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 CPUE (adj_raw_pink_log; a proxy for abundance) or 2) the vessel-adjusted juvenile pink salmon 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 either 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).

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);
- 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 SECM survey (m2a); and
- vessel-adjusted CPUE models with an odd/even year factor, and satellite-derived SST data (m3a-m18a).

The adj_raw_pink_log variable is defined as the natural logarithm of the maximum juvenile pink salmon catch, adjusted to a 20 minute haul, from either June or July. This CPUE variable is not vessel-calibrated. The Stellar and Chellissa vessels were only used for one year each, 2008 and 2009, respectively, and so those two years are not used in the assessment models that incorporated an adj_raw_pink_log variable (Table 1).

The vessel-adjusted CPUE variable is defined as the average natural log transformed CPUE (adjusted to a 20 minute haul) for juvenile pink salmon catches in either June or July, whichever month had the highest catch in a given year, adjusted by the pooled-species vessel calibration coefficient from the R/V Cobb. As there was not a SECM survey in May, temperature data from May was unavailable. Therefore, the temperature variable from the SECM survey (ISTI20_JJ) was the average from June and July. In prior forecasting years, the ISTI variable was the average from May through July.

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 19.3 million fish (80% prediction interval: 12.6 to 29.8 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),

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

The reference category is an even year with the R/V 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 research 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 and Table 3; 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,

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

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

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

   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 and Table 3). Lower AICc values are preferred, 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. As the data set of the response variable is reduced for the model set m1-m18 compared to the model set m1a-m18a, AICc can only be used to compare within the nested models (e.g., among m1-m18).

Adjusted R-squared

The adjusted R-squared is a modified version of the R-squared value that adjusts for the number of predictors in the model and prevents overfitting by balancing model performance and complexity. A higher adjusted R-squared value is preferred. As the adjusted R-squared metric depends on both sample size and the variance of the dependent variable in the data set, the adjusted R-squared can only be compared for the models with the same response variable data set. As the data set for the model set m1-m18 is reduced, the adjusted R-squared can only be compared within the model group (i.e., among m1-m18).

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 5; Appendix C) was the best performing model. The 2026-forecast using this model has a point estimate of 19.3 million fish (80% prediction interval: 12.6 to 29.8 million fish).

Table 1: Summary of the data used for the 2026-forecast. The Stellar and Chellissa vessels were only used for one year each, 2008 and 2009, respectively, and so those two years are not used in the assessment models that incorporated an adj_raw_pink_log variable. The CPUE variable is the vessel-adjusted CPUE, JYear is the juvenile year, and Year is the calendar year.

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	Steller	6.64	2.32
2009	2010	24.1	even	Chellissa	6.19	2.33
2010	2011	58.9	odd	NW Explorer	9.43	4.11
2011	2012	21.3	even	NW Explorer	5.71	1.45

JYear	Year	Harvest	odd_even_factor	vessel	adj_raw_pink_log	CPUE
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	48.5	odd	Medeia	4.33	1.45
2023	2024	20.1	even	Medeia	3.40	1.19
2024	2025	21.3	odd	Medeia	3.85	1.66
2025	2026	NA	even	Medeia	5.02	1.29

Table 2: Summary of the performance metrics for the 18 regression models with adj_raw_pink_log. The AICc value is the change in AICc value.

Terms	Model	Fit	Fit_LPI	Fit_UPI	AdjR2	MAPE5	AICc
ISTI20_JJ	m2a	22.5	13.6	37.3	0.68	28.3	9.7
Chatham_SST_AMJ	m5a	19.0	12.4	29.1	0.77	31.1	0.8
NSEAK_SST_AMJ	m13a	19.3	12.6	29.8	0.76	31.5	1.7
Icy_Strait_SST_AMJ	m9a	20.0	13.0	30.9	0.76	32.8	1.8
SEAK_SST_AMJ	m17a	18.4	11.8	28.7	0.75	33.0	3.3
NSEAK_SST_May	m11a	19.0	12.4	28.9	0.77	33.7	0.6
Chatham_SST_May	m3a	18.4	12.1	28.0	0.78	34.0	0.0
NSEAK_SST_AMJJ	m14a	20.1	12.6	32.0	0.72	35.0	6.0
SEAK_SST_May	m15a	18.8	12.1	29.1	0.76	35.0	2.4
Icy_Strait_SST_AMJJ	m10a	21.5	13.5	34.4	0.72	35.6	6.0
Icy_Strait_SST_May	m7a	18.5	12.1	28.3	0.77	35.6	0.8
Chatham_SST_AMJJ	m6a	20.0	12.6	31.7	0.73	35.7	5.6
SEAK_SST_AMJJ	m18a	19.0	11.8	30.4	0.71	36.2	6.8
NSEAK_SST_MJJ	m12a	21.1	12.9	34.5	0.69	39.1	8.8
SEAK_SST_MJJ	m16a	20.0	12.2	32.8	0.69	39.9	9.1
Icy_Strait_SST_MJJ	m8a	22.7	13.8	37.4	0.69	40.6	8.9
Chatham_SST_MJJ	m4a	21.1	12.8	34.6	0.69	41.4	9.1
no temperature index included	m1a	19.3	11.1	33.3	0.61	46.4	13.4

Table 3: Summary of the performance metrics for the 18 regression models with vessel-adjusted CPUE. The AICc value is the change in AICc value.

