

# PRE-SEASON RUN SIZE FORECASTS FOR FRASER RIVER SOCKEYE (*ONCORHYNCHUS NERKA*) IN 2024

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## ABSTRACT

Dionne, K. and Gao, J. 2025. Pre-Season Run Size Forecasts for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) in 2024. Can. Tech. Rep. Fish. Aquat. Sci. 3714: v + 32 p.  
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Forecasts for the 2024 Fraser River Sockeye and Pink salmon returns were prepared with Bayesian statistical models and presented as cumulative probability distributions. The total Fraser River Sockeye return for 2024 has a median estimate of 567,000 (80% PI:167,000 to 2,173,000) expected mainly from the Chilko and Harrison River stocks in the Summer run timing group. Forecasts for 8 stocks included environmental covariates while sibling models were used to calculate the age-5 forecast for 6 stocks. Nearshore sea surface temperature suggest mixed environmental signals for salmon productivity while the Pacific Decadal Oscillation suggests that sea surface temperatures offshore are more favourable. The 2024 Pre-season Fraser Sockeye forecast represents the lowest forecast on record, with the next lowest being on the same cycle line in 2024.

## RÉSUMÉ

Dionne, K. and Gao, J. 2025. Pre-Season Run Size Forecasts for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) in 2024. Can. Tech. Rep. Fish. Aquat. Sci. 3714: v + 32 p.  
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Les prévisions concernant les remontes de saumon rouge et de saumon rose en 2024 ont été préparées à l'aide de modèles statistiques bayésiens et présentées sous forme de distributions de probabilités cumulées. L'estimation médiane des remontes totales de saumon rouge du fleuve Fraser pour 2024 est de 567 000 individus (intervalle de précision à 80 % : de 167 000 à 2 173 000 individus), provenant principalement des stocks des rivières Chilko et Harrison dans le groupe de montaison estivale. Les prévisions pour 8 stocks comprenaient des covariables environnementales, et on a utilisé des modèles de classes d'âge jumelles afin de calculer les prévisions pour les poissons d'âge 5 de 6 stocks. La température de la surface de la mer près du rivage indique des signaux environnementaux mixtes pour la productivité du saumon, tandis que l'oscillation décennale du Pacifique indique que les températures de la surface de la mer au large sont plus favorables. Les prévisions d'avant la saison de 2024 pour le saumon rouge du fleuve Fraser sont les plus faibles jamais enregistrées; la deuxième prévision la plus faible est sur la même lignée du cycle en 2020.

# 1. BACKGROUND

## 1.1 FRASER SOCKEYE SALMON

The Fraser River is the largest watershed in British Columbia and home to all species of Pacific Salmon found in the Eastern Pacific Ocean. Fraser River Sockeye salmon (*Oncorhynchus nerka*) typically demonstrate a four year, lake-type life cycle where juveniles rear in a lake for one full year prior to migrating to the marine environment. There they spend two or three years at sea before returning to spawn in their natal streams. The exception to this life history strategy are the river-type Harrison Sockeye that migrate to the Strait of Georgia shortly after egg emergence and return as 3- and 4-year-old adults. Several stocks also display cyclic dominance with one return year being more abundant than the remaining three cycle lines.

Fraser River Sockeye salmon have historically supported large commercial, recreational, and First Nations harvests (Gilhousen 1992). However, recent productivity trends have become more variable, resulting in both the largest (2010) and lowest (2020) Fraser Sockeye returns in recorded history (Figure 1; Pacific Salmon Commission 2021). 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 (CUs) or Designatable Units (DUs), which are the discrete and evolutionary distinct constituent populations of the Fraser River Sockeye aggregate. The WSP process identified seven of the 19 forecasted 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).

The increased variability of returns of Fraser River Sockeye beginning in the 1990s has resulted in reduced predictability by forecast models. Since this time returns have generally been lower, on average, than forecasts based on long-term average survival (with the exception of several years of larger than expected returns). Several studies have linked ocean warming and environmental volatility associated with climate change to low survival of Fraser Sockeye salmon (Mueter et al. 2002; Connors et al. 2020; MacDonald et al. 2020). Environmental covariates are included in the forecasting process and show mixed signals for the 2024 return. Nearshore sea surface temperature (SST) measured at Entrance Island in the spring of 2022 (at the time of early marine entry for the 2024 return) show colder than average conditions while Pine Island (2022) show near average conditions (Figure 3). Moreover, the Pacific Decadal Oscillation (PDO) was cooler than average in 2022 (Figure 3) indicating off shore SST have been more favourable for salmon production. Additionally, a summary of ocean ecosystem indicators used to characterize juvenile marine salmon survival in the Northern California Current put 2022 in the middle of all the years with respect to overall condition ranks (1998-2022) (Figure 9).

Escapement data is collected by DFO staff using a variety of methods. In general, higher precision methods (sonar or mark-recapture studies) are used to enumerate larger populations, while lower precision methods (e.g., visual surveys, peak count via aerial or ground-based surveys, carcass recovery surveys) are used to enumerate smaller populations (Sean Everitt, DFO, Fraser River Stock Assessment Program Head Sockeye, pers. comm.). The specifics of the escapement programs as well as the escapement estimates are provided annually for the

forecasting process by DFO Stock Assessment and are the primary driver of the forecasts (Macdonald and Grant 2012).

The 2024 Fraser River Sockeye salmon forecast of 567,000 (167,000 – 2,173,000) is lower than the long term and cycle line average return, and is the lowest forecast on record. However, both freshwater and marine survival have been showing an increasing trend in the last several cycle lines (Figure 2) and environmental conditions in the marine environment are near average for salmon production (Figure 9).

## **1.2 SPECIAL CONSIDERATIONS: BIG BAR LANDSLIDE**

In 2019, the Big Bar landslide resulted in a persistent migratory barrier throughout the adult migration season and caused the blockage and delay of several stocks attempting to reach their spawning grounds. This migratory impediment persisted in 2020 and high discharge in the Fraser Canyon resulted in further migratory stress for Sockeye salmon. Migratory challenges resulted in significant en-route losses for Middle and Upper Fraser sockeye and the lowest escapement estimates on record for several stocks. Stocks that were particularly affected were Early Stuart and Bowron while Chilko, Nadina, Late Stuart, Stellako, and Quesnel were impacted to a lesser extent. Given that 2024 is the first return of both 4-year-old and 5-year-old broods (i.e. 2019 and 2020) affected by Big Bar many forecasted stocks are predicted to return well below cycle average. For further information on the Big Bar landslide and its perceived impacts on Fraser salmon populations see the Big Bar Landslide Hydroacoustic Technical Report (Hanson-Wright et al., DRAFT).

## **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 forecast methods have not changed dramatically over time, there have been innovations both in the modeling frameworks applied and the sophistication of computation (e.g. Cass et al 2006, MacDonald and Grant 2012; Akenhead et al. 2016). The recent low, yet highly variable productivity for most Fraser Sockeye stocks has added additional challenges to forecasting returns, with many years falling at the low end of the forecast distributions. In 2022, the retrospective analysis was updated using a one-step-ahead approach to replace the previous jackknife retrospective analysis that was conducted in 2012. (MacDonald and Grant 2012; Liu and Xu, 2024; Xu et al., 2024).

The Fraser River Sockeye salmon preseason forecast is required to inform pre-season planning of First Nations, recreational, and commercial fisheries and stock assessment programs, and provides informative priors for the in-season run-size assessment programs. It also supports planning decisions of the bilateral Fraser River Panel and provides advice to DFO fisheries managers regarding in-season harvest management of Sockeye salmon (Pacific Salmon Treaty 1985).

## 2. DATA AND METHODS

### 2.1 DATA

#### 2.1.1 Sockeye Data

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

##### *Spawners*

- Effective Female Spawners (EFS) data are included up to the 2020 brood year for all stocks, except Harrison (2021 brood year), following previous forecasts (DFO 2021; 2022; Appendix D). Brood year EFS among most of major stocks are below the historic cycle-year average for the primary age cohorts returning in 2024 except the Nadina, Scotch, and Chilliwack stocks (Table 1B).

##### *Juveniles*

- Fry data for the 2020 brood year are available for Nadina and Weaver. Each stock typically has a large proportion of fry production originating from a spawning channel with a monitoring program in place, along with a smaller proportion of fry originating from the adjacent natural spawning grounds. Fry data were available for the channels and natural rivers/creeks historically, but limited to the channels in 2020 and 2021 brood years. 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. This infilling approach is consistent with previous model settings (Grant et al. 2010; MacDonald and Grant 2012). Gates channel fry survey has stopped since 2019 brood year (1968-2018) due to the termination of the spawning channel usage.
- Juvenile smolt data in the 2020 brood year are available for Cultus and Chilko.

##### *Recruitment*

- The most recent brood year for which full recruitment data are available (2020 brood year; 2021 for Harrison) is included in the dataset although values are considered preliminary. There were changes in recruitment data between current and previous forecasts due to the run-size adjustment process (return year: 2021 and 2022) and recalculation of age composition (return year 2019-2020).
- The time series (by brood year) of EFS, juveniles, and recruitment data used to run the models are from 1948-2020 for all stocks except for Nadina (1973-2020), Gates (1968-2020), Scotch (1980-2020), Fennell (1967-2020), Weaver (1966-2020), Portage (1953-2020) and Chilliwack (1998-2020).

#### 2.1.2 Environmental Data

The following environmental data were collected and incorporated in several biological models (used in 2006-2022; See Cass et al. 2006 and MacDonald and Grant 2012 for further details; DFO 2021):

- Pacific Decadal Oscillation (PDO) in the winter preceding outmigration (November to March), with a negative (colder ocean) condition for 2022 (Zhang et al. 1997, Mantua et al. 1997; data available online; Figure 3).
- 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 (data available online; Sebastien Donnet, DFO, Sidney, BC, pers. comm.; Figure 3) of the year of outmigration. The SST variables in 2022 show colder than average conditions at the Entrance Island location while warmer than average conditions at the Pine Island location.
- Peak Fraser Discharge (FrD-peak) and average Fraser Discharge (FrD-average) from April to June of the outmigration year measured at Hope, BC, with higher discharge in both variables in 2022 compared with the time series average (David Patterson, DFO, Vancouver, BC, pers. comm.; Figure 4).

## 2.2 METHODS

The 2024 Fraser Sockeye forecasts followed recent forecasting methods using a Bayesian statistical approach to estimate parameters from biological models and MCMC (Markov Chain Monte Carlo) to assess the uncertainties (Cass et al. 2006; MacDonald and Grant 2012; DFO 2013; DFO 2014; DFO 2015; DFO 2016; DFO 2017; DFO 2018; Hawkshaw et al. 2020a; Hawkshaw et al. 2020b; DFO 2021). Visualization tools including Taylor diagrams and an R markdown HTML Viewer that were developed in the 2022 forecast season were also implemented for the 2024 forecast.

