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Pacific Region

Fraser Stock Assessment
Technical Memo

PRE-SEASON RUN SIZE FORECASTS FOR FRASER RIVER SOCKEYE *(ONCORHYNCHUS NERKA)* AND PINK *(ONCORHYNCHUS GORBUSCHA)* SALMON IN 2019

ABSTRACT

Fraser River sockeye and pink stocks have been experiencing lower than long term average productivity in recent years. Forecasts for these stocks have been prepared with Bayesian models and presented as a probability distribution. This distribution represents the range of survival the stocks have exhibited historically. Environmental variation and especially warming associated with climate change are incorporated into the forecast for several stocks where they were shown to improve performance. In general this has the effect of reducing the forecast abundance when temperatures are higher. The large return in 2018 results in an expectation of a larger than typical return of older 5_2 sockeye salmon. Sibling models were used to estimate the 5_2 return for several stocks. The Fraser River pink salmon return is forecast to be 5,018,600, (80% PI[2,530,000-10,610,000]) fish. The 2019 Fraser River sockeye return is forecast to be 4,795,000 (80% PI [1,794,000-14,297,000]). The return in 2019 is dominated by the Summer Run management group expected to contribute 3,930,000 (80% PI [1,553,000-11,187,000]) salmon to the return. The Chilko stock makes up the bulk of this management group and contributes 61.5% of the total forecast sockeye return.

BACKGROUND

Fraser Salmon Population Descriptions

The Fraser River is the largest watershed in British Columbia and hosts a diversity of salmon species. Fraser River sockeye and pink salmon have historically supported large commercial, recreational, and First Nations harvests (Gilhousen 1992). Recent productivity of the stocks has become more variable leading to both the largest (2010) and lowest (2016) returns in recorded history (Pacific Salmon Commission 2017). In 2017, a Wild Salmon Policy (WSP) status evaluation, and a Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report both identified persistent patterns of decline in many of the Conservation Units (CU) or Designatable Units (DU), which are the discrete and evolutionary distinct constituent populations of the Fraser River sockeye aggregate. The WSP process identified seven of the 19 forecast CUs as being in a state of significant conservation concern, while the COSEWIC status report recommends that seven of these stocks be listed as endangered (Grant et al. in press, COSEWIC 2017).

Pink

Fraser River pink salmon are the largest run of pink salmon in British Columbia and exhibiting a two year life history. Adults spawn in the fall, fry emerge in the spring and migrate immediately to sea. Adults return a year later to spawn 2 years after the eggs from which they hatched were deposited. Fraser River Pink salmon have a strong bi-annual pattern with significant returns of adult pink salmon occurring only on odd years. Adult returns are estimated by the Pacific Salmon Commission (PSC), while juvenile abundance data is collected by Fisheries and Oceans Canada (DFO). The methods, time series, and the history of data collection are detailed in Grant et al. 2014.

The 2019 Pink salmon forecast of 5.0 million is lower than the long term average (12.7 million), and the 2018 fry outmigration of 192.2 million is the lowest observed since the method for enumerating outmigrating fry was standardized in 1968 and less than half of the long term average of 431.9 million.

Sockeye

Fraser River sockeye salmon have historically supported an important commercial fishery in British Columbia, are an ongoing major contributor to First Nations food, social, ceremonial fisheries, and recreational activities (Cohen 2013). Changes to management of the fisheries and productivities of the stocks have resulted in reduced fishing opportunities for all sectors in recent years (Cohen 2013), and a particularity low return in 2009 lead to a judicial enquiry. Because of the difficulty of in-season management of mixed stock fisheries Fraser River sockeye are managed in four aggregates based upon shared return timing to the Fraser River. Escapement and harvest plans are made at the management group level, so aggregate forecasts are presented in addition to stock specific return forecasts.

Fraser Sockeye Escapements

The 2019 return is made up of four year old fish spawned in 2015 and five year old fish spawned in 2014. Escapement is enumerated by DFO staff using a variety of methods. In general a higher precision method (either sonar counting stations, or mark-recapture studies) is used to enumerate the large populations, while visual surveys or other methods with lower precision are used to enumerate the smaller systems (Keri Benner, DFO, Fraser River Stock Assessment Program Head Sockeye, personal communication). The specifics of the escapement programs as well as the escapement estimates are detailed annually by the stock assessment program and are the primary driver of the forecasts (Macdonald and Grant 2012).

Fraser Sockeye Survival Trends

Since 2002 Fraser River Sockeye has been generally returning lower than the long term 1950-2015 average survival would predict (i.e. recruits per spawner have been below the long term average, Figure 1). Environmental volatility and warming associated with climate change are associated with negative survivals of Fraser Sockeye salmon populations (Mueter et al. 2002). Several environmental covariates are used as part of the quantitative forecasts, and for the 2019 return are showing a mixed signal with two (Pine Island SST and PDO) of the three main temperature covariates suggesting negative environmental conditions, and the third (Entrance Island SST) suggesting near normal conditions (Figure 3). In addition to the quantitative inclusion of environmental covariates, there is an ongoing effort to document the changes to freshwater and marine ecosystems and environmental conditions faced by Fraser River sockeye. This additional information is not yet incorporated in a quantitative way. For the 2019 return year, as for the last five years, the marine rearing conditions experienced by a large proportion of the return were anomalously warm, which is hypothesized to be causing an atypical zooplankton community. Detailed information on the environmental conditions experienced at specific life history stages is outside the scope of this forecasting document, but is captured by the state of the salmon program and in general points to the need for caution when applying the forecast returns for fisheries planning (Program Leads: Sue Grant & Bronwyn MacDonald, DFO)

Forecasting

Forecasting salmon returns has been an area of study for generations of fisheries scientists (see Haeseker et al. 2008 for an overview of salmon forecasting methods). The general methods of forecast have not changed dramatically over time, though there have been innovations both in the modeling frameworks applied, and the sophistication of the computation (e.g. Cass et al 2006, Grant et al. 2010, MacDonald and Grant 2012). For 2019, the forecasting methods developed in previous years will be extended (Macdonald and Grant 2012) and are detailed in the methods section below.

The importance of the Fraser River sockeye and pink fisheries to commercial, recreational, and First Nations fisheries means that a quantitative forecast of abundance is required, both to inform pre-season planning of fisheries, and to serve as informative priors for the in-season run-size assessment programs. This is used to inform the planning decisions of the bilateral Fraser Panel which manages in-season harvest (Pacific Salmon Treaty 1985).

DATA AND METHODS

Data

Fraser Sockeye data used in the forecast process includes the following:

- The last brood year for which full recruitment data (four and five year olds) are available for the 2019 forecast is 2011, with the exception of Harrison Sockeye (data are included to the 2012 brood year).
- Effective Female Spawners (EFS) data are included up to the 2015 brood year (2016 for Harrison).
- Juvenile fry data for the 2015 brood year are available for Nadina, Weaver, and Gates stocks. Due to inconsistencies in data collection methods over time, juvenile data are not used to produce forecasts for Gates. Historically, fry data were available for both the channels and rivers/creeks for these three stocks. In recent years, only channel fry data have been available for Nadina and Weaver, while both channel and creek fry data are available for Gates. Fry data gaps in the historic time series were infilled using the average historical fry/EFS production by stream multiplied by the relevant brood year EFS.
- Juvenile smolt data in the 2015 brood year are available for Cultus and Chilko.

In addition to stock-recruitment data, several biological models are used incorporate the following environmental data (See MacDonald and Grant (2012) for further details):

- Pacific Decadal Oscillation (PDO) in winter (November to March)

- Average of monthly sea surface temperature (SST) from Entrance Island lighthouse (Ei; Strait of Georgia, near Nanaimo, B.C. from April to June and Pine Island (Pi; Northeast corner of Vancouver Island) from April to July
- Fraser Discharge (peak (FrD-peak) and average (FrD-average) from April to June measured at Hope, B.C.)

2019 Forecast Sockeye Brood Year Escapements (2015 and 2014)

Brood year escapements are presented in Table 1B. 12 of the 19 forecast sockeye stocks have brood year escapements lower than the cycle line (for cyclic stocks) or average escapements. In addition, 18 of the 19 forecast stocks have escapements lower than the four-year average calculated for the 2017 WSP status re-assessment (Grant et al. in press).

Fraser Sockeye Forecast Methods

The 2019 Fraser Sockeye forecasts follow the same approach as recent forecasts (DFO 2012; MacDonald & Grant 2012; DFO 2013; Grant and MacDonald 2012; DFO 2014a; DFO 2015a; DFO 2016a, DFO 2017, DFO 2018), which were adapted from methods used in earlier forecasts (Cass et al. 2006).

For 19 modelled stocks, forecasts are based on a model selected from a shortlist of top ranked models. Table 4 lists the full suite of candidate models. For most miscellaneous stocks, forecasts are based on brood year escapements and long-term observed survival rates for proxy stocks. Chilliwack was forecasted like other miscellaneous stocks until recently (DFO, 2018), but is now based on a Ricker model.

Model performance, ranking, and the primary model selection process for Fraser Sockeye Salmon are based on the analyses conducted in 2012 (MacDonald & Grant 2012). Given the environmental conditions in the past few years, an additional criterion (number five below) was added to the 2017 model selection process, and has been retained for the 2019 forecast. Methods are summarized in the bullets below (see Appendix 2 for model selection process by stock for 2019 forecasts):

1. Forecasts are presented in Table 1A. The most appropriate model for each stock is selected based on model performance measures that compare forecasts to observed returns across the full stock-recruitment time series (see #2 - #4 below) in combination with model selection criteria (see #5) and Bayesian convergence criteria (see #6).
2. Model performance (forecasts compared to actual returns) was compared across all applicable candidate models for each stock, excluding the recent-survival models (RS4yr, RS8yr, and KF) introduced in the 2010 forecast, and sibling models (all model forms are described in Appendices 1 to 3 of Grant et al. 2010).
3. A jackknife (leave-one-out) cross-validation analysis was used to generate the historical forecast time series for each stock and model (MacDonald & Grant 2012); performance was then measured by comparing forecasts to observed returns across the full time series.
4. Four performance measures (mean raw error, mean absolute error, mean proportional error and root mean square error; described in Appendix 4 of Grant et al. 2010), which assess the accuracy and/or precision of each model, were used to summarize jackknife cross-validation results and rank models (results are summarized in MacDonald & Grant 2012);

5. The model selection criteria identified in the 2012 forecast (see beginning of Appendix 2; originally published on page 8 of MacDonald and Grant 2012) were applied. In addition, new since the 2017 forecast, a criterion was developed to address the anomalous environmental conditions that have persisted since late 2013 (see Figure 3 for sea-surface temperature anomalies). In cases where the top ranked forecast was a Ricker, power (juvenile), or non-biological model, and a temperature covariate model (Ricker (Ei), Ricker (Pi), or Ricker (PDO)) ranked within the top three models, the forecasting performance of the covariate model specifically in warmer than average years was examined (Appendix 2 of DFO 2017). Due to the additional information contained in the covariate, the superior ranking of these models in anomalously warm years, and the consistent signal of lower survival implied by the addition of the covariate across the applicable stocks, a temperature covariate forecast was adopted for these seven stocks in 2017 (Table A2 in Appendix 3 of DFO 2017). A temperature covariate forecast was again selected for 2019.
6. Forecasts were produced using the top ranked models for each stock, and Bayesian diagnostics were applied to ensure model convergence (see DFO 2015a for an explanation of diagnostic usage).
7. Miscellaneous stocks (except Chilliwack since the 2016 forecasts), which do not have recruitment data, were forecast using the product of their brood year escapements and the geometric average survival (across the entire available time series) for spatially and temporally similar stocks with stock recruitment data (index stocks) (see Appendix 1 of Grant et al. 2010, as identified in Table 1A).
8. Non-parametric models using cycle-line returns (R1C, R2C, and RAC) have been modified compared to previous forecast papers. Uncertainty bounds are now being calculated using only cycle-line residuals rather than residuals for all years in the time series. This produced considerably narrower bounds for most stocks. For stock-specific details, see the statistical notes in Appendix 2.

Fraser Sockeye 2019 Sibling Model

A large proportion of the forecast return is age 5_2 sockeye, that is, five year old fish returning from the large 2014 brood year. This contribution is expected to be especially strong in the Early Summer and Late management groups. In 2018, the age 4_2 sockeye again showed lower than average survival, with preliminary returns for most stocks estimated to be well below the p50 forecast. This additional information on stock specific age 4_2 survival can be used to forecast the age 5_2 return with a sibling model. A sibling model takes advantage of the relationship between returning year classes of salmon. Sibling models are widely used in forecasting salmon returns; for the 2019 forecast a sibling model of the form laid out in Peterman (1982) was used. The model was adapted into a Bayesian framework to provide probability intervals for the age 5_2 return for specific stocks that can be compared to those generated by other forecasting methods, using the following relationship:

$$ln\,(5_2) \sim normal(a - b * ln(4_2))$$

Sibling models have been prepared for Fraser River sockeye stocks in the past (Grant et al. 2015, Grant et al. 2016). Though the performance of sibling models has not been qualitatively compared to other forecast models, it was decided to use these models for situations where there was a significant expected contribution of 5_2 sockeye. In 2019, the top ranked model estimates, we've found large proportion age 5_2 of for seven stocks (Fennell, Pitt, Scotch, Seymour, Quesnel, Late Shuswap and Weaver). Therefore, sibling models are performed for these stocks.

Results

Fraser Pink 2019 Forecasts

The Fraser Pink forecast for 2019 is based upon the best performing model; a power fry model with sea surface salinity (SSS) as an environmental covariate. The forecast return is 5,018,600, (80% PI[2,530,000-10,610,000]) pink salmon. This forecast is consistent amongst the different forecasting models (Appendix 2, pg. 57), and is driven by the extremely low pink salmon fry outmigration observed in 2018 (Figure 6).

Fraser Sockeye 2019 Forecasts

In 2019 the total Fraser River sockeye return is forecast to be 4,795,000 (80% PI [1,794,000-14,297,000]). Stock specific forecasts are presented in Table 1A, and Appendix 2. This return forecast is similar to the cycle average return, though lower than the all cycle average return (Table 1B). The distribution of abundance among management groups is dominated by the summer run, with 61.5% of the forecast from a single stock (Chilko), and the next three most significant contributions coming from other summer stocks, Stellako (8.2%), Quesnel (7.4%), and Harrison (6.5%) (Table 6).

The Early Stuart sockeye aggregate is composed of a single CU and is forecast to return at 41,000, (80% PI [18,000- 92,000]). This return is forecast based on a Ricker model with the Entrance Island sea surface temperature as an environmental covariate (Table 1A). The return is driven mostly by the low escapement in 2014 and 2015 (Table 1B), as the sea surface temperature was near average at Entrance Island for the forecast period (Figure 3).

The Early Summer sockeye aggregate is composed of eleven CUs, which are divided into seven forecast stocks and four miscellaneous stocks (see Grant et al. in press for detailed descriptions of the CUs). The forecast for this management group is 465,000 (80% PI [112,000-1,753,000]). The individual forecast units within the management group are made with a variety of models (Table 1A). In general for this aggregate the lower than average forecast returns are driven by lower than average escapements (Table 1B). For some stocks in the early summer aggregate, where a large proportion of the return is expected to be age 5_2 fish returning from brood year 2014, a sibling model is used taking advantage of the relationship between age 4_2 and age 5_2 returns (Peterman 1982, DFO 2015, DFO 2016). Sibling models are used for forecasting the Upper Barrier (Fennel), Pitt, Scotch, and Seymour forecast groups.

The Summer sockeye aggregate is composed of six CUs divided into six forecast stocks and three miscellaneous stocks (see Grant et al. in press for detailed descriptions of the CUs). The forecast for this management group is 3,930,000 (80% PI [1,553,000-11,187,000]). The individual forecast units within the management group are made with a variety of models (Table 1A). In general for this aggregate the higher than average forecast returns are driven by higher than average escapements (Table 1B). For the 2019 forecast the Quesnel return is expected to have a large contribution of age 5_2 fish returning from brood year 2014; because of this a sibling model was again used to take advantage of the relationship between age 4_2 and 5_2 returns.

The Chilko stock is unique in the Summer run aggregate because in addition to the escapement time series, there is a long time series of smolt outmigration observations that are used to generate the forecast. There is an alternative Larkin model that could be used to forecast the Chilko. The Larkin model predicts significantly different and lower return for the Chilko stock (Appendix 2 pg. 42). There were 71 million smolts estimated to leave Chilko Lake in 2015. This is more than twice the cycle average (31 million smolts), and reflects a high freshwater survival. Models using smolt data were favoured over models using effective female spawners or non-parametric models for the forecast which was consistent with past forecasts.

The Late sockeye aggregate is composed of six CUs represented in the forecast by five forecast stocks and one miscellaneous stock (see Grant et al. in press for detailed descriptions of the CUs). The forecast for this management group is 359,000 (80% PI [111,000-1,265,000]). The individual forecast units within the management group are made with a variety of models (Table 1A). In general for this aggregate the lower than average forecast returns are driven by lower than average escapements (Table 1B). For Late Shuswap and Weaver stocks, where a large proportion of the return was expected to be age 5_2 fish returning from brood year 2014, a sibling model was used taking advantage of the relationship between age 4_2 and 5_2 returns.

