Appendix 3: Gulf of Alaska salmon analysis

Here we show the LM, GAM, and DLM analysis for the Gulf of Alaska salmon dataset. For complete code, see the full quarto document

Data Processing

First, we standardize and examine the trends in SST and salmon abundace from Litzow et al. 2018.

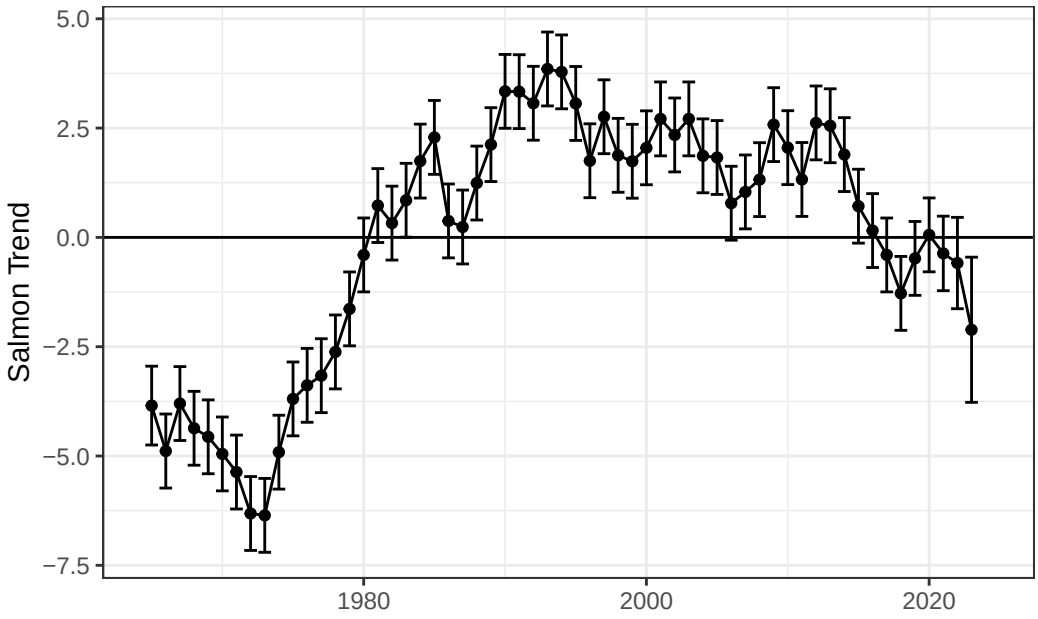

Figure S1: Time series of salmon catch from Lizow et al. 2018

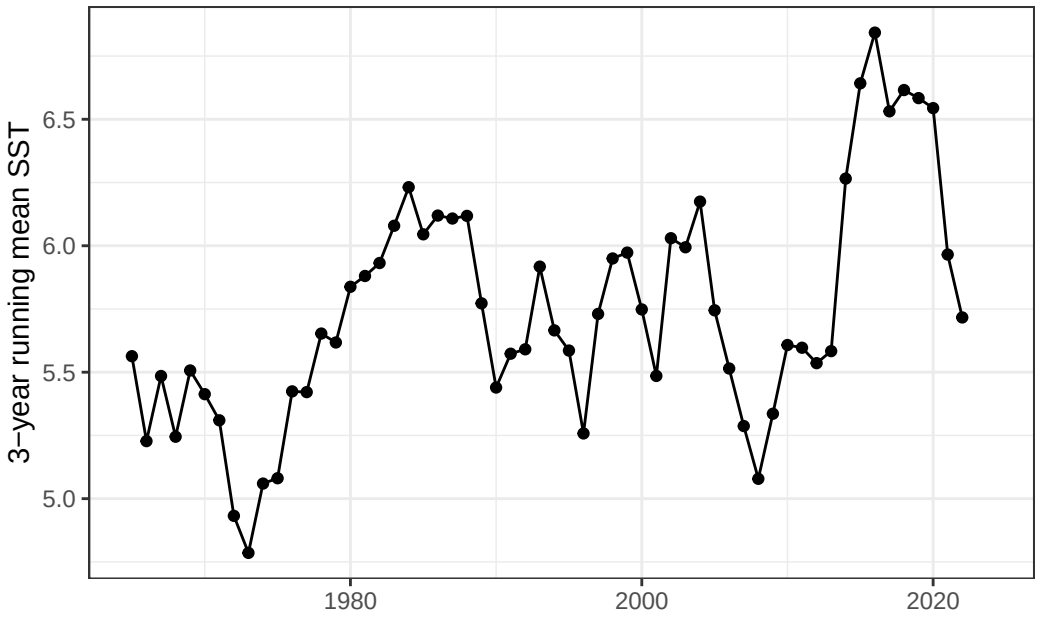

Figure S2: Time series of sea surface temperature anomalies from Lizow et al. 2018

