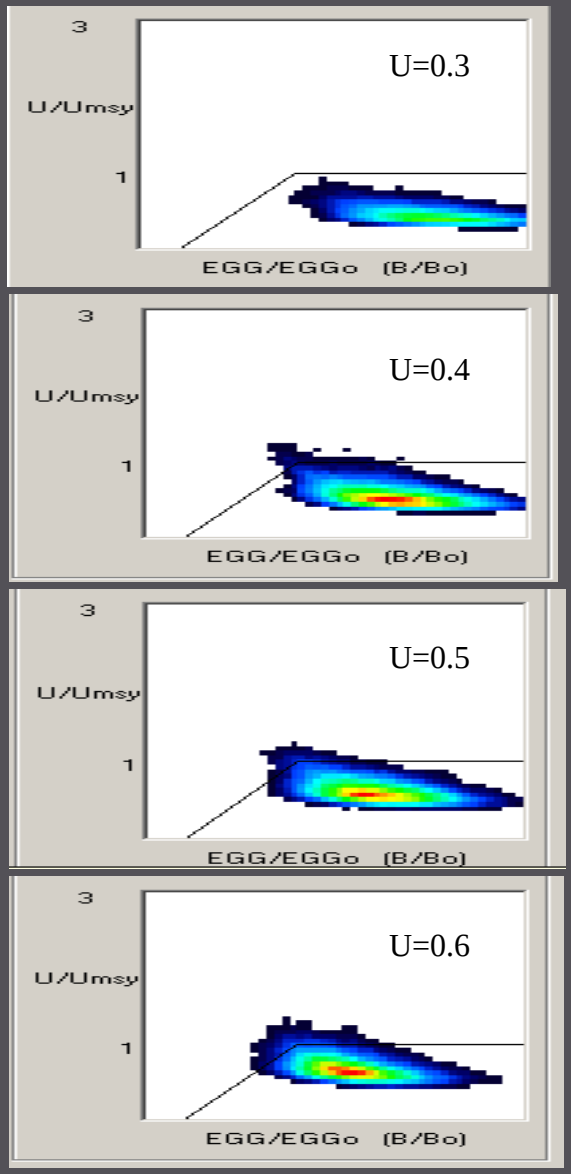
SRA Results:

Control Harvest Plot

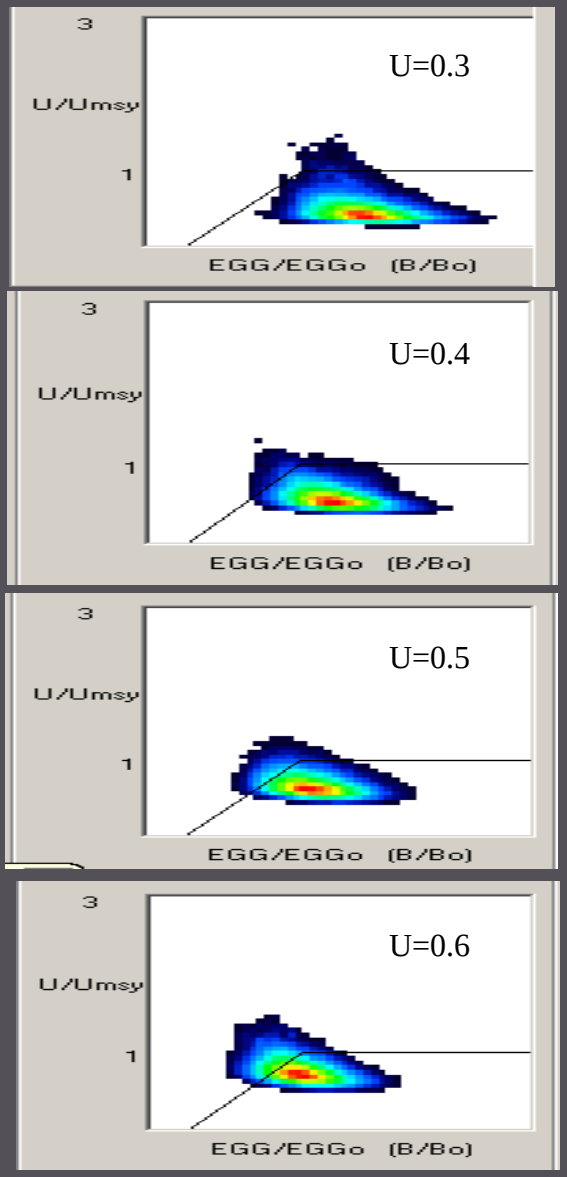
- MCMC posterior distributions of current stock status and harvest rate for alternate-1 (left panel) and alternate-2 (right panel) model runs

