Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

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

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

October 2019

Canada

Tables

Table 1. Operating model posterior mean (standard deviation) biological parameter and reference point estimates for the full posterior and 5 sampled regions for each productivity/biomass scenario.

	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_{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

Table 2. Weighted performance metrics for all candidate management procedures on the reference set of operating models, where recruitment is taken from the OM estimate in 2016. Conservation performance metrics that pass the criteria in the header are indicated by a bullet.

		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Other Important Quantities**			
		P > .95	**Obs < Acc**	**P > .5**	**min**	**max**				
No.	**MP Label**	$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	AAV	C_{2019}	D_{2019}	F_{2022}
14	frt	•	•	•	0.0148	4.51	7.81	3.39	0.353	0.0738
3	cap.5_hstAI_am5	•	•	•	0.0217	4.01	8.01	3.39	0.353	0.0728
5	cap.5_rctAI_am5	•	•	•	0.0217	3.93	7.95	3.39	0.353	0.0712
7	cap1.0_hstAI_am5	•	•	•	0.0217	3.93	8.07	3.39	0.353	0.0680
2	cap.5_hstAI_am10	•	•	•	0.0217	3.92	7.99	3.39	0.353	0.0665
4	cap.5_rctAI_am10	•	•	•	0.0232	3.86	8.10	3.39	0.353	0.0654
6	cap1.0_hstAI_am10	•	•	•	0.0217	3.85	8.23	3.39	0.353	0.0636
11	cap1.5_hstAI_am5	•	•	•	0.0232	3.84	8.34	3.39	0.353	0.0638
10	cap1.5_hstAI_am10	•	•	•	0.0232	3.80	8.03	3.39	0.353	0.0613
8	cap1.0_rctAI_am10	•	•	•	0.0265	3.78	8.18	3.39	0.353	0.0624
9	cap1.0_rctAI_am5	•	•	•	0.0232	3.77	8.17	3.39	0.353	0.0651
15	noCap	•	•	•	0.0265	3.73	7.02	3.39	0.353	0.0582
12	cap1.5_rctAI_am10	•	•	•	0.0265	3.72	8.26	3.39	0.353	0.0603
13	cap1.5_rctAI_am5	•	•	•	0.0232	3.70	8.37	3.39	0.353	0.0621
1	NoFish	•	•	•	1.0000	0.00	0.00	0.00	0.353	0.0550

Table 3. Weighted performance metrics for all candidate management procedures on the robustness set of operating models, where recruitment is simulated stochastically off the stock-recruit curve in 2016. Conservation performance metrics that pass the criteria in the header are indicated by a bullet.

		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Other Important Quantities**			
		P > .95	**Obs < Acc**	**P > .5**	**min**	**max**				
No.	**MP Label**	$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	AAV	C_{2019}	D_{2019}	F_{2022}
14	frt	•	•	•	0.0798	2.77	11.2	3.39	0.24	0.0674
3	cap.5_hstAl_am5	•	•	•	0.1750	2.44	14.8	3.40	0.24	0.0643
7	cap1.0_hstAl_am5	•	$0.267 > 0.263$	•	0.2030	2.39	14.8	3.40	0.24	0.0589
2	cap.5_hstAl_am10	•	•	•	0.2050	2.39	15.0	3.40	0.24	0.0592
5	cap.5_rctAl_am5	•	•	•	0.2120	2.38	15.3	3.40	0.24	0.0622
6	cap1.0_hstAl_am10	•	•	•	0.2220	2.36	14.9	3.40	0.24	0.0564
11	cap1.5_hstAl_am5	•	$0.272 > 0.263$	•	0.2230	2.36	14.5	3.40	0.24	0.0556
4	cap.5_rctAl_am10	•	•	•	0.2280	2.35	15.3	3.40	0.24	0.0580
10	cap1.5_hstAl_am10	•	•	•	0.2380	2.34	14.3	3.40	0.24	0.0543
12	cap1.5_rctAl_am10	•	•	•	0.2440	2.32	14.6	3.40	0.24	0.0540
8	cap1.0_rctAl_am10	•	•	•	0.2380	2.32	15.3	3.40	0.24	0.0552
13	cap1.5_rctAl_am5	•	•	•	0.2400	2.31	15.2	3.40	0.24	0.0546
9	cap1.0_rctAl_am5	•	•	•	0.2430	2.31	15.7	3.40	0.24	0.0567
15	noCap	•	•	•	0.2540	2.31	14.2	3.40	0.24	0.0524
1	NoFish	•	•	•	1.0000	0.00	0.0	0.00	0.24	0.0550

Table 4. Weighted economic performance metrics for the first 10 years of the projections in the reference OM set. Column 3 shows the average catch over the first 10 years, and the remaining columns show the total value ($m) of catch C and discards D for all sectors, and the yearly average income I in dollars per tonne of catch, over the next 10 years. All values are taken at 4 significant figures.

		Av. Catch (kt)	**10 year value ($ millions)**						**Av. income ($/t)**		
No.	**MP Label**	$\bar{C}_{2019:2028}$	C^{trap}	C^{hook}	C^{trawl}	D^{trap}	D^{hook}	D^{trawl}	I^{trap}	I^{hook}	I^{trawl}
14	frt	4.510	417.6	335.4	60.81	0.000	0.00	0.00	17970	18320	16270
3	cap.5_hstAl_am5	4.005	370.9	312.5	46.34	10.550	13.08	27.75	18130	18340	17330
5	cap.5_rctAl_am5	3.930	362.8	302.2	50.54	10.320	12.65	29.97	18140	18340	17330
7	cap1.0_hstAl_am5	3.927	358.3	305.8	50.07	10.210	12.78	29.71	18140	18340	17330
2	cap.5_hstAl_am10	3.921	364.1	299.3	49.78	10.400	12.53	29.86	18130	18340	17330
4	cap.5_rctAl_am10	3.864	358.6	292.9	52.15	10.240	12.27	31.12	18140	18340	17340
6	cap1.0_hstAl_am10	3.850	355.3	294.0	51.77	10.160	12.31	30.90	18140	18340	17340
11	cap1.5_hstAl_am5	3.842	348.0	298.1	52.75	9.943	12.46	31.14	18140	18340	17340
10	cap1.5_hstAl_am10	3.804	349.1	289.1	53.25	10.000	12.11	31.70	18140	18340	17340
8	cap1.0_rctAl_am10	3.782	348.5	284.7	55.07	9.982	11.93	32.71	18140	18340	17340
9	cap1.0_rctAl_am5	3.767	343.6	286.5	55.58	9.818	12.00	32.67	18140	18340	17340
15	noCap	3.729	347.9	277.5	53.58	10.010	11.66	32.11	18140	18340	17340
12	cap1.5_rctAl_am10	3.721	342.4	279.8	54.97	9.830	11.73	32.73	18140	18340	17340
13	cap1.5_rctAl_am5	3.702	336.7	280.8	56.10	9.642	11.76	33.18	18140	18340	17340
1	NoFish	0.000	0.0	0.0	0.00	0.000	0.00	0.00	0	0	0

