Nicola Watershed Steelhead and Chinook Drought Response Monitoring - Fall 2015

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And

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By

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Executive Summary

The Nicola Basin supports populations of Steelhead (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Pink (*Oncorhynchus gorbuscha*), and Chum (*Oncorhynchus keta*) including several stocks with high conservation concern. Agriculture is the primary land use within valley bottoms of the Nicola River and the lower Coldwater River Spius Creek that draw surface water for irrigation during the typically dry summer months. During the summer of 2015, the Nicola Basin experienced severe drought conditions following a winter with record low snowpack and low precipitation and high temperatures in spring and summer. Discharge in the Coldwater River fell below the Theoretical Critical Level for juvenile salmonids triggering a Fish Protection Order which limited water or banned withdrawals for irrigation starting July 31st and continued until September 18th, 2015. The objective of the study was to evaluate if fish abundance in the fall of 2015 was lower than expected at the reach, river and watershed level.

The study was limited to three Steelhead age-classes: fry, age-1+ parr and age-2+ parr; and Chinook fry for which there were relatively long term reliable population estimates available for both juveniles and brood spawners. The study area included the Nicola and Coldwater River, Spius Creek, and the Thompson River between the Fraser and Nicola Rivers to match the area of prior juvenile surveys. Night snorkel surveys were used to estimate fish abundance in run habitat on the Nicola, Coldwater and Spius, and all habitats on the Thompson. Riffle habitat was not sampled on account of low water temperature and high stream flows preventing backpack electroshocking, the established method for sampling riffle habitat. Abundance in run habitat was used as an index of stream-wide abundance for the Nicola, Coldwater and Spius. Population estimates were generated for each species and age-class using the same hierarchical Bayesian model used for juvenile estimates 2001-2012. Expected abundance was based on mean abundance, predicted abundance from stock-recruitment relationships, or in the case of Chinook fry, mean juvenile abundance under similar brood spawner abundance (±50%). The difference between observed and expected was based on comparing overlap of 95% confidence intervals.

Chinook fry abundance for the entire Nicola watershed was 43% of that predicted using the Ricker stock-recruitment model and 51% based on similar brood spawner abundance, both of

which were considered significantly different. Based on the similar brood prediction method , abundance was significantly less than predicted in Coldwater (33%), Spius (30%) and in lower Spius (26%) and likely below predicted in lower Coldwater (32%) where 95% confidence limits overlapped minimally. Though the point estimate of abundance for the Nicola was also well under the predicted, there was considerable overlap of confidence intervals.

Steelhead fry abundance was likely near normal or slightly below normal for the Nicola watershed and for individual reaches. The exception to this was the upper Spius and reach T3 of the Thompson where abundance based on snorkeler count data was 30% and 34% of mean abundance, respectively. However this interpretation should be considered highly uncertain on account that the vast majority of preferred fry habitat, which is riffle, was not sampled.

For age-1+ Steelhead parr, abundance estimates were significantly lower than mean abundance based on no or minimal overlap of 95% confidence limits for reaches CW1,SP1, and T3, Coldwater and Spius, and for all reaches combined. Point estimates ranged 31% to 55% of mean abundance. Abundance in reaches CW2, N1 and Nicola River were near normal. Predicted abundance based on the Beverton-Holt stock-recruitment model also suggested abundance for all reaches combined and for Spius individually were well below normal (50%) with minimal overlap of 95% confidence intervals. Age-2+ Steelhead parr 2015 point estimate for sampled habitats were greater than mean abundance in reaches N1, N2, SP1; near the mean in CW2 and T3, and well less than the mean in CW1 and SP2.

The results provides partial support for the hypothesis fish abundance was affected by drought conditions in that abundance reductions were greatest in tributaries versus the Nicola mainstem and also that reductions were greatest in the lower Coldwater where water withdrawals were most acute. However, the hypothesis assumed drought effects would impact all species and age-classes to some degree, which was poorly supported by the results. The results also provide support for an alternative hypothesis that flood events during the 2014-15 winter mobilize river bottom substrate and or dislodge surface ice leading to scour and loss of Chinook redds, and increased Steelhead fry mortality. However, the current study design was not sufficient to evaluate the relative importance of these events on juvenile abundance or whether there was an additive effect from both. Adaptations to the current study design as well as additional studies to more accurately measure drought affects are provided.

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1.0 Introduction

The Nicola Basin supports populations of Steelhead (*Oncorhynchus mykiss*), Bull Trout (*Salvelinus confluentus*), Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Pink (*Oncorhynchus gorbuscha*), and Chum (*Oncorhynchus keta*) salmon and other species. This included several stocks of high conservation concern including Interior Coho stocks, designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); Bull Trout, listed as a Species of Concern by British Columbia Conservation Data Centre; and Thompson River Steelhead, which have had decreasing adult stock productivity since 1990 (Johnston 2013).

The Nicola Basin has widespread industrial uses. Agriculture is the primary land use within the valley bottom of the Nicola River from its confluence with the Fraser River upstream to Nicola Lake and is common along the lower half of the Coldwater River and lowest 10km of Spius Creek. Agriculture operations draw surface water primarily for irrigation during the typically dry summer months. Upland areas of these watersheds are commonly used for forestry and cattle grazing.

During the summer of 2015, the Nicola Basin experienced severe drought conditions following a winter with record low snowpack and low precipitation and high temperatures in spring and summer. A Drought Level 4 (extremely dry) was declared to the Nicola Region on July 21, 2015. Discharge in the Coldwater fell below Theoretical Critical Level (TCL) for juvenile salmonids (5% of Mean Annual Discharge or 0.48m^3/sec at gauge station WSC 08LG010). As a result, a Fish Protection Act Order was issued July 31, 2015 for the Coldwater River, which limited water withdrawals to between 6pm -6am and then transitioned to a complete ban on surface water withdrawals August 11th. Due to precipitation and an increase in streamflow, on August 19th, the order reverted back to partial restrictions. Restrictions were modified according to flow conditions until September 18th, 2015, when the order was rescinded for the season. Flows in the Nicola River below Merritt remained near of above the TCL but relied on increased releases from the Nicola Lake Dam to do so (McCleary, personal communication) though water temperatures during July and August frequently exceeded BC Water Quality Guidelines for steams with rearing juvenile salmonids (daily maximum 19ºC).

There is interest by resource managers to evaluate if the single-threshold approach and levels of such a threshold (e.g. 5% of MAD, Coldwater River) to trigger increased conservation measures are suitable to protect juvenile salmonids population and maintain surface water diversion opportunities. This project was initiated to begin evaluating the impact of drought conditions and drought management approaches on juvenile salmonids rearing in the Nicola River basin. We restricted the evaluation to stream sections, species and age-classes for which long term reliable population estimates are available for both juveniles and brood spawners and that also have relatively long freshwater residence times. This limited the study to three Steelhead age-classes: fry, age-1+ parr and age-2+ parr; and Chinook fry. Steelhead in the Nicola River watershed emerge from redds in early summer, then spend two to three winters in freshwater before smolting (migrate from freshwater to the ocean). Chinook stocks in the Nicola Basin are primarily ‘stream-type’ meaning they spend at least a year in freshwater before smolting. The hypotheses tested in this study are whether abundance by species and age-classes is lower than expected at the reach, stream and watershed level. The ‘expected’ abundance levels will be based on 2001-2012 abundance juvenile abundance estimates, and if justified, in combination with stock size to incorporate stock-recruitment relationships.