- Overall Low probability for the gulf menhaden stock to be considered overfished and undergoing overfishing

Alternate-1 Model Runs



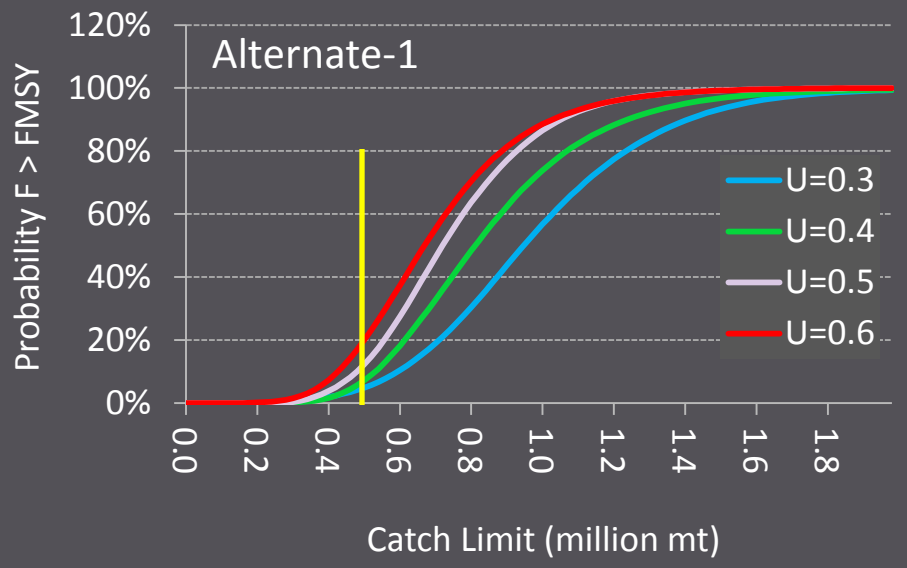
Alternate-2 Model Runs

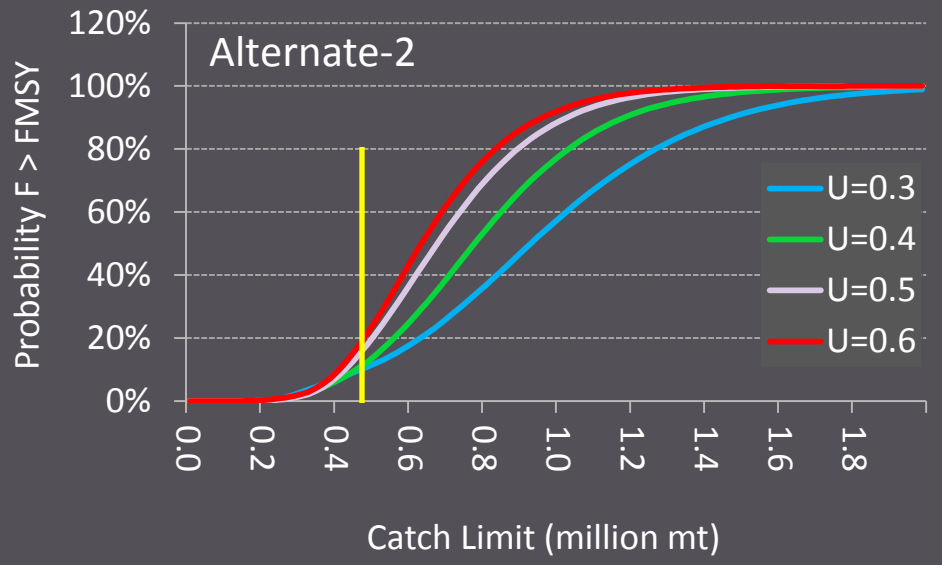


SRA Results:

