2026 SEAK Pink Salmon Forecast

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Objective

To forecast the Southeast Alaska (SEAK) pink salmon commercial harvest in 2026. This document is for guidance as to what was done for the current forecast year. It is for internal use only.

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), but assuming a log-normal error structure (Miller et al. 2022). This approach is based on a multiple linear regression model with either; 1) the raw juvenile pink salmon catch-per-unit-effort (adj_raw_pink_log; a proxy for abundance) or 2) the vessel-adjusted juvenile CPUE adjusted by the pooled-species vessel calibration coefficient for the Cobb (vessel-adjusted CPUE; a proxy for abundance). Additional variables included a vessel factor to account for the survey vessels through time, an odd and even year factor to account for potential odd and even year cycles of abundance, and temperature data from the Southeast Alaska Coastal Monitoring Survey (SECM; Piston et al. 2021; ISTI20_JJ) or from satellite-derived sea surface temperature (SST) data (Huang et al. 2017). The adj_raw_pink variable is defined as the natural logarithm of the maximum untransformed catch, adjusted to a 20 minute haul, from either June or July. The Stellar and Chellissa vessels were only used for one year each, 2008 and 2009, respectively, and so these two years are not used in the assessment (Table 1). The vessel-adjusted CPUE variable is defined as the CPUE, adjusted by the pooled-species vessel calibration coefficient for the Cobb and was then the maximum average from either June or July (whichever was higher). As there was not a SECM survey in May, temperature data from May was unavailable. Therefore, the temperature variable from the SECM survey and used in the model (ISTI20_JJ) was the average from June and July. In prior forecasting years, the ISTI variable was the average from May through July.

There were 36 individual models considered:

- adj_raw_pink_log model with a vessel interaction, an odd/even year factor, and a vessel factor (m1);
- adj_raw_pink_log model with a vessel interaction, an odd/even year factor, a vessel factor, and temperature data from the the SECM survey (m2);
- 16 adj_raw_pink_log models with a vessel interaction, an odd/even year factor, a vessel factor, and satellite SST data (m3-m18);
- vessel-adjusted CPUE, and an odd/even year factor (m1a);
- vessel-adjusted CPUE, an odd/even year factor, and temperature data from the the SECM survey (m2a);
- 16 vessel-adjusted CPUE models with an odd/even year factor, and satellite-derived SST data (m3a-m18a);

The model performance metric one-step ahead mean absolute percent error (MAPE) for the last five years (MAPE5; forecast years 2021 through 2025) was used to evaluate the forecast accuracy of the 36 individual models, the AICc values were calculated for each model to prevent over-parameterization of the model, and the adjusted R-squared values, significant terms, and overall p-value of the model were used to the determine fit. Based upon the performance metric the 5-year MAPE, the AICc values, significant parameters in the models, and the adjusted R-squared values, model m13a (a model that included vessel-adjusted CPUE, an odd/even year factor, and satellite-derived SST data from northern SEAK in April, May, and June; Appendix C) was the best performing model and the 2026-forecast using this model has a point estimate of xx million fish (80% prediction interval: xx to xx million fish).

Analysis

Individual, multiple linear regression models

Biophysical variables based on data from Southeast Alaska (Table 1) were used to forecast the harvest of adult pink salmon in Southeast Alaska, one year in advance, using individual, multiple linear regression models with two main structures (models m1-m18 and models m1a–m18a). The first model structure, model m1, consisted of the predictor variable juvenile adj_raw_pink_log (CPUE) with a vessel factor interaction, an odd/even year factor, and a vessel factor (model m1),

$$E(Y) = \beta_0 + \beta_1 X_{V1} + \beta_2 X_{V2} + \beta_3 X_O + \beta_4 CPUE + \beta_5 (X_{V1} \times CPUE) + \beta_6 (X_{V2} \times \mathrm{C}PUE) + \epsilon.$$

The reference category is an even year with the survey vessel Cobb. The vessel factor and even/odd year factor adjust the intercept, and the vessel interaction terms adjust the model slope. For example, during even years when the survey vessel is the Cobb, the model simplifies to $E(Y) = \beta_0 + \beta_4 CPUE + \epsilon$. Although the simplest model does not contain a temperature variable, including temperature data with CPUE has been shown to result in a substantial improvement in the accuracy of model predictions (Murphy et al. 2019). The temperature index for models m2-m18 was either the SECM survey Icy Strait temperature Index (ISTI20_JJ; Murphy et al. 2019) or one of the 16 satellite-derived SST data (Huang et al. 2017; definitions in Appendix A).

The second model structure, model m1a, consisted of the predictor variable vessel-adjusted CPUE (CPUE), and an odd/even year factor,

$$E(Y) = \beta_0 + \beta_2 X_O + \beta_3 CPUE + \epsilon.$$

The reference category (i.e., reference intercept) is an even year. The temperature index for models m2a-m18a was either the SECM survey Icy Strait temperature Index (ISTI20_JJ; Murphy et al. 2019) or one of the 16 satellite-derived SST data (Huang et al. 2017).

The response variable (Y; Southeast Alaska adult pink salmon harvest in millions), the adj_raw_pink_log, and the vessel-adjusted CPUE were log transformed in the model, but temperature data were not. The forecast ($\hat{Y}_i$), and 80% prediction intervals (based on output from program R; R Core Team 2025) from the 36 regression models were exponentiated and bias-corrected (Miller 1984),

$$\hat{F}_i = exp(\hat{Y}_i + \frac{{\sigma_i}^2}{2}), \tag{2}$$

where $\hat{F}_i$ is the preseason forecast (for each model i) in millions of fish, and σ_i is the variance (for each model i).

Performance metric: One-step ahead MAPE

The model summary results using the performance metric one-step ahead MAPE are shown in Table 2; the smallest value is the preferred model. The performance metric one-step ahead MAPE was calculated as follows.

1. Estimate the regression parameters at time t-1 from data up to time t-1.
2. Make a prediction of $\hat{Y}_t$ at time t based on the predictor variables at time t and the estimate of the regression parameters at time t-1 (i.e., the fitted regression equation).
3. Calculate the MAPE based on the prediction of $\hat{Y}_t$ at time t and the observed value of Y_t at time t,

$$\text{MAPE} = |\frac{exp(Y_t) - exp(\hat{Y}_t + \frac{{\sigma_t}^2}{2})}{exp(Y_t)}|. \tag{3}$$

4. For each individual model, average the MAPEs calculated from the forecasts,

$$\frac{1}{n}\sum_{t=1}^{n}|\frac{exp(Y_t) - exp(\hat{Y}_t + \frac{{\sigma_t}^2}{2})}{exp(Y_t)}|, \tag{4}$$

   where n is the number of forecasts in the average (5 forecasts for the 5-year MAPE and 10 forecasts for the 10-year MAPE). For example, to calculate the five year one-step-ahead MAPE for model m1 for the 2022 forecast, use data up through year 2016 (e.g., data up through year 2016 is t -1 and the forecast is for t, or year 2017). Then, calculate a MAPE based on the 2017 forecast and the observed pink salmon harvest in 2017 using equation 3. Next, use data up through year 2017 (e.g., data up through year 2017 is t -1 and the forecast is for year 2018; t) and calculate a MAPE based on the 2018 forecast and the observed pink salmon harvest in 2018 using equation 3. Repeat this process for each subsequent year through year 2020 to forecast 2021. Finally, average the five MAPEs to calculate a five year one-step-ahead MAPE for model m1. As the results of the 5-year MAPEs with or without the forecast bias adjustment have been similar (i.e., the model performance order did not change whether the five year one-step-ahead MAPE or the bias-corrected five year one-step-ahead MAPE was compared), for simplicity, the bias adjustment for the forecast was not used in the calculation of the five year one-step-ahead MAPE for model comparison.