LM

We start our investigation using linear models, to evaluate the relationship between salmon catch and SST anomalies with periods defined a-priori as before and after 1988/1989 (from Litzow et al. 2018). Previous investigations used this approach, and while we primarily discuss DLMs and GAMs for this dataset in the main text, we include this illustrative example here for completeness and comparability to the previous study.

We compare linear model structures using classic model selection criteria, AIC. First, we examine a 1) intercept only model, 2) salmon abundance with period as a predictor, 3) salmon abundance with period and SST anomalies as predictors, and 4) an interaction between SST anomalies and period. This shows that model 2 is a better fit to the data than model one illustrating that a time-varying intercept is an improvement to model fit than a time-invariant intercept. Similarly, model 4 is the best model showing that a time-varying slope with SST is an improvement to a time-invariant slope (Table S1).

Model	AIC
1. Intercept only	289.46
2. Intercept by period only (time-varying intercept)	251.43
3. Intercept by period and SST	248.80
4. Interaction between SST and period (time-varying slope and intercept)	179.02
5. Time-varying slope	247.52

Table S1: AIC values for four linear models

Functionally, model 4 has a time-varying slope and a time-varying intercept which we can see by both plotting the relationships and examining the model output. We can see a strong positive correlation prior to 1988 (Figure S3) followed by a weak negative relationship which is represented in the slopes of the relationship (Table S2 & Figure S4).

term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.40	0.23	-5.96	0
z_sst	2.78	0.24	11.49	0
as.factor(period)late	3.29	0.30	10.89	0
z_sst:as.factor(period)late	-3.53	0.31	-11.50	0

Table S2: Summary of the output of the best supported model (model 4)

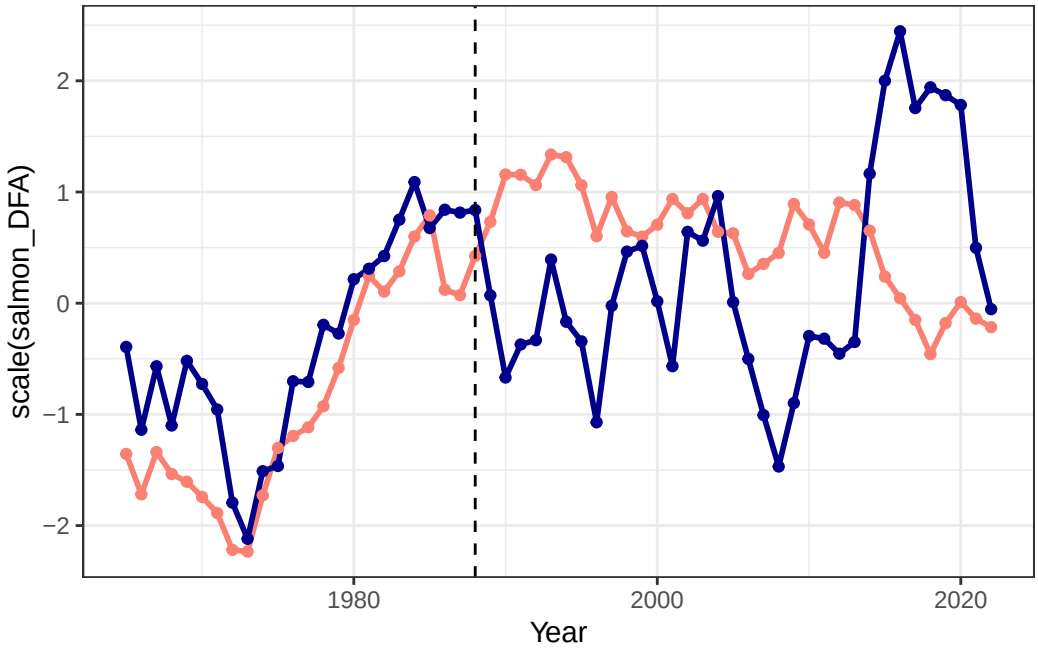

Figure S3: Time series of scaled salmon catch trend (salmon color) and SST anomalies (dark blue)