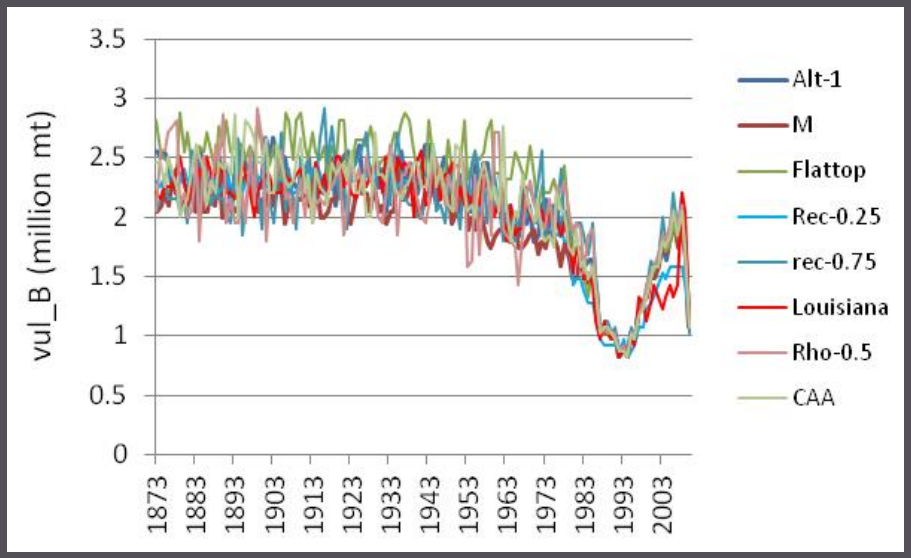
Probability of overfishing $F > F_{MSY}$ under various TAC

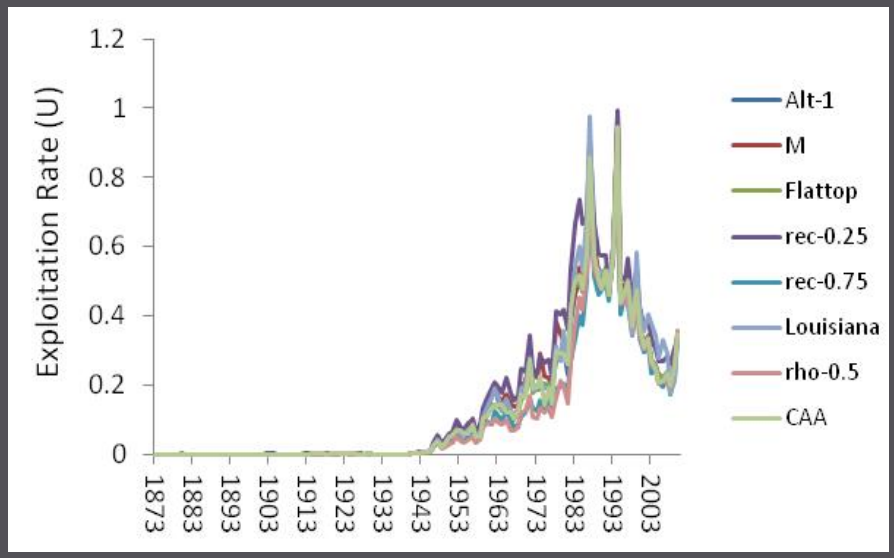
- Given the average landings in the past 10 years (470,000 mt), prob. varied between 3 and 14% from the Alternate-1 model runs and between 10% and 18% from the Alternate-2 model runs based on