Akaike Information Criterion corrected for small sample sizes (AICc)

Hierarchical models were compared with the AICc criterion. The best fit models, according to the AICc criterion, is one that explains the greatest amount of variation with the fewest independent variables (i.e., the most parsimonious; Table 2). The lower AICc values are better, and the AICc criterion penalizes models that use more parameters. Comparing the AICc values of two hierarchical models, a $\Delta_i \leq 2$ suggests that the two models are essentially the same, and the most parsimonious model should be chosen (Burnham and Anderson 2004). If the $\Delta_i > 2$, the model with the lower AICc value should be chosen.

Results

Based upon the 5-year MAPE performance metric, the AICc values, significant parameters in the models, and the adjusted R-squared values, model m13a (a model that included vessel-adjusted CPUE and the satellite SST variable from northern SEAK in April, May, and June; model m13a in Table 4; Appendix C) was the best performing model and the 2026-forecast using this model has a point estimate of xx million fish (80% prediction interval: xx to xx million fish).

Table 1: Summary of the data used for the 2026-forecast.

JYear	Year	Harvest	odd_even_factor	vessel	adj_raw_pink_log	CPUE
1997	1998	42.4	even	Cobb	5.33	2.48
1998	1999	77.8	odd	Cobb	7.14	5.62
1999	2000	20.2	even	Cobb	5.05	1.60
2000	2001	67.0	odd	Cobb	6.39	3.73
2001	2002	45.3	even	Cobb	5.50	2.87
2002	2003	52.5	odd	Cobb	6.11	2.78
2003	2004	45.3	even	Cobb	5.32	3.08
2004	2005	59.1	odd	Cobb	6.80	3.90
2005	2006	11.6	even	Cobb	5.06	2.04
2006	2007	44.8	odd	Cobb	6.14	2.57
2007	2008	15.9	even	Cobb	3.85	1.17
2008	2009	38.0	odd	NA	NA	2.32
2009	2010	24.1	even	NA	NA	2.33
2010	2011	58.9	odd	NW Explorer	9.43	4.11
2011	2012	21.3	even	NW Explorer	5.71	1.45
2012	2013	94.7	odd	NW Explorer	8.52	3.52
2013	2014	37.2	even	NW Explorer	6.80	2.14
2014	2015	35.1	odd	NW Explorer	7.67	3.82
2015	2016	18.4	even	NW Explorer	6.72	2.45
2016	2017	34.7	odd	NW Explorer	7.94	4.35
2017	2018	8.1	even	NW Explorer	3.56	0.35
2018	2019	21.1	odd	Medeia	3.93	1.17
2019	2020	8.1	even	Medeia	5.32	1.14
2020	2021	48.5	odd	Medeia	4.41	2.15
2021	2022	18.3	even	Medeia	4.46	0.87
2022	2023	47.8	odd	Medeia	4.33	1.45
2023	2024	20.1	even	Medeia	3.40	1.19
2024	2025	22.0	odd	Medeia	3.85	1.66
2025	2026	NA	even	Medeia	5.02	1.29

Table 2: Summary of the performance metrics for the 36 regression models.

Terms	Model	Fit	Fit_LPI	Fit_UPI	AdjR2	AICc	MAPE5
ISTI20_JJ	m2a	22.5	13.6	37.2	0.68	31.0	27.6
Chatham_SST_AMJ	m5a	19.0	12.5	29.0	0.77	22.0	30.3
NSEAK_SST_AMJ	m13a	19.3	12.6	29.7	0.76	22.9	30.7
Icy_Strait_SST_AMJ	m9a	20.0	13.0	30.8	0.76	22.9	31.9
SEAK_SST_AMJ	m17a	18.4	11.8	28.6	0.75	24.5	32.2
NSEAK_SST_May	m11a	19.0	12.5	28.9	0.77	21.7	32.8
Chatham_SST_May	m3a	18.4	12.1	27.9	0.78	21.1	33.2
NSEAK_SST_AMJJ	m14a	20.1	12.6	31.9	0.72	27.2	34.1
SEAK_SST_May	m15a	18.8	12.2	29.0	0.76	23.6	34.2
Icy_Strait_SST_AMJJ	m10a	21.5	13.5	34.3	0.72	27.2	34.7
Icy_Strait_SST_May	m7a	18.5	12.1	28.2	0.77	22.0	34.8
Chatham_SST_AMJJ	m6a	20.0	12.6	31.7	0.73	26.8	34.9
SEAK_SST_AMJJ	m18a	19.0	11.9	30.4	0.72	28.0	35.3
NSEAK_SST_MJJ	m12a	21.1	12.9	34.4	0.70	29.9	38.1
SEAK_SST_MJJ	m16a	20.0	12.2	32.7	0.69	30.3	39.0
Icy_Strait_SST_MJJ	m8a	22.7	13.8	37.3	0.70	30.0	39.6
Chatham_SST_MJJ	m4a	21.1	12.9	34.5	0.69	30.3	40.5
no temperature index included	m1a	19.2	11.1	33.3	0.62	34.7	45.4
Icy_Strait_SST_May	m7	17.9	9.6	33.3	0.67	43.7	53.5
Chatham_SST_May	m3	18.0	9.7	33.6	0.67	43.4	56.3
NSEAK_SST_May	m11	19.1	10.2	35.7	0.67	43.4	56.9
NSEAK_SST_AMJ	m13	20.6	11.0	38.5	0.68	42.8	58.3
ISTI20_JJ	m2	21.9	11.0	43.5	0.64	45.6	58.6
Icy_Strait_SST_AMJ	m9	20.2	10.7	38.0	0.67	43.4	58.7
Chatham_SST_AMJ	m5	19.2	10.4	35.7	0.68	42.7	58.8
SEAK_SST_May	m15	18.9	10.1	35.7	0.67	43.9	60.0
NSEAK_SST_AMJJ	m14	21.6	11.2	41.8	0.66	44.3	60.2
Chatham_SST_AMJJ	m6	20.2	10.6	38.7	0.66	44.4	60.6
no temperature index included	m1	15.9	8.0	31.3	0.60	45.3	61.1
SEAK_SST_AMJ	m17	19.8	10.6	37.1	0.67	43.2	61.1
SEAK_SST_AMJJ	m18	20.6	10.8	39.4	0.66	44.2	61.1
Icy_Strait_SST_AMJJ	m10	21.6	11.1	42.0	0.65	44.9	61.8
SEAK_SST_MJJ	m16	20.9	10.7	41.1	0.64	45.6	64.0
Chatham_SST_MJJ	m4	20.2	10.2	39.8	0.63	46.3	64.2
NSEAK_SST_MJJ	m12	21.8	10.9	43.5	0.64	45.9	64.3
Icy_Strait_SST_MJJ	m8	21.5	10.7	43.0	0.63	46.3	65.3