Terms	Model	Fit	Fit_LPI	Fit_UPI	AdjR2	MAPE5	AICc
Icy_Strait_SST_May	m7	17.9	9.6	33.6	0.67	54.8	1.0
Chatham_SST_May	m3	18.1	9.7	33.8	0.67	57.6	0.7
NSEAK_SST_May	m11	19.2	10.2	36.0	0.67	58.2	0.7
NSEAK_SST_AMJ	m13	20.7	11.0	38.9	0.68	59.5	0.1
ISTI20_JJ	m2	22.1	11.1	43.9	0.64	59.7	2.9
Chatham_SST_AMJ	m5	19.3	10.4	36.0	0.68	60.0	0.0
Icy_Strait_SST_AMJ	m9	20.3	10.7	38.3	0.67	60.0	0.7
SEAK_SST_May	m15	19.0	10.1	36.0	0.66	61.3	1.2
NSEAK_SST_AMJJ	m14	21.7	11.2	42.1	0.66	61.5	1.7
Chatham_SST_AMJJ	m6	20.3	10.6	39.0	0.66	61.9	1.8
SEAK_SST_AMJ	m17	19.9	10.6	37.4	0.67	62.4	0.5
no temperature index included	m1	15.9	8.0	31.6	0.60	62.5	2.6
SEAK_SST_AMJJ	m18	20.7	10.8	39.8	0.66	62.5	1.6
Icy_Strait_SST_AMJJ	m10	21.7	11.1	42.4	0.65	63.2	2.2
SEAK_SST_MJJ	m16	21.0	10.6	41.4	0.64	65.5	3.0
Chatham_SST_MJJ	m4	20.2	10.2	40.1	0.63	65.6	3.7
NSEAK_SST_MJJ	m12	21.9	10.9	43.9	0.64	65.7	3.2
Icy_Strait_SST_MJJ	m8	21.5	10.7	43.4	0.63	66.8	3.7

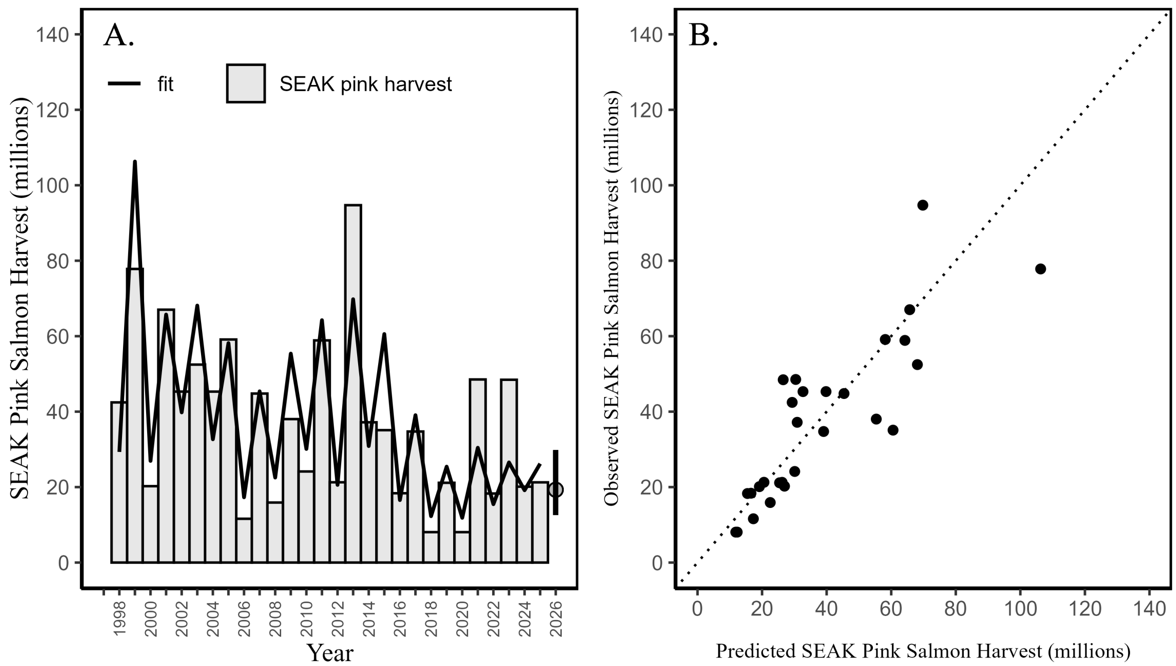

Figure 1: A. SEAK pink salmon harvest (millions) by year with the model fit (line) based upon the best performing model (model m13a). The predicted 2026 forecast (19.3 million fish) is symbolized as a grey circle with an 80% prediction interval (12.6 to 29.8 million fish). B. SEAK pink salmon harvest (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 juvenile pink salmon 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_log value for the year (i.e., adj_raw_pink_log_ = maximum(ln(raw_pink_catch + 1)) in either June or July).

vessel-adjusted CPUE: The average Ln(CPUE+1) for juvenile pink salmon catches in either June or July, whichever month had the highest average in a given year, where effort was a standard trawl haul (20 minutes). 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 4: Parameter estimates for the 18 individual models for Models m1-m18.

