Pre-Season Run Size Forecasts for Fraser River Sockeye *(Oncorhynchus nerka)* and Pink *(Oncorhynchus gorbuscha)* Salmon in 2019

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ABSTRACT

Hawkshaw, M., Xu, Y., and Davis, B. 2020. Pre-season Run Size Forecasts for Fraser River Sockeye (*Oncorhynchus nerka*) and Pink (*Oncorhynchus gorbuscha*) Salmon in 2019. Can. Tech. Rep. Fish. Aquat. Sci. 3391: vi + 52 p.

Fraser River sockeye and pink stocks have been experiencing productivity lower than the long-term average in recent decades. Forecasts for these stocks are carried out using Bayesian models and presented as probability distributions. These distributions represent the range of survival and productivity the stocks have exhibited historically. Environmental variation, especially warming associated with climate change, are incorporated into the forecast models for nine sockeye stocks, following the approach initiated in the 2018 forecast. In general, adding these variables has the effect of reducing the forecast abundance when temperatures are warmer. Sibling models were used to estimate the age-5 return for seven sockeye stocks, due to exceptionally low numbers of age-4 fish observed in 2018. The 2019 Fraser River sockeye return is forecast to be 4,786,000 fish (80% PI: 1,795,000-14,172,000). The forecast return in 2019 is dominated by the Summer Run management group expected to contribute 3,930,000 (80% PI: 1,554,000-11,188,000) salmon to the return. The Chilko stock makes up the bulk of this management group and contributes 57.5% of the total forecast sockeye return. The Fraser River pink salmon return is forecast to be 5,018,600 (80% PI: 2,530,000-10,610,000) fish.

RÉSUMÉ

Hawkshaw, M., Xu, Y., and Davis, B. 2020. Pre-season Run Size Forecasts for Fraser River Sockeye (*Oncorhynchus nerka*) and Pink (*Oncorhynchus gorbuscha*) Salmon in 2019. Can. Tech. Rep. Fish. Aquat. Sci. 3391: vi + 52 p.

Au cours des dernières décennies, on a observé que la productivité des stocks de saumons rouges et de saumons roses du fleuve Fraser était inférieure à la moyenne à long terme. On a préparé les prévisions relatives à ces stocks au moyen de modèles bayésiens et on les a présentées comme des distributions de probabilité. Une telle distribution représente la plage des taux de survie et productivité historiques d'un stock. Des variables concernant la variation environnementale, plus particulièrement le réchauffement lié aux changements climatiques, ont été intégrées aux prévisions de neuf stocks suivant l'approche initiée dans les prévisions 2018. De façon générale, l'ajout de ces variables réduit l'abondance prévue lorsque les températures sont élevées. On a utilisé des modèles fondés sur les classes d'âge jumelles afin d'estimer l'abondance de la remonte de saumons d'âge 5_2 pour sept stocks, en raison du faible nombre de saumons d'âge 4 observé en 2018. Les prévisions indiquent que 4 786 000 saumons rouges du Fraser effectueraient la migration de retour de 2019 (IP 80 % : 1 795 000 à 14 172 000 individus). Les saumons du groupe de gestion qui remontent pendant l'été ont dominé la migration de retour de 2019; ils devraient représenter 3 930 000 individus de cette migration (IP 80 % : 1 554 000 à 11 188 000 individus). Ce groupe de gestion est formé en majorité d'individus du stock de la rivière Chilko, qui représentent 57,5 % de l'abondance totale de la remonte du saumon rouge. Les prévisions indiquent que 5 018 600 saumons roses effectueraient la migration de retour de 2019 (IP 80 % : 2 530 000 à 10 610 000 individus).

1. BACKGROUND

1.1. FRASER SOCKEYE SALMON

Fraser River sockeye salmon (*Oncorhynchus nerka*) have historically supported an important commercial fishery in British Columbia, and are an ongoing major contributor to First Nations food, social, ceremonial fisheries, and recreational activities (Cohen 2013). Recent productivity of the stocks has become highly 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 declining trends in abundance 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 Sockeye 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. 2020, COSEWIC 2017).

Changes to management of the fisheries and productivities of the stocks have resulted in reduced fishing opportunities for all sectors in recent years, and a particularity low return in 2009 led to a judicial enquiry (Cohen 2013). Because of the difficulties associated with 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 run-timing aggregate level, so aggregate forecasts are presented in addition to stock-specific return forecasts.

1.1.1. 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, higher precision methods (hydroacoustic counting sites, counting weirs, complete dead-pitch censuses in spawning channels or mark-recapture studies) are used to enumerate the large populations, while visual surveys or other low precision methods are used to enumerate the smaller systems (Keri Benner, DFO, Fraser River Stock Assessment Program Head Sockeye, pers. comm.). 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 & Grant 2012).

1.1.2. Fraser Sockeye Survival Trends

Since 2002 Fraser River Sockeye returns have been lower than predictions based on the long-term (1950-2015) average survival (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 low survival 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 sea-surface temperature (SST) and the Pacific Decadal Oscillation (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. 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 generally points to the need for caution when applying the forecast returns for fisheries planning (DFO 2014b, DFO 2015b, DFO 2016b).

1.2. FRASER PINK SALMON

Fraser River pink salmon(*O. gorbuscha*) are the largest run of pink salmon in British Columbia and exhibit 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 in odd years.

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

1.3. 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). Although forecasting methods have not changed dramatically over time, 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 & Grant 2012). For 2019, the forecasting methods developed in previous years will continue to be used, with some modifications detailed in the methods section below.

The importance of the Fraser River sockeye and pink salmon 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 assessment, and to serve as informative priors for the in-season run-size assessment programs. The forecast informs planning decisions of the bilateral Fraser Panel, which are used to form advice to DFO on in-season harvest management of sockeye salmon (Pacific Salmon Treaty 1985).

2. DATA AND METHODS

2.1. DATA

2.1.1. <u>Sockeye Data</u>

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; each of these stocks typically has a large proportion of fry production originating from a spawning channel with a monitoring program in place. 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 spawning channels and rivers/creek habitat 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. Gaps in the historic fry data time series were infilled using the average historical fry/EFS production by stream multiplied by the relevant brood year EFS.

- Juvenile smolt abundance data corresponding to the 2015 brood year are available for Cultus and Chilko.

Brood year escapements are presented in Table 1B. Twelve 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. 2020).

2.1.2. Pink Data

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).

2.1.3. Environmental Data

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

- Pacific Decadal Oscillation (PDO) in winter (November to March) (Zhang et al. 1997, Mantua et al. 1997; data available online)
- 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 (used for Sockeye salmon)
- Peak Fraser discharge (FrD-peak) and average Fraser discharge (FrD-average) from April to June measured at Hope, B.C. (David Patterson, DFO, pers. comm.; used for Sockeye salmon)
- Average of monthly sea surface salinity (SSS) from Race Rocks from July to September and Amphitrite Point from July to August (used for pink salmon)

2.2. FRASER SOCKEYE FORECAST METHODS

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

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 a subset of “miscellaneous stocks”, for which stock-recruitment time series are not generally available, forecasts are based on brood year escapements and long-term observed survival rates for proxy stocks. Chilliwack is still designated as a miscellaneous stock, and was forecast using this approach until recently (DFO 2016a), but is now forecast using 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 anomalous environmental conditions in recent years, an additional criterion was added to the 2017 model selection process, and has been retained for the 2019 forecast. 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.

2.2.1. Fraser Sockeye 2019 Sibling Model

A large proportion of the forecast return is age-5 sockeye, that is, five-year-old fish returning from the 2014 brood year due to the large numbers of spawners observed in 2014 (Table 1B). The traditional forecast models (described above) produced large numbers of age-5 fish returning in 2019, especially in the Early Summer and Late management groups. However, in 2018 the age 4_2 sockeye showed lower than average survival, with preliminary returns for most stocks estimated to be well below the median forecast. Using a sibling model that describes the relationship between returning abundances of two age groups from the same brood year, it is possible to use the age-4 survival implied by the low returns in 2018 to forecast the age 5_2 return in 2019. Sibling models are have been found to be an effective tool in forecasting salmon returns where more than one age-class exist (Peterman 1982, Haeseker et al. 2007, Haeseker et al. 2008) and have been used for Fraser River sockeye forecasts in the past (DFO 2015a, DFO 2016a), and are used for Bristol Bay Sockeye forecasting (Adkison & Peterman 1999). For the 2019 forecast, the sibling model followed the approach of Peterman (1982).

The sibling model assumes a linear relationship between the natural logarithms of age-4 and age-5 recruits from the same brood year, with intercept a and slope b:

$$\ln(R_{5,y}) = \mathrm{a} + \mathrm{b}\ln(R_{4,y}) + \epsilon_y$$

$$for\ y \in [1980,2011]$$

Where $R_{5,y}$ is age-5 recruits from brood year y (return year y+5), $R_{4,y}$ is age-4 recruits from brood year y (return year y+4), and ϵ_y is a normally distributed error term with a mean of zero and a standard deviation of σ.

Age-5 recruits in 2019 ($R_{5,2014}$), and their associated uncertainty are estimated using the parameter estimates from the linear model parameters $\hat{a}$, $\hat{b}$, and $\widehat{\sigma^2}$, and last year's (2018) observed age-4 recruitment ($R_{4,2014}$):

$$\ln(R_{5,2014}) \sim \mathrm{Normal}(\hat{\mathrm{a}} + \hat{\mathrm{b}}\ln(R_{4,2014}), \widehat{\sigma^2})$$

The model was fit using a Bayesian approach to provide probability intervals for the age-5 returns that can be compared to those generated by other forecasting methods. Though the performance of sibling models has not been quantitatively compared to other forecast models, it was decided to use these models for situations where there was more than 50% of expected contribution of 5_2 sockeye for each stock (Brownwyn MacDonald, DFO, pers. comm.). In the 2019 forecast model estimates, we found large proportions of age-5_2 returns for seven stocks (Fennell, Pitt, Scotch, Seymour, Quesnel, Late Shuswap and Weaver). Therefore, sibling models are used for these stocks to estimate age-5 recruits, and then combined with age-4 recruits from the top-ranked forecast model to get the total recruits.

2.2.2. Code updates

In 2019 there were substantial code updates from 2018 in the modelling of the 19 major stocks. The new code was aimed at providing a more generic and flexible framework, which would allow us to run more than two dozen models for each of the 19 major stocks, in a relatively short time period. However, the new code was not exhaustively cross-validated with the old code in time for the preparation of the 2019 forecast. After the forecast was finished, a comparison study was conducted and the preliminary results show the new code cannot reproduce exact results from Grant et al. (2010). Ensuring that all forecast results going forward are reproducible remains a priority of ongoing work, as methods currently in place do not guarantee this. The new code is stored in a private GitHub repository and is available upon request.

New code for the sibling models has been developed for 2019, using a more modern software for Bayesian analysis (Stan Development Team 2018). This new code has been pre-reviewed with members of Sockeye Technical Committee but was not compared with code from 2018 or previous years, due to resource constraints.

For the Chilliwack stock (still characterized as "miscellaneous"), we developed a Ricker model following the Grant et al. (2018) approach, but coded in Stan (Stan Development Team 2018). Following pre-season presentation of the model, an error was found in this code. Additionally, following the 2020 forecast, but prior to this report being published, it was noted that some data should have been omitted, due to data quality issues, but had been included in estimates for both 2019 and 2020. Therefore, following a sensitivity analysis documented in the 2020 forecast document (Hawkshaw et al. 2020), results for 2019 and 2020 were corrected.

2.3. FRASER PINK FORECAST METHODS

The method used to forecast Fraser Pink salmon returns remains unchanged from the last forecast performed in 2017 (DFO 2017). The forecast is based on the best performing model identified in a jackknife analysis carried out in 2015 (DFO 2015a). The forecast was produced using a power model based on fry data, with an environmental covariate; average July-September sea-surface-salinity (SSS) measured at Race Rocks and Amphitrite Point lighthouse.

3. RESULTS

3.1. FRASER SOCKEYE 2019 FORECASTS

In 2019 the total Fraser River sockeye return is forecast to be 4,786,000 fish (80% PI: 1,795,000-14,172,000). Stock-specific forecasts are presented in Table 1A, and Appendix C. This return forecast is similar to the cycle average return, though lower than the all-cycle-average return (Table 1B). Among management groups, returns are dominated by the summer run. The summer-run Chilko stock contributes 57.5% of the total forecast, and 61.5% of non-miscellaneous forecast (Table 6). The next three most significant contributions are also from other summer stocks; Stellako (8.2% of non-miscellaneous), Quesnel (7.4% of non-miscellaneous), and Harrison (6.5% of non-miscellaneous; Table 6).

