Fisheries and Oceans Canada | Pêches et Océans Canada

2022 Fraser Sockeye Pre-season Forecast

Yi Xu and Qi Liu

2022.3.1.

Fraser and Approach Salmon Forum Meeting

Acknowledgements

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  - Fisheries Data: Steve Latham, Tracy Cone, Scott Decker, Tanya Vivian, Paul Welch, Stu LaPage, Brian Leaf, Lucas Pon, Jennifer Lynne, Doug Lofthouse, Angus Straight, Catharina De Monye, Mary Beth Fagan, Catherine McClean, Maxine Forest
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- Model Contributors
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- Fraser Panel Technical Committee Participants & Guests
  - Les Jantz, Jamie Scroggie, Gordon Rose, Mike Hawkshaw, Catherine Michielsens, Merran Hague, Mickey Agha, Michael Staley, Kelsey Campbell, Nicole Frederickson, Matt Mortimer, Scott Decker, Rice Robert, Amy Seiders, Madeline Thomson, Maxime Veilleux, Serena Wong, Qi Liu, Jin Gao
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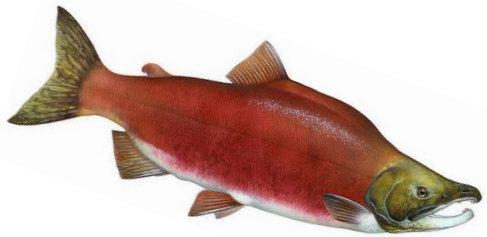
  - 2nd review Dec 9th, 2021
  - 3rd review Dec 14th, 2021

Outline

Background	Method	Results	Summary
Historical forecasts Process Review	Changes made in 2022 forecast Data, Model, Model Selection	Forecast table Uncertainties	Questions



Return Year	Forecast Probability Level						Actual Returns
	<10%	10%	25%	50%	75%	90%	
2009	NA	3,556,000	6,039,000	10,578,000	19,451,000	37,617,000	**1,590,000**
2010	NA	5,360,000	8,351,000	13,989,000	23,541,000	40,924,000	**28,250,000**
2011	NA	1,700,000	2,693,000	4,627,000	9,074,000	15,086,000	**5,110,000**
2012	NA	743,000	1,203,000	2,119,000	3,763,000	6,634,000	**2,050,000**
2013	NA	1,554,000	2,655,000	4,765,000	8,595,000	15,608,000	**4,130,000**
2014	NA	7,237,000	12,788,000	22,854,000	41,121,000	72,014,000	**20,000,000**
2015	NA	2,364,000	3,824,000	6,778,000	12,635,000	23,580,000	**2,120,000**
2016	NA	814,000	1,296,000	2,271,000	4,227,000	8,181,000	**853,000**
2017	NA	1,315,000[R]	2,338,000	4,432,000	8,873,000	17,633,000	**1,641,000**
2018	NA	5,265,000	8,423,000	13,981,000	22,937,000	36,893,000	10,675,000
2019	NA	1,832,000	2,979,000	5,056,000	9,133,000	15,313,000	564,000
2020	NA	275,000	486,000	924,000	1,834,000	3,573,000	288,000

(DFO,2021)

Summary of 2021 Sockeye Runs

	Forecast Return	Estimated Return	Return Relative to Forecast
Bristol Bay [1]	51,000,000	65,860,000	+ 29%
Nass [2]	318,000	417,000	+ 31%
Skeena [3]	1,690,000	1,030,000	- 39%
Somass [4]	350,000	365,000+	+ 4%
Fraser River	1,330,000	2,549,000	+ 92%
Baker Lake [5]	11,400	20,800	+ 82%
Lake Washington [6]	24,800	38,600	+ 56%
Columbia River [7]	155,600	151,800	- 2%

[1] https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareabristolbay.harvestsummary
[2] https://www.nisgaanation.ca/stock-assessments
[3] http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/skeenatyee-eng.html
[4] https://www.roundtables.westcoastaquatic.ca/area-23-barkley-harvest
[5] https://wdfw.wa.gov/fishing/reports/counts/baker-river#returns
[6] https://wdfw.wa.gov/fishing/reports/counts/lake-washington#sockeye
[7] https://www.fpc.org/webapps/adultsalmon/Q_adultcounts_dataquery.php

(Source: PSC, 2021)

Early Stuart

Table A2-2. Candidate model forecasts table – Early Stuart Stock and MU (Takla-Trembleur-Early Stuart CU).

Model	Rank	Forecast Return 10%	25%	50%	75%	90%	Forecast Age4 Survival 10%	25%	50%	75%	90%
RickerEi	1	15,000	22,000	35,000	57,000	93,000	1.6	2.6	4.6	7.7	12.9
RickerPi	1	8,000	12,000	18,000	30,000	47,000	0.9	1.4	2.3	3.9	6.3
RickerBasic	3	18,000	28,000	45,000	80,000	137,000	2.1	3.5	5.8	10.5	18.7
RickerPDO	3	16,000	23,000	39,000	66,000	103,000	1.9	2.8	5	8.7	14.1

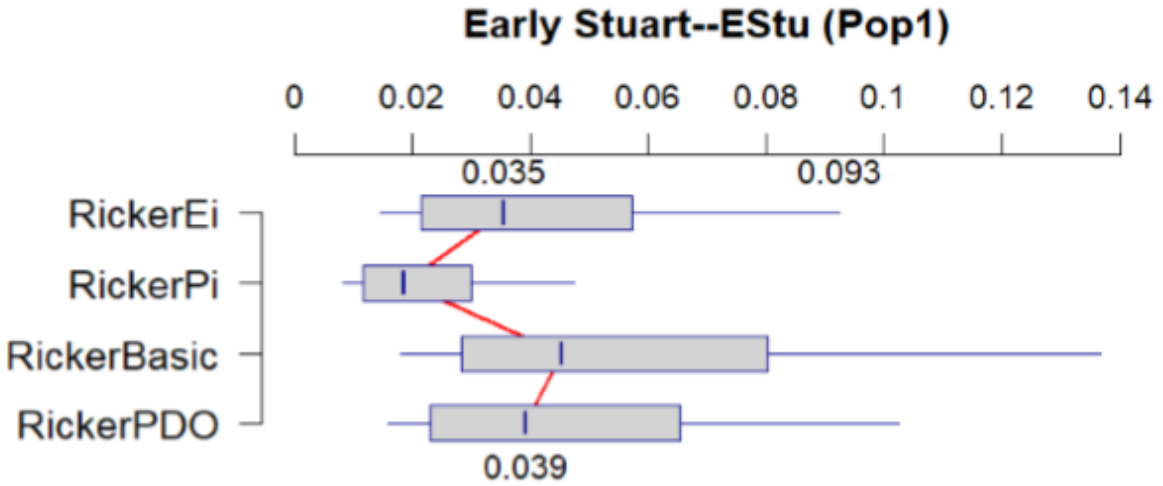
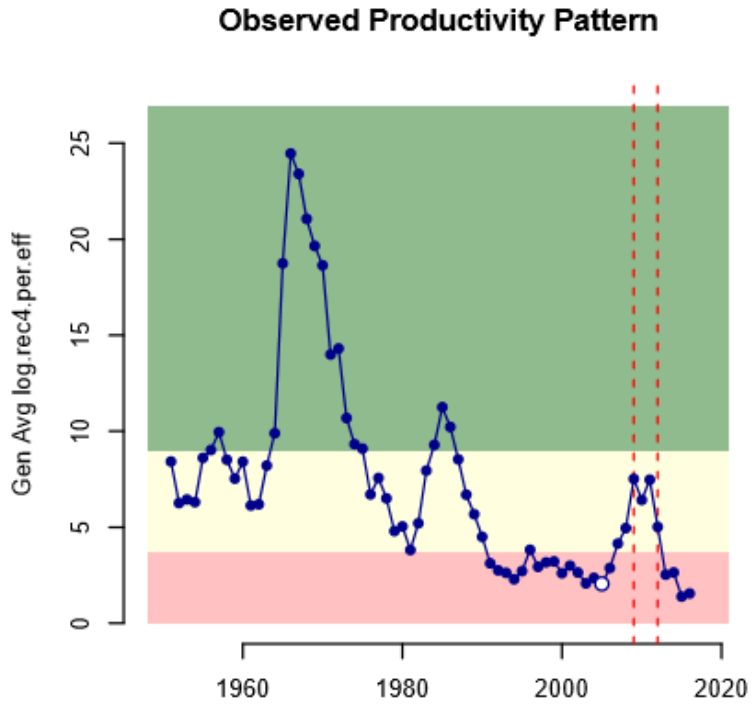


Figure A2-1. Candidate model forecasts (all numbers in millions of fish) – Early Stuart Stock and MU (Takla-Trembleur-Early Stuart CU).



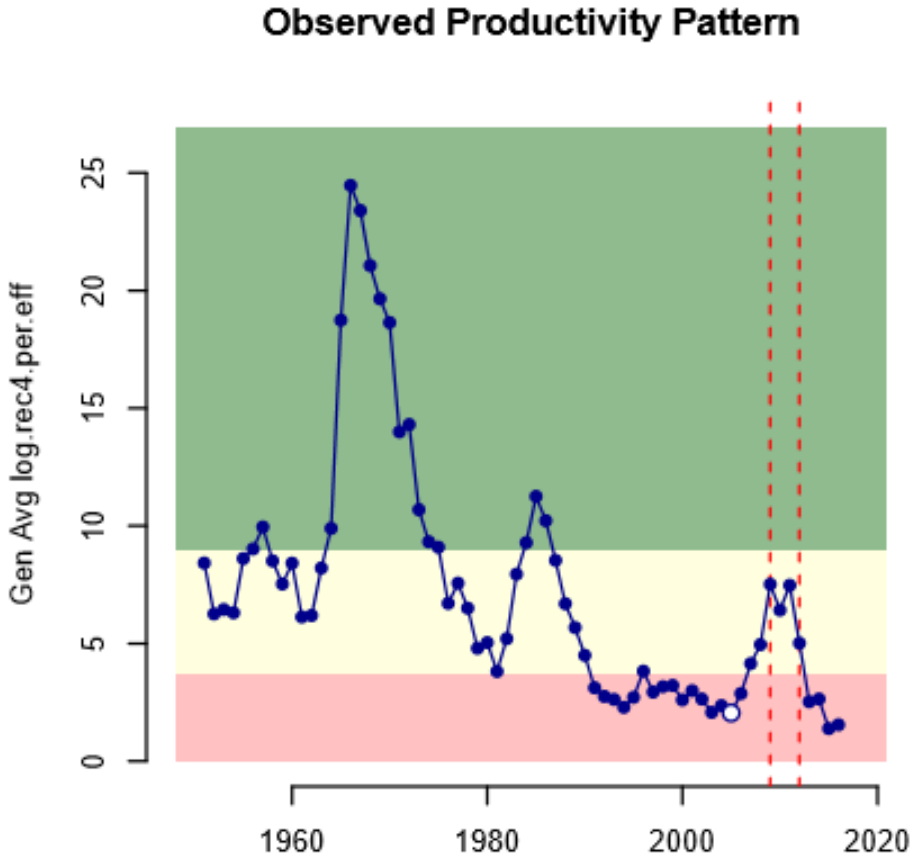
(Source: DFO, 2021)

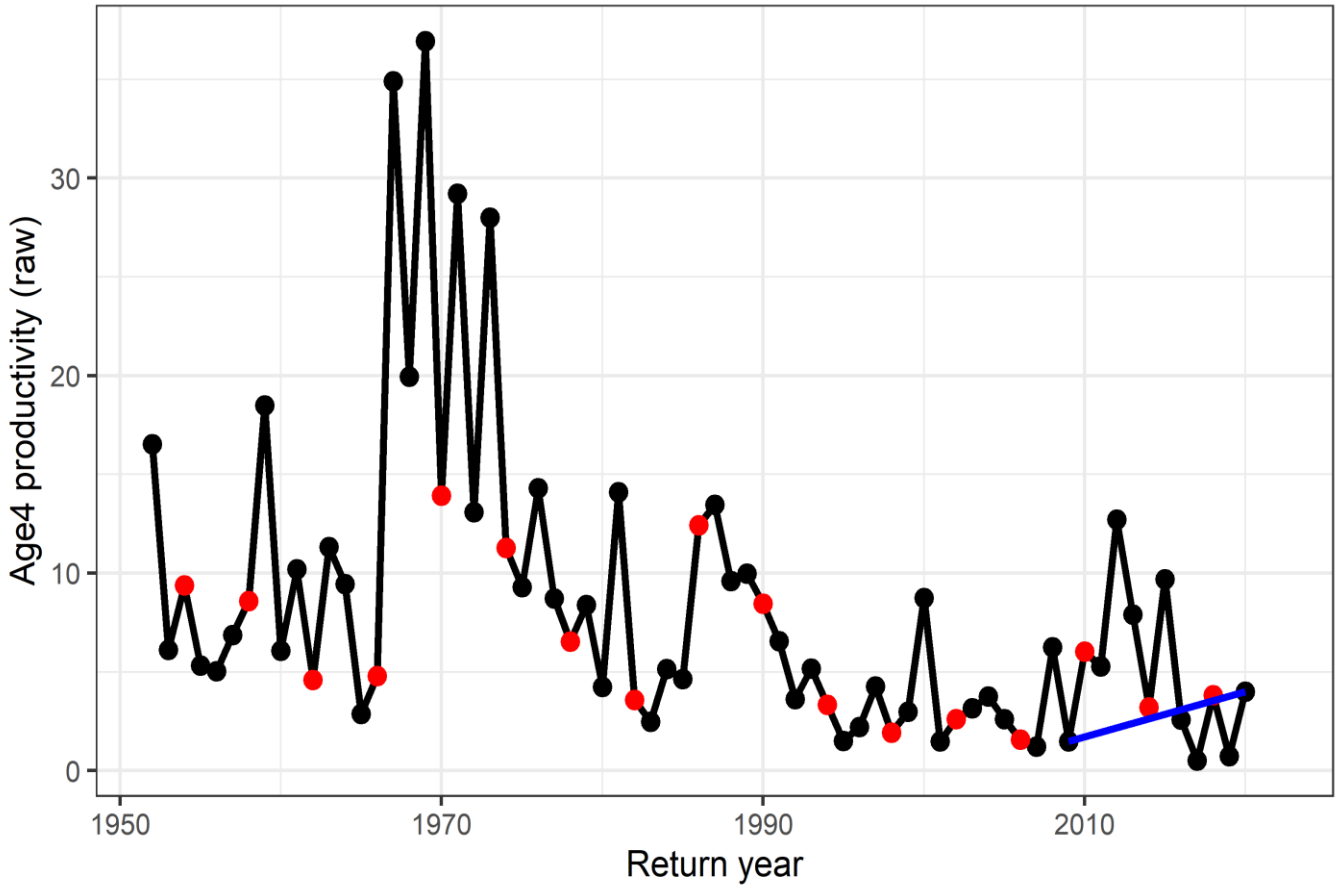
Stock Group	Pre-season p50 Run Size	In-season Run Size	Difference
Early Stuart	18,000	69,000	+289%

(Source: PSC, 2021)

Escapement 54,000 (S. Decker, DFO)

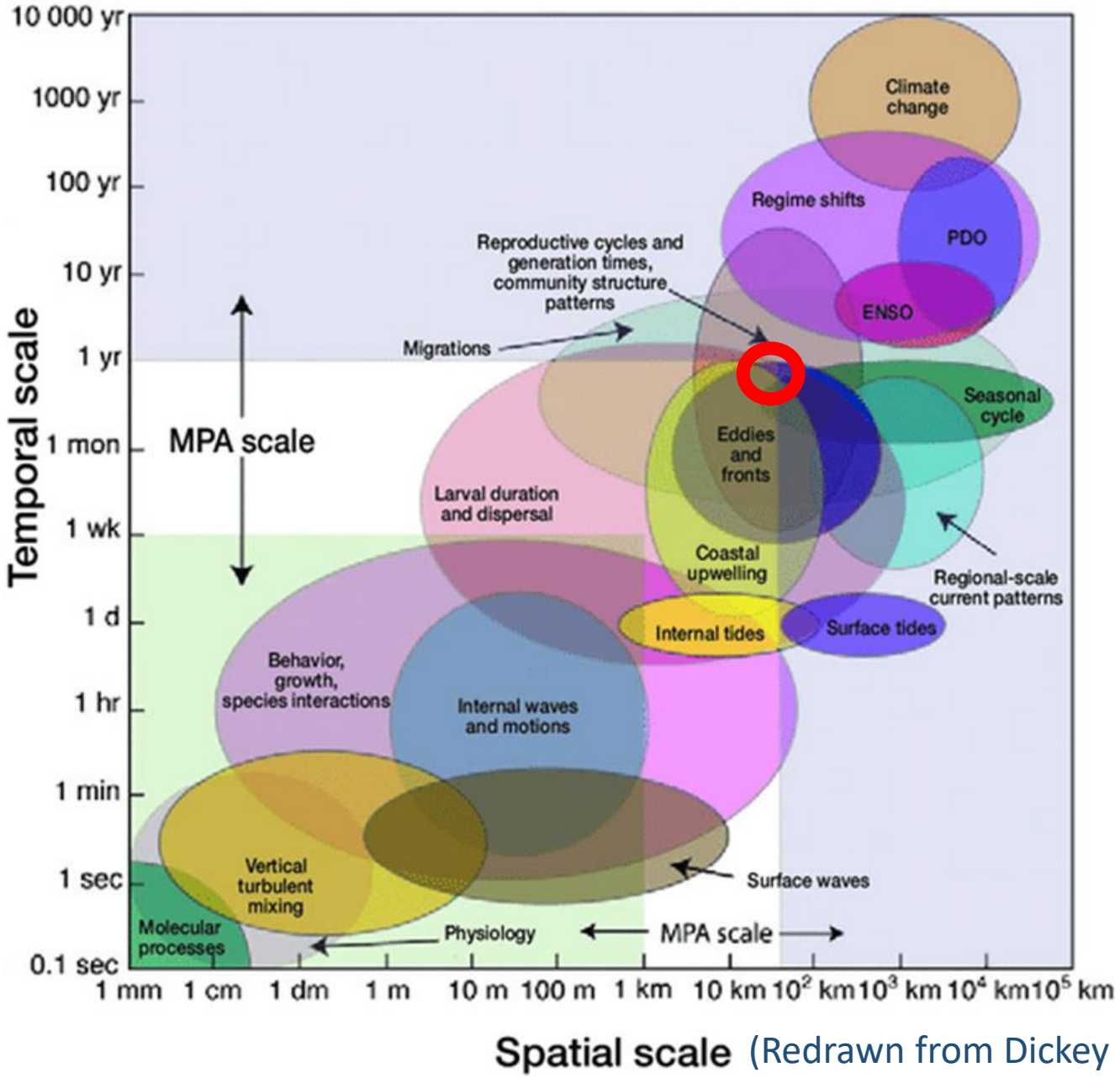
Smoothed productivity vs Raw productivity





