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PRE-SEASON RUN SIZE FORECASTS FOR FRASER RIVER SOCKEYE *(ONCORHYNCHUS NERKA)* AND PINK *(O. GORBUSCHA)* SALMON IN 2015

Context

Pre-season run size forecasts of returning Fraser River adult Sockeye and Pink Salmon in 2015 were requested by Fisheries and Oceans Canada (DFO) Fisheries Management. Forecasts are used for pre-season planning purposes and for in-season management. They are most useful early in each stock-group's return migration, before in-season test fisheries are able to provide reliable in-season run size estimates. Forecasts are produced by DFO as stipulated in Annex IV, Chapter 4 of the Pacific Salmon Treaty and are presented by stock and run timing group.

Forecasts are presented as cumulative probabilities (10%, 25%, 50%, 75%, and 90%) to capture inter-annual random (stochastic) uncertainty in Fraser Sockeye and Pink returns. A stock's forecast probability distribution represents largely the range of survival it has exhibited historically (although other factors such as observation error also influence the distribution). Forecast values at the lower p-levels represent lower stock survival and, conversely, values at the higher p-levels represent higher stock survival. The 50% (median) probability level (p-level) is the mid-point of the forecast distribution, indicating a one in two chance that returns will be at or below this value (or conversely a one in two chance returns will be above this value), assuming that stock survival is similar to past observations. Since not all stocks will exhibit similar survival, current methods used to estimate the total Fraser Sockeye Salmon return forecast distribution, which sums the individual stock return forecasts for each p-level, over-estimate the range of potential total returns. It is therefore more appropriate to reference individual stock's return forecasts versus the total Fraser Sockeye forecast. Alternative forecasts, generated from different model forms (e.g. Ricker, Power, Larkin, etc.), are also presented for each stock to capture the structural uncertainty in the forecasts.

The 2015 Fraser Sockeye forecast is dominated by the following stocks: Chilko: 35%; Harrison: 21%; and Late Shuswap 7% (Table 1A). The Summer Run timing group contributes the most to the total return forecast at 69%, followed by the Late Run (18%), the Early Summer Run (12%), with the Early Stuart Run contributing the smallest percentage (<1%) to the total return forecast in 2015.

Forecasts for 2015 that are particularly uncertain due to either additional uncertainty that is not quantified in the forecast distribution, or, different model forms that indicate notably different return forecasts (and, therefore survival), include the following:

Chilko Sockeye: median forecasts of four year olds (based on preliminary in-season three year old returns in 2014 used in alternative sibling models) indicate that returns for this stock could be substantially lower than the predictions from the traditional set of models presented.

Harrison Sockeye: this stock has exhibited dramatic increases in survival and abundance starting in 2000, and exceptional escapement in 2011 (four year old Harrison Sockeye returning in 2015). Little data exists to predict this stock's survival following the record escapement, and therefore, this forecast is highly uncertain.

Canada

Scotch, Seymour, Late Shuswap, Portage, Gates: these stocks exhibited record escapement in the 2010 brood year (or in the case of Gates the 2011 brood year), which will contribute to the 2015 five year old returns (or four year old returns in the case of Gates); as a result five year old forecast models (or four year old in the case of Gates) are being extrapolated beyond the observed stock-recruitment range for these stocks, which adds additional uncertainty to these forecasts. Note: Scotch forecasts are additionally uncertain since the stock-recruitment time series is short (brood years 1980-2007) and this stock has been increasing in abundance since the start of the time series.

Fraser Pink Salmon: the Pink fry time series is considered an index of abundance only, and observation error remains unquantified. In addition, there have been considerable methodological changes in the recruitment time series (both in escapement and catch) over time. As a result, the Fraser Pink 2015 forecast distribution of returns does not reflect the full range of uncertainty.

This Science Response Report results from the Science Response Process of November 25, 2014 on the Pre-season abundance forecasts for Fraser River Sockeye and Pink Salmon returns in 2015. The 2015 forecast relies methods of past CSAS processes and publications (Cass et al. 2006; DFO 2006, 2009, 2011, 2012, 2013a, 2014a, 2014b; Grant & MacDonald 2013; MacDonald & Grant 2012).

To support the 2015 Fraser Sockeye forecast, an additional Science Response process occurred on January 27 and 28, 2015 to summarize data and information on fish condition and/or survival from the 2011 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 and Pink Forecasts

Pre-season return forecasts are produced annually for 19 Fraser Sockeye stocks, eight additional miscellaneous stock groups, and Fraser Pink Salmon using a suite of forecast models (Table 4). To capture inter-annual random (stochastic) uncertainty in returns (largely attributed to variations in stock survival), forecasts are presented as standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%) using Bayesian statistics for biological models, or residual error for non-parametric models (Grant et al. 2010). At the 25% p-level, for example, there is a one in four chance that the actual return will fall at or below the specified return prediction, given the historical data. In addition to stochastic uncertainty, structural uncertainty was also explored in the forecast process through the comparison of alternative (lower ranked in terms of model performance) model forecasts (Table 6). In cases where preliminary 2014 recruitment data of four year olds were available (Table 5), this also included an exploration of forecasts of five year olds using sibling models (four-to-five year old recruitment) (Table 6). In one case, where 2014 returns indicated extremely poor survival for a stock (Birkenhead), the forecasted number of five year olds based on the sibling model was used (Tables 5 & 6). For two stocks (Chilko and Cultus), four year old forecasts were also generated using sibling jack models (three-to-four year old recruitment) with preliminary three year old jack escapement data combined with assumptions regarding exploitation rates for these stocks in 2014 (Table 6). Sibling models are described in Appendix 2 of Grant et al. (2010). Note: sibling model performance (forecast versus actual returns) has not been evaluated relative to other models, since five year old forecasts generally represent a minor component of total returns for most stocks, and, in the case of four year old forecasts, three year old jack numbers post-1980 have been relatively small.

Fraser Sockeye Returns

Total Fraser Sockeye adult returns have historically varied (Figure 1 A) due to the four-year pattern of abundances (cyclic dominance) exhibited by some of the larger stocks, and variability in annual survival (Figures 1 A & B) and exploitation. After reaching a peak in the early 1990s, returns decreased to a record low in 2009 due to declines in stock survivals (Figures 1A and 1B). In subsequent years, survival, and consequently, returns have increased. The 2010 and 2014 returns were particularly large since this is the dominant cycle line for the Late Shuswap stock, and the combination of above average escapements relative to other cycle lines and above average to average survivals resulted in large returns in these years.

For the 2015 return cycle (the current forecast year), Chilko and Late Shuswap have historically contributed the greatest proportion (30% and 26%, respectively) to the total returns (Table 1B, column G). The 2015 cycle has the second smallest average return of the four cycles of Fraser River Sockeye, with an average annual return (1955-2011) of 5.2 million for all 19 forecasted stocks combined (excluding miscellaneous stocks) (Table 1B, column G; Figure 1A).

Fraser Sockeye Survival

Total survival (returns-per-spawner) aggregated across all Fraser Sockeye stocks declined in the 1990s and culminated in the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2014), survival was close to average (Figure 1 B). 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 and inter-annual variability in mortality occur in the freshwater and marine ecosystems, as indicated by freshwater and marine survival data for Chilko River Sockeye (Fraser Sockeye indicator stock) (Figure 2 A & B). Chilko is the only Fraser Sockeye stock with a long and complete time series of smolt data (estimated using an enumeration weir located at the outlet of Chilko Lake), 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 to the Strait of Georgia). It is likely that a number of factors in both the freshwater and marine environments influence Fraser Sockeye survival, and these factors may vary between stocks and years.

2015 Forecast Fraser Sockeye Brood Year Escapement (2010 & 2011)

The two dominant age classes for Fraser Sockeye are ages four and five. On average, age of maturity for Fraser Sockeye is predominantly four years, with these fish typically spending two winters in freshwater and two winters in the marine environment. A smaller proportion of recruits (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, however, can vary, depending on variability in age of maturity, differences in brood year escapements between the four and five year old brood years, and differences in survival between these brood years. Most notable for the 2015 returns are the record high or above average escapements exhibited by a number of stocks in the 2010 brood year (contributing five year olds to the 2015 returns) and the relatively low escapements in the 2011 brood year (contributing four year olds to the 2015 returns). There are a number of stocks where the 2010 escapements were much larger than the 2011 escapements (Early Stuart, Bowron, Nadina, Late Stuart, Quesnel, Stellako, and Cultus), and for some in particular (Scotch, Seymour, Harrison, Late Shuswap, and Portage) the 2010 escapements were the largest on record for the stock.

For the four year old returns in 2015, the number of effective female spawners (EFS) in the 2011 brood year (1,165,000 EFS) for all stocks was double the cycle average (583,000). For just over half of the 19 stocks (10 out of 19), brood year EFS or smolt (Chilko) abundances were close to, or above, average (Fennell, Gates, Pitt, Scotch, Chilko, Quesnel, Raft, Harrison, Weaver, and Birkenhead). For the remaining stocks (9 out of 19), brood year EFS in the 2011 brood year was below average (Early Stuart, Bowron, Nadina, Seymour, Late Stuart, Stellako, Cultus, Late Shuswap, and Portage). The Summer Run stocks Chilko (40%) and Harrison (34%) contributed the greatest proportion to the total 2011 EFS abundance. The next largest contributors to the total EFS abundance were two stocks in the Late Run timing group, Late Shuswap (4%) and Birkenhead (8%). All other stocks contributed less than 4% to the total EFS abundance.

Fraser Pink Returns

Fraser River Pink Salmon return as two-year old fish (spending one winter in freshwater and one winter in the marine environment), spawning in odd years. Fraser Pink returns from 1961 to 2013 were on average 13.4 million fish. Return abundances have varied over the time series, ranging from a minimum of 1.9 million in 1961 to a maximum of 24.5 million in 2003. Returns in recent years (2009 to 2013) have ranged from 15.9 to 20.6 million and have been above average (Figure 3 A).

Fraser Pink Survival

Total survival (returns-per-fry) data are associated with high uncertainty due to variability in escapement and catch methods over time (Figure 3 B). Due to this uncertainty, only a returns-per-fry survival was estimated for this stock to provide a broad indication of survival over the time series (brood years: 1967 to 2011). Over this period survival has been variable, with no clear patterns across the time series, unlike Fraser Sockeye stocks that have exhibited productivity patterns over time. Average productivity over the Fraser Pink Salmon time series was 3% (Table 2; Figure 3 B).

2015 Forecast Fraser Pink Brood Year Fry (2013)

Fraser Pink Salmon fry emerge from the gravel in early spring and migrate immediately to the Fraser estuary (Grant & Pestal 2009). Subsequently, they migrate through the Strait of Georgia into the North Pacific where they rear for one year (Grant & Pestal 2009) before returning to the Fraser River watershed to spawn. Pink fry abundance, which is an index of abundance only, has been on average 450 million (Figure 4). Fry abundances, similar to return abundances, have varied over the time series ranging from a minimum of 212 million in the 1973 brood year to a maximum of 1 billion in the 2009 brood year. In the 2013 brood year (2014 fry outmigration year), used to forecast 2015 returns, the preliminary estimate of fry abundance is 609 million, which is greater than the time series average (450 million) (Figure 4).

Analysis and Response

Methods

Fraser Sockeye Forecast Data

The last brood year for which full recruitment data (four and five year olds) are available for the 2015 forecast is 2007, with the exception of Harrison Sockeye. For Harrison, preliminary data are included for the 2008 to 2010 brood years to provide additional data points for years with exceptional escapements. For all stocks, although recruitment data have not been finalized for the 2012 return year, several 2015 forecast models require 2007 brood year data, and given the small proportion five year old recruits contribute to the total, 2012 five year old recruits were added to the time series.

Juvenile (fall fry) data are available for both Shuswap and Quesnel for the 2010 brood year (five year old returns in 2015) and the 2011 brood year (four year old returns in 2015). For both Late Shuswap and Quesnel, fry assessments are conducted sporadically (large gaps in the fry time series) and, as a result, the performance of fry models was not evaluated in the 2012 cross-validation analysis (Table 5 in MacDonald and Grant, 2012).

In addition to biological data, several biological models incorporate environmental data: Pacific Decadal Oscillation (PDO) in the winter (November to March), average sea-surface-temperature (SST) from Entrance Island (Strait of Georgia, proximate to Nanaimo) (April to June) and Pine Island (NE corner of Vancouver Island) (April to July) lighthouse stations, and Fraser discharge (peak and average April to June average discharge). See MacDonald and Grant (2012) for further details. Data are available at the following websites:

- Joint Institute for the Study of the Atmosphere and Ocean: Pacific Decadal Oscillation (PDO) Index
- Fisheries and Oceans Canada, Pacific Region: Data from BC Lighthouses
- Environment Canada, Wateroffice: Historical Hydrometric Data Search

Fraser Sockeye Forecast Methods

The 2015 Fraser Sockeye forecasts follow the same approach as recent forecasts (DFO 2012; MacDonald & Grant 2012; DFO 2013; Grant & MacDonald 2013; DFO 2014a), which were adapted from methods used in earlier forecasts (Cass et al. 2006; DFO 2006; DFO 2007; DFO 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:

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 #8).
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 model forms 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 2015 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 2015 forecast (see page 8 of MacDonald and Grant 2012);

6) Given the larger proportion of five year olds expected for a number of stocks in 2015, due to their exceptional or high escapement in the 2010 brood year, sibling models were used to generate five year old forecasts where preliminary data on the number of four year olds returning in 2014 were available (Table 5). For two stocks (Chilko and Cultus), the preliminary number of three year olds returning in 2014 were used in sibling models to forecast four year olds. Sibling forecast models use linear regressions, respectively, of four-to-five year or three-to-four year old post-1980 recruitment data. These models are applied using Bayesian methods (1,000,000 iterations with a burn-in of 20,000) and are further described in Appendix 2 of Grant et al. 2010. Previous studies indicated that their performance does not outperform standard models across all years (Haeseker et al. 2008). Sibling models can be applied in years when proportions of five year olds are expected to be large, or following a year with large proportions of three year olds (jacks). The results of these models are useful comparisons to the official forecasts as a possible indication of poor or good survival for an age class, using the return abundance of a younger age-class from the same brood year.

7) An evaluation of preliminary returns in 2014 compared to the 2014 forecast (Table 5) was used to determine if survival was anomalously low or high, and in these cases, a sibling five year old forecast was merged with the four year old forecast selected using methods described above.

8) For the 2015 forecasts, biological model fit was re-examined for each of the top three ranked models by stock to ensure successful convergence of two separate Bayesian runs (each run was started using different initial parameter values). Though model convergence cannot be concretely demonstrated, diagnostics can be used to indicate if convergence has not occurred (Toft et al. 2007). Specifically, four diagnostics (trace plots, Gelman-Rubin diagnostics, Geweke values, and MC Error) were used to confirm that Monte-Carlo Markov-Chains (MCMC) exhibited the three stages of convergence: exploration, stationarity, and estimation (Mengersen et al. 1999) as described by Dodds and Vicini (2004). Exploration involved the visual confirmation that trace plots of the two MCMC chains effectively mixed. Further, the Gelman-Rubin diagnostic (modified by Brooks and Gelman), which compares the within-chain to the between-chain variance (Cowles & Carlin 1996), was considered acceptable as long as values were less than 1.1. To test for stationarity, Geweke's convergence diagnostic provides Z-scores for each parameter by comparing the first 10% of the MCMC chain to the last 50%. Z-scores below -2.5 and above +2.5 were determined significant, which indicates that chains were not stationary and therefore had not converged. In all cases where models did not satisfy these three convergence criteria, the burn-in was increased in size until they were satisfied, to a maximum of 100,000,000 iterations (default 20,000 iterations). In the few cases where convergence criteria were not satisfied at 100,000,000 MCMC iterations, the affected models were not considered for the 2015 forecast. Finally, to evaluate the estimation component of convergence, the Markov Chain standard error (MC Error) was used to measure how well the mean estimate of the posterior sample represents the true value of the parameter (Toft et al. 2007). The general rule requires that the MC error be less that 5% of the sample standard deviation when the posterior sample size is sufficient (Toft et al. 2007). For models that did not satisfy the MC Error criteria, the size of the posterior sample was increased until this criterion was satisfied. The final model selected for each stock for the 2015 forecast (presented in Tables 1 - 3) is based on a combination of their relative ranks and a set of consistent selection criteria (see MacDonald & Grant 2012).

9) Miscellaneous stocks, for which recruitment data are unavailable, were forecast using the product of their brood year escapements and the 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).

The merging of a four year old forecast using the selected model (based on methods described above), and a five year old sibling forecast, was conducted as follows:

1) each individual MCMC value for the five year old component of the selected model forecast was $\log_e$ transformed;
2) next, each of these $\log_e$ transformed values was standardized by subtracting the mean and dividing by the standard deviation calculated across all MCMC iterations;
3) separately, for the sibling model, each individual MCMC value for the five year old forecast was also $\log_e$ transformed;
4) then the transformed and normalized forecast five year old values from step 1 & 2 are multiplied by the standard deviation and the average estimated across all iterations from the $\log_e$ transformed sibling model forecast from step 3;
5) next this product for each iteration is back-transformed to its original scale by taking the exponent of each value; and
6) finally, the distribution of the total forecast is calculated by summing each iteration of the forecast four (output from the selected model) and the sibling five year old forecasts and from this new distribution and this distribution is used to estimate the various forecast percentiles.

Age proportion data using Bayesian approaches was pulled directly from the code for five year olds in Tables 3 and 6, with the exceptions of the following stocks (Fennell, Scotch, Seymour, Chilko, Late Stuart, Quesnel, Stellako, Raft, Late Shuswap), where the following methods were applied to pull age information from MCMC outputs:

1) use the MCMC values of the total forecast, four year old forecast, and five year old forecast (so within an MCMC iteration all the numbers are consistent and the number of fours plus five year olds add up to the total);
2) filter the MCMC values that have a total run size similar to each of the p-level forecast estimates (from 10% to 90% p-levels); and
3) for those selected MCMC records, select the median values for associated four and five year old values (so that the reported values now will add up).

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.