Sensitivity Runs: MCMC *vul_B* and *U* modes and posterior summary statistics



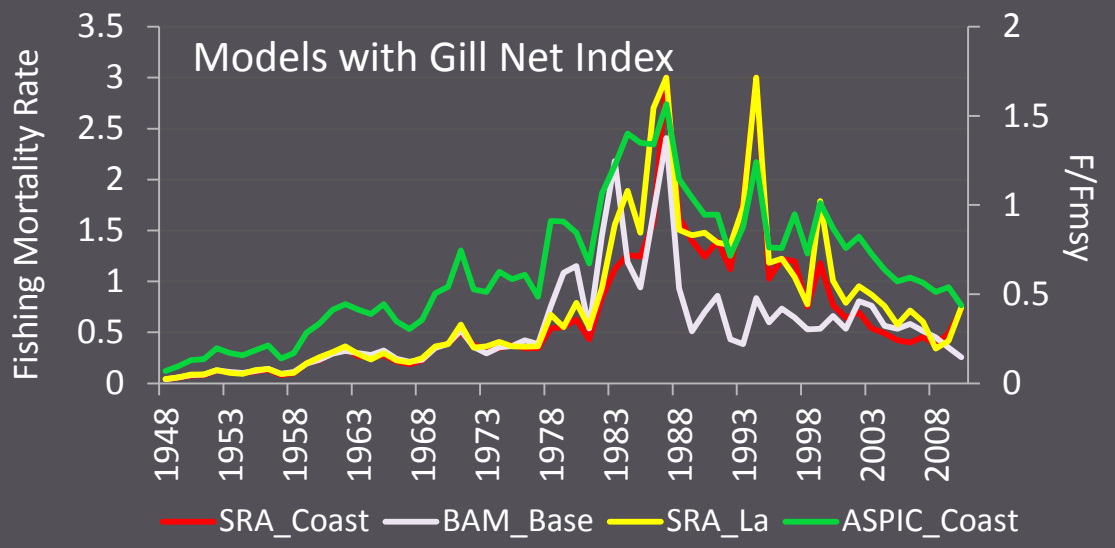


Sensitivity Runs	MSY*	U_{MSY}	S	U_{2010}/U_{MSY}	E_{2010}/E_0	recK
Alternate-1 Model	820.6	0.74	0.37	0.48	0.67	4.72
M-prior (0.6-0.9)	813.6	0.73	0.46	0.48	0.63	6.83
Rec_Rho (0.5)	991.5	0.71	0.37	0.51	0.58	4.53
Vul-at-age (flattop)	806.8	0.73	0.37	0.49	0.67	4.67
Rec SD=0.25	719.5	0.75	0.39	0.45	0.62	4.50
Rec SD=0.75	988.4	0.72	0.37	0.51	0.71	4.61
Louisian-Gillnet Index	772.8	0.72	0.36	0.49	0.82	4.37
Reduction-index	792.6	0.72	0.41	0.53	0.47	4.51
Adding BAM CAA	815.8	0.72	0.37	0.50	0.66	4.57

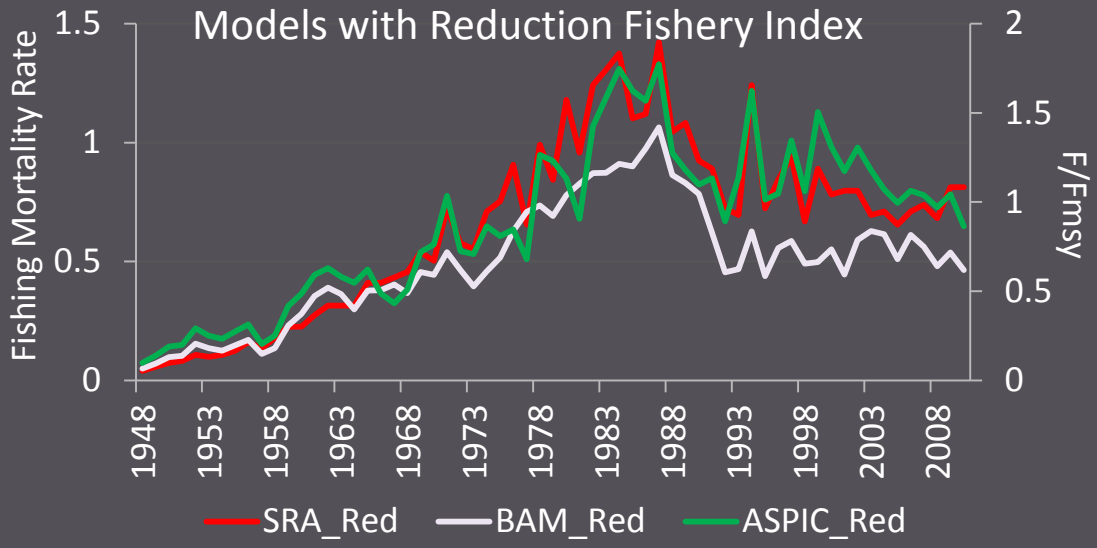
* 1000 mt

SRA Results- Model Comparisons (*F*)