Model selection for the 19 major stocks is completed through consensus by expert opinion where a shortlist of top-ranked models from the retrospective analysis are considered. Model performance and ranking for Fraser Sockeye salmon are presented on Taylor diagrams and ranking tables based on the one-step-ahead retrospective analyses developed in the 2022 forecast season (Liu and Xu, 2024, Xu et al., 2024). The updated analysis hindcasts the run size for last three generations between 2009 and 2020 for all 27 stocks and is more reflective of recent population dynamics, current productivities, and environmental conditions. The total and age-specific forecasts resulted from the top-ranked models and their corresponding implied productivities are presented and compared to the historical time-series of observed productivity. Preference was given to models that can capture the dynamics of recent productivity. Detailed descriptions of all models are listed in Table 4. For miscellaneous stocks with no recruitment data available, in general forecasts are based on brood year escapements and ‘recent’ observed survival rates for proxy stocks (See Appendix A). Although Chilliwack is considered a miscellaneous stock, it is analyzed separately using both the aforementioned methodology and biological models in 2024 as this is the dominant cycle line for this stock.

For the last several years, sibling models have been used to inform older age-class productivity, using return data from their brood-year mates that returned the previous year. A description of the sibling model can be found in the 2019 forecast document (Hawkshaw et al. 2020a), and a description of the recently updated sibling model selection criteria can be found in the 2020 forecast document (Hawkshaw et al. 2020b). In the context of 2024, the goal of using sibling

models is to forecast older age class fish by using data from the 2023 return to align the forecast of age 5 fish to the recent productivity trend observed for many stocks in 2023.

### 3. RESULTS

The 2024 total p50 Fraser River Sockeye return is estimated to be 567,000 (80 %PI: 167,000 - 2,173,000). This is the lowest forecasted return on record and is substantially lower than both the cycle line average (3.2 million) and all-years average return (7.1million; Table 1B).

The 2024 forecast for Early Stuart sockeye is 200 (80 to 400) and was generated using a Ricker model with sea surface temperature at Entrance Island as a covariate (Ricker(Ei)). The forecasted proportion of age-4 returns is 80% (Table 3). The extremely poor forecast for Early Stuart is due to two consecutive near zero escapements in 2019 and 2020 (46 and 15 EFS respectively). Enhancement efforts to reduce the impact of the Big Bar landslide saw the release of 119,000 smolts to Takla Lake from the 2020 brood year. In the absence of data to inform any stock-recruit modelling, a distribution of possible hatchery-based returns was generated using freshwater and marine survival estimates from Chilko as a proxy. The approximate expected hatchery return for Early Stuart in 2024 is 1,000 (500 to 2,000) but should not be considered a true forecast as it is uninformed by any data for the Early Stuart population at this time.

The total forecasted return for the Early Summer aggregate, including miscellaneous stocks, is 159,000 (58,000 to 465,000) and 121,000 (37,000 to 379,000) excluding miscellaneous stocks. The primary contributing stocks to the Early Summer return at the p50 forecast are Nadina (65,000) and the Chilliwack miscellaneous stock (41,000). Nadina was forecasted using a Ricker model with a Fraser River Discharge Peak environmental covariate for age-4s and sibling model for age-5s, and is expected dominated by age-4 returns (91%). Although Chilliwack is considered a miscellaneous stock, a shortened stock-recruit dataset exist allowing the stock to be forecasted on the Chilliwack specific dominant cycle line (2024) using biological models typically reserved for major stocks. In 2024, Chilliwack was forecasted using a Ricker model to predict age-4 returns and a sibling model to predict age-5 returns. There was a great deal of variability among models for the Chilliwack forecast which is typical of shorter datasets.

The Summer run-timing group is expected to be the largest contributor to the 2024 forecast with a forecasted return of 379,000 (101,000 to 1,554,000). At the p50 forecast, Chilko is predicted to be the largest contributing stock with a p50 forecast of 176,000 (51,000 to 564,000). Chilko was forecasted using a Ricker model with a cycle line covariate (RickerCyc) for the 4-year-old return and a sibling model for the 5-year-old return. Although Chilko is a data rich stock with a robust smolt enumeration program, models that include the juvenile abundance covariate have tended to be overly optimistic in recent years. The sibling model performed well for the age- 5 component of the Chilko forecasts in both the Taylor diagrams and is the top ranked model in the age-specific retrospective ranking table. Top models for the age-4 Chilko forecast included Larkin and RickerCyc. Larkin models have historically been favoured for forecasting Chilko sockeye as they were highly ranked in the previous retrospective analysis (MacDonald 2012) but have had a tendency to over forecast in recent years. The implied productivity using the RickerCyc more closely aligns with recent observations and was therefore selected for 2024. Harrison is expected to be the second most abundant stock in 2024 with a p50 forecast of 106,000 (17,000 to 663,000). Although this relative contribution is atypical, Harrison sockeye were also the most abundant stock in 2020 where poor returns of other stocks led to the lowest

return on record. The stock-recruit time series for Harrison is highly variable, with an approximate 10 year period (~2001-2011) where returns were significantly stronger than previous years; however, recent returns and returned to previous lower levels. The variability in Harrison returns results in a stock-recruit relationship that does not fit well with biological models such as a Ricker model. Therefore, we tend to use naïve models for predicting age-3s for Harrison and a sibling model to predict age-5s. The top ranked naïve model for forecasting Harrison is a time series average. Stellako is expected to be the third most abundant stock in 2024 with a p50 forecast of 65,000 (25,000 to 169,000). This forecast was generated using a naïve model that estimates the average recruits across the last 2 cycle line returns and a sibling model to estimate the number of age-5s. Model selection for the remaining stocks in the Summer run timing aggregate can be found in Table 1A.

The forecast for the Late run timing group is 29,000 (8,000 to 154,000) with the vast majority expected to be Birkenhead sockeye (24,000; 7,000 to 87,000). The Birkenhead forecast was generated using a Ricker model with an Entrance Island SST covariate. Sibling models are highly ranked for Birkenhead, however the implied productivity of the 2024 sibling model (30) is greater than previous productivity values for this stock. Therefore a single Ricker ( $E_i$ ) model was selected for both age classes as the implied productivity of the model aligned well with previous observations. Late Shuswap and Weaver are forecasted to contribute 2,000 Sockeye each at the p50 level. The forecast for Cultus Sockeye is 100 (40 to 600).

For further details on model selection rationale at the stock level, see Appendix B.

#### **4. DISCUSSION**

The 2022 Fraser River Sockeye forecast was the first year that the updated retrospective analysis was used for model selection. From 2015 to 2020, forecast performance was exceptionally poor with post-season returns closer to the p10 forecast or lower for all years except 2018. Returns in 2021 were better than forecasted (p75) despite not having an updated retrospective analysis available. Forecast performance improved in 2022 and 2023 relative to the previous 10 years, with 2023 being the most accurate forecast on record. However, while the 2023 total return was very close to the pre-season p50 forecast, there was some variability at the MU and stock-level and future retrospective work will look to improve MU forecasts. The updated retrospective analysis uses a one-step-ahead approach that assesses model performance between 2009 and 2020. This ensures forecasting models are capturing recent relationships between abundance and covariates and are not based on historical correlations that are no longer relevant in the current environment. The strong forecast performance in 2023 can likely be attributed to these updated methods and environmental conditions that were near the long term average.

The 2024 Fraser River Sockeye forecast is the lowest forecasted return on record as these are recruits coming from the two lowest consecutive returns in the time series (2019 and 2020). Although environmental conditions for salmon production still largely remain better than recent years, brood year escapements are so low that depensation may be occurring on some stocks. Additionally, the enhancement contribution from some of the stocks impacted by Big Bar, which are expected to return in 2024, are currently unknown. Beginning in 2020, the development of sibling models has resulted in improved forecasts of the age-5 component of the run. These

models should continue to be used when highly ranked and implied productivity aligns with recent observations.

## **5. CONCLUSIONS**

The 2024 Fraser Sockeye forecast of 567,000 (167,000 -2,173,000) is the lowest forecast on record, due in large part to record low brood year returns in 2019 and 2020 (Figure 1). Forecast performance over the past decade has generally been poor and unable to capture recent patterns of low productivity that were observed over the past decade, with the exception of 2021. However, recent updates to the retrospective analysis are likely capturing current productivity and population dynamics which has resulted in improvements in forecast accuracy.

In 2024, the expected proportion of age-4 fish is 69%, which is higher than 2023 but still below the long term average of 91% (Table 3). Environmental indicators are mixed for the 2020 brood year with nearshore temperatures above average at Pine Island station but below average at Entrance Island station in the outmigration year of 2022. PDO was below average signifying cooler conditions, which is often better for offshore salmon production (Figure 3). A stoplight chart of ocean indicators generated by the National Oceanic and Atmospheric Administration (NOAA) suggests that overall marine conditions in 2022 returned to near average for salmon production (Figure 9). It is important to note that while marine conditions offshore suggest a potential for higher productivity and marine survival, the brood year EFS values for 2019 and 2020 are well below average. This adds some uncertainty to the forecast as there is potential for higher productivity (in the absence of density-dependence in freshwater) but also for low productivity and associated low returns in 2024 due to depensation.

## 6. TABLES

Table 1A. The 2024 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 median 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. Results above 1,000 have been rounded to the nearest 1,000; between 100 and 1,000 to the nearest 100; and between 10 and 100 to the nearest 10. Asterices are to highlight stocks that are predicted to return at or less than 1,000 at the p50.