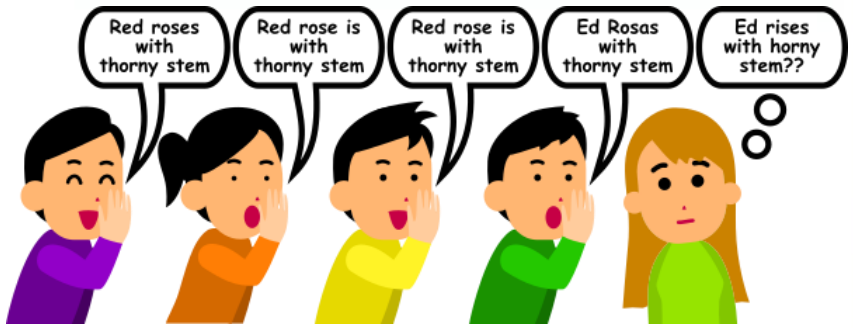
(Source: DFO, 2021)

Temporal and Spatial Scales of Ocean processes



(Redrawn from Dickey 1990; Carr et al 2011)

(Burke et al, 2021)

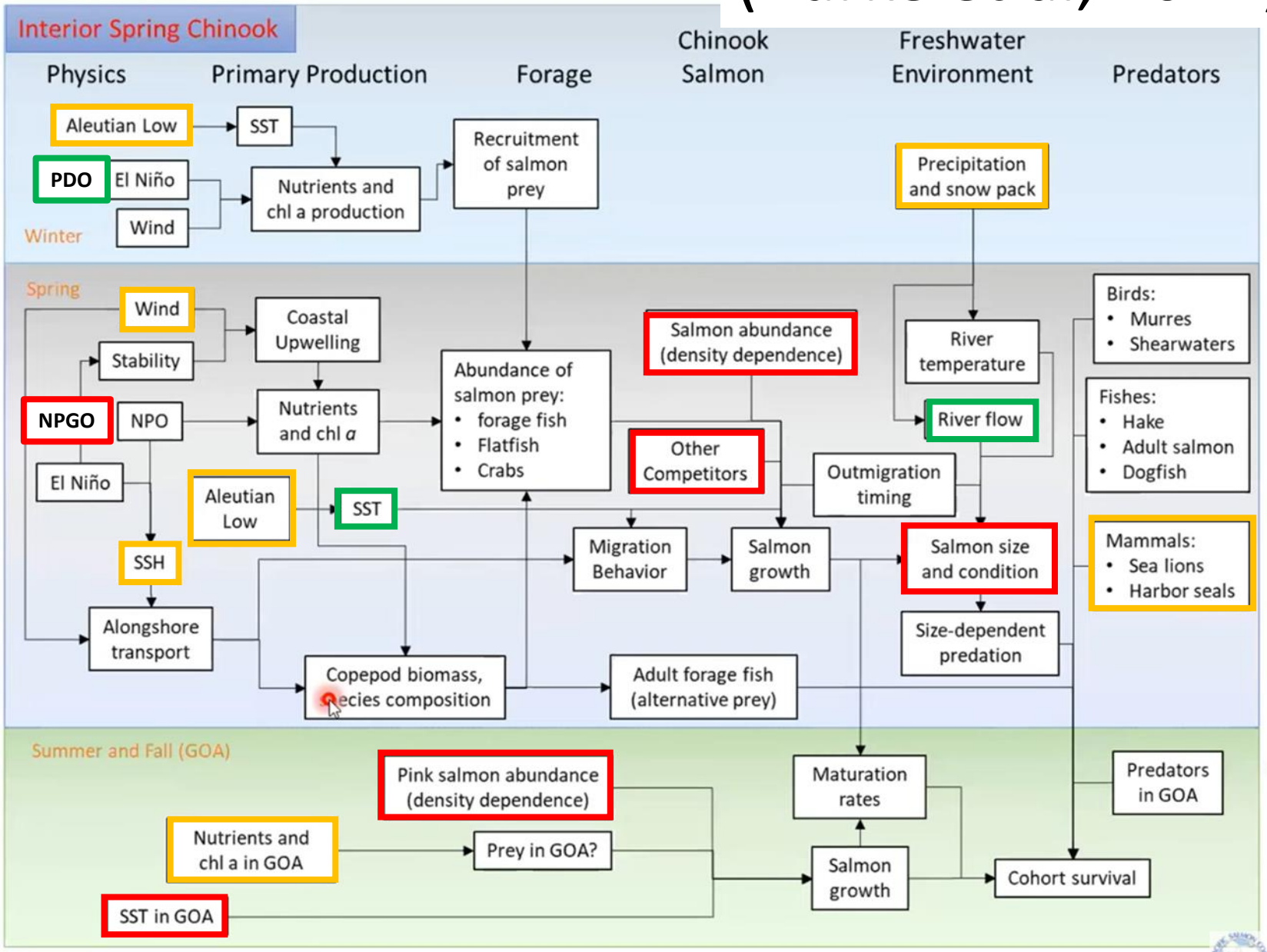


Chinese Whispers Game

Existing Variables

Available Variables

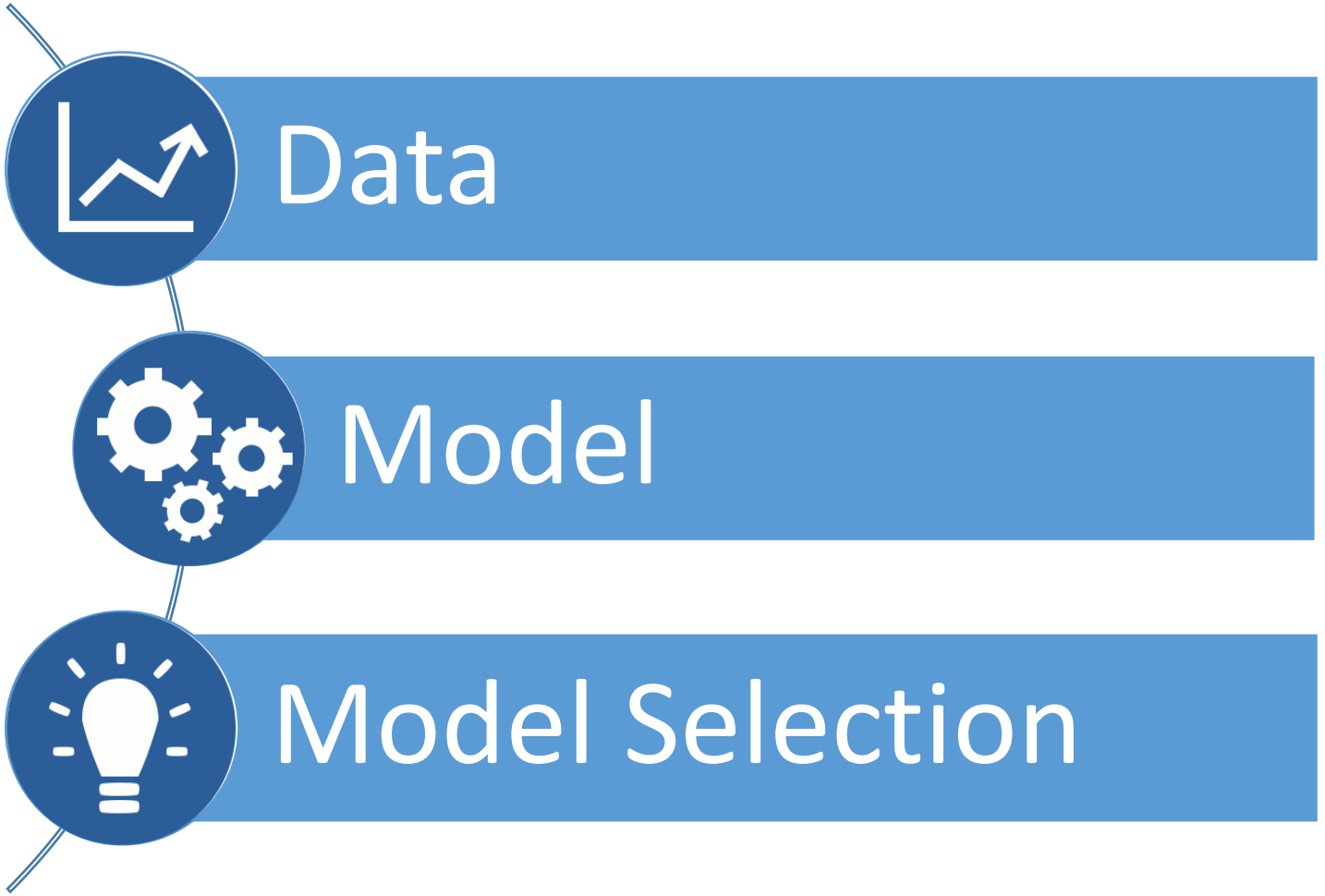
Adopted Variables



Env variable selection guidelines

- Temporal scale needs to **match** with spatial scale. Forecast needs to focus on processes that at relative scale-**interannual**.
- Variables are relative straight forward mechanisms to **cohort survival**. The closer, the better.
- Use **best available** information (i.e. most recent data available by the time of our forecast on annual basis)
- Use variables that recently **succeeds** for other stocks (e.g. Columbia River)

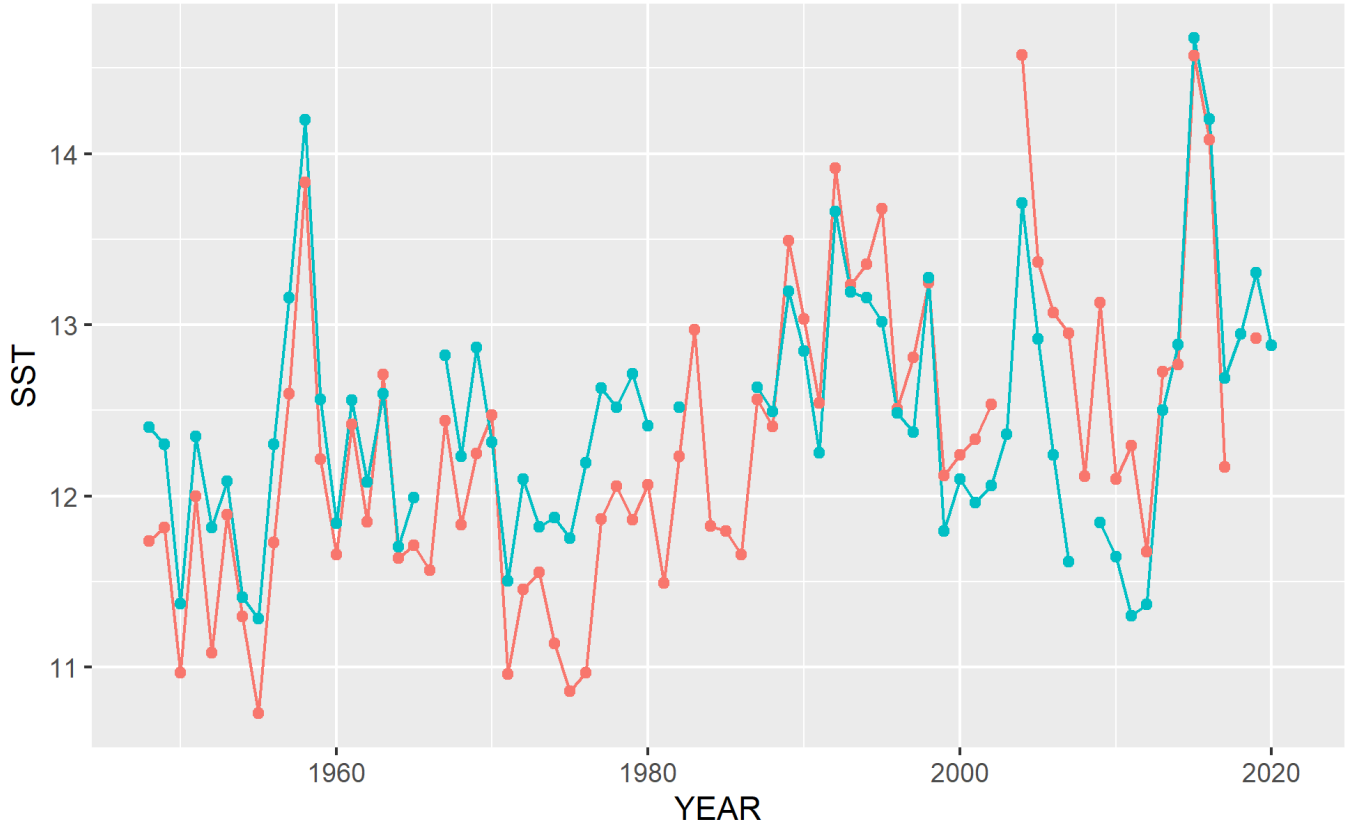
Methods update in 2022 forecast

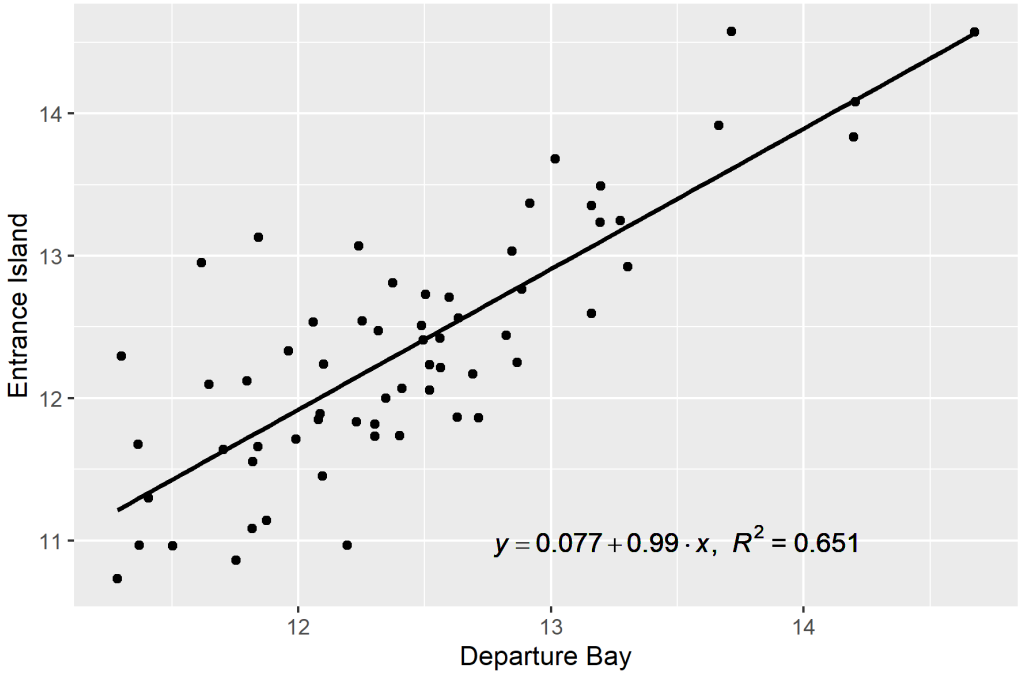


Data collection at a glance

	Environmental Data	Fish Data
Existing	Pine Island SST	Escapement
	Entrance Island SST (not available)	Recruitment
	Pacific Decadal Oscillation	Channel Fry – Weaver/Nadina/Pitt
	Fraser River discharge	Fall fry – Late Shuswap/Quesnel
		Smolt - Cultus (not available)
		Smolt - Chilko (not available)
New	Gulf of Alaska SST	Fry length – Late Shuswap/Quesnel
	North Pacific Gyre Oscillation	Fry weight – Late Shuswap/Quesnel
		Sockeye/Pink/Chum/Salmon_Total