The Early Stuart sockeye aggregate is composed of a single CU and is forecast to return at 41,000 fish (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 low escapements 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 11 CUs, which are divided into seven forecast stocks and four miscellaneous stocks (see Grant et al. 2020 for detailed descriptions of the CUs). The forecast for this management group is 457,000 fish (80% PI: 111,000-1,628,000). Forecasts for individual stocks 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 to take advantage of the relationship between age 4_2 and age 5_2 returns (Peterman 1982, DFO 2015a, DFO 2016a). Sibling models are used for forecasting the Upper Barrier (Fennell), Pitt, Scotch, and Seymour stocks. It should be noted that the estimates for the Chilliwack stock were changed following further post-season investigation. A discussion of the uncertainties associated with the Chilliwack stock can be found in the 2020 forecast (Hawkshaw et al. 2020).

The Summer sockeye aggregate is composed of six CUs divided into six forecast stocks and three miscellaneous stocks (see Grant et al. 2020 for detailed descriptions of the CUs). The forecast for this management group is 3,930,000 fish (80% PI: 1,554,000-11,188,000). Forecasts for individual stocks 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). The 2019 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 is used to generate forecasts. In additions to the smolt (juv) abundance-based models, a Larkin model could also be used to forecast Chilko. The Larkin model forecasts significantly lower returns than the smolt-based predictions (Appendix C.9). There were 71 million smolts estimated to leave Chilko Lake in 2015, which is more than twice the cycle average (31 million smolts), and reflects a high freshwater survival. Models using smolt data had more support than models using effective female spawners or non-parametric models, 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. 2020 for detailed descriptions of the CUs). The forecast for this management group is 358,000 fish (80% PI: 111,000-1,265,000). Forecast for individual stocks 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.

3.2. FRASER PINK 2019 FORECASTS

The median forecast return for Fraser Pink salmon is 5,018,600 fish (80% PI: 2,530,000-10,610,000). This forecast is consistent amongst the three candidate forecasting models tested in 2015, and the alternate models (fry power model with no covariate, naïve MRS model) also gave median forecast values between five and six million (Appendix C.21). This forecast is well below the historical average return of 12.7 million (Figure 5) and is driven by the extremely low pink salmon fry outmigration observed in 2018 (Figure 6).

4. DISCUSSION

4.1. RECENT PERFORMANCE OF FORECAST MODELS

Recent returns have been consistently below the median forecast (Table 5) and in the last eight years the aggregate return has been less than the p50 value. These results could be a result of many different factors (see Hilborn & Walters 1992 or Walters & Martell 2002 for a discussion of problems with stock-recruitment (SR) models), but points to the need for a re-evaluation of model selection and 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; having been seven years since the last re-evaluation, and 3-4 years since an update to the 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 undertaken.

4.2. ENVIRONMENTAL AND ECOSYSTEM CHANGES

Given the recent pattern of lower-than-long-term-average survival, 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 & Mahnken 2001, Peterman & Dorner 2012). Being able to relate changes in marine survival to environmental indices would improve forecasts. With increasing uncertainty in ocean and freshwater environments, there should be a renewed focus on the collection/compilation of relevant indices of ocean conditions, freshwater limnological data, and juvenile sockeye assessment. Many authors have demonstrated that juvenile rearing habitat and spawning area can be used to establish population capacity estimates for sockeye and other salmon (Hume et al. 1996, Cox-Rogers et al. 2004). Incorporating additional data sources (for example: juvenile abundance estimates, freshwater abundance indices, additional environmental variables) could reduce uncertainty (Punt & Hilborn 1997, Maunder 2003, Gelman 2013,Thorsen & 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)

5. 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.

Run timing group	Forecast	Probability that Return will be at/or Below Specified Run Size				
Stocks	Model [a]	10%	25%	50%	75%	90%
Early Stuart	*Ricker (Ei)*	18,000	27,000	41,000	61,000	92,000
Early Summer Total		**111,000**	**111,000**	**219,000**	**457,000**	**864,000**
Total excluding misc. stocks		**76,000**	**76,000**	**140,000**	**277,000**	**558,000**
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) [d]	*Ricker*	1,000	3,000	8,000	24,000	71,000
Misc (Nahatlatch) [e]	*R/S*	3,000	6,000	12,000	23,000	42,000
Summer Total		**1,553,000**	**1,554,000**	**2,453,000**	**3,930,000**	**7,047,000**
Total excluding misc. stocks		**1,526,000**	**1,526,000**	**2,398,000**	**3,835,000**	**6,851,000**
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 [f]	*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) [f & g]	*R/S*	1,000	3,000	5,000	10,000	20,000
Misc (N. Thomp River) [f & g]	*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 Total		**111,000**	**111,000**	**189,000**	**358,000**	**669,000**
Total excluding misc. stocks		**100,000**	**100,000**	**168,000**	**319,000**	**596,000**
Cultus [h]	*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 [i]	*R/S*	11,000	20,000	39,000	73,000	127,000
TOTAL SOCKEYE SALMON		**1,795,000**	**2,888,000**	**4,786,000**	**8,641,000**	**14,172,000**
Total sockeye excluding misc. stocks		**1,721,000**	**2,733,000**	**4,472,000**	**8,066,000**	**13,079,000**
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. Following further investigation into the Chilliwack data and Ricker model, errors were found both in the application of the Chilliwack data, and the Ricker model. Models were re-ran in the post-season, and results for Chilliwack have therefore changed from 17,000 to 8,000 at the P50 level.
e. Misc. Nahatlach uses Early summer-run stocks R/EFS
f. Raft, Harrison, Misc. North Thompson stocks moved to Summer run-timing group
g. Misc. North Thompson stocks use Raft & Fennell R/EFS
h. Results have been rounded to the nearest 1,000, therefore values below 500 seen for Cultus have been rounded down to 0.
i. Misc. Late Run stocks (Harrison Lake down-stream migrants including Big Silver, Cogburn, etc.), and river-type Widgeon use Birkenhead R/EFS

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. Brood year EFS are colour coded relative to their cycle average from 1949-2015 brood years. Fraser Sockeye average run sizes are presented across all cycles and the 2019 cycle for each stock. Forecast 2019 returns (FC RET) for non-miscellaneous stocks are compared to cycle averages at the median (50%) probability level. Colour 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.

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	41,000	286,600	156,100
Early Summer (excl. misc.)				516,000	460,400
Bowron	2,200	6,300	15,000	33,900	68,700
Upper Barriere(Fennell)	900	6,800	10,000	23,000	27,700
Gates	9,600	8,500	41,000	54,300	29,400
Nadina	9,400	30,700	129,000	77,500	76,000
Pitt	18,400	14,400	34,000	68,700	83,900
Scotch	3,500	68,800	19,000	112,500	20,000
Seymour	4,000	57,400	29,000	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	2,750,000	1,435,000	1,524,800
Late Stuart	4,400	27,900	39,000	526,100	79,400
Quesnel	25,700	431,000	333,000	1,360,900	108,000
Stellako	47,600	240,400	368,000	463,300	540,300
Harrison[c]	34,400	58,300	293,000	138,400	63,400
Raft	8,800	9,500	52,000	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	1,000	31,600	70,300
Late Shuswap	3,200	1,053,500	140,000	2,320,200	1,276,500
Portage	17	12,300	8,000	39,600	21,500
Weaver	1,100	10,400	55,000	329,700	174,300
Birkenhead	26,700	19,600	391,000	335,000	296,500
Misc(Non-Shuswap)	5,300	3,600			
Total Sockeye (excl. misc.)	691,577	2,931,750	4,786,000	7,812,200	4,789,100
Total Pink Salmon	Fry in 2017 192M		5,018,600	5,018,600	

a. Sockeye: 1953-2015 (start of time series varies across stocks)
b. Sockeye: 1955-2014 (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 forecast Fraser Sockeye returns (p50) are presented and colour-coded relative to their cycle average from 1949-2015 brood years. Colour 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			
Stock	Mean	Mean	Mn-0.5SD	Mn+0.5SD	2019 FC (p50)
Early Stuart	292,761	157,234	78,116	236,351	41,000
Early Summer					
Bowron	36,218	70,898	36,995	104,800	15,000
Upper Barriere (Fennell)	23,022	27,735	16,037	39,433	10,000
Gates	54,304	29,355	15,280	43,430	41,000
Nadina	77,479	76,016	40,907	111,125	129,000
Pitt	70,057	86,182	58,071	114,292	34,000
Scotch	112,531	19,954	11,806	28,102	19,000
Seymour	141,090	149,334	91,079	207,589	29,000
Summer					
Chilko	1,395,040	1,471,120	1,019,359	1,922,880	2,750,000
Late Stuart	518,594	78,376	28,169	128,583	39,000
Quesnel	1,281,929	101,261	866	201,655	333,000
Stellako	460,569	534,963	298,072	771,854	368,000
Harrison	129,873	44,505	17,844	71,165	293,000
Raft	30,800	19,449	9,457	29,442	52,000
Late					
Cultus	35,252	76,607	38,784	114,430	1,000
Late Shuswap	2,329,677	1,229,317	642,783	1,815,852	61,000
Portage	39,621	21,483	10,719	32,247	2,000
Weaver	329,744	174,283	127,354	221,213	27,000
Birkenhead	327,014	288,839	159,689	417,989	229,000

Table 2. Geometric average four-year-old recruits-per-EFS for each of the forecast Fraser Sockeye stocks presented for the following: the entire time series brood years: 1948-2014. The peak generational (4-year) geometric average, the 2005 brood year (one of the worst years for survival), the most recent generation with recruitment data (2011-2014). Cultus is presented as four-year-old recruits-per-smolt. Forecast four-year-old recruits-per-EFS associated with the various probability levels of the 2019 forecast are presented for comparison. Red (< average), yellow (average) and green (>average), with the average range defined as average +/- 0.5 standard deviation of historical time series.

Run-timing Group,Stock	Geo. Average R_4/EFS	Peak Geo. Ave. R_4/EFS	2005 R_4/EFS	Recent Gen. R_4/EFS (2011-2014)	2019 Forecast R_4/EFS by Probability Level				
					10%	25%	50%	75%	90%
Early Stuart	6.0	24.5	1.5	2.6	2.6	4.1	6.6	11.0	17.6
Early Summer									
Bowron	6.1	20.4	2.2	1.8	1.2	2.2	4.0	7.1	11.6
Upper Barriere	5.7	53.5	0.3	0.6	2.3	4.3	8.7	16.6	28.1
Gates	8.7	41.0	1.6	1.1	0.9	1.7	3.5	7.5	14.1
Nadina	5.9	13.5	1.0	3.4	2.0	4.0	8.8	19.3	39.2
Pitt[a]	3.2	10.4	0.2	1.6	0.1	0.3	0.5	1.0	1.7
Scotch	6.0	21.5	2.1	1.4	1.0	1.9	4.3	9.0	17.9
Seymour	6.9	29.2	3.4	1.8	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]	2.6	5.8	0.6	1.0	0.3	0.8	2.3	6.9	20.3
Misc (Nahatlatch) [c]	-	-	-		1.4	3.1	5.7	10.8	20.2
Summer									
Chilko	6.4	25.3	0.9	1.6	2.2	3.5	5.7	10.2	15.7
Late Stuart	8.2	57.2	0.6	3.5	1.0	2.5	6.8	18.4	45.0
Quesnel	8.0	31.4	0.4	2.8	2.1	4.0	8.1	18.4	33.4
Stellako	6.4	16.3	0.1	1.4	1.5	2.5	4.1	6.7	11.7
Harrison[d]	6.5	33.8	0.1	0.7	0.4	1.1	2.9	7.5	16.4
Raft	5.4	14.3	0.4	1.9	1.0	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 [e]	0.036	0.06	0.0092	0.017	0.0046	0.0104	0.0220	0.0543	0.1117
Late Shuswap	4.7	21.2	2.8	0.5	1.1	2.5	6.2	14.1	36.1
Portage	10.8	69.1	0.3	1.7	1.3	2.9	7.0	17.8	39.1
Weaver	9.7	41.8	2.6	0.8	1.6	3.6	9.7	23.1	56.5
Birkenhead	4.6	21.5	1.2	0.8	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 displayed as Five-Year-Old survival, therefore recent generation is 2010-2013.
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
d. Harrison is presented as total survival;.
e. Cultus survivals are presented as marine survival; recruits-per-juvenile.

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. Values below 1,000 were rounded to the nearest 100, rather than the nearest 1,000, in order to demonstrate age distributions.