Table 5. Weighted economic performance metrics for the first 10 years of the projections in the reference OM set. Column 3 shows the average catch over the first 10 years, and the remaining columns show the total value ($m) of catch C and discards D for all sectors, and the yearly average income I in dollars per tonne of catch, over the next 10 years. All values are taken at 4 significant figures.

		Av. Catch (kt)	**10 year value ($ millions)**						**Av. income ($/t)**		
No.	**MP Label**	$\bar{C}_{2019:2028}$	C^{trap}	C^{hook}	C^{trawl}	D^{trap}	D^{hook}	D^{trawl}	I^{trap}	I^{hook}	I^{trawl}
14	frt	2.767	256.2	205.8	36.44	0.000	0.000	0.00	18030	18340	15880
3	cap.5_hstAl_am5	2.440	226.8	189.8	26.25	5.976	7.804	19.56	18200	18370	17220
7	cap1.0_hstAl_am5	2.392	220.4	184.6	29.42	5.778	7.571	22.07	18200	18370	17230
2	cap.5_hstAl_am10	2.385	223.0	182.3	28.56	5.853	7.482	21.69	18200	18370	17230
5	cap.5_rctAl_am5	2.377	220.6	181.0	29.58	5.776	7.426	22.12	18200	18370	17230
6	cap1.0_hstAl_am10	2.364	219.4	179.3	30.70	5.741	7.351	23.39	18200	18370	17240
11	cap1.5_hstAl_am5	2.358	218.2	178.0	31.63	5.696	7.292	23.92	18200	18370	17240
4	cap.5_rctAl_am10	2.349	219.3	177.4	30.72	5.735	7.274	23.37	18200	18370	17240
10	cap1.5_hstAl_am10	2.340	217.2	175.1	32.03	5.670	7.176	24.50	18210	18370	17240
12	cap1.5_rctAl_am10	2.322	214.6	173.2	33.28	5.590	7.083	25.58	18210	18370	17240
8	cap1.0_rctAl_am10	2.322	215.0	173.8	33.06	5.605	7.114	25.30	18210	18370	17240
13	cap1.5_rctAl_am5	2.312	212.5	173.4	33.49	5.526	7.091	25.62	18210	18370	17240
9	cap1.0_rctAl_am5	2.309	212.7	174.3	33.22	5.537	7.131	25.16	18210	18370	17250
15	noCap	2.305	214.7	171.1	32.79	5.600	7.004	25.31	18210	18370	17240
1	NoFish	0.000	0.0	0.0	0.00	0.000	0.000	0.00	0	0	0

Table 6. Weighted performance metrics for all candidate management procedures, with harvest rates tuned to performance on the reference set of operating models, and applied to the robustness set of operating models where recruitment is simulated stochastically off the stock-recruit curve in 2016. Conservation performance metrics that pass the criteria in the header are indicated by a bullet.

		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Other Important Quantities**			
		P > .95	**Obs < Acc**	**P > .5**	**min**	**max**				
No.	**MP Label**	$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	AAV	C_{2019}	D_{2019}	F_{2022}
14	frt	•	•	$0.419 < 0.5$	0.0882	2.92	10.9	3.39	0.24	0.0738
3	cap.5_hstAl_am5	•	$0.324 > 0.263$	$0.408 < 0.5$	0.1370	2.61	13.8	3.40	0.24	0.0728
7	cap1.0_hstAl_am5	•	$0.344 > 0.263$	$0.4 < 0.5$	0.1470	2.59	13.7	3.40	0.24	0.0680
5	cap.5_rctAl_am5	•	$0.331 > 0.263$	$0.402 < 0.5$	0.1580	2.56	14.0	3.40	0.24	0.0712
2	cap.5_hstAl_am10	•	$0.324 > 0.263$	$0.422 < 0.5$	0.1530	2.55	13.9	3.40	0.24	0.0665
11	cap1.5_hstAl_am5	•	$0.35 > 0.263$	$0.411 < 0.5$	0.1680	2.54	13.5	3.40	0.24	0.0638
6	cap1.0_hstAl_am10	•	$0.338 > 0.263$	$0.422 < 0.5$	0.1700	2.53	13.9	3.40	0.24	0.0636
4	cap.5_rctAl_am10	•	$0.33 > 0.263$	$0.424 < 0.5$	0.1770	2.52	14.0	3.40	0.24	0.0654
10	cap1.5_hstAl_am10	•	$0.336 > 0.263$	$0.427 < 0.5$	0.1880	2.50	13.3	3.40	0.24	0.0613
9	cap1.0_rctAl_am5	•	$0.338 > 0.263$	$0.413 < 0.5$	0.1800	2.49	14.3	3.40	0.24	0.0651
8	cap1.0_rctAl_am10	•	$0.339 > 0.263$	$0.417 < 0.5$	0.1900	2.49	14.2	3.40	0.24	0.0624
13	cap1.5_rctAl_am5	•	$0.338 > 0.263$	$0.413 < 0.5$	0.1880	2.48	14.1	3.40	0.24	0.0621
12	cap1.5_rctAl_am10	•	$0.331 > 0.263$	$0.425 < 0.5$	0.2000	2.46	13.6	3.40	0.24	0.0603
15	noCap	•	$0.325 > 0.263$	$0.437 < 0.5$	0.2080	2.45	13.0	3.40	0.24	0.0582
1	NoFish	•	•	•	1.0000	0.00	0.0	0.00	0.24	0.0550

Table 7. Weighted performance metrics for all candidate management procedures, with harvest rates tuned to performance on the robustness set of operating models, and applied to the reference set of operating models accepting the high 2016 year class. Conservation performance metrics that pass the criteria in the header are indicated by a bullet.

