Preliminary Discussion about the 2022 Forecast Process

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Contents

1 Objective

To determine the process for the 2022 Southeast Alaska (SEAK) preseason pink salmon forecast using data through 2020.

2 Executive Summary

Forecasts were developed using an approach originally described in Wertheimer et al. (2006), and modified in Orsi et al. (2016) and Murphy et al. (2019). We used a similar approach to Murphy et al. (2019), but assumed a log-normal error. This approach is based on a multiple regression model with juvenile pink salmon catch-per-unit-effort (CPUE) and temperature data from the Southeast Alaska Coastal Monitoring Survey (SECM; Murphy et al. 2020) or satellite sea surface temperature data (SST and SST Anomaly, NOAA Global Coral Bleaching Monitoring, 5km, V.3.1, Monthly, 1985-Present' time series (https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW_monthly.html). See the document satellite_SST_process_27_May_2021 for details about the temperature variables. Based on prior discussions, the index of juvenile abundance (i.e., CPUE) was based on the pooled-species vessel calibration coefficient.

Leave-one-out cross validation (hindcast) and model performance metrics were used to evaluate the forecast accuracy of models. These metrics included Akaike Information Criterion corrected for small sample sizes (AICc values; Burnham and Anderson 2004), the mean absolute scaled error (*MASE* metric; Hyndman and Kohler 2006), the weighted mean absolute percentage error (*wMAPE*; based on the last 5 years), leave one out cross validation *MAPE* (*MAPE_LOOCV*), one step ahead forecasts (*MAPE_one_step_ahead*) for the last five years (juvenile years 2015 through 2019), and significant coefficients (i.e., covariates) in the model.

Conclusions:

- Overall, the performance metrics recommended models m13 (Chatham_Strait_SST_May), m16 (Icy_Strait_SST_May), m19 (NSEAK_SST_May), m20 (NSEAK_SST_AMJJ), and m22 (SST_Jordan_May). These five models were additive models with CPUE and a temperature variable.

- With the exclusion of juvenile years 1998 and 2016, the performance metrics still recommended models m13, m16, m19, m20, and m22.

3 Analysis

3.1 Hierarchical models

Fifty one hierarchical models were investigated. The full model was:

$$E(y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2,$$

where X_1 is the average CPUE for catches in either the June or July survey, whichever month had the highest average catches in a given year, and was based on the pooled-species vessel calibration coefficient, X_2 is a temperature index, and β_3 is the interaction term between CPUE and the temperature index. The CPUE data were log-transformed in the model, but temperature data was not. The simplest model did not contain a temperature variable (model m1). None of the interactions were significant (see Appendix Table 6 for detailed output); therefore only additive models (26 models; Table 1 and Figure 1) were considered further.

Table 1: Parameter estimates for the 26 potential models.

model	term	estimate	std.error	statistic	p.value
m1	(Intercept)	2.2891818	0.208	11.019	0.000
m1	CPUE	0.4379654	0.071	6.157	0.000
m2	(Intercept)	4.4699466	0.545	8.196	0.000
m2	CPUE	0.4595498	0.054	8.582	0.000
m2	ISTI3_May	-0.2774746	0.067	-4.172	0.000
m3	(Intercept)	4.7958758	0.582	8.244	0.000
m3	CPUE	0.4650143	0.052	8.950	0.000
m3	ISTI10_May	-0.3320310	0.074	-4.461	0.000
m4	(Intercept)	5.0332354	0.613	8.204	0.000
m4	CPUE	0.4668849	0.051	9.129	0.000
m4	ISTI15_May	-0.3761665	0.082	-4.609	0.000
m5	(Intercept)	5.1986918	0.628	8.275	0.000
m5	CPUE	0.4692675	0.050	9.323	0.000
m5	ISTI20_May	-0.4111851	0.086	-4.761	0.000
m6	(Intercept)	6.1885346	1.089	5.681	0.000
m6	CPUE	0.4879450	0.058	8.369	0.000
m6	ISTI3_MJJ	-0.3785836	0.105	-3.621	0.002
m7	(Intercept)	6.7120995	1.035	6.487	0.000
m7	CPUE	0.4962538	0.054	9.170	0.000
m7	ISTI10_MJJ	-0.4555927	0.105	-4.322	0.000
m8	(Intercept)	6.9551755	0.965	7.209	0.000
m8	CPUE	0.4990322	0.051	9.833	0.000
m8	ISTI15_MJJ	-0.5075099	0.104	-4.891	0.000
m9	(Intercept)	7.0782279	0.909	7.783	0.000

model	term	estimate	std.error	statistic	p.value
m9	CPUE	0.5015600	0.048	10.371	0.000
m9	ISTI20_MJJ	-0.5456648	0.102	-5.327	0.000
m10	(Intercept)	4.7146749	0.560	8.423	0.000
m10	CPUE	0.4536812	0.052	8.807	0.000
m10	IS3_May	-0.3102179	0.069	-4.498	0.000
m11	(Intercept)	5.8517417	1.125	5.202	0.000
m11	CPUE	0.4731809	0.060	7.853	0.000
m11	IS3_MJJ	-0.3460234	0.108	-3.205	0.004
m12	(Intercept)	6.9293673	1.093	6.341	0.000
m12	CPUE	0.4725788	0.053	8.879	0.000
m12	Chatham_Strait_SST_MJJ	-0.4837577	0.113	-4.289	0.000
m13	(Intercept)	5.8907128	0.570	10.339	0.000
m13	CPUE	0.5001176	0.043	11.754	0.000
m13	Chatham_Strait_SST_May	-0.4935996	0.076	-6.469	0.000
m14	(Intercept)	6.9449013	0.952	7.293	0.000
m14	CPUE	0.4800203	0.050	9.673	0.000
m14	Chatham_Strait_SST_AMJJ	-0.5461599	0.110	-4.945	0.000
m15	(Intercept)	6.5665654	0.986	6.662	0.000
m15	CPUE	0.4752439	0.053	9.019	0.000
m15	Icy_Strait_SST_MJJ	-0.4280415	0.097	-4.392	0.000
m16	(Intercept)	5.4564543	0.519	10.509	0.000
m16	CPUE	0.5144098	0.044	11.692	0.000
m16	Icy_Strait_SST_May	-0.4594586	0.073	-6.280	0.000
m17	(Intercept)	6.5378101	0.890	7.342	0.000
m17	CPUE	0.4849005	0.050	9.615	0.000
m17	Icy_Strait_SST_AMJJ	-0.4923234	0.102	-4.835	0.000
m18	(Intercept)	6.8011220	0.976	6.967	0.000
m18	CPUE	0.4604035	0.051	9.097	0.000
m18	NSEAK_SST_MJJ	-0.4648662	0.099	-4.675	0.000
m19	(Intercept)	5.6755303	0.525	10.810	0.000
m19	CPUE	0.4852638	0.041	11.718	0.000
m19	NSEAK_SST_May	-0.4697650	0.071	-6.623	0.000
m20	(Intercept)	6.7569868	0.887	7.617	0.000
m20	CPUE	0.4701853	0.048	9.701	0.000
m20	NSEAK_SST_AMJJ	-0.5257282	0.103	-5.101	0.000
m21	(Intercept)	6.4006714	0.997	6.419	0.000
m21	CPUE	0.4784909	0.054	8.835	0.000
m21	SST_Jordan_MJJ	-0.4161797	0.100	-4.174	0.000
m22	(Intercept)	5.3700806	0.536	10.017	0.000
m22	CPUE	0.5185630	0.046	11.273	0.000
m22	SST_Jordan_May	-0.4529434	0.077	-5.919	0.000
m23	(Intercept)	6.4146402	0.898	7.143	0.000
m23	CPUE	0.4875430	0.052	9.449	0.000
m23	SST_Jordan_AMJJ	-0.4822201	0.104	-4.657	0.000
m24	(Intercept)	6.5160237	1.007	6.468	0.000
m24	CPUE	0.4524101	0.053	8.541	0.000
m24	SEAK_SST_MJJ	-0.4131161	0.097	-4.246	0.000
m25	(Intercept)	5.7091930	0.591	9.652	0.000
m25	CPUE	0.4853470	0.045	10.872	0.000
m25	SEAK_SST_May	-0.4395554	0.074	-5.923	0.000
m26	(Intercept)	6.5577162	0.929	7.062	0.000
m26	CPUE	0.4634645	0.051	9.125	0.000

model	term	estimate	std.error	statistic	p.value
m26	SEAK_SST_AMJJ	-0.4719916	0.101	-4.656	0.000

3.2 Performance metrics

The model summary results (Tables 2 and 3) using the performance metrics AICc, *MASE*, *wMAPE*, *MAPE_LOOCV*, and *MAPE_one_step_ahead* are shown in Table 2. For all of these metrics, the smallest value is the preferred model. Models with Δ_iAICc ≤ 2 have substantial support, those in which $4 \leq \Delta_i$AICc ≤ 7 have considerably less support, and models with Δ_iAICc > 10 have essentially no support (Burnham and Anderson 2004). The performance metric *MAPE* was calculated as:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}|\frac{A_t - F_t}{A_t}|$$

where A_t is the observed value and F_t is the predicted value. The performance metric *wMAPE* was calculated as:

$$wMAPE = \sum_{t=1}^{n}\frac{1}{w_t}\sum_{t=1}^{n}|\frac{A_t - F_t}{A_t}|w_t.$$

where w_t is the weight for each year. For the *wMAPE* metric, the last 5 years (juvenile years 2015-2019) were given a weight of 1 and all other years, a weight of 0.001. Therefore, compared to the performance metric *MAPE_LOOCV*, the performance of the model in the last 5 years was given more weight in the *wMAPE* metric.

