Appendices: Covariate tests

Table A1. Covariate tests for the July-September catch (S_t). M is the base model with only prior season October-March catch (N_{t-1}) as the covariate. To the base model, the environmental covariates are added. ns-SST is nearshore (0-80km) and r-SST is regional (0-160km) SST. Similarly, ns-Chl is nearshore chlorophyll. The models are nested sets, e.g. 1, 2a, 3a and 1, 2b, 3b.

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
catch only models 1983-2015 data						
null model: $ln(S_t) = ln(S_{t-1}) + \epsilon_t$	33		1.596	126.6	1.596	0.559
base (M): 1. $ln(S_t) = \alpha + s(ln(N_{t-1})) + \epsilon_t$	30	21.7	1.204	115.2	1.313	0.692
Precipitation						
V_t = Jun-Jul Precipitation - satellite (S1)						
2a. $ln(S_t)$ = M + βV_t	29.1	19.7	1.199	117.7	1.34	0.731
3a. $ln(S_t)$ = M + $s(V_t)$	27.9	21.4	1.163	119.1	1.322	0.656‡
V_t = Jun-Jul Precipitation - land gauges (S1)						
2a. $ln(S_t)$ = M + βV_t	29.1	25.4	1.156	115.3	1.308	0.564‡‡
3a. $ln(S_t)$ = M + $s(V_t)$	28	29.9	1.1	115.3	1.327	0.62‡‡
V_t = Apr-May Precipitation - satellite (S2)						
2a. $ln(S_t)$ = M + βV_t	29.1	24.1	1.166	115.8	1.312	0.666
3a. $ln(S_t)$ = M + $s(V_t)$	27.7	22.2	1.152	119.3	1.335	0.638‡
V_t = Apr-May Precipitation - land gauges (S2)						
2a. $ln(S_t)$ = M + βV_t	29.1	26.9	1.144	114.6	1.329	0.78
3a. $ln(S_t)$ = M + $s(V_t)$	27.2	25.1	1.12	119	1.37	0.642‡
Sea surface temperature						
V_t = Mar-May r-SST (S5)						
2a. $ln(S_t)$ = M + βV_t	29	21.1	1.188	117.1	1.335	0.82
3a. $ln(S_t)$ = M + $s(V_t)$	27.7	24.8	1.133	118.1	1.316	0.829
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21.1	1.189	117.1	1.318	0.658
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.7	24.8	1.133	118.1	1.283	0.679
V_t = Oct-Dec ns-SST (L1)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	19.1	1.203	117.9	1.343	0.826
3a. $ln(S_t)$ = M + $s(V_{t-1})$	28.1	19.1	1.183	119.8	1.357	0.671
Upwelling						
V_t = Jun-Sep SST-derived UPW (L2)						
2a. $ln(S_t)$ = M + βV_t	29	28.6	1.13	113.8	1.275	0.606‡‡

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
3a. $ln(S_t)$ = M + $s(V_t)$	27.5	28.1	1.105	116.9	1.306	0.55‡‡‡
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21.1	1.189	117.1	1.366	0.67
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.2	26.7	1.108	118.3	1.407	0.726
V_t = Jun-Sep ns-SST (L2)						
2a. $ln(S_t)$ = M + βV_t	29.1	27.5	1.139	114.3	1.292	0.585‡‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.9	35.3	1.055	112.7†	1.238‡	0.641‡
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21.4	1.187	117	1.356	0.631‡
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.5	18.8	1.174	120.9	1.435	0.653‡
V_t = Jun-Sep Bakun-UPW (L2)						
2a. $ln(S_t)$ = M + βV_t	29.1	27.4	1.14	114.4	1.391	0.637‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.6	43.1	0.984	109.1††	1.354	0.733
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	22.2	1.18	116.6	1.432	0.673
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.7	21.5	1.157	119.5	1.622	0.668
Ocean climate						
V_t = 2.5-year average r-SST - AVHRR (A1)						
2a. $ln(S_t)$ = M + βV_t	29.1	32	1.103	112.2†	1.286	0.63‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.8	37.3	1.037	111.8†	1.288	0.49‡‡‡
V_t = ONI (A2)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	20.5	1.193	117.4	1.355	0.707
3a. $ln(S_t)$ = M + $s(V_{t-1})$	27.4	19.8	1.164	120.7	1.358	0.606‡‡
V_t = Sep-Nov DMI (A3)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	19.2	1.204	117.9	1.328	0.733
3a. $ln(S_t)$ = M + $s(V_{t-1})$	27	15.8	1.184	123.2	1.374	0.811
catch only models 1998-2015 data						
null model: $ln(S_t) = ln(S_{t-1}) + \epsilon_t$	18		0.616	35.9	0.616	0.425
base (M): 1. $ln(S_t) = \alpha + p(ln(N_{t-1})) + \epsilon_t$	15	16.2	0.364	25.8	0.478	0.228
Chlorophyll						
V_t = Jul-Sep ns-CHL (L3)						
2a. $ln(S_t)$ = M + βV_t	14	12	0.361	29.4	0.536	0.24
3a. $ln(S_t)$ = M + $p(V_t)$	13	16.4	0.339	31.7	0.763	0.274
2b. $ln(S_t)$ = M + βV_{t-1}	14	10.2	0.364	29.7	0.489	0.251
3b. $ln(S_t)$ = M + $p(V_{t-1})$	13	3.4	0.364	34.3	0.572	0.299
V_t = Oct-Dec ns-CHL (L3)						
2a. $ln(S_t)$ = M + βV_{t-1}	14	10.8	0.363	29.6	0.514	0.26
3a. $ln(S_t)$ = M + $p(V_{t-1})$	13	23	0.325	30.3	0.527	0.242