		Objective 1	**Objective 2**	**Objective 3**	**Objective 4**	**Objective 5**	**Other Important Quantities**			
		P > .95	**Obs < Acc**	**P > .5**	**min**	**max**				
No.	**MP Label**	$P(B_t \geq .4B_{MSY})$	$P(Decline)$	$P(B_{2052} > B_{MSY})$	$P(C_t < 1.992)$	$\bar{C}_{2019:2028}$	AAV	C_{2019}	D_{2019}	F_{2022}
14	frt	•	•	•	0.0132	4.21	7.36	3.39	0.353	0.0674
3	cap.5_hstAl_am5	•	•	•	0.0149	3.66	8.29	3.39	0.353	0.0643
2	cap.5_hstAl_am10	•	•	•	0.0201	3.59	8.43	3.39	0.353	0.0592
5	cap.5_rctAl_am5	•	•	•	0.0201	3.56	8.36	3.39	0.353	0.0622
4	cap.5_rctAl_am10	•	•	•	0.0201	3.54	8.57	3.39	0.353	0.0580
6	cap1.0_hstAl_am10	•	•	•	0.0201	3.54	8.56	3.39	0.353	0.0564
7	cap1.0_hstAl_am5	•	•	•	0.0165	3.54	8.84	3.39	0.353	0.0589
11	cap1.5_hstAl_am5	•	•	•	0.0201	3.49	8.98	3.39	0.353	0.0556
10	cap1.5_hstAl_am10	•	•	•	0.0201	3.48	8.39	3.39	0.353	0.0543
8	cap1.0_rctAl_am10	•	•	•	0.0201	3.47	8.74	3.39	0.353	0.0552
15	noCap	•	•	•	0.0201	3.46	7.52	3.39	0.353	0.0524
12	cap1.5_rctAl_am10	•	•	•	0.0201	3.44	8.69	3.39	0.353	0.0540
9	cap1.0_rctAl_am5	•	•	•	0.0201	3.41	9.11	3.39	0.353	0.0567
13	cap1.5_rctAl_am5	•	•	•	0.0201	3.38	9.36	3.39	0.353	0.0546
1	NoFish	•	•	•	1.0000	0.00	0.00	0.00	0.353	0.0550

Figures

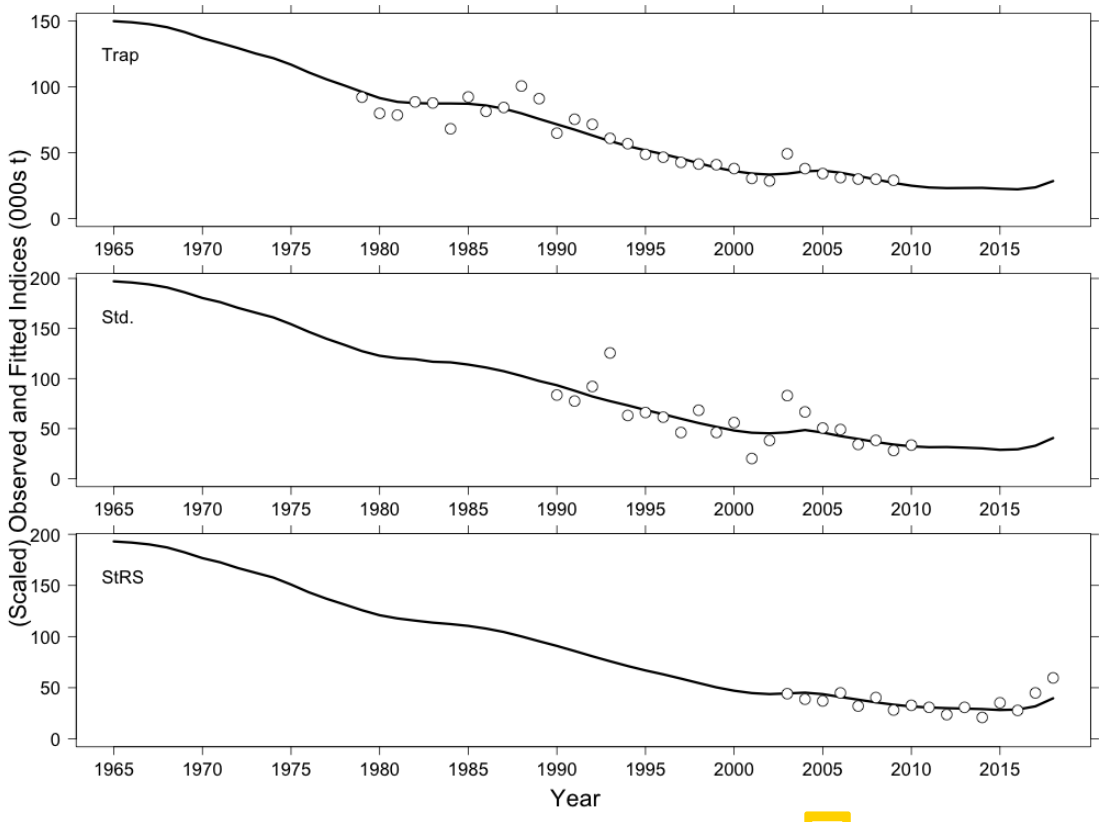

Figure 1. Operating model fits to biomass indices from the commercial trap fishery (Trap, top panel), standardized sablefish survey (Std., middle panel), and stratified random sablefish survey (StRS, bottom panel). Points show observations scaled by catchability, and lines show operating model vulnerable biomass.