2.0 Methods

2.1 Study Area

The study area includes the Nicola River between Merritt and the confluence with the Thompson River (75km), the Thompson River between confluence with the Fraser and Nicola Rivers (26km) and the entire anadromous sections of Spius Creek (40km) and the Coldwater River (79km) described by Decker et al. (2015). Other tributaries of the Nicola with known steelhead spawners (e.g., Nuaitch, Skuhun, Shakan, and Maka Creeks) were not included because they are known to provide limited habitat for juvenile rearing; furthermore, because these tributaries were excluded from previous juvenile abundance studies, there was no historical context for evaluating the relative abundance juveniles from our 2015 studies (Decker *et al.*2015). The Thompson River between the Nicola and Fraser Rivers was also included in the study because: (1) based on studies of anadromous maternal origin, juvenile Steelhead rearing in this reach likely originate from the Nicola River watershed (Hagen et al. 2012); and (2) there is a sharp increase in age 1+ parr density below the confluence with Nicola River (Decker et al. 2015).

The hydrograph for the Nicola and Coldwater Rivers and Spius Creek are driven by snowmelt. Peak flows occur in May and June followed by a sharp decrease to base summer flows that continue to decrease until fall storms increase flows before upper elevation temperatures cool and precipitation accumulates as snow. Flows in the Nicola mainstem during summer and fall are moderated by Nicola Lake and regulated to some degree by the Nicola Lake Dam. The Thompson River drains extensive high elevation watersheds that include both snow and glacier melt. This, in combination with the moderating effect of many large lakes prolongs relatively high flows from May through to September.

2.2 Sampling design

We used the same two-stage sampling design that was used to generate abundance estimates for lower Thompson juvenile Steelhead and Chinook from 2001-2012, as detailed by Decker et al. (2015). This method can provide accurate and precise population estimates across a range of stream sizes and juvenile age classes (Korman et al. 2008) and in particular for Steelhead parr in large rivers (Hagen et al. 2010). This method includes an index sampling component which consists of a single survey at a large number of sites in the study area using a specific gear-type (night snorkelling only in 2015). The second stage or calibration stage involves a series of mark-recapture experiments to estimate the effectiveness of the gear-type for detecting or capturing all individuals in a site (observer efficiency or detection probability). While the index sampling component must be completed for every year an abundance estimates is required, the calibration stage occurs only until the detection probability is sufficiently defined to not limit the precision of abundance estimates or unless index sampling conditions vary sufficiently from those when the calibration stages were carried out that they are no longer comparable.

We utilized habitat types, habitat mapping, sampling locations and reach breaks from Decker et al. (2015), including the total amount of each habitat type by reach and river within the study area. There was one exception. We separated the Coldwater River into two reaches to delineate the lower river reach encompassing all major surface-water withdrawals (CW1) from the upper river with no water diversions (CW2). The amount of run and riffle habitats in CW1 and CW2 was estimated by assuming the proportions of each habitat type were similar in both reach. Table 1 lists the length of each reach and stream by habitat type.

Night snorkelling was the only gear-type employed in 2015. Surveys were restricted to those sites that were surveyed by this method during 2001-2012 studies. Increased flows, low water temperatures and limited resources eliminated backpack electroshocking as a viable sampling option. Since all riffle habitats, with the exception of those in the lower portion of the Nicola River reach N1, were previously sampled by backpack electroshocking, there was no attempted to provide reliable population estimates for riffle habitat. Night snorkelling surveys are only capable of producing reliable population statistics for run habitats of the Nicola and Coldwater Rivers and Spius Creek as mark-recapture calibration of snorkelling detection probability only occurred in run habitats (Decker et al. 2015). The use of only one gear type does not restrict the range of habitats sampled on the Thompson River since all habitats were previously sampled by night snorkelling. Due to the absence of detection probabilities for Steelhead fry, inferences about this age-class based on night snorkelling are limited to indices of abundance (i.e. population estimates are not applicable); furthermore, these abundance indices may be inaccurate (Korman et al. 2010). This allows for credible population statistics for Chinook fry, Age 1+ and age 2+ Steelhead parr in run habitats of the Nicola and Coldwater Rivers, Spius Creek and all habitat types of Reach T3 of the Thompson River.

We selected sample sites that replicated the 2001-2012 sampling locations as closely as possible. Original site selection used a stratified – systematic sampling approach which resulted in relatively evenly spaced sample locations throughout the study area. One to three sampling sites were group together at each location, representing the habitat types and sample size targets of that reach (Decker et al. 2015). This is an effective approach when sample size is minimal, and reach and habitat specific estimates are of interest (Krebs 1998). It can also reduce the between-site variance for whole river or watershed estimates when there is an expectation of strong spatial heterogeneity in fish abundance (Hankin and Reeves 1988).

2.3 Survey Methods

During the day, crews located sample sites, marked site boundaries, measured wetted width and length to the nearest metre and, if moving a site to a new location, completed a more detailed site description. We used hand-held GPS receivers, upstream and downstream coordinates, as well as site descriptions to locate the boundaries of pre-established sites. If river bed movement had altered the physical characteristics within the previously marked boundaries, sites were shifted on the order of tens-of-meters to maintain similar habitat characteristics between historic and 2015 surveys.

Night snorkel surveys followed methods of Decker et al. (2009). One or two divers, depending if the site included one bank or the entire cross section, traverse laterally as far towards the thalweg as possible while searching for fish before moving upstream. This pattern is continued until reaching the upstream site boundary. Divers used handheld waterproof lights to illuminate the immediate area while minimizing the disturbance to fish by directing the light at the water surface. Night snorkel surveys commenced at least 1hr after sunset. Fish were identified by species. For Steelhead, fork length was estimated to the nearest 5mm if less than 100mm and to the nearest 10mm if greater. If Steelhead fork length was well within the historic size range of fry for each reach, size was categorized as a fry. Their observations were recorded in waterproof notebooks.

Calibration sampling was not included in 2015 as none of the criteria to warrant a re-evaluation of existing detection probabilities were met (i.e., unfamiliar crew, unusual water levels or temperatures, unusual underwater visibility). See Decker et al (2009) and Korman et al. (2014) for a thorough description of calibration methodologies.

2.4 Length-at-age

Length-at-age relationships relied on length frequency histograms and scale samples obtained during 2010-2012 surveys. Past reach-specific age cut-offs are likely good approximation for 2015 since length-age relationships varied minimally (±10 mm) across years (2001-2012) but considerable across reaches (±30 mm), with generally larger size-at-age as stream order increased (Decker et al. 2015). Table 2 lists age-class length cut-offs for each reach in the study area.