Run timing group Stocks	Forecast Model	Probability that Return will be at/or Below Specified Run Size				
		10%	25%	50%	75%	90%
<b>Early Stuart</b>	<i>Ricker (Ei)</i>	80	100	200*	300	400
<i>Early Stuart Hatchery*</i>		500	800	1,000	2,000	2,000
<b>Early Summer Total</b>		58,000	93,000	159,000	281,000	465,000
<i>Total excluding misc. stocks</i>		37,000	66,000	121,000	226,000	379,000
Bowron	<i>RickerCyc</i>	400	700	1,000*	2,000	4,000
Upper Barriere (Fennell)	<i>PowerBasic4Sibling5</i>	1,000	3,000	5,000	12,000	23,000
Gates	<i>Ricker (Pi)</i>	9,000	15,000	27,000	47,000	76,000
Nadina	<i>RickerFrDpeak4, Sibling5</i>	18,000	33,000	65,000	127,000	216,000
Pitt	<i>LarkinBasicCyc</i>	7,000	10,000	16,000	24,000	36,000
Scotch	<i>Larkin</i>	1,000	3,000	5,000	10,000	18,000
Seymour	<i>Ricker (Pi)</i>	700	1,000	2,000	4,000	7,000
Misc (EShu)	<i>R/S</i>	100	100	700*	1,000	2,000
Misc (Taseko)	<i>R/S</i>	10	20	70*	90	100
Misc (Chilliwack)	<i>Ricker4Sibling5</i>	20,000	26,000	34,000	48,000	71,000
Misc (Nahatlatch)	<i>R/S</i>	500	900	3,000	6,000	12,000
<b>Summer Total</b>		101,000	192,000	379,000	774,000	1,554,000
<i>Total excluding misc. stocks</i>		101,000	192,000	379,000	772,000	1,551,000
Chilko	<i>RickerCyc4Sibling5</i>	51,000	96,000	176,000	317,000	564,000
Late Stuart	<i>R1C</i>	2,000	5,000	12,000	33,000	80,000
Quesnel	<i>R2C</i>	300	900	3,000	9,000	26,000
Stellako	<i>R2C4Sibling5</i>	25,000	39,000	65,000	107,000	169,000
Harrison	<i>TSA3Sibling4</i>	17,000	41,000	106,000	277,000	663,000
Raft	<i>PowerBasicCyc</i>	6,000	10,000	17,000	29,000	51,000
Misc (N. Thomp. Tribs)	<i>R/S</i>	50	80	200*	500	700
Misc (N. Thomp River)	<i>R/S</i>	50	80	200*	500	700
Misc (Widgeon)	<i>R/S</i>	20	60	80*	1,100	1,600
<b>Late Total</b>		8,000	15,000	29,000	66,000	154,000
<i>Total excluding misc. stocks</i>		8,000	15,000	29,000	63,000	150,000
Cultus	<i>PowerJuv(Pi)</i>	40	70	100*	300	600
Late Shuswap	<i>Ricker(Pi)4Sibling5</i>	100	500	2,000	10,000	42,000
Portage	<i>Ricker (Pi)</i>	30	80	200*	600	1,000
Weaver	<i>RickerCyc</i>	400	700	2,000	5,000	19,000
Birkenhead	<i>Ricker (Ei)</i>	7,000	13,000	24,000	46,000	87,000
Misc Harrison/Lillooet	<i>R/S</i>	50	100	200*	3,000	4,000
<b>TOTAL SOCKEYE SALMON</b>		167,000	299,000	567,000	1,121,000	2,173,000
<i>Total Sockeye excluding misc. stocks</i>		147,000	272,000	529,000	1,061,000	2,081,000

Table 1B. Fraser Sockeye brood year effective female spawners (EFS, except smolts for Cultus) for the four- and five-year-old recruits returning in 2024 (2020 and 2019 brood years). Brood year EFS are colour-coded by comparing to the cycle-line average from the historical time series (start years vary; “Mean EFS, Cyc. Years” column). Fraser Sockeye average run sizes are presented across all years and for the 2024 cycle-line for each stock. Median 2024 forecast returns for non-miscellaneous stocks are compared to cycle averages for colour-coding (“Mean Run Size, Cyc. Years” column). Red, yellow, and green shading represents below, near, and above average, respectively. With the near-average range defined as average +/- 0.5 standard deviation of historical time series. For Harrison, 2021 EFS are presented in the 2019 EFS column.

Run Timing Group Stocks	2020 EFS	2019 EFS	Mean EFS		2024 FC Return	Mean Run Size	
			All Years	Cyc. Years		Stocks	Cyc. Years
<b>Early Stuart</b>	20	50	39,000	17,000	200	<b>Early Stuart</b>	20
<b>Early Summer (excl.</b>	24,300	17,500	9,000	6,000	121,000	<b>Early Summer</b>	24,300
Bowron	200	10	4,000	3,000	1,000	Bowron	200
Upper Barriere	600	300	3,000	3,000	5,000	Upper Barriere	600
Gates	3,300	5,000	4,000	7,000	27,000	Gates	3,300
Nadina	15,900	8,400	9,000	9,000	65,000	Nadina	15,900
Pitt	3,300	2,100	14,000	15,000	16,000	Pitt	3,300
Scotch	600	1,000	9,000	500	5,000	Scotch	600
Seymour	400	700	19,000	3,000	2,000	Seymour	400
Misc(EShu)	100	1,300	9,000	5,000	700	Misc(EShu)	100
Misc(Taseko)	30	0	1,000	1,000	100	Misc(Taseko)	30
Misc(Chilliwack)	19,300	600	3,000	14,000	34,000	Misc(Chilliwack)	19,300
Misc(Nahatlatch)	1,400	600	1,000	3,000	3,000	Misc(Nahatlatch)	1,400
<b>Summer (excl. misc.)</b>	95,500	170,100	58,200	365,732	379,000	<b>Summer (excl.</b>	95,500
Chilko	27,100	74,600	221,000	231,000	176,000	Chilko	27,100
Late Stuart	2,500	3,000	66,300	22,500	12,000	Late Stuart	2,500
Quesnel	500	14,300	148,400	4,100	3,000	Quesnel	500
Stellako	22,100	26,700	54,300	57,000	65,000	Stellako	22,100
Harrison	40,600	51,100	29,700	9,800	106,000	Harrison	40,600
Raft	2,700	400	4,200	6,200	17,000	Raft	2,700
Misc(N. Thomp. Tribs)	100	70	300	300	200	Misc(N. Thomp.	100
Misc(N. Thomp. River)	100	100	2,000	500	200	Misc(N. Thomp.	100
Misc (Widgeon)	90	90	300	300	80	Misc (Widgeon)	90
<b>Late (excl. misc.)</b>	9,600	7,100	78,400	9,200	29,000	<b>Late (excl.</b>	9,600
Cultus	30	10	800	100	100	Cultus	30
Late Shuswap	10	3,400	330,800	2,500	2,000	Late Shuswap	10
Portage	10	300	3,400	440	200	Portage	10
Weaver	40	1,000	17,400	13,500	2,000	Weaver	40
Birkenhead	1,600	2,000	39,300	29,700	24,000	Birkenhead	1,600
Misc(Non-Shuswap)	300	40	2,000	2,000	192	Misc(Non-	300
<b>Total Sockeye</b>	129,400	194,700	NA	NA	528,879	<b>Total Sockeye</b>	129,400

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 of brood years: 1948-2018, peak generational (4-year) geometric average, the most recent three generations (2009-2020). 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 2024 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 <sub>4</sub> /EFS	Peak Geo. Ave. R <sub>4</sub> /EFS	Min. Geo. Ave. R <sub>4</sub> /EFS	Recent Gen. R <sub>4</sub> /EFS (2009-2020)	2024 Forecast R <sub>4</sub> /EFS by Probability Level				
					10%	25%	50%	75%	90%
<b>Early Stuart</b>	5.9	24.5	1.4	4.1	3.35	5.53	8.99	15.26	25.51
<b>Early Summer</b>									
Bowron	5.7	20.4	0.4	3.3	1.87	3.35	6.18	11.48	18.61
Upper Barriere	5.1	53.5	0.5	2.3	1.64	3.77	7.39	15.58	30.27
Gates	8.0	41.0	1.1	9.4	1.88	3.32	6.43	12.39	21.64
Nadina	5.4	13.5	1.4	4.8	1.71	2.65	4.49	8.18	13.46
Pitt <sup>a</sup>	2.9	10.4	0.5	1.8	0.37	0.72	1.39	2.57	4.67
Scotch	5.6	21.5	1.2	5.3	1.82	3.42	7.38	14.89	30.00
Seymour	6.4	29.2	1.0	3.7	1.17	2.20	4.25	8.32	15.26
Misc (Early Shuswap) <sup>b</sup>	-	-	-	-	0.47	0.64	2.92	5.50	7.70
Misc (Taseko) <sup>b</sup>	-	-	-	-	0.46	0.57	2.22	3.00	4.20
Misc (Chilliwack) <sup>b</sup>	-	-	-	-	0.31	0.57	1.70	3.40	7.40
Misc (Nahatlatch) <sup>b</sup>	-	-	-	-	0.31	0.57	1.70	3.40	7.40
<b>Summer</b>									
Chilko	5.8	25.3	0.7	3.7	1.47	2.61	5.02	9.96	19.44
Late Stuart	7.8	57.2	2.1	3.2	0.66	1.60	4.29	11.50	27.93
Quesnel	7.2	31.4	0.6	2.1	0.37	1.06	3.36	10.67	30.16
Stellako	5.9	16.3	0.7	2.8	0.84	1.30	2.14	3.50	5.45
Harrison <sup>c</sup>	5.9	33.8	0.5	4.9	0.25	0.59	1.58	4.19	10.07
Raft	4.9	14.3	0.5	2.6	1.80	3.07	5.52	10.04	18.39
Misc (N. Thomp. Tribs) <sup>b</sup>	-	-	-	-	0.33	0.50	1.27	2.90	4.30
Misc (N. Thomp River) <sup>b</sup>	-	-	-	-	0.33	0.50	1.27	2.90	4.30
Misc (Widgeon) <sup>b</sup>	-	-	-	-	0.13	0.41	0.54	7.30	10.60
<b>Late</b>									
Cultus <sup>d</sup>	0.03	0.06	0.005	0.02	1.18	2.21	4.81	10.01	20.22
Late Shuswap	4.8	21.2	0.2	0.9	0.26	0.99	2.64	6.34	14.37
Portage	9.9	69.1	1.4	2.7	1.36	3.26	8.35	21.91	48.51
Weaver	9.5	41.8	0.8	6.1	1.99	4.91	11.51	27.74	57.21
Birkenhead	4.3	21.5	0.2	1.4	1.63	3.29	7.96	18.37	36.42
Misc Lillooet-Harrison <sup>b</sup>	-	-	-	-	0.01	0.03	0.04	0.50	0.80

a. Pitt displayed as Five-Year-Old survival, therefore recent generation is 2008-2019.

b. Naïve (non-biological) models do not have recruitment time series; so averages could not be compiled

c. Harrison is presented as total survival;

d. Cultus survivals are presented as marine survival; recruits-per-juvenile.

Table 3. Four- and five-year-old and total 2024 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, and values below 100 were rounded to the nearest 10, rather than the nearest 1,000, in order to demonstrate age distributions. Harrison three-year-old returns are presented in the five-year-old column.

