Preliminary Discussion about the 2022 Forecast Process

Sara Miller

May 17, 2021

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). 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. Overall, the performance metrics recommended models m13, m16, m19, m20, and m22.

3 Analysis

3.1 Hierarchical models

Forty five 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 a 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 5); therefore only additive models (23 models; Table 1) were considered further.

Table 1: Parameter estimates for the 23 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
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

model	term	estimate	std.error	statistic	p.value
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

3.2 Performance metrics

The model summary results (Tables 2 and 3) using the performance metrics AICc, *MASE*, *wMAPE*, and *MAPE_LOOCV* 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 values and F_t are the predicted values. The performance metric *wMAPE* was calculated as

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

The AICc in Table 2 is the AICc value and not the Δ_iAICc. The performance metric AICc suggests that models m19, m16, and m13 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 models m13, m16, m19, m20, and m22 are in the appendix (Tables 6 to 10 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	0.176
m2	0.790	18.77	0.284	0.134	0.087	0.143
m3	0.803	17.28	0.276	0.128	0.084	0.139
m4	0.810	16.52	0.278	0.119	0.084	0.132
m5	0.816	15.74	0.274	0.111	0.082	0.123
m6	0.763	21.57	0.308	0.130	0.094	0.138
m7	0.797	17.99	0.286	0.119	0.087	0.127
m8	0.821	15.08	0.263	0.105	0.079	0.114
m9	0.838	12.85	0.246	0.092	0.073	0.102
m10	0.805	17.09	0.269	0.127	0.083	0.138
m11	0.741	23.63	0.321	0.138	0.099	0.145
m12	0.796	18.17	0.298	0.092	0.088	0.113
m13	0.873	7.20	0.238	0.077	0.070	0.091
m14	0.824	14.80	0.277	0.072	0.080	0.084
m15	0.800	17.64	0.294	0.090	0.087	0.107
m16	0.868	8.11	0.212	0.066	0.062	0.072
m17	0.819	15.36	0.282	0.077	0.083	0.091
m18	0.813	16.18	0.286	0.078	0.084	0.094
m19	0.877	6.47	0.224	0.070	0.066	0.089
m20	0.830	14.00	0.270	0.063	0.078	0.073
m21	0.790	18.75	0.306	0.097	0.091	0.113
m22	0.858	9.88	0.221	0.066	0.065	0.072
m23	0.812	16.27	0.290	0.080	0.085	0.094

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

3.3 Sensitivity analysis

A sensitivity analysis was to determine if the juvenile year 1998 was influential. For the sensitivity analysis, juvenile year 1998 and 2016 (high leverage values in a majority of the 5 preferred models) was removed, the models rerun, and the performance metrics calculated (Table 4).The performance metric AICc suggests that model m16 and m22 is 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. 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 year 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), and leave one out cross validation MAPE (MAPE_LOOCV).

model	terms	fit	AdjR2	AICc	MASE	wMAPE	MAPE_LOOCV
m1	CPUE	27.618	0.693	24.16	0.378	0.162	0.106
m2	CPUE + ISTI3_May	24.015	0.847	11.48	0.249	0.126	0.074
m3	CPUE + ISTI10_May	23.686	0.850	11.10	0.245	0.124	0.073
m4	CPUE + ISTI15_May	23.767	0.844	11.94	0.249	0.121	0.073
m5	CPUE + ISTI20_May	24.180	0.841	12.33	0.249	0.121	0.073
m6	CPUE + ISTI3_MJJ	31.126	0.820	14.96	0.276	0.115	0.083
m7	CPUE + ISTI10_MJJ	30.082	0.835	13.09	0.264	0.115	0.079
m8	CPUE + ISTI15_MJJ	28.985	0.844	11.87	0.252	0.109	0.075
m9	CPUE + ISTI20_MJJ	28.163	0.854	10.50	0.240	0.100	0.071
m10	CPUE + IS3_May	23.539	0.850	11.15	0.246	0.124	0.073
m11	CPUE + IS3_MJJ	31.343	0.806	16.55	0.285	0.118	0.087
m12	CPUE + Chatham_Strait_SST_MJJ	23.894	0.821	14.77	0.286	0.095	0.083
m13	CPUE + Chatham_Strait_SST_May	19.447	0.900	2.61	0.212	0.070	0.061
m14	CPUE + Chatham_Strait_SST_AMJJ	24.537	0.837	12.89	0.274	0.074	0.077
m15	CPUE + Icy_Strait_SST_MJJ	20.882	0.833	13.36	0.279	0.094	0.081
m16	CPUE + Icy_Strait_SST_May	16.666	0.920	-2.01	0.179	0.061	0.051
m17	CPUE + Icy_Strait_SST_AMJJ	20.889	0.843	12.05	0.265	0.074	0.076
m18	CPUE + NSEAK_SST_MJJ	22.014	0.831	13.59	0.280	0.082	0.081
m19	CPUE + NSEAK_SST_May	17.818	0.904	1.64	0.203	0.066	0.059
m20	CPUE + NSEAK_SST_AMJJ	22.062	0.839	12.54	0.267	0.064	0.075
m21	CPUE + SST_Jordan_MJJ	21.158	0.824	14.44	0.287	0.101	0.083
m22	CPUE + SST_Jordan_May	17.048	0.910	0.33	0.188	0.061	0.053
m23	CPUE + SST_Jordan_AMJJ	21.097	0.837	12.91	0.274	0.080	0.078