Fraser Pink Forecast Data

Fry abundance is used exclusively as the predictor variable in the relevant non-parametric and biological Fraser Pink forecasts (Figure 4). Escapement is not used as a predictor variable for Fraser Pinks given the large changes in the escapement methodologies over the time series (Figure 3; Grant et al. 2014). In contrast, fry abundances have been estimated using consistent methodology since the 1967 brood year (Vernon 1966; Grant et al. 2014). Although several fry assessments were conducted prior to the 1967 brood year, slightly different methods were applied in these years, and they were therefore excluded from the fry time series. Fraser Pink fry estimates are considered indices of abundance only and have large unquantified observation error associated with them. This uncertainty is not captured in the Fraser Pink forecasts. Pink fry abundance in the 2013 brood year was 609 million, which was above the long term average (450 million) (Table 1; Figure 4).

In addition to the unquantified uncertainty associated with the Fraser Pink fry estimates, recruitment data (brood years 1967 to 2013) are also additionally uncertain due to the variety of methods used to assess escapement and catch over the time series. First, escapement assessment methods have changed considerably over the time series (Figure 3 A). System specific estimates were generated from 1957 to 1991 (e.g. Lower Fraser, Fraser Canyon, Upper Fraser, Seton-Anderson, Thompson, Harrison, Vedder-Chilliwack) using a variety of assessment methods (mark-recapture, fence, tower, visual surveys). From 1993 to 2001, a single system-wide mark-recapture estimate (1993-2001) was generated for the Fraser River as a whole. From 2003 to 2007, directed escapement programs were terminated for Fraser Pinks, and escapements were indirectly estimated using test fishery methods, which were considered less reliable than all other methods applied over the time series. Finally, in recent years (2009 to present), a hydroacoustic program has been conducted to estimate Fraser Pink escapements at Mission, BC. Similarly, catch estimation and assignment of catch to stock (such as Fraser Pinks) in mixed stock fisheries has changed over the assessment period. Due to the large changes in escapement and catch methodologies over the time series, this data is extremely uncertain, the extent to which remains unquantified in the Fraser Pink forecast. The forecast distribution, therefore, does not capture the full range of uncertainty associated with this forecast. Recruitment data were updated for the 2015 forecast to include the 2011 brood year (2013 return year) (Figure 3 A). The total fry-to-recruitment time series used in the forecast includes the 1967 to 2011 brood years.

The only environmental covariate used in the power (juv) biological model is the average surface salinity at both Race Rocks (Juan de Fuca Strait) and Amphitrite Point (West Coast Vancouver Island) lighthouse stations from July to September. Sea surface salinity data are available at the DFO website with the exception of the 2013 brood year (2014 ocean entry year), which was provided separately (P. Chandler, DFO, pers. comm).

Fraser Pink Forecast Methods

The performance of Fraser River Pink Salmon forecast models was re-evaluated for the 2015 forecast (see Table 7) using the same jackknife approach used for Fraser Sockeye (methods presented in the 2012 forecast; MacDonald and Grant 2012). Similar to Fraser Sockeye forecasts, the models evaluated for Fraser Pink Salmon include non-parametric models that summarize past returns (TSA, R1C, and R2C; Table 4; and see Grant et al. 2011, Appendix 1 for details) and those that are the product of recent survivals and the brood year fry abundance for this stock (MRJ, RJ1, RJ2; Table 4; and see Grant et al. 2010, Appendix 1 for details). Uncertainty in these non-parametric forecasts is estimated as residual error, which is the deviation of annual forecasts from actual returns (Grant et al. 2010, Appendix 1). In addition, there are two biological forecast models that use fry abundance as a predictor variable (power, power-sea surface salinity; Grant et al. 2010, Appendix 2). Biological model forecasts are estimated using Bayesian methods, identical to the Fraser Sockeye forecasts (Grant et al. 2010, Appendix 2).

Results

Fraser Sockeye 2015 Forecasts: Overview

The 2015 forecast is dominated by the following stocks: Chilko: 35%; Harrison: 21%; and Late Shuswap 7% (Table 1A). The Summer Run timing group contributes the most to the total return forecast at 69%, followed by the Late Run (18%), the Early Summer Run (12%), with the Early Stuart Run contributing the smallest percentage (<1%) to the total return forecast in 2015.

Fraser Sockeye forecasts are associated with relatively high uncertainty (Table 1A), in large part due to wide variability in annual salmon survival (recruits-per-spawner), and observation error in the stock-recruitment data. High forecast uncertainty is consistent with previous Fraser Sockeye forecasts (Cass et al. 2006, DFO 2006, 2007, 2009, 2011, 2012; Grant & MacDonald 2013; MacDonald & Grant 2012) and recent research conducted on coast-wide salmon stocks (Haeseker et al. 2007; Haeseker et al. 2008).

For a number of Fraser Sockeye stocks, the 2015 returns are expected to be dominated by five year old recruits from the 2010 brood year. The 2010 Fraser Sockeye escapements were above average for most stocks (12 out of 19 stocks) and were the largest on record for some; therefore, the forecasted five year old returns from this large brood year make up a large proportion of the 2015 returns for particular stocks (Table 3). In cases where the large 2010 brood year escapements fell outside the range of previously recorded data (Scotch, Seymour, Harrison, Late Shuswap & Portage), or record 2011 brood year escapements in the case of Gates, EFS-based biological model were extrapolated outside their fitted range to generate forecasts, creating additional uncertainty in these forecasts. This issue is explained in the 2014 Fraser Sockeye Forecast Science Response (DFO 2014) for the four year old return forecasts from the same 2010 brood year.

Since fish from the same brood year (2010) will largely experience similar survival conditions, apart from the additional year five year olds spend in the ocean, comparing the 2014 returns to the 2014 forecasts can provide an indication of the survival experienced by the five year olds returning in 2015. For most stocks, returns in 2014 fell within the 25% to 75% p-levels, indicating average survival for these stocks (Table 5). The first exception is Harrison Sockeye, which returned at the high end of the 2014 forecast distribution (between the 75% and 90% p-levels). However, the 2014 Harrison Sockeye forecast had been flagged as extremely uncertain, given the lack of data to determine the level of density-dependent survival that this stock would experience following record escapement in 2010 and 2011.

In contrast to Harrison, the return of Birkenhead Sockeye in 2014 fell below the lowest p-level (10%) of the 2014 forecast, indicating extremely poor survival for this stock (Table 5). Given that Birkenhead was the only Fraser Sockeye stock that experienced exceptionally poor survival in 2014, it is likely that a unique mechanism(s) affected survival of this stock. For example, in the 2010 brood year a major landslide occurred in the Birkenhead system, caused by the Capricorn and Glacier Mountains (North of Pemberton), which resulted in rock and debris flows that blocked Meager Creek. Even though this event did not occur directly in the Birkenhead River, and the causal mechanism impacting Birkenhead Sockeye survival is unclear, it is possible that this event could have contributed to these poor returns.

Individual Stock Forecasts

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

The 2011 Early Stuart cycle line is the first off cycle following the dominant and subdominant cycle years. The 2011 brood year EFS for the Early Stuart stock (200) was the smallest escapement on record for this stock (1948-2013), which is less than 1% of the cycle average

(2011 cycle average 1951-2011: 25,200) (Table 1B, column C). In this brood year (2011), Sockeye Salmon returning to the Early Stuart system experienced extreme migratory conditions. Specifically, due to a delayed freshet, Early Stuart Sockeye encountered near record high water levels and flows in the lower Fraser River in June and July 2011, exceeding levels historically associated with poor migratory success for this stock. Subsequently, Early Stuart Sockeye arrived at the spawning grounds two to three weeks later than normal. Physical conditions on the spawning grounds appeared to be conducive to successful spawning, despite higher than average water levels. Spawner success was 81% (average: 89%), however, this estimate is uncertain, as access to carcasses was limited due to the low abundance of spawners, and carcass recoveries had to be pooled to produce system-wide estimates of spawning success and sex ratio. Early Stuart EFS estimates for 2011 may also be slightly biased low compared to previous years: a substantial fraction of the female carcasses may have been removed from the spawning stock by predators in the system prior to being surveyed; most streams were surveyed using aerial methods in 2011, which consistently produce lower counts than the typically used ground-based methods, upon which the expansion factors are based. However, since the streams that contributed the most to the 2011 escapement were assessed with ground surveys (i.e. Sidney (Felix), Paula, Kynoch, Forfar, Narrows (or Gluske)), and these represented 87% of the escapement in the brood year, the bias due to aerial assessments is considered limited. Although forecasts of four year old returns are more uncertain for Early Stuart for the reasons described above, this age class is only expected to contribute 5% to the Early Stuart forecast (see subsequent paragraphs).

In contrast to the record low escapement in the 2011 brood year, the 2010 brood year EFS for the Early Stuart stock (34,200) was the second largest on record for this cycle (the 1990 brood year was largest on record at 47,000), and almost double the cycle average (2010 cycle average 1950-2010: 18,400) (Table 1B, column D) (see DFO 2014a for more information on the 2010 brood year). Therefore, given the record low escapement in 2011, and high escapement in 2010, five year old returns are expected to dominate the total return for 2015.

Average 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; Figures 3 & 4). In recent years (2006 and 2007 brood years), survival (5.2 R/EFS) has been closer to the long-term average (6.3 R/EFS).

For Early Stuart, the top ranked models (based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE) are 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 15% from the largest forecast (Ricker (Ei)) (Table 6, see results overview for method of calculation). The Ricker (Ei) model was used for the 2015 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). 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 16,000 (3.0 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 58,000 (8.1 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 30,000 (4.8 age-4 R/EFS) is less than 20% of the average return on this cycle (162,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 95% (29,000) to the Early Stuart total forecast (at the 50% p-level) due to the well above average escapement in the 2010 brood year (34,200 EFS) (contributes 5 year olds in 2015) in comparison to the extremely small brood year escapement in 2011 (200 EFS) (contributes four year olds in 2015) (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Early Stuart (Ricker (Ei) model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 205,000) was the product of the in-season 2014 Early Stuart total return (four plus five year olds: 233,000) and the Early Stuart four year old proportion from the 2014 forecast (0.88) (in-season age composition data were not available at the time of this publication). The 50% probability interval of the five year old forecast for the sibling model (10,000 to 37,000 at the 25% and 75% p-levels) encompassed the median five year old forecast produced by the Ricker (Ei) model (29,000).

Early Summer Run

The Early Summer Run consists of a number of less abundant stocks relative 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, Fennell, Gates, Nadina, Pitt, Scotch, and Seymour (Table 1A). In 2012, the Fraser River Panel re-assigned Raft River, the North Thompson mainstem, and several stocks associated with miscellaneous streams that are tributary to the North Thompson River, to the Summer Run timing group (from the Early Summer-run group), following a re-evaluation of their migration timing. Thus, these reassigned stocks are excluded from the Early Summer-run data and forecasts in this section. Escapement in the 2011 brood year for all Early Summer stocks combined, excluding miscellaneous stocks, was 85,000 EFS (dominated by Pitt and Gates, which together comprise 67% of this total), falling above the long-term cycle average (59,000 EFS). Pitt Sockeye, which are comprised of predominantly five year old recruits, had an above average brood year escapement in 2011 (30,400), though the brood year escapement for 2010 (8,800 EFS, contributing the 5 year old recruits in 2015) was average (all cycle average 1948-2011: 14,100). Scotch contributed 15% of the total EFS for this group, and Nadina made up 14%. All others stocks comprised less than 10% of the total Early Summer escapement. The total 2011 brood year EFS for the Early Summer Run, including the miscellaneous stocks (miscellaneous Early Shuswap, Taseko, Chilliwack, and Nahatlatch) was 98,800.

Physical conditions on the Early Summer run spawning grounds were favourable for most of the spawning period, despite higher than average water levels. High water events occurred in the Chilliwack, Pitt, Nahatlatch and Nadina systems towards the end of the spawning period. Arrival and spawning timing were normal for all stocks. Elevated levels of pre-spawn mortality were observed in some areas, particularly in Nahatlatch, Nadina and the South Thompson system. Spawning success for the Early Summer aggregate in 2011 was 82%, falling below the long-term average (89%).

Bowron (Bowron-ES CU)

The 2011 brood year escapement for Bowron (2,000 EFS) was one quarter of the long-term cycle average (1951-2011 average: 8,200 EFS) (Table 1B, column C). Spawner success for Bowron in 2011 was 97% (average: 90%). The 2010 brood year escapements (4,400 EFS) was greater than the cycle average (1950-2006: 3,100 EFS) and greater than the 2011 brood year escapement.

Average 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; Figures 3 & 4). In recent years (2006 and 2007 brood years), survival (13.4 R/EFS) has been above average (6.9 R/EFS).

For Bowron, the top ranked models are MRS, Ricker (Pi), and Ricker (Ei) (Table 6). Forecasts produced by the top ranked models varied by 17% (Table 6), with the MRS model producing a slightly lower forecast than the two Ricker-environmental covariate models. The MRS model was used for the 2015 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). Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Bowron Sockeye return will be below 11,000 (3.4 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 40,000 (12.7 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 21,000 (6.5 age-4 R/EFS) is less than one third of the average return on this cycle (75,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 35% (~8,000) to the Bowron total forecast (at the 50% p-level) (Table 3). Sibling model forecasts could not be generated for Bowron, as 2014 four year old recruitment estimates were not yet available at the time of this publication.

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

The 2011 brood year escapement for Fennell (4,500 EFS) was similar to the cycle average (1967-2011 average: 5,000 EFS) (Table 1B, column C). Spawner success for Fennell in 2011 was 84% (average: 90%). The 2010 brood year escapement (5,500 EFS) was greater than the cycle average (1970-20106: 3,400 EFS) and greater than the 2011 brood year escapement.

Average four year old survival (R/EFS) for Fennell 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 recent years (2006 and 2007 brood years), survival (1.3 R/EFS) has remained below average (6.2 R/EFS).

For Fennell, the top ranked models are 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 32%, with the power model generating the smallest forecast and the Ricker model producing the largest (Table 6). The power model was used for the 2015 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). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Fennell Sockeye return will be below 16,000 (2.1 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 47,000 (7.8 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 27,000 (4.0 age-4 R/EFS) is smaller than the average return on this cycle (30,000), but is still within the average range (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 19% (5,000) of the Fennell total forecast (at the 50% p-level) (Table 3). Sibling model forecasts could not be generated for Fennell, as 2014 four year old recruitment estimates were not yet available at the time of this publication.

Gates (Anderson-Seton-ES CU)

The 2011 brood year escapement for Gates (26,400 EFS) was the largest on record for this stock and was five times higher than the cycle average (1971-2011 average: 4,900 EFS) (Table 1B, column C). Spawning success in Gates Channel was 53% (average: 68%) and in Gates Creek was 82% (average: 70%). High water in the system in mid-August delayed channel operations until after Sockeye arrival to the system. Once operational (August 15th), channel loading was weighted towards the front end of the run (loaded to capacity by August 26th). As pre-spawn mortality is more common in the earliest arrivals, spawning success in the channel was notably lower than in the creek population. Juvenile data for Gates are not used in the forecast process due to inconsistencies in data collection methods over time. The 2010 brood year escapement (5,900 EFS) was greater than the cycle average (1970-2010: 1,700 EFS), but much lower than the 2011 brood year escapement.

Average 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 recent years (2006 and 2007 brood years), survival (41.0 R/EFS) has been well above average (10.2 R/EFS), and identical to the record high survival period in the early-1970 brood years. Survival was particularly high in the 2007 brood year (98 R/EFS).

For Gates, the top ranked models are the RAC, R2C, Larkin (tied third) and MRS (tied third) models (Table 6) Since the brood year escapement for Gates was well above average, only top ranked models that use brood year escapement as a predictor variable were considered to generate the 2015 forecast. 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 49% (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 2015 Gates forecast, as it ranked high on average across performance measures, and it ranked well relative to alternative models on each individual performance measure. Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Gates Sockeye return will be below 79,000 (2.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 280,000 (9.9 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 141,000 (4.8 age-4 R/EFS) is much larger than the average return on this cycle (31,000) (Tables 1A, 1B, & 2; Figure 5). The previous brood years escapement (2010: 5,900 EFS) was higher than the 2010 cycle average (1970-2010 average: 1,700), which would have contributed to the lower Larkin model forecast relative to other model results. Due to the record 2011 escapement, the four year old forecast produced for this stock is extrapolated outside the range of the historic data used to define the model, which increases the uncertainty associated with the overall 2015 forecast for this stock.

Five year olds contribute 10% (13,000) to the Gates total forecast (at the 50% p-level) (Table 3). Sibling model forecasts could not be generated for Gates, as 2014 four year old recruitment estimates were not yet available at the time of this publication.

Nadina (Nadina-Francois-ES CU)

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 C). 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. Carcass recoveries in Nadina River were limited by heavy predator activity and a high water event towards the end of the spawning period. As a result, channel estimates of sex ratio and spawning success had to be applied to Nadina River. In contrast to the low EFS in 2011, the 2010 brood year escapement for Nadina (11,900 EFS) was greater than four times the cycle average (1974-2010 average: 3,100 EFS) (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year). Therefore, given the low escapement in 2011, and the high escapement in 2010, five year old returns would be expected to dominate the total return for 2015.

Given the low EFS in the 2011 brood year, fry abundance (1.3 million fry) was similarly well below average (brood years 1973-2010 average: 9.5 million fry). Freshwater survival in the 2011 brood year (1,100 fry/EFS) was close to average (1975-2011 average: 1,000 fry/EFS). In contrast, fry abundance for the 2010 brood year (19.3 million fry) was well above average, and freshwater survival in this brood year (1,600 fry/EFS) was above average

Average 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 recent years (2006 and 2007 brood years), survival (9.9 R/EFS) has been above average (6.2 R/EFS).

For Nadina, the top ranked models are 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 were different, varying by 60% (Table 6). Since five year olds contributed, on average, 70% to the forecasts produced by the top three models, the higher than average freshwater survival from the 2010 brood year resulted in larger fry models forecasts compared to EFS models. Further, the models that included peak Fraser discharge (during smolt outmigration) as a covariate (Ricker (FrD-peak: tied second, and power (juv) (FrD-peak): tied second), produced notably lower forecasts than all other Ricker model forms considered (Table 6). Given the high fry survival for the 2010 brood year, which contributed the greatest proportion to the total forecast, a fry model is considered the most appropriate model form.