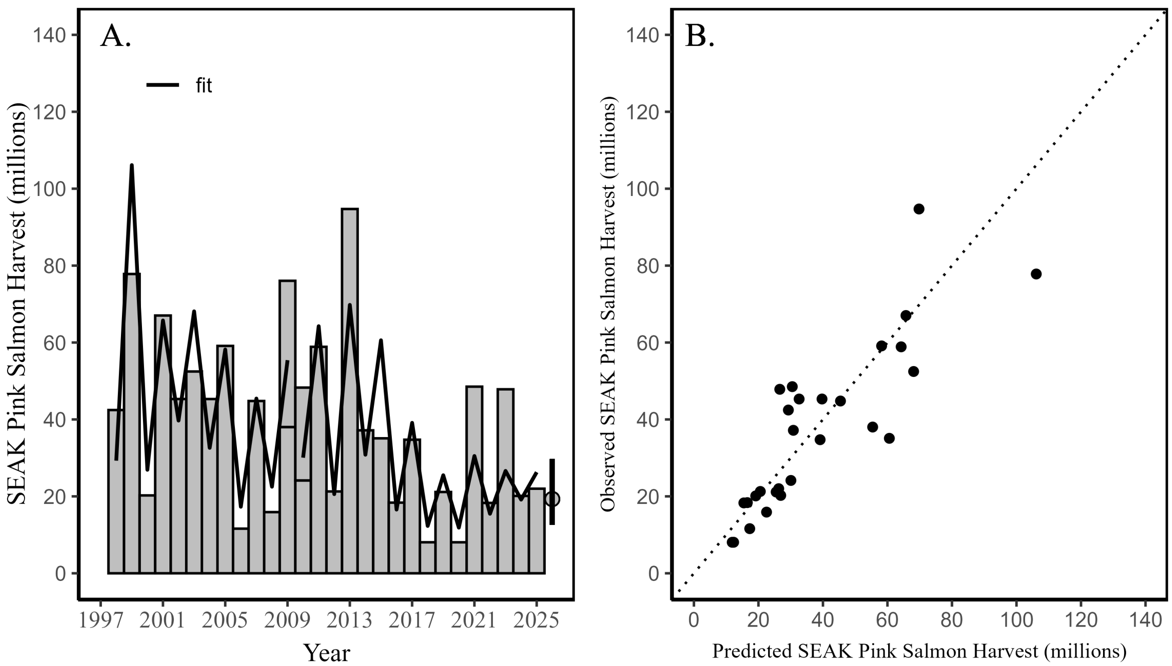

Figure 1: A. SEAK pink salmon harvest (millions) by year with the model fit (line) based upon the best performing model (model m13a). The predicted 2026 forecast (xx million fish) is symbolized as a grey circle with an 80% prediction interval (xx to xx million fish). B. SEAK pink salmon harvest (millions) against the fitted values from model m13a by year. The dotted line is a one to one reference line.

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Appendix A

Variable definitions

adj_raw_pink_log: First, the raw untransformed juvenile catch by year, month, haul, and area was adjusted to a 20 minute haul (raw_pink_catch). Then, these values were log-transformed (i.e., ln(raw_pink_catch + 1). Next, the maximum value in either June or July, whichever month had the highest in a given year, was used as the adj_raw_pink value for the year (i.e., adj_raw_pink_ = maximum(ln(raw_pink_catch + 1)) in either June or July).

CPUE: The average Ln(CPUE+1) for juvenile catches in either June or July, whichever month had the highest average in a given year, where effort was a standard trawl haul. The juvenile CPUE data was adjusted using vessel calibration factors to account for differences in fishing power among vessels.

ISTI20_JJ: The average 20-m integrated water column temperature at the eight stations in Icy Strait (Icy Strait and Upper Chatham transects) sampled during the SECM surveys in June and July of each year (in degrees Celsius). In 2025, there was no survey in May. Therefore, this temperature index no longer includes May in the average.

Satellite SST variables

Icy_Strait_SST_May: The Icy Strait region encompasses waters of Icy Strait from the east end of Lemesurier Island to a line from Point Couverden south to Point Augusta. This variable is the average SST in May.

Icy_Strait_SST_MJJ: The Icy Strait region encompasses waters of Icy Strait from the east end of Lemesurier Island to a line from Point Couverden south to Point Augusta. This variable is the average SST in May through July.

Icy_Strait_SST_AMJ: The Icy Strait region encompasses waters of Icy Strait from the east end of Lemesurier Island to a line from Point Couverden south to Point Augusta. This variable is the average SST in April through June.

Icy_Strait_SST_AMJJ: The Icy Strait region encompasses waters of Icy Strait from the east end of Lemesurier Island to a line from Point Couverden south to Point Augusta. This variable is the average SST in April through July.

Chatham_SST_May: The Chatham and Icy Straits region encompasses waters of Chatham and Icy Straits east of Lemesurier Island to Point Couverden, and south to the approximate latitude of 56.025 degrees north (roughly Cape Decision off Kuiu Island). This variable is the average SST in May.

Chatham_SST_MJJ: The Chatham and Icy Straits region encompasses waters of Chatham and Icy Straits east of Lemesurier Island to Point Couverden, south to the approximate latitude of 56.025 degrees north (roughly Cape Decision off Kuiu Island). This variable is the average SST in May through July.

Chatham_SST_AMJ: The Chatham and Icy Straits region encompasses waters of Chatham and Icy Straits east of Lemesurier Island to Point Couverden, south to the approximate latitude of 56.025 degrees north (roughly Cape Decision off Kuiu Island). This variable is the average SST in April through June. The last time this variable was incorporated in the forecasting process was the 2023 forecast.

Chatham_SST_AMJJ: The Chatham and Icy Straits region encompasses waters of Chatham and Icy Straits east of Lemesurier Island to Point Couverden, south to the approximate latitude of 56.025 degrees north (roughly Cape Decision off Kuiu Island). This variable is the average SST in April through July.

NSEAK_SST_May: The NSEAK region encompasses northern Southeast Alaska from 59.475 to 56.075 degrees north latitude (approximately Districts 9 through 15, and District 13 inside area only; northern Southeast Inside subregion for Southeast Alaska (NSEI)). This variable is the average SST in May.