DISCUSSION

Recent performance of forecast models

Recent returns have come in below the median forecast (Table 5). In the last eight years the aggregate return has been less than the p50 value. This could be a result of many different factors (see Hilborn and Walters 1992 or Walters and Martell 2002 for a discussion of problems with stock-recruitment (SR) models), but points to the need for a re-evaluation of model performance. In the absence of this re-evaluation, and with the warm ocean conditions that have persisted since 2013, it is recommended that the p25 forecast results be considered in pre-season planning. Re-evaluation of model performance is overdue. It has been seven years since the last re-evaluation, and 3-4 years since an update to the stock-recruitment (SR) time series. The SR time series needs to be updated and a new retrospective model selection exercise undertaken to provide advice on the best performing forecast models. As part of this retrospective analysis quantitative comparisons of the performance of models that include sibling information needs to be done.

Environmental and ecosystem changes

Given the recent pattern of lower than long term average survivals, exploration of environmental predictors of marine (and freshwater) survival and advice for their use in forecasting salmon returns should be undertaken. Environmental variability or persistent long term changes in environmental conditions can lead to non-stationarity in stock recruitment parameters (Beamish and Mahnken 2001, Peterman And Dorner 2012). Being able to relate changes in marine survival to environmental indices would improve forecasts. With increasing uncertainty in freshwater and ocean environments there should be a renewed focus on collection of freshwater limnological data and juvenile sockeye assessment. Many authors have demonstrated the that for sockeye and other salmon juvenile rearing habitat and spawning area can be used to establish population capacity estimates (Hume et al. 2006, Cox-Rogers et al. 2004). Incorporating additional data sources should reduce uncertainty (Punt and Hilborn 1997, Maunder 2003, Gelman 2013,Thorsen and Cope 2017). Limnological and juvenile data are prerequisites for the types of informative priors that can be used to improve the ability to forecast returns. Given that climate change is expected to drive changes to lake rearing environments tracking these changes should reduce the lag in detecting both regime shifts or non-stationarity in stock recruitment parameters, improving forecasts.(Vert-pre et al. 2013, Perälä 2016)

TABLES

Table 1A. The 2019 Fraser River Sockeye forecasts. Forecasts are presented from their 10% to 90% probability levels (probability that returns will be at or below the specified run size). At the mid-point (median value) of the forecast distribution (50% probability level), there is a one in two chance the return will fall above or below the specified forecast value for each stock, based on the historical data. The model used to generate the forecast for each stock is in the second column.

Run timing group Stocks	Forecast Model [a]	Probability that Return will be at/or Below Specified Run Size				
		10%	25%	50%	75%	90%
Early Stuart	*Ricker (Ei)*	18,000	27,000	41,000	61,000	92,000
Early Summer		112,000	221,000	465,000	898,000	1,753,000
(total excluding miscellaneous)		76,000	140,000	277,000	557,000	1,059,000
Bowron	*Ricker (Pi)*	6,000	9,000	15,000	24,000	39,000
Upper Barriere (Fennell)	*PowerAge4 /SiblingAge5*	3,000	5,000	10,000	19,000	32,000
Gates	*Larkin*	12,000	22,000	41,000	81,000	152,000
Nadina	*MRJ*	29,000	59,000	129,000	283,000	576,000
Pitt	*LarkinAge4 /SiblingAge5*	13,000	20,000	34,000	57,000	90,000
Scotch	*LarkinAge4 /SiblingAge5*	4,000	9,000	19,000	38,000	75,000
Seymour	*LarkinAge4 /SiblingAge5*	9,000	16,000	29,000	55,000	95,000
Misc (EShu) [b]	*R/S*	30,000	68,000	156,000	253,000	448,000
Misc (Taseko) [c]	*R/S*	1,000	2,000	3,000	6,000	9,000
Misc (Chilliwack)	*Ricker*	2,000	5,000	17,000	59,000	195,000
Misc (Nahatlatch) [d]	*R/S*	3,000	6,000	12,000	23,000	42,000
Summer		1,553,000	2,454,000	3,930,000	7,048,000	11,187,000
(total excluding miscellaneous)		1,526,000	2,398,000	3,835,000	6,852,000	10,789,000
Chilko	*Power Juv (Pi)*	1,151,000	1,773,000	2,750,000	4,761,000	7,143,000
Late Stuart	*R1C*	6,000	14,000	39,000	105,000	256,000
Quesnel	*Ricker (Ei)Age4 /SiblingAge5*	100,000	177,000	333,000	687,000	1,207,000
Stellako	*Larkin*	175,000	261,000	368,000	572,000	848,000
Harrison [e]	*Ricker/Odd(Ei)*	71,000	140,000	293,000	646,000	1,205,000
Raft [e]	*Ricker(PDO)*	23,000	33,000	52,000	81,000	130,000
Misc (N. Thomp. Tribs) [e & f]	*R/S*	1,000	3,000	5,000	10,000	20,000
Misc (N. Thomp River) [e & f]	*R/S*	26,000	53,000	89,000	185,000	375,000
Misc (Widgeon) [g]	*R/S*	0	0	1,000	1,000	3,000
Late		111,000	189,000	359,000	669,000	1,265,000
(total excluding miscellaneous)		100,000	169,000	320,000	596,000	1,138,000
Cultus	*PowerJuv (Pi)*	0	0	1,000	2,000	3,000
Late Shuswap	*RickerCycAge4 /SiblingAge5*	11,000	26,000	61,000	140,000	325,000
Portage	*Larkin*	0	0	2,000	8,000	29,000
Weaver	*Ricker(PDO)Age4 /SiblingAge5*	7,000	13,000	27,000	55,000	116,000
Birkenhead	*Ricker (Ei)*	82,000	130,000	229,000	391,000	665,000
Misc Harrison/Lillooet [g]	*R/S*	11,000	20,000	39,000	73,000	127,000
TOTAL SOCKEYE SALMON		1,794,000	2,891,000	4,795,000	8,676,000	14,297,000
(TOTAL excluding miscellaneous)		1,720,000	2,734,000	4,473,000	8,066,000	13,078,000
TOTAL PINK SALMON	*Power(fry) SSS*	2,530,000	3,577,000	5,018,600	7,513,000	10,610,000

a. See Table 4 for model descriptions
b. Misc. Early Shuswap uses Scotch & Seymour R/EFS
c. Misc. Taseko uses Chilko R/EFS
d. Misc. Nahatlach uses Early summer-run stocks R/EFS
e. Raft, Harrison, Misc. North Thompson stocks moved to Summer run-timing group
f. Misc. North Thompson stocks use Raft & Fennel R/EFS
g. Misc. Late Run stocks (Harrison Lake down-stream migrants including Big Silver, Cogburn, etc.), and river-type Widgeon use Birkenhead R/EFS

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Table 1B. Fraser Sockeye brood year (BY) escapements (EFS, except smolts for Cultus) for the four (BY15) and five year old (BY14) recruits returning in 2019 are presented and colour coded relative to their cycle average from 1949-2015 brood years (columns C & D). Fraser Sockeye average run sizes are presented across all cycles (column F) and the 2019 cycle (column G) for each stock. Forecasted 2019 returns at the median (50%) probability level (column E) from Table 1A are colour coded relative to their cycle average. Color codes represent the following: red (< average), yellow (average) and green (> average), with the average range defined as average +/- 0.5 standard deviation of historical time series (See Table 1C).

Run timing group	BY15	BY14	FC RET	Mean Run Size	
Stocks	(EFS)	(EFS)	2019	All cycles[a]	2019 cycle[b]
Early Stuart	4,100	23,300	R	286,600	156,100
Early Summer (excl. misc.)				516,000	460,400
Bowron	2,200	6,300	R	33,900	68,700
Upper Barriere(Fennell)	900	6,800	R	23,000	27,700
Gates	9,600	8,500	Y	54,300	29,400
Nadina	9,400	30,700	G	77,500	76,000
Pitt	18,400	14,400	R	68,700	83,900
Scotch	3,500	68,800	Y	112,500	20,000
Seymour	4,000	57,400	R	146,100	154,700
Misc(EShu)	7,600	115,400			
Misc(Taseko)	500	50			
Misc(Chilliwack)	3,000	1,700			
Misc(Nahatlatch)	1,400	2,100			
Summer (excl. misc.)				3,953,500	2,333,500
Chilko	429,000	666,000	G	1,435,000	1,524,800
Late Stuart	4,400	27,900	Y	526,100	79,400
Quesnel	25,700	431,000	G	1,360,900	108,000
Stellako	47,600	240,400	Y	463,300	540,300
Harrison[c]	34,400	58,300	G	138,400	63,400
Raft	8,800	9,500	G	29,800	17,600
Misc(N. Thomp. Tribs)	500	800			
Misc (N. Thomp. River)	11,600	12,000			
Misc (Widgeon)	60	100			
Late (excl. misc.)				3,056,100	1,839,100
Cultus[d]	28,600	50,900	R	31,600	70,300
Late Shuswap	3,200	1,053,500	R	2,320,200	1,276,500
Portage	17	12,300	R	39,600	21,500
Weaver	1,100	10,400	R	329,700	174,300
Birkenhead	26,700	19,600	Y	335,000	296,500
Misc(Non-Shuswap)	5,300	3,600			
Total Sockeye Salmon (excl. misc)				7,812,200	4,789,100
Total Pink Salmon	Fry in 2017 192M			5,018,600	

a. Sockeye: 1953-2014 (start of time series varies across stocks)
b. Sockeye: 1955-2013 (start of time series varies across stocks)
c. 2014 brood year is presented in the 2016 brood year column
d. Cultus brood year smolts presented in columns C & D (not EFS)

Table 1C. Median forecasted Fraser Sockeye returns (p50) are presented and colour-coded relative to their cycle average from 1949-2015 brood years. Color codes represent the following: red (< average), yellow (average) and green (> average), with the average range defined as average +/- 0.5 standard deviation of historical time series.

	All Years	2019 Cycle Line			2019 FC (p50)	
Stock	Mean	Mean	Mn-0.5SD	Mn+0.5SD	Value	Colour
Early Stuart	292,761	157,234	78,116	236,351	41,000	RED
Early Summer					NA	
Bowron	36,218	70,898	36,995	104,800	15,000	RED
Upper Barriere (Fennell)	23,022	27,735	16,037	39,433	10,000	RED
Gates	54,304	29,355	15,280	43,430	41,000	YELLOW
Nadina	77,479	76,016	40,907	111,125	129,000	GREEN
Pitt	70,057	86,182	58,071	114,292	34,000	RED
Scotch	112,531	19,954	11,806	28,102	19,000	YELLOW
Seymour	141,090	149,334	91,079	207,589	29,000	RED
Summer					NA	
Chilko	1,395,040	1,471,120	1,019,359	1,922,880	2,750,000	GREEN
Late Stuart	518,594	78,376	28,169	128,583	39,000	YELLOW
Quesnel	1,281,929	101,261	866	201,655	333,000	GREEN
Stellako	460,569	534,963	298,072	771,854	368,000	YELLOW
Harrison	129,873	44,505	17,844	71,165	293,000	GREEN
Raft	30,800	19,449	9,457	29,442	52,000	GREEN
Late					NA	
Cultus	35,252	76,607	38,784	114,430	1,000	RED
Late Shuswap	2,329,677	1,229,317	642,783	1,815,852	61,000	RED
Portage	39,621	21,483	10,719	32,247	2,000	RED
Weaver	329,744	174,283	127,354	221,213	27,000	RED
Birkenhead	327,014	288,839	159,689	417,989	229,000	YELLOW

Table 2. For each of the 19 forecasted Fraser Sockeye stocks (column A), geometric average four-year old survivals (four year old recruits-per-EFS) are presented for the following: the entire time series (brood years: 1948-2012) (column B), the highest four consecutive years (column C), the 2005 brood year (one of the lowest survivals on record for all stocks) (column D), the most recent generation with recruitment data (2009-2012) (column E), and the most recent two years of available data (2011-2012) (column F). Cultus is presented as four year old recruits-per-smolt. Four-year old survivals associated with the various probability levels of the 2017 forecast (based on age-4 forecasts in Table 3 and escapements in Table 1B) are presented in columns (G) to (K) for comparison. Red (< average), yellow (average) and green (>average), with the average range defined as average +/- 0.5 standard deviation of historical time series.

A	B	C	D	E	F	G	H	I	J	K
	Total Survival: Four Year Old Recruits-Per-Effective Female Spawner (Smolt for Cultus)									
Run timing group Stock	Geo. Ave.[Y]	Peak Geo. Ave.[G]	2005 Brood Year[R]	Recent Gen. Geo Ave. (2009-2012	Recent Data Geo. Ave. (2011-2012)	2019 forecast four year old R/EFS for each probability level in Table 1A by stock				
						10%	25%	50%	75%	90%
Early Stuart	6.3	24.5	1.5	5.7[Y]	4.9[Y]	2.6	4.1	6.6	11	17.6
Early Summer										
Bowron	6.9	20.4	2.2	10.7[G]	19.5[G]	1.2	2.2	4	7.1	11.6
Upper Barriere	6.4	53.5	0.3	3.0[Y]	1.3[R]	2.3	4.3	8.7	16.6	28.1
Gates	10.0	41.0	1.6	5.6[Y]	2.8[R]	0.9	1.7	3.5	7.5	14.1
Nadina	6.1	13.5	1.0	5.2[Y]	3.9[R]	2	4	8.8	19.3	39.2
Pitt (age5 survival) [a]	3.4	13.3	0.2	3.3[Y]	1.6[R]	0.1	0.3	0.5	1	1.7
Scotch	6.5	21.5	2.2	2.4[R]	1.2[R]	1	1.9	4.3	9	17.9
Seymour	7.3	29.2	3.4	3.4[Y]	3.1[R]	2.1	3.5	6.3	11.4	18.8
Misc (Early Shuswap)	-	-	-	-	-	1.6	3.6	8.3	13.3	23.6
Misc (Taseko)	-	-	-	-	-	1.6	3.8	7	13	17.7
Misc (Chilliwack) [b &c]	2.5	NA	0.6	2.4[Y]	1.8[Y]	1.4	3.1	5.7	10.8	20.2
Misc (Nahatlatch) [c]	-	-	-		-	1.4	3.1	5.7	10.8	20.2
Summer										
Chilko	6.7	14.5	0.9	3.1[Y]	1.9[R]	2.2	3.5	5.7	10.2	15.7
Late Stuart	8.2	57.2	0.6	3.0[R]	2.2[R]	1	2.5	6.8	18.4	45
Quesnel [d]	11.3	18.1	0.3	3.5[Y]	6.7[Y]	2.1	4	8.1	18.4	33.4
Stellako	6.6	15.1	0.1	3.5[Y]	1.1[R]	1.5	2.5	4.1	6.7	11.7
Harrison[e]	3.3	33.8	0.1	1.8[R]	1.0[R]	0.4	1.1	2.9	7.5	16.4
Raft	5.7	13.6	0.4	6.4[Y]	5.6[Y]	1	1.9	3.5	6.4	10.9
Misc (N. Thomp.Tribs) [c]	-	-	-	-	-	1.7	3.3	5.6	11.6	23.5
Misc (N. Thomp River) [c]	-	-	-	-	-	1.7	3.3	5.6	11.6	23.5
Misc (Widgeon) [c]	-	-	-	-	-	1.4	2.7	5.1	9.7	16.8
Late										
Cultus (%R/smolt) [f]	4%	15%	1%	3%[Y]	3%[Y]	-	-	-	-	-
Late Shuswap [d]	6.4	10.8	2.8	18.7[G]	2.7[R]	1.1	2.5	6.2	14.1	36.1
Portage	11.6	61.7	0.3	3.5[R]	1.8[R]	1.3	2.9	7	17.8	39.1
Weaver	10.2	41.8	2.6	1.3[R]	0.2[R]	1.6	3.6	9.7	23.1	56.5
Birkenhead	5.0	21.5	1.2	1.3[R]	1.8[R]	1.4	2.5	5.4	10.9	20.4
Misc Lillooet-Harrison [c]	-	-	-	-	-	0.6	1.2	2.2	4.2	7.2

a. Pitt compares five year old survival;
b. Chilliwack recruitment data began in the 2001 brood year;
c. Naïve (non-biological) models do not have recruitment time series; so averages could not be compiled in columns B to F
d. Quesnel and Late Shuswap survivals are cycle averages;
e. Harrison is presented as total survival; forecast survival was not calculated due to the variability in ages
f. Cultus survivals are presented as marine survival (% recruits-per-smolt, 1.8 = 1.8 age4 from 100 smolts)

Table 3. Four and five year old and total 2019 Fraser Sockeye median (50% probability) forecasts for each stock. The four and five year old proportions of the total median forecast are presented in the final two columns.