The MRJ model was used for the 2015 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). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Nadina Sockeye return will be below 15,000 (2.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 65,000 (12.3 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 31,000 (5.9 age-4 R/EFS) is smaller than the average return on this cycle (81,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 78% (24,000) to the Nadina total forecast (at the 50% p-level) due to the well above average escapement in the 2010 brood year (11,900 EFS) (contributes 5 year olds in 2015) in comparison to the much smaller brood year escapement in 2011 (1,200 EFS) (contributes four year olds in 2015) (Table 3). A sibling model was compared to the 2015 five year old Nadina MRJ forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 111,000) was the product of the in-season 2014 Nadina/Bowron/Gates/Nahatlach/Taseko group total return (four plus five year olds: 136,000), the preliminary 2014 Nadina escapement proportion (0.84) relative to the group total, and the preliminary Nadina in-season four year old proportion (0.97). The 50% probability interval of the five year old forecast for the sibling model (10,000 to 34,000 at the 25% and 75% p-levels) encompassed the median five year old forecast produced by the MRJ model (24,000).

Pitt (Pitt-ES CU)

Due to the greater 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 2010 (for five year old recruits returning in 2015: 8,800 EFS, which includes hatchery broodstock females) was smaller than the average escapement from 1948-2011 (14,100 EFS, which includes hatchery broodstock females). The 2011 escapement (for four year old recruits returning in 2014: 30,400 EFS) was double the average (Table 1B, columns D & C). Spawning success in the Upper Pitt in 2010 was 91% and in 2011 was 99% (average: 96%).

Average five year old survival (R/EFS) for Pitt Sockeye 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 two brood years (2006 & 2007), survival (3.0 R/EFS) was close to average (3.6 R/EFS).

For Pitt, the top ranked models are 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 7% (Table 6). The top performing Larkin model was used to generate the 2015 forecast for Pitt (Table 1A). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Pitt Sockeye return will be below 51,000 (3.2 age-5 R/EFS) and a three in four chance (75% probability) the return will be below 120,000 (9.5 age-5 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 79,000 (5.7 age-5 R/EFS) is very similar to the average return (71,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 63% (50,000) to the Pitt total forecast (at the 50% p-level) (Table 3). This proportion is below average (77%), due to the much larger escapement in 2011 relative to 2010. A sibling model five year old forecast was compared to the 2015 five year old Pitt (Larkin model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 16,000) was the product of the in-season 2014 Pitt total return (four plus five year olds: 69,000) and the Pitt four year old proportion from the 2014 forecast (0.23) (in-season age composition data were not available at the time of this publication). The 50% probability interval of the five year old forecast for the sibling model (32,000 to 82,000 at the 25% and 75% p-levels) encompassed the median five year old forecast produced by the Larkin model (50,000).

Scotch (a component of the Shuswap-ES CU)

The 2011 brood year for Scotch is an off cycle year. 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 C) from 1983-2011. Conditions on the Scotch spawning grounds were good, however, spawner success was low in 2011 (73%) compared to average (93%).

Scotch comprised 17% of the Shuswap system escapement in the 2011 brood year. See the subsequent Late Shuswap section for information on freshwater survival and fall fry production for this lake system, which is estimated as a total.

The exceptional escapement in the 2010 brood year (273,900 EFS) for Scotch was almost five times the cycle average (61,100 EFS), and was the largest escapement on record for this stock (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year). This brood year will contribute five year olds to the 2015 forecast. Returns in 2014 for this stock, combined with Seymour and Early Shuswap miscellaneous stocks, were 40% less than the 50% p-level forecast, falling near the 25% p-level forecast for this group (Table 5). This contrasts with most other stocks, including Late Shuswap, which returned closer to the 50% p-level forecast. Since the early-timed stocks (Scotch/Seymour/Early Shuswap Miscellaneous) rear in the same lake as the late-timed group (Late Shuswap) and have similar smolt outmigration timing in the Fraser, and juvenile migration through the SOG (DFO 2014), this difference in survival is likely attributed to spawning ground conditions and/or capacity.

Average 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 recent years (2006 and 2007 brood years), survival (11.9 R/EFS) has been close to average (7.0 R/EFS).

There are a number of issues that complicate the return forecast process for Scotch in 2015. First, the time series is relatively short (brood years 1980-2006). Second, in the past three cycle years, escapements have increased, reaching a record high in the 2010 brood year (273,900 EFS), which fell well above any other observed escapements for the stock across all cycles. These factors result in challenges in the estimation of both Larkin and Ricker carrying capacity parameter values. Therefore, the 2015 forecasts for Scotch Creek are very uncertain.

For Scotch, the top ranked models are 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 70% (Table 6), with the Larkin model producing a much smaller forecast than the Ricker model because this model form accounts for delayed-density dependence between cycle lines and was likely heavily influenced by the record high brood year abundance in 2010. However, because the EFS abundance for Scotch Creek represents less than 5% of the total EFS for the Scotch and Late Shuswap stocks combined on the dominant 2010 cycle (from 1980 to 2006), the Larkin model likely does not accurately capture the cycle line interactions that occur amongst juveniles in the rearing lake (Shuswap Lake) when fit to only stock-recruitment data from Scotch Creek. The second ranked Ricker model was therefore used to generate the 2015 forecast for Scotch, similar to 2014. Since the spawning ground capacity is more limiting than the rearing lake capacity for Scotch Creek, it is appropriate to use stock-recruitment data for this stock to estimate the Ricker beta carrying capacity parameter (see Appendix 2 in Grant et al. 2010 for model). The Ricker model additionally accounts for in-stream competition, which likely occurred in Scotch in 2010 (contributes five year old returns in 2015).

Given the assumptions underlying the Ricker model, there is a one in four chance (25% probability) the Scotch Sockeye return will be below 85,000 (3.3 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 430,000 (14.0 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 185,000 (6.9 age-4 R/EFS) is very large compared to the average return on this cycle (20,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 18% (33,000) of the Scotch total forecast (at the 50% p-level) (Table 3). The five year old forecast for this stock is associated with additional uncertainty due to the record EFS in 2010, which fell out of the fitted range of the Ricker model (for more information on this uncertainty see DFO 2014). A sibling model five year old forecast was compared to the 2015 five year old Scotch (Ricker model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 414,000) was the product of the in-season 2014 Scotch/Seymour/Early Summer Miscellaneous group total return (four plus five year olds: 1.54 M), the preliminary Scotch escapement proportion (0.27) relative to the group total, and the preliminary in-season Scotch four year old proportion (0.99). The 50% probability interval of the five year old forecast for the sibling model (4,000 to 17,000 at the 25% and 75% p-levels) is lower than the median five year old forecast produced by the Ricker model (33,000). If the four year old forecast of the top ranked Ricker model and the sibling five year old forecast were to be combined, the total forecast would be 100,000 at the 50% p-level (range: 55,000 to 95,000 at the 25% to 75% p-levels) (Table 6).

An additional forecast was generated for Scotch using a model that is not part of the official suite of models, to provide further context for the 2015 Scotch forecast. This model uses an estimate of all fry in Shuswap Lake (including Scotch, Seymour, miscellaneous Early Shuswap populations, and Late Shuswap) from the 2010 brood year (i.e. 2011 fall fry) to predict five year old returns in 2015. The power (fry) five year old forecasts were then partitioned into the Scotch component using the proportional contribution of Scotch Sockeye to the total Scotch, Seymour, miscellaneous Early Shuswap, and Late Shuswap Sockeye escapements in 2010. The power (fry) five year old forecast for Scotch is 12,000 at the 50% p-level, and ranges from 3,000 to 40,000 at the 25% to 75% p-levels. This median forecast is similar to the sibling five year old forecast (8,000), but smaller than the Ricker model five year old forecast (33,000).

Seymour (a component of the Shuswap-ES CU)

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 C). Conditions on the Seymour spawning grounds were good, however, elevated pre-spawn mortality was observed. Spawning success for the South Thompson Early Summer runs was low (76%) compared to the long-term average (94%).

Seymour comprises 11% of the Shuswap system escapement in the 2011 brood year. See the subsequent Late Shuswap section for information on freshwater survival and fall fry production for this lake system.

The exceptional escapement in the 2010 brood year (287,500 EFS) for Seymour was almost six times the cycle average (49,300 EFS) from 1950-2010 (Table 1B, column D) (see DFO 2015 for more information on the 2010 brood year), and was the largest escapement on record for this stock (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year). This brood year will contribute five year olds to the 2015 forecast. Returns in 2014 for this stock, combined with Scotch and Early Shuswap miscellaneous stocks, were 40% less than the 50% p-level forecast, falling near the 25% p-level forecast for this group (Table 5). This contrasts with most other stocks, including Late Shuswap, which returned closer to the 50% p-level forecast. Since the early-timed stocks (Scotch/Seymour/Early Shuswap Miscellaneous) rear in the same lake as the late-timed group (Late Shuswap) and have similar smolt outmigration timing in the Fraser, and juvenile migration through the SOG (DFO 2014), this difference in survival is likely attributed to spawning ground conditions and/or capacity.

Average 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 recent years (2006 and 2007 brood years), survival (7.5 R/EFS) has been close to average (7.7 R/EFS).

For Seymour, the top ranked models are the Ricker-cyc, Larkin (tied second) and R1C (tied second) (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 2015 forecast. In addition, due to the unprecedented 2010 escapement in Seymour (contributes five year old returns in 2015), additional considerations and model forms were explored in the model selection process. Given that the EFS abundance for Seymour represents less than 3% of the total EFS for Seymour and Late Shuswap combined on the dominant 2010 cycle (from 1950 to 2006), a large component of the cycle line interactions that occur amongst juveniles in the rearing lake is not captured by a Larkin or Ricker-cyc model using only stock-recruitment data from Seymour. Since the spawning ground capacity is more limiting than the rearing lake capacity for Seymour, the 10^{th} ranked Ricker model was used to generate the 2015 forecast for Seymour using stock-recruitment data for this stock to estimate the carrying capacity parameter (beta in the Ricker model) (see Appendix 2 in Grant et al. 2010 for model). The Ricker model accounts for in-stream competition, which likely occurred in Seymour in 2010.

Given the assumptions underlying the Ricker model, there is a one in four chance (25% probability) the Seymour Sockeye return will be below 68,000 (4.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 274,000 (15.1 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 140,000 (7.6 age-4 R/EFS) is similar to the average return on this cycle (155,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 31% (44,000) of the Seymour total forecast (at the 50% p-level) (Table 3). The five year old forecast for this stock is associated with additional uncertainty due to the record EFS in 2010, which fell out of the fitted range of the Ricker model (for more information on this uncertainty see DFO 2014). A sibling model five year old forecast was compared to the 2015 five year old Seymour (Ricker model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 319,000) was the product of the in-season 2014 Scotch/Seymour/Early Summer Miscellaneous group total return (four plus five year olds: 1.54 M), the preliminary Seymour escapement proportion (0.21) relative to the group total, and the preliminary in-season Seymour four year old proportion (0.98). The 50% probability interval of the five year old forecast for the sibling model (5,000 to 18,000 at the 25% and 75% p-levels) is lower than the median five year old forecast produced by the Ricker model (43,000). If the top ranked Ricker model four year old forecast and the sibling five year old forecast were combined, the total forecast would be 77,000 at the 50% p-level (range: 47,000 to 132,000 at the 25% to 75% p-levels).

An additional forecast was generated for Seymour using a model that is not part of the official suite of models, to provide further context for the 2015 Seymour forecast. This model uses an estimate of all fry in Shuswap Lake (including Scotch, Seymour, miscellaneous Early Shuswap populations, and Late Shuswap) from the 2010 brood year (i.e. 2011 fall fry) to predict five year old returns in 2015. The power (fry) five year old forecast was then partitioned into the Seymour component using the proportional contribution of Seymour Sockeye to the total Scotch, Seymour, miscellaneous Early Shuswap, and Late Shuswap Sockeye escapements in 2010 and 2011. The power (fry) five year old forecast for Seymour is 13,000 at the 50% p-level, and ranges from 4,000 to 42,000 at the 25% to 75% p-levels. This forecast is similar to the sibling five year old forecast (9,000), but smaller than the Ricker model five year old forecast (43,000)(Table 6).

Miscellaneous Early Shuswap (Shuswap-ES)

The 2011 brood year EFS for the miscellaneous Early Shuswap tributary populations is 7,400 EFS (this group includes all Early Shuswap populations, excluding Seymour River, and Scotch and McNomee Creeks). The 2011 escapement to the Early Shuswap tributary miscellaneous populations is below the average EFS for this system (2000-2011: 20,800). Conversely, the 2010 escapement to the Early Shuswap miscellaneous tributary stocks was 118,900 EFS, which was much larger than the average. This brood year contributes the five year old component of the 2015 forecast for this miscellaneous group, based on the average age proportions seen in the Scotch and Seymour populations.

See the subsequent Late Shuswap section for information on freshwater survival and fall fry production for this lake system.

The model used to generate the miscellaneous Early Shuswap tributary forecast is a non-parametric model that uses the recruits-per-spawner from the Scotch and Seymour stocks (from 1980-2007) multiplied by the Early Shuswap miscellaneous tributary stock's total brood year escapement. Given the assumptions underlying the Early Shuswap miscellaneous stock model, there is a one in four chance (25% probability) the return will be below 74,000 and a three in four chance (75% probability) the return will be below 258,000 in 2015. The median (one in two chance: 50% probability) forecast is 164,000 (Table 1A). The five year old component of this return is expected to contribute 63% (103,000) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Taseko (Taseko-ES)

The 2011 brood year EFS for the miscellaneous Taseko population (includes Taseko Lake and Yoheta Creek) was 400 EFS. The 2011 escapement is below the average EFS for this system (1950-2011: 1,400). Note: the Taseko escapement is an index of abundance only, as visual surveys are conducted on Taseko Lake. The model used to generate the miscellaneous Taseko forecast is a non-parametric model that uses the recruits-per-spawner from the Chilko stock (from 1950-2007) 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 2,000 and a three in four chance (75% probability) the return will be below 7,000 in 2015. The median (one in two chance: 50% probability) forecast is 4,000 (Table 1A). The five year old component of this return is expected to contribute 25% (1,000) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Chilliwack (Chilliwack-ES)

The 2011 brood year EFS for the miscellaneous Chilliwack populations includes Upper Chilliwack River (400) and Chilliwack Lake (2,100) (total EFS: 2,500). The 2011 escapement is below the average EFS for this system (2000 to 2011: 6,100). The model used to generate the miscellaneous Chilliwack forecast was a non-parametric model that uses the recruits-per-spawner from the Early Summer stocks (Bowron, Fennell, Gates, Nadina, Pitt, Scotch, Seymour) (from 1980-2007) multiplied by the Chilliwack 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 Chilliwack miscellaneous stocks' return will be below 9,000 and a three in four chance (75% probability) the return will be below 33,000 in 2015. The median (one in two chance: 50% probability) forecast is 18,000 (Table 1A). The five year old component of this return is expected to contribute 17% (3,000) of the total forecasted return at the 50% p-level (Table 3).

Miscellaneous Nahatlach (Nahatlach-ES)

The 2011 brood year EFS for the miscellaneous Nahatlach populations includes Nahatlach River (2,600) and Nahatlach Lake (800) (total EFS: 3,400). The 2011 escapement is larger than the average EFS for this system (average from 1975 to 2011: 2,257). The model used to generate the miscellaneous Nahatlach forecast was a non-parametric model that uses the recruits-per-spawner from the Early Summer stocks (Bowron, Fennell, Gates, Nadina, Pitt, Scotch, Seymour) (from 1980-2007) 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 14,000 and a three in four chance (75% probability) the return will be below 49,000 in 2015. The median (one in two chance: 50%

probability) forecast is 27,000 (Table 1A). The five year old component of this return is expected to contribute 22% (6,000) of the total forecasted return at the 50% p-level (Table 3).

Summer Run

The Summer Run consists of six forecasted stocks: Chilko, Late Stuart, Quesnel, Stellako and the recently added Raft and Harrison (Table 1A). In addition this group also includes three miscellaneous stocks (North Thompson River, North Thompson Tributaries, and Widgeon). Raft, North Thompson River and miscellaneous stocks associated with North Thompson tributaries, and Harrison were re-assigned to this run timing group as of the 2013 forecast, and Widgeon were re-assigned in this year's 2015 forecast, following a re-evaluation of their migration timing. Escapement in the 2011 brood year for these six stocks combined (893,000 EFS), excluding miscellaneous stocks, was well above the long-term cycle average (360,000 EFS). Chilko (51%) contributed the most to the Summer Run EFS, followed by Harrison (43%). The total 2011 brood year EFS for the Summer Run, including miscellaneous stocks (North Thompson tributaries, North Thompson River, and Widgeon) was 896,000 EFS. Physical conditions on the Summer Run aggregate spawning grounds were conducive to spawning in all areas in 2011. Water levels were higher than average in most areas of the watershed, and arrival to the spawning grounds was one week later than normal, though spawning timing was within the normal range for all populations. Elevated pre-spawn mortality was observed throughout the duration of spawning in all areas, though it was weighted more heavily towards the earliest arrivals. The spawning success for the Summer Run aggregate in 2011 of 80% was below average (time series average for the Summer Run aggregate: 90%).

Chilko (Chilko-S & Chilko-ES CU)

The 2011 brood year escapement for Chilko (457,700 EFS) was double the cycle average (230,700 EFS) from 1951-2011. This is the second largest escapement on this cycle for this stock. Escapement in the previous brood year (2010 EFS: 1.2 million) was the largest on record across all cycles (previous highest escapement was 597,000 EFS in the 1991 brood year). Spawning success in this system in 2011 was 82% (average: 91%). Chilko freshwater survival for the 2011 brood year (97 smolts/EFS) was slightly below average (1950-2011 average: 117 smolts/EFS) (Figure 2). However, given the large 2011 escapement, juvenile (smolt) abundance for the 2011 brood year (44.2 million one year old smolts) was still well above the long-term average (brood years 1950-2011: 19.9 million one year old smolts) (Table 1B, column C). Freshwater survival in the previous brood year (2010 survival: 47 smolts/EFS) was well below average. Smolt abundance in the 2010 brood year (55.3 million one year old smolts), which will contribute the five year old Sockeye returning in 2015, was the third largest smolt abundance on record. Average smolt body lengths in the 2010 (77.4 mm) and 2011 (85.3 mm) brood years were respectively below and above the long-term (brood years 1952-2011) average (83.2 mm).

The preliminary return estimate for 2014 (2.6 million) was identical to the 2014 50% p-level forecast (2.6 million), generated using a power (juv)(Pi) model (Table 5). This juvenile model accounted for the well below average freshwater survival this stock experienced (47 smolts/EFS), which was attributed to the record high escapement of 1.2 million in the 2010 brood year.