NSEAK_SST_MJJ: The NSEAK region encompasses northern Southeast Alaska from 59.475 to 56.075 degrees north latitude (approximately Districts 9 through 15, and District 13 inside area only; northern Southeast Inside subregion for Southeast Alaska (NSEI)). This variable is the average SST in May through July.

NSEAK_SST_AMJ: The NSEAK region encompasses northern Southeast Alaska from 59.475 to 56.075 degrees north latitude (approximately Districts 9 through 15, and District 13 inside area only; northern Southeast Inside subregion for Southeast Alaska (NSEI)). This variable is the average SST in April through June.

NSEAK_SST_AMJJ: The NSEAK region encompasses northern Southeast Alaska from 59.475 to 56.075 degrees north latitude (approximately Districts 9 through 15, and District 13 inside area only; northern Southeast Inside subregion for Southeast Alaska (NSEI)). This variable is the average SST in April through July.

SEAK_SST_May: The SEAK region encompasses Southeast Alaska from 59.475 to 54.725 degrees north latitude. This variable is the average SST in May. The last time this variable was incorporated in the forecasting process was the 2023 forecast.

SEAK_SST_MJJ: The SEAK region encompasses northern Southeast Alaska from 59.475 to 54.725 degrees north latitude. This variable is the average SST in May through July.

SEAK_SST_AMJ: The SEAK region encompasses Southeast Alaska from 59.475 to 54.725 degrees north latitude. This variable is the average SST in April through June.

SEAK_SST_AMJJ: The SEAK region encompasses Southeast Alaska from 59.475 to 54.725 degrees north latitude. This variable is the average SST in April through July.

Appendix B

Table 3: Parameter estimates for the 18 individual models for Models m1-m18.

Model	Term	Estimate	Standard Error	Statistic	p value
m1	(Intercept)	1.376	0.980	1.404	0.177
m1	as.factor(odd_even_factor)odd	0.382	0.237	1.613	0.123
m1	as.factor(vessel)Medeia	2.809	1.711	1.642	0.117
m1	as.factor(vessel)NW Explorer	-0.152	1.074	-0.142	0.889
m1	adj_raw_pink_log	0.366	0.181	2.018	0.058
m1	as.factor(vessel)Medeia:adj_raw_pink_log	-0.667	0.357	-1.868	0.077
m1	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.081	0.177	-0.455	0.654
m2	(Intercept)	4.283	1.835	2.334	0.031
m2	as.factor(odd_even_factor)odd	0.223	0.240	0.932	0.364
m2	as.factor(vessel)Medeia	2.676	1.615	1.657	0.115
m2	as.factor(vessel)NW Explorer	-0.356	1.019	-0.350	0.731
m2	ISTI20_JJ	-0.321	0.175	-1.834	0.083
m2	adj_raw_pink_log	0.436	0.175	2.489	0.023
m2	as.factor(vessel)Medeia:adj_raw_pink_log	-0.616	0.338	-1.823	0.085
m2	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.072	0.167	-0.429	0.673
m3	(Intercept)	3.394	1.245	2.726	0.014
m3	as.factor(odd_even_factor)odd	0.380	0.214	1.776	0.093
m3	as.factor(vessel)Medeia	2.670	1.546	1.727	0.101
m3	as.factor(vessel)NW Explorer	0.032	0.973	0.033	0.974
m3	Chatham_SST_May	-0.300	0.130	-2.304	0.033
m3	adj_raw_pink_log	0.400	0.164	2.434	0.026
m3	as.factor(vessel)Medeia:adj_raw_pink_log	-0.600	0.324	-1.853	0.080
m3	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.093	0.160	-0.581	0.568
m4	(Intercept)	3.894	1.764	2.207	0.041
m4	as.factor(odd_even_factor)odd	0.348	0.227	1.531	0.143
m4	as.factor(vessel)Medeia	2.711	1.635	1.658	0.115
m4	as.factor(vessel)NW Explorer	0.063	1.034	0.061	0.952
m4	Chatham_SST_MJJ	-0.284	0.168	-1.684	0.109
m4	adj_raw_pink_log	0.411	0.175	2.345	0.031
m4	as.factor(vessel)Medeia:adj_raw_pink_log	-0.608	0.343	-1.775	0.093
m4	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.112	0.170	-0.656	0.520
m5	(Intercept)	4.029	1.400	2.877	0.010
m5	as.factor(odd_even_factor)odd	0.359	0.212	1.695	0.107
m5	as.factor(vessel)Medeia	2.506	1.531	1.636	0.119
m5	as.factor(vessel)NW Explorer	0.098	0.964	0.102	0.920
m5	Chatham_SST_AMJ	-0.384	0.158	-2.425	0.026

Model	Term	Estimate	Standard Error	Statistic	p value
m5	adj__raw__pink__log	0.410	0.163	2.521	0.021
m5	as.factor(vessel)Medeia:adj__raw__pink__log	-0.559	0.322	-1.738	0.099
m5	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.105	0.158	-0.662	0.516
m6	(Intercept)	4.201	1.624	2.587	0.019
m6	as.factor(odd__even__factor)odd	0.343	0.219	1.563	0.136
m6	as.factor(vessel)Medeia	2.624	1.579	1.662	0.114
m6	as.factor(vessel)NW Explorer	0.130	0.999	0.130	0.898
m6	Chatham__SST__AMJJ	-0.362	0.173	-2.093	0.051
m6	adj__raw__pink__log	0.423	0.169	2.496	0.023
m6	as.factor(vessel)Medeia:adj__raw__pink__log	-0.582	0.331	-1.755	0.096
m6	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.121	0.164	-0.735	0.472
m7	(Intercept)	3.219	1.212	2.656	0.016
m7	as.factor(odd__even__factor)odd	0.412	0.216	1.908	0.072
m7	as.factor(vessel)Medeia	2.609	1.557	1.676	0.111
m7	as.factor(vessel)NW Explorer	-0.071	0.977	-0.073	0.943
m7	Icy__Strait__SST__May	-0.286	0.128	-2.241	0.038
m7	adj__raw__pink__log	0.392	0.165	2.371	0.029
m7	as.factor(vessel)Medeia:adj__raw__pink__log	-0.591	0.326	-1.812	0.087
m7	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.076	0.161	-0.472	0.642
m8	(Intercept)	3.671	1.657	2.216	0.040
m8	as.factor(odd__even__factor)odd	0.375	0.227	1.655	0.115
m8	as.factor(vessel)Medeia	2.483	1.646	1.508	0.149
m8	as.factor(vessel)NW Explorer	0.037	1.032	0.036	0.972
m8	Icy__Strait__SST__MJJ	-0.252	0.150	-1.679	0.110
m8	adj__raw__pink__log	0.405	0.175	2.315	0.033
m8	as.factor(vessel)Medeia:adj__raw__pink__log	-0.565	0.346	-1.630	0.121
m8	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.109	0.170	-0.638	0.531
m9	(Intercept)	3.841	1.389	2.764	0.013
m9	as.factor(odd__even__factor)odd	0.407	0.214	1.900	0.074
m9	as.factor(vessel)Medeia	2.377	1.557	1.527	0.144
m9	as.factor(vessel)NW Explorer	0.013	0.973	0.014	0.989
m9	Icy__Strait__SST__AMJ	-0.366	0.159	-2.301	0.034
m9	adj__raw__pink__log	0.401	0.165	2.439	0.025
m9	as.factor(vessel)Medeia:adj__raw__pink__log	-0.532	0.328	-1.624	0.122
m9	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.091	0.160	-0.570	0.575
m10	(Intercept)	3.875	1.544	2.511	0.022
m10	as.factor(odd__even__factor)odd	0.374	0.220	1.699	0.106
m10	as.factor(vessel)Medeia	2.469	1.598	1.545	0.140
m10	as.factor(vessel)NW Explorer	0.119	1.007	0.118	0.907
m10	Icy__Strait__SST__AMJJ	-0.323	0.161	-2.005	0.060
m10	adj__raw__pink__log	0.421	0.171	2.466	0.024