Sockeye stock/timing group	2019 Fraser Sockeye Forecasts				
	Four-year-old return 50%[a]	Five-year-old Return 50%[a]	Total Return 50%	Four-Year-Old Proportion	Five-Year-Old Proportion
Early Stuart	27,000	15,000	41,000	64%	36%
Early Summer					
Bowron	9,000	6,000	15,000	61%	39%
Upper Barriere (Fennell)	8,000	2,000	10,000	83%	17%
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	28%	72%
Scotch	15,000	3,000	19,000	82%	18%
Seymour	25,000	5,000	29,000	85%	15%
Misc (EShu)	63,000	94,000	156,000	40%	60%
Misc (Taseko)	3,000	40	3,000	99%	1%
Misc (Chilliwack)	7,000	1,000	8,000	85%	15%
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	125,000	293,000	57%	43%
Raft	31,000	22,000	52,000	59%	41%
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	500	800	38%	62%
Late					
Cultus	600	100	700	86%	14%
Late Shuswap	20,000	41,000	61,000	32%	68%
Portage	100	1,500	1,600	7%	93%
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	3,617,000	1,169,000	4,786,000	76%	24%

a. Following further investigation into the Chilliwack data and Ricker model, errors were found both in the application of the Chilliwack data, and the Ricker model. Models were re-ran in the post-season, and results for Chilliwack have therefore changed.
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
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. Total Fraser Sockeye forecasts for 1998 to 2016 from the 10% to 90% p-levels, where available. 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 and 2018 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	1,795,000	2,888,000	4,786,000	8,641,000	14,172,000	

*preliminary return estimates for 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	4,472,000

Table 7. Overview of model selections for 2015, 2018 and 2019 forecast. Models that changed from 2018 to 2019 are highlighted. Note that in most of these cases the specific model changed, but the same criteria for selecting a model have been used. Appendix B and C for further detail..

	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*

6. FIGURES

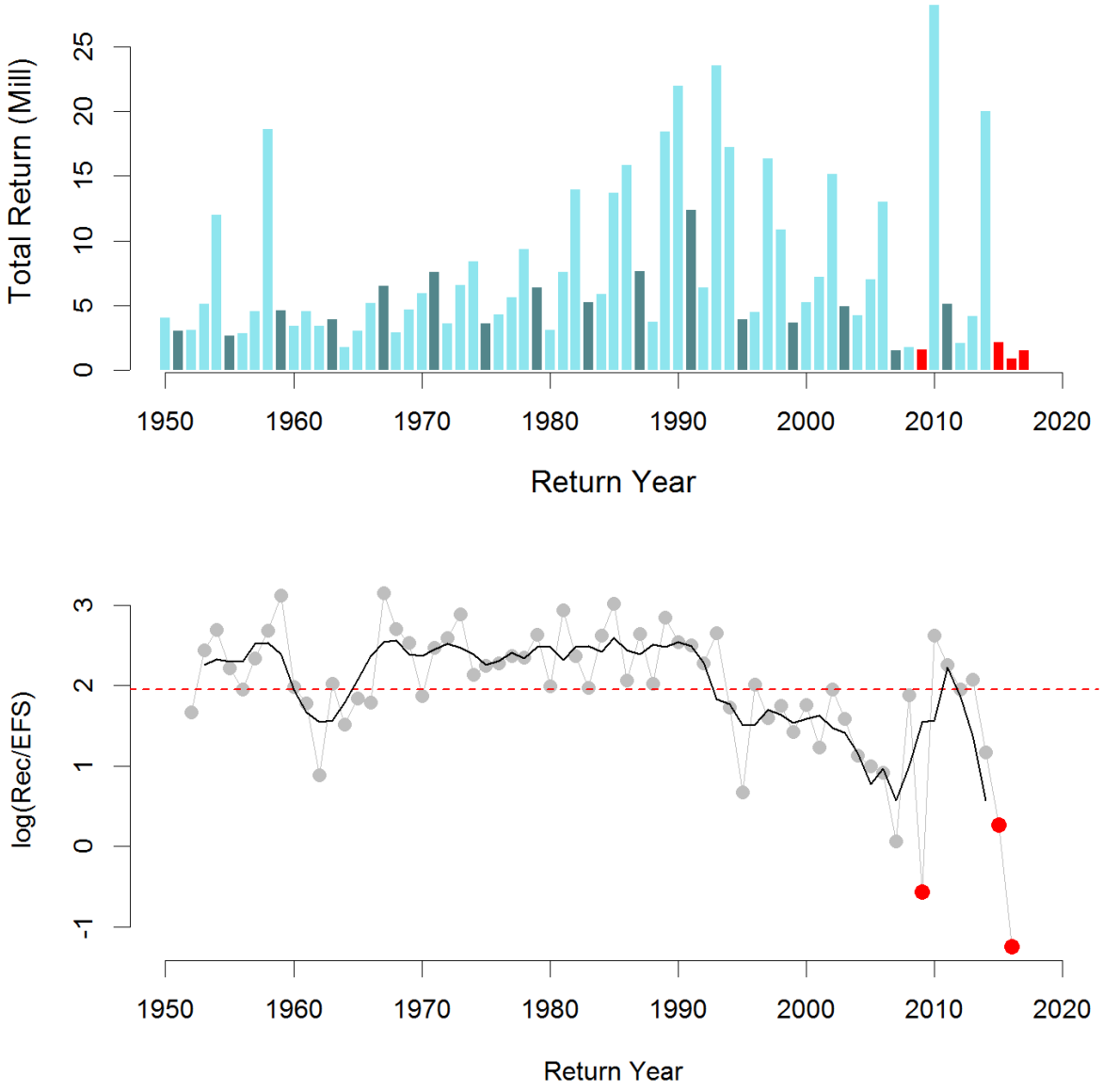

Figure 1. Total returns and overall survival rate of Fraser Sockeye. Top panel shows total adult annual returns (dark blue vertical bars for the 2019 cycle and light blue vertical bars for the three other cycles). Adult returns from 2018 are preliminary. Bottom panel shows overall Fraser Sockeye adult 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.

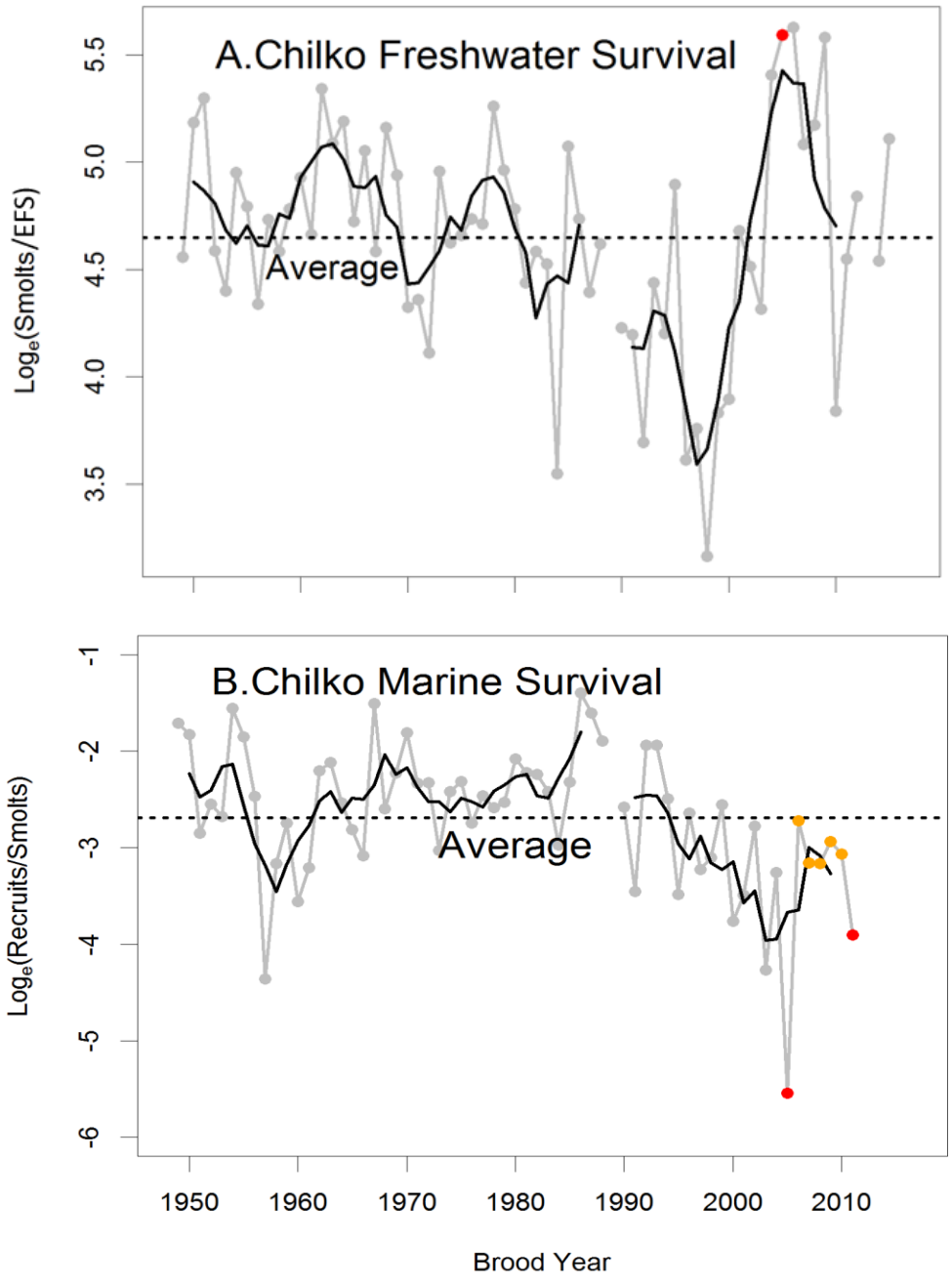

*Figure 2. Chilko River Sockeye **A**. annual freshwater (log$_e$ smolts/effective female spawners) survival (filled grey circles and lines); the red filled circle represents the 2005 brood year (2009 returns); note no smolt assessment was conducted in the 2013 brood year representing a gap in the current 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.*

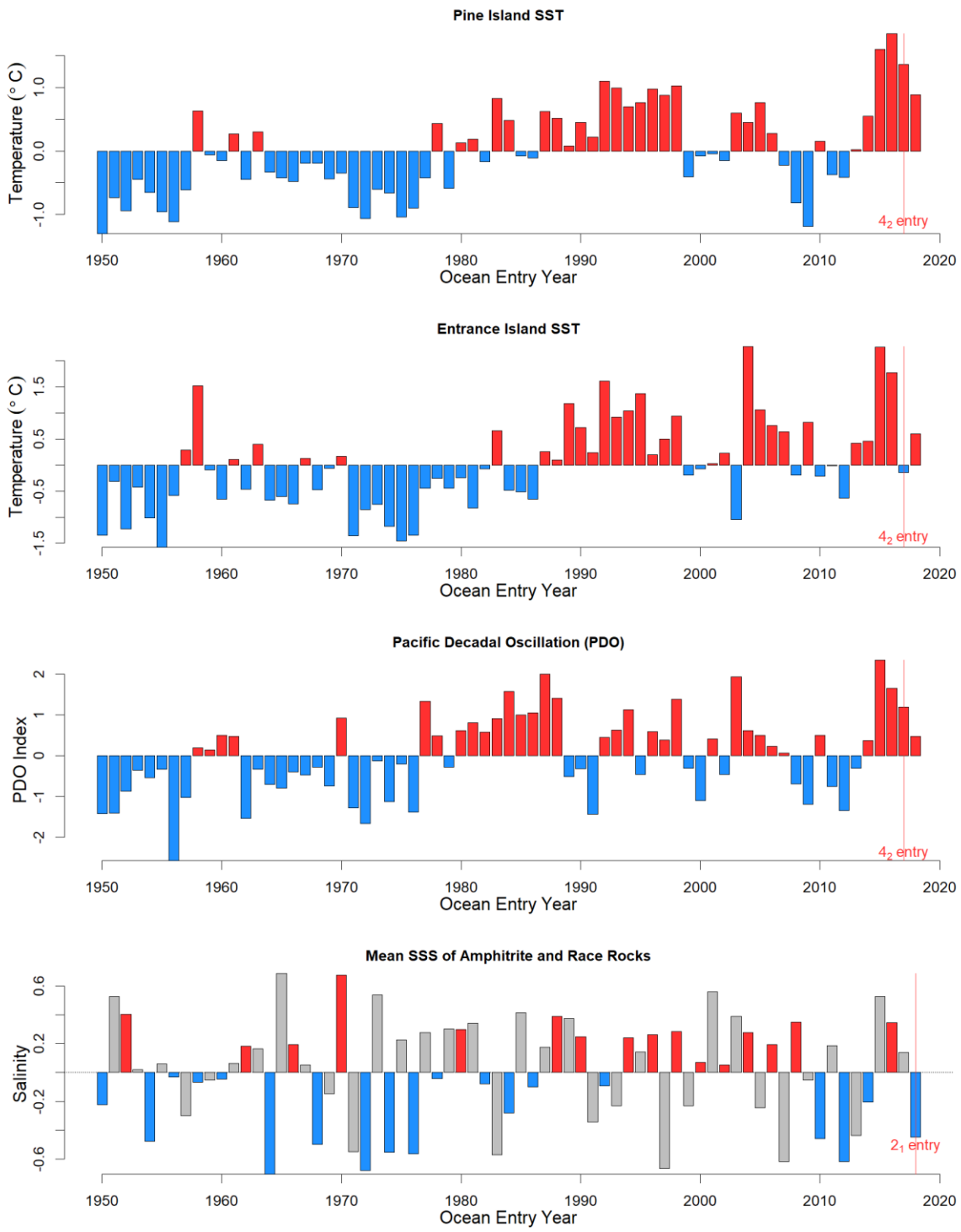

Figure 3. Sea surface temperatures (SST) measured at Entrance Island (Strait of Georgia; April-June average), Pine Island (Queen Charlotte Strait; April-July average), winter PDO index (Nov.-March), and average sea surface salinity (SSS) of Amphitrite and Race Rocks (July-Sept.). Values are presented as raw deviations from time-series averages (1950-2015). Red vertical lines mark the anomalies that most Fraser salmon would have entered into upon outmigration (age 4_2 sockeye, age 2_1 pink). Red bars (positive values) indicate above-average anomalies and blue bars indicate below-average anomalies. SSS for odd entry years are greyed out, since Fraser Pink salmon out-migrate in even years.