Average 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). In recent years (2006 and 2007 brood years), survival (5% R/smolt) has been closer to average (7% R/smolt).

The 2015 forecasts for Chilko were restricted to juvenile-based models only given the below average freshwater survival observed for this stock in the 2011 and 2010 brood years. Despite large escapements, smolt abundances resulting from both the 2010 and 2011 brood years fell within the observed data range.

The top ranked juvenile models for Chilko 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 ranks were used to inform model selection. Forecasts produced by the top ranked models varied by 8% (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. 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 1,587,000 (3% age-4 marine survival) and a three in four chance (75% probability) the return will be below 3,813,000 (8% age-4 marine survival) in 2015. The median (one in two chance: 50% probability) forecast of 2,387,000 (5% age-4 marine survival) is larger than the average return on this cycle (1,545,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute only 11% (265,000) to the Chilko total forecast (at the 50% p-level), despite the record high escapement in 2010 (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Chilko (power (juv)(Pi)) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 2.4 M) was the product of the in-season 2014 Chilko total return (four plus five year olds: 2.57 M) and the preliminary in-season Chilko four year old proportion (0.93). The 50% probability interval of the five year old forecast for the sibling model (89,000 to 327,000 at the 25% and 75% p-levels) encompassed the median five year old forecast produced by the power (juv)(Pi) model (265,000).

Similarly, a sibling model four year old forecast, based on a three-to-four year old Chilko recruit relationship using post-1980 data, was also compared to the 2015 four year old Chilko (power(juv)(Pi)) forecast (Table 6). The predictor variable used to generate the sibling model four year old forecast (4,400) was the preliminary Chilko jack escapements (1,983) divided by one minus the preliminary exploitation rate for this stock (0.55). The 50% probability interval of the four year old forecast for the sibling model (721,000 to 2.1 M at the 25% and 75% p-levels) encompassed the median four year old forecast produced by the power (juv)(Pi) model (2.1 M).

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

The 2011 brood year escapement (800 EFS) for Late Stuart was the smallest on this cycle since 1971, falling well below the cycle average (9,600 EFS) from 1951-2011 (Table 1B, column C). Spawning success in the Late Stuart system in 2011 was 54% (average: 92%).

The 2010 brood year escapement (43,500 EFS) for Late Stuart was almost double the cycle average (23,300 EFS) from 1950-2010 (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year).

Average 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 recent years (2006 and 2007 brood years), survival (3.8 R/EFS) has been below average (9.0 R/EFS).

For Late Stuart, the top ranked models are 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). However, since the brood year escapement for Late Stuart was below average, the top ranked model that uses brood year escapement as a predictor variable (i.e. power model) was used to generate the 2015 forecast. The power model produced a similar forecast to the next highest ranking biological model (Ricker (FrD-mean: ranked fourth)), falling 15% higher than this forecast. Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Late Stuart Sockeye return will be below 25,000 (9.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 118,000 (47.6 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 54,000 (22.2 age-4 R/EFS) is similar to the average return on this cycle (81,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 52% (28,000) to the Late Stuart total forecast (at the 50% p-level) (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Late Stuart (power model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 456,000) was the product of the in-season 2014 Late Stuart/Stellako total return (four plus five year olds: 1.6 M), the proportion of Late Stuart of the total Late Stuart/Stellako group total escapement (0.3) in 2014, and the preliminary in-season Late Stuart four year old proportion (0.95). The median five year old forecast for the sibling model was 27,000 (range: 6,000 to 129,000 at the 25% and 75% p-levels), which is similar to the median five year old forecast produced by the power model (28,000).

Quesnel (Quesnel-S CU)

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 C). Spawner success was 69% (average: 84%). Freshwater survival in the brood year (379 fall fry/EFS) was above average across all cycles (1976-2011 brood years: 197 fall fry/EFS); however, due to the small escapement 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).

The 2010 brood year escapement for Quesnel (133,000 EFS) was similar to the cycle average (175,700 EFS) from 1950-20106 (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year).

Average four year old survival (9.4 R/EFS) 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 recent years (2006 and 2007 brood years), survival (3.8 R/EFS) has remained below average (8.9 R/EFS). This stock exhibits evidence of delayed-density dependence, which may explain post-1990 declines in survival (Peterman and Dorner 2012).

For Quesnel, the top ranked models are 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). The non-parametric models (R1C & R2C) produced lower forecasts than the Ricker-cyc (fourth-ranked) model, given the low survival and low returns exhibited by this stock in the past decade. Since survival has improved in recent years (relative to the below average survival of previous years), a top ranked biological model (Ricker-cyc) was used to generate the 2015 forecast. Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Quesnel Sockeye return will be below 197,000 (3.3 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 684,000 (20.7 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 367,000 (8.0 age-4 R/EFS) is more than double the average return on this cycle (151,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 56% (207,000) to the total Quesnel forecast (at the 50% p-level) (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Quesnel (Ricker-cyc model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 2.4 M) was the product of the in-season 2014 Quesnel total return (four plus five year olds: 2.4 M) and the Quesnel in-season four year old proportion (0.98). The median five year old forecast for the sibling model was 205,000 (range: 112,000 to 377,000 at the 25% and 75% p-levels), which is very similar to the median five year old forecast produced by the Ricker-cyc model (207,000).

Additional forecasts (Larkin, Ricker & power (juv) models) were generated for Quesnel to investigate the sensitivity of this forecast to model form and predictor variables (Table 6). The extra analysis was conducted for this stock in particular as Quesnel appears to have exhibited interactions between cycle lines (delayed-density dependence) in recent years (Peterman and Dorner 2012), therefore the population dynamics of this stock are more uncertain. The Larkin model (ranked 5^{th}) was used since this model form considers delayed-density dependence. The Larkin model forecast is the largest of all models, varying by 31% and 32%, respectively, from those produced by the Ricker-cyc and Ricker models (Table 6). Juvenile (fall fry) data are available for Quesnel for both the 2010 and 2011 brood years. The forecast produced by the power (juv) model was slightly larger than Ricker and Ricker-cyc model forecasts (Table 6), varying by 13% and 14% from these forecasts, respectively, due to the above average freshwater survival experienced by this stock in the brood year. The power (juv) model forecast is 21% smaller than the Larkin model forecast.

Stellako (Francois-Fraser-S CU)

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 C). Spawner success for Stellako was 60% (average: 90%).

The 2010 brood year escapement for Stellako (110,300 EFS) was well above the cycle average (65,900 EFS) from 1950-2010 (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year).

Average 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 recent years (2006 and 2007 brood years), survival (5.3 R/EFS) has been close to average (7.0 R/EFS).

For Stellako, the top ranked models are the R2C, Larkin and Ricker (Ei) (Table 6). Since the brood year escapement for Stellako was below average, only top ranked models that use brood year escapement as a predictor variable (Larkin & Ricker (Ei)) were considered to generate the 2015 forecast. Neither of these models performed within the top 50% of all models on each performance measure, both performed poorly on the MRE performance measure (MacDonald & Grant 2012). Forecasts produced by the two biological models (Larkin & Ricker (Ei)) were extremely similar, varying by only 2% (Table 6). The top ranked biological model (Larkin) was used to generate the 2015 forecast (Table 6). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Stellako Sockeye return will be below 261,000 (3.6 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 552,000 (9.3 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 390,000 (6.0 age-4 R/EFS) is similar to the average return on this cycle (568,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 52% (204,000) to the total Stellako forecast (at the 50% p-level (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Stellako (Larkin model) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 1.1 M) was the product of the in-season 2014 Late Stuart/Stellako total return (four plus five year olds: 1.6 M), the proportion of Stellako of the total Late Stuart/Stellako group total escapement (0.7) in 2014, and the preliminary in-season Late Stuart four year old proportion (0.96). The median five year old forecast for the sibling model was 177,000 (range: 109,000 to 288,000 at the 25% and 75% p-levels), which is similar to the median five year old forecast produced by the Larkin model (204,000).

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

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 C). Spawning success for Raft was 87% (average: 87%).

This stock has not exhibited any systematic survival trends over time (Grant et al. 2011, Peterman and Dorner 2012). Average 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 recent years (2006 and 2007 brood years), survival (1.3 R/EFS) has been below average (5.7 R/EFS).

For Raft, the top ranked models are 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 23%, 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 2015 Raft forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except RMSE (ranked fourth). Given the assumptions underlying the Ricker (PDO) model, there is a one in four chance (25% probability) the Raft Sockeye return will be below 23,000 (2.7 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 56,000 (9.2 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 36,000 (5.1 age-4 R/EFS) is larger than the average return on this cycle (20,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 28% (10,000) to the Raft total forecast (at the 50% p-level) (Table 3). Sibling model forecasts could not be generated for Raft, as 2014 in-season four year old recruitment estimates were not yet available at the time of this publication.

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. Harrison Sockeye 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, respectively, 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 inter-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 higher 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 annual variation in age proportions for Harrison Sockeye increases the level of forecast uncertainty for this stock.

The 2011 brood year escapement (four year old recruits in 2015) for Harrison Sockeye (387,100 EFS) was the second largest on record, similar to the previous (record high) brood year escapement (399,700 EFS in 2010), and almost 30 times larger than the long-term average (25,400 EFS: note that the long-term average increased substantially with the addition of data from the 2009-2011 brood years) from 1948-2011. The 2012 brood year escapement (three year old recruits in 2015) for this stock (32,900 EFS) was much closer to the long-term average (25,400 EFS). 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).

In the 2011 brood year (four year old returns in 2015), abnormally high pre-spawn mortality was observed for Harrison throughout the spawning period. En-route mortalities were also observed in the Harrison River and near terminal areas in September, and Sockeye were reported to be stressed and in poor condition through mid-October. En-route mortalities, observed in the Harrison River and the Lower Fraser River (downstream of the Harrison confluence) in 2011, were attributed the exceptional abundance in this system. Physical conditions on the spawning grounds were conducive to spawning in 2011 despite higher than average water levels. Harrison Sockeye spawning success was 91% in 2011 (four year old returns in 2015), though this estimate does not include mortalities prior to October 4th, before the mark-recapture was implemented. Conditions in 2012 (three year old returns in 2015) were also favorable for spawning; spawning success was 99%, identical to the long-term average (99%).

Unlike most other Fraser Sockeye stocks, average 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 recent years (2006 to 2008 brood years), survival (20.9 R/EFS) has been well above average (7.8 R/EFS).

Harrison Sockeye have been extremely challenging to forecast in recent years 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). 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.

To forecast the 2015 Harrison Sockeye return, the stock-recruitment time series was truncated to include only the 1990 to 2010 brood years, which excludes the majority of data in the low productivity and low abundance years (1950 to 1989 brood years). The 2005 brood year was also removed, as poor survival in this brood year (0.08 R/EFS) was consistent with all stocks indicating a density-independent mechanism, and the inclusion of this data point has a significant effect on the model fit at high escapements, given the large brood year escapement in 2005 (200,000). Preliminary four year old returns in 2014 (~1.4 M) were added to the stock-recruitment time series (2010 brood year) to provide an additional data point from the current, higher productivity and abundance regime.

A number of forecasts were generated for Harrison, including one using a non-parametric model (adjusted RS1 model) that assumes the same productivity as the 2010 brood year (~4 R/EFS) when predicting the four year old returns, and average productivity over the past four brood years (2007-2010 average: ~15 R/EFS) when predicting the three year old returns. The escapement in the 2010 brood year was very similar to the 2011 escapement (~300K), thus it is reasonable to assume that productivity for these two brood years would be similar. For this forecast there is a one in four chance (25% probability) the Harrison Sockeye return will be below 573,000 and a three in four chance (75% probability) the return will be below 3.5 M in 2014. The median (one in two chance: 50% probability) forecast of 1.4 M is much larger than the average return across all cycles (105,000) (Tables 1A, 1B, & 2; Figure 5). The four year old component of the 2015 return forecast is 90% (1.3 M) of the total (Table 3). This is greater than the average percentage of four year old returns (odd year average: 58%), due to the much higher brood year escapement in 2011 versus 2012.

Although highly uncertain, given the regime shift for this stock in terms of productivity and abundance since 2000, truncating the time series, removing the 2005 brood year data point, and adding the 2010 recruitment data resulted in a larger Ricker (Ei) (2.0 M) and Ricker (2.5 M) model forecasts than the non-parametric forecast model at the 50% p-level. The power model forecast (1.5 M) was similar to the non-parametric model (Table 6).

The forecast for Harrison Sockeye is associated with extremely high uncertainty given the limited recruitment data corresponding to recent years of exceptional escapements. Returns for this stock have not exceeded 1.5 million, therefore forecasts that are larger than this (which are the case at the 75% and 90% p-levels) have not yet been observed. Additional years of recruitment data at high escapements, similar to those observed in 2010 and 2011, are required to obtain information on limits to the production capacity of this stock and reduce the uncertainty of the Harrison Sockeye forecasts at high escapement levels.

A sensitivity analyses was conducted to explore the effect of varying the Harrison data set on the biological model forecasts (Appendix 1). Biological models using the original forecast stock-recruitment data (base case scenario), which include the 1948 to 2008 brood years only, generated the lowest forecasts (see scenario a. in Appendix 1). Excluding some of the earlier lower productivity and abundance data (prior to the 1990 brood year) from the original stock-recruitment data resulted in only small increases in the power or Ricker model forecasts from the base case scenario (see scenario b. in Appendix 1). Including the 2010 brood year stock-recruitment data, which were added to provide additional data at high spawner abundances for this stock, also resulted in only small increases in the power model forecast, but a larger increase in the Ricker model forecast, compared to the base case scenario (see scenario d. in Appendix 1). The largest effect on the forecasts occurred when the 2004 and 2005 years were removed from the time series (see scenario c. in Appendix 1), which were years when large Harrison escapements coincided with the lowest survivals on record for this stock.

Miscellaneous North Thompson Tributaries (Kamloops-ES)

The 2011 brood year EFS for the miscellaneous North Thompson tributaries is 400 (populations: Barriere and Clearwater Rivers, and Dunn, Finn, Grouse, Harper, Hemp, Lemieux, Lion, Mann Creeks). The 2011 escapement is below the average EFS for this system (2000-2011: 1,000). The model used to generate the miscellaneous North Thompson tributaries miscellaneous forecast was a non-parametric model that uses the recruits-per-spawner from the Raft and Fennell stocks 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 2,000 and a three in four chance (75% probability) the return will be below 7,000 in 2015. The median (one in two chance: 50% probability) forecast is 3,000 (Table 1A).

Miscellaneous North Thompson River (Kamloops-ES)

The 2011 brood year EFS for the miscellaneous North Thompson River is 2,000. The 2011 escapement is below average (2000-2011: 8,300 EFS). However, due to high water and glacial turbidity, counting conditions in this system were extremely poor in 2011 and this estimate is considered a minimum. The model used to generate the miscellaneous North Thompson River forecast was a non-parametric model that uses the recruits-per-spawner from the Raft and Fennell stocks 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 10,000 and a three in four chance (75% probability) the return will be below 37,000 in 2014. The median (one in two chance: 50% probability) forecast is 18,000 (Table 1A).

Miscellaneous Widgeon (Widgeon (River-Type))

The 2011 brood year EFS for the miscellaneous Widgeon River is 700. The 2011 escapement is above average for this system (1950-2011: 300). The model used to generate the Widgeon miscellaneous forecast was a non-parametric model that uses the recruits-per-spawner from the Birkenhead stock 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 3,000 and a three in four chance (75% probability) the return will be below 10,000 in 2015. The median (one in two chance: 50% probability) forecast is 6,000 (Table 1A).

Late Run

The Late Run consists of five forecasted stocks (Cultus, Late Shuswap, Portage, Weaver, and Birkenhead) and one miscellaneous stock (miscellaneous non-Shuswap that includes 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 2011 was 163,300 EFS (excluding Cultus), falling below the cycle average of 235,100 EFS, though still within the average range (Table 1B). The combined brood year EFS for the miscellaneous Late Run stocks (e.g. Harrison Lake rearing stocks such as Big Silver and Cogburn) was 6,507 (Table 1B). Elevated levels of pre-spawn mortality were observed across the watershed. Generally, early arrivals experienced the highest pre-spawn mortality, though it remained high throughout the spawning period. A small amount of en-route mortality was observed in the Late Shuswap terminal area (shoreline of the Adams River outlet). Sockeye in the Harrison and Adams River were also reported as stressed and in poor condition through mid-October. Harrison en-route mortalities were confirmed in the rear and near terminal areas of the Harrison-Lillooet system through the month of September. Physical conditions on the Late Run aggregate spawning grounds were favorable despite higher than average water levels, with the exception of the Lillooet system, which experienced high water in mid-September. Overall, average spawner success for the Late Run aggregate in 2011 was 81% (average: 88%).

Cultus (Cultus-L CU)

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. However, due to extremely low spawning success

(9%), the effective female spawner abundance was much smaller, at 359 spawners. Spawning success was estimated based on a relatively large carcass sample (>10% of the population), however, this estimate is still likely biased low and 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 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. 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). For the 2014 return year, the very preliminary jack escapement is 35, based on fence estimates only. The jack escapement estimate is lower than the time series (1949-2008) average for three year old recruits (1,000), and the recent (1980-2008) average (200).

Total Cultus Sockeye adult escapement (counted through the Sweltzer Creek enumeration fence) in the 2010 brood year (9,700) was the largest escapement observed since 1999, and fell above the post-1980 cycle average (1982-2006 cycle average: 5,200). The smolt abundance for the 2010 brood year was 318,000, of which 41% were hatchery origin. This smolt abundance falls above the post-1980 cycle average (1982-2006 cycle average: 228,000 smolts), and below the long-term cycle average (1954-2006 cycle average: 988,000 smolts) (see DFO 2014 for more information on the 2010 brood year).

Average four year old post-smolt (mostly marine) 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 recent years (2006 and 2007 brood years), survival (4% R/smolt) has been identical to average (4% R/smolt). Note: the survival time series is patchy as smolt abundances were not assessed in all years.

For Cultus, the top ranked models are 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 similar, varying by 8% (Table 6). The MRJ model was used to generate the forecast for 2015, 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. Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Cultus Sockeye return will be below 3,000 (2% age-4 marine survival) and a three in four chance (75% probability) the return will be below 12,000 (8% age-4 marine survival) in 2015. The median (one in two chance: 50% probability) forecast of 6,000 (4% age-4 marine survival) is well below the average return on this cycle (81,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 0% (0) to the total Cultus forecast (at the 50% p-level) (Table 6). A five year old sibling model forecast could not be generated for Cultus since 2014 in-season four year old recruitment estimates were not yet available at the time of this publication.