- Pattern in F estimates from the Alt-1 model runs compared well with estimates from BAM-base and ASPIC models—generally lower Fs from BAM-base for recent years

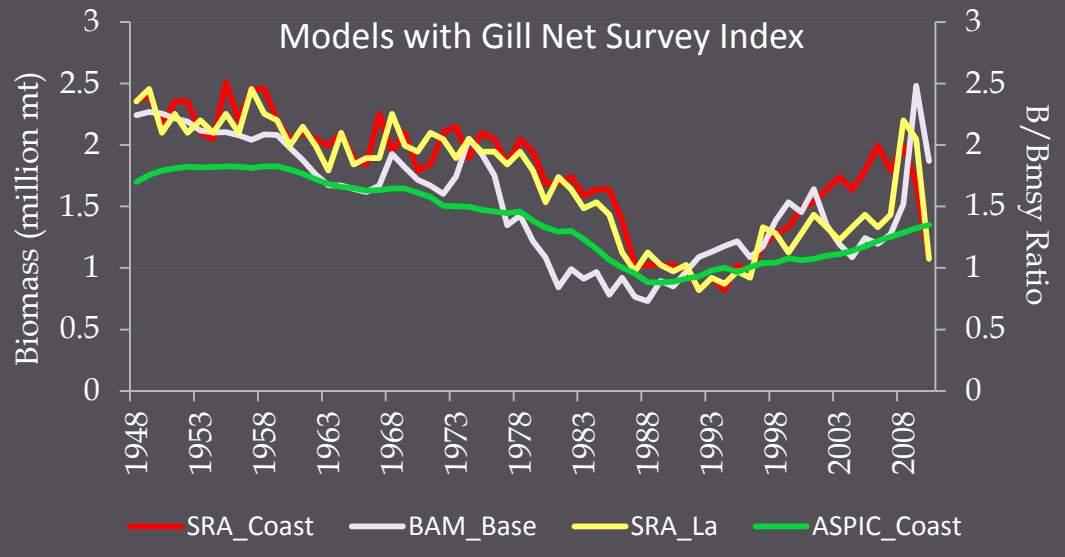


- Pattern in F estimate from the Alt-2 model runs compared well with estimates from the BAM and ASPIC models

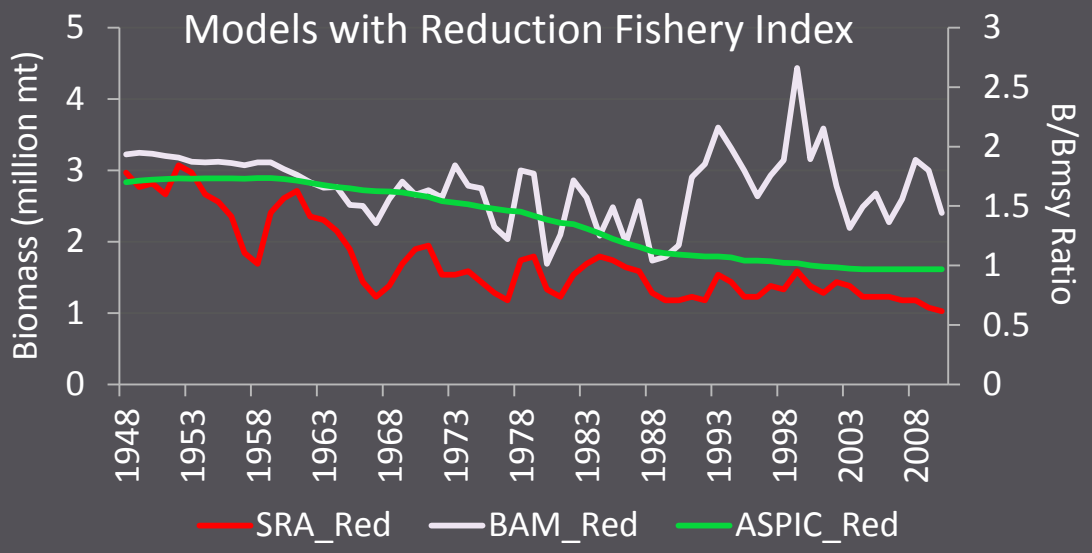


SRA Results- Model Comparisons (*B*)