2.5 Analytic Methods

In 2015, fish density (D_i) and standing stock (SS_i) for each species, age-class, reach and habitat type were computed as the point estimate from the sample. This approach was used for two reasons: (1) it was consistent with 2001-2012 abundance estimates; and (2) simulations suggest that point estimates perform better than the mean or median from Bootstrapping (Efron and Tibshirani 1993):

$$D_i = \frac{\sum_{j=1}^{n} N_{ij}}{\beta_i \sum_{j=1}^{n} L_i} \tag{1}$$

$$SS_i = D_i \times L_i$$

where:

j = sample site in stratum i
n_i = the number of sites in stratum i for which data were collected
N_{ij} = unadjusted snorkeler count catch at one of n sample sites randomly selected by the bootstrap model from stratum i.
β_i = mean snorkeling efficiency capture efficiency for stratum i

L_{ij} = stream length (m) for site j in stratum i
L_i = total stream length (m) for stratum i

To estimate the precision of point estimates, we used the hierarchical Bayesian model (HBM) developed by Korman et al (2012) and used by Decker et al (2015) for previous juvenile Steelhead abundance estimates in the Thompson River mainstem and tributaries. The HBM incorporates process error (variation in fish abundance across sites) and measurement error (variation in detection probability that leads to variation of fish counts within a site). The precision of point estimates for Steelhead fry are not reported since detection probability has only been estimated for electrofishing riffle habitats and not for snorkelling run habitats. A full description of the HBM including how it was parameterized in cases with insufficient index sampling or mark-recapture data is reported by Decker et al. (2015).

2.6 Comparing Observed and Predicted Abundance

The nature of observed and predicted abundance estimates exclude most parametric and non-parametric two-sample hypothesis tests due to the observed estimates having a sample size of one, yet with considerable uncertainty about this estimate. As a result, to determine if the 2015 abundance estimates were less than expected, we compared the confidence limits of each estimate. Throughout this report, we refer to 2015 estimates as ‘observed’ abundance and those based on from 2001-2012 as the ‘predicted’ abundance. The weakness of using confidence intervals for evaluating statistical significance is that while non-overlap indicates a statistically significant difference, in this case between sample means, the opposite is not true. Specifically, in the cases with overlapping confidence intervals, differences between samples may or may not be significantly different. If there were brood stock estimates corresponding to the same reach / river as juvenile estimates, predicted estimates were based on stock-recruitment models. Where this wasn’t possible, observed values were compared with the mean juvenile abundance from 2001-2012.

For reaches or streams with sufficient information for stock-recruitment relationship (i.e., area specific stock and juvenile estimates), we used the juvenile abundance predicted from the stock-recruitment model using the brood stock size corresponding the 2015 juvenile age-class. For Steelhead, we used the Beverton-Holt model (Ricker 1975) in the form of:

$$R = \frac{aS}{b+S} e^{\varepsilon} \quad (2)$$

where R is recruitment produced from S, stock size, e^{ϵ} is lognormal expectation of residual errors, a is the maximum number of recruits produced and b is the spawning stock needed to produce recruitment equal to half of the maximum and the Ricker model in the form of:

$$R = aSe^{-bS} e^{\epsilon} \quad (3)$$

where R is recruitment resulting from S, the spawning stock, a is the maximum number of recruits (fall fry) per spawner at low stock size, b relates to the rate of decrease of recruits per spawner as the spawning stock increases, and e^{ϵ} indicates that the residual errors between predictions of R and the observed production of recruits are expected to be log-normal. The model with the best fit (lowest standard deviation of residuals in log space) was then as the basis for predicted abundance. For Chinook, we used only the Ricker model based on its prior effectiveness describing Chinook stock-recruitment relationship in the Nicola Basin (Decker et al. 2008).

Parameters were estimated as the values that maximized the lognormal probability of the observed recruitment estimates across all sampling years, given the observed estimates of brood spawner abundance. Maximum likelihood estimates were computed in Excel using the Solver non-linear iterative search routine. Maximum likelihood estimates of Ricker and Beverton-Holt stock-recruitment parameters were estimated using juvenile abundance from 2001-2003, 2005-2006, 2008, 2010-2012 and corresponding brood estimates, referred to for convenience as 2001-2012. The 2004 juvenile abundance year for Chinook fry was excluded from model fitting since it was considered an outlier by Decker et al. (2008) attributed to abnormally low stream flows during spawning the previous summer.

95% confidence limits of predicted values were computed under the assumption that error in stock-recruitment models in lognormally distributed since stock-recruitment processes are a series of individual life-history stages and the total survival from egg to recruit is the product of those survivals (Hilborn and Walters, 1992). Lognormal error also avoids predicting negative recruitment with error is high, which is possible assuming error is normally distributed. To compute the standard deviation for a prediction of juvenile abundance in log space, we used the method described in Zar (1999):

$$S_Y = \sqrt{S_{Y*X}{}^2 \left[\frac{1}{n} + \frac{(X_i - X_{mean})^2}{\sum x^2}\right]} \tag{4}$$

$$\sum x^2 = \sum X^2 - \frac{(\sum X)^2}{n} \tag{5}$$

and 95% confidence interval of predicted abundance in log space was computed as:

$$Upper\ 95\%\ CL_{\ ln(Ri)} = ln\ (R_i) + (t_{0.05(2),n\text{-}3})\ (S_Y) \tag{6}$$

$$Lower\ 95\%\ CL_{\ ln(Ri)} = ln\ (R_i) - (t_{0.05(2),n\text{-}3})\ (S_Y) \tag{7}$$

then take the inverse log to back transform confidence limits in log space to generate 95% confidence limits of predicted abundance:

$$Upper\ 95\%\ CL_{\ ln(Ri)} = exp^{\ Upper\ 95\%\ CL\ ln(Ri)} \tag{8}$$

$$Lower\ 95\%\ CL_{\ ln(Ri)} = exp^{\ Lower\ 95\%\ CL\ ln(Ri)} \tag{9}$$

Where:

$S_{Y*X}{}^2$ = sum of residuals squared
X_i = 2015 adult escapement
X_{mean} = mean escapement
X = escapement in each year
N = number of years included in stock-recruitment model
t = two-tailed t-value with α = 0.05 and n -3 degrees of freedom
R_i = 2015 predicted juvenile abundance

In addition to the two stock-recruitment models, predicted abundance was also estimated using the mean abundance under conditions of similar brood spawner escapement referred to in this report as the Similar Adult method. The criteria used to define conditions of similar escapements were set as ± 50% of the brood spawner escapement corresponding to 2015 juvenile abundance. This approach is likely only useful under conditions of relatively high brood spawner escapement since juvenile abundance would be at or near carrying capacity and vary less than under the high productivity conditions typical at low escapement levels. Under these conditions, a predicted estimate based on the Similar Adult method could be of similar or greater precision than using either the Beverton-Holt or Ricker methods particularly if there is considerable scatter at low spawner escapement.