A sibling model four year old forecast was also compared to the 2015 four year old Cultus MRJ forecast (Table 6). The predictor variable used to generate the sibling model four year old forecast (78 Sockeye) was the preliminary Cultus jack (three year old) escapements (35) divided by one minus the preliminary exploitation rate for this stock (0.55). The median four year old forecast for the sibling model was 5,000 (range: 2,000 to 12,000 at the 25% and 75% p-levels), which is similar to the median four year old forecast produced by the MRJ model (6,000).

Late Shuswap (Shuswap-L CU)

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 C). Spawning timing was very protracted in the Late Shuswap system in 2011, with Sockeye spawning immediately upon arrival in late September and continuing through early November. Pre-spawn mortality was abnormally high throughout the run, and Sockeye were reported to be in poor condition on the spawning grounds. Estimates of spawning success in 2011 include mortalities that occurred in the terminal area prior to spawning. Spawning success in the South Thompson system in 2011 was 55%, falling well below the average (95%).

Late Shuswap comprises 62% of the entire Shuswap system escapement in the 2011 brood year. Freshwater survival in Shuswap Lake (includes Scotch, Seymour, and Late Shuswap stocks, excluding miscellaneous populations) in the 2011 brood year (168 fall fry/EFS) was below cycle average (1975-2011: 207 fall fry/EFS). 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).

In contrast to the below average escapement in the 2011 brood year (contributing four year olds to the 2015 returns), escapement in the 2010 brood year (contributing five year olds to the 2015 return) was the highest on record for this stock (3.1 M EFS), falling well above the cycle average (1950-2006: 1.1 million EFS) (Table 1B, column D). Freshwater survival in the brood year (51 fall fry/EFS) was below the cycle average (1974-2006: 95 fall fry/EFS) and, given the exceptional brood year escapement in 2010, fry abundance of 187 million fall fry was the largest on record (average 1974-2010: 110 million fall fry).

Average 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). Cycle-line survival, however, peaked in the early 1990s, and subsequently declined (Figure 3). Similar to other stocks, Late Shuswap exhibited one of it's lowest productivities on record (2.8 R/EFS) in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3). In recent years (2006 to 2007 brood years), survival (9.8 R/EFS) has been similar to average (6.5 R/EFS).

For Late Shuswap, the top ranked models are the R1C, Ricker-cyc & RAC models (Table 6). However, due to the below average escapement in Late Shuswap in 2011 and above average escapement in 2010, only the top ranked model that uses brood year escapement as a predictor variable (Ricker-cyc) was considered to generate the 2015 forecast. Other biological models (Ricker, power, Larkin) were also used to generate forecasts for comparison with the Ricker-cyc model. The first ranked biological model (Ricker-cyc) generated the lowest forecast compared to the standard Ricker model and power model. This is attributed to the cycle-specific age proportion used by the Ricker-cyc model that particularly influences the contributions of five year olds to the total forecast. The 2011 cycle-specific five year old proportion post-1980 (used by the Ricker-cyc model) is 0.01, while the all-cycle five year old proportion post-1980 (used by all other models) is 0.1. Given the exceptional brood year escapement in 2010, this difference in age proportions has a large effect on the final forecast. For reference, the 2011 cycle line five year old proportions have been relatively constant through time and similar to 0.01 during the post-1980 period. Also, the Ricker-cyc model was used to generate the 2014 forecast, and the resulting return fell largely at the forecast 50 p-level forecast in that year. The Ricker-cyc model generated a larger forecast than the Larkin model, which is likely because the Larkin model form accounts for delayed-density dependence between cycle lines, and was heavily influenced by the large brood year abundance in 2010 (3,073,300 EFS) (Table 6).

The Ricker-cyc model was used to generate the Late Shuswap forecast for 2015, as this model ranked high on average across performance measures, and it ranked high on each individual performance measure (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Late Shuswap Sockeye return will be below 293,000 (3.3 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 924,000 (13.2 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 517,000 (6.3 age-4 R/EFS) is much smaller than the average return on this cycle (1.36 Million) (Tables 1A, 1B, & 2; Figure 5). Due to the large (record) 2010 escapement, the five year old forecast produced for this stock is extrapolated outside the range of the fitted model, which increases the uncertainty associated with the overall 2015 forecast.

Five year olds contribute 32% (167,000) to the total Late Shuswap forecast (at the 50% p-level) (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Late Shuswap (Ricker-cyc) forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 9.2 M) was the product of the in-season 2014 Late Shuswap/Portage returns (assuming Portage is negligible relative to Late Shuswap: 9.2 M) and the Late Shuswap four year old proportion from the 2014 forecast (1.0) (age composition data were not available at the time of this publication). The 50% probability interval of the five year old forecast from the sibling model (48,000 to 138,000 at the 25% and 75% p-levels) is smaller than the median five year old forecast generated by the Ricker-cyc model (167,000).

An additional forecast was generated using a model that was not part of the official suite (power (fry)), to provide further context for the 2015 Late Shuswap forecast. This model uses an estimate of all fry in Shuswap Lake (including Scotch, Seymour, miscellaneous Early Shuswap populations, and Late Shuswap) from the 2011 brood year (i.e. 2012 fall fry) to predict five year old returns in 2015. The power (fry) five year old forecasts were then partitioned into the Late Shuswap component using the proportional contribution of Late Shuswap Sockeye to the total Scotch, Seymour, miscellaneous Early Shuswap, and Late Shuswap Sockeye escapements in 2011. The power (fry) forecast for Late Shuswap is 139,000 at the 50% p-level, and ranges from 39,000 to 452,000 at the 25% to 75% p-levels, which is similar to the Ricker-cyc forecast (167,000).

Portage (Seton-L (de novo) CU)

The 2011 brood year escapement for Portage (300 EFS) was much smaller than the cycle average (1955-2011: 2,300 EFS) (Table 1B, column C). Escapements in Portage have been consistently declining for the past five cycles, though the 2011 abundance was not the smallest EFS observed for this stock. Spawning success for Portage was 79% (average: 95%).

In contrast to the low brood year escapement in 2011, the 2010 brood year escapement for Portage (26,700 EFS), which will contribute five year olds to the total 2015 forecast, was more than three times the cycle average (1954-2010: 8,300 EFS), and was the largest on record for this stock (Table 1B, column D) (see DFO 2014 for more information on the 2010 brood year).

Average 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 recent years (2006 and 2007 brood years), survival (7.0 R/EFS) has been below average (13.1 R/EFS).

For Portage, the top ranked models are the Larkin, Ricker-cyc, and power 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 47% (Table 6), with the Larkin model producing a lower forecast than the power model. The Larkin model, however, produced a similar forecast to the Ricker model, varying by 16%. Despite the record escapement in the 2010 brood year (producing five year olds in 2015), the low relative proportion of five year olds to total recruits (25%) and the effects of delayed density dependence in the Larkin model, or carrying capacity in the Ricker model, resulted in a relatively low forecast in 2015. The power model generated a higher forecast, roughly double the Larkin and Ricker models, since the power model does not account for overcompensation at large spawner abundances.

The Larkin model was used for the 2015 Portage forecast, as it ranked first on average across performance measures, and it ranked well on each individual performance measure. Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Portage Sockeye return will be below 3,000 (2.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 19,000 (18.0 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 8,000 (7.4 age-4 R/EFS) is much smaller than the average return on this cycle (25,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 37% (3,000) to the Portage total forecast (at the 50% p-level) (Table 3). Sibling model forecasts could not be generated for Portage, as 2014 four year old recruitment estimates were not yet available at the time of this publication. Due to the large (record) 2010 escapement, the five year old forecast produced for this stock is extrapolated outside the range of the fitted model, which increases the uncertainty associated with the overall 2015 forecast.

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

The 2011 brood year escapement for Weaver (24,500 EFS) was larger than the cycle average (1967-2011: 18,300 EFS) (Table 1B, column C). 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 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 recent years (2006 and 2007 brood years), survival (18.6 R/EFS) has been above average (12.1 R/EFS).

For Weaver, the top ranked models are 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 22% (Table 6). Since freshwater survival in the 2011 brood year was identical to average, the lower ranked power (fry) model (not included in Table 6) generated a similar forecast to the MRS model. The MRS model was used for the 2015 Weaver forecast, because it had the highest average rank across all four performance measures. Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Weaver Sockeye return will be below 189,000 (6.4 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 635,000 (21.4 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 346,000 (11.7 age-4 R/EFS) is larger than the average return on this cycle (222,000) (Tables 1A, 1B, & 2; Figure 5).

Five year olds contribute 21% (72,000) to the Weaver total forecast (at the 50% p-level) (Table 3). A sibling model five year old forecast was compared to the 2015 five year old Weaver MRS forecast (Table 6). The predictor variable used to generate the sibling model five year old forecast (preliminary four year old recruits in 2014: 170,000) was the product of the in-season 2014 Weaver/Cultus (assuming Cultus recruitment was negligible in 2014) total return (four plus five year olds: 192,000) and the four year old proportion from the 2014 forecast (0.90) (in-season age composition data were not available at the time of this publication). The 50% probability interval of the five year old forecast for the sibling model (17,000 to 53,000 at the 25% and 75% p-levels) was lower than the median five year old forecast produced by the MRS model (72,000).

Birkenhead (Lillooet-Harrison-L CU)

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 C). Heavy rainfall and high water levels in the Birkenhead system resulted in the removal of the Birkenhead counting fence on September 22nd, resulting in an incomplete escapement assessment for Birkenhead for the second year in a row. Visual assessments could not be completed due to continued high water and poor visibility, therefore the estimate for Birkenhead is considered a minimum (biased low by approximately 30% or ~40,000 EFS). Spawning success in 2011 was 74% (average: 90%).

Average 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 recent years (2006 and 2007 brood years), survival (2.6 R/EFS) has been below average (5.5 R/EFS).

In 2014, Birkenhead was the only stock that exhibited particularly low survival (preliminary returns fell below the 10% p-level; see Table 5). As a result, an alternative sibling model was run to forecast the number of five year olds for this stock based on preliminary returns of four year olds in 2014 (preliminary four year old recruits in 2014: 90,000). This preliminary number of four year old recruits was the product of the in-season 2014 Birkenhead total return (four plus five year olds: 100,000) and the preliminary 2014 in-season four year old proportion (0.9). The sibling model predicted a lower five year old forecast (50 p-level: 63,000), compared to the top ranked Ricker (Ei) model (50 p-level: 183,000) (Table 6).

For the four year old forecast, the top ranked Birkenhead models were considered: Ricker (Ei), Ricker (tied second) and RAC (tied second) (Table 6). Due to the above average Birkenhead escapement in 2011, only the top ranked models that use brood year escapement as a predictor variable (Ricker (Ei) & Ricker) were considered to generate the 2015 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). Total (four plus five year old) forecasts produced by the top ranked models were quite similar, varying by only 6% (Table 6). Therefore, the first ranked Ricker (Ei) model was used for the 2015 four year old Birkenhead forecast (Table 6).

Given the assumptions underlying the Ricker (Ei) four year old forecast and the sibling five year old forecast, there is a one in four chance (25% probability) the Birkenhead Sockeye return will be below 183,000 (1.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 513,000 (4.8 age-4 R/EFS) in 2015. The median (one in two chance: 50% probability) forecast of 299,000 (2.5 age-4 R/EFS) is lower than the average return on this cycle (376,000) (Tables 1A, 1B, & 2; Figure 5). Five year olds in 2015 are expected to contribute 21% (63,000) to the total return at the 50% p-level (Table 3).

A sensitivity analysis was conducted to assess the effects of the biased (low) escapement estimate in 2011 on the forecast (using the Ricker (Ei) four year old forecast and the sibling five year old forecast), through the addition of the estimated bias (40,000) to the 2011 brood year escapement. Despite increasing the 2011 brood year escapement to correct for this bias, the median total forecast (290,000; range: 176,000 to 500,000 at the 25% to 75% p-levels) was smaller than the forecast generated using the unmodified 2011 escapement data (see previous paragraph).

Miscellaneous Non-Shuswap (Harrison (downstream)-L)

The 2011 brood year EFS for the miscellaneous Non-Shuswap stocks is 6,500. 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, Ryan, Sampson, Sloquet and Tipella Creeks). The 2011 escapement is identical to the average EFS for this system (2000 to 2011: 6,500). The model used to generate the Non-Shuswap miscellaneous forecast was a non-parametric model that uses the recruits-per-spawner from the Birkenhead stock 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 32,000 and a three in four chance (75% probability) the return will be below 107,000 in 2015. The median (one in two chance: 50% probability) forecast is 60,000 (Table 1A).

Fraser Pink Salmon

Pink fry abundance in the 2013 brood year was 609 million, which was above the long term average (450 million) (Table 1; Figure 4). Productivity (recruits-per-fry) in the 2012 brood year was 3%, which is average (1967-2011 brood years: 3%). The maximum productivity on record for this time series was 10% in 1999 (Table 2).

Fraser Pink Salmon forecasts are particularly uncertain given the shifts in methodology over time, particularly with regards to the recruitment data (changes in escapement and catch methods) (see Methods above and Grant et al. 2014). The power model including the environmental covariate average sea-surface salinity (SSS) from July to September at the Race Rocks and Amphitrite Point lighthouse stations ranked first in a jackknife analysis of Fraser Pink Salmon forecast models (Table 7).

Given the assumptions underlying the Power (fry)-SSS model there is a one in four chance (25% probability) the Pink returns will be below 10,385,000 (2% recruits/fry) and a three in four chance (75% probability) the return will be below 20,450,000 (3% recruits/fry) in 2015. The median (one in two chance: 50% probability) forecast of 14,455,000 (2% age-4 R/EFS) is similar to the cycle average (13,400,000). This forecast is similar (11% difference) to that produced by the second ranked power model with no environmental covariate (50% probability: 16,165,000). The slightly lower forecast produced by the power model with the sea-surface-salinity covariate is attributed to the slightly below average sea-surface-salinity in the Juan de Fuca (Race Rocks lighthouse station) and West Coast of Vancouver Island (Amphitrite Point lighthouse station) in the summer of 2014 (July to August).

Conclusions

Similar to 2013 and 2014, a single forecast scenario is presented for the 2015 forecast (Table 1A). Survival in the 2006 to 2008 brood years (corresponding to the 2010 to 2012 return years) improved for most stocks, following a multi-decadal period of systematic declines in survival observed in most stocks (Grant et al. 2010; Grant et al. 2011; Grant et al. 2012; Peterman & Dorner 2011). In the absence of predictive indicators, it is unclear whether average survival will persist through to 2015. Forecast distributions therefore represent the range of survival that Fraser Sockeye stocks have historically exhibited. Survivals associated with each stock's forecast at the different p-levels are presented in both tabular and graphical form (Table 2; Figure 5), so they can be placed in the context of historical survival levels for each stock. Forecasts at the 10% p-level (Table 1A) represent lower survival within the time series of each stock (Table 2, column F), while at the opposite end of the probability distribution (Table 1A, 90% p-level), forecasts represent higher survival within the time series' (Table 2, column J). If survival for the 2015 brood year falls below average, as seen within the past decade for most stocks (1995-2005 brood years), returns will fall at the lowest end of the probability distribution (10% p-level) for each stock (Figure 5). Conversely, if survival falls near the historical time series maximum, returns will fall at the highest end of the probability distributions (90% p-level) (Figure 5). The median forecast (50% p-level) generally represents long-term average survival for each stock. Therefore, when stock productivities are average, returns will fall close to this median p-level, as was seen in the 2011, 2012, and 2013 return years (see Figures 1B & 5). Although the forecast distributions bracket a wide range of potential returns, they may not capture extreme survival events, such as occurred in the 2005 brood year (2009 return).

To date, the inclusion of environmental variables has not significantly decreased forecast uncertainty (i.e. it has not significantly explained inter-annual variation in survival). In response to previous recommendations to explore environmental and biological variables, an additional CSAS RPR process was initiated as part of the 2014 Fraser Sockeye forecast process, and was repeated for the 2015 forecast. Included in the CSAS Special Response are comparisons of the proportional representation of each stock within the Fraser Sockeye forecast to their corresponding proportions in other sampling programs (i.e. adult escapements in 2011, and smolt and juvenile programs in 2013).

Since not all stocks will exhibit the same survival in a given year, the forecast distribution for total Fraser River Sockeye Salmon will over-estimate total returns, particularly at the high p-levels. It is therefore more appropriate to reference individual stock forecast distributions versus the total Fraser Sockeye forecast. Alternative forecasts, generated from different model forms (e.g. Ricker, Power, Larkin, etc.), are presented for each stock to capture the structural uncertainty in the forecasts. Combining individual forecast into a total will be analytically resolved in subsequent year's forecasts.

