



Fisheries and Oceans
Canada

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Ecosystems and
Oceans Science

Sciences des écosystèmes
et des océans

**Canadian Science Advisory Secretariat
Science Response 2019/nnn**

Pacific Region

**EVALUATING THE ROBUSTNESS OF CANDIDATE MANAGEMENT
PROCEDURES IN THE BC SABLEFISH (*ANOPLOPOMA FIBRIA*)
FISHERY FOR 2019-2020.**

Tables

Table 1. Operating model posterior distribution mean (standard deviation) biological parameter, reference point estimates, and stock status indicators for fits to the 2016 data and 2018 data. The columns **2016 Fit** and **2018 Fit** show the mean and standard deviation of the full posterior for the respective fits, while the remaining columns show posterior mean values from the five posterior strata defining the productivity/biomass scenarios indicated by the column label (see Figure 1). Stock status is shown relative to unfished (B_t/B_0), theoretical most productive spawning biomass (B_t/B_{MSY}), and the limit reference point ($B_t/(.4B_{MSY})$) for $t \in \{2016, 2018\}$. The bottom two rows show the posterior probability of spawning biomass being above the limit reference point in both 2016 and 2018.

	2016 Fit	2018 Fit	hiB	hih	loB	loh	mhmB
B_0	57 (1.3)	54.1 (3.3)	55.6	53.9	52.2	54.2	54
M_m	0.0411 (0.00027)	0.0421 (0.0026)	0.0425	0.0419	0.0412	0.0422	0.042
M_f	0.0788 (0.0014)	0.0877 (0.0025)	0.087	0.0874	0.0879	0.0879	0.0876
h	0.556 (0.064)	0.617 (0.062)	0.62	0.689	0.617	0.545	0.618
B_{2016}	10.9 (1.2)	12.5 (1.4)	14	12.4	11	12.5	12.5
B_{2018}		16.3 (2)	18.6	16.2	14.1	16.4	16.3
B_{MSY}	23.4 (0.96)	20.4 (1.7)	20.9	18.9	19.8	21.9	20.4
U_{MSY}	0.0433 (0.0062)	0.0734 (0.01)	0.0736	0.0853	0.0729	0.0619	0.0733
Legal U_{MSY}	0.0423 (0.006)	0.0773 (0.011)	0.0775	0.0902	0.0766	0.0647	0.0771
MSY	2.79 (0.27)	4.37 (0.45)	4.46	4.75	4.27	3.98	4.38
B_{2016}/B_0	0.191 (0.018)	0.231 (0.021)	0.253	0.231	0.212	0.232	0.231
B_{2016}/B_{MSY}	0.467 (0.049)	0.613 (0.065)	0.673	0.66	0.558	0.573	0.612
$B_{2016}/(.4B_{MSY})$	1.17 (0.12)	1.53 (0.16)	1.68	1.65	1.39	1.43	1.53
B_{2018}/B_0		0.301 (0.032)	0.335	0.301	0.271	0.304	0.302
B_{2018}/B_{MSY}		0.8 (0.096)	0.891	0.86	0.714	0.75	0.799
$B_{2018}/(.4B_{MSY})$		2 (0.24)	2.23	2.15	1.79	1.88	2
$P(B_{2016} \geq .4B_{MSY})$	0.93	1					
$P(B_{2018} \geq .4B_{MSY})$		1					

Table 2. Weighted performance metrics for all candidate management procedures on the **reference operating models**. Conservation performance metrics that pass the criteria in the header are indicated by a bullet. Catch is given in biomass units, which are measured in kilotonnes. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$. For Objective 2, Obs refers to the observed probability of decline, and Acc to the acceptable probability of decline, linearly interpolated between 0.05 at $0.4B_{MSY}$ and 0.5 at B_{MSY} .

No.	MP Label	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5		Other Important Quantities			Region
		P > .95	Obs < Acc	P > .5	min	max	max	AAV	C ₂₀₁₉	B ₂₀₁₉ /B ₀	
		$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	$TAC_{2019:2028}$				
17	NSL_rctAl_am5	•	•	0.49 < 0.5	0.02	4.527	4.555	8	3.22	0.35	0.0750
6	cap0_rctAl_am5	•	•	•	0.02	4.095	4.765	8	3.36	0.35	0.0783
2	cap.5_hstAl_am5	•	•	•	0.02	4.012	4.513	8	3.18	0.35	0.0741
5	cap0_rctAl_am10	•	•	•	0.02	3.957	4.293	7	3.05	0.35	0.0705
4	cap.5_rctAl_am5	•	•	•	0.02	3.939	4.439	8	3.12	0.35	0.0728
8	cap1.0_hstAl_am5	•	•	•	0.02	3.926	4.248	7	3.05	0.35	0.0696
1	cap.5_hstAl_am10	•	•	•	0.02	3.912	4.168	7	3.05	0.35	0.0681
12	cap1.5_hstAl_am5	•	•	•	0.03	3.876	4.071	7	3.05	0.35	0.0663
3	cap.5_rctAl_am10	•	•	•	0.02	3.858	4.115	7	3.05	0.35	0.0670
7	cap1.0_hstAl_am10	•	•	•	0.02	3.852	4.021	7	3.05	0.35	0.0654
11	cap1.5_hstAl_am10	•	•	•	0.02	3.812	3.919	7	3.05	0.35	0.0634
10	cap1.0_rctAl_am5	•	•	•	0.02	3.799	4.154	7	3.05	0.35	0.0676
9	cap1.0_rctAl_am10	•	•	•	0.02	3.771	3.949	7	3.05	0.35	0.0639
15	noCap_rctAl_am5	•	•	•	0.03	3.721	3.739	6	3.05	0.35	0.0599
14	cap1.5_rctAl_am5	•	•	•	0.02	3.713	3.969	7	3.05	0.35	0.0641
13	cap1.5_rctAl_am10	•	•	•	0.02	3.708	3.848	7	3.05	0.35	0.0619
16	NoFish	•	•	•	1.00	0.000		0	0.00	0.35	0.0650

Robustness of Sablefish MPs in BC

Table 3. Price per pound of Sablefish in each weight class. Weight classes are defined by the limits of that class, in pounds (e.g., 2/3 is the class of fish between 2 and 3 pounds).