Model	Term	Estimate	Standard Error	Statistic	p value
m1	(Intercept)	1.371	0.986	1.392	0.180
m1	as.factor(odd_even_factor)odd	0.380	0.238	1.595	0.127
m1	as.factor(vessel)Medeia	2.785	1.721	1.619	0.122
m1	as.factor(vessel)NW Explorer	-0.150	1.080	-0.139	0.891
m1	adj_raw_pink_log	0.367	0.182	2.012	0.059
m1	as.factor(vessel)Medeia:adj_raw_pink_log	-0.662	0.359	-1.843	0.081
m1	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.081	0.178	-0.455	0.654
m2	(Intercept)	4.311	1.843	2.339	0.031
m2	as.factor(odd_even_factor)odd	0.220	0.241	0.912	0.374
m2	as.factor(vessel)Medeia	2.651	1.623	1.634	0.120
m2	as.factor(vessel)NW Explorer	-0.357	1.024	-0.348	0.732
m2	ISTI20_JJ	-0.325	0.176	-1.846	0.081
m2	adj_raw_pink_log	0.438	0.176	2.487	0.023
m2	as.factor(vessel)Medeia:adj_raw_pink_log	-0.610	0.339	-1.798	0.089
m2	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.072	0.168	-0.429	0.673
m3	(Intercept)	3.398	1.253	2.712	0.014
m3	as.factor(odd_even_factor)odd	0.378	0.215	1.756	0.096
m3	as.factor(vessel)Medeia	2.646	1.555	1.701	0.106
m3	as.factor(vessel)NW Explorer	0.035	0.979	0.036	0.972
m3	Chatham_SST_May	-0.302	0.131	-2.299	0.034
m3	adj_raw_pink_log	0.401	0.165	2.425	0.026
m3	as.factor(vessel)Medeia:adj_raw_pink_log	-0.594	0.326	-1.825	0.085
m3	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.094	0.161	-0.581	0.568
m4	(Intercept)	3.881	1.777	2.184	0.042
m4	as.factor(odd_even_factor)odd	0.346	0.229	1.512	0.148
m4	as.factor(vessel)Medeia	2.687	1.646	1.632	0.120
m4	as.factor(vessel)NW Explorer	0.064	1.041	0.062	0.952
m4	Chatham_SST_MJJ	-0.283	0.170	-1.666	0.113
m4	adj_raw_pink_log	0.412	0.177	2.333	0.031
m4	as.factor(vessel)Medeia:adj_raw_pink_log	-0.603	0.345	-1.748	0.097
m4	as.factor(vessel)NW Explorer:adj_raw_pink_log	-0.112	0.171	-0.654	0.522
m5	(Intercept)	4.040	1.408	2.870	0.010
m5	as.factor(odd_even_factor)odd	0.357	0.213	1.676	0.111
m5	as.factor(vessel)Medeia	2.480	1.540	1.611	0.125
m5	as.factor(vessel)NW Explorer	0.102	0.969	0.105	0.917
m5	Chatham_SST_AMJ	-0.386	0.159	-2.426	0.026

Model	Term	Estimate	Standard Error	Statistic	p value
m5	adj__raw__pink__log	0.412	0.164	2.514	0.022
m5	as.factor(vessel)Medeia:adj__raw__pink__log	-0.553	0.323	-1.710	0.104
m5	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.105	0.159	-0.662	0.516
m6	(Intercept)	4.203	1.635	2.571	0.019
m6	as.factor(odd__even__factor)odd	0.341	0.221	1.544	0.140
m6	as.factor(vessel)Medeia	2.600	1.589	1.636	0.119
m6	as.factor(vessel)NW Explorer	0.133	1.005	0.132	0.896
m6	Chatham__SST__AMJJ	-0.363	0.174	-2.084	0.052
m6	adj__raw__pink__log	0.424	0.170	2.486	0.023
m6	as.factor(vessel)Medeia:adj__raw__pink__log	-0.576	0.334	-1.727	0.101
m6	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.121	0.165	-0.733	0.473
m7	(Intercept)	3.222	1.220	2.642	0.017
m7	as.factor(odd__even__factor)odd	0.410	0.217	1.888	0.075
m7	as.factor(vessel)Medeia	2.585	1.566	1.650	0.116
m7	as.factor(vessel)NW Explorer	-0.069	0.983	-0.070	0.945
m7	Icy__Strait__SST__May	-0.287	0.129	-2.236	0.038
m7	adj__raw__pink__log	0.393	0.166	2.362	0.030
m7	as.factor(vessel)Medeia:adj__raw__pink__log	-0.585	0.328	-1.784	0.091
m7	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.077	0.162	-0.472	0.642
m8	(Intercept)	3.661	1.668	2.195	0.042
m8	as.factor(odd__even__factor)odd	0.373	0.228	1.635	0.119
m8	as.factor(vessel)Medeia	2.460	1.657	1.484	0.155
m8	as.factor(vessel)NW Explorer	0.039	1.039	0.037	0.971
m8	Icy__Strait__SST__MJJ	-0.251	0.151	-1.663	0.114
m8	adj__raw__pink__log	0.406	0.176	2.304	0.033
m8	as.factor(vessel)Medeia:adj__raw__pink__log	-0.559	0.349	-1.604	0.126
m8	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.109	0.171	-0.636	0.533
m9	(Intercept)	3.849	1.397	2.754	0.013
m9	as.factor(odd__even__factor)odd	0.406	0.216	1.881	0.076
m9	as.factor(vessel)Medeia	2.351	1.565	1.502	0.150
m9	as.factor(vessel)NW Explorer	0.016	0.978	0.017	0.987
m9	Icy__Strait__SST__AMJ	-0.368	0.160	-2.300	0.034
m9	adj__raw__pink__log	0.402	0.165	2.431	0.026
m9	as.factor(vessel)Medeia:adj__raw__pink__log	-0.526	0.330	-1.596	0.128
m9	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.092	0.161	-0.570	0.576
m10	(Intercept)	3.877	1.553	2.496	0.023
m10	as.factor(odd__even__factor)odd	0.372	0.222	1.680	0.110
m10	as.factor(vessel)Medeia	2.444	1.608	1.519	0.146
m10	as.factor(vessel)NW Explorer	0.122	1.013	0.120	0.906
m10	Icy__Strait__SST__AMJJ	-0.324	0.162	-1.997	0.061
m10	adj__raw__pink__log	0.422	0.172	2.457	0.024

