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

Context

To provide background for the 2016 Fraser Sockeye returns (DFO 2016), this year's Fraser Sockeye forecast supplement presents information on these fish from their spawning parents through to their three-year-old siblings that returned in 2015. The brood year (year they were spawned by their parents) for 2016 four-year-old lake-type Fraser Sockeye returns, which represents most stocks, is 2012. The brood year for three and four year old river-type Sockeye (Harrison) returns are 2013 and 2012, respectively. The forecast supplement synthesizes information on adult Fraser River upstream migration conditions, escapements, spawner success, fry abundance and condition, the lake rearing conditions for fry (if available, and applicable to lake-type stocks only), and juvenile migration and ocean conditions in the Fraser River and Strait of Georgia (SOG). In addition, proportions of key lake-type stocks in various sampling components of the 2012 brood year are compared: 2012 escapements, 2014 smolt Fraser River downstream migration, 2014 juvenile ocean migration, and 2016 return forecasts.

Based on the 2016 Fraser Sockeye return forecasts, the stocks expected to contribute the largest percentages to the 2016 returns include the lake-type Chilko stock (44% of the forecast return at the 50% probability level), Late Stuart and Stellako stocks (combined contribute 20% to the forecast return) and the river-type Harrison stock (8%) (DFO 2016). The Chilliwack lake-type stock is also expected to contribute a larger proportion (6%) than average to the total return, given its exceptional brood year escapement in 2012 (DFO 2016). Given the differences in ages, life-history, and ocean distribution, lake-type stocks are considered separately from Harrison, the only large river-type stock in this system.

There are mixed survival signals for 2016 Fraser Sockeye returns. Some indicators suggest survival could be poor, whereas other indicators suggest survival could be average or better. The 'warm blob' has persisted during the ocean residence of both the 2015 returns and the upcoming 2016 returns, affecting the environmental conditions experienced by these fish. However, given the mixed survival responses across Sockeye stocks in 2015, no conclusion can be drawn regarding the potential effects of the continued persistence of the 'warm blob' in the Northeast Pacific Ocean on 2016 returns.

New information from the Mission smolt project in the lower Fraser River and the expanded SOG surveys provide enhanced resolution on the out-migration timing and distribution of Fraser Sockeye stocks throughout both the lower Fraser River and the SOG. Combined with assessments of ocean conditions, these projects have the potential to link smolt out-migration timing and distribution in the Fraser River and SOG to temporal and spatial variation in ocean conditions. However, large gaps remain in the marine assessments, particularly outside the SOG, required to link changes in Fraser Sockeye survival to marine conditions. Similar gaps remain in understanding the influence of freshwater factors on Fraser Sockeye survival. No assessments of spawning habitat are conducted, and assessments of lake ecosystems have remained limited and sporadic.

This Science Response Report results from the Science Response Process of January 21-22, 2016 on the Supplement to the pre-season abundance forecasts for Fraser River Sockeye Salmon returns in 2016.

Background

Fraser Sockeye Life-History

Fraser Sockeye exhibit two distinct life-history types: lake-type (Figure 1) and river-type (Figure 2). Most Fraser Sockeye are lake-type, spending their first two winters in freshwater (one winter as eggs in the spawning gravel, and one winter rearing as fry in a lake). After their second winter in freshwater, these fish migrate rapidly out of their rearing lakes, and migrate downstream in the Fraser River, northward through the SOG, Johnstone Strait, and along the continental shelf, en-route to the GOA. They spend their final two winters in this part of the Pacific before they return to their spawning grounds as four-year-olds (Figure 1). The age of these fish is 4_2 (Gilbert-Rich aging convention), where the total age is indicated by the '4' (including freshwater and marine stages), and the winters spent in freshwater are indicated by the subscript '2'. Chilko, a lake-type stock, is expected to contribute the largest percentage (44%) to the total return in 2016 (DFO 2016). Note that there are other lake-type Sockeye age classes, however, the 4_2 age class described above dominates the age structure of most Fraser Sockeye lake-type stocks.

Harrison Sockeye is a river-type stock (Figure 2). Unlike most Fraser Sockeye, this stock spends a single winter in freshwater incubating in the spawning gravel, and subsequently migrates downstream to the SOG shortly after gravel emergence. Most Harrison Sockeye migrate into the SOG after mid-July and then remain in the SOG for several months after all other Fraser Sockeye stocks have migrated out of this system (Beamish et al. 2016). They largely migrate out into the northeast Pacific via the southern Juan de Fuca Strait route, although a small proportion also migrates out the northern Johnstone Strait route (Beamish et al. 2016). Harrison Sockeye return to spawn as three- (3_1) or four-year-olds (4_1) and this stock is expected to contribute 8% to the total return in 2016 (DFO 2016).

Returns

Total Fraser Sockeye returns exhibit high inter-annual variability (Figure 3A). One cause of this variation is the cyclic four year pattern in returns of the stocks that produce large abundances once every four years. For example, the dominant Adams run (identified as Late Shuswap in the forecast table) has very large returns once every four years (i.e. …2006, 2010, 2014), which results in larger total Fraser Sockeye returns in these years (Figure 3A). Other factors that influence Fraser Sockeye returns include annual variability in survival (Figure 3B), and spawning escapement.

Fraser Sockeye abundances peaked in the 1990's, and then subsequently decreased, reaching an exceptionally low abundance in 2009 (Figure 3A). Poor returns in 2009 coincided with poor returns for most salmon stocks along the Canada-U.S. west coast, and were attributed to poor ocean conditions. Then, for the next five years (2010-2014), returns generally improved, with 2010 being a record high escapement year for the Fraser Sockeye aggregate. However, last year's (2015) Fraser Sockeye total returns were again poor (Figure 3A); Chilko (55%) and Harrison (11%) contributed the largest percentages to these returns.

Survival

Total survival (returns-per-spawner) across all Fraser Sockeye stocks declined in the 1990s and reached the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2013) survival was close to average (Figure 3B). Very preliminary information on total 2014 and 2015 returns indicate survival has again decreased (Figure 3B). These broader survival trends (Figure 3B) are driven by the more abundant stocks in a given year, and in 2015, it was the particularly low survival of Summer Run stocks that resulted in the low total survival for the Fraser Sockeye aggregate.

Individual stock survival trends vary (Grant et al. 2011; Peterman & Dorner 2012) and in recent years survival has ranged from below to above average across stocks. Most notably, the river-type Harrison stock has exhibited a large increase in survival in recent years (Grant et al. 2010; Grant et al. 2011).

Considerable mortality occurs in both the freshwater and marine ecosystems, as indicated by freshwater and marine survival data for Chilko River Sockeye (Figure 4A & B). Chilko is the only stock with a long time series of smolt data, which can be used with escapement and return data to partition total survival into freshwater and ‘marine’ components (‘marine’ survival includes their migration downstream from the counting weir at the outlet of Chilko Lake to the SOG). Chilko marine survival, similar to the total Fraser Sockeye survival trend, declined in the 1990’s and culminated in the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2014 return years), survival was close to average. A very preliminary estimate for 2015 returns indicates that survival was below average for this cohort (Figure 4B).

Pre-season Abundance Forecasts

The 2016 forecast for total Fraser Sockeye returns ranges from 1,296,000 to 4,227,000 at the 25% to 75% probability levels (DFO 2016). The 50% (median) forecast is 2,271,000 (DFO 2016). Four-year-olds comprise 82% of the total 2016 return forecast, which is slightly lower than the historical average contribution of four-year-olds (87%). A number of stocks that contribute small numbers to the total 2016 forecast are expected to return as mostly five-year-olds and include the following: Bowron (95% five-year-olds as a percentage of four- plus five-year-olds), Pitt (80%), Quesnel (93%), Late Shuswap (100%) and Birkenhead (76%). Chilko lake-type Sockeye are expected to contribute the greatest proportion to the total 2016 forecast overall (44% of the total at the 50% probability level). The forecast for Chilko is dominated by four-year-olds (97% as a percentage of four- plus five-year-olds) (DFO 2016). The Harrison river-type stock is expected to contribute 8% to the total.

Understanding the mechanisms that influence Fraser Sockeye population dynamics is challenging given the broad range of ecosystems these fish inhabit during their freshwater and marine life stages. These mechanisms also likely vary annually; in some years freshwater factors might have the largest effect on a stock’s productivity, where in other years, marine factors or a combination of the two might have the larger effect. Therefore, the forecast probability distributions remain wide and uncertain, covering the range of productivities a stock has experienced throughout its time series for a similar range of escapements in the parental generation. This forecast supplement pulls together monitoring and research conducted on Fraser Sockeye to better understand and, ultimately, quantitatively predict Fraser Sockeye returns. For lake-type Sockeye, data are presented from the 2012 parental spawner generation through to the three-year-old (jack) sibling returns in 2015. Auxiliary information on the five-year-old returns of lake-type Fraser Sockeye in 2015 (brood year 2010) is presented last year (DFO 2015b). For river-type Sockeye (i.e. Harrison), data from the 2012 and 2013 brood years through to the juvenile rearing environments in 2013 and 2014 are presented.

Analysis and Response

Review of 2015 Returns in the Context of the 2015 Forecast and Supplement

Overview

- Total returns for Fraser Sockeye were 2.1 million in 2015 (Figure 3A); the Chilko (lake-type) stock contributed 50% to this total return and the Harrison (river-type) stock contributed 10%. This 2015 return falls at the lowest probability distribution of the 2015 pre-season return forecast (10% probability level) (DFO 2015a). For context, the 50% probability level forecast (where there is a one in two chance returns can fall above or below this value given past observations for similar escapements) was 6.8 million (DFO 2015a). This indicates that for the Fraser Sockeye aggregate, survival was very low. Although, when evaluated at the individual stock level, survival varied. This return is among the lowest since 1950 (Figure 3A).
- In 2015, poor returns were largely influenced by the poor survival of the lake-type Chilko and the river-type Harrison populations, which contributed the largest proportions to the total returns. These two stocks have very different life histories, ocean entry years, and ocean distribution, so mechanisms influencing the 2015 poor survival of these two stocks would not likely be the same.
- Although a few lake-type stocks, including Chilko, experienced poor survival associated with the 2015 returns, the response across all 18 lake-type stocks varied. This contrasts with the similarly poor total Fraser Sockeye returns in 2009 that were attributed to extremely poor survivals for almost all stocks, including the river-type Harrison stock.
- In last year's 2015 forecast supplement (DFO 2015b), there were mixed signals for Chilko survival. A three-to-four year-old sibling model generated a 2015 four-year-old forecast that was half the official forecast (at the 50% probability level), which indicated the potential for poor survival for this stock. Some signals in the SOG ecosystem provided by the trawl surveys, conducted late-June 2013, were average in regards to Fraser Sockeye (including Chilko) juvenile body sizes and stomach fullness.
- Information provided by the SOG trawl surveys conducted in late-June in 2013 for lake-type Sockeye and in September 2012 (four-year-old returns in 2015) and 2013 (three-year-old returns in 2015) for river-type Harrison Sockeye were not comparable to past years observations. For the 2012 and 2013 sampling periods, CPUE's were much lower than expected based on pre-season return forecasts (DFO 2015a). Although these CPUE's could have been used as an indicator of poorer returns in 2015, they were flagged as uncertain due to observations of unusual early migration of the lake-type Sockeye through the SOG in the spring, and unusual distribution of Harrison (river-type) Sockeye in the SOG in the fall. The unusual early migration timing meant these results could not be compared to the typical timing observed in all previous years. Therefore, the poor returns in 2015 and the low SOG CPUE's in the ocean entry years for these returns are considered coincidental, rather than predictive.

Stock Proportions

- Fraser Sockeye lake-type stock proportions in various sampling components starting in the 2011 brood year, as presented in last year's 2015 supplement, were informative for return proportions in 2015 (Figure 5). Fraser Sockeye lake-type stocks returned in proportions similar to those observed in the brood year escapements, and in the Mission smolt and SOG juvenile surveys. Chilko was the dominant stock, whereas lower proportions were observed for Shuswap (early and late), Birkenhead, Stellako, Quesnel, and Gates (Figure 5).

- One very notable signal in the proportion data was an early indication that Weaver Sockeye might return in 2015 at very low abundances (Figure 5). Although the brood year escapement in 2011 for Weaver was above average at 24,000 EFS, and, as a result, the four-year-old forecast was above average (50% probability level four year old forecast: 274,000), no Weaver fish were caught in either the Mission smolt project or the SOG surveys in 2013. In contrast, other stocks (Stellako, Quesnel, and Gates) with similar brood year escapements were detected in both these programs in 2013 (Figure 5). The proportion data also provides an indication of where in the Weaver stock's life-history they experienced the most mortality. Since egg-to-fry survival was average for Weaver in the 2011 brood year (DFO 2015), yet no Weaver fish were observed in either the Mission or SOG juvenile programs (Figure 5), these observations suggest that survival was exceptionally poor while this stock was rearing in Harrison Lake as fry. Coincidentally, Birkenhead was the only stock to exhibit exceptionally poor survival the previous year in 2014, and this stock rears as juveniles in the northern part of the same Lillooet-Harrison Lake system.
- One plausible explanation for Birkenhead and Weaver's poor survivals associated with the 2015 returns could be linked to the Meager Creek landslide that occurred in 2010, which dumped large amounts of sediment into the north end of Lillooet Lake (the upper lake in the Lillooet-Harrison Lake system). This sediment was most pronounced in the upper end of the Lillooet Lake in the fall of 2010, and resulted in high turbidity in the lower Harrison Lake in the following years (M. Townsend, DFO, pers. comm.). Through various mechanisms acting on the fry, sediment could have influenced survival of Birkenhead Sockeye from the 2010 and 2011 brood years (2014 and 2015 returns, respectively), and the 2011 brood year (2015 returns) for Weaver Sockeye. Unfortunately, due to the limited lake research being conducted in the Fraser Watershed, no assessment of the impact of the Meager Creek landslide on the Lillooet-Harrison Lake system was conducted.

Ocean Conditions ('Warm Blob') and 2015 Returns

- The 'warm blob' was flagged in the 2015 supplement (DFO 2015b) since it developed in the second half of 2013, when many of the fish returning in 2015 would have entered the ocean. This notable warming in the Northeast Pacific Ocean received considerable media attention. The 2015 forecast supplement presented this information and concluded that given the 'warm blob' and associated ocean conditions are outside our previous observations, it was unclear how Fraser Sockeye stocks would respond (DFO 2015b). Differences in ocean conditions spatially and temporally, nuances in lower trophic level (phytoplankton and zooplankton) responses to these conditions, and the degree of overlap of Fraser Sockeye juveniles to these ocean conditions and their survival responses to these conditions were poorly resolved.
- Similar survival responses across stocks can indicate a common mechanism, likely occurring in common ecosystem, such as the Northeast Pacific (Dorner et al. 2008, Peterman and Dorner 2012). Given variable survival across Fraser Sockeye stocks, and for other non-Fraser stocks including the Skeena, Barkley, Nass and Columbia, the warm blob was not likely a strong driver of Sockeye survival associated with 2015 returns.
- Chilko is the only Fraser Sockeye stock with a long term marine survival time series (which includes their downstream migration in the Fraser River as smolts). Marine survival associated with the 2015 returns (2011 brood year) was below average (Figure 4B) for this stock, whereas freshwater survival was slightly above average in the 2011 brood year (Figure 4A). Therefore, the mechanism causing poor Chilko survival and returns occurred

somewhere in their life-history between leaving their rearing lake and returning to their natal spawning rivers from the Northeast Pacific two years later. This stock, and a few other lake-type stocks that include Stellako, Quesnel, and Upper Barriere (Fennell), also experienced similarly poor survival. However, survival for other Fraser Sockeye stocks was either average (Early Stuart, Nadina, Raft) or poor, but linked to either freshwater mechanisms (delayed density mechanisms: Scotch, Seymour, Late Shuswap; Meager Creek landslide: Weaver and Birkenhead) or the stock's life-history was completely different from other stocks, resulting in a different ocean entry year and ocean distribution (Harrison river-type stock). Outside of the Fraser River, the Skeena, Nass, Barkley and Okanagan and Columbia stocks all experienced above average survival.

- Not all Fraser and non-Fraser Sockeye stocks share a common spawning or lake-rearing habitat. However, after the lake-rearing stage, all Fraser lake-type stocks share a common smolt migration route down the Fraser River, and then consecutively move north through the SOG, exit the SOG via the Johnstone Strait, and follow the continental shelf north (Tucker et al. 2009; Figures 1 & 2). Migration timing can vary within and between stocks by up to one month. After this period of migration, Fraser Sockeye move into the GOA (Walter et al. 1997) for their final years of life before they return to spawn. It is in the GOA where these Fraser stocks overlap with other Sockeye stocks such as Nass and Skeena, based on historical tagging data collected in the 1950s and 1960s (Figure 6). Limited data suggest that Barkley Sound Sockeye are also located in the same broad geographic area, and no data are available for Okanagan Sockeye.
- Chilko Sockeye, and other stocks such as Quesnel, Stellako, and Fennel that exhibited poor survival not linked to freshwater mechanisms, likely overlap geographically and temporally with all other Fraser Sockeye stocks, except Harrison, during their downstream migration and ocean phase. These stocks also overlap geographically and temporally with non-Fraser Sockeye stocks in the GOA. Given the varied survival responses across all these stocks during periods of overlap, it is a challenge to determine specifically where the mechanisms influencing Fraser Sockeye survival occurred.
- Information from the Mission smolt project and the SOG surveys indicate variability between stocks in smolt out-migration timing in the Fraser River and juvenile migration timing through the SOG. Future data from these projects will contribute to understanding how the distributions of Fraser Sockeye stocks vary temporally and spatially in these ecosystems. In addition, Fraser Sockeye stocks could be distributed differently in the GOA (Blackbourn 1987; Welch and Parsons 1993), therefore poor survival of some stocks in the 2015 return year (e.g. Chilko), may be due to unique conditions they experienced. Furthermore, while historical tagging data place Fraser lake-type and some non-Fraser Sockeye stocks in a similar area in the GOA, these are based on older data, and Fraser Sockeye may currently exhibit a different geographic distribution. Notably, some studies have suggested that Sockeye would migrate further north under warmer climate conditions (Welch et al. 1998; Abdul-Aziz et al. 2011). There remains uncertainty in the spatial distribution of different Sockeye populations, which makes it difficult to draw definitive conclusions regarding the impacts of these unusually warm conditions on Fraser Sockeye.

Supplement information to Support the 2016 Return Forecasts Lake-Type Stocks: Adult Migration and Spawning in 2012

Adult Migration and Spawning Conditions

- High discharge in the Fraser Canyon has been associated with migration delays (>7,000 m^3/s) and can create a complete barrier to migration (>9,000 m^3/s), leading to severe stress and increased risk of fish mortality (MacDonald 2000; Macdonald et al. 2010). On the spawning grounds, low discharge can affect spawning success (crowding due to limited spawning habitat) and egg survival (dewatering of redds). Alternatively, high flow events in these habitats can cause bed movement, scouring, and egg mortality. High temperatures (above 18°C) may decrease swimming performance of migrating salmon (Eliason et al. 2011). Sustained temperatures above 20°C can lead to increased mortality, disease, and legacy effects on egg quality (Burt et al. 2011). Optimal spawning ground temperatures are between 10-12°C, while egg survival is reduced once values approach 15°C (Whitney et al. 2013).

- Based on their Fraser River upstream migration timing, ranging from July through to September, Fraser Sockeye stocks are grouped into four run-timing groups: Early Stuart, Early Summer, Summer, and Late Run. The Early Stuart Run is the first group to enter the Fraser River, and is comprised of a single stock (Early Stuart), they are followed by Early Summer Run Stocks (Bowron, Upper Barriere, Gates, Nadina, Pitt, Scotch, Seymour, Chilliwack, and Nahatlatch), and Summer Run stocks (Chilko, Quesnel, Late Stuart, Stellako, Harrison, Raft, North Thompson, and Widgeon) and the last run timing group to enter the Fraser is the Late Run (Cultus, Late Shuswap, Portage, Weaver, Birkenhead). There is considerable overlap in these run timing groups, and exact timing varies inter-annually by stock.
- In 2012, Fraser River discharge levels were over 8,000 m^3/s from mid-June to mid-July, peaking near 11,000 m^3/s on June 23rd (Figures 7 & 8). The early portion of the Early Stuart migrants experienced unusually high discharge levels, above 9,000 m^3/s, which would have been a migration barrier at Hell's Gate. Given that high discharge levels in the Fraser River exceeded levels historically associated with poor migratory success during the Early Stuart migration in 2012, upstream stock assessment coverage was augmented to include the near-terminal migratory approach areas. En-route mortalities and moribund live Sockeye were observed in several non-natal tributaries of the Fraser, Nechako and Stuart Rivers. The remainder of the run experienced discharge levels above 6,000 m^3/s (Figure 7A), which could have delayed migration and caused physiological stress. Early Summer migrants experienced moderately high discharge levels (above 7,000 m^3/s) at the beginning of migration, and above average temperatures (above 18^{o}C) for the later portion.
- Although Summer Run stocks experienced benign discharge conditions, a large proportion were exposed to above average temperatures (1 to 2 °C higher; Figure 7B and 8), possibly affecting swimming performance and en-route survival. These conditions occurred during Chilko's upstream migration (Figure 8), the stock expected to contribute most (44%) to total forecast returns in 2016.

Adult Escapements

- The arrival timing of most stocks to their spawning grounds was average in 2012 with the following exceptions: arrival timing to the Early Stuart spawning grounds was slightly delayed (approximately one week later than normal), and arrival timing of the late run Harrison-Lillooet stocks (i.e. Birkenhead River and Big Silver Creek) to their spawning grounds was one week earlier than normal.
- Spawning timing and behaviour of most stocks was normal with the exception of the Stellako River where spawning timing was delayed as Sockeye held in the river for a prolonged period after arrival with very little active spawning observed.
- Sockeye were reported to be in poor condition on the spawning grounds in most areas of the watershed in 2012. Histological assessment of tissue samples taken from Sockeye at

Birkenhead, Raft, Stellako and Gates all exhibited poor gill condition and the presence of *Parvicapsula minibicornis*, a parasite that has been previously associated with salmon pre-spawn mortality events in the Fraser River and other systems. IHNv (Infectious Hematopoietic Necrosis virus), a viral disease commonly found in salmonids, was detected in samples from Gates and Birkenhead.

- The largest escapements in 2012 were Chilko (246,600), Stellako (138,000), Chilliwack (126,200) and Late Stuart (93,200), together accounting for 65% of the total spawning escapement.
- Record escapements were recorded in the Chilliwack (126,200) and Upper Pitt (78,000) systems.
- At or near record low escapements were recorded in the Early South Thompson (3,500), Bowron (56), Quesnel (600), Weaver (924) and Late South Thompson (12).
- The sex ratio at Early Stuart was skewed towards males (66%). This is often observed on years with poor migratory conditions as females are known to suffer greater physiological stress and higher mortality levels than males under stressful environmental conditions (Cooke et al. 2012).
- According to observations by Fraser Sockeye stock assessment staff during the adult escapement enumeration projects, environmental conditions (water levels and temperatures) on the spawning grounds were considered favourable for spawning throughout the Fraser River watershed in 2012. It is important to note that environmental conditions are not assessed by field crews after the escapement enumeration projects have ended, so environmental events that occur between the end of the spawning period and the following spring could affect egg-to-fry survival, but are not recorded.

Spawner Success: Egg Retention and Egg Viability

Escapement Enumeration Program Observations and Estimates

- Spawner success for a stock is calculated as the proportion of eggs spawned, based on spawning ground carcass surveys conducted during escapement enumeration. Spawner success is recorded as 0%, 50%, or 100% for each female carcass sampled, then averaged across all populations in a stock. Pre-spawn mortality (PSM) is 100% minus the spawner success percentage.
- Spawning success across all Fraser Sockeye populations was the lowest observed in over 50 years at 71% in 2012, well below the long term average of 89%. At or near record high levels of PSM were observed in several areas of the watershed in 2012, including Nahatlatch (56%), Birkenhead (89%), Gates (68%), Early South Thompson (42%), North Thompson (61%), Chilko (33%), Quesnel (36%), Stellako (43%) and Late Stuart (39%).
- For Chilko and Stellako, the dominant stocks in the 2016 forecast, pre-spawn mortality (PSM) levels in the 2012 brood year (33% and 43% respectively) were much higher than average (8% and 9%, respectively).
- Estimates of effective female spawners (female escapement multiplied by spawner success: EFS) in 2012 may be biased for several stocks due to limited accessibility of carcasses due to a stock’s low abundance (Early South Thompson, Bowron, Portage and Late South Thompson) or due to heavy bear predation (Chilko), and in one case difficulty in assessing spawning success was attributed to under-developed egg skeins (Stellako).

- Spawner success is incorporated into annual forecasts by using either EFS or smolt abundances to predict future returns.