3.0 Results and Discussion

3.1 Field Sampling

During October 22-28, we conducted snorkel surveys of run habitats on the Nicola, Coldwater Rivers and Spius Creek (0.48%, 0.44% and 0.36% of stream length, respectively), and all habitats on the Thompson River between Spences Bridge and Lytton (16, 16, 11 and 15 sites, respectively). Site length ranged from 15-109 meters and totaled 1180 m of bank-length surveyed over 15 Thompson River sites and 1638 m surveyed over 16 Nicola sites, 16 Coldwater sites and 11 Spius Creek sites, amounting to 1.9% of habitats sampled. We did not sample riffle habitat with the exception of four riffle sites in the lower section of reach N1 of the Nicola that were surveyed by snorkelers.

Underwater visibility at all sites was good to excellent (≥3m), which is within the range of previous years' abundance sampling and mark-recapture experiments. Water temperature was within the range of previous sampling years even though we surveyed some sites up to 4-weeks later than in previous years (Table 3). The snorkel survey crew was highly consistent with past surveys. Each of the four crew members participated in 10, 10, 8, and 4 prior survey sessions. Considering the similar range of sampling conditions and personnel, detection probability estimates obtained during 2001-2012 sampling likely apply equally well to sampling during 2015.

3.2 Juvenile abundance

3.2.1 All Habitats

Since riffles habitats were not sampled on the Coldwater River and Spius Creek, and insufficiently sampled on the Nicola River, we cannot provide reliable abundance estimates for riffles. Thus, estimates incorporating riffle habitat were not used in any comparisons between observed and predicted 2015 abundance (Table 7). To provide information about the abundance in all habitats, we estimated fish densities in the unsampled riffles by adjusting the densities in runs by the ratio of density in runs versus riffles for each species and age-class averaged across both reaches and years. This approach relies on the assumption that fish densities in runs and riffles varied similarly across years. However, this was not the case for most reaches. The density in run versus riffle habitat across years when separated by reach, species and age-class were generally poorly to moderately correlated, (Table 8). When all reaches were pooled, abundance in each of the two habitat types were moderately to strongly correlated across years for Chinook fry and age-1+ and 2+ Steelhead parr (r = 0.87, 0.68, and 0.83; respectively). By reach, Steelhead fry abundance in run and riffle habitats were poorly correlated for Coldwater River and Spius Creek and moderately and strongly correlated in reaches N1 and N2 of the Nicola River. However, when compared across all reaches, the correlation was close to zero (r = -0.10). With such a poor ability to predict abundance in riffle habitats based on the index of abundance in runs, extrapolating whole river estimates for Steelhead fry is not justified. Considering this, abundance estimates listed in Table 4 include only river and basin wide estimates for Steelhead parr age-1 and age-2, and Chinook fry. Note that 95% confidence limits reported in Table 4 do not incorporate the substantial variation in the ratio of abundance in run versus riffle habitat across years

3.2.1 Sampled Habitats

Point estimates for Chinook fry, Steelhead fry and age-1+ and age-2+ Steelhead parr are listed in Table 5. For all but Steelhead fry, abundance in runs is likely a reliable indicator of whole river abundance (Table 8). Abundance in run habitats was moderately to strongly correlated with whole river abundance for Steelhead parr and Chinook fry across most reaches and typically better than, or similar to the correlation between riffles and whole river estimates. The notable exception to this was reach SP1, where abundance in riffle was a better predictor of whole river abundance of Steelhead age-1 (riffle, r = 0.86 and run, r = 0.53) and age-2 (riffle, r = 0.96; run, r = 0.66). With all reaches combined, abundance in run habits was highly correlated with overall abundance across years (r ≥ 95%).

The point estimates for Steelhead fry listed in Table 5 are based on raw snorkeler counts unadjusted by estimated detection probability since this it is unknown. There is insufficient information to support that fry estimates based on snorkeler count data for run habitats is a reliable index of abundance. This is largely due to the lack of reliable whole river population estimates to compare snorkel based estimate with. Without it, it is difficult to say if abundance in riffles based on electrofishing or the snorkeler based index of abundance in run habitats is the better indicator of overall abundance. Also, without mark-recapture based detection probability estimates for this age class, it is unclear whether the lack of agreement between abundance in run versus riffle habitats described previously reflect actual differences in fish abundance, variations or instability of snorkeler detection probability, or other factors. Thus, snorkel counts of Steelhead fry in run habitats should be considered as uncertain estimators of whole-river abundance across years and given less weight when considering if abundance is 2015 is less than expected compared with results from other species/age-classes.

Point estimates of 2015 standing stock for Chinook fry and Steelhead age-1 parr and age-2 parr in sampled habitats are listed in Table 5 along with the 95% credible intervals estimated using the HBM. Table 4 also lists point estimates for Steelhead fry, based on snorkel counts, and should be considered as an index of abundance rather than as a population estimate due to the lack of mark-recapture based estimates of snorkeler detection probability for this age-class.

The precision of 2015 estimates for Chinook fry by reach were moderate to low with coefficients of variation ranging from 0.28 – 0.60 (Table 4) and adequate for the estimate of entire Nicola River Basin (cv = 0.22). For Steelhead parr, the precision of estimates by reach were considerably better than for Chinook, with coefficient of variation ranging from 0.17 – 0.38 for age-1+ and 0.19 – 0.55 for age-2+ parr. With all reaches in the study area combined, including reach T3 of the lower Thompson River, precisions were relatively good for age-1+ (cv = 0.11) and age-2+ parr (cv = 0.13). The possibly insufficient precision for reach level estimates is expected considering the basis of the sampling design was to produce estimates of stock productivity and carrying capacity at the river and watershed level, not at the reach level.

Fish density in sampled habitats varied considerably across reaches, including between reaches of the same river, however the general trends were similar to 2001-2012 (Figure 2). The density of Chinook fry generally decreased with stream order and distance from confluence. Density was highest in reach N1 (2.5 fry/m) and lowest in the SP2 (0.15 fry/m) and CW2 (0.6 fry/m).

The 2015 density of Steelhead fry based on raw snorkeler counts varied considerably across reaches with a low of 0.07 fry/m in T3 to a high of 0.8 fry/m in SP1 (Figure 2). There was also a seven-fold difference between the density in SP1 and SP2. For the Coldwater River and Spius Creek, densities were decreased with distance from confluence.

Age-1+ Steelhead parr density varies less across reaches than other species and age-classes with the high in SP1 (0.69 parr/m) and low in N2 (0.23 parr/m) differing by a factor of three. The density of both parr age-classes decreased as distance from confluence increased for Spius Creek and Nicola River and with similar densities in the CW1 and CW2. The two parr age-classes differed markedly in terms of the relative density in reach T3 where for age-1+ parr it had one of the lowest densities yet for age-2+ parr it had the highest compared to other reaches.