Model	Term	Estimate	Standard Error	Statistic	p value
m10	as.factor(vessel)Medeia:adj__raw__pink__log	-0.551	0.337	-1.639	0.119
m10	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.121	0.166	-0.731	0.474
m11	(Intercept)	3.314	1.221	2.714	0.014
m11	as.factor(odd__even__factor)odd	0.399	0.214	1.862	0.079
m11	as.factor(vessel)Medeia	2.582	1.548	1.668	0.113
m11	as.factor(vessel)NW Explorer	0.118	0.977	0.121	0.905
m11	NSEAK__SST__May	-0.289	0.126	-2.304	0.033
m11	adj__raw__pink__log	0.393	0.164	2.392	0.028
m11	as.factor(vessel)Medeia:adj__raw__pink__log	-0.568	0.325	-1.748	0.097
m11	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.102	0.160	-0.638	0.532
m12	(Intercept)	3.950	1.716	2.302	0.033
m12	as.factor(odd__even__factor)odd	0.353	0.225	1.566	0.135
m12	as.factor(vessel)Medeia	2.681	1.622	1.653	0.116
m12	as.factor(vessel)NW Explorer	0.190	1.035	0.183	0.857
m12	NSEAK__SST__MJJ	-0.293	0.165	-1.784	0.091
m12	adj__raw__pink__log	0.417	0.174	2.394	0.028
m12	as.factor(vessel)Medeia:adj__raw__pink__log	-0.580	0.342	-1.699	0.107
m12	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.127	0.170	-0.748	0.464
m13	(Intercept)	3.952	1.383	2.858	0.010
m13	as.factor(odd__even__factor)odd	0.374	0.212	1.766	0.094
m13	as.factor(vessel)Medeia	2.500	1.534	1.629	0.121
m13	as.factor(vessel)NW Explorer	0.232	0.973	0.238	0.815
m13	NSEAK__SST__AMJ	-0.384	0.160	-2.407	0.027
m13	adj__raw__pink__log	0.412	0.163	2.524	0.021
m13	as.factor(vessel)Medeia:adj__raw__pink__log	-0.538	0.323	-1.664	0.113
m13	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.121	0.159	-0.759	0.458
m14	(Intercept)	4.169	1.600	2.605	0.018
m14	as.factor(odd__even__factor)odd	0.355	0.218	1.625	0.122
m14	as.factor(vessel)Medeia	2.625	1.576	1.666	0.113
m14	as.factor(vessel)NW Explorer	0.258	1.007	0.256	0.801
m14	NSEAK__SST__AMJJ	-0.365	0.173	-2.113	0.049
m14	adj__raw__pink__log	0.427	0.169	2.521	0.021
m14	as.factor(vessel)Medeia:adj__raw__pink__log	-0.562	0.332	-1.693	0.108
m14	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.137	0.165	-0.830	0.417
m15	(Intercept)	3.281	1.243	2.639	0.017
m15	as.factor(odd__even__factor)odd	0.378	0.216	1.751	0.097
m15	as.factor(vessel)Medeia	2.796	1.560	1.792	0.090
m15	as.factor(vessel)NW Explorer	0.173	0.990	0.175	0.863
m15	SEAK__SST__May	-0.274	0.124	-2.204	0.041
m15	adj__raw__pink__log	0.409	0.167	2.454	0.025
m15	as.factor(vessel)Medeia:adj__raw__pink__log	-0.610	0.326	-1.869	0.078

Model	Term	Estimate	Standard Error	Statistic	p value
m15	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.113	0.162	-0.698	0.494
m16	(Intercept)	3.952	1.679	2.354	0.030
m16	as.factor(odd__even__factor)odd	0.336	0.225	1.492	0.153
m16	as.factor(vessel)Medeia	2.860	1.613	1.773	0.093
m16	as.factor(vessel)NW Explorer	0.212	1.032	0.205	0.840
m16	SEAK__SST__MJJ	-0.284	0.154	-1.838	0.083
m16	adj__raw__pink__log	0.423	0.174	2.433	0.026
m16	as.factor(vessel)Medeia:adj__raw__pink__log	-0.611	0.338	-1.808	0.087
m16	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.128	0.169	-0.756	0.459
m17	(Intercept)	3.905	1.396	2.796	0.012
m17	as.factor(odd__even__factor)odd	0.359	0.214	1.679	0.110
m17	as.factor(vessel)Medeia	2.676	1.541	1.736	0.100
m17	as.factor(vessel)NW Explorer	0.290	0.985	0.294	0.772
m17	SEAK__SST__AMJ	-0.361	0.155	-2.336	0.031
m17	adj__raw__pink__log	0.427	0.165	2.583	0.019
m17	as.factor(vessel)Medeia:adj__raw__pink__log	-0.571	0.324	-1.763	0.095
m17	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.133	0.161	-0.825	0.420
m18	(Intercept)	4.178	1.593	2.623	0.017
m18	as.factor(odd__even__factor)odd	0.343	0.218	1.569	0.134
m18	as.factor(vessel)Medeia	2.793	1.571	1.779	0.092
m18	as.factor(vessel)NW Explorer	0.291	1.008	0.289	0.776
m18	SEAK__SST__AMJJ	-0.350	0.164	-2.132	0.047
m18	adj__raw__pink__log	0.433	0.169	2.555	0.020
m18	as.factor(vessel)Medeia:adj__raw__pink__log	-0.591	0.330	-1.792	0.090
m18	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.140	0.165	-0.846	0.409

Table 4: Parameter estimates for the 18 individual models for Models m1a-m18a.