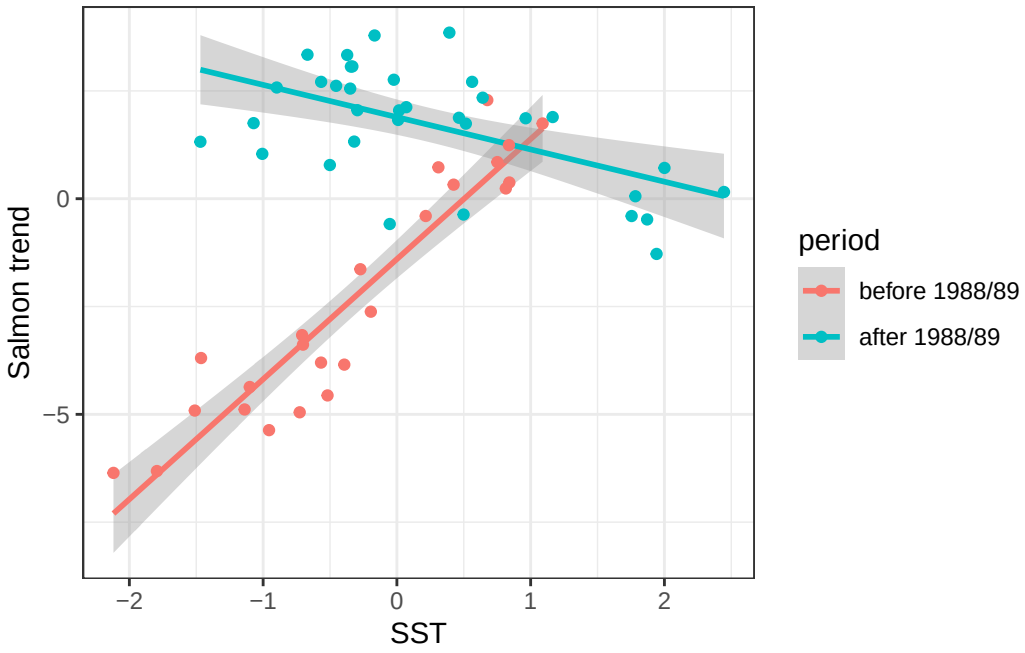

Figure S4: The relationship between salmon catch and SST anomalies before and after the 1988/1989 time periods

GAM

We fit two distinct GAM models to the salmon catch data and SST anomalies to illustrate the differences in a model with a time-varying slope and a time-varying intercept, and a model that only has a time-varying slope. We find that when fitting a time-varying slope and time-varying intercept model, most of the variability in the relationship is explained by the time-varying intercept (Figure S5) while the time-varying slope does not change much through time (Figure S6). When only a time-varying slope is fit to the data, the slope parameter is much more variable through time (Figure S6), and looks similar to the slope estimated by the linear models (Figure S4).

DLM

We fit two distinct DLM models to the salmon catch data and SST anomalies to compare to the results of the GAM models. Generally, the parameters estimated by the DLM are more certain and follow similar patterns through time as the GAM (Figure S7 & Figure S8). There is also more interannual variability in the parameter estimates of the DLM compared to the continuously smoothed pattern of the GAM.