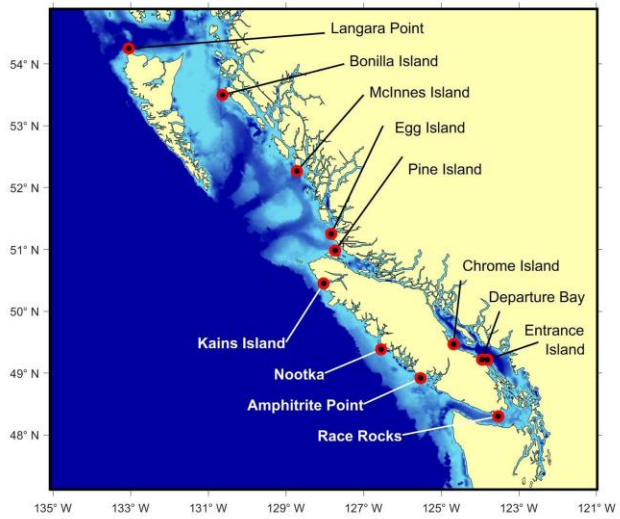
Entrance Island SST vs. Departure Bay (Apr-Jun)





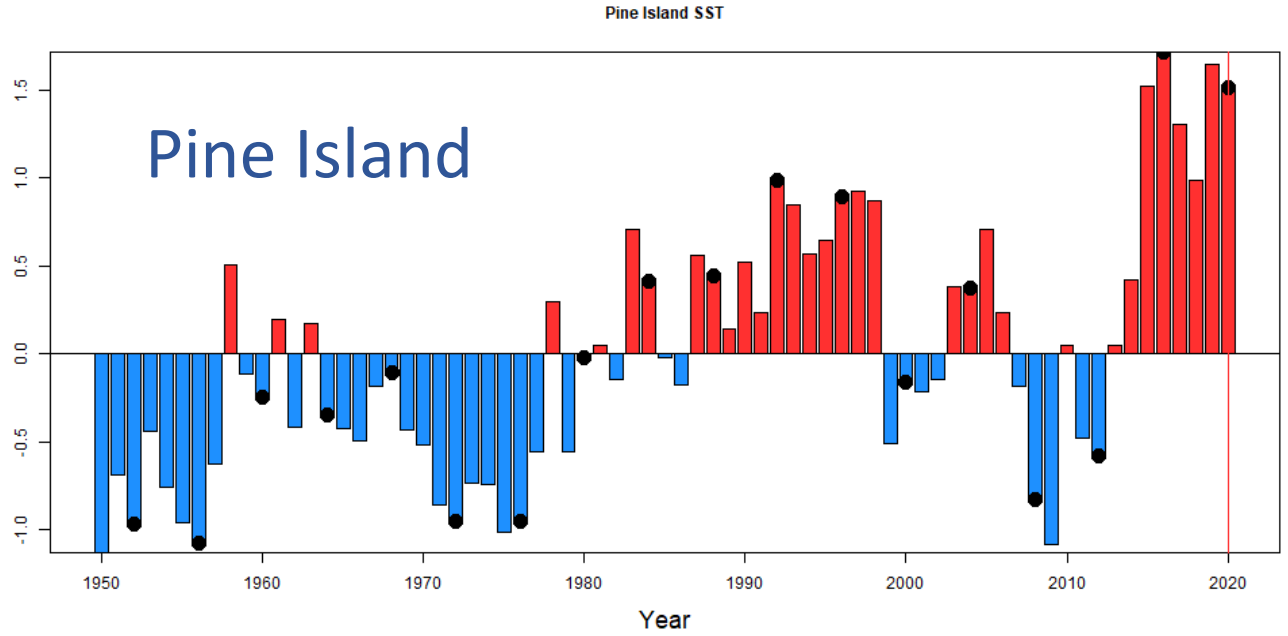
Locations

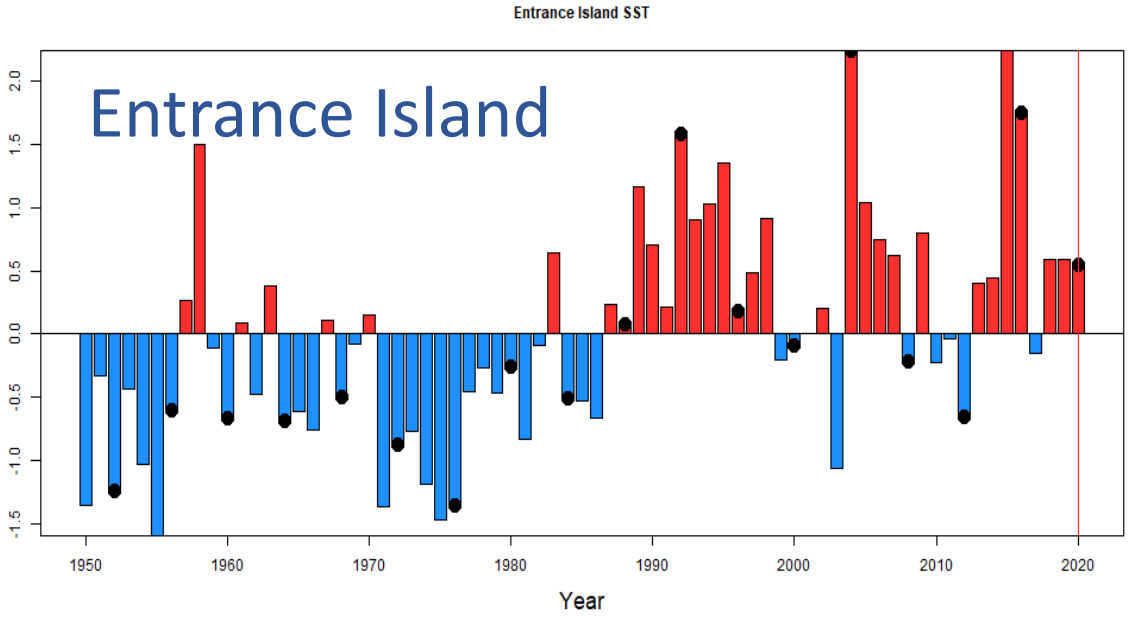
- Entrance Island
- Departure Bay

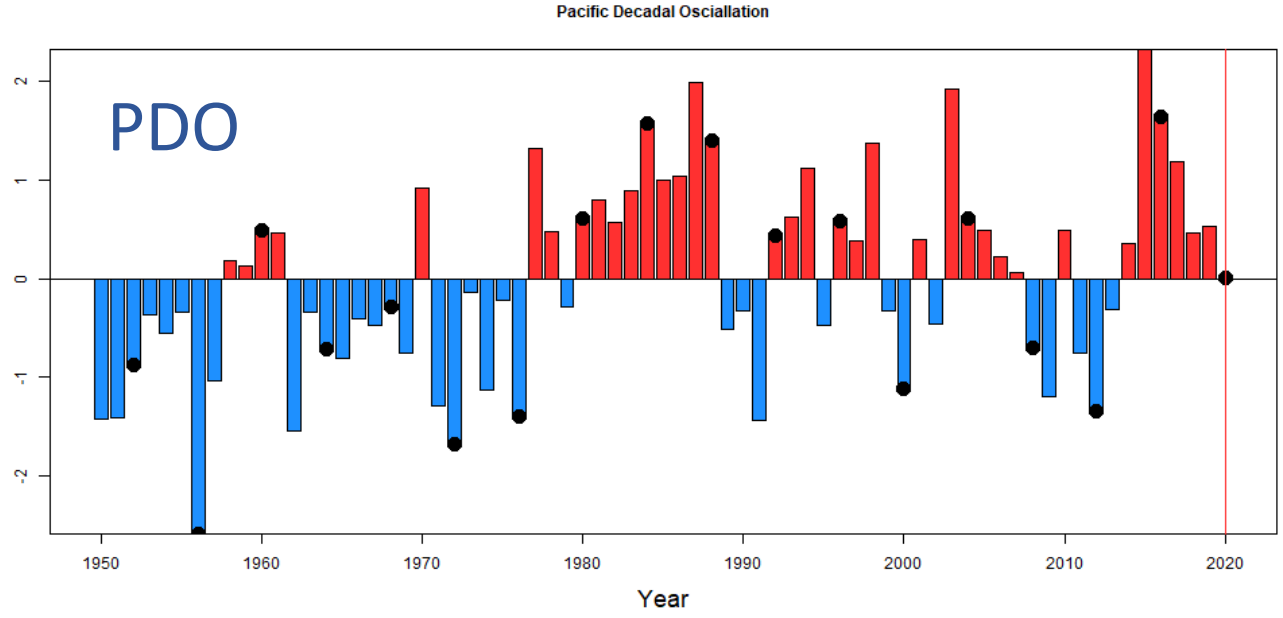


Env data used in 2022 forecast

- Entrance Island: **warm**
- Pine Island: **very warm**
- PDO: **neutral**

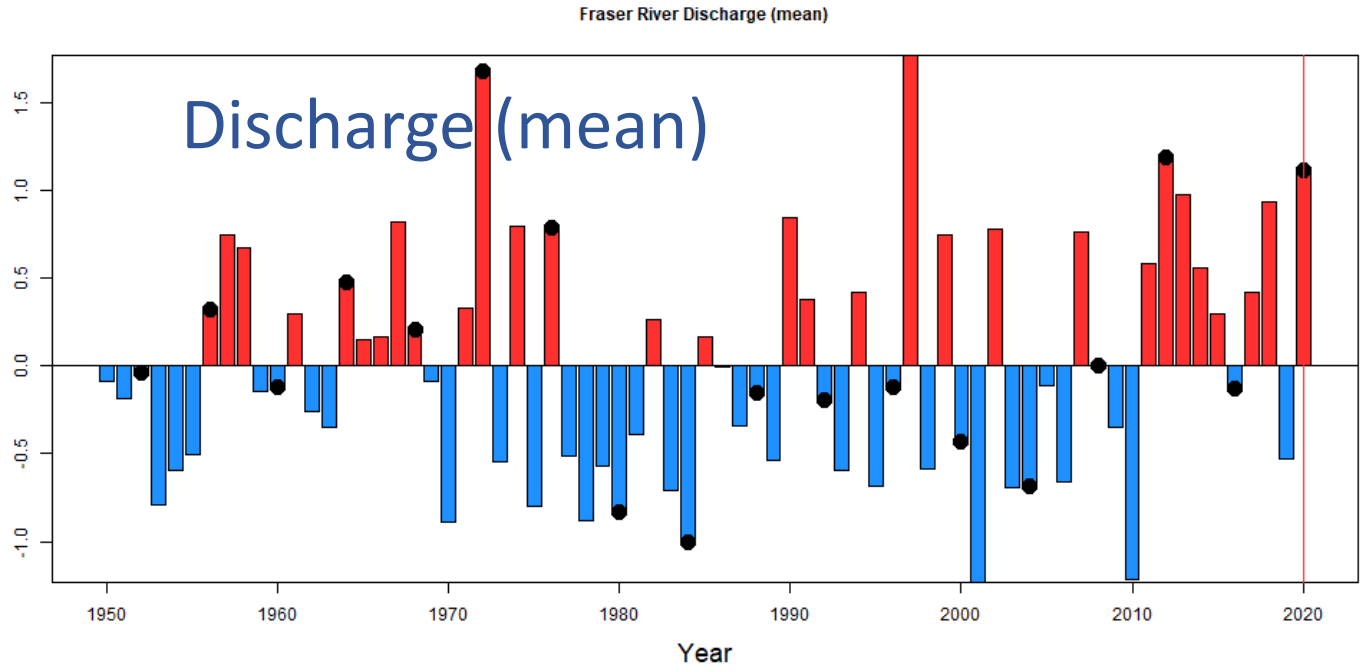


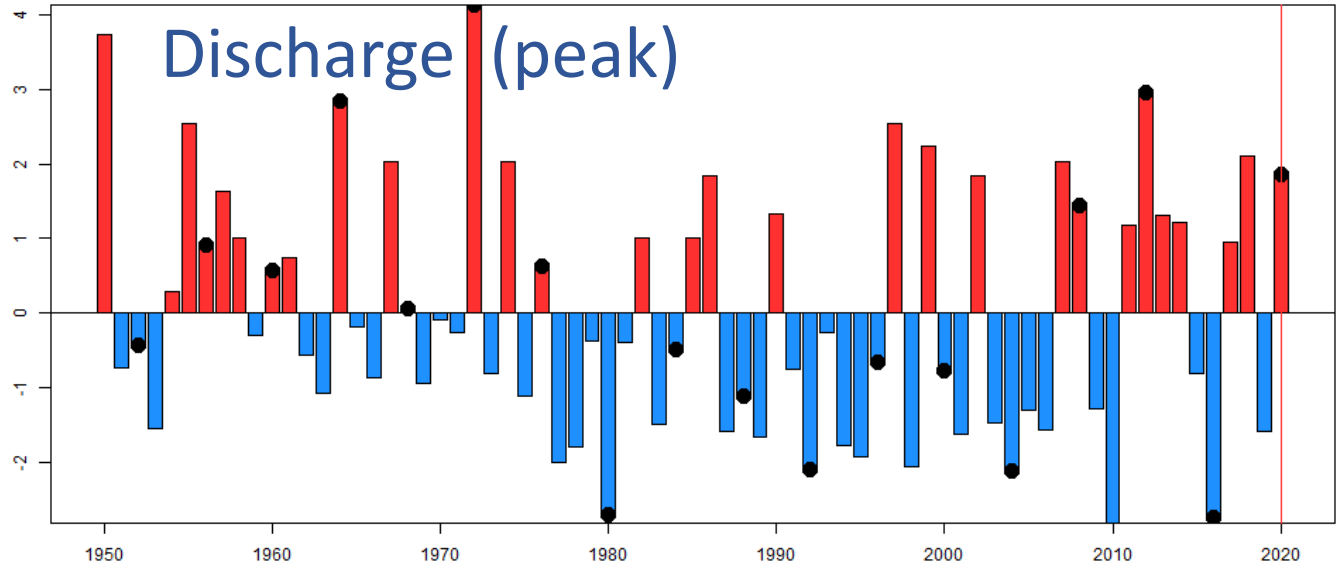




Env data used in 2022 forecast

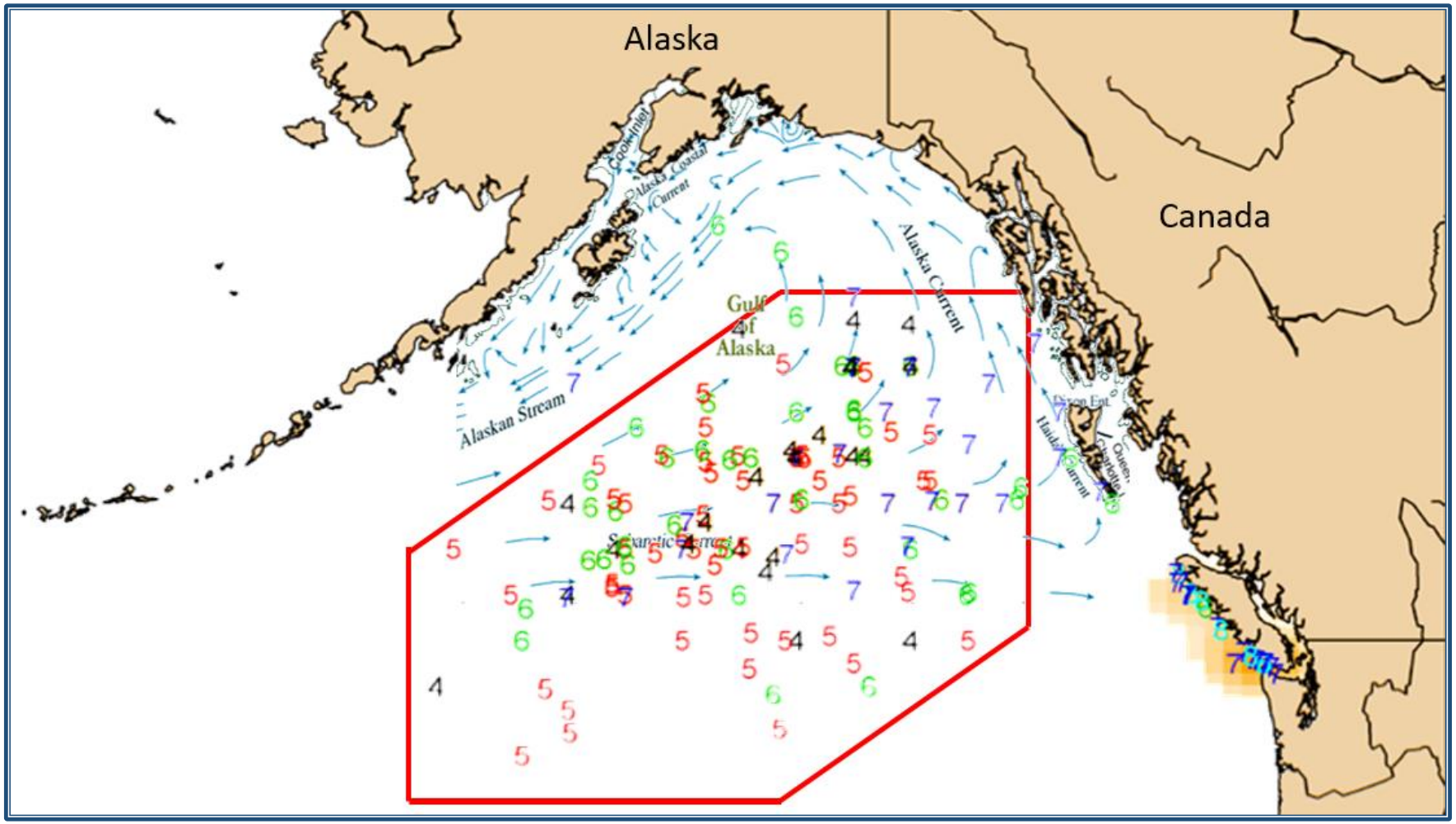
- Discharge (mean): **high**
- Discharge (peak): **high**





Source: D. Patterson, DFO
(Water Survey from ECCC)

