PRE-SEASON RUN SIZE FORECASTS FOR FRASER RIVER SOCKEYE *(ONCORHYNCHUS NERKA)* SALMON IN 2016

Context

The Fraser Sockeye return forecast is not a single value. Instead, the forecast is a probability distribution: at the 25% probability level, for example, there is a one in four chance returns will fall at or below the forecast value. The forecast value at the middle of the distribution, the 50% probability level, indicates where there is an equal chance returns will fall above or below this value. A stock's forecast distribution reflects its past survival. If a stock's return falls at the lower end of its forecast distribution, it is because the stock has experienced lower survival compared to previous years with similar numbers of spawners. Conversely, a return that falls at the higher end of a stock's forecast distribution will indicate higher than average survival. If survival has been exceptional, then returns can fall outside the lowest or highest forecast value presented.

Most Fraser Sockeye mature as four year olds. Four year olds returning in 2016 are the offspring of adults that spawned in 2012. This consistent age-at-maturity is one of the factors that leads to persistent four year patterns in return abundances. The 2016 cycle has the lowest average return (3.9 M) of any of the four cycles and most of the forecast range for 2016 falls below this average. The 2016 forecast distribution indicates there is a one in 10 chance that the return will be less than 800,000, and a nine in 10 chance that the return will be less than 8.2 M. The median forecast (equal chances of higher or lower returns) is 2.3 million. A major factor driving the lower forecast in 2016 is the low escapement in 2012. For over half of the Fraser Sockeye stocks, spawner abundances in 2012 were below average and for six of these stocks they were the lowest on record. Bowron, Late Shuswap and Portage, for example, had particularly low effective female abundances in 2012 of only 10 fish each. Chilko, the stock expected to contribute the most to the 2016 returns, had a small brood year escapement in 2012 that was almost one third of its cycle average. If Fraser Sockeye survivals are below average, they could compound the impact of the low 2012 escapements, and result in return abundances that are less than the median forecast of 2.3 million.

With the exception of the large returns in 2010, total Fraser Sockeye returns have been less than their median forecasts (50% probability level) for much of the past decade. The returns for a number of stocks that contributed the most to last year's 2015 forecast fell at the lower end of their forecast distributions. This pattern is consistent with lower than average survival during this period. For example, the marine survival for Chilko Sockeye, that contribute the most to the total 2016 forecast, has not exceeded 8% in each of the last 18 years. Yet, the median 2016 forecast for Chilko implies a marine survival of 9%. Thus, the potential impact of lower than average survival on the 2016 returns warrants consideration.

The 2016 return is concentrated among a few key stocks. Summer Run stocks contribute the most (70%) to the median (50% probability level) total forecast, especially Chilko (44%), and to a lesser extent Late Stuart and Stellako (20% combined), and Harrison (8%). Of the Early Summer Run stocks, two lower Fraser populations (Chilliwack: 6%; Pitt: 4%) are major contributors to the overall forecast. The forecast return to the Late Run aggregate is particularly poor. Even at the highest probability level (90%), the forecast (366,000) is close to half the cycle average return for this group (689,000). In the Late Run Timing group, Cultus Sockeye have been assessed as 'endangered' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The forecast distribution for the Cultus return indicates there is a nine in 10 chance of a return less than 17,000 fish. Almost all of these fish will be of hatchery origin. This forecast range is below its cycle average of 22,000, and also well below this stock's lower Wild Salmon Policy benchmark of 12,000 wild effective total spawners.

Unusually warm ocean temperatures developed in the Northeast Pacific Ocean in the second half of 2013, and these conditions have persisted to the time of this publication. These warmer temperatures, referred to as the 'warm blob', cover a broad spatial area in the Northeast Pacific Ocean, are as much as 3°C above average, and extend down to depths of 100 m. Fraser Sockeye stocks that returned in 2015 spent their final two years of life in these warmer waters, and a number of these stocks, including Chilko Sockeye, experienced low survival. However, it is unclear whether these high ocean temperatures influenced the poor Fraser Sockeye returns in 2015 because of the inconsistent responses across Fraser Sockeye stocks (Early Stuart, Raft, and Nadina had average to above average survivals), the information that suggests that freshwater strongly influenced the survival of some stocks (e.g. Weaver, Birkenhead and Shuswap), and because of the average to above average survival of other Sockeye stocks outside the Fraser (Barkley Sound, Nass, Columbia Sockeye). The inconsistent response of sockeye stocks to the 'warm blob' in the Northeast Pacific Ocean confounds attempts to draw an inference about the potential marine survival of four year old Fraser Sockeye returning in 2016.

We can, however, use estimates of returns for the 2015 four year olds to help generate estimates of 2016 five year olds. These siblings were together as eggs in their spawning gravel, and as juveniles in their rearing lakes and the North Pacific Ocean. The only difference between these siblings is that five year olds spend an additional year in the ocean. Sibling models were used to quantify the relationships between four year old and five year old returns for three Fraser River sockeye populations (Quesnel, Weaver and Birkenhead) with significant fractions of five year old fish expected to return in 2016. Due to the poor return of 2015 four year olds for these stocks, the application of sibling models reduced the total median forecast for these stocks by up to 75%. A similar approach was used for Harrison Sockeye where estimates of three year old returns in 2015 were used to forecast their four year old siblings in 2016, which reduced this stock's forecast by 50%.

For Scotch, Seymour and Late Shuswap, Larkin models were applied since the 2015 median forecasts from these models were much closer to the actual returns compared to the Ricker model.

Due to the low total return of four year olds in 2015, a sensitivity analysis was conducted that compared forecasts resulting from adjusted five year old returns to those resulting from standard forecast models. This analysis adjusted the forecasts of five year old returns for all stocks, not just those that had a higher proportion of five year olds expected in 2016, as was the case for the official forecast. The total adjusted median forecast return (2.7 M at the mid-point of the forecast distribution) was slightly higher than the official median forecast (2.3 M) as presented in this document. This was attributed to the higher survival for a few stocks in 2015 for the Early Summer and Summer Run Timing groups. The Early Stuart forecasts were identical and the Late Run forecast was slightly smaller for the adjusted forecast.

This Science Response Report results from the Science Response Process of December 14, 2015 on the Pre-season abundance forecast for Fraser River Sockeye Salmon returns in 2016. The 2016 forecast relies on methods of past CSAS processes and publications

(Cass et al. 2006; DFO 2006, 2009, 2011, 2012, 2013, 2014a, 2014b, 2015a, 2015b; Grant et al. 2010; Grant and MacDonald 2012; MacDonald and Grant 2012).

To support the 2016 Fraser Sockeye forecast, an additional Science Response process occurred on January 21-22 to summarize data and information on fish condition and/or survival from the 2013 spawners and their offspring. This Science Response will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as it becomes available.

Background

Fraser Sockeye Salmon Forecasts

Return forecasts are produced annually for 27 Fraser Sockeye stocks (Table 1A). Nineteen stocks are forecast using a variety of models fit to historical escapement (or juvenile) and return data (Table 4). In addition, eight miscellaneous stocks with generally only escapement data are forecast using a single model (Table 4). The one exception to this miscellaneous group is the Chilliwack stock for which a short time series of preliminary return data became available. Thus, the 2016 forecast for Chilliwack is based on a Ricker model fit to stock-recruitment data.

Forecasts are presented as a range of values corresponding to cumulative probabilities from 10% to 90% (Table 1A). These probabilities represent the chance actual returns will fall below the predicted return values, given what has been observed on a stock's historical time series. At the 25% probability-level (p-level), for example, there is a one in four chance the actual return will fall at or below the predicted return value. Presenting a forecast as a probability distribution, rather than a single point estimate, communicates the uncertainty associated with how well a model fits a stock's data set. The forecast is the entire distribution of values, and not a single data point selected from the distribution.

Lower probability level forecast values are smaller and represent lower survival than a stock has experienced historically. Conversely, higher probability level forecast values represent higher survival than a stock has experienced historically.

The forecast distribution is generated using Bayesian statistics for biological models, or residual error for non-parametric (naïve) models (Grant et al. 2010).

Forecasts presented in the tables are generally the best performing models over the time series: they generate the lowest difference between the predicted and actual returns. However, lower ranked model forecasts are also compared to the top ranked model (Table 6). In cases where preliminary recruitment data are available for three and four year olds in the previous return year (i.e. 2015 for this year's 2016 forecast), sibling models also are explored (Tables 1A and 6).

Fraser Sockeye Returns

Total Fraser Sockeye returns vary annually (Figure 1A). One cause of this variation is the four year pattern in returns of the stocks that produce large abundances once every four years. For example, the dominant Adams run (identified as Late Shuswap in the forecast table) has very large returns once every four years (i.e. …2006, 2010, 2014), which results in larger total Fraser Sockeye returns in these years (Figure 1A). Other factors that influence Fraser Sockeye returns include annual variability in survival (Figure 1A & B), and spawning escapement.

Fraser Sockeye abundances peaked in the 1990's, and then subsequently decreased, reaching an exceptionally low abundance in 2009 (Figures 1A). Then, for the next five years (2010-2014), returns increased. Last year (2015), however, returns were again poor (Table 5; Figure 1A); Chilko (55%) and Harrison (11%) contributed the largest percentages to 2015 returns.

For the upcoming return year (2016), this Fraser Sockeye cycle has the smallest average return of the four cycles (Table 1B). The average annual return (1956-2008) on this cycle is 3.9 million for all 19 forecasted stocks combined (excluding miscellaneous stocks, which generally do not have return data) (Table 1B, column G; Figure 1A). For the 2016 return cycle (the current forecast year), Chilko has historically contributed the greatest proportion (46%) to the total return (Table 1B, column G), followed by Stellako (12%), Weaver (9%), Birkenhead (7%), and Late Stuart (5%). All other stocks have historically contributed less than 4% to the total return abundance.

Fraser Sockeye Survival

Total survival (returns-per-spawner) across all Fraser Sockeye stocks declined in the 1990s and reached the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2014), survival was close to average (Figure 1B). Very preliminary information on total 2015 returns indicate survival has again decreased (Figure 1B), although, as calculated as returns-per-spawner four years previous, this year's survival is confounded by the higher proportion of five year olds. These broader survival trends are driven by the more abundant stocks for any given year, and in 2015, it was the particularly low survival of Summer Run stocks that resulted in the low total survival for the Fraser Sockeye aggregate (Figure 1B).

Individual stock survival trends, however, vary (Figure 3; Grant et al. 2011; Peterman & Dorner 2012), and specific stocks have exhibited below to above average survival in recent years (see text below). Most notably, Harrison Sockeye have exhibited a large increase in survival in recent years (Grant et al. 2010; Grant et al. 2011), though this stock has a unique age-structure and life-history compared to all other Fraser Sockeye stocks.

Considerable mortality occurs in the freshwater and marine ecosystems, as indicated by freshwater and marine survival data for Chilko River Sockeye (Fraser Sockeye indicator stock) (Figure 2A & B). Chilko is the only stock with a long time series of smolt data, which can be used with escapement and return data to partition total survival into freshwater and 'marine' components ('marine' survival includes their migration downstream from the counting weir at the outlet of Chilko Lake to the Strait of Georgia). A number of factors in both the freshwater and marine environments influence Fraser Sockeye survival, and these factors may vary between stocks and years. Chilko marine survival, similar to the total Fraser Sockeye survival trend, declined in the 1990's and culminated in the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2014 return years), survival was close to average (Figure 2B). A very preliminary estimate of 2015 return survivals indicates that survival has dropped relative to the 2010 to 2014 return years and was below average (Figure 2B).

2016 Forecast Brood Year Escapement (2011 & 2012)

The two dominant ages for Fraser Sockeye are four and five year olds. Most Fraser Sockeye return as four year olds, with these fish typically spending two winters in freshwater and two winters in the ocean. A smaller proportion of returns (average: 20%) spend an additional winter in the marine environment and return as five year olds. The proportion of four and five year old fish in Fraser Sockeye returns can vary, largely due to differences in brood year escapements between the four and five year old brood years and differences in survival between these years.

Fraser Sockeye four year olds that will return in 2016 come from the 2012 brood year escapement. For this brood year, escapements were well below average (Table 1B). Specifically, the 2012 brood year escapement (284,300 effective female spawners (EFS)) for the 19 forecasted stocks was 60% of the cycle average (476,900 EFS). For individual stocks, more than half (12 out of 19) had below average escapements or smolt abundances: Early

Stuart, Bowron, Upper Barriere (Fennell), Seymour, Chilko, Quesnel, Raft, Late Shuswap, Cultus, Portage, Weaver, and Birkenhead. These 2012 escapements were the lowest on record for several of these stocks: Bowron, Seymour, Quesnel, Late Shuswap, Birkenhead, and Weaver. Most of the remaining stocks (6 out of 19), had close to average escapements in 2012: Gates, Nadina, Scotch, Late Stuart, Stellako, and Harrison. The 2012 brood year EFS was above average for only two stocks (Pitt and Chilliwack). Note that the escapement for the miscellaneous Chilliwack stock was the largest on record in 2012 (78,000 EFS).

Chilko (25%) and the miscellaneous Chilliwack stock (22%) contributed the greatest proportion to the total 2012 EFS abundance. The next largest contributors to the total EFS abundance were Stellako (14%), Pitt (11%), Harrison (9%), and Late Stuart (9%). All other stocks contributed less than 6% to the total EFS abundance.

Analysis and Response

Data

Fraser Sockeye stock-recruitment 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 2016 forecast is 2009, with the exception of Harrison Sockeye (three and four year olds) where data are included to the 2010 brood year.
- Effective female spawner (EFS) data are included up to the 2012 brood year (2013 for Harrison).
- Juvenile fall fry data are not available for both Shuswap and Quesnel in the 2012 brood year (four year old returns in 2016), as fry assessments are only conducted on dominant (2010 and 2009) and subdominant (2011 and 2010) cycle years.
- Juvenile smolt data are available for Chilko and Cultus for the 2012 brood year.
- Juvenile fry data are available for Nadina, Weaver, and Gates (although due to inconsistencies in data collection methods over time for Gates, these data are not used in forecasts for this stock). Historically, these data were available for both the channel and rivers/creeks, however, in recent years only channel data are available for Nadina and Weaver; both Gates Creek and Channel fry have been assessed in very recent years. Gaps in the historical time series associated with years without fry data for rivers/creeks were filled using the average historical fry/EFS production multiplied by a particular year's brood year EFS.

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

- Pacific Decadal Oscillation (PDO) in winter (November to March)
- Average seas-surface temperature (SST) from Entrance Island (Ei; Strait of Georgia, near Nanaimo, B.C. from April to June and Pine Island (Pi; Northeast corner of Vancouver Island) from April to July
- Fraser Discharge (peak (FrD-peak) and average (FrD-average) from April to June measure at Hope, B.C.)

Methods

The 2016 Fraser Sockeye forecasts follow the same approach as recent forecasts (DFO 2012; MacDonald & Grant 2012; DFO 2013; Grant and MacDonald 2012; DFO 2014a; DFO 2015a), which were adapted from methods used in earlier forecasts (Cass et al. 2006, DFO 2006, 2008, 2009). Model performance, ranking, and model selection for Fraser Sockeye Salmon are based on the analyses conducted in 2012 (MacDonald & Grant 2012), with methods summarized in the bullets below (see Appendix 1 for model selection process by stock for 2016 forecasts):

1. Forecasts are presented in Table 1A, which includes the most appropriate model for each stock; models are selected based on model performance (forecasts compared to actual returns) over the full stock-recruitment time series (see #2 - #4 below) in combination with model selection criteria (see #5) and Bayesian convergence criteria (see #6).
2. Model performance (forecasts compared to actual returns) was compared across all applicable candidate models for each stock, excluding the recent-survival models (RS4yr, RS8yr, & KF) introduced in the 2010 forecast and sibling models. All models are described in Appendices 1 to 3 of Grant et al. 2010.
3. Jackknife (leave-one-out) cross-validation analysis was used to generate the historical forecast time series for each stock and model (MacDonald & Grant 2012); performance was then measured by comparing forecasts to observed returns across the full time series.
4. Four performance measures (mean raw error, mean absolute error, mean proportional error and root mean square error) (described in Appendix 4 of Grant et al. 2010), which assess the accuracy and/or precision of each model, were used to summarize jackknife cross-validation results, and rank models by their performance (results used in this year's 2016 forecast are summarized in MacDonald & Grant 2012);
5. After ranking models, the model selection process and criteria identified in the 2012 forecast were used to select the models for each 2016 forecast (see page 8 of MacDonald and Grant 2012);
6. See previous year's forecast on Bayesian diagnostics applied (DFO 2015a).
7. Miscellaneous stocks (except Chilliwack in recent years), for which recruitment data are unavailable, were forecast using the product of their brood year escapements and the geometric average survival (across the entire available time-series) for spatially and temporally similar stocks with stock recruitment data (index stocks) (see Appendix 1 of Grant et al. 2010, as identified in Table 1A).

For stocks where five year olds contribute a large proportion (>50%) to the forecast, where 2015 preliminary four year old returns indicated poor survival, and where stock-specific estimates of four year old return abundances were available, a sibling model approach (using the estimated number of four year olds in 2015 to predict the abundance of five year olds expected in 2016) was adopted, similar to the previous year's forecast (DFO 2015a). This approach involved running a Bayesian linear regression between a stock's $\log_e$ transformed four and five year old recruitment time series, using the preliminary $\log_e$ transformed four year old returns in 2015 as predictors of the older five year old sibling returns in 2016. For Harrison, a similar approach was adopted, except that for this stock a three-to-four year old sibling model was applied and even year data only were applied given the different age of maturities between even and odd years. Regression data was truncated to post-1980, given the increases of average age of maturity after 1980. All recruitment data was first transformed to millions. Five year old forecasts derived from the sibling model were used for the following stocks and the rationales for using the sibling model are described below:

- **Weaver:** a high proportion of five year olds in the original selected model forecast (93%) due to the very low brood year escapement in 2012 (400 EFS), exceptionally low survival associated with the 2015 four year old returns, and the availability of an in-season return estimate for this stock.
- **Birkenhead:** a high proportion of five year olds in the original selected model forecast (90%) due to low escapements in 2012 (2,500 EFS), low survival associated with the 2015 four year old returns, and the availability of an in-season return estimate for this stock.
- **Quesnel:** a high proportion of five year olds in the original selected model forecast (99%) due to the low escapements in 2012 (100 EFS), low survival associated with the 2015 four year old returns, and the availability of an in-season return estimate for this stock.
- **Harrison:** a high proportion of three year olds in the original selected model forecast (33%), low survival associated with the three year old returns, and the availability of an in-season return estimate for this stock.

A separate sensitivity analysis was conducted to evaluate the effect of the survival indicated by the 2015 four year old returns on the five year old forecasts in 2016 (Appendix 2). Although a number of stocks experienced lower survival than average in 2015, there were exceptions. For example, Early Stuart, Nadina, Pitt, Raft, and stocks in the North Thompson experienced average to above average survival. Forecasts for Harrison and Chilliwack stocks were not adjusted in the sensitivity analysis because of differences between the methods used to generate the 2015 and 2016 forecasts.

For the sensitivity analysis, a scalar was calculated for each stock from the preliminary number of four year olds returning in 2015 divided by the four year old 2015 50% p-level forecast of these fish (Appendix 2, Table A1). For example, the preliminary number of Chilko four year olds returning in 2015 (755,900) was divided by the 2015 Chilko 50% p-level four year old forecast (2,122,000) to produce a scalar of 0.36 (Appendix 2, Table A2). For each stock, the scalar was applied to the five year old forecast for 2016, generated using the same forecast model that was used in 2015 (DFO 2015a). The revised five year old forecast was added to the four year old forecast to generate a new adjusted total forecast for each stock (Appendix 2, Tables A1, A3 and A4). The resulting total adjusted forecasts (Appendix 2, Table A1) were then compared to the official forecast (Table 1A) as part of the sensitivity analysis. So for example, the median adjusted total forecast for Chilko sockeye of 985,000 is similar to the median of the official forecast of 1,002,000.

Preliminary returns are based on end-of-season estimates only, because a more comprehensive post-season assessment of catch, escapement, and run-size adjustments was not complete prior to analysis for this 2016 forecast publication. In cases where preliminary returns are only available for stock aggregates (such as Late Stuart/Stellako), these returns were partitioned into their individual stocks by applying stock's preliminary 2015 escapement proportion (relative to the total escapement of all stocks that comprise the in-season return aggregate) to the total return for the aggregate. This approach assumes the same en-route loss and exploitation for each stock in the aggregate, which cannot be verified in time for this publication. For Cultus, preliminary escapement fence counts and preliminary data on exploitation rate on the Late Run timing group were used as the basis for preliminary return estimate.

Results

Fraser Sockeye 2016 Forecasts: Overview

Fraser Sockeye returns in 2016 are not expected to be large. Most Sockeye expected to return in 2016 are four year olds, and escapements four years ago in 2012 were below average for most stocks (Table 1B). For some stocks, 2012 escapements were exceptionally small (e.g. Table 1B: Bowron: 10 EFS; Quesnel: 100 EFS; Late Shuswap: 10 EFS; and Portage: 10 EFS). Chilko, the stock expected to contribute the most to the 2016 returns, had a small brood year escapement in 2012 (90,800 EFS) that was almost one third of its cycle average (252,800 EFS). Freshwater survival was average for Chilko, therefore, the one year old smolt abundance in the 2012 brood year (11.4 M), which were used in the 2016 forecast process, was almost half its cycle average (19.8 M).

The total forecast for Fraser Sockeye ranged from 800,000 to 2.3 million from the 10% to 50% p-levels (Table 1A). At these p-levels, forecast returns fall below the cycle average of 3.9 M (Table 1B). In the past decade, total returns have not exceeded the middle values (50% probability levels) of their forecast distributions, with the exception of 2010 (Table 8). Chilko Sockeye contributes the most to the total 2016 forecast and this stock's 50% p-level forecast in 2016 indicates a 9% marine survival (Table 2). However in the past 18 years, Chilko marine survivals have not exceeded 8% in a single year (Table 2; Figure 2B).

The key stocks that contribute the largest proportion (70%) to the total 2016 forecast at the 50% p-level include Chilko, and to a lesser extent Late Stuart, Stellako, and Chilliwack. Since these stocks are expected to return as mostly four year old fish, the total forecast is comprised of 82% four year olds.

There are a number of stocks, however, that are expected to return as mostly five year olds (Table 3). Since preliminary return data indicates extremely poor survival of their four year old siblings in 2015 (Table 5; Appendix 2, Table A2), four-to-five year old sibling models were used for several of these stocks (Quesnel, Weaver, and Birkenhead) to take this poor survival into consideration (Tables 1 & 6). Although, not expected to contribute large amounts to the total forecast, the use of sibling models to forecast five year old returns for these stocks reduced each of their total forecasts by ~75% (Table 6).

Sibling models were also applied to the Harrison Sockeye 2016 four year old forecast, due to the very poor survival of their three year old siblings in 2016 (Table 5). The use of a three-to-four year old sibling forecast for Harrison Sockeye reduced its forecast by 50% (Table 6). This stock is expected to contribute 8% to the total forecasted return (Table 1).

Scotch, Seymour and Late Shuswap stocks also had poor returns relative to their forecasts in 2015 (Table 5). However, if the Larkin model had been used for these stocks in 2015, instead of the Ricker model, then the returns (which were comprised of ~75% four year olds) would have fallen closer to the mid-point of the forecast distribution. Given the exceptional brood year escapement in 2010, the improved performance (return minus forecast) of the Larkin model to predict four year old recruits from the 2011 brood year that returned in 2015, indicates the possibility that these stocks experienced delayed-density dependent survival in the 2011 brood year. Since the five year olds returning in 2016 would have experienced similar mechanisms to their sibling four year olds that returned in 2015, a Larkin model was used for these forecasts.