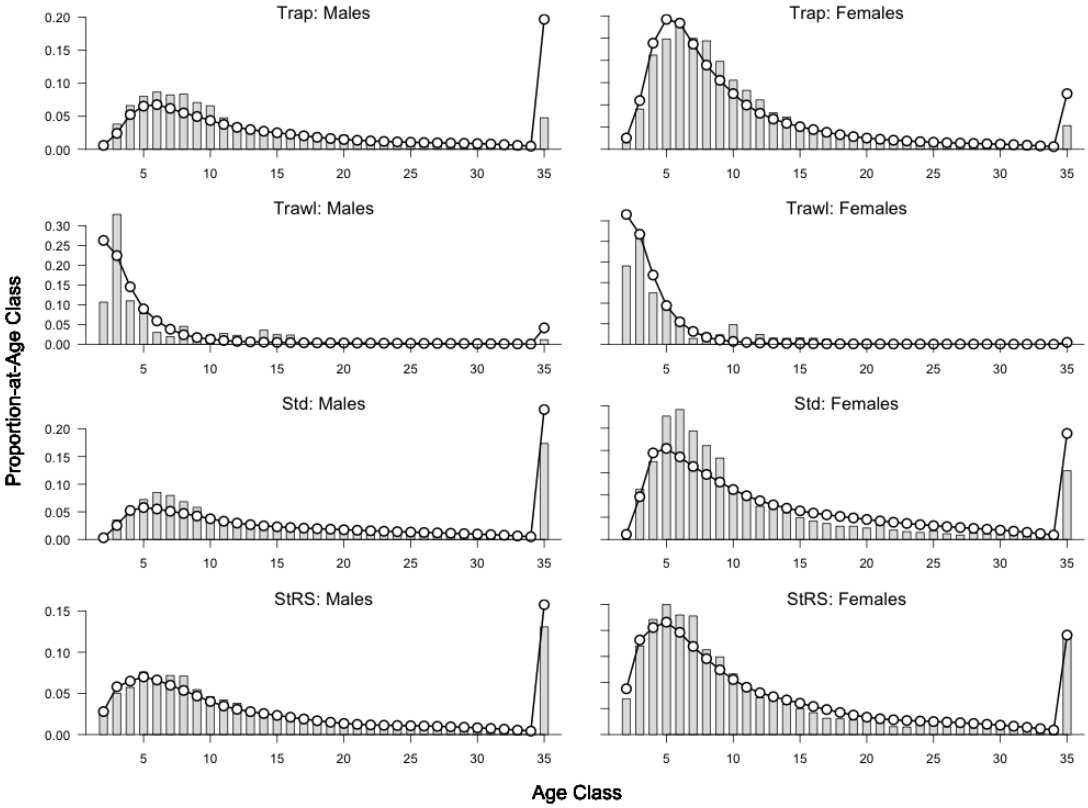

Figure 2. Averaged operating model fits to age observations for, from top to bottom, the commercial trap fishery (Trap), commercial trawl fishery (Trawl), standardized survey (Std.), and stratified random survey (StRS). Grey bars are the average proportion of age observations, and the points joined with a line show the average expected distribution of age observations in the operating model. Averages are taken over the years with observations.

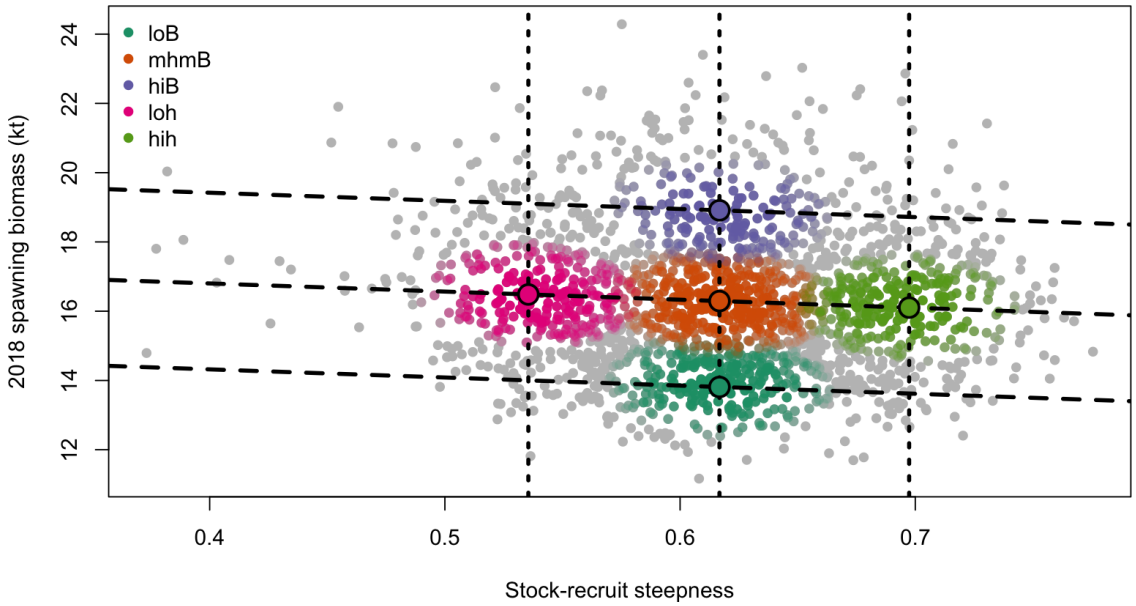

Figure 3. Joint marginal posterior distribution MCMC samples (grey dots) for stock-recruit steepness (h) and spawning biomass in 2018 (B_{2018}). Dashed lines indicate the mean, 10th and 90th percentiles of each marginal distribution, with the percentiles of the spawning biomass distribution adjusted 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/biomass operating model scenarios, 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.