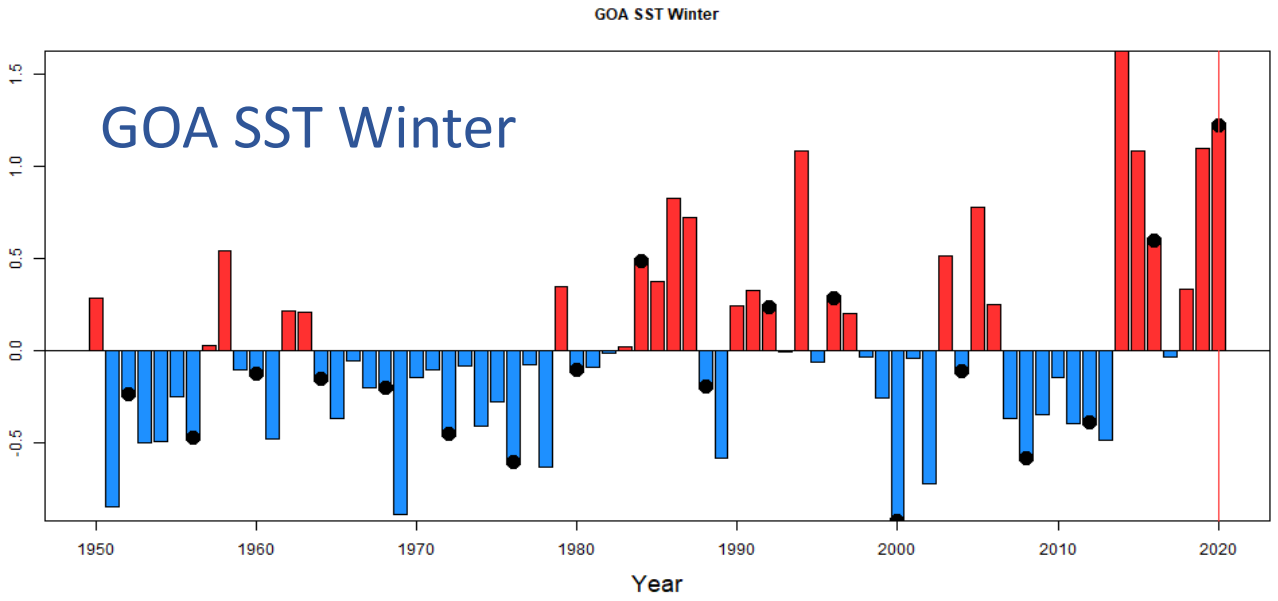
New Variable:
Gulf of Alaska SST

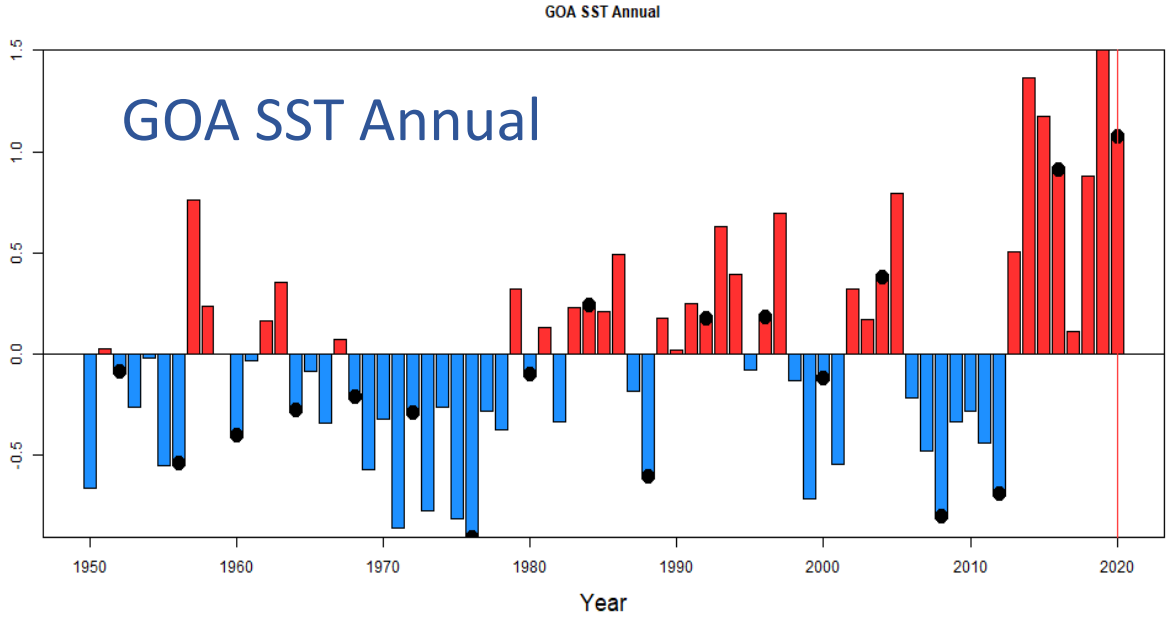


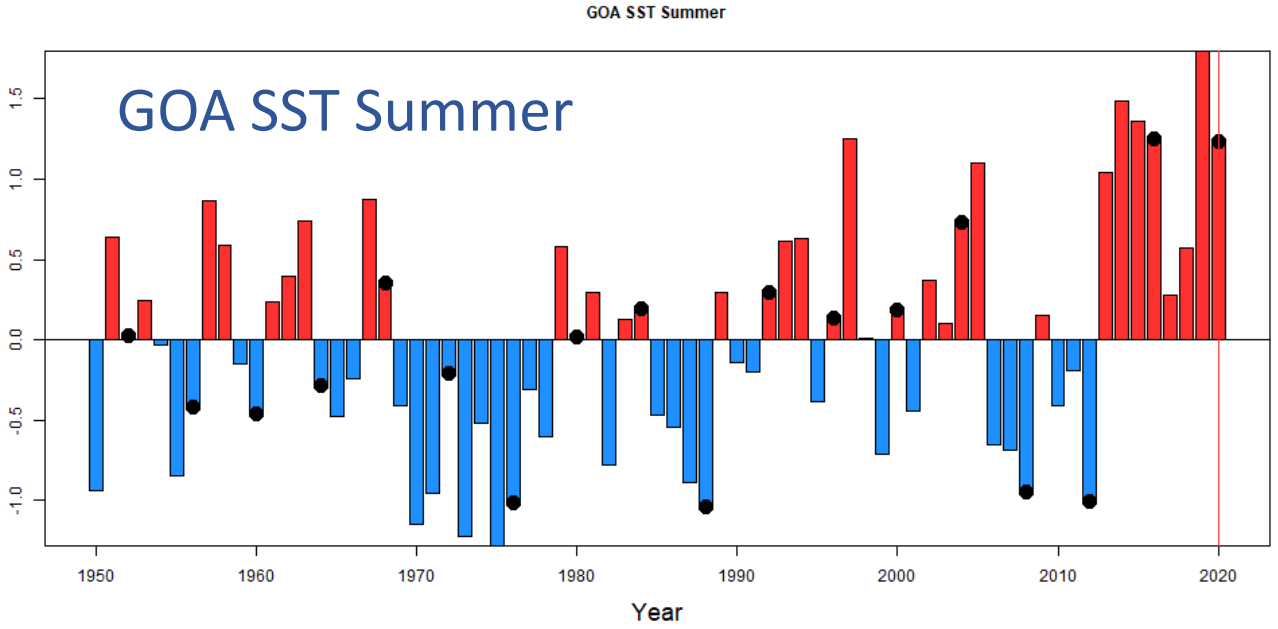
(Myers et al., 1996; Ishii et al. 2005)

New Variable: Gulf of Alaska SST

- Winter: **warm**
- Summer: **warm**
- Annual: **warm**

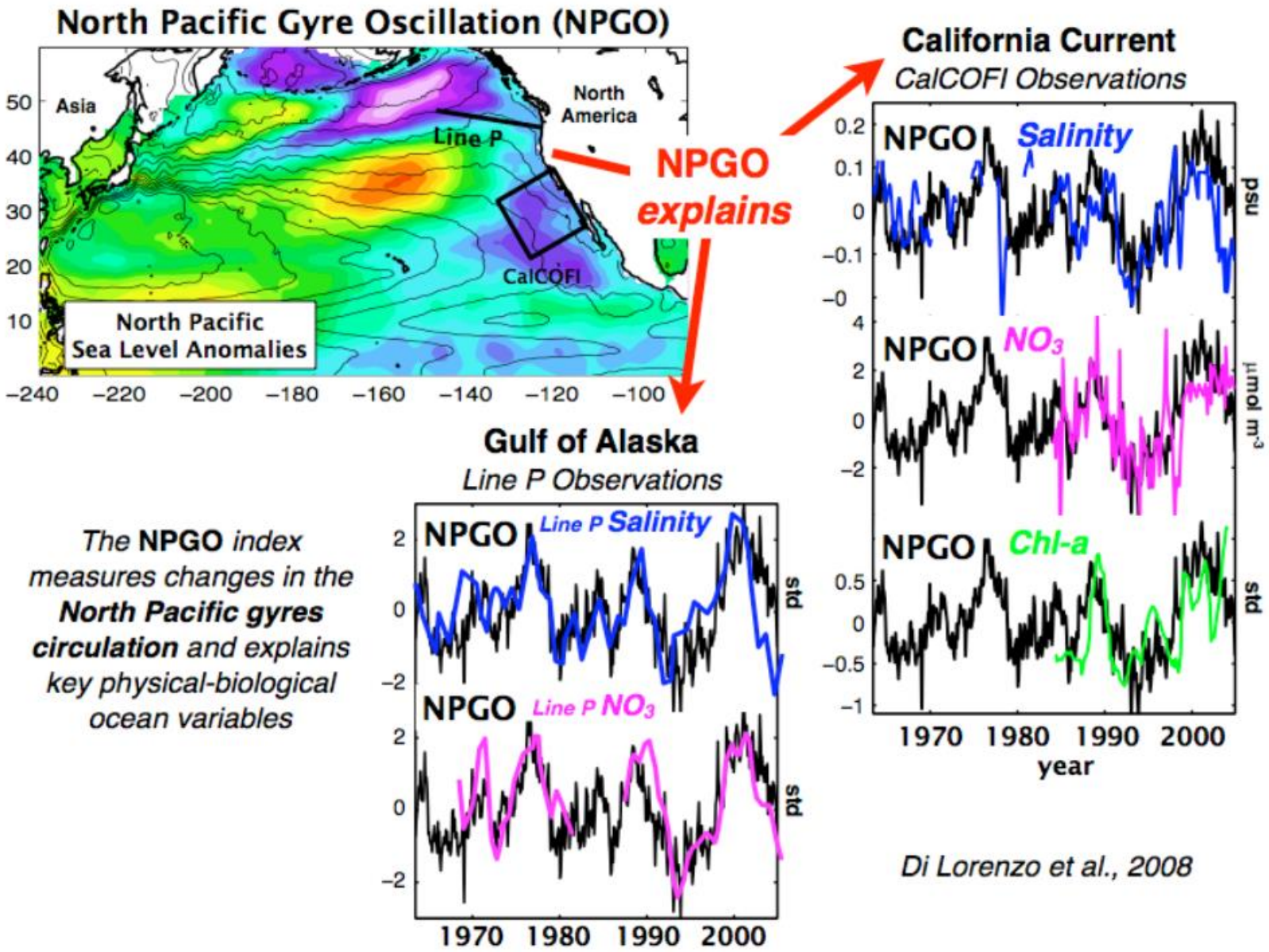






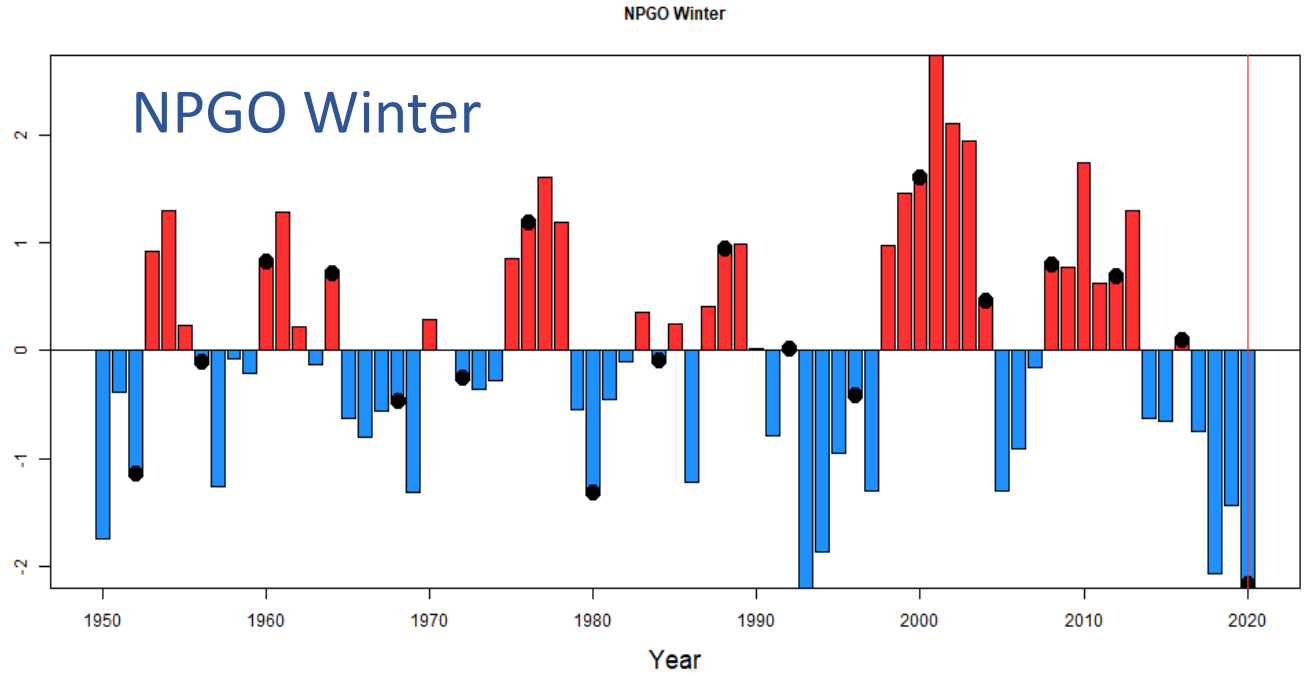
New Variable: North Pacific Gyre Oscillation (NPGO)

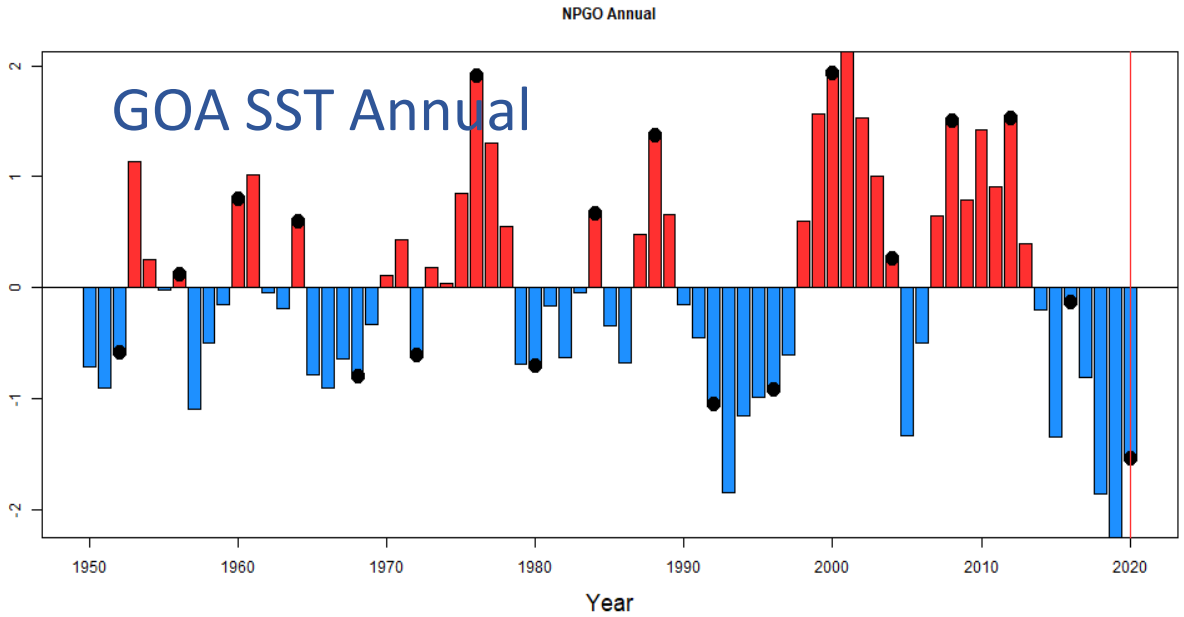
- Related to multiple physical-biological ocean variables
- Used in Columbia River forecast

