Forecast simulations and outlook for Aleutian Islands golden king crab under proposed state harvest strategy

Contribution to Ben Daley et al.'s Aleutian Islands golden king crab state harvest strategy

Introduction

The Aleutian Islands golden king crab (AIGKC) model-based assessment was accepted by the NPFMC in 2017 for annual overfishing level (OFL) and acceptable biological catch (ABC) determination. The fishery in the two management regions (east (EAG) and west (WAG) of 174 degree W longitude) is still managed by the constant harvest strategy. To use the assessment model estimated abundance in the calculation of total allowable catch (TAC), Alaska Department of Fish and Game (ADF&G) plans to submit a state harvest control rule proposal to the Board of Fisheries (BOF) in March 2019. This report provides a number of simulation results on the effect of different harvest policies on the sustainability and productivity of the stock.

Simulation Method

We simulated the future male stock abundances from the 2018 base model (scenario 18_1) estimated abundances by length-class and parameters. We projected the abundances for 30 years with 100 random replicates under federal control rule and state harvest control rule and estimated various management parameters: mature male biomass (MMB), mature male abundance (MMA), legal male biomass (LMB), OFL, ABC, total catch (TOTC), retained catch (RETC), retained catch-per-unit effort (CPUE), number of annual recruits to the model size-class (Recruit) under established Ricker stock-recruit model, and probability of overfishing [exceeding ABC (under 25% buffer of OFL)].

Future population projections primarily depend on future recruitment, but crab recruitment is difficult to predict. Therefore, annual recruitment for the projections was selected two ways: 1) a random selection from estimated recruitments during 1987– 2012 (CPT and SSC agreed time period; Siddeek et al., 2018), and 2) an established Ricker stock-recruitment model. Besides recruitment, another major uncertainty for the projections is the estimated terminal abundance in 2017. The estimated recruitments were randomly selected using a uniform random distribution whereas the terminal year abundance (i.e., 2017 abundance) was randomized by a lognormal random distribution. When the stock recruitment model was used, a lognormal random error was added.

The simulation steps

1) Run assessment model scenario 18_1 (base model) from the start year to the terminal year (2017/18) of the data. Model equations are provided in Appendix A of Siddeek et al. (2018).

2) After estimating the abundances and parameters in step 1, run the forecast function (at the standard deviation phase of the ADMB optimization). In the forecast, we used a constant last 10-yr mean groundfish fishing mortality and a constant *M* of 0.21 yr^{-1}:

2.a) Randomize the recruitment

i. Random selection of model estimated recruits for 1987 to 2012 was done in the program as follows:

$$R_i = e^{[logMeanRec\ +recdev(ii)+0.2\times standard\ normal\ \ deviate\ (i,j)]} \tag{1}$$

where i = 2 to 30 years; $ii = 1987 + unifrom\ random\ error(i,j) * (2012 - 1987)$; and

j = number of simulations.

ii. Ricker stock-recruitment relationship with lognormal errors was formulated as follows:

$$R_i = aS_{i-k}e^{-bS_{i-k}}e^{\varepsilon_i - \frac{\sigma^2_{\epsilon_i}}{2}} \tag{2}$$

Which was transformed into a linear form for fitting:

$$ln\left(\frac{R_i}{S_{i-k}}\right) = \left(\ln(a) - \frac{\sigma^2_{\epsilon_i}}{2}\right) - bS_{i-k} + \epsilon_i \tag{3}$$

where

$\epsilon_i = \rho\,\epsilon_{i-1} + e_i$ $\qquad e_i \sim N(0,\sigma^2)$

$\sigma^2_{\epsilon_i} = \frac{\sigma^2}{1-\rho^2}$

where *a*, *b*, σ, and ρ are density-independent, density-dependent, standard deviation, and first order autocorrelation parameters, respectively, and are estimated by stock-recruitment model fitting, S = mature male biomass (MMB), and *k* = lag years to produce the recruitment from the spawning year.

We considered *k* =8 years based on the mean recruitment length. We used the mean growth increment ~14.5 mm CL to estimate the mean recruitment age. Thus,

(mean recruitment length: 108.949 mm for EAG and 109.035 mm for WAG) / 14.5 + 0.7 (brooding time to start of growth) ~ 8 years.

The stock-recruitment model was used as follows:

$$R_{i+1} = aS_{i-k}e^{-bS_{i-k}}e^{normal\ random\ error(i,j)\sqrt{\frac{\sigma^2}{1-\rho^2}} - \frac{\frac{\sigma^2}{1-\rho^2}}{2}} \tag{4}$$

2.b) Randomize the abundance

The lognormal random error to the initial abundance at each replication (j) is added in the following steps:

We first scaled the standard error based on the standard error of the terminal year abundance (i.e., CV= $\frac{Std.Error\ of\ terminal\ MMA}{terminal\ MMA}$). Then we added the lognormal random error to abundance as follows:

$$N_{1,j} = N_{1,j} e^{\varepsilon_j - \frac{\sigma_\varepsilon^2}{2}} \quad (5)$$

where $\sigma_\varepsilon = \frac{Std.Error\ of\ terminal\ year\ MMA}{terminal\ year\ MMA}$

$N_{1,j}$= initial abundance to be randomized for jth replication; and MMA = mature male abundance (number of crab).

The log normal error to the abundance was implemented as follows:

$$N_{i=1} = N_{i=1}\, e^{normal\ random\ error\ (j)\frac{Std.Error\ terminal\ year\ MMA}{terminal\ year\ MMA}} - \frac{\left(\frac{Std.Error\ terminal\ year\ MMA}{terminal\ year\ MMA}\right)^2}{2} \quad (6)$$

3. Projection

3.a) Federal overfishing level OFL catch is needed to assess the total catch determined by each state harvest control rule scenario (NPFMC, 2007). We used ABC (75% of OFL) as a bench mark to assess whether the total harvest has been overfishing under a state harvest control rule. Hence, in addition to state harvest control rule, the federal control rule F (i.e., F_{ofl}) was also used in the simulations.

The proposed state harvest control rule scenarios are listed in Table 1.

Table 1. Ten state harvest strategy scenarios (Sc) for the directed pot fishery were considered in the simulations.

	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Time period for mean MMA[1] (MMA_{ave})	1985–2017	1985–2017	1985–2017	1985–2017	1985–2017	1985–2017	1985–2017	1985–2017	1985–2017	1985– 2017
Threshold for opening/closing $\frac{MMA}{MMA_{ave}}\%$	25%	25%$_{e}$	25%	25%	25%	25%	25%	25%	25%	25%
Exploitation rate on MMA when $\frac{MMA}{MMA_{ave}}\% < 100\%$	$\frac{MMA}{MMA_{ave}} \times 0.1$	$\frac{MMA}{MMA_{ave}} \times 0.125$	$\frac{MMA}{MMA_{ave}} \times 0.15$	$\frac{MMA}{MMA_{ave}} \times 0.20$	$\frac{MMA}{MMA_{ave}} \times 0.3$	$\frac{MMA}{MMA_{ave}} \times 0.1$	$\frac{MMA}{MMA_{ave}} \times 0.125$	$\frac{MMA}{MMA_{ave}} \times 0.15$	$\frac{MMA}{MMA_{av}} \times 0.20$	$\frac{MMA}{MMA_{ave}} \times 0.30$
Max Exploitation rate on MMA when $\frac{MMA}{MMA_{ave}}\% \geq 100\%$	10%	12.5%	15%	20%	30%	10%	12.5%	15%	20%	30%
Max exploitation rate on legal male abundance	25%	25%	25%	25%	25%	30%	30%	30%	30%	30%

1 MMA: mature male abundance (number of crab)

The proposed state harvest rate (HR) was converted into directed pot fishery fishing mortality (F yr^{-1}) by a grid search method to satisfy:

$$HR = \frac{F \times total\ selectivity}{Z} \times (1. - e^{-Z}) \quad (7)$$

where F (size invariable) and Z are fishing and total mortality, respectively. HR is re-estimated by the grid search function for F determination using

$$HR = \frac{Catch\ (number\ of\ crab)}{MMA} \quad (8)$$

The F determined for a given state harvest rate was used in the population dynamics formula (Appendix A; Siddeek et al., 2018).

The stock depletion for each projected year was determined by

$$depletion = \frac{MMA}{MMA_{ave}} \quad (9)$$

Each scenario was replicated 100 times and projections made over 30 years beginning in 2017

At each time step in the future:

3.b) Calculated MMB, MMA, LMB, and depletion.

3.c) Calculated Tier 3 OFL and ABC using Fofl.

3.d) Calculated TOTC, RETC, CPUE, and Recruit using state harvest control rule on MMA.

Note: Calculation formulas for 3.b), 3.c), and 3.d) are given either in this report or Appendix A of Siddeek et al. (2018).

3.e) Implemented the fishery and removed the total catch and groundfish bycatch from the simulated population.

3.f) Drew new recruitment numbers from either the historical distribution or the stock-recruitment model and distributed them to length bins.

3.g) Updated the number-at-length.

4) Repeated step-3 for 30 years into the future.

5) Repeated steps 3 and 4 for a set number of 100 Monte Carlo trials, randomizing recruitment and abundance.

6) Used the annual distribution of simulated OFL, ABC, TOTC, CPUE, MMA, MMB, LMB, depletion, state harvest control rule F, and Recruit (only for stock-recruit model generated recruits) to calculate performance statistics:

a) Mean and median annual MMB, MMA, LMB, OFL, ABC, TOTC, stock depletion, F, CPUE, and Recruit with standard errors.

b) Probability that TOTC exceeding ABC during the 30-yr projection period; comparison of the trends in TOTC against OFL, MMB, and MMA relative to the respective 1985-2017 means, and stock depletion relative to the respective 1985-2017 means.

Results

Ricker Stock Recruitment Fit

We used the generalized least square (GLS) procedure with the maximum likelihood option (R Core Team, 2018) to fit the linear form of the Ricker stock-recruitment model (Eq.3) with (model M1) and without (model M2) the first order autocorrelation to the assessment model estimated MMB lagged by 8 years and number of annual recruits R (i.e., 1986-2009 MMB vs. 1994-2017 R). Then we compared the fits by ANOVA to assess whether the auto correlation parameter significantly improved model fit. The results are listed below for EAG followed by WAG:

EAG:

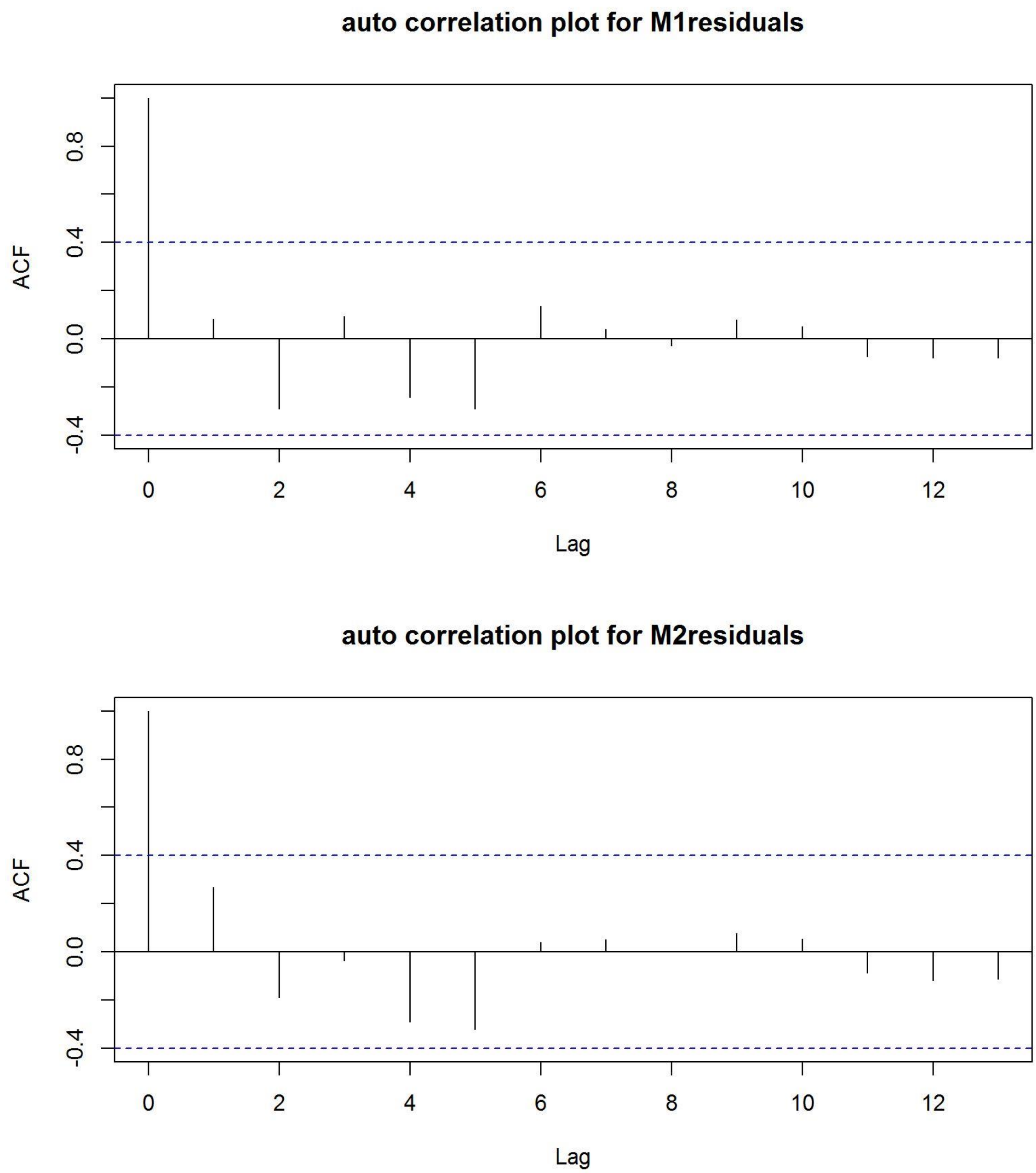


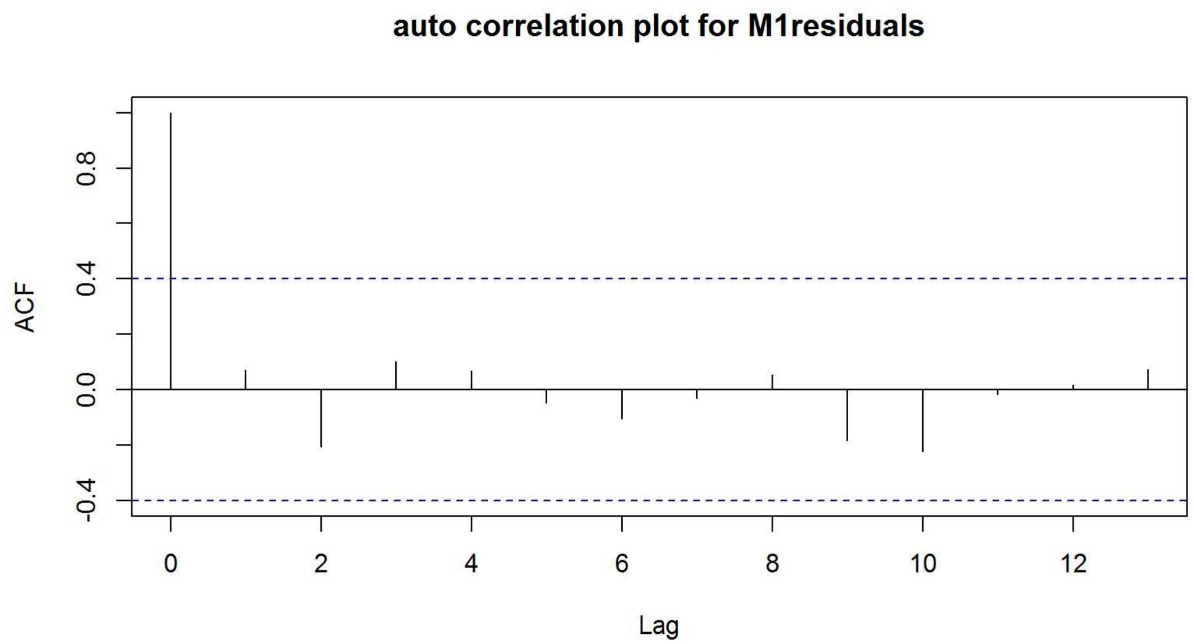
Figure 1. Autocorrelation plots for EAG MMB vs R. Top: With first order autocorrelation; and bottom: without first order autocorrelation. Including the autocorrelation parameter did not remove the autocorrelation.

Model	Model Code	Df	AIC	BIC	Loglik	Test	Likelihood Ratio	p-value
AR1 model	M1	4	2.1644	6.8766	2.9178			
Without AR1 model	M2	3	1.9948	5.5289	2.0026	1 vs 2	1.8304	0.1761

Thus, model 2 (without AR1) was selected for EAG. The stock recruitment parameters are:

a = 0.000665, b = 0.000077, $\sigma = 0.2226$, and $\rho = 0$.

WAG:



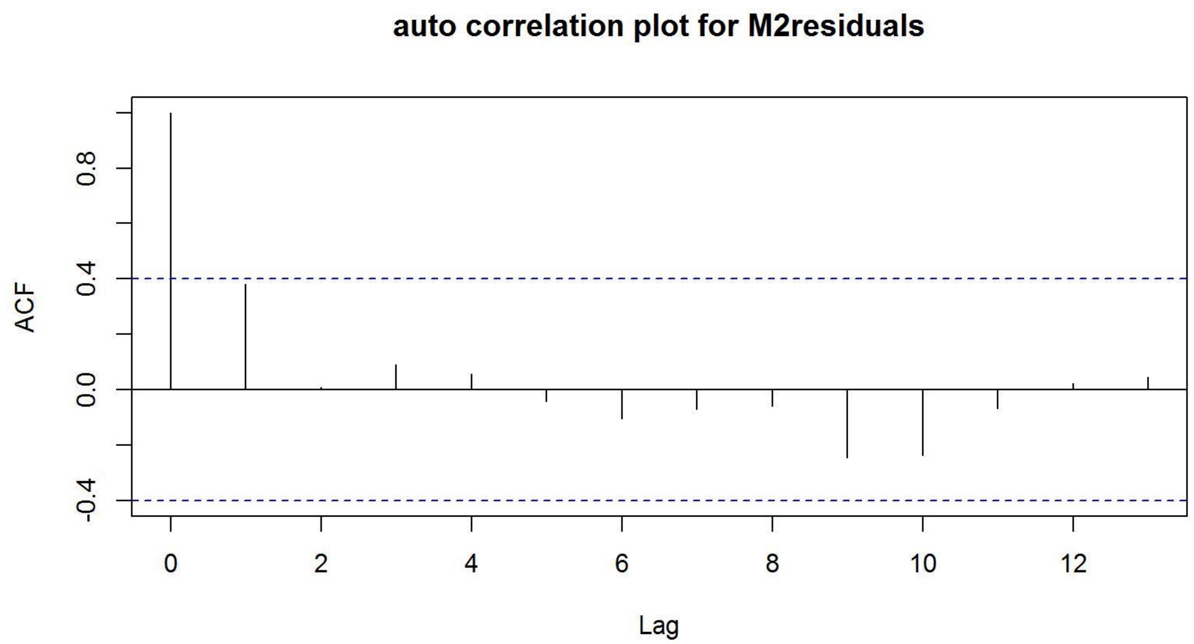


Figure 2. Autocorrelation plots for WAG MMB vs R. Top: With first order autocorrelation; and bottom: without first order autocorrelation. Including the autocorrelation parameter significantly improved model fit.

Model	Model Code	Df	AIC	BIC	Loglik	Test	Likelihood Ratio	p-value
AR1 model	M1	4	-7.0092	-2.2969	7.5046			
Without AR1 model	M2	3	-4.8077	-1.2736	5.4039	1 vs 2	4.2014	0.0404

Thus, model 1 (with AR1) was selected for WAG. The stock recruitment parameters are:

a = 0.000971, b = 0.000171, σ = 0.1938, and ρ = 0.4157.

Terminal abundance standard error

The scaled standard error estimates (CVs) for terminal abundance are:

WAG: σ_{ε} = 0.1582
EAG: σ_{ε} = 0.1817

Simulation results

We compared the simulation outputs from different state harvest strategy scenarios with the Federal ABC and mean MMB; state average MMA, and stock depletion during the 30-yr projection time horizon. We used the zero harvest rate as a control for output comparison. We investigated the probability of the stock being overfishing (i.e., total catch exceeding Federal ABC estimates) during the 30-yr projection time horizon. We used the ABC for limit reference point because of state total allowable catch (TAC) setting aims not to reach ABC. The standard errors of TOTC are provided to assess the variability of the harvest under different state harvest strategies.

We provide the results for all state harvest scenarios including the zero harvest rate (Tables 2 and 3, and Figures 3 to 9 for EAG and Tables 4 and 5, and Figures 10 to 16 for WAG). We show the mean value trends for MMB, MMA, LMB, TOTC, CPUE, state harvest rate equivalent F, and Recruit in the figures. Tables 2 and 3 compare the 30-yr projected total catches with that of ABC under F_{MSY} control rule for all state harvest strategy scenarios for EAG while Tables 4 and 5 list similar results for WAG.

We can make the following provisional conclusions from the simulation results:

1. EAG: The probabilities of mean TOTC exceeding mean ABC exceeded 0.5 for state harvest rates of 20% and 30% when the maximum exploitation rate on legal male abundance was set at either 25% or 30% under random recruit selection (Table 2). On the other hand, under the Ricker stock-recruit model predicted recruitment, the probability of mean TOTC exceeding mean ABC was above 0.5 for 15%, 20%, and 30% harvest rates when the maximum exploitation rate on legal male abundance was set at 25%, but not when the maximum exploitation rate on legal male was set at 30%. In the latter case, above 0.5 probabilities were observed only for the 20% and 30% state harvest rates (Table 3).

The MMB trend was below the Federal control rule average (Figure 3) and stock depletion proportion trend was below 1.0 (Figure 5) for the state harvest rate of 30% and approaching this threshold for the harvest rate of 20%. The trends in LMB (Figure 4) and CPUE (Figure 7) were lower and state harvest rate equivalent F were higher (Figure 8) as the state harvest rate increased. The recruitment trends fluctuated and significantly reduced for the state harvest rate of 30% (Figure 9).

2. WAG: The probabilities of mean TOTC exceeding mean ABC exceeded 0.5 for state harvest rates of 15%, 20%, and 30% when the maximum exploitation rate on legal male abundance was set at 25% under either random recruit selection or Ricker stock-recruit model predicted recruitment (Tables4 and 5). On the other hand, the probability of mean TOTC exceeding mean ABC exceeded 0.5 only for 20% and 30% harvest rates when the maximum exploitation rate on legal male abundance was set at 30% under either random recruit selection or Ricker stock-recruit model predicted recruitment (Tables 4 and 5).

The MMB trend was below the Federal control rule average (Figure 10) and stock depletion proportion trend was below 1.0 (Figure 12) for the state harvest rate of 30%. On the other hand, the MMB and depletion trends approached these thresholds for the harvest rate of 20% when the maximum exploitation rate on legal male abundance was set at 30% . The trends in LMB (Figure 11) and CPUE (Figure 14) were lower and state harvest rate equivalent Fs were higher (Figure 15) as the state harvest rate increased. The recruitment trends for WAG were quite different from those of the EAG by fluctuating about a horizontal mean trend as the state harvest rate increased from 0.0 when the maximum exploitation rate on legal male was set at 25%. However, the trends were similar to those of EAG for the maximum exploitation rate on legal male was set at 30%, reduced for the state harvest rate of 30% (Figure 16).

3. Overall results suggest that a 15% harvest rate is a safe strategy. This is largely based on the comparison of TOTC with ABC; and MMB and stock depletion trends with the threshold levels.
4. The same comparison suggests that a 20% harvest rate is risky and a 30% harvest rate is too high.
5. We compared the TOTC trends with those of ABC for determining the probability of overfishing. However, if we compared them with the OFL trends, the probability of overfishing would be lower.

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Reference

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Table 2. Comparison of projected mean total catch (TOT) with ABC for state harvest control rule scenarios (Sc.) 1 to 10 under random recruitment for EAG. The standard errors (SE) of the mean TOT were estimated from 100 Monte Carlo trials. Probability of TOT exceeding ABC is also listed.

	Sc1			Sc2			Sc3			Sc4			Sc5			Sc6		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	2,417	1,677	265.37	2,417	2,146	544.54	2,417	2,626	678.76	2,417	3,240	920.32	2,417	4,358	1,123.17	2,417	1,677	265.37
2018	2,715	1,612	235.21	2,582	1,912	259.71	2,446	2,198	338.89	2,273	2,627	471.22	1,959	3,100	661.11	2,715	1,612	235.21
2019	2,849	1,584	208.49	2,642	1,855	241.17	2,436	2,078	266.58	2,156	2,382	379.16	1,732	2,512	437.25	2,849	1,584	208.49
2020	2,854	1,559	183.09	2,591	1,807	218.45	2,343	2,014	258.36	2,003	2,144	342.25	1,575	2,256	362.25	2,854	1,559	183.09
2021	2,798	1,544	171.34	2,495	1,764	194.60	2,215	1,950	261.82	1,872	1,988	280.78	1,448	2,159	350.08	2,798	1,544	171.34
2022	2,730	1,516	166.02	2,400	1,716	194.76	2,099	1,870	235.47	1,783	1,881	256.92	1,352	2,076	305.16	2,730	1,516	165.97
2023	2,662	1,506	183.72	2,318	1,697	215.07	2,010	1,854	289.97	1,727	1,863	300.43	1,281	2,062	335.86	2,662	1,506	183.68
2024	2,603	1,497	191.43	2,248	1,677	227.60	1,933	1,834	329.44	1,683	1,841	324.16	1,229	2,041	331.58	2,603	1,497	191.39
2025	2,565	1,473	172.08	2,205	1,647	204.88	1,886	1,774	258.02	1,665	1,790	283.50	1,200	1,997	282.67	2,565	1,473	172.05
2026	2,536	1,457	149.95	2,175	1,626	179.45	1,861	1,757	244.88	1,663	1,777	246.26	1,184	1,970	266.79	2,536	1,457	149.92
2027	2,507	1,450	146.34	2,148	1,622	190.46	1,835	1,741	227.03	1,657	1,772	243.08	1,166	1,958	257.46	2,507	1,450	146.33
2028	2,481	1,457	145.75	2,122	1,626	171.21	1,815	1,750	247.47	1,648	1,789	257.99	1,154	1,983	272.50	2,481	1,457	145.76
2029	2,462	1,465	147.72	2,103	1,642	190.99	1,801	1,758	227.79	1,643	1,819	287.54	1,149	1,999	273.99	2,462	1,465	147.72
2030	2,461	1,457	151.25	2,099	1,623	182.72	1,801	1,753	242.31	1,645	1,810	277.59	1,149	2,005	304.85	2,461	1,457	151.25
2031	2,466	1,451	136.93	2,105	1,617	162.09	1,807	1,749	220.33	1,654	1,795	225.38	1,155	1,993	263.72	2,466	1,451	136.91
2032	2,467	1,453	126.37	2,107	1,627	167.04	1,811	1,753	202.66	1,664	1,799	228.64	1,157	1,979	225.69	2,467	1,453	126.37
2033	2,464	1,454	138.25	2,103	1,621	162.33	1,807	1,753	236.67	1,663	1,820	255.02	1,152	1,989	270.80	2,464	1,454	138.25
2034	2,464	1,452	140.21	2,103	1,618	168.64	1,805	1,755	244.83	1,659	1,805	259.43	1,153	1,993	278.53	2,464	1,452	140.21
2035	2,464	1,451	149.77	2,102	1,616	181.07	1,802	1,747	243.83	1,657	1,814	275.12	1,150	1,982	273.45	2,464	1,451	149.73
2036	2,463	1,453	154.03	2,101	1,621	192.41	1,802	1,758	253.76	1,657	1,812	292.11	1,152	1,992	281.09	2,463	1,453	153.97
2037	2,463	1,458	156.05	2,102	1,626	188.24	1,800	1,742	227.00	1,656	1,821	288.26	1,153	2,002	294.08	2,463	1,458	156.01
2038	2,466	1,461	150.53	2,107	1,629	180.33	1,809	1,762	251.41	1,659	1,834	267.63	1,158	2,019	303.43	2,466	1,461	150.49
2039	2,470	1,471	160.83	2,109	1,638	195.97	1,809	1,770	249.94	1,655	1,859	288.10	1,156	2,026	308.42	2,470	1,471	160.82
2040	2,477	1,465	161.11	2,116	1,638	208.80	1,817	1,771	271.04	1,653	1,840	285.63	1,156	2,015	301.88	2,477	1,465	161.08
2041	2,488	1,463	153.60	2,126	1,633	200.18	1,824	1,772	259.93	1,660	1,827	278.92	1,165	2,015	288.12	2,488	1,463	153.59
2042	2,488	1,476	167.79	2,125	1,659	230.20	1,822	1,782	274.88	1,661	1,863	329.64	1,161	2,014	298.24	2,488	1,477	167.77
2043	2,490	1,471	166.25	2,124	1,647	219.15	1,825	1,784	287.69	1,659	1,848	331.43	1,163	2,015	310.56	2,490	1,471	166.22
2044	2,498	1,463	158.51	2,130	1,640	221.81	1,829	1,759	259.00	1,664	1,829	309.73	1,169	2,003	317.82	2,498	1,463	158.48
2045	2,498	1,469	165.69	2,128	1,642	207.27	1,831	1,765	256.16	1,665	1,838	322.11	1,169	2,013	327.46	2,498	1,469	165.67
2046	2,492	1,481	208.09	2,123	1,652	248.25	1,825	1,787	309.75	1,656	1,846	346.04	1,163	2,027	333.67	2,492	1,476	182.40
Prob TOT> ABC		0			0			0.03			1.0			1.0			0	

Table 2 continued.