Model	Term	Estimate	Standard Error	Statistic	p value
m1a	(Intercept)	2.484	0.170	14.615	0.000
m1a	CPUE	0.305	0.074	4.150	0.000
m1a	as.factor(odd_even_factor)odd	0.409	0.178	2.293	0.031
m2a	(Intercept)	6.028	1.403	4.296	0.000
m2a	CPUE	0.394	0.075	5.237	0.000
m2a	as.factor(odd_even_factor)odd	0.197	0.182	1.082	0.290
m2a	ISTI20_JJ	-0.367	0.145	-2.541	0.018
m3a	(Intercept)	5.512	0.701	7.864	0.000
m3a	CPUE	0.364	0.057	6.338	0.000
m3a	as.factor(odd_even_factor)odd	0.366	0.136	2.694	0.013
m3a	Chatham_SST_May	-0.417	0.095	-4.395	0.000
m4a	(Intercept)	5.825	1.250	4.660	0.000
m4a	CPUE	0.334	0.067	5.010	0.000
m4a	as.factor(odd_even_factor)odd	0.350	0.161	2.175	0.040
m4a	Chatham_SST_MJJ	-0.345	0.128	-2.693	0.013
m5a	(Intercept)	6.100	0.864	7.058	0.000
m5a	CPUE	0.361	0.058	6.186	0.000
m5a	as.factor(odd_even_factor)odd	0.340	0.139	2.455	0.022
m5a	Chatham_SST_AMJ	-0.484	0.114	-4.233	0.000
m6a	(Intercept)	6.195	1.108	5.593	0.000
m6a	CPUE	0.345	0.063	5.490	0.000
m6a	as.factor(odd_even_factor)odd	0.341	0.151	2.254	0.034
m6a	Chatham_SST_AMJJ	-0.433	0.128	-3.379	0.002
m7a	(Intercept)	5.204	0.655	7.951	0.000
m7a	CPUE	0.371	0.059	6.308	0.000
m7a	as.factor(odd_even_factor)odd	0.393	0.138	2.856	0.009
m7a	Icy_Strait_SST_May	-0.399	0.094	-4.243	0.000
m8a	(Intercept)	5.596	1.145	4.886	0.000
m8a	CPUE	0.340	0.067	5.098	0.000
m8a	as.factor(odd_even_factor)odd	0.362	0.160	2.269	0.033
m8a	Icy_Strait_SST_MJJ	-0.316	0.115	-2.741	0.011
m9a	(Intercept)	5.852	0.837	6.990	0.000
m9a	CPUE	0.361	0.059	6.084	0.000
m9a	as.factor(odd_even_factor)odd	0.393	0.140	2.813	0.010
m9a	Icy_Strait_SST_AMJ	-0.468	0.115	-4.075	0.000
m10a	(Intercept)	5.873	1.038	5.658	0.000
m10a	CPUE	0.349	0.064	5.485	0.000
m10a	as.factor(odd_even_factor)odd	0.367	0.151	2.425	0.023
m10a	Icy_Strait_SST_AMJJ	-0.397	0.120	-3.297	0.003

Model	Term	Estimate	Standard Error	Statistic	p value
m11a	(Intercept)	5.247	0.657	7.990	0.000
m11a	CPUE	0.335	0.057	5.888	0.000
m11a	as.factor(odd_even_factor)odd	0.401	0.137	2.930	0.007
m11a	NSEAK_SST_May	-0.377	0.088	-4.293	0.000
m12a	(Intercept)	5.623	1.145	4.912	0.000
m12a	CPUE	0.310	0.065	4.746	0.000
m12a	as.factor(odd_even_factor)odd	0.386	0.159	2.431	0.023
m12a	NSEAK_SST_MJJ	-0.317	0.115	-2.766	0.011
m13a	(Intercept)	5.833	0.831	7.018	0.000
m13a	CPUE	0.329	0.058	5.670	0.000
m13a	as.factor(odd_even_factor)odd	0.391	0.140	2.798	0.010
m13a	NSEAK_SST_AMJ	-0.448	0.110	-4.082	0.000
m14a	(Intercept)	5.904	1.048	5.635	0.000
m14a	CPUE	0.319	0.062	5.104	0.000
m14a	as.factor(odd_even_factor)odd	0.386	0.151	2.553	0.017
m14a	NSEAK_SST_AMJJ	-0.395	0.120	-3.296	0.003
m15a	(Intercept)	5.248	0.710	7.391	0.000
m15a	CPUE	0.331	0.059	5.634	0.000
m15a	as.factor(odd_even_factor)odd	0.406	0.141	2.871	0.008
m15a	SEAK_SST_May	-0.348	0.088	-3.965	0.001
m16a	(Intercept)	5.509	1.136	4.850	0.000
m16a	CPUE	0.301	0.066	4.569	0.000
m16a	as.factor(odd_even_factor)odd	0.398	0.160	2.495	0.020
m16a	SEAK_SST_MJJ	-0.289	0.108	-2.687	0.013
m17a	(Intercept)	5.771	0.875	6.594	0.000
m17a	CPUE	0.323	0.059	5.437	0.000
m17a	as.factor(odd_even_factor)odd	0.399	0.144	2.774	0.011
m17a	SEAK_SST_AMJ	-0.408	0.107	-3.803	0.001
m18a	(Intercept)	5.784	1.057	5.472	0.000
m18a	CPUE	0.308	0.063	4.884	0.000
m18a	as.factor(odd_even_factor)odd	0.402	0.153	2.626	0.015
m18a	SEAK_SST_AMJJ	-0.357	0.113	-3.152	0.004

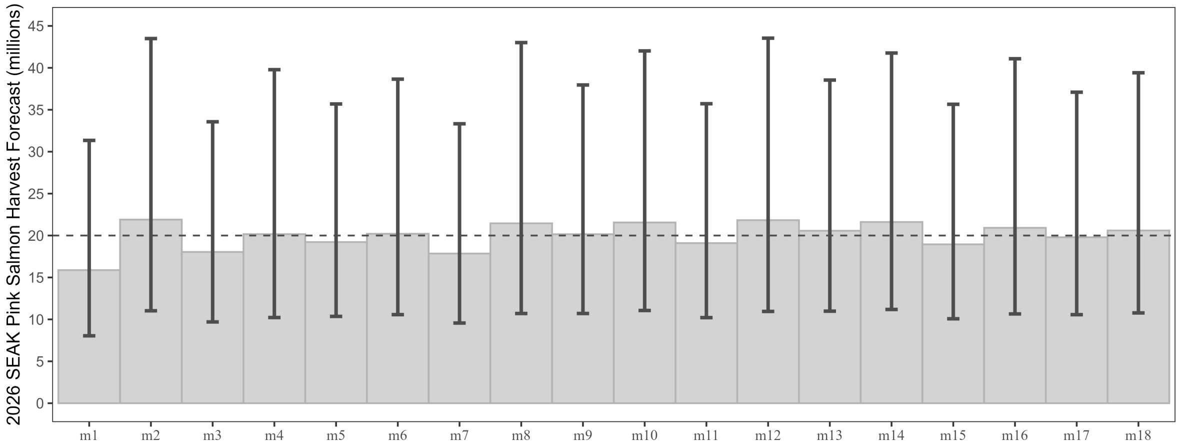

Figure B1: Bias-corrected forecasts (grey bars) for the 18 regression models (Models m1-m18) with 80% prediction intervals (vertical grey lines). A horizontal dotted line at 20 million fish is placed on the figure for reference only. The 2026-forecast using the model mxx has a point estimate of xx million fish (80% prediction interval: xx to xx million fish).

