Supplementary material; Long-term population trend of northern anchovy (*Engraulis mordax*) in the California Current system.

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Supplementary Appendix A: Fishery Catch Data

Catches (mt) were available from 1962-2021 from the major anchovy fishing regions off central California (Monterey Bay) and southern California (Los Angeles to Santa Barbara), USA, and from northern Baja California (Ensenada), Mexico. Landings from California were extracted from the Pacific Fisheries Information Network (PacFin) database 1950-2021, and landings from Mexico were obtained from Comisión Nacional de Acuacultura y Pesca's (CONAPESCA 2020) web archive for 1962-2018 and from Instituto Nacional de Pesca y Acuacultura (INAPESCA) for 2018 to 2021.

Biological samples were collected from catches off California by the CDFW from the ports of Monterey Bay, Santa Barbara, and San Pedro, 1967-1989 and 2015-2021, and used to derive fishery age-compositions and fishery mean weight-at-age estimates (Kuriyama *et al.* 2022). Biological samples were also collected from Ensenada, Mexico, from 1967-1989. For select hauls 25 individuals were collected, lengths and weights were measured, and otoliths were removed for ageing. Age compositions for the fishing fleet were the sums of catch-weighted age observations, with monthly landings within each port and season as the weighting unit. Fishery mean weight-at-age values were calculated for each season. Missing weight-at-age values were linearly interpolated by cohort. The biological data from California were assumed to be representative of the catch from both California and Mexico from 2015-2021, as similar biological data were not available for Mexico. This is an assumption also made by the benchmark anchovy assessment (Kuriyama *et al.* 2022). The sample sizes input for each fishing season's value was the total number of aged fish divided by the typical number of fish collected per sampled load (25 fish per sample).

Weight-at-age data are based on the time-step-specific weight-at-age from the combined port landings for year-time-steps when data were available (1967-1989 and 2015-2021). Weight-at-ages were assigned the mean weight for each age class from the year-seasons with fishery data for year-seasons when data were not available (1990-2014). Weights-at-age values were calculated by converting the abundance-at-length to biomass-at-length and hence to weight-at-age. Age determination for 2015-2021 data were based on the techniques described by Schwartzkopf *et al.* (2021), which used a June 1 birthdate based on the results of otolith edge and marginal increment analyses. Age determination for 1967-1989 data were based on techniques described by Collins and Spratt (1969), in which June 1 was also the birthdate assumed from an examination of when newly completed rings were formed in otoliths.

CONAPESCA (2020) Anuario Estad´ıstico de Acuacultura y Pesca. Available from https:www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca.

Pacific Fisheries Information Network (PacFIN) retrieval dated 02/28/2023, Pacific States Marine Fisheries Commission, Portland, Oregon (www.psmfc.org).

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Schwartzkopf, B.D., Dorval, E., James, K.C., Walker, J.M., Snodgrass, O.E., Porzio, D.L., and Erisman, B.E. (2021) A summary report of life history information on the central subpopulation of Northern Anchovy (*Engraulis mordax*) for the 2021 stock assessment. NOAA Technical Memorandum, NMFS NOAA-TM-NMFS-SWFSC-659

Collins R. A., and Spratt J. D. (1969) Age determination of northern anchovies, *Engraulis mordax*, from otoliths. *California Fish Game Bulletin, 147*, 39–55.

Supplementary Appendix B: Model Selection

The final base case model after the process of model selection contained the fishery catch, and biological data from the fishery and California Department of Fish and Wildlife (CDFW) and NOAA Southwest Fisheries Science Center Acoustic-Trawl (AT) surveys. Indices of abundance were the AT survey, CDFW sonar, daily egg production method (DEPM) and relative egg and larvae-derived SSB index (RELSSB). The Rockfish Recruitment and Ecosystem Assessment Survey (RREAS) young-of the-year (YOY) index was included as an index of recruitment (abundance of age-0 fish).

We outline below the model selection decisions taken to arrive at this model:

- Fitting the model using only the RELSSB index with catch, age-composition, and weight-at-age data from the fishery (model 1, Table S2) or those data plus the AT index and its associated biological data (model 2, Table S2) led to a Hessian matrix that was not positive definite (-266.025 and -180.29, respectively Table S2).
- The model converged with the addition of the CDFW index and its associated biological data (model 3, Table S2). The model with the RELSSB, AT, CDFW surveys and the fishery data had a small final gradient, and a positive definite Hessian matrix. M was estimated at 0.76 yr^{-1}, while the estimated biomass peaked at around 2.6 million mt age1+ biomass in 1973, with the peak in mid-2000s of around 0.5 million mt. There was a second peak in age 1+ biomass in 2021 of around 2.1 million mt. There was no evidence to reject the null hypothesis of the residuals of any index being randomly distributed based on a runs test (P > 0.05), and the root-mean squared error (RMSE) of the combined residuals decreased with the addition of the CDFW index (93.7%). Mean absolute scaled error (MASE) of the indices was 0.74. Retrospective bias over a 4-year period was increased with the addition of the CDFW data, although remained reasonable (ρ_M = -0.13) for a short-lived species (i.e., within -0.22 and 0.30; Hurtado-Ferro *et al.* 2015).
- The DEPM index data was then included as it was deemed to be the best survey index of biomass during the time period it was available (model 4, Table S2). Again, there was no evidence to reject the null hypothesis that the residuals of any index are randomly distributed based on a runs test (P > 0.05), and the RMSE of the combined residuals decreased with the addition of the DEPM index (91.4%). Retrospective bias was marginally reduced with the addition of the DEPM index (ρ_M = -0.12) and there was no change to the MASE. We retained this model since the DEPM index provided information on biomass scaling from 1979-1984 and the improved RMSE of the index

residuals. Integrating this data marginally reduced the estimated biomass from 1980-1985, and the estimate of M dropped to 0.73 yr^{-1} (Table S2).

- Given the lack of biological data available between 1990 and 2015, the RREAS YOY data were then included as a recruitment index (model 5, Table S2), which helped to inform the recruitment estimates between 2004 and 2015, increasing the year-to-year variability among recruitment deviations during this period. This model variant converged with a positive definite Hessian matrix and the fits to the other indices were not degraded. Again, there was no evidence to reject the null hypothesis of the residuals of the indices being randomly distributed based on a runs test ($P > 0.05$), and the RMSE of the combined residuals decreased to 87.5% (Fig. S7). The MASE was 0.79. Retrospective bias over a 4-year period increased marginally with the addition of the RREAS YOY, although remained reasonable (ρ_M = -0.14, Fig. S8). Estimates of age 1+ biomass reduced to 2.2 million mt at the peak during the 1970s, and biomass peaked at 2.1 million mt in 2021 (see Results; *Biomass* section for a full description of the biomass time series for this model variant). The addition of the RREAS YOY index reduced the estimate of M to 0.68 yr^{-1} (Table S2).
- We then added the additional SSB indices that were available starting with the RREAS (model 6, Table S2) followed by the California sea lion (CSL) diet SSB index (model 8, Table S2), as the spatial coverage and ability to separate population components by size was greater for the RREAS. The changes in estimated biomass and recruitment and the estimates of the parameters were inconsequential with the addition of these indices (Table S2). However, there was evidence to reject the null hypothesis that the residuals of the RREAS index were randomly distributed based on a runs test ($P = 0.001$), and the RMSE of the combined residuals increased to 101.6% and 94.2%, respectively. Retrospective bias remained unchanged with the addition of the RREAS index, and then increased with the addition of the CSL (ρ_M = -0.2). MASE was 0.87 and 0.95, respectively. As such, we chose to not retain either the RREAS or CSL SSB index in the final model.
- The recruitment index provided by the CSL data was not retained in the model because the fits to that index were poor (model 10, Table S2), evidenced by the predicted survey index values being outside the CVs of the data in 30% of years.
- We also investigated estimation of an additional variance term for the AT and CDFW surveys when the RREAS (model 7, Table S2) and CSL (model 9, Table S2) indices were included. This had the effect of reducing the biomass estimates of the recent peak post-2015. Including this parameter for the AT and CDFW biomass estimates had the effect of increasing the weighting of the age-composition data, as a result of forcing the model to estimate the weight of the AT and CDFW

indices based on the age-compositions. As we considered the AT index to be the best available survey estimate of biomass, and more reliable than the age composition data, we chose to not retain this model configuration.

Supplementary Tables

Table S1. Comparison of model configurations with alternative stock-recruitment relationship (S-R) and mortality (M yr^{-1}) parameter settings. For S-R options, h is steepness, σ_R is recruitment variance. For M options, Constant is constant mortality, Lorenzen is age-based Lorenzen mortality, and Prior is the age-based Lorenzen mortality with a prior of 5.4/3=1.8 (based on Hamel and Cope 2022). The base model is shown in the first row.

S-R option	M option	Objective function	M	M_{age-0}	M_{age-1}	M_{age-2}	M_{age-3+}	log(R0)
h=0.6, σ_R=1	Constant	213.973	0.68	-	-	-	-	17.36
	Lorenzen	216.647	0.80	1.25	0.73	0.66	0.54	17.87
	Prior	225.132	0.81	1.28	0.75	0.67	0.56	17.86
h=0.6, σ_R=0.75	Constant	222.809	0.71	-	-	-	-	17.39
	Lorenzen	223.457	0.84	1.32	0.77	0.7	0.57	17.88
	Prior	226.176	0.91	1.42	0.83	0.75	0.62	18.08
h=0.6, σ_R=1.25	Constant	216.487	0.67	-	-	-	-	17.60
	Lorenzen	217.422	0.78	1.22	0.71	0.64	0.53	18.00
	Prior	220.451	0.88	1.38	0.80	0.73	0.6	18.30
h=1, σ_R=1	Constant	221.691	0.67	-	-	-	-	17.23
	Lorenzen	222.454	0.80	1.25	0.73	0.66	0.54	17.71
	Prior	225.513	0.87	1.37	0.8	0.72	0.6	17.94
h=1, σ_R=0.75	Constant	229.957	0.69	-	-	-	-	17.35
	Lorenzen	230.558	0.82	1.29	0.75	0.68	0.56	17.85
	Prior	233.463	0.88	1.39	0.81	0.73	0.60	18.04
h=1, σ_R=1.25	Constant	219.49	0.64	-	-	-	-	17.25
	Lorenzen	220.324	0.74	1.17	0.68	0.62	0.51	17.64
	Prior	223.889	0.83	1.30	0.76	0.69	0.57	17.88

Table S2. Final gradient, Hessian matrix, objective function (OF), mean absolute scaled error (MASE), Mohn's Rho (ρ_M), root-mean squared error (RMSE), mortality (M yr^{-1}), and logarithm of equilibrium recruitment (ln(R_0)) estimates for models with different data sources included for model selection.