Cultus Sockeye, assessed as 'endangered' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), is expected to return at very low abundances that range from 1,000 to 4,000 at the 10% to 50% p-levels (Table 1). Almost all of these fish will be hatchery origin. The Cultus return forecast is well below its cycle average of 22,000 (Table 1B), and also well below this stock's lower Wild Salmon Policy benchmark of 12,000 effective total spawners.

The adjusted five year old forecasts generated for each stock in the sensitivity analyses were added to the four year olds forecasts. This total sensitivity analysis forecast (Appendix 2, Table A1: 2.7 M at the 50% p-level) was similar to the official forecast (Table 1A: 2.3 M at the 50% p-level). There are three reasons for this similarity. First, the overall forecast is dominated by four year olds under both methods, thus changing the forecasts for five year olds had minimal impact on the total. Second, the sibling models used to forecast the returns of five year olds of the Quesnel, Weaver, and Birkenhead stocks generated estimates that were similar to the adjusted values in the sensitivity analysis. Third, a few stocks (e.g. Pitt, Raft and other North Thompson stocks) experienced four year old returns that fell above the 50% p-level forecast in 2015, which indicates above average productivity. The scalars for these populations exceeded 1.4 (Table A2), and their application led to increased forecasts for five year old returns, that compensated for the decreases in age five forecasts for many other populations.

At the Run Timing group level, the sensitivity analyses conducted on the five year old forecasts resulted in no difference in the total Early Stuart Run timing group forecast (Appendix 2, Table A1 versus Table 1), since this stock is expected to return as largely four year olds (Table 3). The Early Summer Run forecast increased slightly with the sensitivity analyses, given Pitt Sockeye, unlike most other stocks, experienced higher survival in 2015. However, almost all other stocks in this Run Timing Group decreased, though this decrease was small since most returns in 2016 are expected to be four year olds. Note that Chilliwack was not adjusted for in the sensitivity analyses given very different models were used in 2015 versus 2016, making comparisons meaningless. Therefore the official Chilliwack forecast was included also in the sensitivity analysis table. Adjusting Chilliwack, however, would have resulted in a negligible difference given only 1% of 2016 returns for this stock are expected to be five year olds (Table 3).

The Summer Run sensitivity analyses forecast (Appendix 2, Table 1A: 1.9 M at the 50% p-level), was also slightly larger than the forecast (Table 1: 1.7 at the 50% p-level). Chilko's forecast did not change since returns are expected to be largely four year olds. Similar to Chilliwack, no adjustments were made to the Harrison forecast, given models used between 2015 and 2016 were very different. However, since a sibling four year old model was used for Harrison in the official forecast, this stock's lower survival in 2015 was accounted for.

The Late Run forecast for the sensitivity analysis was slightly smaller at 69,000, compared to the official forecast at 111,000. This occurred since many of these stocks experienced poor survival in 2015, in addition to the Weaver and Birkenhead stock that were adjusted for in both the official forecast and sensitivity analysis.

Individual Stock Forecasts (See Appendix 1 for Model Selection Rationale)

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

The 2012 cycle line is the second of two off cycle years following the dominant and subdominant cycle years for Early Stuart (i.e. 2012 immediately precedes the 2013 dominant cycle). The 2012 brood year EFS for the Early Stuart stock (6,800) was less than half the cycle average for this stock (1948-2012 cycle average: 18,700) (Table 1B, column C). Sockeye Salmon returning to the Early Stuart system in 2012 experienced difficult migratory conditions. Due to the above average snowpack and cool, wet spring, Early Stuart Sockeye encountered water levels that were approximately 50% higher than average during their migratory period, exceeding levels historically associated with poor migratory success for this stock. En-route mortalities were observed in several areas downstream of the spawning areas. Additionally, Sockeye were observed in several non-natal areas downstream of the traditional terminal area spawning grounds. Early Stuart Sockeye arrived at the spawning grounds one week later than normal, though spawning timing was within the normal range. Physical conditions on the spawning grounds appeared to be conducive to successful spawning, despite higher than average water levels. Spawner success was 76%, falling below the average of 89%, and the escapement was heavily skewed towards male spawners.

In the 2011 brood year, EFS for the Early Stuart stock (200) was the smallest on record across all cycles (Table 1B, column D), and was less than 1% of the cycle average (2011 cycle average 1951-2011: 25,200) (see DFO 2015 for more information on the 2011 brood year).

Average (geometric) four year old survival (age-4 R/EFS) for Early Stuart Sockeye declined from a peak of 24.5 R/EFS in the mid-1960 brood years (four year consecutive peak average) to one of the lowest survivals on record (1.5 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (7.1 R/EFS) has exceeded the long-term average (6.4 R/EFS). The 2011 brood year (2015 returns) four year old returns indicated above average survival (Appendix 2: Table A2).

The Ricker (Ei) model was used for the 2016 Early Stuart forecast (Appendix 1). Given the assumptions underlying the Ricker (Ei) model there is a one in four chance (25% probability) the Early Stuart Sockeye return will be below 22,000 (the age-4 component of this forecast implies 3.2 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 36,000 (the age-4 component of this forecast implies 5.2 age-4 R/EFS) in 2016 (Tables 1A & 2; Figure 3). This median forecast (36,000) is less than 30% of the average return on this cycle (128,000) (Tables 1A & B).

Five year olds contribute 0% (100) to the Early Stuart total forecast (at the 50% p-level) (Table 3) due to the small brood year escapement in 2011 (200) compared to 2012 (6,800) (Table 1B).

Early Summer Run

The Early Summer Run consists of a number of stocks that are typically less abundant than the major contributors to the large Summer and Late Run stock groups. Seven stocks in this timing group are forecast using the standard suite of forecast models: Bowron, Upper Barriere (Fennell), Gates, Nadina, Pitt, Scotch, and Seymour (Table 1A). There are also four miscellaneous stocks in this run timing group that include Early Shuswap, Taseko, Chilliwack and Nahatlatch. Starting in the 2013 forecast process, Raft River, the North Thompson mainstem, and several stocks associated with miscellaneous streams that are tributary to the North Thompson River, were reassigned to the Summer Run timing group (from the Early Summer Run group), following a re-evaluation of their migration timing by the Fraser Panel in 2012. Thus, these reassigned stocks are excluded from the Early Summer Run data and forecasts in this section.

Escapement in the 2012 brood year for all Early Summer stocks combined (147,000 EFS), was the third largest escapement on this cycle for this aggregate. The Chilliwack miscellaneous stock comprised the greatest proportion (54%) to this total, and this escapement was the highest on record (although complete assessments only began in 2002). Pitt (28%), Nadina (11%) and Gates (5%) also contributed the next highest percentages to the total Early Summer Run escapement. Pitt Sockeye, which are comprised of predominantly five year old recruits, had above average brood year escapements in 2012 (41,400 EFS) and 2011 (30,400 EFS) (all cycle average 1948-2012: 14,500 EFS). All remaining stocks had extremely small escapements (<1,000 EFS) and comprise less than 1% of the total Early Summer escapement.

Physical conditions on the Early Summer Run spawning grounds were favourable during the spawning period, exhibiting higher than average water levels in areas of the lower watershed. Arrival and spawning timing were normal for all stocks. Elevated levels of pre-spawn mortality were observed in some areas, particularly in Nahatlatch, Gates and the Thompson system. In contrast, pre-spawn mortality was very low in the Chilliwack and Pitt systems. Spawning success for the Early Summer aggregate in 2012 was equal to the long-term average (89%).

Bowron (Bowron-ES CU)

The 2012 brood year escapement for Bowron (30 EFS) was the smallest on record for this stock, falling well below the cycle average (1948-2012 average: 3,500 EFS) (Table 1B, column C). The sex ratio and spawner success (100%) for Bowron in 2012 were both assumed, due to the extremely low escapement and, therefore, limited availability of carcasses. The 2011 brood year escapement for Bowron (2,000 EFS) (Table 1B, column D) was also extremely small compared to the cycle average (1951-2011: 81,700 EFS).

Average (geometric) four year old survival (R/EFS) for Bowron Sockeye declined from a peak of 20.4 R/EFS in the mid-1960 brood years (four year average at peak) to one of the lowest survivals on record (2.2 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (3.9 R/EFS) has been below the long term average (6.7 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old returns indicated below average survival (Appendix 2, Table A2).

The MRS model was used for the 2016 Bowron forecast (Appendix 1). Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Bowron Sockeye return will be below 2,000 (negligible four year old brood year EFS to derive a meaningful estimate of R/EFS) and a one in two chance (50% probability) the return will be below 4,000 in 2016 (Table 1A & 2; Figure 3). This median forecast (4,000) is less than 15% of the average return on this cycle (29,000) (Tables 1A & B).

Five year olds contribute 95% (4,000) to the Bowron total forecast (at the 50% p-level) (Table 3) due to the large brood year escapement in 2011 (2,000) compared to 2012 (30) (Table 1B).

Upper Barriere (Fennell) (Upper Barriere-ES (de novo) CU)

The 2012 brood year escapement for Upper Barriere (700 EFS) was 15% of the cycle average (1968-2012 average: 4,700 EFS) (Table 1B, column C). Spawner success for Upper Barriere in 2012 was 70% (average: 90%). The 2011 brood year escapement for Upper Barriere (4,500 EFS) was similar to the cycle average (1967-2011 average: 5,000 EFS) (Table 1B, column D).

Average (geometric) four year old survival (R/EFS) for Upper Barriere Sockeye declined from a peak of 53.5 R/EFS in the early 1970s brood years (four year average at peak) to one of the lowest survivals on record (0.3 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (5.8 R/EFS) has been below the long term average (6.9 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).

The power model was used for the 2016 Upper Barriere forecast (Appendix 1). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Upper Barriere Sockeye return will be below 9,000 (the age-4 component of this forecast implies 7.8 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 14,000 (11.5 age-4 R/EFS) in 2016 (Tables 1A & 2; Figure 3). This median (50% probability) forecast (14,000) is almost half the average return on this cycle (32,000) (Tables 1A & B).

Five year olds contribute 39% (5,000) of the Upper Barriere total forecast (at the 50% p-level) (Table 3) due to the large brood year escapement in 2011 (4,500) compared to 2012 (700) (Table 1B).

Gates (Anderson-Seton-ES CU)

The 2012 brood year escapement for Gates (6,900 EFS), which includes both the channel and creek, was similar to the cycle average (1968-2012 average: 9,000 EFS) (Table 1B, column C). Spawning success in the Gates system was the lowest in the watershed at 38% (average: 74%). Samples collected in Gates Creek indicated a high level of IHN (Infectious Haematopoietic Necrosis) in these fish. Juvenile data for Gates are not used in the forecast process due to historical inconsistencies in data collection methods. However, in recent years (2011 to 2013 brood years), juveniles have been consistently assessed and early freshwater survival in the 2012 brood year (600 fry/EFS) was close to this three year average (651 fry/EFS). Early freshwater survival (fry/EFS) in the 2012 brood year, however, is below the long-term average (1,300), which is comparable to fry/EFS averages for other Fraser Sockeye channel systems (Nadina: 1,100; Weaver: 1,400). The 2011 brood year escapement for Gates (28,400 EFS) was the largest on record for this stock and was five times larger than the cycle average (1971-2011 average: 4,900 EFS) (Table 1B, column D).

Average (geometric) four year old survival (R/EFS) for Gates Sockeye declined steadily from a peak of 41.0 R/EFS in the early-1970 brood years (four year average at peak) to one of the lowest survivals on record (1.6 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (26.1 R/EFS) has been well above the long-term average (10.6 R/EFS). The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).

The Larkin model was used for the 2016 Gates forecast (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Gates Sockeye return will be below 40,000 (the age-4 component of this forecast implies 4.6 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 76,000 (8.7 age-4 R/EFS) in 2016 (Tables 1A & 2; Figure 3). This median (50% probability) forecast (76,000) is smaller than the average return on this cycle (124,000) (Tables 1A & B).

Five year olds contribute 20% (15,000) to the Gates total forecast (at the 50% p-level) (Table 3).

Nadina (Nadina-Francois-ES CU)

The 2012 brood year escapement for Nadina (16,800 EFS), which includes both the channel and river, was larger than the cycle average (1976-2012 average: 13,700 EFS) (Table 1B, column C), though within the calculated average range. Spawning success in Nadina (97%) was higher than the long term average (89%). It should be noted that the channel loading strategy employed in 2012 differed from the typical procedure. Sockeye were allowed to passively enter the channel without use of the river diversion fence and channel counting fence, and therefore, escapement estimates to the channel were derived from live counts in the channel rather than fence counts at the channel outlet. The 2011 brood year escapement for Nadina (1,200 EFS) was well below the cycle average (1975-2011 average: 11,200 EFS) (Table 1B, column D). Effective female escapement was much lower than total escapement (10,100) in this system due to a depressed spawner success observed for Nadina in 2011 (43%) compared to average (90%), and a high proportion of males in the system (72% males), as indicated by carcass recoveries from Nadina Channel.

The fry abundance in Nadina in the 2012 brood year (16.6 million fry) was above average (brood years 1973-2012 average: 9.5 million fry). Freshwater survival in the 2012 brood year (1,000 fry/EFS) was similar to the average across cycles (1975-2012 average: 1,200 fry/EFS). In the 2011 brood year, fry abundance (1.3 million fry) was well below average (brood years 1973-2012 average: 9.5 million fry), given the extremely low abundance of EFS in 2011.

Freshwater survival in the 2011 brood year (1,100 fry/EFS) was close to average (1975-2012 average: 1,200 fry/EFS).

Average (geometric) four year old survival (R/EFS) for Nadina Sockeye declined from a peak of 13.5 R/EFS in the mid-1970 brood years (four year average at peak) to one of the lowest survivals on record (1.0 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (8.0 R/EFS) has been above the long term average (6.2 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old returns indicated average survival (Appendix 2, Table A2).

The MRJ model was used for the 2016 Nadina forecast (Appendix 1). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Nadina Sockeye return will be below 45,000 (the age-4 component of this forecast implies 2.7 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 90,000 (5.3 age-4 R/EFS) in 2016 (Table 1A & 2; Figure 3). This median (50% probability) forecast falls within the average range of returns on this cycle (average: 118,000) (Tables 1A & B).

Five year olds contribute 2% (2,000) to the total Nadina forecast (at the 50% p-level) (Table 3).

Pitt (Pitt-ES CU)

Due to the high average proportion of five year old recruits (~70%) relative to four year old recruits for Pitt, brood year escapements were compared to the time-series average, rather than the cycle average. The brood year escapement for Pitt in 2012 (for four year old recruits returning in 2016: 41,400 EFS, including hatchery broodstock females) was almost three times larger than the average escapement from 1948-2012 (14,500 EFS, including hatchery broodstock females). The 2011 escapement (for five year old recruits returning in 2016: 30,400 EFS) was double the average (Table 1B, column D). Estimates of spawning success in the Upper Pitt in 2012 (98%) and in 2011 (99%) were both above average (89%).

Average (geometric) five year old survival (R/EFS) for Pitt Sockeye (which includes hatchery broodstock females) has been variable throughout the time series, with a second peak of 13.3 five year old R/EFS (four year average at peak) occurring in the early 1990s. Subsequently, survival declined for this stock, culminating in one of the lowest survivals on record (0.2 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average five year old survival (3.7 R/EFS) was close to the long-term average (3.4 R/EFS). The 2011 brood year (2015 returns) four year old returns indicated above average survival (Appendix 2, Table A2).

The Larkin model was used to generate the 2016 forecast for Pitt (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Pitt Sockeye return will be below 60,000 (the age-5 component of this forecast implies 1.5 age-5 R/EFS) and a one in two chance (50% probability) the return will be below 90,000 (2.4 age-5 R/EFS) in 2016 (Tables 1A & 2; Figure 3). This median (50% probability) forecast is similar to the average return (78,000) (Tables 1A & B).

Five year olds contribute 80% (72,000) to the Pitt total forecast (at the 50% p-level) (Table 3).

Scotch (a component of the Shuswap-ES CU)

The 2012 brood year escapement for Scotch (640 EFS) was similar to the cycle average (800 EFS) (Table 1B, column C) from 1980-2012 (time series commences in 1980 for this stock). Spawner success in Scotch was very low in 2012 (59%) compared to average (94%). However, access to carcasses was limited by the low spawner abundance, so recoveries were pooled across the South Thompson system to create a system-wide estimate of sex ratio and spawner success that was applied to each component's spawner abundance to generate an estimate of the EFS. Escapement in the 2011 brood year for Scotch (12,500 EFS) was the largest escapement on this cycle, falling almost three times above the cycle average (4,400 EFS) (Table 1B, column D) from 1983-2011.

Average (geometric) four year old survival (R/EFS) for Scotch Sockeye declined from a peak of 21.5 R/EFS in the early 1980 brood years (four year average at peak) to one of the lowest survivals (2.2 R/EFS) on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (9.8 R/EFS) has been above the long-term average (7.2 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).. Although if a Larkin model had been used in the 2015 forecast, this would have indicated closer to average survival (DFO 2015, Table 6).

The Larkin model was used to produce the 2016 forecasts for the Scotch (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Scotch Sockeye return will be below 2,000 (uncertainty in model estimates precludes the ability to derive a meaningful estimate of R/EFS) and a one in two chance (50% probability) the return will be below 12,000 in 2016 (Table 1A; Figure 3). This median return forecast is similar to the cycle average (10,000) (Tables 1A & B).

Five year olds contribute 0% (30) of the Scotch total forecast (at the 50% p-level) (Table 3).

Seymour (a component of the Shuswap-ES CU)

The 2012 brood year escapement for Seymour (300 EFS) was much smaller than the cycle average (3,800 EFS) from 1948-2012 (Table 1B, column C), and was the smallest on record. Spawner success in Seymour was low in 2012 (57%) compared to average (94%), though similar to Scotch, EFS was based on the South Thompson system-wide estimate of sex ratio and spawner success. The 2011 brood year escapement for Seymour (8,000 EFS) was smaller than the cycle average (19,300 EFS) from 1951-2011 (Table 1B, column D).

Average (geometric) four year old survival (R/EFS) for Seymour Sockeye declined steadily from a peak of 29.2 R/EFS at the start of the time series in the 1970s (four year average at peak) to one of the lowest survivals on record (3.4 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (4.2 R/EFS) has been below the long-term average (7.5 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2). Although if a Larkin model had been used in the 2015 forecast, this would have indicated closer to average survival (DFO 2015, Table 6).

The Larkin model was used to produce the 2016 forecasts for the Seymour (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Seymour Sockeye return will be below 100 (negligible brood year abundance to estimate R/EFS) and a one in two chance (50% probability) the return will be below 400 in 2016 (Table 1A; Figure 3). This median forecast is well below to the average return on this cycle (32,000) (Tables 1A & B).

Five year olds contribute 0% (30) of the Seymour total forecast (at the 50% p-level) (Table 3).

Miscellaneous Early Shuswap (Shuswap-ES)

The 2012 brood year EFS for the miscellaneous Early Shuswap tributary populations is 200 EFS (this group includes all Early Shuswap populations, excluding Seymour River, and Scotch and McNomee Creeks) (Table 1B, column C). This group is dominated by the Eagle River and its tributaries. The 2012 escapement to the Early Shuswap tributary miscellaneous populations was well below the average EFS for this system (2000-2011: 20,800). The 2011 escapement to the Early Shuswap miscellaneous tributary stocks (7,400 EFS) was much larger than the 2012 EFS abundance, but was also below average (Table 1B, column D).

The model used to generate the miscellaneous Early Shuswap tributary forecast uses the geometric mean of the recruits-per-EFS from the Scotch and Seymour stocks (from brood years 1950-2009) multiplied by the Early Shuswap miscellaneous tributary stock's total brood year escapement (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the Early Shuswap miscellaneous stock model, there is a one in four chance (25% probability) the return will be below 4,000 (the age-4 component of this forecast implies 3.8 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 8,000 (8.3 age-4 R/EFS) in 2016 (Tables 1A & B).

The five year old component of this return is expected to contribute 75% (6,000) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Taseko (Taseko-ES)

The 2012 brood year EFS for the miscellaneous Taseko population (includes Taseko Lake and Yohetta Creek) was 40 EFS. The 2012 escapement is well below the average EFS for this system (1994-2010: 900). The 2011 Taseko escapement was (400 EFS) (Table 1B, column D). Note: due to the extremely turbid nature of Taseko Lake the Taseko escapement should be considered an index of abundance only, as it is derived from carcass surveys conducted throughout the lake.

The model used to generate the miscellaneous Taseko forecast uses the geometric mean of the recruits-per-EFS from the Chilko stock (from brood years 1948-2009) multiplied by the Taseko brood year escapement (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the Taseko miscellaneous stock model, there is a one in four chance (25% probability) the return will be below 0 (negligible four year olds to estimate R/EFS)) and a one in two chance (50% probability) the return will be below 1,000 in 2016 (Table 1A).

The five year old component of this return is expected to contribute 50% (300) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Chilliwack (Chilliwack-ES)

The 2012 brood year EFS for the miscellaneous Chilliwack populations includes Upper Chilliwack River (77,300) and Chilliwack Lake (1,500) (total EFS: 78,800) (Table 1B, column C). The 2012 escapement is well above the average EFS for this system, calculated using only years when both Chilliwack Lake and the upper Chilliwack River were surveyed (2001 to 2014: 22,000), and is the largest escapement on record for this stock. The 2011 Chilliwack escapement was 2,500 EFS (Table 1B, column D).

The model typically used to generate the miscellaneous Chilliwack uses the geometric mean of the recruits-per-EFS from the Early Summer stocks (Bowron, Upper Barriere (Fennell), Gates, Nadina, Pitt, Scotch, Seymour)(from brood years 1948-2009) multiplied by the Chilliwack stock's total brood year escapement (see Appendix 1 to 3 in Grant et al. 2011; Table 7). Using this model the forecast for Chilliwack in 2016 is 255,000 (the age-4 component of this forecast implies 3.2 age-4 R/EFS) at the 25% probability level, and 475,000 (6.0 age-4 R/EFS) at the 50% probability level (Appendix 1: Table A5). However, due to the large effective female spawner abundance in 2012, and the availability of a limited time series of recruitment data (brood years 1999-2010) for Chilliwack, a Ricker model was used to forecast the 2016 return.

Given the assumptions underlying the Ricker model, there is a one in four chance (25% probability) the Chilliwack miscellaneous stocks' return will be below 46,000 (the age-4 component of this forecast implies 0.6 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 138,000 (1.7 age-4 R/EFS) in 2016 (Tables 1A & B).

The five year old component is expected to contribute 1% (1,000) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Nahatlach (Nahatlach-ES)

The 2012 brood year EFS for the miscellaneous Nahatlach populations includes Nahatlach River (500) and Nahatlach Lake (600) (total EFS: 1,100) (Table 1B, column C). The 2012 escapement is smaller than the average EFS for this system (cycle average from 1976 to 2012: 2,500). The 2011 brood year EFS for Nahatlach is 3,500 (Table 1B, column D.).

The model used to generate the miscellaneous Nahatlach forecast uses the geometric mean of the recruits-per-spawner from the Early Summer stocks (Bowron, Upper Barriere (Fennell), Gates, Nadina, Pitt, Scotch, Seymour) (from brood years 1948-2009) multiplied by the Nahatlach miscellaneous stock's total brood year escapement (see Appendix 1 to 3 in Grant et al. 2011).