Weight Class (lb)	Price (\$/lb)
0/2	6.0
2/3	7.7
3/4	8.0
4/5	9.0
5/7	11.0
7+	12.0

Table 4. Weighted economic performance metrics for the first 10 years of the projections in the **reference operating models**. Column 3 shows the average catch over the first 10 years, and the remaining columns show the total cumulative revenue (\$m) of catch C and discards D for each sector, catch revenue C^{tot} for all sectors combined, and the yearly average revenue R in dollars per tonne of catch, over the next 10 years. All values are taken at 4 significant figures. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$.

No.	MP Label	Av. Catch/TAC (kt)		10 year revenue (\$ millions)							Av. revenue (\$/t)		
		$\bar{C}_{2019:2028}$	$T\bar{A}C_{2019:2028}$	C^{trap}	C^{hook}	C^{trawl}	D^{trap}	D^{hook}	D^{trawl}	C^{tot}	R^{trap}	R^{hook}	R^{trawl}
17	NSL_rctAl_am5	4.527	4.555	419.4	336.7	61.06	0.000	0.00	0.00	817.2	17970	18320	16270
6	cap0_rctAl_am5	4.095	4.765	383.9	319.5	42.49	10.890	13.38	25.67	745.9	18130	18340	17320
2	cap.5_hstAl_am5	4.012	4.513	371.7	312.7	46.54	10.460	13.04	27.67	730.9	18130	18340	17330
5	cap0_rctAl_am10	3.957	4.293	371.0	302.4	47.59	10.390	12.59	28.38	721.0	18140	18340	17330
4	cap.5_rctAl_am5	3.939	4.439	364.1	302.6	50.83	10.220	12.61	29.88	717.6	18140	18340	17340
8	cap1.0_hstAl_am5	3.926	4.248	358.8	305.3	50.33	10.040	12.67	29.53	714.4	18140	18340	17340
1	cap.5_hstAl_am10	3.912	4.168	364.1	298.7	49.93	10.190	12.41	29.64	712.6	18140	18340	17340
12	cap1.5_hstAl_am5	3.876	4.071	352.0	300.2	53.35	9.835	12.44	31.19	705.5	18140	18340	17340
3	cap.5_rctAl_am10	3.858	4.115	358.3	292.1	52.27	10.030	12.14	30.88	702.7	18140	18340	17340
7	cap1.0_hstAl_am10	3.852	4.021	355.8	293.8	52.00	9.962	12.19	30.72	701.6	18140	18340	17340
11	cap1.5_hstAl_am10	3.812	3.919	350.7	289.7	53.54	9.819	12.01	31.56	693.9	18140	18340	17340
10	cap1.0_rctAl_am5	3.799	4.154	347.1	288.5	56.02	9.712	11.98	32.63	691.6	18140	18340	17340
9	cap1.0_rctAl_am10	3.771	3.949	347.5	283.3	54.89	9.735	11.76	32.30	685.7	18140	18340	17340
15	noCap_rctAl_am5	3.721	3.739	346.8	276.5	53.45	9.734	11.47	31.74	676.7	18140	18340	17340
14	cap1.5_rctAl_am5	3.713	3.969	338.3	281.2	56.10	9.469	11.66	32.89	675.5	18140	18340	17350
13	cap1.5_rctAl_am10	3.708	3.848	341.6	278.6	54.71	9.577	11.55	32.28	674.9	18140	18340	17350
16	NoFish	0.000		0.0	0.0	0.00	0.000	0.00	0.00	0.0	0	0	0

Table 5. Weighted performance metrics for all candidate management procedures on the **robustness operating models**. Conservation performance metrics that pass the criteria in the header are indicated by a bullet. Catch is given in biomass units, which are measured in kilotonnes. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$. For Objective 2, Obs refers to the observed probability of decline, and Acc to the acceptable probability of decline, linearly interpolated between 0.05 at $0.4B_{MSY}$ and 0.5 at B_{MSY} .

No.	MP Label	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5		Other Important Quantities			Region
		P > .95	Obs < Acc	P > .5	min	max	max	AAV	C ₂₀₁₉	B ₂₀₁₉ /B ₀	
		$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	$TAC_{2019:2028}$				
17	NSL_rctAl_am5	•	•	•	0.07	2.760	2.778	9	3.05	0.24	0.0682
6	cap0_rctAl_am5	•	•	•	0.14	2.489	2.889	11	3.11	0.24	0.0724
2	cap.5_hstAl_am5	•	•	•	0.16	2.428	2.673	11	3.05	0.24	0.0655
5	cap0_rctAl_am10	•	•	•	0.17	2.418	2.633	11	3.05	0.24	0.0644
1	cap.5_hstAl_am10	•	•	•	0.18	2.383	2.515	11	3.05	0.24	0.0606
8	cap1.0_hstAl_am5	•	•	•	0.19	2.362	2.468	11	3.05	0.24	0.0590
4	cap.5_rctAl_am5	•	•	•	0.19	2.350	2.597	11	3.05	0.24	0.0628
7	cap1.0_hstAl_am10	•	•	•	0.20	2.344	2.410	11	3.05	0.24	0.0572
3	cap.5_rctAl_am10	•	•	•	0.20	2.334	2.468	11	3.05	0.24	0.0589
12	cap1.5_hstAl_am5	•	•	•	0.21	2.330	2.371	11	3.05	0.24	0.0562
11	cap1.5_hstAl_am10	•	•	•	0.21	2.310	2.340	11	3.05	0.24	0.0551
10	cap1.0_rctAl_am5	•	•	•	0.22	2.295	2.428	11	3.05	0.24	0.0576
13	cap1.5_rctAl_am10	•	•	•	0.22	2.287	2.330	11	3.05	0.24	0.0546
15	noCap_rctAl_am5	•	•	•	0.23	2.282	2.293	11	3.05	0.24	0.0537
9	cap1.0_rctAl_am10	•	•	•	0.22	2.280	2.357	11	3.05	0.24	0.0554
14	cap1.5_rctAl_am5	•	•	•	0.22	2.277	2.342	11	3.05	0.24	0.0549
16	NoFish	•	•	•	1.00	0.000		0	0.00	0.24	0.0550

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Table 6. Weighted economic performance metrics for the first 10 years of the projections in the **robustness operating models**. Column 3 shows the average catch over the first 10 years, and the remaining columns show the total cumulative revenue (\$m) of catch C and discards D for each sector, catch revenue C^{tot} for all sectors combined, and the yearly average revenue R in dollars per tonne of catch, over the next 10 years. All values are taken at 4 significant figures. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$.