Tables

Table 1A. Fraser River Sockeye (by stock and timing group) and Fraser River Pink forecasts are presented from the 10% to 90% probability levels. ***See Table 1B & 2 for forecast background data.***

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**	**58,000**	**108,000**
Early Summer		**236,000**	**424,000**	**837,000**	**1,603,000**	**2,963,000**
(total excluding miscellaneous)		**192,000**	**325,000**	**624,000**	**1,256,000**	**2,342,000**
Bowron	*MRS*	6,000	11,000	21,000	40,000	72,000
Fennell	*power*	10,000	16,000	27,000	47,000	78,000
*Gates	*Larkin*	46,000	79,000	141,000	280,000	502,000
Nadina	*MRJ*	8,000	15,000	31,000	65,000	126,000
Pitt	*Larkin*	33,000	51,000	79,000	120,000	190,000
*Scotch	*Ricker*	48,000	85,000	185,000	430,000	845,000
*Seymour	*Ricker*	41,000	68,000	140,000	274,000	529,000
Misc (EShu) [c]	*RS (Scotch/Seymour)*	33,000	74,000	164,000	258,000	459,000
Misc (Taseko) [d]	*R/S (Chilko)*	1,000	2,000	4,000	7,000	9,000
Misc (Chilliwack) [e]	*RS (Esum)*	4,000	9,000	18,000	33,000	61,000
Misc (Nahatlatch) [e]	*RS (Esum)*	6,000	14,000	27,000	49,000	92,000
Summer		**1,701,000**	**2,681,000**	**4,675,000**	**8,764,000**	**16,511,000**
(total excluding miscellaneous)		**1,693,000**	**2,666,000**	**4,648,000**	**8,710,000**	**16,406,000**
Chilko	*power (juv) (Pi)*	1,117,000	1,587,000	2,387,000	3,813,000	5,972,000
Late Stuart	*power*	12,000	25,000	54,000	118,000	245,000
Quesnel	*Ricker-cyc*	108,000	197,000	367,000	684,000	1,421,000
Stellako	*Larkin*	186,000	261,000	390,000	552,000	823,000
Raft [f]	*Ricker (PDO)*	15,000	23,000	36,000	56,000	87,000
**Harrison [f]	*Adjusted RS1*	255,000	573,000	1,414,000	3,487,000	7,858,000
Misc (N. Thomp. Tribs) [f & g]	*R/S (Raft/Fennell)*	1,000	2,000	3,000	7,000	14,000
Misc (N. Thomp River) [f & g]	*R/S (Raft/Fennell)*	5,000	10,000	18,000	37,000	74,000
Misc (Widgeon) [f & h]	*R/S (Birkenhead)*	2,000	3,000	6,000	10,000	17,000
Late		**419,000**	**703,000**	**1,236,000**	**2,210,000**	**3,998,000**
(total excluding miscellaneous)		**400,000**	**671,000**	**1,176,000**	**2,103,000**	**3,809,000**
Cultus	*MRJ*	1,000	3,000	6,000	12,000	22,000
*Late Shuswap	Ricker-cyc	168,000	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	189,000	346,000	635,000	1,095,000
Birkenhead	*Ricker (Ei)+Sibling*	120,000	183,000	299,000	513,000	879,000
Misc. non-Shuswap [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**
(TOTAL excluding miscellaneous)		**2,293,000**	**3,678,000**	**6,478,000**	**12,127,000**	**22,665,000**
TOTAL PINK SALMON	power(juv)-SSS	**7,661,000**	**10,385,000**	**14,455,000**	**20,450,000**	**27,776,000**

a. Probability that return will be at, or below, specified projection
b. Forecast model used for stock; see Table 4 for model descriptions
c. Misc. Early Shuswap uses Scotch and Seymour R/EFS in forecast
d. Misc. Taseko uses Chilko R/EFS in forecast; note this forecast is extremely uncertain as escapements are indices of abundance
e. Misc. Chilliwack and Nahatlach use Early Summer Run stocks R/EFS in forecast
f. Raft, Harrison, North Thompson Tributaries and River, and Widgeon were moved into the Summer Run stocks
g. Misc. North Thompson stocks use Raft & Fennel R/EFS in forecast
h. Misc. Widgeon uses Birkenhead R/ESF in forecast
i. Misc. non-Shuswap stocks (includes Big Silver, Cogburn, etc.) use Birkenhead R/EFS in forecast
* Stocks with uncertain five year old forecasts due to exceptional EFS in 2010; Gates had exceptional EFS in 2011
** Harrison forecasts are extremely uncertain due to age-proportion variations & the exceptionally large 2011 brood year EFS
Definitions: BY: Brood year; R/EFS: recruits-per-effective female spawner; Ei (Entrance Island sea-surface- temperature); Pi (Pine Island sea-surface temperature); PDO (Pacific Decadal Oscillation); SSS (sea surface salinity)

Table 1B. Average run sizes are presented across all cycles (F) and for the 2015 cycle (G). Brood year escapements (smolts for Chilko and Cultus) for four (2011) and five year old (2010) recruits returning in 2015 (columns C & D) are presented and colour coded relative to their cycle average from 1951-2011 (brood year). Forecasted returns (column E), corresponding to the 50% probability level (column J) are also colour coded relative to their cycle average. Color codes represent the following: red (< average), yellow (average) and green (> average), with the average range defined as average +/- 0.5 standard dev.

A	B	C	D	E	F	G
Run timing group Stocks	**Forecast Model** [a]	**BY (11)** **(EFS)**	**BY (10)** **(EFS)**	**Ret** **2015**	**Mean Run Size** **All cycles** [b]	 **2015 cycle** [b]
Early Stuart	*Ricker (Ei)*	200	34,200		**303,000**	**162,000**
Early Summer					--	--
(total excluding miscellaneous)					**507,000**	**462,000**
Bowron	*MRS*	2,000	4,400		38,000	75,000
Fennell	*power*	4,500	5,500		24,000	30,000
Gates	*Larkin*	26,400	5,900		54,000	31,000
Nadina	*MRJ*	1,200	11,900		75,000	81,000
Pitt	*Larkin*	30,400	8,800		71,000	70,000
*Scotch	*Ricker*	12,500	273,900		100,000	20,000
*Seymour	*Ricker*	8,000	287,500		145,000	155,000
Misc (EShu)	*RS (Scotch/Seymour)*	7,400	118,900		--	--
Misc (Taseko)	*RS (Chilko)*	400	600		--	--
Misc (Chilliwack)	*RS (Esum)*	2,500	1,500		--	--
Misc (Nahatlatch)	*RS (Esum)*	3,400	2,900		--	--
Summer					--	--
(total excluding miscellaneous)					**3,866,000**	**2,524,000**
Chilko [c]	*power (juv) (Pi)*	44.2 M	55.3 M		1,405,000	1,545,000
Late Stuart	*power*	800	43,500		544,000	81,000
Quesnel	*Ricker-cyc*	17,000	133,000		1,324,000	151,000
Stellako	*Larkin*	26,000	110,300		457,000	568,000
Raft	*Ricker (PDO)*	4,400	2,400		31,000	20,000
**Harrison [d]	*Adjusted RS1*	387,100	32,900		105,000	159,000
Misc (N. Thomp. Tribs) [j]	*R/S (Raft/Fennell)*	400	600		--	--
Misc (N. Thomp River)	*R/S (Raft/Fennell)*	2,000	3,200		--	--
Mis. (Widgeon)	R/S (Birkenhead)	700	400		--	--
Late						
(total excluding miscellaneous)					**3,169,000**	**2,061,000**
Cultus [c]	*MRJ*	119,800	318,400		38,000	81,000
*Late Shuswap	Ricker-cyc	46,000	3.1 M		2,379,000	1,357,000
*Portage	*Larkin*	300	26,700		41,000	25,000
Weaver	*MRS*	24,500	25,300		346,000	222,000
Birkenhead	*Ricker (Ei)+sibling*	92,400	67,800		365,000	376,000
Misc. non-Shuswap	*R/S (Birkenhead)*	6,500	7,000		--	--
TOTAL SOCKEYE SALMON					**7,845,000**	**5,209,000**
TOTAL PINK SALMON		*Fry in 2013 BY:609 M*			**13,432,000**	**13,432,000**

a. Forecast model used for stock; see Table 4 for model descriptions
b. Sockeye average run size from 1953-2010 (depending on the start of the time series); either across all cycles (column F) or 2015 cycle only (column G)
c. Chilko & Cultus brood year smolts are presented in columns C & D, as opposed to effective female spawners for all other stocks
d. Harrison four year olds are presented in column C and three year olds are presented in column D

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: 1948-2007) (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 two most recent brood years with recruitment data (2006 & 2007) (column E). Four-year old survivals associated with the various probability levels of the 2015 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 standard deviation. A similar comparison for Fraser Pink recruits-per-fry are also presented using the same methods.

A	B	C	D	E	F	G	H	I	J
Run timing group / Stocks	**Average**	**Peak Average** (Over Four Consecutive Years)	**2005 Brood Year**	**Avg R/EFS (2006-07)***	**2015 forecast survivals (R/EFS) for each probability level in Table 1A by stock**				
					10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	6.3	24.5	1.5	5.2	2.0	3.0	4.8	8.1	13.2
Early Summer									
Bowron	6.9	20.4	2.2	13.4	1.9	3.4	6.5	12.7	23.0
Fennell	6.2	53.5	0.3	1.3	1.0	2.1	4.0	7.8	14.7
Gates	10.2	41.0	1.6	41.0	1.3	2.5	4.8	9.9	18.3
Nadina	6.2	13.5	1.0	9.9	1.5	2.8	5.9	12.3	23.8
Pitt (age5 prod) [a]	3.6	13.3	0.2	3.0	2.1	3.2	5.7	9.5	16.6
Scotch	7.0	21.5	2.2	11.9	1.6	3.3	6.9	14.0	30.9
Seymour	7.7	29.2	3.4	7.5	2.1	4.2	7.6	15.1	26.6
Summer									
Chilko (% R/smolt) [b]	7%	18%	0.3%	5%	2%	3%	5%	8%	13%
Late Stuart	9.0	57.2	0.6	3.8	4.2	9.8	22.2	47.6	104.6
Quesnel [c]	8.9	18.1	0.3	3.8	1.5	3.3	8.0	20.7	49.8
Stellako	7.0	15.1	0.1	5.3	2.2	3.6	6.0	9.3	13.9
Raft	5.7	13.6	0.4	1.3	1.6	2.7	5.1	9.2	15.6
Harrison [d]	7.8	33.8	0.1	20.9	NA	NA	NA	NA	NA
Late									
Cultus (% R/smolt) [b]	4%	15%	1%	4%	1%	2%	4%	8%	16%
Late Shuswap [c]	6.5	10.8	2.8	9.8	1.7	3.3	6.3	13.2	27.0
Portage	13.1	61.7	0.3	7.0	1.1	2.9	7.4	18.0	42.8
Weaver	12.1	41.8	2.6	18.6	3.7	6.4	11.7	21.4	36.9
Birkenhead	5.5	21.5	1.2	2.6	0.7	1.2	2.5	4.8	8.8
Fraser Pink Salmon (R/Fry)	3%	10% (1999 BY max.)	--	*2% (recent 2009 & 2011 avg,)*	*1%*	*2%*	*2%*	*3%*	*5%*

**for Harrison in column E is for the brood years 2006-2008*

Table 3. Age composition of forecasted returns for each stock at the 50% probability level.

Sockeye stock/timing group	2014 Fraser Sockeye Forecasts				
	Model	FOUR YEAR OLDS 50%	FIVE YEAR OLDS 50%	TOTAL 50%	Four Year Old Proportion
Early Stuart	*Ricker (Ei)*	**1,000**	**29,000**	**30,000**	**5%**
Early Summer		**547,000**	**290,000**	**837,000**	**65%**
Bowron	*MRS*	13,000	8,000	21,000	65%
Fennell	*power*	22,000	5,000	27,000	81%
Gates	*Larkin*	128,000	13,000	141,000	90%
Nadina	*MRJ*	7,000	24,000	31,000	22%
Pitt	*Larkin*	29,000	50,000	79,000	37%
Scotch	*Ricker*	152,000	33,000	185,000	82%
Seymour	*Ricker*	96,000	44,000	140,000	69%
Misc (EShu)	*RS (Scotch/Seymour)*	61,000	103,000	164,000	37%
Misc (Taseko)	*RS(Chilko)*	3,000	1,000	4,000	75%
Misc (Chilliwack)	*RS (Esum)*	15,000	3,000	18,000	83%
Misc (Nahatlatch)	*RS (Esum)*	21,000	6,000	27,000	78%
Summer		**3,810,000**	**865,000**	**4,675,000**	**81%**
Chilko	*power (juv) (Pi)*	2,122,000	265,000	2,387,000	89%
Late Stuart	*power*	26,000	28,000	54,000	48%
Quesnel	*Ricker-cyc*	160,000	207,000	367,000	44%
Stellako	*Larkin*	186,000	204,000	390,000	48%
Raft	*Ricker (PDO)*	26,000	10,000	36,000	72%
Harrison[b]	*Adjusted RS1*	1,273,000	141,000	1,414,000	90%
Misc (N. Thomp. Tribs)	*R/S (Ra/Fe)*	2,000	1,000	3,000	67%
Misc (N. Thomp River)	*R/S (Ra/Fe)*	11,000	7,000	18,000	61%
Widgeon	*R/S (Birkenhead)*	4,000	2,000	6,000	67%
Late		**910,000**	**326,000**	**1,236,000**	**74%**
Cultus	*MRJ*	6,000	0	6,000	100%
Late Shuswap	*Ricker-cyc*	350,000	167,000	517,000	68%
Portage	*Larkin*	5,000	3,000	8,000	63%
Weaver	*MRS*	274,000	72,000	346,000	79%
Birkenhead	*Ricker (Ei) + sibling*	236,000	63,000	299,000	79%
Misc. non-Shuswap	*R/S (Birkenhead)*	39,000	21,000	60,000	65%
Total		**5,268,000**	**1,510,000**	**6,778,000**	**78%**

Table 4. List of candidate models organized by their two broad categories (non-parametric and biological) with descriptions. Models that emphasize recent stock survival are indicated. 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, 1B & 2), where fry data or smolt data are used instead.

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

Table 5. The 2014 forecasts from the 10% to 90% p-levels are summarized into their in-season return groupings for comparison with preliminary in-season returns (final returns were not available at the time of this publication at the individual stock level). Highlighted yellow forecasts (or when returns fell between p-levels, the filled circles) represent roughly where returns fell for each stock groupings forecast distribution. Returns for most stocks fell within the 25% to 75% probability distribution, which indicates roughly average survivals for these stocks (yellow cells or circles). One notable exception was the Birkenhead stock, where returns fell below the lowest (10%) p-level, and therefore, experienced well below average survival during its life-history (between the egg stage in 2010 to returns in 2014) (red filled circle). Another exception was Harrison Sockeye, where returns fell above the 75% p-level (green filled circle), although this difference is largely attributed to extremely large uncertainty associated with the 2014 forecast for this stock due to exceptional escapements in the brood years.

Probability that the return will be at/or below the specified run size

Run Timing Group Stock	**10%**	**25%**	**50%**	**75%**	**90%**	**Preliminary 2014 Returns**
Early Stuart	132,000	189,000	299,000	476,000	709,000	**233,000**
Early Summer	**730,000**	**1,741,000**	**4,126,000**	**458,000**	**865,000**	**1,840,000**
Nad/Bow/Gat/Nahat	70,000	123,000	237,000	458,000	865,000	209,000
Pitt	31,000	46,000	73,000	127,000	208,000	69,000
Early Thompson	616,000	1,551,000	3,778,000	7,818,000	15,616,000	1,537,000
Misc. (Chilliwack)	4,000	8,000	14,000	26,000	48,000	25,000
Summer	**2,127,000**	**3,393,000**	**5,669,000**	**10,116,000**	**17,781,000**	**8,134,000**
Chilko	1,121,000	1,670,000	2,615,000	4,274,000	6,790,000	2,570,000
Late Stuart/Stellako	395,000	609,000	1,019,000	1,791,000	3,027,000	1,605,000
Quesnel	467,000	845,000	1,524,000	2,950,000	5,864,000	2,358,000
Raft/North Thompson	26,000	41,000	68,000	121,000	212,000	127,000
Harrison	118,000	228,000	473,000	980,000	1,888,000	1,474,000
Late	**4,230,000**	**7,432,000**	**12,670,000**	**21,995,000**	**36,534,000**	
Late Shuswap	3,920,000	6,939,000	11,841,000	20,505,000	34,160,000	9,290,000
Weaver/Cultus	105,000	182,000	336,000	619,000	2,075,000	192,000
Birkenhead	205,000	311,000	493,000	831,000	1,299,000	100,000

Table 6. Top ranked model forecasts evaluated for each stock for the 2015 forecast. Model ranks determined from the 2010 forecast jackknife analysis results (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). Forecasts marked with an asterisks (*) indicate that the model is being extrapolated outside its fitted range due to large brood year escapements particularly in 2010 (five year old return forecasts in 2015) or, in the case of Harrison, 2011 (four year old return forecast in 2015).

RUN TIMING GROUP: EARLY STUART

	Rank	**Return Forecast**				
EARLY STUART		**10%**	**25%**	**50%**	**75%**	**90%**
Ricker (Ei)	**1**	**8,000**	**16,000**	**30,000**	**58,000**	**108,000**
Ricker (Pi)	1	7,000	13,000	27,000	54,000	100,000
Ricker	3	7,000	13,000	25,000	47,000	90,000
Ricker (PDO)	3	8,000	14,000	29,000	60,000	109,000
Ricker (Ei) five year old	NA	7,000	14,000	29,000	56,000	107,000
sibling five year old	NA	6,000	10,000	20,000	37,000	66,000

RUN TIMING GROUP: EARLY SUMMER

	Rank	**Return Forecast**				
BOWRON		**10%**	**25%**	**50%**	**75%**	**90%**
MRS	**1**	**6,000**	**11,000**	**21,000**	**40,000**	**72,000**
Ricker (Pi)	2	10,000	15,000	25,000	40,000	60,000
Ricker (Ei)	3	10,000	15,000	23,000	38,000	60,000

	Rank	**Return Forecast**				
FENNELL		**10%**	**25%**	**50%**	**75%**	**90%**
power	**1**	**10,000**	**16,000**	**27,000**	**47,000**	**78,000**
RAC	2	8,000	15,000	32,000	65,000	123,000
Ricker	3	14,000	23,000	40,000	71,000	117,000

	Rank	**Return Forecast**				
GATES		**10%**	**25%**	**50%**	**75%**	**90%**
RAC	1	10,000	17,000	31,000	55,000	95,000
R2C	2	18,000	32,000	62,000	119,000	214,000
Larkin	**3**	**46,000**	**79,000**	**141,000**	**280,000**	**502,000**
MRS	3	59,000	122,000	274,000	616,000	1,276,000
Ricker (Pi)	6	79,000	140,000	251,000	475,000	810,000
power	6	47,000	87,000	161,000	283,000	520,000

	Rank	**Return Forecast**				
NADINA		**10%**	**25%**	**50%**	**75%**	**90%**
MRJ	**1**	**8,000**	**15,000**	**31,000**	**65,000**	**126,000**
Ricker (FrD-peak)	2	4,000	8,000	13,000	22,000	40,000
power (juv) (FrD-peak)	2	6,000	11,000	21,000	37,000	64,000
Ricker	14	7,000	13,000	22,000	39,000	66,000
power (juv)	8	9,000	15,000	26,000	47,000	86,000
MRJ five year old	1	98,000	51,000	24,000	12,000	6,000
sibling five year old	NA	6,000	10,000	19,000	34,000	59,000

PITT	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	**1**	**33,000**	**51,000**	**79,000**	**120,000**	**190,000**
TSA	2	20,000	37,000	71,000	137,000	247,000
Ricker (PDO)	3	36,000	54,000	86,000	133,000	208,000
Larkin five year old	1	18,000	29,000	50,000	84,000	146,000
sibling five year old	NA	21,000	32,000	51,000	82,000	127,000