Given the assumptions underlying the miscellaneous stocks model, there is a one in four chance (25% probability) the Nahatlach miscellaneous stocks' return will be below 8,000 (the age-4 component of this forecast implies 3.2 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 14,000 (6.0 age-4 R/EFS) in 2016 (Tables 1A & 2).

The five year old component of this return is expected to contribute 50% (7,000) of the total forecasted return at the 50% p-level (Table 3).

Summer Run

In most years, the Summer Run stocks dominate total Fraser Sockeye returns. Six stocks in this timing group are forecast using the standard suite of forecast models: Chilko, Late Stuart, Quesnel, Stellako and the recently added Raft and Harrison (Table 1A). There are also three miscellaneous stocks in this run timing group that include North Thompson River, North Thompson Tributaries, and Widgeon. Starting in the 2013 forecast process, Raft River, the North Thompson mainstem, and several stocks associated with miscellaneous streams that are tributary to the North Thompson River, were re-assigned to the Summer Run timing group (from the Early Summer Run group), following a re-evaluation of their migration timing by the Fraser Panel in 2012. Widgeon was re-assigned as of the 2015 forecast.

Escapement in the 2012 brood year for all Summer Run stocks combined (208,300 EFS), was below the long-term cycle average (355,800 EFS). Chilko (44%) contributed the most to the Summer Run EFS, followed by Stellako (24%), Harrison (16%) and Late Stuart (15%). All other Summer Run stocks contributed <1% of the total 2012 brood year escapement. Physical conditions on the Summer Run aggregate spawning grounds were conducive to successful spawning in all areas in 2012. Arrival to the spawning grounds and spawning timing was within the normal range for all populations except Stellako, which displayed delayed, abnormal spawning behavior, with Sockeye holding in the river for a prolonged period. Elevated pre-spawn mortality was observed in all areas except Harrison-Lillooet; notably high pre-spawn mortality was observed in North Thompson and Quesnel. The spawning success for the Summer Run aggregate in 2012 of 66% was well below average (time series average for the Summer Run aggregate: 90%).

Chilko (Chilko-S & Chilko-ES CU)

The 2012 brood year escapement for Chilko (90,800 EFS) was below the cycle average (252,800 EFS) from 1948-2012. Spawning success in this system in 2012 was 67% (average: 92%), though this estimate is likely biased low due to high bear predation in the area, which limited access to carcasses after the peak of spawn. The 2011 brood year escapement for Chilko (457,700 EFS) was double the cycle average (230,700 EFS) from 1951-2011 and was the second largest escapement on this cycle for this stock.

Chilko freshwater survival for the 2012 brood year (126 age-1 smolts/EFS) was within the calculated average range (1950-2012 average: 117 age-1 smolts/EFS) (Figure 2 A), though given the low brood year escapements, the resulting smolt abundance (11.4 million age-1 smolts) was below average (brood years 1950-2012: 19.8 million age-1 smolts) (Table 1B, column C). Smolts are enumerated at a counting fence located at the outlet of Chilko Lake. Chilko freshwater survival for the 2011 brood year (97 age-1 smolts/EFS) was slightly below average (1950-2012 average: 117 age-1 smolts/EFS); however, given the large 2011 escapement, juvenile (smolt) abundance for the 2011 brood year (43.2 million age-1 old smolts) was still well above the long-term average (brood years 1950-2012: 19.8 million age-1 smolts) (Table 1B, column D). Average age-1 smolt body lengths in the 2012 (98.3 mm) and 2011 (85.3 mm) brood years were respectively above and similar to the long-term (brood years 1952-2012) average (83.5 mm).

Average (geometric) four year old post-smolt (Fraser downstream migration plus marine) survival (R/smolt) for Chilko Sockeye declined steadily from a peak of 18% in the late-1980 brood years (four year average at peak) to one of the lowest post-smolt survivals on record (0.3%) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figures 2 B & 3). In the most recent generation (2007 to 2010 brood years), the average survival (4% R/smolt) has been below the long-term average (7% R/smolt), though within the calculated average range. The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).

The power (juv) (Pi) model was used to generate the 2016 Chilko forecast (Appendix 1). Given the assumptions underlying the power (juv) (Pi) model, there is a one in four chance (25% probability) the Chilko Sockeye return will be below 658,000 (the age-4 component of this forecast implies 5% age-4 marine survival) and a one in two chance (50% probability) the return will be below 1,002,000 (9% age-4 marine survival) in 2016 (Tables 1A & 2; Figure 3). This median forecast (50% probability) is just over half the size of the average return on this cycle (1,781,000) (Tables 1A & B).

Five year olds contribute 3% (26,000) to the Chilko total forecast (at the 50% p-level) (Table 3).

Preliminary Chilko three year old (jack) recruits in 2015 (2,500) were used to predict four year old recruits in 2016, using a three-to-four year old recruit relationship (Table 6; Figure 6). Only data post-1980 were used given the shift in age of maturity after 1980 (Grant et al. 2010). The sibling model four year old 50% p-level forecast was 976,000, which is very close to the power (juv) (Pi) four year old 50% p-level forecast of 971,000 (Table 6).

Quesnel (Quesnel-S CU)

The 2012 brood year escapement for Quesnel (100 EFS) was extremely small, though it was not the smallest EFS on record for this stock. The 2012 EFS fell well below the cycle average (4,500 EFS) from 1948-2012 (Table 1B, column C). Spawner success was the second lowest on record, at 33% (average: 84%). Fry surveys (hydroacoustic) were not conducted in the 2012 brood year. The 2011 brood year escapement for Quesnel (17,000 EFS) was smaller than the cycle average (28,800 EFS) from 1951-2011, but still within the average range (Table 1B, column D). Freshwater survival for the 2011 brood year (379 fall fry/EFS) was above the average across all cycles (1976-2011 brood years: 197 fall fry/EFS), however, this covers a range of escapements. Given the small escapement in 2011, the resulting fall fry abundance (6.4 million) was below average (1976-2011 average: 28.8 million). The 2011 brood year fall fry body sizes (3.1 g) were also similar to the average (1976-2010 all cycle average: 3.7 g). Note: the Mount Polley mine breach occurred in August 2014, after juveniles would have migrated out of this system en-route to the Strait of Georgia. This breach of the tailing pond spilled into Polley Lake, flooding Hazeltine Creek, and spilling into Quesnel Lake, releasing mining waste comprised of various metal contaminants into these waters.

Average (geometric) four year old survival on the 2012 cycle for Quesnel Sockeye declined from a peak of 18.1 R/EFS in the late-1960's to one of the lowest productivities on record (0.3 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (3.8 R/EFS) has been below the long-term 2012 cycle average (6.5 R/EFS), though within the calculated average range. The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).

Due to the extremely small brood year escapement, four year olds are expected to contribute negligible numbers to the total forecast, and five year olds are expected to make up most of the return. Preliminary data on four year old returns in 2015 suggest that this brood year experienced poor survival, therefore, the five year old siblings returning in 2016 would be expected to have experienced similar low survival. The five year old component of the Quesnel forecast was therefore generated using a sibling model in 2016 (Table 6; Figure 4).

The Ricker-cyc model was used to generate the 2015 four-year old forecast for Quesnel. Given the assumptions underlying the Ricker-cyc model (four year olds) and the sibling model (five year olds), there is a one in four chance (25% probability) the Quesnel Sockeye return will be below 9,000 (negligible brood year abundance to estimate R/EFS) and a one in two (50% probability) the return will be below 15,000 in 2016 (Table 1A; Figure 3). The median forecast is below the average return on this cycle (55,000) (Tables 1A & B).

Five year olds contribute 93% (14,000) to the total Quesnel forecast (at the 50% p-level) (Table 3). This is much lower than the five year old abundance predicted by the Ricker-cyc model (62,000), which does not consider the poorer survival of the four year old Quesnel recruits in 2015 (Table 6).

Late Stuart (Takla-Trembleur-Stuart-S CU)

The 2012 brood year escapement (31,800 EFS) for Late Stuart was similar to the cycle average (26,000 EFS) from 1948-2012 (Table 1B, column C). Spawning success in the Late Stuart system in 2012 was well below average at 61% (average: 91%). The 2011 brood year escapement (800 EFS) for Late Stuart was well below the cycle average (9,600 EFS) from 1951-2011 (Table 1B, column D) (see DFO 2014 for more information on the 2011 brood year).

Average (geometric) four year old survival (R/EFS) for Late Stuart Sockeye declined from a peak of 57.2 R/EFS in the early 1950's, with subsequent, lower peaks in the late 1960's and mid-1980's to one of the lowest survivals on record (0.6 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (2.8 R/EFS) has been below the long-term average (8.6 R/EFS). The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2).

The R1C model was used to generate the 2016 forecast for Late Stuart (Appendix 1). Given the assumptions underlying the R1C model, there is a one in four chance (25% probability) the Late

Stuart Sockeye return will be below 86,000 (the age-4 component of this forecast implies 2.7 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 192,000 (5.9 age-4 R/EFS) in 2016 (Tables 1A & 2; Figure 3). This median (50% probability) forecast is similar to the average return on this cycle (175,000) (Tables 1A & B).

Five year olds contribute 2% (4,000) to the Late Stuart total forecast (at the 50% p-level)(Table 3). The estimate of five year olds for this model is based on the return age proportion produced by the power model, since the R1C model does not produce age-specific return forecasts.

Stellako (Francois-Fraser-S CU)

The 2012 brood year escapement for Stellako (50,600 EFS) was very similar to the cycle average (61,500 EFS) from 1948-2012 (Table 1B, column C). Spawner success for Stellako was the second lowest on record, at 57% (average: 91%). Spawning behavior in Stellako was unusual in 2012. Fish held for an abnormally long time, and very little active spawning was observed. DFO stock assessment biologists indicate that the reported spawner success could be biased high in 2012 (i.e. higher egg retention was observed for females reported as 100% spawned). The 2011 brood year escapement for Stellako (26,000 EFS) was much smaller than the cycle average (53,100 EFS) from 1951-2011 (Table 1B, column D).

Average (geometric) four year old survival (R/EFS) for Stellako Sockeye declined from a peak of 15.1 R/EFS in the early 1970s to one of the lowest survivals on record (0.1 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), survival (7.1 R/EFS) has been close to average (7.0 R/EFS). The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Table 5).

The R2C model was used to generate the 2016 forecast for Stellako (Appendix 1). Given the assumptions underlying the R2C model, there is a one in four chance (25% probability) the Stellako Sockeye return will be below 144,000 (the age-4 component of this forecast implies 2.6 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 256,000 (4.7 age-4 R/EFS) in 2016 (Table 1A & 2; Figure 3). This forecast falls well below the average return on this cycle (448,000) (Appendix 2, Table A2).

Five year olds contribute 8% (20,000) to the total Stellako forecast (at the 50% p-level (Table 3)). The estimate of five year olds for this model is based on the return age proportion produced by the Larkin model, since the R2C model does not produce age-specific return forecasts (Table 3).

Preliminary Stellako three year old (jack) recruits in 2015 (58) were used to predict four year old recruits in 2016, using a three-to-four year old recruit relationship (Table 6; Figure 6). Only data post-1980 were used given the shift in age of maturity after 1980 (Grant et al. 2010). The sibling model four year old 50% p-level forecast was 257,000, which is very close to the R2C four year old 50% p-level forecast of 235,000 (note: Larkin model age proportions were applied to the total R2C model to generate forecasts by age) (Table 6).

Harrison (Harrison-River Type CU): Recently re-assigned from Late Run Group to the Summer group

Harrison Sockeye have a unique life history and age structure compared to other Fraser Sockeye stocks. They migrate to the ocean shortly after gravel emergence (most Fraser Sockeye rear in lakes for one year after gravel emergence prior to their ocean migration). After two to three years in the ocean, Harrison Sockeye return as three or four year old fish (most Fraser Sockeye return as four and five year old fish). Proportions of three and four year old

Harrison recruits vary considerably annually, with four year old proportions ranging from 10% to 90% of total recruits (Grant et al. 2010). Odd brood years, on average, produce a higher proportion of four year old recruits, and even years produce a similar proportion of three year old recruits (Grant et al. 2010). Though the difference in odd versus even year age proportions is accounted for in the Harrison forecast models (MacDonald & Grant 2012), the extreme variation in age-at-maturity for Harrison Sockeye increases the level of forecast uncertainty for this stock.

The 2012 brood year escapement (four year old recruits in 2016) for this stock (32,900 EFS) was close to the long-term average (25,500 EFS)(Table 1B, column C). Harrison Sockeye escapements are compared to the entire time series instead of the cycle average, since Harrison has variable proportions of four year old returns, and is therefore not cyclic (Table 1B, columns C & D). The 2013 brood year escapement (three year old recruits in 2016) for Harrison (78,000 EFS) was larger than the average for this stock (25,500 EFS) (Table 1B, column D). Conditions in 2012 (four year old returns in 2016) and 2013 (three year old recruits in 2016) were favorable for spawning; spawning success was 99% in 2012 and 96% in 2013, both similar to the long-term average (99%).

Unlike most other Fraser Sockeye stocks, average (geometric) survival (R/EFS) for Harrison Sockeye increased to a maximum of 33.8 R/EFS in mid-1990's (Table 2, columns B to E). Similar to other stocks, however, the 2005 brood year survival (i.e. 2009 four year old return year) (Table 2, column E) of 0.1 R/EFS was the lowest on record. In the most recent generation (2007 to 2010 brood years), survival (13.2 R/EFS) has been well above average (7.6 R/EFS). Productivity for Harrison in the 2011 brood year (three year olds in 2014 and four year olds in 2015) indicated low survival. Harrison three year old recruits in 2015 would have entered the ocean in 2013, and four year olds in 2015 would have entered the ocean in 2012. Most other stocks that returned in 2015 entered the ocean in 2013.

In recent years Harrison Sockeye have been extremely challenging to forecast due to the large increases in escapements and survival (Grant et al. 2010; Grant et al. 2011), and the inter-annual variation in this stock's four year old proportions (see first paragraph of this Harrison forecast section). Escapement methodology has also changed considerably, from visual aerial surveys over most of the time series, to mark recapture methods in recent years when escapements were expected to exceed 75,000. Historically (up to the year 2000), Harrison Sockeye escapements averaged 6,500 EFS, while survival averaged 15 R/EFS. In recent years (post-2000), escapements have averaged 100,000 EFS, and survival has been well above average at 26 R/EFS. As a result, various naïve and biological forms have been explored in recent year's forecasts, but a rigorous retrospective evaluation of forecast performance for these alternative models is confounded by the dramatic shifts in productivity for this stock.

In the 2016 forecast, however, brood year escapements now fall within the data range, with six recent previous years being as high as or higher than the 2012 and 2013 brood year escapements. So the top ranked biological model (Ricker-Ei) was used to forecast three year olds, and given the much lower survival of three year olds in 2015, a sibling (three to four year old) model was used to forecast four year olds for Harrison (Figure 5). Post-1980 data were used in sibling models given shifts in age of maturity after 1980 and even years were selected because of the tendency for even years to produce a lower fraction of four year olds. (Even years produce on average 58% four year olds, which is lower than odd years (75% four year olds)).

Given the assumptions underlying the Ricker-Ei three year old and sibling four year old models, there is a one in four chance (25% probability) the Harrison Sockeye return will be below 73,000 and a one in two (50% probability) the return will be below 176,000 in 2016 (Table 1A).

Three year olds contribute 73% (128,000) to the total Harrison forecast (at the 50% p-level) (Table 3).

For comparison, if post-1980 three and four year old recruits for odd years, or all years, are used in the sibling model relationship, the forecasts of four year olds, and therefore, total forecast are higher (Table 6). This is attributed to the higher proportion of four year olds that occur on odd versus even years.

Raft (Kamloops-ES CU): Recently re-assigned to Summer from the Early Summer Run Group

The 2012 brood year escapement for Raft (1,700 EFS) was much smaller than the cycle average (6,600 EFS) from 1948-2012 (Table 1B, column C). Spawning success for Raft was the lowest on record, at 32% (average: 87%). The 2011 brood year escapement for Raft (4,400 EFS) was larger than the cycle average (2,600 EFS) from 1951-2011 (Table 1B, column D).

This stock has not exhibited any systematic survival trends over time. Average (geometric) four year old survival (R/EFS) for Raft Sockeye has been variable, with the largest peak of 13.6 R/EFS in the late-1960's/early-1970 brood years (four year average at peak). However, similar to other Fraser Sockeye stocks, Raft exhibited its lowest survival on record (0.4 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, column E; Figure 3). In the most recent generation (2007 to 2010 brood years), survival (3.6 R/EFS) has been below average (5.7 R/EFS). The 2011 brood year (2015 returns) four year old returns indicated above average survival (Appendix 2, Table A2).

The Ricker (PDO) model was used for the 2016 Raft forecast (Appendix 1). Given the assumptions underlying the Ricker (PDO) model, there is a one in four chance (25% probability) the Raft Sockeye return will be below 16,000 (the age-4 component of this forecast implies 5.2 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 26,000 (6.4 age-4 R/EFS) in 2016 (Table 1A & 2; Figure 3). This median (50% probability) forecast is less than half the average return on this cycle (57,000) (Tables 1A & B).

Five year olds contribute 58% (15,000) to the Raft total forecast (at the 50% p-level) (Table 3).

Miscellaneous North Thompson Tributaries (Kamloops-ES)

The 2012 brood year EFS for the miscellaneous North Thompson tributaries is 240 (populations: Barriere and Clearwater Rivers, and Dunn, Finn, Grouse, Harper, Hemp, Lemieux, Lion, Mann Creeks) (Table 1B, column C). The 2012 escapement is below the average EFS for this system (2000-2011: 1,000). Spawning success in these tributaries in 2012 averaged 50%. The 2011 brood year EFS was 300 (Table 1B, column D).

The model used to generate the miscellaneous North Thompson tributaries miscellaneous forecast uses the geometric mean of the recruits-per-spawner from the Raft and Upper Barriere stocks (from brood years 1948-2009) multiplied by the North Thompson Tributaries miscellaneous stocks' brood year escapement (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the miscellaneous stocks' model, there is a one in four chance (25% probability) the North Thompson tributaries miscellaneous stocks' return will be below 1,000 (the age-4 component of this forecast implies 3.3 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 2,000 (5.6 age-4 R/EFS) in 2016 (Table 1A & 2).

Five year olds contribute 50% (1,000) to the miscellaneous North Thompson tributaries total forecast (at the 50% p-level) (Table 3).

Miscellaneous North Thompson River (Kamloops-ES)

The 2012 brood year EFS for the miscellaneous North Thompson River is 30. The 2012 escapement is well below average (2000-2011: 8,300 EFS) (Table 1B, column C). The 2011 brood year escapement is 2,000 (Table 1B, column D). Given the extreme variability in assessment conditions annually for this river, these escapement estimates are associated with considerable inter-annual variability in precision and accuracy relative to other stocks. Spawning success in the North Thompson system in 2012 was the lowest on record, at 32%.

The model used to generate the miscellaneous North Thompson River forecast uses the geometric mean of the recruits-per-spawner from the Raft and Upper Barriere stocks (from brood years 1948-2009) multiplied by the North Thompson River miscellaneous stock's brood year escapement (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the miscellaneous stock's model, there is a one in four chance (25% probability) the North Thompson River miscellaneous stocks' return will be below 3,000 (the age-4 component of this forecast implies 3.3 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 4,000 (5.6 age-4 R/EFS) in 2016 (Table 1A & 2).

Five year olds contribute 95% (4,000) to the miscellaneous North Thompson River total forecast (at the 50% p-level) (Table 3).

Miscellaneous Widgeon (Widgeon (River-Type))

The 2012 brood year EFS for the miscellaneous Widgeon River is 230. The 2012 escapement is close to the average for this system (1950-2011: 300) (Table 1B, column C). The 2011 escapement is 700 EFS (Table 1B, column D). Spawning success in Widgeon in 2012 was 99%. Like Harrison River Sockeye, Widgeon Sockeye have a unique life history and an age structure where the majority of Sockeye migrate to the ocean as fry. However, a small to moderate fraction of fry overwinter, presumably in Widgeon Slough or Pitt Lake, before migrating to the ocean as smolts.

The model used to generate the Widgeon miscellaneous forecast was a non-parametric model that uses the recruits-per-spawner from the Birkenhead stock (from brood years 1948-2009) multiplied by the Widgeon miscellaneous stock's brood year escapements (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the miscellaneous stock's model, there is a one in four chance (25% probability) the Widgeon miscellaneous stocks' return will be below 2,000 (the age-4 component of this forecast implies 2.8 age-4 R/EFS) and a one in two chance (50% probability) the return will be below 4,000 (5.4 age-4 R/EFS) in 2016 (Table 1A & 2).

Five year olds contribute 75% (3,000) to the miscellaneous Widgeon total forecast (at the 50% p-level) (Table 3).

Late Run

The Late Run consists of five forecasted stocks (Cultus, Late Shuswap, Portage, Weaver, and Birkenhead) and one miscellaneous stock (miscellaneous non-Shuswap including Harrison stocks that migrate downstream to Harrison Lake as fry to rear in this lake) (Table 1A); Harrison and Widgeon were recently re-assigned to the Summer Run timing group following a re-evaluation of the migration timing of these stocks. The total escapement for the Late Run aggregate in 2012 was 4,300 EFS, falling well below the cycle average of 48,500 EFS (Table 1B). Physical conditions were conducive to spawning throughout the Late Run spawning grounds. Arrival and spawning timing were both within the normal range for all stocks apart from Birkenhead and the Harrison Lake tributaries, where arrival was one week early. However, low spawner success was observed in all areas of the Late Run spawning grounds (excluding the Seton-Anderson and South Thompson watersheds, where due to limited carcass availability, the accurate assessment of spawner success was impossible). Overall, average spawner success for the Late Run aggregate in 2012 was the lowest on record, at 17% (average: 87%).

Cultus (Cultus-L CU)

Total Cultus Sockeye adult escapement (counted through the Sweltzer Creek enumeration fence) in the 2012 brood year (1,100) was similar to the cycle average from 1992-2012 (1,000); 97% of these adults were hatchery marked. Due to extremely low spawning success (4%), the effective female spawner abundance was much smaller, at only 20 spawners. However, this estimate is likely biased low, and is not representative of the entire population, as sampling is biased towards unsuccessful spawners. Hatchery supplementation of fry into Cultus Lake and smolts into Sweltzer Creek (downstream of the enumeration fence) has increased the number of outmigrating smolts since the hatchery program commenced in the 2000 brood year. The smolt abundance for the 2012 brood year was 64,000 (this includes smolts counted through the fence and smolts released downstream of the fence), of which 97% were hatchery origin (Table 1B, column C). This smolt abundance is close to the post-1980 cycle average (1980-2012 cycle average: 78,000 smolts), and is well below the long-term cycle average (1952-2012 cycle average: 396,000 smolts; note for Cultus there are many gaps in this smolt time series with a total number of smolt estimates during this period of 38).

Total Cultus Sockeye adult escapement (counted through the Sweltzer Creek enumeration fence) in the 2011 brood year (6,900) was 78% of the cycle average from 1991-2007 (9,200); 70% of these adults were hatchery marked. The effective female spawner abundance was much smaller, at 359 spawners, due to low spawning success (9%). The smolt abundance for the 2011 brood year was 120,000 (this includes smolts counted through the fence and smolts released downstream of the fence), of which 92% were hatchery origin (Table 1B, column D). This smolt abundance is somewhat similar to the post-1980 cycle average (1983-2011 cycle average: 155,000 smolts), and is well below the long-term cycle average (1951-2011 cycle average: 977,000 smolts).