	Sc7			Sc8			Sc9			Sc10		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	2,417	2,185	678.04	2,417	2,849	926.89	2,417	3,734	1,035.55	2,417	4,733	986.68
2018	2,571	1,908	251.75	2,383	2,188	383.52	2,134	2,797	569.29	1,854	3,391	721.99
2019	2,633	1,859	258.68	2,382	2,066	288.30	1,980	2,403	377.25	1,547	2,665	436.09
2020	2,582	1,810	237.82	2,298	1,984	250.77	1,838	2,209	327.43	1,349	2,367	297.72
2021	2,486	1,760	190.43	2,184	1,930	253.14	1,702	2,082	322.65	1,205	2,228	309.77
2022	2,393	1,714	191.80	2,078	1,855	230.50	1,605	1,972	290.71	1,110	2,143	307.51
2023	2,312	1,695	212.57	1,996	1,831	278.48	1,541	1,952	343.11	1,047	2,066	303.78
2024	2,245	1,676	225.73	1,928	1,812	302.66	1,492	1,932	363.96	1,015	2,045	305.60
2025	2,202	1,649	213.33	1,888	1,768	258.18	1,470	1,879	308.95	1,007	2,045	310.88
2026	2,172	1,625	178.20	1,865	1,742	214.31	1,465	1,856	261.42	994	2,012	276.91
2027	2,146	1,616	173.17	1,843	1,737	223.15	1,455	1,850	270.58	982	1,992	258.81
2028	2,122	1,626	170.79	1,824	1,751	232.60	1,444	1,874	301.42	979	1,993	260.63
2029	2,103	1,635	171.94	1,808	1,773	256.88	1,440	1,911	315.16	988	2,024	256.50
2030	2,101	1,623	180.93	1,803	1,752	246.09	1,439	1,892	318.49	997	2,035	305.55
2031	2,107	1,618	162.93	1,809	1,736	197.74	1,447	1,881	258.41	1,006	2,049	286.15
2032	2,109	1,625	154.19	1,816	1,749	197.66	1,455	1,883	253.58	1,005	2,036	229.70
2033	2,105	1,622	162.58	1,813	1,755	230.25	1,449	1,896	294.51	997	2,018	245.87
2034	2,104	1,618	168.53	1,810	1,748	225.86	1,449	1,885	294.86	1,002	2,044	268.71
2035	2,103	1,617	180.84	1,808	1,747	247.68	1,447	1,894	313.94	998	2,024	278.82
2036	2,102	1,623	199.75	1,807	1,758	266.23	1,448	1,891	326.13	1,002	2,041	288.57
2037	2,102	1,625	186.39	1,805	1,765	269.39	1,447	1,909	323.32	1,001	2,040	299.34
2038	2,107	1,629	180.21	1,806	1,756	238.74	1,448	1,910	308.23	1,008	2,047	303.44
2039	2,109	1,641	199.81	1,808	1,779	269.68	1,447	1,937	338.74	1,013	2,047	307.56
2040	2,116	1,632	193.05	1,813	1,760	255.89	1,444	1,921	328.36	1,020	2,061	305.68
2041	2,126	1,637	222.54	1,824	1,760	258.93	1,453	1,900	293.08	1,028	2,073	302.99
2042	2,124	1,669	268.01	1,826	1,797	306.98	1,454	1,936	358.20	1,020	2,051	292.32
2043	2,120	1,653	247.57	1,823	1,790	316.80	1,453	1,924	351.44	1,021	2,066	308.60
2044	2,126	1,636	220.89	1,826	1,765	277.76	1,459	1,899	339.32	1,023	2,065	330.24
2045	2,125	1,648	231.55	1,827	1,783	296.10	1,461	1,922	365.11	1,019	2,058	323.86
2046	2,118	1,659	291.69	1,816	1,784	334.59	1,451	1,921	346.07	1,013	2,060	339.40
Prob TOT> ABC		0			0.03			1.0			1.0	

Table 3. Comparison of projected mean total catch (TOT) with ABC for state harvest control rule scenarios (Sc.) 1 to 10 under stock-recruitment predicted recruitment for EAG. Ricker stock-recruitment relationship was used to predict the number of recruits (millions). The standard errors (SE) of the mean TOT were estimated from 100 Monte Carlo trials. Probability of TOT exceeding ABC is also listed.

	Sc1			Sc2			Sc3			Sc4			Sc5			Sc6		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	2,495	1,731	0.22	2,495	2,111	0.27	2,495	2,670	0.62	2,495	3,376	0.76	2,495	4,584	0.99	2,495	1,731	0.22
2018	2,803	1,674	35.46	2,695	1,999	42.96	2,537	2,265	49.84	2,338	2,654	122.62	1,999	3,272	150.65	2,803	1,674	35.46
2019	2,942	1,671	79.91	2,751	1,964	95.57	2,531	2,201	123.39	2,239	2,527	148.72	1,755	2,755	267.68	2,942	1,671	79.91
2020	2,959	1,665	94.39	2,704	1,931	111.67	2,439	2,141	131.79	2,083	2,300	189.20	1,583	2,512	290.26	2,959	1,665	94.39
2021	2,928	1,673	117.92	2,626	1,930	173.77	2,332	2,157	254.02	1,971	2,222	284.99	1,462	2,425	284.84	2,928	1,673	117.92
2022	2,886	1,679	117.27	2,548	1,917	148.73	2,226	2,144	253.44	1,890	2,164	288.31	1,381	2,395	273.14	2,886	1,679	117.27
2023	2,860	1,675	117.85	2,497	1,897	134.81	2,151	2,138	246.22	1,851	2,155	259.85	1,332	2,380	276.82	2,860	1,675	117.85
2024	2,845	1,679	120.49	2,466	1,894	138.93	2,095	2,113	238.18	1,828	2,159	271.27	1,303	2,357	254.36	2,845	1,679	120.49
2025	2,837	1,691	117.43	2,447	1,903	135.60	2,060	2,111	233.91	1,814	2,190	276.70	1,289	2,373	248.97	2,837	1,691	117.43
2026	2,838	1,703	116.93	2,439	1,914	140.09	2,041	2,120	235.29	1,804	2,201	286.13	1,284	2,364	254.54	2,838	1,703	116.93
2027	2,852	1,709	130.04	2,446	1,919	169.33	2,038	2,102	236.65	1,806	2,177	291.97	1,286	2,307	288.72	2,852	1,709	130.04
2028	2,869	1,714	141.78	2,456	1,925	187.83	2,045	2,087	247.66	1,811	2,160	290.93	1,281	2,218	289.68	2,869	1,714	141.78
2029	2,888	1,714	132.14	2,466	1,910	150.58	2,053	2,064	205.51	1,811	2,107	254.86	1,274	2,152	270.67	2,888	1,714	132.14
2030	2,900	1,709	134.98	2,472	1,904	164.81	2,056	2,049	226.14	1,809	2,068	253.82	1,252	2,072	241.17	2,900	1,709	134.98
2031	2,907	1,706	131.35	2,473	1,897	165.74	2,055	2,021	197.04	1,805	2,043	259.37	1,235	2,035	228.27	2,907	1,706	131.35
2032	2,902	1,722	131.05	2,463	1,910	157.44	2,044	2,066	224.05	1,791	2,045	254.74	1,220	2,039	223.49	2,902	1,722	131.05
2033	2,902	1,724	121.80	2,457	1,907	137.95	2,027	2,064	229.96	1,785	2,041	227.91	1,204	2,034	205.45	2,902	1,724	121.80
2034	2,908	1,733	114.77	2,459	1,916	131.14	2,015	2,069	208.97	1,785	2,063	228.27	1,197	2,037	203.28	2,908	1,733	114.77
2035	2,917	1,732	120.95	2,463	1,915	144.17	2,007	2,012	180.65	1,784	2,072	251.34	1,184	2,025	232.52	2,917	1,732	120.95
2036	2,929	1,728	110.80	2,471	1,908	125.05	2,019	2,023	190.72	1,783	2,040	237.53	1,181	2,002	204.34	2,929	1,728	110.80
2037	2,933	1,735	113.19	2,473	1,916	131.58	2,019	2,035	181.01	1,785	2,050	234.70	1,178	1,997	203.93	2,933	1,735	113.19
2038	2,935	1,724	119.99	2,472	1,903	136.99	2,015	2,027	207.65	1,782	2,035	229.37	1,168	1,962	208.66	2,935	1,724	119.99
2039	2,938	1,707	119.14	2,475	1,881	133.63	2,013	1,984	195.13	1,782	1,982	213.20	1,158	1,917	197.03	2,938	1,707	119.14
2040	2,929	1,710	122.82	2,466	1,884	139.02	2,005	1,962	176.27	1,778	1,982	217.56	1,149	1,913	195.30	2,929	1,710	122.82
2041	2,912	1,712	123.53	2,449	1,887	139.23	1,998	1,998	203.89	1,768	1,981	232.23	1,135	1,912	196.49	2,912	1,712	123.53
2042	2,903	1,712	126.07	2,440	1,889	150.10	1,987	1,998	205.03	1,765	1,994	231.69	1,124	1,907	198.05	2,903	1,712	126.07
2043	2,898	1,715	127.15	2,435	1,889	143.93	1,980	1,997	210.64	1,762	2,002	226.47	1,120	1,911	204.19	2,898	1,715	127.15
2044	2,898	1,716	129.39	2,435	1,896	167.70	1,977	2,010	232.72	1,760	1,996	243.65	1,114	1,903	199.18	2,898	1,716	129.39
2045	2,901	1,718	125.26	2,437	1,899	168.56	1,973	2,014	240.36	1,763	2,004	249.30	1,114	1,902	203.11	2,901	1,718	125.26
2046	2,904	1,724	130.63	2,438	1,899	147.32	1,970	2,020	241.10	1,764	2,017	251.71	1,114	1,917	224.64	2,904	1,724	130.63
Prob TOT> ABC		0			0			0.63			1.0			1.0			0	

Table 3 continued.

	Sc7			Sc8			Sc9			Sc10		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	2,495	2,111	0.27	2,495	3,103	0.71	2,495	3,890	0.86	2,495	5,081	0.65
2018	2,695	1,999	42.96	2,415	2,205	49.50	2,194	2,933	145.09	1,861	3,555	145.43
2019	2,751	1,964	95.57	2,436	2,163	164.45	2,028	2,575	229.48	1,550	2,871	217.84
2020	2,704	1,931	111.67	2,366	2,109	147.02	1,880	2,427	222.18	1,358	2,570	209.83
2021	2,626	1,939	226.09	2,277	2,108	253.54	1,754	2,346	282.50	1,237	2,430	175.35
2022	2,546	1,919	167.86	2,193	2,102	236.79	1,663	2,296	301.55	1,174	2,388	184.36
2023	2,494	1,896	133.52	2,134	2,064	207.50	1,613	2,272	280.50	1,146	2,354	240.01
2024	2,464	1,893	138.69	2,102	2,082	245.46	1,584	2,271	293.37	1,144	2,347	220.86
2025	2,445	1,902	135.80	2,076	2,094	242.88	1,565	2,302	300.30	1,149	2,362	217.89
2026	2,438	1,917	157.00	2,061	2,105	266.39	1,551	2,299	301.47	1,158	2,379	230.56
2027	2,443	1,923	197.90	2,060	2,100	276.16	1,553	2,254	294.41	1,160	2,349	277.04
2028	2,453	1,922	196.48	2,063	2,092	288.18	1,556	2,206	309.57	1,133	2,249	288.94
2029	2,464	1,908	147.59	2,065	2,055	227.84	1,556	2,141	263.31	1,093	2,167	270.30
2030	2,471	1,899	151.86	2,066	2,041	246.03	1,552	2,087	259.69	1,041	2,061	243.10
2031	2,474	1,902	194.53	2,062	2,027	257.54	1,548	2,054	257.86	1,004	2,006	223.79
2032	2,462	1,907	146.83	2,047	2,042	249.97	1,534	2,056	255.22	981	2,009	218.44
2033	2,457	1,907	137.82	2,036	2,020	193.92	1,527	2,051	226.14	965	1,994	208.06
2034	2,459	1,916	131.16	2,036	2,044	220.04	1,524	2,066	232.45	961	1,993	185.74
2035	2,463	1,919	162.10	2,034	2,055	253.58	1,520	2,065	261.30	957	1,961	206.01
2036	2,470	1,907	124.02	2,033	2,025	217.73	1,521	2,038	235.19	963	1,970	198.36
2037	2,472	1,914	126.91	2,033	2,036	225.38	1,521	2,041	239.66	958	1,950	204.62
2038	2,472	1,902	135.17	2,029	2,011	203.73	1,515	2,016	235.71	943	1,901	224.64
2039	2,475	1,881	133.84	2,032	1,979	196.59	1,514	1,965	218.83	926	1,848	221.20
2040	2,466	1,884	139.04	2,025	1,975	187.99	1,512	1,965	219.27	914	1,831	222.69
2041	2,449	1,887	139.20	2,013	1,985	205.17	1,503	1,966	225.81	898	1,815	187.73
2042	2,440	1,886	143.05	2,005	1,979	204.21	1,499	1,970	234.45	889	1,806	207.06
2043	2,436	1,889	144.32	2,003	1,992	207.52	1,495	1,980	231.48	887	1,810	215.76
2044	2,436	1,904	209.23	2,001	1,992	229.40	1,492	1,977	247.33	884	1,807	206.95
2045	2,435	1,907	206.66	2,002	2,000	235.51	1,494	1,979	248.54	885	1,815	220.90
2046	2,434	1,897	144.53	2,002	2,010	233.87	1,497	1,993	248.15	886	1,816	239.72
Prob TOT> ABC		0			0.30			1.0			1.0	

Table 4. Comparison of projected mean total catch (TOT) with ABC for state harvest control rule scenarios (Sc.) 1 to 10 under random recruitment for WAG. The standard errors (SE) of the mean TOT were estimated from 100 Monte Carlo trials. Probability of TOT exceeding ABC is also listed.