Sockeye stock/timing group	2019 Fraser Sockeye Forecasts				
	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%[a]	TOTAL 50%[a]	Four Year Old Proportion	Five Year Old Proportion
Early Stuart	27,000	14,000	41,000	66%	34%
Early Summer					
Bowron	9,000	6,000	15,000	60%	40%
Upper Barriere (Fennell)	8,000	2,000	10,000	80%	20%
Gates	34,000	7,000	41,000	83%	17%
Nadina	83,000	46,000	129,000	64%	36%
Pitt	9,000	25,000	34,000	26%	74%
Scotch	15,000	4,000	19,000	79%	21%
Seymour	25,000	4,000	29,000	86%	14%
Misc (EShu)	63,000	94,000	156,000	40%	60%
Misc (Taseko)	3,000	40	3,000	99%	1%
Misc (Chilliwack)	17,000	4,000	21,000	83%	17%
Misc (Nahatlatch)	8,000	4,000	12,000	65%	35%
Summer					
Chilko	2,426,000	324,000	2,750,000	88%	12%
Late Stuart	30,000	9,000	39,000	77%	23%
Quesnel	207,000	126,000	333,000	62%	38%
Stellako	194,000	174,000	368,000	53%	47%
Harrison[b]	167,000	42,000	293,000	80%	20%
Raft	31,000	21,000	52,000	60%	40%
Misc (N. Thomp. Tribs)	3,000	2,000	5,000	65%	35%
Misc (N. Thomp River)	65,000	25,000	89,000	72%	28%
Misc (Widgeon)	300	480	780	38%	62%
Late					
Cultus	1,000	0	1,000	100%	0%
Late Shuswap	20,000	41,000	61,000	33%	67%
Portage	0	2,000	2,000	0%	100%
Weaver	11,000	16,000	27,000	41%	59%
Birkenhead	144,000	85,000	229,000	63%	37%
Misc(Non-Shuswap)	27,000	12,000	39,000	70%	30%
Total	3,627,300	1,089,520	4,798,780	64%	36%

a. Probability that actual return will be at or below specified run size

b. Harrison are four (in four year old columns) and three (in five year old columns) year old forecasts

Table 4. List of candidate models organized by their two broad categories (non-parametric/naïve and biological) with descriptions. Models are described in detail in Appendices 1 to 3 of Grant et al. (2010). Where applicable, models use effective female spawner data (EFS) as a predictor variable unless otherwise indicated by '(juv)' or '(smolt)' next to the model (Tables 1A), where fry data or smolt data are used instead.

MODEL CATEGORY	DESCRIPTION
A. Non-Parametric (Naïve) Models	
R1C	Return from 4 years before to forecast year
R2C	Average return from 4 & 8 years before the forecast year
RAC	Average return on the forecast cycle line for all years
TSA	Average return across all years
RS1 (or RJ1)	Product of average survival from 4 years before the forecast year and the forecast brood year EFS (or juv/smolt)
RS2 (or RJ2)	Product of average survival from 4 & 8 years before the forecast year and the forecast brood year EFS (or juv/smolt)
RS4yr (or RJ4yr)	Product of average survival from the last 4 consecutive years and the forecast brood year EFS (or juv/smolt)
RS8yr (or RJ8yr)	Product of average survival from the last consecutive 8 years and the forecast brood year EFS (or juv/smolt)
MRS (or MRJ)	Product of average survival for all years and the forecast brood year EFS (or juv/smolt)
RSC (or RJC)	Product of average cycle-line survival (entire time-series) and the forecast brood year EFS (or juv/smolt)
RS (used for miscellaneous stocks)	Product of average survival on time series for specified stocks and the forecast brood year EFS
B. Biological Models	
power	Bayesian
power-cyc	Bayesian (cycle line data only)
Ricker	Bayesian
Ricker-cyc	Bayesian (cycle line data only)
Larkin	Bayesian
Kalman Filter Ricker	Bayesian
Smolt-jack	Bayesian
Sibling model (4 year old)	Bayesian
Sibling model (5 year old)	Bayesian
C. Biological Models Covariates	(e.g. Power (FrD-mean))
FrD-mean	Mean Fraser discharge (April - June)
Ei	Entrance Island spring sea-surface temperature
Pi	Pine Island spring sea-surface temperature
FrD-peak	Peak Fraser Discharge
PDO	Pacific Decadal Oscillation
SSS	Sea Surface Salinity (Race Rocks & Amphitrite Point light house stations) from July to September

Table 5. The total Fraser Sockeye forecasts for 1998 to 2016 from the 10% to 90% p-levels. Note, all p-level values are not available for all years. The forecast value that corresponded to the actual return is highlighted. For returns that fell above the 50% p-level, the cells are highlighted green. For returns that fell at the 50% p-level, cells are highlighted yellow. Returns falling below the 50% p-level are highlighted orange, and below the 25% p-level are highlighted red. Since 2005 (past 12 years), total returns have fallen at or below the 50% p-level, with the exception of the 2010 returns. Returns for 2017 are preliminary based on in-season estimates only at the time of this publication.

Return Year	Forecast Probability Level						Actual Returns
	<10%	10%	25%	50%	75%	90%	
1998	NA	4,391,000	6,040,000	6,822,000	11,218,000[G]	18,801,000	**10,870,000**
1999	NA	3,067,000[R]	4,267,000	4,843,000	8,248,000	14,587,000	**3,640,000**
2000	NA	1,487,000	2,449,000	4,304,000[Y]	7,752,000	NA	**5,200,000**
2001	NA	3,869,000	6,797,000[O]	12,864,000	24,660,000	NA	**7,190,000**
2002	NA	4,859,000	7,694,400	12,915,900[Y]	22,308,500	NA	**15,130,000**
2003	NA	1,908,000	2,742,000	3,141,000[Y]	5,502,000[G]	9,744,000	**4,890,000**
2004	NA	1,858,000	2,615,000	2,980,000[Y]	5,139,000[G]	9,107,000	**4,180,000**
2005	NA	5,149,000[O]	8,734,000[O]	16,160,000	30,085,000	53,191,000	**7,020,000**
2006	NA	5,683,000	9,530,000[O]	17,357,000	31,902,000	56,546,000	**12,980,000**
2007	NA[R]	2,242,500	3,602,000	6,247,000	11,257,000	19,706,000	**1,510,000**
2008	NA	1,258,000[O]	1,854,000[O]	2,899,000	4,480,000	7,057,000	**1,740,000**
2009	NA[R]	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[G]	40,924,000	**28,250,000**
2011	NA	1,700,000	2,693,000	4,627,000[Y]	9,074,000	15,086,000	**5,110,000**
2012	NA	743,000	1,203,000	2,119,000[Y]	3,763,000	6,634,000	**2,050,000**
2013	NA	1,554,000	2,655,000	4,765,000[Y]	8,595,000	15,608,000	**4,130,000**
2014	NA	7,237,000	12,788,000	22,854,000[Y]	41,121,000	72,014,000	**20,000,000**
2015	NA	2,364,000[R]	3,824,000	6,778,000	12,635,000	23,580,000	**2,120,000**
2016	NA	814,000[R]	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	**1,487,000***
2018	NA	5,265,000	8,423,000	13,981,000	22,937,000	36,893,000	**10,725,000***
2019	NA	1,794,000	2,891,000	4,795,000	8,676,000	14,297,000	**-**

*preliminary return estimate in 2017 and 2018

Table 6. Stock composition of 2013-2015 Brood Years and 2019 Forecast (Excluding Miscellaneous Stocks). The 5 largest stocks in each column are highlighted in bold font, and the largest stock marked in red font.

Stock	2013 EFS	2014 EFS	2015 EFS	2019 FC Ret (p50)
Early Stuart	3.3%	0.8%	0.6%	0.9%
Early Summer				
Bowron	0.2%	0.2%	0.3%	0.3%
Upper Barriere (Fennell)	0.2%	0.2%	0.1%	0.2%
Gates	1.9%	0.3%	1.5%	0.9%
Nadina	0.6%	1.1%	1.4%	2.9%
Pitt	2.5%	0.5%	2.8%	0.8%
Scotch	0.9%	2.4%	0.5%	0.4%
Seymour	1.1%	2.0%	0.6%	0.7%
Summer				
Chilko	**51.5%**	**22.8%**	**65.3%**	**61.5%**
Late Stuart	**5.8%**	1.0%	0.7%	0.9%
Quesnel	**7.7%**	**14.7%**	**3.9%**	**7.4%**
Stellako	4.5%	**8.2%**	**7.2%**	**8.2%**
Harrison	**6.4%**	**8.1%**	**8.9%**	**6.5%**
Raft	0.7%	0.3%	1.3%	1.2%
Late				
Cultus	NA	NA	NA	NA
Late Shuswap	**7.2%**	**36.0%**	0.5%	1.4%
Portage	0.3%	0.4%	0.0%	0.0%
Weaver	1.3%	0.4%	0.2%	0.6%
Birkenhead	3.9%	0.7%	**4.1%**	**5.1%**
Total Number	1,214,000	2,925,000	657,000	4,471,000

Table 7. Overview of model selections for 2015, 2018 and 2019FC. Models that changed from 2018 to 2019 are highlighted. Note that in these cases the specific model changed, but the same criteria for selecting a model have been used. Appendix 2 lists the general criteria at the beginning, and then documents the stock-specific rationale.

	2015 Model	2018 Model	2019 Model
Early Stuart	*Ricker Ei*	*Ricker (Ei)*	*Ricker (Ei)*
Early Summer			
Bowron	*MRS*	*Ricker (Pi)*	*Ricker (Pi)*
Upper Barriere (Fennell)	*Power*	*Power*	***Power4/Sibling5***
Gates	*Larkin*	*Larkin*	*Larkin*
Nadina	*MRJ*	*MRJ*	*MRJ*
Pitt	*Larkin*	*Larkin*	***Larkin4/Sibling5***
Scotch	*Ricker*	*Larkin*	***Larkin4/Sibling5***
Seymour	*Ricker*	*RickCyc*	***Larkin4/Sibling5***
Misc (EShu)	*R/S*	*R/S*	*R/S*
Misc (Taseko)	*R/S*	*R/S*	*R/S*
Misc (Chilliwack)	*R/S*	*Ricker*	*Ricker*
Misc (Nahatlatch)	*R/S*	*R/S*	*R/S*
Summer			
Chilko	*Power Juv (Pi)*	*4-PowJuvPi / 5-Sibling*	***Power Juv (Pi)***
Late Stuart	*Power*	*R1C*	*R1C*
Quesnel	*Ricker-Cyc*	*Ricker (Ei)*	***Ricker (Ei)4 /Sibling5***
Stellako	*Larkin*	*Larkin*	*Larkin*
Harrison	*Adj. RS1*	*3-Ricker; 4-sibling*	***Ricker (Ei) odd***
Raft	*Ricker (PDO)*	*Ricker (PDO)*	*Ricker (PDO)*
Misc (N. Thomp. Tribs)	*R/S*	*R/S*	*R/S*
Misc (N. Thomp River)	*R/S*	*R/S*	*R/S*
Misc (Widgeon)	*R/S*	*R/S*	*R/S*
Late			
Cultus	*MRJ*	*Power (juv) (Pi)*	*PowerJuv (Pi)*
Late Shuswap	*Ricker Cyc*	*Ricker Cyc*	***Ricker Cyc4 /Sibling5***
Portage	*Larkin*	*Larkin*	*Larkin*
Weaver	*MRS*	*Ricker (PDO)*	***Ricker (PDO)4 /Sibling5***
Birkenhead	*Ricker (Ei)+silbling*	*Ricker (Ei)*	*Ricker (Ei)*
Misc(Non-Shuswap)	*R/S*	*R/S*	*R/S*

FIGURES

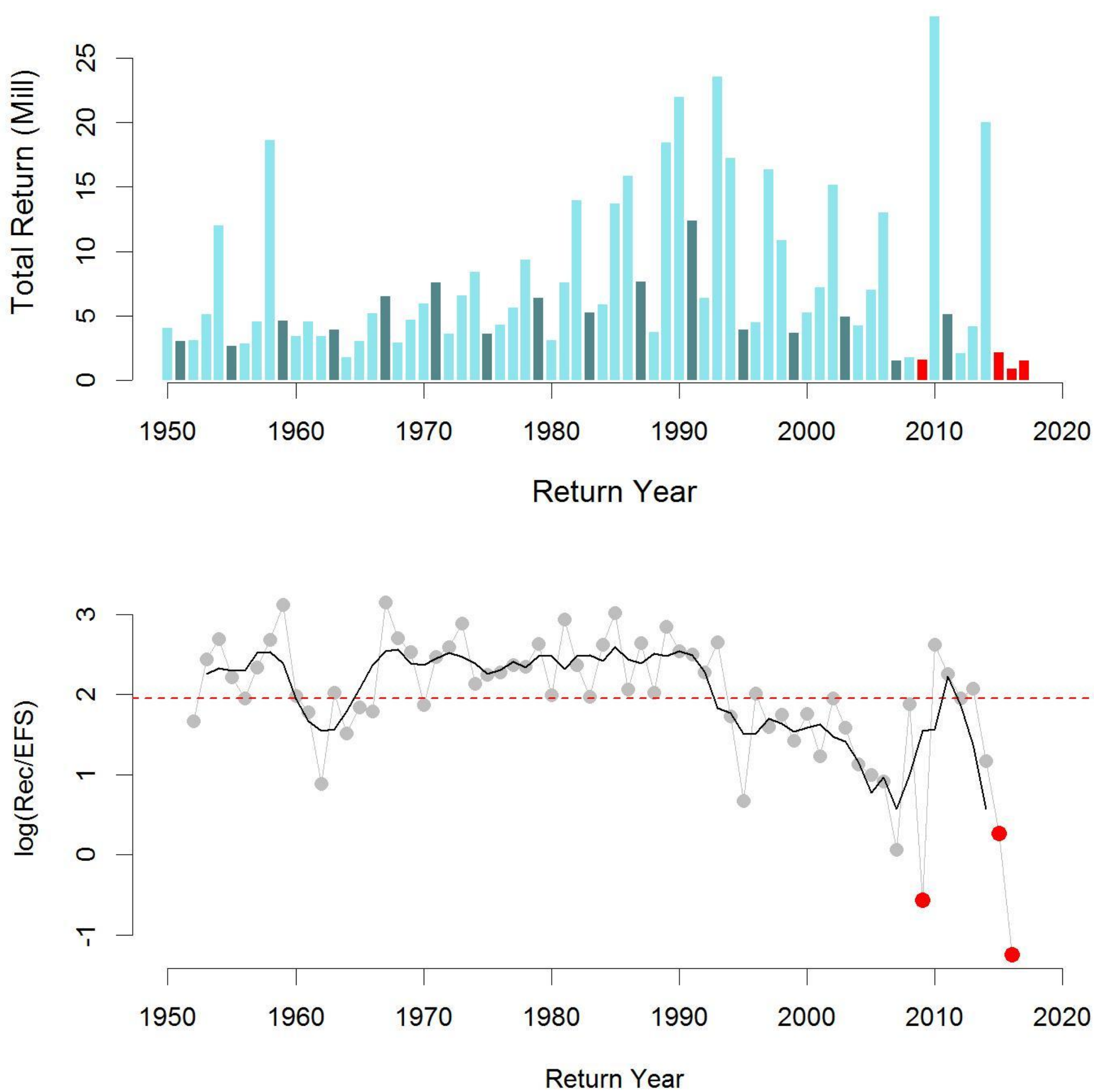

Figure 1. Total returns and overall survival rate of Fraser Sockeye. Top panel shows total adult annual returns (dark blue vertical bars for the 2019 cycle and light blue vertical bars for the three other cycles). Adult returns from 2018 are preliminary. Bottom panel shows overall Fraser Sockeye adult survival (log_e(recruits / effective females) up to the 2015 return year for the 19 stocks with long time series of spawner and recruit estimates. The light grey filled circles and lines present annual survival and the black line presents the smoothed four year running average. The dashed horizontal red line is the time series average. In both panels, the 2009, and 2015-2017 returns (low survival) are highlighted in red.

