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	126.63	1.596	0.559
base (M) 1. $ln(S_t) = \alpha + s(ln(N_{t-1})) + \epsilon_t$	30	22	1.204	115.22	1.313	0.692
Precipitation						
V_t = Jun-Jul Precipitation - satellite (S1)						
2a. $ln(S_t)$ = M + βV_t	29.1	20	1.199	117.7	1.34	0.731
3a. $ln(S_t)$ = M + $s(V_t)$	27.9	21	1.163	119.09	1.322	0.656‡
V_t = Jun-Jul Precipitation - land gauges (S1)						
2a. $ln(S_t)$ = M + βV_t	29.1	25	1.156	115.26	1.308	0.564‡‡
3a. $ln(S_t)$ = M + $s(V_t)$	28	30	1.1	115.26	1.327	0.62‡‡
V_t = Apr-May Precipitation - satellite (S2)						
2a. $ln(S_t)$ = M + βV_t	29.1	24	1.166	115.82	1.312	0.666
3a. $ln(S_t)$ = M + $s(V_t)$	27.7	22	1.152	119.28	1.335	0.638‡
V_t = Apr-May Precipitation - land gauges (S2)						
2a. $ln(S_t)$ = M + βV_t	29.1	27	1.144	114.56	1.329	0.78
3a. $ln(S_t)$ = M + $s(V_t)$	27.2	25	1.12	118.98	1.37	0.642‡
Sea surface temperature						
V_t = Mar-May r-SST (S5)						
2a. $ln(S_t)$ = M + βV_t	29	21	1.188	117.12	1.335	0.82
3a. $ln(S_t)$ = M + $s(V_t)$	27.7	25	1.133	118.12	1.316	0.829
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21	1.189	117.11	1.318	0.658
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.7	25	1.133	118.07	1.283	0.679
V_t = Oct-Dec ns-SST (L1)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	19	1.203	117.94	1.343	0.826
3a. $ln(S_t)$ = M + $s(V_{t-1})$	28.1	19	1.183	119.79	1.357	0.671
Upwelling						
V_t = Jun-Sep SST-derived UPW (L2)						
2a. $ln(S_t)$ = M + βV_t	29	29	1.13	113.83	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	1.105	116.92	1.306	0.55‡‡‡
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21	1.189	117.12	1.366	0.67
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.2	27	1.108	118.33	1.407	0.726
V_t = Jun-Sep ns-SST (L2)						
2a. $ln(S_t)$ = M + βV_t	29.1	28	1.139	114.33	1.292	0.585‡‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.9	35	1.055	112.65†	1.238‡	0.641‡
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	21	1.187	117	1.356	0.631‡
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.5	19	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	1.14	114.39	1.391	0.637‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.6	43	0.984	109.12††	1.354	0.733
2b. $ln(S_t)$ = M + βV_{t-1}	29.1	22	1.18	116.62	1.432	0.673
3b. $ln(S_t)$ = M + $s(V_{t-1})$	27.7	22	1.157	119.55	1.622	0.668
Ocean climate						
V_t = 2.5-year ave r-SST (A1)						
2a. $ln(S_t)$ = M + βV_t	29.1	32	1.103	112.17†	1.286	0.63‡
3a. $ln(S_t)$ = M + $s(V_t)$	27.8	37	1.037	111.84†	1.288	0.49‡‡‡
V_t = ONI (A2)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	21	1.193	117.36	1.355	0.707
3a. $ln(S_t)$ = M + $s(V_{t-1})$	27.4	20	1.164	120.73	1.358	0.606‡‡
V_t = Sep-Nov DMI (A3)						
2a. $ln(S_t)$ = M + βV_{t-1}	29.1	19	1.204	117.87	1.328	0.733
3a. $ln(S_t)$ = M + $s(V_{t-1})$	27	16	1.184	123.21	1.374	0.811