SCOTCH	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin*	1	1,000	7,000	55,000	611,000	4,999,000
Ricker*	**2**	**48,000**	**85,000**	**185,000**	**430,000**	**845,000**
RS1*	3	42,000	119,000	383,000	1,230,000	3,514,000
Ricker four & sibling five	NA	33,000	55,000	100,000	195,000	377,000
Ricker five year old	2	4,000	12,000	33,000	208,000	745,000
sibling five year old	NA	2,000	4,000	8,000	17,000	34,000
Shuswap Power(fry) x prop Scotch EFS) five	NA	1,000	3,000	12,000	40,000	111,000

SEYMOUR	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker-cyc*	1	**Does not converge**		70K		
Larkin*	2	1,000	5,000	17,000	95,000	397,000
R1C	2	11,000	20,000	40,000	79,000	146,000
Ricker*	**10**	**41,000**	**68,000**	**140,000**	**274,000**	**529,000**
power*	10	38,000	71,000	140,000	289,000	644,000
Ricker four and sibling five	NA	30,000	47,000	77,000	132,000	228,000
Ricker five year old	10	5,000	9,000	44,000	152,000	432,000
sibling (five year old)	NA	3,000	5,000	9,000	18,000	33,000
Shuswap Power (fry) x prop Seymour EFS five	NA	1,000	4,000	13,000	42,000	117,000

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
power (juv) (Pi)	**1**	**1,117,000**	**1,587,000**	**2,387,000**	**3,813,000**	**5,972,000**
Larkin	1	139,000	229,000	426,000	793,000	1,374,000
power (juv)	3	1,054,000	1,558,000	2,344,000	3,674,000	5,466,000
power (juv) (FrD-peak)	4	1,003,000	1,427,000	2,207,000	3,437,000	5,641,000
power (juv) (Pi) five year old	1	139,000	201,000	265,000	285,000	321,000
sibling (five year old)	NA	49,000	89,000	170,000	327,000	596,000
power (juv) (Pi) four year old	NA	977,000	1,385,000	2,122,000	3,526,000	5,648,000
sibling (four year old)	NA	440,000	721,000	1,230,000	2,100,000	3,439,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	2,000	4,000	10,000	24,000	51,000
R2C	2	3,000	6,000	15,000	38,000	84,000
power	**3**	**12,000**	**25,000**	**54,000**	**118,000**	**245,000**
Ricker (FrD)-mean	4	7,0000	17,000	46,000	126,000	315,000
power five year old	1	3,000	9,000	28,000	77,000	224,000
sibling (five year old)	NA	1,000	6,000	27,000	129,000	548,000

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	29,000	57,000	121,000	259,000	512,000
R2C	2	25,000	52,000	120,000	276,000	583,000
Ricker-cyc	**3**	**108,000**	**197,000**	**367,000**	**684,000**	**1,421,000**
Larkin	4	177,000	303,000	533,000	909,000	1,478,000
Ricker	6	86,000	168,000	363,000	716,000	1,426,000
power(juv)	N/A	95,000	191,000	423,000	957,000	2,203,000
Ricker-cyc five year old	3	59,000	111,000	207,000	465,000	1,027,000
sibling five year old	NA	63,000	112,000	205,000	377,000	671,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
R2C	1	41,000	70,000	126,000	226,000	385,000
Larkin	**2**	**186,000**	**261,000**	**390,000**	**552,000**	**823,000**
Ricker (Ei)	3	169,000	251,000	384,000	628,000	979,000
Larkin five year old	2	89,000	137,000	204,000	325,000	664,000
sibling five year old	NA	70,000	109,000	177,000	288,000	451,000

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)	1	**15,000**	**23,000**	**36,000**	**56,000**	**87,000**
Ricker-cyc	2	**Does not converge**				
power	2	12,000	18,000	28,000	46,000	73,000

HARRISON	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)*	1	336,000	815,000	2,016,000	5,263,000	12,524,000
Ricker*	5	489,000	1,006,000	2,488,000	6,111,000	12,709,000
power*	6	309,000	657,000	1,452,000	3,563,000	8,344,000
adjusted RS1	**N/A**	**255,000**	**573,000**	**1,414,000**	**3,487,000**	**7,858,000**

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	**1**	**1,000**	**3,000**	**6,000**	**12,000**	**22,000**
power (juv) (FrD-peak)	2	1,000	3,000	5,000	10,000	20,000
power (juv) (Pi)	3	1,000	3,000	5,000	10,000	19,000
MRJ four year old	1	1,000	2,000	6,000	10,000	19,000
sibling four year old	NA	1,000	2,000	5,000	12,000	28,000

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	70,000	154,000	369,000	884,000	1,945,000
Ricker-cyc*	**2**	**168,000**	**293,000**	**517,000**	**924,000**	**1,758,000**
RAC	3	281,000	592,000	1,356,000	3,107,000	6,554,000
Larkin*	5	23,000	51,000	134,000	494,000	1,772,000
Ricker*	7	142,000	264,000	604,000	1,586,000	4,830,000
power*	11	133,000	242,000	546,000	1,516,000	4,864,000
Ricker-cyc five year old	2	46,000	95,000	167,000	310,000	655,000
sibling five year old	NA	29,000	48,000	81,000	138,000	227,000
Shuswap power(fry) x prop L-Shuswap EFS five	NA	10,000	39,000	139,000	452,000	1,246,000

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin*	**1**	**1,000**	**3,000**	**8,000**	**19,000**	**55,000**
Ricker-cyc*	2	**Does not converge**				
power*	4	3,000	7,000	15,000	29,000	59,000
Ricker*	7	2,000	4,000	9,000	20,000	42,000

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS	**2**	**110,000**	**189,000**	**346,000**	**635,000**	**1,095,000**
Ricker (PDO)	3	171,000	252,000	415,000	697,000	1,098,000
RJC	5	106,000	179,000	323,000	583,000	992,000
MRS five year old	2	24,000	42,000	72,000	127,000	213,000
sibling five year old	NA	10,000	17,000	30,000	53,000	88,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	1	189,000	298,000	497,000	819,000	1,392,000
Ricker	2	175,000	281,000	469,000	788,000	1,282,000
RAC	2	70,000	151,000	359,000	851,000	1,852,000
Ricker (Ei) four & sibling five	**NA**	**120,000**	**183,000**	**299,000**	**513,000**	**879,000**
Ricker (Ei) five year old	1	42,000	84,000	183,000	370,000	729,000
sibling five year old	NA	23,000	38,000	63,000	107,000	172,000

FRASER PINK SALMON	Rank	Return Forecast 10%	25%	50%	75%	90%
Power (juv) SSS	**2**	7,661,000	10,385,000	14,455,000	20,450,000	27,776,000
Power (juv)	3	8,279,000	11,835,000	16,165,000	22,580,000	31,261,000
MRJ	3	5,581,000	7,936,000	11,734,000	17,349,000	24,668,000

Table 7. Fraser River Pink Salmon performance measure calculations and rankings used for the 2015 forecast. Performance measures were calculated by model using the full jack-knife forecast time-series. The first ranked model out of all the models explored was the power model with a sea-surface salinity covariate (average SSS from July-September at the Amphitrite Point and Race Race Rocks lighthouse stations).

Model	**MRE**		**MAE**		**MPE**		**RMSE**		**Average**
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	**Rank**
Power	-0.946	5	4.323	3	-0.003	1	5.773	2	**3**
Power (SSS)	-0.794	4	4.023	1	0.1261	3	5.498	1	**1**
TSA	-1.708	7	6.008	5	0.2021	6	6.734	4	**5**
R1C	-0.128	1	6.056	6	0.2235	7	7.374	5	**6**
R2C	-1.199	6	6.584	7	0.1461	4	7.913	7	**7**
MRS	-0.606	3	4.206	2	0.1091	2	5.865	3	**3**
RS1	2.714	8	9.079	8	0.2939	8	13.545	8	**8**
RS2	0.429	2	5.527	4	0.1682	5	7.377	6	**5**

Figures

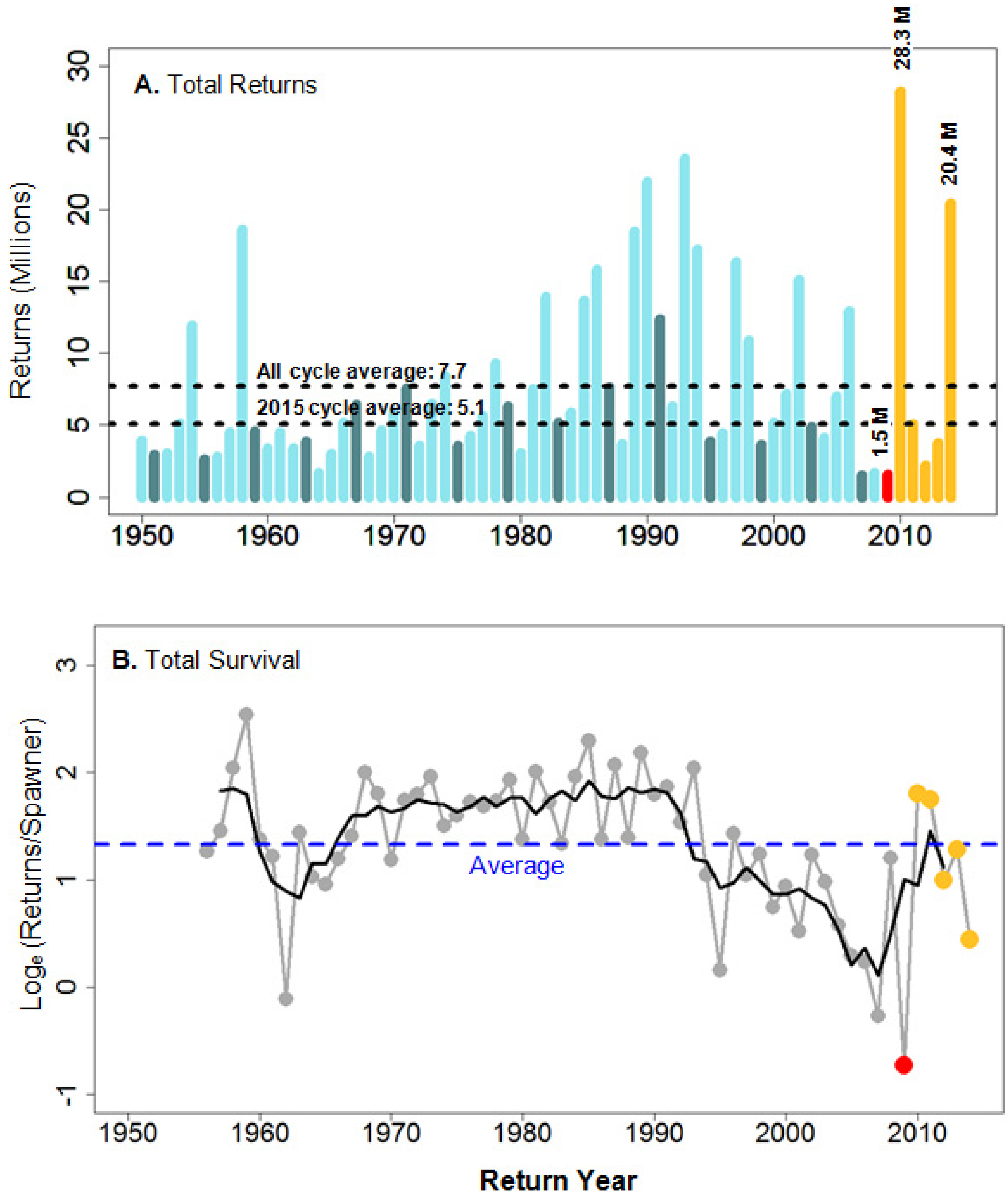

Figure 1 ***A****. Total Fraser Sockeye annual returns (dark blue vertical bars for the 2015 cycle and light blue vertical bars for the three other cycles). Recent returns from 2012 to 2014 are preliminary.* ***B****. Total Fraser Sockeye survival (loge (returns/total spawner)) up to the 2014 return 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 blue dashed line is the time series average. The red vertical bar in Figure A (or filled circles in B) represents the 2009 returns (low survival), and the yellow vertical bars in Figure A (or filled circles in B) represents the 2010 to 2014 returns (average survival for the Fraser Sockeye aggregate).*

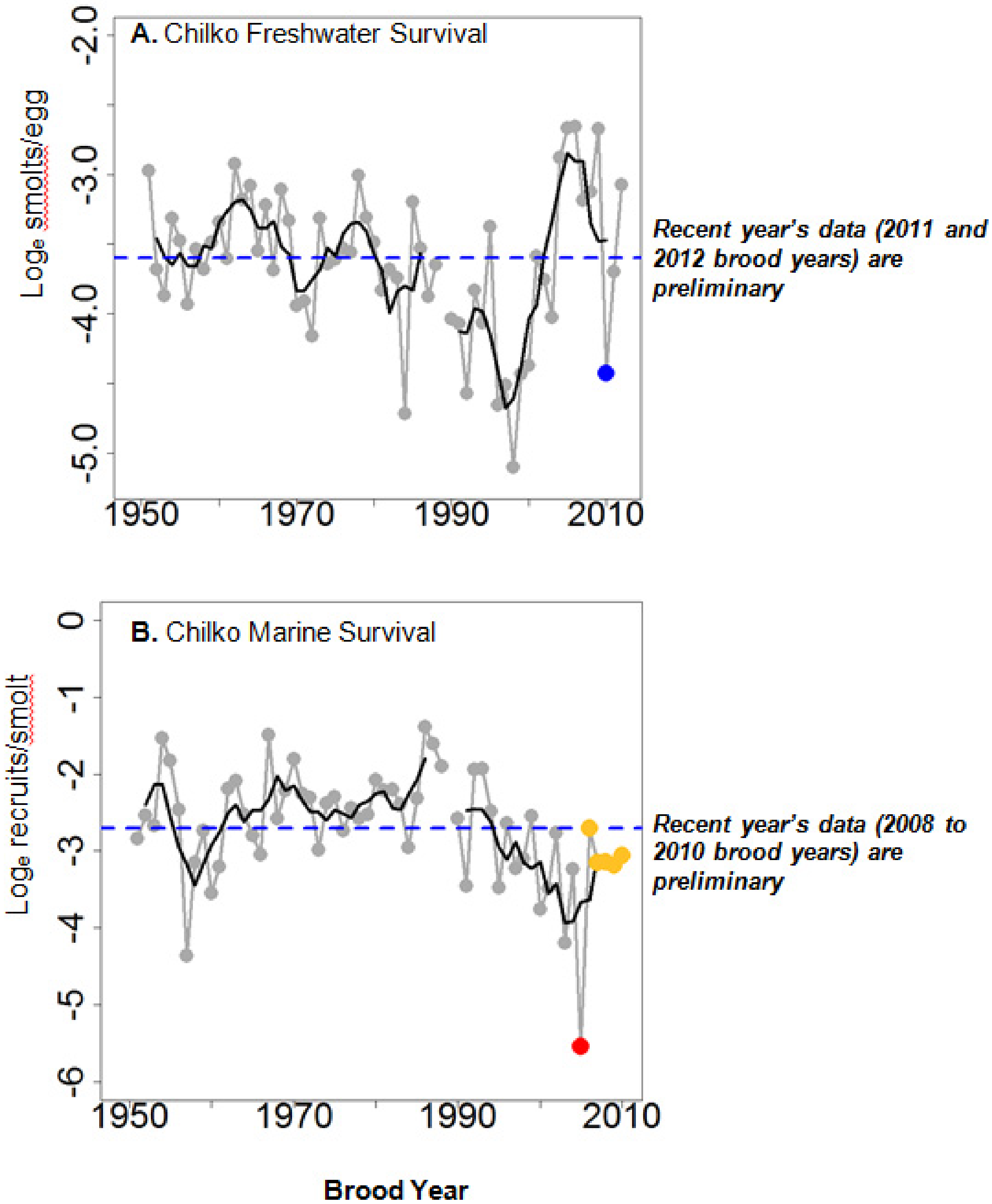

*Figure 2. Chilko River Sockeye **A**. annual freshwater (loge smolts-per-egg) survival (filled grey circles and lines) with the 2010 brood year survival indicated by the blue filled circle and **B**. annual marine (loge recruit-per-smolt) survival (filled grey circles and lines) with the 2005 brood year survival indicated by the red filled circle. The black line in both figures represents the smoothed four-year running average survival and the blue dashed lines indicate average survival.*