Sockeye stock/timing group	2024 Fraser Sockeye Forecasts				
	Four-year-old return	Five-year-old Return	Total Return	Four-Year-Old Proportion	Five-Year-Old Proportion
	50%	50%	50%		
<b>Early Stuart</b>	160	40	200	80%	20%
<b>Early Summer</b>					
Bowron	900	100	1,000	90%	10%
Upper Barriere (Fennell)	4,100	900	5,000	82%	18%
Gates	21,000	6,000	27,000	78%	22%
Nadina	59,000	6,000	65,000	91%	9%
Pitt	2,000	14,000	16,000	13%	88%
Scotch	4,200	800	5,000	84%	16%
Seymour	1,700	300	2,000	85%	15%
Misc (EShu)	300	400	700	43%	57%
Misc (Taseko)	70	0	70	100%	0%
Misc (Chilliwack)	32,600	400	33,000	99%	1%
Misc (Nahatlatch)	2,600	400	3,000	87%	13%
<b>Summer</b>					
Chilko	132,000	44,000	176,000	75%	25%
Late Stuart	10,000	2,000	12,000	83%	17%
Quesnel	2,000	1,000	3,000	67%	33%
Stellako	47,000	18,000	65,000	72%	28%
Harrison	42,000	64,000	106,000	40%	60%
Raft	15,000	2,000	17,000	88%	12%
Misc (N. Thomp. Tribs)	170	30	200	85%	15%
Misc (N. Thomp River)	140	60	200	70%	30%
Misc (Widgeon)	50	30	80	63%	38%
<b>Late</b>					
Cultus	100	0	100	100%	0%
Late Shuswap	30	1,970	2,000	2%	99%
Portage	80	120	200	40%	60%
Weaver	400	1,600	2,000	20%	80%
Birkenhead	13,000	11,000	24,000	54%	46%
Misc(Non-Shuswap)	190	10	200	95%	5%
<b>Total</b>	<b>391,000</b>	<b>175,000</b>	<b>566,000</b>	<b>69%</b>	<b>31%</b>

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 or smolt data are used instead.

MODEL CATEGORY	DESCRIPTION
<b>A. Non-Parametric (Naïve) Models</b>	
LLY	Return from the previous year
R1C	Return from 4 years before to forecast year
R2C	Average return from 4 and 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 and 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)
R/S (used for miscellaneous stocks)	Product of average survival on time series for specified stocks and the forecast brood year EFS
<b>B. Biological Models</b>	
Power	Bayesian power model, see Appendix 2 of Grant et al. 2010
Power-cyc	Same as above, using cycle line data only
Ricker	Bayesian Ricker model, see Appendix 2 of Grant et al. 2010
Ricker-cyc	Same as above, using cycle line data only
Larkin	Bayesian Larkin model, see Appendix 2 of Grant et al. 2010
Sibling	Bayesian sibling model, see 2.2.1 of Hawkshaw et al. 2020a
<b>C. Biological Models Covariates</b>	
FrD-mean, AprFrD, MayFrD, JunFrD	(e.g. Power (FrD-mean)) Mean Fraser discharge (April - June), Mean April flow, May flow, June flow
FrD-peak	Peak Fraser Discharge
Ei, AprEi, MayEi, JunEi, JulEi	Mean Entrance Island spring-summer sea-surface temperature (SST) (April-July), Mean April SST, May SST, June SST, July SST
Pi, MayPi, JunPi, JulPi	Mean Pine Island spring-summer SST (May-July), Mean May SST, June SST, July SST
PDO	Pacific Decadal Oscillation

Table 5. Total Fraser Sockeye forecasts for 1998 to 2023 from the 10% to 90% p-levels, where available. The forecast value (or values) that corresponded most closely 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. Returns for 2023 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	18,801,000	10,870,000
1999	NA	3,067,000	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	7,752,000	NA	5,200,000
2001	NA	3,869,000	6,797,000	12,864,000	24,660,000	NA	7,190,000
2002	NA	4,859,000	7,694,400	12,915,900	22,308,500	NA	15,130,000
2003	NA	1,908,000	2,742,000	3,141,000	5,502,000	9,744,000	4,890,000
2004	NA	1,858,000	2,615,000	2,980,000	5,139,000	9,107,000	4,180,000
2005	NA	5,149,000	8,734,000	16,160,000	30,085,000	53,191,000	7,020,000
2006	NA	5,683,000	9,530,000	17,357,000	31,902,000	56,546,000	12,980,000
2007	NA	2,242,500	3,602,000	6,247,000	11,257,000	19,706,000	1,510,000
2008	NA	1,258,000	1,854,000	2,899,000	4,480,000	7,057,000	1,740,000
2009	NA	3,556,000	6,039,000	10,578,000	19,451,000	37,617,000	1,590,000
2010	NA	5,360,000	8,351,000	13,989,000	23,541,000	40,924,000	28,250,000
2011	NA	1,700,000	2,693,000	4,627,000	9,074,000	15,086,000	5,110,000
2012	NA	743,000	1,203,000	2,119,000	3,763,000	6,634,000	2,050,000
2013	NA	1,554,000	2,655,000	4,765,000	8,595,000	15,608,000	4,130,000
2014	NA	7,237,000	12,788,000	22,854,000	41,121,000	72,014,000	20,000,000
2015	NA	2,364,000	3,824,000	6,778,000	12,635,000	23,580,000	2,120,000
2016	NA	814,000	1,296,000	2,271,000	4,227,000	8,181,000	853,000
2017	NA	1,315,000 <sup>R</sup>	2,338,000	4,432,000	8,873,000	17,633,000	1,641,000
2018	NA	5,265,000	8,423,000	13,981,000	22,937,000	36,893,000	10,675,000
2019	NA	1,832,000	2,979,000	5,056,000	9,133,000	15,313,000	564,000
2020	NA	275,000	486,000	924,000	1,834,000	3,573,000	288,000
2021	NA	313,000	624,000	1,330,000	2,775,000	5,496,000	2,549,000
2022	NA	2,374,000	4,662,000	9,775,000	20,395,000	41,707,000	6,886,000
2023	NA	453,000	800,000	1,564,000	3,185,000	5,952,000	1,653,000*

Table 6. Stock composition of 2017-2019 Brood Years and 2023 median forecast (excluding misc. stocks). The five largest stocks in each column are highlighted in bold font, and the largest stock marked in red.

Stock	2018 EFS	2019 EFS	2020 EFS	2024 Median Forecast Return
<b>Early Stuart</b>	1%	0%	0%	0%
<b>Early Summer</b>				
Bowron	0%	0%	0%	0%
Upper Barriere (Fennell)	0%	0%	1%	1%
Gates	0%	<b>3%</b>	<b>3%</b>	<b>5%</b>
Nadina	3%	<b>6%</b>	<b>12%</b>	<b>11%</b>
Pitt	0%	1%	<b>3%</b>	3%
Scotch	2%	1%	0%	1%
Seymour	3%	1%	0%	0%
<b>Summer</b>				
Chilko	<b>20%</b>	<b>52%</b>	<b>21%</b>	<b>31%</b>
Late Stuart	<b>4%</b>	2%	2%	2%
Quesnel	<b>17%</b>	<b>10%</b>	0%	1%
Stellako	<b>5%</b>	<b>19%</b>	<b>17%</b>	<b>11%</b>
Harrison	0%	1%	<b>39%</b>	<b>19%</b>
Raft	0%	0%	2%	3%
<b>Late</b>				
Cultus	NA	NA	NA	NA
Late Shuswap	<b>42%</b>	2%	0%	0%
Portage	1%	0%	0%	0%
Weaver	0%	1%	0%	0%
Birkenhead	0%	1%	1%	4%
<b>Total Number</b>	1,920,000	144,000	132,000	567,000

Table 7. Overview of model selections for 2020, 2023 and 2024 forecast. Models that changed from 2023 to 2024 are bolded. See Appendix 3 for stock-specific model choice rationales.

Year/Model	2020	2023	2024
<b>Early Stuart</b>	<i>Ricker(Pi)4/Sibling5</i>	<i>Ricker (Ei)4/Sibling5</i>	<b><i>Ricker (Ei)</i></b>
<b>Early Summer</b>			
Bowron	<i>Ricker(Pi)</i>	<i>Ricker (Pi)</i>	<b><i>RickerCyc</i></b>
Upper Barriere	<i>Power4/Sibling5</i>	<i>Ricker (Pi)4/Sibling5</i>	<b><i>PowerBasic4/Sibling5</i></b>
Gates	<i>Larkin4/Sibling5</i>	<i>LLY4/Sibling5</i>	<b><i>Ricker(Pi)</i></b>
Nadina	<i>PowerJuvFRDpeak4/Sibling5</i>	<i>RickerCyc4/Sibling5</i>	<b><i>RickerFRDpeak4/Sibling5</i></b>
Pitt	<i>Larkin4/Sibling5</i>	<i>Larkin4/Sibling5</i>	<b><i>LarkinBasicCyc</i></b>
Scotch	<i>Larkin</i>	<i>Larkin4/Sibling5</i>	<i>Larkin</i>
Seymour	<i>Larkin</i>	<i>Ricker(Pi)</i>	<i>Ricker(Pi)</i>
Misc (EShu)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
Misc (Taseko)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
Misc (Chilliwack)	<b><i>Ricker</i></b>	<i>R/S</i>	<b><i>Ricker4/Sibling5</i></b>
Misc (Nahatlatch)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
<b>Summer</b>			
Chilko	<i>Larkin4/Sibling5</i>	<i>Larkin4/Sibling5</i>	<b><i>RickerCyc4/Sibling5</i></b>
Late Stuart	<i>RickerFRDMn4/Sibling5</i>	<i>R1C4/Sibling5</i>	<b><i>R1C</i></b>
Quesnel	<i>Ricker(Ei)4/Sibling5</i>	<i>Ricker(Ei)</i>	<b><i>R2C</i></b>
Stellako	<i>Larkin4/Sibling5</i>	<i>Ricker(Ei)4/Sibling5</i>	<b><i>R2C4/Sibling5</i></b>
Harrison	<i>RickerEiEven3/Sibling4</i>	<i>TSA3/LLY4</i>	<b><i>TSA3/Sibling4</i></b>
Raft	<i>Ricker (PDO)4/Sibling5</i>	<i>LLY4/Sibling5</i>	<i>PowerBasicCyc</i>
Misc (N. Thomp. Tribs)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
Misc (N. Thomp River)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
Misc (Widgeon)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>
<b>Late</b>			
Cultus	<i>PowerJuv(Pi)4/Sibling5</i>	<i>PowerJuvPi</i>	<i>PowerJuvPi</i>
Late Shuswap	<i>RickerCyc4/Sibling5</i>	<i>Ricker(Pi)4/Sibling5</i>	<i>Ricker(Pi)4/Sibling5</i>
Portage	<i>Larkin</i>	<i>Ricker(Ei)</i>	<b><i>Ricker(Pi)</i></b>
Weaver	<i>Ricker(PDO)4/Sibling5</i>	<i>RickerCyc4/Sibling5</i>	<b><i>RickerCyc</i></b>
Birkenhead	<i>Ricker(Ei)4/Sibling5</i>	<i>Ricker(Pi)4/Sibling5</i>	<b><i>Ricker(Ei)</i></b>
Misc(Non-Shuswap)	<i>R/S</i>	<i>R/S</i>	<i>R/S</i>