Model	Data	Maximum Gradient	Hessian Invertible	OF	MASE	ρ_M	RMSE	M yr^{-1}	ln(R_0)
1	RELSSB	9.36e-06	-266.03	108.1	-	-	-	-	-
2	RELSSB & AT	3.61E-06	-180.29	126.48	-	-	-	-	-
3	RELSSB, AT, & CDFW	9.32E-06	40.93	197.03	0.74	-0.13	93.2%	0.76	17.63
4	RELSSB, AT, CDFW, DEPM	4.86E-06	56.57	197.12	0.74	-0.13	91.4%	0.73	17.56
5	**RELSSB, AT, CDFW, DEPM, RREAS YOY**	3.56E-06	100.2	213.97	0.79	-0.14	87.5%	0.68	17.36
6	RELSSB, AT, CDFW, DEPM, RREAS YOY, RREAS Adult	5.72E-06	131.76	239.31	0.87	-0.13	101.6%	0.71	17.47
7	RELSSB, AT (add extra SD), CDFW (add extra SD), DEPM, RREAS YOY, RREAS Adult	2.67e-05	171.02	229.22	0.81	-0.09	112.4%	0.74	17.64
8	RELSSB, AT, CDFW, DEPM, RREAS YOY, RREAS Adult, CSL Adult	1.58E-05	164.1	236.92	0.95	-0.20	94.3%	0.67	17.28
9	RELSSB, AT (add extra SD), CDFW (add extra SD), DEPM, RREAS YOY, RREAS Adult, CSL Adult.	3.09E-06	191.19	222.37	0.88	-0.08	96.4%	0.69	17.37
10	RELSSB, AT, CDFW, DEPM, RREAS YOY, RREAS Adult, CSL Adult, CSL YOY	3.74E-06	198.37	310.48	1.35	0.04	85.5%	0.66	17.29
11	RELSSB, AT (add extra SD), CDFW (add extra SD), DEPM, RREAS YOY, RREAS Adult, CSL Adult, CSL YOY	3.84E-04	213.37	298.45	1.40	0.09	97.1%	0.69	17.43

Table S3. Calendar and model year (Y) and season (S) model estimates and standard deviations (SD) for spawning stock biomass (SSB), age1+ biomass (Age1+), number of recruits (billions of individuals) and log transformed recruitment deviations (RecDev). Note model years 1965 and 1966 were included in the 'early recruitment deviation' period in Stock Synthesis.

Calender Y-S	Model Y-S	SSB (mt)	SSB SD	Age1+ (mt)	Age1+ SD	Recruits (Billions)	Recruits SD	RecDev	RecDev SD
1965-2	1965-1	-	-	448590	164177	9.93	5.81	-1.12	0.5
1966-1	1965-2	542518	139337	-	-	-	-	-	-
1966-2	1966-1	-	-	613316	134740	52.34	17.2	0.64	0.18
1967-1	1966-2	374270	89594.7	-	-	-	-	-	-
1967-2	1967-1	-	-	390769	97039.4	46.99	15.73	0.43	0.2
1968-1	1967-2	665824	165901	-	-	-	-	-	-
1968-2	1968-1	-	-	599549	144014	79.67	26.83	0.96	0.18
1969-1	1968-2	701646	169984	-	-	-	-	-	-
1969-2	1969-1	-	-	742934	176959	191.14	62.07	1.81	0.15
1970-1	1969-2	973154	242040	-	-	-	-	-	-
1970-2	1970-1	-	-	1081460	267724	101.08	35.44	1.12	0.18
1971-1	1970-2	2000070	503304	-	-	-	-	-	-
1971-2	1971-1	-	-	1962230	466442	134.93	46.6	1.43	0.17
1972-1	1971-2	1788940	391364	-	-	-	-	-	-
1972-2	1972-1	-	-	1431170	292399	71.16	25.39	0.79	0.2
1973-1	1972-2	2227860	460326	-	-	-	-	-	-
1973-2	1973-1	-	-	2187190	412366	16.31	7.21	-0.65	0.32
1974-1	1973-2	1721870	302707	-	-	-	-	-	-
1974-2	1974-1	-	-	1660390	281124	14.36	4.23	-0.74	0.23
1975-1	1974-2	1370500	194296	-	-	-	-	-	-
1975-2	1975-1	-	-	1095140	145913	52.39	13.15	0.65	0.15
1976-1	1975-2	729109	78450.3	-	-	-	-	-	-
1976-2	1976-1	-	-	515888	50263.5	12.72	4.82	-0.72	0.36
1977-1	1976-2	608713	86629.4	-	-	-	-	-	-
1977-2	1977-1	-	-	689311	102863	120.34	24.46	1.68	0.12
1978-1	1977-2	342414	58202.4	-	-	-	-	-	-

1978-2	1978-1	-	-	318900	55892.9	80.07	16.4	1.08	0.15
1979-1	1978-2	986639	160401	-	-	-	-	-	-
1979-2	1979-1	-	-	919356	136426	66.56	11.47	0.92	0.15
1980-1	1979-2	895559	110639	-	-	-	-	-	-
1980-2	1980-1	-	-	995374	99722.4	14.88	3.77	-0.55	0.24
1981-1	1980-2	847689	83230.5	-	-	-	-	-	-
1981-2	1981-1	-	-	770348	63375.3	34.69	7.87	0.44	0.23
1982-1	1981-2	428492	49951.6	-	-	-	-	-	-
1982-2	1982-1	-	-	333496	41758.9	115.15	34.69	1.96	0.24
1983-1	1982-2	168049	31384.3	-	-	-	-	-	-
1983-2	1983-1	-	-	238428	55649.6	30.36	9.99	0.3	0.28
1984-1	1983-2	455915	122256	-	-	-	-	-	-
1984-2	1984-1	-	-	469888	124008	26.75	10.48	0.1	0.33
1985-1	1984-2	661577	185055	-	-	-	-	-	-
1985-2	1985-1	-	-	619589	178872	61.15	19.38	1.02	0.24
1986-1	1985-2	421700	123480	-	-	-	-	-	-
1986-2	1986-1	-	-	480662	143363	24.99	12.1	0.07	0.45
1987-1	1986-2	526831	149253	-	-	-	-	-	-
1987-2	1987-1	-	-	601930	187598	3.57	2.22	-1.83	0.55
1988-1	1987-2	431498	153422	-	-	-	-	-	-
1988-2	1988-1	-	-	446198	162466	22.65	18.21	0.15	0.7
1989-1	1988-2	270739	118093	-	-	-	-	-	-
1989-2	1989-1	-	-	212579	97724.6	12.03	10.52	-0.46	0.84
1990-1	1989-2	251918	151043	-	-	-	-	-	-
1990-2	1990-1	-	-	228383	155517	10.5	9.04	-0.58	0.81
1991-1	1990-2	240791	135048	-	-	-	-	-	-
1991-2	1991-1	-	-	215573	125745	11.89	10.39	-0.42	0.84
1992-1	1991-2	220443	114632	-	-	-	-	-	-
1992-2	1992-1	-	-	201008	106177	14.54	12.63	-0.22	0.85
1993-1	1992-2	220556	107558	-	-	-	-	-	-
1993-2	1993-1	-	-	202076	102884	12.57	10.96	-0.4	0.83

1994-1	1993-2	240139	109814	-	-	-	-	-	-
1994-2	1994-1	-	-	225196	109987	14.88	12.75	-0.23	0.83
1995-1	1994-2	243113	109386	-	-	-	-	-	-
1995-2	1995-1	-	-	224032	107046	10.83	9.31	-0.55	0.81
1996-1	1995-2	244074	109041	-	-	-	-	-	-
1996-2	1996-1	-	-	227213	109000	10.36	8.98	-0.58	0.82
1997-1	1996-2	231541	102892	-	-	-	-	-	-
1997-2	1997-1	-	-	207473	98314.2	12.48	11.12	-0.36	0.85
1998-1	1997-2	216051	97886.5	-	-	-	-	-	-
1998-2	1998-1	-	-	196594	94060.6	14.14	13.15	-0.25	0.89
1999-1	1998-2	223681	103427	-	-	-	-	-	-
1999-2	1999-1	-	-	204865	103017	15.64	14.64	-0.17	0.9
2000-1	1999-2	236327	118707	-	-	-	-	-	-
2000-2	2000-1	-	-	209717	116462	15.6	15.05	-0.22	0.92
2001-1	2000-2	266165	140379	-	-	-	-	-	-
2001-2	2001-1	-	-	215115	129187	19.66	20.28	0	0.99
2002-1	2001-2	274378	154252	-	-	-	-	-	-
2002-2	2002-1	-	-	236391	140910	34.39	33.29	0.51	0.95
2003-1	2002-2	321176	188498	-	-	-	-	-	-
2003-2	2003-1	-	-	281057	176508	12.73	12.88	-0.58	0.95
2004-1	2003-2	461847	246536	-	-	-	-	-	-
2004-2	2004-1	-	-	413003	239166	10.81	8.59	-0.71	0.71
2005-1	2004-2	407212	196840	-	-	-	-	-	-
2005-2	2005-1	-	-	329259	163361	5.29	4.39	-1.36	0.74
2006-1	2005-2	324078	148476	-	-	-	-	-	-
2006-2	2006-1	-	-	255377	119779	4.68	3.73	-1.37	0.7
2007-1	2006-2	229135	103268	-	-	-	-	-	-
2007-2	2007-1	-	-	167989	78860.2	3.06	2.54	-1.64	0.74
2008-1	2007-2	159185	72081	-	-	-	-	-	-
2008-2	2008-1	-	-	115847	56082.3	3.28	2.45	-1.36	0.69
2009-1	2008-2	105635	50937.1	-	-	-	-	-	-