	Sc1			Sc2			Sc3			Sc4			Sc5			Sc6		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	1,089	781	160.81	1,089	947	199.81	1,089	1,137	294.39	1,089	1,178	268.47	1,089	1,611	382.09	1,089	781	160.66
2018	1,259	865	138.87	1,209	1,028	172.11	1,153	1,193	256.39	1,140	1,225	243.40	1,009	1,572	292.57	1,259	865	138.71
2019	1,384	928	120.86	1,293	1,092	151.13	1,194	1,197	182.70	1,172	1,288	216.86	947	1,552	239.77	1,384	928	120.76
2020	1,487	963	110.85	1,357	1,124	145.87	1,238	1,243	197.47	1,192	1,309	199.77	911	1,515	200.14	1,487	963	110.79
2021	1,571	990	109.15	1,410	1,135	134.32	1,269	1,270	182.66	1,209	1,312	179.24	893	1,507	211.45	1,571	990	109.09
2022	1,636	1,017	108.56	1,452	1,159	132.09	1,289	1,292	186.55	1,222	1,328	185.62	880	1,509	206.15	1,636	1,017	108.53
2023	1,683	1,043	111.82	1,481	1,188	146.76	1,299	1,313	202.45	1,229	1,352	203.32	870	1,522	221.41	1,683	1,043	111.81
2024	1,725	1,060	114.83	1,507	1,201	144.45	1,311	1,325	191.69	1,237	1,363	217.78	865	1,525	222.19	1,725	1,060	114.85
2025	1,759	1,078	103.31	1,530	1,217	118.42	1,324	1,346	187.69	1,248	1,372	197.30	868	1,537	200.81	1,759	1,078	103.30
2026	1,790	1,090	94.61	1,551	1,233	122.06	1,334	1,338	156.26	1,260	1,389	187.40	872	1,534	181.39	1,790	1,090	94.62
2027	1,816	1,095	94.30	1,569	1,231	105.07	1,348	1,346	141.32	1,269	1,384	181.56	875	1,532	194.63	1,816	1,095	94.31
2028	1,838	1,096	95.63	1,584	1,229	109.05	1,356	1,353	170.90	1,274	1,380	171.69	876	1,523	200.99	1,838	1,096	95.64
2029	1,849	1,099	103.49	1,589	1,232	128.51	1,352	1,342	188.26	1,272	1,387	187.32	871	1,518	214.17	1,849	1,099	103.49
2030	1,856	1,095	103.17	1,592	1,224	124.18	1,352	1,332	180.18	1,268	1,367	198.80	868	1,497	197.42	1,856	1,095	103.18
2031	1,857	1,093	102.54	1,591	1,220	122.93	1,350	1,333	194.56	1,265	1,358	192.80	866	1,496	210.45	1,857	1,093	102.54
2032	1,854	1,100	103.94	1,586	1,227	125.34	1,342	1,332	178.78	1,260	1,370	189.99	864	1,514	212.35	1,854	1,100	103.94
2033	1,850	1,111	96.24	1,583	1,244	118.61	1,340	1,352	156.87	1,256	1,376	183.86	866	1,532	187.62	1,850	1,111	96.24
2034	1,854	1,112	90.53	1,585	1,245	112.32	1,343	1,356	161.11	1,264	1,385	174.83	868	1,529	181.41	1,854	1,112	90.53
2035	1,863	1,111	86.42	1,591	1,243	110.50	1,348	1,360	184.19	1,270	1,393	156.25	873	1,525	177.76	1,863	1,111	86.40
2036	1,870	1,112	89.61	1,598	1,241	105.79	1,351	1,355	158.91	1,273	1,381	175.22	877	1,522	182.90	1,870	1,112	89.61
2037	1,874	1,114	100.22	1,601	1,242	118.85	1,350	1,353	179.95	1,274	1,398	189.08	876	1,531	212.74	1,874	1,114	100.22
2038	1,876	1,113	102.10	1,602	1,242	123.44	1,351	1,342	166.14	1,269	1,393	200.65	874	1,526	209.91	1,876	1,113	102.10
2039	1,878	1,106	97.57	1,604	1,233	118.26	1,355	1,334	167.16	1,268	1,371	187.20	873	1,509	203.82	1,878	1,106	97.57
2040	1,878	1,100	106.02	1,603	1,227	132.69	1,355	1,310	170.23	1,266	1,364	195.13	870	1,495	211.58	1,878	1,100	106.00
2041	1,871	1,100	112.67	1,596	1,225	134.62	1,356	1,330	196.72	1,262	1,365	218.24	865	1,498	213.94	1,871	1,100	112.65
2042	1,863	1,100	107.95	1,589	1,226	127.53	1,349	1,330	183.50	1,256	1,353	191.43	865	1,503	207.47	1,863	1,100	107.93
2043	1,858	1,099	113.88	1,584	1,223	135.90	1,344	1,325	182.84	1,254	1,363	201.98	859	1,500	214.85	1,858	1,099	113.86
2044	1,855	1,100	105.79	1,583	1,228	126.91	1,344	1,349	196.52	1,254	1,349	183.28	860	1,506	197.15	1,855	1,100	105.79
2045	1,852	1,107	101.33	1,580	1,233	120.72	1,338	1,336	168.67	1,259	1,365	172.77	864	1,519	189.66	1,852	1,107	101.33
2046	1,854	1,115	96.69	1,583	1,247	118.43	1,341	1,349	150.82	1,264	1,387	173.12	869	1,534	174.71	1,854	1,115	96.69
Prob TOT> ABC		0			0			0.57			1.0			1.0			0	

Table 4 continued.

	Sc7			Sc8			Sc9			Sc10		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	1,089	947	199.53	1,089	1,107	248.27	1,089	1,363	331.66	1,089	1,840	450.81
2018	1,209	1,028	171.78	1,162	1,174	206.53	1,084	1,378	272.69	938	1,735	313.08
2019	1,293	1,089	148.14	1,207	1,231	193.30	1,075	1,405	239.47	831	1,645	219.29
2020	1,358	1,121	147.47	1,240	1,249	176.68	1,071	1,403	217.56	774	1,581	197.15
2021	1,411	1,135	133.96	1,269	1,258	168.14	1,073	1,393	204.44	750	1,557	215.10
2022	1,453	1,160	131.61	1,292	1,276	168.48	1,078	1,403	209.29	736	1,552	204.19
2023	1,482	1,185	134.01	1,307	1,302	176.69	1,079	1,426	225.07	726	1,545	205.93
2024	1,508	1,199	137.41	1,320	1,316	189.68	1,081	1,439	234.85	728	1,556	206.15
2025	1,533	1,218	119.53	1,335	1,332	157.54	1,089	1,447	208.97	733	1,583	201.85
2026	1,553	1,233	127.10	1,347	1,343	152.54	1,098	1,459	201.54	734	1,571	183.08
2027	1,570	1,232	105.64	1,359	1,346	150.09	1,103	1,452	192.79	739	1,579	184.28
2028	1,585	1,230	109.51	1,366	1,331	135.78	1,106	1,442	193.61	737	1,566	196.38
2029	1,589	1,229	123.55	1,367	1,329	157.60	1,103	1,443	218.39	733	1,547	206.45
2030	1,593	1,224	121.65	1,369	1,327	174.39	1,101	1,428	216.73	731	1,547	193.04
2031	1,592	1,221	122.96	1,366	1,318	164.47	1,097	1,415	214.81	726	1,536	215.00
2032	1,587	1,228	125.17	1,361	1,327	163.91	1,095	1,432	214.52	725	1,541	210.38
2033	1,583	1,242	112.31	1,357	1,344	152.60	1,095	1,451	194.50	731	1,569	179.15
2034	1,586	1,243	105.83	1,361	1,348	144.21	1,098	1,456	189.13	734	1,566	172.26
2035	1,593	1,241	102.67	1,367	1,344	132.51	1,103	1,456	179.37	739	1,567	182.19
2036	1,600	1,245	117.99	1,372	1,344	145.31	1,105	1,446	193.27	742	1,577	179.66
2037	1,602	1,242	118.56	1,372	1,345	166.13	1,105	1,456	220.99	737	1,560	200.90
2038	1,603	1,245	131.87	1,373	1,345	174.09	1,100	1,458	225.09	738	1,559	213.06
2039	1,604	1,236	128.81	1,373	1,335	168.90	1,098	1,433	208.91	739	1,556	208.44
2040	1,602	1,224	127.27	1,371	1,323	177.17	1,097	1,421	221.08	733	1,539	226.21
2041	1,595	1,225	134.06	1,366	1,330	194.88	1,094	1,426	235.98	726	1,538	208.90
2042	1,589	1,226	126.92	1,358	1,322	171.03	1,091	1,417	205.76	725	1,548	215.42
2043	1,584	1,223	135.36	1,354	1,318	172.84	1,088	1,424	222.76	719	1,527	213.02
2044	1,583	1,226	123.91	1,355	1,319	152.57	1,089	1,421	197.83	725	1,554	208.08
2045	1,581	1,233	120.46	1,355	1,332	149.27	1,093	1,433	191.41	725	1,555	189.97
2046	1,583	1,247	124.65	1,358	1,346	146.73	1,098	1,457	188.10	731	1,573	176.34
Prob TOT> ABC		0			0.13			1.0			1.0	

Table 5. Comparison of projected mean total catch (TOT) with ABC for state harvest control rule scenarios (Sc.) 1 to 10 under stock-recruitment predicted recruitment for WAG. Ricker stock-recruitment relationship was used to predict the number of recruits (millions). The standard errors (SE) of the mean TOT were estimated from 100 Monte Carlo trials. Probability of TOT exceeding ABC is also listed.

	Sc1			Sc2			Sc3			Sc4			Sc5			Sc6		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	1,152	823	0.09	1,152	1,004	0.12	1,152	1,151	0.25	1,152	1,155	0.25	1,152	1,579	0.33	1,152	823	0.09
2018	1,295	885	22.89	1,245	1,058	27.70	1,204	1,216	37.14	1,203	1,218	39.85	1,075	1,557	71.49	1,295	885	22.89
2019	1,406	936	56.10	1,310	1,100	67.40	1,227	1,249	89.90	1,225	1,286	117.47	1,004	1,560	148.61	1,406	936	56.10
2020	1,501	977	70.43	1,369	1,136	91.90	1,252	1,283	123.73	1,239	1,322	155.36	957	1,556	169.54	1,501	977	70.43
2021	1,581	1,009	81.10	1,419	1,160	97.10	1,273	1,300	147.92	1,250	1,350	165.85	927	1,556	199.29	1,581	1,009	81.10
2022	1,650	1,027	86.87	1,463	1,173	103.37	1,293	1,302	142.93	1,258	1,348	170.58	906	1,531	189.01	1,650	1,027	86.87
2023	1,702	1,047	95.54	1,497	1,189	114.56	1,309	1,328	176.38	1,264	1,358	174.57	895	1,531	195.25	1,702	1,047	95.52
2024	1,740	1,067	95.82	1,521	1,208	111.77	1,316	1,337	157.59	1,267	1,368	179.44	886	1,538	185.84	1,740	1,067	95.82
2025	1,772	1,078	85.09	1,541	1,217	97.62	1,326	1,346	152.19	1,274	1,365	155.62	884	1,531	157.63	1,772	1,078	85.09
2026	1,799	1,090	77.46	1,558	1,228	88.16	1,332	1,357	137.64	1,282	1,371	137.16	885	1,529	137.99	1,799	1,090	77.46
2027	1,820	1,097	75.28	1,571	1,235	86.18	1,337	1,357	144.20	1,288	1,388	142.36	884	1,528	154.62	1,820	1,097	75.28
2028	1,838	1,103	74.67	1,582	1,242	88.36	1,342	1,368	152.73	1,290	1,405	141.25	884	1,533	162.21	1,838	1,103	74.68
2029	1,850	1,109	75.40	1,592	1,250	89.74	1,346	1,395	153.07	1,289	1,407	152.59	885	1,540	163.36	1,850	1,109	75.40
2030	1,862	1,108	78.72	1,602	1,252	91.99	1,347	1,379	143.36	1,294	1,409	157.35	883	1,536	166.65	1,862	1,108	78.72
2031	1,869	1,107	78.61	1,611	1,254	91.59	1,354	1,390	162.23	1,299	1,420	154.02	884	1,532	158.65	1,869	1,107	78.61
2032	1,872	1,106	77.61	1,615	1,256	90.18	1,357	1,381	141.89	1,300	1,419	159.42	884	1,530	160.64	1,872	1,106	77.61
2033	1,871	1,105	78.30	1,618	1,256	90.86	1,361	1,403	162.71	1,301	1,423	156.32	884	1,534	161.86	1,871	1,105	78.30
2034	1,869	1,097	81.18	1,620	1,250	94.10	1,360	1,390	151.10	1,302	1,405	157.05	882	1,518	158.29	1,869	1,097	81.18
2035	1,865	1,088	85.24	1,621	1,242	99.54	1,361	1,369	152.97	1,306	1,401	165.69	881	1,505	163.84	1,865	1,088	85.24
2036	1,854	1,088	86.30	1,615	1,245	102.17	1,360	1,374	149.32	1,303	1,406	166.98	880	1,515	169.13	1,854	1,088	86.30
2037	1,843	1,088	87.66	1,608	1,246	105.17	1,357	1,376	154.89	1,299	1,415	174.22	876	1,523	179.14	1,843	1,088	87.66
2038	1,836	1,087	84.79	1,606	1,247	100.99	1,359	1,383	149.60	1,297	1,418	173.91	876	1,529	174.70	1,836	1,087	84.79
2039	1,832	1,086	80.31	1,606	1,249	95.34	1,362	1,379	132.33	1,299	1,419	163.74	879	1,531	164.03	1,832	1,086	80.31
2040	1,829	1,079	69.64	1,607	1,241	82.75	1,368	1,373	138.50	1,302	1,410	138.94	879	1,515	149.55	1,829	1,079	69.64
2041	1,828	1,073	65.46	1,609	1,234	77.83	1,373	1,382	141.93	1,305	1,398	128.35	880	1,503	139.91	1,828	1,073	65.46
2042	1,821	1,077	79.95	1,604	1,240	94.47	1,366	1,380	145.79	1,303	1,417	166.98	878	1,519	173.31	1,821	1,077	79.95
2043	1,815	1,078	87.01	1,598	1,241	102.66	1,362	1,382	151.75	1,296	1,408	183.12	874	1,520	178.71	1,815	1,078	87.01
2044	1,814	1,077	82.37	1,598	1,239	96.71	1,362	1,385	161.58	1,298	1,404	165.98	876	1,519	170.29	1,814	1,077	82.37
2045	1,813	1,084	82.50	1,597	1,247	98.17	1,361	1,387	144.69	1,301	1,418	166.71	879	1,534	173.19	1,813	1,084	82.50
2046	1,814	1,085	90.60	1,597	1,248	107.55	1,361	1,383	143.51	1,301	1,433	189.68	876	1,530	178.74	1,814	1,085	90.60
Prob TOT> ABC		0			0			0.97			1.0			1.0			0	