## 7. FIGURES

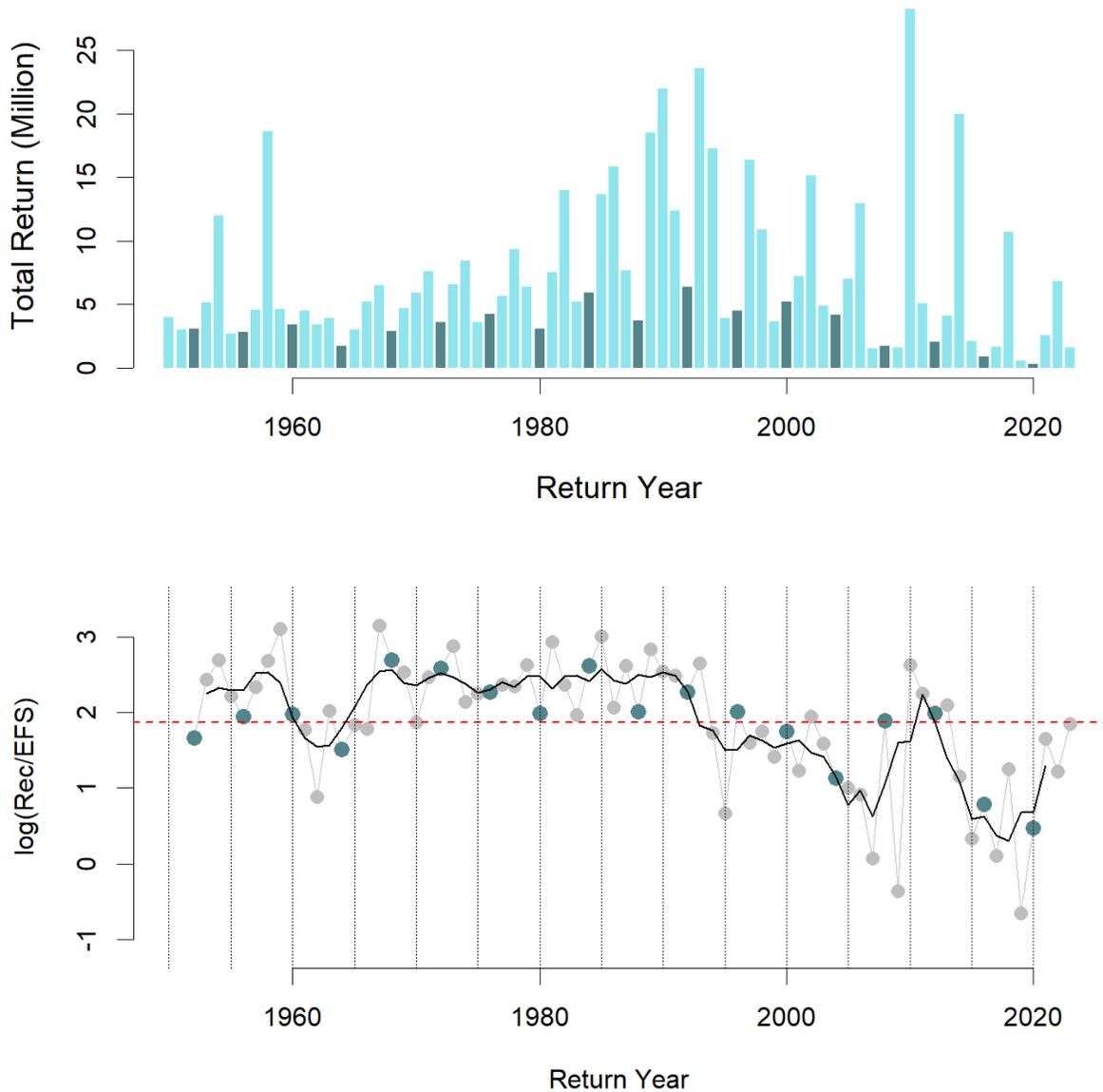


Figure 1. Total returns and overall productivity of Fraser Sockeye: Top panel shows total adult annual returns (note that adult returns in 2023 are preliminary); Bottom panel shows overall Fraser Sockeye productivity ( $\log_e(\text{recruits} / \text{effective female spawners})$ ) up to the 2023 return year for the 19 stocks with long time series of spawner and recruit estimates. Points represent annual productivity and the black line represents the smoothed four year running average. The dashed horizontal red line is the time-series average. In both panels, dark blue represents the 2024 cycle line.

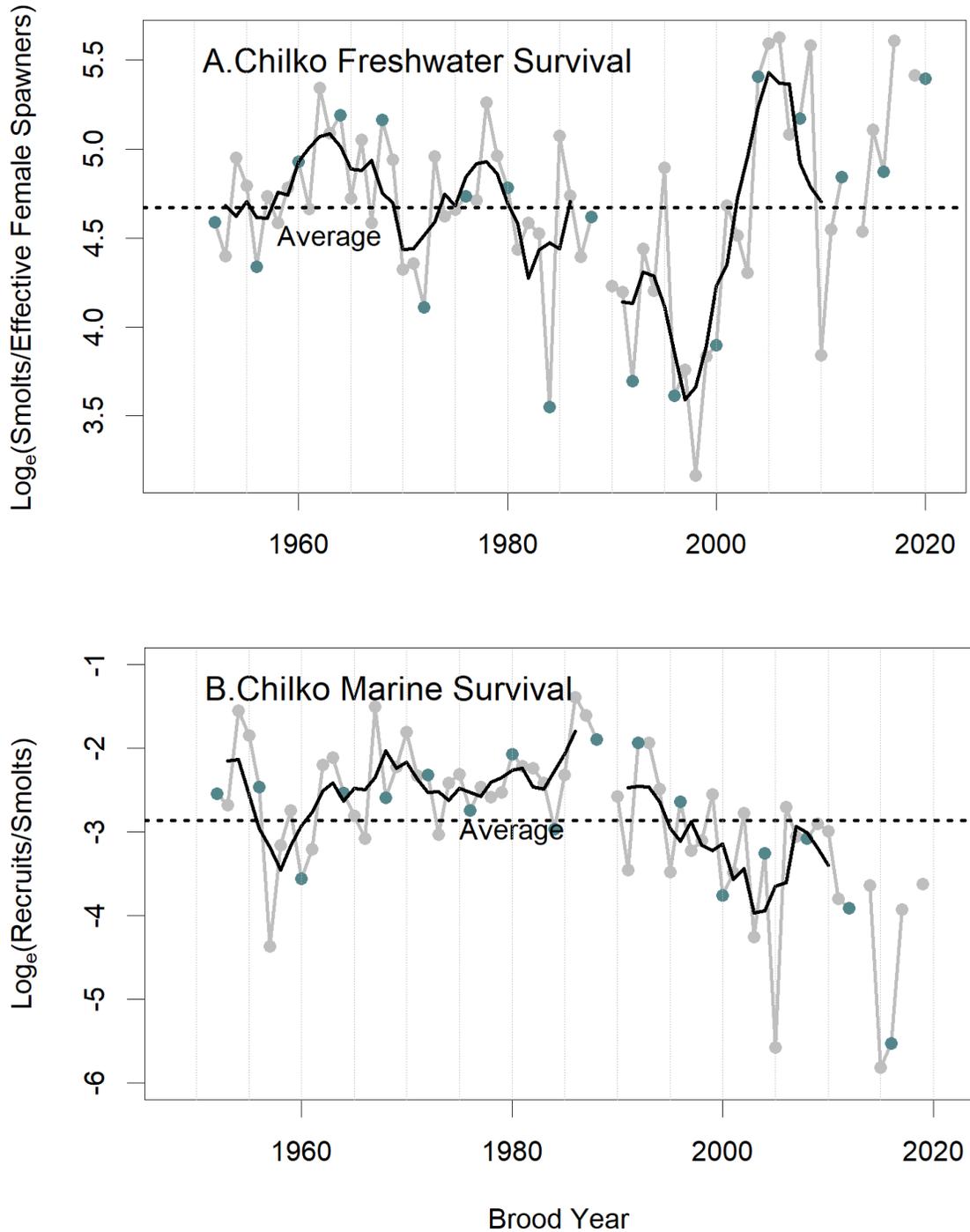


Figure 2. A. Annual freshwater survival (log<sub>e</sub> smolts/effective female spawners; filled grey dots and lines); dark blue circle represents the 2024 cycle line. The black line represents the smoothed four-year running average survival and the black dashed lines indicate average survival. Note that no smolt assessment was conducted in the 2013 and 2018 brood year representing a gap. B. Annual 'marine' (log<sub>e</sub> recruits/smolt) survival (filled grey circles and lines). 'Marine survival' includes the period of time smolts spend migrating from the outlet of Chilkco Lake (where they are enumerated) to when they return as adults and includes their downstream migration in the Fraser River as smolts.