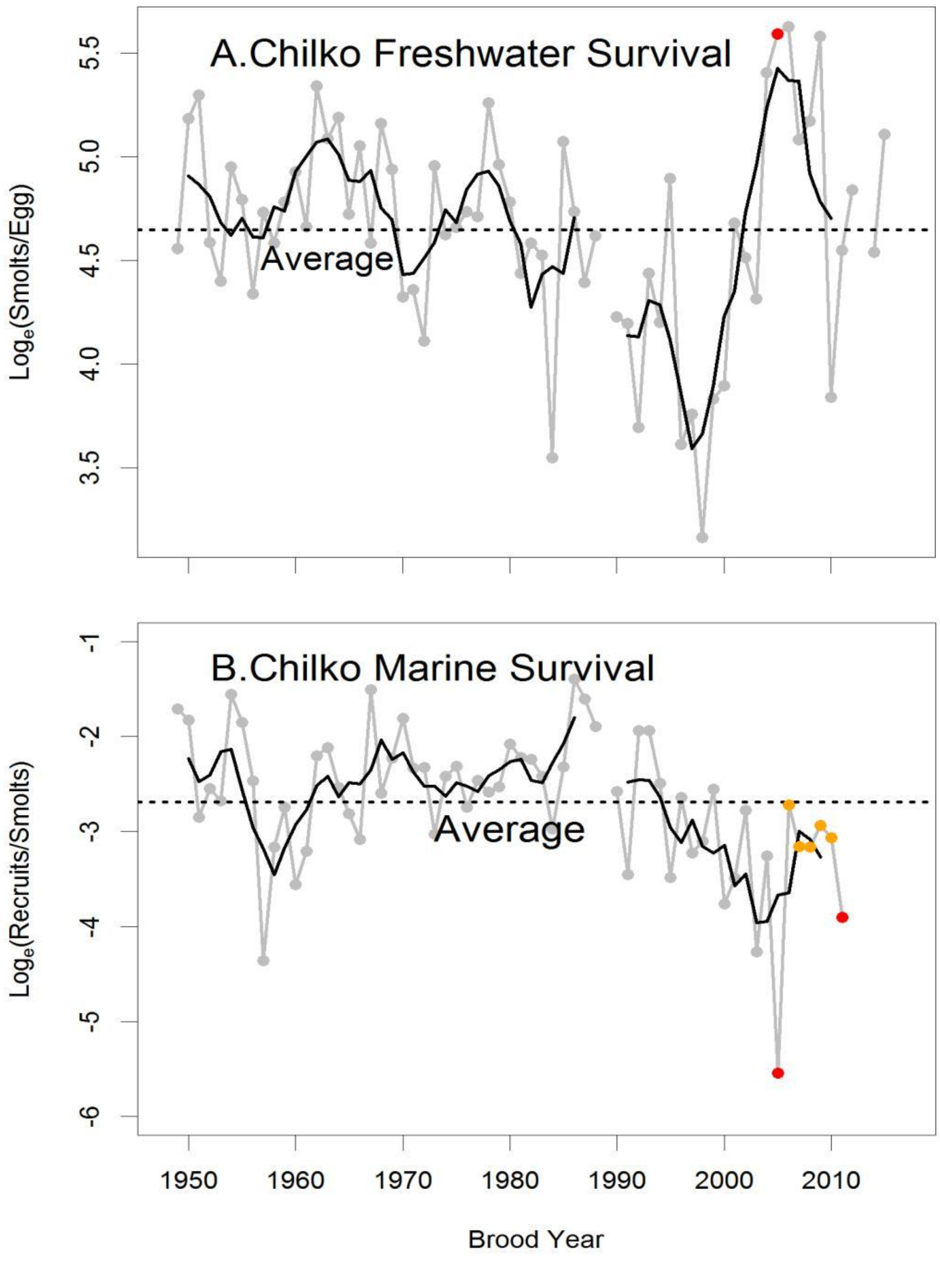

*Figure 2. Chilko River Sockeye **A**. annual freshwater (log$_e$ smolts/egg) survival (filled grey circles and lines); the red filled circle represents the 2005 brood year (2009 returns); note no smolt assessment was conducted in the 2013 brood year representing a gap in the current 2017 Chilko forecast process; **B**. annual 'marine' (log$_e$ recruits/smolt) survival (filled grey circles and lines) with the 2005 brood year survival indicated by the first red filled circle. 'Marine survival' includes the period of time smolts spend migrating from the outlet of Chilko Lake (where they are enumerated) to when they return as adults and includes their downstream migration in the Fraser River as smolts. The 2006 to 2010 brood year survivals are indicated by the amber filled circles and the preliminary 2011 and 2012 brood year survivals are indicated by the final red filled circles. The black line in both figures represents the smoothed four-year running average survival and the black dashed lines indicate average survival. Note that this figure has not been updated from the 2017 forecast paper, because the 2013 juvenile abundance estimate is not available.*

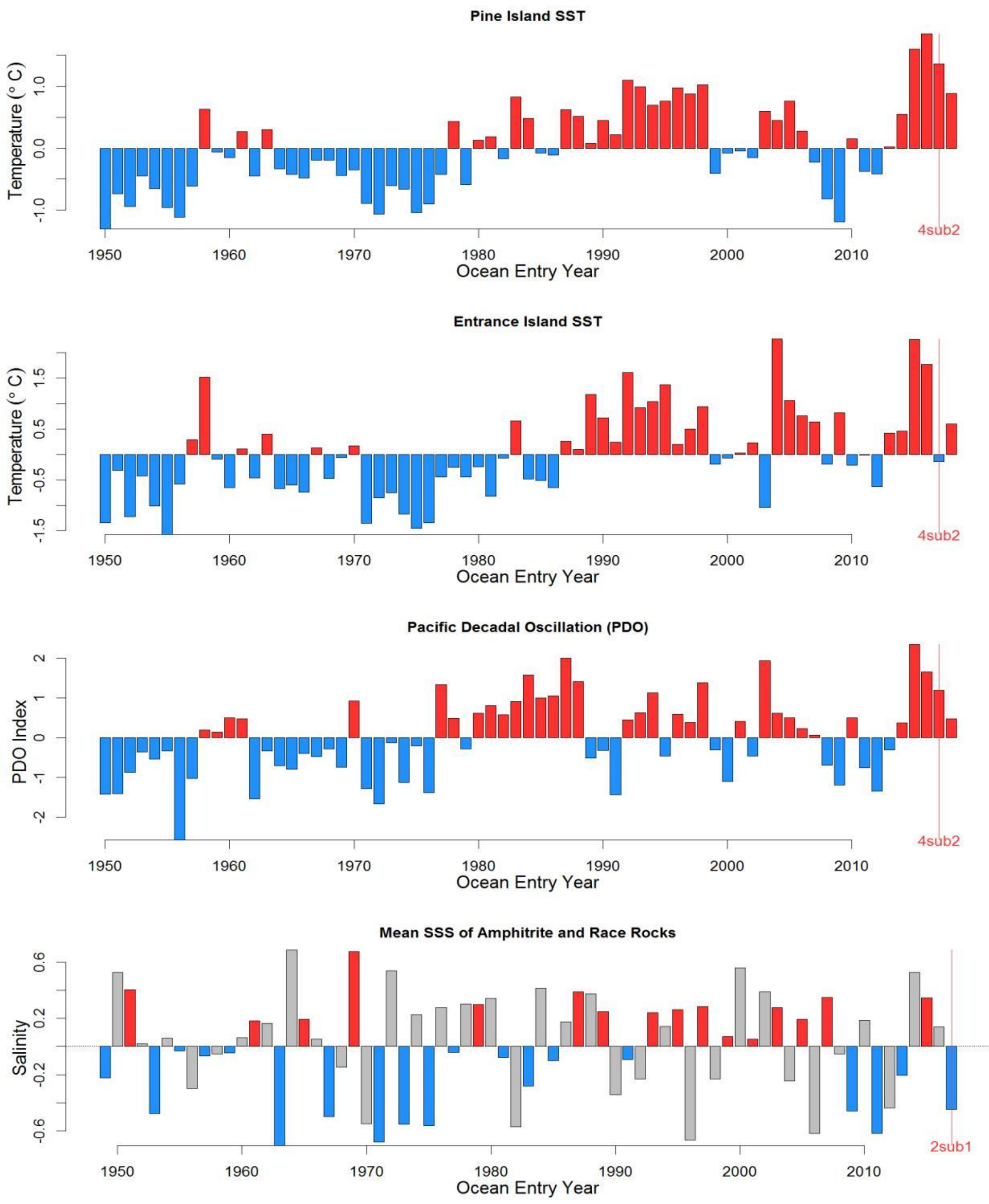

Figure 3. Sea surface temperatures (SST) measured at Entrance Island (Strait of Georgia) (April-June average), Pine Island (Queen Charlotte Strait) (April-July average),standardized winter PDO index (Nov-March), and averaged sea surface salinity (SSS) of Amphitrite and Race Rocks (July-September). Temperatures are presented as raw deviations from time-series averages (1950-2015). The 2016 ocean entry year, highlighted with a red vertical line, marks the temperature anomalies that most Fraser Sockeye from the 2015 brood year entered into upon outmigration as smolts (i.e. a 4_2 life cycle). Red bars (positive values) indicate warm temperature anomalies (above average) and blue bars (negative values) indicate cool temperature anomalies (below average). The grey bars of mean SSS were even year data which wasn't used in the model.

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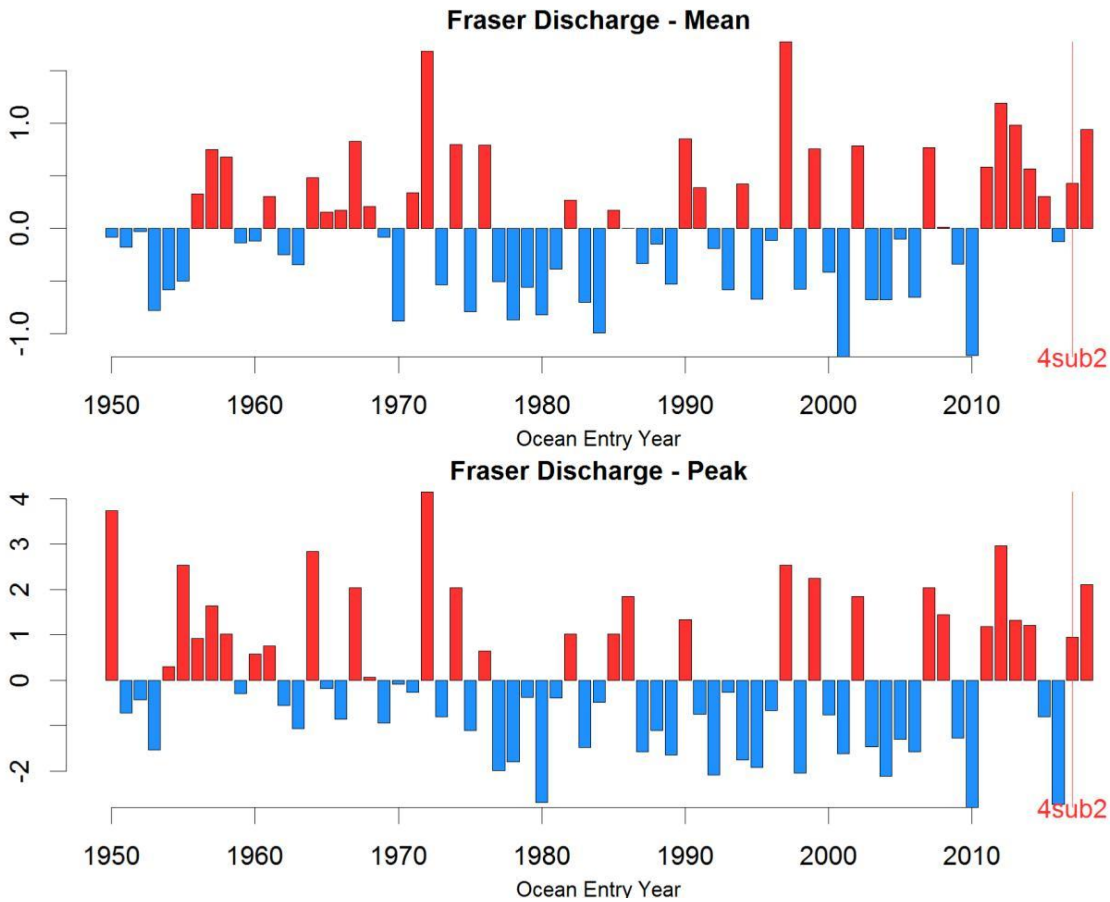
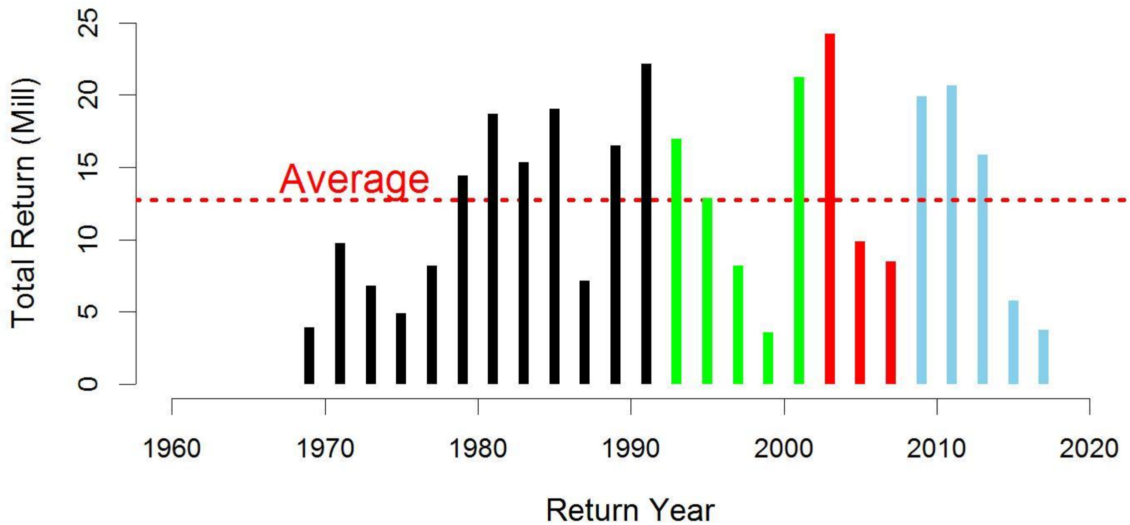


Figure 4. Fraser River discharge shown as mean conditions over April-June and peak discharge. Values are presented as raw deviations from time-series averages (1950-2016). The 2017 ocean entry year, highlighted with a red vertical line, marks the temperature anomalies that most Fraser Sockeye from the 2015 brood year entered into upon outmigration as smolts (i.e. a 4_2 life cycle). Red bars (positive values) indicate warm temperature anomalies (above average) and blue bars (negative values) indicate cool temperature anomalies (below average).



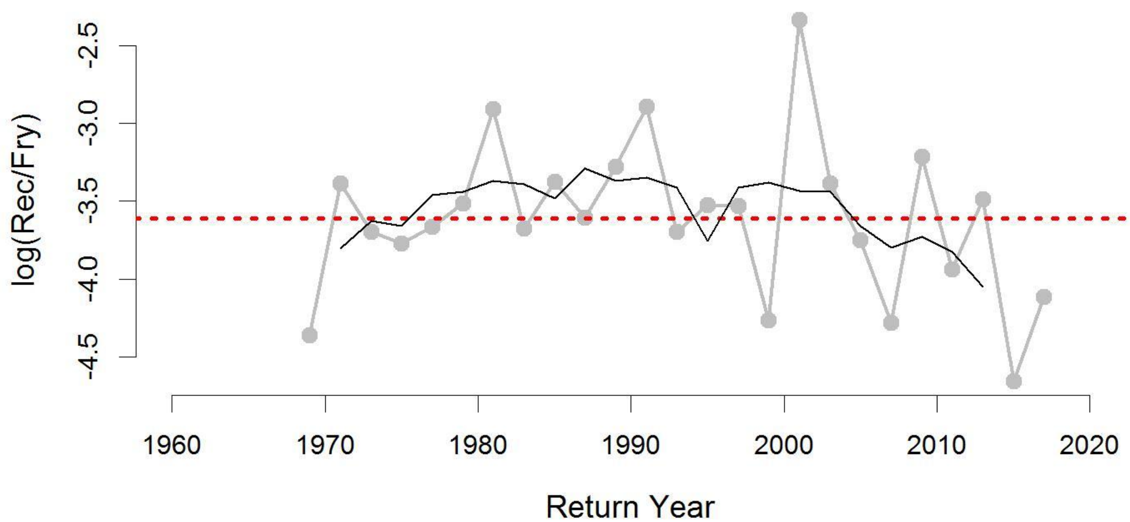


Figure 5. **Upper Panel**. Fraser River Pink Salmon returns (black or coloured bars) estimates. Escapement estimates were generated from system-specific programs from 1957 to 1991 (black bars), system-wide single mark recaptures from 1993 to 2001 (green bars), indirect system-wide marine test fisheries estimates from 2003 to 2007 (red bars), and system-wide hydroacoustic estimate from 2009 to 2017 (blue bars). Given the lack of calibration work between methods, escapement estimates between years are not entirely comparable. The red dashed line is the average Pink return (12.7 M); **Bottom Panel**. Fraser Pink marine survival (recruits-per-fry) from the 1967 to 2017 brood years; these estimates are uncertain and not entirely comparable inter-annually due to differences in return (catch and escapement) estimation methods over time. The red dashed line is the average survival (3%).

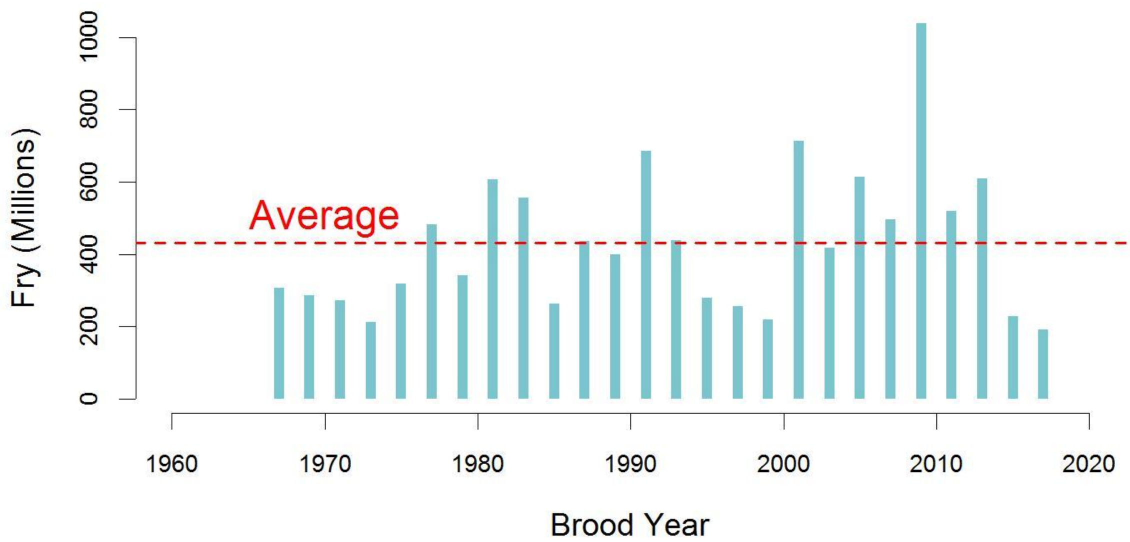


Figure 6. Fraser River Pink Salmon fry abundance. The 2017 fry abundance (192 million), which is the brood year for 2019 returns, is the last bar in the figure. The average fry abundance over the time series is 432 million (dashed red line).