No.	MP Label	Av. Catch/TAC (kt)		10 year revenue (\$ millions)							Av. revenue (\$/t)		
		$\bar{C}_{2019:2028}$	$T\bar{A}C_{2019:2028}$	C^{trap}	C^{hook}	C^{trawl}	D^{trap}	D^{hook}	D^{trawl}	C^{tot}	R^{trap}	R^{hook}	R^{trawl}
17	NSL_rctAI_am5	2.760	2.778	255.1	204.9	36.28	0.000	0.000	0.00	496.3	18030	18340	15880
6	cap0_rctAI_am5	2.489	2.889	236.3	194.1	22.81	6.243	7.974	16.89	453.3	18200	18360	17180
2	cap5_hstAI_am5	2.428	2.673	226.5	189.5	26.23	5.935	7.741	19.55	442.3	18200	18370	17230
5	cap0_rctAI_am10	2.418	2.633	229.0	185.3	26.42	5.996	7.569	20.03	440.7	18200	18370	17220
1	cap5_hstAI_am10	2.383	2.515	222.9	182.2	28.59	5.815	7.424	21.73	433.7	18200	18370	17240
8	cap1.0_hstAI_am5	2.362	2.468	217.7	181.9	29.25	5.663	7.404	21.91	428.8	18200	18370	17240
4	cap5_rctAI_am5	2.350	2.597	218.8	179.5	29.48	5.693	7.309	22.04	427.8	18200	18370	17240
7	cap1.0_hstAI_am10	2.344	2.410	217.7	177.7	30.60	5.655	7.228	23.29	426.1	18210	18370	17240
3	cap5_rctAI_am10	2.334	2.468	217.9	176.2	30.64	5.656	7.167	23.30	424.7	18210	18370	17240
12	cap1.5_hstAI_am5	2.330	2.371	216.3	175.6	31.47	5.605	7.139	23.75	423.4	18210	18370	17250
11	cap1.5_hstAI_am10	2.310	2.340	215.3	173.1	31.84	5.577	7.035	24.29	420.3	18210	18370	17250
10	cap1.0_rctAI_am5	2.295	2.428	211.3	173.1	33.04	5.458	7.024	25.00	417.4	18210	18370	17250
13	cap1.5_rctAI_am10	2.287	2.330	212.2	171.1	32.88	5.485	6.945	25.21	416.2	18210	18370	17250
15	noCap_rctAI_am5	2.282	2.293	213.4	170.0	32.60	5.522	6.906	25.09	416.0	18210	18370	17250
9	cap1.0_rctAI_am10	2.280	2.357	211.7	171.1	32.62	5.473	6.946	24.90	415.5	18210	18370	17250
14	cap1.5_rctAI_am5	2.277	2.342	209.8	171.1	32.98	5.417	6.941	25.18	413.9	18210	18370	17250
16	NoFish	0.000		0.0	0.0	0.00	0.000	0.000	0.00	0.0	0	0	0

Table 7. Weighted performance metrics for all candidate management procedures, with harvest rates tuned to performance on the **reference operating models**, and applied to the **robustness operating models** where recruitment is simulated stochastically off the stock-recruit curve for the 2015 year class. Conservation performance metrics that pass the criteria in the header are indicated by a bullet. Catch is given in biomass units, which are measured in kilotonnes. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$. For Objective 2, Obs refers to the observed probability of decline, and Acc to the acceptable probability of decline, linearly interpolated between 0.05 at $0.4B_{MSY}$ and 0.5 at B_{MSY} .

No.	MP Label	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5		Other Important Quantities			
		P > .95	Obs < Acc	P > .5	min	max	max	AAV	C_{2019}	B_{2019}/B_0	F_{2022}
		$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	$T\bar{A}C_{2019:2028}$				
17	NSL_rctAI_am5	•	•	$0.41 < 0.5$	0.09	2.937	2.956	9	3.22	0.24	0.0750
2	cap.5_hstAI_am5	•	$0.33 > 0.26$	$0.4 < 0.5$	0.13	2.619	2.894	11	3.19	0.24	0.0741
6	cap0_rctAI_am5	•	$0.3 > 0.26$	$0.42 < 0.5$	0.12	2.618	3.045	13	3.37	0.24	0.0783
8	cap1.0_hstAI_am5	•	$0.35 > 0.26$	$0.38 < 0.5$	0.14	2.596	2.731	10	3.05	0.24	0.0696
12	cap1.5_hstAI_am5	•	$0.35 > 0.26$	$0.38 < 0.5$	0.14	2.570	2.626	10	3.05	0.24	0.0663
4	cap.5_rctAI_am5	•	$0.34 > 0.26$	$0.4 < 0.5$	0.14	2.565	2.850	11	3.13	0.24	0.0728
5	cap0_rctAI_am10	•	$0.3 > 0.26$	$0.41 < 0.5$	0.13	2.560	2.783	10	3.05	0.24	0.0705
1	cap.5_hstAI_am10	•	$0.33 > 0.26$	$0.4 < 0.5$	0.13	2.555	2.702	10	3.05	0.24	0.0681
7	cap1.0_hstAI_am10	•	$0.34 > 0.26$	$0.4 < 0.5$	0.14	2.536	2.615	10	3.05	0.24	0.0654
3	cap.5_rctAI_am10	•	$0.33 > 0.26$	$0.4 < 0.5$	0.15	2.520	2.672	10	3.05	0.24	0.0670
11	cap1.5_hstAI_am10	•	$0.34 > 0.26$	$0.39 < 0.5$	0.16	2.519	2.553	10	3.05	0.24	0.0634
10	cap1.0_rctAI_am5	•	$0.35 > 0.26$	$0.39 < 0.5$	0.15	2.516	2.685	10	3.05	0.24	0.0676
14	cap1.5_rctAI_am5	•	$0.34 > 0.26$	$0.39 < 0.5$	0.16	2.490	2.583	10	3.05	0.24	0.0641
9	cap1.0_rctAI_am10	•	$0.33 > 0.26$	$0.39 < 0.5$	0.17	2.487	2.579	10	3.05	0.24	0.0639
13	cap1.5_rctAI_am10	•	$0.33 > 0.26$	$0.4 < 0.5$	0.17	2.467	2.520	10	3.05	0.24	0.0619
15	noCap_rctAI_am5	•	$0.31 > 0.26$	$0.41 < 0.5$	0.19	2.449	2.463	10	3.05	0.24	0.0599
16	NoFish	•	•	•	1.00	0.000		0	0.00	0.24	0.0550