V_t = DMI 3-yr ave (A3)						
2a. $ln(S_t)$ = M + βV_t	29.1	30	1.12	113.06†	1.343	0.521‡‡‡
3a. $ln(S_t)$ = M + $s(V_t)$	28.2	36	1.052	111.53†	1.342	0.59‡‡
catch only models 1998-2015 data						
null model: $ln(S_t) = ln(S_{t-1}) + \epsilon_t$	18		0.616	35.89	0.616	0.425
base (M) 1. $ln(S_t) = \alpha + p(ln(N_{t-1})) + \epsilon_t$	15	16	0.364	25.81	0.478	0.228
Chlorophyll						
V_t = Jul-Sep ns-CHL (L3)						
2a. $ln(S_t)$ = M + βV_t	14	12	0.361	29.36	0.536	0.24
3a. $ln(S_t)$ = M + $p(V_t)$	13	16	0.339	31.75	0.763	0.274
2b. $ln(S_t)$ = M + βV_{t-1}	14	10	0.364	29.73	0.489	0.251
3b. $ln(S_t)$ = M + $p(V_{t-1})$	13	3	0.364	34.35	0.572	0.299
V_t = Oct-Dec ns-CHL (L3)						
2a. $ln(S_t)$ = M + βV_{t-1}	14	11	0.363	29.6	0.514	0.26
3a. $ln(S_t)$ = M + $p(V_{t-1})$	13	23	0.325	30.27	0.527	0.242

Notes: The nested F-tests are given in Supporting Information. 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	92.86	0.999	0.256
base (M) 1. $ln(N_t) = \alpha + s(ln(N_{t-1})) + \epsilon_t$	29.1	46	0.824	87.74	0.955	0.323
Precipitation						
V_t = Jun-Jul Precipitation - satellite (S1)						
2a. $ln(N_t)$ = M + βV_t	28.1	44	0.824	90.54	0.99	0.353
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	46	0.791	91.48	1.037	0.354
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45	0.819	90.12	0.989	0.315
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.8	44	0.804	92.81	1.021	0.337
V_t = Jun-Jul Precipitation - land gauges (S1)						
2a. $ln(N_t)$ = M + βV_t	28.1	54	0.745	84.14†	0.964	0.351
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	60	0.685	82.15††	0.906‡	0.246‡‡‡
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45	0.815	89.8	1.01	0.339
3b. $ln(N_t)$ = M + $s(V_{t-1})$	27	43	0.814	93.03	1.05	0.356
V_t = Apr-May Precipitation - satellite (S2)						
2a. $ln(N_t)$ = M + βV_t	28.1	44	0.823	90.49	0.968	0.36
3a. $ln(N_t)$ = M + $s(V_t)$	26.8	42	0.819	94.15	0.996	0.457
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45	0.82	90.2	0.958	0.374
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.8	45	0.794	92.14	0.954	0.381
V_t = Apr-May Precipitation - land gauges (S2)						
2a. $ln(N_t)$ = M + βV_t	28.1	47	0.799	88.49	0.913	0.368
3a. $ln(N_t)$ = M + $s(V_t)$	26.2	46	0.781	92.98	0.93	0.389
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44	0.824	90.51	0.965	0.314
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.1	42	0.808	95.37	0.994	0.359
Sea surface temperature						
V_t = Mar-May r-SST (S5)						
2a. $ln(N_t)$ = M + βV_t	28.1	46	0.805	89.1	0.961	0.34
3a. $ln(N_t)$ = M + $s(V_t)$	26.7	47	0.784	91.39	0.961	0.423
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	50	0.778	86.86	0.941	0.475
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.6	51	0.751	89.12	0.928	0.398
V_t = Oct-Dec ns-SST (L1)						
2a. $ln(N_t)$ = M + βV_t	28.1	45	0.817	89.96	0.981	0.416