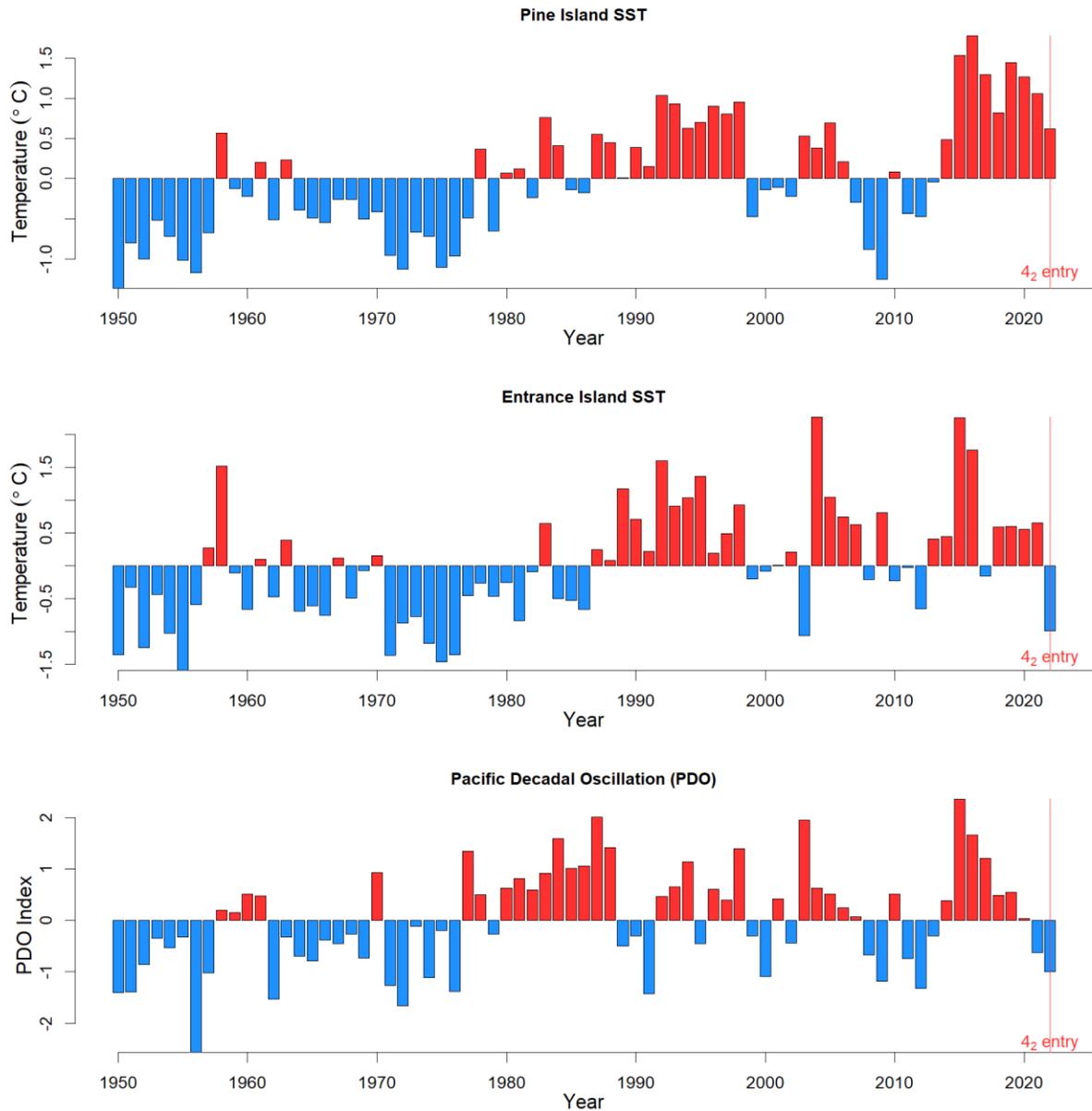


Figure 3. Sea surface temperatures (SST) measured at Entrance Island (Strait of Georgia) (April-June average), Pine Island (Queen Charlotte Strait) (April-July average), and standardized winter PDO index (Nov-March). Temperatures are presented as raw deviations from time-series averages (1950-2022). The 2022 ocean entry year, highlighted with a red vertical line, marks the temperature anomalies that most Fraser Sockeye from the 2020 brood year entered into upon outmigration as smolts (i.e. a 4<sub>2</sub> life cycle). Red bars (positive values) indicate warm temperature anomalies (above average) and blue bars (negative values) indicate cool temperature anomalies (below average).

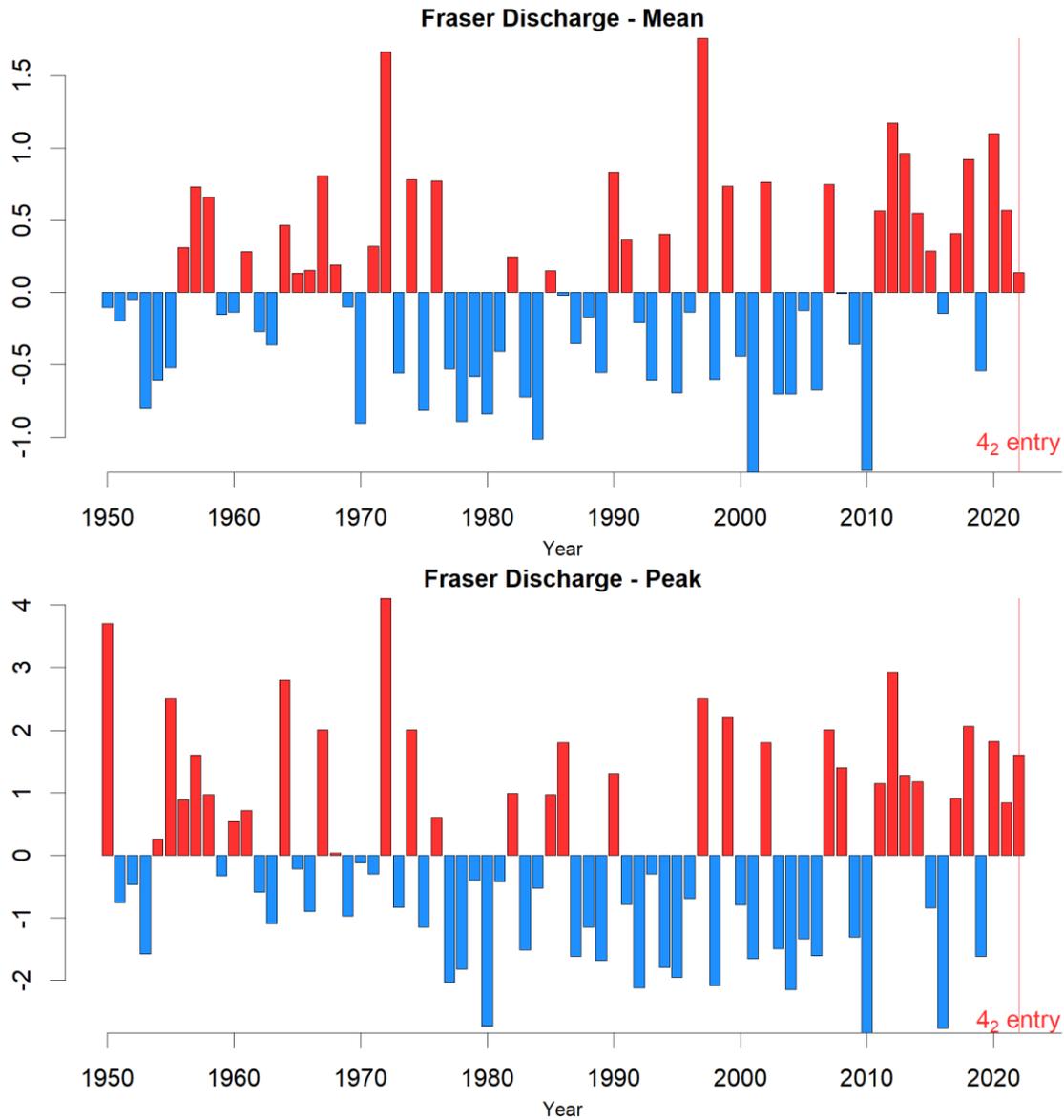


Figure 4. Fraser River discharge shown as mean conditions over April-June and peak discharge. Values are presented as raw deviations from time-series averages (1950-2022). The 2022 ocean entry year, highlighted with a red vertical line, marks the temperature anomalies that most Fraser Sockeye from the 2020 brood year entered into upon outmigration as smolts (i.e. a 42 life cycle). Red bars (positive values ) indicate increased discharge anomalies (above average) and blue bars (negative values) indicate decreased discharge anomalies (below average).

## OCEAN CONDITION INDICATORS TREND

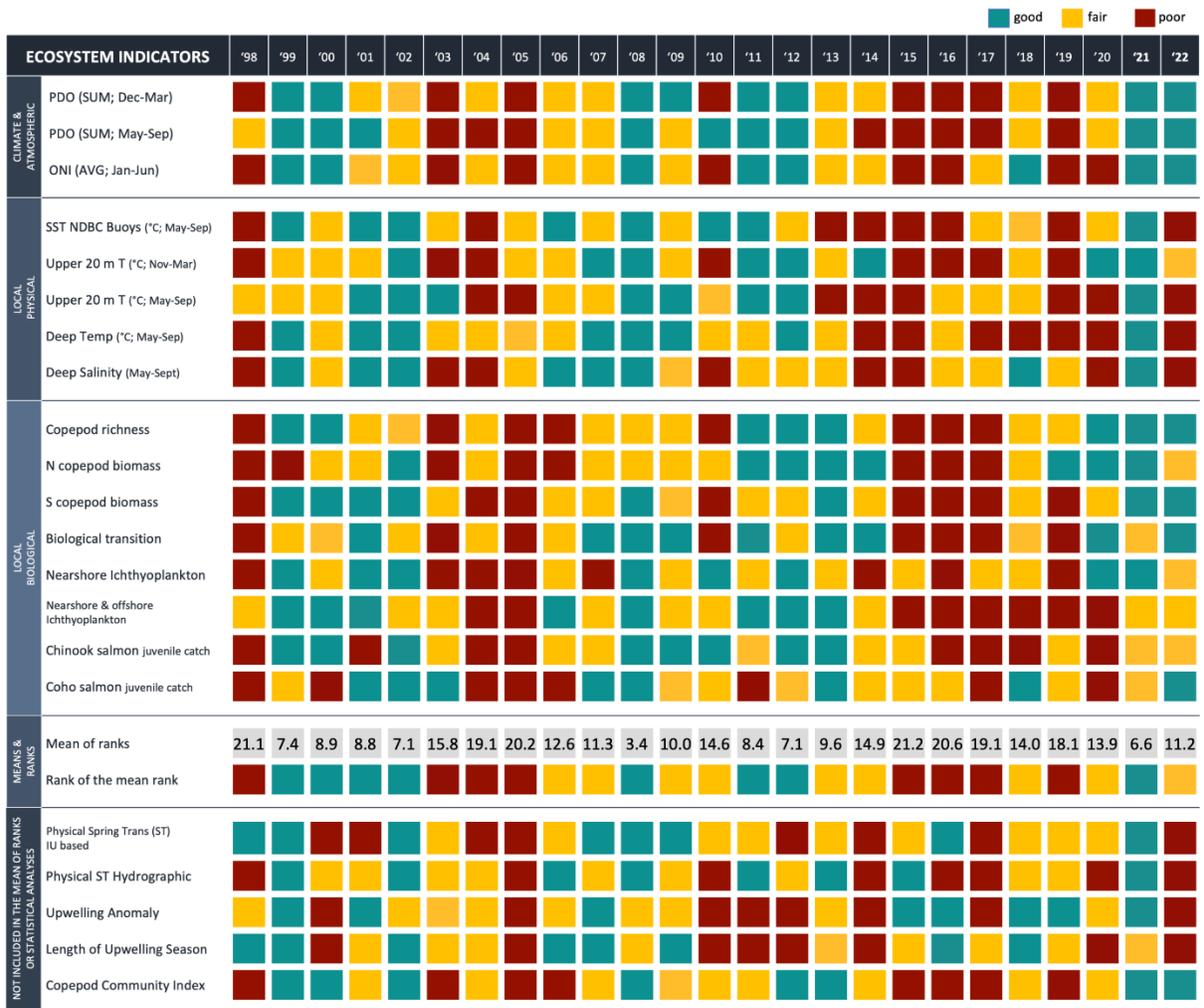


Figure 9. Stoplight chart of ocean indicators favourable for the production of juvenile salmon in the California Current. Source NOAA 2024 (<https://www.fisheries.noaa.gov/west-coast/science-data/ocean-conditions-indicators-trends>)