Average four year old post-smolt (mostly marine) (geometric) survival (R/smolt) for Cultus Sockeye declined from a peak of 15% in the late-1980 brood years (four year average at peak) to one of the lowest post-smolt survivals on record (1%) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E). In the most recent generation (2007 to 2010 brood years), survival (2% R/smolt) has been below average (4% R/smolt). Note: the survival time series is patchy as smolt abundances were not assessed in all years. Similar to most other stocks, the 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (see Appendix 2, Table A2).

The MRJ model was used to generate the Cultus forecast for 2016 (Appendix 1). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Cultus Sockeye return will be below 2,000 (the age-4 component of this forecast implies 3% age-4 marine survival) and a one in two chance (50% probability) the return will be below 4,000 (6% age-4 marine survival) in 2016 (Table 1A & 2; Figure 3). This median (50% probability) forecast is well below the average return on this cycle (22,000) (Tables 1A & B).

Five year olds contribute 0% (300) to the total Cultus forecast (at the 50% p-level) (Table 3).

Late Shuswap (Shuswap-L CU)

The 2012 brood year is an off-cycle (low abundance) year for the highly cyclic Late Shuswap population. Adult escapement for Late Shuswap in 2012 (10 EFS) was the smallest on record across all cycles, falling well below the cycle average (1948-2012: 2,800 EFS) (Table 1B, column C). Since only 12 spawners in total returned to the Late Shuswap spawning grounds, few carcasses were available for sampling, therefore the sex ratio (50%) and spawner success

(100%) were assumed. Adult escapement for Late Shuswap in 2011 (46,000 EFS) was the third smallest on record for this cycle, falling well below the cycle average (1951-2011: 172,400 EFS) (Table 1B, column D). Spawning success in the South Thompson system in 2011 was 55%, falling well below the average (95%).

No fry assessments were conducted in the 2012 brood year for stocks that rear in Shuswap Lakes (i.e. Scotch, Seymour and Late Shuswap). Fall fry abundance from the 2011 brood year (11.2 million fall fry) was also below the cycle average (1975-2011: 50 million fall fry). Fry body sizes from the 2011 brood year (3.2 g) were above average for the cycle (cycle average 1975-2011: 2.8 g).

Average (geometric) four year old survival (R/EFS) for Late Shuswap Sockeye has been variable, with the largest peak of 10.8 R/EFS occurring in the early-1970 brood years (four year average at peak); this is one of the Fraser Sockeye stocks that have not exhibited systematic declines in survival (Grant et al. 2010; Grant et al. 2011). In the most recent generation (2007 to 2010 brood years), the average survival (1.4 R/EFS) has been below the long-term 2012 cycle average (2.1 R/EFS). The 2011 brood year (2015 returns) four year old preliminary returns for this group indicated below average survival (Appendix 2, Table A2). Although if a Larkin model had been used in the 2015 forecast, this would have indicated closer to average survival (DFO 2015, Table 6).

The Larkin model was used to produce the 2016 forecast for Late Shuswap (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Late Shuswap Sockeye return will be below 100 (negligible brood year abundance to estimate R/EFS) and a one in two chance (50% probability) the return will be below 4,000 in 2016 (Tables 1A & 2; Figure 5). This median return forecast is well below the cycle average (29,000) (Tables 1A & B).

Five year olds contribute 100% (4,000) to the total Late Shuswap forecast (at the 50% p-level) (Table 3).

Portage (Seton-L (de novo) CU)

The 2012 brood year escapement for Portage (10 EFS) was much smaller than the cycle average (1964-2012: 600 EFS) (Table 1B, column C). Escapements in Portage have been consistently declining for the past two cycles, and the 2012 escapement was the smallest observed on this cycle since the population was restored with hatchery transplants in the 1960's. Due to the small number of spawners, few carcasses were available for sampling, therefore the sex ratio and spawner success (100%) were assumed. The 2011 brood year escapement for Portage (300 EFS) was also much smaller than the cycle average (1955-2011: 2,300 EFS) (Table 1B, column D). Spawning success for Portage in 2011 was 79% (average: 95%).

Average (geometric) four year old survival (R/EFS) for Portage Sockeye declined from a peak of 61.7 R/EFS in the early 1960 brood years (four year average at peak), to one of the lowest survivals on record (0.3 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (4.5 R/EFS) has been below the long-term average (12.4 R/EFS). Preliminary 2015 returns were not available at the time of this publication.

Preliminary 2015 returns for Portage creek sockeye were not available at the time of this publication, but estimates of returns were available for Late Shuswap and Portage combined. The 2011 brood year (2015 returns) four year old preliminary returns for this group indicated below average survival (Appendix 2, Table A2).

The Larkin model was used for the 2016 Portage forecast (Appendix 1). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Portage Sockeye return will be below 200 (negligible brood year abundance to estimate R/EFS) and a one in two chance (50% probability) the return will be below 400 (negligible four year olds to estimate R/EFS) in 2016 (Table 1A; Figure 3). This median (50% probability) forecast is extremely small compared to the average return on this cycle (16,000) (Tables 1A & B).

Five year olds contribute 25% (~100) to the Portage total forecast (at the 50% p-level) (Table 3).

Weaver (Harrison (U/S)-L CU)

The 2012 brood year escapement for Weaver (400 EFS) was the smallest escapement on record, falling well below the cycle average (1968-2012: 18,300 EFS) (Table 1B, column C). Spawning success in Weaver Channel (89%) was similar to average (90%); however, spawning success in Weaver Creek (61%) was well below average (87%). Early freshwater survival in the 2012 brood year (1,000 fry/EFS) was below average (1966-2012 average: 1,600 fry/EFS), and the resulting juvenile abundance (470,000 fry) was also below average (1966-2012 average: 31 million fry). The 2011 brood year escapement for Weaver (24,500 EFS) was larger than the cycle average (1967-2011: 18,300 EFS) (Table 1B, column D). Early freshwater survival in the 2011 brood year (1,600 fry/EFS) was identical to average (1966-2012 average: 1,600 fry/EFS), and juvenile abundance (39 million fry) was above average (1966-2012 average: 31 million fry).

Average (geometric) four year old survival (R/EFS) for Weaver Sockeye has been variable, with the largest peak of 41.8 R/EFS occurring in the late-1960 brood years (four year average at peak). This stock has not exhibited systematic survival trends through time (Grant et al. 2011; Peterman & Dorner 2012). Similar to other stocks, however, Weaver exhibited one of its lowest survivals on record (2.6 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), the average survival (15.0 R/EFS) has been above the long-term average (12.2 R/EFS). Amongst all Fraser Sockeye stocks, this stock exhibited exceptionally poor returns in 2015. Interestingly, this stock was not detected at the Mission smolt program or Strait of Georgia surveys in the 2013 outmigration year in expected proportions based on brood year escapements (DFO 2015b). The 2011 brood year fry assessments indicated average egg-to-fry survival, so one potential hypothesis is that lake rearing conditions were poor in this brood year, assuming there was no bias in the Mission or SOG sampling programs in 2013. These fish would have moved into Harrison Lake 1.5 years after the large Meager Creek landslide in 2010.

Preliminary data on four year old returns to Weaver in 2015 suggest that this brood year experienced extremely poor survival (Appendix 2, Table A2). Five year olds returning in 2016 would be expected to have experienced similar low survival, having been exposed to the same freshwater and early marine conditions as the 2015 four year old returns. The five year old component of the 2016 Weaver forecast was therefore generated using a sibling model (Table 6; Figure 4).

The MRS model was used for the 2016 age-4 Weaver forecast (Appendix 1). Given the assumptions underlying the MRS model (four year olds) and the sibling model (five year olds), there is a one in four chance (25% probability) the Weaver Sockeye return will be below 4,000 (negligible brood year abundance to estimate R/EFS) and a one in two chance (50% probability) the return will be below 8,000 in 2016 (Table 1A; Figure 3). This median forecast is extremely small compared to the average return on this cycle (345,000) (Tables 1A & B).

Five year olds contribute 38% (3,000) to the total Weaver forecast (at the 50% p-level) (Table 3).

Note for Weaver that due to the extremely small brood year escapement in 2012, the model being used to generate a forecast is extrapolating outside of the fitted range of data; therefore forecasts for this stock are particularly uncertain.

Birkenhead (Lillooet-Harrison-L CU)

The 2012 brood year escapement for Birkenhead (2,500 EFS) was much smaller than the cycle average (32,300 EFS) from 1948-2012 (Table 1B, column C), and was the smallest escapement on record for this stock. Arrival timing to the Birkenhead River was one week earlier than normal. Spawning success was the lowest on record in 2012 (11%), falling well below average (91%). The 2011 brood year escapement for Birkenhead (92,400 EFS) was larger than the cycle average (46,800 EFS) from 1951-2011 (Table 1B, column D). The fence counts were extrapolated to account for the tail end of the migration that was missed during spawning ground assessments due to the early removal of the counting fence (due to heavy rainfall and high water). This extrapolation assumed 82% of migration was counted through the fence based on a previous five year average. Spawning success in 2011 was 74% (average: 90%).

Average (geometric) four year old survival (R/EFS) for Birkenhead Sockeye declined from a peak of 21.5 R/EFS in the early 1970 brood years (four year average at peak), to one of the lowest survivals on record (1.2 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In the most recent generation (2007 to 2010 brood years), survival (2.1 R/EFS) has been below average (5.2 R/EFS). The 2011 brood year (2015 returns) four year old preliminary returns indicated below average survival (Appendix 2, Table A2). Note, that Birkenhead exhibited extremely poor survival in the 2010 brood year (0.4 four year old R/EFS), a year that coincided with the Meager Creek landslide. Preliminary four year old survival in the 2011 brood year (0.7 R/EFS) was similar.

Five year olds returning in 2016 would be expected to have experienced similar low survival, having been exposed to the same freshwater and early marine conditions as the 2015 age-4 return. Therefore, similar to the 2015 forecast, the five year old component of the 2016 Birkenhead forecast was generated using a sibling model (Table 6; Figure 4).

The Ricker (Ei) model was used for the 2016 four year old Birkenhead forecast (Appendix 1). Given the assumptions underlying the Ricker (Ei) model (four year olds) and the sibling model (five year olds), there is a one in four chance (25% probability) the Birkenhead Sockeye return will be below 45,000 (negligible brood year abundance to estimate R/EFS) and a one in two (50% probability) the return will be below 68,000 in 2016 (Table 1A; Figure 3). This median forecast is quite small compared to the average return on this cycle (277,000) (Tables 1A & B).

Five year olds contribute 76% (52,000) to the total Birkenhead forecast (at the 50% p-level) (Table 3).

Miscellaneous Harrison/Lillooet Lakes (Harrison (downstream)-L)

The 2012 brood year EFS for the miscellaneous Harrison/Lillooet Lake stocks is 1,400 (Table 1B, column C). Populations included in this group include those that rear in the Harrison-Lillooet Lake system, and are not included in the Harrison or Birkenhead forecasts (Big Silver, Cogburn, Crazy, Douglas, Green, Pemberton, Pool, Railroad/Sampson, Ryan, Sloquet and Tipella Creeks). The 2012 escapement is much smaller than the average EFS for this system (2000 to 2011: 6,500). The 2011 escapement was 6,500 (Table 1B, column D).

The model used to generate the Non-Shuswap miscellaneous forecast uses the geometric mean of the recruits-per-spawner from the Birkenhead stock (from the brood years 1948-2009) multiplied by the Non-Shuswap miscellaneous stock's brood year escapements (see Appendix 1 to 3 in Grant et al. 2011). Given the assumptions underlying the miscellaneous stocks model, there is a one in four chance (25% probability) the Non-Shuswap miscellaneous stocks' return will be below 14,000 (the age-4 component of this forecast implies 2.8 age-4 E/EFS) and a one in two chance (50% probability) the return will be below 27,000 (5.4 age-4 R/EFS) in 2016 (Table 1A).

Five year olds contribute 78% (21,000) to the miscellaneous Non-Shuswap total forecast (at the 50% p-level) (Table 3).

Conclusions

Low numbers of Fraser Sockeye returns are expected in 2016. The total forecast for Fraser Sockeye ranged from 800,000 to 2.3 million from the 10% to 50% probability-levels, which falls below the cycle average of 3.9 M. Over 80% of the returns are expected to be four year olds. The Summer Run is expected to contribute most (70%) to the 2016 returns, with Chilko expected to contribute the largest proportion (44%) of the total. The Early Summer Run is expected to have average returns in 2016, largely due to the high relative number of returns predicted for the miscellaneous Chilliwack stock. The two remaining Run Timing Groups (Early Stuart and the Late Run) are expected to return at relatively small numbers compared to these first two Run Timing groups, and also compared to their cycle averages.

Despite the recent (2010-2014) improvements in survival trends for Fraser Sockeye stocks, 2015 survivals were poor for a number of stocks, particularly those that contributed the most to the 2015 returns. Although research efforts continue to expand our understanding of freshwater and marine mechanisms that influence Fraser Sockeye population dynamics (e.g. Tucker et al. 2009, Peterman and Dorner 2012, Beamish et al. 2012, Connors et al. 2012, Irvine and Akenhead 2014, Ye et al. 2015), predicting future Fraser Sockeye survival remains a challenge.

There was a rare opportunity in the 2016 forecast process to apply the survival of the younger aged fish that returned in 2015 to the survival of their older siblings that will return in 2016. A variety of approaches, which included sibling models (Quesnel, Harrison, Weaver and Birkenhead) or Larkin models (Scotch, Seymour and Late Shuswap), were applied to these stocks' five year old (or four year old in the case of Harrison) forecasts to account for the generally poor survival in 2015. These approaches reduced the forecasts for these stocks significantly but were only used for stocks that met a specific set of criteria. These criteria included:

a) the availability of preliminary 2015 return data,

b) poor survival of the 2015 four year olds, and

c) a relative large fraction of age five fish expected in the 2016 return.

In addition to these approaches taken for specific stocks, a separate sensitivity analysis was conducted for all stocks to quantify the five year old Fraser Sockeye forecasts in 2016, scaled to the four year old survival of their siblings that returned in 2015. The potential overall impact of these adjustments to the forecast was small because most of the 2016 return is expected to be four year olds and because the potential survival of five year olds had already been taken into account in the methods (e.g. sibling and Larkin model) used to generate the official forecast.

Despite the adjustments to the five year old forecasts for some stocks, the total forecasts remains uncertain since most returns are expected to be four year olds. Based on historic evaluations of the forecast, we do know that in the past decade total Fraser Sockeye returns of four year olds have not exceeded probability levels at the middle (50% probability level) of their forecast distributions, with the exception of the large returns in 2010. Chilko Sockeye contribute the most to the total 2016 forecast and this stock's 50% probability level forecast in 2016 indicates a 9% marine survival. However in the past 18 years, Chilko marine survivals have not exceeded 8%. Therefore, given recent survival rates, it seems more likely Chilko sockeye will return at the levels less than median forecast.

Furthermore, the poor return of some Fraser Sockeye stocks in 2015 coincided with the development of unusually warm ocean temperatures in the Northeast Pacific Ocean. These warmer temperatures, referred to as the ‘warm blob’, cover a broad spatial area in the Northeast Pacific Ocean, are as much as 3°C above average, and extend down to depths of 100 m. Fraser Sockeye stocks that returned in 2015 spent their final two years of life in these warmer waters, and a number of these stocks experienced low survival, following a previous five year period of average survivals. Since the ‘warm blob’ has persisted to the time of this publication, Fraser Sockeye returns in 2016, will also have experienced these conditions. However, the response across Fraser Sockeye stocks (Early Stuart, Raft, and Nadina) was not consistently poor. Harrison Sockeye, which contributed 11% to the total four year old returns, entered the ocean in 2012 prior to the formation of ‘the blob’, not 2013 like all other stocks, so the mechanism for their poor survival would be different from other stocks. The Birkenhead and Weaver stocks had very poor survival possibly linked to the Meager Creek landslide in the freshwater ecosystem that dumped considerable amounts of sediment into the lakes where these fish rear as juveniles for one year. The Shuswap stocks’ (Scotch, Seymour, and Late Shuswap) survival is also possibly linked to a freshwater delayed density dependent mechanism, rather than a marine mechanism. Other Sockeye stocks outside the Fraser River (Barkley Sound, Nass, Columbia Sockeye) did not experience poor survival. Given the range of survivals observed across sockeye stocks, and the variety of mechanism(s) influencing their survival, it is not possible to predict whether the survival of four year old Fraser Sockeye in 2016 will be similar to that observed in 2015.

Three-to-four year old sibling model forecasts were generated for two key stocks, Chilko and Late Stuart, to see if preliminary three year old (jack) returns in 2015, provided any information on the survival of their older four year old siblings in 2016. The medians and the forecast distributions from the sibling models and the 2016 official methods were almost identical for both of these stocks. Although this is comforting, the distributions are wide, so returns to falling within this range span a broad range of survivals.

To assist with improving our understanding of Fraser Sockeye population dynamics, a separate CSAS Science Response process was conducted January 21 and 22, 2016, which was a supplement to the 2016 Forecast process. Through this DFO Science process, attendees from DFO and the Pacific Salmon Commission synthesized information on the different life-history stages of Fraser Sockeye from the 2012 brood year through to current ocean conditions. This year’s process also reviewed 2015 returns in the context of the previous year’s 2015 supplement (DFO 2015a) and forecast (DFO 2015b). This process was also conducted for the 2014 and 2015 forecasts ((DFO 2014b, 2015b). It is hoped that this process, and the number of new and expanded projects that cover all the life-history stages of Fraser Sockeye, will help improve our understanding of what drives fluctuations in the annual survival of these stocks. Forecasts of return abundances are one tool where this type of information can be explored quantitatively, to determine factors that influence population dynamics.

Tables

Table 1A. The 2016 Fraser River Sockeye forecasts. Forecasts are the entire distribution of values from the 10% to 90% probability levels (probability that returns will be at or below the specified run size). At the mid-point of the distribution (50% probability level), there is a one in two change the return will fall above or below the specified forecast value for each stock, based on the historical time series. The model used to generate the forecast for each stock is in the second column. ***See Table 1B & 2 for background.***

Run timing group Stocks	Forecast Model [b]	Probability that Return will be at/or Below Specified Run Size [a]				
		10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	*Ricker (Ei)*	**13,000**	**22,000**	**36,000**	**59,000**	**89,000**
Early Summer		**120,000**	**217,000**	**447,000**	**1,003,000**	**2,703,000**
(total excluding miscellaneous)		**97,000**	**158,000**	**286,000**	**585,000**	**1,527,000**
Bowron	*MRS*	1,000	2,000	4,000	8,000	13,000
Upper Barriere (Fennell)	*power*	6,000	9,000	14,000	23,000	39,000
Gates	*Larkin*	24,000	40,000	76,000	138,000	231,000
Nadina	*MRJ*	24,000	45,000	90,000	179,000	331,000
Pitt	*Larkin*	42,000	60,000	90,000	147,000	212,000
Scotch	*Larkin*	300	2,000	12,000	89,000	698,000
Seymour	*Larkin*	0	100	400	1,000	3,000
Misc (EShu) [c]	*RS(Scotch/Seymour)*	2,000	4,000	8,000	13,000	24,000
Misc (Taseko) [d]	*RS (Chilko)*	100	400	1,000	1,000	2,000
Misc (Chilliwack)	*Ricker*	17,000	46,000	138,000	378,000	1,101,000
Misc (Nahatlatch) [e]	*RS (Esum)*	4,000	8,000	14,000	26,000	49,000
Summer		**640,000**	**992,000**	**1,677,000**	**2,962,000**	**5,023,000**
(total excluding miscellaneous)		**637,000**	**986,000**	**1,667,000**	**2,942,000**	**4,983,000**
Chilko	*power (juv) (Pi)*	459,000	658,000	1,002,000	1,573,000	2,283,000
Quesnel [i]	*4-Ricker-cyc; 5-sibling*	6,000	9,000	15,000	25,000	40,000
Late Stuart	*R1C*	42,000	86,000	192,000	427,000	880,000
Stellako	*R2C*	86,000	144,000	256,000	454,000	761,000
Harrison [f & i]	*3-Ricker(Ei); 4-sibling*	33,000	73,000	176,000	425,000	957,000
Raft [f]	*Ricker (PDO)*	11,000	16,000	26,000	38,000	62,000
Misc (N. Thomp. Tribs) [f & g]	*R/S (Raft/Fennell)*	600	1,000	2,000	4,000	9,000
Misc (N. Thomp River) [f & g]	*R/S (Raft/Fennell)*	1,000	3,000	4,000	9,000	19,000
Misc (Widgeon) [f & h]	*R/S (Birkenhead)*	1,000	2,000	4,000	7,000	12,000
Late		**41,000**	**65,000**	**111,000**	**203,000**	**366,000**
(total excluding miscellaneous)		**33,000**	**51,000**	**84,000**	**155,000**	**282,000**
Cultus	*MRJ*	1,000	2,000	4,000	9,000	17,000
Late Shuswap	*Larkin*	0	100	4,000	25,000	76,000
Portage	*Larkin*	0	200	400	1,000	2,000
Weaver [i]	*4-MRS; 5-sibling*	2,000	4,000	8,000	15,000	29,000
Birkenhead [i]	*4-Ricker (Ei); 5-sibling*	30,000	45,000	68,000	105,000	158,000
Misc Harrison/Lillooet [h & i]	*R/S (Birkenhead)*	8,000	14,000	27,000	48,000	84,000
TOTAL SOCKEYE SALMON		**814,000**	**1,296,000**	**2,271,000**	**4,227,000**	**8,181,000**
(TOTAL excluding miscellaneous)		**780,000**	**1,217,000**	**2,073,000**	**3,741,000**	**6,881,000**

a. Probability that return will be at, or below, specified value
b. See Table 4 for model descriptions
c. Misc. Early Shuswap use Scotch and Seymour R/EFS
d. Misc. Taseko uses Chilko R/EFS
e. Misc. Nahatlach uses Early Summer Run stocks R/EFS
f. Raft, Harrison, Misc. North Thompson stocks re-assigned to Summer Run timing group
g. Misc. North Thompson stocks use Raft & Fennel R/EFS
h. Misc. Late Run stocks (Harrison Lake downstream migrants including Big Silver, Cogburn, etc.), and river-type Widgeon both use Birkenhead R/EFS
i. Stocks forecasts with sibling models for their older age class; 4-: indicates the model used to forecast four-year old returns; 5-: indicates the model used to forecast five year old returns.

Table 1B. Average run sizes are presented across all cycles (F) and the 2016 cycle (G). Brood year escapements (smolts for Chilko and Cultus) for the four (2012) and five year old (2011) recruits returning in 2016 (columns C & D) are presented and colour coded relative to their cycle average from 1948-2012 brood years. Forecasted 2016 returns at the 50% probability level from Table 1 are colour coded relative to their cycle average (column E). Color codes represent the following: red (< average), yellow (average) and green (> average), with the average range defined as average +/- 0.5 standard deviation.