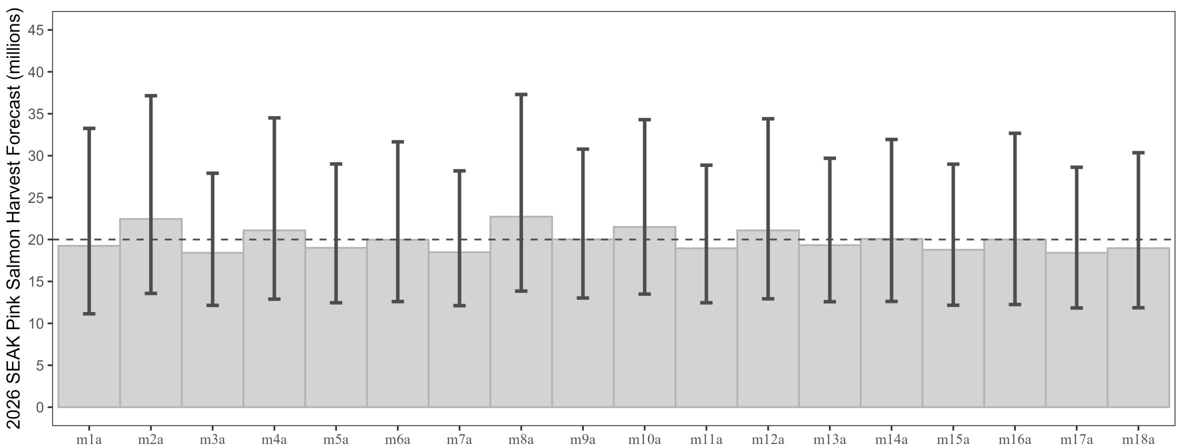

Figure B2: Bias-corrected forecasts (grey bars) for the 18 regression models (Models m1a-m18a) with 80% prediction intervals (vertical grey lines). A horizontal dotted line at 20 million fish is placed on the figure for reference only. The 2026-forecast using the model mxx has a point estimate of xx million fish (80% prediction interval: xx to xx million fish).

Appendix C

Model Diagnostics

Model m13a included vessel-adjusted CPUE, an odd/even year factor, and satellite-derived SST data from northern SEAK in April, May, and June. Model diagnostics for model m13a included residual plots, the lack of fit test, and influential observation diagnostics using Cook's distance (Cook 1977), the Bonferroni outlier test, and leverage plots (Table 4; Figure C1; Figure C2). Model diagnostics were used to identify observations that were potential outliers, had high leverage, or were influential (Zhang 2016).

Table 5: Detailed output for model m13a. Fitted values (in millions of fish) are bias-corrected.

Year	Harvest	Residuals	Hat values	Cooks distance	Std. residuals	Fitted values
1998	42.45	0.42	0.09	0.05	1.41	29.28
1999	77.82	-0.26	0.29	0.10	-0.99	106.13
2000	20.25	-0.24	0.12	0.02	-0.80	26.91
2001	67.02	0.07	0.09	0.00	0.23	65.73
2002	45.32	0.18	0.16	0.02	0.63	39.71
2003	52.47	-0.21	0.19	0.03	-0.75	68.11
2004	45.31	0.38	0.13	0.06	1.29	32.62
2005	59.12	0.07	0.10	0.00	0.22	58.18
2006	11.61	-0.35	0.13	0.05	-1.20	17.30
2007	44.80	0.03	0.09	0.00	0.12	45.44
2008	15.91	-0.30	0.12	0.03	-1.01	22.52
2009	38.02	-0.33	0.17	0.07	-1.15	55.41
2010	24.14	-0.17	0.10	0.01	-0.57	30.07
2011	58.88	-0.04	0.11	0.00	-0.13	64.25
2012	21.28	0.08	0.08	0.00	0.27	20.58
2013	94.72	0.35	0.11	0.04	1.20	69.78
2014	37.17	0.24	0.11	0.02	0.80	30.83
2015	35.09	-0.50	0.09	0.07	-1.66	60.59
2016	18.37	0.15	0.22	0.02	0.55	16.56
2017	34.73	-0.07	0.35	0.01	-0.28	39.12
2018	8.07	-0.37	0.15	0.08	-1.29	12.31
2019	21.14	-0.14	0.20	0.01	-0.49	25.49
2020	8.06	-0.34	0.19	0.08	-1.20	11.87
2021	48.53	0.51	0.12	0.10	1.75	30.49
2022	18.30	0.22	0.10	0.02	0.73	15.48
2023	47.84	0.64	0.17	0.25	2.22	26.62
2024	20.12	0.10	0.09	0.00	0.33	19.16
2025	22.00	-0.13	0.16	0.01	-0.45	26.29

Cook's distance

Cook's distance is a measure of influence, or the product of both leverage and outlier. Cook's distance,

$$D_i = \frac{e^2_{PSi}}{k+1} * \frac{h_i}{1-h_i}, \tag{5}$$

where e^2_{PSi} is the standardized Pearson residuals, h_i are the hat values (measure of leverage), and k is the number of predictor variables in the model, is a measure of overall influence of the i_{th} data point on all n fitted values (Fox and Weisburg 2019). A large value of Cook's distance indicates that the data point is an influential observation. Cook's distance values greater than $4/(n-k-1)$, where n is the number of observations (i.e., 28), was used as a benchmark for identifying the subset of influential observations (Ren et al. 2016). Therefore, a Cook's distance cut-off of 0.17 was used; observations with a Cook's distance greater than 0.17 may be influential observations (Figure C1a).

Leverage

An observation that is distant from the average covariate pattern is considered to have high leverage or hat-value. If an individual observation has a leverage value h_i greater than 2 or 3 times p/n (Ren et al. 2016), it may be a concern (where p is the number of parameters in the model including the intercept (i.e., 4), and n is the number of observations in the model (i.e., 28); $p/n = 4/28 = 0.14$ for this study). Therefore, a leverage cut-off of 0.29 was used; observations with a leverage value greater than 0.29 may affect the model properties (e.g., summary statistics, standard errors, predicted values) (Figure C1b).

Influential datapoints

A lack-of fit test was performed between model m13a (full model) and a reduced model with just the CPUE and odd/even factor. Based on an anova between the full and reduced models, the p-value was less than .05, the null hypothesis of the test is rejected, and it can be concluded that the full model offers a statistically significantly better fit than the reduced model. Diagnostics indicated that one of the data points was above the cut-off value for the Cook's distance (Figure C1a; juvenile year 2022). One observation had high leverage values (Figure C1b; 2016). Based on the Bonferroni outlier test, none of the data points had studentized residuals with a significant Bonferroni P-value suggesting that none of the data points impacted the model fitting; although observation 26 was the most extreme (juvenile year 2022) based on standardized residuals (Figure C2c; Table 5). Based on the lightly curved fitted lines in the residual versus fitted plot (Figure C2d), the fitted plot shows some lack of fit of the model.