The AICc in Table 2 is the AICc value and not the Δ_iAICc. The performance metric AICc suggests that models m13, m16, and m19 are the recommended models (Table 2). The performance metrics *MASE* and *MAPE_LOOCV* suggest that models m13, m16, m19, and m22 are the recommended models (Table 2). The performance metric *wMAPE* suggests that models m16, m19, m20, and m22 are the recommended models (Table 2). The performance metric *MAPE_one_step_ahead* suggests that models m16, m20, and m22 are the recommended models (Table 2). Detailed outputs for recommended models m13, m16, m19, m20, and m22 are in the appendix (Tables 7 to 11, and Figures 2 through 11).

Table 2: Summary of model outputs and forecast error measures. These metrics included Akaike Information Criterion corrected for small sample sizes (AICc values), the mean absolute scaled error (MASE metric), the weighted mean absolute percentage error (wMAPE; based on the last 5 years), leave one out cross validation MAPE (MAPE_LOOCV), and one step ahead forecasts (MAPE_one_step_ahead).

model	AdjR2	AICc	MASE	wMAPE	MAPE_LOOCV	MAPE_one_step_ahead
m1	0.627	30.21	0.399	0.184	0.116	0.220
m2	0.790	18.77	0.284	0.134	0.087	0.161
m3	0.803	17.28	0.276	0.128	0.084	0.151
m4	0.810	16.52	0.278	0.119	0.084	0.139
m5	0.816	15.74	0.274	0.111	0.082	0.125
m6	0.763	21.57	0.308	0.130	0.094	0.167
m7	0.797	17.99	0.286	0.119	0.087	0.153
m8	0.821	15.08	0.263	0.105	0.079	0.134
m9	0.838	12.85	0.246	0.092	0.073	0.118
m10	0.805	17.09	0.269	0.127	0.083	0.151
m11	0.741	23.63	0.321	0.138	0.099	0.181
m12	0.796	18.17	0.298	0.092	0.088	0.123
m13	0.873	7.20	0.238	0.077	0.070	0.093
m14	0.824	14.80	0.277	0.072	0.080	0.089
m15	0.800	17.64	0.294	0.090	0.087	0.118
m16	0.868	8.11	0.212	0.066	0.062	0.078
m17	0.819	15.36	0.282	0.077	0.083	0.095
m18	0.813	16.18	0.286	0.078	0.084	0.097
m19	0.877	6.47	0.224	0.070	0.066	0.086
m20	0.830	14.00	0.270	0.063	0.078	0.072
m21	0.790	18.75	0.306	0.097	0.091	0.127
m22	0.858	9.88	0.221	0.066	0.065	0.077
m23	0.812	16.27	0.290	0.080	0.085	0.100
m24	0.794	18.39	0.297	0.088	0.088	0.110
m25	0.858	9.87	0.246	0.083	0.074	0.103
m26	0.812	16.28	0.281	0.073	0.082	0.083

Table 3: Summary of model forecasts including the 80 percent prediction intervals (corrected for log transformation bias in a linear-model).

model	terms	fit	fit_LPI	fit_UPI
m1	CPUE	27.568	15.659	48.536
m2	CPUE + ISTI3_May	23.986	15.670	36.716
m3	CPUE + ISTI10_May	23.592	15.619	35.635
m4	CPUE + ISTI15_May	23.599	15.731	35.403
m5	CPUE + ISTI20_May	23.994	16.111	35.736
m6	CPUE + ISTI3_MJJ	31.465	19.960	49.603
m7	CPUE + ISTI10_MJJ	30.411	19.990	46.264
m8	CPUE + ISTI15_MJJ	29.191	19.709	43.234
m9	CPUE + ISTI20_MJJ	28.281	19.461	41.097
m10	CPUE + IS3_May	23.412	15.523	35.309
m11	CPUE + IS3_MJJ	31.628	19.634	50.946
m12	CPUE + Chatham_Strait_SST_MJJ	23.659	15.538	36.026
m13	CPUE + Chatham_Strait_SST_May	19.138	13.675	26.783
m14	CPUE + Chatham_Strait_SST_AMJJ	24.394	16.517	36.027
m15	CPUE + Icy_Strait_SST_MJJ	20.922	13.743	31.850
m16	CPUE + Icy_Strait_SST_May	16.927	11.942	23.993
m17	CPUE + Icy_Strait_SST_AMJJ	21.063	14.133	31.389
m18	CPUE + NSEAK_SST_MJJ	21.710	14.479	32.553
m19	CPUE + NSEAK_SST_May	17.566	12.575	24.537
m20	CPUE + NSEAK_SST_AMJJ	21.877	14.876	32.173
m21	CPUE + SST_Jordan_MJJ	21.177	13.770	32.567
m22	CPUE + SST_Jordan_May	17.334	12.071	24.891
m23	CPUE + SST_Jordan_AMJJ	21.212	14.121	31.863
m24	CPUE + SEAK_SST_MJJ	22.540	14.750	34.445
m25	CPUE + SEAK_SST_May	17.680	12.328	25.356
m26	CPUE + SEAK_SST_AMJJ	22.275	14.856	33.399

3.3 Sensitivity analysis

A sensitivity analysis was done to determine if the juvenile years 1998 and 2016 were influential in the models. For the sensitivity analysis, juvenile years 1998 and 2016 (high leverage values in a majority of the six preferred models) were removed, the models rerun, and the performance metrics recalculated (Tables 4 and 5).The performance metric AICc suggests that models m16 and m22 are the recommended model. The performance metrics *MASE* and *MAPE_LOOCV* suggest that models m13, m16, m19, and m22 are the recommended models. The performance metric *wMAPE* suggests that models m16, m19, m20, and m22 are the recommended models. The performance metric *MAPE_one_step_ahead* suggests that models m16, m20, and m22 are the recommended models. Therefore, based on the performance metrics, models m13, m16, m19, m20, and m22 are recommended.

Table 4: Summary of model outputs and forecast error measures for the sensitivity analysis (exclusion of juvenile years 1998 and 2016). These metrics included Akaike Information Criterion corrected for small sample sizes (AICc values), the mean absolute scaled error (MASE metric), the weighted mean absolute percentage error (wMAPE; based on the last 5 years), leave one out cross validation MAPE (MAPE_LOOCV), and one step ahead forecasts (MAPE_one_step_ahead).

model	AdjR2	AICc	MASE	wMAPE	MAPE_LOOCV	MAPE_one_step_ahead
m1s	0.693	24.16	0.378	0.162	0.106	0.195
m2s	0.847	11.48	0.249	0.126	0.074	0.137
m3s	0.850	11.10	0.245	0.124	0.073	0.136
m4s	0.844	11.94	0.249	0.121	0.073	0.142
m5s	0.841	12.33	0.249	0.121	0.073	0.150
m6s	0.820	14.96	0.276	0.115	0.083	0.148
m7s	0.835	13.09	0.264	0.115	0.079	0.148
m8s	0.844	11.87	0.252	0.109	0.075	0.140
m9s	0.854	10.50	0.240	0.100	0.071	0.127
m10s	0.850	11.15	0.246	0.124	0.073	0.133
m11s	0.806	16.55	0.285	0.118	0.087	0.159
m12s	0.821	14.77	0.286	0.095	0.083	0.116
m13s	0.900	2.61	0.212	0.070	0.061	0.086
m14s	0.837	12.89	0.274	0.074	0.077	0.088
m15s	0.833	13.36	0.279	0.094	0.081	0.114
m16s	0.920	-2.01	0.179	0.061	0.051	0.078
m17s	0.843	12.05	0.265	0.074	0.076	0.082
m18s	0.831	13.59	0.280	0.082	0.081	0.092
m19s	0.904	1.64	0.203	0.066	0.059	0.102
m20s	0.839	12.54	0.267	0.064	0.075	0.068
m21s	0.824	14.44	0.287	0.101	0.083	0.123
m22s	0.910	0.33	0.188	0.061	0.053	0.078
m23s	0.837	12.91	0.274	0.080	0.078	0.092
m24s	0.812	15.81	0.288	0.092	0.083	0.104
m25s	0.875	7.26	0.239	0.082	0.069	0.105
m26s	0.821	14.87	0.278	0.077	0.079	0.082