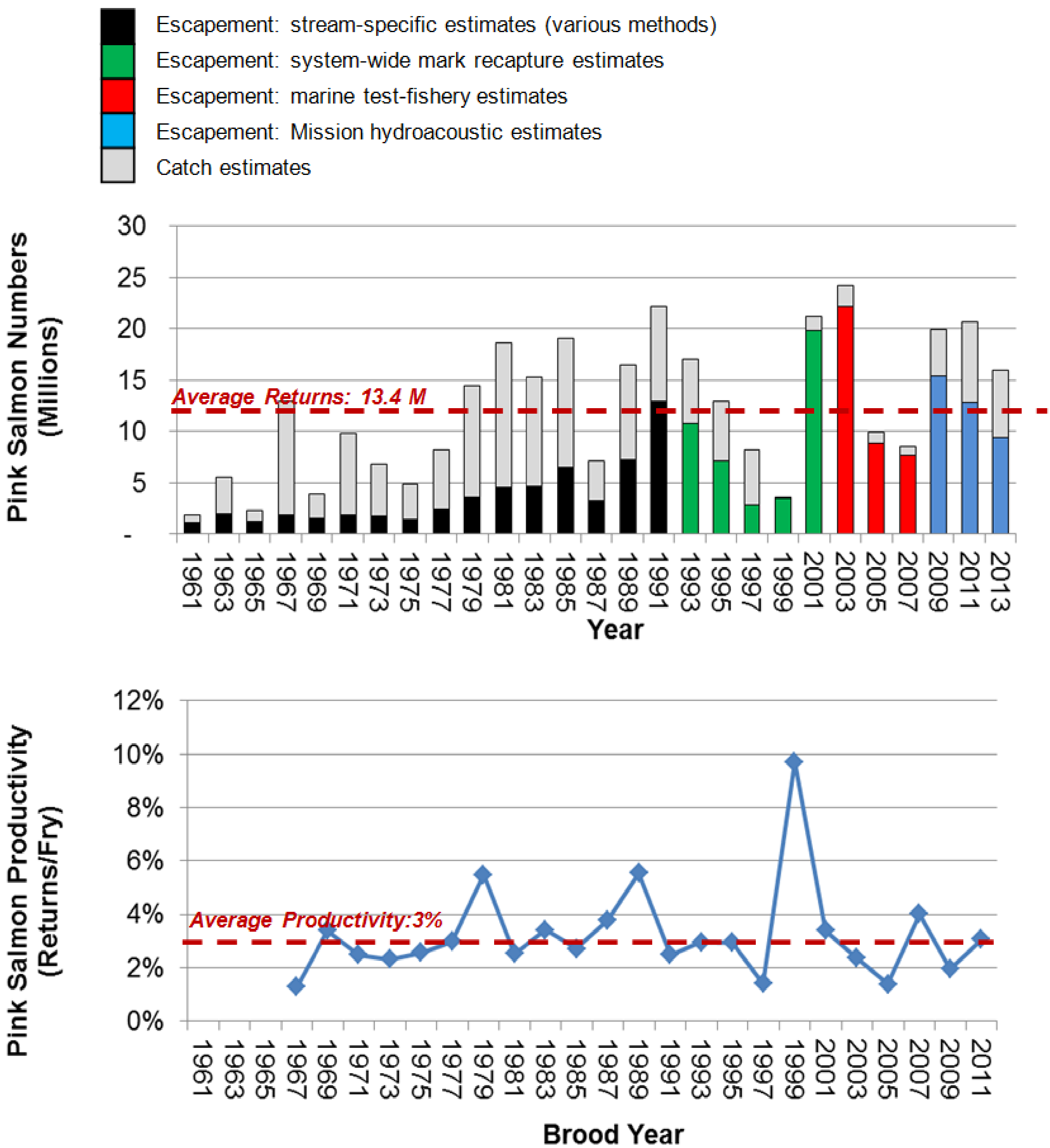

Figure 3 ***A****. Fraser River Pink Salmon escapement (black or coloured bars), catch (grey bars), and return (total height of annual bars) estimates. Escapement estimates were generated from system-specific programs from 1957 to 1991 (black bars), system-wide single mark recaptures from 1993 to 2001 (green bars), indirect system-wide marine test fisheries estimates from 2003 to 2007 (red bars), and system-wide hydroacoustic estimate from 2009 to 2013 (blue bars). Given the lack of calibration work between methods, escapement estimates between years are not entirely comparable. The red dashed line is the average Pink returns (13.4 M);* ***B****. Fraser Pink total survival (recruits-per-fry) from the 1967 to 2011 brood years; these estimates are uncertain and not entirely comparable inter-annually due to differences in return estimate (catch and escapement) methods over time. The red dashed line is the average productivity (3%).*

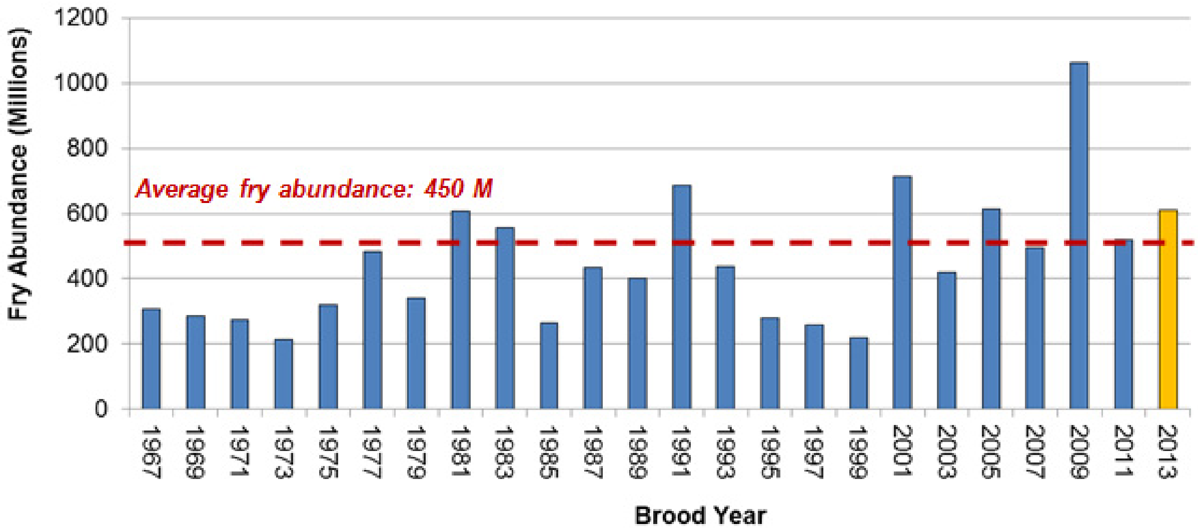

Figure 4: Fraser River Pink fry abundance from the 1967 to 2013 brood years. The preliminary 2013 (yellow bar) brood year (2014 fry outmigration year) was used as the predictor variable for the 2015 Fraser Pink forecast. The red dashed line represents the average fry abundance from the 1967-2013 brood years (450 M).

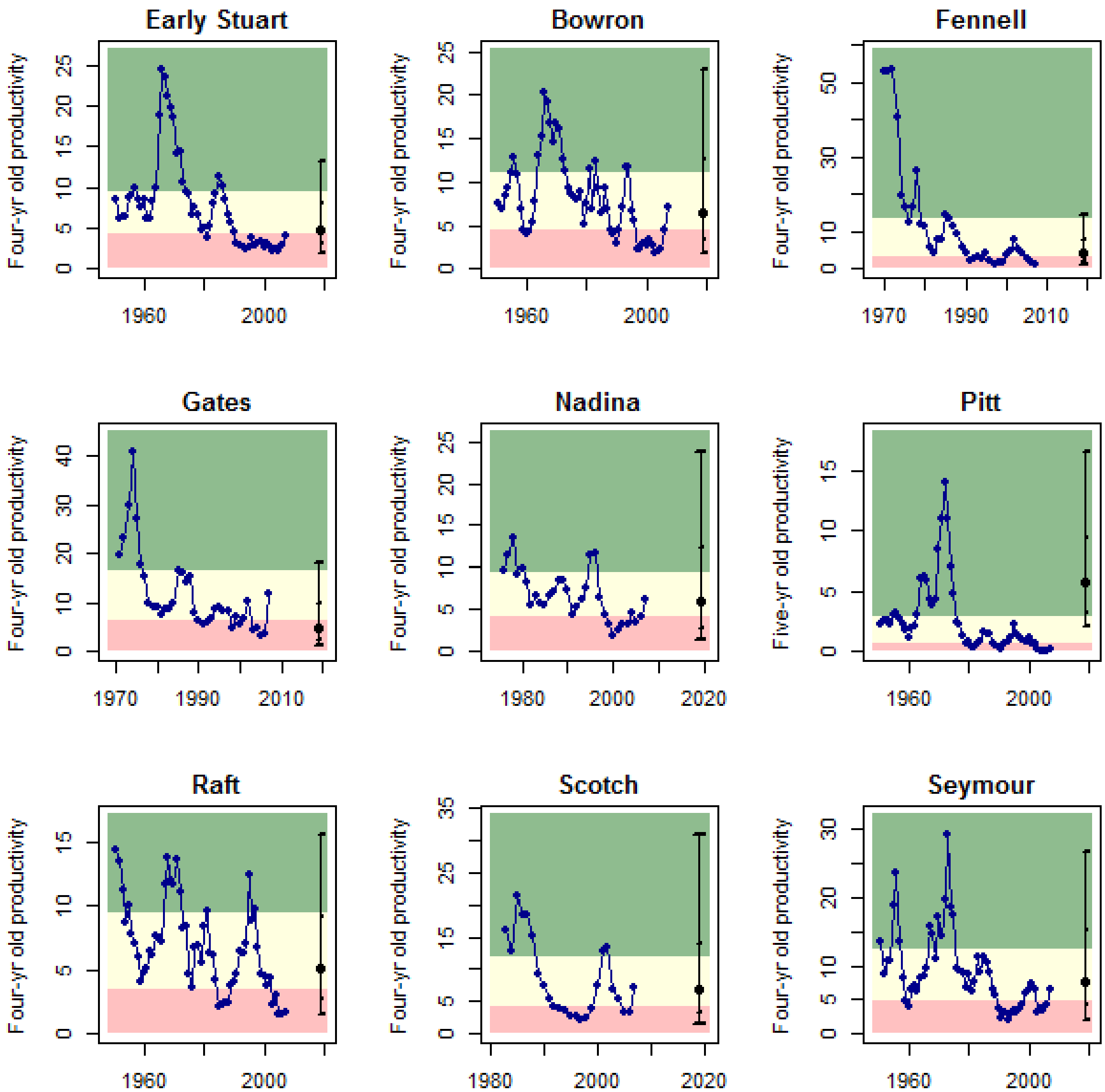

Figure 5. Blue lines present each stock's smoothed four year old survival (four year running geometric mean) using data from the beginning of the time series to the 2007 brood year. For Pitt, five-year old survival is used (up to 2006 brood year). For Quesnel and Late Shuswap, survival on the 2015 cycle-line is presented (not smoothed geometric mean). For Chilko and Cultus, four year old recruits-per-smolt are used. Black bars indicate the range of survivals associated with the 2015 forecasts, at the 10% (lower horizontal bar), 25%, 50% (black filled circle), 75%, and 90% (upper horizontal bars) p-levels. Colours (Red, Amber, Green) show where the productivities fall out in terms of the long-term geometric average (+/- 0.5 standard deviation): Red (< average), yellow (average) and green (>average).*

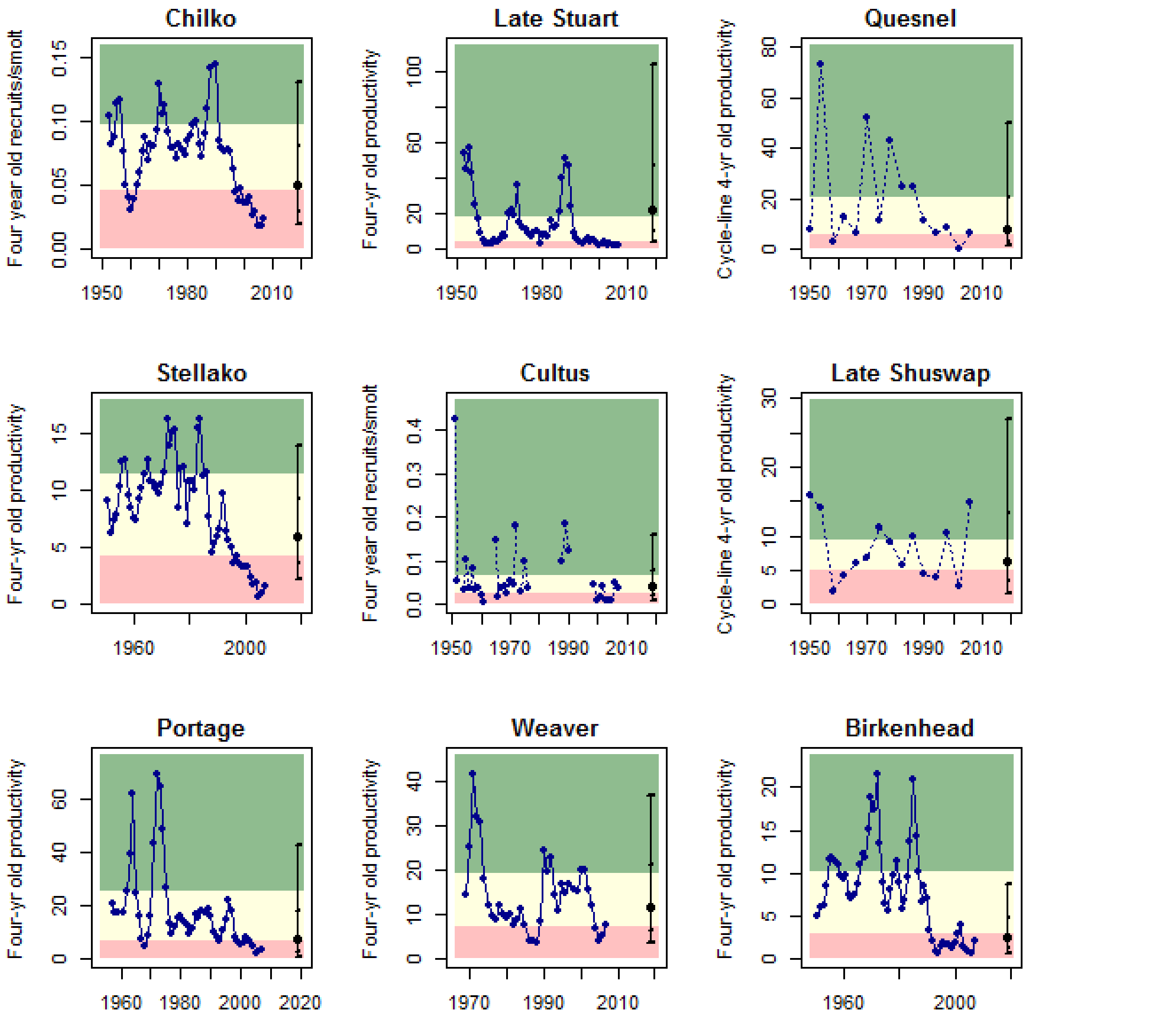

Figure 5 Continued. Blue lines present each stock's smoothed four year old survival (four year running geometric mean) using data from the beginning of the time series to the 2007 brood year. For Pitt, five-year old survival is used (up to 2006 brood year). For Quesnel and Late Shuswap, survival on the 2015 cycle-line is presented (not smoothed geometric mean). For Chilko and Cultus, four year old recruits-per-smolt are used. Black bars indicate the range of survivals associated with the 2015 forecasts, at the 10% (lower horizontal bar), 25%, 50% (black filled circle), 75%, and 90% (upper horizontal bars) p-levels. Colours (Red, Amber, Green) show where the productivities fall out in terms of the long-term geometric average (+/- 0.5 standard deviation): Red (< average), yellow (average) and green (>average).*

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Sources of information

This Science Response Report results from the Science Response Process of November 25, 2014 on the Pre-season abundance forecasts for Fraser River Sockeye and Pink Salmon returns in 2015.

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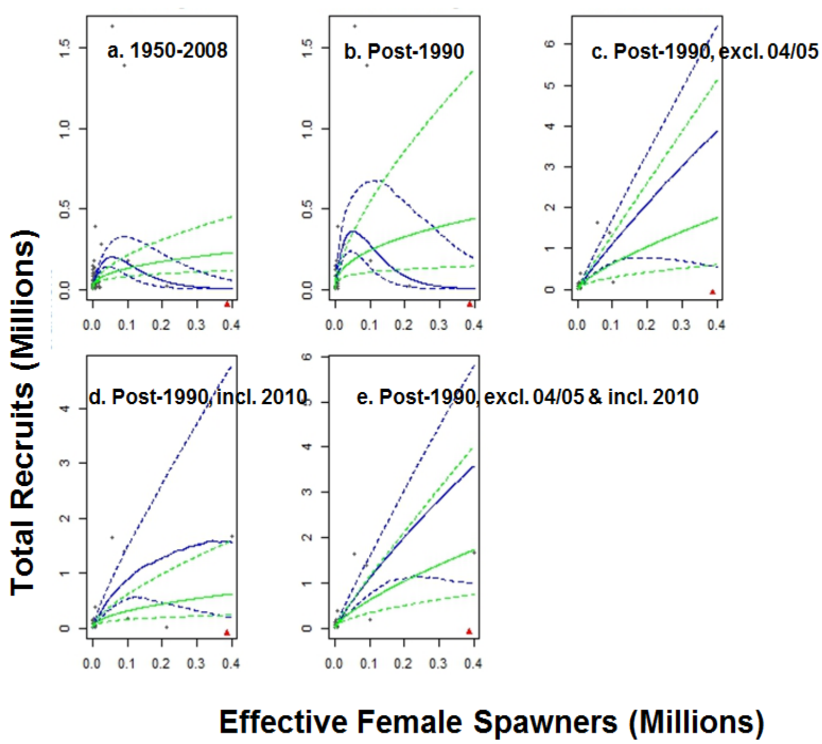
Appendix 1: Harrison Sockeye biological model sensitivity analyses

Appendix Table 1. Ricker and Power model forecasts generated using different data sets including the following: (a) original forecast file; (b) original forecast file but only including post-1990 data; (c) post-1990 data set excluding the 2004 & 2005 brood; (d) post-1990 data set including the preliminary 2010 brood year returns (2014 four year olds) to provide an additional data point to inform the models at recent years high escapements; and (e) post-1990 data set, including the 2010 brood year, but excluding 2004 and 2005 brood years.

	Return Forecast				
Model and Data Variants	**10%**	**25%**	**50%**	**75%**	**90%**
Power Model					
a. 1950-2008 (original forecast dataset)	52,000	103,000	219,000	489,000	990,000
b. post-1990 (original forecast dataset)	76,000	175,000	502,000	1,304,000	3,637,000
c. post-1990 excl. 04/05	285,000	604,000	1,481,000	3,946,000	9,419,000
d. post-1990 incl. 2010	113,000	250,000	634,000	1,724,000	5,356,000
e. post-1990 incl. 2010 & excl. 04/05	309,000	657,000	1,452,000	3,563,000	8,344,000
Ricker Model					
a. 1950-2008 (original forecast dataset)	12,000	33,000	85,000	208,000	454,000
b. post-1990 (original forecast dataset)	15,000	40,000	123,000	377,000	1,283,000
c. post-1990 excl. 04/05	297,000	939,000	2,339,000	5,840,000	14,301,000
d. post-1990 incl. 2010	142,000	421,000	1,420,000	5,052,000	15,472,000
e. post-1990 incl. 2010 & excl. 04/05	488,000	1,006,000	2,488,000	6,111,000	12,709,000



Appendix Figure 1. Fit of Ricker (blue lines) and Power (green lines) models to various subsets of Harrison data. Solid lines denote the fit of the 50% p-level, while dashed lines show the 10% and 90% p-levels. Small red triangle indicates the exceptional escapement in the 2010 brood year. Note: the forecasts in Table 1A predict the combination of three and four olds in 2015, and therefore, will not completely line up with these figures.

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