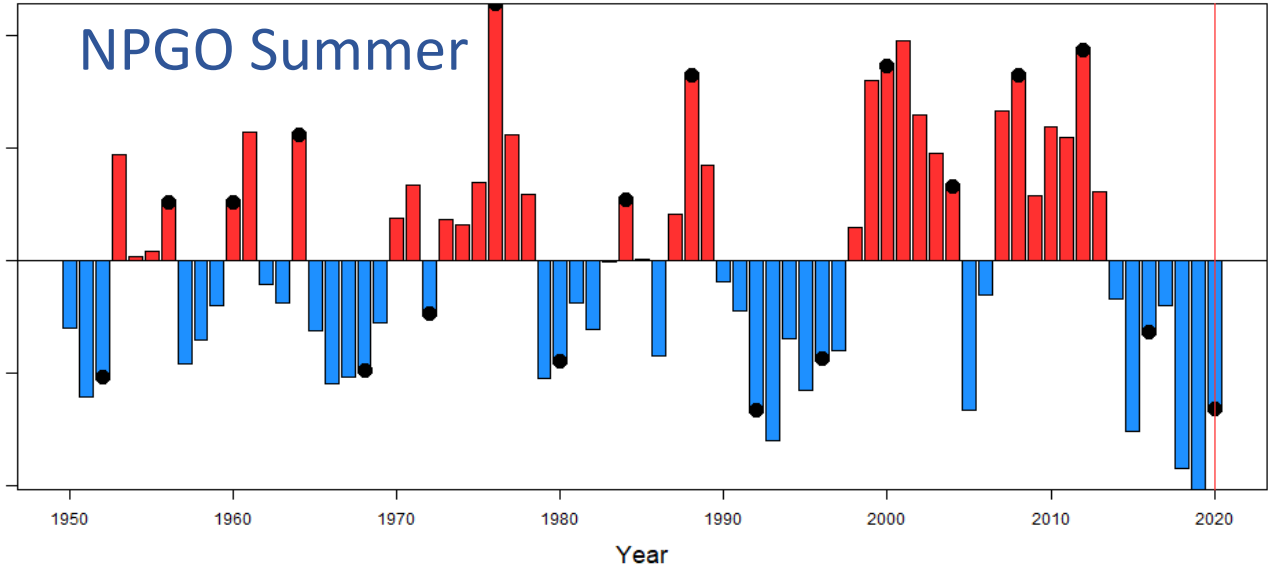


New Variable: NPGO

- Winter: **weak**
- Summer: **weak**
- Annual: **weak**

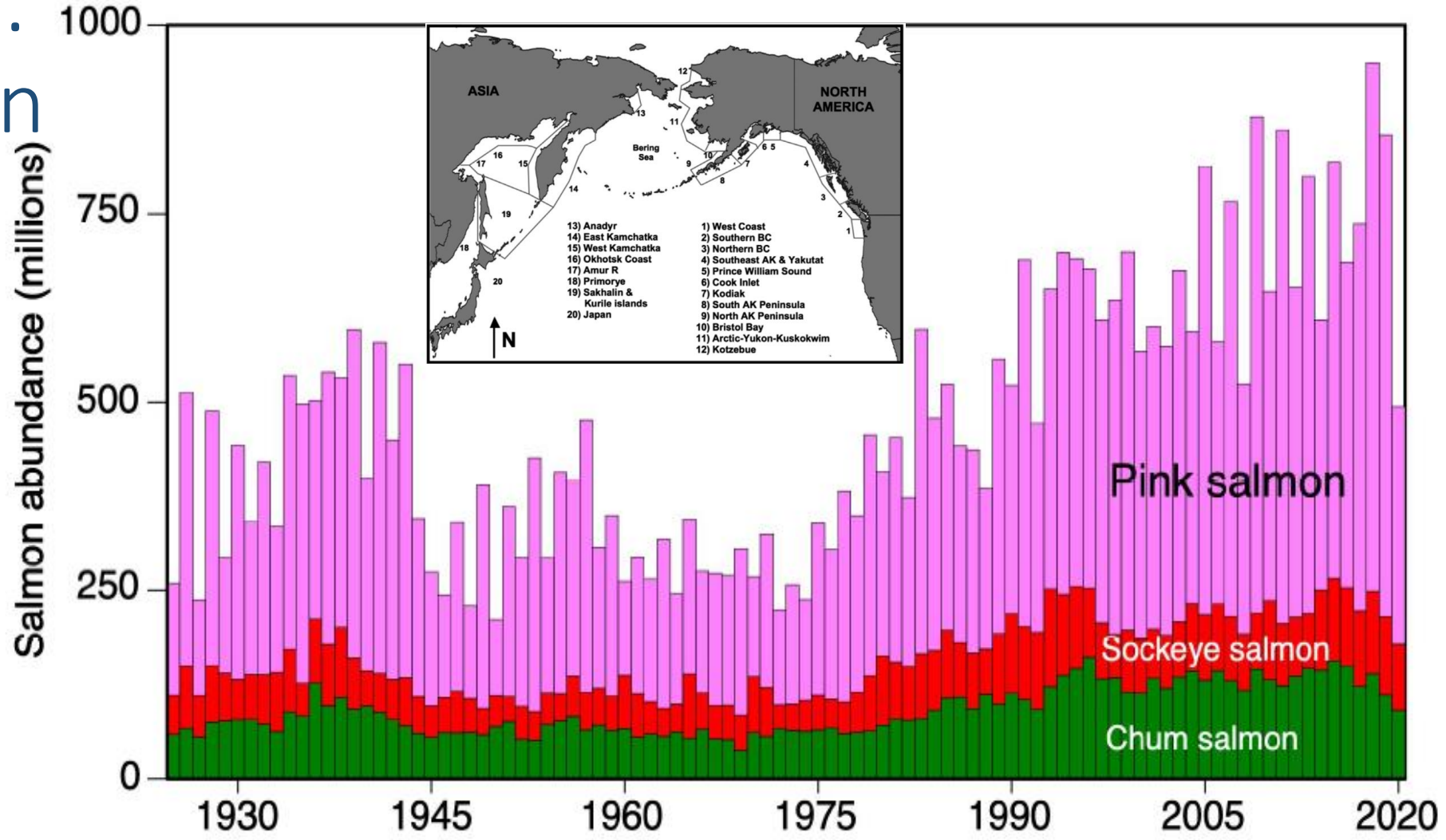






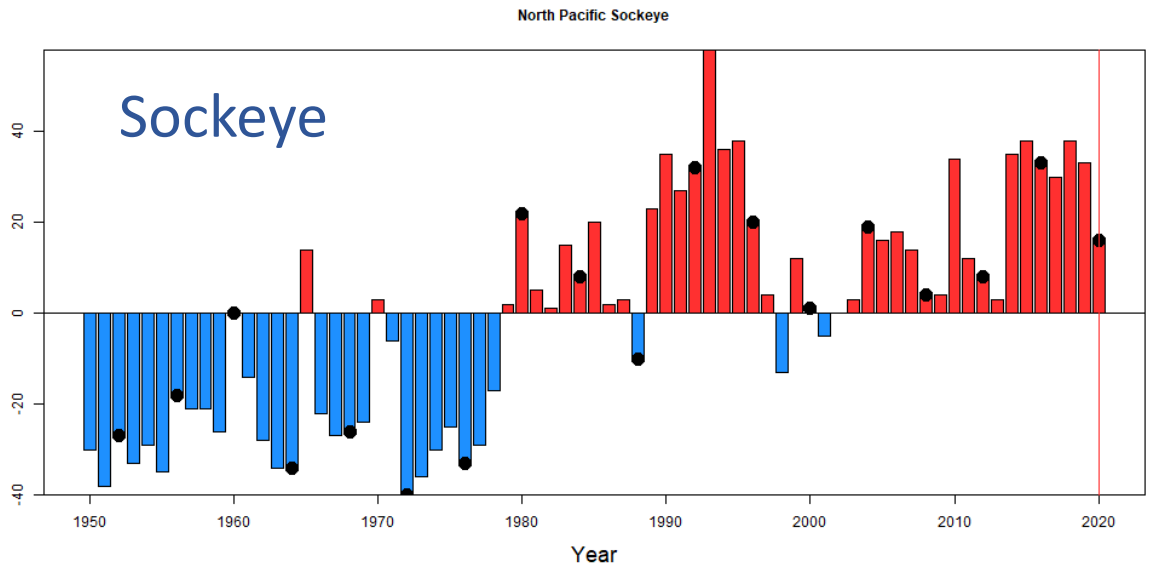
New Variable: Pacific Salmon

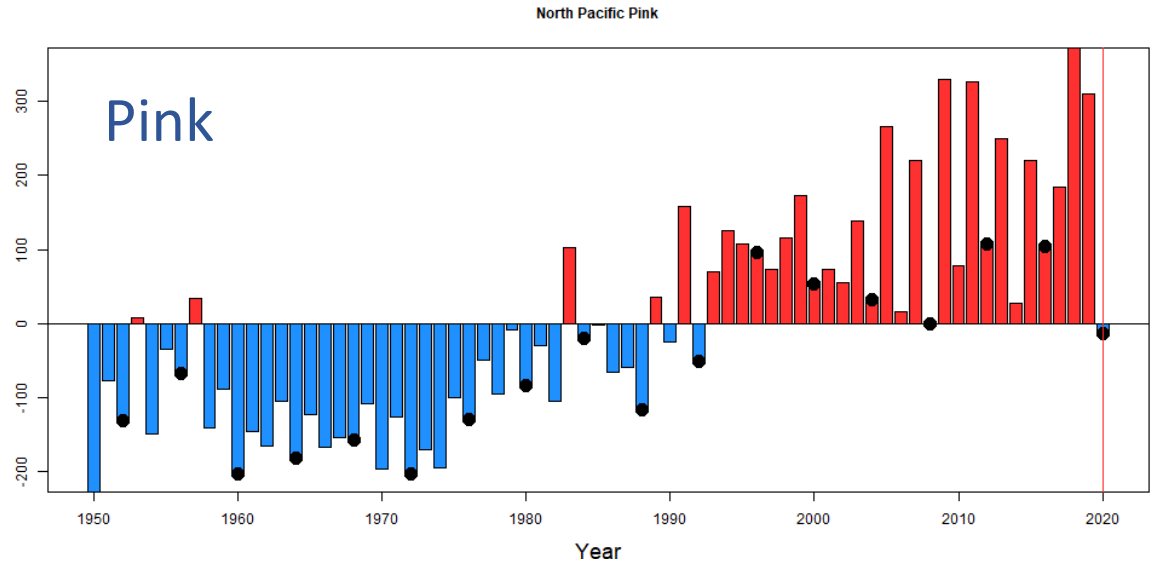
Total abundance of pink, chum, and sockeye salmon (catch plus spawning escapement) returning from the North Pacific Ocean to streams in North America and Asia, 1925–2020.

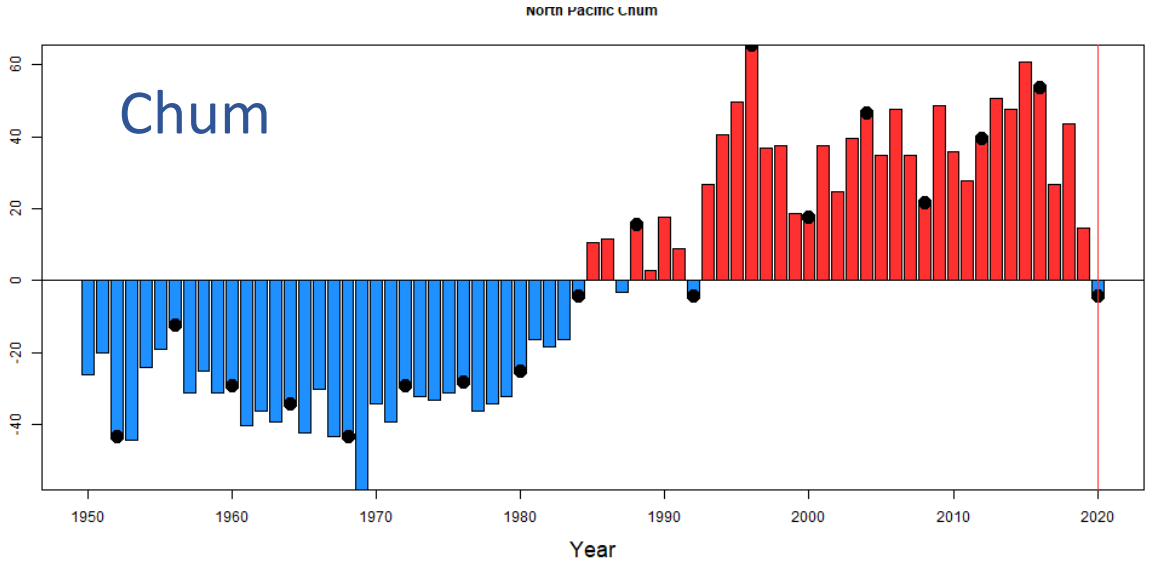


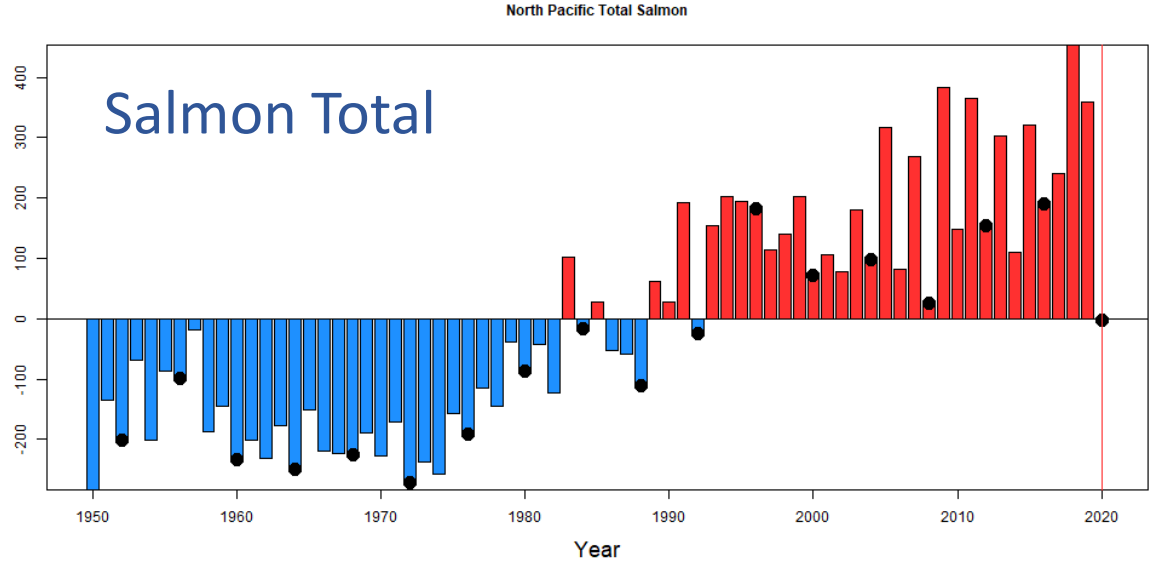
Ruggerone et al., 2021.
Updated from Ruggerone and Irvine 2018