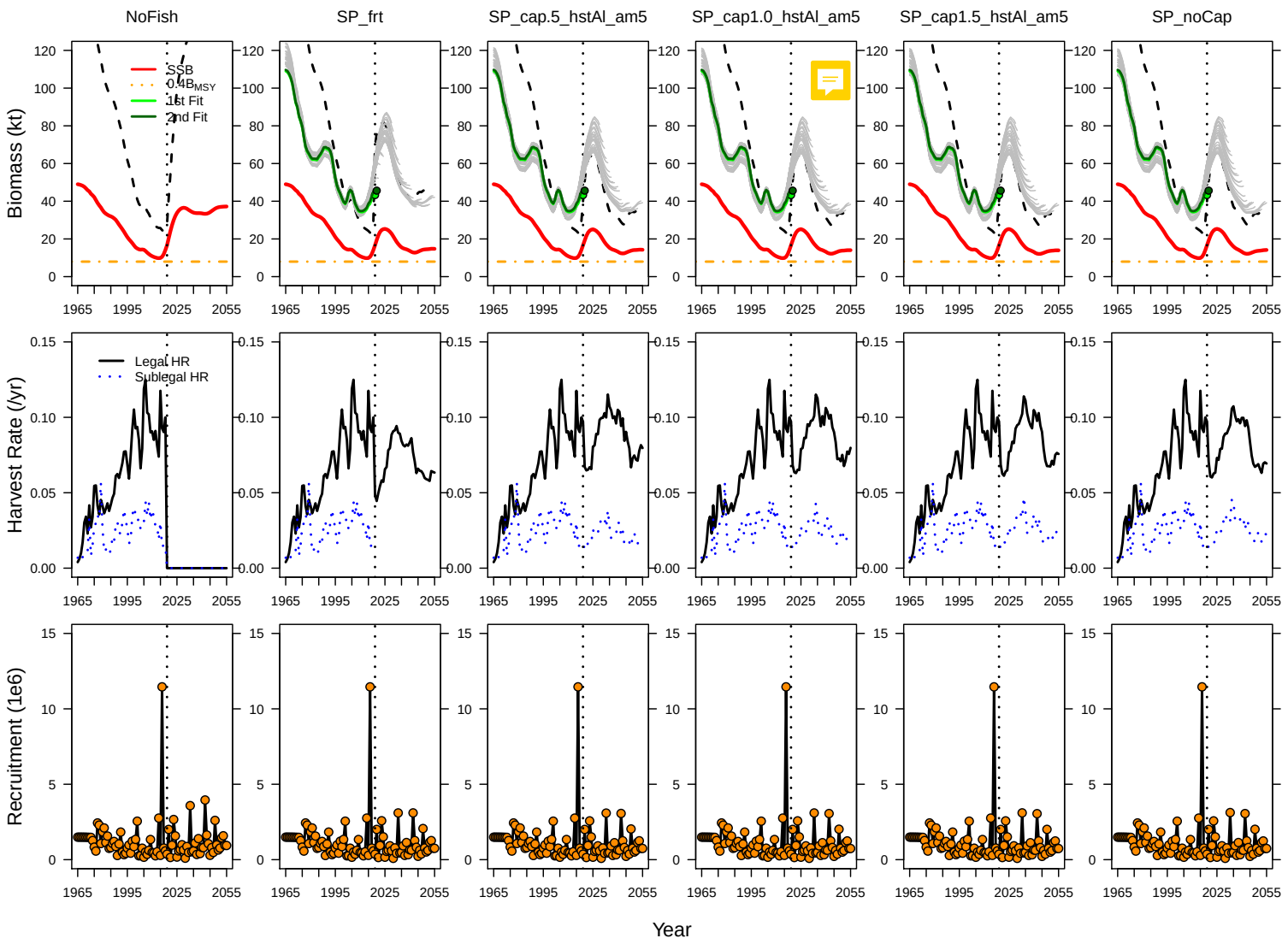

Figure 4. A single simulation replicate drawn from the reference set of high 2016 recruitment scenario operating models. The top row of panels show the spawning biomass and AM fits when estimated by an MP, the middle row shows the legal and sub-legal harvest rates, and the bottom row shows the OM recruitments.