Table 8. Weighted performance metrics for all candidate management procedures, with harvest rates tuned to performance on the **robustness operating models**, and applied to the **reference operating models** accepting the high 2015 year class. Conservation performance metrics that pass the criteria in the header are indicated by a bullet. Catch is given in biomass units, which are measured in kilotonnes. Table is sorted by 10 year average catch $\bar{C}_{2019:2028}$. For Objective 2, Obs refers to the observed probability of decline, and Acc to the acceptable probability of decline, linearly interpolated between 0.05 at $0.4B_{MSY}$ and 0.5 at B_{MSY} .

No.	MP Label	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5		Other Important Quantities			
		P > .95	Obs < Acc	P > .5	min	max	max	AAV	C_{2019}	B_{2019}/B_0	F_{2022}
		$P(B_t \geq .4B_{MSY})$	$P(\text{Decline})$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	$T\bar{A}C_{2019:2028}$				
17	NSL_rctAl_am5	•	•	•	0.01	4.172	4.195	7	3.05	0.35	0.0682
6	cap0_rctAl_am5	•	•	•	0.01	3.815	4.435	8	3.11	0.35	0.0724
5	cap0_rctAl_am10	•	•	•	0.02	3.681	3.998	7	3.05	0.35	0.0644
2	cap.5_hstAl_am5	•	•	•	0.01	3.631	4.064	8	3.05	0.35	0.0655
1	cap.5_hstAl_am10	•	•	•	0.02	3.568	3.794	7	3.05	0.35	0.0606
4	cap.5_rctAl_am5	•	•	•	0.02	3.504	3.935	8	3.05	0.35	0.0628
3	cap.5_rctAl_am10	•	•	•	0.02	3.488	3.715	7	3.05	0.35	0.0589
7	cap1.0_hstAl_am10	•	•	•	0.02	3.483	3.623	7	3.05	0.35	0.0572
8	cap1.0_hstAl_am5	•	•	•	0.01	3.464	3.725	8	3.05	0.35	0.0590
11	cap1.5_hstAl_am10	•	•	•	0.02	3.423	3.509	7	3.05	0.35	0.0551
12	cap1.5_hstAl_am5	•	•	•	0.02	3.423	3.569	7	3.05	0.35	0.0562
15	noCap_rctAl_am5	•	•	•	0.02	3.413	3.433	7	3.05	0.35	0.0537
9	cap1.0_rctAl_am10	•	•	•	0.02	3.371	3.535	7	3.05	0.35	0.0554
13	cap1.5_rctAl_am10	•	•	•	0.02	3.370	3.489	7	3.05	0.35	0.0546
10	cap1.0_rctAl_am5	•	•	•	0.02	3.368	3.661	8	3.05	0.35	0.0576
14	cap1.5_rctAl_am5	•	•	•	0.02	3.301	3.518	8	3.05	0.35	0.0549
16	NoFish	•	•	•	1.00	0.000		0	0.00	0.35	0.0550

Figures

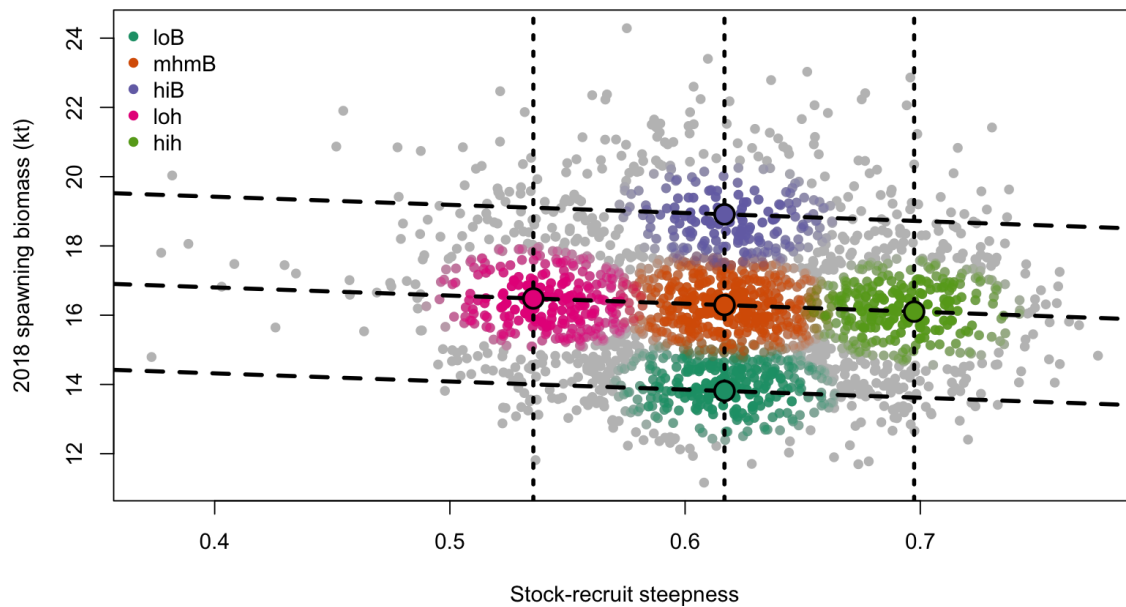


Figure 1. Joint marginal posterior distribution MCMC samples (grey dots) for stock-recruit steepness (h ; x -axis) and spawning biomass in 2018 (B_{2018} ; y -axis). Dashed lines indicate the mean, 10th and 90th percentiles of each marginal distribution, with the percentiles of the spawning biomass distribution adjusted to match the regression line between the two marginal distributions. Coloured dots with black borders at the intersections of selected percentiles are the sample centres for the 5 productivity and biomass operating model scenarios with labels matching columns of Table 1, with the coloured posterior MCMC samples showing the set of all points within a Mahalanobis distance of .6 from the centre of the same colour.