Table 5: Summary of model forecasts including the 80 percent prediction intervals (corrected for log transformation bias in a linear-model) for the sensitivity analysis (exclusion of juvenile years 1998 and 2016).

| model	terms	fit	fit_LPI	fit_UPI
m1s	CPUE	27.618	16.486	46.269
m2s	CPUE + ISTI3_May	24.012	16.648	34.633
m3s	CPUE + ISTI10_May	23.686	16.471	34.062
m4s	CPUE + ISTI15_May	23.770	16.409	34.433
m5s	CPUE + ISTI20_May	24.180	16.642	35.132
m6s	CPUE + ISTI3_MJJ	31.123	20.864	46.428
m7s	CPUE + ISTI10_MJJ	30.082	20.549	44.039
m8s	CPUE + ISTI15_MJJ	28.985	20.037	41.929
m9s	CPUE + ISTI20_MJJ	28.165	19.712	40.244
m10s	CPUE + IS3_May	23.542	16.362	33.872
m11s	CPUE + IS3_MJJ	31.342	20.677	47.506
m12s	CPUE + Chatham_Strait_SST_MJJ	23.896	16.071	35.531
m13s	CPUE + Chatham_Strait_SST_May	19.446	14.374	26.307
m14s	CPUE + Chatham_Strait_SST_AMJJ	24.535	16.807	35.817
m15s	CPUE + Icy_Strait_SST_MJJ	20.881	14.139	30.838
m16s	CPUE + Icy_Strait_SST_May	16.666	12.634	21.983
m17s	CPUE + Icy_Strait_SST_AMJJ	20.890	14.324	30.465
m18s	CPUE + NSEAK_SST_MJJ	22.016	14.921	32.485
m19s	CPUE + NSEAK_SST_May	17.816	13.208	24.033
m20s	CPUE + NSEAK_SST_AMJJ	22.064	15.105	32.229
m21s	CPUE + SST_Jordan_MJJ	21.158	14.185	31.559
m22s	CPUE + SST_Jordan_May	17.048	12.729	22.832
m23s	CPUE + SST_Jordan_AMJJ	21.095	14.356	30.999
m24s	CPUE + SEAK_SST_MJJ	22.937	15.241	34.519
m25s	CPUE + SEAK_SST_May	18.104	12.843	25.520
m26s	CPUE + SEAK_SST_AMJJ	22.618	15.160	33.743
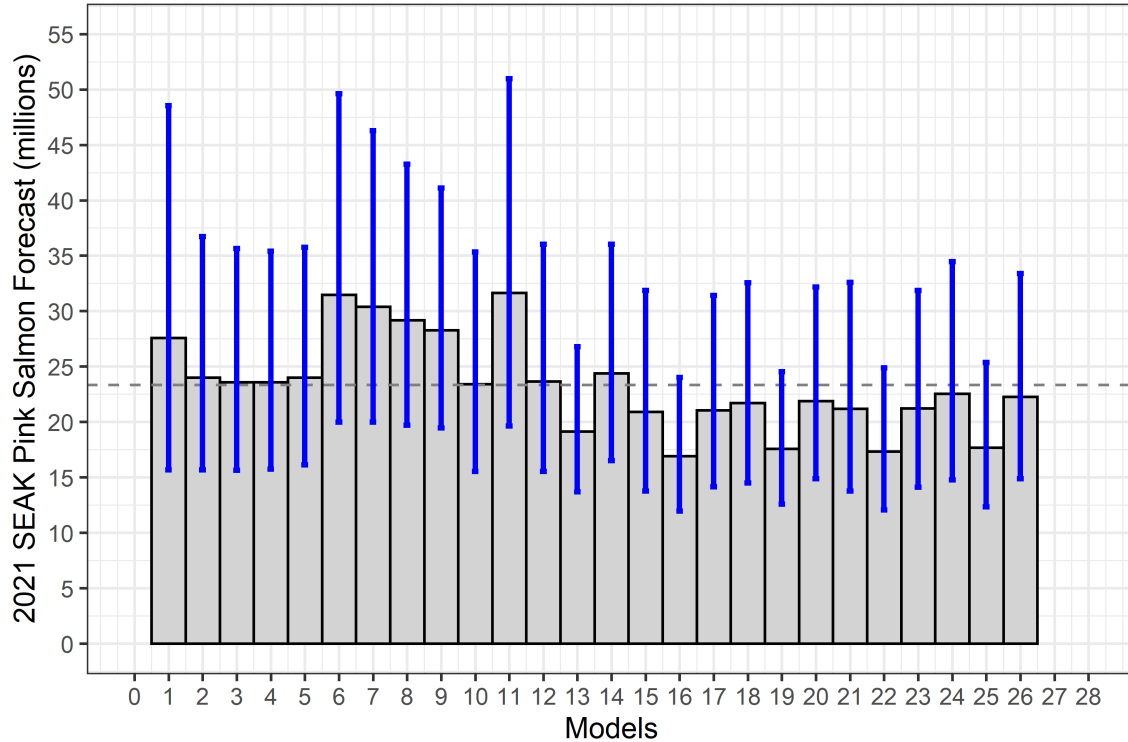
Figure 1: The 2021 SEAK pink salmon harvest (millions) forecast by model. The 80% prediction intervals (corrected for log transformation bias in a linear-model) around each forecast were calculated using the car package (Fox and Weisberg 2019) in program R (R Core Team 2020). The dotted horizontal line is the average forecast across all models. The SEAK pink salmon harvest in 2021 (based on the November 18, 2020 advisory announcement) was a point estimate of 28 million fish (80% prediction interval: 19–42 million fish). ## Model averaging # References Burnham, K. P., and D. R. Anderson. 2004. Multimodel inference: Understanding AIC and BIC in model selection. Sociological Methods and Research 33: 261-304.

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4   Appendix

Table 6: Parameter estimates for the 25 interaction models. None of the interactions were significant.

model	term	estimate	std.error	statistic	p.value
m2i	(Intercept)	5.5000607	1.678	3.277	0.004
m2i	CPUE	0.1034146	0.550	0.188	0.853
m2i	ISTI3_May	-0.4028292	0.204	-1.972	0.063
m2i	CPUE:ISTI3_May	0.0430304	0.066	0.650	0.523
m3i	(Intercept)	5.3476073	1.787	2.992	0.007
m3i	CPUE	0.2701309	0.598	0.452	0.656
m3i	ISTI10_May	-0.4017039	0.226	-1.777	0.092
m3i	CPUE:ISTI10_May	0.0244329	0.075	0.327	0.747
m4i	(Intercept)	5.0806682	1.871	2.715	0.014
m4i	CPUE	0.4499176	0.633	0.711	0.486
m4i	ISTI15_May	-0.3823424	0.244	-1.565	0.134
m4i	CPUE:ISTI15_May	0.0021937	0.081	0.027	0.979
m5i	(Intercept)	4.7960554	1.886	2.543	0.020
m5i	CPUE	0.6149077	0.643	0.956	0.351
m5i	ISTI20_May	-0.3574078	0.253	-1.414	0.174
m5i	CPUE:ISTI20_May	-0.0193146	0.085	-0.227	0.823
m6i	(Intercept)	1.9591583	2.592	0.756	0.459
m6i	CPUE	2.4143936	1.084	2.227	0.038
m6i	ISTI3_MJJ	0.0165585	0.243	0.068	0.946
m6i	CPUE:ISTI3_MJJ	-0.1788905	0.101	-1.780	0.091
m7i	(Intercept)	2.2233006	2.370	0.938	0.360
m7i	CPUE	2.4377236	0.939	2.596	0.018
m7i	ISTI10_MJJ	-0.0114003	0.236	-0.048	0.962
m7i	CPUE:ISTI10_MJJ	-0.1908928	0.092	-2.071	0.052
m8i	(Intercept)	3.1474179	2.310	1.363	0.189
m8i	CPUE	2.0406049	0.860	2.373	0.028
m8i	ISTI15_MJJ	-0.1099114	0.242	-0.454	0.655
m8i	CPUE:ISTI15_MJJ	-0.1599028	0.089	-1.796	0.088
m9i	(Intercept)	3.9888764	2.279	1.750	0.096
m9i	CPUE	1.7040630	0.819	2.081	0.051
m9i	ISTI20_MJJ	-0.2082355	0.250	-0.833	0.415
m9i	CPUE:ISTI20_MJJ	-0.1304306	0.089	-1.471	0.158
m10i	(Intercept)	5.4729832	1.743	3.139	0.005
m10i	CPUE	0.1891072	0.577	0.328	0.747
m10i	IS3_May	-0.4033029	0.214	-1.884	0.075
m10i	CPUE:IS3_May	0.0322978	0.070	0.460	0.650
m11i	(Intercept)	2.4527240	2.679	0.916	0.371
m11i	CPUE	2.0869230	1.161	1.797	0.088
m11i	IS3_MJJ	-0.0250873	0.254	-0.099	0.922
m11i	CPUE:IS3_MJJ	-0.1516223	0.109	-1.391	0.180
m12i	(Intercept)	5.1805161	3.350	1.546	0.139
m12i	CPUE	1.1206497	1.172	0.956	0.351
m12i	Chatham_Strait_SST_MJJ	-0.3064132	0.340	-0.900	0.379