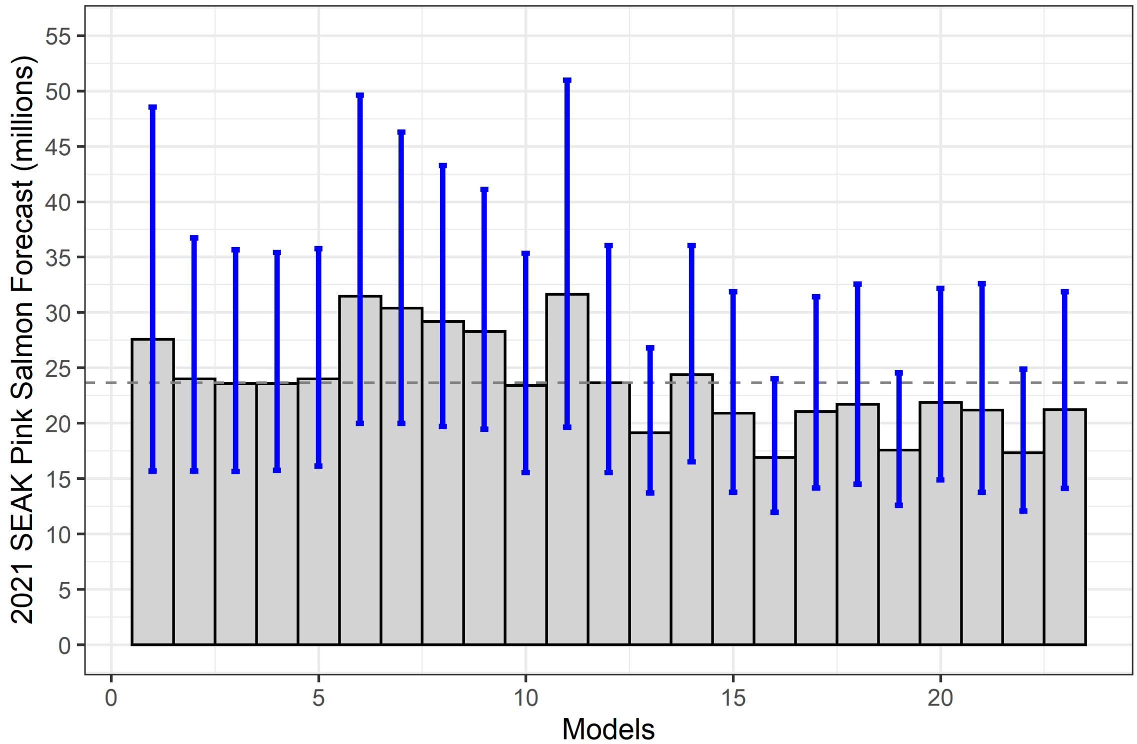

Figure 1: The 2021 SEAK pink salmon harvest (millions) forecast by model. The 80% prediction intervals (corrected for log transformation bias in a linear-model) around each forecast were calculated using the car package (Fox and Weisberg 2019) in program R (R Core Team 2020). The dotted horizontal line 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).

4 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.

Fox, J. and S. Weisburg. 2019. An R Companion to Applied Regression, Third Edition. Thousand Oaks CA: Sage Publications, Inc.

Hyndman, R. J. and A. B. Koehler. 2006. Another look at measures of forecast accuracy. International Journal of Forecasting 22: 679-688.

Murphy, J. M., E. A. Fergusson, A. Piston, A. Gray, and E. Farley. 2019. Southeast Alaska pink salmon growth and harvest forecast models. North Pacific Anadromous Fish Commission Technical Report No. 15: 75-81.

NOAA Coral Reef Watch. 2021, updated daily. NOAA Coral Reef Watch Version 3.1 Monthly 5km SST and SST Anomaly, NOAA Global Coral Bleaching Monitoring Time Series Data, May 1997-July 2020. College Park, Maryland, USA: NOAA/NESDIS/STAR Coral Reef Watch program. Data set accessed 2021-04-09 at https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW_monthly.html.

Orsi, J. A., E. A. Fergusson, A. C. Wertheimer, E. V. Farley, and P. R. Mundy. 2016. Forecasting pink salmon production in Southeast Alaska using ecosystem indicators in times of climate change. N. Pac. Anadr. Fish Comm. Bull. 6: 483–499. (Available at https://npafc.org)

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.r-project.org/index.html

Wertheimer A. C., J. A. Orsi, M. V. Sturdevant, and E. A. Fergusson. 2006. Forecasting pink salmon harvest in Southeast Alaska from juvenile salmon abundance and associated environmental parameters. In Proceedings of the 22nd Northeast Pacific Pink and Chum Workshop. Edited by H. Geiger (Rapporteur). Pac. Salmon Comm. Vancouver, British Columbia. pp. 65–72.