Environmental Watch Program Observations and Estimates

- While spawning success provides a direct measure of eggs released by females, it does not provide a true measure of spawning success related to deposition of eggs into spawning gravel or egg viability. A number of physiological metrics have been used to evaluate overall health of spawning fish. These can be used to determine the potential for successful redd construction and deposition of eggs into them by the spawners; not simply their release of eggs. Similarly, direct estimates of egg and sperm quality are used to assess gamete viability of eggs that were deposited. For the few stocks with juvenile data, such as Weaver or Chilko, using fry or smolt information as predictor variables can eliminate uncertainty in egg-to-fry and egg-to-smolt survival, respectively. However, most stocks do not have juvenile stock assessment information, and therefore, information on spawning success and egg viability from a physiological perspective only, can be used to qualitatively inform Fraser Sockeye survival.
- A suite of biological samples were collected from migrating and spawning Sockeye in 2012 to assess several aspects of fish condition: homeostasis (ions & metabolites), maturation & stress (steroid hormones), condition (energy & lipids), disease (RNA & histopathology), and reproductive success (egg viability) (Table 1). Ideally, a multivariate analysis of these variables would provide a holistic representation of fish condition but, in the absence of such in-depth analyses, there are some key surrogates of overall condition that can be used. For example, migrator or spawner glucose can represent an integrated measure of the ability to maintain metabolic homeostasis, while body fat content is an indicator of energy reserves.
- Returning adult Sockeye were intercepted at various locations along their migration routes in 2012 (Figure 9). In many sampling locations stock ID has not yet been determined, however DNA samples were collected. Timing of sampling was coordinated to target specific run timing groups; Early Stuart (Lower Fraser), Early Summer and Summer Run Sockeye (marine approach, Lower Fraser and spawning ground). Lab analysis priorities and completion varies from year to year, but all samples are inventoried and stored for possible future analyses such as energetic status, stress, and pathogen status.
- Healthy glucose levels are between 4-7 micromol-per-litre (mmol/L) and values above or below this range are considered abnormal and are linked to physiological stress and pre-spawn mortality (Figure 9). In 2012, plasma glucose concentrations in marine approach areas for all stocks were within normal range (between 4-7mmol/L; Figure 9). Freshwater migrants were within normal range except fish sampled in the Seton River (average12 mmol/L) and Cayoosh Creek (average19 mmol/L) (Figure 9). Stock analyses on these samples revealed that 60% (8 of 20) were from other Summer Run stocks: Chilko South, Stellako and Tachie. The Fraser River was above 18^{o}C at the time of sampling and it is possible that these fish were seeking thermal refuge. Fish sampled at spawning locations were within normal range except actively spawning fish sampled at Chilko (10.6 mmol/L) and Stellako (4.8 mmol/L). Though it is normal for glucose levels to be above normal in fish that are actively spawning, due to the mobilization of glucose by glycogenolysis, it is also an indication of physiological stress and can lead to rapid senescence (Kubokowa et al. 2001; Hruska et al. 2011).
- Normal fat content for fish arriving on the spawning grounds is between 2.5-4.0% (Crossin et al. 2004). For fish that are actively spawning fat content can drop to just below 2%. If fish have not engaged in active spawning and are close to the 2% threshold it is unlikely they will

successfully spawn. The interpretation of any physiological variable, such as glucose or fat content, for fish on the spawning grounds is relative to their behavioural state (i.e. arrival/holding, paired/spawning, spent/moribund). Lipid content was assessed on Sockeye collected in the Seton River and Cayoosh Creek. Based on stock ID of samples taken, Gates Creek Sockeye were slightly low for fish still migrating (2.1%). Non-natal stocks sampled in the Seton watershed had variable levels of lipid content (Chilko South 2.7%, *n*=2; Tachie 5.9%, *n*=4; Stellako 3.5%, *n*=2) however sample sizes were small.

- Gamete quality (egg survival to eyed stage) was slightly below average for Chilko (78%), average for Stellako (78%) and below average for Harrison (46%).

Lake-Type Stocks: Juvenile Freshwater Rearing from 2012 to 2014

Overview

- After they emerge from the spawning gravel, lake-type Fraser Sockeye rear in nearby lakes, or in the lakes they were directly spawned in. Most of these Sockeye spend two years rearing in these lakes before they migrate to the ocean. Only very limited information for a few stocks is available on lake limnology, fry or smolt abundances.
- Fry abundance data immediately following emergence from the spawning gravel are available for systems with hatchery channels: Weaver, Gates, and Nadina. These data can provide an estimate of egg-to-fry survival.
- Limnological data are available for Chilko, Quesnel, the Shuswap Lake complex, as well as Cultus, but with large gaps in these time series. Cultus information will not be included in the current paper since this stock comprises a negligible component of the total return, and is studied in detail through a separate Cultus Conservation Team process.
- Quesnel and Shuswap fall fry (predominant age: 1_1) abundances in their rearing lakes have been assessed regularly on particular cycles (generally on dominant and subdominant cycle years) using hydroacoustic and trawl methods. Since the 2012 brood year is a weak cycle year for these stocks, no fry assessments were conducted. In recent years (1996-2012), Chilliwack fry have also been assessed on the dominant years, including the 2012 brood year. Fry abundances have also been assessed for Cultus, but will not be presented in the current report.
- Only two stocks have smolt migration information at the outlet of their lakes that can be used to estimate freshwater survival: Chilko and Cultus. Chilko contributes the greatest proportion to the 2016 forecast (44% at the 50% probability level). For this stock, smolt out-migration (predominant age: 2_2) abundances have been assessed consistently since 1949 by DFO's Stock Assessment Division. Smolt abundances for Cultus Sockeye, which contributed less than 1% to the total 2016 forecast, have been sporadically assessed since the 1920's. Given the limited contribution of Cultus expected in the 2016 returns, detailed information on this stock is not provided in the current publication.

Egg-to-Fry Survival

- Only three stocks have fry counted during their out-migration from their artificial spawning channels to their rearing lakes, and these include Weaver, Gates, and Nadina. These stocks also have effective female spawner (EFS) data, which are used as a proxy for egg numbers (DFO 2016a). Using fry and EFS data, egg-to-fry survival can be estimated.
- Weaver egg-to-fry survival in the 2012 brood year (1,000 fry/EFS) was well below the cycle average (1966-2012: 1,600 fry/EFS). Given the egg-to-fry survival and very low EFS, fry

abundances (470,000 fry) in the 2012 brood year was well below average (brood years 1966-2012 average: 31 million fry).

- Gates fry have only been rigorously assessed in recent years. Therefore, the 2012 egg-to-fry survival for this stock in the 2012 brood year (600 fry/EFS) is compared to cycle averages for the two other stocks with long time series of these data: Weaver (1,600 fry/EFS) and Nadina (1,200) egg-to-fry survival.
- Nadina egg-to-fry survival in the 2012 brood year (1,000 fry/EFS) was similar to the cycle average (1,200 fry/EFS). Fry abundance in the 2012 brood year (16.6 million fry) was above average (brood years 1973-2012 average: 9.5 million fry).

Chilko Lake Limnology

- Limnological assessments of Chilko Lake were conducted between 1985 and 1993, and more recently between 2009 and 2014. A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to lake thermal structure, photosynthetic rates, and zooplankton species assemblage and biomass. Methods were similar to those used in Shuswap Lake and are generally described in Bradford et al. (2000) and Shortreed (2007).
- Chilko Lake was experimentally fertilized in the late-1980’s and early-1990’s to evaluate the enhancement of freshwater survival (see Bradford et al. 2000). Though there was a long hiatus from limnological assessments conducted in Chilko Lake (1994-2008), recent data show that photosynthetic rates (PR) appear to have increased approximately 74% since the early-1990’s (unfertilized years) to a new productivity state similar to that observed when over 100 tons of inorganic fertilizers were being applied annually (Selbie et al. 2010). This shift represents a rapid change in lake productivity for such a large system. Increased PR should be correlated with enhanced freshwater survival (Hume et al. 1996; Shortreed et al. 2000).

Chilko Sockeye Freshwater Survival and Fish Condition: Lake Outlet

- Chilko is the only stock where freshwater survival is available consistently since 1950. The number of smolts migrating out of the Chilko rearing lake after two winters in freshwater and EFS (a proxy for numbers of eggs spawned) are used to estimate freshwater survival for Chilko Sockeye.
- Freshwater survival in the 2012 brood year (126 smolts/EFS) was close to average (1950-2012 average: 117 smolts/EFS; Figure 2). For the 2012 brood year, the lower than average EFS and average freshwater survival resulted in one-year-old smolt abundances (2014 smolt out-migration year: 11.4 million) that were below average (brood years 1950-2012: 20.7 million).
- Average smolt fork length assessed at the outlet of Chilko Lake at the enumeration weir in 2014 (2012 brood year: 98.3 mm) was much larger than the time series average (brood years 1952-2012: 83.5 mm) and the 2013 average (2011 brood year: 85.5 mm). This evidence is consistent with the lake’s limnology that indicated rearing conditions were above average for the 2012 brood year.

Quesnel (Limnology)

- Limnological assessments of Quesnel Lake were conducted between 1985 and 1994, and, more recently, between 2003 and 2007. A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to lake thermal structure, photosynthetic rates, and zooplankton species assemblage and biomass. Methods were similar to those used in Shuswap Lake and are generally described in Bradford et al. (2000) and Shortreed (2007).

- A limnological assessment of Quesnel Lake was conducted in 2015, largely to evaluate juvenile Sockeye Salmon rearing condition changes that may be affected by the Mount Polley Mine tailings impoundment failure, which impacted, at a minimum, the west and main basins of Quesnel lake (Petticrew et al. 2015). Increases in spring nutrient availability were observed (phosphorus) in the west basin, and reduced seasonal average photosynthetic rates were observed relative to the main basin in 2015. A full analysis of the limnological data is pending, which will compare spatial patterns of lake variables in 2015, and where possible, comparisons will be made to historical information to evaluate lake rearing status for juvenile Sockeye Salmon.

Quesnel Sockeye Freshwater Survival and Fish Condition: in Lake

- Since 2012 is a weak cycle for Quesnel, no hydroacoustic surveys were conducted in the 2012 brood year (2013 fry year).

Shuswap Lake (Limnology)

- Limnological assessments of the Shuswap system (Shuswap and Mara lakes) were conducted in the years 1987-1993, 2011, and 2012. This sampling coverage includes rearing years (brood year+1) for dominant (1991, 2011), subdominant (1988, 1992, 2012), and weak cycles (1989, 1990, 1993). A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to, lake thermal structure, photosynthetic rates, and zooplankton species assemblages and biomass. Methods for these surveys are generally described in Nidle and Shortreed (1996), Morton and Shortreed (1996) and Shortreed (2007).
- Macrozooplankton and Daphnia biomass (the latter is preferentially preyed upon by juvenile salmonids and comprise 85% to 95% of the fall diet of age-0 Sockeye in Shuswap Lake) was higher in 2012 versus 2011 (2011 vs. 2010 brood years), given the much lower fry densities, and therefore, lower density-dependent grazing pressure in 2012.
- Freshwater survival (fry/EFS) in Shuswap Lake has declined post-1990, particularly on the subdominant cycle line. Though there was a long hiatus from conducting limnological assessments in Shuswap Lake (no assessments were conducted from 1994-2010), recent data show that photosynthetic rates (PR) increased ~ 45% between the early 1990's and 2011-2012. Increasing PR should be correlated with enhanced freshwater survival (Hume et al. 1996; Shortreed et al. 2000). However, increases in fry densities in the past decade (in several cases exceeding the lake's estimated carrying capacity) and other stressors in Shuswap Lake), may have resulted in density-dependent effects on food web structure and function, and thus reduced freshwater growth and survival.

Shuswap Sockeye Freshwater Survival and Fish Condition: in Lake

- Since the 2012 brood year is a weak cycle line for Shuswap stocks, no hydroacoustic surveys were conducted in the 2012 brood year (2013 fry year).

Chilliwack Lake Limnology

- Currently there is no limnological information available for this lake.

Chilliwack Lake Freshwater Survival and Fish Condition: in Lake

- A hydroacoustic and trawl survey was conducted in late October of 2013 to assess the abundance of 2012 brood year Chilliwack Sockeye (that will return in 2016 as four-year-olds); the estimate of fry abundance in 2012 was 1.8 million ± 0. 3 m (95% CI) fall fry. Despite the record return of 78,800 EFS in 2012 brood year, the total number of fall fry in the lake in was only marginally higher than that observed under much lower EFS (19,700) in the 2008 brood year (Figure 10). This may be an indication of an apparent stabilization of fall fry densities at lower EFS (likely somewhere between recent observations of 19,700 (2008 brood year) and 78,800 (2012 brood year) EFS. However, more data are required to establish a fish-based optimal spawning abundance for Chilliwack Lake Sockeye.

- Fall fry from the 2012 brood year were on average (± SE) 72.1 ± 1.4 mm in length and 3.93 ± 0.11 g in weight. These measurements were consistent with historical means for Chilliwack Sockeye fry sampled in the fall (Figure 11). Notably, fry in subsequent (i.e. sub-dominant) years show reduced growth relative to the preceding year's fish. This is reflected in observations of reductions in fish energetic condition and changes in diet composition.

Lake-Type Stocks: Juvenile Fraser River Outmigration (Smolts)

Juvenile Outmigration Conditions

- Higher river discharge rates could increase smolt out-migration rates and also increase water turbidity -- both of which could reduce their exposure to predators in this ecosystem (McCormick et al. 1998). Physiological and optimal temperatures for Sockeye salmon range from 14 to 18°C (Brett et al. 1967, Brett 1971, Chittenden et al. 2009).
- Chilko Sockeye exit Chilko Lake at its south end in the spring, migrating out through the Chilko, Chilcotin, and Fraser Rivers, en-route to the SOG. Discharge conditions for the Chilko and Chilcotin Rivers were above average in the 2012 brood year (2014 Chilko smolt out-migration year) (Figure 12). Water temperatures in the Fraser River during their out-migration timing remained below 14°C for the duration of the Chilko smolt out-migration. Temperatures were below average for roughly the first half of their out-migration and above average for the second half of their out-migration (Figure 13).
- Peak freshet timing in the Fraser River was earlier than average in 2014, occurring in late-May. Consequently, discharge levels were above average for the peak out-migration of the majority of Fraser Sockeye smolts (late-April to mid-May; Figures 14A). Temperatures in the Lower Fraser River were average in 2014 for the majority of the smolt out-migration (Figure 14B). Harrison river-type Sockeye migrate out later than most Fraser Sockeye stocks, as sub-yearling smolts (Birtwell et al. 1987), rather than as yearling smolts. They would have experienced close to average discharge in both 2013 (three-year-olds returning in 2016; DFO 2015: Figure 12B) and 2014 (four-year-olds returning in 2016; Figure 14A).

Juvenile Outmigration Timing: Lake Outlet

- Two smolt assessment programs at the outlet of rearing lakes were conducted in the 2014 out-migration year: Chilko and Cultus.
    - Cultus smolt assessments have been sporadically conducted from 1926 to present. The Cultus smolt 50% out-migration date (the date when 50% of the run had moved through the counting location) in 2014 (2012 brood year) was April 14 (Figure 15A).
    - Chilko smolt out-migration has been assessed consistently, using a weir and counting system located at the outlet of Chilko Lake, from 1951 to present. The Chilko smolt 50% out-migration date in 2014 (2012 brood year) was April 28, which is slightly earlier than average (1986-2014: May 4) (Figure 15B).

Juvenile Outmigration Timing: Mission, British Columbia

- Starting in 2012 a project to assess timing and relative abundance of outmigrating Sockeye smolts has been conducted annually in the Fraser River.
- During the spring and early summer of 2014, a vessel towed mobile fish traps every fourth day between April 2 and June 17 in the lower Fraser River near Mission B.C. (Figures 16 & 17) for the purpose of evaluating the timing, size, abundance, and stock composition (by Wild Salmon Policy Conservation Unit: WSP CU) of downstream migrating juvenile Sockeye. Details on the study design are presented in Appendix 1. In 2014, days surveyed were similar in frequency to the 2012 project (i.e. one survey every fourth day) but differed from both the 2012 and 2013 projects in duration. In 2014, the duration of the survey day was 24 consecutive hours rather than 8 hours, as in the previous two years. This protocol was implemented to investigate the nocturnal migration patterns of juvenile salmon at Mission.
- Stock (CU) out-migration timing at Mission is challenging to interpret given the need to maintain the water velocity at the fish trap mouth (1.0 m/s) and the fairly consistent increase in discharge as the study progressed (Figures 14A and 18). Two consequences must be considered as a result of this operational protocol and environmental condition: 1) that the volume of water sampled for each sampling event (15 min fishing “run”) remained constant through the study; and 2) that the proportion of the volume of water sampled relative to the total volume of water passing Mission for each run was inversely related to discharge.
- Given the discharge pattern seen in the lower Fraser River in 2014 (Figure 18), out-migration timing for all stocks may be biased early if a correction is not made for the inverse relationship between the proportion of water volume sampled at Mission and discharge at Mission. Out-migration timing reported in the current report (Appendix 1: Table A1-1; Figure 19) is not adjusted for this relationship and should be considered preliminary pending this correction (Figures 18 and 19).
- In 2014, the average 50% out-migration date for all CUs was estimated to be April 28 (Figure 19).
- For Chilko Sockeye sampled at Mission in 2014, their 50% out-migration date is May 1 (Figures 20 and 21), which is three days after the 50% out-migration date of Chilko Sockeye observed at the outlet of Chilko Lake (Figures 15B and 21). This out-migration date is identical to the average date from 2012 to 2014 (Figure 20).

Juvenile Outmigration Sizes: Mission, British Columbia

- Fork length has been recorded for sampled Sockeye smolts since 2012. Chilliwack-ES was the only CU where a decrease average length in 2014 versus 2013 was observed (Figure 22). This difference may be linked to large differences in brood year escapements in 2011 (2,500 EFS) versus 2012 (78,800 EFS) that resulted in large differences in juvenile densities in Chilliwack Lake between years (Figure 10). Higher densities of juveniles would result in greater competition for food (less food per fish) leading to decreased juvenile sizes, when compared to lower density years.
- Annual average fork length of Chilko smolts sampled at Mission compared to upstream at the lake outlet have been similar for all three years of the Mission project (Figure 23). Since travel time is very short between the lake outlet and Mission, lengths would be expected to be similar, and these results confirm sampling at Mission is likely unbiased for length.

Lake-Type Stocks: Juvenile Migration in the Strait of Georgia

Juvenile Strait of Georgia Sampling Background

- Lake-type juvenile Fraser Sockeye spend four to six weeks rearing and growing in the SOG prior to moving north through Johnstone Strait (Preikshot et al. 2012). Trawl surveys have been conducted twice a year in the SOG since 1998. These surveys are conducted over a nine to ten day period in late-June/early-July and in September/early-October. The survey targets fish in the surface waters (0-60 m) along a standard track line (Figure 24). The gear and protocol are described in Beamish et al. (2000) and Sweeting et al. (2003). In 2014, the survey was conducted between June 25 and July 8 using the Canadian Coast Guard research vessel W.E. Ricker. In addition to fishing the standard track line, sets were also conducted in the Gulf Islands, Howe Sound, Johnstone Strait, Discovery Islands, and Desolation Sound. In 2014 an additional trawl survey was conducted June 2-11 using the commercial trawler Viking Storm. This early-June survey was designed to target the peak abundance of juvenile Sockeye in the SOG and followed the same protocols and track line as the annual surveys. In addition to the standard track line, additional sets were conducted in the Discovery Island region during this survey.
- In 2014, a new program was also initiated to examine the residence time of juvenile salmon in the SOG and the migration window of juvenile salmon through the Discovery Islands and southern Johnstone Strait region. The sampling was conducted in the Discovery Islands and southern Johnstone Strait regions (Figure 24). The primary sampling area was just north of Hardwicke Island where all passages of the Discovery Islands merge and all juvenile salmon migrating north out of the SOG must pass. This sampling was conducted twice weekly between May 15 and July 11, using a small mesh purse seine fished from the commercial seiner Nordic Queen. This survey, in combination with the Mission downstream sampling program in the Fraser River, was the first integrated study to directly sample the juvenile salmon at two distinct bottlenecks (i.e. location where all fish must migrate past): one just prior to their ocean entry and one just as they left the SOG. Therefore, the study is the first direct measure of the residence period of juvenile lake type Sockeye in the SOG. In addition, the catch of the Sockeye in the purse seine survey provided the first information on migration of these juveniles through the Discovery Island region.

Juvenile Strait of Georgia Migration Timing

- The annual trawl survey that follows a standard cruise track-line in the SOG is conducted in late-June/early-July was originally designed to sample juvenile Coho Salmon. Although all species are sampled, the timing of these surveys is at the tail end of the residence of juvenile Sockeye in the SOG with only about 10% or less of the juvenile Sockeye remaining in the region during this period (Preikshot et al. 2012). For the 2008 ocean entry year, Thomson et al. (2012) reported that the stock structure present during the standard survey in late June was roughly representative of the expected stock composition based on brood year escapements in the 2006 brood year. However, based on information resulting from the Mission downstream trapping of juvenile salmon, there is evidence of differences in out-migration timing among Fraser Sockeye stocks (DFO 2014). Residence time of juvenile lake-type Fraser Sockeye in the SOG also may vary between stocks based on preliminary observations. In addition, due to the strong cyclic nature of Fraser River Sockeye (Figure 3A) the number of juveniles entering the ocean in a given year can vary widely. Therefore, relative abundance (CPUE) from this annual survey could change depending on the dominant stock(s) migrating through the SOG and inter-stock and inter-annual variability in Fraser Sockeye smolts out-migration timing in the Fraser River (Figure 19).

- The CPUE of juvenile Sockeye in the late-June/early-July 2014 standard trawl survey was the lowest for this run cycle (2002, 2006, 2010, 2014; Figure 25). This low CPUE was the result of only 44 juvenile Sockeye captured in 87 sets conducted in the surface 30 m of the survey.
- Additional early-June standard trawl surveys have also been conducted in recent years to capture the larger relative numbers of Sockeye in the SOG, compared to the annual late-June/early-July. The CPUE from the 2014 early-June survey is compared with a similar early-June survey conducted on the previous 2010 cycle year (Figure 26). In both years, the majority of the juvenile Sockeye caught were in the SOG near the top third of the SOG, north of Texada Island and south of the Discovery Islands (Figure 26). This distribution was based both on the results of the trawl survey as well as supplemental information from purse seine sampling that occurred in both years (Neville et al. 2013). A difference between years, however, was the negligible numbers of Sockeye captured on the east side of Texada Island in Malaspina Strait in 2014 compared to large catches in the same area in 2010 (Figure 26). Currently, the information on how these differences in distribution of the juveniles within the SOG may impact early marine survival is unknown. In 2014 the total CPUE for the early-June standard track line surveys in the SOG was 63.2 Sockeye/hour. This was lower than the CPUE of 95.0 observed in 2010 and follows the trend of the decreased CPUE observed in the late June/early-July survey (Figure 25).
- Using a Bayesian linear regression analysis (four-year-old total returns versus CPUE), the 2014 CPUE predicts a total four-year-old Fraser Sockeye return in 2016 of 400,000 at the 50% probability level. This relationship uses the four-year-old returns compared to the SOG CPUE from 1999 to 2015, excluding 2003 when no survey was conducted. The official four-year-old forecast is much higher: 1.9 million at the 50% probability level (DFO 2016). However, it should be noted that the SOG surveys are conducted at the end of the Fraser Sockeye migration through the SOG, therefore, in addition to changes in annual juvenile Sockeye abundances, differences in stock composition and out-migration timing will influence the CPUE.
- The combination of new purse seine survey and the downstream Mission trapping program in 2014 provides the first measure of Fraser Sockeye residence time in the SOG. Although one caveat is that a Fraser River discharge correction on sampling numbers has not yet been applied to the Mission data. Using the peak abundance in both surveys, the results indicate that in 2014 the juvenile lake-type Sockeye from the Fraser River reared in the SOG for 7-8 weeks (Figure 27). This estimate is similar to those made by Preikshot et al. (2012) using the standard surveys in the late June/early-July. The catch of Sockeye in the purse seine survey also indicated that the majority of the migration through this region in 2014 occurred over a two week period in mid-June (Figure 27).

Juvenile Sizes in the Strait of Georgia

- Juveniles caught in the early-June trawl survey (*n*=1,134 Sockeye) had an average (± standard error) fork length of 122.9 ± 13.5 mm (Figure 28). These were slightly larger than, but similar in length to, the Sockeye captured in the 2010 early-June trawl survey (117.37 ± 13.94 mm). The 44 fish captured in the standard survey at the end of June/early-July were 124.3 ± 22.5 mm. Although this was a small sample size, they were on average, with the exception of 2001, 2005 and 2013, the largest fish observed in the standard June/July trawl survey. The fish in both trawl surveys were significantly larger than the average size of the juvenile Sockeye sampled at Mission in 2014 (92 ± 14.2mm; Figure 22). The Sockeye captured in the purse seine survey in the Discovery Islands were also significantly larger than the fish sampled at Mission (126 ± 11.0 mm). There were some stock specific differences in the length of the juvenile Sockeye, and these differences remained consistent across all sampling regions from the lower River to the Discovery Island.

Juvenile Diets in the Strait of Georgia

- The diet of juvenile Sockeye in the SOG in 2014 was consistent with what would be expected from previous surveys. Crab megalops and hyperiids represented about 80% of the diet by volume. About 29% of the stomachs examined from within the SOG in early-June were empty (< 0.1 cc volume). This proportion of empty stomachs was consistent with observations in June 2008, 2010, 2012 and 2013 and would therefore not be considered to be out of the normal range expected.