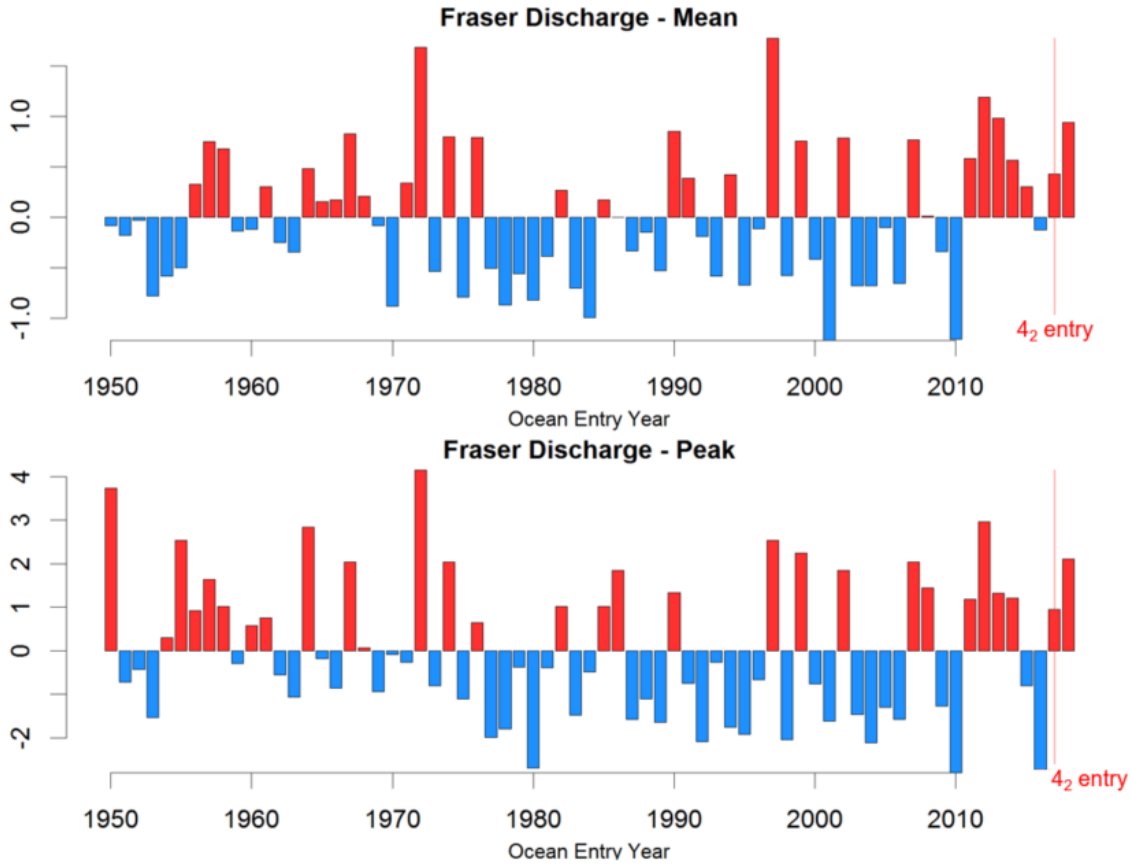

Figure 4. Fraser River discharge shown as mean conditions over April-June and peak discharge. Values are presented as raw deviations from time-series averages (1950-2016). The 2017 ocean entry year, highlighted with a red vertical line, marks the temperature anomalies that most Fraser Sockeye from the 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).

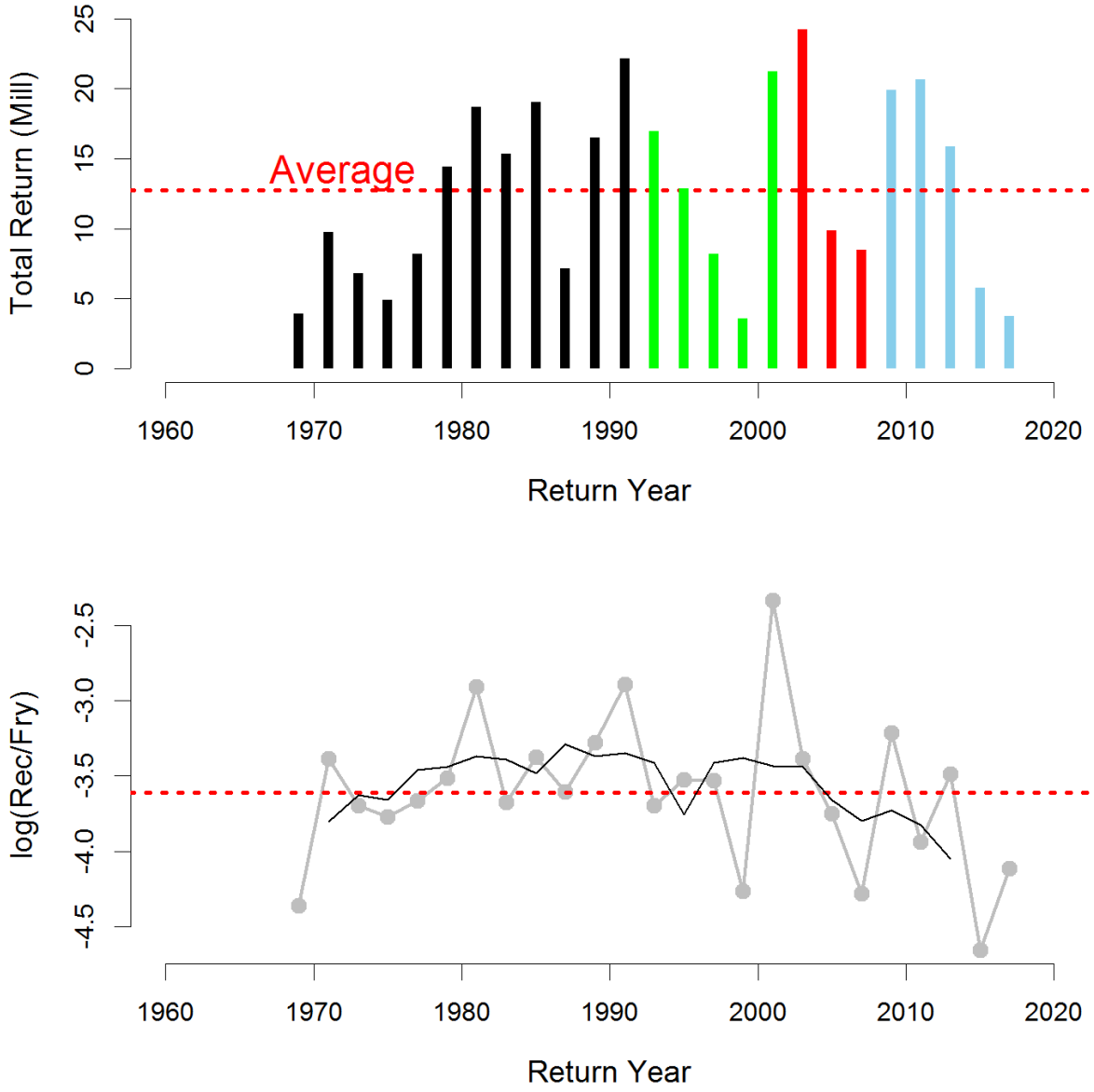

Figure 5. **Upper Panel**. Fraser River Pink Salmon returns (black or coloured bars) estimates. Escapement estimates were generated from system-specific programs from 1957 to 1991 (black bars), system-wide single mark recaptures from 1993 to 2001 (green bars), indirect system-wide marine test fisheries 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%).

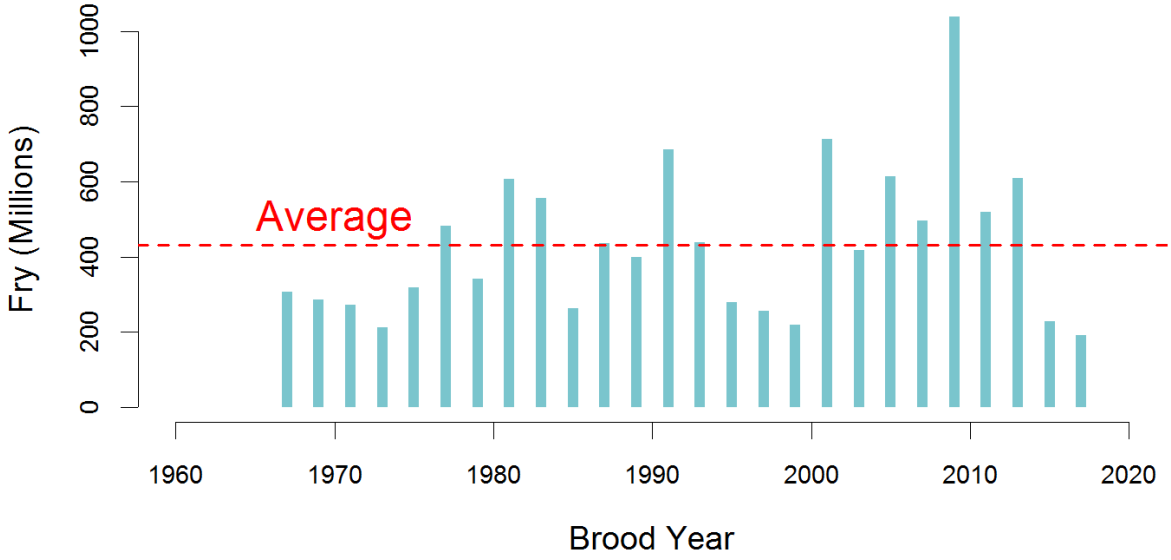

Figure 6. Fraser River Pink Salmon fry abundance. The 2017 fry abundance (192 million), which is the brood year for 2019 returns, is the last bar in the figure. The average fry abundance over the time series is 432 million (dashed red line).