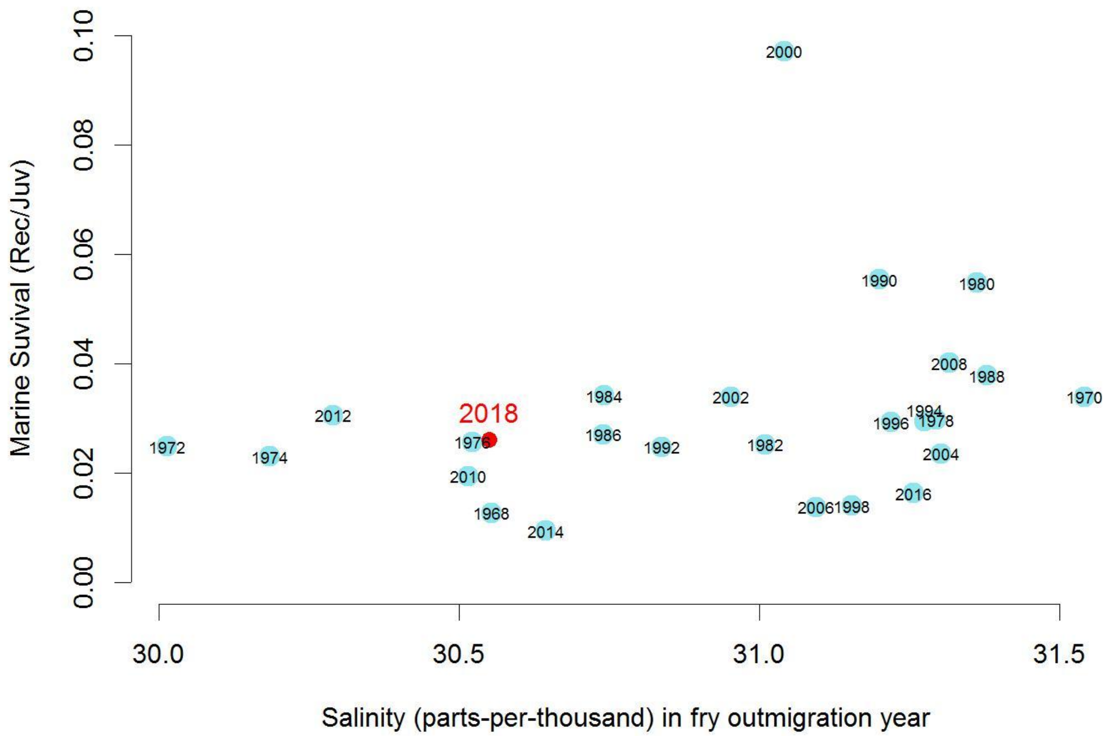


Figure 7. Fraser Pink marine survival (returns/fry) versus salinity (parts-per-thousand: ppt) in the Strait of Georgia in the pink fry outmigration year. The 2018 salinity estimate that coincides with the 2019 returning Fraser pink ocean entry year is indicated.

CONTRIBUTORS

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APPENDIX 1. STOCK GROUP DATA SUMMARIES

Early Stuart (Takla-Trembleur-Early Stuart CU)

Run Timing Group	Escapement				2015 Stock Contributions
Early Stuart	Avg	Cyc.Avg	BY(2015)	BY Trend[a]	Early Stuart
All stocks[b]	40,200	24,000	4,100	UP	100%

a. Trend refers to change from previous brood year (2011)

b. Escapement and cycle year average 1951-2015

Early Summer

Run Timing Group	Escapement				2015 Stock Contributions										
Early Summer	Avg	Cyc.Avg	BY(2015)	BY Trend[a]	Bowron	Seymour	Fennel	Scotch	Gates	Nad ina	Pitt	South Thom	Taseko	Chilli wack	Nahat latch
Primary stocks[b]	62,000	57,900	48,100	DOWN	5%	8%	2%	7%	20%	20%	38%	NA	NA	NA	NA
Total (including misc.)[c]	152,800	72,700	60,500	DOWN	4%	6%	2%	6%	16%	15%	30%	12%	1%	4%	6%

a. Trend refers to change from previous brood year (2011)

b. Escapement and cycle year average 1951-2015

c. Escapement and cycle year average 2003-2015

Summer

Run Timing Group	Escapement				2015 Stock Contributions								
Summer	Avg	Cyc.Avg	BY (2015)	BY Trend[a]	Late Stuart	Stellako	Raft	Quesnel	Chilko	Harrison	North Thom. Trib	North Thom. Riv	Widgeon
Primary stocks[b]	570,400	372,200	573,800	DOWN	1%	8%	2%	4%	75%	10%	NA	NA	NA
Total (including misc.)[c]	762,500	585,900	586,000	DOWN	1%	8%	2%	4%	74%	10%	0%	0%	0%

a. Trend refers to change from previous brood year (2011)

b. Escapement and cycle year average 1951-2015

c. Escapement and cycle year average 2003-2015

Late

Run Timing Group	Escapement				2015 Stock Contributions					
Late	Avg	Cyc.Avg	BY (2015)	BY Trend[a]	Late Shuswap	Birkenhead	Portage	Weaver	NonShu Harrison	Cultus[d]
Primary stocks[b]	413,500	223,100	31,000	DOWN	10%	86%	0%	4%	NA	--
Total (including misc.)[c]	515,200	172,400	36,300	UP	8%	71%	0%	3%	17%	--

a. Trend refers to change from previous brood year (2011)

b. Escapement and cycle year average 1951-2015

c. Escapement and cycle year average 2003-2015

d. Cultus Is not included because only juvenile data are used for this stock

APPENDIX 2. INDIVIDUAL STOCK FORECAST SUMMARIES

GENERAL MODEL SELECTION CRITERIA

Unless otherwise noted, models were selected for each stock using the following process:

1) For each stock, models are ranked according to their relative performance on each of four performance measures (MRE, MAE, MPE & RMSE). Ranks across the four performance measures are then averaged to generate an average rank for each model evaluated (See Table 5 in MacDonald & Grant 2012). Forecasts are generated for the top three ranked models for each stock (based on their average rank);
2) To ensure that selected models do not perform poorly on individual performance measures, top ranked models for each stock are evaluated for consistent performance across each of the four performance measures (MRE, MAE, MPE & RMSE). For each stock, models that do not consistency rank within the top half of all models (e.g. if 20 models were evaluated, the models must rank within the top 10) on each performance measure (i.e. MRE, MAE, MPE and RMSE) are generally not considered. There are individual cases where this criterion is relaxed; these are indicated;
3) Brood year escapements (or juvenile abundances) for each stock are compared to stock-specific cycle averages. If the brood year escapement (or juvenile abundance) falls above or below the cycle average range (+/- one standard deviation from the mean), only top ranked models that use EFS (or juveniles) as a predictor variable are considered;
4) In cases where the top ranked forecast was a Ricker, power (juvenile), or non-biological model, and a temperature covariate model (Ricker (Ei), Ricker (Pi), or Ricker (PDO)) ranks within the top three models, the forecasting performance of the covariate model specifically in warmer than average years is examined (Appendix 3 of DFO 2017). If these models rank superior under extreme conditions (e.g. periods of high SST), and there is a consistent signal in terms of forecasted survival implied by the addition of the covariate across the applicable stocks, temperature covariate forecasts are adopted for these stocks;
5) Error checks include a comparison of stock-specific forecasts across all top-ranked models to investigate mechanisms underlying similarities and differences in forecasts. In addition, the four year old survivals associated with each forecast are compared to averages for each stock, to analyze where forecast survivals fall out in terms of recent and long-term observations.

Early Stuart (Takla-Trembleur-Early Stuart CU) - Early Stuart MU

Early Stuart		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	54%	54%	51%
Summary	Spawner Success	89%	75%	88%	67%
	EFS	24,000	4,100	18,700	23,300

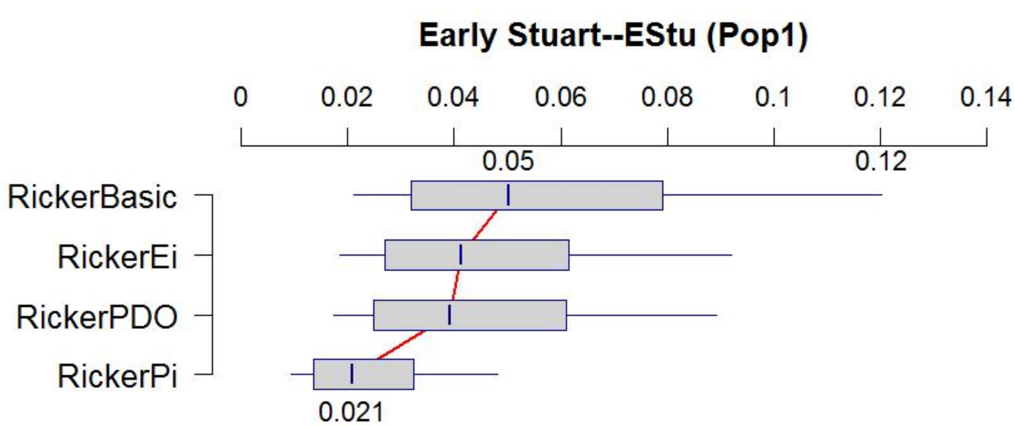
a.Brood years 1951-2015

b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
RickerBasic	3	21,000	32,000	50,000	79,000	120,000	2.3	3.7	6.2	10.4	18.6
RickerEi60k	1	18,000	27,000	41,000	61,000	92,000	2.6	4.1	6.6	11	17.6
RickerPDO40k	3	17,000	25,000	39,000	61,000	89,000	2	3.1	5	8.7	14.6
RickerPi	1	9,000	14,000	21,000	32,000	48,000	1.1	1.8	3	4.9	7.9

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



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Bowron (Bowron-ES) – Early Summer Mgmt Unit

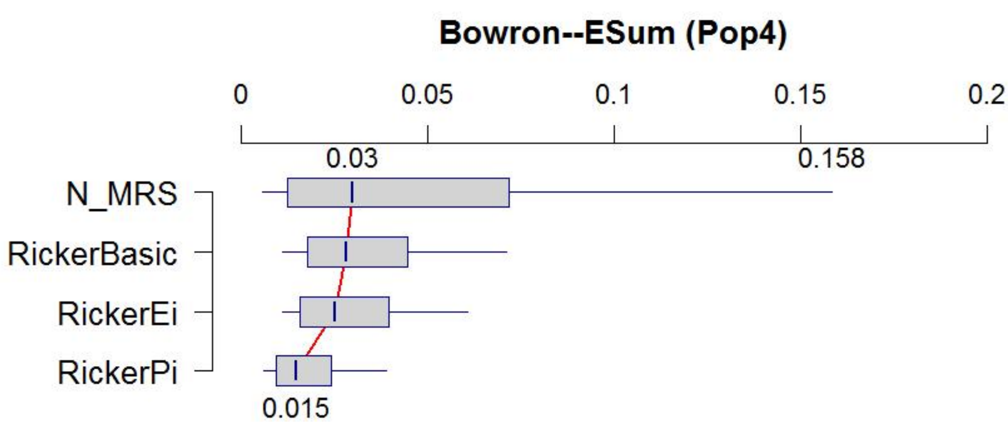
Bowron		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	53%	64%	55%	55%
Summary	Spawner Success	87%	90%	92%	95%
	EFS	7,800	2,200	3,300	6,300

a.Brood years 1951-2015   b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_MRS	1	6,000	12,000	30,000	72,000	158,000	1.9	4.3	10.3	24.8	54.7
RickerBasic	11	11,000	17,000	29,000	44,000	69,000	2.1	3.8	7.2	12.5	21.1
RickerEi60k	3	10,000	16,000	25,000	40,000	59,000	2.2	3.8	7	12.4	21.2
RickerPi80k	2	6,000	9,000	15,000	24,000	36,000	1.3	2.3	4	7.1	12.5

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017291

Fennel (North Barriere CU) – Early Summer Mgmt Unit

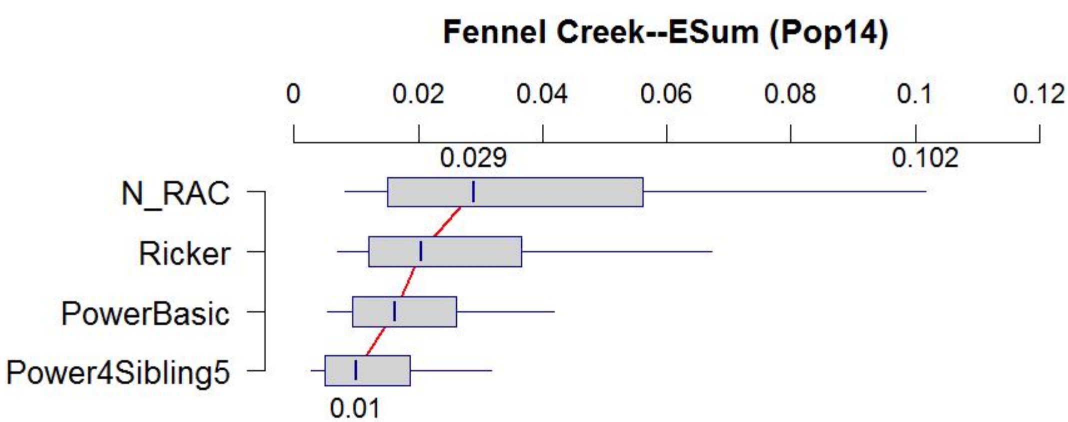
Fennel		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	57%	68%	63%	61%
Summary	Spawner Success	95%	98%	96%	98%
	EFS	4,700	900	3,700	6,800

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_RAC	2	8,000	15,000	29,000	56,000	102,000	6.7	12.2	23.6	45.7	82.7
Ricker1Mill	3	7,000	12,000	21,000	37,000	67,000	2.9	6.2	12.3	25.4	49.8
PowerBasic	1	5,000	9,000	16,000	26,000	42,000	2.3	4.3	8.7	16.6	28.1
Power4Sibling5	99	3,000	5,000	10,000	19,000	32,000	2.3	4.2	8.5	16.2	27.9

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017292

Gates (Anderson-Seton-ES CU) – Early Summer Mgmt Unit

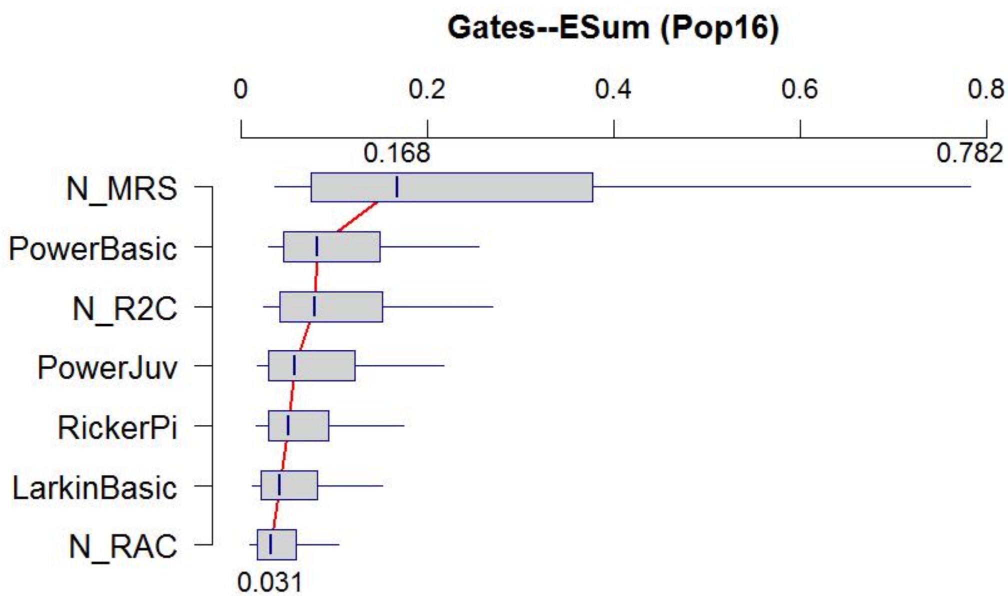
Gates		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	62%	57%	61%	63%
Summary	Spawner Success	77%	93%	77%	85%
	EFS	5,300	9,600	2,200	8,500

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_MRS	3	36,000	75,000	168,000	377,000	782,000	3.5	7.2	16.3	36.6	75.8
PowerBasic	6	29,000	46,000	81,000	149,000	255,000	2.1	3.6	7.2	13.9	24.7
N_R2C	2	23,000	42,000	79,000	151,000	269,000	2.2	4	7.5	14.3	25.6
PowerJuv	99	17,000	30,000	58,000	122,000	217,000	1	2.2	4.7	11.1	21.1
RickerPi	6	16,000	29,000	51,000	94,000	174,000	1.3	2.4	4.7	9	17.4
LarkinBasic	3	12,000	22,000	41,000	81,000	152,000	0.9	1.7	3.5	7.5	14.1
N_RAC	1	9,000	17,000	31,000	59,000	105,000	0.9	1.6	3	5.6	10