New Variable: Pacific Salmon **neutral**



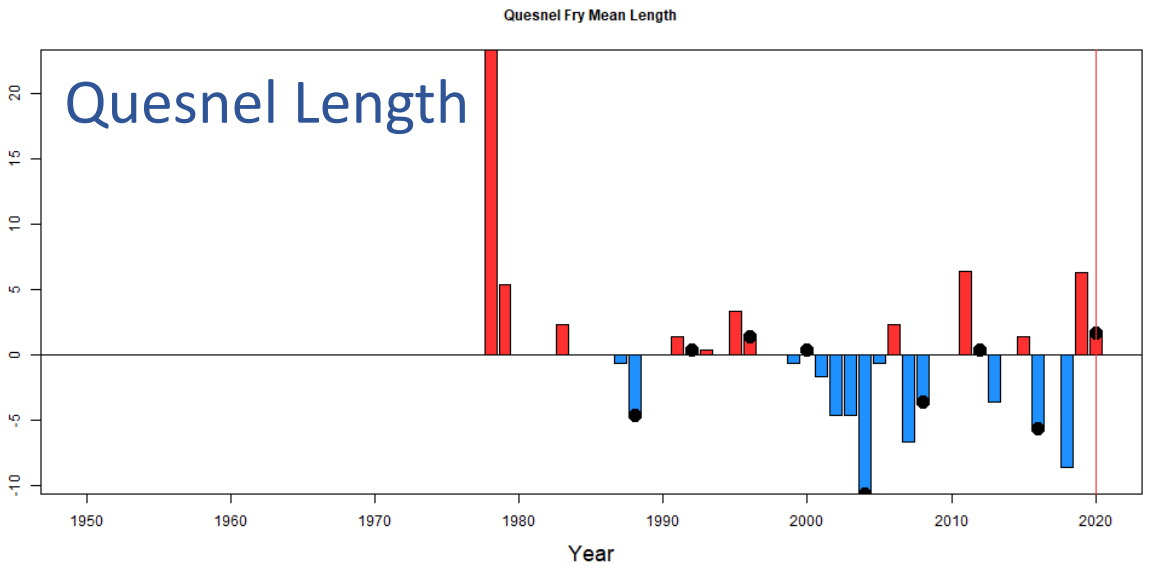


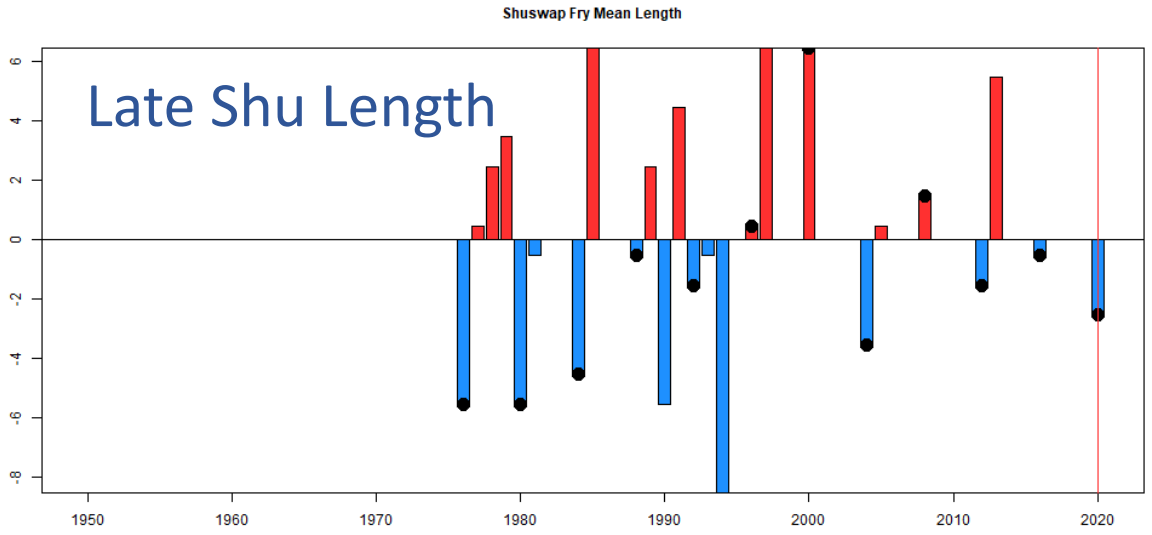


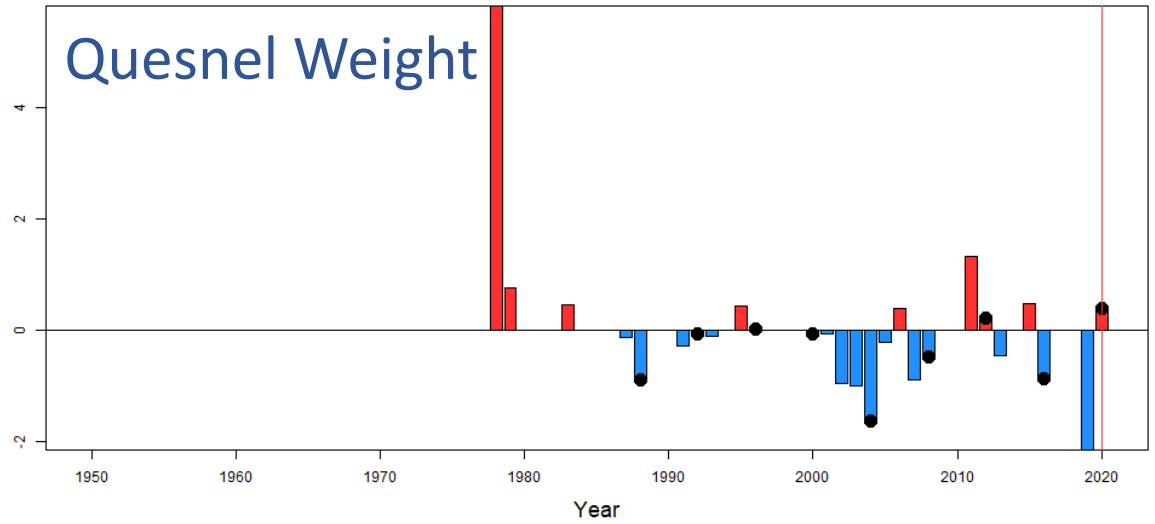


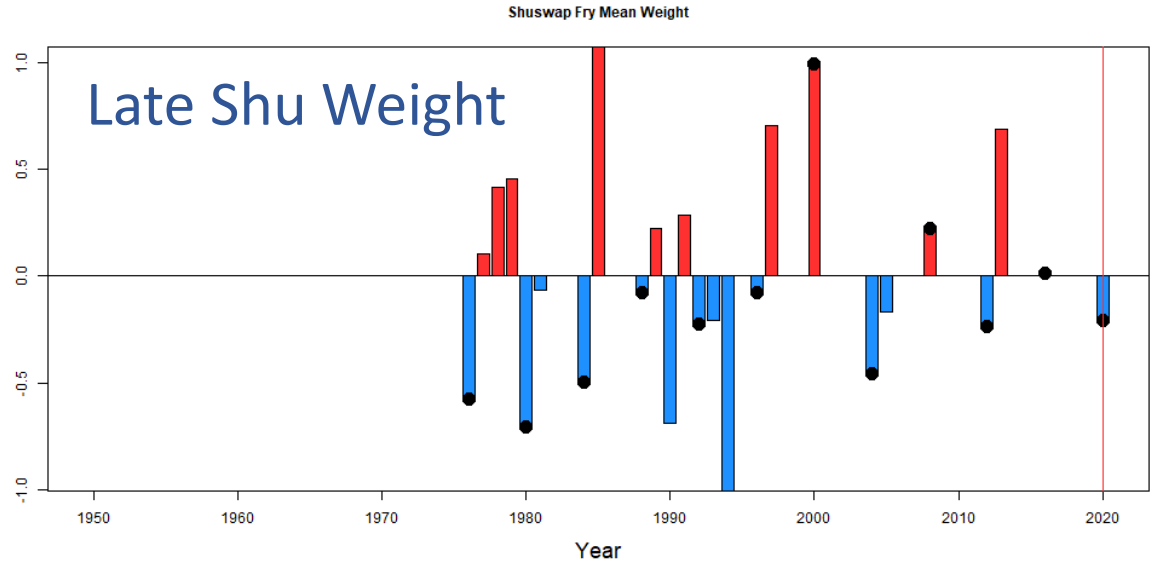
New Variable: Fry length and weight

Quesnel: normal
Late Shuswap: poor









Shiny App

C:/DFO-MPO/Work/forecast2022/EnvApp - Shiny

http://127.0.0.1:6443 | Open in Browser | Publish

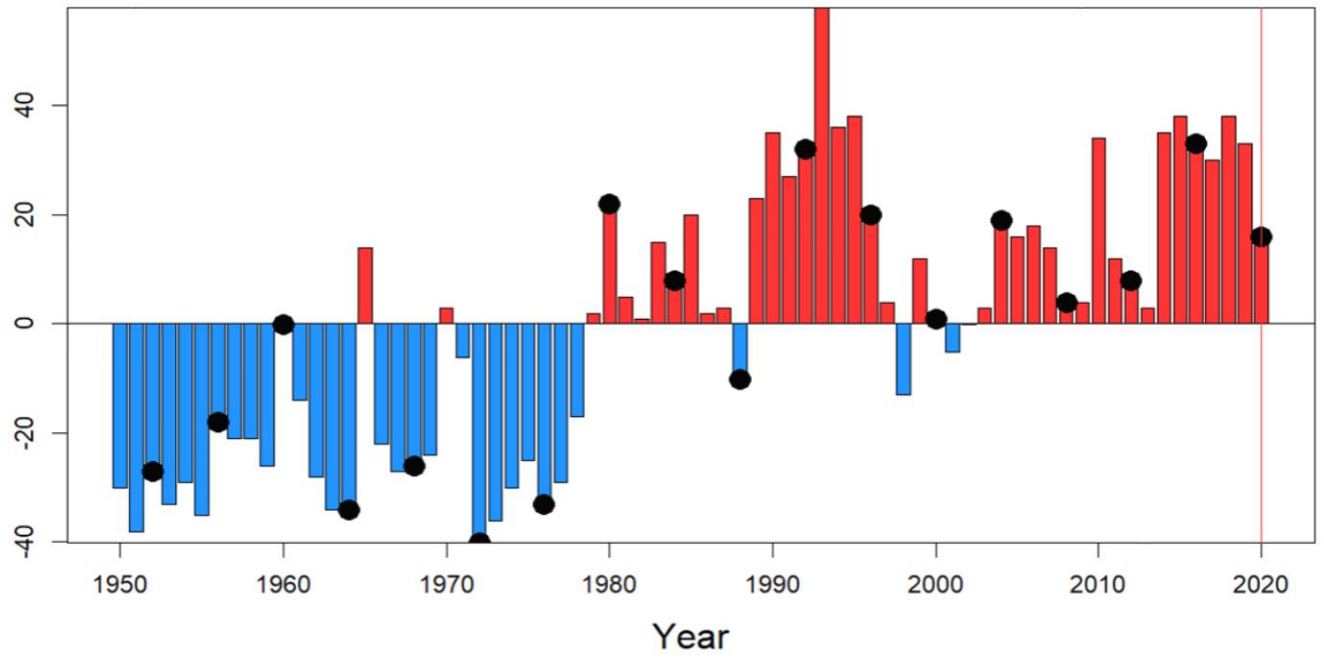
Environmental Data Viewer

Current environmental variables:

- ○ Entrance Island SST
- ○ Pine Island SST
- ○ Fraser River Discharge (mean)
- ○ Fraser River Discharge (peak)
- ○ Pacific Decadal Osciallation

New variables:

- ○ GOA SST Summer ○ NPGO Summer
- ○ GOA SST Winter ○ NPGO Winter
- ○ GOA SST Annual ○ NPGO Annual
- ○ Global Pink ◉ Global Sockeye
- ○ Global Chum ○ Global Total Salmon
- ○ Shuswap Fry Mean Length
- ○ Shuswap Fry Mean Weight
- ○ Quesnel Fry Mean Length
- ○ Quesnel Fry Mean Weight



Highlight

○ All years ◉ Cycle years

Forecast Year

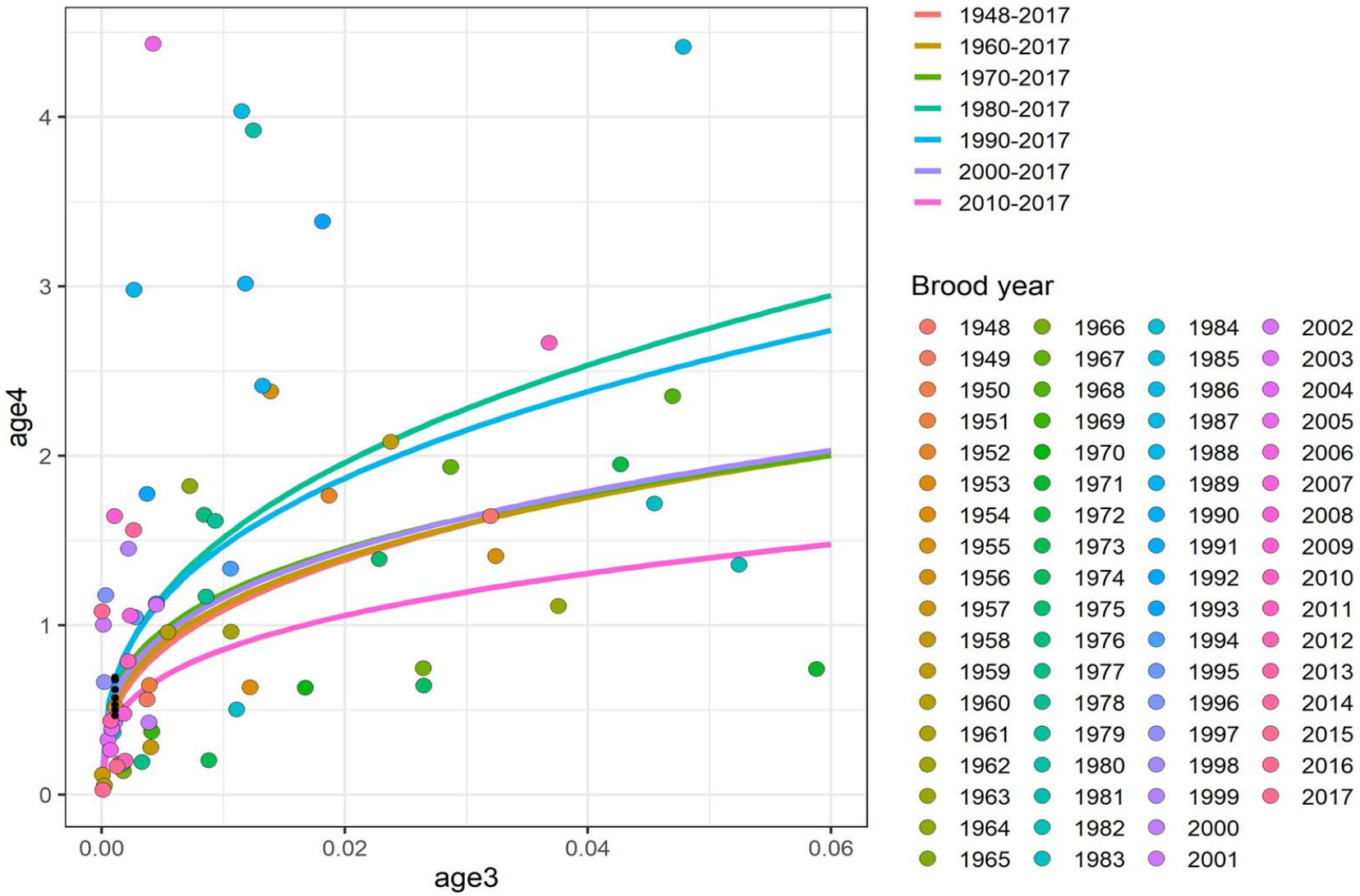
○ 2018 ○ 2019 ○ 2020 ○ 2021 ◉ 2022

Model Development

	Model Type	Stock
Existing	Naïve model	19 major stocks
	Biological model (with/without env covaries)	19 major stocks
	Sibling model	19 major stocks
	R/S model	8 miscellaneous stocks
New	Jacks sibling model	Chilko
	Fry-to-smolt model	Cultus
	Biological model with GOA SST and NPGO	18 major stocks
	Biological model with Pink/Sockeye/Chum Salmon indices	18 major stocks
	Biological model with fry length/weight	Quesnel/Late Shuswap
Dropped	Naïve/biological env model using TMB code	Chilliwack/Pink

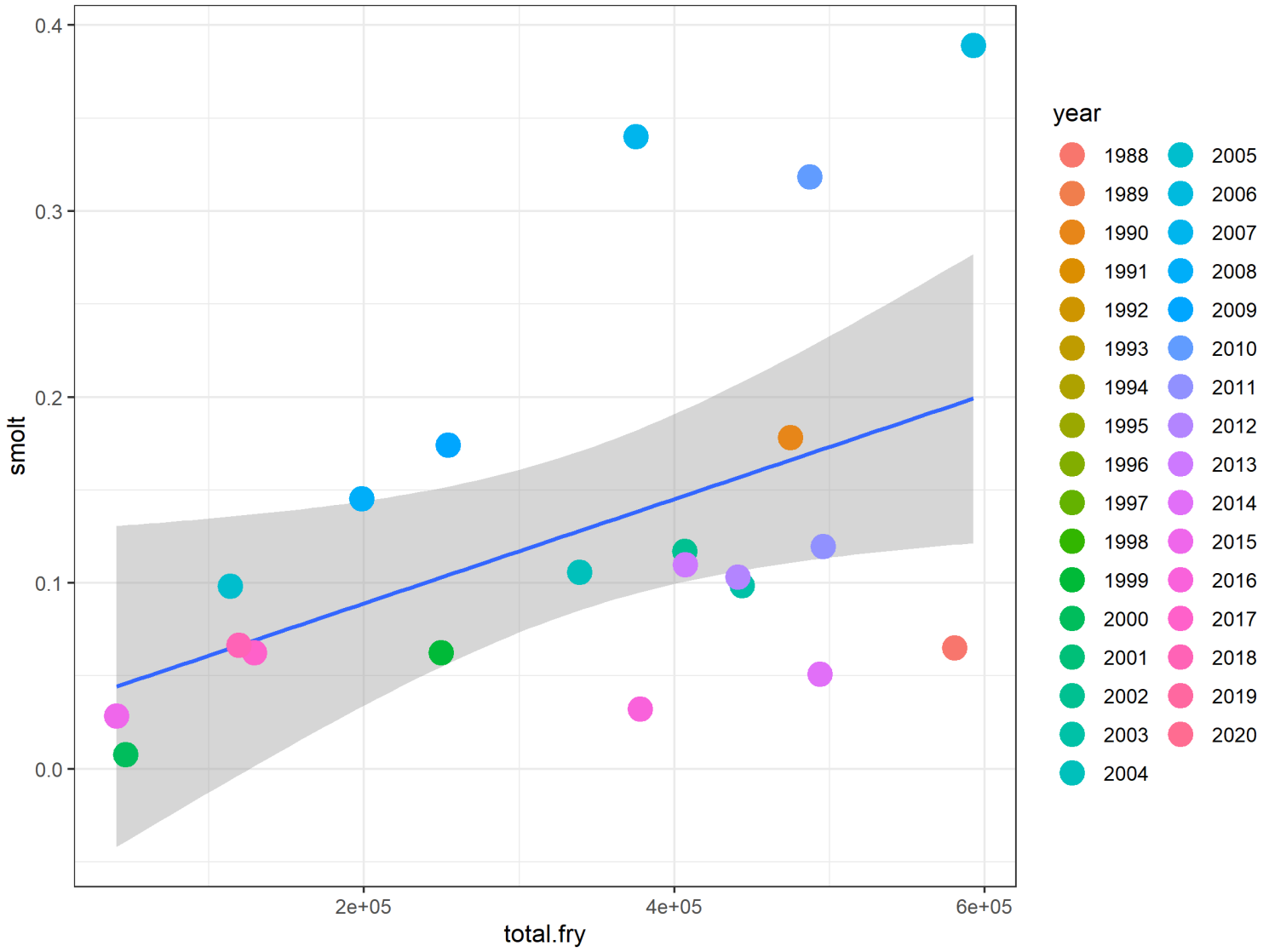
Chilko jack-sibling model

Use age-3 to forecast age-4



Cultus Fry-to-Smolt model

Use fry to estimate smolt abundance



119,426 fry -> 66,409 smolts (2020)
129,445 fry -> 62,609 smolts (2019)