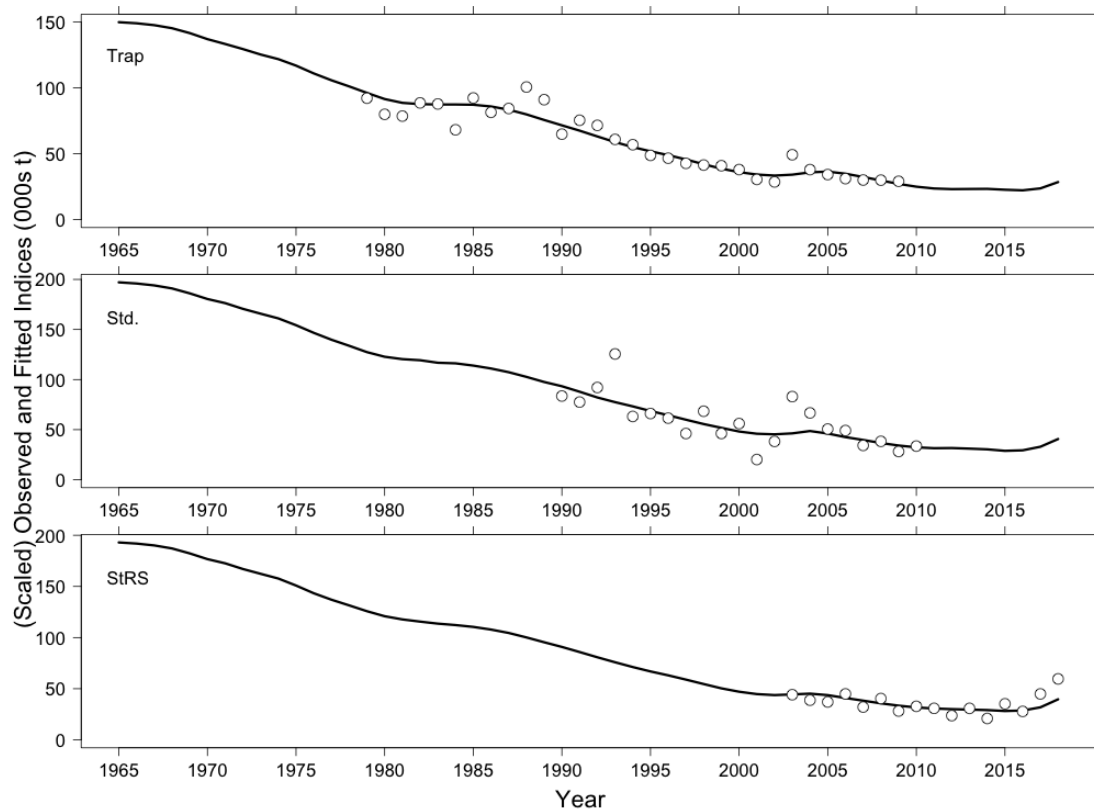


Figure 2. Operating model fits to Catch per Unit of Effort (CPUE) indices (kg/trap) from the commercial trap fishery (Trap, top), standardized Sablefish survey (Std., middle), and stratified random Sablefish survey (StRS, bottom). Points show observations scaled by catchability, and lines show operating model vulnerable biomass.

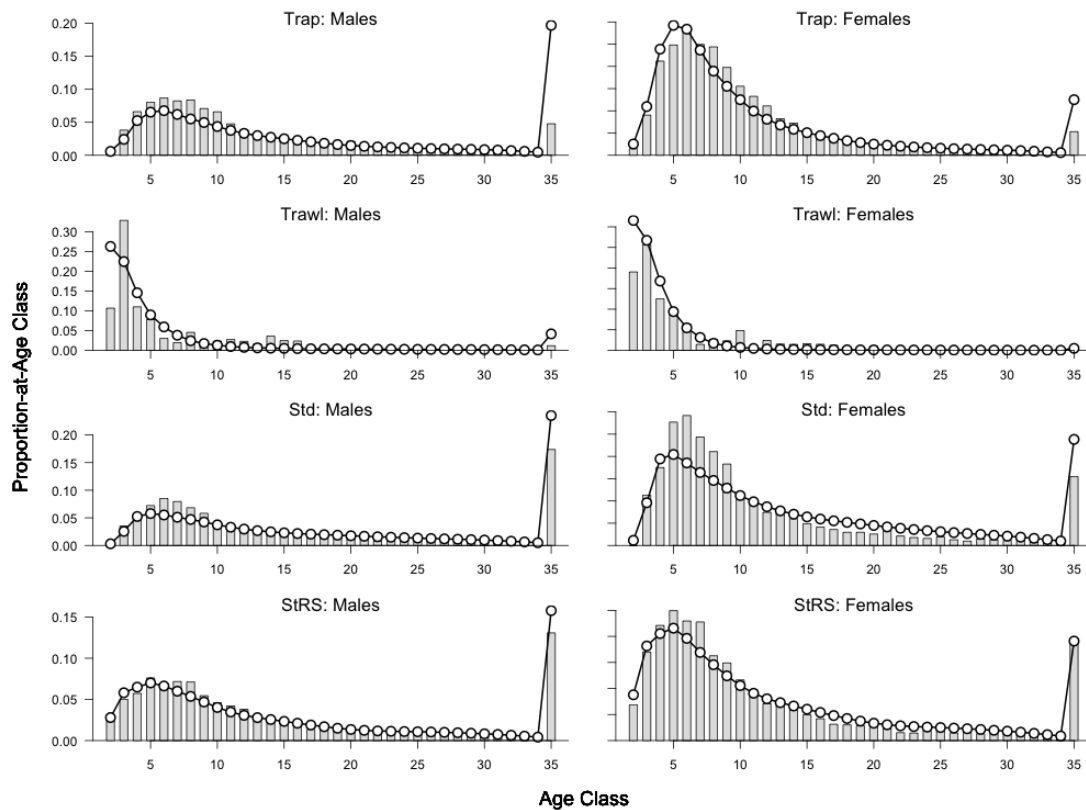


Figure 3. Averaged operating model fits to age observations for, from top to bottom, the commercial trap fishery (Trap), commercial trawl fishery (Trawl), standardized survey (Std.), and stratified random survey (StRS). Grey bars are the average proportion of age observations, and the points joined with a line show the average expected distribution of age observations in the operating model. Averages are taken over the years with observations.