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



Nadina (Nadina-Francois-ES CU) – Early Summer Mgmt Unit

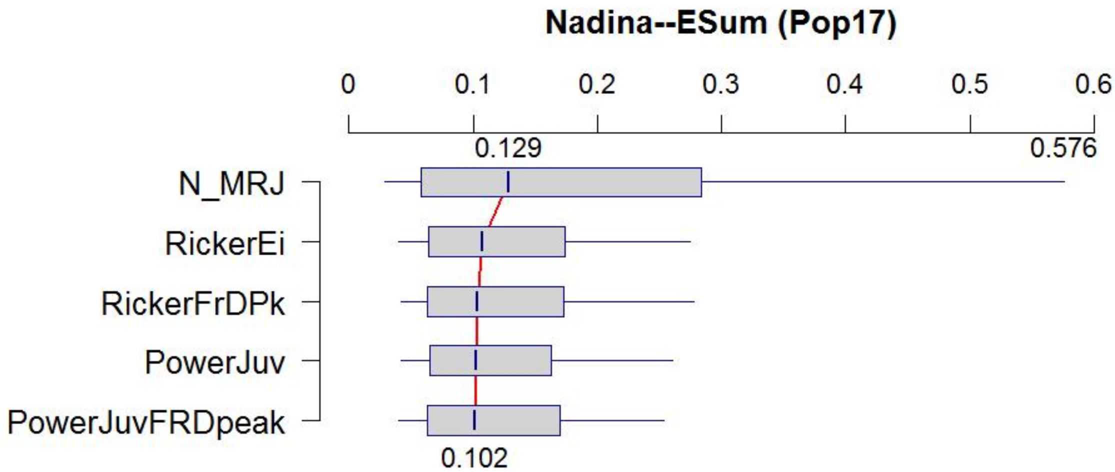
Nadina		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	52%	41%	58%	57%
	Spawner Success	82%	67%	87%	88%
	EFS	11,100	9,400	5,600	30,700
	Freshwater Surv.(fry/EFS)	1,100	1,200	1,400	900
	Fry Abundance	11M	11M	7M	26M

a.Brood years 1975-2015
b. Brood years 1974-2014

Top Ranked Forecasts - Table

Model	Rank	Forecasted Return 10%	25%	50%	75%	90%	Forecasted Age4 Survival 10%	25%	50%	75%	90%
N_MRJ	1	29,000	59,000	129,000	283,000	576,000	2	4	8.8	19.3	39.2
RickerEi	17	41,000	64,000	106,000	178,000	277,000	2	3.5	6.6	11.9	19.2
RickerFrDPk60k	2	40,000	62,000	106,000	170,000	257,000	1.8	3	5.2	9	16.1
PowerJuv	9	41,000	65,000	103,000	165,000	260,000	2.4	4	6.9	12	20.1
PowerJuvFRDpeak	2	39,000	64,000	103,000	159,000	245,000	2.2	3.7	6.5	11.4	19.4

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



Pitt (Pitt-ES CU) – Early Summer Mgmt Unit

Upper Pitt		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	47%	52%	48%
Summary	Spawner Success	94%	98%	90%	80%
	EFS	14,900	18,400	13,800	14,400

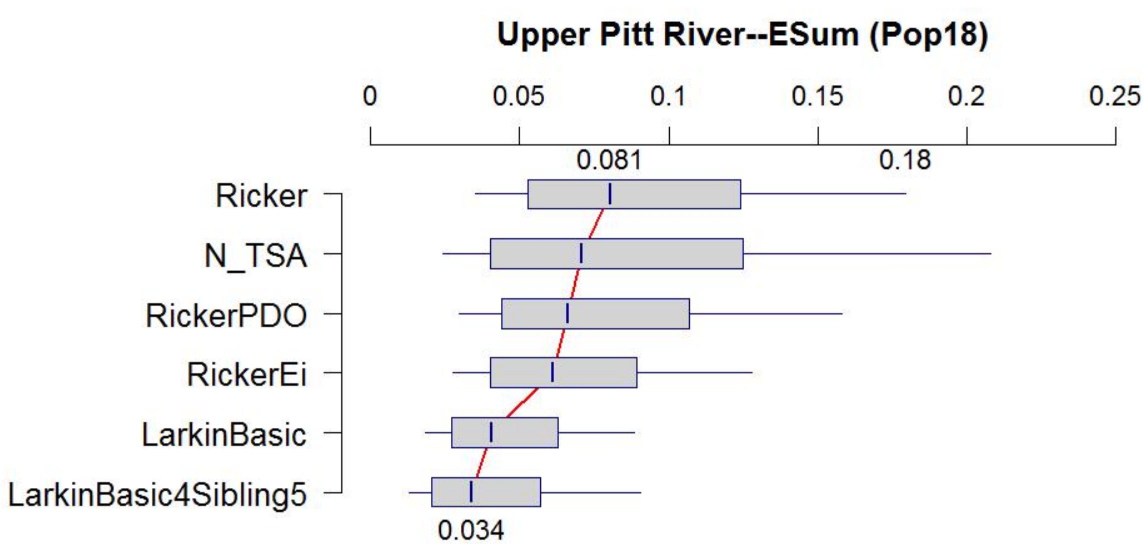
a.Brood years 1951-2015

b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Ricker100k	9	35,000	53,000	81,000	124,000	180,000	0.2	0.4	0.8	1.5	2.6
N_TSA	2	24,000	40,000	71,000	125,000	208,000	0.5	0.9	1.6	2.7	4.6
RickerPDO40k	3	30,000	44,000	66,000	107,000	158,000	0.2	0.3	0.7	1.3	2.3
RickerEi	4	28,000	40,000	61,000	89,000	128,000	0.2	0.4	0.8	1.4	2.5
LarkinBasic	1	19,000	27,000	40,000	63,000	88,000	0.1	0.3	0.5	1	1.7
Larkin4Sibling5	99	13,000	20,000	34,000	57,000	90,000	0.1	0.3	0.5	1	1.8

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



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Scotch (Part of Shuswap-ES CU) – Early Summer Mgmt Unit

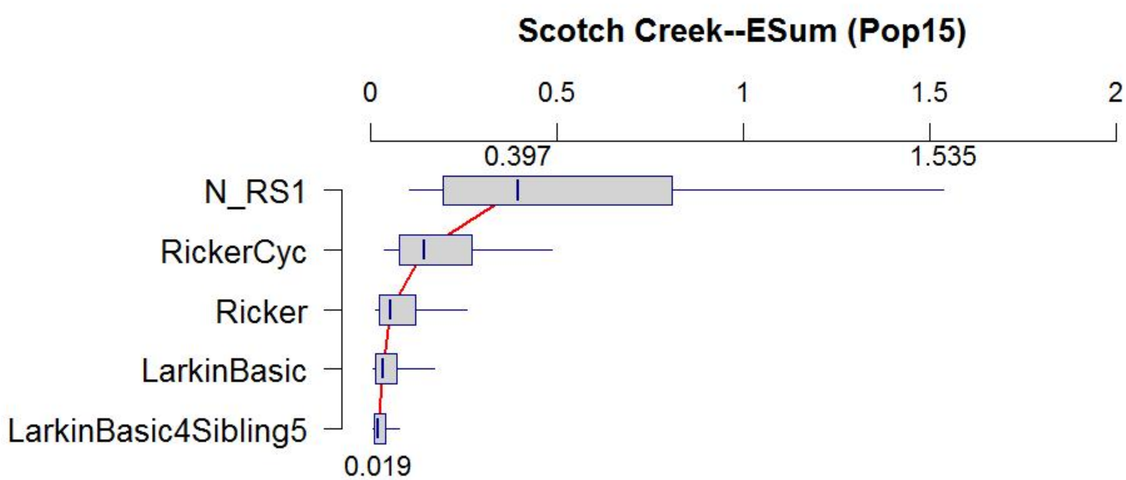
Scotch		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	55%	54%	55%
Summary	Spawner Success	87%	97%	92%	93%
	EFS	4,300	3,500	62,000	68,800

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_RS1	3	102,000	195,000	397,000	809,000	1,535,000	1.7	3.2	6.5	13.2	25
RickerCyc40k	99	37,000	75,000	144,000	269,000	485,000	0.5	1.3	4	11.9	33.9
Ricker40k	2	11,000	23,000	52,000	118,000	258,000	1.5	3.2	7.3	17.8	35
LarkinBasic	1	7,000	14,000	32,000	70,000	169,000	1	1.9	4.3	9	17.9
Larkin4/Sibling5	99	4,000	9,000	19,000	38,000	75,000	1	1.9	4.3	9	17.9

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



Seymour (Part of Shuswap-ES CU) – Early Summer Mgmt Unit

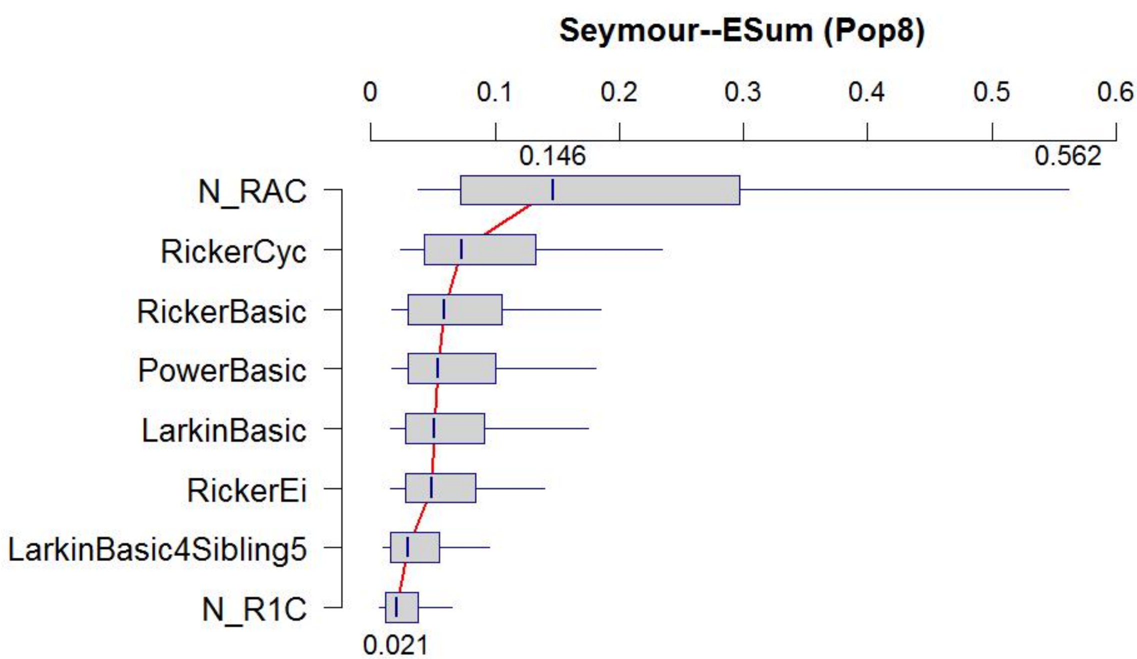
Seymour		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	51%	51%	51%	55%
Summary	Spawner Success	93%	98%	94%	93%
	EFS	18,400	4,000	49,700	57,400

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts – Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_RAC	4	38,000	72,000	146,000	297,000	562,000	8.7	16.5	33.5	68	129
RickerCyc80k	99	24,000	43,000	74,000	133,000	235,000	1.2	2.8	7.2	16.6	36.8
RickerBasic	8	17,000	30,000	59,000	105,000	185,000	2.4	4.1	7.8	15.6	27.4
PowerBasic	99	17,000	30,000	54,000	100,000	181,000	2.3	4.1	7.5	14.8	27
LarkinBasic	2	16,000	28,000	51,000	92,000	174,000	2.1	3.5	6.3	11.4	18.8
RickerEi	5	16,000	28,000	49,000	85,000	139,000	2.7	4.5	8.3	15.5	26.6
Larkin4/Sibling5	99	9,000	16,000	29,000	55,000	95,000	2.1	3.5	6.3	11.4	18.8
N_R1C	2	7,000	12,000	21,000	38,000	65,000	1.6	2.7	4.8	8.7	14.9

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017297

Chilko (Chilko-S CU) – Summer Mgmt Unit

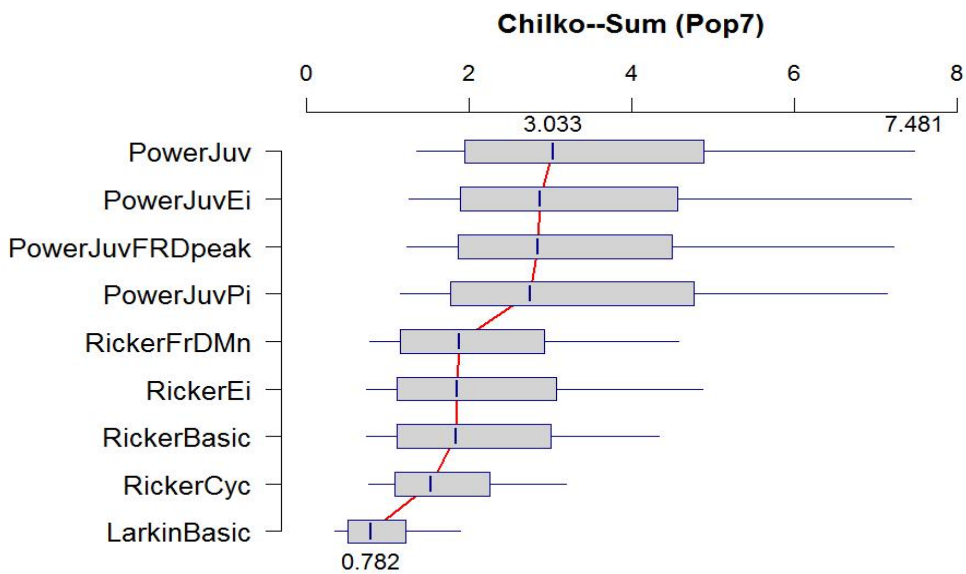
Chilko		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	58%	66%	59%	65%
	Spawner Success	93%	99%	93%	100%
	EFS	315,400	429,000	364,400	666,000
	Freshwater Surv.(fry/EFS)	100	200	100	100
	Fry Abundance	31M	71M	30M	62M

a.Brood years 1975-2015 b. Brood years 1974-2014

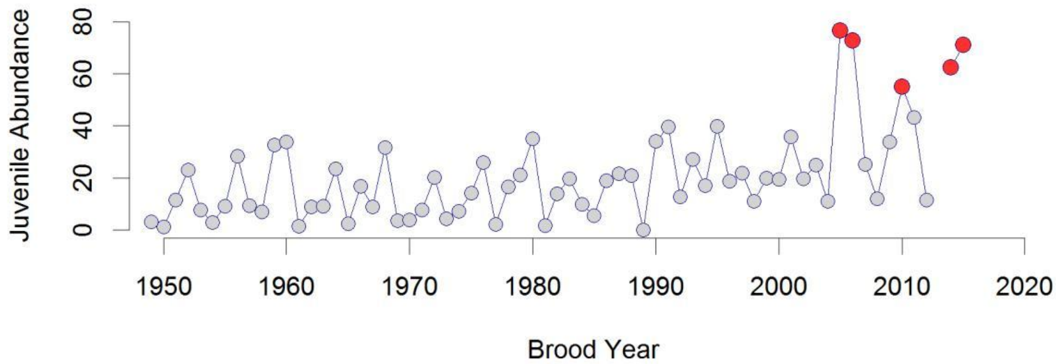
Top Ranked Forecasts – Table

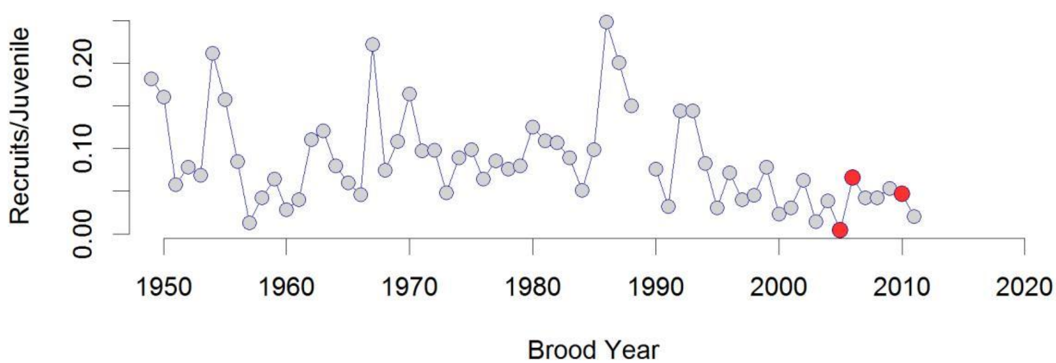
		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
LarkinBasic	1	343,000	506,000	782,000	1,225,000	1,884,000	0.5	0.8	1.4	2.4	3.8
PowerJuv	3	1,352,000	1,950,000	3,033,000	4,880,000	7,481,000	2.5	3.8	6.2	10.6	16.4
PowerJuvEi	99	1,256,000	1,891,000	2,870,000	4,566,000	7,439,000	2.4	3.6	6.1	9.9	16.6
PowerJuvFRDpeak	4	1,234,000	1,862,000	2,847,000	4,497,000	7,227,000	2.3	3.6	5.7	9.7	16.1
PowerJuvPi	1	1,151,000	1,773,000	2,750,000	4,761,000	7,143,000	2.2	3.5	5.7	10.2	15.7
RickerBasic	12	729,000	1,111,000	1,841,000	3,003,000	4,339,000	1.4	2.1	3.8	6.6	9.7
RickerCyc	99	765,000	1,084,000	1,526,000	2,256,000	3,196,000	1.3	2	2.9	4.4	6.2
RickerEi	99	739,000	1,113,000	1,853,000	3,075,000	4,869,000	1.4	2.2	3.8	6.7	10.7
RickerFrDMn80k	10	771,000	1,154,000	1,871,000	2,923,000	4,578,000	1.4	2.3	3.8	6.5	10.2