2009-2	2009-1	-	-	79528.4	39706.9	2.61	1.88	-1.44	0.69
2010-1	2009-2	83036.5	38198.1	-	-	-	-	-	-
2010-2	2010-1	-	-	67026.4	30792.5	2.87	1.68	-1.21	0.68
2011-1	2010-2	66542.3	28164.7	-	-	-	-	-	-
2011-2	2011-1	-	-	51078.6	22684.9	4.98	2.27	-0.57	0.52
2012-1	2011-2	58251.4	17730.9	-	-	-	-	-	-
2012-2	2012-1	-	-	46369.2	14158.8	4.05	1.46	-0.9	0.4
2013-1	2012-2	69821.1	15502.1	-	-	-	-	-	-
2013-2	2013-1	-	-	61703.4	14227.9	4.1	1.32	-0.88	0.35
2014-1	2013-2	69206.5	11243.7	-	-	-	-	-	-
2014-2	2014-1	-	-	49142.6	9225.35	23.44	5.78	0.91	0.26
2015-1	2014-2	65313.3	10277.9	-	-	-	-	-	-
2015-2	2015-1	-	-	33290.3	6666.26	28.67	8.53	0.56	0.28
2016-1	2015-2	173770	38993.9	-	-	-	-	-	-
2016-2	2016-1	-	-	153576	35148.4	49.46	12.5	0.82	0.24
2017-1	2016-2	396732	80840.9	-	-	-	-	-	-
2017-2	2017-1	-	-	399510	83174.2	43.96	14.12	0.56	0.31
2018-1	2017-2	689075	108112	-	-	-	-	-	-
2018-2	2018-1	-	-	577471	89278.3	85.35	41.69	1.14	0.44
2019-1	2018-2	789281	124966	-	-	-	-	-	-
2019-2	2019-1	-	-	591386	90580.3	229.98	60.91	2.02	0.31
2020-1	2019-2	1229870	360211	-	-	-	-	-	-
2020-2	2020-1	-	-	926314	257276	24.32	23.26	-0.32	0.89
2021-1	2020-2	1865880	264602	-	-	-	-	-	-
2021-2	2021-1	-	-	2140080	328486	30.18	31.5	-0.16	0.99
2022-1	2021-2	1723270	259253	-	-	-	-	-	-

Table S4. Additional estimated parameters. Ln(Q) is the estimate of catchability of the relative indices. Q extra SD is the estimated extra variance parameters. Early InitAge 3, 2 and 1 are the first three early recruit deviation estimates. Early RecDev 1965 and 1966 are the additional early recruitment deviations. AgeSel is the age-selectivity parameter estimate for age 1 (A1), age 2 (A2) and age 3+ (A3), for season 1 (S1) and season 2 (S2), and for time varying blocks (Block-X) where X is the first year of the block.

Parameter	Estimate	Asymptotic SD
Ln(Q) RREAS YOY	-17.99	0.5
Ln(Q) CDFW Sonar	1.88	0.26
Ln(Q) RELSSB	-6.8	0.22
Q extra SD DEPM	0.38	0.18
Q extra SD RREAS YOY	0.64	0.31
Q extra SD RELSSB	0.45	0.1
Early InitAge 3	-0.19	0.85
Early InitAge 2	-0.23	0.85
Early InitAge 1	-0.4	0.71
Early RecDev 1965	-1.12	0.50
Early RecDev 1966	0.64	0.18
AgeSel A1 MexCal S1	8.34	16.38
AgeSel A2 MexCal S1	2	2.72
AgeSel A3 MexCal S1	0	0.2
AgeSel A1 MexCal S2	3.25	2.57
AgeSel A2 MexCal S2	0.67	1.56
AgeSel A3 MexCal S2	0.47	0.26
AgeSel A1 AT summer	0.86	0.56
AgeSel A1 AT spring	2.78	1.34
AgeSel A1 CDFW Sonar	6.12	54.93
AgeSel A2 CDFW Sonar	0.31	8.41
AgeSel A3 CDFW Sonar	3.85	8.21
AgeSel A1 MexCal S1 Block-1968	5.72	6.98
AgeSel A1 MexCal S1 Block-1970	8.92	2.46
AgeSel A1 MexCal S1 Block-1976	2	0.68
AgeSel A1 MexCal S1 Block-1977	0.28	0.59
AgeSel A1 MexCal S1 Block-1978	2.22	0.3
AgeSel A1 MexCal S1 Block-1982	1.96	0.37
AgeSel A1 MexCal S1 Block-1984	-0.73	0.44
AgeSel A1 MexCal S1 Block-1986	1.64	0.46
AgeSel A1 MexCal S1 Block-1988	-2.55	1.37
AgeSel A1 MexCal S1 Block-1990	2.04	0.76
AgeSel A1 MexCal S1 Block-2016	1.48	0.92
AgeSel A1 MexCal S1 Block-2017	4.22	4.16
AgeSel A1 MexCal S1 Block-2018	8.61	10.4
AgeSel A1 MexCal S1 Block-2019	8.66	9.22

AgeSel A1 MexCal S1 Block-2020	8.7	8.38
AgeSel A2 MexCal S1 Block-1968	1.49	0.3
AgeSel A2 MexCal S1 Block-1970	1.85	0.21
AgeSel A2 MexCal S1 Block-1976	1.18	0.53
AgeSel A2 MexCal S1 Block-1977	2.08	0.32
AgeSel A2 MexCal S1 Block-1978	0.57	0.25
AgeSel A2 MexCal S1 Block-1982	0.8	0.32
AgeSel A2 MexCal S1 Block-1984	0	0.54
AgeSel A2 MexCal S1 Block-1986	-3.02	0.7
AgeSel A2 MexCal S1 Block-1988	1.08	0.83
AgeSel A2 MexCal S1 Block-1990	1.48	0.86
AgeSel A2 MexCal S1 Block-2016	0.88	1.94
AgeSel A2 MexCal S1 Block-2017	1.78	0.82
AgeSel A2 MexCal S1 Block-2018	0.96	0.48
AgeSel A2 MexCal S1 Block-2019	1.38	0.59
AgeSel A2 MexCal S1 Block-2020	1.55	0.85
AgeSel A1 MexCal S2 Block-1968	1.02	0.3
AgeSel A1 MexCal S2 Block-1970	2.1	0.32
AgeSel A1 MexCal S2 Block-1976	-0.27	1.22
AgeSel A1 MexCal S2 Block-1977	2.54	115.6
AgeSel A1 MexCal S2 Block-1978	0.97	0.22
AgeSel A1 MexCal S2 Block-1982	-5.14	19.2
AgeSel A1 MexCal S2 Block-1984	-0.74	0.51
AgeSel A1 MexCal S2 Block-1986	0.13	0.85
AgeSel A1 MexCal S2 Block-1988	-1.91	2.41
AgeSel A1 MexCal S2 Block-1990	1.73	0.68
AgeSel A1 MexCal S2 Block-2016	-4.13	38.96
AgeSel A1 MexCal S2 Block-2017	0.74	0.7
AgeSel A1 MexCal S2 Block-2018	1.1	0.72
AgeSel A1 MexCal S2 Block-2019	2.64	1.01
AgeSel A1 MexCal S2 Block-2020	-0.31	3.65
AgeSel A2 MexCal S2 Block-1968	-0.25	0.38
AgeSel A2 MexCal S2 Block-1970	0.44	0.2
AgeSel A2 MexCal S2 Block-1976	0.9	1.22
AgeSel A2 MexCal S2 Block-1977	8.31	17
AgeSel A2 MexCal S2 Block-1978	0.48	0.29
AgeSel A2 MexCal S2 Block-1982	3.76	19.49
AgeSel A2 MexCal S2 Block-1984	-1.22	0.89
AgeSel A2 MexCal S2 Block-1986	-1.66	1.22
AgeSel A2 MexCal S2 Block-1988	-1.01	0.91
AgeSel A2 MexCal S2 Block-1990	1.18	0.91
AgeSel A2 MexCal S2 Block-2016	-1.5	78.11
AgeSel A2 MexCal S2 Block-2017	-0.04	0.97

AgeSel A2 MexCal S2 Block-2018	0.11	0.77
AgeSel A2 MexCal S2 Block-2019	-0.31	0.74
AgeSel A2 MexCal S2 Block-2020	-0.16	5.67
AgeSel A1 AT summer Block-2016	2.44	1.14
AgeSel A1 AT summer Block-2017	2.94	1.76
AgeSel A1 AT summer Block-2018	1.06	0.59
AgeSel A1 AT summer Block-2019	0.41	0.56
AgeSel A1 AT spring Block-2020	0.95	0.38
AgeSel A1 CDFW Sonar Block-1967	8.54	12.11
AgeSel A1 CDFW Sonar Block-1970	8.25	18.22
AgeSel A1 CDFW Sonar Block-1976	8.82	5.21
AgeSel A1 CDFW Sonar Block-1977	6.98	40.21
AgeSel A1 CDFW Sonar Block-1978	8.92	2.37
AgeSel A1 CDFW Sonar Block-1982	8.97	0.83
AgeSel A1 CDFW Sonar Block-1984	8.57	11.49
AgeSel A2 CDFW Sonar Block-1967	0.05	1.23
AgeSel A2 CDFW Sonar Block-1970	1.5	1.61
AgeSel A2 CDFW Sonar Block-1976	0	0.02
AgeSel A2 CDFW Sonar Block-1977	5.01	2.13
AgeSel A2 CDFW Sonar Block-1978	1.04	0.82
AgeSel A2 CDFW Sonar Block-1982	0	0.04
AgeSel A2 CDFW Sonar Block-1984	1.33	0.75
AgeSel A3 CDFW Sonar Block-1967	2.45	1.1
AgeSel A3 CDFW Sonar Block-1970	2.93	1.11
AgeSel A3 CDFW Sonar Block-1976	0	0.03
AgeSel A3 CDFW Sonar Block-1977	0	0.02
AgeSel A3 CDFW Sonar Block-1978	1.59	0.66
AgeSel A3 CDFW Sonar Block-1982	0	0.03
AgeSel A3 CDFW Sonar Block-1984	0.2	0.82