5 Appendix

Table 5: Parameter estimates for the 23 interaction 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
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

model	term	estimate	std.error	statistic	p.value
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
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

Table 6: 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 7: 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 8: 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 9: 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 10: 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

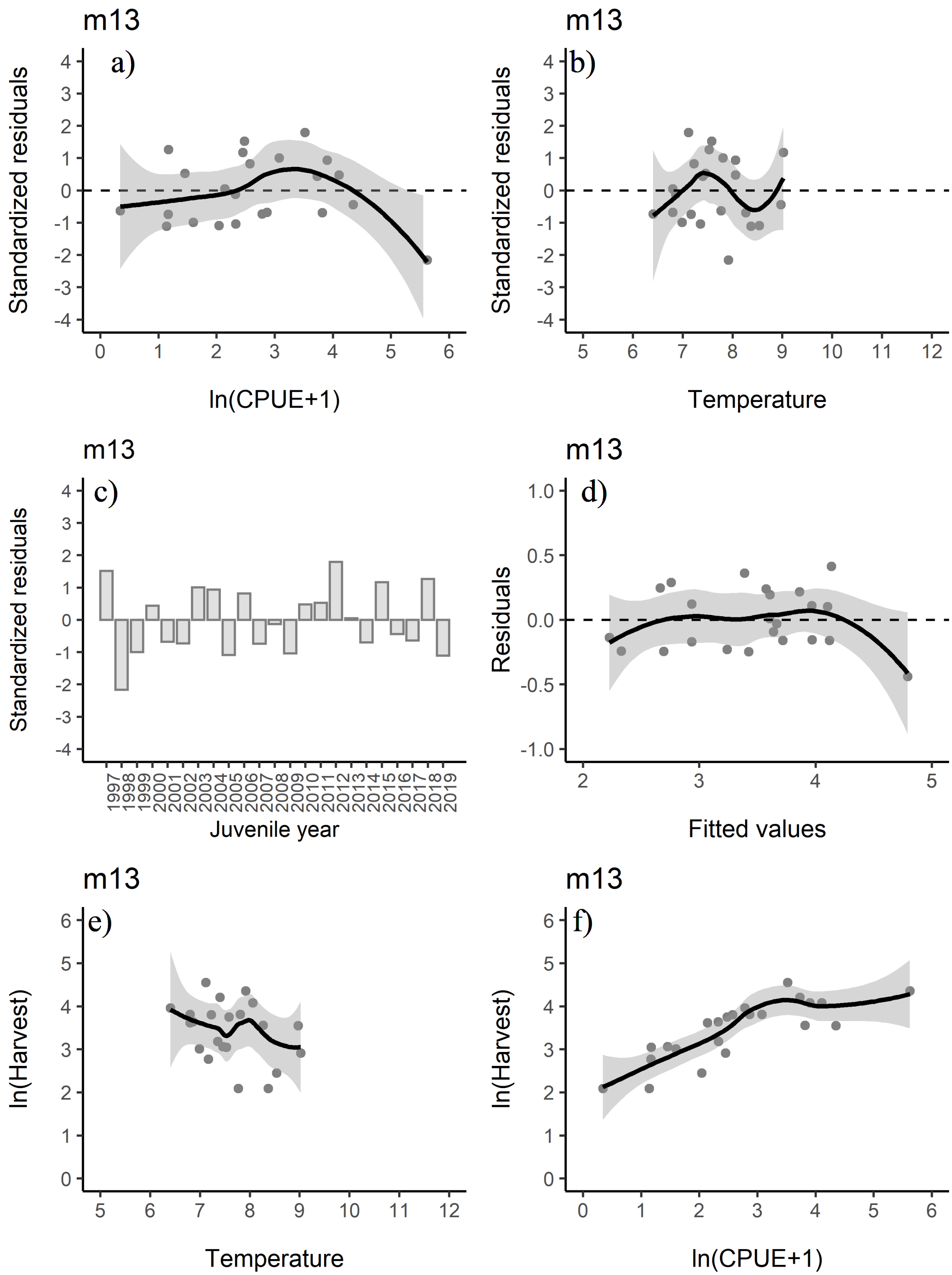

Figure 2: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m13. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