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017298


Juvenile Abundance
0
20
40
60
80
1950
1960
1970
1980
1990
2000
2010
2020
Brood Year


Recruits/Juvenile
0.00
0.10
0.20
1950
1960
1970
1980
1990
2000
2010
2020
Brood Year

Late Stuart (Takla-Trembleur-S CU) – Summer Mgmt Unit

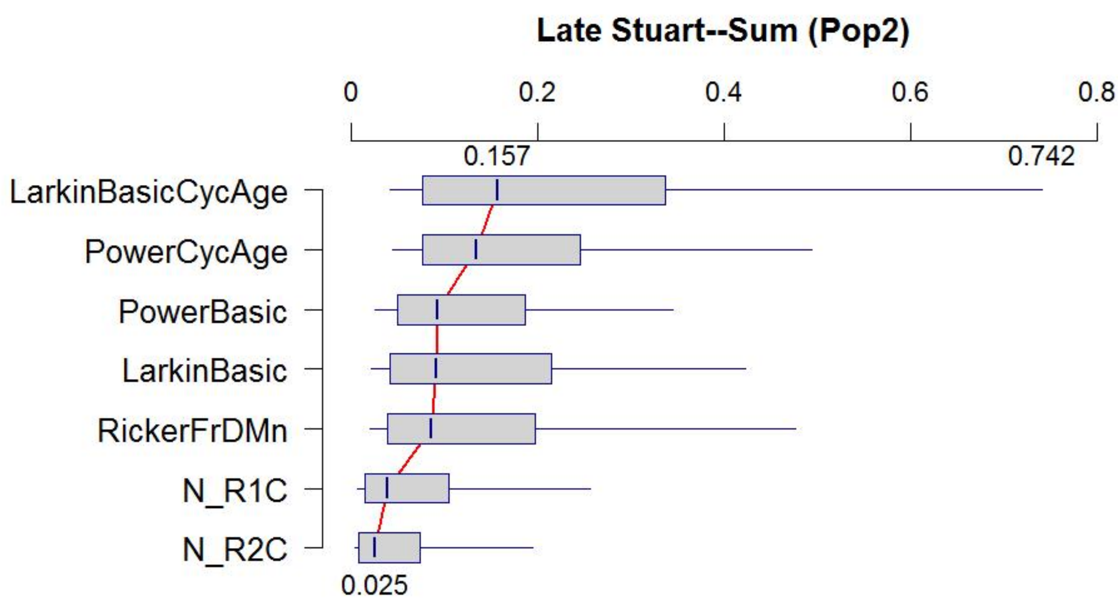
Late Stuart		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	40%	55%	58%
Summary	Spawner Success	96%	98%	98%	95%
	EFS	9,200	4,400	23,600	27,900

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts – Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
LarkinBasicCycAge	99	41,000	76,000	157,000	336,000	742,000	1.3	3.2	7.7	17	40.8
PowerBasicCycAge	99	44,000	76,000	134,000	246,000	494,000	2.1	4.3	9.8	20.9	45.7
PowerBasic	3	26,000	49,000	92,000	186,000	345,000	2.7	5.8	12.9	25.8	52.2
LarkinBasic	99	21,000	41,000	91,000	214,000	422,000	1.8	4.2	9.7	21	52.8
RickerFrDMn80k	4	20,000	38,000	86,000	197,000	477,000	1.4	3.1	8.8	21.9	50.7
N_R1C	1	6,000	14,000	39,000	105,000	256,000	1	2.5	6.8	18.4	45
N_R2C	2	3,000	8,000	25,000	73,000	194,000	0.5	1.5	4.3	12.8	34.1

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



Quesnel (Quesnel-S CU) - Summer Mgmt Unit

Quesnel		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	56%	59%	52%	53%
Summary	Spawner Success	95%	95%	95%	98%
	EFS	28,600	25,700	190,600	431,000

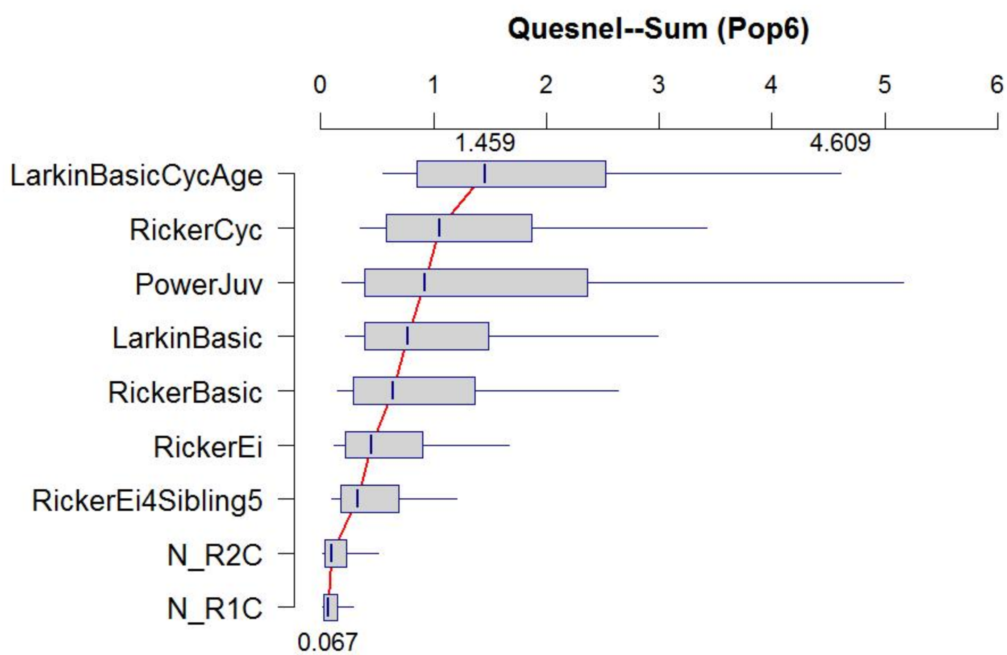
a.Brood years 1951-2015

b. Brood years 1950-2014

Top Ranked Forecasts – Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
LarkinBasicCycAge	99	525,000	872,000	1,496,000	2,609,000	4,749,000	2.7	4.8	9	16.8	28.1
RickerCyc80k	99	330,000	558,000	1,011,000	1,959,000	3,543,000	1.7	3.7	8.1	16.3	30.4
PowerJuv	99	185,000	392,000	936,000	2,243,000	5,349,000	1	2.7	7.1	17.4	44
LarkinBasic	4	226,000	397,000	744,000	1,635,000	3,373,000	3	5.5	10.4	18.9	32.9
RickerBasic	6	139,000	293,000	666,000	1,387,000	2,720,000	2	3.9	8.8	19.9	40.9
RickerEi	5	115,000	209,000	427,000	855,000	1,675,000	2.1	4.2	8.3	18	33.5
RickerEi4/Sibling5	99	100,000	177,000	333,000	687,000	1,207,000	2.1	4.2	8.3	18	33.5
N_R2C	2	17,000	39,000	94,000	228,000	507,000	0.4	1	2.3	5.7	12.6
N_R1C	1	15,000	31,000	67,000	145,000	291,000	0.4	0.8	1.7	3.6	7.3

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017301

Stellako (Francois-Fraser-S CU) – Summer Mgmt Unit

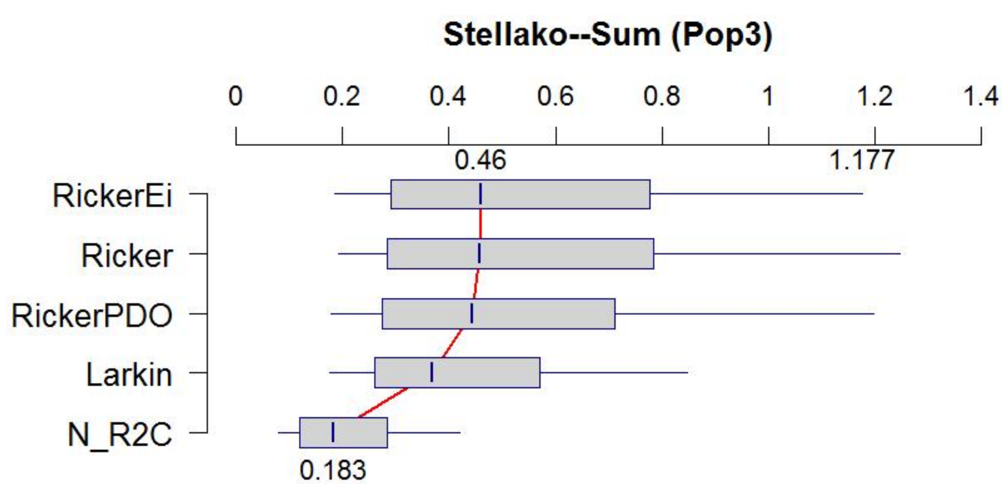
Stellako		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	51%	55%	52%
Summary	Spawner Success	84%	93%	94%	91%
	EFS	52,700	47,600	76,100	240,400

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Larkin40k	2	175,000	261,000	368,000	572,000	848,000	1.5	2.5	4.1	6.7	11.7
N_R2C	1	80,000	119,000	183,000	283,000	419,000	1.3	2	3	4.7	6.9
Ricker40k	8	192,000	284,000	457,000	784,000	1,249,000	2.1	3.5	6.1	11.2	20.2
RickerEi40k	3	185,000	291,000	460,000	778,000	1,177,000	2.1	3.4	6.2	11.9	19.2
RickerPDO40k	4	178,000	273,000	444,000	711,000	1,199,000	1.8	3.2	5.5	10.6	17.9

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017302

Harrison (Harrison River – River Type CU) – Summer Mgmt Unit

Harrison		Four Year Olds		Three Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	51%	57%	53%
Summary	Spawner Success	94%	99%	96%	99%
	EFS	36,300	58,300	50,200	34,400

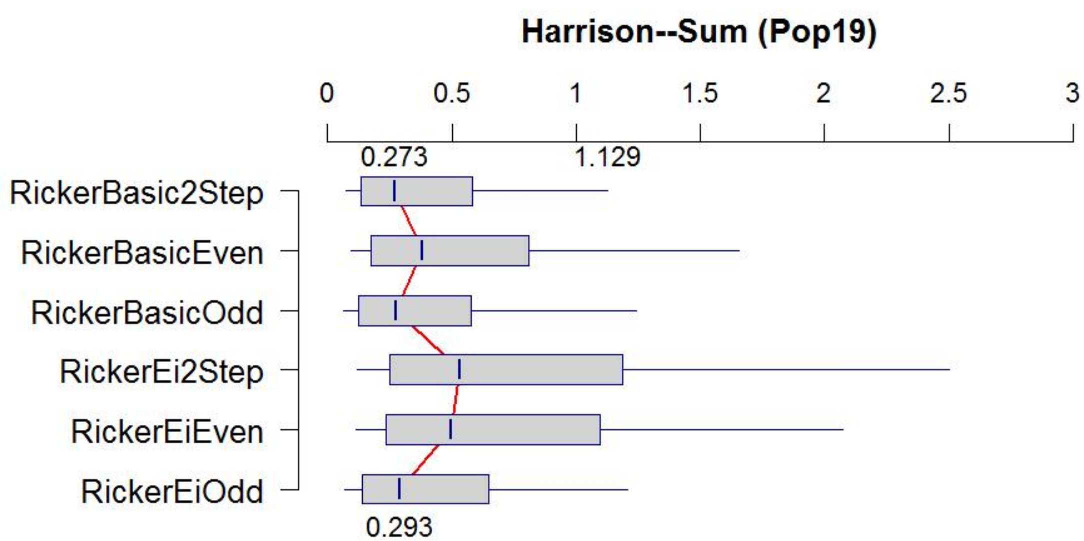
a.Brood years 1951-2015

b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
RickerEi2Step	99	118,000	248,000	535,000	1,187,000	2,504,000	1	2.5	7	16.9	39.7
RickerEiEven	99	113,000	236,000	499,000	1,097,000	2,072,000	0.6	1.7	4.8	12.9	28.5
RickerBasicEven	99	92,000	175,000	382,000	810,000	1,654,000	0.4	1.2	3.1	8.1	18.4
RickerEiOdd	99	71,000	140,000	293,000	646,000	1,205,000	0.4	1.1	2.9	7.5	16.4
RickerBasicOdd	99	65,000	123,000	276,000	579,000	1,241,000	0.5	1.1	2.9	7.2	15.2
RickerBasic2Step	99	72,000	135,000	273,000	583,000	1,129,000	0.4	0.9	2.4	6.4	12.8

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



Raft (Kamloops-ES CU) – Summer Mgmt Unit

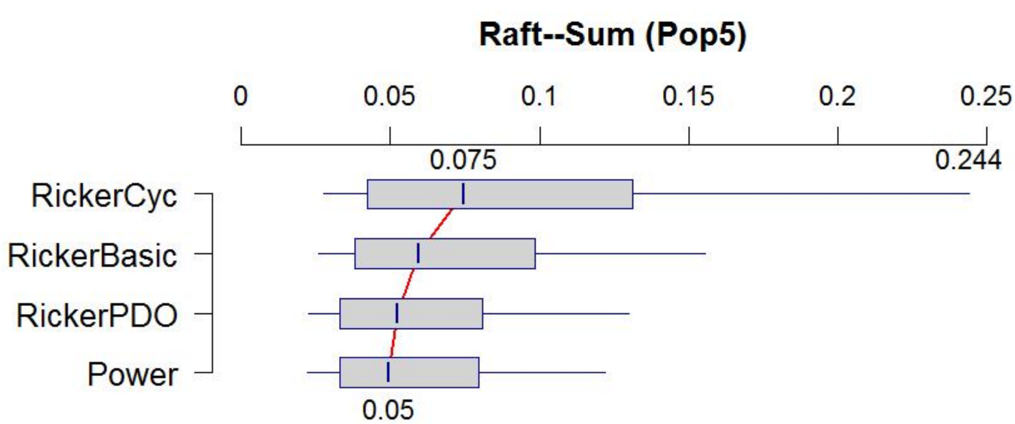
Raft		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	53%	55%	57%
Summary	Spawner Success	93%	98%	94%	98%
	EFS	2,900	8,800	3,300	9,500

a.Brood years 1951-2015　　b. Brood years 1950-2014

Top Ranked Forecasts – Table

Model	Rank	Forecasted Return 10%	25%	50%	75%	90%	Forecasted Age4 Survival 10%	25%	50%	75%	90%
RickerCyc40k	99	27,000	42,000	75,000	131,000	244,000	0.8	1.6	3.8	9	20.6
RickerBasic	7	26,000	38,000	59,000	99,000	155,000	1.2	2.1	3.8	7.1	12.9
RickerPDO40k	1	23,000	33,000	52,000	81,000	130,000	1	1.9	3.5	6.4	10.9
Power40k	2	22,000	33,000	50,000	80,000	122,000	1.1	1.8	3.3	6	10

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017304

Cultus (Cultus-L CU) – Late Mgmt Unit

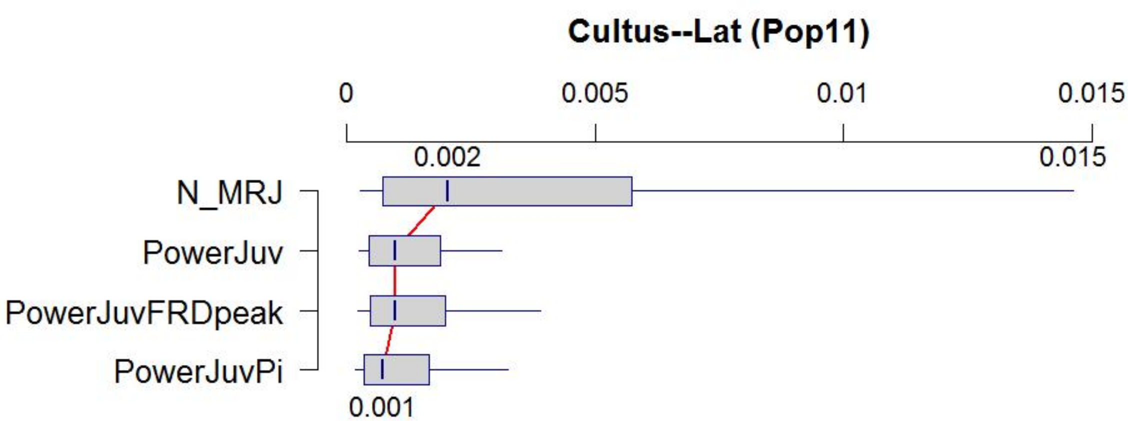
Cultus		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	60%	50%	60%	49%
	Spawner Success	24%	0%	10%	64%
	EFS	NA	NA	NA	NA
	Freshwater Surv.(fry/EFS)	NA	NA	NA	NA
	Fry Abundance	891,000	29,000	827,000	51,000