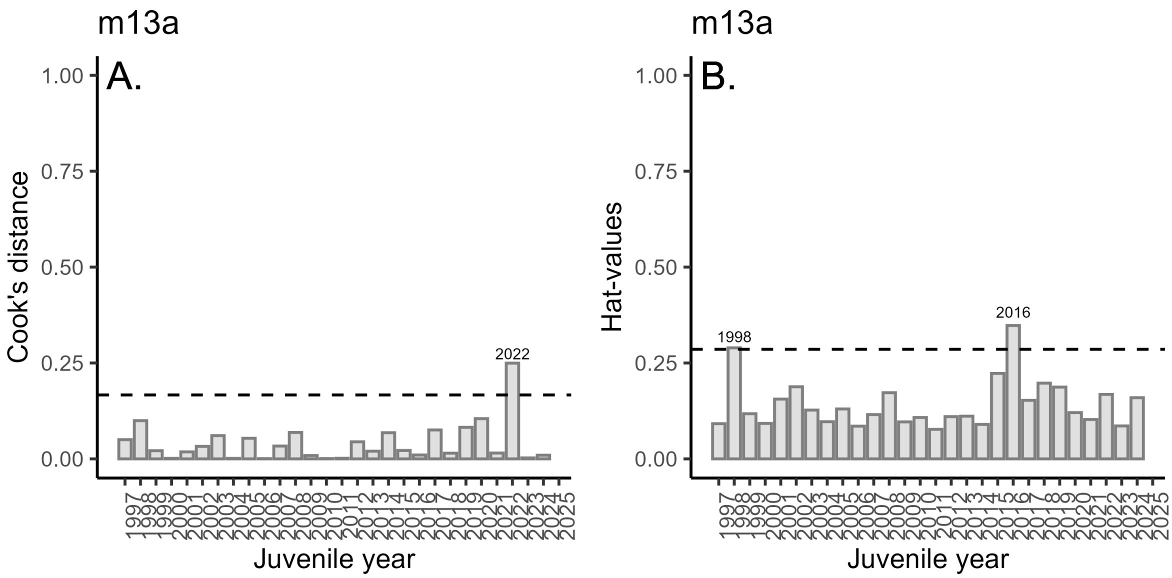

Figure C1: Diagnostics plots of influential observations including A. Cook's distance (with a cut-off value of 0.17), and B. leverage values (with a cut-off value of 0.29) from model m13a.

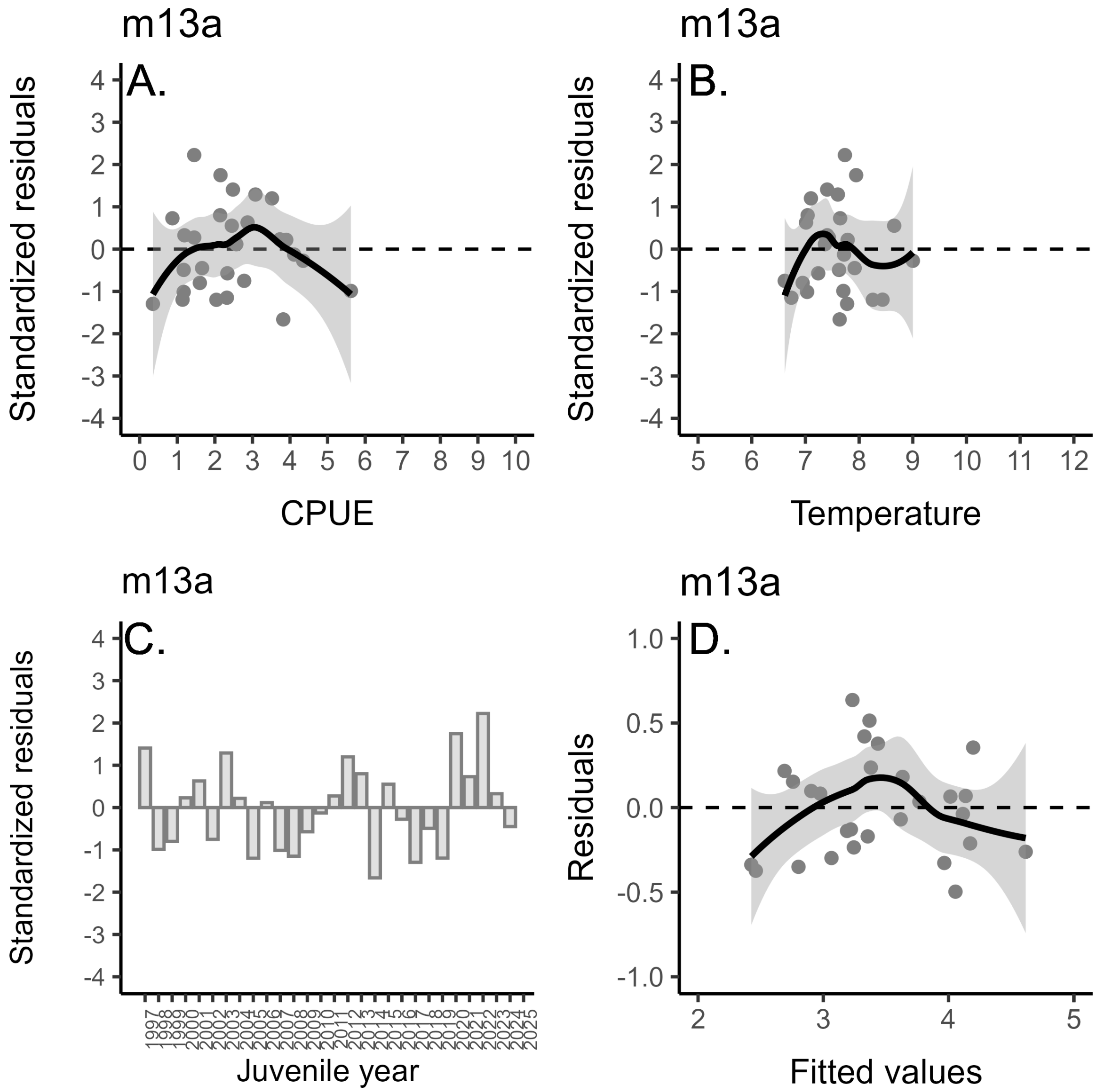

Figure C2: Standardized residuals versus predicted plots for A. CPUE and B. temperature (average April, May, June SST in northern Southeast Alaska) for model m13a. C. Standardized residuals versus juvenile year, and D. residuals versus fitted values for model m13a. Positive residuals indicate that the observed harvest was larger than predicted by the model.