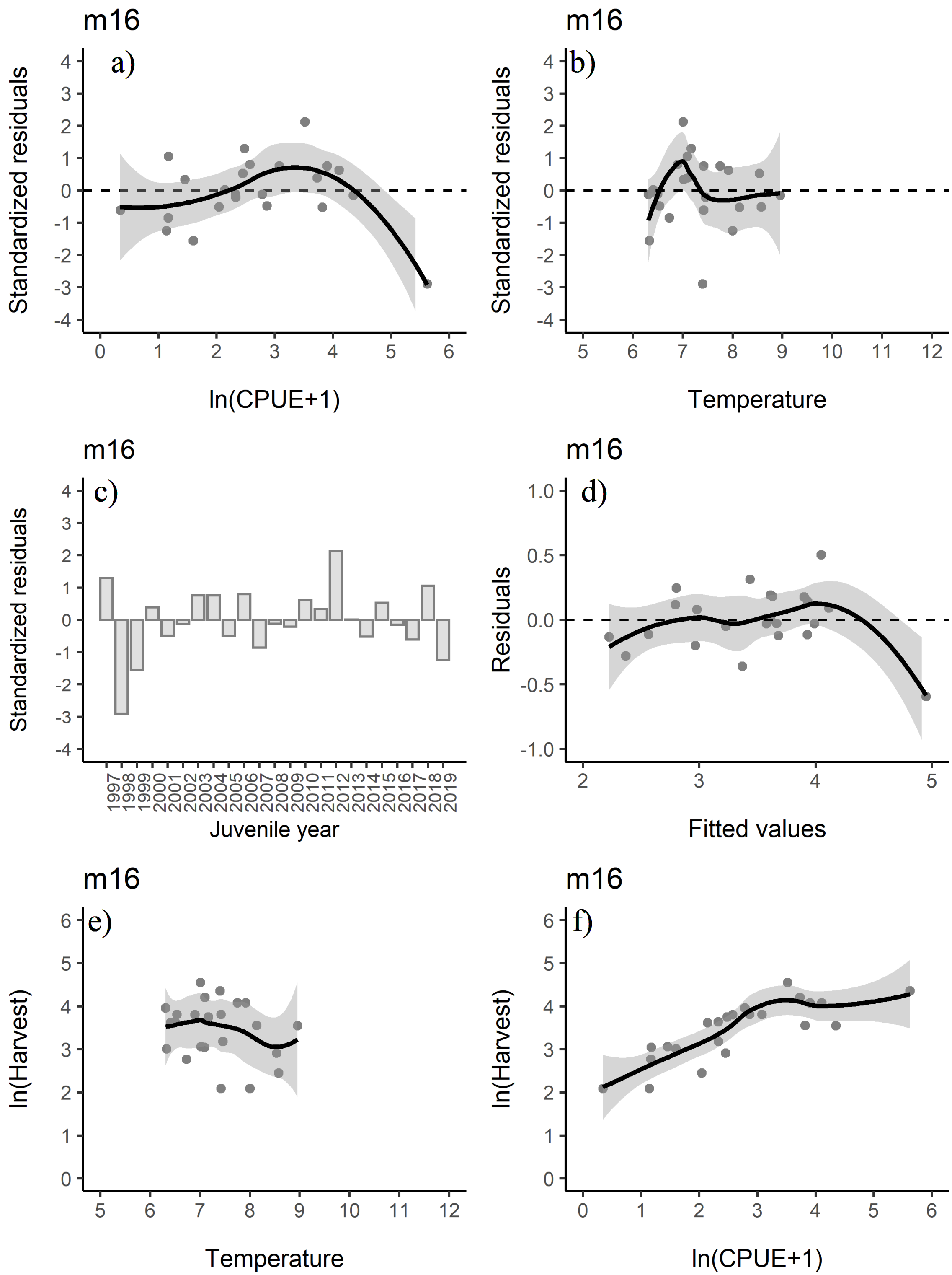

Figure 3: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m16. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