Lake-Type Stock Proportions (2012 Escapements; 2014 Juveniles; 2016 Forecast Returns)

- Proportions of key lake-type Fraser Sockeye stocks (contributing largest proportions to the total estimates or samples) were compared across five sampling components (and life history stages) of the 2012 brood year: 2012 adult escapement (EFS), 2014 smolt out-migration sampled in the Fraser River at Mission, B.C., 2014 SOG juveniles (sampled in June), 2014 SOG purse seines (sampled from May to July in the Discovery Islands), and the 2016 four-year-old forecasts. Stock proportions were compared across the five sampling components for only eight stocks: Chilko, Chilliwack, Late Stuart, Stellako, Gates, Early Stuart, Raft, and Birkenhead. All other stocks were removed from the calculations of stock proportion, for these eight stocks, for each sampling component (Figure 29).
- For the 2012 EFS, the stocks in the group of eight that represented the greatest proportion included Chilko (32%) and Chilliwack (29%) (grey vertical bars in Figure 29). Late Stuart (19%) and Stellako (11%) contributed the next highest proportions to the total EFS for the key stocks. The remaining stocks (Gates, Early Stuart, Raft, and Birkenhead) contributed less than a combined 5% to the total EFS abundance for key stocks.
- For the 2014 smolts sampled in the Fraser River at Mission, B.C., Chilliwack represented the highest proportion in the samples (close to 56%), and Chilko the second highest (22%). Gates represented 7% and all other five stocks contributed less than or equal to 5% each (green vertical bars in Figure 29). However, similar to out-migration timing, stock (CU) proportions at Mission are currently challenging to interpret given the need to maintain the water velocity at the trap mouth and the fairly consistent increase in discharge as the study progressed (see previous sections and Appendix 1).
- Stock composition has only been examined for the early-June trawl survey in the SOG (dark blue vertical bars in Figure 29) and the Discovery Islands (light blue vertical bars in Figure 29) due to the low number of Sockeye captured in late June. Almost 800 fish were stock identified between the early-June trawl and purse seine surveys. The dominant stock in both surveys was Chilko, representing 40% and 50% (of the eight identified key stocks) respectively, in the purse seine and trawl surveys (Figure 29). Chilliwack also represented a relatively high proportion, ranging from 20% to 30%. Birkenhead proportions varied considerably between the trawl surveys (<10%) to the purse seine surveys (30%) in the SOG; 85% of the catch of this stock occurred in the in the Discovery Islands purse seine surveys after the completion of the trawl survey on June 11. Other stocks listed above contributed under 15% in both SOG surveys. The differences in the stock proportions between the surveys of the smaller groups (e.g. Late Stuart; Figure 29) may be a function of the small sample size in the Discovery Island (*n*=244 DNA results) and should be considered with caution.

- The end point for proportional comparisons across stocks is the official forecast at the 50% probability level (DFO 2016; black vertical bars in Figure 29). Given differences in model forms, stock-recruitment relationships, and predictor variables used, the forecasted stock proportions are different from the EFS abundance proportions. For example, the Chilko forecast proportion is much higher than the EFS proportion for this stock and conversely, the Chilliwack forecast proportion is much lower than the EFS proportion for this stock. For the remaining stocks presented in Figure 29 these two proportions (EFS versus forecast; black and grey vertical bars) are similar.
- Proportions were much less consistent this year across the sampling components, compared to previous years (DFO 2014b; DFO 2015b; Figure 29). Therefore, our ability to interpret the results in the context of 2016 returns is limited. One consistent result is that the Chilko and Chilliwack stocks dominated across all sampling components and periods. With the exception of Mission sampling, Chilko represents a much higher proportion than Chilliwack (in the SOG trawl, purse seine and forecasts) despite their relatively similar brood year escapements. Since stock proportions at Mission are likely biased given they have not been corrected for the differences in discharge and flow that occurred throughout the assessment period; the Mission proportions presented in Figure 31 should currently be considered only broadly for 2014.
- Mission smolt samples are likely biased given they have not been corrected for the differences in discharge that occurred throughout the assessment period. Therefore, although presented in Figure 29, the proportions are considered broadly only. For example, Chilliwack and Chilko represent the highest proportions in the Mission samples for the key stocks, followed by smaller proportions for the remaining six key stocks.
- Comparing other sampling components to the forecast (excluding the Mission smolts), proportions of Early Stuart, Birkenhead and Raft were higher than forecast, Gates was similar, and Late Stuart and Stellako were estimated lower (Figure 29).

River-Type Stocks: Adult Migration and Spawning in 2012 and 2013

Adult Migration and Spawning

- Unlike most areas of the watershed in 2012, Harrison Sockeye (contributing four-year-olds to 2016 returns) were reported to be in good condition on the spawning grounds with an average spawner success of 99%. Physical conditions (water levels and temperatures) on the spawning grounds were favourable throughout the arrival and spawning period. The 2012 escapement was 32,900 EFS, above the long-term average of 24,600.
- In 2013, Harrison Sockeye (contributing three-year-olds to 2016 returns) were reported to be in good condition on the spawning grounds with a spawner success of 96%. The 2013 escapement in this year was even higher than the previous brood year, at 78,000 EFS.

River-Type Stocks: Juvenile Fraser River Outmigration

- Negligible numbers of sub-yearling smolts were caught in the Mission smolt enumeration program in 2014. The low number of sub-yearlings intercepted in the Mission program could be due to later out-migration than yearling smolts, as reported in previous research (Birtwell et al. 1987). Sub-yearling smolts tend to migrate downstream in the Fraser River from late June to early July, compared to yearling smolts that predominately migrate downstream from April to mid-June. The Mission smolt project has in previous years sampled to the end of July with extremely limited catch. The current project is timed to capture samples of smolts migrating during the early April to mid-June period.

- However, the low number of sub-yearlings caught is also likely due, in part, to differences in out-migration distribution across the river channel and the inability of the Mission sampling platform to access the extreme margins where small sub-yearling juveniles from nearby stocks may be migrating downstream (depending on the traps employed, the minimum depth to allow for vessel and trap clearance is 2.0-4.0 m).

River-Type Stocks: Juvenile Migration in the Strait of Georgia

Juvenile Migration Timing in the Strait of Georgia

- Harrison River Sockeye enter the SOG in late June/early-July (Beamish et al. 2016) as sub-yearling fish. They are generally captured in Howe Sound in early-July during the annual trawl survey. Howe Sound, however, is not part of the standard track line (Figure 24), so these fish are not included in the early-July CPUE estimates. Harrison River Sockeye only occur in the standard track line in the SOG in the September/October trawl survey and represent the majority of the juvenile Sockeye in these catches, which are concentrated on the mainland side of the SOG (Beamish et al. 2016).
- Harrison River Sockeye returning in 2016 will have entered the ocean as juveniles in the summer of 2013 or 2014, returning as four- or three-year-olds, respectively. The 2013 SOG trawl survey was conducted from September 18 to October 1. The survey in 2014 was delayed due to mechanical issues with the research vessel and was conducted from September 29 to October 12. Although this timing was later than 2013 it was not outside the time period of other surveys between 1998 and present.
- The average size of the juvenile Sockeye in September 2013 and 2014 was 131.1 mm and 130.1 mm, respectively (Figure 30). These averages were slightly above the long-term average for September. Both years have approximately uni-modal size distributions, suggesting that the majority of the fish were Harrison River in origin (Beamish et al. 2012).
- The CPUE of Harrison Sockeye on the standard track line in the September/October survey was extremely low in 2013 and moderate in 2014 (Figure 31). These surveys capture fish returning as four- and three-year-olds in 2016, respectively (Beamish et al. 2016). In even years, when juvenile Fraser River Pink Salmon are entering the ocean (e.g. 2014), a greater proportion of the Harrison River Sockeye return as four-year-olds, compared to odd years, possibly influenced by competition with Pink salmon that spawn only in odd years and migrate to the ocean in even years (Grant et al. 2010). The very low CPUE in 2013 coincides with a very low predicted 2016 four-year-old return presented in the official forecast of 48,000 (at the 50% probability level), compared to the average four-year-old return for this stock in recent years (2001 to 2011 brood years) of 430,000. The moderate CPUE in 2013 coincides with a moderate predicted 2016 three-year-old return presented in the official forecast of 128,000 (at the 50% probability level).

Strait of Georgia Coho: Explored as Potential Indicators of Fraser Sockeye Salmon Survival in this Ecosystem

- Both Coho and Fraser Sockeye lake-type stocks migrate into the SOG in June/July. The Harrison river-type Sockeye stock migrates into the SOG a month or more later (Birtwell et al. 1987). Most Fraser Sockeye stocks are lake-type and once in the SOG they generally migrate north, exiting via the Johnstone Strait. Their residence time in the SOG is up to two months. Coho and river-type Harrison Sockeye have a longer residence time in the SOG compared to most other Fraser Sockeye stocks (Chittenden et al. 2009; Beamish et al. 2010). Despite differences in SOG residence time, there is overlap in the distribution of particularly lake-type Sockeye and Coho since these stocks are distributed in the SOG offshore, and typically feed on similar prey during their SOG residence period. Harrison river-type Sockeye, in contrast, spend more time in near-shore environments in the SOG. As a result, the lake-type Sockeye and Coho stocks may be similarly affected by ocean conditions in the SOG. If this is the case, since Coho salmon mature as three year olds returning one year prior to Fraser Sockeye four year olds, Coho salmon could potentially be used as a predictor of the upcoming year's survival for Fraser Sockeye. This hypothesis is supported by the strong positive correlation between the marine survival of Chilko Sockeye with the marine survival of SOG Coho (Figure 32). No such correlation was apparent for Chilko Lake Sockeye with Barkley Sound Coho ($F_{1,34}$=1.5; p>0.2), a Coho stock that does not enter the SOG but remains off the West Coast of Vancouver Island or the GOA for their marine residence. These correlations support the hypothesis that ocean conditions experienced by Chilko Sockeye in the SOG regulate, in part, their recruitment.

- This correlation between Coho and Chilko marine survival although strong, explains less than half the variance in Chilko marine survival (36-40%). With this level of predictive power, the best that can achieved with these correlations is to predict low or high marine survival (Prairie 1996): when the marine survival of SOG Coho is below average, marine survival of Chilko Lake Sockeye is expected to be below average, and vice versa. Although the marine survival of SOG Coho was not available for the 2012 brood year (2015 return year) at the time this report was written, the overall qualitative description of adult Coho Salmon returns for that brood year was very poor. Therefore, the marine survival of Chilko Lake Sockeye also could be very poor for the 2012 brood year (2016 return year), although see caveat in subsequent bullet.
- In particular years, it is important to evaluate more detailed information where available to determine whether or not it is possible that these correlations might break. For example, while Coho CPUE in the SOG is predictive of subsequent Coho returns (Beamish et al. 2010), Coho CPUE and sizes in the SOG trawl surveys (above average CPUE and large sizes) in September 2014 predicted much higher Coho returns in 2015 than actually occurred. So in this particular year SOG survey year (2014), information on Coho in the SOG was not predictive of this stock's subsequent year's return. This suggests that the factors contributing to the poor Coho survival in the 2015 return year occurred outside the SOG, likely attributed to the ocean conditions these fish experienced after they left the SOG, exiting via the Juan de Fuca Strait, and remaining off the West Coast of Vancouver Island for the remainder of their marine residence. If this is where the poor survival occurred for Coho stocks that returned in 2015, then this would not influence most Fraser Sockeye stocks since they do not use these areas during their marine distribution. The only stock that could possibly be similarly affected by poor West Coast of Vancouver Island conditions are Harrison Sockeye three-year-olds that also migrated out of the SOG via the Juan de Fuca Strait, and remained off the West Coast of Vancouver Island in the winter of 2014. Harrison Sockeye are typically captured off the west coast of Vancouver Island during trawl surveys in February and therefore may have a distribution, at least in part, similar to juvenile Coho salmon. Coho survival, driven by factors experienced by these fish beyond the first few months at sea, was also observed for Oregon Coho Salmon during the 1982-1983 El Nino (Fisher and Pearcy 1988). In summary, there may be a decoupling in the survival of Chilko Lake Sockeye from SOG Coho for the 2012 brood year.

Fraser Sockeye Three-Year-Old Jack Returns in 2015: Explored as Indicators of Fraser Sockeye Four-Year-Old Sibling Returns in 2016

- Jack (three-year-old: 3_2) abundances that returned in 2015 were used to provide an indication of their sibling four-year-old (4_2) returns in 2016. This was evaluated only for stocks where four year old 50% probability level forecasts of returns were greater than 50,000 (DFO 2016). This included Gates (61,000), Nadina (88,000), Chilko (976,000), and Stellako (188,000). Although Chilliwack four-year-olds forecasts in 2016 at the 50% probability level were 137,000, the short recruitment time series for this stock was not sufficient to compare jack to four-year-old relationships.
- Applying the above considerations, linear regression analysis of the $\log_e$ transformed three- and four-year-old recruitment data was conducted for Nadina, Gates, Chilko and Stellako (Figure 33). The three-year-old jack escapements in 2015, which assumes negligible exploitation of jacks in 2015, were used in this relationship to predict four-year-old returns in 2016. The fit for Nadina was extremely poor ($R^2 = 0.03$) so is not presented in this paper. The sibling model forecasts of four-year-old returns in 2016 were very similar to the official forecasts 2016 returns (DFO 2016; Table 2).

Ocean Conditions from 2014 to Present

- The Northeast Pacific Ocean in 2014 and 2015 was dominated by the very strong warm temperature anomaly (referred to as the warm blob), the likes of which had never been seen in the 65 years of modern temperature measurements in this region. Through the first half of 2014, upper water layers (shallower than 100 m) were 3-4°C above seasonal average in the GOA, but slightly cooler than normal along the west coast of Vancouver Island. In fall 2014 this very warm anomaly reached the outer coast of BC, causing record high temperatures at many locations which persisted until 2016 (Figure 34).
- Biological impacts of this very warm water included changes in zooplankton composition, from the normal cold-water fauna of large lipid-rich copepod species (which are excellent food for fish), to increased abundances of small lipid-poor copepod species more typical of California waters. In addition, a number of fish species rarely or never seen in BC waters migrated north along the coast, including potential predators of juvenile salmon, such as mackerel. It should be noted that, although these conditions would be somewhat consistent with El Niño events, which occur periodically in BC outer coastal waters, they occurred in the absence of an El Niño event.
- Fraser Sockeye migrate from the Fraser River into the SOG, and then north into the Queen Charlotte Sound, and then resided in the GOA until their return migration. Most Fraser Sockeye returning in 2016 will be four year olds, and these fish would have entered the ocean in 2014. Therefore, most of these fish will have experienced atypical ocean conditions. In contrast five year olds returning in 2016 that contributed generally less to the total Fraser Sockeye abundance experienced (with the exception of some stocks that will return as largely five year olds due to their brood year escapements; DFO 2016) more typical ocean conditions.
- Available data from the SOG in 2013 (Figure 35) show about normal sea surface temperatures (SST) in Departure Bay in spring and summer, followed by relatively cool conditions from August to October. Along the north (Langara Island; Figure 35) and NW coast of Vancouver Island (Kains Island; Figure 35). Sea surface temperatures were cool until September, when they became unusually warm through November 2013. The spring

phytoplankton bloom in the SOG, representing the start of the marine growing season, which is estimated to have been about normal in 2013 (end of March; Figure 36).

- Fraser River Sockeye entering the SOG in spring 2014 encountered generally warm conditions from June to August (Figures 37). The spring phytoplankton bloom in the SOG in 2014 occurred at the same time as in 2013 (late March). During their migrations into Queen Charlotte Sound and northwards, these fish would have begun to encounter the very warm anomaly after October 2014 (Figure 37). They would have continued to experience the very warm conditions through 2015 while in the GOA. Anecdotal reports of other salmon stocks returning to BC in summer-fall 2015 suggest the fish were returning at about expected abundances but that individual fish were smaller in size. The very warm conditions in the GOA in 2014 and 2015 suggest poor food conditions for salmon. This is consistent with the hypothesis that salmon abundances may be established mostly during their early coastal/continental shelf migrations, whereas final sizes of individual fish would be determined by their feeding environment in the GOA prior to beginning their return migrations.

Conclusions

- To provide support of the official 2016 Fraser Sockeye forecast (DFO 2016), supplemental data on Fraser Sockeye condition, survival, and relative abundances were presented for the parental spawners in 2012 through to the 2015 jack (three-year-old) returns. Ocean conditions these fish would have experienced are also presented in the current publication. This publication's synthesis of existing data represents a starting point for reducing uncertainty in Fraser Sockeye forecasts, through improving our understanding of inter-annual variability of survival in these stocks. As our understanding evolves, it may provide qualitative, and ultimately quantitative, information on understanding and predicting Fraser Sockeye populations.
- The key stocks expected to contribute the most to the 2016 returns include the Summer Run lake-type stocks: Chilko (44% of the forecast return at the 50% probability level), Late Stuart and Stellako (combined contribute 20% to the forecast return), and the river-type Harrison stock (8%). The Early Summer Run Chilliwack stock is also expected to contribute more than it does in most years (6%) to the total forecast, given its exceptional brood year escapement in 2012. Similar to the previous year, different information suggests that survival might vary depending on the life-history stage and stock, or indicator applied.

Some information indicates a negative influence on Fraser Sockeye survival:

- Poor upstream migration conditions existed (high discharge) for the 2012 brood year Early Stuart and Early Summer stocks. Although discharge conditions were benign for Summer Run stocks (such as Chilko), these stocks would have experienced high temperatures (above 18^{o}C). There were observations of fish from upstream stocks (e.g. Chilko and Stellako) in poor condition (based on high plasma glucose levels), sampled at Seton, a site upstream but near Hells Gate. These fish might have been seeking refuge from the warm Fraser River temperatures in cooler water, en-route to the upper river spawning sites.
- In 2012, many stocks were reported to be in poor condition on the spawning grounds and spawner success across all Fraser Sockeye populations was the lowest observed in over 50 years (71%, compared to an average of 89%). Gamete quality (egg survival to the eyed stage) was slightly below average for Chilko. Histological assessment of tissue samples taken from Sockeye at Birkenhead, Raft, Stellako and Gates all exhibited poor gill condition and the presence of *Parvicapsula minibicornis*, a parasite that has been previously

associated with salmon pre-spawn mortality events in the Fraser River and other systems. IHNv (Infectious Hematopoietic Necrosis virus), a viral disease commonly found in salmonids, was detected in samples from Gates and Birkenhead. Although observed spawner success (based on observation of eggs retention in spawned out female carcasses) is incorporated into the current quantitative forecast process, fecundity, egg survival and quality, and legacy effects of this on juveniles are not included.

- SOG Coho (three-year-old fish) marine survival in 2015 was very poor, and was linked to conditions on the west coast of Vancouver Island. Therefore, correlations between Coho and Fraser Sockeye likely are uncoupled for the 2016 Fraser Sockeye returns broadly, given Fraser Sockeye does not rear on the west coast of Vancouver Island. Although no correlations have been explored with Harrison Sockeye, it is possible that given the overlap in their distributions on the west coast of Vancouver Island, the poor Coho survivals in the 2015 returns could indicate poor Harrison Sockeye three year old returns in 2016.
- SOG juvenile late-June/early-July surveys that sample largely lake-type Fraser Sockeye (which includes Chilko) reported an extremely low CPUE for these fish. Unlike the previous year, out-migration timing through this system was considered normal in 2014, and therefore, this CPUE information is considered reliable, unlike the previous year (DFO 2015b). These data indicate that Fraser Sockeye returns could fall at lower probability levels of the forecast in 2016 (DFO 2016), with the caveat is that these surveys capture only 10% of Fraser Sockeye out-migration.
- SOG juvenile September surveys that sample largely river-type Fraser Sockeye (i.e. Harrison) also reported extremely low CPUE for these fish in 2013. This is consistent with the poor returns of three-year-old Harrison Sockeye in 2015, information that was used to reduce the four-year-old forecast in 2016 using a sibling three-to-four year-old model (DFO 2016).

Alternatively, other information indicates a positive influence on Fraser Sockeye survival:

- Although there are large gaps in the middle of the time series, limnological assessments of Chilko and Shuswap Lakes indicate these lakes have increased in primary productivity in recent years, compared to the historic time series. Chilko freshwater survival in the 2012 brood year was slightly above average (no data are available for Shuswap stocks on freshwater survival). This was accounted for specifically in the Chilko forecast that uses smolt abundances to predict returns.
- During 2014 smolt out-migration, Fraser River discharge was high and temperatures were average. It is hypothesized that higher discharge may improve survival of smolts, although this relationship has not been evaluated.
- Sizes of outmigrating Chilko smolts in 2014 compared to their 50 year time series were much larger than average. Smolt average fork length at Mission in 2014 was larger than the previous two years of assessments for Chilko and other stocks (e.g. Cultus-L and Kamloops-ES); Chilliwack was the exception which decreased slightly since the previous year. Chilliwack fry were average sized compared to the time series assessed (starting in 1996, largely on dominant years), despite the exceptionally large brood year escapement in 2012.
- The proportion of empty stomachs in Fraser Sockeye lake-type stocks in 2014 sampled in the SOG was average. This is in contrast to the 2007 out-migration year where a high proportion of empty stomachs was observed, and coincided with exceptionally poor survival of all stocks in 2009.

- The 2014 SOG CPUE for Harrison was moderate, which is consistent with a moderate forecast generated for three-year-olds in 2016 (DFO 2016). This contradicts the poor survival indicated by poor Coho survivals presented in the previous section.
- Three-to-four year-old sibling models produced identical 2016 four-year-old forecast Bayesian posterior distributions for Chilko and Stellako to the official forecast models (DFO 2016). Both of these distributions are uncertain (characterized by wide distributions).
- Chilko was consistently the largest stock proportion sampled in the SOG, and was comparable in proportion to the 2016 return forecast. Higher proportions of Chilliwack were detected in the SOG compared to the return forecast. Other stocks were also detected at higher proportions in the SOG compared to forecast (Gates, Early Stuart, Raft and Birkenhead), and other stocks at lower proportions (Late Stuart and Stellako). Outmigration timing and proportions of stocks detected at Mission might be biased since assessments do not currently correct for the large changes in discharge conditions from the start to the end of the project. Therefore, Mission results were not heavily weighted in the interpretation of stock proportions across all sampling components.

The Warm Blob:

- The ‘warm blob’ spanned a more coastal distribution in the second half of 2014, and water temperatures have remained high in the SOG and in the Northeast Pacific through 2016. However, given the broad range of responses to these conditions observed across Fraser Sockeye stocks and non-Fraser Sockeye stocks in the previous year’s returns, it is not possible to determine how Fraser Sockeye will respond given these conditions alone.

Tables

Table 1. Adult Fraser Sockeye sample sizes for blood physiology, disease and fish condition in the 2012 migration year in three sampling locations (marine, in-river, and on the spawning grounds).

		Blood Physiology	**Disease**		**Condition**
Ecosystem	**Location**	Stress, Metabolism, Reproduction	RNA	Histology	Lipid Metrics
Marine	Johnstone St.	41	41	41	41
	Port Renfrew	63	63	63	63
In-River	Whonnock	19			19
	Harrison	24	24	24	24
	Seton/Cayoosh	20	20	20	20
Spawning	Chilko	30	30	30	-
	Harrison	14	14	14	-
	Stellako	38	40	40	20
Total		**249**	**232**	**232**	**187**

Table 2. The 2016 four-year-old forecasts for Gates, Chilko, and Stellako (DFO 2016) compared to the four-year-old sibling model estimated from the three-to-four year-old recruitment relationship for each stock (compared using Bayesian linear regression).

	10%	**25%**	**50%**	**75%**	**90%**
Gates					
Larkin	12,000	22,000	47,000	95,000	178,000
Sibling (3 to 4 yr)	11,000	20,000	41,000	82,000	155,000
Chilko					
Power (juv) (Pi)	400,000	618,000	976,000	1,548,000	2,255,000
Sibling (3 to 4 yr)	356,000	575,000	971,000	1,638,000	2,651,000
Stellako					
R2C (Larkin ages)	79,000	133,000	235,000	418,000	700,000
Sibling (3 to 4 yr)	70,000	131,000	257,000	507,000	942,000

Table 3. Proportions of key lake-type Fraser Sockeye stocks (those that comprise the greatest numbers in most sampling components). These proportions are for EFS estimated on the spawning grounds, and four-year-old forecasts predicted (DFO 2016). It also includes proportions sampled at Mission and in SOG trawl and purse seine surveys (sample sizes are indicated for these assessments). Sample sizes are related to numbers of fish caught for the stocks specifically listed in this table; sample sizes are larger if all Fraser Sockeye stocks are included.