model	term	estimate	std.error	statistic	p.value
m12i	CPUE:Chatham_Strait_SST_MJJ	-0.0654395	0.118	-0.553	0.586
m13i	(Intercept)	4.4920196	1.991	2.257	0.036
m13i	CPUE	1.0189622	0.708	1.439	0.166
m13i	Chatham_Strait_SST_May	-0.3141302	0.256	-1.225	0.235
m13i	CPUE:Chatham_Strait_SST_May	-0.0659378	0.090	-0.734	0.472
m14i	(Intercept)	6.0246372	2.972	2.027	0.057
m14i	CPUE	0.8146399	1.022	0.797	0.435
m14i	Chatham_Strait_SST_AMJJ	-0.4422199	0.337	-1.313	0.205
m14i	CPUE:Chatham_Strait_SST_AMJJ	-0.0375871	0.115	-0.328	0.747
m15i	(Intercept)	5.8840374	2.742	2.146	0.045
m15i	CPUE	0.7199518	0.916	0.786	0.441
m15i	Icy_Strait_SST_MJJ	-0.3614611	0.268	-1.349	0.193
m15i	CPUE:Icy_Strait_SST_MJJ	-0.0237539	0.089	-0.268	0.792
m16i	(Intercept)	4.9193092	1.621	3.035	0.007
m16i	CPUE	0.7136394	0.570	1.253	0.226
m16i	Icy_Strait_SST_May	-0.3869900	0.220	-1.761	0.094
m16i	CPUE:Icy_Strait_SST_May	-0.0265351	0.076	-0.351	0.730
m17i	(Intercept)	6.2205746	2.471	2.517	0.021
m17i	CPUE	0.5975071	0.817	0.732	0.473
m17i	Icy_Strait_SST_AMJJ	-0.4569134	0.277	-1.651	0.115
m17i	CPUE:Icy_Strait_SST_AMJJ	-0.0124870	0.090	-0.138	0.892
m18i	(Intercept)	5.3567440	2.736	1.958	0.065
m18i	CPUE	1.0065245	0.965	1.043	0.310
m18i	NSEAK_SST_MJJ	-0.3198518	0.275	-1.162	0.260
m18i	CPUE:NSEAK_SST_MJJ	-0.0546809	0.097	-0.567	0.578
m19i	(Intercept)	4.4982267	1.664	2.703	0.014
m19i	CPUE	0.9336459	0.602	1.551	0.137
m19i	NSEAK_SST_May	-0.3162165	0.218	-1.452	0.163
m19i	CPUE:NSEAK_SST_May	-0.0580543	0.078	-0.747	0.464
m20i	(Intercept)	5.8500460	2.514	2.327	0.031
m20i	CPUE	0.8068581	0.872	0.925	0.366
m20i	NSEAK_SST_AMJJ	-0.4229203	0.286	-1.479	0.156
m20i	CPUE:NSEAK_SST_AMJJ	-0.0380016	0.098	-0.387	0.703
m21i	(Intercept)	5.8349102	2.817	2.071	0.052
m21i	CPUE	0.6796370	0.935	0.727	0.476
m21i	SST_Jordan_MJJ	-0.3604203	0.278	-1.296	0.211
m21i	CPUE:SST_Jordan_MJJ	-0.0197165	0.091	-0.216	0.832
m22i	(Intercept)	4.4637880	1.599	2.791	0.012
m22i	CPUE	0.8607822	0.570	1.511	0.147
m22i	SST_Jordan_May	-0.3294812	0.219	-1.504	0.149
m22i	CPUE:SST_Jordan_May	-0.0459866	0.076	-0.603	0.554
m23i	(Intercept)	6.1341893	2.519	2.435	0.025
m23i	CPUE	0.5868566	0.832	0.705	0.489
m23i	SST_Jordan_AMJJ	-0.4506805	0.284	-1.586	0.129
m23i	CPUE:SST_Jordan_AMJJ	-0.0110908	0.093	-0.120	0.906
m24i	(Intercept)	4.7177981	2.797	1.687	0.108
m24i	CPUE	1.1410860	0.999	1.142	0.267
m24i	SEAK_SST_MJJ	-0.2413948	0.268	-0.902	0.378
m24i	CPUE:SEAK_SST_MJJ	-0.0656543	0.095	-0.691	0.498
m25i	(Intercept)	4.1684624	1.897	2.198	0.041
m25i	CPUE	1.0582224	0.671	1.577	0.131
m25i	SEAK_SST_May	-0.2531580	0.230	-1.099	0.285

model	term	estimate	std.error	statistic	p.value
m25i	CPUE:SEAK_SST_May	-0.0687647	0.080	-0.856	0.403
m26i	(Intercept)	5.2125548	2.638	1.976	0.063
m26i	CPUE	0.9662559	0.922	1.048	0.308
m26i	SEAK_SST_AMJJ	-0.3283874	0.282	-1.162	0.259
m26i	CPUE:SEAK_SST_AMJJ	-0.0534897	0.098	-0.546	0.591

Table 7: Detailed output for model m13. Fitted values are log-transformed.

model	year	juvenile_year	resid	hat_values	Cooks_distance	std_resid	fitted
m13	1998	1997	0.361	0.044	0.036	1.520	3.388
m13	1999	1998	-0.439	0.301	0.670	-2.161	4.793
m13	2000	1999	-0.229	0.101	0.037	-0.994	3.240
m13	2001	2000	0.101	0.090	0.006	0.437	4.104
m13	2002	2001	-0.156	0.117	0.021	-0.682	3.969
m13	2003	2002	-0.159	0.195	0.043	-0.727	4.119
m13	2004	2003	0.238	0.050	0.018	1.006	3.575
m13	2005	2004	0.217	0.096	0.031	0.938	3.862
m13	2006	2005	-0.245	0.150	0.070	-1.093	2.696
m13	2007	2006	0.194	0.059	0.014	0.821	3.609
m13	2008	2007	-0.169	0.115	0.024	-0.740	2.936
m13	2009	2008	-0.029	0.099	0.001	-0.126	3.667
m13	2010	2009	-0.247	0.052	0.020	-1.042	3.425
m13	2011	2010	0.109	0.111	0.009	0.475	3.967
m13	2012	2011	0.123	0.085	0.009	0.528	2.936
m13	2013	2012	0.413	0.103	0.124	1.796	4.137
m13	2014	2013	0.010	0.109	0.000	0.046	3.606
m13	2015	2014	-0.160	0.107	0.019	-0.695	3.718
m13	2016	2015	0.247	0.242	0.145	1.169	2.665
m13	2017	2016	-0.092	0.252	0.022	-0.440	3.639
m13	2018	2017	-0.137	0.217	0.037	-0.635	2.228
m13	2019	2018	0.289	0.108	0.064	1.261	2.760
m13	2020	2019	-0.243	0.195	0.100	-1.112	2.330

Table 8: Detailed output for model m16. Fitted values are log-transformed.

model	year	juvenile_year	resid	hat_values	Cooks_distance	std_resid	fitted
m16	1998	1997	0.313	0.046	0.027	1.292	3.437
m16	1999	1998	-0.595	0.316	1.297	-2.901	4.949
m16	2000	1999	-0.359	0.136	0.127	-1.560	3.370
m16	2001	2000	0.092	0.092	0.005	0.388	4.113
m16	2002	2001	-0.114	0.105	0.009	-0.486	3.927
m16	2003	2002	-0.029	0.139	0.001	-0.126	3.990
m16	2004	2003	0.183	0.049	0.010	0.756	3.631
m16	2005	2004	0.178	0.092	0.019	0.753	3.902
m16	2006	2005	-0.113	0.212	0.024	-0.513	2.564
m16	2007	2006	0.193	0.059	0.013	0.801	3.610
m16	2008	2007	-0.199	0.119	0.033	-0.854	2.965
m16	2009	2008	-0.028	0.100	0.001	-0.117	3.665
m16	2010	2009	-0.051	0.049	0.001	-0.211	3.229
m16	2011	2010	0.145	0.115	0.017	0.622	3.931
m16	2012	2011	0.079	0.086	0.004	0.335	2.979
m16	2013	2012	0.504	0.085	0.139	2.124	4.047
m16	2014	2013	0.003	0.113	0.000	0.012	3.614
m16	2015	2014	-0.122	0.116	0.012	-0.523	3.680
m16	2016	2015	0.118	0.178	0.020	0.525	2.794
m16	2017	2016	-0.031	0.284	0.003	-0.149	3.578
m16	2018	2017	-0.133	0.217	0.034	-0.608	2.225
m16	2019	2018	0.248	0.107	0.045	1.058	2.802
m16	2020	2019	-0.280	0.183	0.117	-1.251	2.368