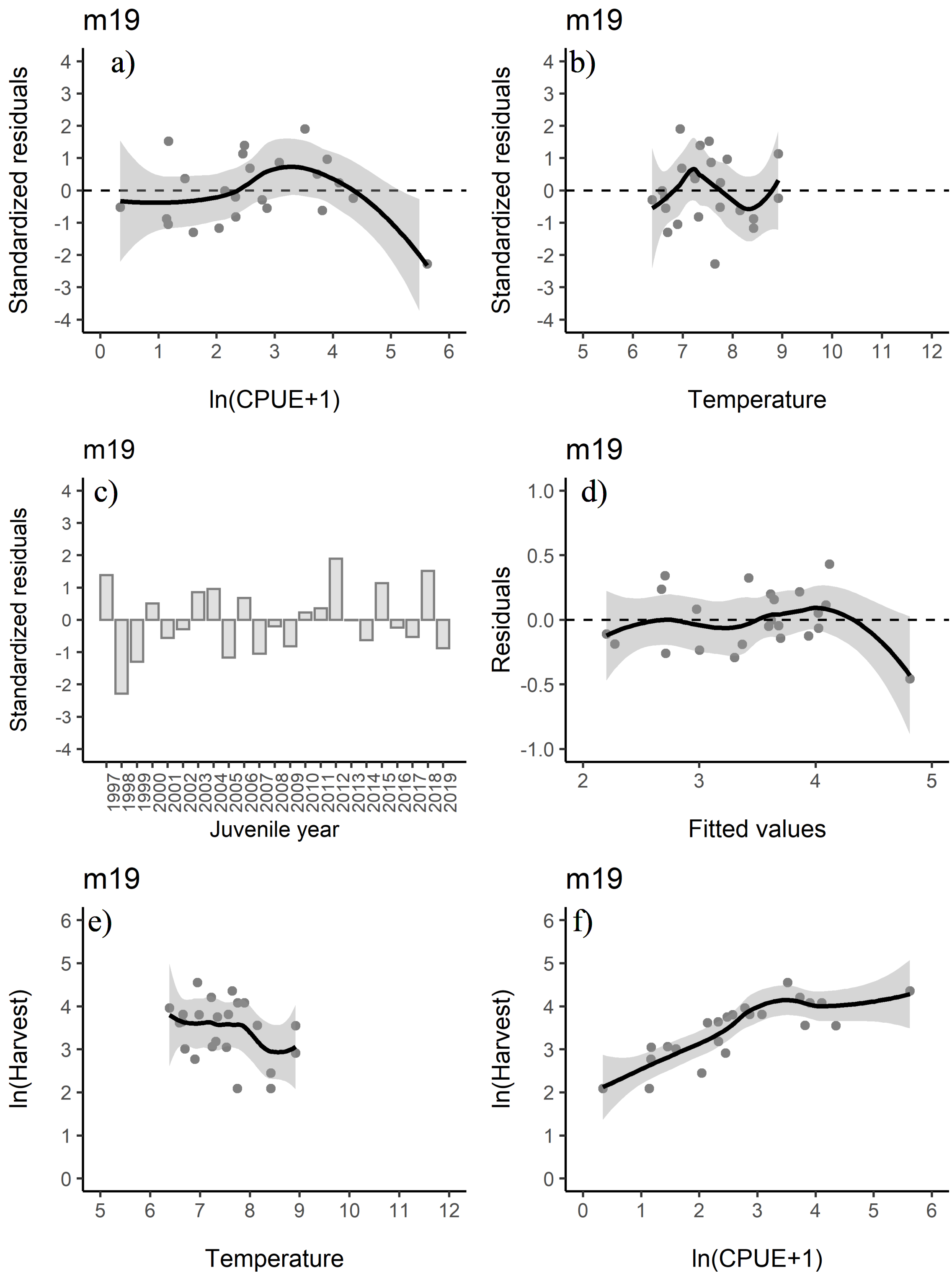

Figure 4: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m19. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and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

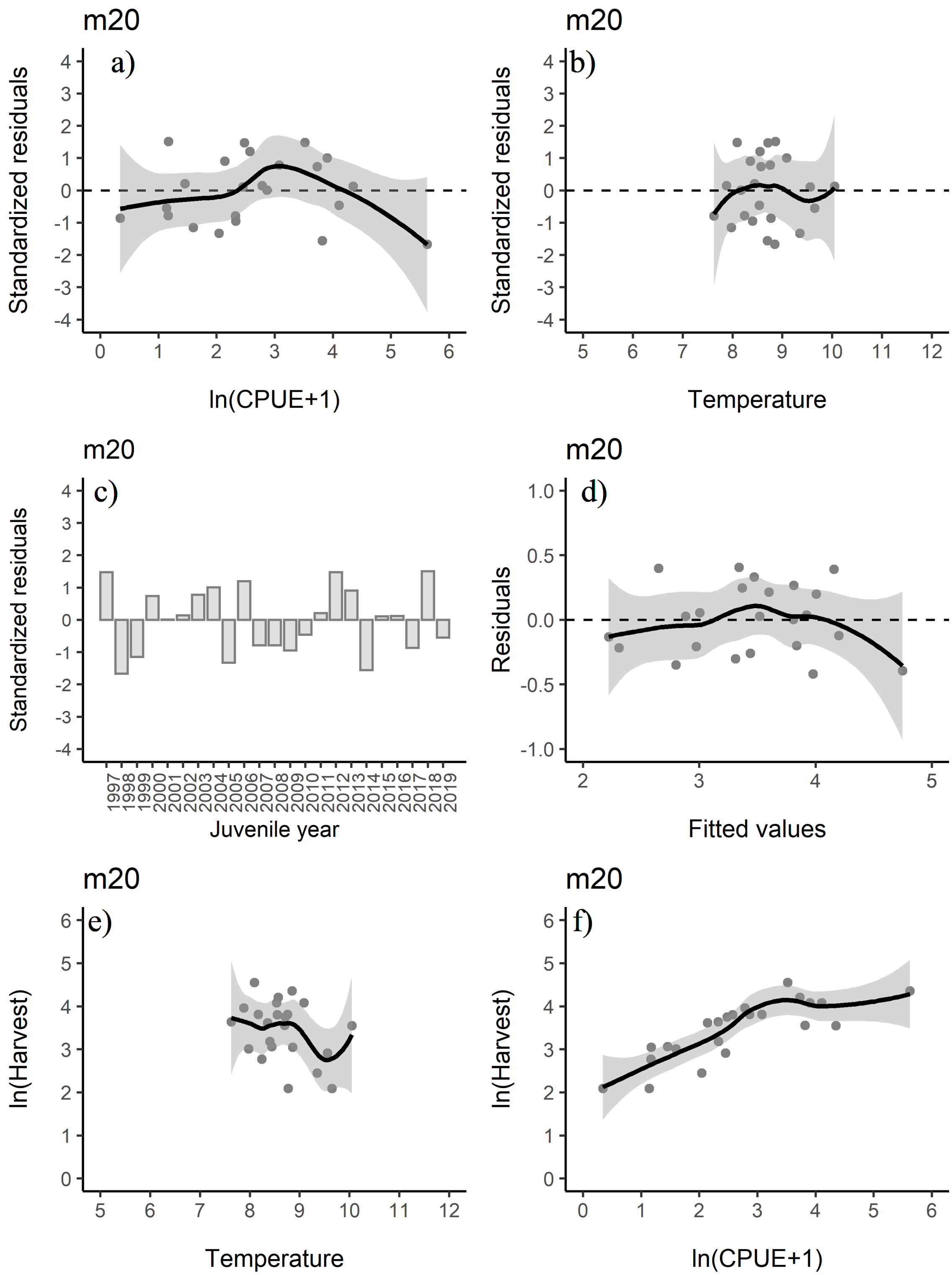

Figure 5: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m20. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and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