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## APPENDIX A. STOCK GROUP DATA SUMMARIES

### Early stuart (Takla-Trembleur-Early Stuart CU)

Run Timing Group	Escapement				2019 Stock Contributions
	Avg.	Cyc. Avg	BY(2019)	BY Trend <sup>a</sup>	Early Stuart
Early Stuart	38,500	22,200	50	DOWN	100%

a. Trend refers to change from previous brood year (2015)

b. Escapement and cycle year average 1952-2019

### Early summer

Run Timing Group	Escapement				2019 Stock Contributions											
	Avg.	Cyc. Avg.	BY(2019)	BY Trend <sup>a</sup>	Bowron	Seymour	Fennell	Scotch	Gates	Nadina	Pitt	South Thom	Taseko	Chil-wack	Nah-atlatch	
Primary stocks <sup>b</sup>	62,600	56,600	17,300	DOWN	0%	4%	2%	6%	29%	48%	12%	NA	NA	NA	NA	
Total (including misc.) <sup>c</sup>	146,400	56,900	19,900	DOWN	0%	2%	1%	3%	17%	28%	7%	26%	2%	10%	5%	

a. Trend refers to change from previous brood year (2015)

b. Escapement and cycle year average 1952-2019

c. Escapement and cycle year average 2003-2019

Summer

Run Timing Group	Escapement				2019 Stock Contributions								
	Avg.	Cyc. Avg.	BY (2019)	BY Trend <sup>a</sup>	Late Stuart	Stellako	Raft	Quenel	Chilko	Harrison	North Thom. Trib	North Thom. Riv	Widgeon
Summer													
Primary stocks <sup>b</sup>	562,000	371,800	120,400	DOWN	3%	22%	0%	12%	62%	1%	NA	NA	NA
Total (including misc.) <sup>c</sup>	663,900	473,100	120,700	DOWN	2%	20%	0%	11%	56%	1%	0%	9%	0%

a. Trend refers to change from previous brood year (2015)

b. Escapement and cycle year average 1952-2019

c. Escapement and cycle year average 2003-2019

Late

Run Timing Group	Escapement				2019 Stock Contributions					
	Avg.	Cyc. Avg.	BY (2019)	BY Trend <sup>a</sup>	Late Shuswap	Birkenhead	Portage	Weaver	NonS hu Harrison	Cultus <sup>d</sup>
Late										
Primary stocks <sup>b</sup>	406,800	217,300	6,700	DOWN	51%	30%	4%	15%	NA	--
Total (including misc.) <sup>c</sup>	451,200	79,700	6,700	UP	28%	17%	2%	8%	44%	--

a. Trend refers to change from previous brood year (2015)

b. Escapement and cycle year average 1952-2019

c. Escapement and cycle year average 2003-2019

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

**Miscellaneous Stocks – All Management Units**

<b>Forecast Unit</b>	<b>Populations*</b>
<b>Early Summer</b>	
EShu	Adams Channel, Adams River (upper and lower), Anstey River, Blueberry Creek, Burton Creek, Cayenne Creek, Celista Creek, Craigellachie Creek, Crazy Creek, Eagle River, Four Mile Creek, Hiuhill Creek, Hunakwa Creek, Loftus Creek, Momoch River(upper and lower), Nikwikwaia Creek, Onyx Creek, Perry River, Ross Creek, Salmon River, Sinmax Creek, Yard Creek
Taseko	Taseko Lake, Taseko River(upper), Yoheta (upper and lower), Lastman Creek
Chilliwack	Chilliwack Lake, Chilliwack River, Chilliwack River(upper)
Nahatlatch	Nahatlatch River, Nahatlatch Lake
<b>Summer</b>	
North Thompson Tributaries	Barriere River, Clearwater River, Dunn Creek, Finn Creek, Grouse Creek, Hemp Creek, Lemieux Creek, Lion Creek, Mann Creek
North Thompson River	North Thompson River
Widgeon	Widgeon Creek, Widgeon Slough
<b>Late</b>	
Non-Shuswap	Big Silver Creek, Cogburn Creek, Crazy Creek, Douglas Creek, Green River, Joffre Creek, Miller Creek, North Creek, Pemberton Creek, Railroad Creek, Sampson Creek, Sloquet Creek, Tipella Creek, Ure Creek

**Forecast total return of miscellaneous stocks and the proxy used for long term productivity**

	Effective Females		Proxy for long-term Prod.	Forecast total Return				
	2018	2019		10%	25%	50%	75%	90%
<b>Early Summer</b>								
Misc(EShu)	128,313	1,306	Scotch/Seymour	6,685	8,549	40,902	64,193	99,524
Misc(Taseko)	35	0	Chilko	2	2	6	8	11
Misc(Chilliwack)	975	619	All ES Stocks	264	441	1,518	2,544	6,337
Misc(Nahatlatch)	987	644	All ES Stocks	272	454	1,564	2,621	6,527
<b>Summer</b>								
Misc(N. Thomp. Tribs)	50	73	Raft/Fennell	24	35	97	213	319
Misc (N. Thomp. River)	1,710	133	Raft/Fennell	205	298	820	1,806	2,699
Misc (Widgeon)	68	88	Birkenhead	18	58	78	242	730
<b>Late</b>								
Misc (Non-Shuswap)	724	36	Birkenhead	68	221	296	924	2,783

**Age-4 return and productivity.**

	Forecast Age-4 Return					Forecast Age-4 Productivity				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
<b>Early Summer</b>										
Misc(EShu)	600	768	3,673	5,764	8,936	0.5	0.6	2.8	4.4	6.8
Misc(Taseko)	0	0	0	0	0	NA	NA	NA	NA	NA
Misc(Chilliwack)	264	441	1,518	2,544	6,337	0.3	0.4	1.5	2.6	6.5
Misc(Nahatlatch)	173	290	997	1,671	4,161	0.3	0.4	1.5	2.6	6.5
<b>Summer</b>										
Misc(N. Thomp. Tribs)	19	28	77	170	253	0.3	0.4	1.1	2.3	3.5
Misc (N. Thomp. River)	35	51	140	309	462	0.3	0.4	1.1	2.3	3.5
Misc (Widgeon)	12	39	52	162	488	0.1	0.4	0.6	1.8	5.5
<b>Late</b>										
Misc(Non-Shuswap)	5	16	21	66	199	1.8	5.7	7.6	23.8	71.8

## APPENDIX B. MODEL SELECTION CRITERIA AND RATIONALE

The Fraser River Sockeye forecast model selection process is an expert-driven process, which took place over a two day meeting in December 2023. Previously, forecast model selection was based on methods and results (model ranking from retrospective analysis) summarized in MacDonald and Grant (2012) in conjunction with the recent productivity trend. Recognition of relatively inaccurate forecast results from recent years (2015-2020) led to the update and revision of the retrospective analysis used for the model selection process and the addition of a new tool: Taylor Diagrams. Additionally, a set of new environmental covariates were incorporated into the existing biological models for assessment. Generally the model selection process follows the steps outlined below but deviations at the stock level can occur.

1. Taylor diagram	2. Ranking table	3. Historical performance	4. Forecast and implied productivity
<ul style="list-style-type: none"> <li>•Age4 model</li> <li>•Age5 model</li> <li>•Total model</li> </ul>	<ul style="list-style-type: none"> <li>•Overall ranking</li> <li>•Age4 ranking</li> <li>•Age5 ranking</li> <li>•Age4-cyclic</li> <li>•Age5-cyclic</li> <li>•Age4-other</li> <li>•Age5-other</li> <li>•Old ranking</li> </ul>	<ul style="list-style-type: none"> <li>•Used model</li> <li>•Overall performance</li> <li>•Age-specific performance</li> </ul>	<ul style="list-style-type: none"> <li>•Forecast Numbers</li> <li>•Implied productivity and trend</li> <li>•Brood year effective female spawners</li> <li>•Mean Run size</li> </ul>

- Step 1: Taylor diagram:** For each stock, models are compared graphically on the Taylor diagram as it comparatively demonstrates the differences between model and observation and among models in regard to three statistics: the Pearson correlation coefficient, the root-mean-square error (RMSE), and the standard deviation (SD). All the candidate models for the forecast are presented on a Taylor diagram among age 4, age 5 and total population (age 4 and 5 combined). Generally, a model is desired and considered for further selection process when it shows relatively high correlation coefficient, low RMSE, and SD similar to the observation.
- Step 2: Ranking table:** Models are then ranked according to their relative performance on each of four performance measures: mean raw error (RME), mean absolute error (MAE), mean percent error (MPE) and RMSE (see Cass et al. 2006 for details). Ranks across the four performance measures are then averaged to generate an overall score and rank for each model evaluated. The previous retrospective analysis was based on returns from 1997-2004 (see Table 5 in MacDonald and Grant 2012). To update the model performance, the current analysis was conducted to produce new model ranking tables based on the returns from the past three generations (2009-2020). The ranking tables are divided into all-year, cyclical year and other (non-cyclical year) categories in an age-specific manner. For cyclical stocks, rankings based on the cycle-line years are preferred.

3. **Step 3: Historical performance:** Performance of previously used forecast models in 2009-2020 is presented for each stock by comparing the estimates with actual returns in number and percentage for both age classes (age 4 & 5) and total population. The yearly deviation and overall correlation between the past forecast number and observation are reviewed. Performance of the historically top-ranked models is considered in addition to the tendency to over or under estimate returns in recent years which may result in the selection of alternate models.
4. **Step 4: Forecast and implied productivity:** The total and age-specific forecasts resulted from top-ranked models and their corresponding implied productivities are presented; they are compared with historical time-series of observed productivity (both raw and log scale). Since many stocks have shown lower-than-average productivities in recent generations, efforts are made to choose models that might capture the dynamics of these recent declines in productivity (i.e. using environmental covariates). In addition, models with new covariates are proposed but they are mainly used as reference for comparison.