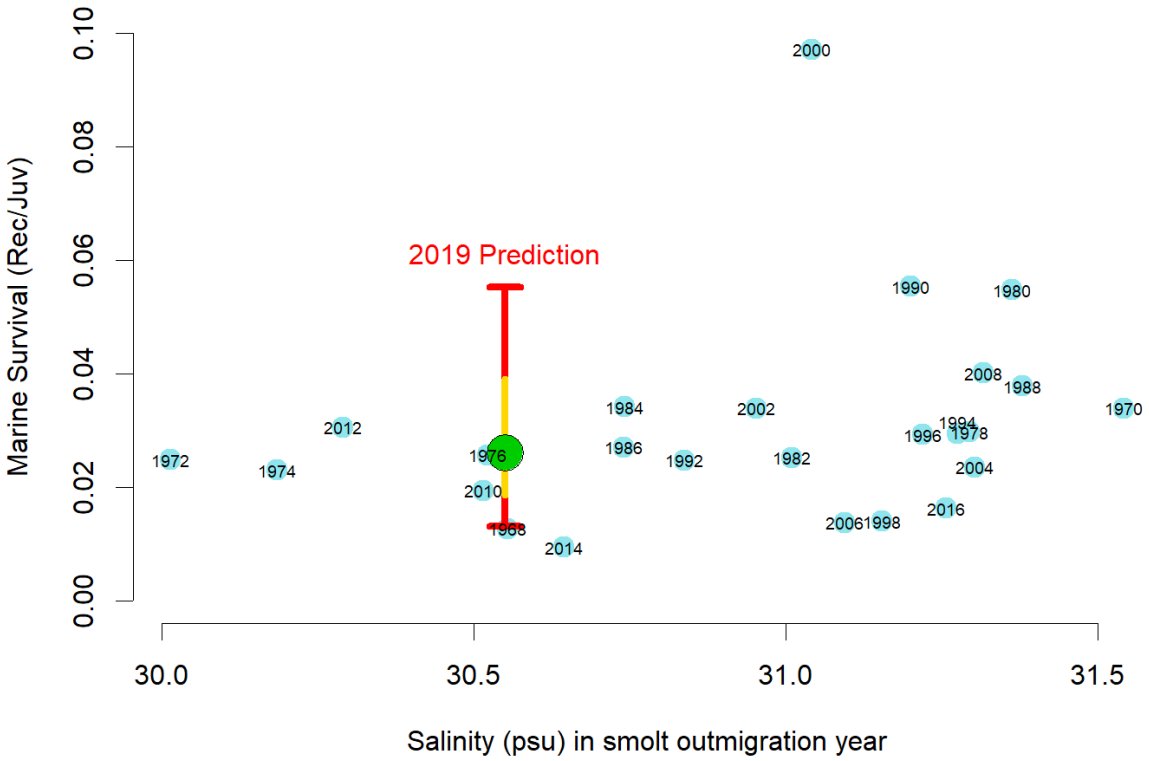

Figure 7. Fraser Pink marine survival (returns/smolt) versus salinity (Practical Salinity Units) in the Strait of Georgia in the pink fry outmigration year, with the marine survival associated with the 2019 forecast (and associated uncertainty) overlaid at observed 2018 salinity. Green circle represents P50, yellow bar representing P25-P75 range, and red bar representing P10-P90 range.

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8. CONTRIBUTORS

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APPENDIX A. STOCK GROUP DATA SUMMARIES

A.1. 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

A.2. EARLY SUMMER

Run Timing Group	Escapement				2015 Stock Contributions										
Early Summer	Avg	Cyc.Avg	BY(2015)	BY Trend[a]	Bowron	Seymour	Fennell	Scotch	Gates	Nadina	Pitt	South Thom	Taseko	Chilli-wack	Naha-tlatch
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

A.3. 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

-

A.4. 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 B. 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 consistently 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 forecast survival implied by the addition of the covariate across the applicable stocks, temperature covariate forecasts are adopted for these stocks;
5) In cases where age-5 returns (age-3 for Harrison) were forecast to make up more than 50% of the return, sibling models are applied. In these cases, age-4 returns (age-3 for Harrison) are still modelled using the criteria described above, and combined with age-5 forecasts (age-4 for Harrison) produced using the sibling model.
6) 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 (see Table 2).

APPENDIX C. INDIVIDUAL STOCK FORECAST SUMMARIES

C.1. EARLY STUART (TAKLA-TREMBLEUR-EARLY STUART CU) - EARLY STUART MU

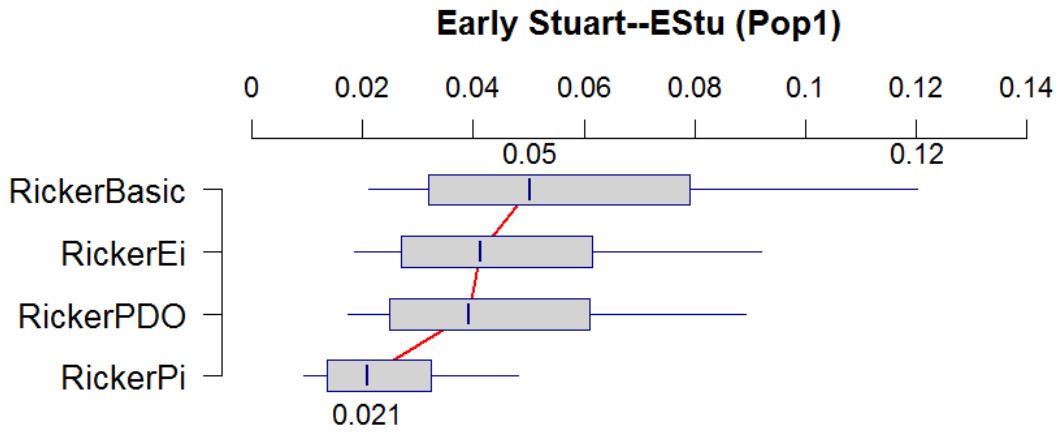
Early Stuart		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	54%	54%	51%
Summary	Spawner Success	89%	75%	88%	67%
	EFS	24,000	4,100	18,700	23,300

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.2. BOWRON (BOWRON-ES) – EARLY SUMMER MGMT UNIT

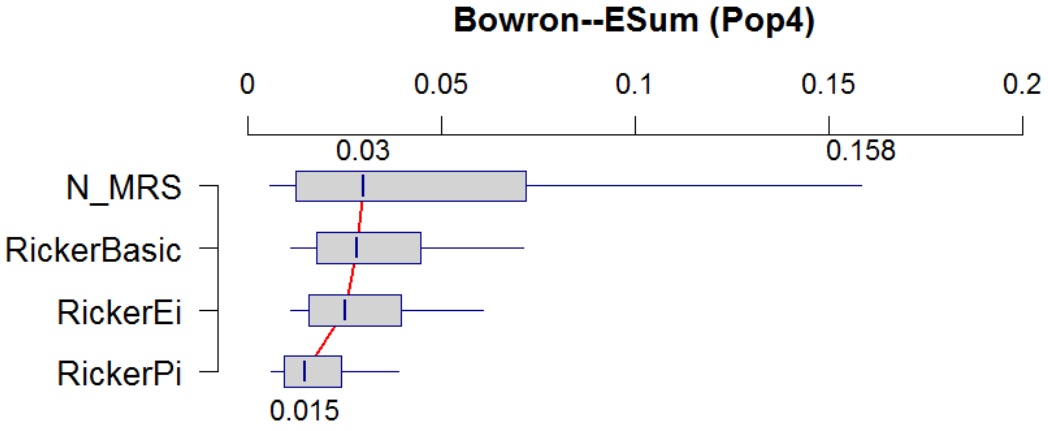
Bowron		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	53%	64%	55%	55%
Summary	Spawner Success	87%	90%	92%	95%
	EFS	7,800	2,200	3,300	6,300

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.3. FENNELL (NORTH BARRIERE CU) – EARLY SUMMER MGMT UNIT

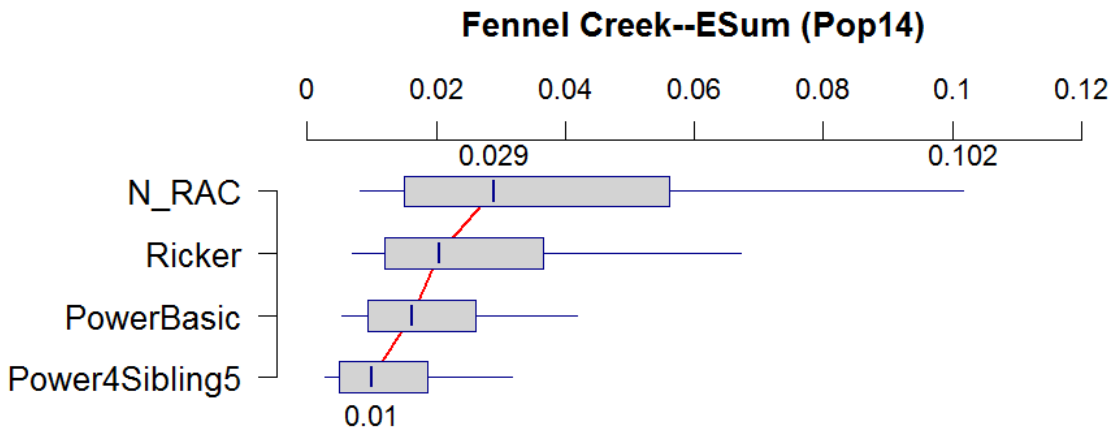
Fennell		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	57%	68%	63%	61%
Summary	Spawner Success	95%	98%	96%	98%
	EFS	4,700	900	3,700	6,800

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.4. GATES (ANDERSON-SETON-ES CU) – EARLY SUMMER MGMT UNIT

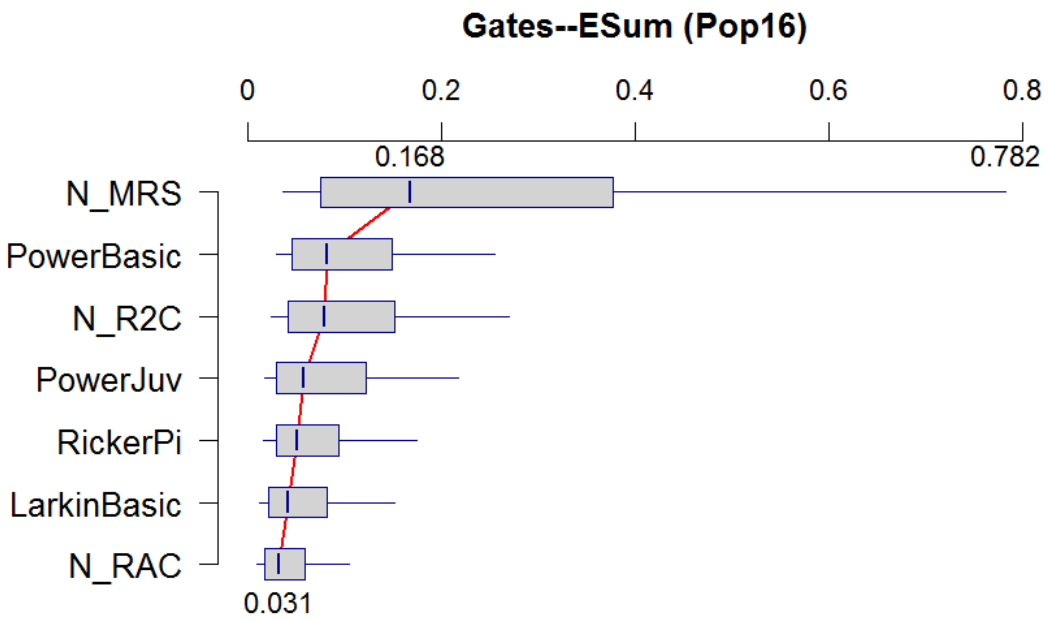
Gates		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	62%	57%	61%	63%
Summary	Spawner Success	77%	93%	77%	85%
	EFS	5,300	9,600	2,200	8,500

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.5. NADINA (NADINA-FRANCOIS-ES CU) – EARLY SUMMER MGMT UNIT

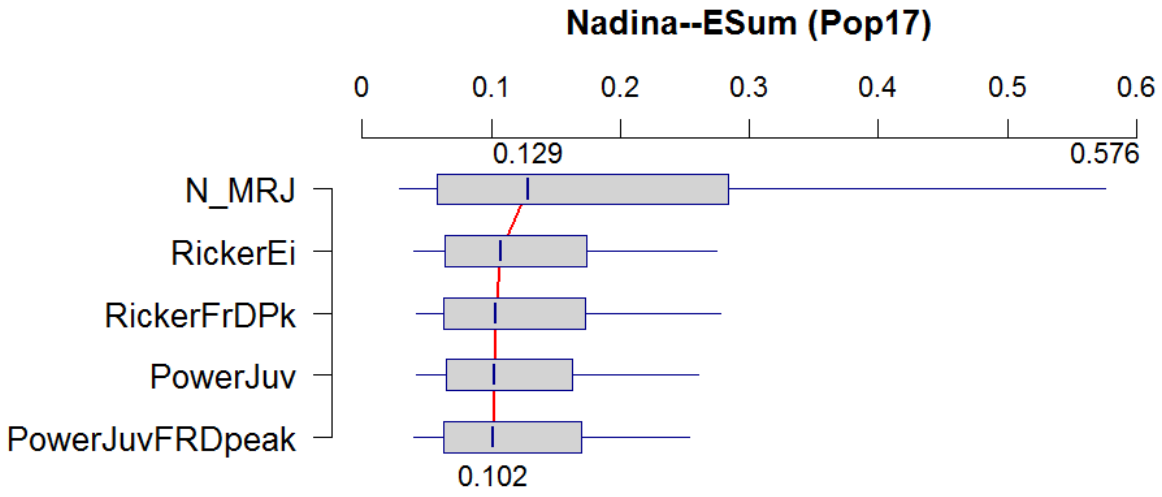
Nadina		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	52%	41%	58%	57%
	Spawner Success	82%	67%	87%	88%
	EFS	11,100	9,400	5,600	30,700
	Freshwater Surv.(fry/EFS)	1,100	1,200	1,400	900
	Fry Abundance	11M	11M	7M	26M