Model	Term	Estimate	Standard Error	Statistic	p value
m10	as.factor(vessel)Medeia:adj__raw__pink__log	-0.546	0.339	-1.612	0.124
m10	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.122	0.167	-0.729	0.475
m11	(Intercept)	3.316	1.229	2.699	0.015
m11	as.factor(odd__even__factor)odd	0.397	0.216	1.841	0.082
m11	as.factor(vessel)Medeia	2.557	1.558	1.642	0.118
m11	as.factor(vessel)NW Explorer	0.121	0.983	0.123	0.903
m11	NSEAK__SST__May	-0.290	0.126	-2.297	0.034
m11	adj__raw__pink__log	0.394	0.165	2.383	0.028
m11	as.factor(vessel)Medeia:adj__raw__pink__log	-0.563	0.327	-1.720	0.103
m11	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.103	0.161	-0.637	0.532
m12	(Intercept)	3.936	1.728	2.277	0.035
m12	as.factor(odd__even__factor)odd	0.351	0.227	1.547	0.139
m12	as.factor(vessel)Medeia	2.658	1.634	1.627	0.121
m12	as.factor(vessel)NW Explorer	0.191	1.043	0.183	0.857
m12	NSEAK__SST__MJJ	-0.292	0.166	-1.764	0.095
m12	adj__raw__pink__log	0.418	0.175	2.381	0.029
m12	as.factor(vessel)Medeia:adj__raw__pink__log	-0.575	0.344	-1.672	0.112
m12	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.127	0.171	-0.745	0.466
m13	(Intercept)	3.961	1.391	2.848	0.011
m13	as.factor(odd__even__factor)odd	0.372	0.213	1.747	0.098
m13	as.factor(vessel)Medeia	2.474	1.543	1.603	0.126
m13	as.factor(vessel)NW Explorer	0.236	0.979	0.241	0.812
m13	NSEAK__SST__AMJ	-0.386	0.161	-2.406	0.027
m13	adj__raw__pink__log	0.413	0.164	2.517	0.022
m13	as.factor(vessel)Medeia:adj__raw__pink__log	-0.532	0.325	-1.636	0.119
m13	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.121	0.160	-0.759	0.458
m14	(Intercept)	4.169	1.611	2.588	0.019
m14	as.factor(odd__even__factor)odd	0.353	0.220	1.605	0.126
m14	as.factor(vessel)Medeia	2.601	1.586	1.640	0.118
m14	as.factor(vessel)NW Explorer	0.260	1.013	0.257	0.800
m14	NSEAK__SST__AMJJ	-0.366	0.174	-2.102	0.050
m14	adj__raw__pink__log	0.428	0.170	2.510	0.022
m14	as.factor(vessel)Medeia:adj__raw__pink__log	-0.557	0.334	-1.665	0.113
m14	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.138	0.166	-0.828	0.419
m15	(Intercept)	3.283	1.251	2.624	0.017
m15	as.factor(odd__even__factor)odd	0.376	0.217	1.731	0.101
m15	as.factor(vessel)Medeia	2.772	1.570	1.766	0.094
m15	as.factor(vessel)NW Explorer	0.176	0.997	0.177	0.861
m15	SEAK__SST__May	-0.275	0.125	-2.198	0.041
m15	adj__raw__pink__log	0.410	0.168	2.445	0.025
m15	as.factor(vessel)Medeia:adj__raw__pink__log	-0.605	0.329	-1.840	0.082

Model	Term	Estimate	Standard Error	Statistic	p value
m15	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.114	0.163	-0.697	0.495
m16	(Intercept)	3.938	1.692	2.328	0.032
m16	as.factor(odd__even__factor)odd	0.334	0.227	1.473	0.158
m16	as.factor(vessel)Medeia	2.835	1.625	1.745	0.098
m16	as.factor(vessel)NW Explorer	0.212	1.040	0.204	0.840
m16	SEAK__SST__MJJ	-0.282	0.155	-1.817	0.086
m16	adj__raw__pink__log	0.424	0.175	2.419	0.026
m16	as.factor(vessel)Medeia:adj__raw__pink__log	-0.606	0.340	-1.780	0.092
m16	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.128	0.170	-0.752	0.462
m17	(Intercept)	3.912	1.405	2.785	0.012
m17	as.factor(odd__even__factor)odd	0.357	0.215	1.660	0.114
m17	as.factor(vessel)Medeia	2.651	1.550	1.710	0.104
m17	as.factor(vessel)NW Explorer	0.294	0.991	0.297	0.770
m17	SEAK__SST__AMJ	-0.363	0.155	-2.333	0.031
m17	adj__raw__pink__log	0.428	0.166	2.575	0.019
m17	as.factor(vessel)Medeia:adj__raw__pink__log	-0.565	0.326	-1.735	0.100
m17	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.133	0.162	-0.824	0.421
m18	(Intercept)	4.177	1.603	2.605	0.018
m18	as.factor(odd__even__factor)odd	0.341	0.220	1.550	0.139
m18	as.factor(vessel)Medeia	2.769	1.581	1.751	0.097
m18	as.factor(vessel)NW Explorer	0.293	1.015	0.289	0.776
m18	SEAK__SST__AMJJ	-0.350	0.165	-2.120	0.048
m18	adj__raw__pink__log	0.434	0.171	2.544	0.020
m18	as.factor(vessel)Medeia:adj__raw__pink__log	-0.585	0.332	-1.764	0.095
m18	as.factor(vessel)NW Explorer:adj__raw__pink__log	-0.140	0.166	-0.843	0.410

Table 5: Parameter estimates for the 18 individual models for Models m1a-m18a.