3.3 Observed and Predicted Abundance

All comparisons are based on abundance in habitats sampled in 2015. This includes run habitat for Nicola, Coldwater and Spius, and all habitats in reach T3 of the lower Thompson River referred to as the Nicola aggregate for estimates for Steelhead age-classes. For Chinook fry, Nicola aggregate estimates incorporate abundance in the same areas with the exception of reach T3 of the lower Thompson. Genetic stock identification indicates that less than a third of stream-type Chinook fry in T3 are the progeny of the Nicola basin (Decker et al. 2008) and, if included, could weaken the relationship between juvenile and brood spawner abundance.

3.3.1 Chinook fry

Table 6 lists mean abundance estimates for 2001-2012, point estimates for 2015 including 95% credible limits, and relative abundance in 2015 compared with the 2001-2012 mean (% of mean) in run habitat. For Chinook fry, difference between mean abundance 2001-2012 and 2015 point estimates varied considerably across reaches and river. Point estimates were less than half of the 2001-2012 mean abundance for Coldwater (45%) and Spius (46%) while for the Nicola, it was near normal (84%). The point estimate for reach T3 was 59% of mean abundance. Within rivers, point estimates were closer to mean abundance in upstream reaches for Nicola and Coldwater Rivers, while the opposite was the case for Spius Creek. However, 95% confidence limits of mean abundance overlapped with the 95% credible limits of 2015 abundance estimates for each reach, river and the watershed as a whole.

With predicted abundance based on Ricker stock-recruitment model, observed and predicted abundance was only statistically different for the Nicola aggregate in spite of predicted values 2-3 fold larger than observed for other reach and river estimates (Figure 3 and Table 7). This is in large part due to the low precision of the stock-recruitment relationship that resulted in very broad 95% confidence limits of predicted estimates that reached zero for estimates for Coldwater and Spius reach and river estimates.

With predicted abundance based on the Similar Adult predictive method, confidence limits did not overlap for the Coldwater, Spius and SP1 predicted and observed estimates and only minimally overlapped in the case of CW1 (Table 7). Precision of predicted values were considerably higher than using the Ricker based method. The difference between observed and predicted estimates followed a similar pattern to when using the Ricker model with predicted abundance four-fold higher than observed for Spius, followed by the Coldwater (three-fold), Nicola aggregate (1.9 fold) and Nicola (1.6 fold). Considering the minimal or lack of overlap, 2015 Chinook fry abundance was very likely much lower than expected for Nicola aggregate, Coldwater and Spius, and reaches CW1 and SP1.

3.3.2 Steelhead fry

For Steelhead fry, 2015 point estimates for sampled habitats were relatively similar to 2001-2012 mean abundance for all reaches and rivers. The exceptions to this were SP2 and T3, which were 30% and 34% of mean abundance, based on unadjusted snorkel count data (Table 6). The point estimate for the Nicola aggregate was 75% of mean abundance. It is very likely that for reaches other than SP2 and T3 that the 2015 point estimate for Steelhead fry did not differ significantly from the mean 2001-2012 considering all are within the 95% confidence intervals.

The Beverton-Holt and Ricker stock-recruitment curves also suggest 2015 abundance was similar to predicted for both Spius Creek and for all reaches combined. For both areas, the 2015 observed abundance was in near perfect agreement with predicted values (Figure 4). This suggests normal to slightly less than normal fry abundance in run habitats. It also suggests a similar trend for river-wide abundance for Nicola, Coldwater and Spius, however this interpretation should be considered highly uncertain on account that the vast majority of preferred fry habitat, which is riffle, was not sampled.

3.3.3 Age-1+ Steelhead parr

For age-1+ Steelhead parr, 2015 abundance estimates were significantly lower than 2001-2012 mean abundance based on 95% confidence limits not overlapping for reaches CW1and T3, Coldwater, Spius and for all reaches combined (Table 6). For these areas, the 2015 estimates ranged from 31% to 55% of mean abundance. The overlap of confidence intervals for SP1 were also minimal with the 2015 estimate 52% of mean abundance. 2015 point estimates for reaches CW2 and N1, and Nicola River were 71% - 78% of mean abundance. The differences were greatest in the lower reaches of Coldwater and Nicola Rivers compared to their upper reaches, similar to Chinook fry. Reductions from the mean were greater for Coldwater and Spius reaches but did not show a systematic relationship with distance from confluence. Compared to mean abundance, reductions were greater in the lower Coldwater (48% of mean) than in the upper reach (71% of mean) while reductions were similar for upper and lower Spius reaches (56% and 52% of mean, respectively). As well, 2015 abundance in the Nicola was relatively close to normal whereas the tributaries were significantly lower.

With the predicted abundance based on the Beverton-Holt stock-recruitment model for Spius and Nicola aggregate, 95% confidence limits overlapped minimally (Table 7). For both areas, the observed estimates were 50% of predicted abundance. Brood spawner escapement for age-1+ parr in 2015 for the Spius and Nicola aggregate was relatively low resulting in the predicted abundance positioned near to where the Beverton-Holt curve becomes asymptotic (Figure 4). At this point, predicted values become very sensitive to small decreases in brood spawner level. Considering the relatively high fit between the observed and predicted values used to fit the curve and the magnitude of difference between the 2015 observed and predicted age-1+ parr abundance, 2015 abundance likely does represent a well below average year.

3.3.4 Age-2+ Steelhead parr

Age-2+ Steelhead parr 2015 point estimated for sampled habitats were considerably greater the mean abundance 2001-2012 in reaches N1, N2, SP1; near the mean in CW2 and T3, and well less than the mean in CW1 and SP2 (Table 6). 2015 point estimates ranged for 26% of mean abundance in SP2 to 162% of mean in SP1. By river, 2015 point estimates were 145% of the mean for Nicola, 124% for Spius and 64% for Coldwater. For the Nicola aggregate, 2015 abundance was 92% of mean abundance. SP2 was only reach or river with which the 2015 and

2001-2012 confidence limits did not overlap (Table 6). Age-2+ parr abundance appears unrelated to brood spawner escapement for Nicola aggregate and for Spius Creek and poorly characterized by stock-recruitment models (Figure 5), thus predicted abundance for 2015 based on spawner brood stock was not estimated.

3.4 Spatial Trends

For both Chinook fry and age-1+ Steelhead parr, 2015 abundance was significantly less than expected for Coldwater, Spius and Nicola basin (including T3 for Steelhead) as well as for CW1. For all species and age-classes, abundance was near or above predicted for the Nicola. Also, within rivers, the reduction from mean or predicted abundance was greater in lower reach for the Coldwater, whereas Spius had the opposite trend. For all but age-2+ steelhead parr, abundance was also lower than expected in reach T3 of the lower Thompson, though the difference was only significant for age-1+ parr.

At the broadest level, these trends suggest the cause(s) that led to lower than expected abundance, particularly for Chinook fry and age-1+ Steelhead parr, was more pronounced in the Coldwater and Spius than Nicola and had greater effect in the lower versus upper Coldwater. As well, considering most juvenile Steelhead in reach T3 are the progeny of the Nicola basin, the lower than expected abundance of fry and age-1+ parr could indicate lower rates of immigration or a lower population size moving at rate similar to past years.