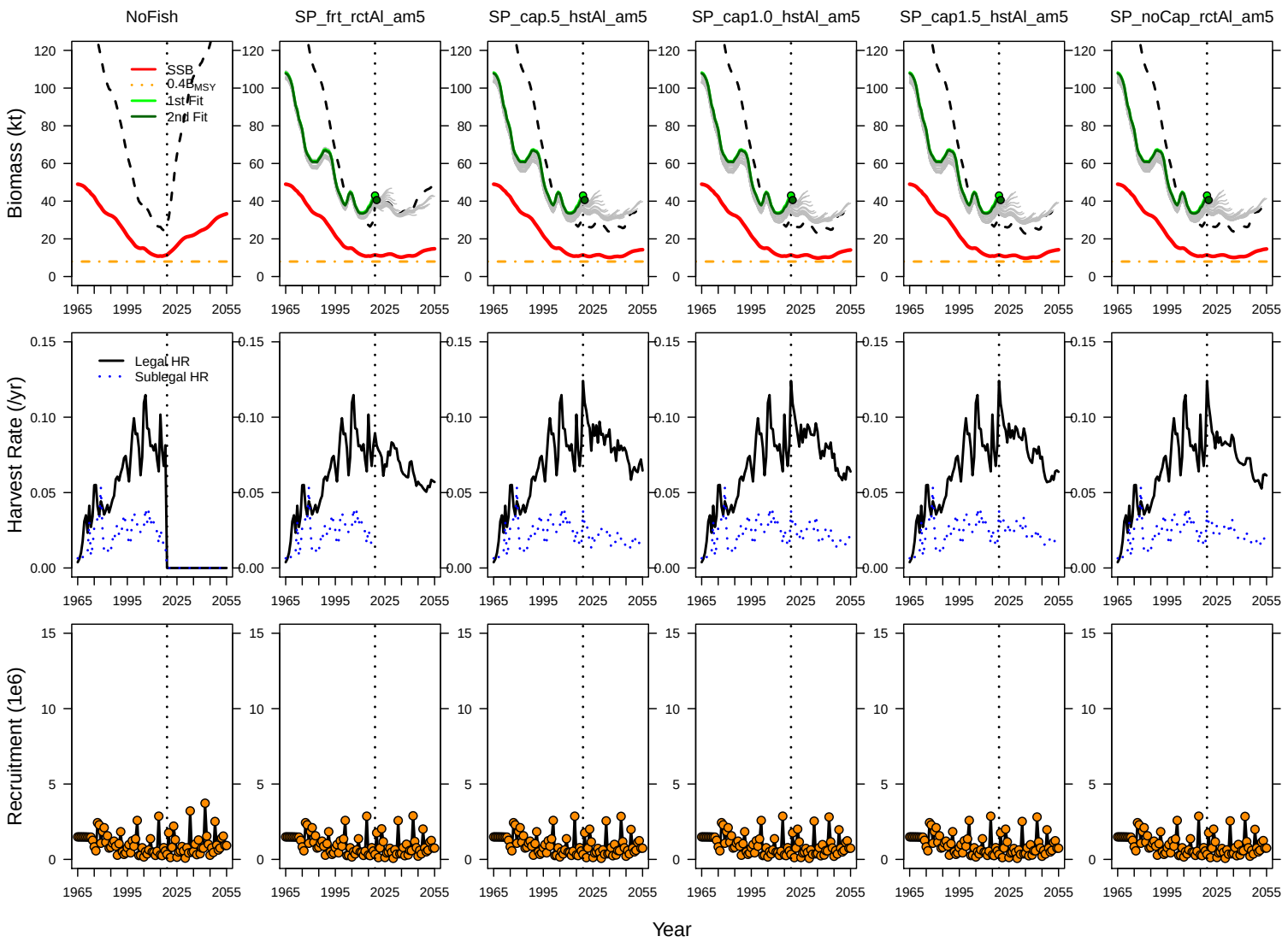

Figure 5. A single simulation replicate drawn from the reference set of high 2016 recruitment scenario operating models. The top row of panels show the spawning biomass and AM fits when estimated by an MP, the middle row shows the legal and sub-legal harvest rates, and the bottom row shows the OM recruitments.

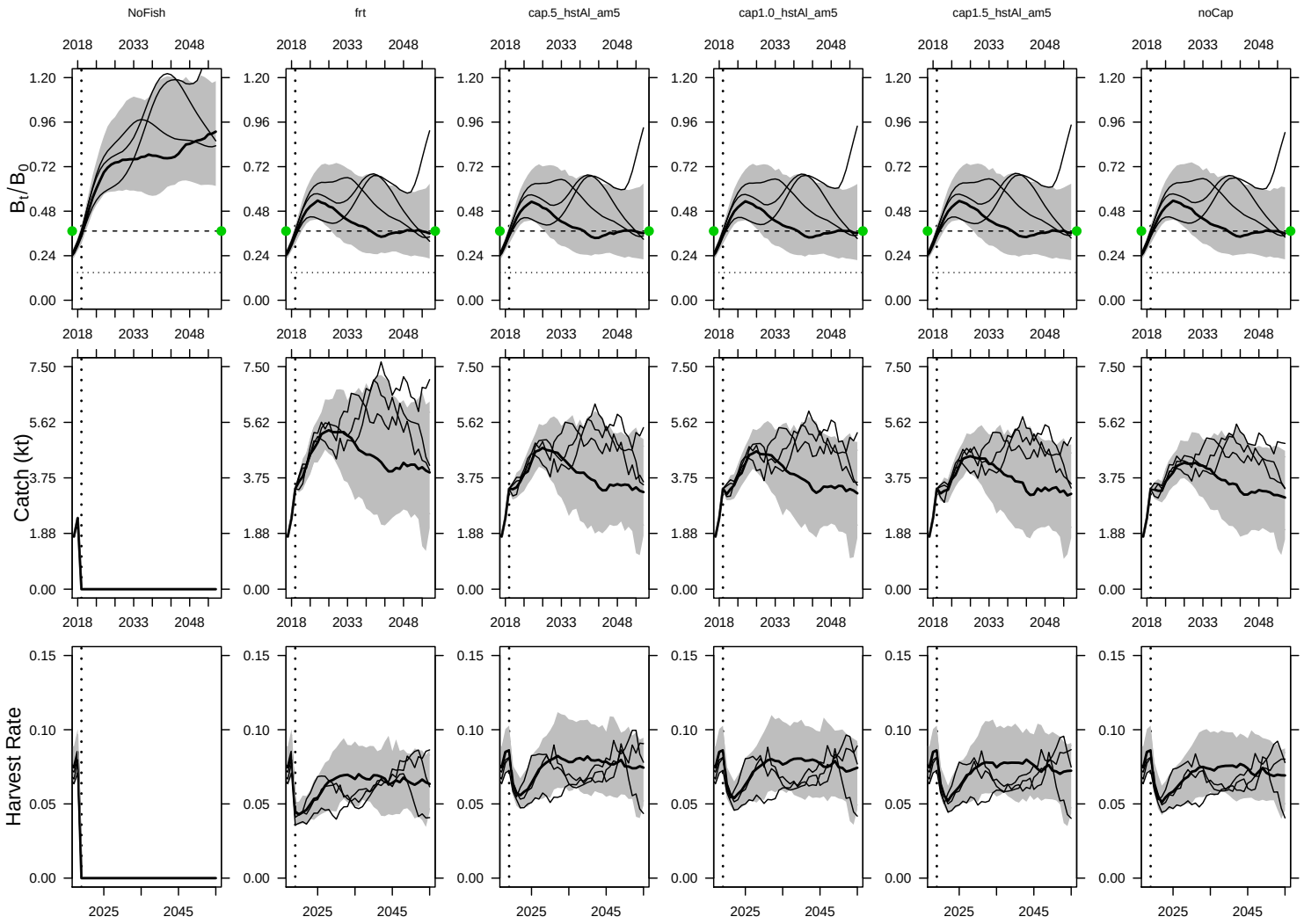

Figure 6. Weighted combined simulation envelopes from the 5 productivity and biomass operating models in the reference recruitment scenario, showing SP management procedures that applied the historical allocation of discarding, and amortized penalties over 5 years. The top row hows projected biomass relative to unfished, the second row shows the landed catch, and the bottom row shows the legal harvest rate.