Figures

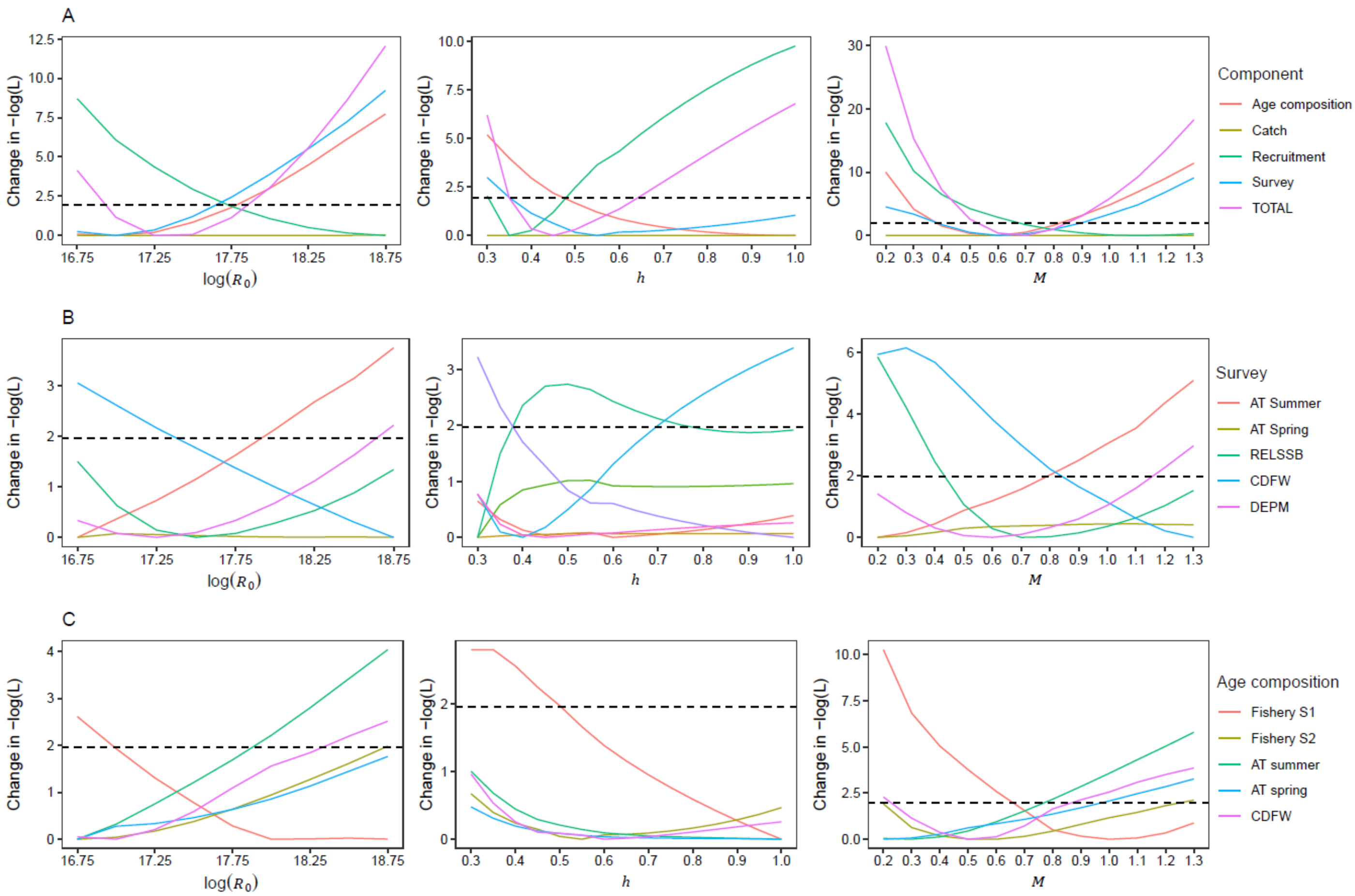

Figure S1. Likelihood component profiles for the logarithm of equilibrium recruitment (log(R_0)), stock-recruitment steepness (h), and natural mortality (M), by A) data components, B) survey data source and C) age-composition data source.

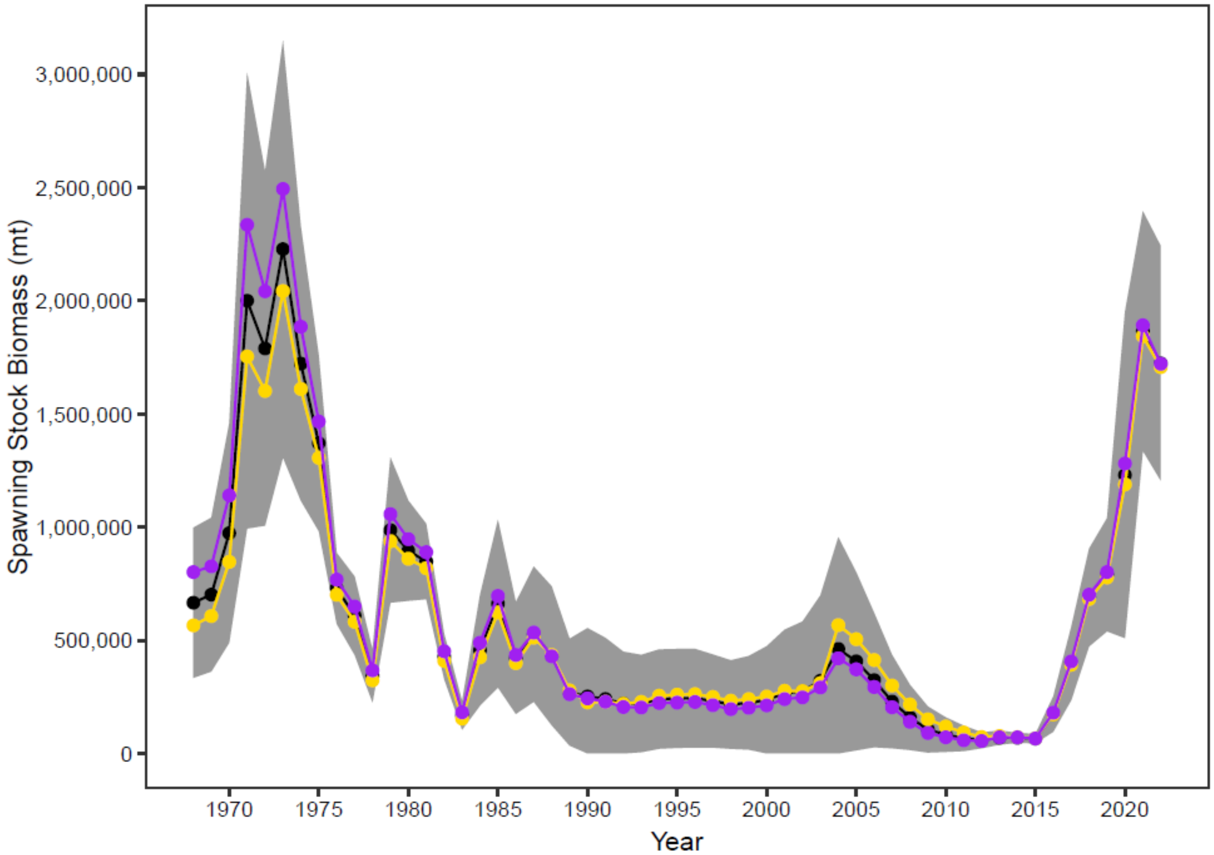

Figure S2. Spawning stock biomass (mt) estimates for base model variants with steepness set at *h* = 0.45 (purple points), 0.6 (black points) and 1 (yellow points).