Table 5 continued.

	Sc7			Sc8			Sc9			Sc10		
	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE	ABC	TOT	SE
2017	1,152	1,004	0.12	1,152	1,174	0.25	1,152	1,371	0.18	1,152	1,821	0.37
2018	1,245	1,058	27.70	1,197	1,213	37.07	1,140	1,372	42.60	994	1,743	70.89
2019	1,310	1,103	79.63	1,222	1,243	105.43	1,120	1,408	136.52	873	1,691	121.41
2020	1,368	1,141	113.99	1,249	1,270	130.55	1,109	1,425	174.84	798	1,642	135.70
2021	1,417	1,159	95.09	1,274	1,289	137.58	1,103	1,439	185.75	757	1,600	167.38
2022	1,462	1,173	101.92	1,298	1,296	149.97	1,101	1,428	186.39	737	1,577	179.59
2023	1,496	1,188	113.34	1,315	1,301	147.05	1,102	1,432	193.65	729	1,570	196.42
2024	1,520	1,208	110.88	1,328	1,322	151.13	1,102	1,442	189.71	725	1,570	172.87
2025	1,540	1,217	97.01	1,342	1,323	111.89	1,107	1,438	159.75	725	1,577	161.03
2026	1,557	1,227	87.79	1,352	1,333	103.87	1,113	1,442	143.05	726	1,577	144.28
2027	1,571	1,235	85.94	1,361	1,340	99.52	1,118	1,456	151.37	720	1,552	133.41
2028	1,582	1,242	88.25	1,369	1,346	100.58	1,118	1,467	161.75	721	1,548	151.93
2029	1,592	1,250	89.80	1,376	1,360	113.05	1,118	1,475	166.57	721	1,555	150.26
2030	1,602	1,252	92.10	1,384	1,360	112.13	1,121	1,477	169.62	716	1,542	153.72
2031	1,611	1,254	91.68	1,392	1,365	115.53	1,124	1,479	166.56	713	1,537	151.65
2032	1,616	1,256	90.31	1,397	1,372	121.04	1,127	1,482	172.06	709	1,527	140.36
2033	1,618	1,256	90.94	1,399	1,373	118.46	1,128	1,486	170.10	709	1,535	153.53
2034	1,620	1,250	94.08	1,402	1,368	125.54	1,127	1,471	167.31	705	1,527	156.63
2035	1,621	1,242	99.52	1,404	1,363	139.96	1,130	1,458	177.38	698	1,511	166.05
2036	1,615	1,245	102.10	1,398	1,367	143.98	1,129	1,471	180.11	695	1,509	163.19
2037	1,608	1,246	105.05	1,392	1,367	137.67	1,124	1,482	191.92	694	1,506	168.47
2038	1,606	1,247	100.86	1,392	1,366	128.94	1,122	1,483	188.60	699	1,518	160.17
2039	1,606	1,249	95.29	1,395	1,375	128.19	1,126	1,486	175.23	702	1,525	158.78
2040	1,607	1,241	82.73	1,396	1,358	98.72	1,128	1,472	152.40	701	1,513	150.78
2041	1,609	1,234	77.84	1,400	1,353	97.14	1,132	1,459	140.72	700	1,509	147.76
2042	1,604	1,240	94.48	1,398	1,365	127.44	1,130	1,483	184.32	695	1,497	151.92
2043	1,598	1,241	102.68	1,393	1,371	151.36	1,122	1,480	199.26	695	1,504	164.94
2044	1,598	1,239	96.73	1,391	1,363	127.30	1,124	1,469	178.48	697	1,515	170.48
2045	1,597	1,247	98.18	1,391	1,374	134.98	1,128	1,490	177.65	697	1,519	155.41
2046	1,597	1,248	107.55	1,391	1,381	164.50	1,125	1,497	204.61	695	1,512	159.42
Prob TOT> ABC		0			0.17			1.0			1.0	