Stock	**Effective Females**	**Mission Smolts** (*n*=941)	**SOG Trawl** (*n*=530)	**SOG Purse Seine** (*n*=244)	**Four Year Old Forecast**
Chilko	0.34	0.22	0.45	0.55	0.59
Chilliwack	0.29	0.56	0.19	0.30	0.11
Late Stuart	0.19	0.02	0.03	0.09	0.14
Stellako	0.12	0.05	0.04	0.00	0.08
Gates	0.03	0.07	0.08	0.06	0.04
Early Stuart	0.03	0.02	0.12	0.16	0.01
Raft	0.01	0.05	0.03	0.00	0.01
Birkenhead	0.01	0.01	0.07	0.3	0.02

Figures

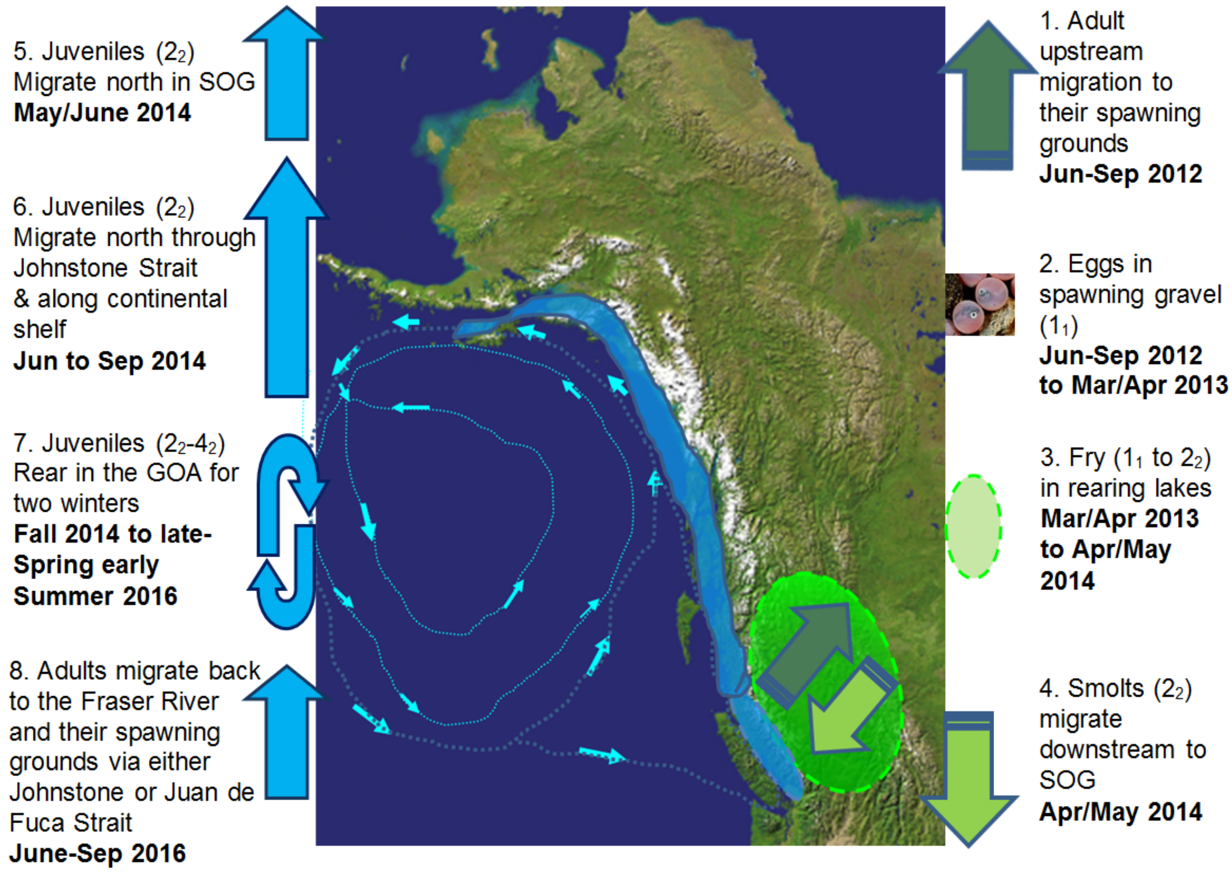

Figure 1. Lake-type Fraser Sockeye life-history for individuals that will return to spawn in 2016 as four-year-olds. Most Fraser Sockeye return as 42 fish. The 42 Fraser Sockeye expected to return in 2016 are offspring of those fish that spawned in 2012, and will have spent their first two winters in freshwater (one winter as eggs in the gravel and one winter as fry in rearing lakes). After their second winter in freshwater (2014) these fish migrated downstream through the Fraser River and entered the SOG. From here they migrated north, through Johnstone Strait and along the continental shelf out into the Northeast Pacific. They spent two winters (2014 & 2015) in the GOA and will return back to their spawning grounds in the late-summer/fall of 2016.

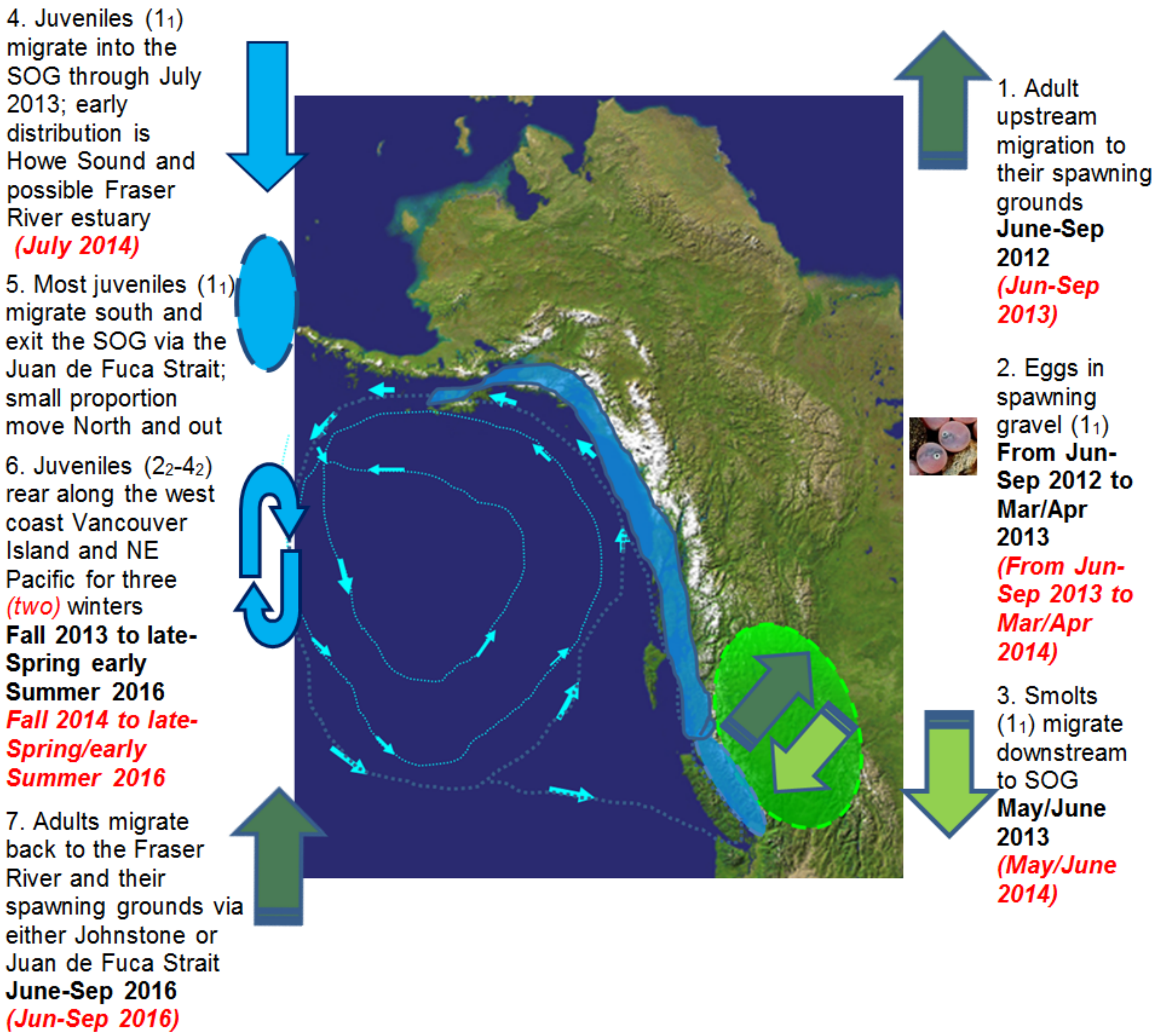

Figure 2. River-Type Fraser Sockeye (specifically Harrison Sockeye) life-history for individuals that will return to spawn in 2016 as three- (italisized red text) and ***four-year-olds (bolded black text)****. River-Type Fraser Sockeye return as 4_1 or 3_1 fish and returns in 2016 are offspring of those fish that spawned in 2012 (or 2013 for 3_1 fish), and will have spent one winter in freshwater (as eggs in their spawning gravel) then migrated, about a month later than river-type stocks, downstream to the SOG in 2013 (or 2014 for 3_1 fish). Most Harrison Sockeye then migrated south out of the SOG (they remain in the SOG longer than other stocks, leaving in the fall of 2013/2014) through the Juan de Fuca Strait to rear along the west coast of Vancouver Island and in the north east Pacific. A small proportion also migrates north and exits the SOG through the Johnstone Strait. After three winters (or two for 3_1 fish) in the marine environment they will return back to their spawning grounds in the late-summer of 2016.*

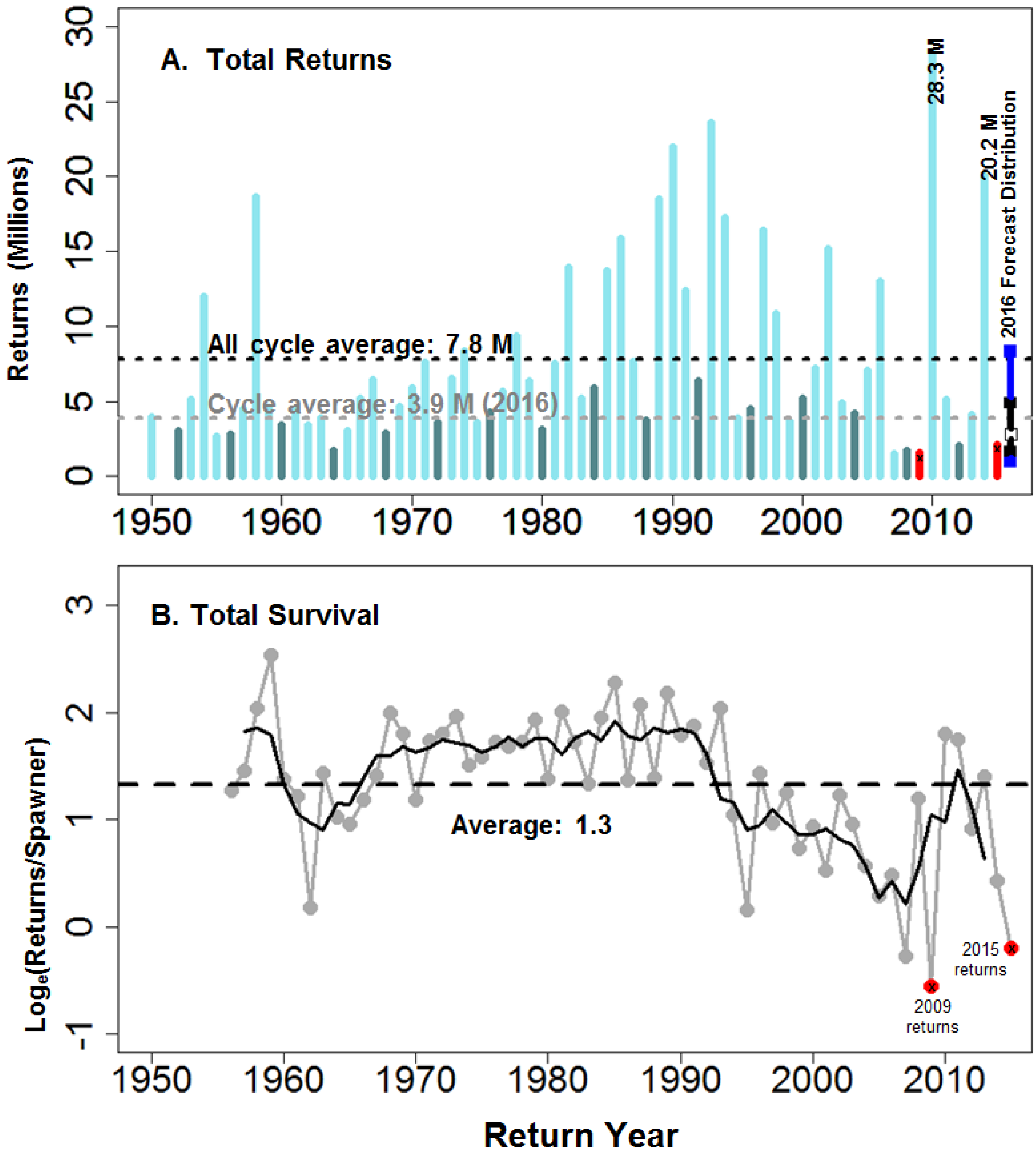

*Figure 3. **A.** Total Fraser Sockeye adult annual returns (dark [blue] coloured vertical bars for the 2016 cycle and light [blue] coloured vertical bars for the three other cycles). Recent adult returns from 2012 to 2015 are preliminary. The vertical bar aligned with the 2016 return year represents the 2016 forecast (length of the lighter [blue] bar represents the 10% to 90% p-level, length of the darker [black] bar represents the 25% to 75% p-level, and the white bar represents the 50% p-level). **B.** Total Fraser Sockeye adult survival ($\log_e$(returns/total spawner)) up to the 2015 return year. The (light grey) filled circles and lines present annual survival and the dark solid (black) line presents the smoothed four year running average. For both figures, the dashed horizontal line is the time series average. In Figure A the lower, lighter dashed horizontal line is the 2016 cycle line average. The first and last red vertical bar (Figure A) or filled circles – marked x to denote them (Figure B) represents, respectively, the 2009 and 2015 returns (low survival). Note that the 2015 return year survival is not entirely appropriate given the higher proportion of five-year-olds, and the assumption in these survival estimates is that four-year-olds dominate total returns.*

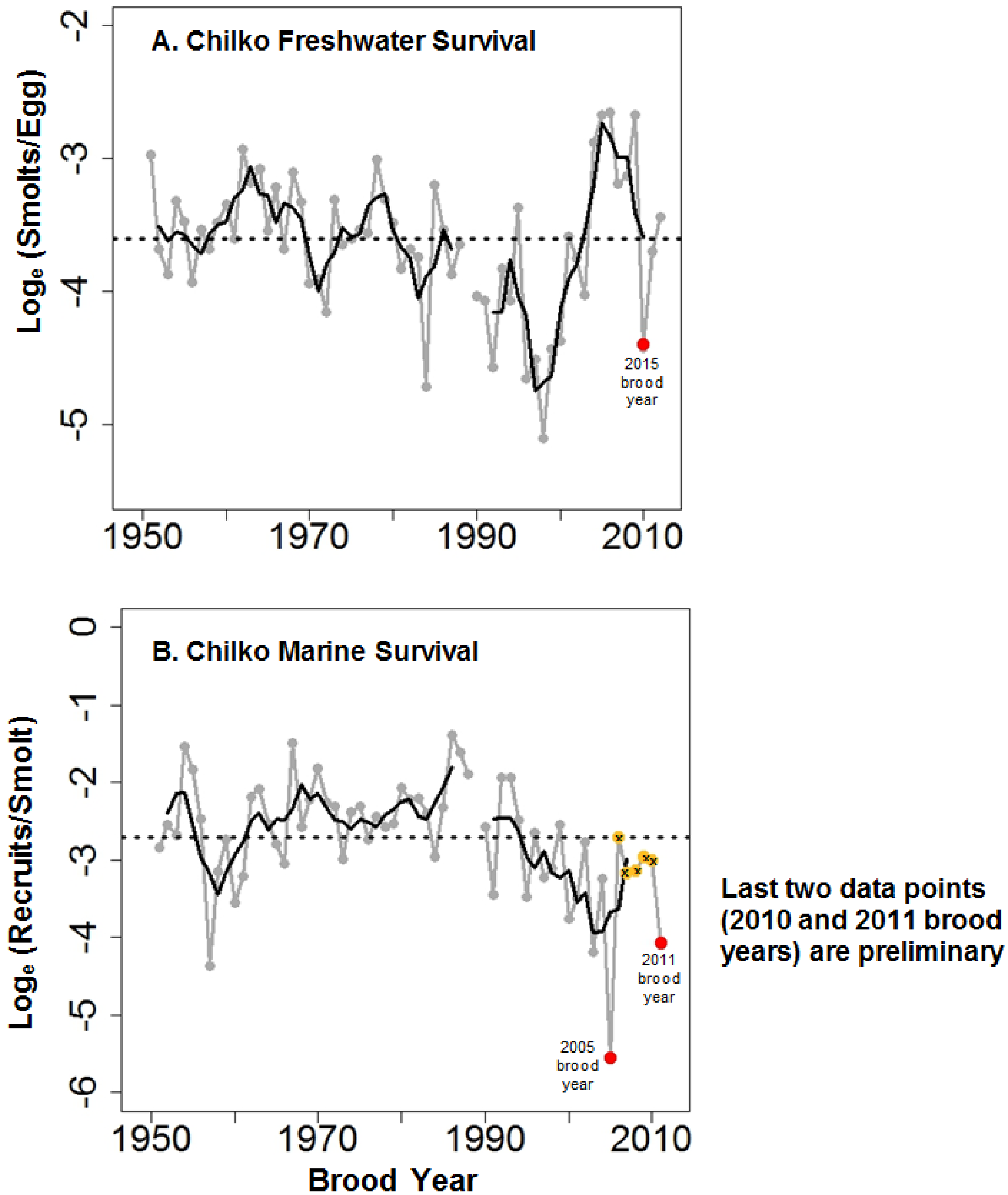

Figure 4. Chilko River Sockeye ***A.*** *annual freshwater (log$_e$ smolts-per-egg) survival (filled light coloured [grey] circles and lines) with the 2005 brood year survival indicated by the red filled circle and* ***B.*** *annual marine (log$_e$ recruit-per-smolt) survival (filled [grey] circles and lines) with the 2005 brood year survival indicated by the first red filled circle. The 2006 to 2010 brood year survivals are indicated by the amber filled circles (marked x) and the preliminary 2011 brood year survival is indicated by the final red filled circle. The solid black line in both figures represents the smoothed four year running average survival and the black dashed lines indicate average survival.*

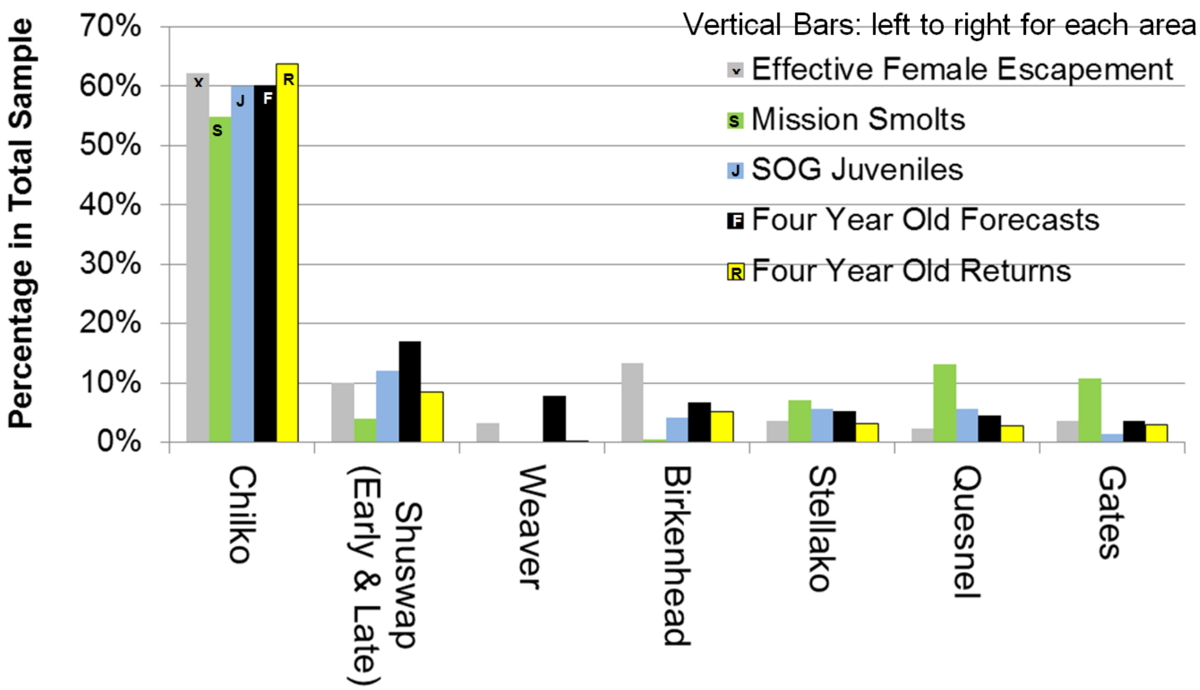

Figure 5. Stock composition (percentages) estimated from the various Fraser Sockeye sampling periods: 2011 escapements (EFS), 2013 smolt out-migration in the Fraser River at Mission, SOG juvenile sampling (SOG lake-type Sockeye sampled in the June 1 to June 11 period), and the official four-year-old forecasts at the 50% probability level (DFO 2015). Note: because Mission sampling was disrupted from May 16 to June 1, percentages of early migrating stocks (e.g. Chilko, Stellako, Quesnel) may be biased high, and later migrating stocks (e.g. Shuswap) biased low.

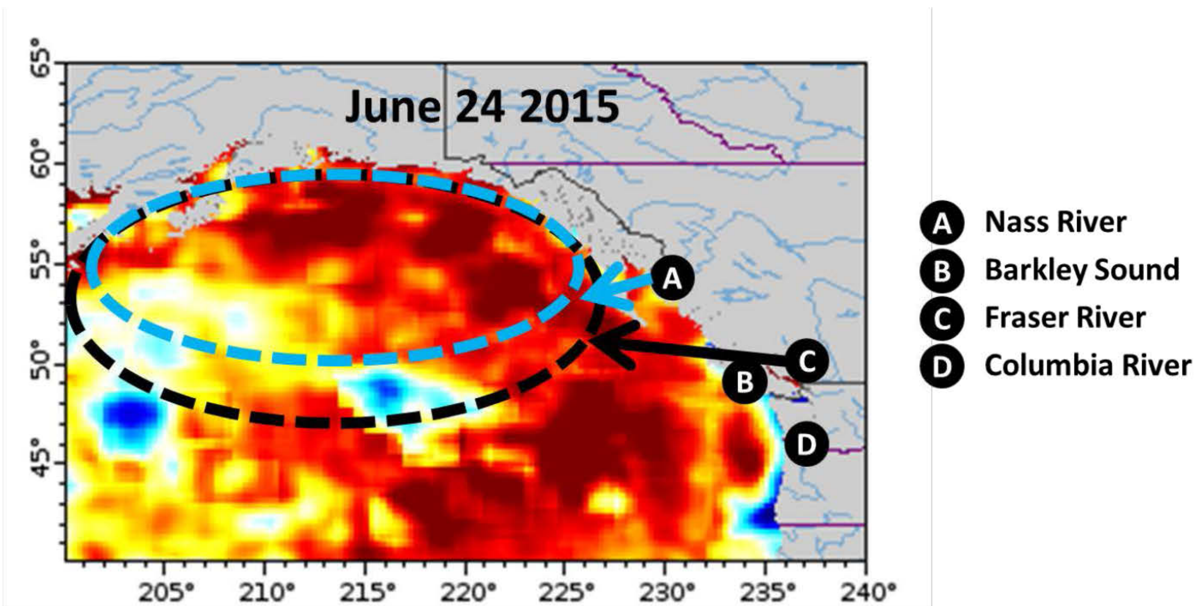

Figure 6. Historical distribution of Nass/Skeena River Sockeye (dashed blue ellipse) and Fraser River Sockeye (dashed black ellipse) based on tag recovery data from 1950s-1960s (data from [North Pacific Anadromous Fish Commission](#)).