Model	Term	Estimate	Standard Error	Statistic	p value
m1a	(Intercept)	2.482	0.171	14.540	0.000
m1a	CPUE	0.306	0.074	4.144	0.000
m1a	as.factor(odd_even_factor)odd	0.406	0.179	2.268	0.032
m2a	(Intercept)	6.055	1.408	4.300	0.000
m2a	CPUE	0.396	0.076	5.240	0.000
m2a	as.factor(odd_even_factor)odd	0.192	0.182	1.054	0.302
m2a	ISTI20_JJ	-0.370	0.145	-2.552	0.017
m3a	(Intercept)	5.517	0.705	7.825	0.000
m3a	CPUE	0.365	0.058	6.318	0.000
m3a	as.factor(odd_even_factor)odd	0.363	0.137	2.657	0.014
m3a	Chatham_SST_May	-0.418	0.095	-4.379	0.000
m4a	(Intercept)	5.817	1.258	4.624	0.000
m4a	CPUE	0.335	0.067	4.991	0.000
m4a	as.factor(odd_even_factor)odd	0.347	0.162	2.145	0.042
m4a	Chatham_SST_MJJ	-0.344	0.129	-2.671	0.013
m5a	(Intercept)	6.111	0.869	7.032	0.000
m5a	CPUE	0.362	0.059	6.172	0.000
m5a	as.factor(odd_even_factor)odd	0.337	0.139	2.420	0.023
m5a	Chatham_SST_AMJ	-0.486	0.115	-4.225	0.000
m6a	(Intercept)	6.198	1.114	5.562	0.000
m6a	CPUE	0.346	0.063	5.473	0.000
m6a	as.factor(odd_even_factor)odd	0.338	0.152	2.222	0.036
m6a	Chatham_SST_AMJJ	-0.433	0.129	-3.363	0.003
m7a	(Intercept)	5.209	0.658	7.912	0.000
m7a	CPUE	0.372	0.059	6.289	0.000
m7a	as.factor(odd_even_factor)odd	0.390	0.138	2.818	0.010
m7a	Icy_Strait_SST_May	-0.400	0.095	-4.228	0.000
m8a	(Intercept)	5.587	1.153	4.846	0.000
m8a	CPUE	0.341	0.067	5.077	0.000
m8a	as.factor(odd_even_factor)odd	0.359	0.161	2.237	0.035
m8a	Icy_Strait_SST_MJJ	-0.315	0.116	-2.717	0.012
m9a	(Intercept)	5.859	0.842	6.958	0.000
m9a	CPUE	0.362	0.060	6.067	0.000
m9a	as.factor(odd_even_factor)odd	0.391	0.141	2.777	0.010
m9a	Icy_Strait_SST_AMJ	-0.470	0.116	-4.062	0.000
m10a	(Intercept)	5.874	1.045	5.624	0.000
m10a	CPUE	0.350	0.064	5.467	0.000
m10a	as.factor(odd_even_factor)odd	0.364	0.152	2.392	0.025
m10a	Icy_Strait_SST_AMJJ	-0.398	0.121	-3.279	0.003

Model	Term	Estimate	Standard Error	Statistic	p value
m11a	(Intercept)	5.251	0.661	7.947	0.000
m11a	CPUE	0.336	0.057	5.869	0.000
m11a	as.factor(odd_even_factor)odd	0.398	0.138	2.892	0.008
m11a	NSEAK_SST_May	-0.378	0.088	-4.276	0.000
m12a	(Intercept)	5.616	1.152	4.874	0.000
m12a	CPUE	0.311	0.066	4.730	0.000
m12a	as.factor(odd_even_factor)odd	0.383	0.160	2.399	0.025
m12a	NSEAK_SST_MJJ	-0.317	0.115	-2.744	0.011
m13a	(Intercept)	5.842	0.836	6.989	0.000
m13a	CPUE	0.330	0.058	5.656	0.000
m13a	as.factor(odd_even_factor)odd	0.388	0.141	2.763	0.011
m13a	NSEAK_SST_AMJ	-0.450	0.110	-4.072	0.000
m14a	(Intercept)	5.906	1.054	5.603	0.000
m14a	CPUE	0.320	0.063	5.089	0.000
m14a	as.factor(odd_even_factor)odd	0.383	0.152	2.520	0.019
m14a	NSEAK_SST_AMJJ	-0.396	0.121	-3.279	0.003
m15a	(Intercept)	5.253	0.714	7.356	0.000
m15a	CPUE	0.332	0.059	5.619	0.000
m15a	as.factor(odd_even_factor)odd	0.403	0.142	2.835	0.009
m15a	SEAK_SST_May	-0.349	0.088	-3.952	0.001
m16a	(Intercept)	5.502	1.143	4.814	0.000
m16a	CPUE	0.302	0.066	4.554	0.000
m16a	as.factor(odd_even_factor)odd	0.395	0.161	2.462	0.021
m16a	SEAK_SST_MJJ	-0.289	0.108	-2.666	0.014
m17a	(Intercept)	5.779	0.880	6.567	0.000
m17a	CPUE	0.324	0.060	5.424	0.000
m17a	as.factor(odd_even_factor)odd	0.396	0.144	2.740	0.011
m17a	SEAK_SST_AMJ	-0.409	0.108	-3.793	0.001
m18a	(Intercept)	5.787	1.063	5.442	0.000
m18a	CPUE	0.309	0.064	4.870	0.000
m18a	as.factor(odd_even_factor)odd	0.399	0.154	2.593	0.016
m18a	SEAK_SST_AMJJ	-0.358	0.114	-3.138	0.004