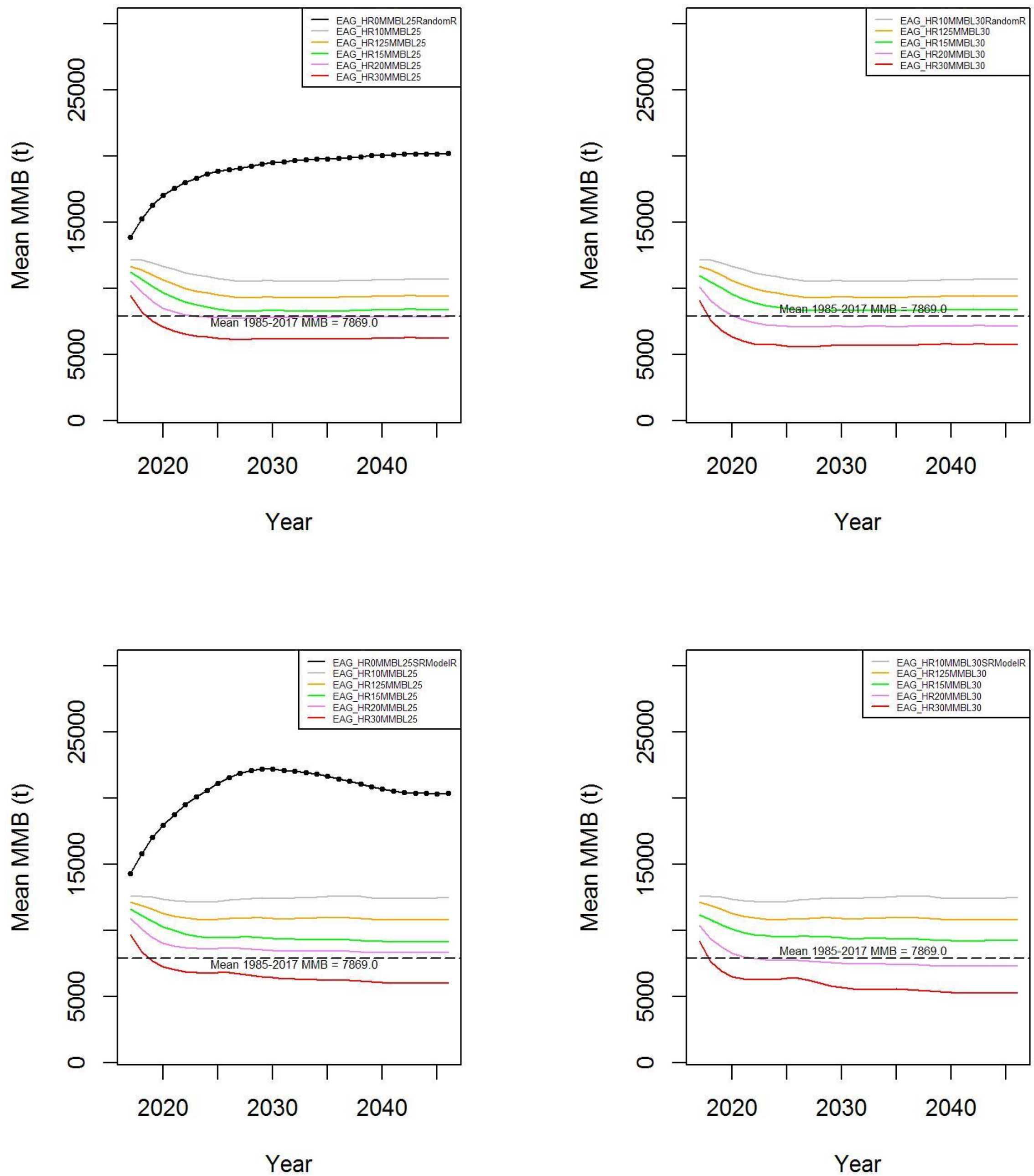

Figure 3. MMB projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

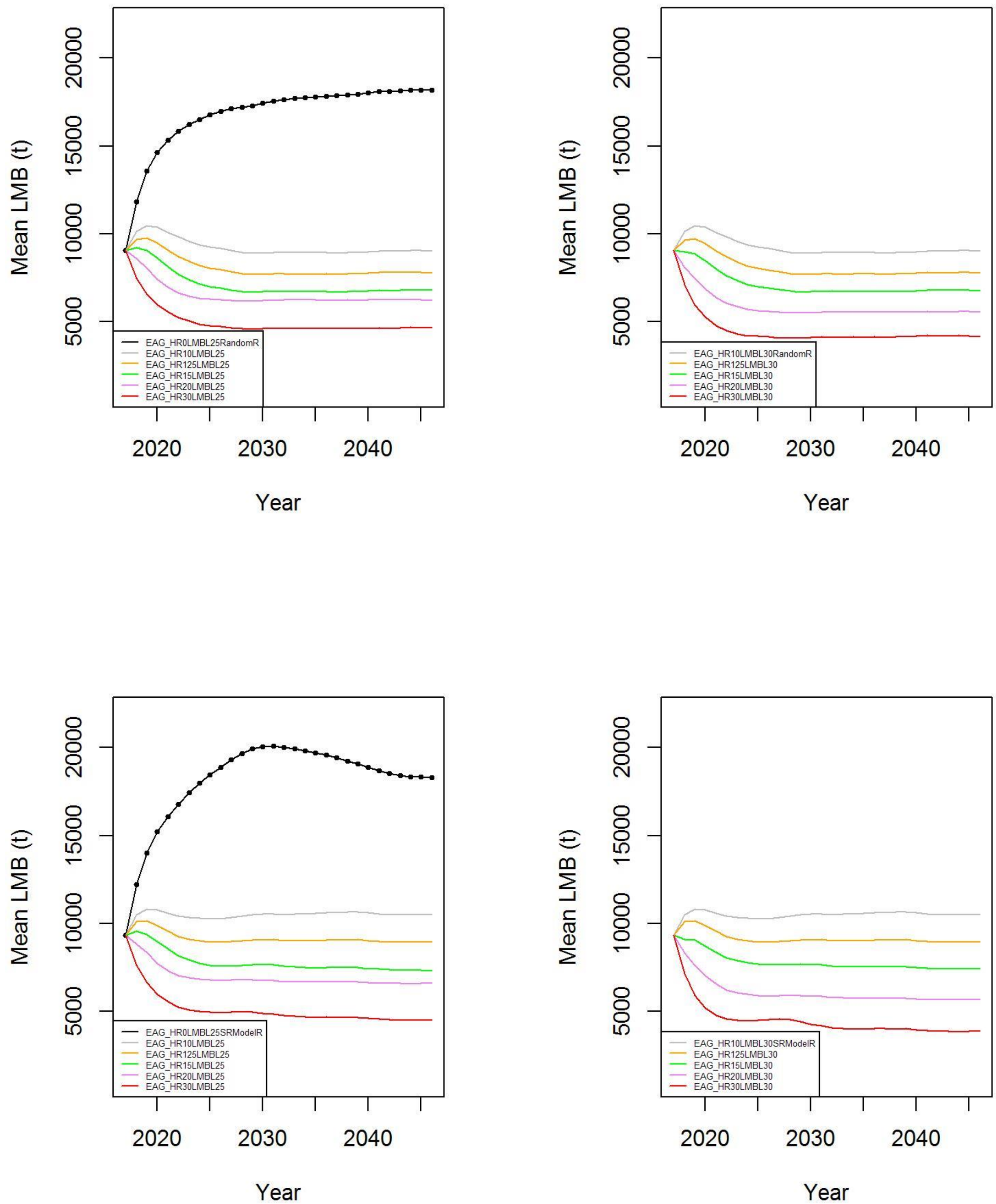

Figure 4. LMB projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

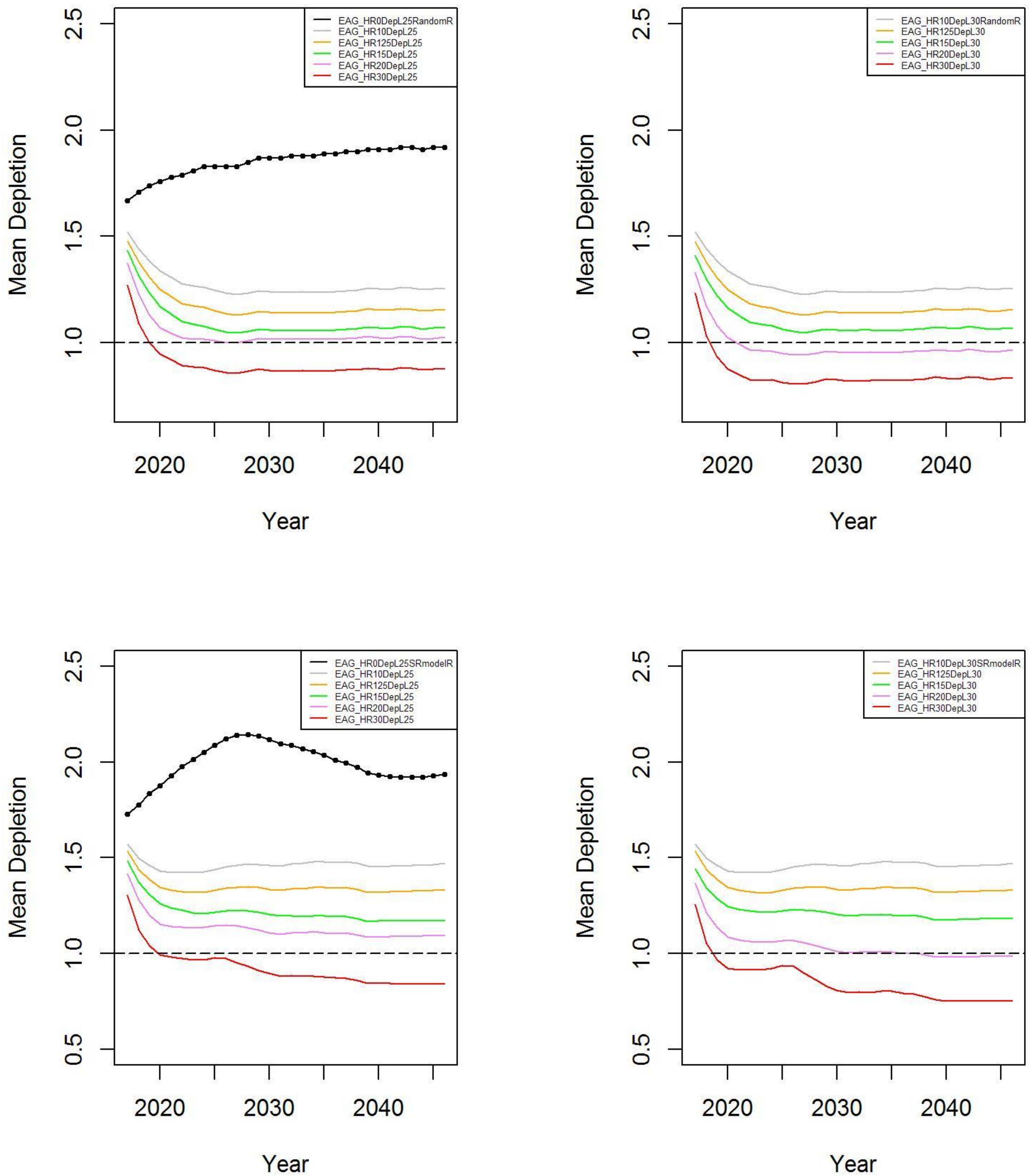

Figure 5. Stock depletion projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

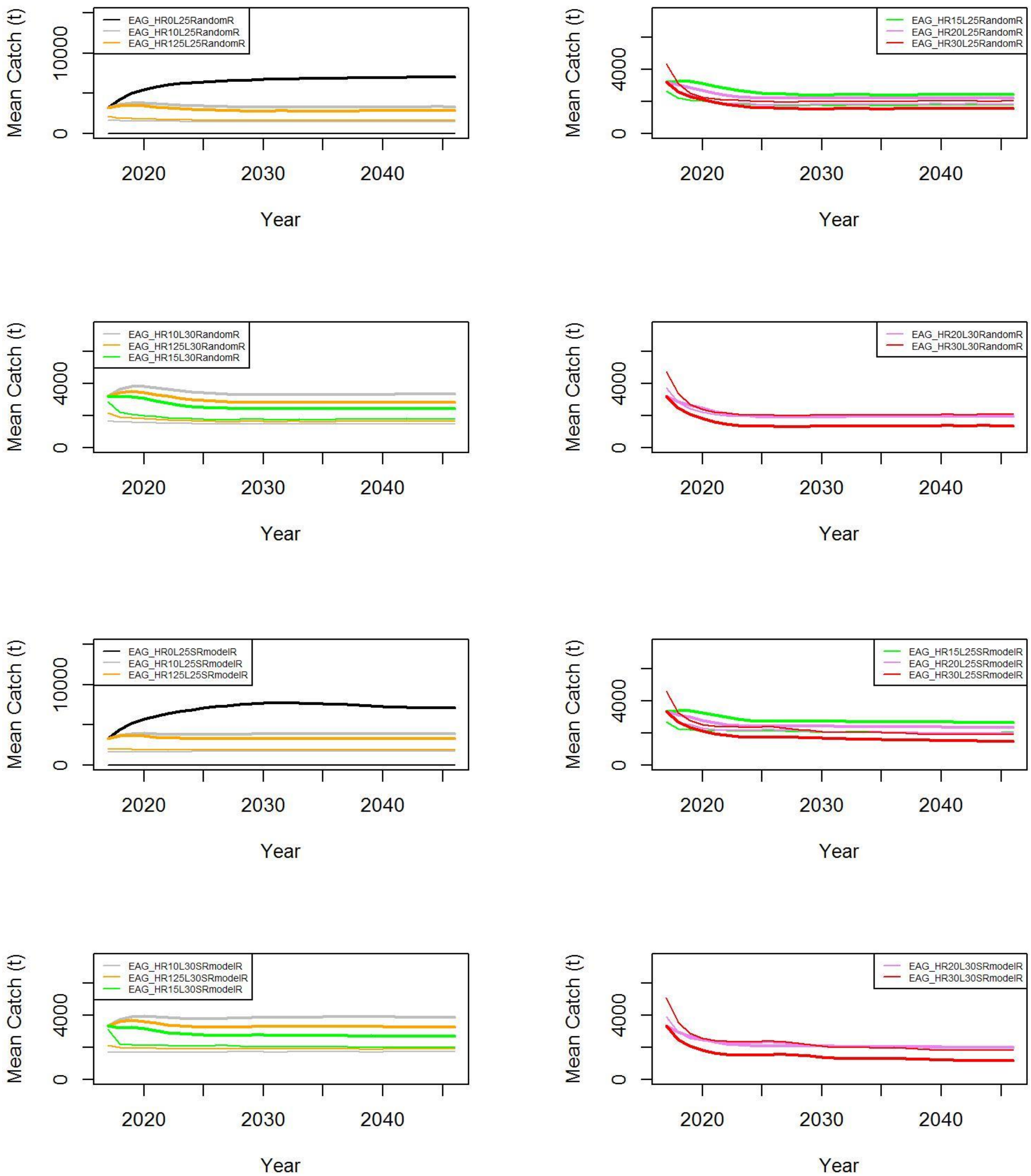

Figure 6. Total catch vs. OFL projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

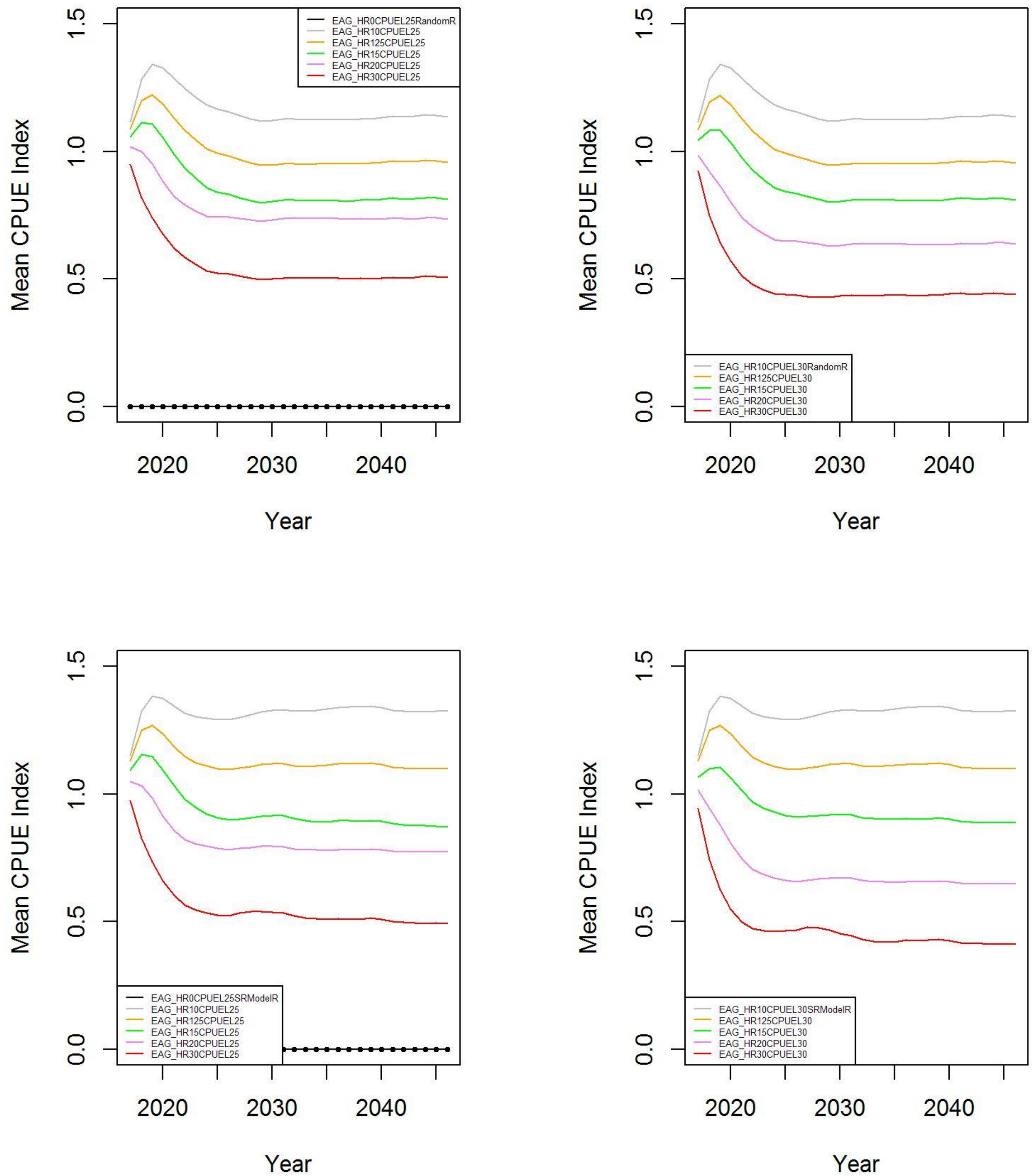

Figure 7. CPUE index projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

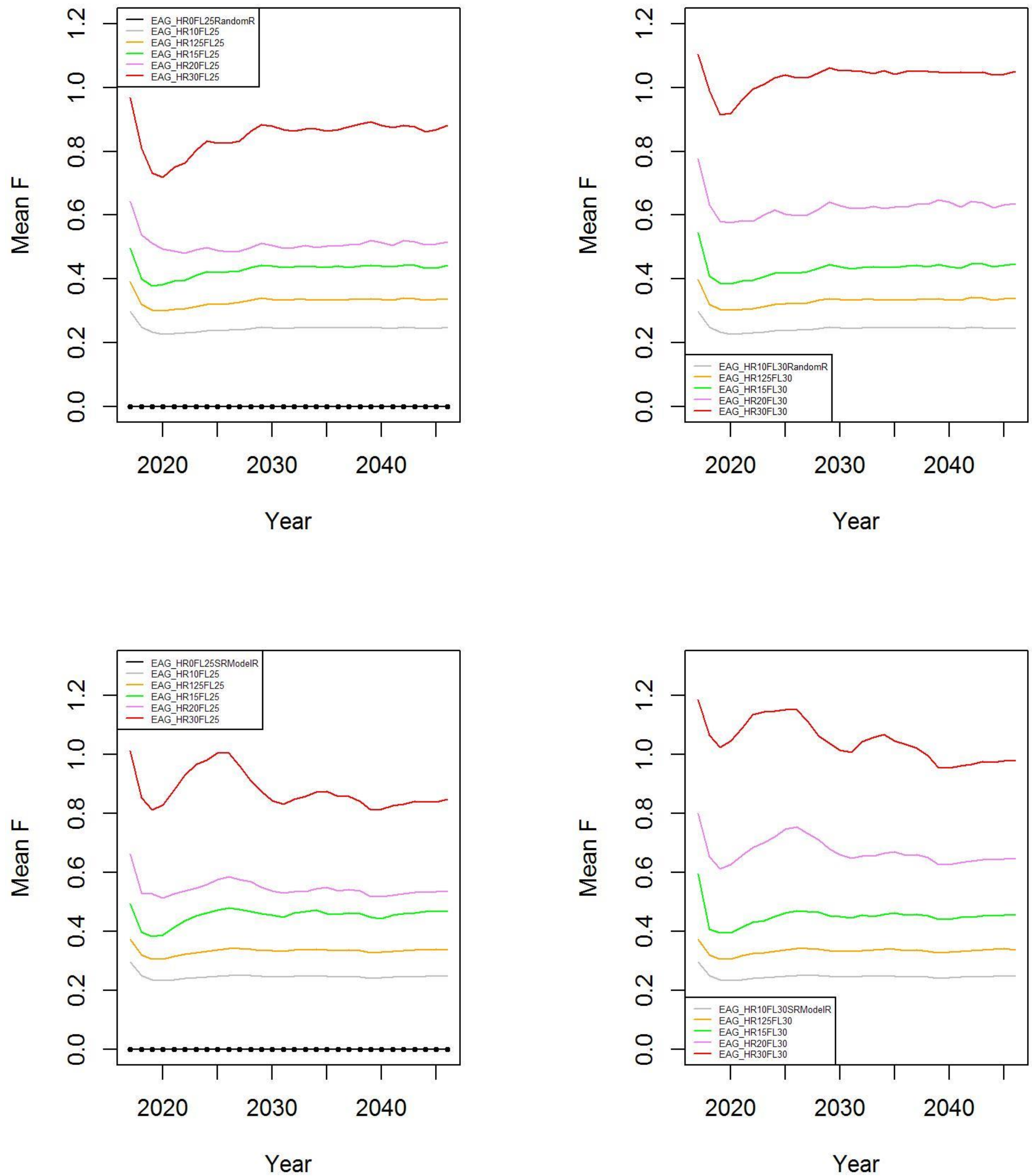

Figure 8. Total pot fishery mortality F projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for EAG.