3.5 Drought vs Other Causes

Drought conditions (increased water temperature / low flows) could lead to many changes to fish population including increased mortality and emigration, and reduced growth rates. In the Nicola basin, the effects of drought were hypothesised to be greatest in the lower reaches of the tributaries, the Coldwater in particular due to the added impact of surface water diversion. Drought impacts would be lower for the Nicola mainstem since flows were buffered somewhat from drought conditions by increased discharge from Nicola Lake dam. Also part of the drought hypothesis is that all species and age-classes exposed to drought conditions would be impacted to some degree.

These results are consistent with the drought hypothesis in some ways but differ as well. Abundance was more reduced in tributaries versus mainstem than in the upper reach and for the Coldwater, was also more reduced in the lower reach where water withdrawals occur. However in Spius, abundance was most reduced in the upper reach across species and age-classes. Contrary to the Coldwater, survey of agricultural water use suggest stream water withdrawals in the lower Spius were minimal during the drought period, thus abundance declines would not necessarily be greater in the lower versus upper reach. This is consistent with results for age-1+ Steelhead parr but at odds with Chinook fry where reductions where greatest in upper Spius. Reductions in abundance were not consistent across species or age-classes. It is very likely that age-2+ parr Steelhead parr were affected very little or not at all while age-1+ parr and Chinook fry were affected most. Snorkel count data suggests Steelhead fry were relatively unaffected in 2015. Assuming this is an accurate reflection of overall Steelhead fry abundance, it is difficult to reconcile that while Steelhead age-1+ parr and Chinook were similarly and significantly affected, Steelhead fry were only minimally impacted. However, it is worth noting that in the lower Coldwater where drought impacts were likely most acute that point estimates of abundance for all species and age-classes were less than expected (42% - 70% of mean) though these differences were only significant for age-1+ Steelhead parr and Chinook fry.

Many investigators have observed that full stream bed mobility occurs at flows near bankfull discharge (see review in McKean and Tonina 2012). Bankfull discharge can be roughly approximated by the median annual maximum flood. Based on these factors, an alternative hypothesis is that at locations where high flow events during the winter of 2014-2015 exceeded the median value of the maximum annual flood, the flows may have been large enough to mobilize river bottom substrate and or dislodge surface ice leading to scour and loss of Chinook redds, and increased Steelhead fry mortality. Eggs in the Chinook redds and Steelhead fry during winter would then become the Chinook fry and age-1+ parr counted in the fall. Age-1+ parr would be less susceptible to the impacts of flood due to their increased swimming ability. Since Steelhead spawners had not yet entered the river by this time, Steelhead fall fry abundance would be largely unaffected. As indicated in Table 9, an analysis of provisional data indicates that flows may have exceeded a theoretical threshold for bed mobility in the Coldwater River, but not in the Nicola River. Although winter flow data for Spius Creek was collected by the Water Survey of Canada for the period of interest, this data was not readily available at the time of writing. Under a flood hypothesis, abundance would be most reduced for Chinook fry and age-1+ Steelhead parr while Steelhead fry would be unaffected and age-2+ parr minimally affected. Also, vulnerable species and age classes would be most reduced in the Coldwater than the Nicola. The results support both aspects of the drought hypothesis. What this hypothesis doesn't explain is that abundance was most reduced in the lower versus upper Coldwater considering flows were similarly elevated above median flood levels at the water survey stations located in each reach. As with the drought hypothesis, it is difficult to reconcile the large reduction in abundance in upper compared to lower Spius. Both drought and flood hypotheses could produce the low abundance of Steelhead fry and age-1 parr in Thompson River reach T3 if migration from the Nicola and tributaries was somewhat density dependant.

3.6 Recommendations

Key uncertainties remain about the effects of drought at the individual fish level and at the population level. The sampling design, intended for stock-recruitment analysis at a large geographic scale, does not provide sufficient information to distinguish between drought effects and other affects nor does it

1. Carry out a literature review of the effects of drought (flow and temperature) on salmonids.

2. Adapt the current sampling design for improved precision of reach level abundance estimates while continuing to provide similar basin wide population estimates necessary for stock-recruitment analysis. Include sampling riffle habitat particularly if Steelhead fry abundance is of interest as an index of drought effects.

3. Adapt the study design to differentiate between over-winter and over-summer survival. This would likely involve a 2nd survey in early summer.

4. Initiate a study capable of measuring fish movement at the reach or river level separate from survival. One of the uncertainties of this study is how much of the low abundance in the Coldwater and Spius was attributable to mortality versus downstream movement.

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Tables

Table 1. Stream length, reach length and reach length and proportion of each habitat type.

			Habitat Type			
Stream	**Reach**	km	Run km	Riffle km	Run %	Riffle %
Coldwater		79.0	34.9	44.1	44%	56%
Lower	CW1	44.0	19.5	24.5	44%	56%
Upper	CW2	35.0	15.5	19.5	44%	56%
Nicola		74.6	36.5	38.1	49%	51%
Lower	N1	50.6	22.8	27.8	45%	55%
Upper	N2	24.0	13.8	10.2	57%	43%
Spius		38.9	14.1	24.8	36%	64%
Lower	SP1	25.3	8.7	16.6	34%	66%
Upper	SP2	13.6	5.4	8.2	40%	60%
Nicola Basin		192.5	85.6	106.9	44%	56%
Thompson	T3	26.1				
Nicola Basin and T3		218.6				

Table 2. Age-class length cut-offs for streams and reaches sampled during 2015 based on length-frequency from snorkel counts and electrofishing, and scale samples obtained during surveys 2010-2012. Lengths equal to or greater than the listed value are included in the older, rather than younger age-class.

		Age-class length cut-offs		
River	**Reach**	0+/1+ (mm)	1+/2+ (mm)	2+/3+ (mm)
Coldwater	CW	75	135	200
Upper Spius	SP2	75	135	200
Lower Spius	SP1	75	140	200
Upper Nicola	N2	95	150	200
Lower Nicola	N1	95	150	200
Lower Thompson	T3	95	155	210

Table 3. Minimum and maximum water temperature, during snorkel surveys 2001-2012 and 2015.

	Temperature (C °)			
	2001-2012		2015	
River	Min	Max	Min	Max
Coldwater	4	12	5	12
Nicola	8	14	7	9
Lower Spius	4	10	5	7
Upper Spius	4	12	4	4
Thompson	8	14	12	12

Table 4. Aggregate abundance of juvenile age-classes of Chinook salmon and Steelhead trout for the Nicola watershed and Thompson River between its confluences with the Nicola and Fraser Rivers based on two gear-types sampling all habitat types (2001-2012) and on snorkel counts during 2015. Abundance in unsampled riffle habitat in 2015 was inferred from the species/age-class specific ratios of abundance in run versus riffle habits averaged across all reaches and years (see Section 3.2.1).