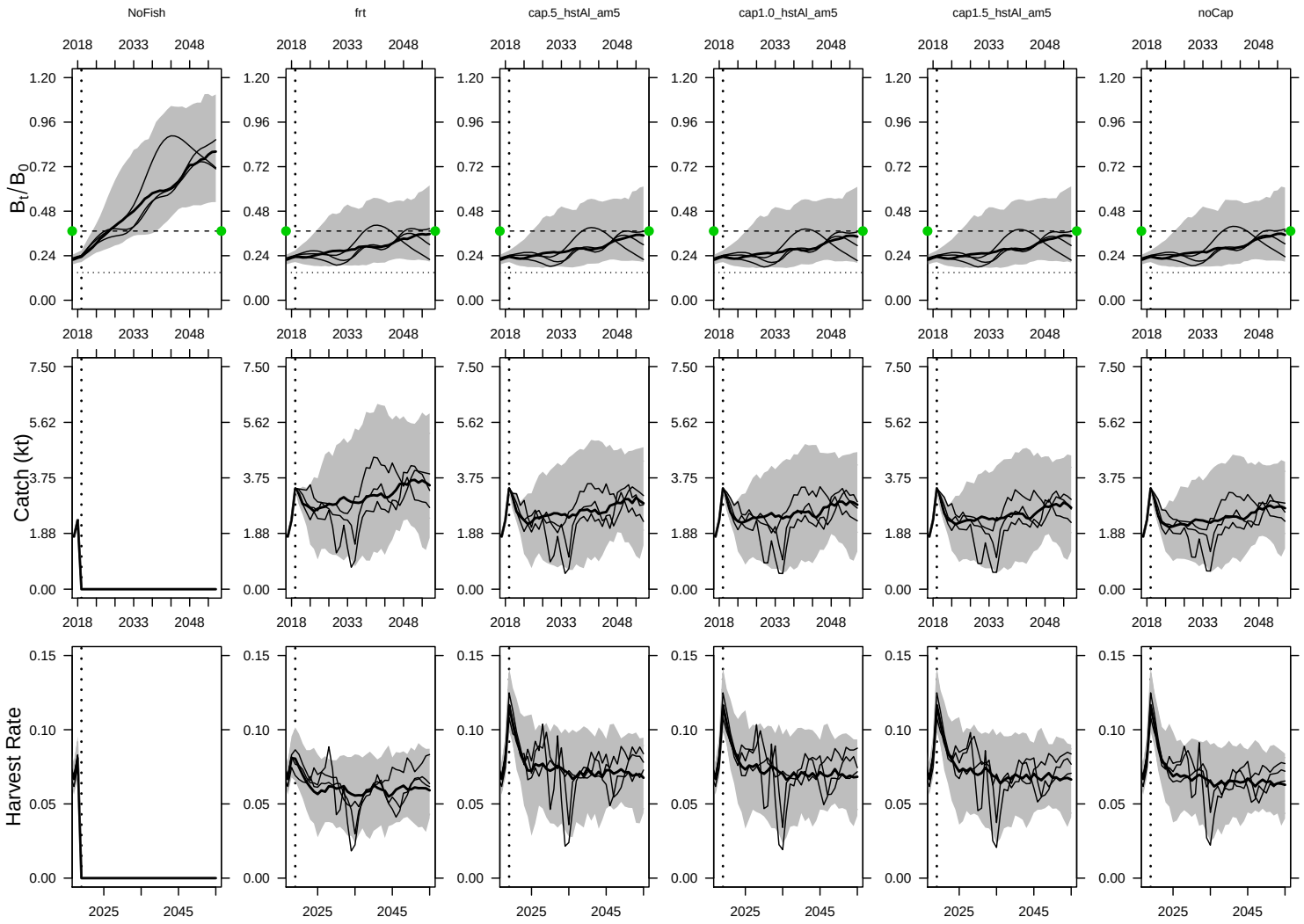

Figure 7. Weighted combined simulation envelopes from the 5 productivity and biomass operating models in the robustness recruitment scenario, showing SP management procedures that applied the historical allocation of discarding, and amortized penalties over 5 years. The top row hows projected biomass relative to unfished, the second row shows the landed catch, and the bottom row shows the legal harvest rate.