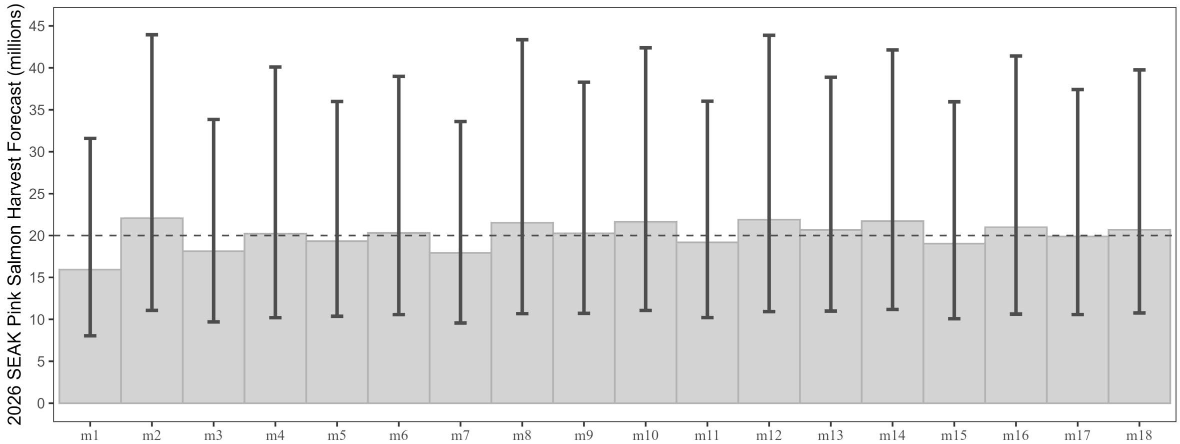

Figure B1: Bias-corrected forecasts (grey bars) for the 18 regression models (Models m1-m18) with 80% prediction intervals (vertical grey lines). A horizontal dotted line at 20 million fish is placed on the figure for reference only. The 2026-forecast using the model m13a has a point estimate of 19.3 million fish (80% prediction interval: 12.6 to 29.8 million fish).

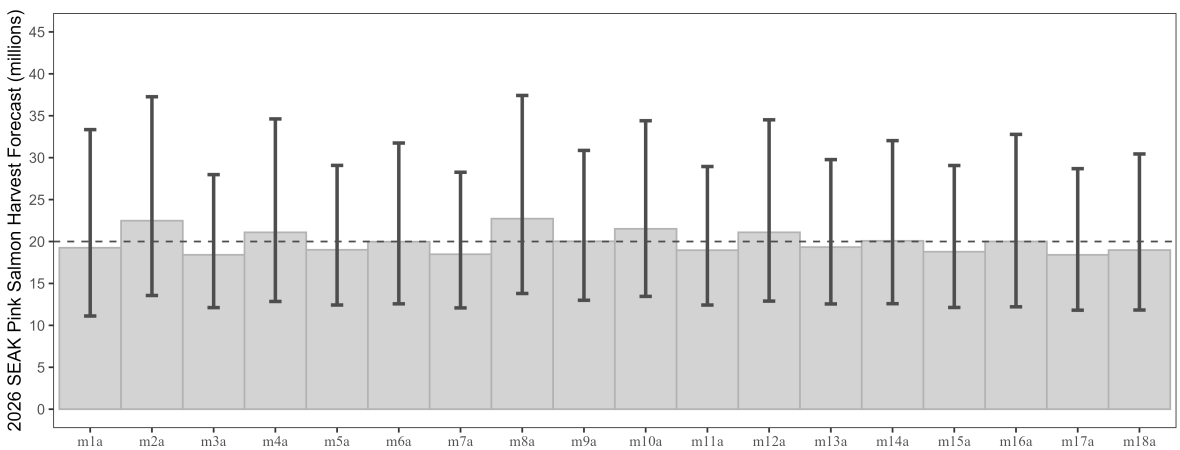

Figure B2: Bias-corrected forecasts (grey bars) for the 18 regression models (Models m1a-m18a) with 80% prediction intervals (vertical grey lines). A horizontal dotted line at 20 million fish is placed on the figure for reference only. The 2026-forecast using the model m13a has a point estimate of 19.3 million fish (80% prediction interval: 12.6 to 29.8 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 6; Figure C1; Figure C2). Model diagnostics were used to identify observations that were potential outliers, had high leverage, or were influential (Zhang 2016).