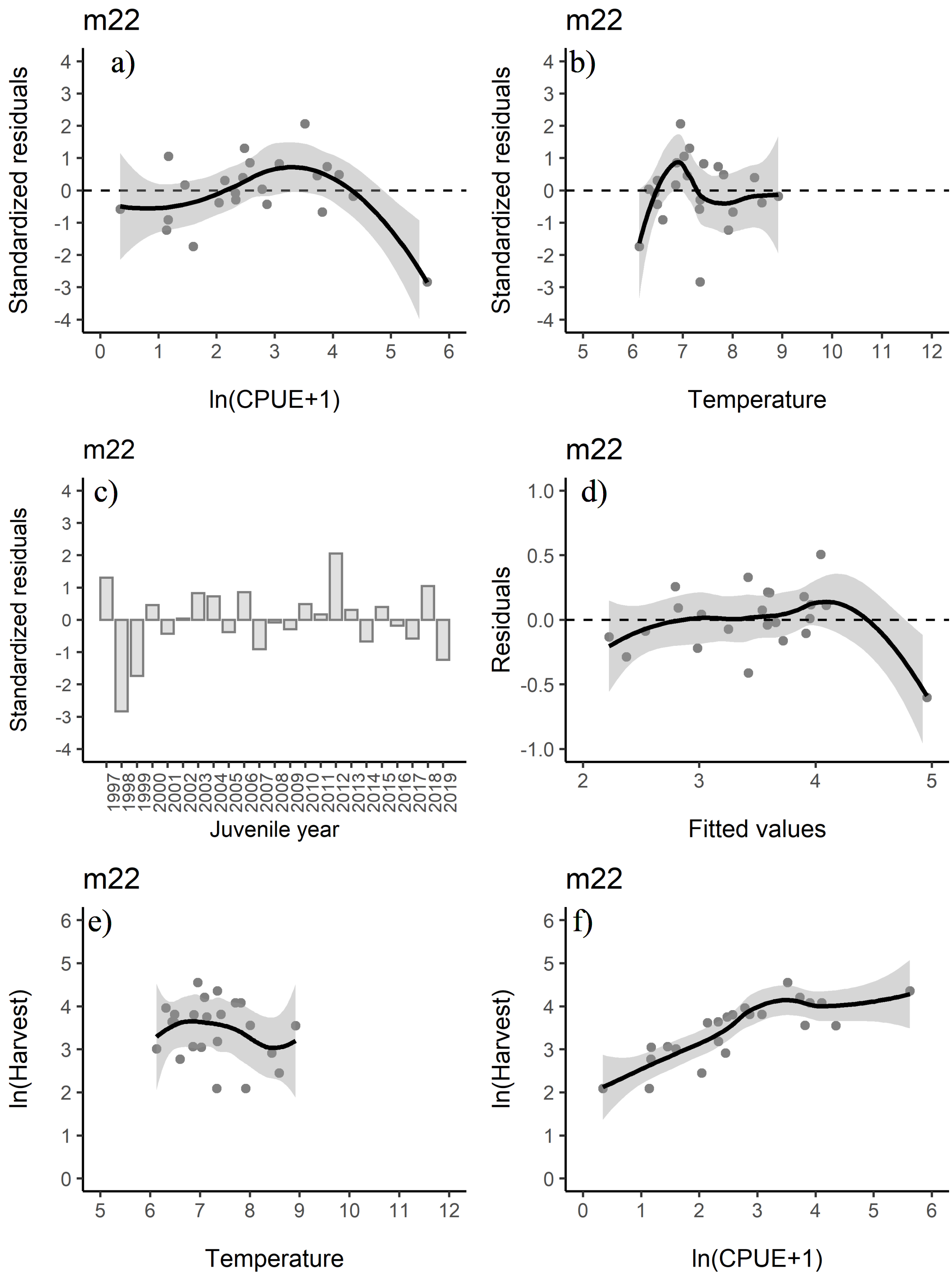

Figure 6: Standardized residuals versus the predicted plots for a) CPUE and b) temperature. c) Standardized residuals versus juvenile year and d) residuals versus fitted values for model m22. Relationship between e) temperature and harvest and f) CPUE and harvest. The line in figures a, b, d, e, and f is a smoothing function applied to the relationship with a 95% confidence interval.