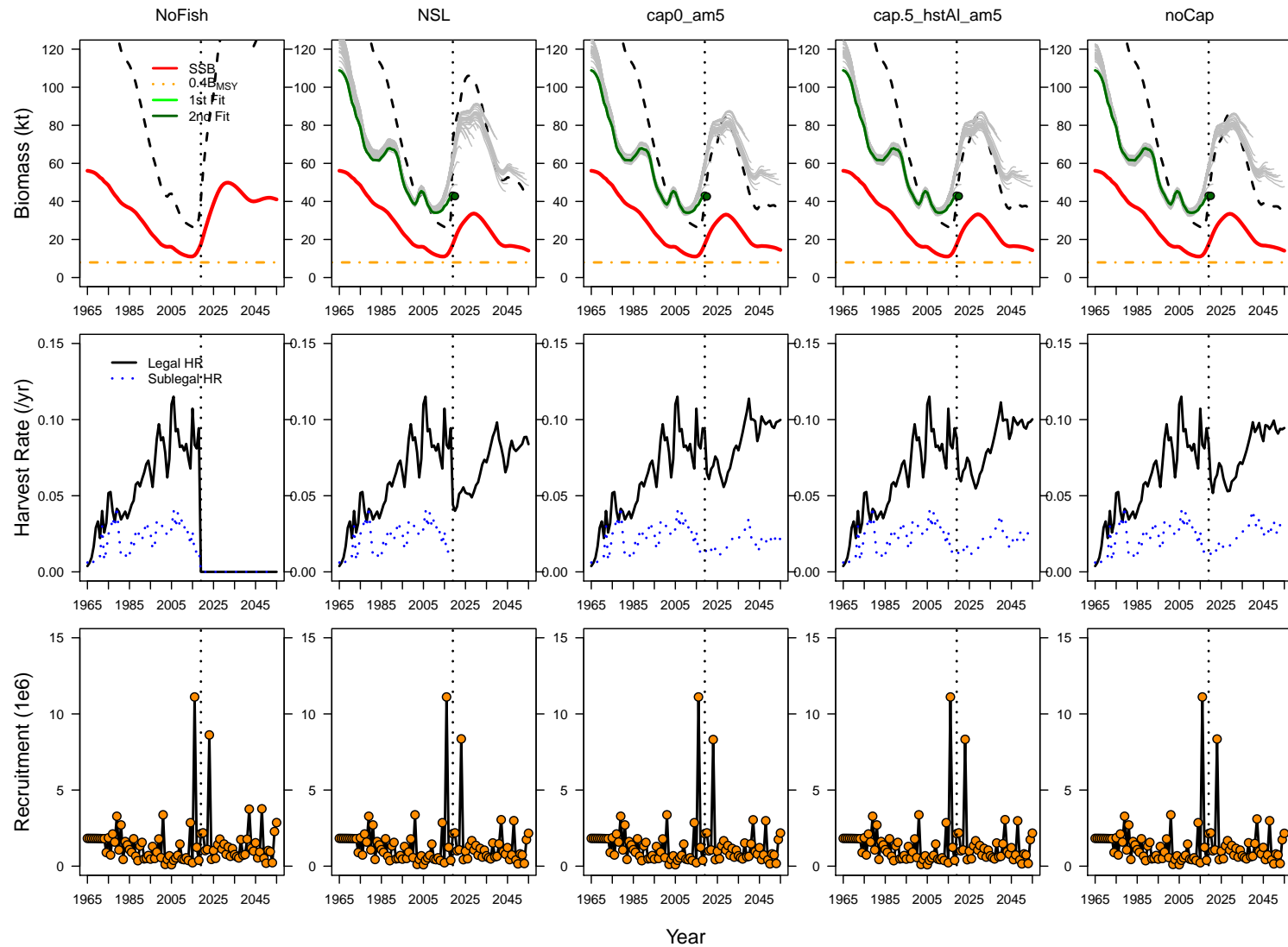


Figure 4. A single simulation replicate drawn from the **reference operating models** with the high estimated 2015 year class. The top row of panels show the spawning biomass (red line), legal biomass (black dashed line), and surplus production model estimated biomass (green and grey lines) when estimated as part of the management procedure. The middle row shows the legal (black solid line) and sub-legal (blue dotted line) harvest rates, and the bottom row shows the OM recruitments (black line with orange points). First and second fit refer to the first and second years that the management procedure was applied.