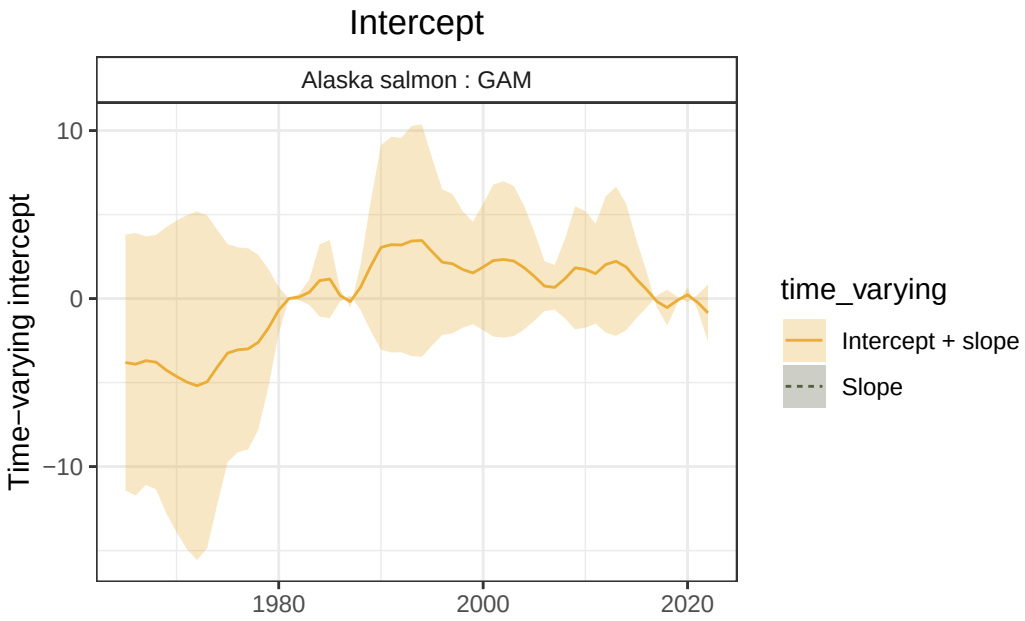

Figure S5: Time-varying intercept of the GAM model representing the relationship between SST anomalies and salmon catch.

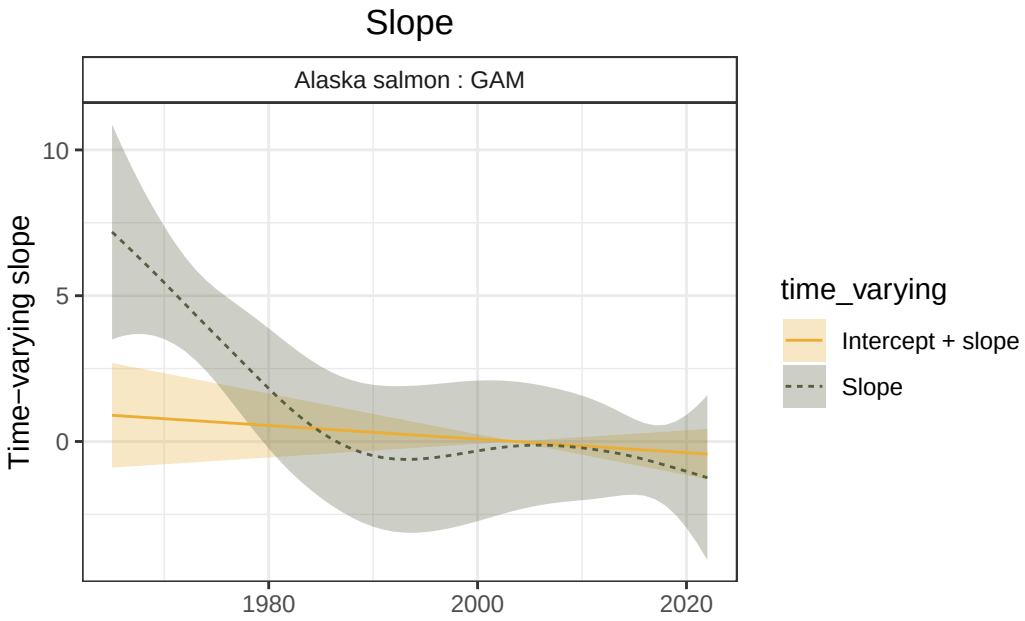

Figure S6: Time-varying slope of the GAM model representing the relationship between SST anomalies and salmon catch.