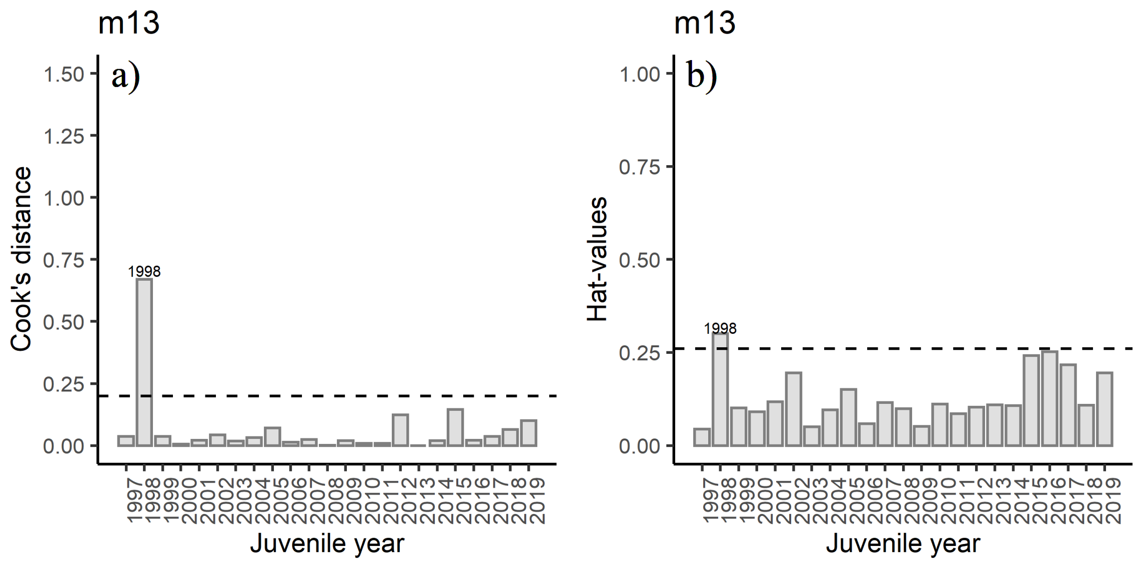

Figure 7: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m13.

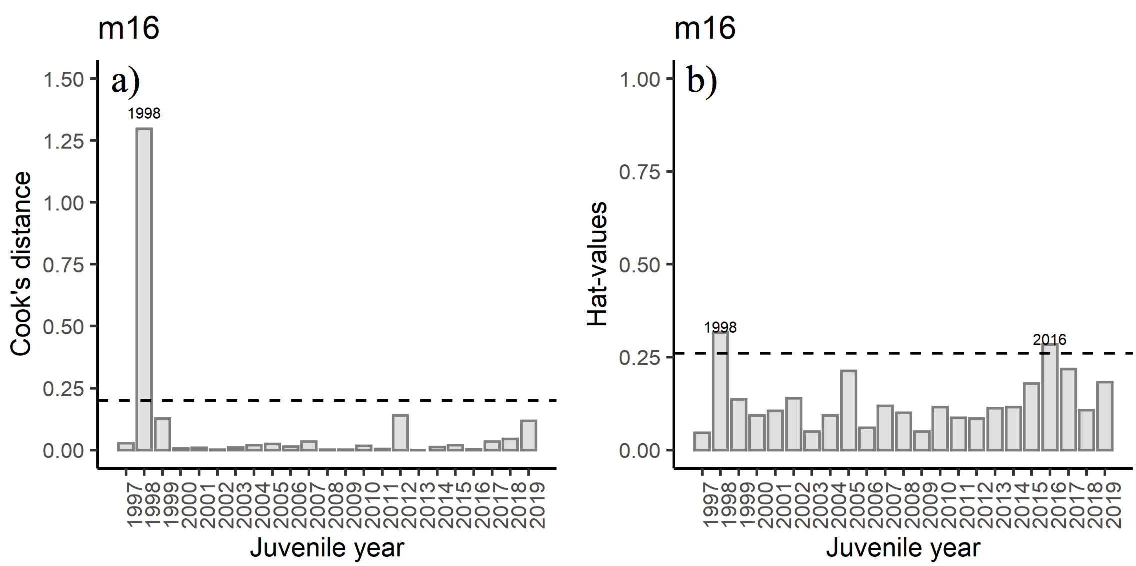

Figure 8: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m16.

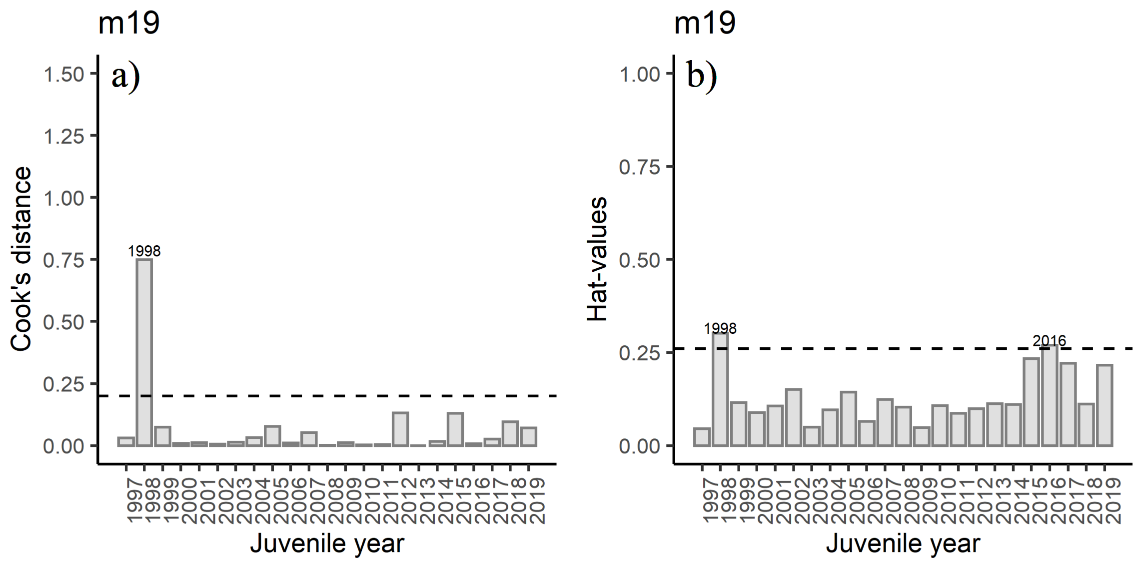

Figure 9: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m19.