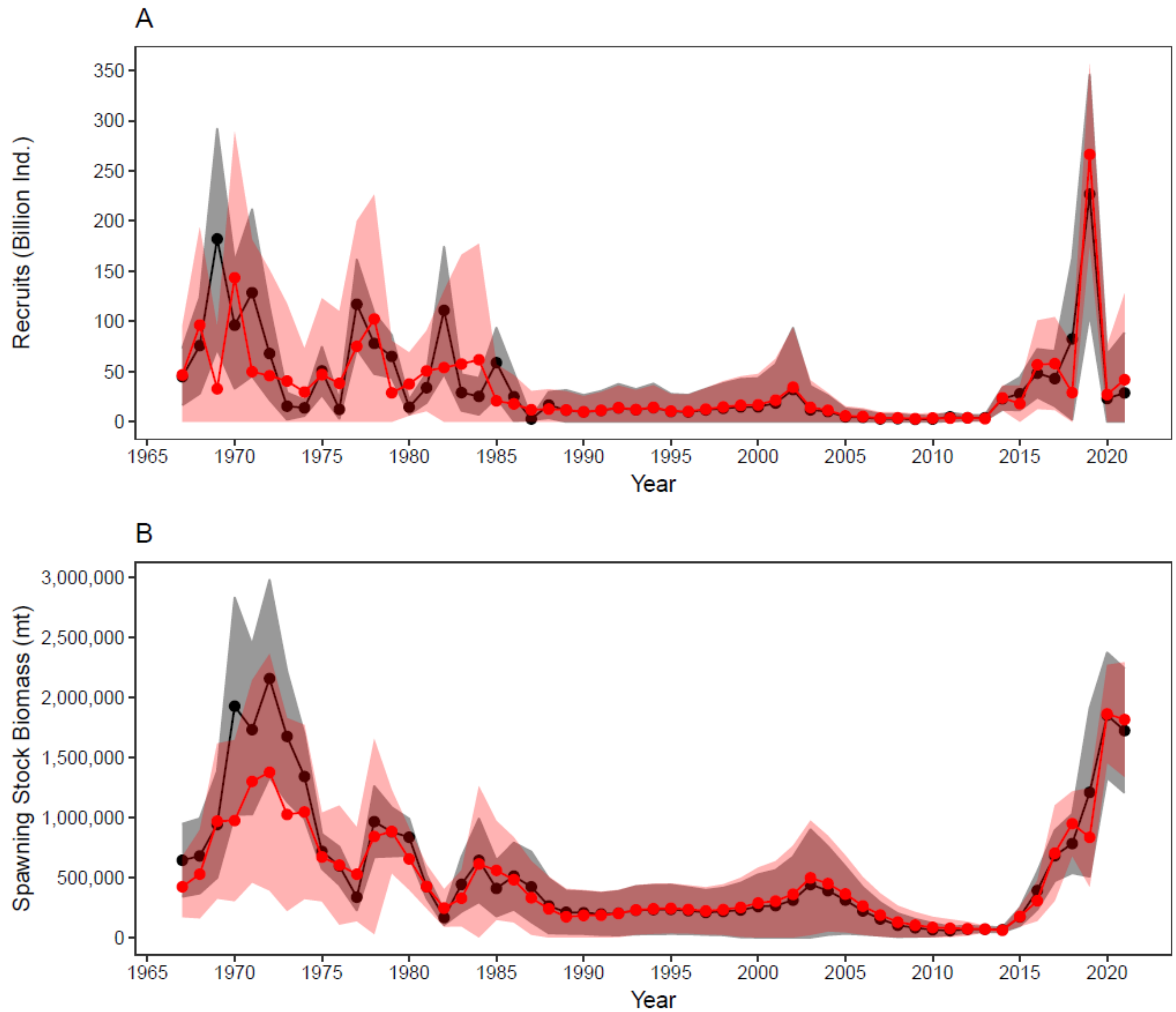

Figure S3. Comparison of base case (black) and ASPM-r (red) output. A) recruits and B) Spawning Stock Biomass time series.

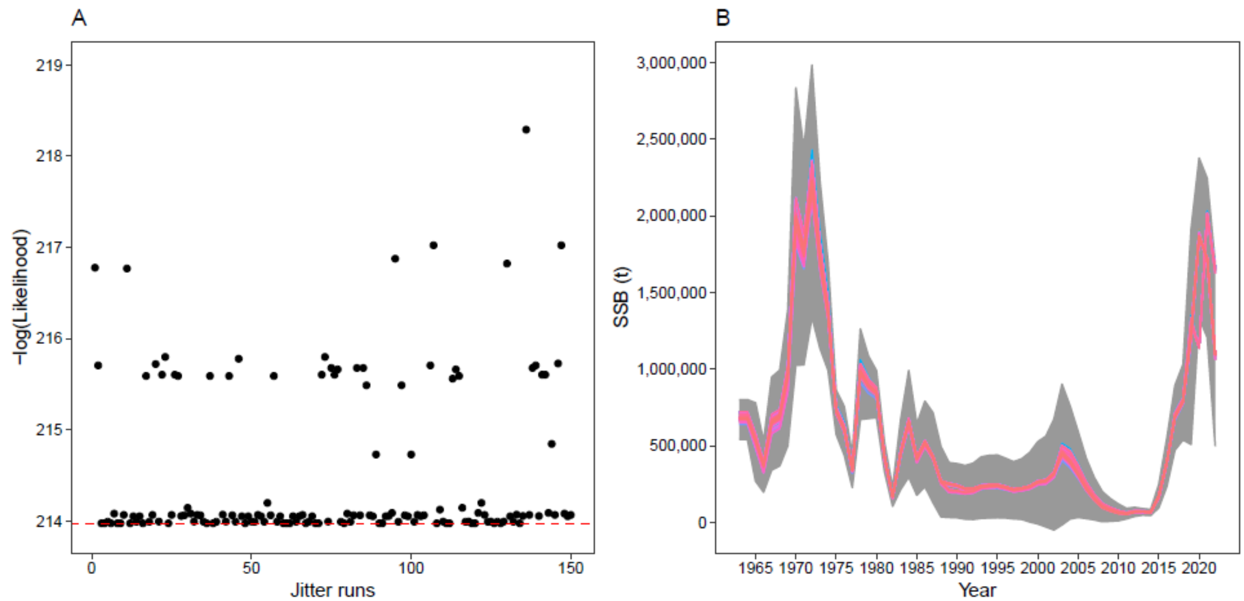

Figure S4. Results from 150 jitters of starting values by 10%. A) Total likelihoods from 149 converged runs of 150 total runs, B) SSB timeseries for each converged run shown in different coloured lines, with 95% confidence intervals of base model shown in grey ribbon.

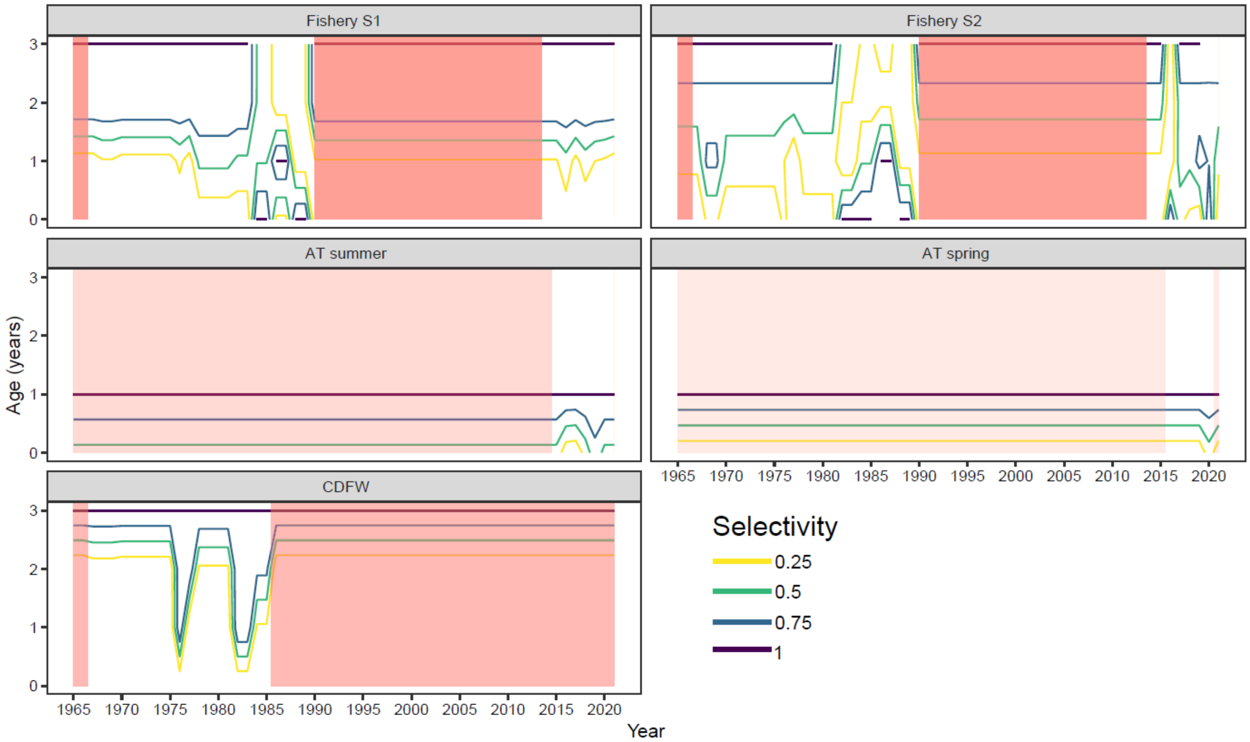

Figure S5. Time-varying age-selectivity for each fleet for the selected model configuration. Contours show age (years) at age-selectivity of 0.25, 0.5, 0.75 and 1. Red boxes show years without data.