### **Model choice rationales for individual stock**

#### Early Stuart: Ricker(Ei)

For the wild Early Stuart return, the Ricker(Ei) model is the highest ranked model followed by the Ricker(PDO). The Taylor Diagram shows strong support for the performance of the sibling model for forecasting the age-5 component. When considering the top performing models for the total forecast, Ricker(Ei) and Ricker(PDO) rank highly. Preference is given to the more conservative biological model (Ricker(Ei)) given the near zero escapements in 2019 and 2020.

#### Bowron: RickerCyc

The sibling model ranks highest in age-5 Taylor diagram, but the implied productivity of 54 exceeds historical observations. The top ranked model for the total forecast is the naive R1C, models with salmon covariates, and RickerCyc. All top models predict abundances at around 1,000. Ricker(Pi) is also reasonable with 840 in total forecast and an implied productivity of 4.89. Historically, Ricker(Pi) has been regularly selected but have frequently resulted in over forecasts. Final choice with CSAS approved models is RickerCyc..

#### Upper Barriere/Fennell: PowerBasic4/Sibling5

Based on the age-5 Taylor diagram, the sibling model performs well predicting 876 age-5 and an implied productivity consistent with historical observations. The sibling model has been chosen for three of the last four years due to consistency between models, but has a tendency to overpredict. All the top ranked models for total give similar estimates around 4000. The Power basic model gives an implied productivity of 7 for age-4, which aligns closely with observations.

#### Gates: Ricker(Pi)

The Age-5 Taylor diagram does not indicate clear top models. For the total forecast, like last year (LLY) is the best performing model followed by PowerJuvPi, TSA and R2C, all of which have implied productivities outside of historical observations for this stock. The final choice is

between Ricker(Pi) and Larkin basic. Ricker(Pi) is selected as the implied productivity most closely aligns with the time series of observations.

#### Nadina: RickerFRDpeak4/Sibling5

Both the sibling model and LLY rank high in the age 5 Taylor diagram. The sibling model also ranks the highest in the retrospective ranking table. The sibling model predicts 5,725 age-5 in total with an implied productivity of 0.68. The age-5 productivity has been below 2.5 in most years and has been quite low until last year so the sibling model is selected to forecast the age-5 component. For age-4, Ricker FRD PeakRS1 and RickerCyc are the top ranked models. RickerCyc was selected in 2023 and predicts 126,000 fishes with an implied productivity of 8. The observed productivity has been near 10 in recent years. The other top models have lower forecasts that don't align with the RickerCyc forecast. In the past, the Power juvenile discharge peak was chosen for 2020 and 2021. Ricker with a peak Fraser River discharge covariate and a sibling was chosen in 2022. Ricker Fraser discharge model is the top ranked age-4 model from retrospective ranking table. It also has a low mean raw error rank, therefore is the chosen model for this year.

#### Upper Pitt: LarkinBasicCyc

Age-5 Taylor diagram shows strong support for the sibling model, but an implied productivity of 24 exceeds historical observations. Although Pitt tends to have higher productivity for age-5 than age-4, 24 is still higher than recently observed productivities. Larkin basic model implies a productivity of 3.29, higher than recent years but still similar. Both LarkinBasicCycAge and LarkinBasic predict around the same number of returns, so LarkinBasicCycAge was chosen based on the rankings from the retrospective ranking table.

#### Scotch: Larkin

Based on the age-5 Taylor diagram, the sibling model and Ricker(Pi) model are highly ranked. Ricker(Pi) model produces a productivity of 1.02, which is too high and the sibling model also implies a higher productivity of 0.88. The implied productivity for the Larkin model falls within the range of observations and therefore it was selected to forecast the total return for Scotch.

#### Seymour: Ricker(Pi)

The sibling model performs well for the age-5 forecast for Seymour sockeye based on the Taylor Diagram and retrospective ranking tables. However, the implied productivity from the sibling model exceeded recent historic observations and was therefore excluded from selection. Both Ricker(Pi) and RickerCyc are reasonable choices based on their implied productivities. The RickerCyc model has been selected several times and has a tendency to over forecast. Ricker(Pi) is the highest ranked based on the retrospective ranking table therefore is chosen.

#### Chilliwack: Ricker4/Sibling5

Chilliwack is considered a miscellaneous stock but is analyzed separately since 2024 is the dominant cycle line for this stock. There is great variability between 21,000 to 300,000 in the forecasts by the biological models. The highest ranked models from the retrospective analysis is a Ricker to forecast the age-4 component and a sibling model to forecast the age-5 component with Fraser peak discharge and PDO covariates. The conventional model for miscellaneous stocks (MISC) ranked 16<sup>th</sup> with biological models. Specifically, biological models without

discharge covariates that have lower forecasts are ranked higher than the miscellaneous model. Given the variability of the forecasts, it was determined that it was best to use a Ricker model with a sibling model to forecast the age-5 returns as it aligned well with the miscellaneous forecast and did not have implied productivities that were outside of historical observations.

#### Chilko: RickerCyc4/Sibling5

Historically, we have selected juvenile models, but not in recent years due to their overly optimistic forecasts as freshwater survival has greatly improved while marine survival has been poor but trending toward average. The sibling model ranks the highest on Taylor diagram and the retrospective ranking table for the age 5 component. The implied productivity from the sibling model aligns well with recent observations and was therefore selected. The highest ranked models are RickerCyc and Larkin Basic cycle age. The models differ in their age-4 forecasts by ~80,000 with the RickerCyc being more conservative. Since Big Bar affected this stock by reducing the number of effective females in 2020, RickerCyc was determined to be more suitable given the lower implied productivity.

#### Late Stuart: R1C

Based on the age-5 Taylor diagram, the sibling model performs well but the implied productivity is high relative to recent observations. The top two models for the total forecast based on the retrospective ranking table are RS1 and R1C. These naïve models predict half or less of the Power basic model which was also highly ranked. The average productivity over the last few years is around 5 which aligns most closely with the R1C forecast.

#### Quesnel: R2C

The sibling model does not rank well based on the age-5 Taylor diagram. The highest ranked model for the total forecast based on the retrospective ranking table is Ricker(Ei) but the implied productivity exceeds observed values for most years. In the past, R1C, Ricker(Ei), RickerCyc models all tend to overpredict. Both R1C and R2C are highly ranked for the total forecast but the R2C has an implied productivity that most closely aligns with recent observations.

#### Stellako: R2C4/Sibling5

The sibling model, Ricker salmon, and Ricker pink models rank highly for forecasting age-5 in the Taylor Diagram. For age-4, both Ricker(Pi) and R2C model predict the low productivity (less than 5) observed in recent years. R2C ranks higher than Ricker(Pi) model and is consistent with observations in recent years. R2C has not been chosen since 2012. Historically, the chosen Larkin model has been overpredicting.

#### Harrison: TSA3/Sibling4

The extreme variability in this time series has resulted in a stock-recruit dataset that does not fit well with biological models. Ricker does not rank well in the retrospective ranking table either providing further evidence that we should not pursue selecting biological models to forecast Harrison Sockeye. There are two different regimes, with consistent low numbers and then extremely high returns (>1M) and then back to similar consistent low numbers. Historically, there is a tendency to overpredict age-3 but predict well on age-4. For age-3, TSA is the top ranked naive model with an implied productivity 1.6. The sibling model is top ranked to forecast

the age-4 component, with implied productivity of 0.8 based on age-3 returns for the last year. All models produce similar age-3 predictions and therefore the TSA model is selected.

#### Raft: PowerBasicCyc

The sibling model ranks well on the age-5 Taylor diagram and is similarly ranked high in the retrospective ranking table. However, the implied productivity is 11, which has not been observed since early 2000. For total returns, the Power basic cycle model predicts a return of 16,000 with implied productivity of 6 and 6.7 for age-5 which align well with observations of productivity for Raft Sockeye. TSA also ranks high for total returns, but may rely hard on only the last few years. Past choices of Ricker(PDO) and Ricker(Pi) models tend to overpredict. Power basic cycle model gives similar predictions with TSA and has been given reasonable forecasts in recent years.

#### Cultus: PowerJuvPi

The sibling model does not rank well based on the age-5 Taylor diagram and is therefore not favoured to forecast age-5 Cultus Sockeye. RJ1, Power juvenil(Pi) and Power juvenile(Ei) are the top ranked models based on total forecast. The observed productivity is virtually 0 expect for the 2017 cycle line. Power juvenile(Pi) has been used historically and gives similar forecasts compared with other models.

#### Late Shuswap: Ricker(Pi)4/Sibling5

The sibling model is highly ranked on the age-5 Taylor diagram with a reasonable productivity of 0.67. For age-4 forecasts, both Ricker(Pi) and RickerCyc model rank high but the Ricker(Pi) has productivity values that are more closely aligned with observations and is therefore selected.

#### Portage: Ricker(Pi)

The sibling model does not rank well based on age-5 Taylor diagram. Ricker(Ei) ranks the highest based on total forecast, but has an implied productivity of 41 which is too high compared to observations. Historically, the Larkin models have been used and they tend to overpredict. Ricker(Pi) ranks a little lower than Ricker(Ei). The Ricker(Pi) forecast predicts a return of 221 sockeye and implied productivity of 22, which is about half of Ricke(Ei) and more closely aligned with recent observations.

#### Weaver: RickerCyc

The sibling model does not rank well on the age-5 Taylor diagram. For total forecast, the Ricker salmon and Ricker pink rank high, but these models have not yet been peer reviewed. Other top models include RS1 for naïve model, RickerCyc and Ricker(Ei) models. The RS1 model gives a productivity of 3, which is too low relative to the last three returns. The juvenile models all give high productivities, most likely from the five year olds based on the test fishery data. Both RickerCyc and Ricker(Ei) give similar total predictions. RickerCyc implies a productivity of 46, which is more realistic than Ricker(Ei) and is therefore selected.

#### Birkenhead: Ricker(Ei)

The sibling model estimates an implied a productivity of around 30 for the age-5 component of the return, which is too high based on observations of productivity for Birkenhead Sockeye so it is excluded from further consideration. The 2023 return for Birkenhead was quite strong and

suggestive of a potential change in productivity trends for the stock. Recent productivity for the total return has been trending up aggressively since the 2020 return on this cycle line where it was very low. The total forecast models that are highly ranked in both the Taylor Diagrams and retrospective ranking table are Ricker(Ei) and Ricker(Pi). Ricker(Pi) has a slightly more pessimistic forecast than Ricker(Ei). The implied productivity of Ricker(Ei) for the total forecast is around 15 which closely aligns with recent observations of productivity for Birkenhead and given its high ranking in the retrospective ranking table it is the preferred model for forecasting this stock in 2024.