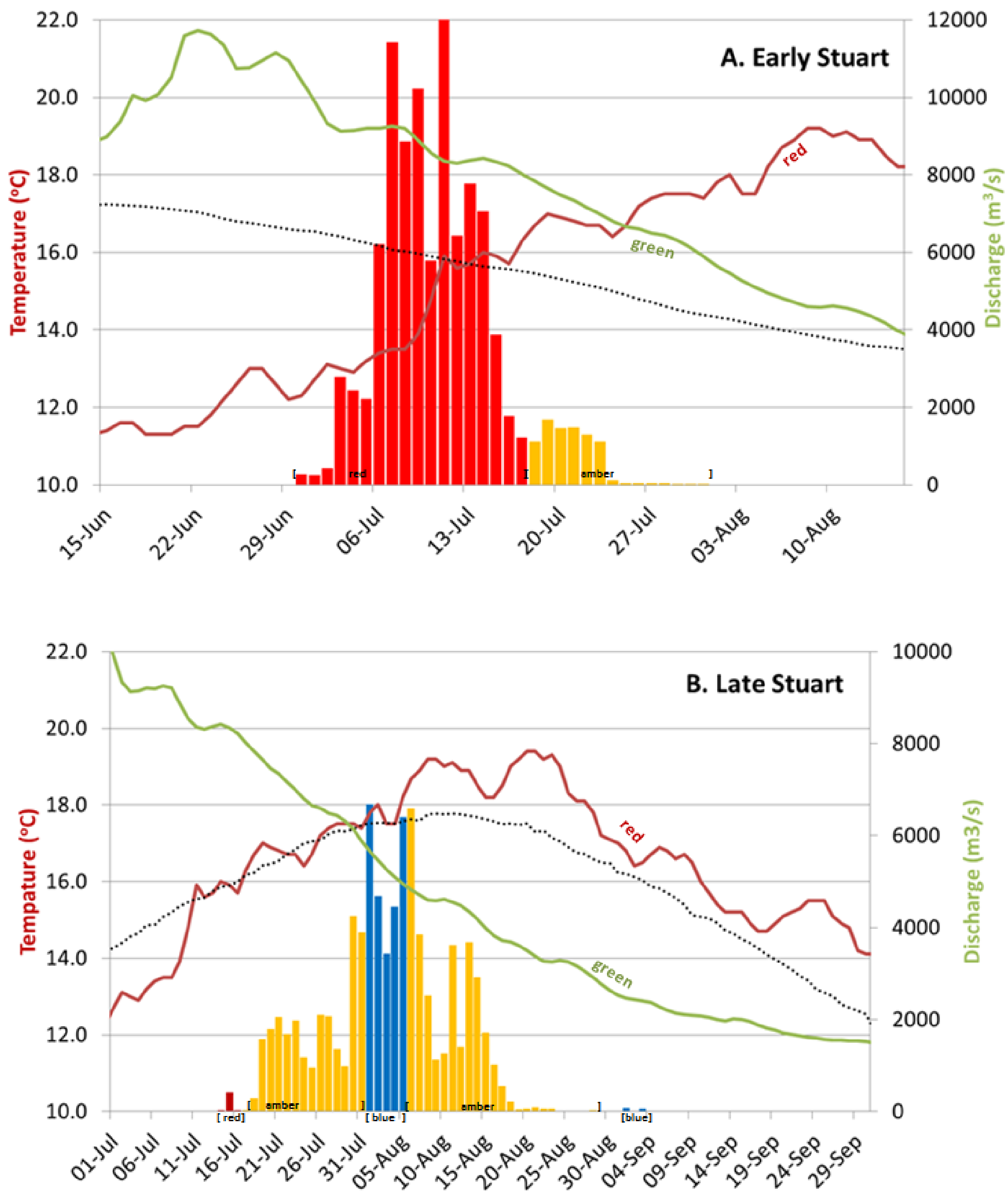

*Figure 7. Migration conditions in 2012 (red line: temperature; green line: discharge; black dotted line: historical average temperatures 1941-2009) for **A. Early Stuart** (low temperature and high discharge conditions) and **B. Late Stuart** Sockeye stocks (somewhat poor temperature and discharge conditions). The vertical coloured bars represent relative abundance of migrating salmon for each of these stocks; bars coloured blue represent the portion of the run that experienced benign temperature and discharge conditions (water temperatures between 14°C and 16°C and discharge below 6,000 m^3/s); red coloured bars represent the portion of the run that experienced conditions thought to negatively influence upstream migration and survival to the spawning grounds (water temperatures above 20°C and discharge above 8,000 m^3/s); amber coloured bars represent the portion of the run that experienced conditions thought to moderately influence upstream migration and survival to the spawning grounds (water temperatures between 18°C and 20°C and discharge between 6,000 m^3/s and 8,000 m^3/s).*

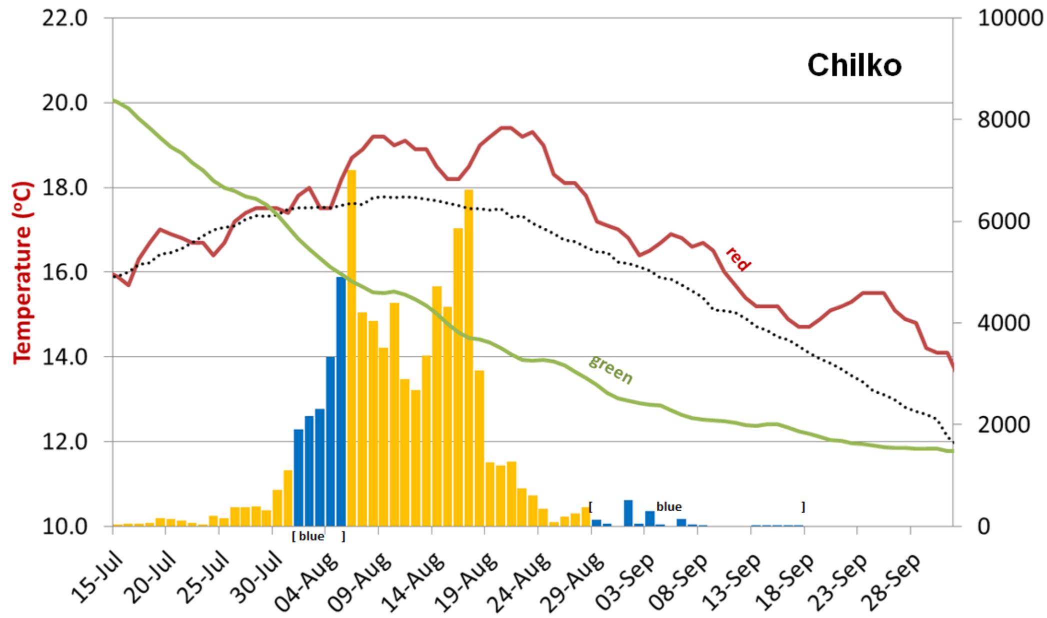

Figure 8. Migration conditions in 2012 (red line: temperature; green line: discharge; black dotted line: historical average temperatures 1941-2009) for the Chilko stock (somewhat poor temperature and discharge conditions). The vertical coloured bars represent relative abundance of migrating salmon for each of these stocks. Blue bars are labelled, amber bars are not. (see previous Figure 5 for details).

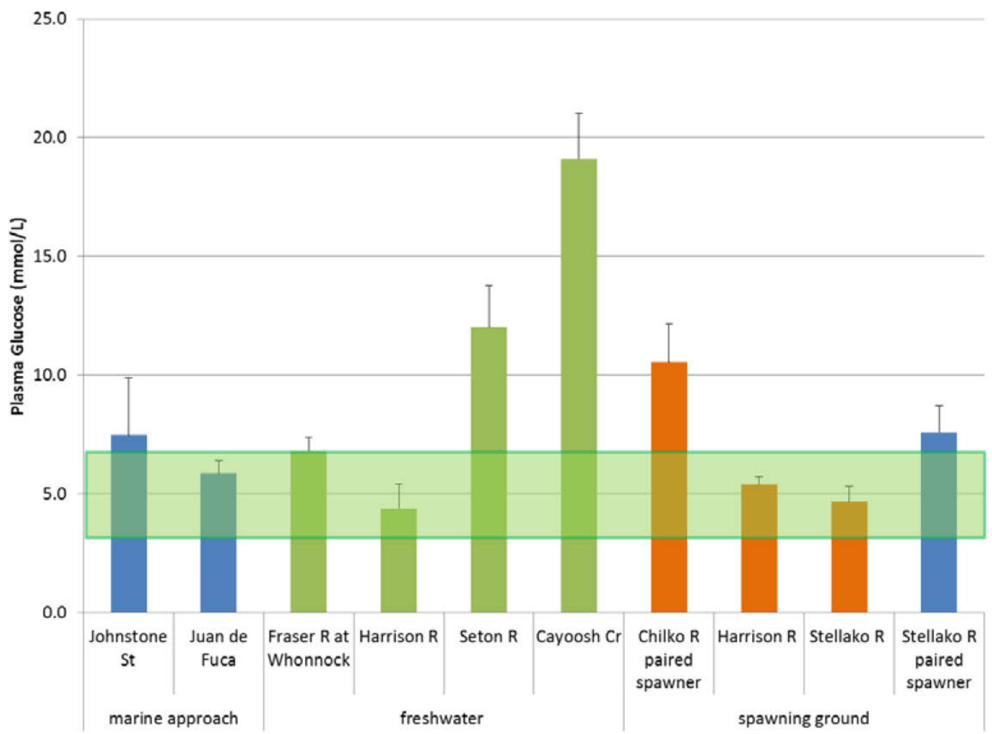

Figure 9. Fraser River Sockeye plasma glucose measurements across sampling locations (marine, freshwater, and spawning ground) in 2012. The normal range is represented by the green shaded area (4 to 7 mmol/L), coloured bars below or above this range are outside the normal range. Bars are standard error.

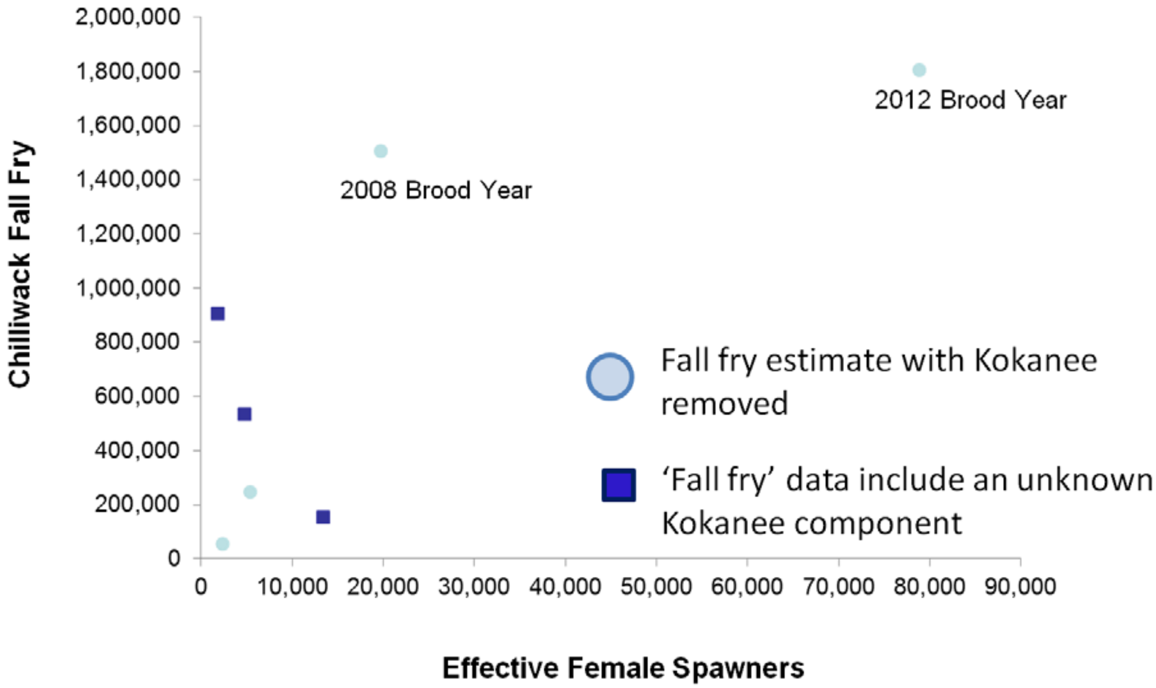

Figure 10. Chilliwack fall fry estimated in Chilliwack Lake by hydroacoustic methods. Fry rearing in this lake are from the Chilliwack stock, which includes fry from two spawning populations: Upper Chilliwack River (Dolly Varden Creek) and Chilliwack Lake. The estimate of 1.8 million fry produced from the 2012 brood year escapement is similar to the estimate of 1.5 million fry produced from the 2008 brood year escapement even though the estimates of EFS differed significantly (19,700 EFS in 2008 compared to 78,000 EFS in 2012).

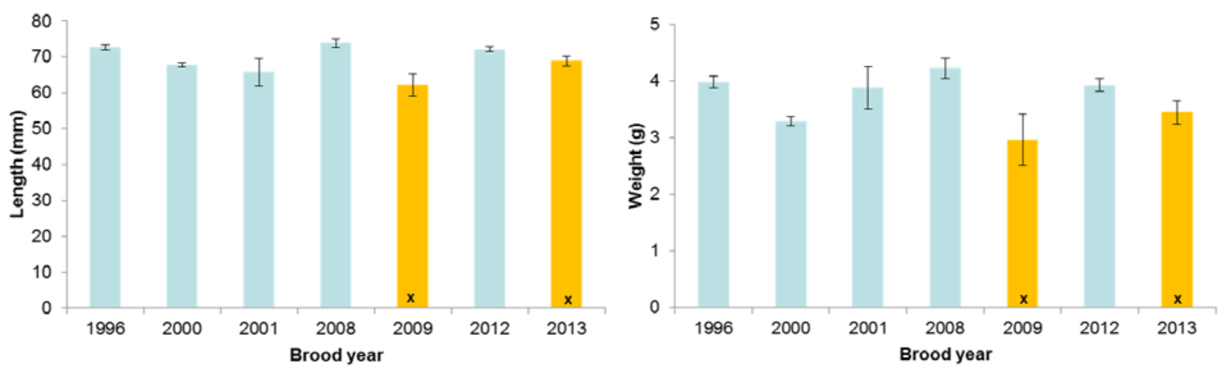

Figure 11. Chilliwack fall fry length and weight from 1996 to 2013. Despite the exceptional escapement in 2012 for this stock (78,000 EFS), sizes were not smaller for fry of this brood year. The yellow bars (marked x) indicate the same cycle line.

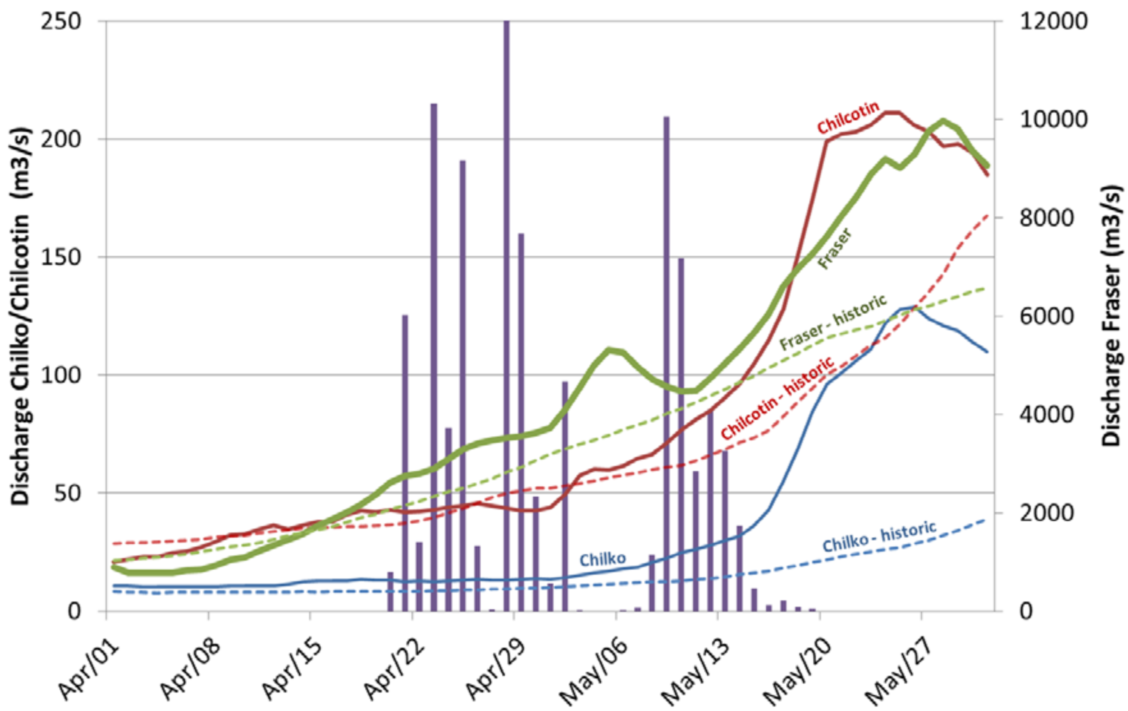

Figure 12. Discharge conditions for the Chilko River (blue line), Chilcotin River (red line) and Fraser (green line) compared to Chilko smolt relative abundance during their out-migration from Chilko Lake (purple vertical bars) in 2014. Historic means for the Chilko and Chilcotin (1996-2009) and Fraser (1912-2009) rivers are corresponding dashed lines.

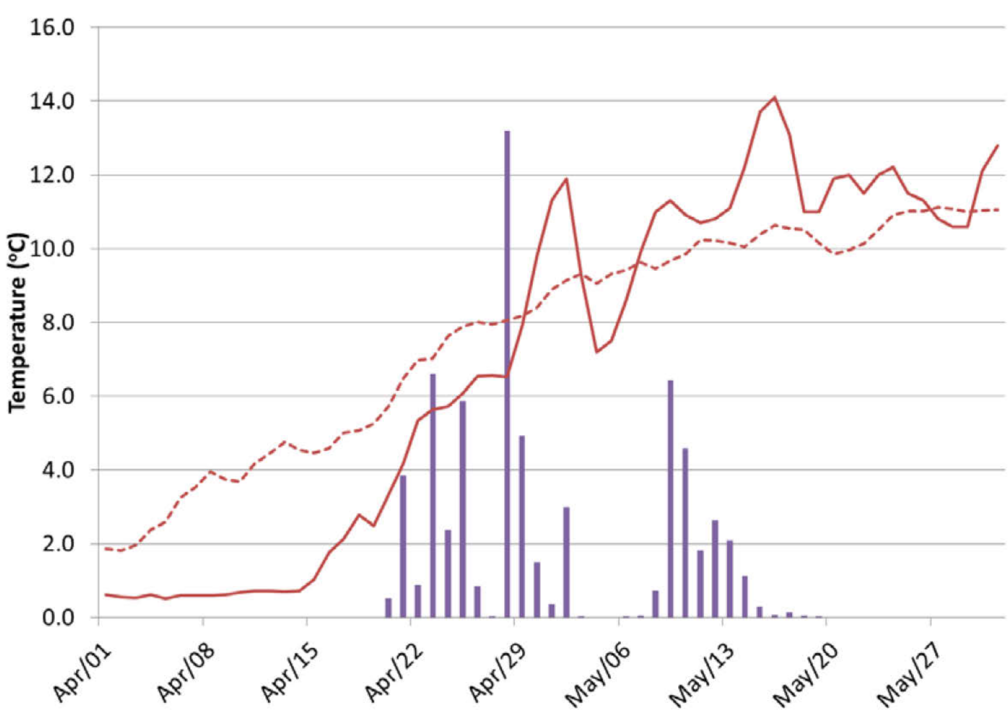

Figure 13. Temperature conditions for the 2014 Chilko Sockeye out-migration year (red line) and historic average(1996-2009, dashed line) compared to Chilko smolt relative abundance during their out-migration from Chilko Lake (purple vertical bars).

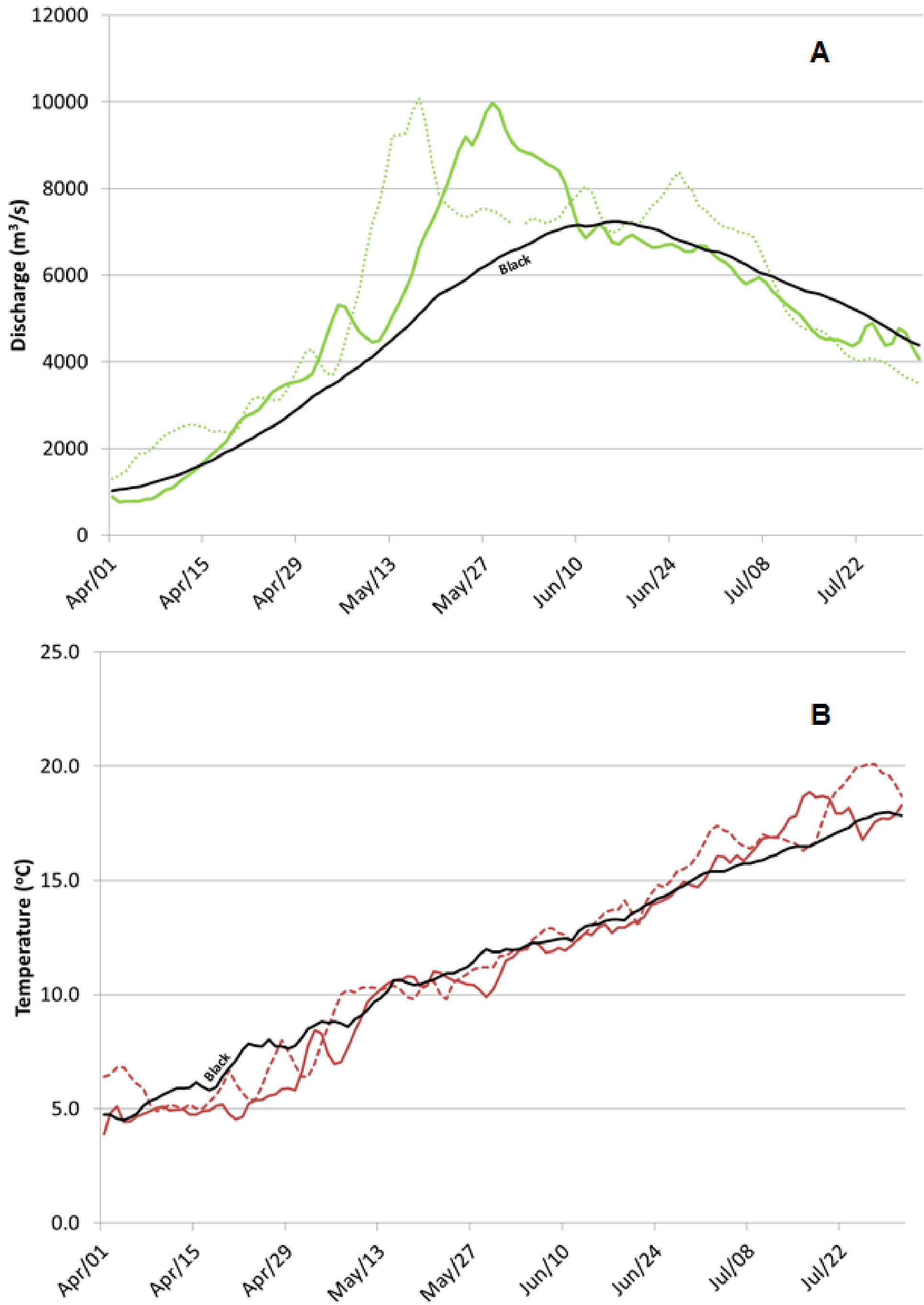

*Figure 14. Discharge (**A**) and temperature (**B**) conditions in the Fraser River during smolt out-migration in 2013 (dotted line) and 2014 (solid line). Discharge was above average and temperatures below or near average in 2014 (1912-2009 average black line).*

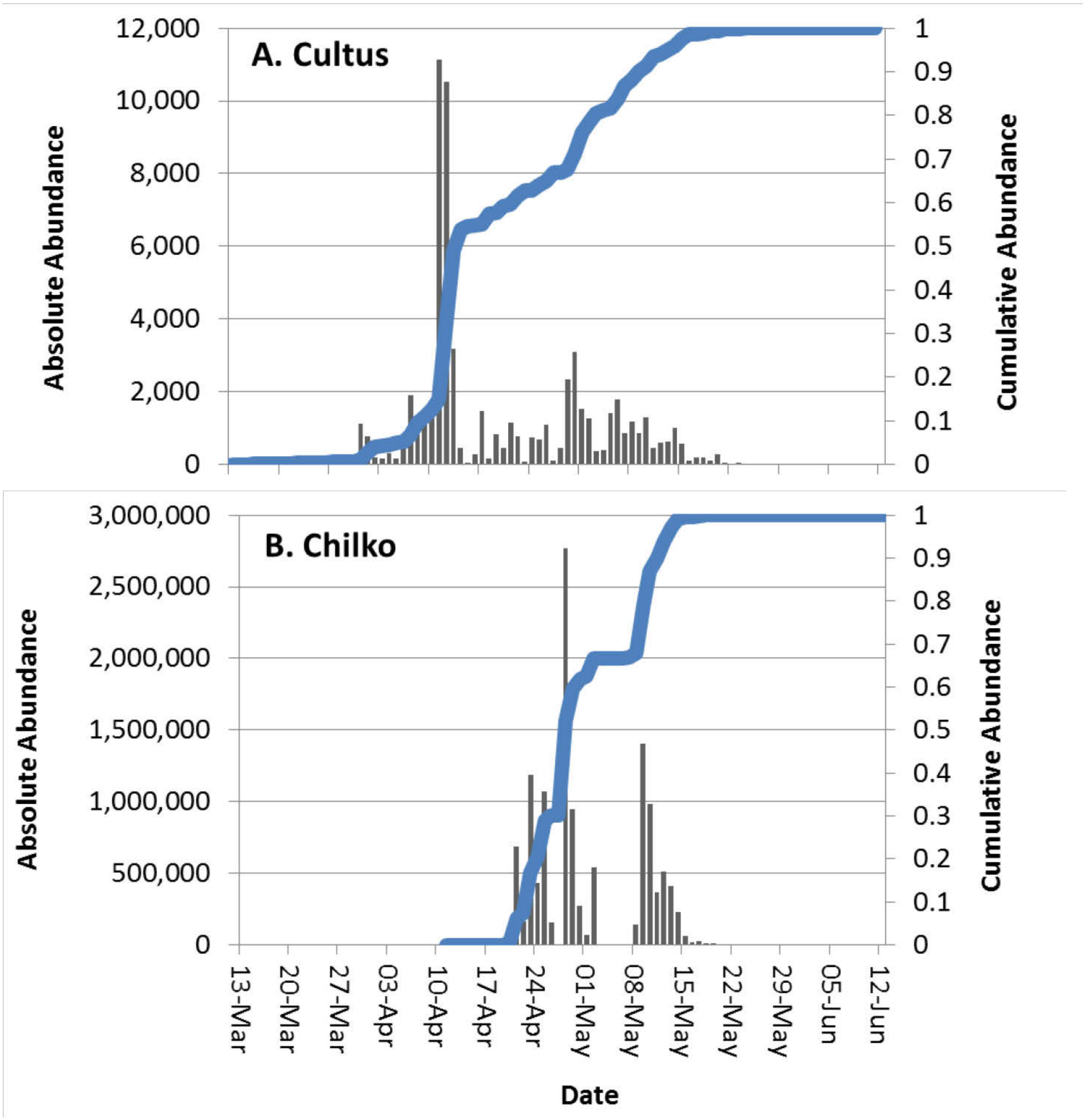

*Figure 15. Smolt out-migration timing at lake outlets for **A.** Cultus; and **B.** Chilko stocks in the 2014 out-migration year. The vertical bars for Cultus and Chilko are absolute smolt abundances and the blue lines are the cumulative smolt abundances over the smolt out-migration period. The 50% out-migration date for Cultus is April 13 and for Chilko is April 28. Note: smolt sampling for Cultus and Chilko are fence/weir counts conducted throughout the migration period.*

Figure 16. Aerial image of the juvenile Sockeye project location in the lower Fraser River at Mission, BC relative to Vancouver and select upstream (Harrison & Chilliwack) and downstream (Pitt) Sockeye stocks.