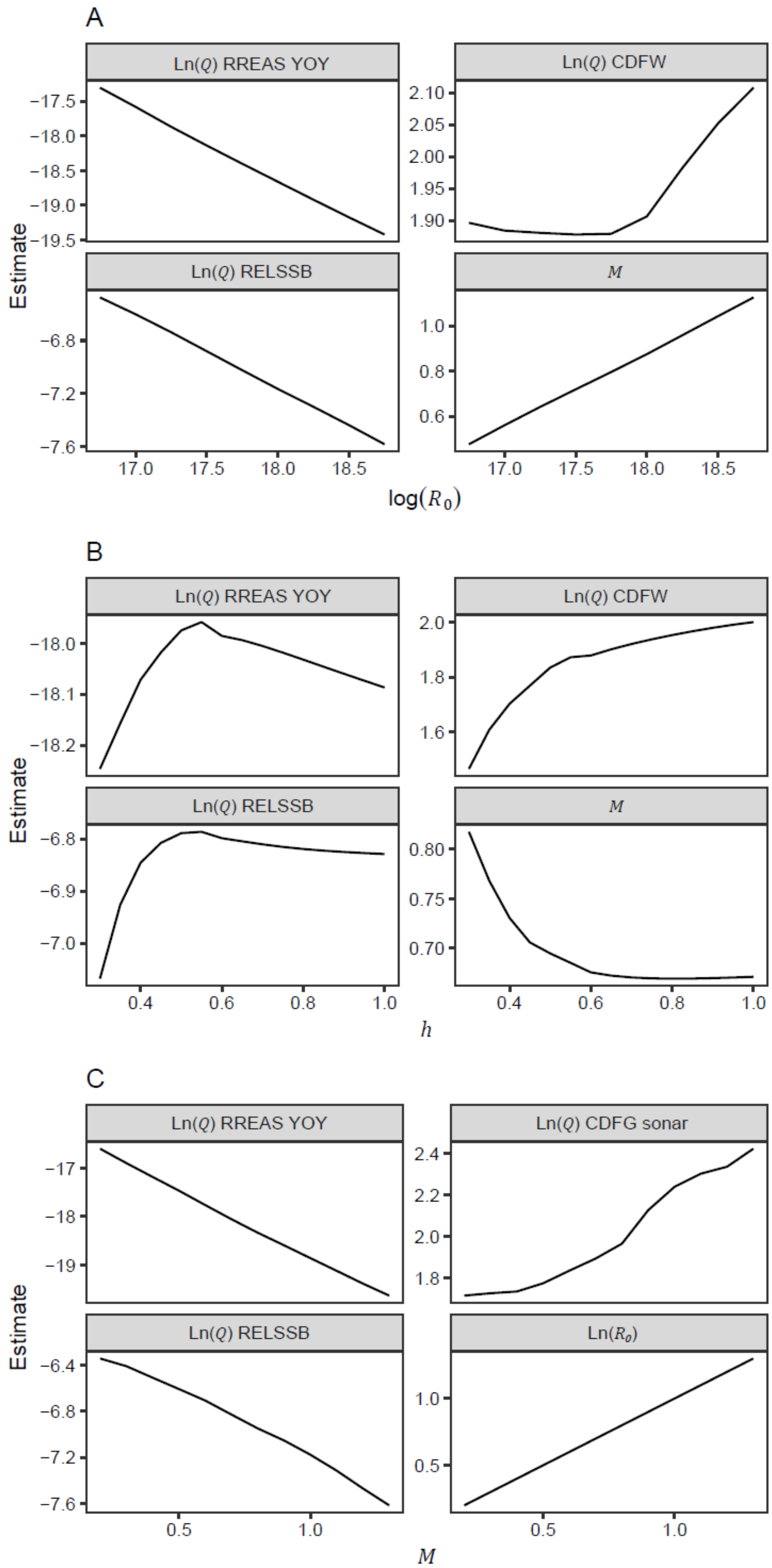

Figure S6. Parameter estimate profiles for A) equilibrium recruitment (log(R_0)), B) steepness (h), and C) natural mortality (M).

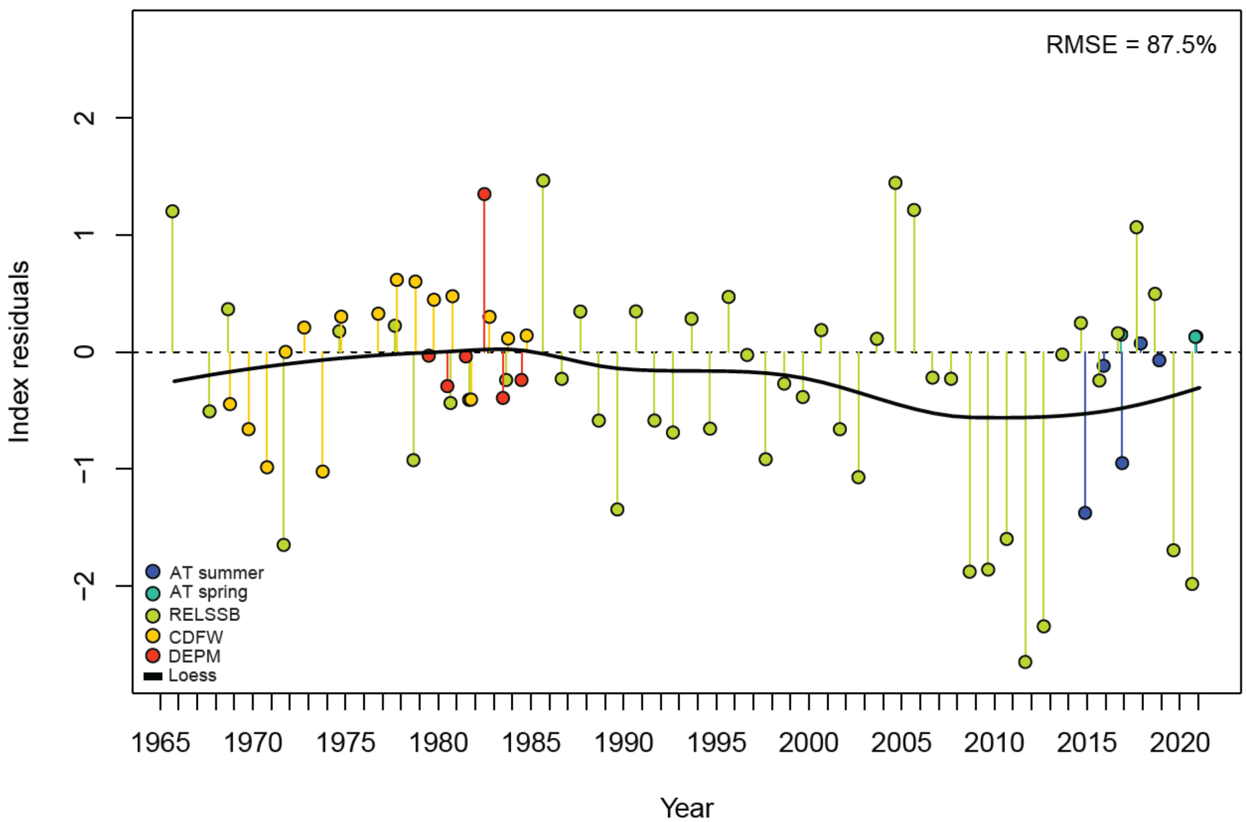

Figure S7. Residuals of biomass indices for the selected model configuration (model 5, Table S2). Vertical lines with points show the residuals coloured by index, and solid black line shows a loess smoother through all residuals. RMSE is the root-mean squared error.

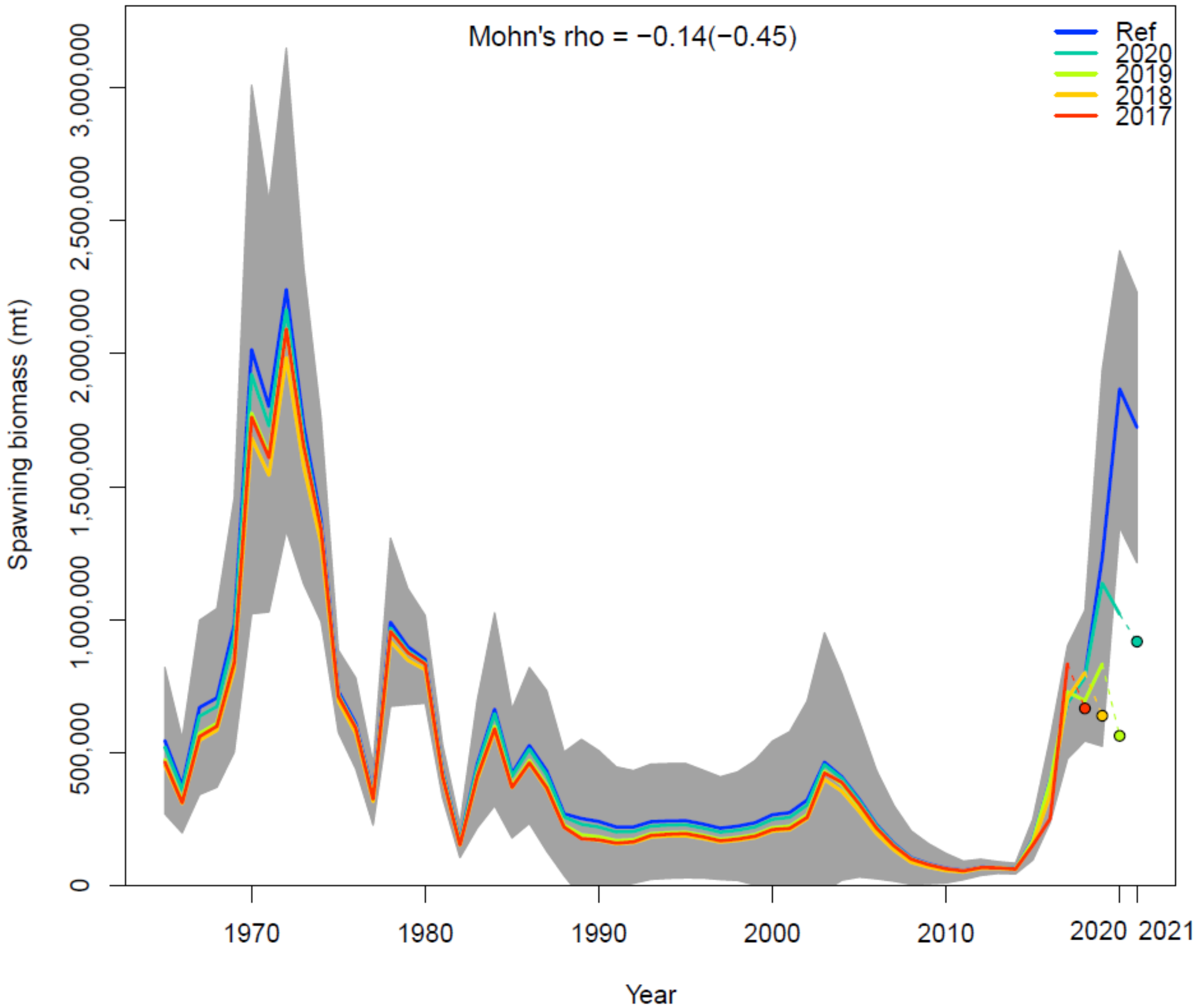

Figure S8. Retrospective analysis of spawning stock biomass (SSB) estimates after re-fitting the reference selected model configuration (Ref) after sequentially removing one year at a time for 4 years. Year-ahead projections shown by dashed lines. Mohn's rho statistic and corresponding 'hindcast rho' (in brackets) printed at the top of the panel. Grey ribbon shows 95% confidence interval of SSB estimates from Ref.