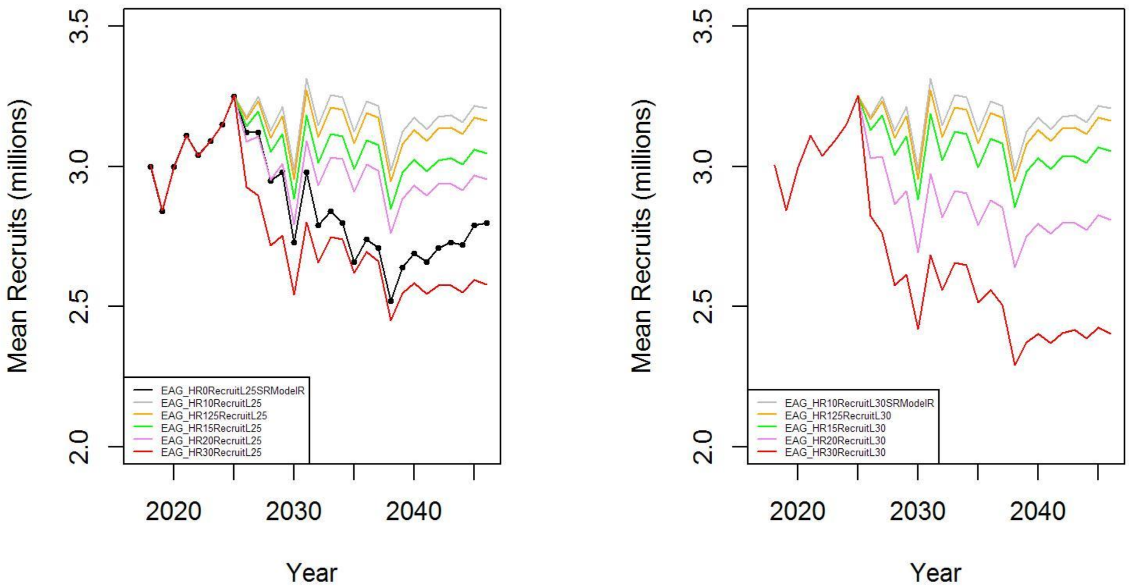

Figure 9. Recruit projections for 11 state harvest control rule scenarios under Ricker stock-recruit model for EAG.

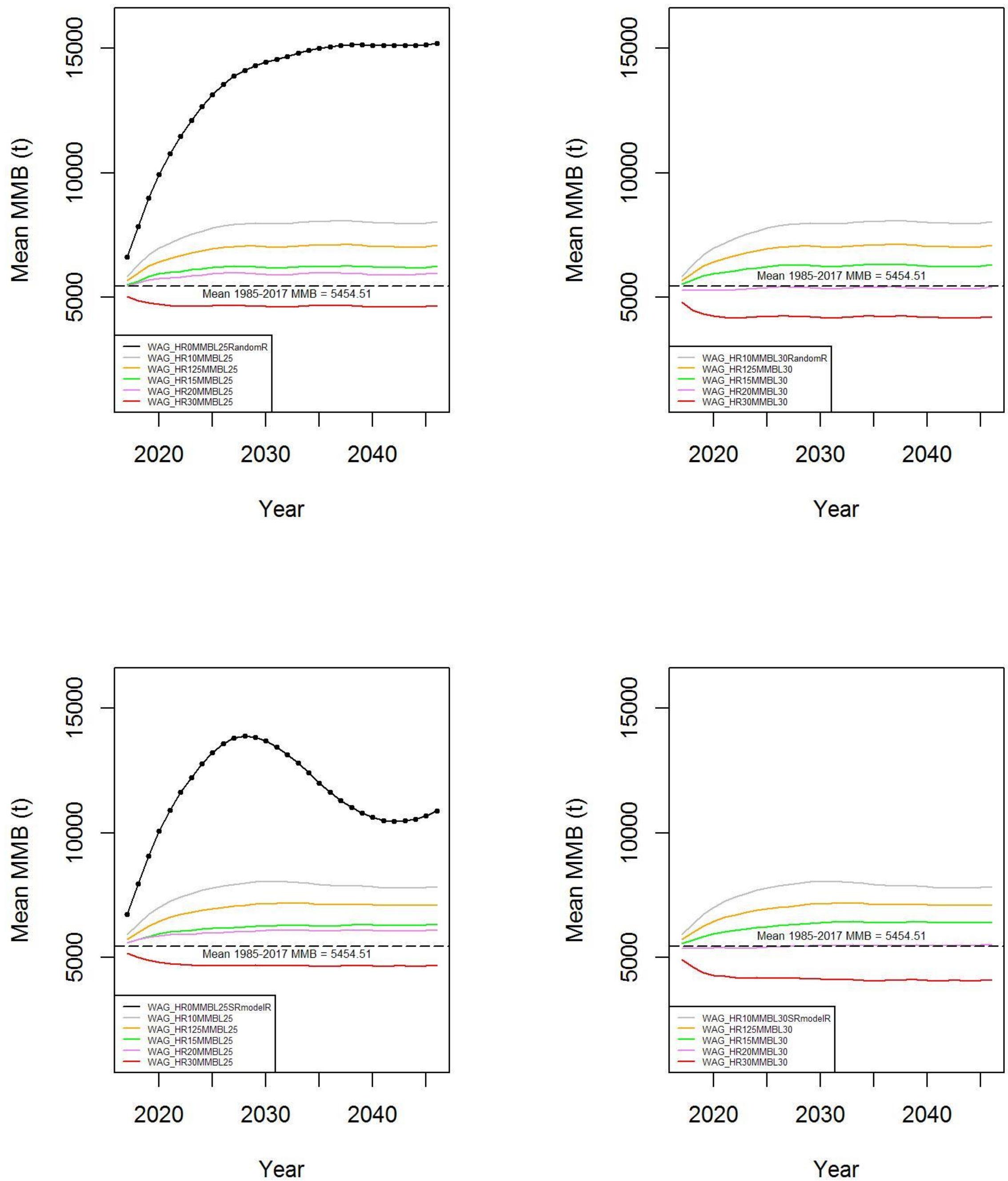

Figure 10. MMB projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

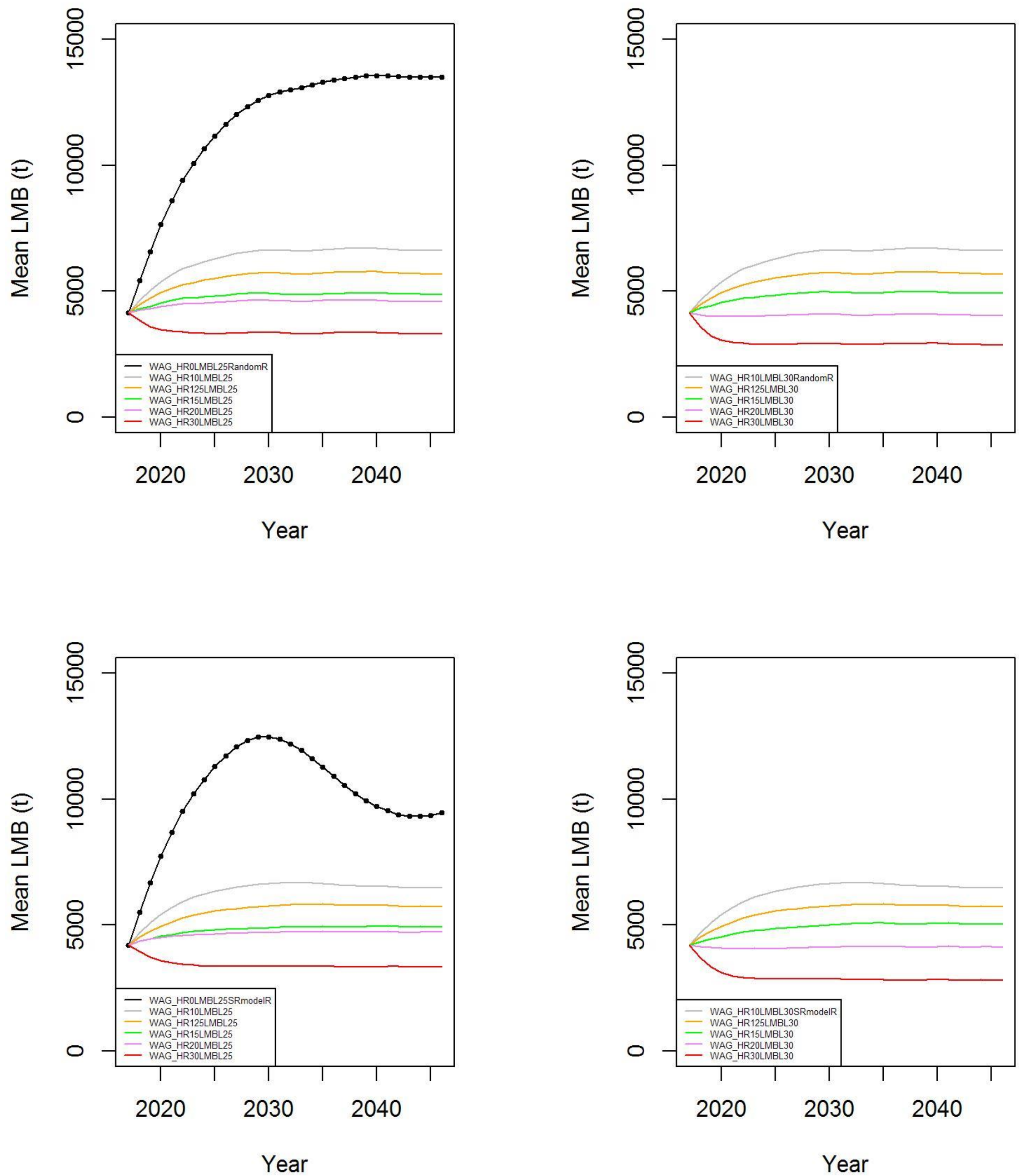

Figure 11. LMB projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

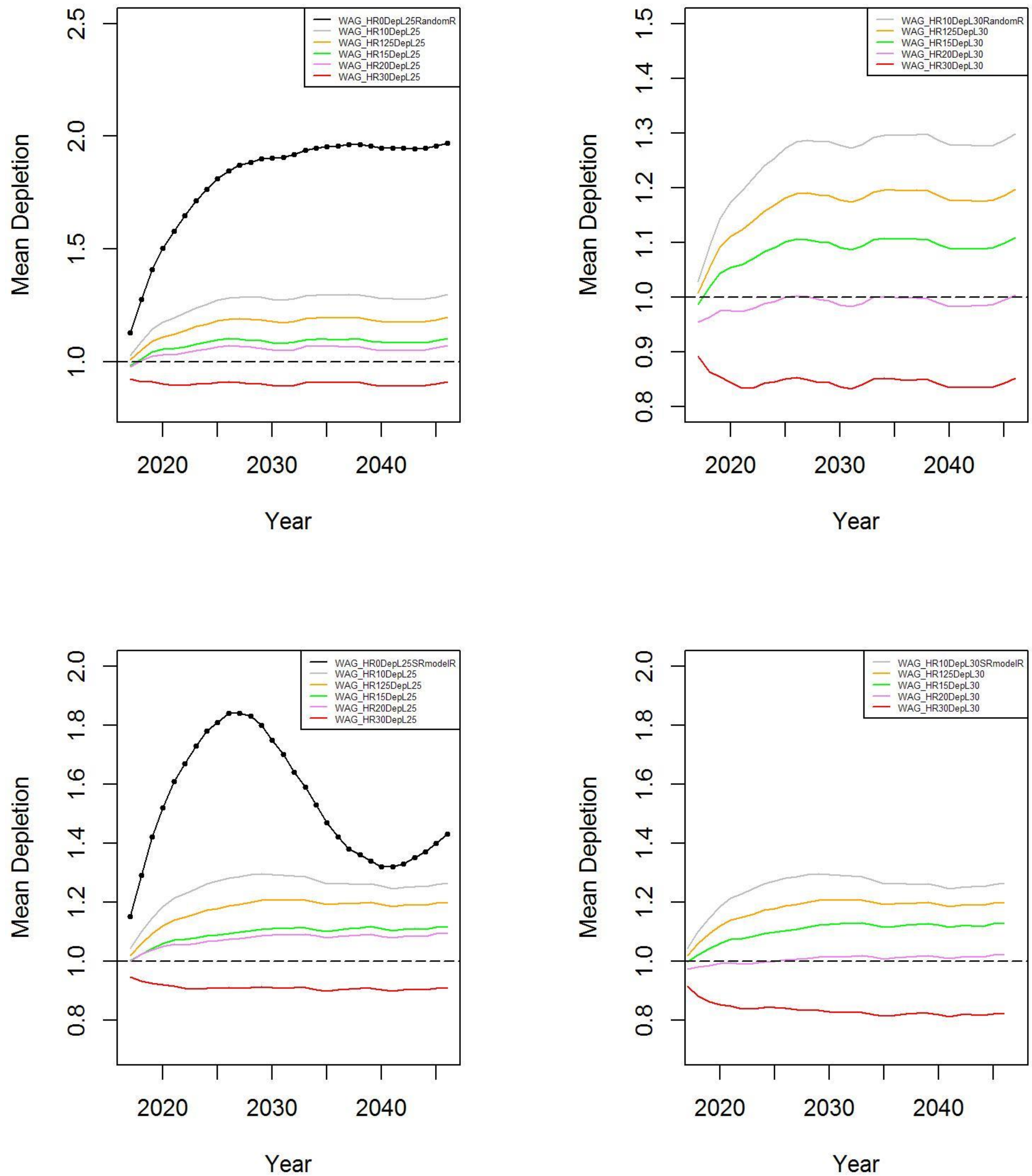

Figure 12. Stock depletion projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