Table 9: Detailed output for model m19. Fitted values are log-transformed.

model	year	juvenile_year	resid	hat_values	Cooks_distance	std_resid	fitted
m19	1998	1997	0.324	0.045	0.031	1.388	3.425
m19	1999	1998	-0.456	0.302	0.749	-2.282	4.810
m19	2000	1999	-0.293	0.115	0.074	-1.302	3.303
m19	2001	2000	0.116	0.088	0.008	0.506	4.089
m19	2002	2001	-0.126	0.107	0.012	-0.556	3.939
m19	2003	2002	-0.064	0.150	0.005	-0.291	4.025
m19	2004	2003	0.200	0.049	0.013	0.859	3.613
m19	2005	2004	0.218	0.096	0.033	0.958	3.861
m19	2006	2005	-0.259	0.143	0.077	-1.171	2.710
m19	2007	2006	0.157	0.065	0.011	0.680	3.645
m19	2008	2007	-0.234	0.124	0.052	-1.047	3.001
m19	2009	2008	-0.046	0.103	0.002	-0.204	3.684
m19	2010	2009	-0.191	0.048	0.011	-0.818	3.369
m19	2011	2010	0.052	0.107	0.002	0.230	4.024
m19	2012	2011	0.083	0.086	0.004	0.363	2.976
m19	2013	2012	0.431	0.099	0.131	1.899	4.120
m19	2014	2013	-0.003	0.112	0.000	-0.015	3.620
m19	2015	2014	-0.141	0.110	0.016	-0.626	3.699
m19	2016	2015	0.237	0.233	0.130	1.132	2.675
m19	2017	2016	-0.050	0.270	0.007	-0.244	3.597
m19	2018	2017	-0.111	0.221	0.026	-0.525	2.203
m19	2019	2018	0.343	0.111	0.096	1.519	2.707
m19	2020	2019	-0.186	0.216	0.071	-0.880	2.274

Table 10: Detailed output for model m20. Fitted values are log-transformed.

model	year	juvenile_year	resid	hat_values	Cooks_distance	std_resid	fitted
m20	1998	1997	0.407	0.045	0.034	1.477	3.343
m20	1999	1998	-0.394	0.300	0.399	-1.671	4.748
m20	2000	1999	-0.302	0.127	0.064	-1.148	3.313
m20	2001	2000	0.199	0.081	0.016	0.738	4.005
m20	2002	2001	0.003	0.079	0.000	0.010	3.811
m20	2003	2002	0.037	0.127	0.001	0.142	3.924
m20	2004	2003	0.215	0.049	0.011	0.781	3.599
m20	2005	2004	0.268	0.105	0.040	1.005	3.812
m20	2006	2005	-0.350	0.125	0.084	-1.327	2.801
m20	2007	2006	0.331	0.045	0.023	1.201	3.472
m20	2008	2007	-0.208	0.122	0.029	-0.787	2.974
m20	2009	2008	-0.201	0.183	0.046	-0.788	3.838
m20	2010	2009	-0.260	0.054	0.017	-0.948	3.438
m20	2011	2010	-0.123	0.111	0.009	-0.463	4.199
m20	2012	2011	0.055	0.088	0.001	0.204	3.004
m20	2013	2012	0.391	0.118	0.097	1.478	4.160
m20	2014	2013	0.247	0.061	0.018	0.904	3.369
m20	2015	2014	-0.420	0.083	0.073	-1.556	3.978
m20	2016	2015	0.028	0.156	0.001	0.109	2.884
m20	2017	2016	0.028	0.348	0.003	0.121	3.519
m20	2018	2017	-0.217	0.207	0.065	-0.865	2.309
m20	2019	2018	0.399	0.119	0.102	1.510	2.650
m20	2020	2019	-0.133	0.266	0.037	-0.550	2.221

Table 11: Detailed output for model m22. Fitted values are log-transformed.