Notes: LOOCV = Leave one out cross-validation. RMSE = root mean square error. MdAE = median absolute error. AICc = Akaike Information Criterion corrected for small sample size. † and †† = AICc greater than 2 and greater than 5 below model M (base catch model). ‡, ‡‡, and ‡‡‡ = LOOCV RMSE 5%, 10% and 20% below model M, respectively. t indicates current season (Jul-Jun) and $t-1$ is prior season. Thus a Jan-Mar covariate with $t-1$ would be in the same calendar year as the Jul-Sep catch, though in a prior fishing season. With the exception that for covariates that are calendar year (Jan-Dec) or multiyear, t is the current calendar year.

Table A2. Covariate tests for the October-March catch (N_t). M is the base model with prior season October-March catch (N_{t-1}) and July-September catch two seasons prior (S_{t-2}) as the covariates. To the base model, the environmental covariates are added. ns-SST is nearshore (0-80km) and r-SST is regional (0-160km) SST. Similarly, ns-Chl is nearshore chlorophyll. The models are nested sets, e.g. 1, 2a, 3a and 1, 2b, 3b.

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
catch only models 1983-2014 data						
null model: $ln(N_t) = ln(N_{t-1}) + \epsilon_t$	32		0.999	92.9	0.999	0.256
base (M): 1. $ln(N_t) = \alpha + s(ln(N_{t-1})) + \epsilon_t$	29.1	45.9	0.824	87.7	0.955	0.323
Precipitation						
V_t = Jun-Jul Precipitation - satellite (S1)						
2a. $ln(N_t)$ = M + βV_t	28.1	44	0.824	90.5	0.99	0.353
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	46.1	0.791	91.5	1.037	0.354
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44.7	0.819	90.1	0.989	0.315
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.8	44.2	0.804	92.8	1.021	0.337
V_t = Jun-Jul Precipitation - land gauges (S1)						
2a. $ln(N_t)$ = M + βV_t	28.1	54.1	0.745	84.1†	0.964	0.351
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	59.6	0.685	82.1††	0.906‡	0.246‡‡‡
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45.2	0.815	89.8	1.01	0.339
3b. $ln(N_t)$ = M + $s(V_{t-1})$	27	43.2	0.814	93	1.05	0.356
V_t = Apr-May Precipitation - satellite (S2)						
2a. $ln(N_t)$ = M + βV_t	28.1	44	0.823	90.5	0.968	0.36
3a. $ln(N_t)$ = M + $s(V_t)$	26.8	41.9	0.819	94.2	0.996	0.457
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44.5	0.82	90.2	0.958	0.374
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.8	45.4	0.794	92.1	0.954	0.381
V_t = Apr-May Precipitation - land gauges (S2)						
2a. $ln(N_t)$ = M + βV_t	28.1	47.4	0.799	88.5	0.913	0.368
3a. $ln(N_t)$ = M + $s(V_t)$	26.2	46.1	0.781	93	0.93	0.389
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44	0.824	90.5	0.965	0.314
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.1	42.1	0.808	95.4	0.994	0.359
Sea surface temperature						
V_t = Mar-May r-SST (S5)						
2a. $ln(N_t)$ = M + βV_t	28.1	46.4	0.805	89.1	0.961	0.34
3a. $ln(N_t)$ = M + $s(V_t)$	26.7	46.8	0.784	91.4	0.961	0.423
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	50	0.778	86.9	0.941	0.475
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.6	50.9	0.751	89.1	0.928	0.398
V_t = Oct-Dec ns-SST (L1)						
2a. $ln(N_t)$ = M + βV_t	28.1	44.9	0.817	90	0.981	0.416
3a. $ln(N_t)$ = M + $s(V_t)$	27.1	43.9	0.81	92.4	0.99	0.434
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	46.3	0.806	89.2	0.964	0.289‡‡
3b. $ln(N_t)$ = M + $s(V_{t-1})$	27.1	45.3	0.8	91.6	1.019	0.324
Upwelling						