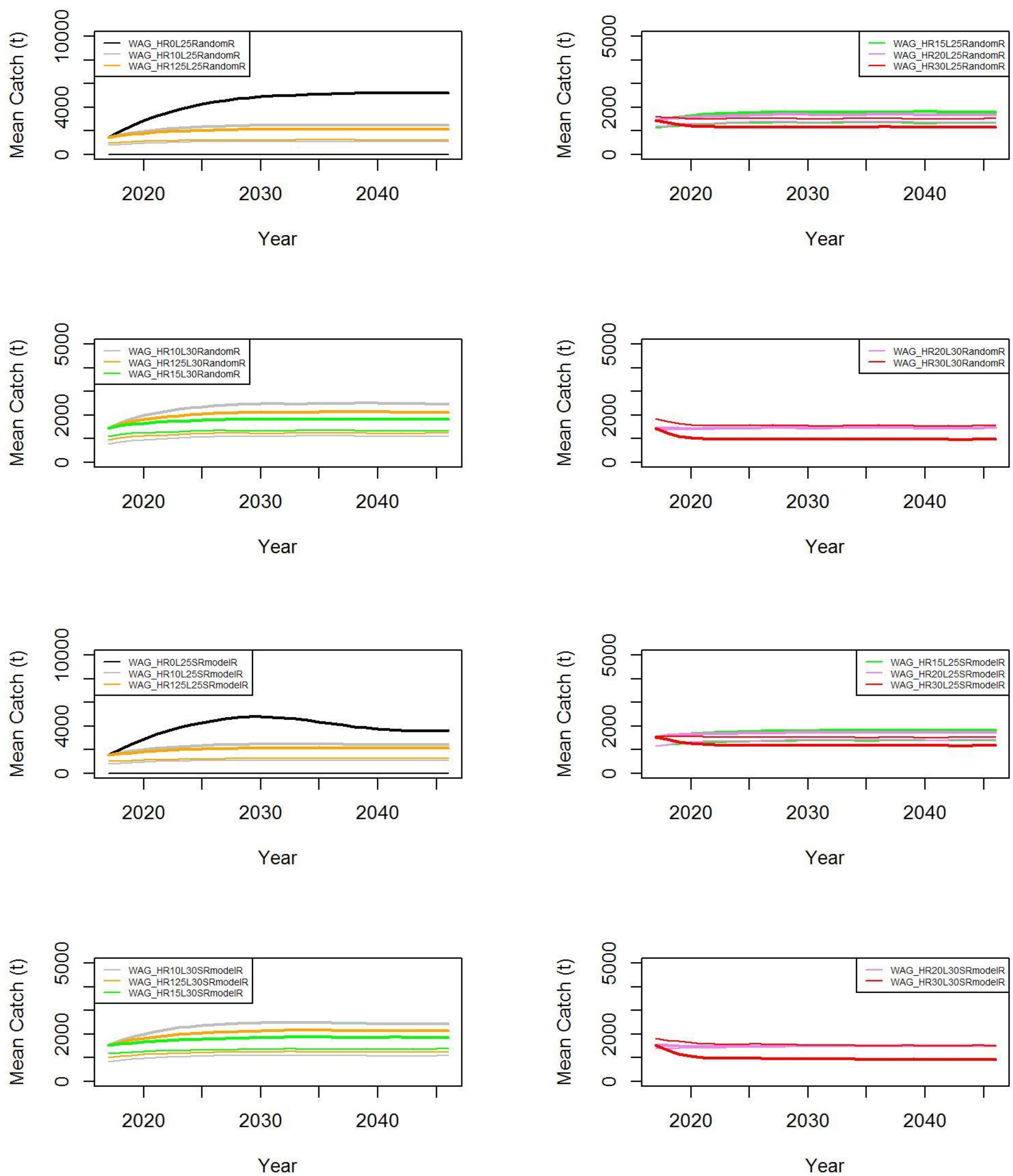

Figure 13. Total catch vs. OFL projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

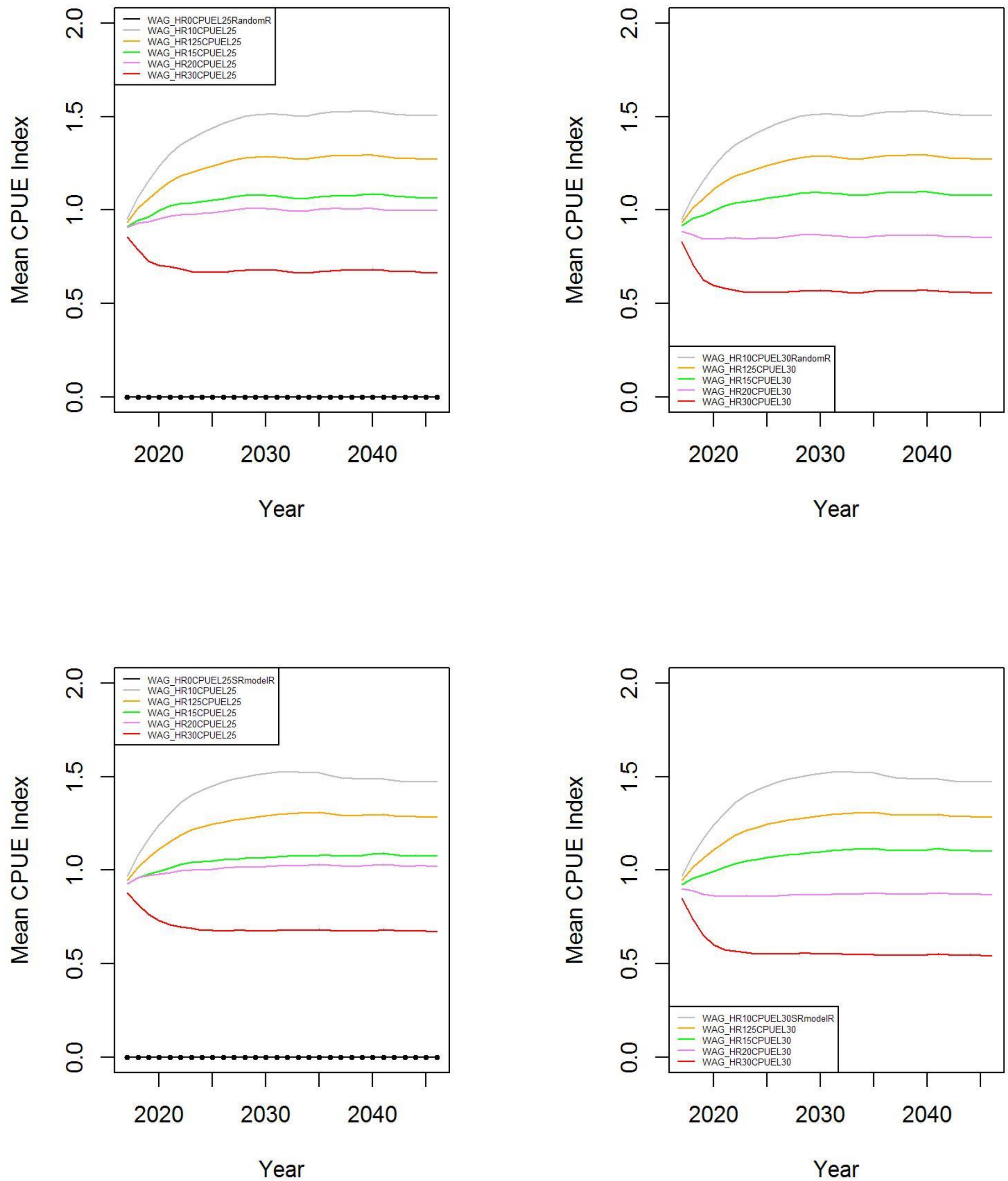

Figure 14. CPUE index projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

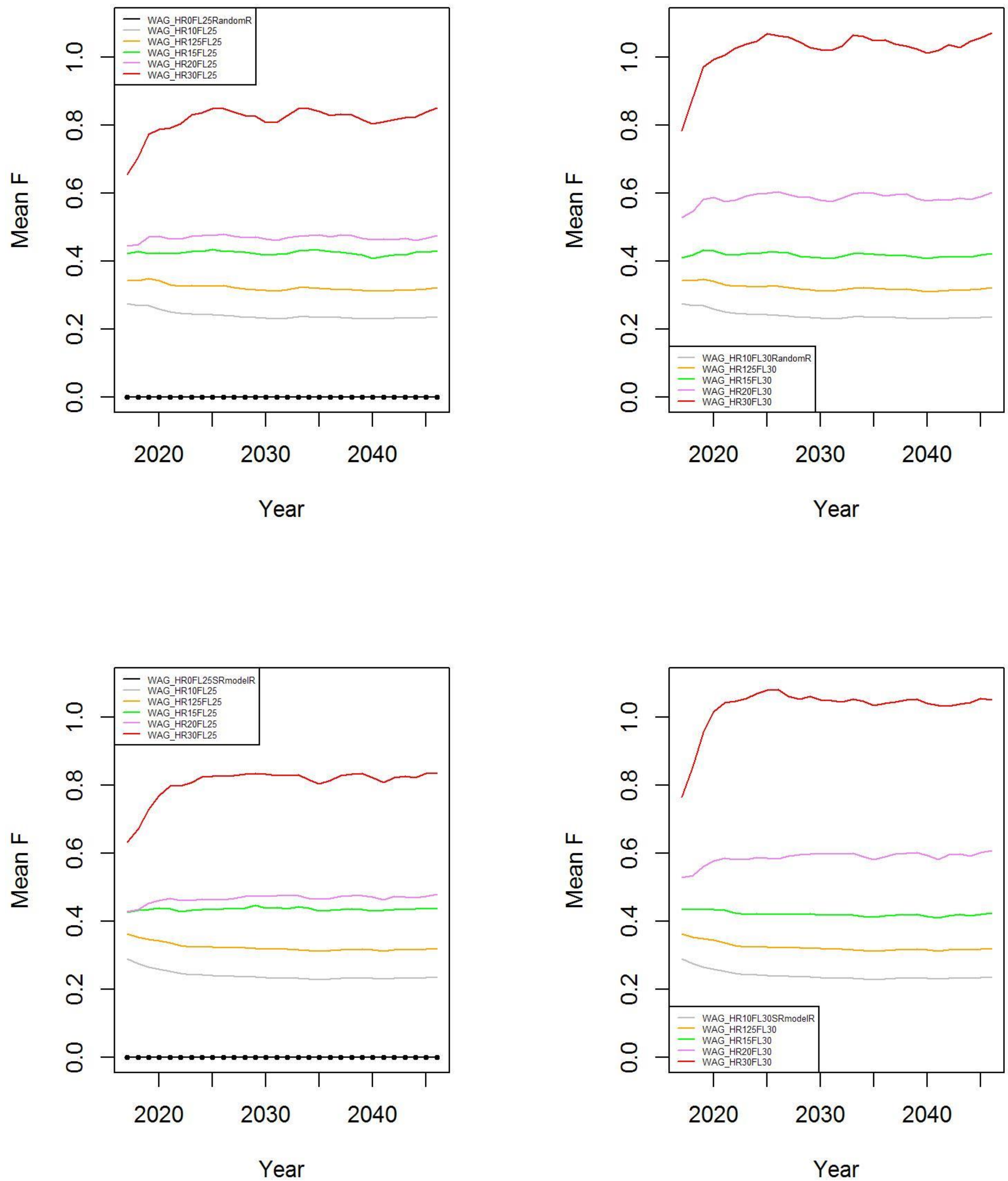

Figure 15. Total pot fishery mortality F projections for 11 state harvest control rule scenarios under random (top) and Ricker stock-recruit model (bottom) generated recruits for WAG.

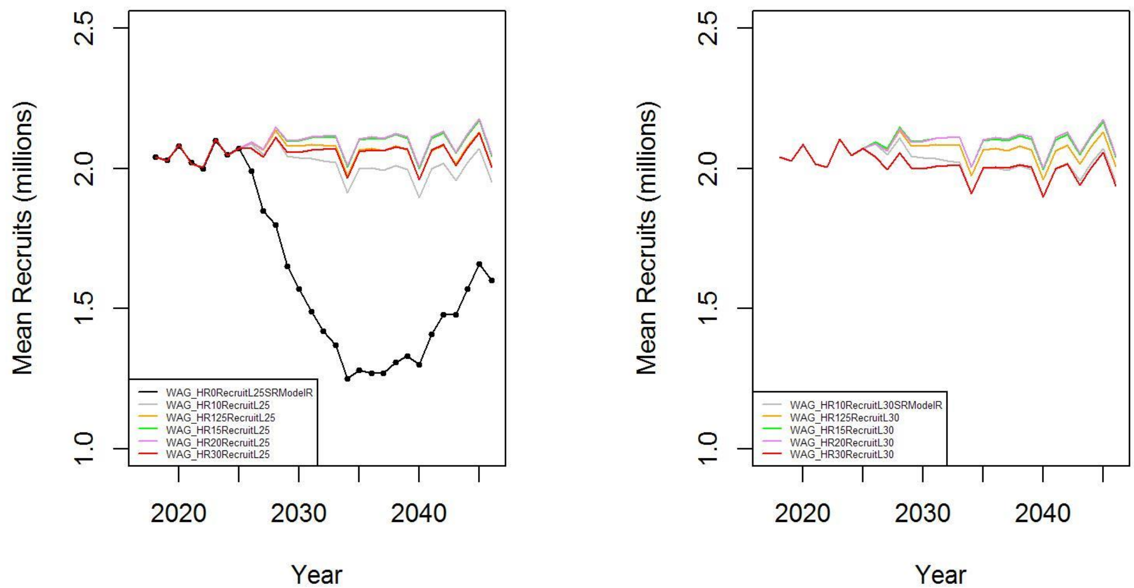

Figure 16. Recruit projections for 11 state harvest control rule scenarios under Ricker stock-recruit model for WAG.