model	year	juvenile_year	resid	hat_values	Cooks_distance	std_resid	fitted
m22	1998	1997	0.329	0.045	0.027	1.305	3.421
m22	1999	1998	-0.602	0.318	1.248	-2.832	4.957
m22	2000	1999	-0.411	0.157	0.187	-1.739	3.422
m22	2001	2000	0.112	0.090	0.007	0.455	4.093
m22	2002	2001	-0.105	0.105	0.007	-0.430	3.918
m22	2003	2002	0.009	0.128	0.000	0.039	3.952
m22	2004	2003	0.208	0.049	0.012	0.828	3.605
m22	2005	2004	0.179	0.093	0.018	0.731	3.900
m22	2006	2005	-0.086	0.234	0.015	-0.383	2.537
m22	2007	2006	0.214	0.056	0.015	0.856	3.588
m22	2008	2007	-0.220	0.122	0.039	-0.911	2.986
m22	2009	2008	-0.020	0.100	0.000	-0.083	3.658
m22	2010	2009	-0.073	0.048	0.001	-0.289	3.251
m22	2011	2010	0.117	0.112	0.010	0.484	3.958
m22	2012	2011	0.041	0.089	0.001	0.168	3.017
m22	2013	2012	0.507	0.085	0.131	2.057	4.044