Table 6: 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	1.40	29.32
1999	77.82	-0.26	0.29	0.10	-0.99	106.28
2000	20.25	-0.24	0.12	0.02	-0.80	26.94
2001	67.02	0.07	0.09	0.00	0.23	65.73
2002	45.32	0.18	0.16	0.02	0.62	39.80
2003	52.47	-0.21	0.19	0.03	-0.74	68.11
2004	45.31	0.38	0.13	0.06	1.28	32.68
2005	59.12	0.07	0.10	0.00	0.22	58.16
2006	11.61	-0.35	0.13	0.05	-1.19	17.30
2007	44.80	0.04	0.09	0.00	0.12	45.38
2008	15.91	-0.30	0.12	0.03	-1.01	22.53
2009	38.02	-0.33	0.17	0.07	-1.14	55.38
2010	24.14	-0.17	0.10	0.01	-0.57	30.11
2011	58.88	-0.04	0.11	0.00	-0.13	64.24
2012	21.28	0.08	0.08	0.00	0.27	20.59
2013	94.72	0.36	0.11	0.04	1.19	69.79
2014	37.17	0.24	0.11	0.02	0.79	30.88
2015	35.09	-0.50	0.09	0.07	-1.65	60.57
2016	18.37	0.15	0.22	0.02	0.55	16.56
2017	34.73	-0.07	0.35	0.01	-0.27	39.06
2018	8.07	-0.37	0.15	0.07	-1.28	12.29
2019	21.14	-0.13	0.20	0.01	-0.48	25.42
2020	8.06	-0.34	0.19	0.08	-1.18	11.86
2021	48.53	0.52	0.12	0.10	1.75	30.42
2022	18.30	0.22	0.10	0.02	0.73	15.47
2023	48.45	0.65	0.17	0.26	2.27	26.54
2024	20.12	0.10	0.09	0.00	0.33	19.16
2025	21.26	-0.16	0.16	0.01	-0.55	26.21

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; year 2023). One observation had high leverage values (Figure C1b; year 2017). 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 (year 2023) based on standardized residuals (Figure C2c; Table 6). 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.

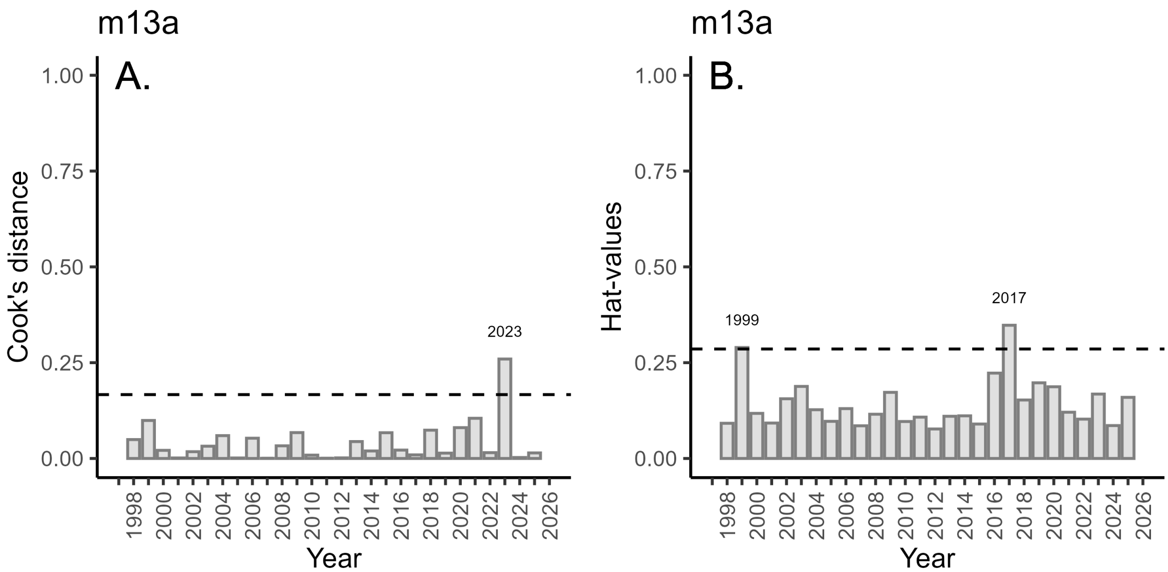

Figure C1: Diagnostics plots of influential observations including A. Cook's distance (with a cut-off value of 0.17), and B. leverage values (with a cut-off value of 0.29) from model m13a.