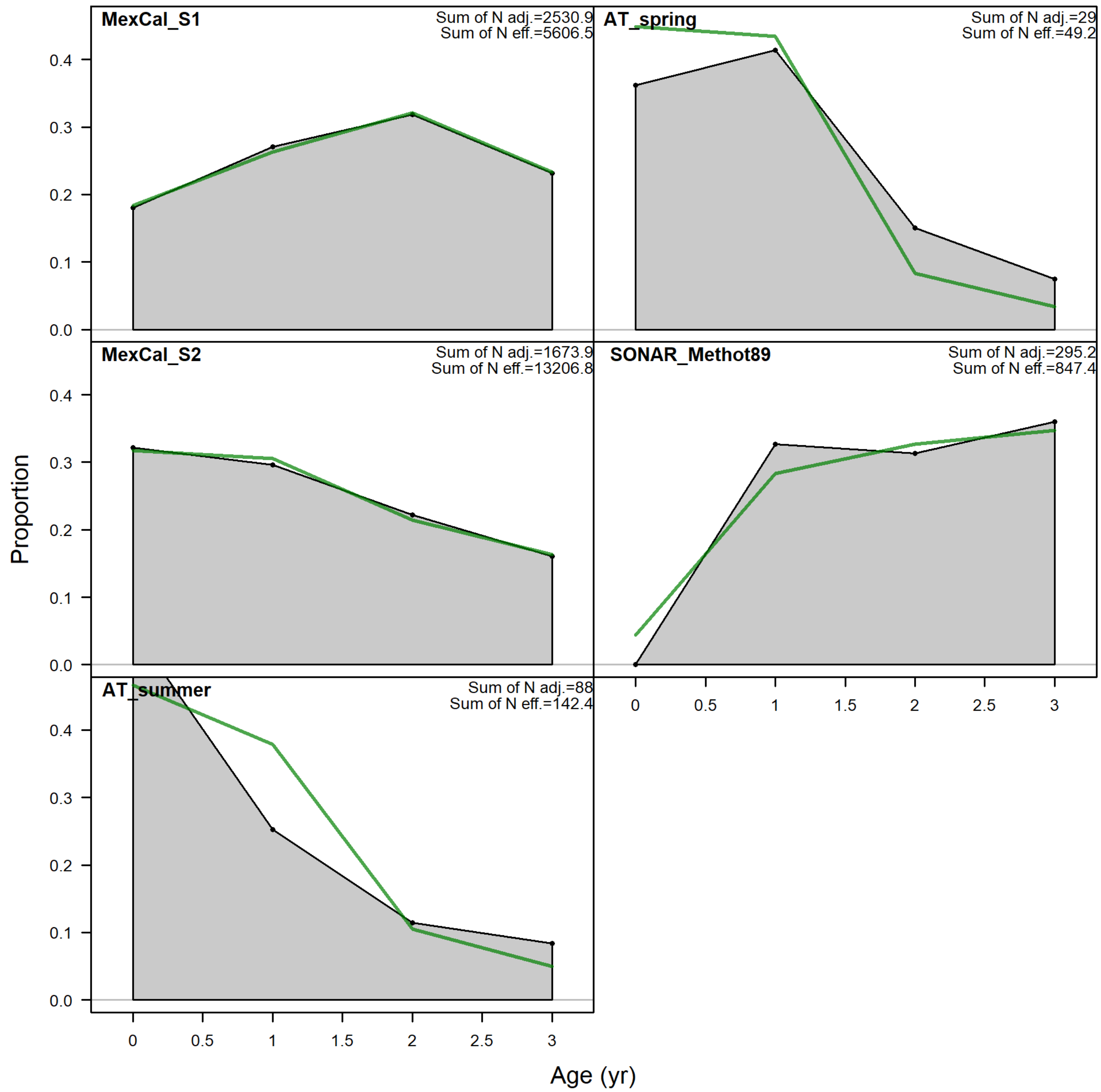

Figure S9. Fits to the age-composition data aggregated across time by fleet for the selected model configuration.

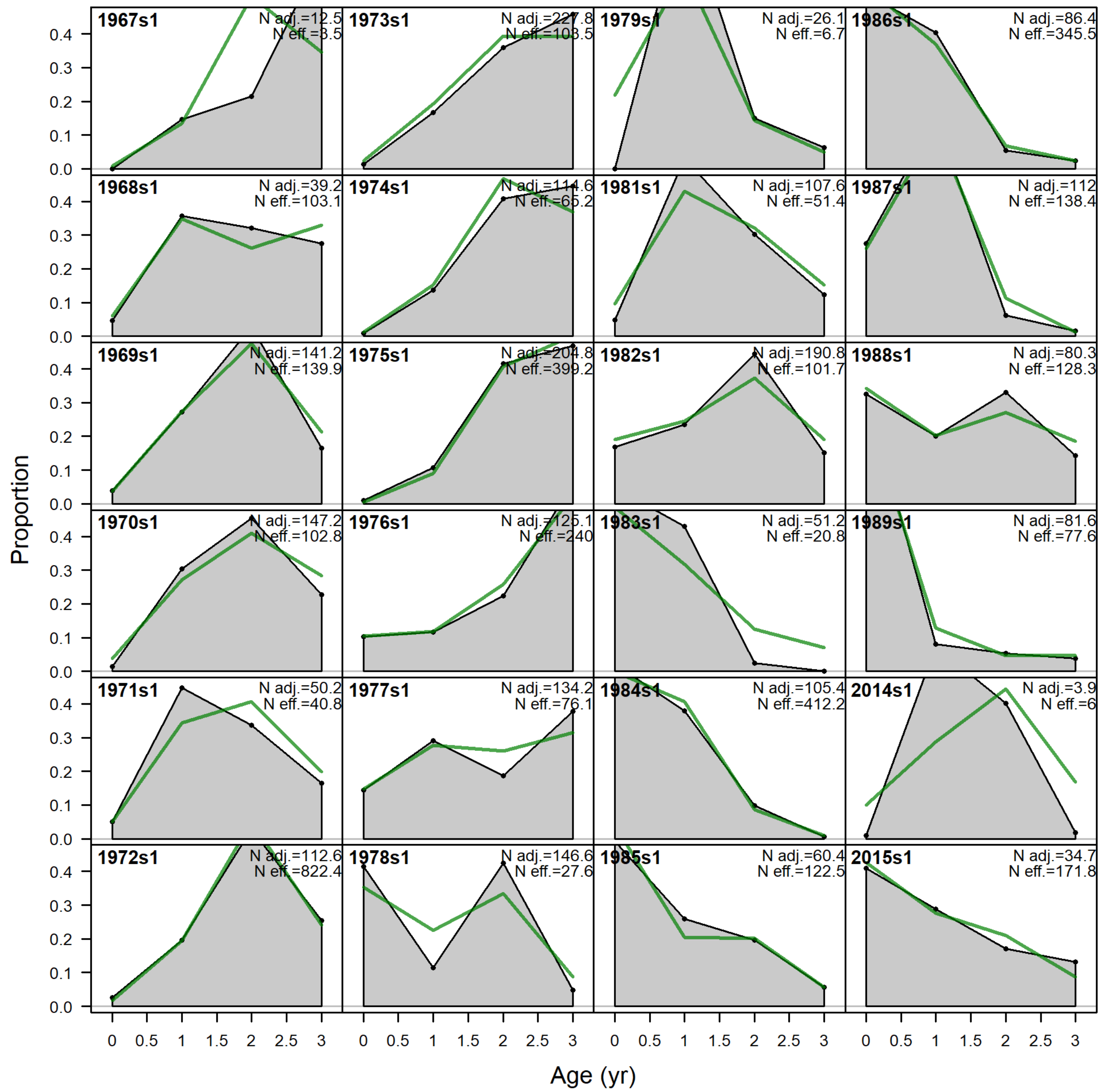

Figure S10. Fits to the age-composition data from the fishery during season 1 for the selected model configuration.

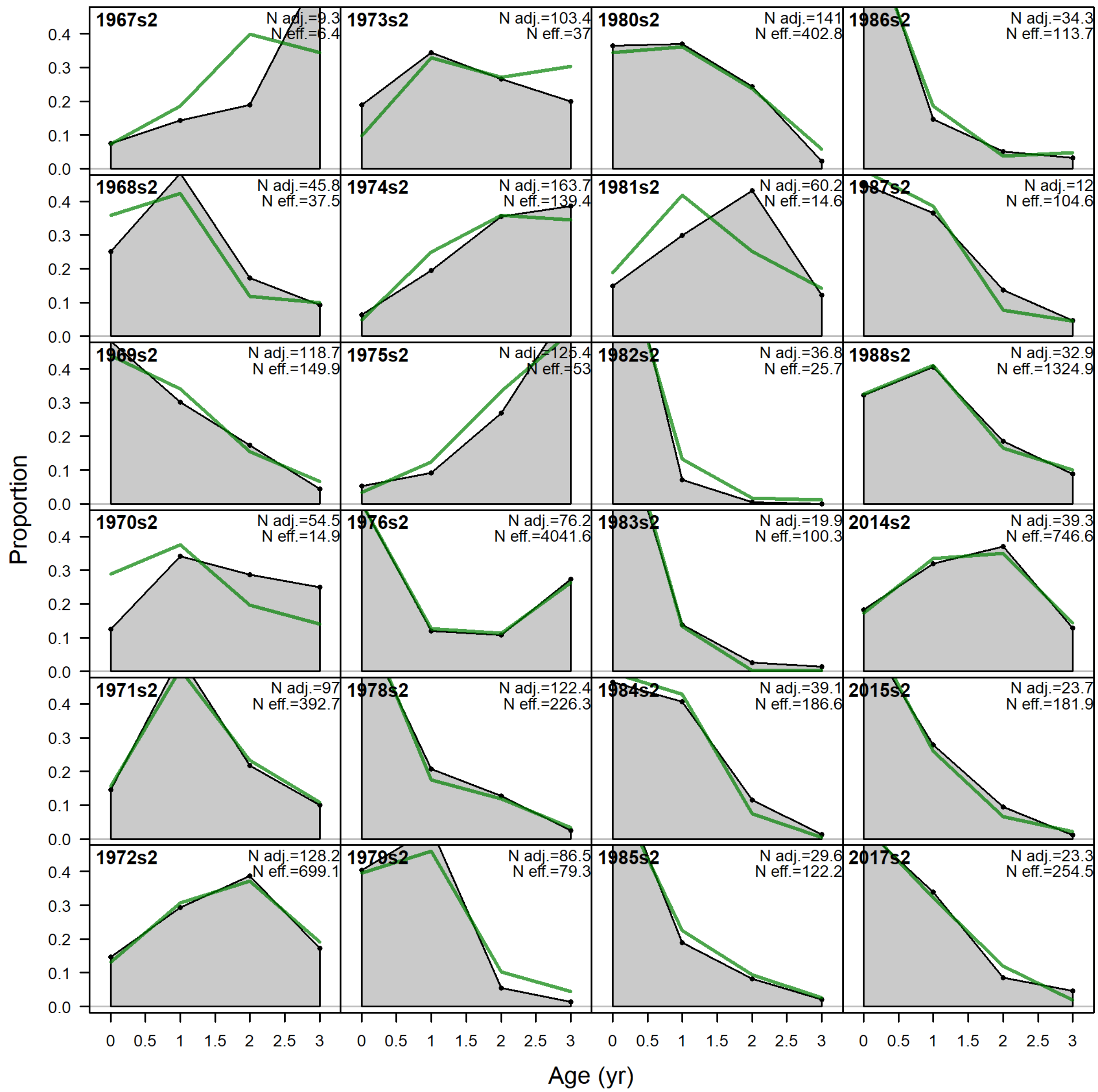

Figure S11. Fits to the age composition data from the fishery during season 2 for the selected model configuration.