Model Selection

	Existing	New
Retrospective analysis	1997-2004 ranking table	1997-2004 and 2009-2020 ranking table
		Age-specific ranking table
		Cycle-specific ranking table
Productivity	Recent trend	Raw productivity
Sibling model selection	In-sample (Model fit, R^2)	Out-of-sample (one-year ahead cross validation)
Visualization tool	None	Taylor diagram (3-metrics in 1 plot)
		R markdown HTML Viewer
Meeting duration	16 hours +	11 hours

New Retrospective Analyses

- One-year ahead approach
  - training: 1948-2008 testing: 2009
  - training: 1948-2009 testing: 2010
  - …
  - training: 1948-2019 testing: 2020

- Retro years : 2009-2020 (2021 not included)

- Total models: 8,187
  - Naïve models: 2,828
  - Biological models: 5,496 (including 1,704 new models)
  - Sibling models: 285

Retrospective results-Ranking tables

Model	MRE	MAE	MPE	RMSE	MRE rank	MAE rank	MPE rank	RMSE rank	average	Overall rank
LLY	0.001498	0.05244	0.68989	0.069014	1	6	6	4	4.25	5
R1C	0.013625	0.070063	1.343155	0.095339	5	13	13	10	10.25	9
R2C	0.017275	0.056606	1.271061	0.07154	7	7	9	5	7	7
RAC	0.225167	0.236388	6.108102	0.361432	21	22	21	22	21.5	21
TSA	0.231412	0.231412	7.240516	0.238134	22	21	22	21	21.5	22
RS1	-0.01727	0.047543	0.264624	0.060522	6	3	1	2	3	3
RS2	-0.01111	0.04328	0.270488	0.057077	4	2	2	1	2.25	1
RSC	0.104126	0.113767	2.529135	0.179956	19	19	19	19	19	19
MRS	0.114621	0.123336	2.598285	0.180702	20	20	20	20	20	20
RS4yr	-0.0019	0.048158	0.401594	0.072627	2	4	4	6	4	4
RS8yr	-0.0035	0.039515	0.338449	0.063252	3	1	3	3	2.5	2
LarkinBasic	0.087886	0.098243	2.069618	0.149912	18	17	18	17	17.5	17
LarkinBasicCycAge	0.086997	0.098669	2.058928	0.152601	17	18	17	18	17.5	18
PowerBasic	0.044466	0.063336	1.305992	0.08634	13	10	11	8	10.5	12
PowerBasicCycAge	0.043461	0.063619	1.302811	0.088445	11	11	10	9	10.25	10
RickerBasic	0.052094	0.073465	1.406817	0.106603	14	14	14	14	14	14
RickerCyc	0.042965	0.061847	1.333418	0.097447	10	9	12	12	10.75	13
RickerEi	0.027088	0.048974	0.605336	0.073588	8	5	5	7	6.25	6
RickerFrDMn80k	0.061754	0.080831	1.547228	0.122222	16	15	16	15	15.5	15
RickerFrDPk60k	0.061054	0.082012	1.521666	0.12445	15	16	15	16	15.5	16
RickerPDO40k	0.044178	0.06091	0.960316	0.095838	12	8	8	11	9.75	8
RickerPi	0.039561	0.065631	0.721016	0.101261	9	12	7	13	10.25	11

- MRE
- MAE
- MPE
- RMSE

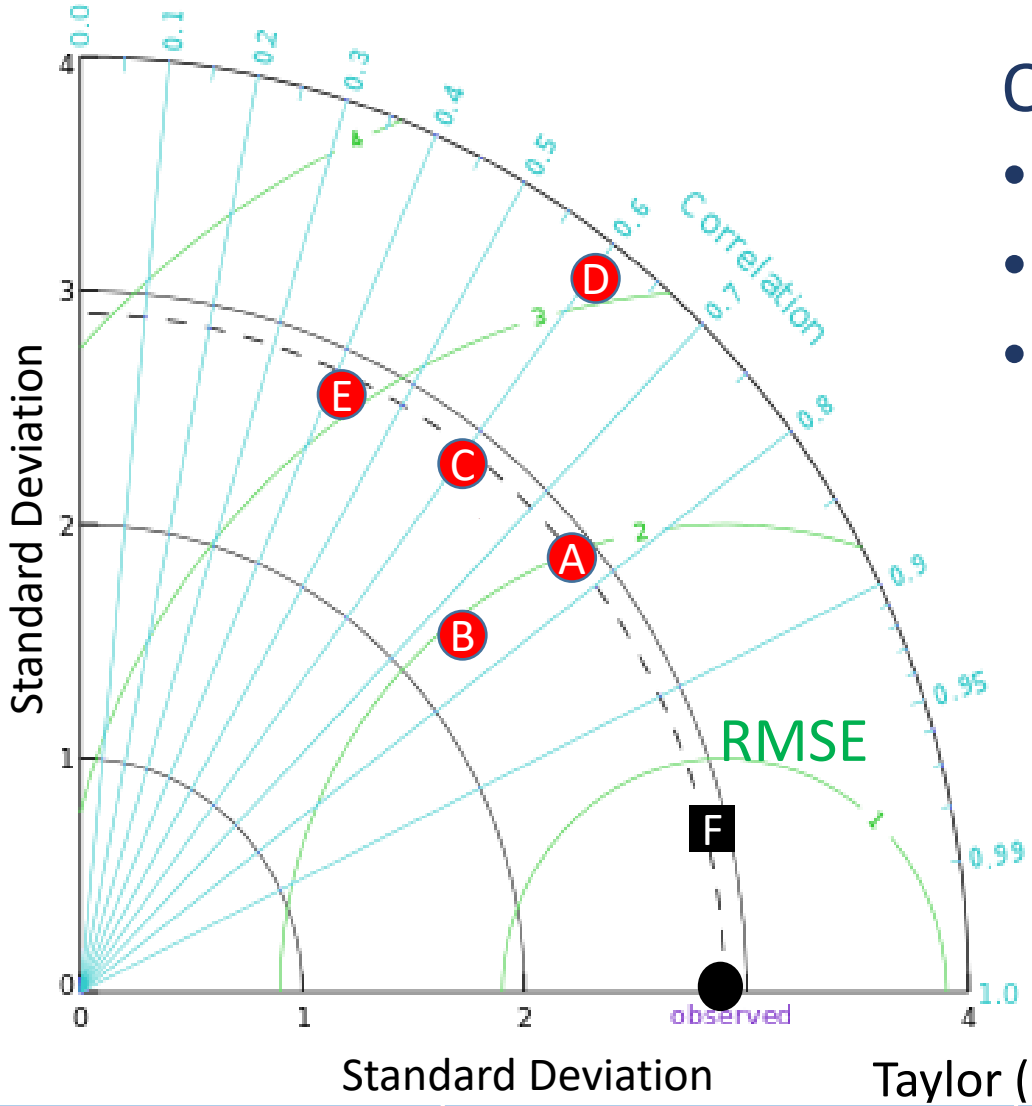
(Grant et al. 2012)

Retrospective results-Ranking tables

model	MRE	MAE	MPE	RMSE	MRE_rank	MAE_rank	MPE_rank	RMSE_rank	average	Overall_rank
PowerChum	-0.009	0.036	0.204	0.053	5	2	3	1	2.75	1
PowerSalmon_Total	-0.011	0.035	0.206	0.055	6.5	1	4	2	3.375	2
PowerPink	-0.006	0.038	0.326	0.056	4	3	7	3	4.25	3
RickerChum	-0.012	0.04	0.124	0.061	8	5.5	2	5.5	5.25	4
RS8yr	-0.003	0.04	0.338	0.063	3	5.5	8	7	5.875	5
RS2	-0.011	0.043	0.27	0.057	6.5	7.5	6	4	6	6
RickerPink	-0.019	0.043	0.043	0.067	14	7.5	1	9	7.875	7
RS1	-0.017	0.048	0.265	0.061	12.5	11	5	5.5	8.5	8
RS4yr	-0.002	0.048	0.402	0.073	2	11	9	13.5	8.875	9
PowerSockeye	0.013	0.044	0.562	0.064	9	9	12	8	9.5	10
LLY	0.001	0.052	0.69	0.069	1	14	14	11	10	11
RickerSalmon_Total	-0.036	0.039	-0.417	0.068	16	4	10	10	10	12
RickerSockeye	0.014	0.048	0.494	0.073	10.5	11	11	13.5	11.5	13
RickerEi	0.027	0.049	0.605	0.074	15	13	13	15	14	14
R2C	0.017	0.057	1.271	0.072	12.5	15	20	12	14.875	15
RickerPDO	0.044	0.061	0.96	0.096	21	16	17	19	18.25	16
PowerBasicCycAge	0.043	0.064	1.303	0.088	18.5	19.5	21	17	19	17
RickerPi	0.04	0.066	0.721	0.101	17	21	15	23	19	18
R1C	0.014	0.07	1.343	0.095	10.5	24.5	24	18	19.25	19
PowerBasic	0.044	0.063	1.306	0.086	21	18	22	16	19.25	20
RickerCyc	0.043	0.062	1.333	0.097	18.5	17	23	20	19.625	21
RickerGOA.SST.Win	0.046	0.064	1.001	0.1	23	19.5	19	21.5	20.75	22
RickerNPGO.Sum	0.044	0.068	1.385	0.1	21	22.5	25	21.5	22.5	23
RickerGOA.SST.Sum	0.051	0.068	0.98	0.111	25	22.5	18	26	22.875	24
RickerGOA.SST.Ann	0.058	0.07	0.955	0.12	28	24.5	16	28	24.125	25
RickerNPGO.Ann	0.048	0.071	1.41	0.105	24	26	27	24	25.25	26
RickerBasic	0.052	0.073	1.407	0.107	26	27	26	25	26	27
RickerNPGO.Win	0.055	0.078	1.509	0.114	27	28	28	27	27.5	28
RickerFRDMean	0.062	0.081	1.547	0.122	30	29	30	29	29.5	29
RickerFRDpeak	0.061	0.082	1.522	0.124	29	30	29	30	29.5	30
LarkinBasic	0.088	0.098	2.07	0.15	32	31	32	31	31.5	31
LarkinBasicCycAge	0.087	0.099	2.059	0.153	31	32	31	32	31.5	32
RSC	0.104	0.114	2.529	0.18	33	33	33	33	33	33
MRS	0.115	0.123	2.598	0.181	34	34	34	34	34	34
RAC	0.225	0.236	6.108	0.361	35	36	35	36	35.5	35
TSA	0.231	0.231	7.241	0.238	36	35	36	35	35.5	36

- Stock-specific ranking tables
- Stock/age-specific ranking tables
- Stock/age-specific ranking tables for cycle years and non-cycle years
- Implemented models with new env co-varies
- Compared with existing models retrospectively
- All models are up to date for 2022 forecast

New model performance measures: Taylor Diagram

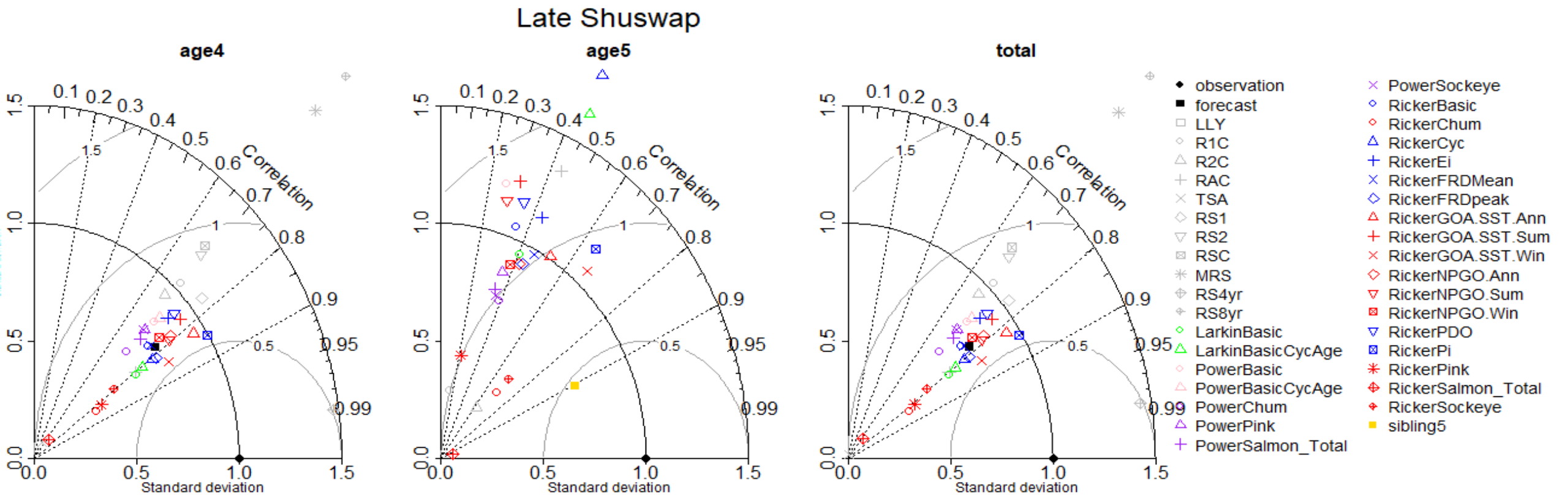


Taylor (2001)

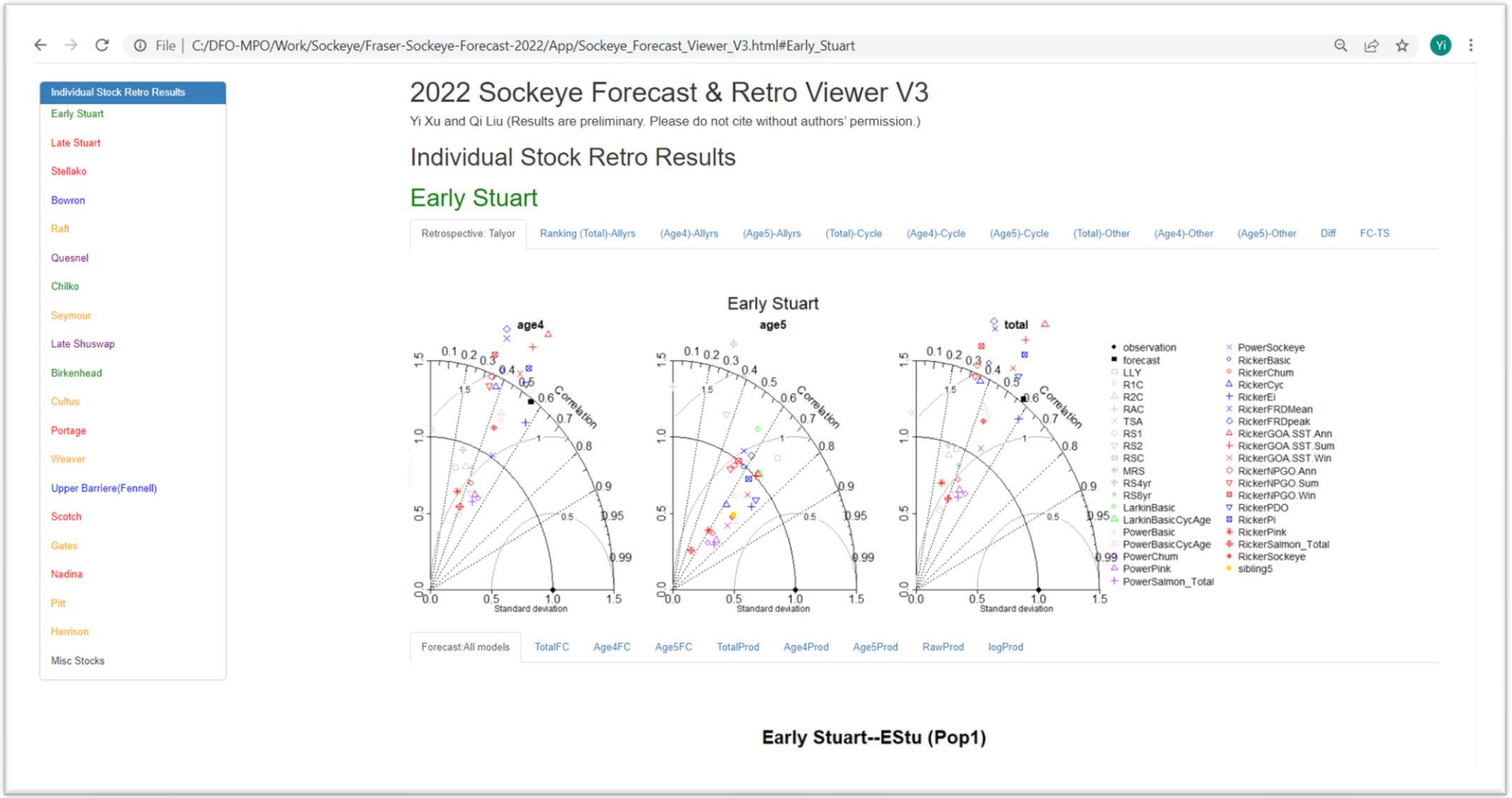
One plot, three metrics:

- Correlation
- SD
- RMSE

Age-specific Taylor Diagram



HTML Viewer-2022 Sockeye Forecast & Retrospective Viewer



Methods update in 2022 forecast

Data

- Provided alternative solutions for data not collected due to COVID.
- 14 new explanatory variables (env, climate indices, biological indicators)
- Env Viewer Shiny App

Model

- Cultus fry-to-smolt model
- Chilko jacks-sibling model
- Ricker/Power models coupled with new co-varies