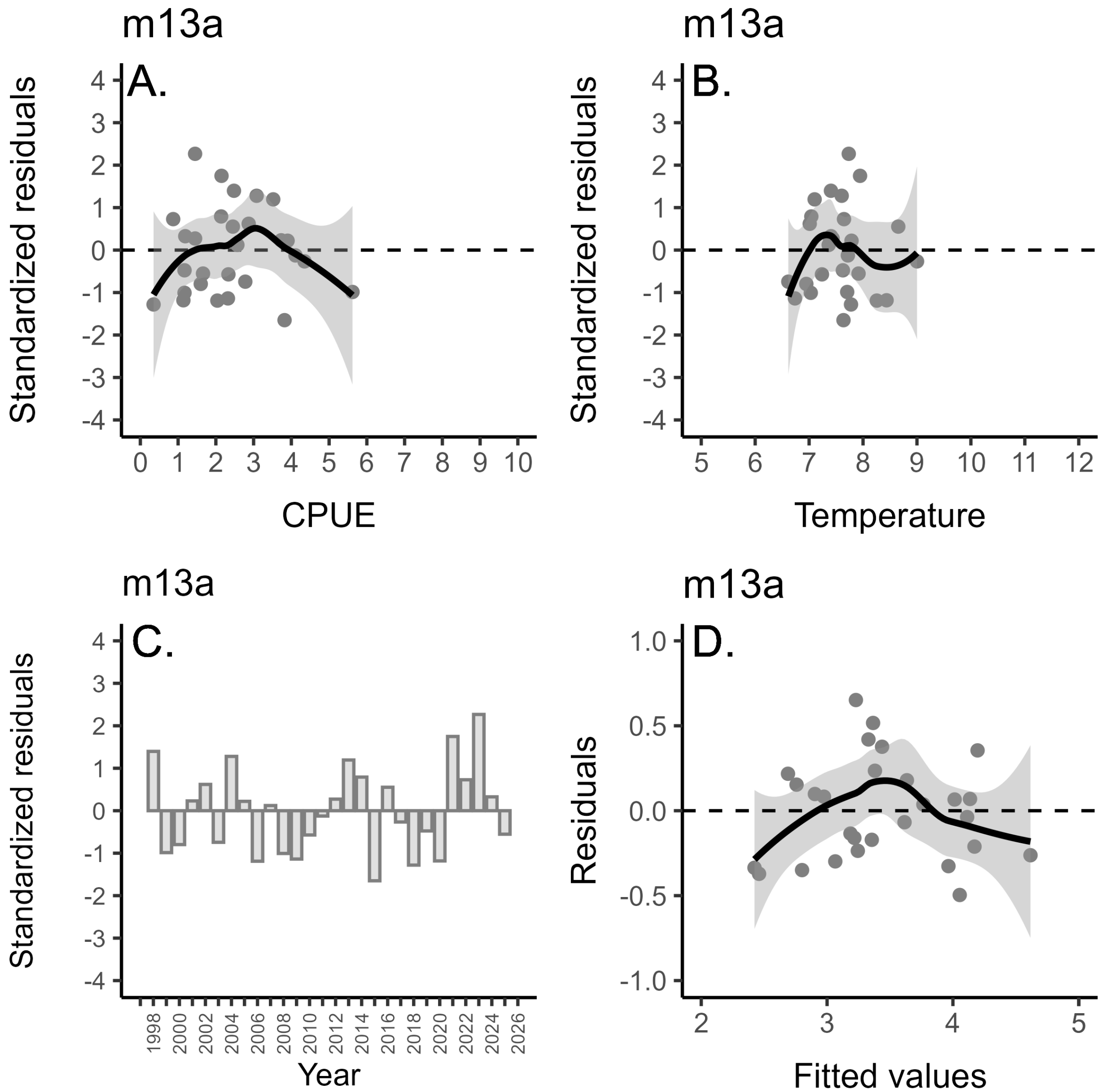

Figure C2: Standardized residuals versus predicted plots for A. CPUE and B. temperature (average April, May, June SST in northern Southeast Alaska) for model m13a. C. Standardized residuals versus juvenile year, and D. residuals versus fitted values for model m13a. Positive residuals indicate that the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

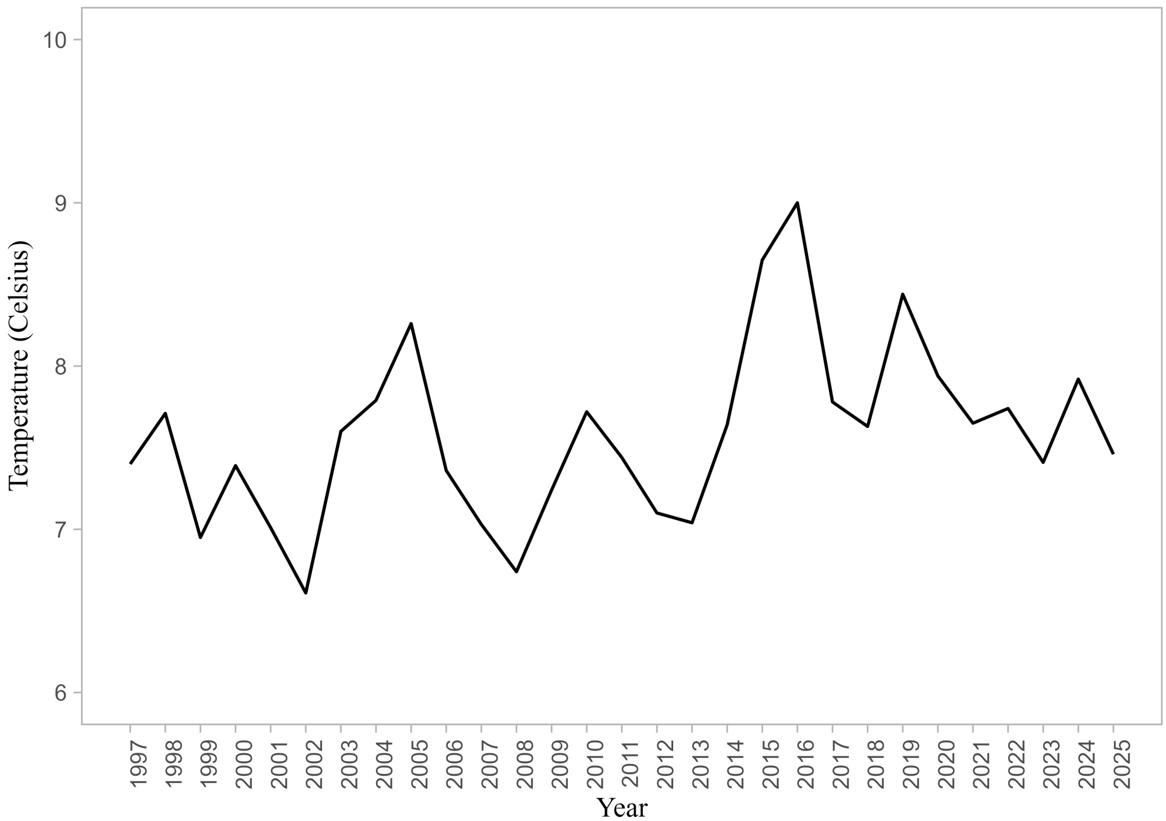

Figure C3: The April through June temperature averaged over the NSEAK region from 1997 through 2025.