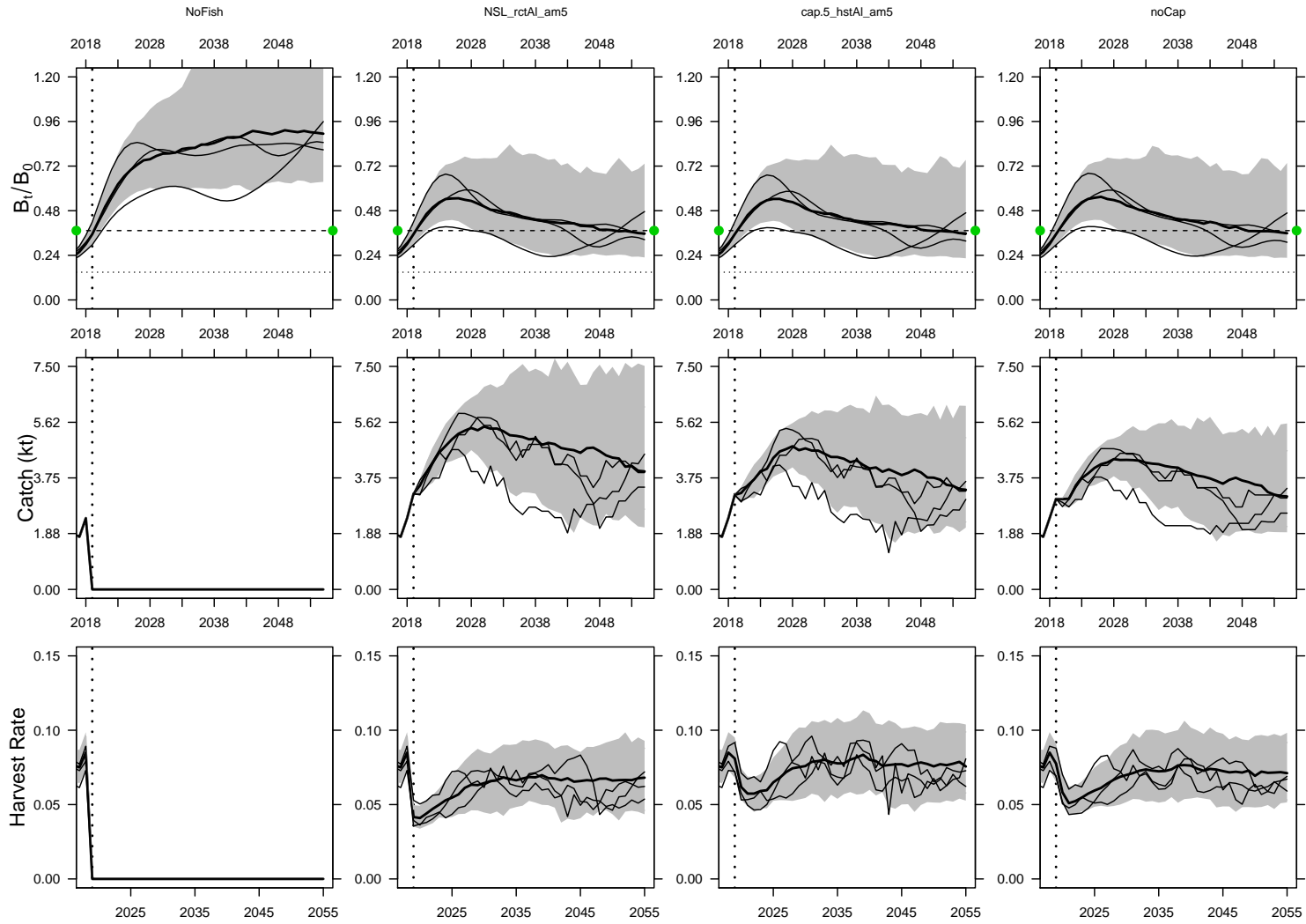


Figure 5. Weighted combined simulation envelopes from the 5 productivity and biomass operating models in the **reference recruitment scenario**, showing the current MP (noCap), three illustrative at-sea-release management measure MPs, and the no fishing MP (NoFish). The top row shows projected biomass relative to unfished, the second row shows the landed catch, and the bottom row shows the legal harvest rate. In each panel, median projections are shown as thick black lines, the central 90 % of the envelope is shown as grey shading, and the three illustrated simulation replicates as thin black lines.