Model Selection

- Updated ranking tables with most recent time series
- Used Raw productivity instead of the smoothed trend
- Taylor diagram visualization tool (3 metrics-in-1)
- R markdown HTML Viewer

2022 Fraser Sockeye Forecast Table

Median [p10, p90]

- Total Sockeye 9.8M [2.4M, 41.7M]
  - Early Stuart 105K [39K, 268K]
  - Early Summer 1.6M [384K, 5.7M]
    - Major 757K [196K, 2.8M]
  - Summer 4.4M [1.2M, 17.5M]
    - Major 4.39M [1.2M, 17.4M]
  - Late 3.69M [708K, 18.31M]
    - Major 3.67M [706K, 18.26M]

Run timing group / Stocks	Forecast Model	Probability that Return will be at/or Below Specified Run Size				
		10%	25%	50%	75%	90%
Early Stuart	*Ricker (Ei)*	39,000	63,000	105,000	172,000	268,000
Early Summer Total		384,000	767,000	1,579,000	3,159,000	5,686,000
Total excluding misc. stocks		196,000	370,000	757,000	1,474,000	2,769,000
Bowron	*Ricker (Ei)*	5,000	11,000	21,000	48,000	87,000
Upper Barriere (Fennell)	*Ricker (Pi)4Sibling5*	800	2,000	4,000	9,000	19,000
Gates	*LLY4Sibling5*	11,000	19,000	36,000	70,000	126,000
Nadina	*RickerFrDPk4Sibling5*	51,000	100,000	193,000	381,000	703,000
Pitt	*LLY4Sibling5*	13,000	21,000	35,000	58,000	89,000
Scotch	*Larkin4Sibling5*	45,000	89,000	199,000	403,000	825,000
Seymour	*Ricker(Ei)4Sibling5*	70,000	128,000	269,000	505,000	920,000
Misc (EShu)	*R/S*	184,000	388,000	804,000	1,650,000	2,850,000
Misc (Taseko)	*R/S*	40	100	200	400	600
Misc (Chilliwack)	*R/S*	2,000	5,000	10,000	20,000	37,000
Misc (Nahatlatch)	*R/S*	2,000	4,000	8,000	15,000	29,000
Summer Total		1,239,000	2,231,000	4,403,000	8,904,000	17,468,000
Total excluding misc. stocks		1,237,000	2,223,000	4,387,000	8,872,000	17,402,000
Chilko	*Ricker(Ei)4Sibling5*	482,000	806,000	1,463,000	2,662,000	4,732,000
Late Stuart	*Ricker(FrDMn)4Sibling5*	80,000	184,000	458,000	1,091,000	2,520,000
Quesnel	*Ricker(Ei)*	485,000	917,000	1,907,000	4,178,000	8,531,000
Stellako	*Larkin4Sibling5*	185,000	306,000	536,000	885,000	1,491,000
Harrison	*Ricker(Ei)Even3Sibling4*	2,000	5,000	13,000	37,000	94,000
Raft	*LLY4/Sibling5*	3,000	5,000	10,000	19,000	34,000
Misc (N. Thomp. Tribs)	*R/S*	300	900	2,000	3,000	7,000
Misc (N. Thomp River)	*R/S*	2,000	7,000	13,000	28,000	57,000
Misc (Widgeon)	*R/S*	70	300	600	1,000	2,000
Late Total		711,000	1,604,000	3,688,000	8,160,000	18,285,000
Total excluding misc. stocks		709,000	1,597,000	3,672,000	8,132,000	18,234,000
Cultus	*PowerJuvPi*	400	600	1,000	3,000	5,000
Late Shuswap	*Ricker(Ei)*	645,000	1,473,000	3,418,000	7,582,000	17,166,000
Portage	*RickerCyc*	27,000	52,000	107,000	226,000	444,000
Weaver	*PowerJuv(Pi)4Sibling5*	16,000	36,000	85,000	206,000	423,000
Birkenhead	*Ricker(Ei)*	21,000	35,000	61,000	115,000	196,000
Misc Harrison/Lillooet	*R/S*	2,000	7,000	16,000	28,000	51,000
TOTAL SOCKEYE SALMON		2,374,000	4,662,000	9,775,000	20,395,000	41,707,000
Total Sockeye excluding misc. stocks		2,181,000	4,250,000	8,921,000	18,650,000	38,673,000

2022 Fraser Sockeye Forecast Table

Median [p10, p90]

- Total Sockeye 9.8M [2.4M, 41.7M]
  - Early Stuart 105K [39K, 268K]
  - Early Summer 1.6M [384K, 5.7M]
    - Major 757K [196K, 2.8M]
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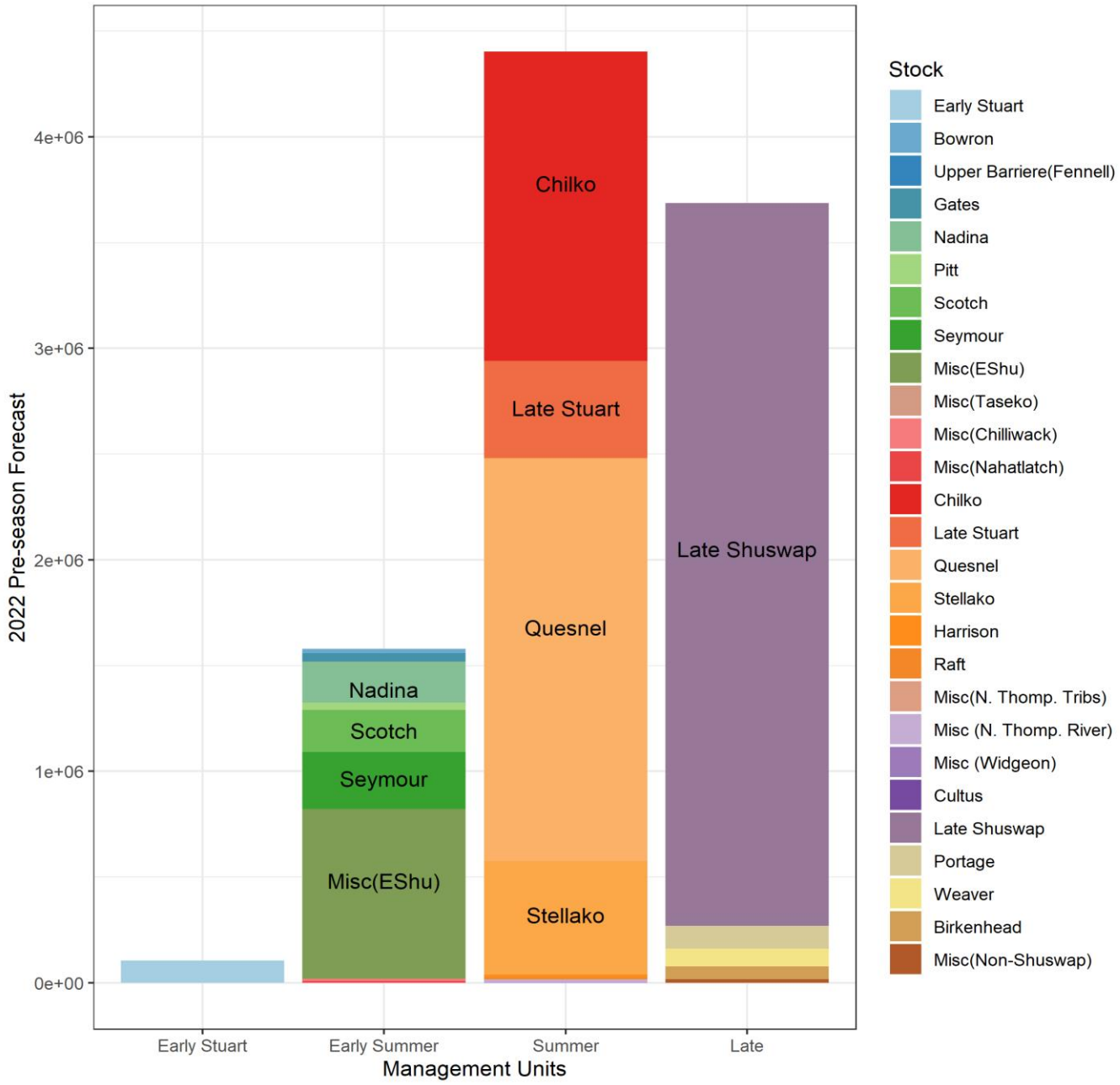
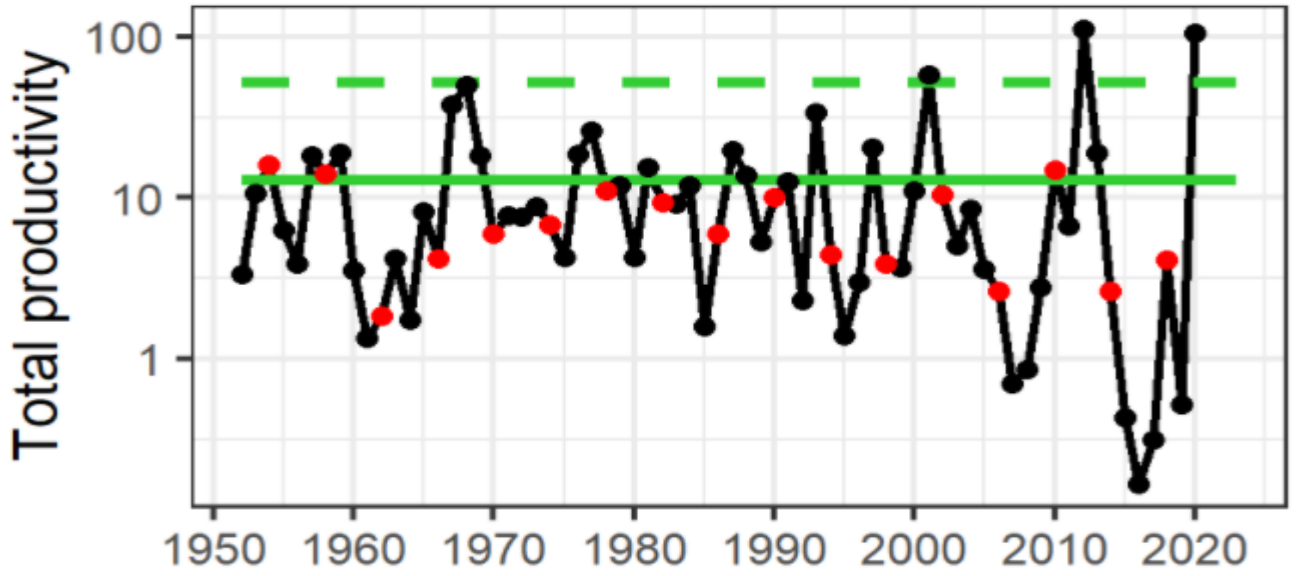


Uncertainties

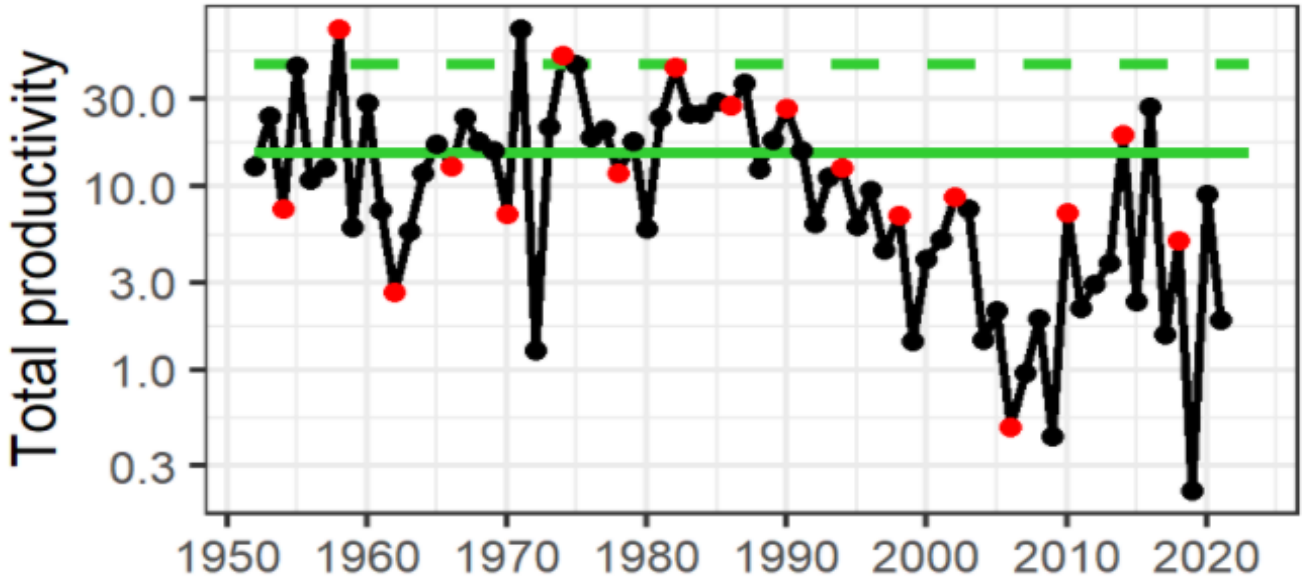
Late Shuswap

- Models results 3.4M (1.1M~42M)
- Implied prod 4.27 (1.5~53)



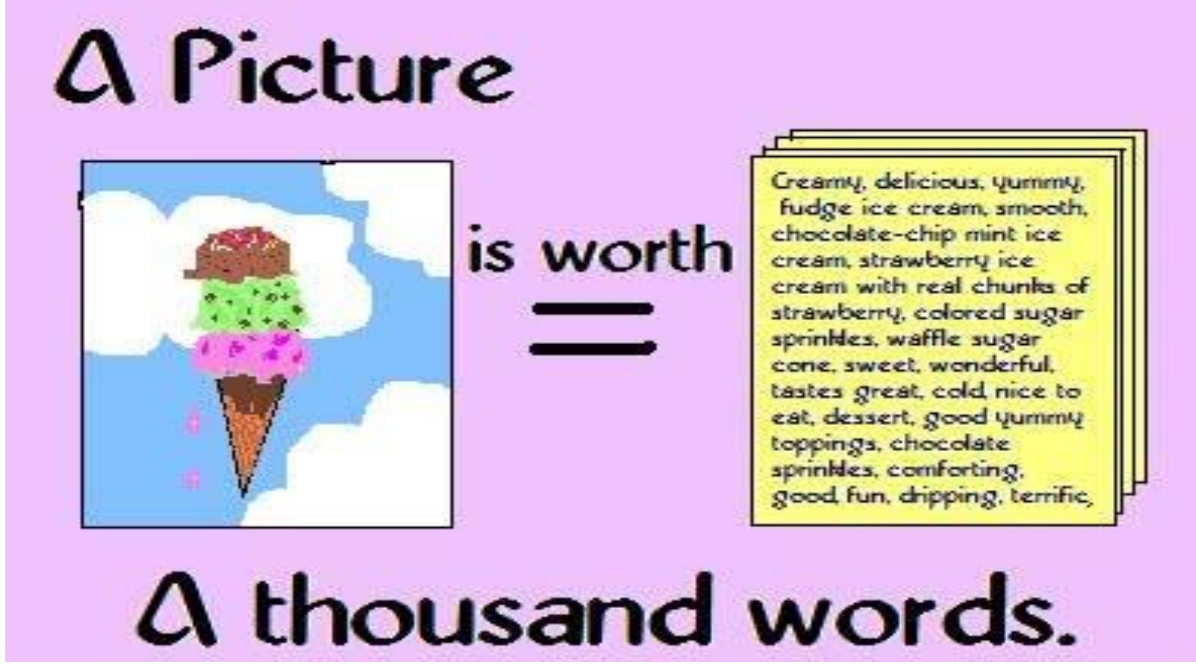
Quesnel

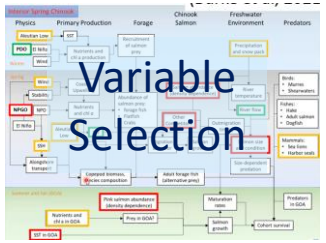
- Models results 1.9M (1.5M~3.5M)
- Implied prod 5.73 (4.4~10.4)

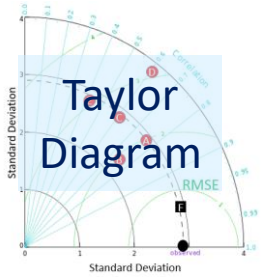


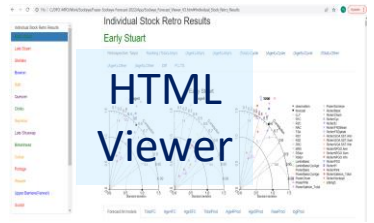
Summary

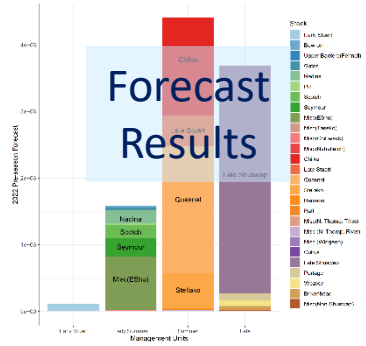
- Data, model and model selection criteria were updated in 2022 toward improving the forecast returns and panel discussion process.
- 2022 Fraser Sockeye expected total run size is 9.8M [2.4M, 41.7M].
- Management units: Early Stuart 105K, Early Summer 1.6M, Summer 4.4M, Late 3.69M
- High uncertainties are associated with stocks like Late Shuswap and Quesnel.











Questions? Contact Yi: yi.xu2@dfo-mpo.gc.ca