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

Model	Rank	Forecasted Return 10%	25%	50%	75%	90%	Forecasted Age4 Survival 10%	25%	50%	75%	90%
N_MRJ	1	0	1,000	2,000	6,000	15,000	NA	NA	NA	NA	NA
PowerJuv	99	0	0	1,000	2,000	3,000	NA	NA	NA	NA	NA
PowerJuvFRDpeak	2	0	0	1,000	2,000	4,000	NA	NA	NA	NA	NA
PowerJuvPi	3	0	0	1,000	2,000	3,000	NA	NA	NA	NA	NA

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017305

Late Shuswap (Shuswap-L CU) – Late Mgmt Unit

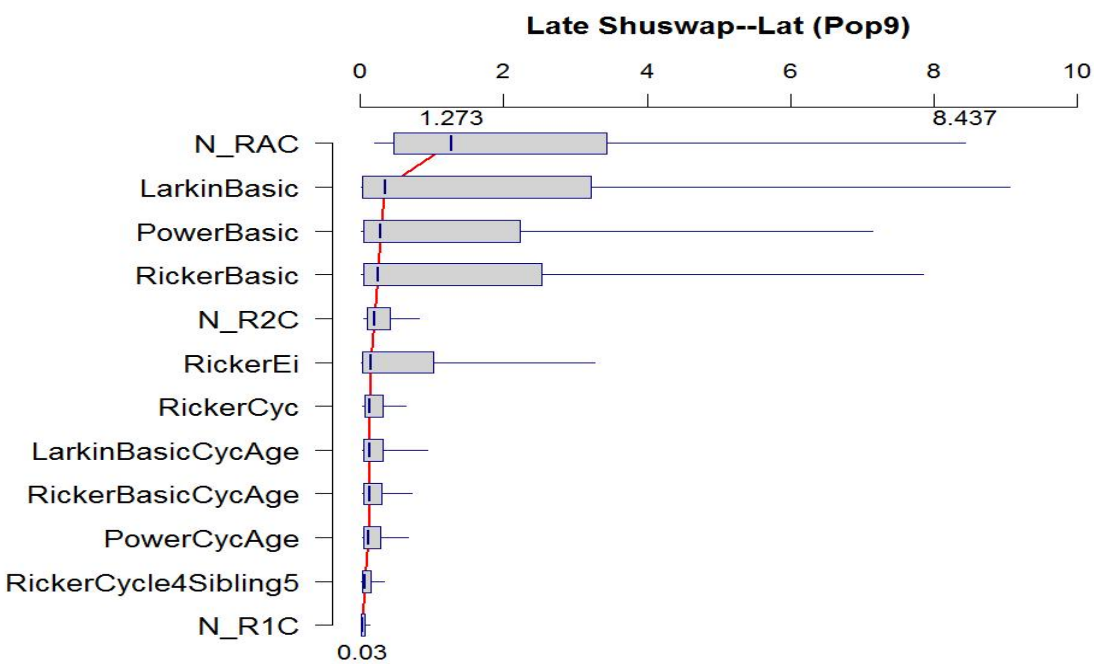
Late Shuswap		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	53%	50%	53%	50%
Summary	Spawner Success	94%	66%	91%	96%
	EFS	162,400	3,200	1,199,100	1,053,500

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts – Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
N_RAC	3	192,000	471,000	1,273,000	3,444,000	8,437,000	54.7	134	362	980	2402
LarkinBasic	99	13,000	35,000	353,000	3,219,000	9,060,000	0.3	1.6	4.1	9	16.9
PowerBasic	99	17,000	48,000	278,000	2,227,000	7,144,000	0.4	2	5.3	12.6	27.7
RickerBasic	99	16,000	49,000	248,000	2,532,000	7,859,000	0.5	1.7	4.6	11.6	26.1
N_R2C	4	49,000	95,000	199,000	417,000	811,000	13.9	27	56.6	119	231
RickerEi	6	15,000	35,000	151,000	1,017,000	3,275,000	0.3	1.8	4.9	11.3	21.3
RickerCyc60k	99	22,000	55,000	134,000	314,000	634,000	1.1	2.5	6.2	14.1	36.1
LarkinBasicCycAge	5	22,000	50,000	125,000	322,000	937,000	1.8	3.1	6.1	11.6	20.4
RickerBasicCycAge	7	22,000	51,000	124,000	301,000	709,000	1.6	3.2	7.1	16.3	32
PowerBasicCycAge	99	24,000	52,000	116,000	274,000	665,000	2.2	3.9	7.9	16.6	31.7
RickerCyc4/Sibling5	99	11,000	26,000	61,000	140,000	325,000	1.1	2.5	6.2	14.1	36.1
N_R1C	1	7,000	14,000	30,000	64,000	128,000	2	4	8.5	18.3	36.5

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017306

Portage (Seton-L CU) – Late Mgmt Unit

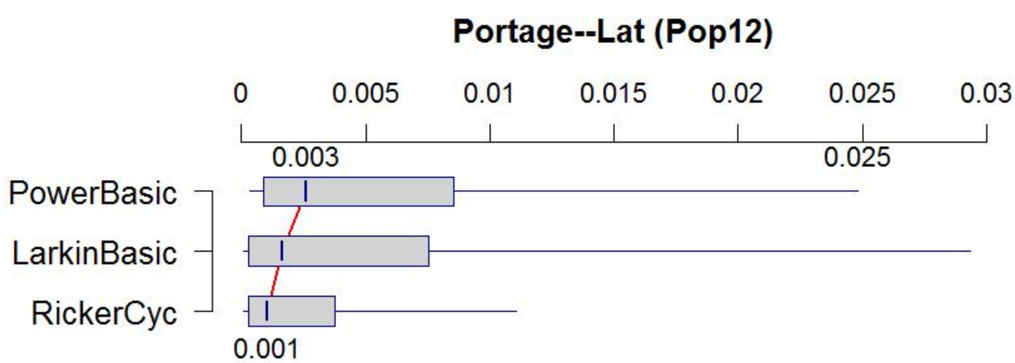
Portage		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	58%	50%	53%	57%
Summary	Spawner Success	95%	94%	92%	90%
	EFS	2,100	NA	8,600	12,300

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts – Table

		Forecasted Return					Forecasted Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
PowerBasic	3	0	1,000	3,000	9,000	25,000	6.5	15.6	39.8	106	231
LarkinBasic	1	0	0	2,000	8,000	29,000	1.3	2.9	7	17.8	39.1
RickerCyc	99	0	0	1,000	4,000	11,000	0.7	2.4	8.4	30.6	101

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017307

Weaver (Harrison (U/S)-L CU) – Late Mgmt Unit

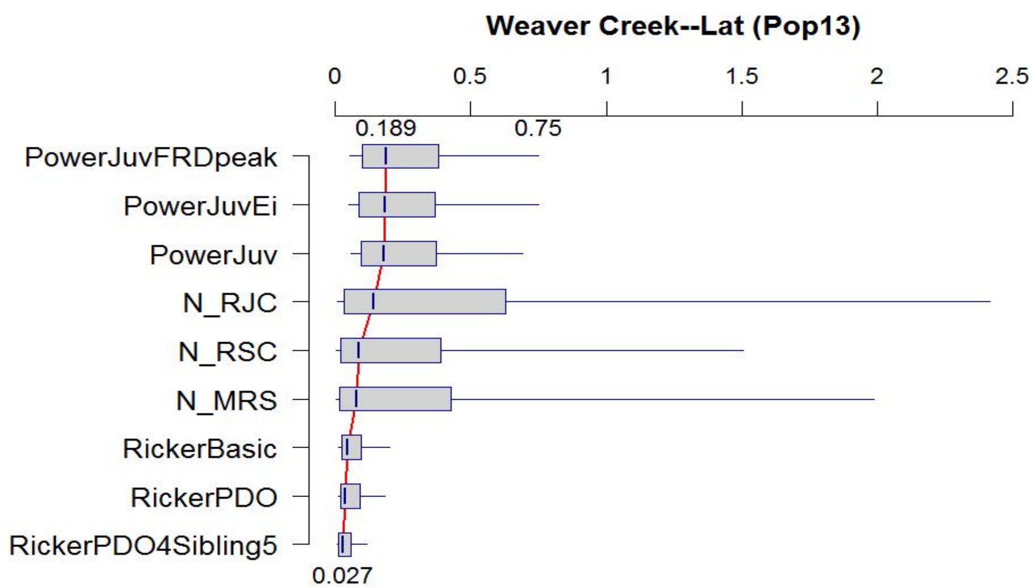
Weaver		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	56%	58%	51%	50%
	Spawner Success	87%	64%	85%	85%
	EFS	17,000	1,100	30,500	10,400
	Freshwater Surv.(fry/EFS)	2,100	8,200	1,600	1,700
	Fry Abundance	27M	9M	36M	17M

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

Model	Rank	Forecasted Return 10%	25%	50%	75%	90%	Forecasted Age4 Survival 10%	25%	50%	75%	90%
PowerJuvFRDpeak	6	52,000	97,000	189,000	381,000	750,000	17.5	38.9	90.2	208	458
PowerJuvEi	8	48,000	87,000	184,000	367,000	749,000	20.8	39.9	101	230	563
PowerJuv	12	56,000	93,000	181,000	371,000	690,000	22.3	45.2	101	241	522
N_RJC	3	8,000	31,000	141,000	628,000	2,416,000	3.2	12.3	54.9	245	943
N_RSC	4	5,000	19,000	86,000	389,000	1,506,000	0.6	2.5	11.1	50	194
N_MRS	1	3,000	14,000	77,000	426,000	1,986,000	0.6	2.7	15	83	387
RickerBasic	99	12,000	22,000	45,000	95,000	199,000	2.1	4.4	11.2	25.6	56.2
RickerPDO40k	2	9,000	18,000	37,000	91,000	181,000	1.6	3.6	9.7	23.1	56.5
RickerPDO4/Sibling5	99	7,000	13,000	27,000	55,000	116,000	1.6	3.6	9.7	23.1	56.5

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017308

Birkenhead (Lillooet-Harrison-L CU) – Late Mgmt Unit

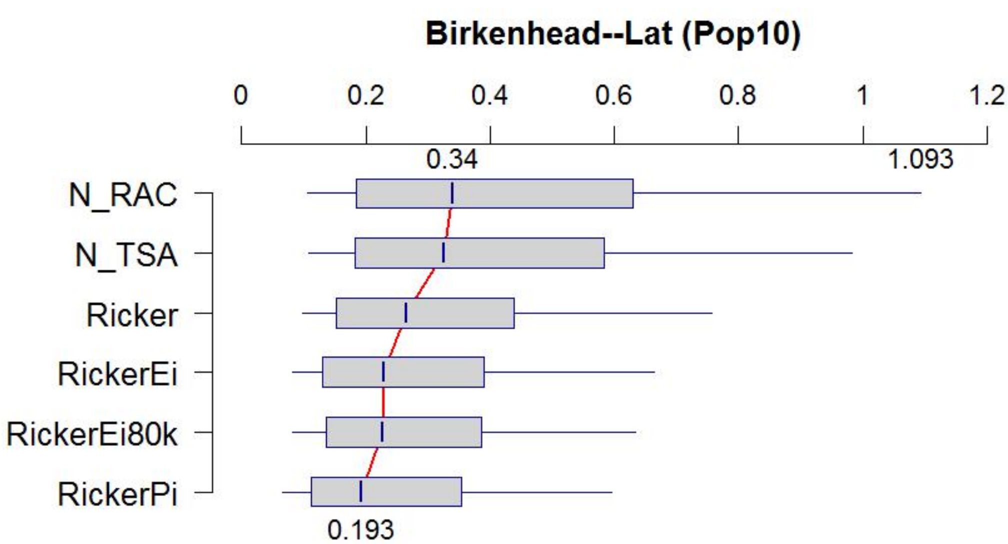
Birkenhead		Four Year Olds		Five Year Olds	
		Cyc Avg[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	61%	59%	59%
Summary	Spawner Success	90%	98%	97%	94%
	EFS	45,600	26,700	66,500	19,600

a.Brood years 1951-2015 b. Brood years 1950-2014

Top Ranked Forecasts - Table

		Forecasted Return					Forecasted Age4 Survival				
Model	Rank	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
N_RAC	2	106,000	184,000	340,000	629,000	1,093,000	2.7	4.6	8.6	15.8	27.5
N_TSA	4	109,000	183,000	327,000	583,000	982,000	2.7	4.6	8.2	14.7	24.7
Ricker100k	2	98,000	153,000	265,000	439,000	757,000	1.4	2.7	5.3	10.3	20.5
RickerEi	1	82,000	130,000	229,000	391,000	665,000	1.4	2.5	5.4	10.9	20.4
RickerEi80k	99	82,000	135,000	227,000	386,000	634,000	1.5	2.6	5.5	10.7	19.5
RickerPi	4	65,000	111,000	193,000	355,000	596,000	1	2	4.4	8.9	16.5

Top Ranked Forecasts - Plot(All numbers in Millions of Fish)



AR017309

Fraser River Pink Salmon

	Rank	10%	25%	50%	75%	90%
Power (fry)-SSS	**1**	**2,530,000**	**3,577,000**	**5,018,600**	**7,513,000**	**10,610,000**
Power(fry)	3	2,868,000	4,051,000	5,892,000	8,563,000	12,140,000
MRS	3	2,721,391	3,694,329	5,188,292	7,286,404	9,891,400

Miscellaneous Stocks – All Management Units

Miscellaneous Stocks – Populations Covered

Forecast Unit	Populations
Early Summer	
EShu	all South Thompson except 4: Scotch Creek, Seymour River, McNomee Creek, and Adams River (upper)
Taseko	Taseko Lake, Taseko River(upper), Yoheta (upper and lower)
Chilliwack	Chilliwack Lake, Chilliwack River, Chilliwack River(upper)
Nahatlatch	Nahatlatch River, Mahatlatch Lake
Summer	
North Thompson Tributaries	Barriere River, Clearwater River, Dunn Creek, Finn Creek, Grouse Creek, Harper Creek, Hemp Creek, Lemieux Creek, Mann Creek, Lion Creek)
North Thompson River	North Thompson River
Widgeon	Widgeon Creek, Widgeon Slough
Late	
Non-Shuswap	Big Silver Creek, Cogburn Creek, Douglas Creek, Green River, Miller Creek, Pemberton Creek, Railroad Creek, Sampson Creek, Tipella Creek

Miscellaneous Stocks – Forecasts based on Long-term Productivity of Proxy Stocks.

	Effective	Females	proxy for long-	Forecasted Return					Forecasted Age-4 Survival				
	2014	2015	term Prod.	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
Early Summer													
Misc(EShu)	115,367	7,600	Scotch/Seymour	30,438	68,016	156,452	252,835	447,507	1.6	3.6	8.3	13.3	23.6
Misc(Taseko)	54	482	Chilko	795	1,855	3,396	6,311	8,646	1.6	3.8	7	13	17.7
Misc(Chilliwack)	1,744	2,966	Bio Model*	1,518	4,912	17,177	58,835	194,569	1.4	3.1	5.7	10.8	20.2
Misc(Nahatlatch)	2,059	1,355	All ES Stocks	2,878	6,496	11,973	22,561	42,288	1.4	3.1	5.7	10.8	20.2
Summer													
Misc(N. Thomp. Tribs)	799	547	Raft/Fennell	1,395	2,777	4,708	9,757	19,769	1.7	3.3	5.6	11.6	23.5
Misc (N. Thomp. River)	11,963	11,562	Raft/Fennell	26,487	52,718	89,358	185,204	375,237	1.7	3.3	5.6	11.6	23.5
Misc (Widgeon)	146	58	Birkenhead	218	405	775	1,460	2,538	1.4	2.7	5.1	9.7	16.8
Late													
Misc(Non-Shuswap)	3,568	5,296	Birkenhead	10,901	20,284	38,856	73,182	127,178	0.6	1.2	2.2	4.2	7.2

* Chilliwack was forecasted using a Ricker model applied to a very limited time series of recruitment data (2001 to 2012). For the 2017 forecast, a sensitivity analysis was performed using a prior on the Ricker model beta parameter to potentially inform the forecast. The prior was derived from information on the juvenile rearing capacity of Chilliwack Lake, generated using a Sockeye-specific photosynthetic rate (PR) model, which was then translated into EFS (Hume et al. 1996; Grant et al. 2011). The prior is log-normally distributed, with a median of 25,000 EFS (Beta=1/C, C~LN(-3.689, 5)). In the 2017 forecast, the PR-based prior produced a much lower forecast, but the basic Ricker forecast was selected. A similar sensitivity test was not completed for the 2018 forecast

APPENDIX 3. ILLUSTRATION OF FORECAST SUMS

The forecasts for Quesnel and Stellako can be summed in each column as in Table 1A, which assumes that both stocks will return at the same probability level (i.e. variation over time is fully correlated, and both stocks have either above-average or below-average survival in 2018). An alternative approach is to assume that the two stocks are completely independent, add up a shuffled set of samples from each stock's distribution (i.e. MCMC samples), and then calculate the percentiles of the sum. This produces narrower bounds, but also shifts the median forecast (p50). A more statistically correct approach would incorporate the observed correlation between the two stocks, and produce a range that falls between the two bookends in this this table.

	p 10	**p 25**	**p 50**	**p 75**	**p 90**
Quesnel	292,343	573,172	1,148,290	2,222,625	4,152,369
Stellako	228,579	346,688	558,609	895,289	1,453,767
Sum (p-levels)	520,922	919,860	1,706,899	3,117,914	5,606,136
Sum (shuffle)	802,886	1,201,584	1,916,934	3,107,526	5,101,293