		2001-2012			2015		
Comparison Group	**Species / age-class**	**Mean**	**Minimum**	**Maximum**	**Point Estimate**	**Lower 95% CL**	**Upper 95% CL**
All Habitats	Chinook Fry[1]	252,574	81,751	427,427	204,978	359,632	466,889
All Habitats	Age 1+ Steelhead	137,578	92,411	173,361	85,959	113,507	133,381
All Habitats	Age 2+ Steelhead	28,337	17,013	54,571	25,432	43,747	54,100

[1] Aggregate excludes abundance from the Thompson River

Table 5. 2015 estimated standing stock, standard deviation, upper and lower 95% credible limits, coefficient of variation and fish density for run habitats in the Nicola and Coldwater Rivers and Spius Creek, and in all habitats types of the Thompson River by species, age-class and reach.

			2015					
Species	Age Class	Reach	Point Estimate	sd	Lower CL	Upper CL	cv	fish/km
Chinook	fry	CW1	20,249	5,670	11,649	34,866	0.28	1,040
Chinook	fry	CW2	7,639	2,521	3,902	14,011	0.33	493
Chinook	fry	N1	56,907	17,072	32,033	98,327	0.30	2,499
Chinook	fry	N2	18,949	9,096	7,575	43,039	0.48	1,378
Chinook	fry	SP1	12,969	4,020	6,974	23,316	0.31	1,497
Chinook	fry	SP2	714	428	208	2,051	0.60	131
Chinook	fry	ALL	117,428	25,834	82,307	183,408	0.22	1,372
Steelhead	fry	CW1	10,246	-	-	-		526
Steelhead	fry	CW2	3,841	-	-	-		248
Steelhead	fry	N1	10,397	-	-	-		457
Steelhead	fry	N2	5,264	-	-	-		383
Steelhead	fry	SP1	7,516	-	-	-		867
Steelhead	fry	SP2	644	-	-	-		118
Steelhead	fry	T3	1,768	-	-	-		68
Steelhead	fry	ALL	39,676	-	-	-		355
Steelhead	1+ parr	CW1	7,839	1,333	5,522	11,030	0.17	403
Steelhead	1+ parr	CW2	5,007	1,252	3,023	7,839	0.25	323
Steelhead	1+ parr	N1	12,541	3,135	7,755	20,669	0.25	551
Steelhead	1+ parr	N2	3,164	1,076	1,623	6,008	0.34	230
Steelhead	1+ parr	SP1	6,018	1,204	4,114	8,815	0.20	695
Steelhead	1+ parr	SP2	1,616	614	783	3,163	0.38	297
Steelhead	1+ parr	T3	6,622	1,324	4,489	9,808	0.20	254
Steelhead	1+ parr	ALL	42,806	4,709	35,102	54,390	0.11	383
Steelhead	2+ parr	CW1	1,335	414	729	2,357	0.31	69
Steelhead	2+ parr	CW2	1,352	473	688	2,563	0.35	87
Steelhead	2+ parr	N1	4,610	1,199	2,755	7,578	0.26	202
Steelhead	2+ parr	N2	478	220	197	1,105	0.46	35
Steelhead	2+ parr	SP1	2,619	838	1,388	4,688	0.32	302
Steelhead	2+ parr	SP2	170	93	61	434	0.55	31
Steelhead	2+ parr	T3	10,211	1,940	6,943	14,520	0.19	391
Steelhead	2+ parr	ALL	20,774	2,701	16,209	27,229	0.13	186

Table 6. Population estimates for run habitats of the Nicola and Coldwater Rivers and Spius Creek, and all habitats types of the Thompson River by species, age-class and reach/river. Mean, minimum, maximum and 95% confidence limits of abundance estimates from 2001-2012. Point estimates of abundance and 95% credible limits for abundance in 2015. Note that for Chinook fry with all reaches combined (ALL) does not include abundance from reach T3 where as it does for Steelhead age-classes.

			2001-2012					2015			
Species	Age Class	Reach / River	Mean	Min	Max	Lower 95% CL	Upper 95% CL	Point Estimate	Lower 95% CL	Upper 95% CL	% of mean
Chinook	fry	CW1	48,010	9,882	77,828	32,855	63,165	20,249	11,649	34,866	42%
Chinook	fry	CW2	13,367	2,331	25,122	7,270	19,464	7,639	3,902	14,011	57%
Chinook	fry	N1	72,548	33,038	130,683	46,402	98,695	56,907	32,033	98,327	78%
Chinook	fry	N2	17,500	4,355	39,456	8,618	26,383	18,949	7,575	43,039	108%
Chinook	fry	SP1	27,361	4,048	54,953	13,679	41,044	12,969	6,974	23,316	47%
Chinook	fry	SP2	2,680	0	11,844	50	5,311	714	208	2,051	27%
Chinook	fry	T3	106,836	28,484	229,251	55,569	158,102	61,754	39,970	98,348	58%
Chinook	fry	Coldwater	61,377	13,853	101,810	42,421	80,334	27,889	18,255	43,383	45%
Chinook	fry	Nicola	90,049	37,393	166,074	56,666	123,431	75,856	45,901	123,295	84%
Chinook	fry	Spius	30,042	4,048	59,165	14,341	45,743	13,683	7,682	23,644	46%
Chinook	fry	All	181,468	60,924	291,356	124,882	238,053	117,428	82,307	183,408	65%
Steelhead	fry	CW1	14,559	3,785	43,115	6,458	22,660	10,246	-	-	70%
Steelhead	fry	CW2	4,158	584	8,055	2,641	5,674	3,841	-	-	92%
Steelhead	fry	N1	9,041	1,319	40,010	1,056	17,025	10,397	-	-	115%
Steelhead	fry	N2	6,939	2,109	26,467	1,878	12,001	5,264	-	-	76%
Steelhead	fry	SP1	7,988	887	19,064	3,419	12,557	7,516	-	-	94%
Steelhead	fry	SP2	2,116	286	5,491	767	3,465	644	-	-	30%
Steelhead	fry	T3	5,207	416	17,884	769	9,645	1,768	-	-	34%
Steelhead	fry	Coldwater	18,717	4,369	48,362	9,771	27,662	14,087	-	-	75%
Steelhead	fry	Nicola	15,980	4,565	66,477	3,117	28,843	15,661	-	-	98%
Steelhead	fry	Spius	10,104	2,512	21,953	5,360	14,848	8,160	-	-	81%
Steelhead	fry	All	50,008	15,929	154,677	21,560	78,456	39,676	-	-	79%