Figure 17. Aerial image of the juvenile Sockeye survey site in the lower Fraser River at Mission BC, highlighting the location of the surveying tracks fished (bays).

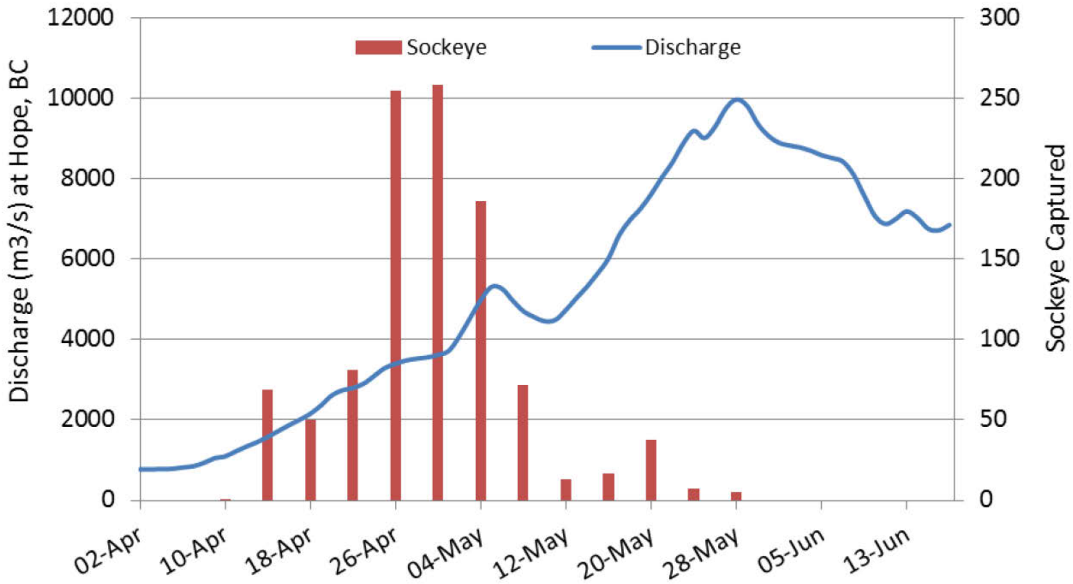

Figure 18. Daily catch of Sockeye smolts in the RST (species confirmed through genetic stock identification) and average daily Fraser River water discharge (m3/s) at Hope, BC during the 2014 lower Fraser juvenile Sockeye assessment project.

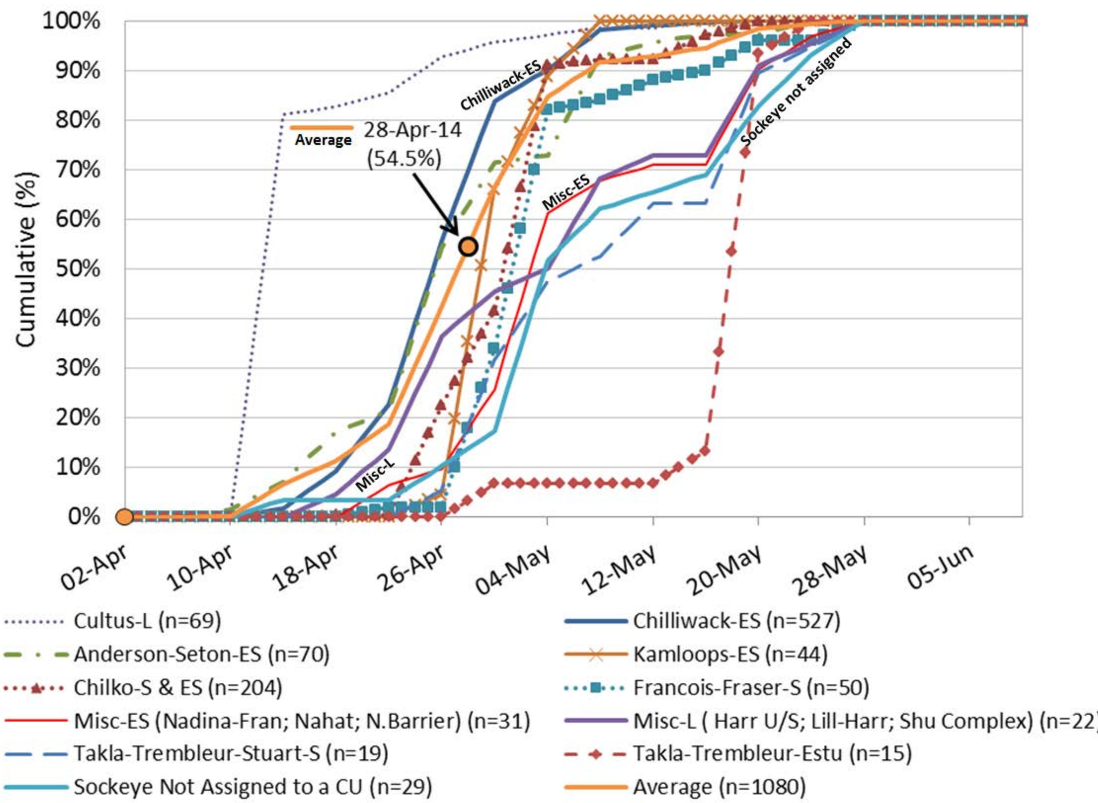

Figure 19. Cumulative Fraser Sockeye smolt catch (as a percent) in the rotary screw trap for select WSP CU's during the 2014 lower Fraser River juvenile Sockeye assessment project at Mission, BC (note: zero Sockeye smolts were caught before April 10 and after May 28, 2014 in any trap). The 50% migration date at Mission in 2014, averaged across all stocks, was April 28.

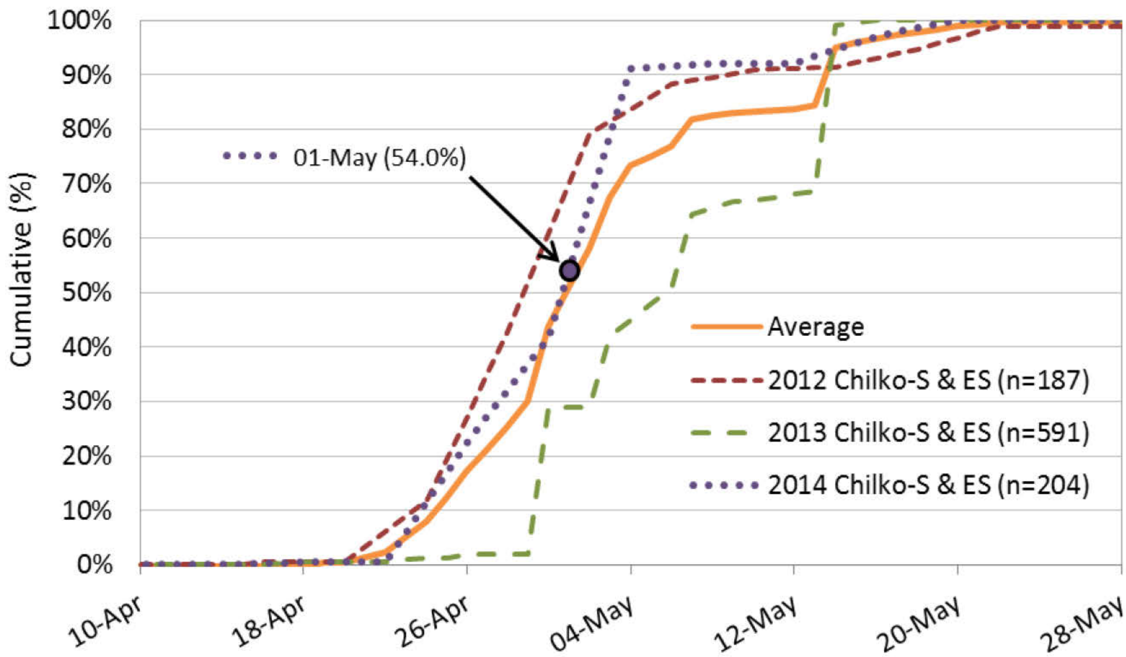

Figure 20. Cumulative Sockeye smolt catch (as a percent) in the RST of Chilko Sockeye smolts (ES and S CUs combined) during the 2012, 2013 and 2014 lower Fraser River juvenile Sockeye assessment projects at Mission, BC. The average 50% migration date for the three years assessed is May 1.

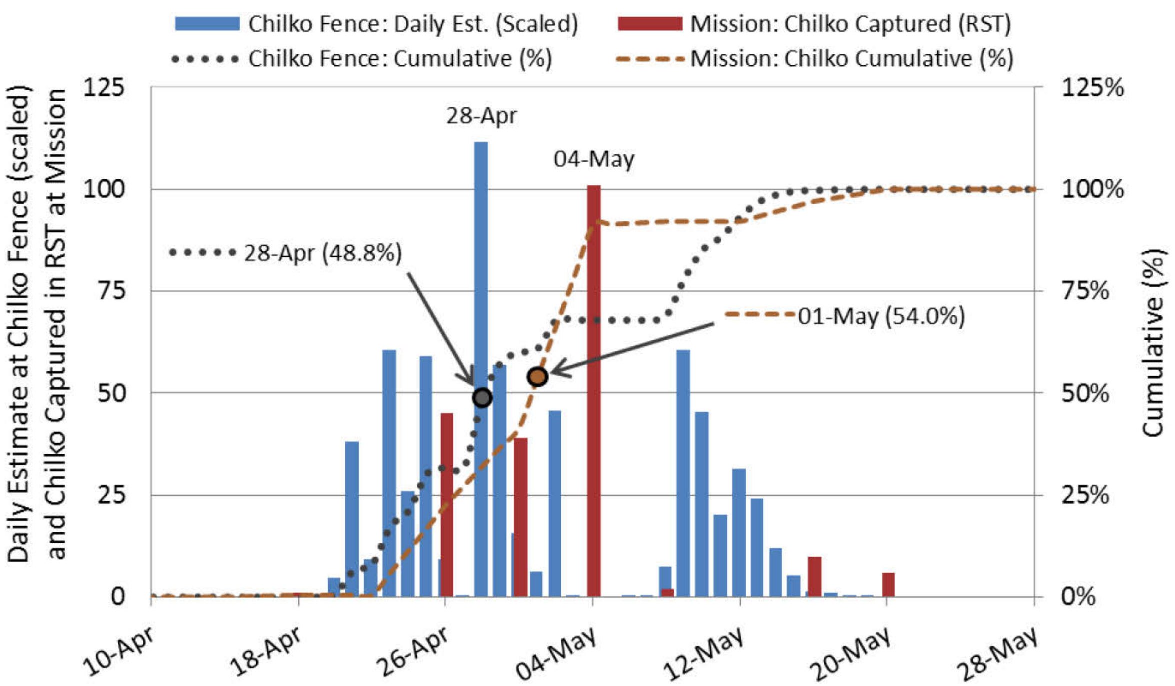

Figure 21. Cumulative migration timing (as a percentage) of Chilko Sockeye smolts (Early Summer and Summer CUs combined) at Chilko fence and Mission (RST only) in 2014 with the daily number of smolts estimated at the Chilko fence and captured at Mission (RST only).

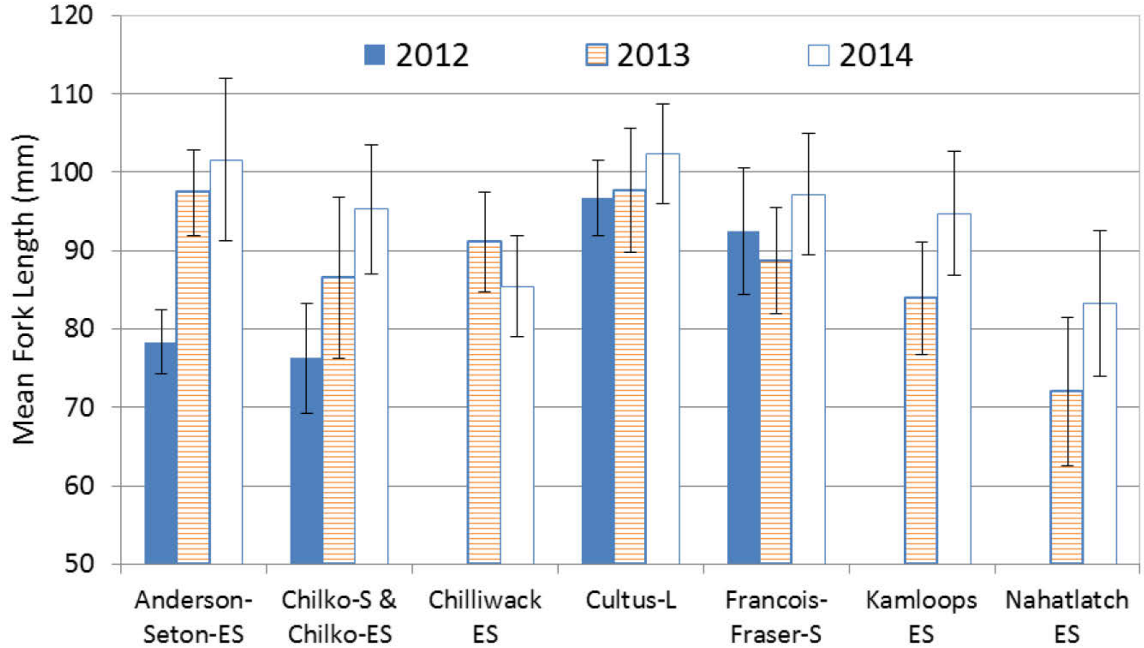

Figure 22. Mean fork length (mm), by WSP CU, of Sockeye smolts captured in the RST during the 2012, 2013, and 2014 lower Fraser River juvenile Sockeye assessment projects at Mission, BC. Note: only the 2014 CUs with a sample size > 14 are shown, along with any previous year for that CU meeting the same sample size criteria.

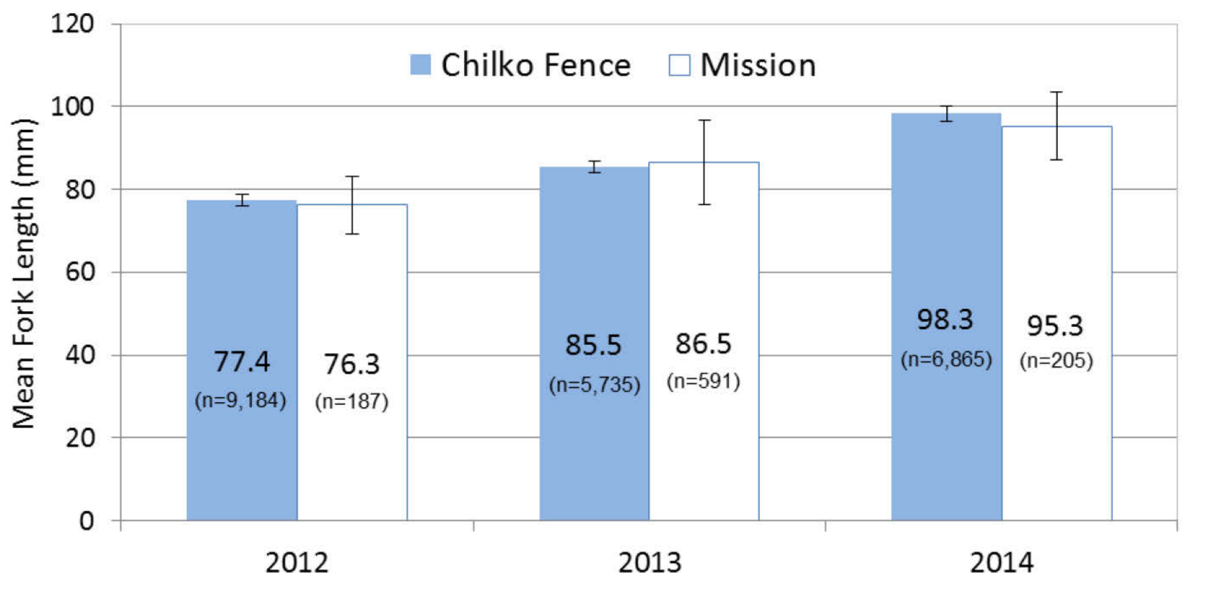

Figure 23. Mean fork length (mm) comparison of migrating Chilko Sockeye smolts (combined ES & S CUs) captured at the Chilko fence during Lake out-migration (1-year-old smolts only) and at Mission (RST only) in 2012, 2013 and 2014.

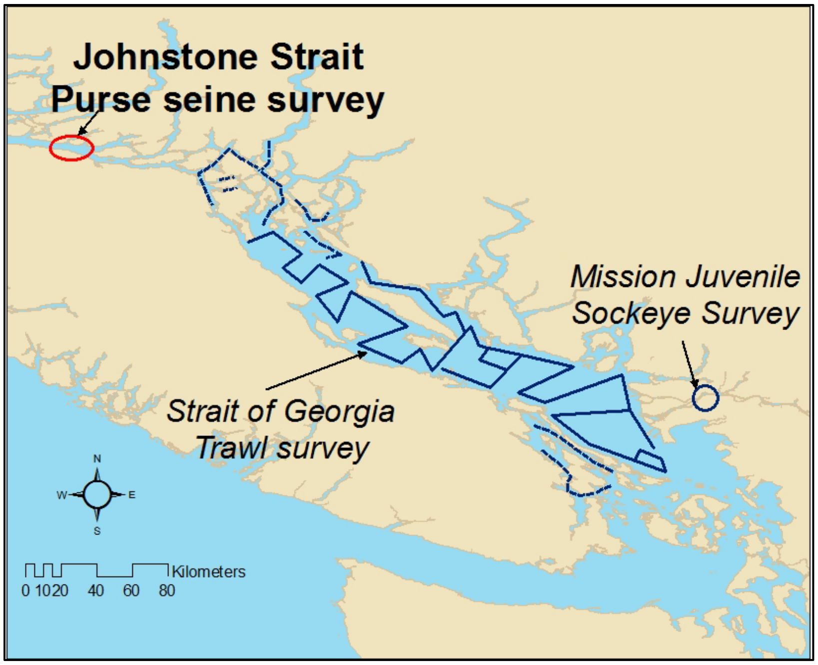

Figure 24. Location of the trawl survey standard track line (solid blue line) conducted annually (1998-2014) in late-June/early-July and in September/early-October. In 2010 and 2014 an additional survey following these track lines was conducted in early June. The dashed blue lines indicate the general locations of additional sets that may be conducted during the survey. The location of the primary location of the purse seine survey (red oval) was conducted weekly from early May through July. The location of the Mission rotary screw trap sampling location is identified by the blue circle.

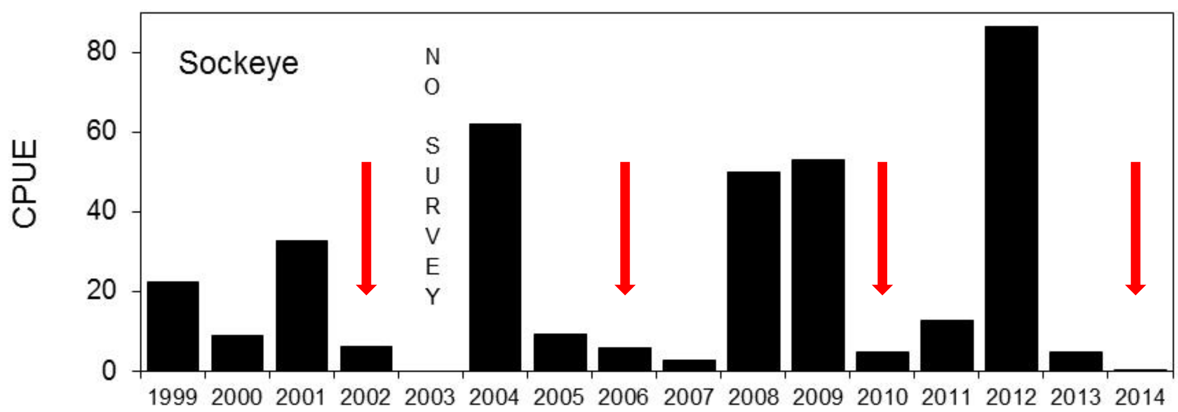

Figure 25. Catch-per-unit-effort (CPUE) of juvenile lake-type Sockeye in the annual late June/early July trawl survey from 1999 to 2014. Arrows indicate the 2014 ocean entry cycle years, which correspond to the 2016 four year old lake-type Fraser Sockeye returns (2012 brood year).

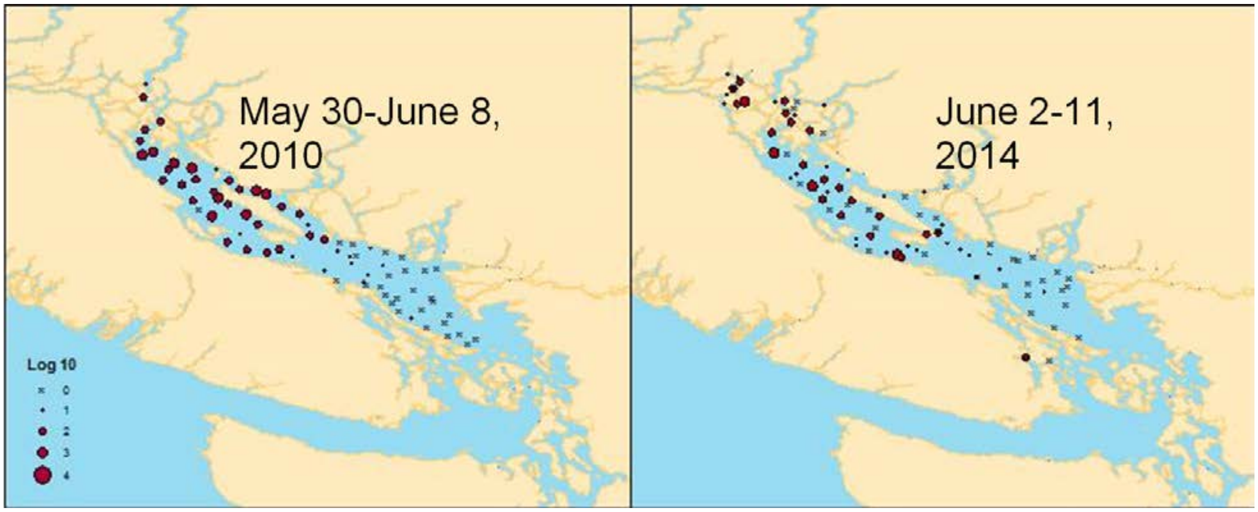

Figure 26. The distribution of juvenile lake-type Sockeye in early June 2010 and 2014 trawl surveys. The X's indicate set locations with no Sockeye. The Log10 (loge) value of the CPUE per hour is shown for Sockeye catch.

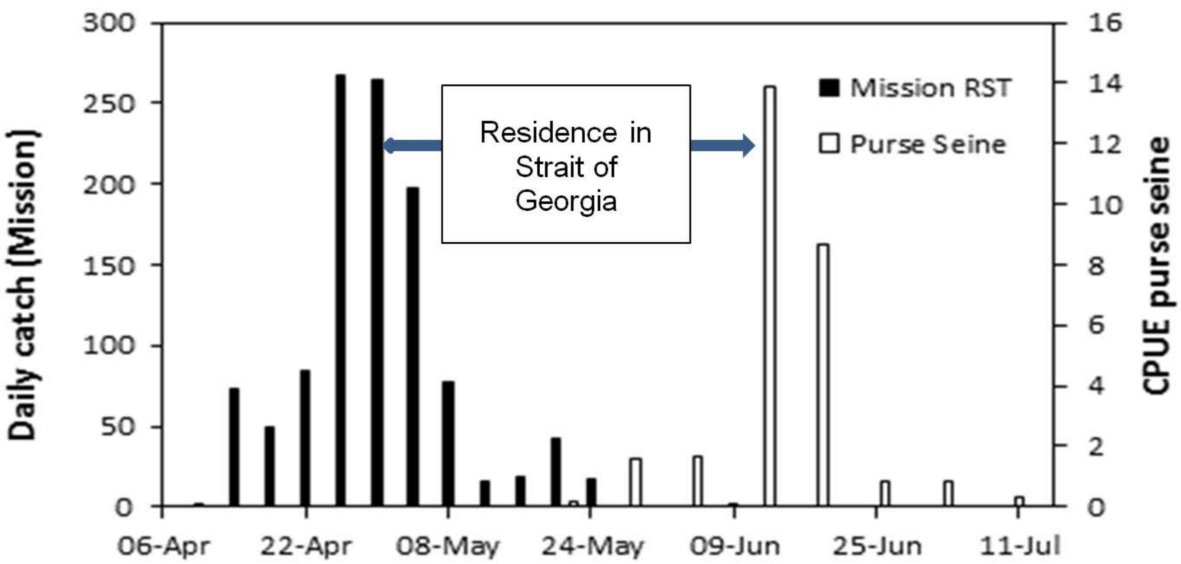

Figure 27. Catch-per-day of juvenile lake-type Sockeye at Mission (black bars) and average catch per set of juvenile Sockeye in the Discovery Island purse seine (open bars). The time between the peak catches at both sampling regions is 7-8 weeks.