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**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)



C.6. PITT (PITT-ES CU) – EARLY SUMMER MGMT UNIT

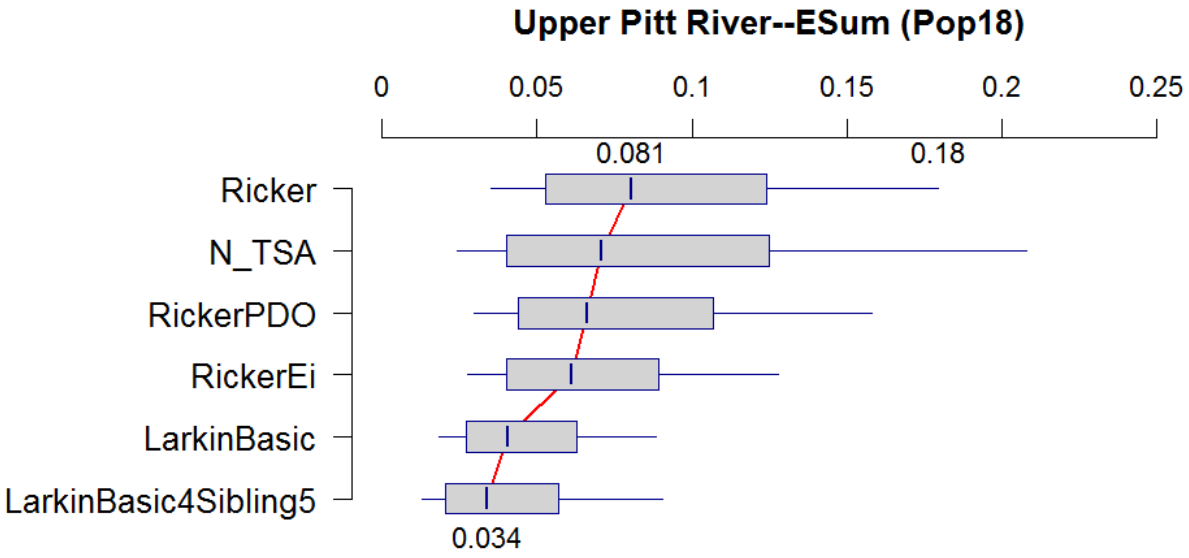
Upper Pitt		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	52%	47%	52%	48%
	Spawner Success	94%	98%	90%	80%
	EFS	14,900	18,400	13,800	14,400

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.7. SCOTCH (PART OF SHUSWAP-ES CU) – EARLY SUMMER MGMT UNIT

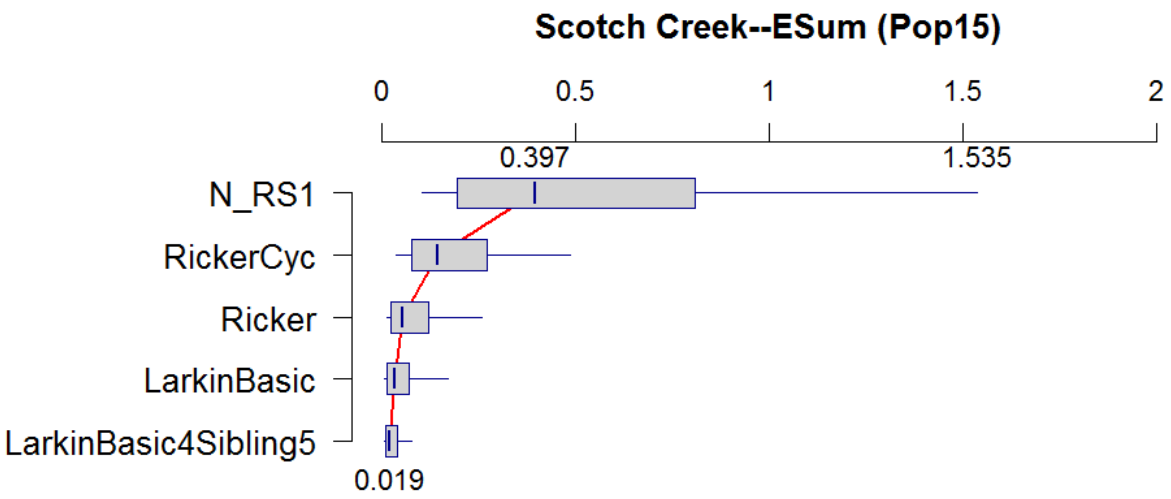
Scotch		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	55%	54%	55%
Summary	Spawner Success	87%	97%	92%	93%
	EFS	4,300	3,500	62,000	68,800

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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
Larkin4Sibling5	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)



C.8. SEYMOUR (PART OF SHUSWAP-ES CU) – EARLY SUMMER MGMT UNIT

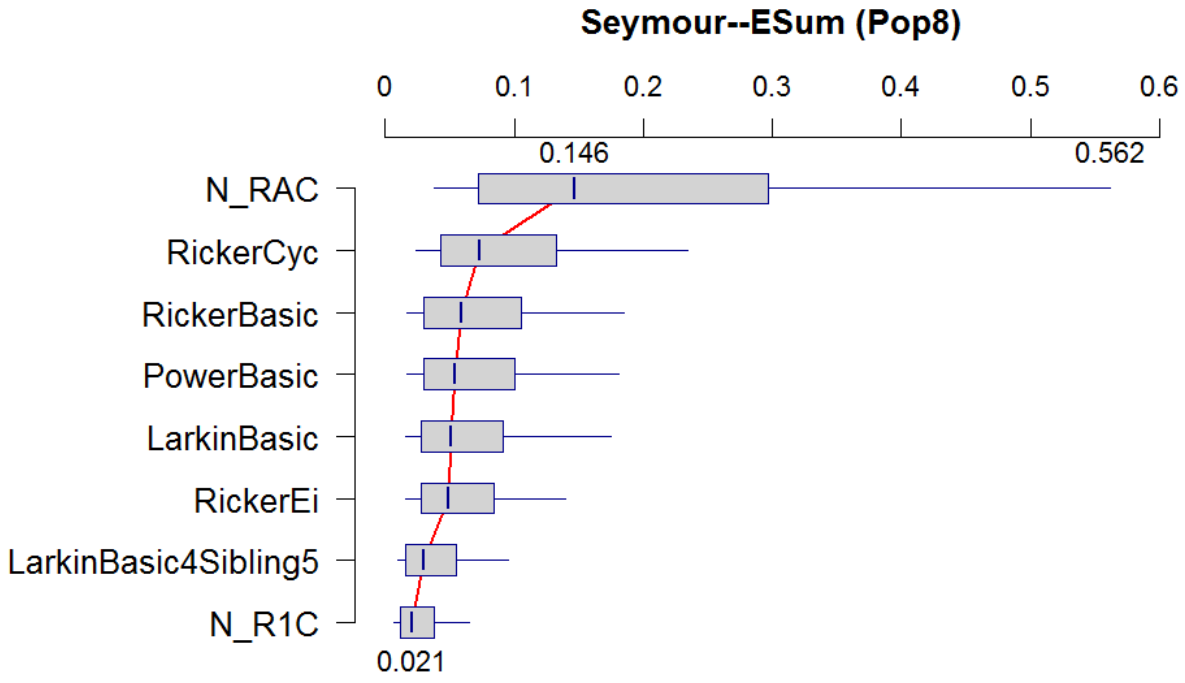
Seymour		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	51%	51%	51%	55%
Summary	Spawner Success	93%	98%	94%	93%
	EFS	18,400	4,000	49,700	57,400

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast 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
Larkin4Sibling5	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)



C.9. CHILKO (CHILKO-S CU) – SUMMER MGMT UNIT

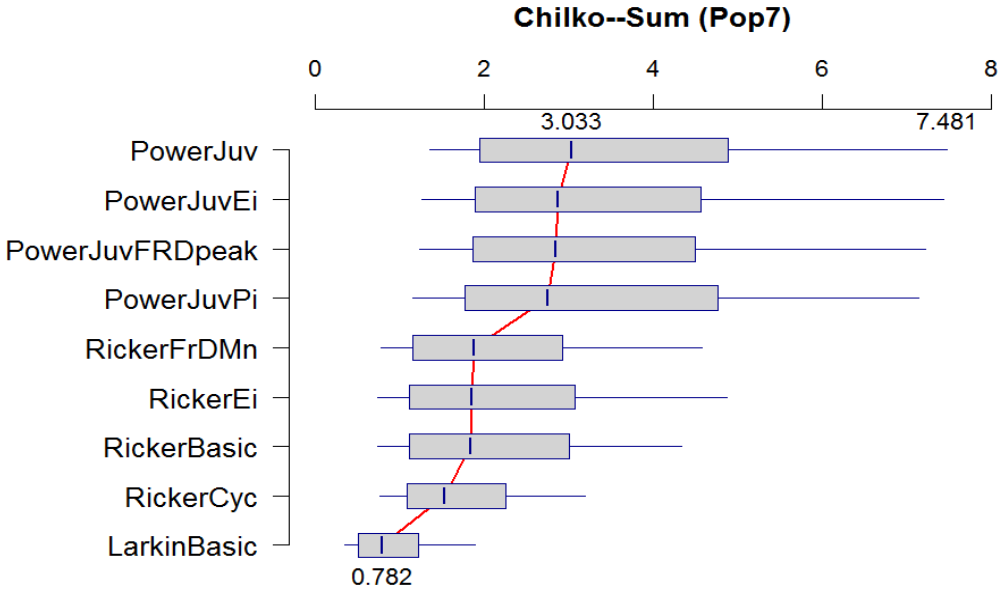
Chilko		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	58%	66%	59%	65%
	Spawner Success	93%	99%	93%	100%
	EFS	315,400	429,000	364,400	666,000
	Freshwater Surv.(fry/EFS)	100	200	100	100
	Fry Abundance	31M	71M	30M	62M

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

Top-ranked Forecasts – Table

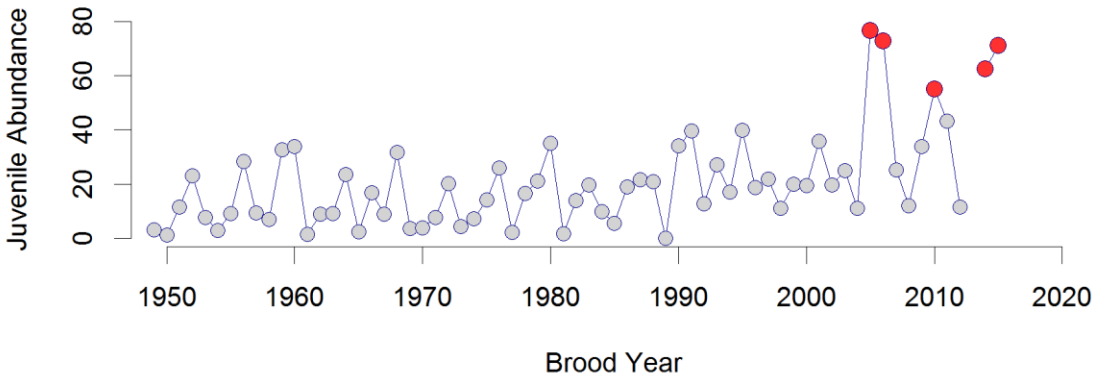
		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
LarkinBasic	1	343,000	506,000	782,000	1,225,000	1,884,000	0.5	0.8	1.4	2.4	3.8
PowerJuv	3	1,352,000	1,950,000	3,033,000	4,880,000	7,481,000	2.5	3.8	6.2	10.6	16.4
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
PowerJuv-FRDpeak	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
RickerFrD-Mn80k	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

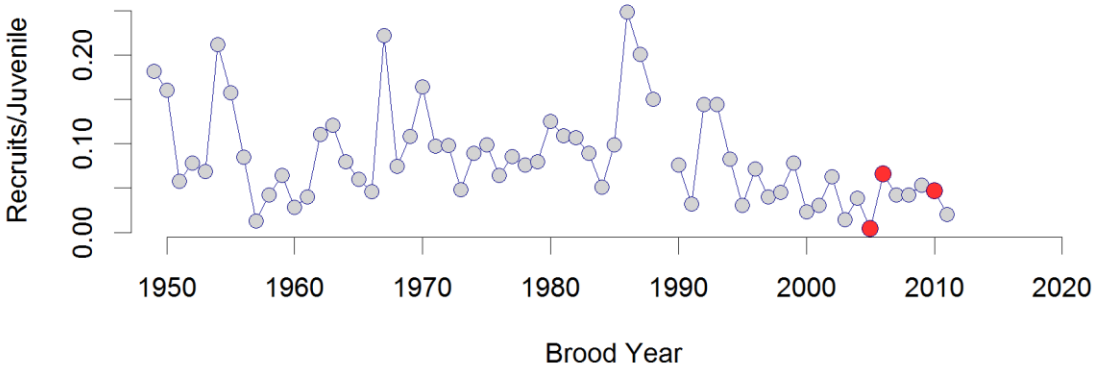
Top-ranked Forecasts - Plot(All numbers in Millions of Fish)



Chilko juvenile abundance and productivity plots:

The time series of juvenile abundance (in millions) and recruits-per-juvenile (productivity during out-migration and marine stage) of the Chilko stock. Red dots represent brood years of high juvenile abundance (more than 50 million) and corresponding productivity of these brood years, which is relatively low compared to historical records.