m22	2014	2013	0.075	0.093	0.003	0.304	3.542
m22	2015	2014	-0.163	0.108	0.018	-0.671	3.722
m22	2016	2015	0.093	0.172	0.011	0.398	2.819
m22	2017	2016	-0.039	0.287	0.004	-0.181	3.586
m22	2018	2017	-0.133	0.218	0.032	-0.584	2.225
m22	2019	2018	0.256	0.107	0.044	1.051	2.793
m22	2020	2019	-0.287	0.184	0.114	-1.233	2.375
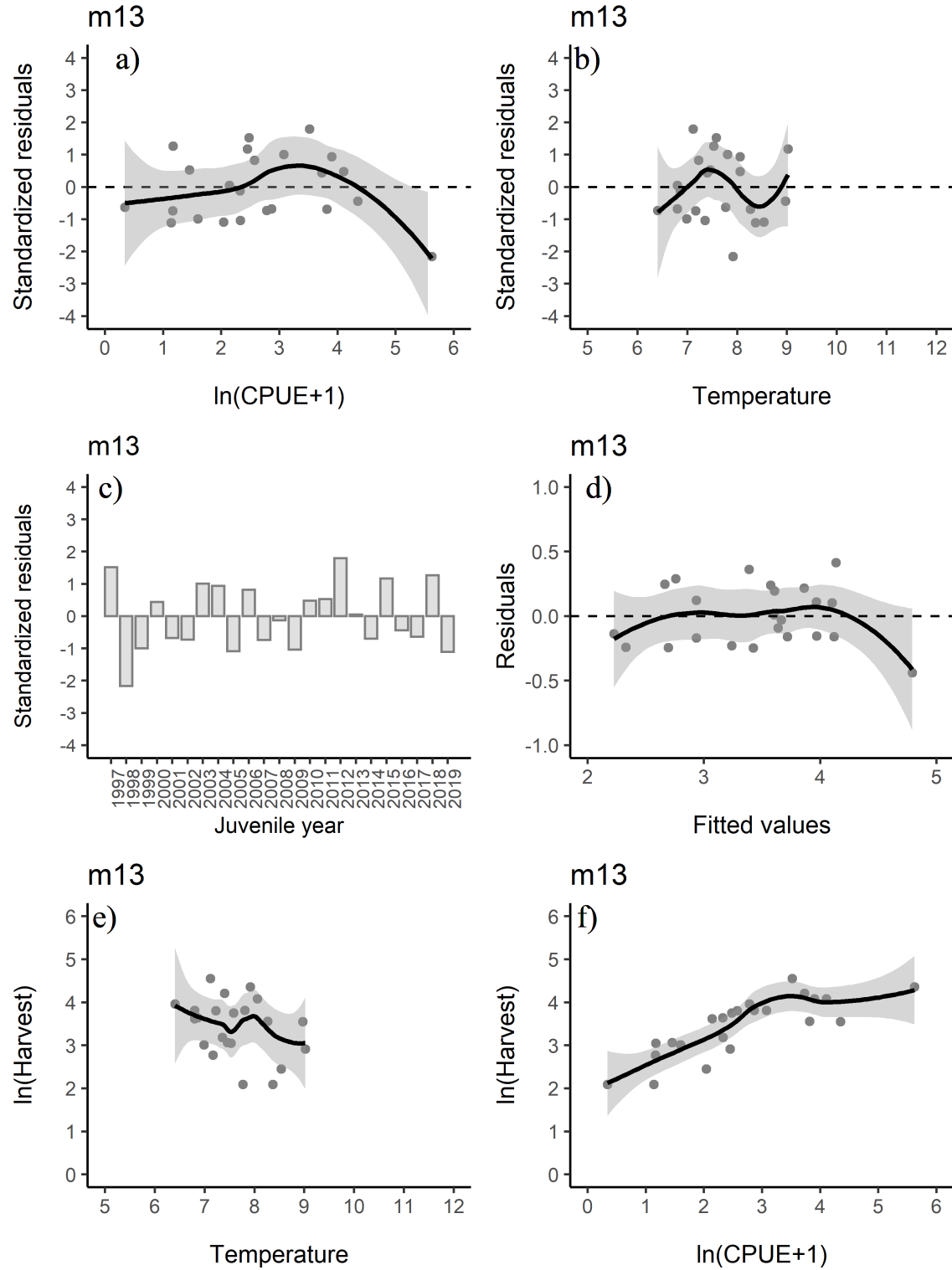
Figure 2: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m13. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.
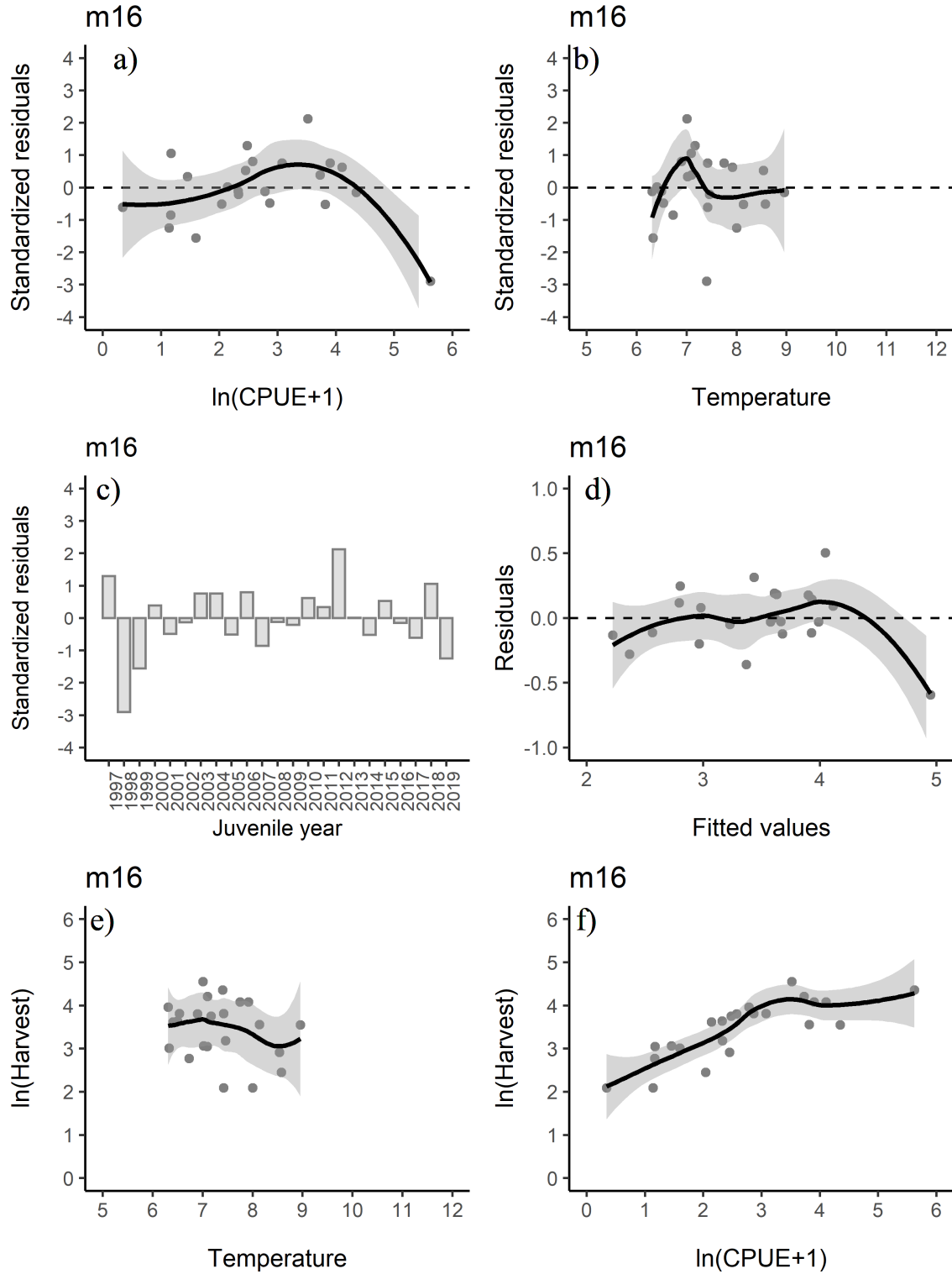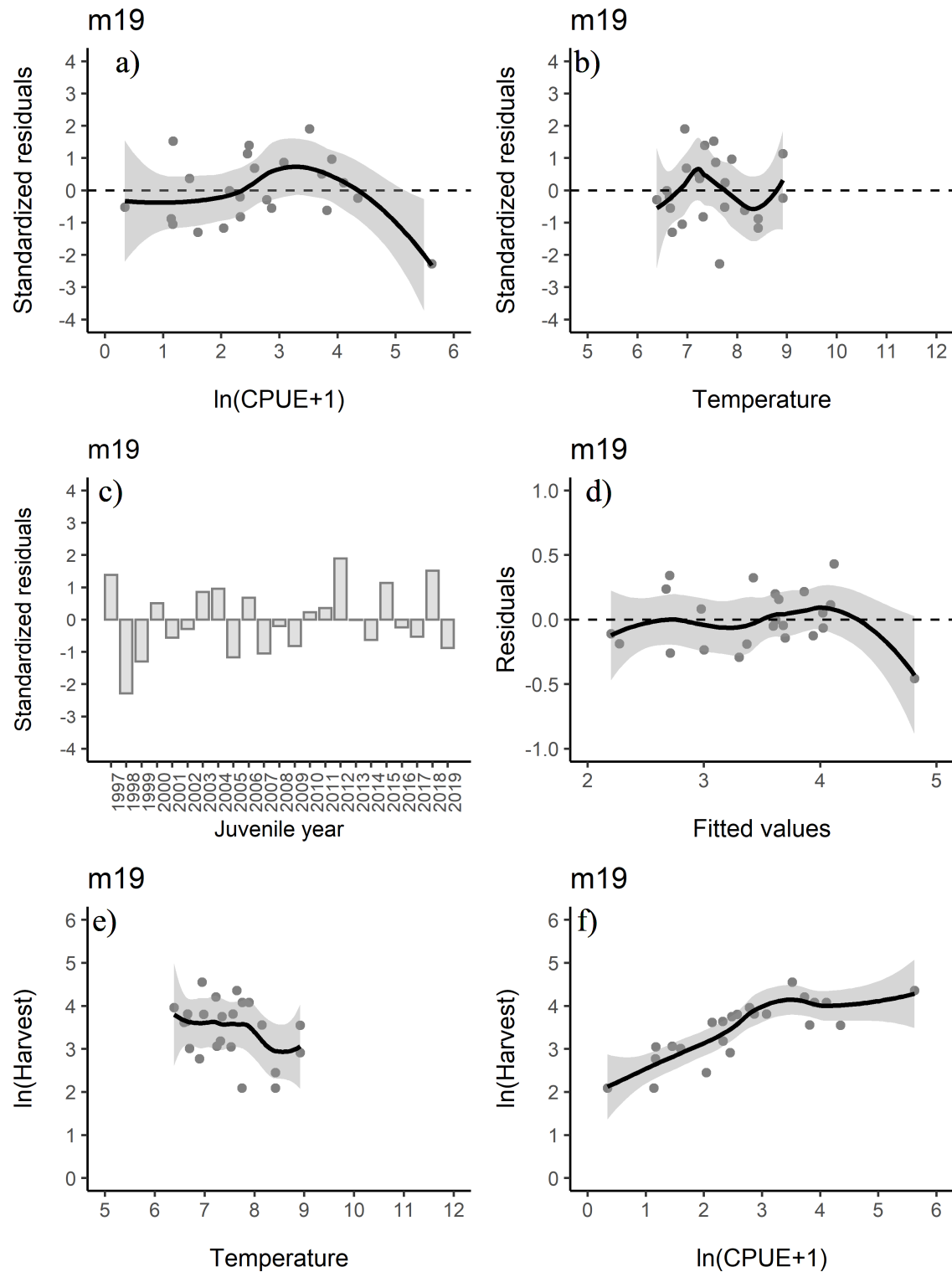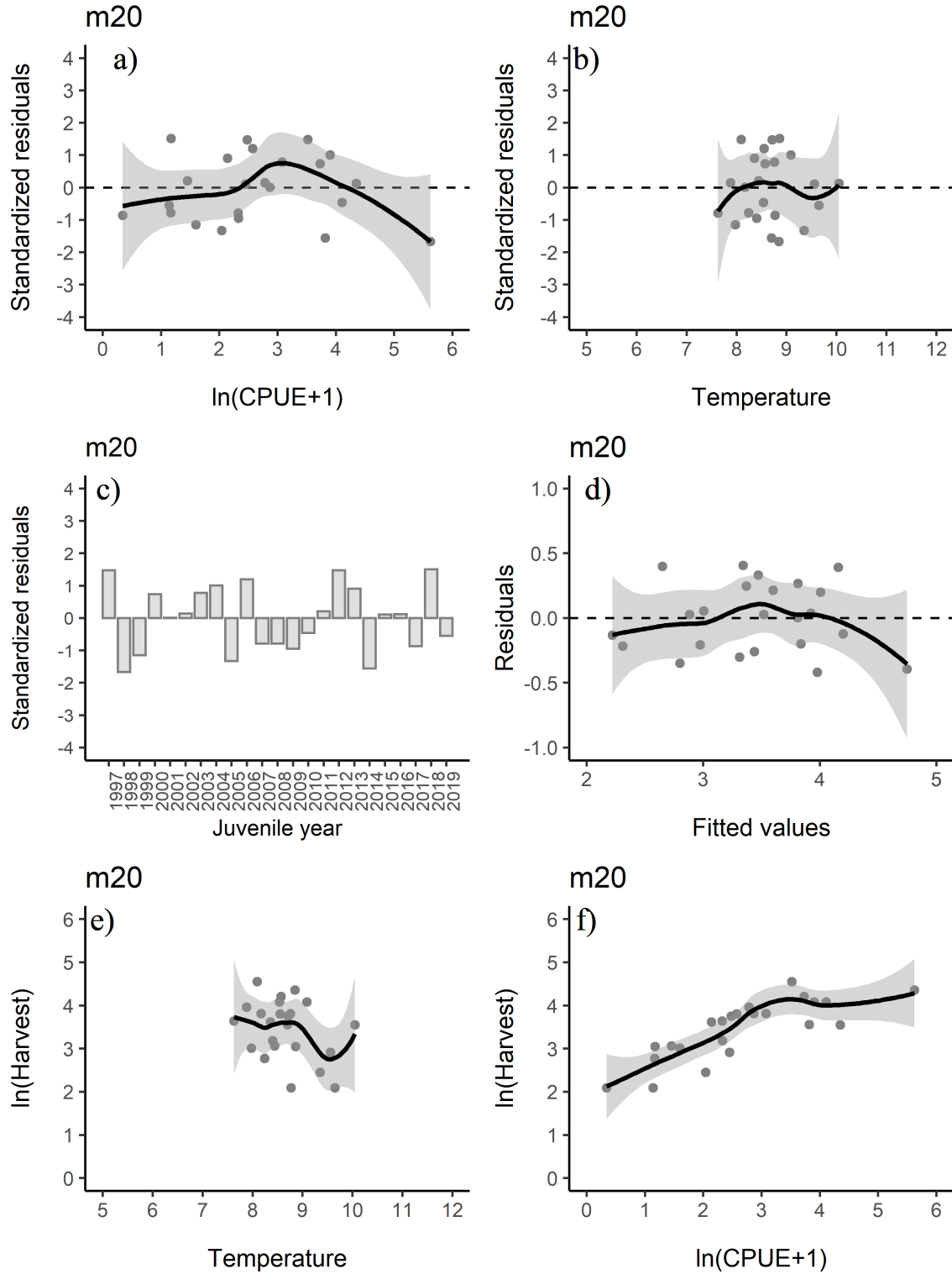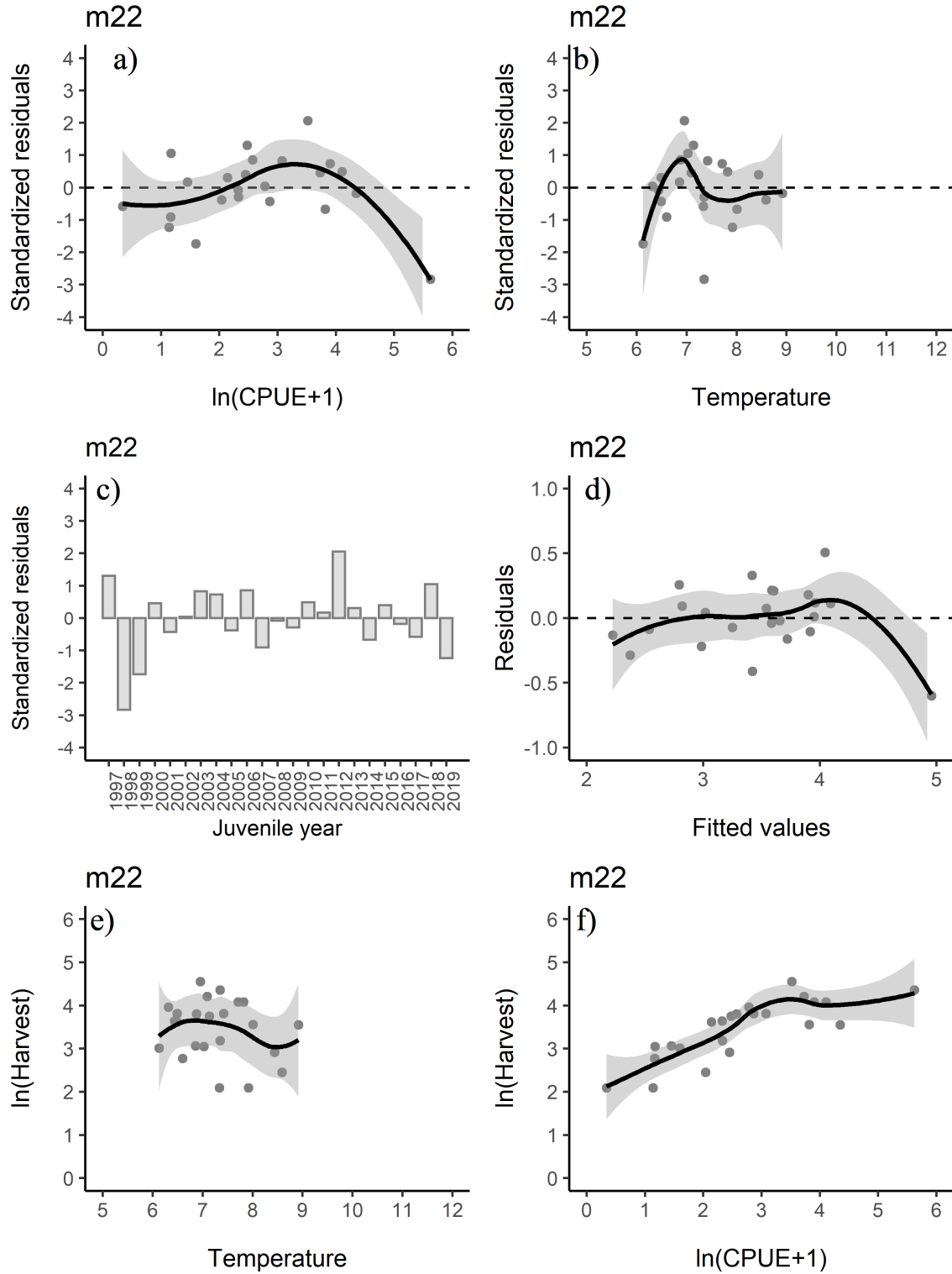
Figure 3: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m16. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