3a. $ln(N_t)$ = M + $s(V_t)$	27.1	44	0.81	92.42	0.99	0.434
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	46	0.806	89.15	0.964	0.289‡‡
3b. $ln(N_t)$ = M + $s(V_{t-1})$	27.1	45	0.8	91.62	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	55	0.741	83.77†	0.913	0.447
3a. $ln(N_t)$ = M + $s(V_t)$	26.2	57	0.699	86	1.017	0.456
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	44	0.824	90.53	1.007	0.322
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.1	47	0.772	92.41	1.084	0.35
V_t = Jun-Sep ns-SST (L2)						
2a. $ln(N_t)$ = M + βV_t	28.1	52	0.76	85.38†	0.914	0.432
3a. $ln(N_t)$ = M + $s(V_t)$	26.6	52	0.742	88.38	0.965	0.519
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	46	0.812	89.55	0.97	0.333
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.6	44	0.798	93.16	0.995	0.307‡
V_t = Jun-Sep Bakun-UPW (L2)						
2a. $ln(N_t)$ = M + βV_t	28.1	47	0.805	89.03	0.948	0.37
3a. $ln(N_t)$ = M + $s(V_t)$	26.6	48	0.775	91.12	0.945	0.309
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45	0.817	89.96	0.951	0.342
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26.7	45	0.794	92.29	0.965	0.392
Ocean climate						
V_t = 2.5-year ave r-SST (A1)						
2a. $ln(N_t)$ = M + βV_t	28.1	57	0.726	82.37††	0.844‡‡	0.324
3a. $ln(N_t)$ = M + $s(V_t)$	26.9	65	0.642	78.08††	0.758‡‡‡	0.351
V_t = ONI (A2)						
2a. $ln(N_t)$ = M + βV_t	28.1	49	0.79	87.82	0.916	0.453
3a. $ln(N_t)$ = M + $s(V_t)$	27.5	48	0.785	89.25	0.929	0.44
V_t = Sep-Nov DMI (A3)						
2a. $ln(N_t)$ = M + βV_t	28.1	49	0.787	87.66	0.978	0.425
3a. $ln(N_t)$ = M + $s(V_t)$	25.8	49	0.754	92.23	1.119	0.493
2b. $ln(N_t)$ = M + βV_{t-1}	28.1	45	0.819	90.09	0.95	0.336
3b. $ln(N_t)$ = M + $s(V_{t-1})$	26	44	0.791	94.41	0.947	0.339
V_t = DMI 3-yr ave (A3)						
2a. $ln(N_t)$ = M + βV_t	28.1	56	0.731	82.78†	0.844‡‡	0.345
3a. $ln(N_t)$ = M + $s(V_t)$	27.2	60	0.688	81.51††	0.818‡‡	0.362
catch only models 1998-2014 data						
null model: $ln(N_t) = ln(N_{t-1}) + \epsilon_t$	17		0.432	21.96	0.432	0.133
base (M) 1. $ln(N_t) = \alpha + p(ln(N_{t-1})) + \epsilon_t$	14	27	0.334	22.28	0.422	0.369
Chlorophyll						
V_t = Jul-Sep ns-CHL (L3)						
2a. $ln(N_t)$ = M + βV_t	13	24	0.327	25.71	0.441	0.344‡
3a. $ln(N_t)$ = M + $p(V_t)$	12	19	0.325	30.47	0.496	0.333‡
2b. $ln(N_t)$ = M + βV_{t-1}	13	31	0.311	23.95	0.418	0.348‡
3b. $ln(N_t)$ = M + $p(V_{t-1})$	12	26	0.311	28.89	1.616	0.362

Model	Resid. df	Adj. R^2	RMSE	AICc	LOOCV RMSE	LOOCV MdAE
V_t = Oct-Dec ns-CHL (L3)						
2a. $ln(N_t)$ = M + βV_t	13	24	0.327	25.71	0.445	0.336‡
3a. $ln(N_t)$ = M + $p(V_t)$	12	35	0.29	26.6	0.391‡	0.217‡‡‡
2b. $ln(N_t)$ = M + βV_{t-1}	13	45	0.277	20.11†	0.364‡‡	0.235‡‡‡
3b. $ln(N_t)$ = M + $p(V_{t-1})$	12	41	0.277	25.06	0.384‡	0.278‡‡‡

Notes: The nested F-tests are given in Supporting Information. 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.