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
V_t = Jun-Sep SST-derived UPW (L2)						
2a. $ln(N_t)$ = M + βV_t	28.1	54.7	0.741	83.8†	0.913	0.447
3a. $ln(N_t)$ = M + $s(V_t)$	26.2	56.8	0.699	86	1.017	0.456
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44	0.824	90.5	1.007	0.322
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.1	47.2	0.772	92.4	1.084	0.35
V_t = Jun-Sep ns-SST (L2)						
2a. $ln(N_t)$ = M + βV_t	28.1	52.3	0.76	85.4†	0.914	0.432
3a. $ln(N_t)$ = M + $s(V_t)$	26.6	52.1	0.742	88.4	0.965	0.519
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45.6	0.812	89.5	0.97	0.333
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.6	44.4	0.798	93.2	0.995	0.307‡
V_t = Jun-Sep Bakun-UPW (L2)						
2a. $ln(N_t)$ = M + βV_t	28.1	46.5	0.805	89	0.948	0.37
3a. $ln(N_t)$ = M + $s(V_t)$	26.6	47.7	0.775	91.1	0.945	0.309
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44.9	0.817	90	0.951	0.342
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.7	45.4	0.794	92.3	0.965	0.392
Ocean climate						
V_t = 2.5-year average r-SST - AVHRR (A1)						
2a. $ln(N_t)$ = M + βV_t	28.1	56.5	0.726	82.4††	0.844‡‡	0.324
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	64.5	0.642	78.1††	0.758‡‡‡	0.351
V_t = ONI (A2)						
2a. $ln(N_t)$ = M + βV_t	28.1	48.5	0.79	87.8	0.916	0.453
3a. $ln(N_t)$ = M + $s(V_t)$	27.5	48	0.785	89.2	0.929	0.44
V_t = Sep-Nov DMI (A3)						
2a. $ln(N_t)$ = M + βV_t	28.1	48.8	0.787	87.7	0.978	0.425
3a. $ln(N_t)$ = M + $s(V_t)$	25.8	48.9	0.754	92.2	1.119	0.493
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44.7	0.819	90.1	0.95	0.336
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26	44.3	0.791	94.4	0.947	0.339
catch only models 1998-2014 data						
null model: $ln(N_t) = ln(N_{t-1}) + \epsilon_t$	17		0.432	22	0.432	0.133
base (M): 1. $ln(N_t) = \alpha + p(ln(N_{t-1})) + \epsilon_t$	14	26.5	0.334	22.3	0.422	0.369
Chlorophyll						
V_t = Jul-Sep ns-CHL (L3)						
2a. $ln(N_t)$ = M + βV_t	13	24	0.327	25.7	0.441	0.344‡
3a. $ln(N_t)$ = M + $p(V_t)$	12	18.6	0.325	30.5	0.496	0.333‡
2b. $ln(N_t)$ = M + βV_{t-1}	13	31.5	0.311	24	0.418	0.348‡
3b. $ln(N_t)$ = M + $p(V_{t-1})$	12	25.8	0.311	28.9	1.616	0.362
V_t = Oct-Dec ns-CHL (L3)						
2a. $ln(N_t)$ = M + βV_t	13	24	0.327	25.7	0.445	0.336‡
3a. $ln(N_t)$ = M + $p(V_t)$	12	35.1	0.29	26.6	0.391‡	0.217‡‡‡
2b. $ln(N_t)$ = M + βV_{t-1}	13	45.3	0.277	20.1†	0.364‡‡	0.235‡‡‡

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
3b. $ln(N_t) = \mathrm{M} + p(V_{t-1})$	12	40.8	0.277	25.1	0.384‡	0.278‡‡‡

Notes: LOOCV = Leave one out cross-validation. RMSE = root mean square error. MdAE = median absolute error. AICc = Akaike Information Criterion corrected for small sample size. † and †† = AICc greater than 2 and greater than 5 below model M (base catch model). ‡, ‡‡, and ‡‡‡ = LOOCV RMSE 5%, 10% and 20% below model M, respectively. t indicates current season (Jul-Jun) and $t-1$ is prior season. Thus a Jan-Mar covariate with $t-1$ would be in the same calendar year as the Jul-Sep catch, though in a prior fishing season. With the exception that for covariates that are calendar year (Jan-Dec) or multiyear, t is the current calendar year.