- Pattern in *B* estimates from the Alt-1 model runs compared well with estimates from BAM-base and ASPIC models



- Pattern in B estimates from the Alt-2 model runs compared well with ASPIC but differed from the BAM model run using the reduction fishery index



MCMC posterior mean and quintiles values estimated for MSY, S, U_{MSY}, E_{2010}/E_0, and U_{2010}/U_{MSY} parameters from the Alternate-1 Runs

Alternate-1 Model Runs with Gill net Survey index

Run1 (U=0.3)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.76	0.16	0.49	0.75	1.11
MSY*	870	159	583	860	1209
S	0.37	0.04	0.31	0.37	0.44
U_{2010}/U_{MSY}	0.40	0.10	0.28	0.38	0.65
U_{MSY}	0.71	0.13	0.43	0.73	0.89

Run2 (U=0.4)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.66	0.13	0.43	0.64	0.94
MSY*	813	138	557	809	1095
S	0.37	0.04	0.31	0.37	0.44
U_{2010}/U_{MSY}	0.50	0.11	0.34	0.47	0.77
U_{MSY}	0.72	0.12	0.45	0.74	0.89

Run3 (U=0.5)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.61	0.13	0.38	0.60	0.87
MSY*	786	130	545	780	1065
S	0.37	0.04	0.30	0.37	0.44
U_{2010}/U_{MSY}	0.56	0.12	0.39	0.54	0.86
U_{MSY}	0.74	0.11	0.48	0.76	0.89

Run4 (U=0.6)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.55	0.11	0.35	0.54	0.80
MSY*	775	120	546	771	1023
S	0.37	0.04	0.30	0.37	0.44
U_{2010}/U_{MSY}	0.63	0.13	0.44	0.61	0.95
U_{MSY}	0.75	0.11	0.49	0.77	0.89

*MSY x 1000mt

MCMC posterior mean and quintiles values estimated for MSY, S, U_{MSY}, E_{2010}/E_0, and U_{2010}/U_{MSY} parameters from the Alternate-2 Model Runs

Alternate -2 Model Runs with the Reduction fishery index

Run1 (U=0.3)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.54	0.10	0.36	0.54	0.76
MSY*	900	185	570	889	1296
S	0.41	0.03	0.34	0.42	0.45
U_{2010}/U_{MSY}	0.42	0.11	0.28	0.40	0.71
U_{MSY}	0.70	0.13	0.39	0.72	0.89

Run2 (U=0.4)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.47	0.09	0.32	0.47	0.66
MSY*	793	141	535	783	1094
S	0.41	0.03	0.34	0.42	0.45
U_{2010}/U_{MSY}	0.53	0.12	0.36	0.50	0.82
U_{MSY}	0.72	0.12	0.44	0.74	0.89

Run3 (U=0.5)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.43	0.08	0.28	0.42	0.61
MSY*	738	110	531	731	971
S	0.41	0.03	0.34	0.42	0.45
U_{2010}/U_{MSY}	0.61	0.12	0.43	0.59	0.89
U_{MSY}	0.75	0.11	0.49	0.77	0.89

Run4 (U=0.6)	Mean	SD	0.025	0.5	0.975
E_{2010}/E_0	0.39	0.08	0.25	0.39	0.57
MSY*	693	101	513	685	912
S	0.41	0.03	0.34	0.42	0.45
U_{2010}/U_{MSY}	0.69	0.13	0.50	0.68	1.00
U_{MSY}	0.76	0.10	0.53	0.78	0.89

*MSY x 1000mt

Concluding Remarks

- Life history traits--short lived, early maturity, fast growth, high natural mortality --tend to predispose gulf menhaden toward high values of F_{MSY} (U_{MSY})
- Estimates of U_{MSY} generated from the alternate-1 and alternate-2 model runs were high, with posterior mean values estimated between 0.70 yr^{-1} and 0.76 yr^{-1}
- MSY estimated varied between 700,000-900,000mt, recent landings (47,000mt 10yrs average) have been below these estimates
- Probability of overfished and overfishing conditions was low for four exploitation scenarios in each alternate model
- $U_{current}/U_{MSY}$ was less than one based on all simulation runs, varied between 0.40 and 0.71
- SRA should be viewed as complementary analysis, analysis of uncertainty, providing historical perspective on stock productivity and the estimation of reference points