C.10. LATE STUART (TAKLA-TREMBLEUR-S CU) – SUMMER MGMT UNIT

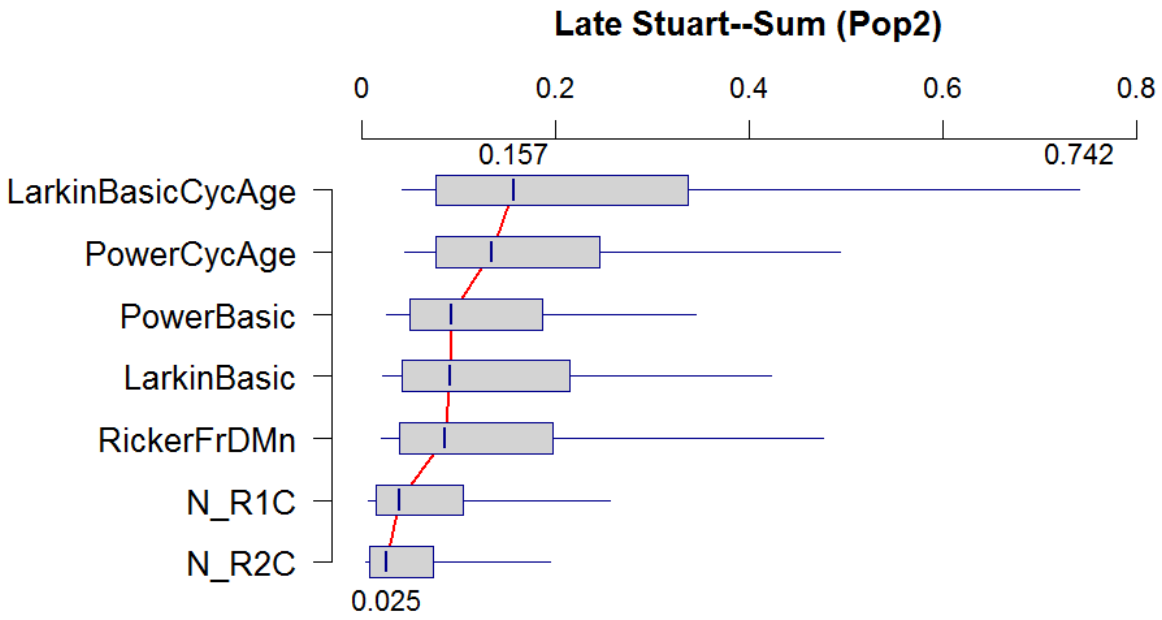
Late Stuart		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	52%	40%	55%	58%
	Spawner Success	96%	98%	98%	95%
	EFS	9,200	4,400	23,600	27,900

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast 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)



C.11. QUESNEL (QUESNEL-S CU) - SUMMER MGMT UNIT

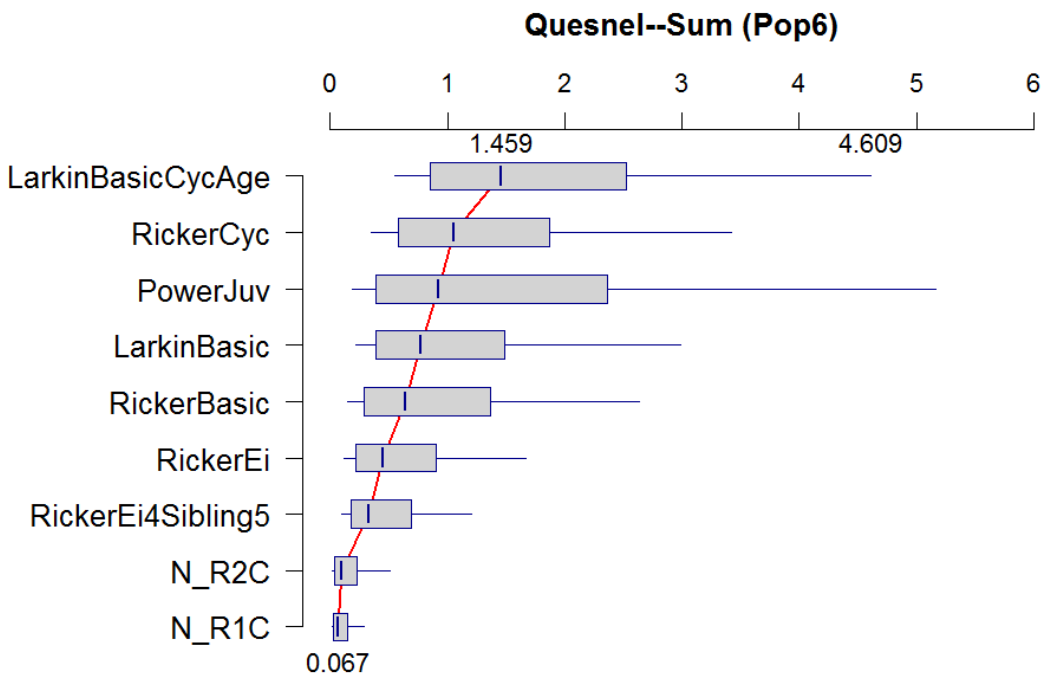
Quesnel		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	56%	59%	52%	53%
	Spawner Success	95%	95%	95%	98%
	EFS	28,600	25,700	190,600	431,000

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
LarkinBasic-CycAge	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)



C.12. STELLAKO (FRANCOIS-FRASER-S CU) – SUMMER MGMT UNIT

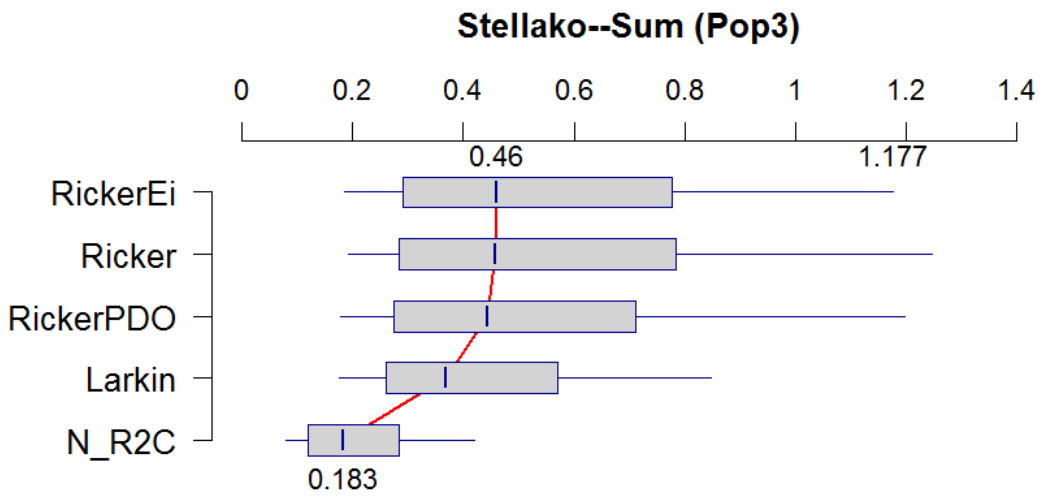
Stellako		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	55%	51%	55%	52%
Summary	Spawner Success	84%	93%	94%	91%
	EFS	52,700	47,600	76,100	240,400

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.13. HARRISON (HARRISON RIVER – RIVER TYPE CU) – SUMMER MGMT UNIT

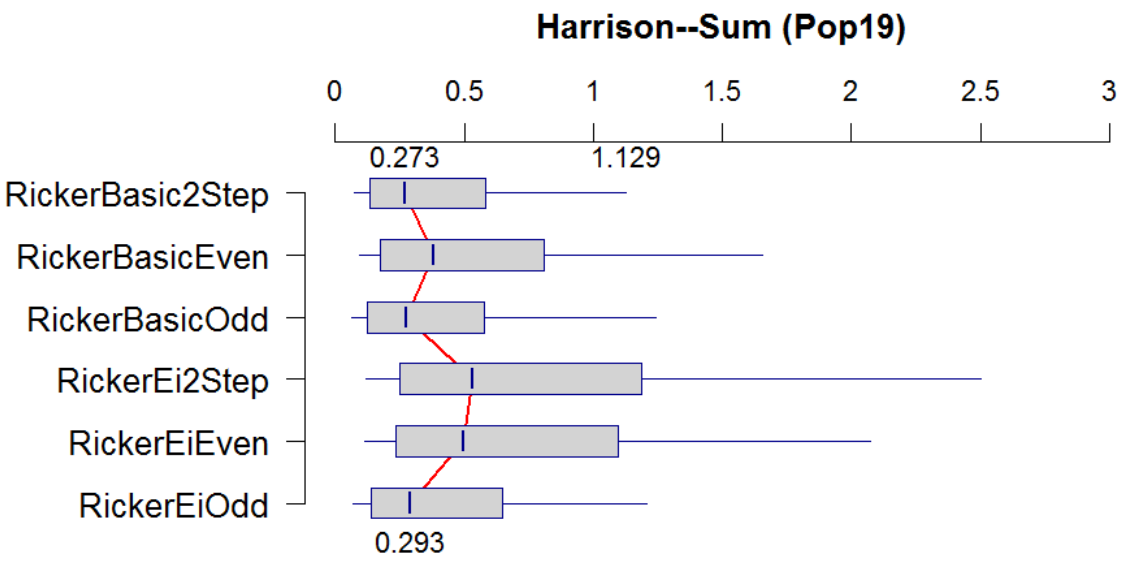
Harrison		Four-Year-Olds		Three-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground	% Female	52%	51%	57%	53%
Summary	Spawner Success	94%	99%	96%	99%
	EFS	36,300	58,300	50,200	34,400

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



C.14. RAFT (KAMLOOPS-ES CU) – SUMMER MGMT UNIT

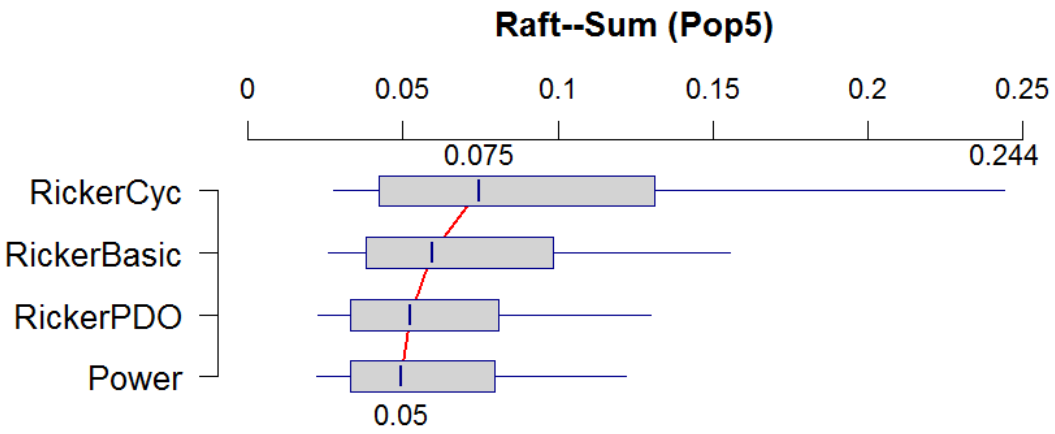
Raft		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	55%	53%	55%	57%
	Spawner Success	93%	98%	94%	98%
	EFS	2,900	8,800	3,300	9,500

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**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)