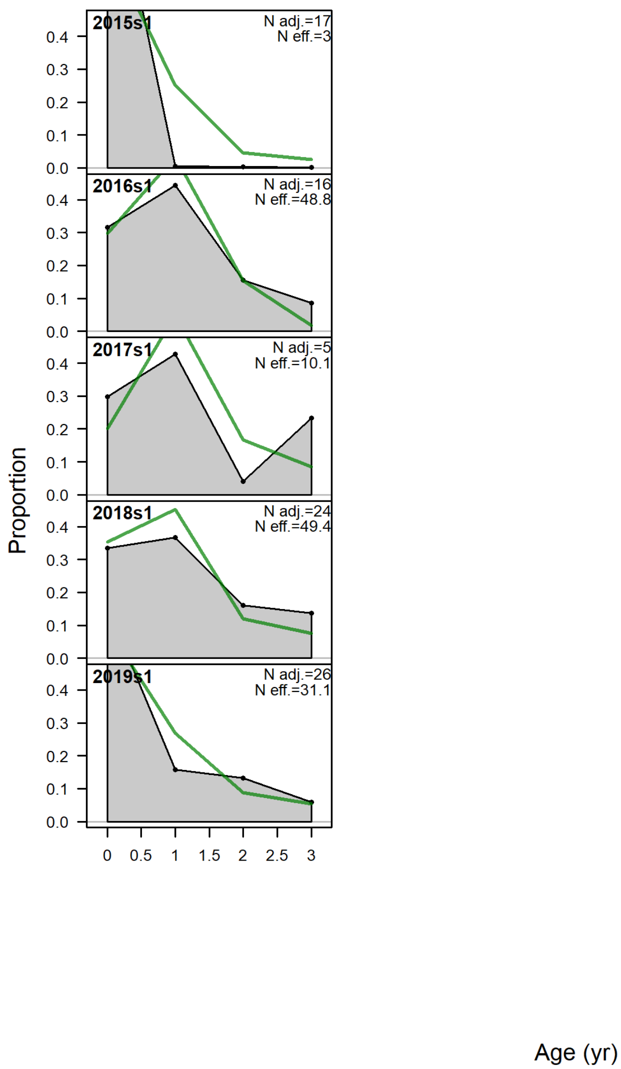

Figure S12. Fits to the age composition data from the AT summer survey for the selected model configuration..

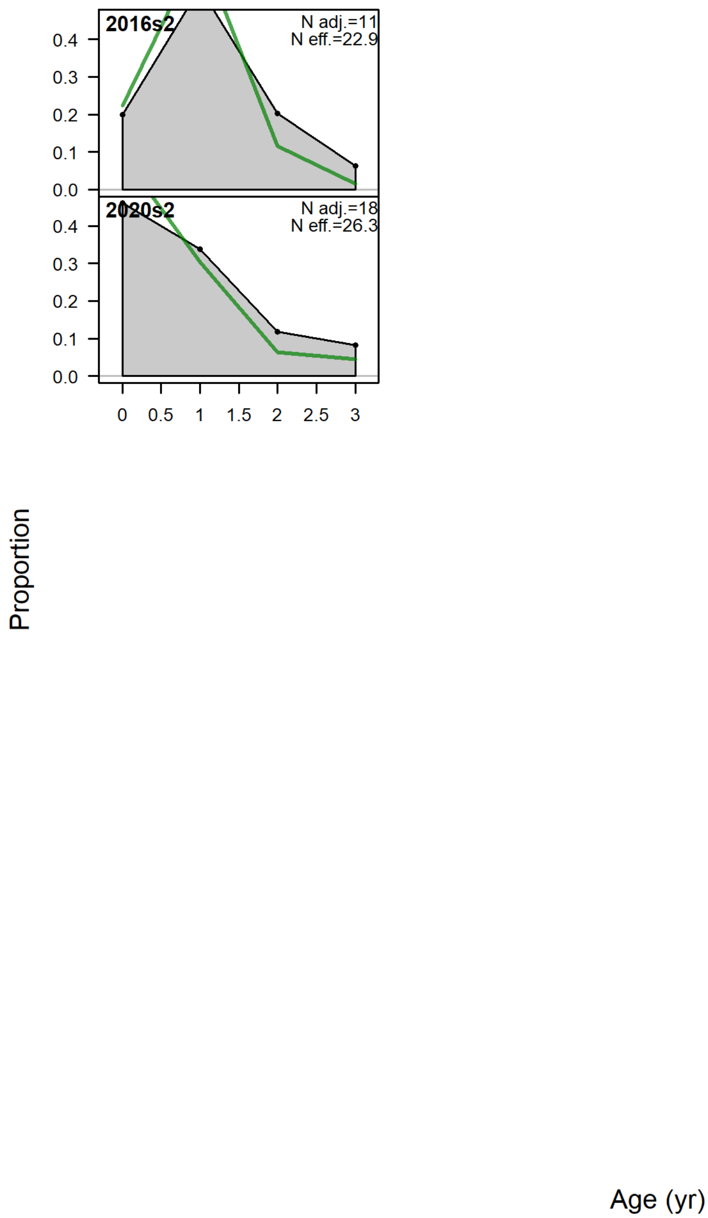

Figure S13. Fits to the age composition data from the AT spring survey for the selected model configuration..

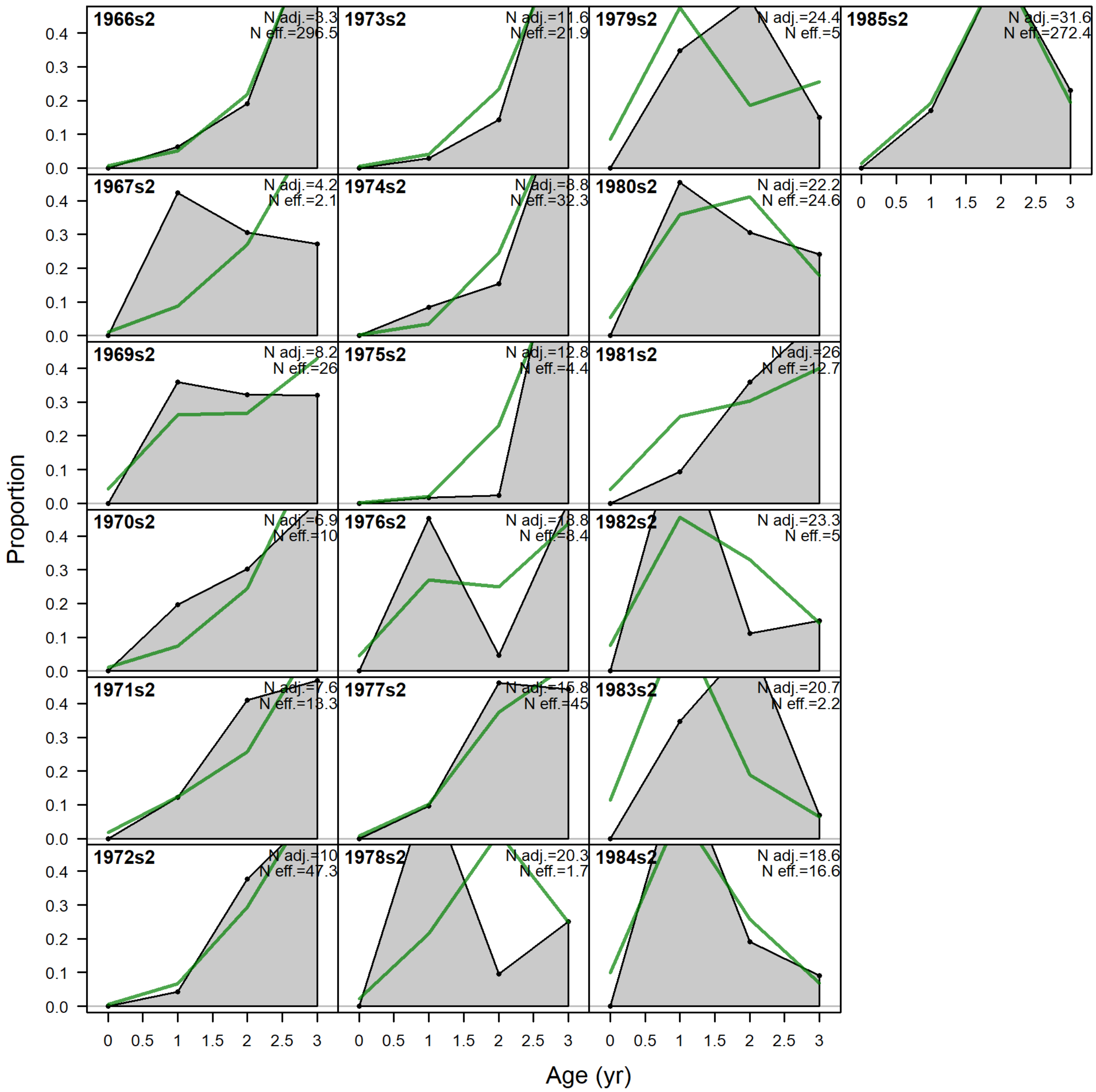

Figure S14. Fits to the age composition data from the CDFW survey for the selected model configuration.