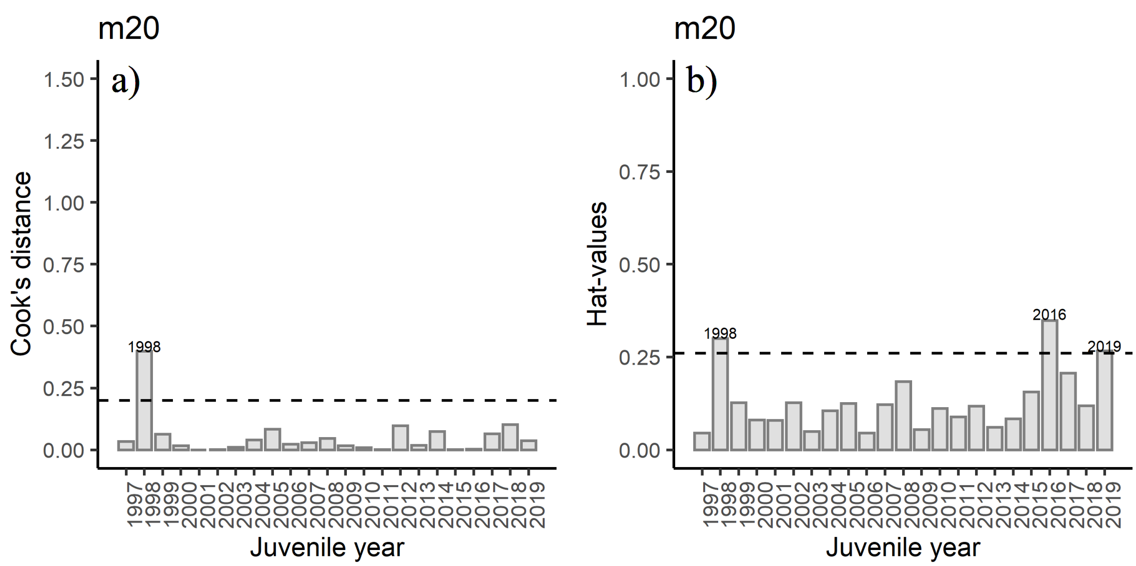

Figure 10: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m20.

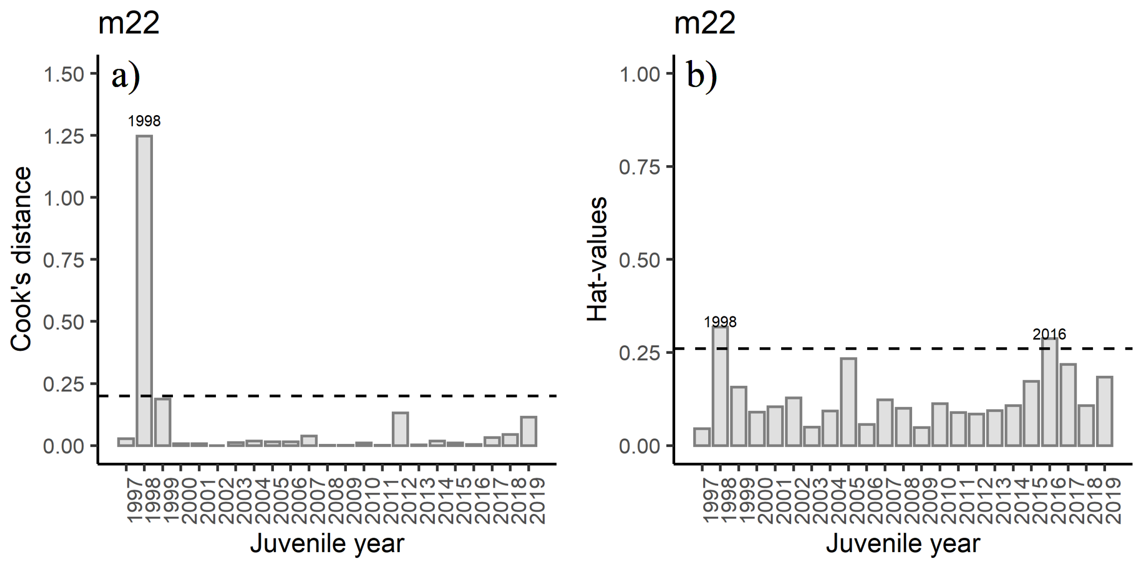

Figure 11: Diagnostics plots of influential observations including a) Cook's Distance (with a cut-off value of 0.20), and b) leverage values (with a cut-off value of 0.26) from model m22.