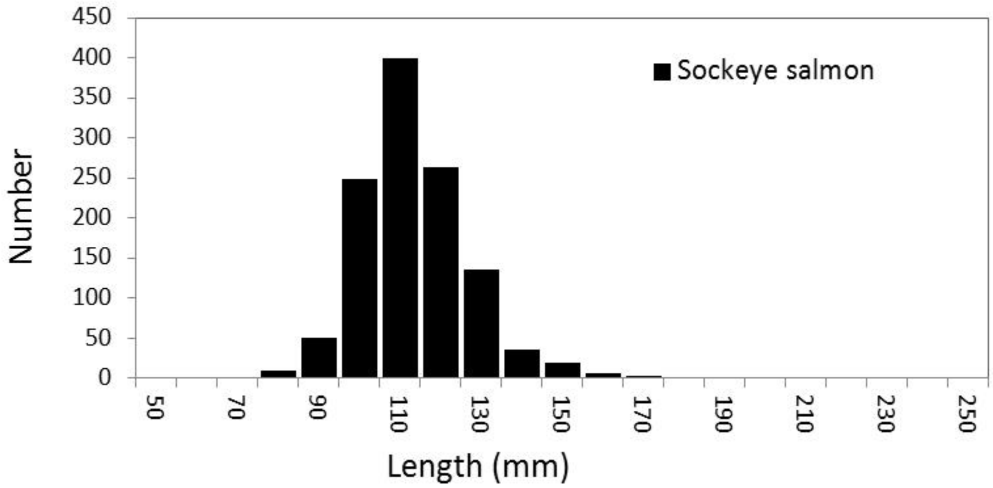

Figure 28. Length frequency of juvenile lake-type Sockeye capture in the early June 2014 trawl survey (N=1,134).

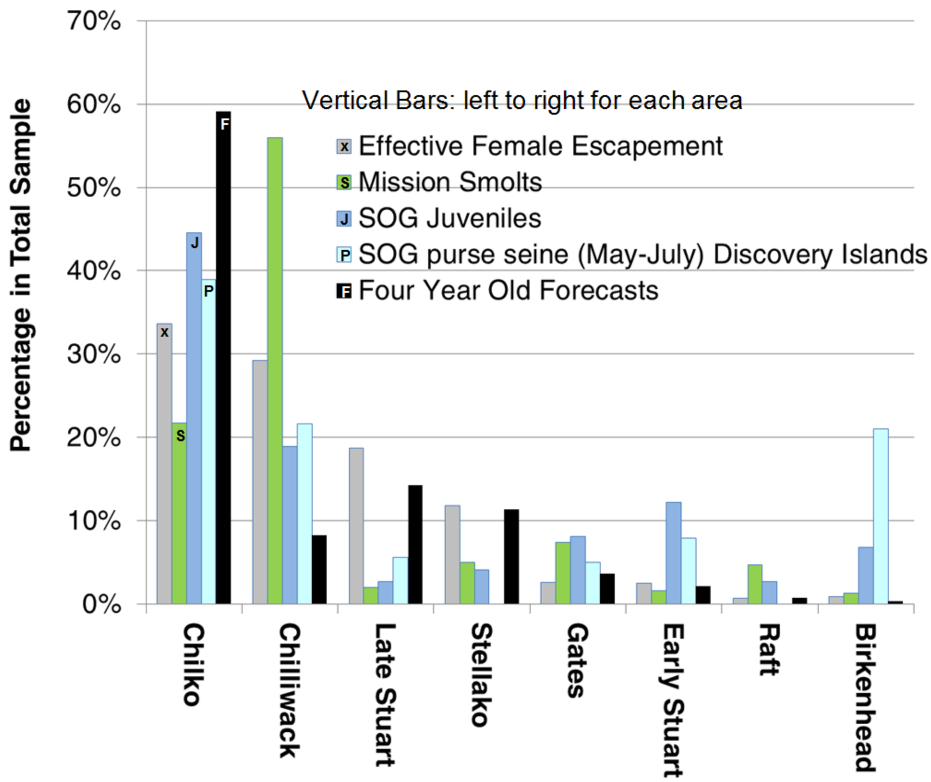

Figure 29. Stock composition (percentages) of eight key stocks in the various Fraser Sockeye sampling components: 2012 EFS, 2014 smolt out-migration at Mission, SOG juvenile lake-type Sockeye trawl sampling (June 1-11 period), SOG May to July purse seine survey in the Discovery Islands (May-July period), and four-year-old forecasts (DFO 2016). Note: Mission smolt samples have not been corrected for changes in the Fraser River discharge that were recorded over the sampling period, therefore, stock proportions are likely biased.

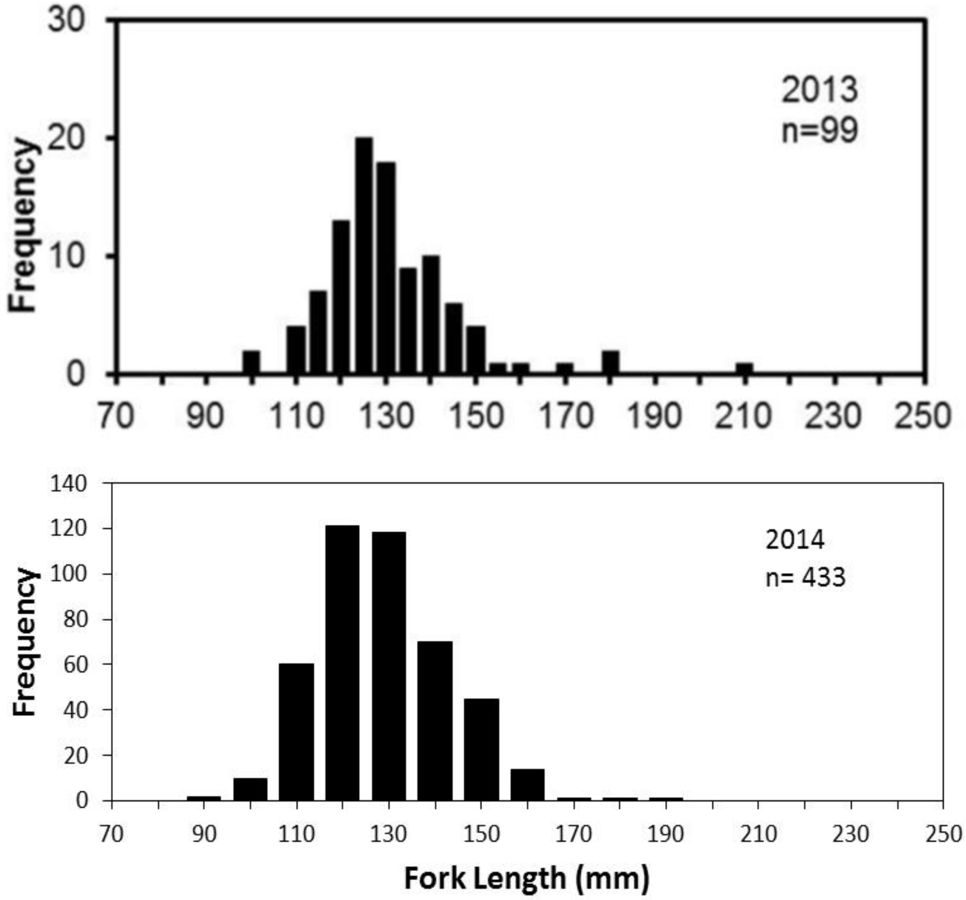

Figure 30. The length frequency of juvenile river-type Sockeye captured in the SOG and Howe Sound trawl surveys in 2013 and 2014.

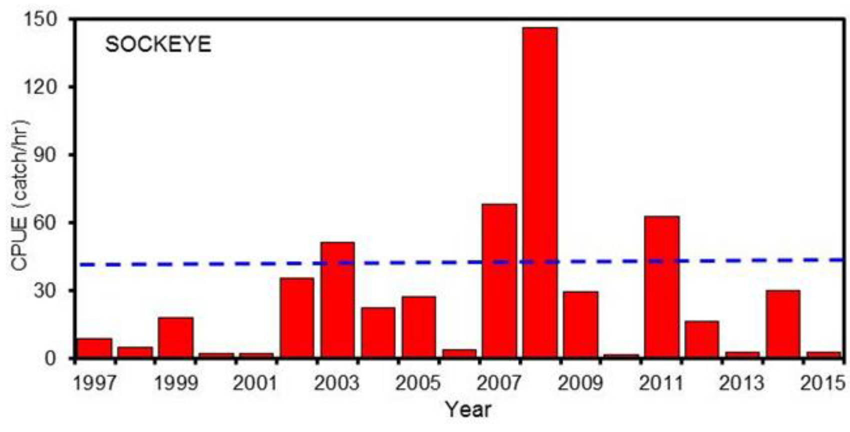

Figure 31. The CPUE of Sockeye, largely comprised of the Harrison Sockeye stock, in the September trawl survey in the SOG. Juveniles captured in 2013 and 2014 could return as four- and three-year-olds in 2016, respectively. 2013 CPUE was extremely low (related to 2016 four-year-olds), and 2014 CPUE was moderate (related to 2016 three-year-olds).

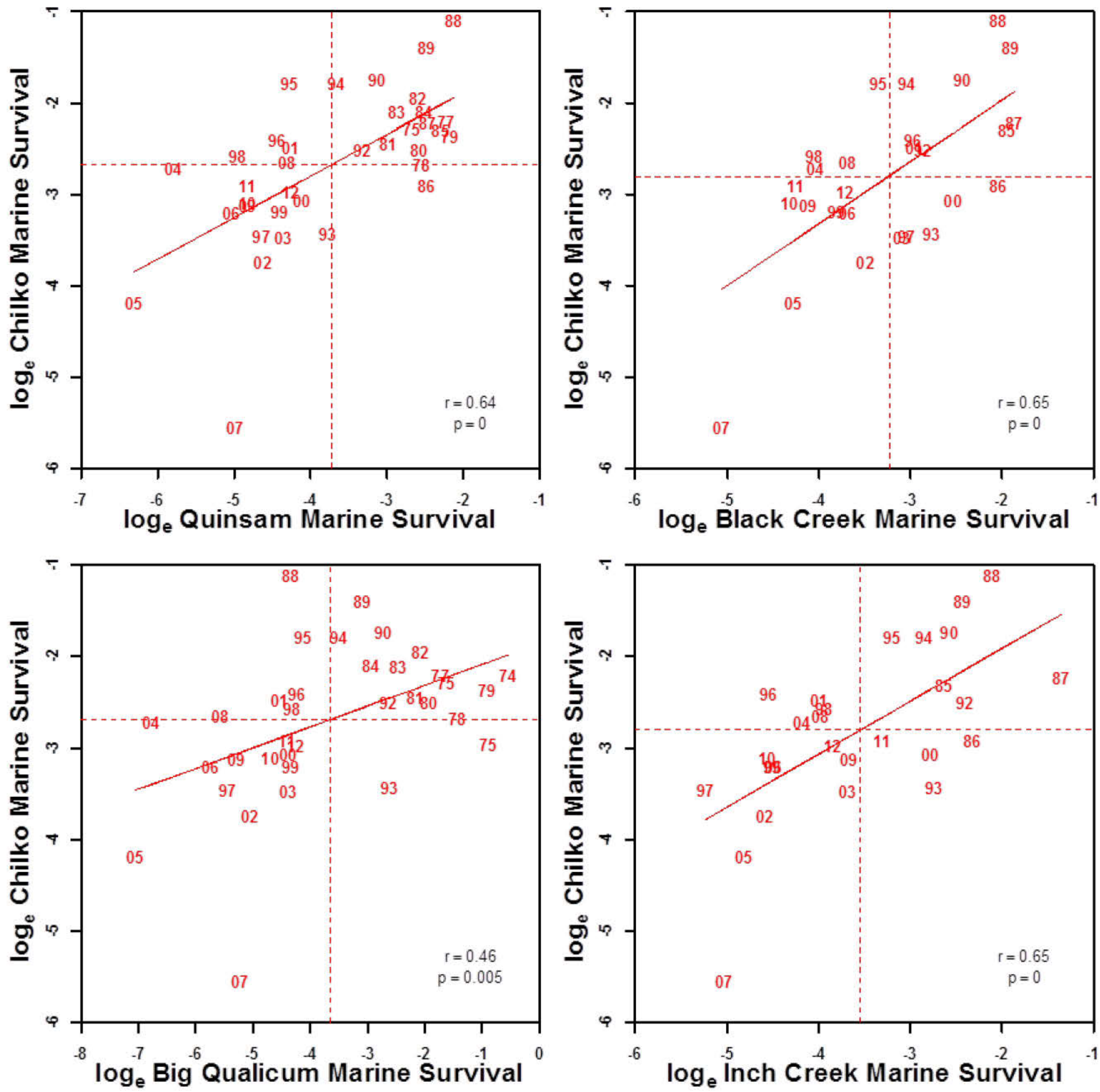

Figure 32. Relationship between the marine survival of Chilko Lake Sockeye and SOG Coho salmon for hatchery populations (Quinsam and Big Qualicum) and wild populations (Black Creek and Inch Creek). The number icons indicate ocean entry year. The dashed lines represent the average survival for Coho (vertical dashed line) and Chilko Lake Sockeye (horizontal dashed line).

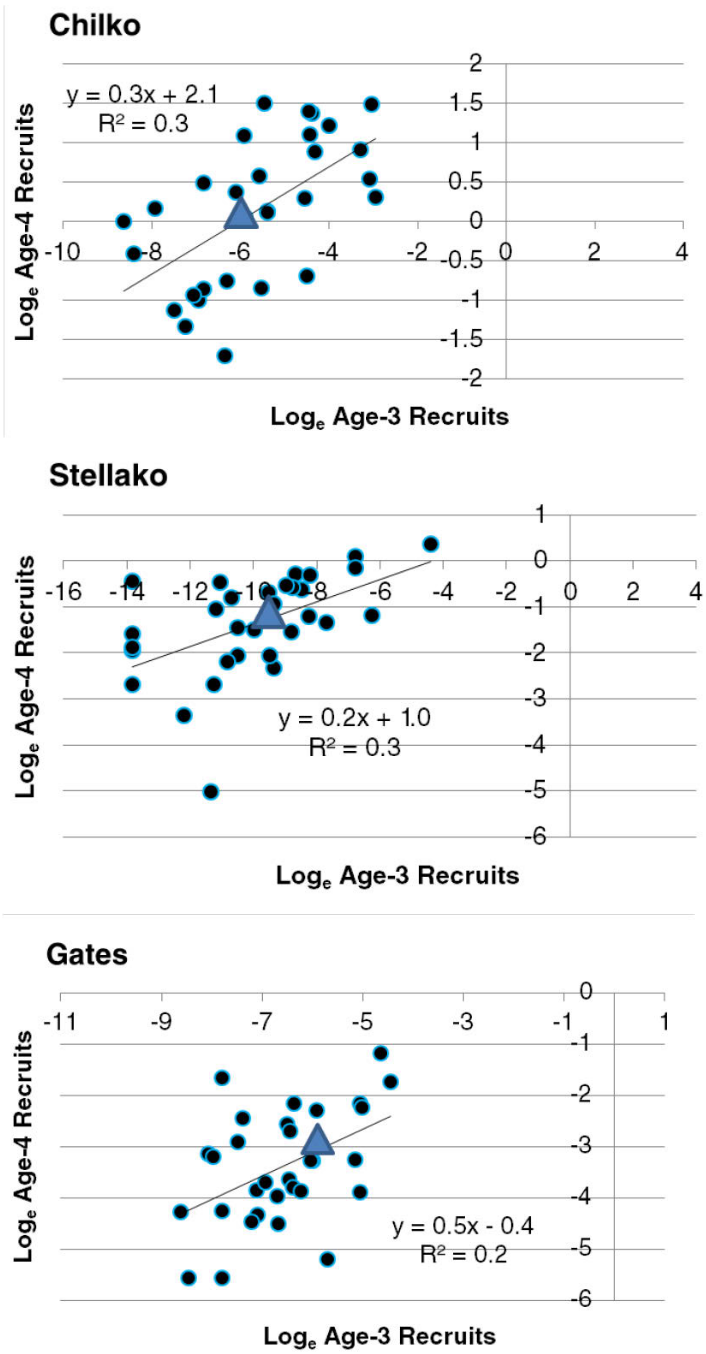

Figure 33. Three (jack)-to-four year old sibling relationships for Chilko, Stellako and Gates. For all other stocks where four-year-old abundances are forecast to be larger than 50,000 at the 50% probability level (DFO 2016), jack abundances were either 0 in 2015 (Late Stuart) or the three-to-four year-old time series was too short (Chilliwack) or the fit (as indicated by low R2) was extremely poor (Nadina). Recruitment data are post-1980 due to shifts in age of maturity. The triangle represents the preliminary three-year-old recruits (in millions) from 2015 for Chilko (0.0025), Stellako (0.000058), Gates (0.002403), which is converted to loge (respectively, -6.0, -9.8, -6.1). These preliminary three-year-old recruits in 2015 were used with Bayesian methods to predict four-year-old recruits for comparison to the 2016 forecast.

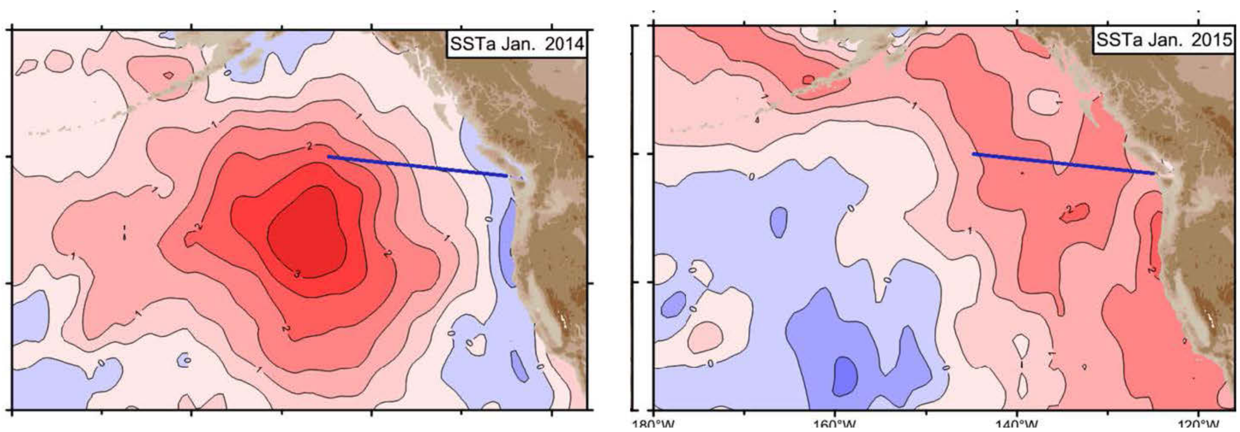

Figure 34. Changes in surface water temperature from average in the NE Pacific, in January 2014 (left) and January 2015 (right). The very warm water (dark red patch, over 3 °C above normal) moved to the coast of BC by January 2015, causing record high water temperatures at some locations. The blue line represents locations monitored by Fisheries and Oceans Canada since 1948. Figure courtesy of Howard Freeland, based on data available from the United State National Oceanic and Atmospheric Administration.

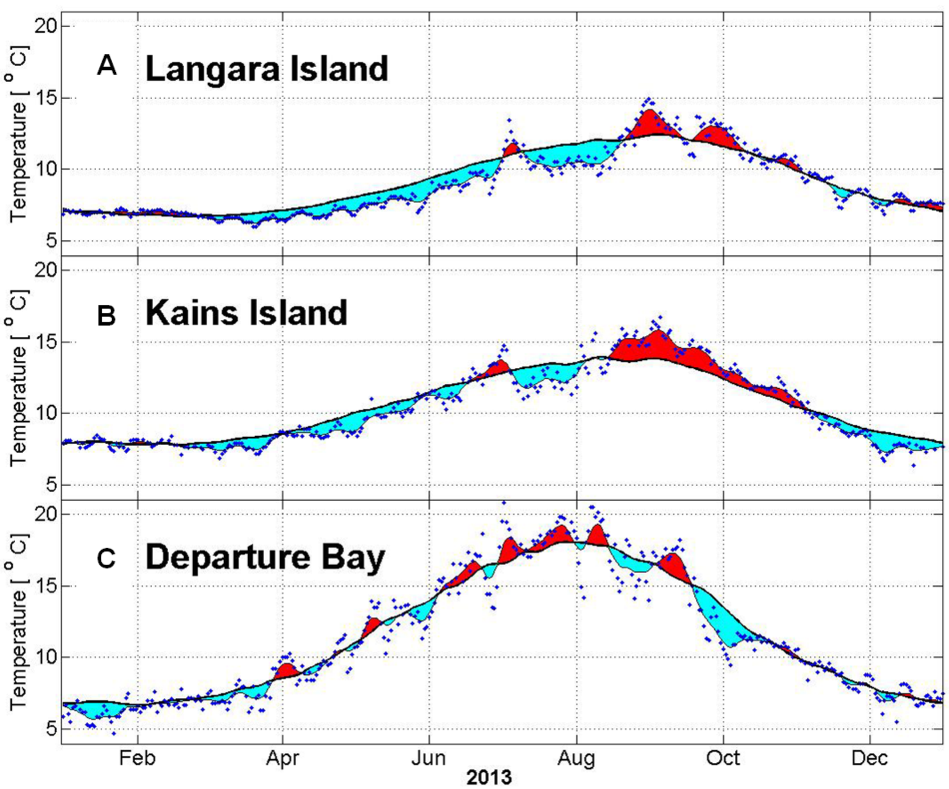

*Figure 35. Daily Sea Surface Temperature (SST) at stations representing **A.** the North and Central Coast, **B.** West Coast Vancouver Island and **C.** SOG. Positive anomalies from the 1981-2010 climatology (7 day low pass rectangular filter) are shown in red, negative anomalies in light blue; the blue dots represent the daily 2013 observations. From Chandler (2014).*

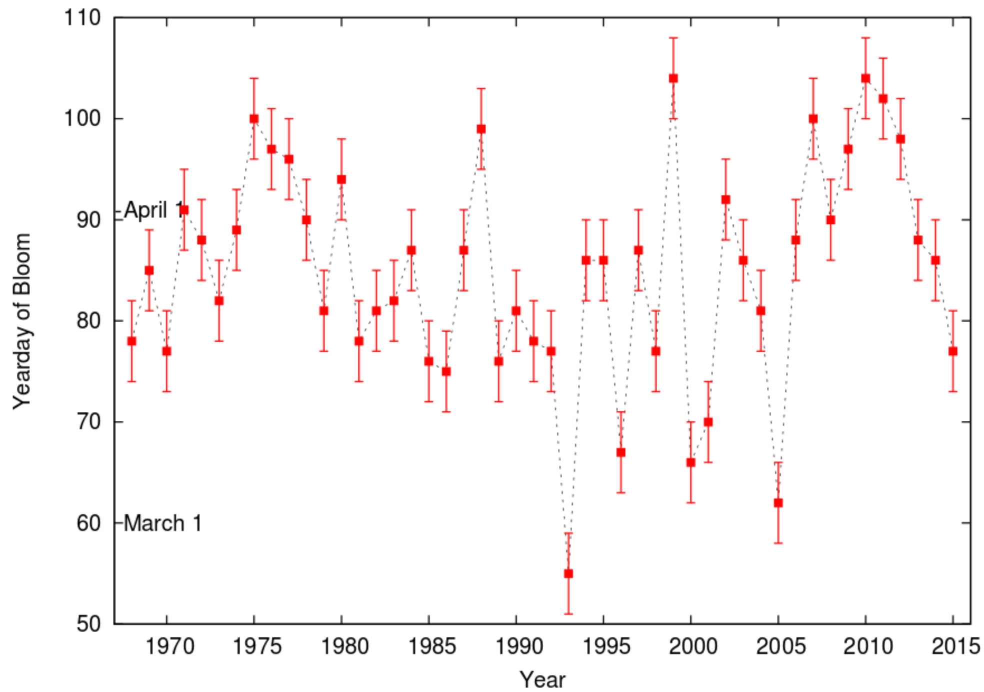

Figure 36. Model-based estimates of the timing of the spring phytoplankton bloom in the SOG. The spring bloom in 2015 was the earliest bloom since 2005. From Allen and Latornell (2015).