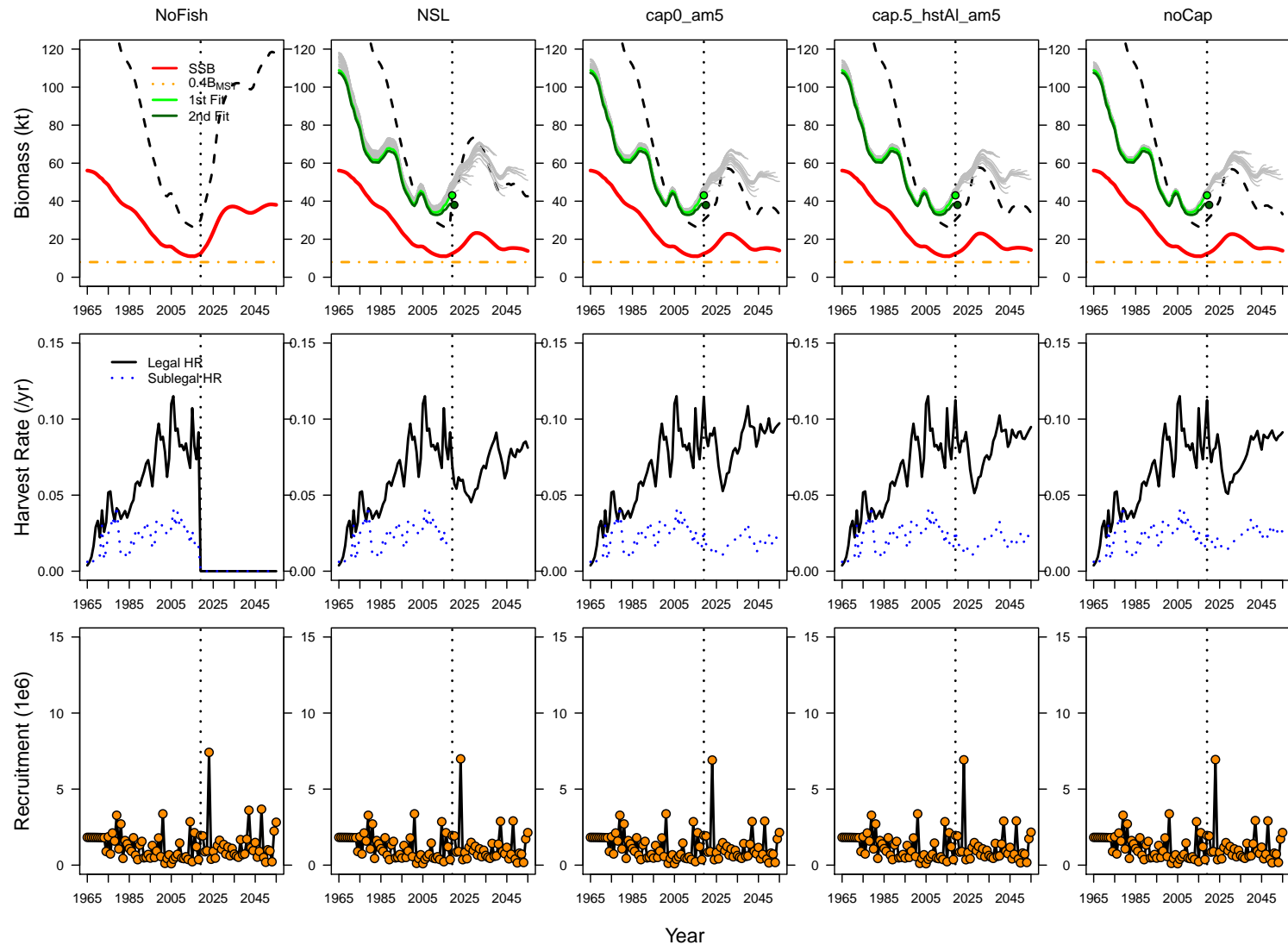


Figure 6. A single simulation replicate drawn from the **robustness operating models** with a stochastically simulated 2015 year class. The top row of panels show the spawning biomass (red line), legal biomass (black dashed line), and surplus production model estimated biomass (green and grey lines) when estimated as part of the management procedure. The middle row shows the legal (black solid line) and sub-legal (blue dotted line) harvest rates, and the bottom row shows the OM recruitments (black line with orange points). First and second fit refer to the first and second years that the management procedure was applied.

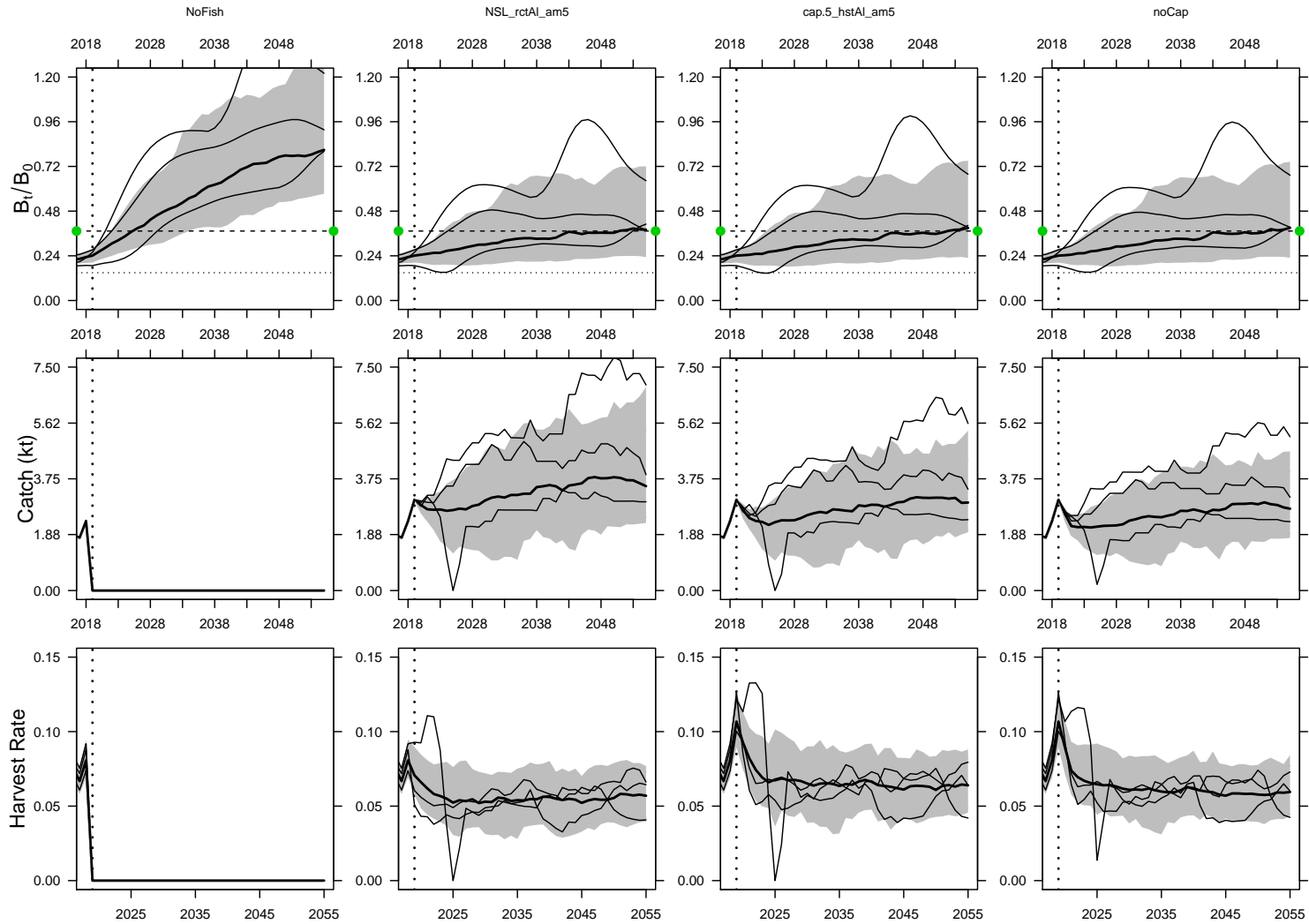


Figure 7. Weighted combined simulation envelopes from the 5 productivity and biomass operating models in the **robustness recruitment scenario**, showing showing the current MP (noCap), three illustrative at-sea-release management measure MPs, and the no fishing MP (NoFish). The top row shows projected biomass relative to unfished, the second row shows the landed catch, and the bottom row shows the legal harvest rate. In each panel, median projections are shown as thick black lines, the central 90 % of the envelope is shown as grey shading, and the three illustrated simulation replicates as thin black lines.

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