Figure 4: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m19. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

Figure 5: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m20. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

Figure 6: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m22. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.
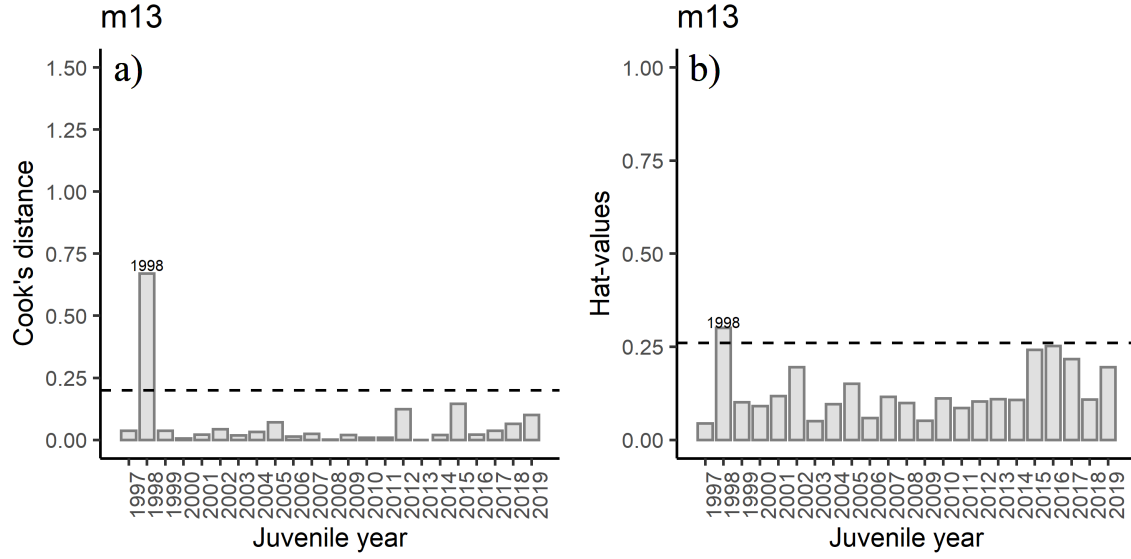
Figure 7: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m13.
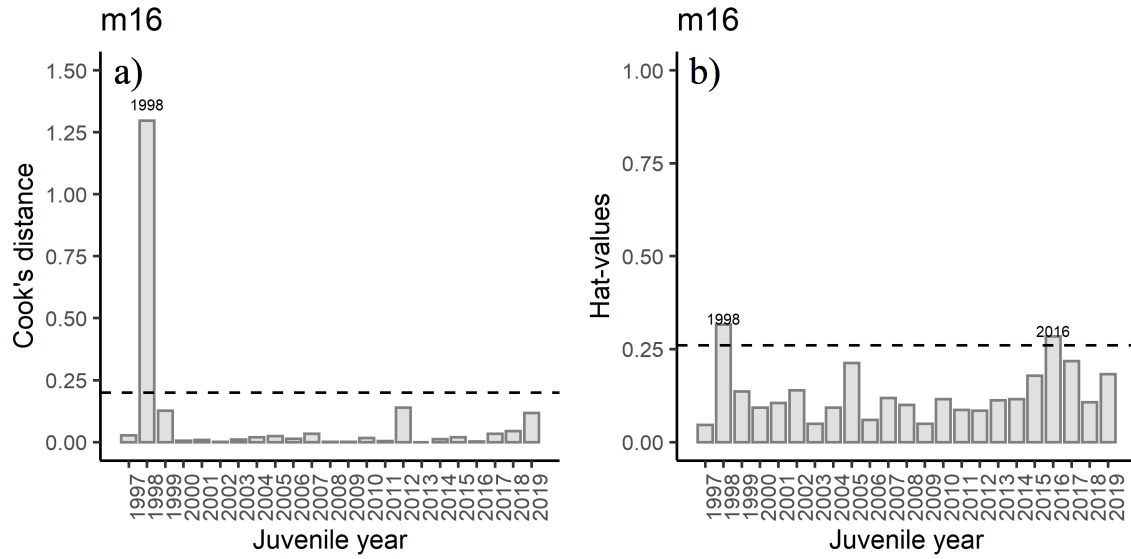
Figure 8: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m16.
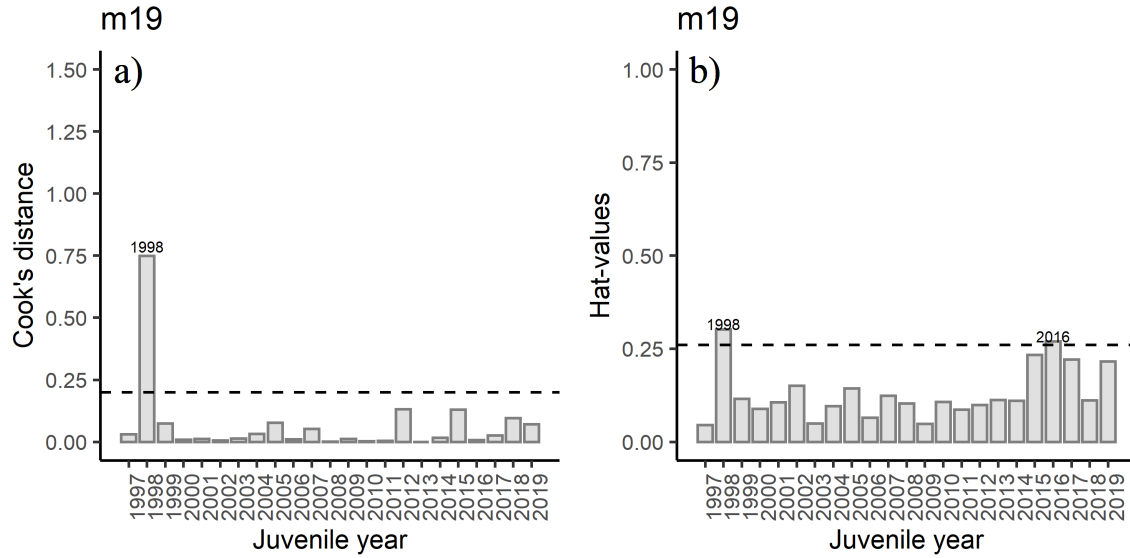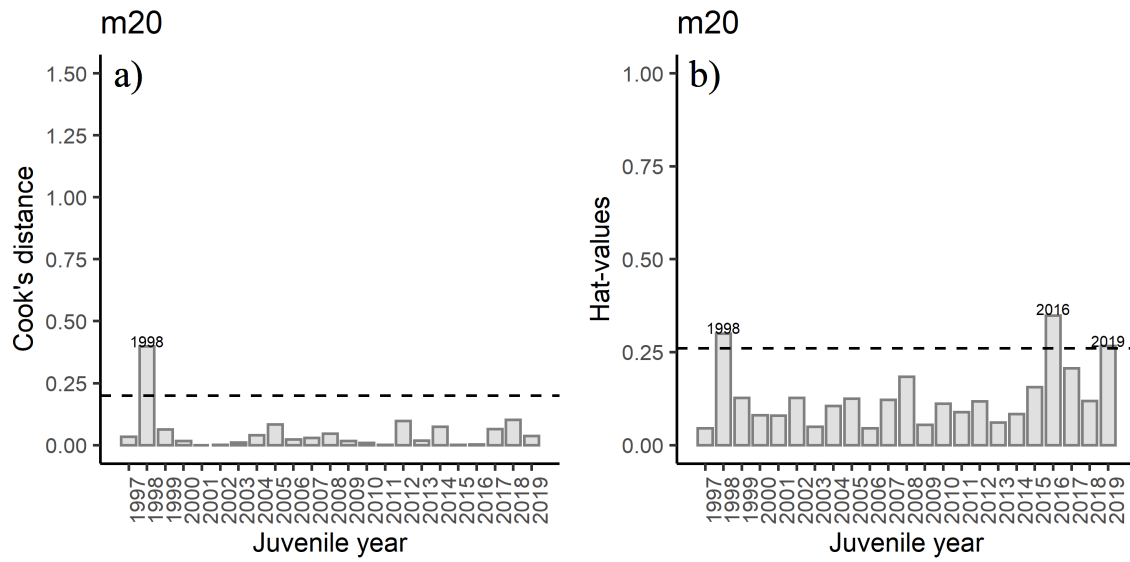
Figure 9: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m19.

Figure 10: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m20.
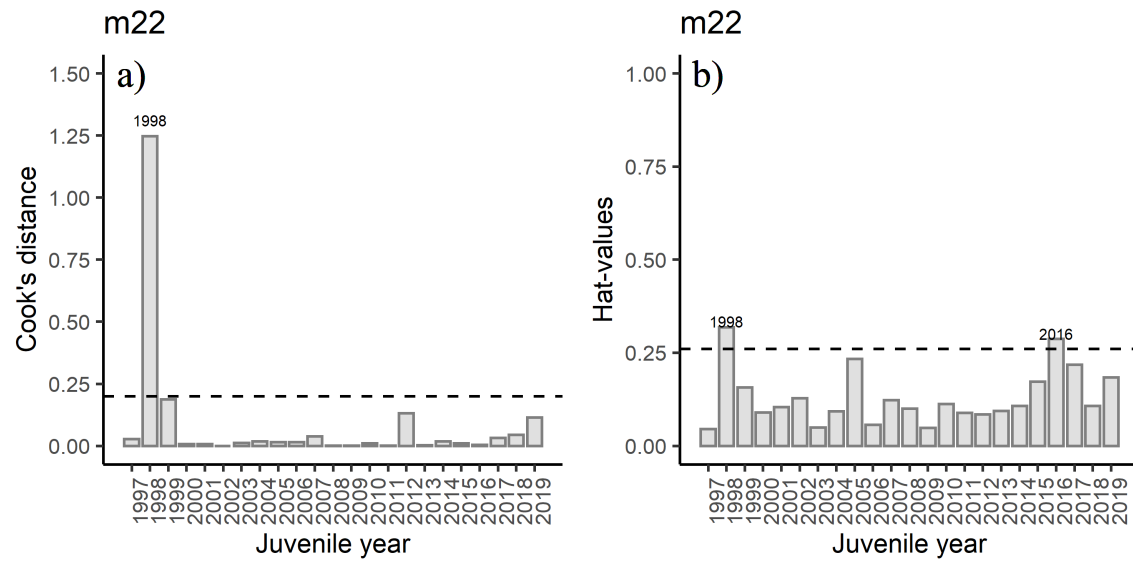
Figure 11: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m22.