A	C	D	E	F	G
Run timing group	**BY (12)**	**BY (11)**	**Ret**	**Mean Run Size**	
Stocks	**(EFS)**	**(EFS)**	**2016**	**All cycles [a]**	**2016 cycle [b]**
Early Stuart	6,800[R]	200[R]	R	**303,000**	**128,000**
Early Summer (excl. misc.)				**507,000**	**423,000**
Bowron	30[R]	2,000[R]	R	37,000	29,000
Upper Barriere (Fennell)	700[R]	4,500[Y]	R	24,000	32,000
Gates	6,900[Y]	28,400[G]	R	54,000	124,000
Nadina	16,800[Y]	1,200[R]	Y	75,000	118,000
Pitt	41,400[G]	30,400[G]	Y	71,000	78,000
Scotch	600[Y]	12,500[G]	Y	98,000	10,000
Seymour	300[R]	8,000[R]	R	143,000	32,000
Misc (Early Shuswap)	200[R]	7,400[R]	NA	--	--
Misc (Taseko)	40[R]	400[R]	NA	--	--
Misc (Chilliwack)	78,800[G]	2,500[R]	NA	--	--
Misc (Nahatlatch)	1,100[R]	3,500[G]	NA	--	--
Summer (excl. misc.)				**3,866,000**	**2,620,000**
Chilko [c]	11.4 M[R]	43.2 M[G]	R	1,405,000	1,781,000
Quesnel	100[R]	17,000[Y]	R	1,324,000	55,000
Late Stuart	31,800[Y]	800	Y	544,000	175,000
Stellako	50,600[Y]	26,000	Y	457,000	448,000
Harrison [d]	32,900[Y]	78,000[G]	G	105,000	104,000
Raft	1,700[R]	4,400[G]	R	31,000	57,000
Misc (N. Thomp. Tribs)	200[R]	300[R]	NA	--	--
Misc (N. Thomp River)	30[R]	2,000[R]	NA	--	--
Misc (Widgeon)	200[Y]	700[Y]	NA	--	--
Late (excl. misc.)				**3,169,000**	**689,000**
Cultus [c]	63,600[R]	119,800[R]	R	38,000	22,000
Late Shuswap	10[R]	46,000[R]	R	2,379,000	29,000
Portage	10[R]	300[R]	R	41,000	16,000
Weaver	400[R]	24,500[G]	R	346,000	345,000
Birkenhead	2,500[R]	92,400[G]	R	365,000	277,000
Misc Lillooet-Harrison	1,400[R]	6,500[Y]	NA	--	--
Total Sockeye Salmon				**7,838,000**	**3,860,000**

a. Sockeye: 1953-2012 (start of time series varies across stocks)
b. Sockeye: 1955-2012 (start of time series varies across stocks)
c. Brood year smolts are presented in columns C & D for Chilko and Cultus (not effective females)
d. Harrison are presented for the 2012 and 2013 brood years (in the respective, 2012 and 2011 columns)

R. < average (red) (see criteria for identifying red zone relative to time series at the end of the table caption above)
Y. average (yellow) (see criteria for identifying yellow zone relative to time series at the end of the table caption above)
G. > average (green) (see criteria for identifying green zone relative to time series at the end of the table caption above)

Definitions: BY: Brood year; BY(11): brood year 2011; BY(12): brood year 2012; EFS: effective female spawners; Ret: 50% p-level forecast return in 2016

Table 2. For each of the 19 forecasted Fraser Sockeye stocks (column A), geometric average four-year old survivals are presented for the entire time series (brood years: 1948-2010) (column B), the highest four consecutive years (column C), the 2005 brood year (one of the lowest survivals on record for all stocks) (column D), and the most recent generation with recruitment data (2007-2010) (column E). Four-year old survivals associated with the various probability levels of the 2016 forecast (based on escapements in Table 1B and age-4 forecasts in Table 3) are presented in columns (F) to (J) for comparison. Forecast survivals are presented as R/EFS. Colour codes represent the following: Red (< average), yellow (average) and green (>average), with the average range defined as average +/- 0.5 SD.

A	B	C	D	E	F	G	H	I	J
Run timing group Stock	**Four Year Old Recruits-Per-Effective Female Spawner (Smolt for Chilko & Cultus)**								
	Average[Y] Geometric	**Peak Average[G]** Geometric **(Over Four Consecutive Years)**	**2005[R] Brood Year**	**Recent Average** Geometric **(2007-10)***	**2016 forecast four year old R/EFS for each probability level in Table 1A by stock**				
					10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	6.4	24.5	1.5	7.1[G]	1.9	3.2	5.2	8.6	13.0
Early Summer									
Bowron[a]	6.7	20.4	2.2	3.9[Y]	NA	NA	NA	NA	NA
Upper Barriere (Fennell)	6.9	53.5	0.3	5.8[Y]	4.3	7.8	11.5	24.0	33.1
Gates	10.6	41.0	1.6	26.1[G]	2.4	4.6	8.7	16.8	29.6
Nadina	6.2	13.5	1.0	8.0[Y]	1.4	2.7	5.3	10.5	19.4
Pitt (age5 productivity) [b]	3.4	13.3	0.2	3.7[Y]	1.1	1.5	2.4	3.8	6.3
Scotch [a]	7.2	21.5	2.2	9.8[Y]	NA	NA	NA	NA	NA
Seymour [a]	7.5	29.2	3.4	4.2	NA	NA	NA	NA	NA
Misc (Early Shuswap)	-	-	-	-	1.7	3.8	8.3	13.7	24.3
Misc (Taseko) [a]	-	-	-	-	NA	NA	NA	NA	NA
Misc (Chilliwack) [c]	3.6	NA	0.6	4.8[Y]	0.2	0.6	1.7	4.8	13.9
Misc (Nahatlatch) [d]	-	-	-	-	1.6	3.2	6.0	10.8	20.2
Summer									
Chilko (% R/smolt) [d]	7%	18%	0.3%	4%[Y]	4%	5%	9%	14%	20%
Quesnel [a & e]	6.5	18.1	0.3	3.8[Y]	NA	NA	NA	NA	NA
Late Stuart	8.6	57.2	0.6	2.8	1.3	2.7	5.9	13.2	27.1
Stellako	7.0	15.1	0.1	7.1[Y]	1.6	2.6	4.7	8.3	13.8
Harrison[f]	7.5	33.8	0.1	13.2[Y]	NA	NA	NA	NA	NA
Raft	5.7	13.6	0.4	3.6[Y]	3.8	5.2	6.4	11.7	14.0
Misc (N. Thomp. Tribs) [h]	-	-	-	-	1.7	3.3	5.6	11.5	24.4
Misc (N. Thomp River) [h]	-	-	-	-	1.7	3.3	5.6	11.5	24.4
Misc (Widgeon) [i]	-	-	-	-	1.7	2.8	5.4	9.6	16.9
Late									
Cultus (% R/smolt) [d]	4%	15%	1%	2%[Y]	1%	3%	6%	13%	25%
Late Shuswap [a & e]	2.1	10.8	2.8	1.4[Y]	NA	NA	NA	NA	NA
Portage [a]	12.4	61.7	0.3	4.5	NA	NA	NA	NA	NA
Weaver [a]	12.2	41.8	2.6	15.0[Y]	NA	NA	NA	NA	NA
Birkenhead [a]	5.2	21.5	1.2	2.1[Y]	NA	NA	NA	NA	NA
Misc Lillooet-Harrison [g]	-	-	-	-	1.7	2.8	5.4	9.6	16.9

a. NA is shown for stocks with insufficient brood year EFS or forecast four year olds to calculate meaningful four year old survival
b. Pitt compares five year old survival; c. Recruitment data for Chilliwack began in the 2001 brood year;
d. Chilko and Cultus survivals are presented as marine survival (recruits-per-smolt) not total productivity
e. Quesnel and Late Shuswap are cycle averages; f. Harrison is presented as total survival; forecast productivity NA (variable ages);
g. Four year old forecast productivities removed in cases where brood year EFS abundance falls outside the historical data
R. < average (red); Y. average (yellow); G. > average (green) *(see criteria for identifying R/A/G at the end of the table caption)*

Table 3. Four and five year old and total 2016 Fraser Sockeye forecasts at the 50% probability level for each stock. The four and five year old proportions of the total forecast at the 50% probability level (p-level) are presented in the final two columns.

Sockeye stock/timing group	2016 Fraser Sockeye Forecasts				
	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%	TOTAL 50%	Four Year Old Proportion	Five Year Old Proportion
Early Stuart	**36,000**	**100**	**36,000**	**100%**	**0%**
Early Summer	**334,000**	**112,000**	**447,000**	**75%**	**25%**
Bowron	200	4,000	4,000	5%	95%
Upper Barriere (Fennell)	8,500	5,000	14,000	61%	39%
Gates	61,000	15,000	76,000	80%	20%
Nadina	88,000	2,000	90,000	98%	2%
Pitt	18,000	72,000	90,000	20%	80%
Scotch	12,000	0	12,000	100%	0%
Seymour	400	0	400	100%	0%
Misc (EShu)	2,000	6,000	8,000	25%	75%
Misc (Taseko)	300	300	600	50%	50%
Misc (Chilliwack)	137,000	1,000	138,000	99%	1%
Misc (Nahatlatch)	7,000	7,000	14,000	50%	50%
Summer	**1,462,000**	**215,000**	**1,677,000**	**87%**	**13%**
Chilko	976,000	26,000	1,002,000	97%	3%
Quesnel	1,000	14,000	15,000	7%	93%
Late Stuart	188,000	4,000	192,000	98%	2%
Stellako	236,000	20,000	256,000	92%	8%
Harrison[b]	48,000 (age-4)	128,000 (age-3)	176,000	27% (age-4)	73% (age-3)
Raft	11,000	15,000	26,000	42%	58%
Misc (N. Thomp. Tribs)	1,000	1,000	2,000	50%	50%
Misc (N. Thomp River)	200	4,000	4,000	5%	95%
Misc (Widgeon)	1,000	3,000	4,000	25%	75%
Late	**31,000**	**80,000**	**111,000**	**28%**	**72%**
Cultus	4,000	300	4,000	100%	0%
Late Shuswap	0	4,000	4,000	0%	100%
Portage	300	100	400	75%	25%
Weaver	5,000	3,000	8,000	62%	38%
Birkenhead	16,000	52,000	68,000	24%	76%
Misc Lillooet-Harrison	6,000	21,000	27,000	22%	78%
Total	**1,863,000**	**407,000**	**2,271,000**	**82%**	**18%**

a. Probability that actual return will be at or below specified run size
b. Harrison are four (in four year old columns) and three (in five year old columns) year old forecasts

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

Table 5. Last year's 2015 forecasts from the 10% to 90% p-levels with preliminary in-season returns (final returns were not available at the time of this publication at the individual stock level). Where returns fall relative to forecast provides a preliminary indication of total survival for a stock. Highlighted rectangles (red, yellow or green), indicate where preliminary returns fell relative to the pre-season forecast. Returns falling at the lower p-levels (<25%) are highlighted red/R superscript (indicating lower survival), those falling at the mid p-levels (25%-50%) are highlighted yellow/Y superscript (indicating average survival), and those at the higher p-levels (>75%) are highlighted green/G superscript (indicating above average survival).

Run timing group Stocks	**Forecast Model** [b]	**Probability that Return will be at/or Below Specified Run Size** [a]				
		10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	*Ricker (Ei)*	**8,000**	**16,000**	**30,000** [Y]	**58,000**	**108,000**
Early Summer		**236,000**	**424,000**	**837,000**	**1,603,000**	**2,963,000**
Bowron	*MRS*	6,000	11,000	21,000 [Y]	40,000	72,000
Fennell	*power*	10,000 [R]	16,000	27,000	47,000	78,000
Gates	*Larkin*	46,000	79,000 [R]	141,000	280,000	502,000
Nadina	*MRJ*	8,000	15,000	31,000	65,000	126,000 [G]
Pitt	*Larkin*	33,000	51,000	79,000	120,000 [Y]	190,000
Scotch	*Ricker*	48,000 [R]	85,000	185,000	430,000	845,000
Seymour	*Ricker*	41,000 [R]	68,000	140,000	274,000	529,000
Misc (EShu) [c]	*RS (Scotch/Seymour)*	33,000	74,000 [R]	164,000	258,000	459,000
Misc (Taseko) [d]	*R/S (Chilko)*	1,000	2,000	4,000 [Y]	7,000	9,000
Misc (Chilliwack) [e]	*RS (Esum)*	4, 000	9,000	18,000 [Y]	33,000	61,000
Misc (Nahatlatch) [e]	*RS (Esum)*	6,000	14,000 [R]	27,000	49,000	92,000
Summer		**1,701,000**	**2,681,000**	**4,675,000**	**8,764,000**	**16,511,000**
Chilko	*power (juv) (Pi)*	1,117,000 [R]	1,587,000	2,387,000	3,813,000	5,972,000
Quesnel	*Ricker-cyc*	108,000 [R]	197,000	367,000	684,000	1,421,000
Late Stuart	*power*	12,000	25,000 [R]	54,000	118,000	245,000
Stellako	*Larkin*	186,000 [R]	261,000	390,000	552,000	823,000
Harrison [f]	*Adjusted RS1*	255,000 [R]	573,000	1,414,000	3,487,000	7,858,000
Raft [f]	*Ricker (PDO)*	15,000	23,000	36,000	56,000 [Y]	87,000
Misc (N. Thomp. Tribs) [f & g]	*R/S (Raft/Fennell)*	1,000	2,000	3,000	7,000	14,000 [G]
Misc (N. Thomp River) [f & g]	*R/S (Raft/Fennell)*	5,000	10,000	18,000	37,000	74,000 [G]
Misc (Widgeon) [f & h]	*R/S (Birkenhead)*	2,000 [R]	3,000	6,000	10,000	17,000
Late		**419,000**	**703,000**	**1,236,000**	**2,210,000**	**3,998,000**
Cultus	*MRJ*	1,000	3,000 [R]	6,000	12,000	22,000
Late Shuswap	Ricker-cyc	168,000 [R]	293,000	517,000	924,000	1,758,000
Portage	*Larkin*	1,000	3,000	8,000	19,000	55,000
Weaver	*MRS*	110,000 [R]	189,000	346,000	635,000	1,095,000
Birkenhead	*Ricker (Ei)+Sibling*	120,000 [R]	183,000	299,000	513,000	879,000
Misc Lillooet-Harrison [i]	*R/S (Birkenhead)*	19,000	32,000	60,000	107,000	189,000
TOTAL SOCKEYE SALMON		**2,364,000**	**3,824,000**	**6,778,000**	**12,635,000**	**23,580,000**

Table 6. Top ranked model forecasts evaluated for each of the stocks for the 2016 forecast. Miscellaneous stocks, except Chilliwack, are excluded since they have escapement data only and only one model is used for each of these stocks. Model ranks were determined from the 2010 forecast jackknife analysis (MacDonald & Grant 2012) using four performance measures (mean raw error: MRE, mean absolute error: MAE, mean proportional error: MPE, and root mean square error: RMSE). Models shaded grey with asterisks beside their name were used to forecast 2016 returns (presented in Table 1).

RUN TIMING GROUP: EARLY STUART

EARLY STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)*	**1**	**13,000**	**22,000**	**36,000**	**59,000**	**89,000**
Ricker (Pi)	1	16,000	27,000	46,000	74,000	123,000
Ricker	3	16,000	25,000	44,000	73,000	122,000
Ricker (PDO)	3	15,000	25,000	42,000	70,000	111,000

RUN TIMING GROUP: EARLY SUMMER

BOWRON	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS*	**1**	**1,000**	**2,000**	**4,000**	**8,000**	**13,000**
Ricker (Pi)	2	1,000	1,000	3,000	7,000	14,000
Ricker (Ei)	3	0	1,000	3,000	7,000	14,000

FENNELL	Rank	Return Forecast 10%	25%	50%	75%	90%
Power *	**1**	**6,000**	**9,000**	**14,000**	**23,000**	**39,000**
RAC	2	8,000	15,000	32,000	65,000	125,000
Ricker	3	7,000	12,000	20,000	37,000	59,000

GATES	Rank	Return Forecast 10%	25%	50%	75%	90%
RAC	1	41,000	70,000	126,000	229,000	390,000
R2C	2	16,000	29,000	55,000	104,000	186,000
Larkin*	**3**	**24,000**	**40,000**	**76,000**	**138,000**	**231,000**
MRS	3	24,000	49,000	108,000	241,000	495,000
Ricker (Pi)	6	33,000	59,000	102,000	179,000	306,000
power	6	31,000	52,000	88,000	161,000	255,000

NADINA	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ*	**1**	**24,000**	**45,000**	**90,000**	**179,000**	**331,000**
Ricker (FrD-peak)	2	27,000	43,000	75,000	133,000	219,000
power (juv) (FrD-peak)	2	27,000	44,000	75,000	136,000	227,000
Ricker	14	38,000	61,000	110,000	195,000	333,000
power (juv)	8	33,000	53,000	92,000	155,000	254,000

PITT	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin*	**1**	**42,000**	**60,000**	**90,000**	**147,000**	**212,000**
TSA	2	21,000	38,000	71,000	134,000	237,000
Ricker (PDO)	3	34,000	51,000	79,000	125,000	197,000

SCOTCH	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin*	**1**	**300**	**2,000**	**12,000**	**89,000**	**698,000**
Ricker	2	2,000	5,000	10,000	23,000	49,000
RS1	3	4,000	11,000	37,000	120,000	344,000

SEYMOUR	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker-cyc	1			Does not converge		
Larkin*	**2**	**0**	**100**	**400**	**1,000**	**3,000**
R1C	2	1,000	1,000	2,000	5,000	9,000
Ricker	10	2,000	3,000	5,000	11,000	21,000
power	10	2,000	4,000	7,000	14,000	24,000

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
power (juv) (Pi)*	**1**	**459,000**	**658,000**	**1,002,000**	**1,573,000**	**2,283,000**
power (juv)	2	483,000	668,000	997,000	1,540,000	2,234,000
power (juv) (FrD-peak)	3	439,000	622,000	953,000	1,499,000	2,237,000
Ricker (for comparison)	NA	449,000	667,000	1,067,000	1,627,000	2,450,000
Four year old forecasts						
power (juv) (Pi)	NA	400,000	618,000	976,000	1,548,000	2,255,000
Sibling (four year old)	NA	356,000	575,000	971,000	1,638,000	2,651,000

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	2,000	3,000	7,000	16,000	31,000
R2C	2	7,000	15,000	37,000	92,000	207,000
Ricker-cyc	3	15,000	30,000	63,000	133,000	253,000
Larkin	4	2,000	6,000	21,000	61,000	140,000
Ricker	6	2,000	5,000	14,000	43,000	113,000
Ricker-cyc four year olds + sibling five year olds*	**NA**	**6,000**	**9,000**	**15,000**	**25,000**	**40,000**
Five year old forecasts						
Ricker-cyc five year olds	NA	14,000	29,000	62,000	130,000	252,000
Sibling (four-to-five year old)	NA	5,000	8,000	14,000	24,000	39,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C*	**1**	**42,000**	**86,000**	**192,000**	**427,000**	**880,000**
R2C	2	43,000	95,000	231,000	560,000	1,242,000
power	3	46,000	91,000	195,000	432,000	885,000
Ricker (FrD-mean)	4	52,000	102,000	244,000	653,000	1,405,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
R2C*	**1**	**86,000**	**144,000**	**256,000**	**454,000**	**761,000**
Larkin	2	230,000	337,000	526,000	780,000	1,176,000
Ricker (Ei)	3	146,000	216,000	358,000	592,000	904,000
Four year old forecasts						
R2C (applied Larkin age prop.)	NA	79,000	133,000	235,000	418,000	700,000
Sibling (three(jack)-to-four yr old)	NA	70,000	131,000	257,000	507,000	942,000

HARRISON**		Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	1	86,000	163,000	359,000	749,000	1,678,000
Ricker	6	67,000	136,000	294,000	678,000	1,448,000
Power	7	28,000	57,000	111,000	225,000	436,000
Ricker (Ei) three yr old + sibling four year old (using post-1980 EVEN years only)**	**NA**	**33,000**	**73,000**	**176,000**	**425,000**	**957,000**
Ricker (Ei) three yr old + sibling four year old (for comparison using post-1980 ODD years only)	**NA**	**50,000**	**102,000**	**222,000**	**487,000**	**1,019,000**
Ricker (Ei) three yr old + sibling four year old (for comparison using post-1980 ALL years)	**NA**	**40,000**	**85,000**	**194,000**	**447,000**	**971,000**
Four year old forecasts						
Ricker (Ei) four year olds	NA	25,000	62,000	165,000	431,000	1,013,000
Sibling-EVEN post-1980 four yr**	NA	12,000	25,000	48,000	68,000	93,000
Sibling-ODD post-1980 four yr	NA	23,000	38,000	77,000	83,000	91,000
Sibling-ALL post-1980 four yr	NA	19,000	40,000	51,000	70,000	85,000

****Harrison:** three-to-four year old sibling models use 2015 three year old recruits to predict 2016 four year old recruits; the 2012 brood year (EVEN year) contributes to both these recruitment years. Since four year old proportions are lower in EVEN (58%) versus ODD (75%) years, and since the 2012 brood year is an EVEN year, only EVEN recruitment years are used in the sibling model. Other sibling models that use ODD years, or ALL years, are used for comparison, and given the higher four year old age-proportion in ODD years, produce larger forecasts than EVEN year only sibling forecasts. Only post-1980 recruitment data are used in any of the sibling models given the shifts in age of maturity before and after 1980.

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)*	1	**11,000**	**16,000**	**26,000**	**38,000**	**62,000**
Ricker-cyc	2		Does not converge			
power	2	10,000	15,000	23,000	35,000	54,000

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ*	**1**	**1,000**	**2,000**	**4,000**	**9,000**	**17,000**
Power (juv) (FrD-peak)	2	1,000	2,000	4,000	8,000	15,000
Power (juv) (Pi)	3	1,000	2,000	4,000	7,000	14,000

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	400	1,000	2,000	5,000	11,000
Ricker-cyc	2	1,000	3,000	9,000	21,000	55,000
RAC	3	5,000	11,000	26,000	63,000	139,000
Larkin *	**5**	**0**	**100**	**4,000**	**25,000**	**76,000**
Ricker	7	100	1,000	22,000	159,000	552,000
power	11	100	1,000	23,000	159,000	429,000

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin *	**1**	**0**	**200**	**400**	**1,000**	**2,000**
Ricker-cyc	2	**Does not converge**				
power	3	300	600	1,000	3,000	6,000
Ricker	7	100	300	1,000	2,000	4,000

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS	1	21,000	38,000	72,000	138,000	246,000
Ricker (PDO)	2	20,000	37,000	75,000	143,000	269,000
RJC	3	19,000	33,000	59,000	107,000	182,000
MRS four year olds + sibling five year olds *	**NA**	**2,000**	**4,000**	**8,000**	**15,000**	**29,000**
Five year old forecasts						
MRS five year olds	NA	20,000	35,000	67,000	128,000	230,000
Sibling (four-to-five year old)	NA	600	1,000	3,000	6,000	13,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	1	56,000	91,000	162,000	306,000	545,000
Ricker	2	57,000	97,000	182,000	317,000	558,000
RAC	2	49,000	107,000	251,000	591,000	1,276,000
Ricker (Ei) four year olds + sibling five year olds *	**NA**	**30,000**	**45,000**	**68,000**	**105,000**	**158,000**
Five year old forecasts						
Ricker (Ei) five year olds	NA	37,000	69,000	137,000	279,000	525,000
Sibling (four-to-five year old)	NA	22,000	31,000	52,000	83,000	136,000

Table 7. Chilliwack Forecasts

CHILLIWACK	10%	25%	50%	75%	90%
Ricker *	**17,000**	**46,000**	**138,000**	**378,000**	**1,101,000**
R/S (Chilliwack)	33,000	157,000	215,000	356,000	659,000
R/S (Early Summers)	126,000	255,000	475,000	860,000	1,610,000

Table 8. The total Fraser Sockeye forecast from 1998 to 2015 from the 10% to 90% p-levels. Note, all p-level values are not available for all years. The forecast value that corresponded to the actual return is highlighted. For returns that fell above the 50% p-level, the cells are highlighted green (G superscript). For returns that fell at the 50% p-level, cells are highlighted yellow (Y superscript). Returns falling below the 50% p-level are highlighted amber (A superscript), and below the 25% p-level are highlighted red (R superscript). Since 2005 (past 11 years), total returns have fallen at or below the 50% p-level, with the exception of the 2010 returns.