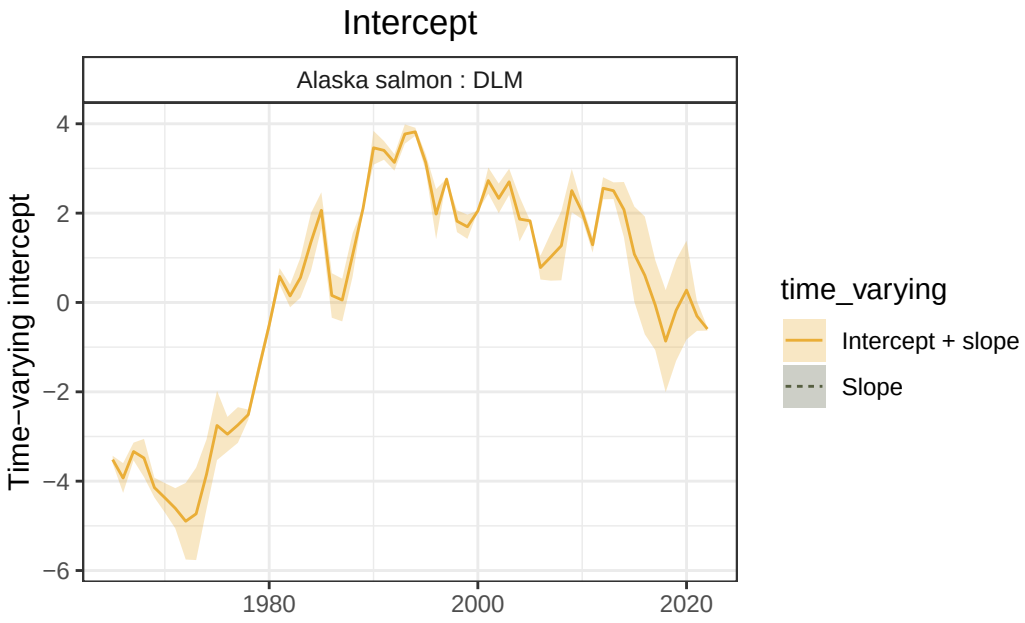

Figure S7: Time-varying intercept of the DLM model representing the relationship between SST anomalies and salmon catch.

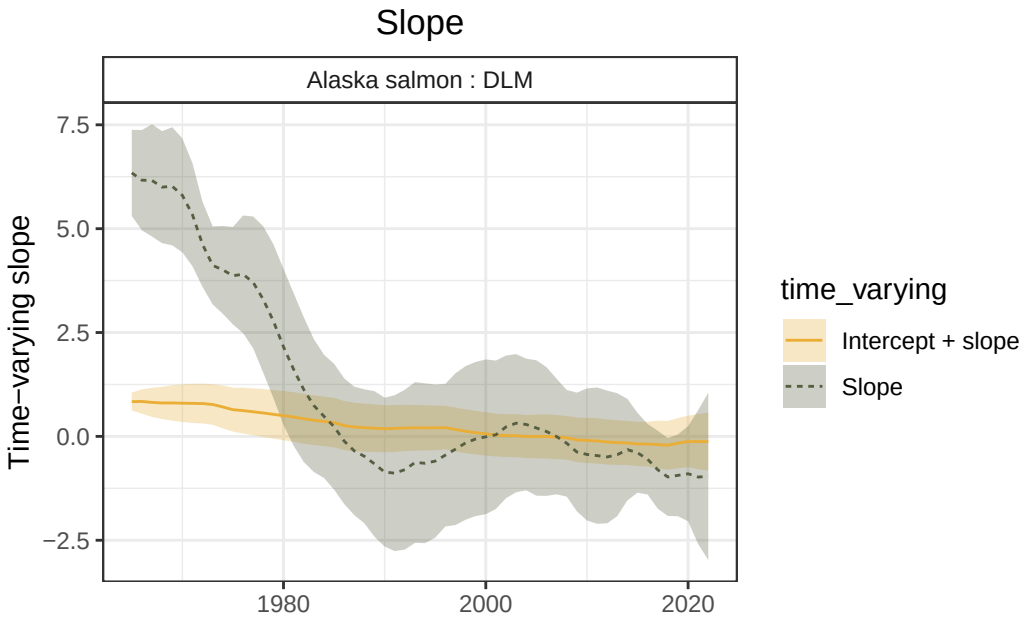

Figure S8: Time-varying slope of the DLM model representing the relationship between SST anomalies and salmon catch.