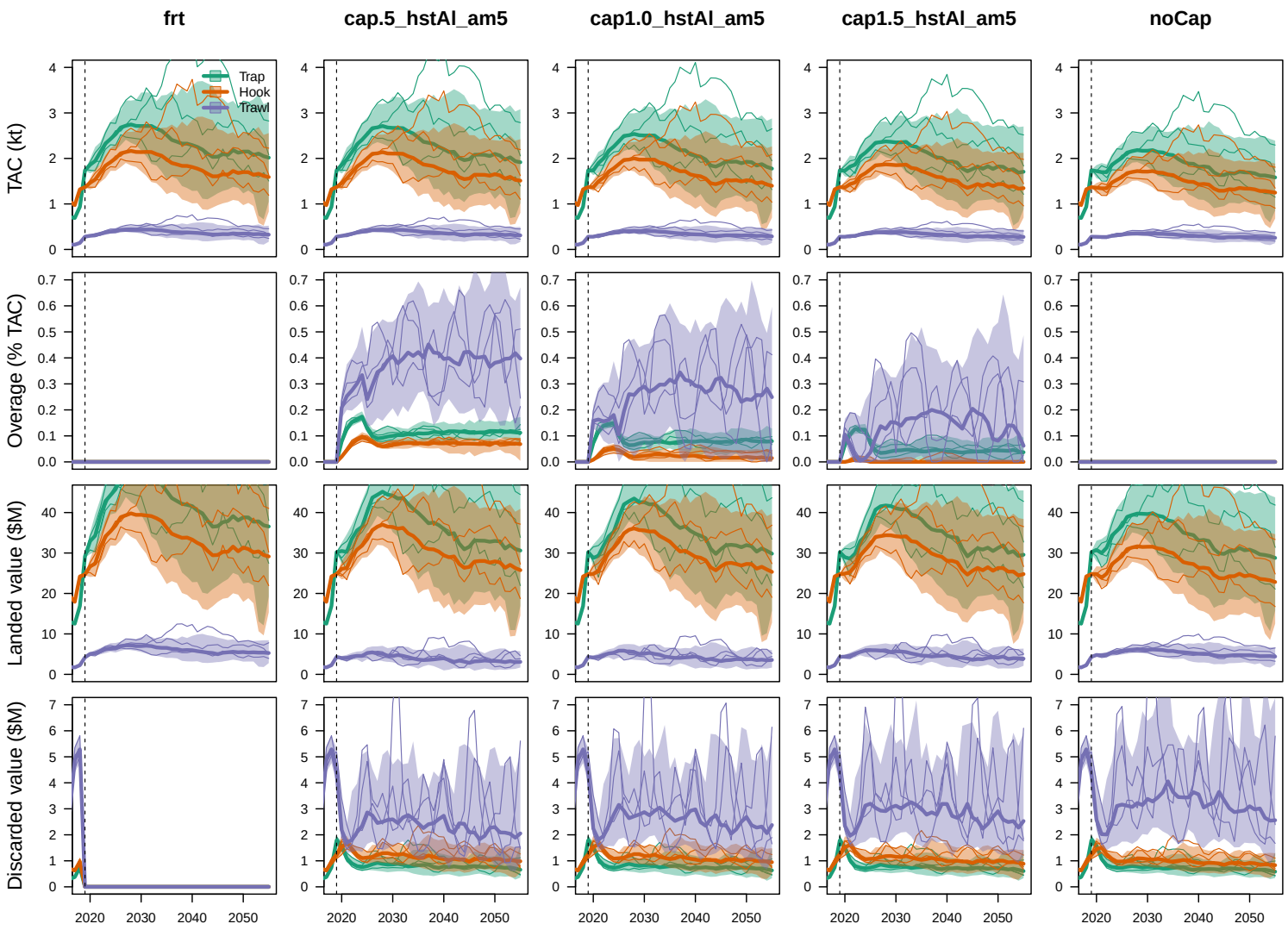

Figure 8. Simulation envelopes showing the effect of at-sea-release regulations by commercial sector under the reference recruitment scenario. Envelopes show decreasing restrictiveness of juvenile release caps from left to right. The top row shows the total available catch, the second row shows release overages as a percentage of the TAC, the third row shows the value of the landed catch, and the bottom row shows the value of released fish.

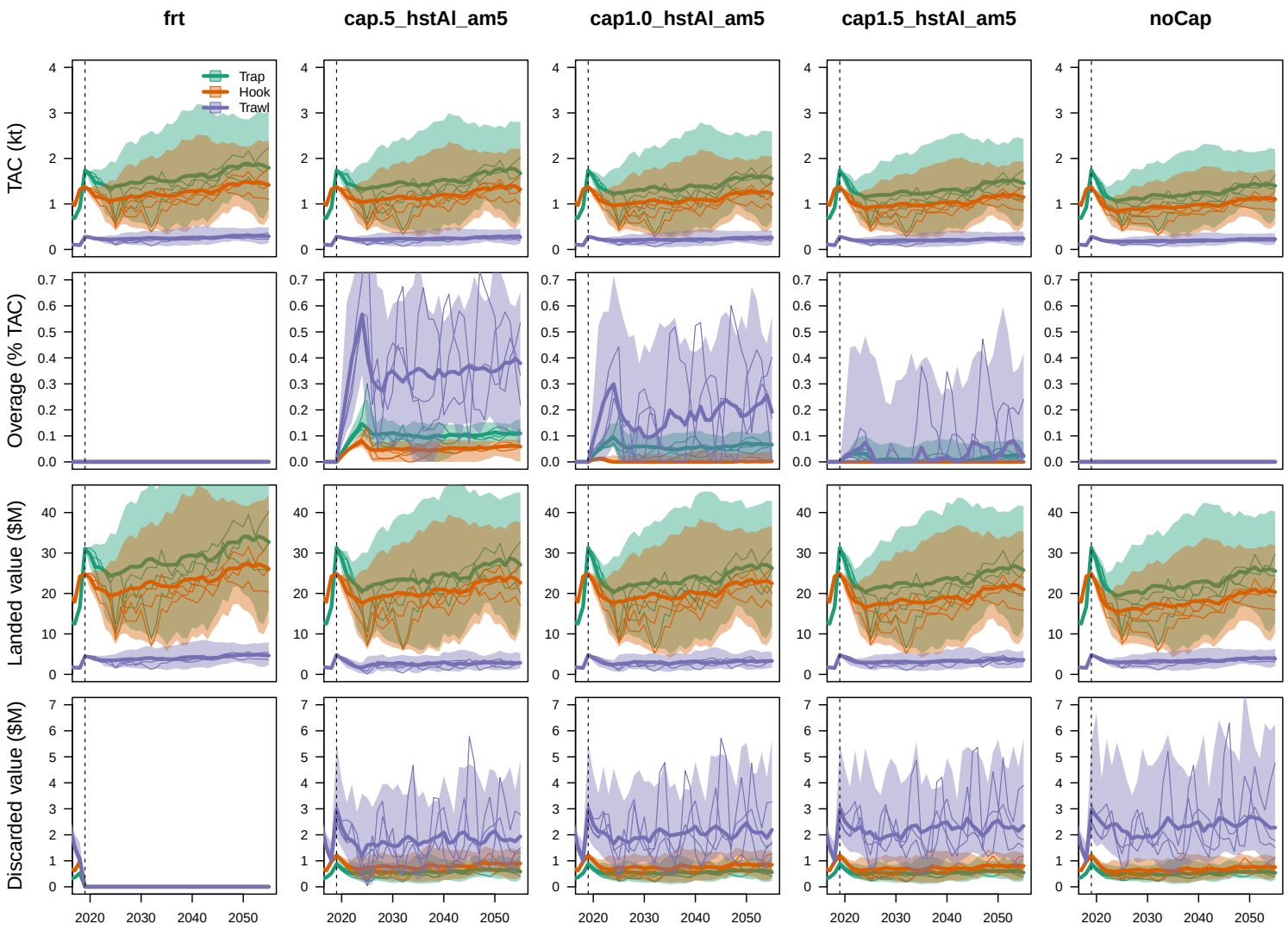

Figure 9. Simulation envelopes showing the effect of at-sea-release regulations by commercial sector under the robustness recruitment scenario. Envelopes show decreasing restrictiveness of juvenile release caps from left to right. The top row shows the total available catch, the second row shows release overages as a percentage of the TAC, the third row shows the value of the landed catch, and the bottom row shows the value of released fish.

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Centre for Science Advice
Pacific Region
[1]Pacific Biological Station
Fisheries and Oceans Canada, 3190 Hammond Bay Road
Nanaimo, British Columbia, V9T 6N7, Canada
[2]Far, far away
Another Galaxy
Telephone: (250) 756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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