C.15. CULTUS (CULTUS-L CU) – LATE MGMT UNIT

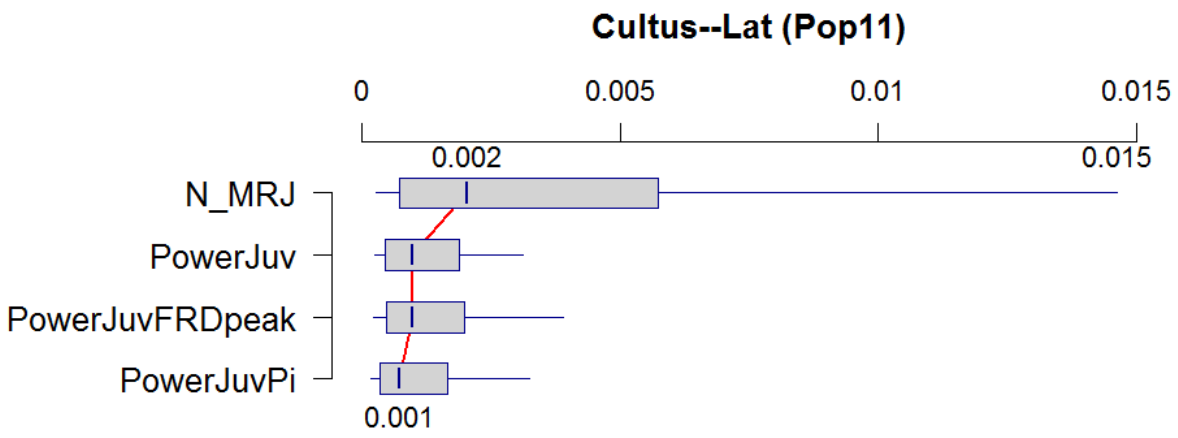
Cultus		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	60%	50%	60%	49%
	Spawner Success	24%	0%	10%	64%
	EFS	NA	NA	NA	NA
	Freshwater Surv.(fry/EFS)	NA	NA	NA	NA
	Fry Abundance	891,000	29,000	827,000	51,000

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
N_MRJ	1	0	1,000	2,000	6,000	15,000	0.009	0.024	0.067	0.190	0.485
PowerJuv	99	0	0	1,000	2,000	3,000	0.006	0.013	0.029	0.062	0.109
PowerJuvFRDpeak	2	0	0	1,000	2,000	4,000	0.006	0.014	0.029	0.067	0.135
PowerJuvPi	3	0	0	1,000	2,000	3,000	0.005	0.010	0.022	0.054	0.112

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



C.16. LATE SHUSWAP (SHUSWAP-L CU) – LATE MGMT UNIT

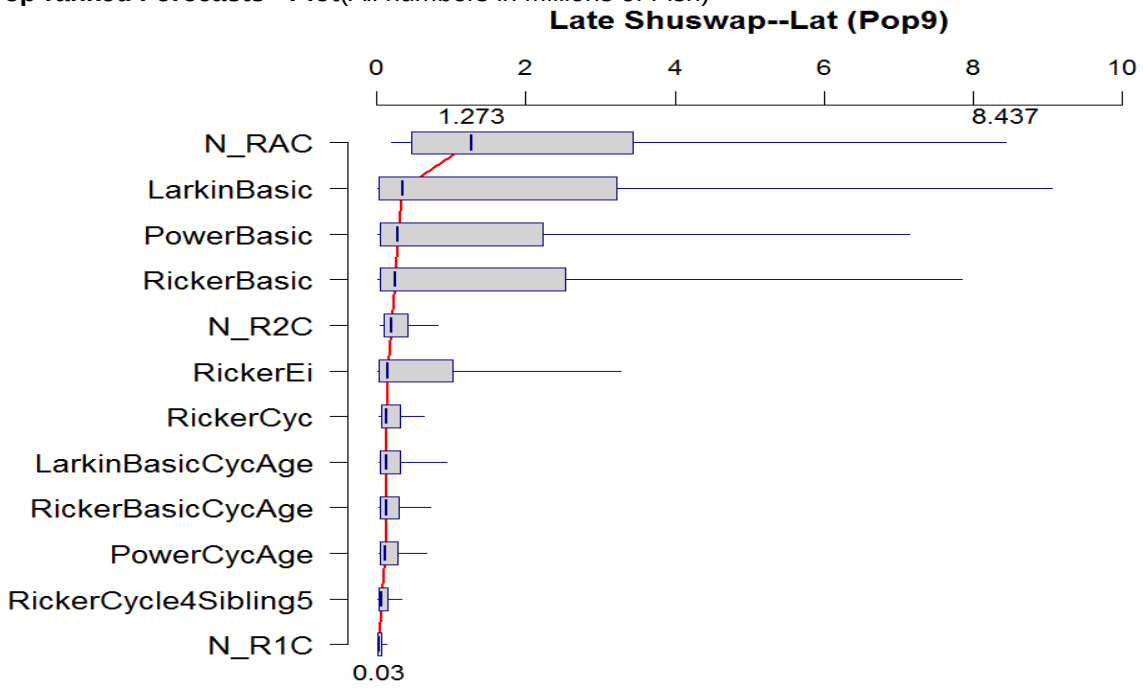
Late Shuswap		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	53%	50%	53%	50%
	Spawner Success	94%	66%	91%	96%
	EFS	162,400	3,200	1,199,100	1,053,500

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast 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
LarkinBasic-CycAge	5	22,000	50,000	125,000	322,000	937,000	1.8	3.1	6.1	11.6	20.4
RickerBasic-CycAge	7	22,000	51,000	124,000	301,000	709,000	1.6	3.2	7.1	16.3	32
PowerBasic-CycAge	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)



C.17. PORTAGE (SETON-L CU) – LATE MGMT UNIT

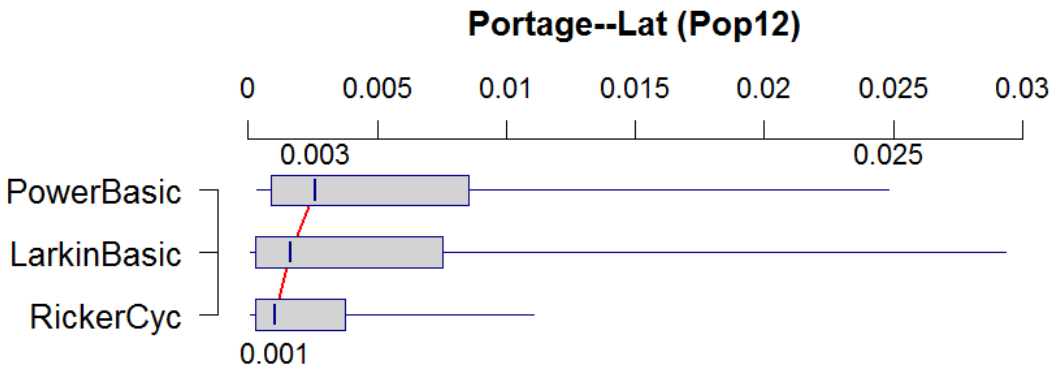
Portage		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	58%	50%	53%	57%
	Spawner Success	95%	94%	92%	90%
	EFS	2,100	NA	8,600	12,300

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

Top-ranked Forecasts – Table

		Forecast Return					Forecast 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)



C.18. WEAVER (HARRISON (U/S)-L CU) – LATE MGMT UNIT

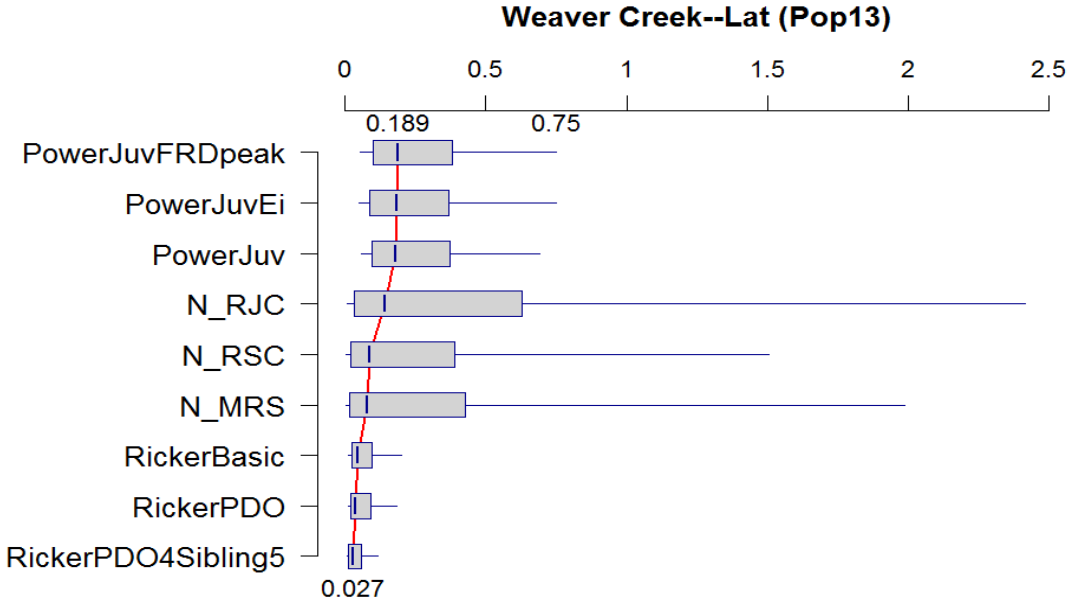
Weaver		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	56%	58%	51%	50%
	Spawner Success	87%	64%	85%	85%
	EFS	17,000	1,100	30,500	10,400
	Freshwater Surv.(fry/EFS)	2,100	8,200	1,600	1,700
	Fry Abundance	27M	9M	36M	17M

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast Age4 Survival				
Model	**Rank**	**10%**	**25%**	**50%**	**75%**	**90%**	**10%**	**25%**	**50%**	**75%**	**90%**
PowerJuv-FRDpeak	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)



C.19. BIRKENHEAD (LILLOOET-HARRISON-L CU) – LATE MGMT UNIT

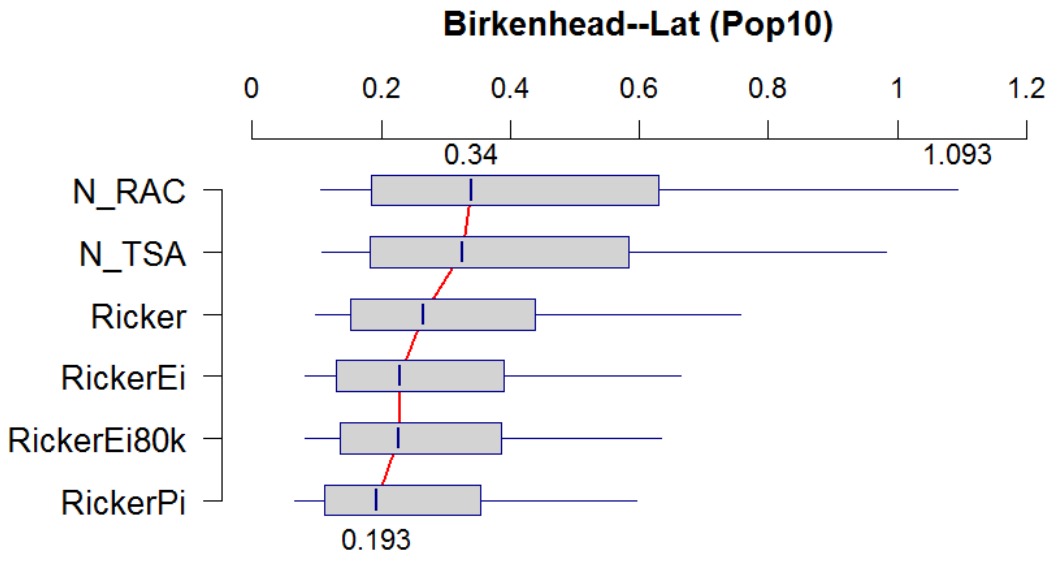
Birkenhead		Four-Year-Olds		Five-Year-Olds	
		Cyc. Avg.[a]	2015 BY	Cyc. Avg.[b]	2014 BY
Spawning Ground Summary	% Female	55%	61%	59%	59%
	Spawner Success	90%	98%	97%	94%
	EFS	45,600	26,700	66,500	19,600

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

Top-ranked Forecasts - Table

		Forecast Return					Forecast 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)



MISCELLANEOUS STOCKS

Miscellaneous Stocks – All Management Units

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.

	EFS 2014	EFS 2015	Proxy for long-term Prod.	Forecast Return					Forecast Age-4 Survival				
				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*	941	2,702	7,999	24,184	70,752	0.3	0.8	2.3	6.9	20.3
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 forecast using a Ricker model applied to a very limited time series of recruitment data (2001 to 2013). due to model instability owing to a short S-R time series, the modelling approach for Chilliwack was revisited after presentation of the forecast results, but prior to publication. Results for Chilliwack have therefore changed from 17,000 to 8,000 at the P50 level*

C.20. 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