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 A	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 R	8,734,000 A	16,160,000	30,085,000	53,191,000	**7,020,000**
2006	NA	5,683,000	9,530,000 A	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 R	1,854,000 A	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 R	2,364,000 R	3,824,000	6,778,000	12,635,000	23,580,000	**2,120,000**

Figures

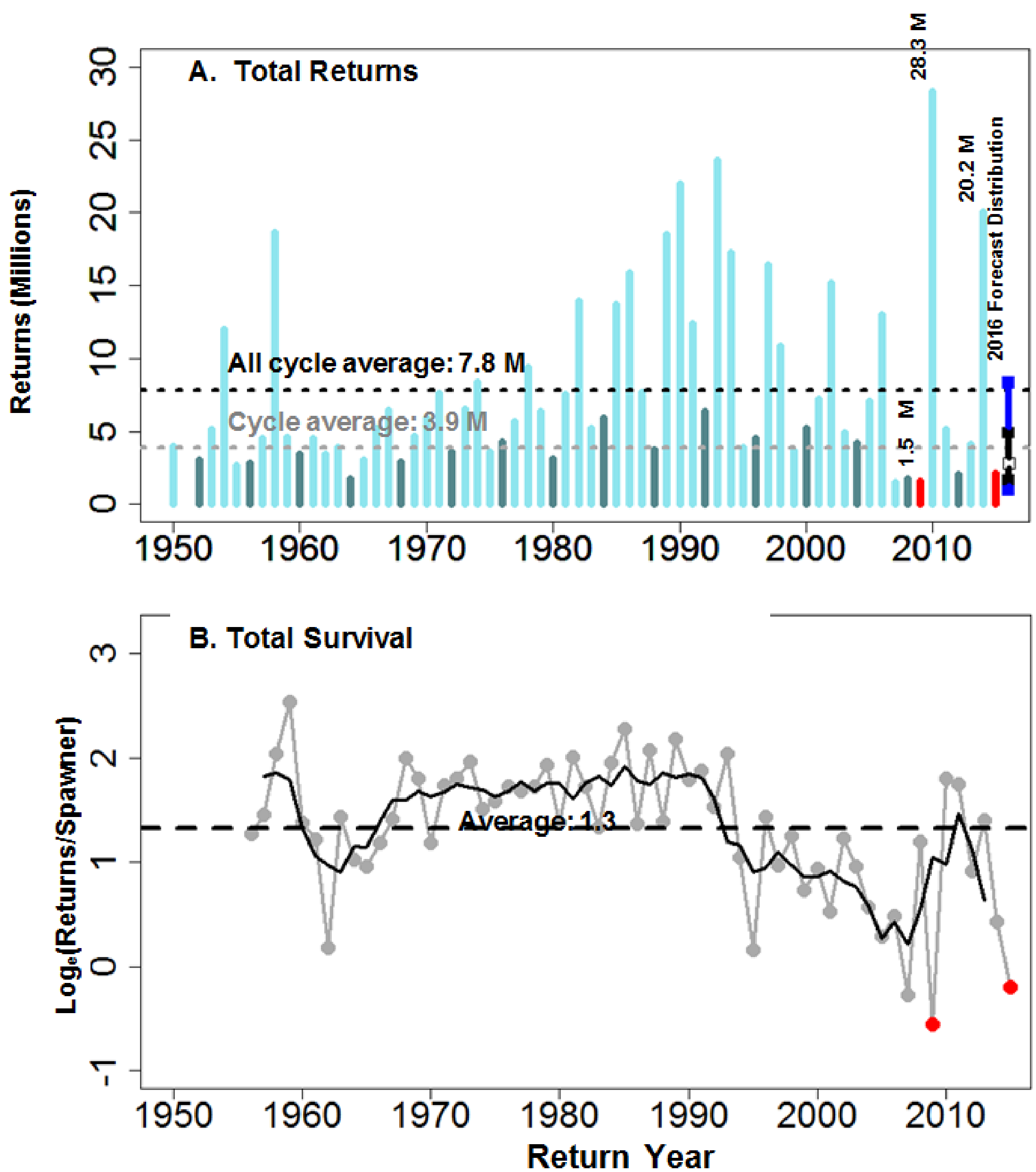

Figure 1. ***A.*** *Total Fraser Sockeye adult annual returns (dark blue vertical bars for the 2016 cycle and light blue vertical bars for the three other cycles). Recent adult returns from 2012 to 2015 are preliminary. The vertical bar aligned with the 2016 return year represents the 2016 forecast (length of the blue bar represents the 10% to 90% p-level, length of the black bar represents the 25% to 75% p-level, and the white bar represents the 50% p-level).* ***B.*** *Total Fraser Sockeye adult survival (loge(returns/total spawner)) up to the 2015 return year. The light grey filled circles and lines present annual survival and the black line presents the smoothed four year running average. For both figures, the dashed horizontal line is the time series average. In Figure A the lighter dashed horizontal line is the 2016 cycle line average. For Figures A and B, the first and last red vertical bar (Figure A) or filled circles (Figure B) represents, respectively, the 2009 and 2015 returns (low survival). Note that the 2015 return year survival is not entirely appropriate given the higher proportion of five year olds, and the assumption in these survival estimates is that four year olds dominate total returns.*

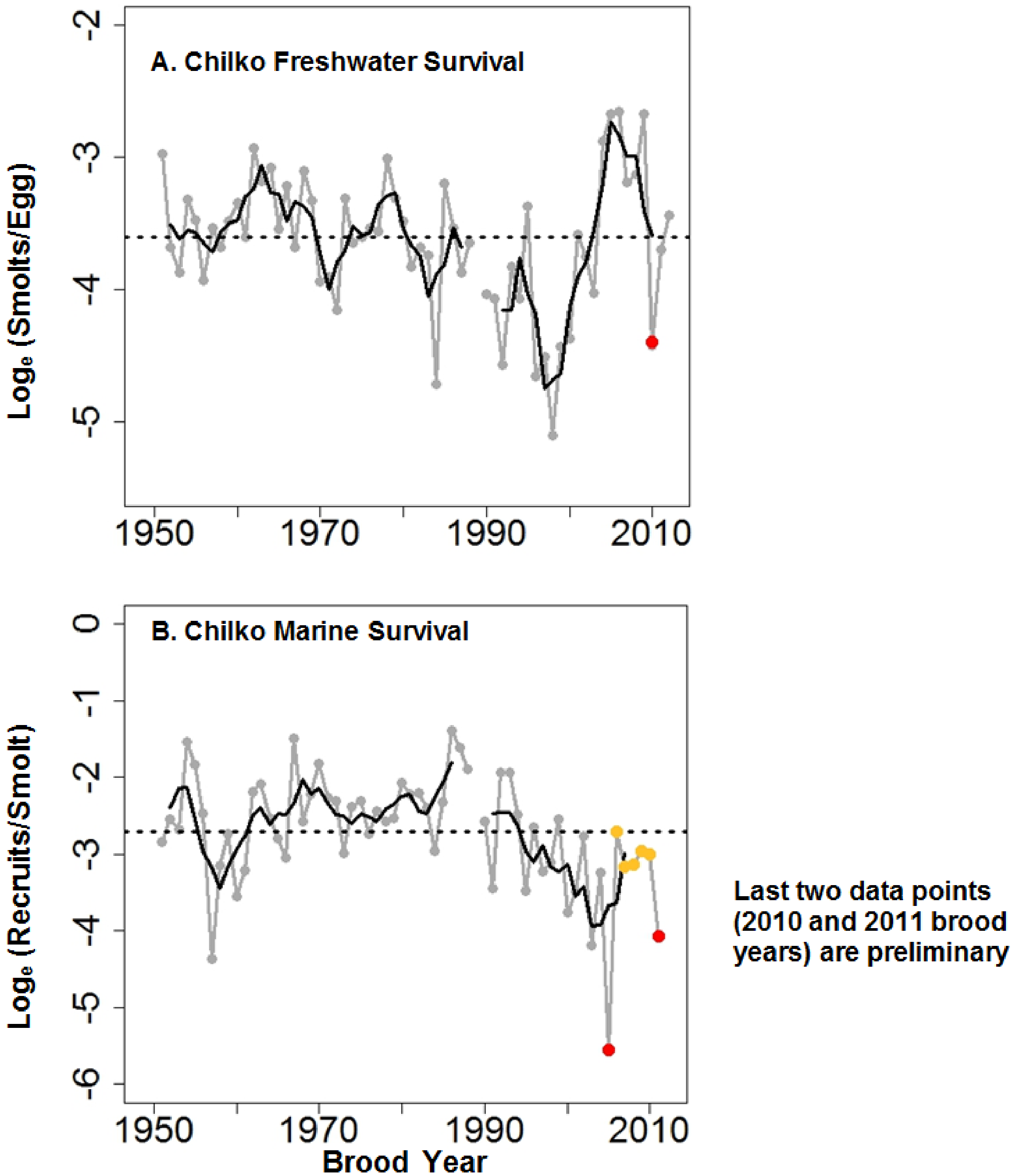

*Figure 2. Chilko River Sockeye **A**. annual freshwater (log_e smolts-per-egg) survival (filled grey circles and lines) with the 2005 brood year survival indicated by the red filled circle and **B**. annual marine (log_e recruit-per-smolt) survival (filled grey circles and lines) with the 2005 brood year survival indicated by the first red filled circle. The 2006 to 2010 brood year survivals are indicated by the amber filled circles and the preliminary 2011 brood year survival is indicated by the final red filled circle. The black line in both figures represents the smoothed four-year running average survival and the black dashed lines indicate average survival.*

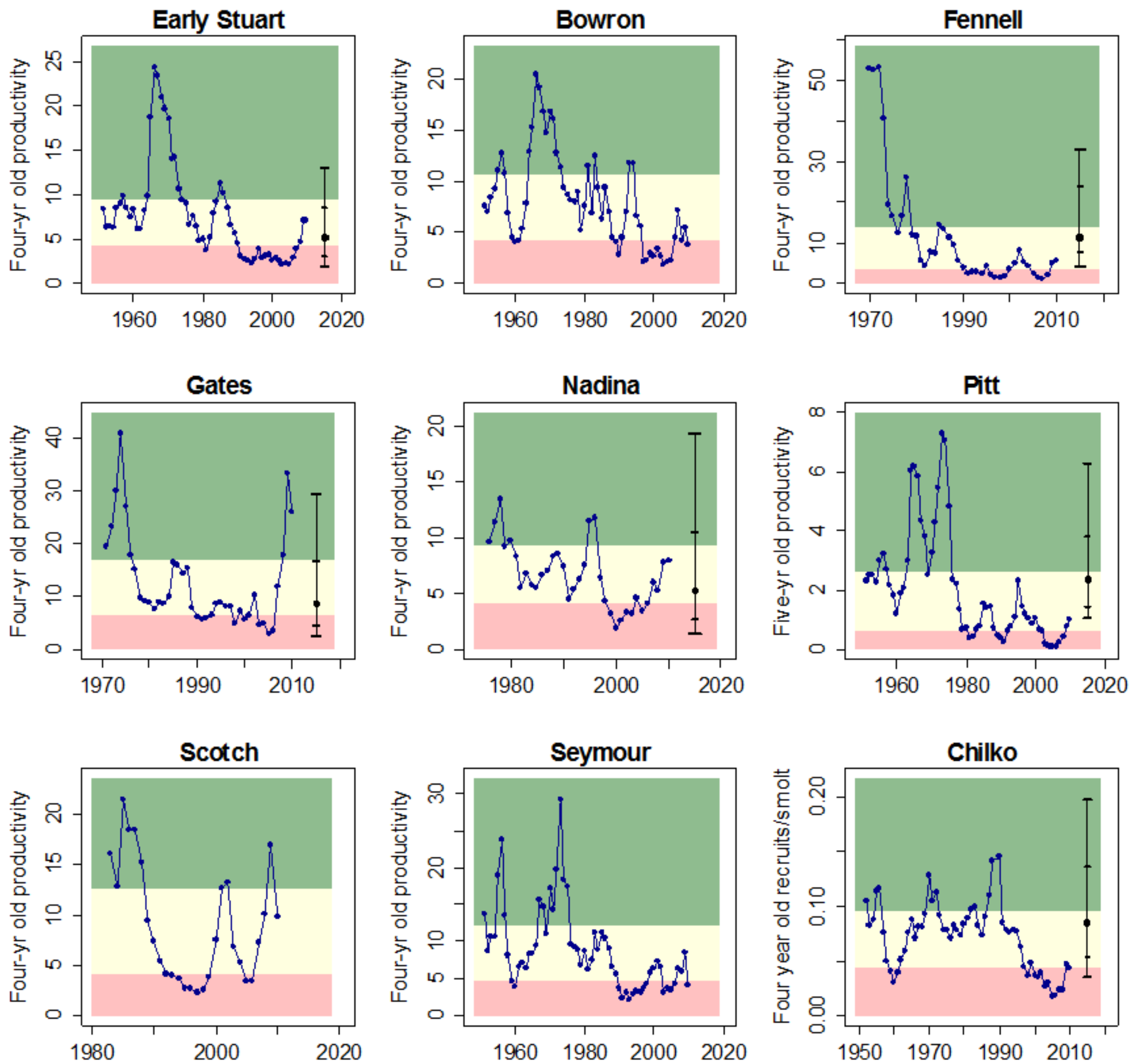

Figure 3. Smoothed four year old survival time-series' (blue lines) calculated as the four year running geometric average four year old recruits/brood year effective female spawners for all stocks except Pitt (five year old recruits/EFS), and Cultus & Chilko (four year old recruits/smolts). Unsmoothed cycle-line data is presented for Quesnel and Late Shuswap. Colours (Red – bottom band, Amber – middle band, Green – top band) show where the productivities fall relative to the long-term geometric average (+/- 0.5 multiplied by the standard deviation): red (< average), yellow (average) and green (>average). Black bars indicate the range of survivals associated with the 2016 forecasts, at the 10% (lower horizontal bar), 25%, 50% (black filled circle), 75%, and 90% (upper horizontal bars) p-levels. Forecast productivities are not presented for stocks where they are not informative (extremely small effective female spawner abundances in the 2012 brood year or extremely small four year old forecasts) or where recruitment data are unavailable (i.e. miscellaneous stocks).

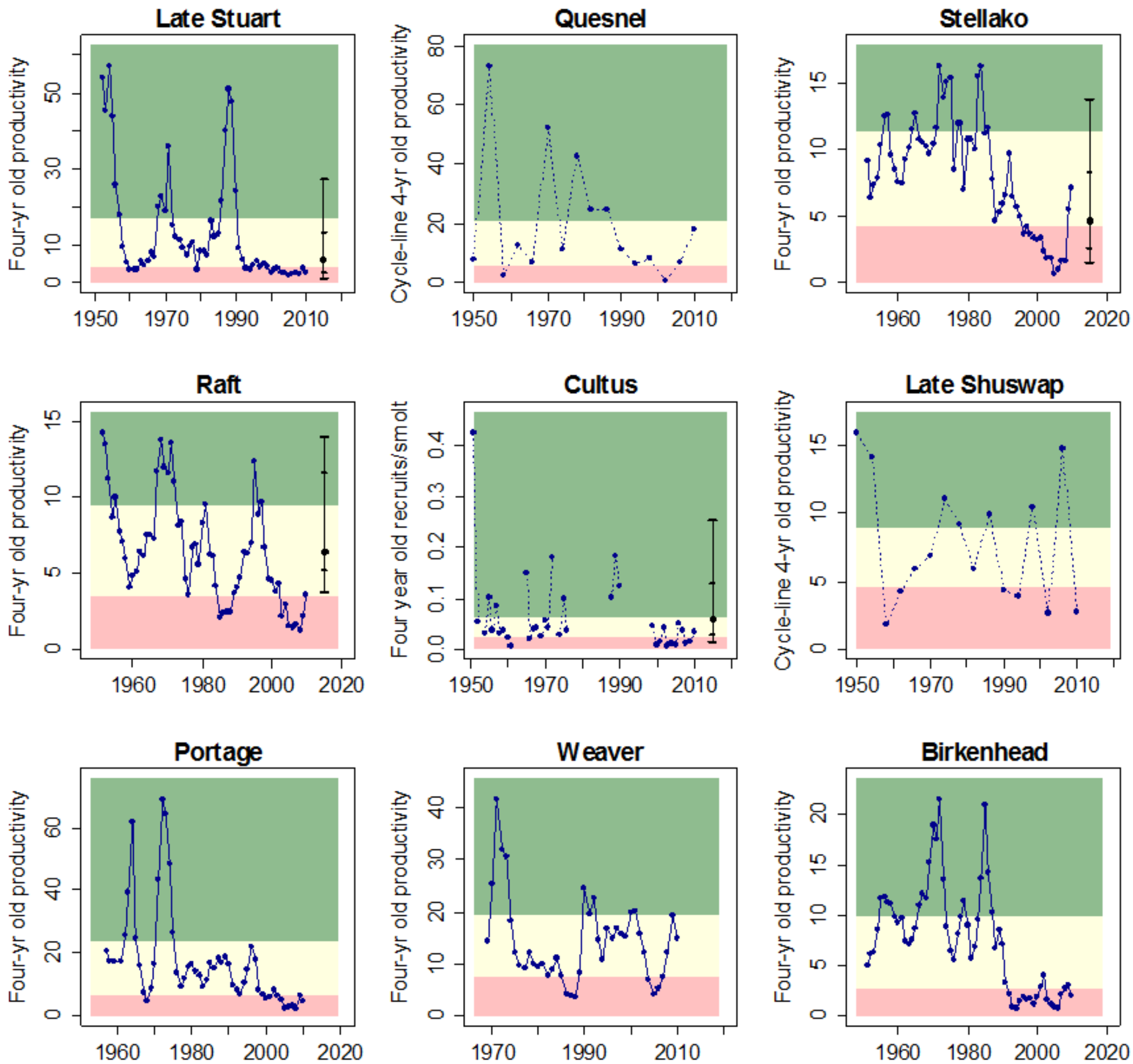

Figure 3 (Continued)

Figure 4. Four-to-five year old sibling relationships for Quesnel, Weaver, and Birkenhead (after conversion of recruitment data to millions and log_e transformation). Recruitment data are post-1980 due to shifts in age of maturity. Triangles represent the preliminary four year old recruits (in millions) in 2015 for Quesnel (0.033), Weaver (0.0024) and Birkenhead (0.063), which are log_e transformed (respectively, -3.4,-6.0,-2.8). Note: the Weaver four year old recruits in 2015 were a record low relative to the post-1980 time series, therefore, the triangle does not fall on the model line fit to the historical data. These preliminary three year old recruits in 2015 were used with each stock's four-to-five year old sibling models and Bayesian methods to forecast five year old returns for the 2016 forecast (Tables 1 & 6).

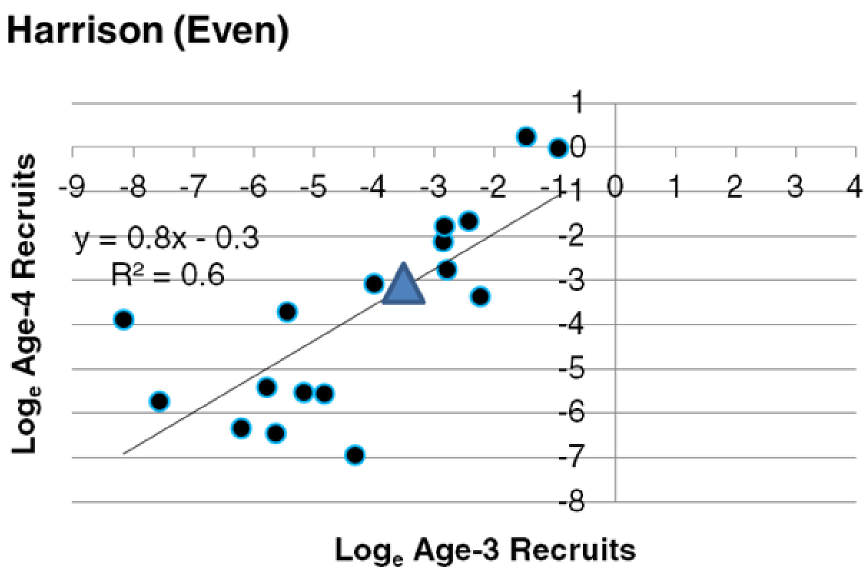

Figure 5. Three-to-four year old sibling relationships for Harrison (after conversion of recruitment data to millions and $\log_e$ transformation). Recruitment data are post-1980 due to shifts in age of maturity. The time series used in the 2016 four year old recruitment forecast used even years only (top graph), since the brood year to forecast 2016 four year old recruits is 2012 (an even year). For comparison, although inappropriate to use, the odd year three-to-four year old sibling relationship is presented in the bottom graph. The triangle represents the preliminary three year old recruits (in millions) from 2015 for Harrison (0.033), which is converted to $\log_e$ (-3.9). These preliminary three year old recruits in 2015 were used with the even year (top) three-to-four year old sibling model and Bayesian methods to forecast four year old returns for the 2016 forecast (Tables 1 & 6).

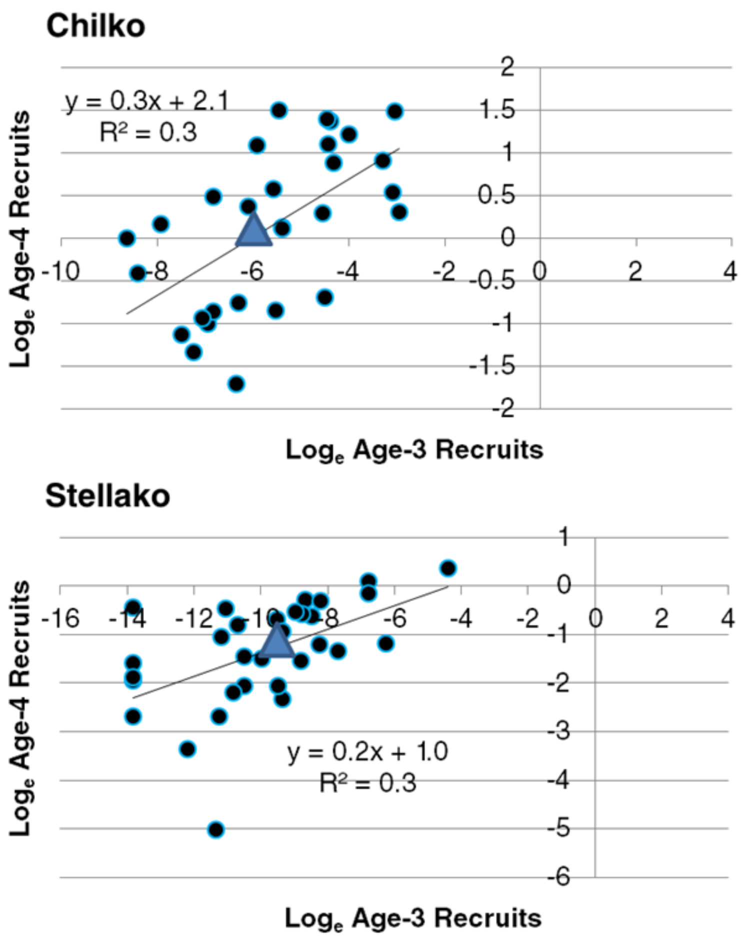

Figure 6. Three (jack)-to-four year old sibling relationships for Chilko and Stellako. Recruitment data are post-1980 due to shifts in age of maturity. The triangle represents the preliminary three year old recruits (in millions) from 2015 for Chilko (0.0025) and Stellako (0.000058), which is converted to log_e (respectively, -6.0 and -9.8). These preliminary three year old recruits in 2015 were used with Bayesian methods to predict four year old recruits for comparison to the 2016 forecast (Table 6).