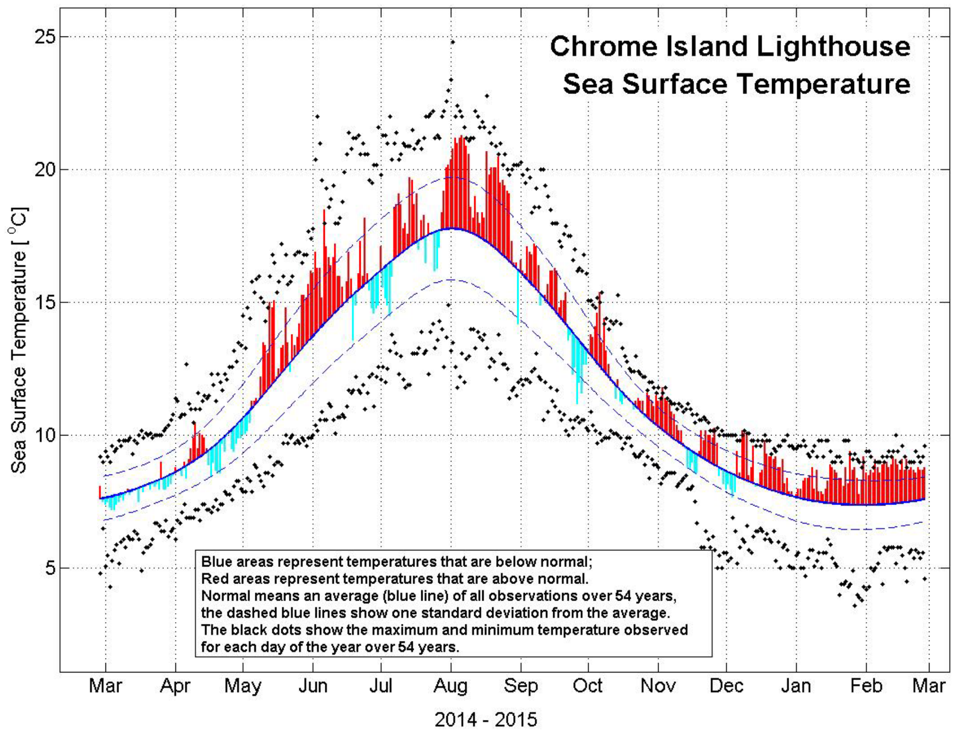

Figure 37. Sea surface temperature (SST) for Chrome Island light station in the SOG, from March 2014 to March 2015. Figure courtesy of Peter Chandler, Fisheries & Oceans Canada.

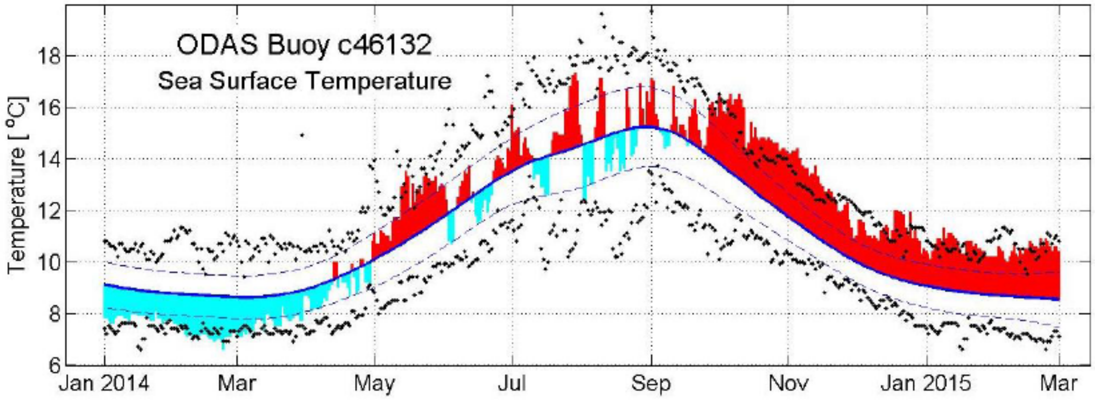

Figure 38. Time series of daily SST, light blue areas represent temperatures that are below normal, red areas represent temperatures that are above normal. Normal (blue line) refers to the average of all observations and the dashed blue lines show one standard deviation from the average. The black dots show the maximum and minimum temperature observed for each day of the year. ODAS Buoy c46132 is located at the south-western entrance to Queen Charlotte Sound. Figure from Chandler (2015).

Contributors

Name	Affiliation
Sue Grant	Fisheries and Oceans Canada, Pacific
David Patterson	Fisheries and Oceans Canada, Pacific
Jayme Hills	Fisheries and Oceans Canada, Pacific
Keri Benner	Fisheries and Oceans Canada, Pacific
Dan Selbie	Fisheries and Oceans Canada, Pacific
Lucas Pon	Fisheries and Oceans Canada, Pacific
Timber Whitehouse	Fisheries and Oceans Canada, Pacific
Joe Tadey	Fisheries and Oceans Canada, Pacific
Chrys Neville	Fisheries and Oceans Canada, Pacific
Marc Trudel	Fisheries and Oceans Canada, Pacific
Ian Perry	Fisheries and Oceans Canada, Pacific
Mike Lapointe	Pacific Salmon Commission
Ann-Marie Huang	Fisheries and Oceans Canada, Pacific
Brooke Davis	Fisheries and Oceans Canada, Pacific
Lesley MacDougall	DFO Centre for Science Advice, Pacific

Approved by

Carmel Lowe
Regional Director
Science Branch, Pacific Region
Fisheries and Oceans Canada

June 30, 2016

Sources of information

This Science Response Report results from the Science Response Process of January 21-22, 2016 on the Supplement to the pre-season abundance forecasts for Fraser River Sockeye Salmon returns in 2016.

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Appendix 1: Mission Sockeye Data/Information

- During the spring and early summer of 2014, a power vessel towed mobile fish traps every fourth day between April 2 and June 17 in the lower Fraser River near Mission BC (Figures 16 & 17) for the purpose of evaluating the timing, size, abundance, and stock composition (CU) of downstream migrating juvenile Sockeye Salmon (*Oncorhynchus nerka*). In 2014, days surveyed were similar in frequency to the 2012 project (i.e. one survey every fourth day) but differed from both the 2012 and 2013 projects in duration. In 2014, the duration of the survey day was 24 consecutive hours rather than 8 hours in the previous two years. This protocol was implemented to investigate the nocturnal migration patterns of juvenile salmon at Mission.
- During the first survey day on April 2, one of the hydraulic system winches (required to lower and raise the traps between the fishing and non-fishing positions) experienced mechanical failure after only three hours of sampling were completed. No other survey day in the 2014 project was significantly affected due to mechanical issues related to the vessel and traps, or unsafe environmental conditions due to freshet and in-river debris. This was a departure from the vessel and trap issues experienced in 2013.
- The type of trap deployed varied among three trap types. Only two traps were deployed (or “fished”) each survey day; a rotary screw trap (RST) was attached to the starboard side of the vessel and fished every survey day; on the port side an incline plane trap (IPT) was alternated every survey day with a vertical trap (VT). Additionally, the VT had various configurations associated with position of the deep net and net type; these configurations were systematically applied when the VT was deployed (every second survey day). The IPT and VT were originally constructed for use in DFO’s biennial Mission Pink Downstream Project and are designed for trapping fry sized migrants. The RST is designed for trapping all juvenile-sized migrants.
- Each survey day started at approximately 6:00 AM (PDT) and ran for a continuous 24 hour period. Within each survey day, consecutive trapping (or fishing) “runs” of 15 minutes were conducted. Other than April 2 when hydraulic system failure necessitated the termination of the survey day early, the number of runs conducted averaged 47 per survey day (range 37 to 64). Generally, fewer runs were conducted on survey days with higher catch due, in part, to catch processing requirements delaying the onset of a subsequent 15 min run. Each run followed a specific path (or tract) in relation to mid-channel at Mission. There were three tracts: one following the North shore, one in mid-channel, and one following the South shore. These tracts were referred to as Bay 2, Bay 6 and Bay 11 respectively (Figure 17). Each subsequent run fished the adjacent Bay to the south with Bay 2 following Bay 11 (i.e. Bay 6 followed Bay 2, Bay 11 followed Bay 6, and Bay 2 followed Bay 11). The starting Bay for each survey day was randomly selected.
- After each run, all salmon captured were enumerated to species and age (i.e. sub-yearling or yearling). Biological sampling was conducted on a subset of captured juvenile Sockeye and included fish length (fork length), weight and adipose fin clip status, as well as tissue samples for genetic stock identification (GSI) and health assessments.
- To ensure trapping effectiveness was consistent across the range of Fraser River discharge (Figures 14A & 18), water velocity through the traps was maintained at a constant value (1.0 m/s) for each run. This was achieved by developing a relationship between water velocity measurements at the trap mouth and the engines tachometer. Two consequences must be considered as a result of this operational protocol: that the volume of water sampled for each 15 min run remained constant through the study and was trap specific; and that the

proportion of the volume of water sampled relative to the total volume of water passing Mission for each run, was trap specific and inversely related to discharge.

- Stock (CU) proportion and out-migration timing at Mission is currently somewhat challenging to interpret given the need to maintain the water velocity at the trap mouth (1.0 m/s) and the fairly consistent increase in discharge as the study progressed (Figure 18; Figure 14 A). On average, if a correction for discharge is not made, CU proportions for stocks that predominately migrate in lower flows early in the migration season, such as Cultus-L, Chilliwack-ES and Anderson-Seton-ES, may be biased high and CU proportions for stocks that predominately migrate in higher flows later in the migration season, such as Takla-Trembleur-Stuart-S, Takla-Trembleur-EStu and Nadina-Francois-ES, may be biased low (Figure 19; Table A1-1).
- Similarly, given the discharge pattern seen in the lower Fraser River in 2014, out-migration timing for all stocks may be biased early if a correction is not made for the inverse relationship between the proportion of water volume sampled at Mission and discharge at Mission. Stock (CU) proportions and out-migration timing reported here are not adjusted for this relationship and should be considered preliminary pending this correction (Figure 19; Table A1-1).
- Irrespective of this sampling effect, Cultus-L, Chilliwack-ES and Anderson-Seton-ES CUs were detected at Mission as early migrants while Takla-Trembleur-Stuart-S, Takla-Trembleur-EStu and Nadina-Francois-ES were detected as later migrants (Figure 19). In 2014, the average 50% migration date (i.e. the date at which the cumulative percent of all Sockeye trapped in the RST reached, or exceeded, 50%) for all CUs was estimated to be April 28 (Figure 19; Table A1-1).
- The Mission project assesses juvenile Sockeye salmon out-migration of virtually all Fraser River stocks; only a few stocks entering the Fraser River downstream of Mission (e.g. upper Pitt River) are unavailable for capture at this location (Figure 16). Consequently, estimates of CU proportions for all CUs upstream of Mission are relative to only those CUs (Table A1-1); these estimates would be biased high when compared to CU proportions from assessments at locations that have all Fraser stocks available for capture, and where detected CUs from downstream of Mission have not been removed from the calculations.
- The most predominant CU detected at Mission in 2014 was Chilliwack-ES (Tables A1-1 & A1-2). The Chilliwack-ES CU's contribution to the EFS proportion in the 2012 Fraser total escapement (EFS) was close to 35%, which is considerably lower than the proportion observed at Mission for key stocks (55%) (Table A1-1). The absolute magnitude of the Chilliwack-ES detected at Mission is notable: more than double the number of Chilko (both ES & S CUs combine) and greater than seven times the number of Anderson-Seton-ES CU juveniles detected (Table A1-1). Anderson-Seton-ES was another CU displaying early-timed migration past Mission in 2014. Of the 13 survey days from April 10 to May 28 where Sockeye smolts were captured in the RST, only the Seton-Anderson CU was detected in more survey days than the Chilliwack-ES CU (11 and 10, respectively). Additionally, there was only 13 events over 7 survey days in 2014 where a CU was represented in the daily catch with greater than 20 individuals and the Chilliwack-ES CU was 6 of the 13 (Table A1-2). These results indicate a persistent migration at relatively high abundance for the Chilliwack-ES CU (Table A1-2) and not dominance associated with one survey day of large catch driving the relative proportion of Chilliwack-ES upward and the other CUs proportions downward.
- However, similar to the need to correct for discharge at Mission as the freshet progressed through May, a need exists to correct within a survey day as flow near the shores (Bay 2 &

Bay 11) is, on average, slower than flow in mid-channel (Bay 6). Given the protocols for determining the fishing Bay for each run, the number of runs conducted in the three Bays was virtually identical (Bay 2: 313; Bay 6: 317; Bay 11: 317) though the distribution of the catch was not equally partitioned into the three Bays. This is important for comparing catch among CUs if the horizontal distribution of the catch is not similar among CUs and a correction for differences in channel track flows (i.e. flow differences between Bays) is not made.

- In 2014, 40% of the Sockeye smolts captured in the RST were from runs in Bay 2; the remaining 60% was divided equally between Bays 6 & 11. However, Chilliwack-ES was one of only three CUs that had RST catch data displaying a pattern of near-shore migration; Anderson-Seton-ES and Cultus-L were the other CUs displaying a similar near-shore pattern. All other CUs displayed a catch pattern that favoured mid-channel migration; Bay 6 catch averaged approximately 46% of the total catch across these CUs. Given the identified need to correct for flow within a survey day by Bay (and possibly by run), the relative abundance of near-shore migrants, like Chilliwack-ES, may be biased high and mid-channel migrants, like Chilko-ES & S, biased low.
- Fork length has been recorded for sampled Sockeye smolts since 2012. Conspicuous in the comparison of average CU fork length between years is that the Chilliwack-ES CU was the only CU where a trend for decreasing average length in 2014 was evident (Figure 22). This appears to align with the Chilliwack Lake fry data indicating larger than average abundances (Figure 10) and a density dependence response that may have restricted growth in the brood from the large Chilliwack-ES CU escapement in 2012; however, fry length (Figure 11) does not appear to reconcile with this supposition.
- It's interesting to note that Cultus-L and Chilliwack-ES CUs enter the Fraser River via the Sumas River approximately 13 km upstream of the Mission project, yet displayed a different horizontal distribution pattern in the RST catch data. Cultus-L showed a strong affinity for the south shore (Bay 11) and Chilliwack-ES appeared to have a strong preference for both North (Bay 2) and South shores (Figure A1-1). The biological or environmental drivers behind this behavior are currently not known.
- As reported above, without a correction for seasonal discharge and Bay-specific flow, CU proportions at Mission (Figure 17; Table A1-1) may be challenging to interpret. Although, given the nature of the Chilliwack-ES catch (magnitude, persistence, and smolt length), it can be argued that, irrespective of any uncorrected discharge and flow bias, a significant number of Chilliwack-ES CU Sockeye juveniles migrated past Mission in 2014.
- As in previous years (DFO 2014b; DFO 2015b) the combined Chilko-ES and Chilko-S CUs continued in 2014 to be one of the most abundant "CUs" detected at Mission (Figure 29; Tables A1-1 and A1-2). The 50% migration date at Mission for the combined Chilko CUs was estimated to be May 1 in 2014 (Figure 20; Table A1-1); this date was within the range set by the previous two years (April 29 and May 6 in 2012 and 2013, respectively). However, unlike the previous two years, out-migration timing at the enumeration weir was not as closely coupled with out-migration timing at Mission (Figure 21). Estimated migration time from Chilko Lake outlet to Mission varied from 3 days when using cumulative 50% migration dates and 6 days using peak migration dates (Figure 21; Table A1-1). Detected differences across years could be related to biological and environmental factors or could be related to sampling at Mission.
- Although a correction for increasing discharge during the migration of Chilko smolts may help resolve the "de-coupling" seen in the 2014 Mission data after May 4, consideration should also be given to the possibility the frequency of surveys at Mission mis-aligned with

abundant lake out-migration days later in the migration given that previous years patterns of Chilko-Mission data have being closely coupled (J.Tadey, DFO pers comm.). Presuming the April 28 peak at Chilko and the May 4 peak at Mission represent the same point in the Chilko migration, Mission trapped approximately 0.002% of the estimated Chilko smolt migration prior to (and including) this point and only 0.0002% after this point; a ten-fold difference. Given the direct and “boxcar”-type migration exhibited by Chilko smolts in previous years, it’s conceivable the majority of smolts migrating from Chilko Lake in May of 2014 reached, and passed, Mission during the days a survey was not occurring (J.Tadey, DFO pers comm.).

- Further support for this de-coupling in the later portion of the 2014 out-migration may well be evident when comparing the percentage of the survey days in April and May that detected Chilko Sockeye when at least one Sockeye Salmon smolt was captured during the survey day (Table M3). The decrease in the percentage of survey days detecting Chilko in April and May in 2014, relative to previous years, could be the result of a mis-alignment of Mission surveys to Chilko abundance at Mission. Alternatively, the pattern could be related to a decrease in Mission’s sensitivity to representatively capture Chilko smolts in years of lower Chilko abundance (total Chilko lake out-migration in 2014 was estimated to be approximately 30% and 40% of the 2013 and 2014 estimates, respectively; Table M3) or a combination of the two possibilities.
- Notwithstanding the determination of an actual mechanism, if the pattern seen in the Chilko catch at Mission in 2014 is a result of a sampling bias against capturing Chilko at Mission, Chilko CUs relative proportion would be biased low and all other CU’s relative proportions would be biased high.
- Similar to previous years, Chilko smolts sampled in the Fraser River at Mission in 2014 had an average fork length almost indistinguishable to those sampled at the Chilko Fence (Figure 23). Given the limited time between their out-migration from Chilko Lake and their migration past Mission (approximately 3-6 days; Figure 21), little change in length would be expected.

Table A1-1. Sockeye Salmon smolts captured in the RST by WSP CU (with first, last, 50% and peak detection dates) during the 2014 lower Fraser River juvenile Sockeye Salmon assessment project at Mission, BC.

Conservation Unit [1]	No. of Sockeye Smolts	% of Total Catch	Date			
			First Detected	Last Detected	50% Migration [2]	Peak Migration
Chilliwack-ES	527	50.1%	14-Apr	20-May	26-Apr	26-Apr
Chilko-S & Chilko-ES	204	19.4%	18-Apr	20-May	01-May	04-May
Anderson-Seton-ES	70	6.7%	10-Apr	24-May	26-Apr	26-Apr
Cultus-L	69	6.6%	14-Apr	16-May	13-Apr	14-Apr
Francois-Fraser-S	50	4.8%	22-Apr	28-May	02-May	04-May
Kamloops-ES	44	4.2%	26-Apr	8-May	29-Apr	30-Apr
Takla-Trembleur-Stuart-S [3]	19	1.8%	26-Apr	28-May	06-May	30-Apr
Takla-Trembleur-EStu	15	1.4%	30-Apr	24-May	18-May	20-May
Nahatlatch-ES	15	1.4%	22-Apr	08-May	04-May	04-May
Lillooet-Harrison-L [3]	12	1.1%	18-Apr	28-May	08-May	26-Apr
Nadina-Francois-ES	11	1.0%	04-May	28-May	19-May	20-May
Shuswap Complex-L	5	0.5%	26-Apr	08-May	02-May	08-May
North Barriere-ES	5	0.5%	30-Apr	12-May	02-May	30-Apr
Harrison U/S-L	5	0.5%	22-Apr	12-May	05-May	08-May
Sub-total	**1,051**	**100%**	**10-Apr**	**28-May**	**28-Apr**	**26-Apr**
Unassigned Fraser Origin	29		14-Apr	28-May	4-May	4-May
Total	**1,080**		**10-Apr**	**28-May**	**28-Apr**	**26-Apr**

[1] CU run timings: EStu = Early Stuart; ES = Early Summer; S = Summer; L = Late.
[2] estimated date when cumulative % equaled or surpassed 50% using linear interpolation between surveys
[3] Second peak on May 20, 2014.

Table A1-2. Sockeye Salmon smolts captured in the RST by survey date and WSP CU during the 2014 lower Fraser River juvenile Sockeye Salmon assessment project at Mission, BC.

Date	Chilliwack-ES	Chilko-S & ES	Anderson-Seton-ES	Cultus-L	Francois-Fraser-S	Kamloops-ES	Takla-Trembleur-Stuart-S	Takla-Trembleur-EStu	Nahatlatch-ES
10-Apr	-	-	1	-	-	-	-	-	-
14-Apr	9	-	4	56	-	-	-	-	-
18-Apr	40	1	7	1	-	-	-	-	-
22-Apr	71	-	3	2	1	-	-	-	2
26-Apr	173	45	23	5	-	2	1	-	1
30-Apr	149	39	12	2	16	27	5	1	3
04-May	33	101	1	1	24	10	3	-	8
08-May	42	2	14	1	1	5	1	-	1
12-May	5	-	2	-	2	-	2	-	-
16-May	3	10	1	1	1	-	-	1	-
20-May	2	6	-	-	3	-	5	12	-
24-May	-	-	2	-		-	1	1	-
28-May	-	-		-	2	-	1	-	-
Total	**527**	**204**	**70**	**69**	**50**	**44**	**19**	**15**	**15**

Table A1-3. Percentage of the surveys in April and May where Chilko Sockeye Salmon smolts (combined ES & S CUs) were captured in the RST during the 2012, 2013 and 2014 lower Fraser River juvenile Sockeye Salmon assessment projects at Mission, BC.

Year	Chilko Lake Outmigration Estimate (millions)	Survey Frequency	No. of Surveys in April and May with > 0 Sockeye Captured		% of Surveys with Chilko-S or Chilko-ES
			All CUs	Chilko-S or Chilko-ES CUs	
2012	37.5	Every 4th Day	12	9	75%
2013	48.5	M, T, Th, F	21	15	71%
2014	16.3	Every 4th Day	13	7	54%

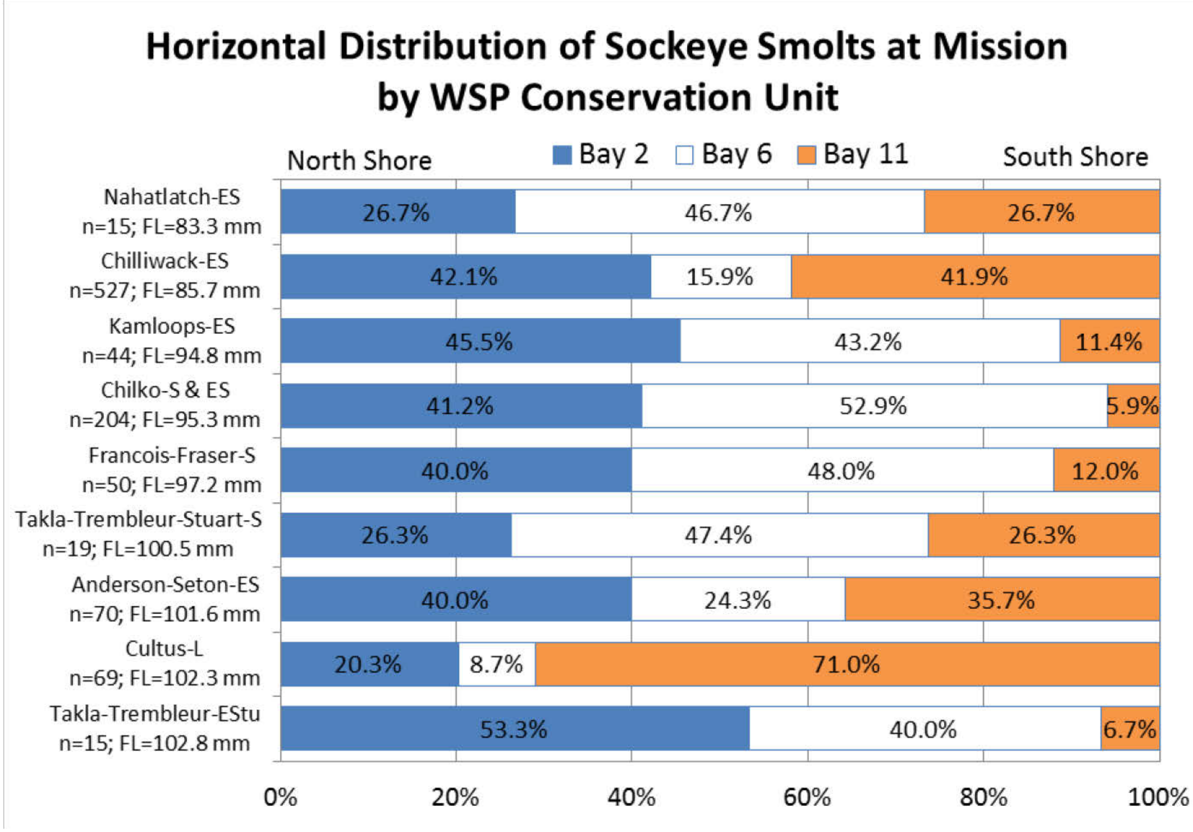

Figure A1. Horizontal distribution, by Bay, of Sockeye Salmon smolts captured in the RST for select WSP CUs during the 2014 lower Fraser River juvenile Sockeye Salmon assessment project at Mission, BC (notes: Bay 2 is adjacent to the North shore, Bay 6 is mid-channel, and Bay 11 is adjacent to the South shore; only the 2014 CUs with a sample size > 14 are shown).

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Pacific Region
Fisheries and Oceans Canada
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

Telephone: (250) 756-7208
E-Mail: csap@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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