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Sources of Information

This Science Response Report results from the Science Response Process of December 14, 2015 on the Pre-season abundance forecast for Fraser River Sockeye Salmon returns in 2016.

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Appendix 1. Model selection rationale for the 2016 forecasts for each stock

For each of the subsequent stock-specific results sections the following procedure was consistently applied:

- When comparing the forecast of the top ranked models, the percentage difference between estimates has been calculated using the 50%-median probably levels (p-levels);
- Unless otherwise noted, the top three models (ranked according to their average rank across all performance measures) only contained those models that also ranked within the top half of all models for each of the four performance measures individually.

Early Stuart

The Early Stuart top ranked models (based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE) include the Ricker (Ei) (tied first), Ricker (Pi) (tied first), Ricker (tied third), and Ricker (PDO) (tied third) (Table 6). For each individual performance measure, these models all ranked within the top 50% (10 out of 20) of models for this stock (see Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were similar, with the smallest forecast (Ricker) deviating by 22% from the largest forecast (Ricker (Ei)) (Table 6). The Ricker (Ei) model was used for the 2016 Early Stuart forecast, as it ranked first on average across performance measures, and it outperformed the other first-ranked model (Ricker (Pi)) on two of the four individual performance measures (and tied on one) (Table 5 in MacDonald & Grant, 2012).

Bowron

The Bowron top ranked models include MRS, Ricker (Pi), and Ricker (Ei) (Table 6). Forecasts produced by the top ranked models varied by 27% (Table 6), with the MRS model producing the largest forecast. The MRS model was used for the 2016 Bowron forecast, as it ranked first on average across performance measures, and it ranked well on each individual performance measure (Table 5 in MacDonald & Grant 2012).

Fennell

The Fennell top ranked models include the power, RAC, and Ricker models (Table 6). All three top models ranked within the top 50% of all evaluated models on each individual performance measure. Forecasts produced by the top ranked models varied by 57%, with the power model generating the smallest forecast and the RAC model producing the largest (Table 6). The power model was used for the 2016 Fennell forecast, as it ranked first on average across performance measures, and it ranked as well as, or better than other top ranked models on each individual performance measure except MAE (ranked third) (Table 5 in MacDonald & Grant 2012).

Gates

The Gates top ranked models include the RAC, R2C, Larkin (tied third) and MRS (tied third) models (Table 6). For each individual performance measure, the Larkin and MRS models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). These two models produced forecasts that varied by 30% (Table 6). Additional high ranked models (Ricker (Pi) & power, both ranked 6th) produced forecasts that fell between the Larkin and MRS model forecasts. The Larkin model was used for the 2016 Gates forecast, as it ranked high on average across performance measures, and it ranked well relative to alternative models on each individual performance measure.

Nadina

The Nadina top ranked models include the MRJ, Ricker (FrD-peak) (tied second), and power (juv) (FrD-peak) (tied second) (Table 6). These three models each ranked within the top 50% (17 out of 33 models) of all models compared for this stock on three of the four individual performance measures. However, all three models each ranked in the bottom 50% (ranked ≥ 19 out of 33 models) on the MRE performance measure (Table 5 in MacDonald & Grant 2012). Of the 33 models explored for Nadina, none ranked in the top 50% for all four performance measures (all models either ranked well on MRE and poorly on all other performance measures, or vice versa). Therefore, the MRE performance measure was not used to inform model selection. Forecasts produced by the top ranked models differed by 17% (Table 6). The MRJ model was used for the 2016 Nadina forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked 28th) (Table 6 in MacDonald & Grant, 2012).

Pitt

The Pitt top ranked models include the Larkin, TSA and Ricker (PDO) models (Table 6). For each individual performance measure, only the Larkin model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant, 2012). Forecasts produced by the top ranked models varied by 21% (Table 6). The top performing Larkin model was used to generate the 2016 forecast for Pitt (Table 1A).

Scotch

The Scotch top ranked models include the Larkin, Ricker and RS1 (Table 6). For each individual performance measure, the Larkin and Ricker models each ranked within the top 50% (10 out of 20) of all models for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the Larkin and Ricker models differed by 16% (Table 6), with the Larkin model producing a slightly larger forecast than the Ricker model. Scotch has a relatively short time series, which increases the uncertainty of these forecasts. The previous 2014 and 2015 forecasts recommended against using the Larkin model for Scotch and Seymour, given that most of the delayed-density dependence in Shuswap Lake should be influenced by the dominant cycle of the Late Shuswap stock, which was considered not accounted for in the Scotch or Seymour Larkin models. However, all stocks that rear in Shuswap Lake (Scotch, Seymour and Late Shuswap) over the past two return years (2014 and 2015), which included exceptional returns from the dominant 2010 cycle escapement for each of these stocks and the sub-dominant 2011 cycle escapement, experienced lower survival. These survivals aligned more closely with the median forecasts generated by the Larkin model, rather than the selected forecast model for 2015 (Ricker), suggesting that delayed-density dependence may have reduced survival of these stocks. Therefore, the Larkin model was used to produce the 2016 forecasts for the Scotch, Seymour and Late Shuswap stocks.

Seymour

The Seymour top ranked models include the Ricker-cyc, Larkin (tied second), R1C (tied second), and Ricker-Ei; note the Ricker-cyc model forecast did not converge so it was excluded from consideration (Table 6). Since the brood year escapement for Seymour was below average, only models that use brood year escapement as a predictor variable were considered to generate the 2016 forecast. The Larkin and Ricker-Ei model differed by 92% (Table 6), with the Larkin model producing a smaller forecast than the Ricker model. The previous 2014 and 2015 forecasts recommended against using the Larkin model for Scotch and Seymour, given that most of the delayed-density dependence in Shuswap Lake should be influenced by the dominant cycle of the Late Shuswap stock, which was considered not accounted for in the Scotch or Seymour Larkin models. However, all stocks that rear in Shuswap Lake (Scotch, Seymour and Late Shuswap) over the past two return years (2014 and 2015), which included exceptional returns from the dominant 2010 cycle escapement for each of these stocks and the sub-dominant 2011 cycle escapement, experienced lower survival. These survivals aligned more closely with the median forecasts generated by the Larkin model, rather than the selected forecast model for 2015 (Ricker), suggesting that delayed-density dependence may have reduced survival of these stocks. Therefore, the Larkin model was used to produce the 2016 forecasts for the Scotch, Seymour and Late Shuswap stocks.

Chilko

The 2016 forecasts for Chilko were restricted to juvenile-based models only given the below average smolt abundance observed for this stock in the 2012 brood year.

The Chilko top ranked juvenile models include are the power (juv) (Pi), power (juv), and power (juv) (FrD-peak) models (Table 6). None of these models ranked within the top 50% (17 out of 33) of all models compared for this stock (including spawner-based models) for all performance measures (Table 5 in MacDonald & Grant 2012). All three models ranked poorly on MRE, therefore the average rank across all four performance measures by model were compared across models used to inform model selection. Forecasts produced by the top ranked models were very similar, varying by 5% (Table 6). The power (juv) (Pi) model was used to generate the Chilko forecast, as it takes advantage of the available data on freshwater survival, and it ranked best overall for the juvenile models.

Late Stuart

The Late Stuart top ranked models include the R1C, R2C, and power models (Table 6) (Note: there is an error in the Ricker model performance measures in Table 5 of MacDonald & Grant 2012. The Ricker model is not actually tied for the third ranked model, but instead is ranked eighth. Performance measure values for Ricker are MRE: -0.033, MAE: 0.521, MPE: -1.673, RMSE: 0.9.). For each individual performance measure, the R1C and R2C models ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant, 2012). Forecasts produced by the top three models varied by 21%, with the R1C and power models generating very similar estimates (Table 6). The top ranked R1C model was used to generate the 2016 forecast because the 2012 brood year escapement was average, and the results were similar to the power model. This model differs from that used for the 2015 forecast, because the brood year EFS driving the 2015 forecast (2011 brood year) was below average, thus the return-based models (R1C & R2C) were not considered.

Quesnel

The Quesnel top ranked models include the R1C, R2C and Ricker-cyc (Table 6). For each individual performance measure, each of these models ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant, 2012). Given the extremely low (below average) brood year escapement in 2012, only biological models were considered for this forecast. The Ricker-cyc model was used to generate the 2016 four year old forecast for Quesnel (Table 6). A sibling four-to-five year old model was used to forecast the 2016 Quesnel five year old forecast (Table 6).

Stellako

The Stellako top ranked models include the R2C, Larkin and Ricker (Ei) (Table 6). Only the R1C model performed within the top 50% of all models on each performance measure (MacDonald &

Grant 2012). Forecasts produced by the top three models varied by 51%, with the R1C model generating the smallest estimate and the Larkin model the largest (Table 6). The top ranked R1C model was used to generate the 2016 forecast because this was the sole model to satisfy the selection criteria, and the 2012 brood year escapement was similar to average. This model differs from that used for the 2015 forecast, because the brood year EFS driving the 2015 forecast (2011 brood year) was below average, thus the return-based model (R2C) was not considered.

Harrison

A sensitivity analyses was conducted to explore the effect of varying the Harrison data set on the biological model forecasts (Appendix 1). The Ricker-Ei model applied to both three and four year old forecasts produced a much higher estimate at 359,000 (50% p-level). Excluding some of the earlier lower productivity and abundance data (prior to the 1990 brood year) or removing the 2005 (lowest survival on record for this and other Fraser Sockeye stocks) brood year from the original stock-recruitment data resulted in only a small change in the Ricker-Ei model forecasts from the base case scenario.

Another sensitivity analyses was conducted to explore three-to-four year old sibling forecasts using odd year post-1980 or all years post-1980 (both odd and even) recruitment data (Table 6). These total forecasts (respectively, 222,000 and 194,000 at the 50% p-level) were greater than the even year post-1980 forecast (176,000 at the 50% p-level). This was expected given the higher proportion of four year olds produced in odd years compared to even years, and the increase in four year old proportions when all years are combined.

Raft

The Raft top ranked models include Ricker (PDO), Ricker-cyc (tied second) and power (tied second) (Table 6). For each individual performance measure, only the Ricker (PDO) model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant, 2012). Forecasts produced by the top ranked models varied by 10%, with the Ricker (PDO) model producing the largest forecast; however, a forecast could not be generated using the Ricker-cyc model due to a lack of model convergence within the pre-defined range, as described in the Methods (Table 6). The Ricker (PDO) model was used for the 2016 Raft forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except RMSE (ranked fourth).

Cultus

The Cultus top ranked models include the MRJ, power (juv) (FrD-peak), and power (juv) (Pi) models (Table 6). Due to significant gaps in the smolt time-series, the number of years that could be forecasted by certain smolt models (RJ1, RJ2 & RJC) in the jack-knife analysis was severely restricted. These models were therefore excluded from the model evaluation process for this stock. In addition, all models that use EFS as a predictor variable were excluded, as EFS data for Cultus do not account for the significant hatchery supplementation (fry & smolts) to this stock since the 2000 brood year. The top models all ranked within the top 50% (7 out of 14) of all models compared for this stock on each individual performance (Table 5 in MacDonald & Grant, 2012). Forecasts produced by the top ranked models were identical (Table 6). The MRJ model was used to generate the forecast for 2016, as it ranked the highest on average across performance measures and ranked better than, or equal to, the other top models on each individual performance measure.

Late Shuswap

The Late Shuswap top ranked models include the R1C, Ricker-cyc, RAC and Larkin models (Table 6). However, due to the well below average escapement in Late Shuswap in 2012, only models that use brood year escapement as a predictor variable were considered to generate the 2016 forecast. In the past two return years (2014 and 2015), that included exceptional returns from the dominant 2010 cycle escapement and the sub-dominant 2011 cycle escapement, all stocks that rear in Shuswap Lake (Scotch, Seymour and Late Shuswap) experienced lower survival. These survivals aligned more closely with the median forecasts generated by the Larkin model, rather than the 2015 selected forecast model (Ricker) model, suggesting that delayed-density dependence may have reduced survival of these stocks. Therefore, given the improved performance of the Larkin model and the exceptional brood year escapements for these stocks in 2010, the Larkin model was used to produce the 2016 forecasts for the Scotch, Seymour and Late Shuswap stocks.

Portage

The Portage top ranked models include the Larkin, power and Ricker-cyc models (Table 6). For each individual performance measure, the Larkin and Ricker-cyc models each ranked within the top 50% (10 out of 20) of all models compared for this stock; the power model ranked low on the MRE performance measure in particular (Table 5 in MacDonald & Grant, 2012). However, the Ricker-cyc model was excluded from consideration due to a lack of model convergence within the pre-defined range, as described in the Methods. Forecasts produced by the top remaining models were not similar, varying by 69% (Table 6), with the Larkin model producing a smaller forecast than the power model. The Larkin model was used for the 2016 Portage forecast, as it ranked first on average across performance measures, and it ranked well on each individual performance measure.

Weaver

The Weaver top ranked models include the MRS, Ricker (PDO), and RJC (Table 6). None of the top models ranked within the top 50% (17 out of 33) of all models compared for this stock on all four performance measures (Table 5 in MacDonald & Grant, 2012); the MRS model ranked particularly low on the MPE performance measure, and the Ricker (PDO) and RJC models ranked poorly on the MRE performance measure. Forecasts produced by the top ranked models were similar, varying by 21% (Table 6). The MRS model was used for the 2016 Weaver four year old forecast, because it had the highest average rank across all four performance measures (Table 6). A sibling four-to-five year old model was used to forecast the 2016 Weaver five year old forecast (Table 6).

Birkenhead

The Birkenhead top ranked models include Ricker (Ei), Ricker (tied second) and RAC (tied second) (Table 6). Due to the below average Birkenhead escapement in 2012, only the top ranked models that use brood year escapement as a predictor variable (Ricker (Ei) & Ricker) were considered to generate the 2016 forecast. For each individual performance measure, neither remaining models ranked within the top 50% (10 out of 20) of all models (Table 5 in MacDonald & Grant, 2012). Forecasts produced by the top ranked models were quite similar, varying by only 11% (Table 6). The first ranked Ricker (Ei) model was used for the 2016 Birkenhead four year old forecast (Table 6). A sibling four-to-five year old model was used to forecast the 2016 Birkenhead five year old forecast (Table 6).

Appendix 2: Sensitivity analysis of 2016 five year old forecasts using 2015 four year old preliminary survivals

This sensitivity analysis uses Fraser River 2016 four year old forecasts generated using the standard models (Table 3) and 2016 five year old forecasts generated using the models used in the 2015 forecast, which are scaled using the preliminary 2015 four year old returns divided by the 2015 four year old forecasts (see Methods).

Early Stuart

For the sensitivity analysis a scalar of 2.44 (Appendix 1: Table A2) was applied to the five year 2016 forecast (100) predicted by the 2015 forecast model for Early Stuart (Ricker (Ei)), increasing the five year old forecast to 200 (Appendix 1: Table A3 & A4). However, the overall forecast for Early Stuart remains unchanged, due to the small contribution of five year olds to the total return (Appendix 1: Tables A1 & A4).

Bowron

For the sensitivity analysis a scalar of 0.53 (Appendix 1: Table A2) was applied to the five year 2016 forecast (4,000) predicted by the 2015 forecast model for Bowron (MRS), reducing the five year old forecast to 2,000 (Appendix 1: Table A3 & A4), and the overall forecast to 2,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 90% (at the 50% probability level) (Appendix 1: Table A3).

Upper Barriere (Fennell)

For the sensitivity analysis a scalar of 0.13 (Appendix 1: Table A2) was applied to the five year 2016 forecast (5,000) predicted by the 2015 forecast model for Upper Barriere (power), reducing the five year old forecast to 1,000 (Appendix 1: Table A3 & A4), and the overall forecast to 9,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 11% (at the 50% probability level) (Appendix 1: Table A3).

Gates

For the sensitivity analysis a scalar of 0.28 (Appendix 1: Table A2) was applied to the five year 2016 forecast (15,000) predicted by the 2015 forecast model for Gates (Larkin), reducing the five year old forecast to 4,000 (Appendix 1: Table A3 & A4), and the overall forecast to 64,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 5% (at the 50% probability level) (Appendix 1: Table A3).

Nadina

For the sensitivity analysis a scalar of 1.01 (Appendix 1: Table A2) was applied to the five year 2016 forecast (2,000) predicted by the 2015 forecast model for Nadina (MRJ), resulting in a negligible increase to the five year old forecast (Appendix 1: Table A3 & A4). The scaled total forecast for Nadina therefore remains unchanged (Appendix 1: Tables A1 & A4).

Pitt

For the sensitivity analysis a scalar of 2.36 (Appendix 1: Table A2) was applied to the five year 2016 forecast (72,000) predicted by the 2015 forecast model for Pitt (Larkin), increasing the five year old forecast to 171,000 (Appendix 1: Table A3 & A4), and the overall forecast to 189,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 90% (at the 50% probability level) (Appendix 1: Table A3). For comparison, a sibling five year old forecast was also generated used preliminary four year old returns for Pitt in 2015 to predict 2016 five year old returns. The sibling model forecast was smaller (50% p-level: 113,000) than the scaled Larkin model (50% p-level: 189,000).

Scotch

Since the model used to generate the 2016 forecast for Scotch differs from 2015, for the sensitivity analysis the 2015 model (Ricker) was used to generate a total forecast for this stock (50% probability level forecast: 10,000) (Appendix 1: Table A4). A scalar of 0.09 (Appendix 1: Table A2) was then applied to the five year old component of the 2016 return forecast (20), reducing the five year old forecast to 0 (Appendix 1: Table A3 & A4); however, the overall forecast produced by the scaled Ricker model (50% probability level forecast: 10,000) remained the same due to the low contribution of five year olds to the total forecast (0%) (Appendix 1: Tables A1, A2 & A4).

Seymour

Since the model used to generate the 2016 forecast for Seymour differs from that used in 2015, for the sensitivity analysis, the 2015 model (Ricker) was used to generate a total forecast for this stock (50% probability level forecast: 5,000) (Appendix 1: Table A4). A scalar of 0.17 (Appendix 1: Table A2) was then applied to the five year old 2016 forecast (2,000), reducing the five year old forecast to 400 (Appendix 1: Table A3 & A4). The overall forecast produced by the scaled Ricker model (50% probability level forecast: 4,000) is lower than the unscaled Ricker forecast; however, it is larger than the Larkin model forecast for Seymour (50% probability level forecast: 400) used Table 1A. The contribution of five year olds to the scaled forecast is 10% (Appendix 1: Tables A1, A2 & A4).

Miscellaneous Early Shuswap

For the sensitivity analysis a scalar of 0.42 (Appendix 1: Table A2) was applied to the five year old return (6,000) predicted by the 2015 forecast model for miscellaneous Early Shuswap (RS (Scotch/Seymour)), reducing the five year old forecast to 2,500 (Appendix 1: Table A3), and the overall forecast to 4,000 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 50% (at the 50% probability level) (Appendix 1: Table A3).

Taseko

For the sensitivity analysis a scalar of 0.51 (Appendix 1: Table A2) was applied to the five year old return (300) predicted by the 2015 forecast model for miscellaneous Taseko (RS (Chilko)), decreasing the five year old forecast to 200 (Appendix 1: Table A3), and the overall forecast to 400 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 25% (at the 50% probability level) (Appendix 1: Table A3). This is an extremely uncertain scalar given the small stock size and uncertainty in return and escapement estimates.

Chilliwack

Since the model used to generate the 2016 forecast for Chilliwack (Ricker) differs from that used in 2015 (RS (Esum)), no sensitivity analysis was conducted. Instead, the official forecast was included in the sensitivity analysis table (Appendix 1: Table A1).

Nahatlach

For the sensitivity analysis a scalar of 0.37 (Appendix 1: Table A2) was applied to the five year old return (7,000) predicted by the 2015 forecast model (RS (Esum)) for miscellaneous Nahatlach, reducing the five year old forecast to 3,000 (Appendix 1: Table A3), and the overall forecast to 10,000 at the 50% probability level (Appendix 1: Table A1). The five year old contribution to the scaled RS (Esum) forecast is 30% (at the 50% probability level) (Appendix 1: Table A3).

Chilko

For the sensitivity analysis a scalar of 0.36 (Appendix 1: Table A2) was applied to the five year 2016 forecast (26,000) predicted by the 2015 forecast model for Chilko (power (juv) (Pi)), reducing the five year old forecast to 9,000 (Appendix 1: Tables A3 & A4), and the overall forecast to 985,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 1% (at the 50% probability level) (Appendix 1: Table A3). For comparison, a sibling five year old forecast was also generated used preliminary four year old returns for Chilko in 2015 to predict 2016 five year old returns. The sibling model five year old forecast was larger (50% p-level: 60,000) than the scaled Larkin model (50% p-level: 9,000).

Quesnel

For the sensitivity analysis a scalar of 0.21 (Appendix 1: Table A2) was applied to the five year 2016 forecast (63,000) predicted by the 2015 forecast model (Ricker-cyc) for Quesnel. The scalar reduced the five year old forecast of the Ricker-cyc model to 13,000 (Appendix 1: Table A4), and the overall forecast to 14,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled Ricker-cyc forecast is 93% (at the 50% probability level). This scaled forecast is very similar to the Ricker-cyc (four year old)-sibling (five year old) forecast of 15,000 (Appendix 1: Table A3).

Late Stuart

Since the model used to generate the 2016 forecast for Late Stuart (R1C) differs from that used in 2015 (power), for the sensitivity analysis the 2015 model (power) was used to generate a total forecast for this stock (50% probability level forecast: 195,000) (Appendix 1: Table A4). A scalar of 0.16 (Appendix 1: Table A2) was then applied to the five year old component of this return forecast (3,000), reducing the five year old forecast to 1,000 (Appendix 1: Table A3 & A4). The overall forecast produced by the scaled power model (50% probability level forecast: 193,000) is slightly smaller than the unscaled power model forecast, and is very similar the official R1C forecast (50% probability level forecast: 192,000). The contribution of five year olds to the scaled power forecast is 1% (Appendix 1: Table A3).

Stellako

Since the model used to generate the 2016 forecast for Stellako (R2C) differs from that used in 2015 (Larkin), for the sensitivity analysis the 2015 model (Larkin) was used to generate a total forecast for this stock (50% probability level forecast: 526,000) (Appendix 1: Table A4). A scalar of 0.20 (Appendix 1: Table A2) was then applied to the five year old component of this return forecast (42,000), reducing the five year old forecast to 8,000 (Appendix 1: Table A3 & A4). The overall forecast produced by the scaled Larkin model (50% probability level forecast: 492,000) is smaller than the unscaled Larkin model forecast, but is still much larger than the official R2C forecast (50% probability level forecast: 256,000). The contribution of five year olds to the scaled Larkin forecast is 2% (Appendix 1: Table A3).

Harrison

Since the model used to generate the 2016 forecast for Harrison differs from that used in 2015, no sensitivity analysis was conducted. Instead, the official forecast was included in the sensitivity analysis table (Appendix 1: Table A1).

Raft

For the sensitivity analysis a scalar of 1.45 (Appendix 1: Table A2) was applied to the five year 2016 forecast (15,000) predicted by the 2015 forecast model for Raft (Ricker (PDO)), increasing the five year old forecast to 21,000 (Appendix 1: Table A3), and the overall forecast to 32,000 at the 50% probability level (Appendix 1: Tables A1 and A4). The five year old contribution to the scaled forecast is 66% (at the 50% probability level) (Appendix 1: Table A3).

Miscellaneous North Thompson Tributaries

For the sensitivity analysis a scalar of 4.33 (Appendix 1: Table A2) was applied to the five year 2016 forecast (1,000) predicted by the 2015 forecast model for Miscellaneous North Thompson tributaries (RS (Raft & Upper Barriere)), increasing the five year old forecast to 3,000 (Appendix 1: Table A3), and the overall forecast to 5,000 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 80% (at the 50% probability level) (Appendix 1: Table A3).

Miscellaneous North Thompson River

For the sensitivity analysis a scalar of 4.33 (Appendix 1: Table A2) was applied to the five year 2016 forecast (4,000) predicted by the 2015 forecast model for the miscellaneous North Thompson River stocks (RS (Raft & Upper Barriere)) increasing the five year old forecast to 19,000 (Appendix 1: Table A3), and the overall forecast to 19,000 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 99% (at the 50% probability level) (Appendix 1: Table A3).

Miscellaneous Widgeon

For the sensitivity analysis a scalar of 0.03 (Appendix 1: Table A2) was applied to the five year 2016 forecast (3,000) predicted by the 2015 forecast model for the miscellaneous Widgeon stocks (RS (Birkenhead)) reducing the five year old forecast to ~100 (Appendix 1: Table A3), and the overall forecast to 1,000 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 0% (at the 50% probability level) (Appendix 1: Table A3).

Cultus

For the sensitivity analysis a scalar of 0.22 (Appendix 1: Table A2) was applied to the five year 2016 forecast (300) predicted by the 2015 model for Cultus (MRJ), reducing the five year old forecast to 100 (Appendix 1: Table A4), though the overall forecast remained the same due to the low contribution of five year olds to the total forecast (0%) (Appendix 1: Tables A1, A3 & A4).

Late Shuswap

Since the model used to generate the 2016 forecast for Late Shuswap (Larkin) differs from that used in 2015 (Ricker-cyc), for the sensitivity analysis the 2015 model (Ricker-cyc) was used to generate a total forecast for this stock (50% probability level forecast: 9,000) (Appendix 1: Table A4). A scalar of 0.13 (Appendix 1: Table A2) was then applied to the five year old component of this return forecast (9,000), reducing the five year old forecast to 1,000 (Appendix 1: Table A3 & A4). The overall forecast produced by the scaled Ricker-cyc model (50% probability level forecast: 1,000) is smaller than the unscaled Ricker-cyc model forecast and the official Larkin model forecast (50% probability level forecast: 4,000). The contribution of five year olds to the scaled Ricker-cyc forecast is 100% (Appendix 1: Table A3).

Portage

For the sensitivity analysis a scalar of 0.13 (Appendix 1: Table A2) was applied to the five year 2016 forecast (100) predicted by the 2015 forecast model for Portage (Larkin), reducing the five year old forecast to 0 (at the 50% p-level) (Appendix 1: Table A4), and the overall forecast to 300 (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled forecast is 0% (Appendix 1: Table A3).

Weaver

For the sensitivity analysis a scalar of 0.001 (Appendix 1: Table A2) was applied to the five year 2016 forecast (67,000) predicted by the 2015 forecast model (MRS) for Weaver. The scalar reduced the five year old forecast to ~100 (Appendix 1: Table A4), and the overall forecast to 5,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled MRS forecast is 0% (at the 50% probability level). This scaled forecast is very similar to the MRS (four year old)-sibling (five year old) forecast (Appendix 1: Table A3).

Birkenhead

For the sensitivity analysis a scalar of 0.23 (Appendix 1: Table A2) was applied to the five year 2016 forecast (52,000) predicted by the 2015 five year old forecast model for Birkenhead (sibling). The scalar reduced the five year old forecast to 34,000 (Appendix 1: Table A4), and the overall forecast (combined Ricker(Ei) + sibling model) to 48,000 at the 50% probability level (Appendix 1: Tables A1 & A4). The five year old contribution to the scaled combined Ricker (Ei) + sibling model forecast is 43% (at the 50% probability level). This scaled forecast is smaller than the unscaled Ricker (Ei) (four year old)-sibling (five year old) forecast (Appendix 1: Table A3 & A4).

Miscellaneous Harrison/Lillooet Lakes

For the sensitivity analysis a scalar of 0.23 (Appendix 1: Table A2) was applied to the five year 2016 forecast (21,000) predicted by the 2015 forecast model for the miscellaneous Non-Shuswap stocks (RS (Birkenhead)) reducing the five year old forecast to 5,000 (Appendix 1: Table A3), and the overall forecast to 11,000 at the 50% probability level (Appendix 1: Tables A1 & A3). The five year old contribution to the scaled forecast is 45% (at the 50% probability level) (Appendix 1: Table A3).

Table A1. Scalar-based 2016 Fraser Sockeye Forecasts

Run timing group / Stocks	Forecast Model [b]	Probability that Return will be at/or Below Specified Run Size [a]				
		10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	*Ricker (Ei)*	**13,000**	**22,000**	**36,000**	**59,000**	**89,000**
Early Summer		**267,000**	**476,000**	**858,000**	**1,541,000**	**2,761,000**
(total excluding miscellaneous)		***137,000***	***213,000***	***368,000***	***655,000***	***1,103,000***
Bowron	*MRS*	1,000	1,000	2,000	4,000	7,000
Fennell	*power*	4,000	6,000	9,000	18,000	25,000
Gates	*Larkin*	19,000	34,000	64,000	122,000	212,000
Nadina	*MRJ*	24,000	45,000	90,000	179,000	331,000
Pitt	*Larkin*	86,000	120,000	189,000	304,000	473,000
Scotch	*Ricker*	2,000	5,000	10,000	23,000	49,000
Seymour	*Ricker*	1,000	2,000	4,000	5,000	6,000
Misc (EShu) [c]	*RS (Scotch/Seymour)*	1,000	2,000	4,000	7,000	13,000
Misc (Taseko) [d]	*R/S (Chilko)*	0	0	0	1,000	1,000
Misc (Chilliwack) [e]	*RS (Esum)*	NA	NA	**138,000	NA	NA
Misc (Nahatlatch) [e]	*RS (Esum)*	3,000	5,000	10,000	17,000	32,000
Summer		**679,000**	**1,062,000**	**1,741,000**	**2,862,000**	**4,542,000**
(total excluding miscellaneous)		***672,000***	***1,047,000***	***1,716,000***	***2,813,000***	***2,829,000***
Chilko	*power (juv) (Pi)*	421,000	632,000	985,000	1,557,000	2,265,000
Quesnel	*Ricker-cyc*	4,000	7,000	14,000	29,000	54,000
Late Stuart	*R1C*	45,000	90,000	193,000	431,000	884,000
Stellako	*R2C*	190,000	299,000	492,000	749,000	1,154,000
Harrison [f]	*NA*	NA	NA	**176,000	NA	NA
Raft [f]	*Ricker (PDO)*	12,000	19,000	32,000	47,000	80,000
Misc (N. Thomp. Tribs) [f & g]	*R/S (Raft/Fennell)*	1,000	3,000	5,000	9,000	20,000
Misc (N. Thomp River) [f & g]	*R/S (Raft/Fennell)*	6,000	11,000	19,000	38,000	81,000
Misc (Widgeon) [f & h]	*R/S (Birkenhead)*	400	1,000	1,000	2,000	4,000
Late		**35,000**	**43,000**	**69,000**	**120,000**	**210,000**
(total excluding miscellaneous)		***32,000***	***37,000***	***58,000***	***101,000***	***176,000***
Cultus	*MRJ*	1,000	2,000	4,000	8,000	16,000
Late Shuswap	*Ricker-cyc*	200	500	1,000	3,000	7,000
Portage	*Larkin*	100	200	300	800	2,000
Weaver	*MRS*	1,000	3,000	5,000	9,000	16,000
Birkenhead	*Ricker (Ei)*	30,000	31,000	48,000	80,000	135,000
Misc. non-Shuswap [i]	*R/S (Birkenhead)*	3,000	6,000	11,000	19,000	34,000
TOTAL SOCKEYE SALMON		**994,000**	**1,603,000**	**2,704,000**	**4,582,000**	**7,602,000**
(TOTAL excluding miscellaneous)		***854,000***	***1,319,000***	***2,178,000***	***3,628,000***	***5,805,000***

a. Probability that return will be at, or below, specified projection.
b. See Table 4 for model descriptions
c. Misc. Early Shuswap stocks use Scotch and Seymour R/EFS in forecast;
d. Misc. Taseko uses Chilko R/EFS in forecast
e. Misc. Chilliwack & Nahatlach uses Early Summer Run stocks R/EFS in forecast
f. Raft, Harrison, Miscellaneous North Thompson stocks were re-assigned to the Summer Run timing group due to changes in run timing of these stocks
g. Misc. North Thompson stocks use Raft & Fennel R/EFS in forecast
h. Misc. Late Run stocks (Harrison Lake downstream migrants including Big Silver, Cogburn, etc.), and river-type Widgeon use Birkenhead R/EFS in forecast
Definitions: Ei (Entrance Island sea-surface-temperature); Pi (Pine Island sea-surface temperature); PDO (Pacific Decadal Oscillation).

Table A2. Scalars used for scalar-based five year old forecasts.

Run timing group Stocks Stocks	**Forecast Model** [b]	**Age 4 Forecast 50% Probability**	**Age 4 Observed Return**	**2015 Near-Final Escapement**	**2016 Age 5 Scalar**
Early Stuart	*Ricker (Ei)*	1,000	2,400	10,000	2.44
***Early Summer** (total excluding miscellaneous)*					
Bowron	*MRS*	13,000	7,200	4,000	0.53
Fennell	*power*	22,000	2,900	1,400	0.13
Gates	*Larkin*	128,000	38,000	20,300	0.28
Nadina	*MRJ*	7,000	7,000	34,400	1.01
Pitt	*Larkin*	29,000	71,300	38,500	2.36
Scotch [b]	*Ricker*	152,000	13,300[b]	6,600	0.09
Seymour [b]	*Ricker*	96,000	15,900[b]	7,900	0.17
Misc (Early Shuswap) [b]	*R/S*	61,000	25,600[b]	12,700	0.42
Misc (Taseko)	*R/S*	3,000	1,500	1,000	0.51
Misc (Chilliwack)	*R/S*	15,000	11,900	6,700	0.79
Misc (Nahatlatch)	*R/S*	21,000	7,800	4,400	0.37
***Summer** (total excluding miscellaneous)*					
Chilko	*power (juv) (Pi)*	2,122,000	755,900	663,000	0.36
Quesnel	*Ricker-cyc*	160,000	33,300	46,000	0.21
Late Stuart [c]	*power*	26,000	4,100[c]	11,000	0.16
Stellako [c]	*Larkin*	186,000	37,600[c]	101,000	0.20
Harrison [d]	*Ricker (Ei)*	141,000	19,400[c]	116,000	0.14
Raft	*Ricker (PDO)*	26,000	37,600	16,000	1.45
Misc (N. Thomp.Trib&River)	*R/S*	13,000	56,200	24,000	4.33
Misc (Widgeon)	*R/S*	4,000	200	137	0.03
***Late** (total excluding miscellaneous)*					
Cultus [e]	*MRJ*	6,000	1,300[d]	1,200[d]	0.22
**Late Shuswap [f]	*Ricker-cyc*	350,000	45,300	10,000	0.13
Portage [f]	*Larkin*	5,000	NA[e]	36	0.13
Weaver	*MRS*	274,000	300	3,000	0.001
[xx]Birkenhead	*Ricker (Ei)*	236,000	62,800	46,000	0.23
Misc non-Shuswap	*R/S*	39,000	NA	8,000	0.23

a. Forecast model used to generate the 2015 four year old forecasts.
b. In-season these stocks are assessed as an aggregate. Individual stock returns were partitioned out of the total using preliminary spawning ground escapement proportions assessed on the spawning grounds.
c. Late Stuart and Stellako are aggregated in in-season returns. Individual stocks were partitioned out using the pre-season forecast abundances at the 50% p-level.
d. Harrison are three year old forecasts and returns in 2015
e. Cultus returns are based on preliminary spawning ground escapement proportions.
f. Portage is combined with Late Shuswap and therefore the same scalar is applied to both these stocks.

Table A3. Age composition of age-5 scalar-based forecasted returns at the 50% probability level

Sockeye stock/timing group	2016 Fraser Sockeye Forecasts				
	Model	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%	TOTAL 50%	Five Year Old Proportion
Early Stuart	*Ricker (Ei)*	**36,000**	**300**	**36,000**	**0%**
Early Summer		**335,000**	**187,000**	**520,000**	**64%**
Bowron	*MRS*	200	2,000	2,000	90%
Fennell	*power*	9,000	0	9,000	6%
Gates	*Larkin*	61,000	4,000	64,000	5%
Nadina	*MRJ*	88,000	2,000	90,000	2%
Pitt	*Larkin*	18,000	171,000	189,000	90%
Scotch	*Ricker*	10,000	0	10,000	0%
Seymour	*Ricker*	3,000	400	4,000	10%
Misc (EShu)	*RS (Scotch/Seymour)*	2,000	2,500	4,000	50%
Misc (Taseko)	*RS (Chilko)*	300	200	400	25%
Misc (Chilliwack) [b]	*RS (Esum)*	137,000	1,000	138,000	1%
Misc (Nahatlatch)	*RS (Esum)*	7,000	3,000	10,000	30%
Summer		**1,714,000**	**202,000**	**1,917,000**	**4%**
Chilko	*power (juv) (Pi)*	976,000	9,000	985,000	1%
Quesnel	*Ricker-cyc*	1,000	13,000	14,000	93%
Late Stuart	*Power*	192,000	1,000	193,000	1%
Stellako	*Larkin*	484,000	8,000	492,000	2%
Harrison [c]	*NA*	48,000 (age-4)	128,000 (age3)	176,000	27% (age-4)
Raft	*Ricker (PDO)*	11,000	21,000	32,000	66%
Misc (N. Thomp. Tribs)	*R/S (Ra/Fe)*	1,000	3,000	5,000	80%
Misc (N. Thomp River)	*R/S (Ra/Fe)*	200	19,000	19,000	99%
Widgeon	*R/S (Birkenhead)*	1,000	100	1,000	0%
Late		**29,000**	**40,000**	**69,000**	**58%**
Cultus	*MRJ*	4,000	100	4,000	0%
Late Shuswap	*Ricker-cyc*	0	1,000	1,000	100%
Portage	*Larkin*	300	0	300	0%
Weaver	*MRS*	5,000	100	5,000	0%
Birkenhead	*Ricker (Ei)*	14,000	34,000	48,000	71%
Misc. non-Shuswap	*R/S (Birkenhead)*	6,000	5,000	11,000	45%
Total		**2,114,000**	**429,000[c]**	**2,542,000**	17%

a. Probability that actual return will be at or below specified run size
b. Chilliwack and Harrison are the official forecasts from Table 1; scalar analysis was not meaningful since models between 2015 and 2016 were very different.
c. Harrison are four (in four year old columns) and three (in five year old columns) year old forecasts

**Chilliwack and Harrison used very different models in the 2016 forecast versus 2015, therefore, no scalars were applied for these stocks and the official forecast was included in the sensitivity analysis table.

Table A4. Top model regular and scaled forecasts of total return and five year old component by stock.

EARLY STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	1	13,000	22,000	36,000	59,000	89,000
Ricker (Ei) Scaled	**NA**	**13,000**	**22,000**	**36,000**	**59,000**	**89,000**
Five year old forecasts						
Ricker (Ei)	NA	--	--	100	--	--
Ricker (Ei) Scaled	NA	--	--	300	--	--

EARLY SUMMER

BOWRON	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS	1	1,000	2,000	4,000	8,000	13,000
MRS Scaled	**NA**	**1,000**	**1,000**	**2,000**	**4,000**	**7,000**
Five year old forecasts						
MRS	NA	--	--	4,000	--	--
MRS Scaled	NA	--	--	2,000	--	--

FENNELL	Rank	Return Forecast 10%	25%	50%	75%	90%
power	1	6,000	9,000	14,000	23,000	39,000
power Scaled	**NA**	**4,000**	**6,000**	**9,000**	**18,000**	**25,000**
Five year old forecasts						
power	NA	--	--	5,000	--	--
power Scaled	NA	--	--	0	--	--

GATES	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	3	24,000	40,000	76,000	138,000	231,000
Larkin Scaled	**NA**	**19,000**	**34,000**	**64,000**	**122,000**	**212,000**
Five year old forecasts						
Larkin	NA	--	--	15,000	--	--
Larkin Scaled	NA	--	--	4,000	--	--

NADINA	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	1	24,000	45,000	90,000	179,000	331,000
MRJ Scaled	**NA**	**24,000**	**45,000**	**90,000**	**179,000**	**331,000**
Five year old forecasts						
MRJ	NA	--	--	2,000	--	--
MRJ Scaled	NA	--	--	2,000	--	--

PITT	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	1	42,000	60,000	90,000	147,000	212,000
Larkin Scaled	**NA**	**86,000**	**120,000**	**189,000**	**304,000**	**473,000**
Five year old forecasts						
Larkin	NA	--	--	72,000	--	--
Larkin Scaled	NA	--	--	171,000	--	--
sibling (five year olds)	NA	44,000	70,000	113,000	183,000	283,000

SCOTCH	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	1	300	2,000	12,000	89,000	698,000
Ricker	2	2,000	5,000	10,000	23,000	49,000
Ricker Rescaled	**NA**	**2,000**	**5,000**	**10,000**	**23,000**	**49,000**
Five year old forecasts						
Larkin	NA	--	--	20	--	--
Ricker	NA	--	--	20	--	--
Ricker Rescaled	NA	--	--	0	--	--

SEYMOUR	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	2	0	100	400	1,000	3,000
Ricker	10	2,000	3,000	5,000	11,000	21,000
Ricker Rescaled	**NA**	**1,000**	**2,000**	**4,000**	**5,000**	**6,000**
Five year old forecasts						
Larkin	NA	--	--	30	--	--
Ricker	NA	--	--	2,000	--	--
Ricker Rescaled	NA	--	--	400	--	--

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
power (juv) (Pi)	1	459,000	658,000	1,002,000	1,573,000	2,283,000
power (juv) (Pi) Scaled	**NA**	**421,000**	**632,000**	**985,000**	**1,557,000**	**2,265,000**
Five year old forecasts						
power (juv) (Pi)	NA	--	--	26,000	--	--
power (juv) (Pi) Scaled	NA	--	--	9,000	--	--
sibling (five year old)	NA	18,000	32,000	60,000	111,000	194,000

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker-cyc	3	15,000	30,000	63,000	133,000	253,000
Ricker-cyc Scaled	**NA**	**4,000**	**7,000**	**14,000**	**29,000**	**54,000**
Ricker-cyc 4 year olds + sibling 5 year olds	NA	6,000	9,000	15,000	25,000	40,000
Five year old forecasts						
Ricker-cyc	NA	--	--	63,000	--	--
Ricker-cyc Scaled	NA	--	--	13,000	--	--
sibling (five year old)	NA	5,000	8,000	14,000	24,000	39,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	42,000	86,000	192,000	427,000	880,000
power	3	46,000	91,000	195,000	432,000	885,000
power Scaled	**NA**	**45,000**	**90,000**	**193,000**	**431,000**	**884,000**
Five year old forecasts						
R1C	NA	--	--	4,000	--	--
power	NA	--	--	3,000	--	--
power Scaled	NA	--	--	1,000	--	--
sibling (five year old)	NA	200	400	1,000	2,000	3,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
R2C	1	86,000	144,000	256,000	454,000	761,000
Larkin	2	230,000	337,000	526,000	780,000	1,176,000
Larkin Scaled	**NA**	**190,000**	**299,000**	**492,000**	**749,000**	**1,154,000**
Five year old forecasts						
R2C	NA	--	--	20,000	--	--
Larkin	NA	--	--	42,000	--	--
Larkin Scaled	NA	--	--	8,000	--	--
sibling (five year old)	NA	8,000	13,000	22,000	36,000	58,000

HARRISON	Rank	Return Forecast 10%	25%	50%	75%	90%
		Scaling not appropriate				

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)	1	11,000	16,000	26,000	38,000	62,000
Ricker (PDO) Scaled	**NA**	**12,000**	**19,000**	**32,000**	**47,000**	**80,000**
Five year old forecasts						
Ricker (PDO)	NA	--	--	15,000	--	--
Ricker (PDO) Scaled	NA	--	--	21,000	--	--

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	1	1,000	2,000	4,000	9,000	17,000
MRJ Rescaled	**NA**	**1,000**	**2,000**	**4,000**	**8,000**	**16,000**
Five year old forecasts						
MRJ	NA	--	--	300	--	--
MRJ Rescaled	NA	--	--	100	--	--

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	5	0	100	4,000	25,000	76,000
Ricker-cyc	2	1,000	3,000	9,000	21,000	55,000
Ricker-cyc Rescaled	**NA**	**200**	**500**	**1,000**	**3,000**	**7,000**
Five year old forecasts						
Larkin	NA	--	--	4,000	--	--
Ricker-cyc	NA	--	--	9,000	--	--
Ricker-cyc Rescaled	NA	--	--	1,000	--	--
sibling (five year old)	NA	700	1,000	3,000	7,000	15,000

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin*	1	100	200	400	900	2,000
Larkin Rescaled	**NA**	**100**	**200**	**300**	**800**	**2,000**
Five year old forecasts						
Larkin	NA	--	--	100	--	--
Larkin Rescaled	NA	--	--	0	--	--

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS	2	21,000	38,000	72,000	138,000	246,000
MRS Scaled	**NA**	**1,000**	**3,000**	**5,000**	**9,000**	**16,000**
MRS four year olds + sibling 5 year olds	NA	2,000	4,000	8,000	15,000	29,000
Five year old forecasts						
MRS	NA	--	--	67,000	--	--
MRS Scaled	NA	--	--	0	--	--
sibling (five year old)	NA	600	1,000	3,000	6,000	13,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker(Ei) four year olds + sibling 5 year olds	NA	30,000	45,000	68,000	105,000	158,000
Ricker(Ei) Scaled	**NA**	**30,000**	**31,000**	**48,000**	**80,000**	**135,000**
Five year old forecasts						
sibling (five year olds)	NA	22,000	31,000	52,000	83,000	136,000
Ricker(Ei) Scaled	NA	8,000	18,000	34,000	68,000	122,000

Table A5. Top model regular and scaled forecasts of total return and five year old component for Chilliwack

CHILLIWACK	10%	25%	50%	75%	90%
Ricker	17,000	46,000	138,000	378,000	1,101,000
R/S (Early Summers)	126,000	255,000	475,000	860,000	1,610,000
R/S (Early Summers) Scaled	126,000	256,000	476,000	861,000	1,612,000
Five year old forecasts					
Ricker	--	--	1,000	--	--
R/S (Early Summers)	--	--	5,000	--	--
R/S (Early Summers) Scaled	--	--	6,000	--	--

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