Table 6 continued

			2001-2012					2015			
Species	Age Class	Reach / River	Mean	Min	Max	Lower 95% CL	Upper 95% CL	Point Estimate	Lower 95% CL	Upper 95% CL	% of mean
Steelhead	1+ parr	CW1	16,203	9,529	24,485	12,719	19,688	7,839	5,522	11,030	48%
Steelhead	1+ parr	CW2	7,035	4,033	11,432	5,379	8,692	5,007	3,023	7,839	71%
Steelhead	1+ parr	N1	16,873	9,590	27,982	12,161	21,585	12,541	7,755	20,669	74%
Steelhead	1+ parr	N2	3,321	1,584	7,848	1,930	4,711	3,164	1,623	6,008	95%
Steelhead	1+ parr	SP1	11,560	8,046	19,056	8,777	14,344	6,018	4,114	8,815	52%
Steelhead	1+ parr	SP2	2,868	1,421	5,540	1,834	3,902	1,616	783	3,163	56%
Steelhead	1+ parr	T3	21,250	9,127	33,312	15,492	27,007	6,622	4,489	9,808	31%
Steelhead	1+ parr	Coldwater	23,239	14,376	34,824	18,326	28,151	12,845	9,753	17,069	55%
Steelhead	1+ parr	Nicola	20,194	11,520	30,292	15,244	25,144	15,705	10,528	24,290	78%
Steelhead	1+ parr	Spius	14,428	9,696	21,586	11,453	17,404	7,634	5,480	10,751	53%
Steelhead	1+ parr	All	79,111	45,346	103,958	66,102	92,119	42,806	35,102	54,390	54%
Steelhead	2+ parr	CW1	2,738	1,372	5,430	1,884	3,593	1,335	729	2,357	49%
Steelhead	2+ parr	CW2	1,434	603	2,449	996	1,873	1,352	688	2,563	94%
Steelhead	2+ parr	N1	3,113	1,017	6,340	1,741	4,486	4,610	2,755	7,578	148%
Steelhead	2+ parr	N2	399	0	1,502	0	807	478	197	1,105	120%
Steelhead	2+ parr	SP1	1,614	866	2,482	1,210	2,018	2,619	1,388	4,688	162%
Steelhead	2+ parr	SP2	644	320	1,100	451	836	170	61	434	26%
Steelhead	2+ parr	T3	12,551	5,269	35,445	6,270	18,832	10,211	6,943	14,520	81%
Steelhead	2+ parr	Coldwater	4,173	2,393	6,244	3,189	5,157	2,686	1,705	4,190	64%
Steelhead	2+ parr	Nicola	3,513	1,355	7,841	1,804	5,222	5,088	3,137	8,009	145%
Steelhead	2+ parr	Spius	2,258	1,412	3,353	1,807	2,708	2,788	1,598	4,719	124%
Steelhead	2+ parr	All	22,494	14,289	47,417	15,185	29,803	20,774	16,209	27,229	92%

Table 7. Observed and predicted abundance of Chinook fry and Steelhead age-1+ parr by reach and river. Predicted abundance based on the Ricker or Beverton-Holt stock-recruitment models or mean juvenile abundance for years with similar (±50%) brood spawner abundance.

Reach	**Species**	**Age class**	**Predicted**			**Observed**				
			Mean	Lower 95% CL	Upper 95% CL	Mean	Lower 95% CL	Upper 95% CL	% of predicted	**Prediction method**
Coldwater	CH	0	82,181	17,853	379,559	27,889	18,255	42,869	34%	Ricker
CW1	CH	0	60,135	10,936	330,608	20,249	11,649	34,266	34%	Ricker
CW2	CH	0	17,824	3,012	105,459	7,639	3,902	13,641	43%	Ricker
Nicola	CH	0	259,922	51,533	314,185	75,856	45,901	121,434	29%	Ricker
Spius	CH	0	46,138	10,136	209,893	13,683	7,682	23,226	30%	Ricker
SP1	CH	0	42,287	10,030	178,290	12,969	6,974	22,808	31%	Ricker
Nicola, Spius, Coldwater	CH	0	273,623	167,805	446,171	117,428	86,047	164,036	43%	Ricker
Coldwater	CH	0	83,377	59,001	107,753	27,889	18,255	42,869	33%	Similar Adult
CW1	CH	0	62,340	34,251	90,428	20,249	11,649	34,266	32%	Similar Adult
CW2	CH	0	20,335	1,233	39,437	7,639	3,902	13,641	38%	Similar Adult
Nicola	CH	0	121,233	20,868	221,598	75,856	45,901	121,434	63%	Similar Adult
Spius	CH	0	55,242	40,533	69,950	13,683	7,682	23,226	25%	Similar Adult
SP1	CH	0	49,128	36,297	61,958	12,969	6,974	22,808	26%	Similar Adult
Nicola, Spius, Coldwater	CH	0	228,503	167,639	289,367	117,428	86,047	164,036	51%	Similar Adult
Spius	RB	1	15,580	9,637	25,187	7,749	5,562	10,849	50%	Beverton-Holt
Nicola aggregate	RB	1	80,611	51,834	125,366	42,921	35,196	54,345	53%	Beverton-Holt

Table 8. Pearson correlation coefficients for comparisons of fish density in riffle habitat and run habitat compared to the total of both types and to each other based on sampling of the Nicola River watershed 2001-2012. Comparison are by reach, species and age-class.

		Correlation Coefficient		
Reach	Age-class	riffle vs both	run vs both	riffle vs run
CW1	CH0	0.70	0.97	0.49
CW2	CH0	0.37	0.99	0.24
N1	CH0	0.95	0.97	0.86
N2	CH0	0.79	0.97	0.63
SP1	CH0	0.77	0.98	0.62
SP2	CH0	0.78	1.00	0.73
All	CH0	0.94	0.99	0.87
CW1	RB0	0.78	-0.01	-0.64
CW2	RB0	0.99	0.26	0.10
N1	RB0	0.98	0.96	0.89
N2	RB0	0.91	0.75	0.41
SP1	RB0	0.86	0.53	0.02
SP2	RB0	0.91	0.65	0.27
ALL	RB0	0.94	0.23	-0.11
CW1	RB1	0.79	0.80	0.27
CW2	RB1	0.93	0.83	0.57
N1	RB1	0.87	0.93	0.63
N2	RB1	0.85	0.97	0.71
SP1	RB1	0.93	0.78	0.50
SP2	RB1	0.72	0.79	0.15
ALL	RB1	0.89	0.94	0.68
CW1	RB2	0.45	0.88	-0.04
CW2	RB2	0.92	0.95	0.76
N1	RB2	0.97	0.92	0.79
N2	RB2	0.02	0.97	-0.21
SP1	RB2	0.96	0.66	0.43
SP2	RB2	0.93	0.69	0.36
ALL	RB2	0.97	0.94	0.83

Table 9. Preliminary review of historic annual maximum floods and peak flows of winter 2014-2015 for selected Water Survey of Canada gauging stations in the Nicola River watershed.

Station	Median value of the maximum annual flood for period of record to 2010 (m^3/s)	Date of 2014-2015 winter maximum flow	Provisional estimate of 2014-2015 winter maximum flow (m^3/s)	Provisional winter maximum flow exceeds median historic flood (yes/no)
Coldwater River at Brookmere (08LG048)	58.9 m^3/s	Nov. 28, 2014	71.8 m^3/s	yes
Coldwater River at Merritt (08LG010)	64.5 m^3/s	Nov. 28, 2014	66.4 m^3/s	yes
Nicola River at Spences Bridge (08LG006)	176 m^3/s	Nov. 28, 2014	98.9 m^3/s	no

Figures

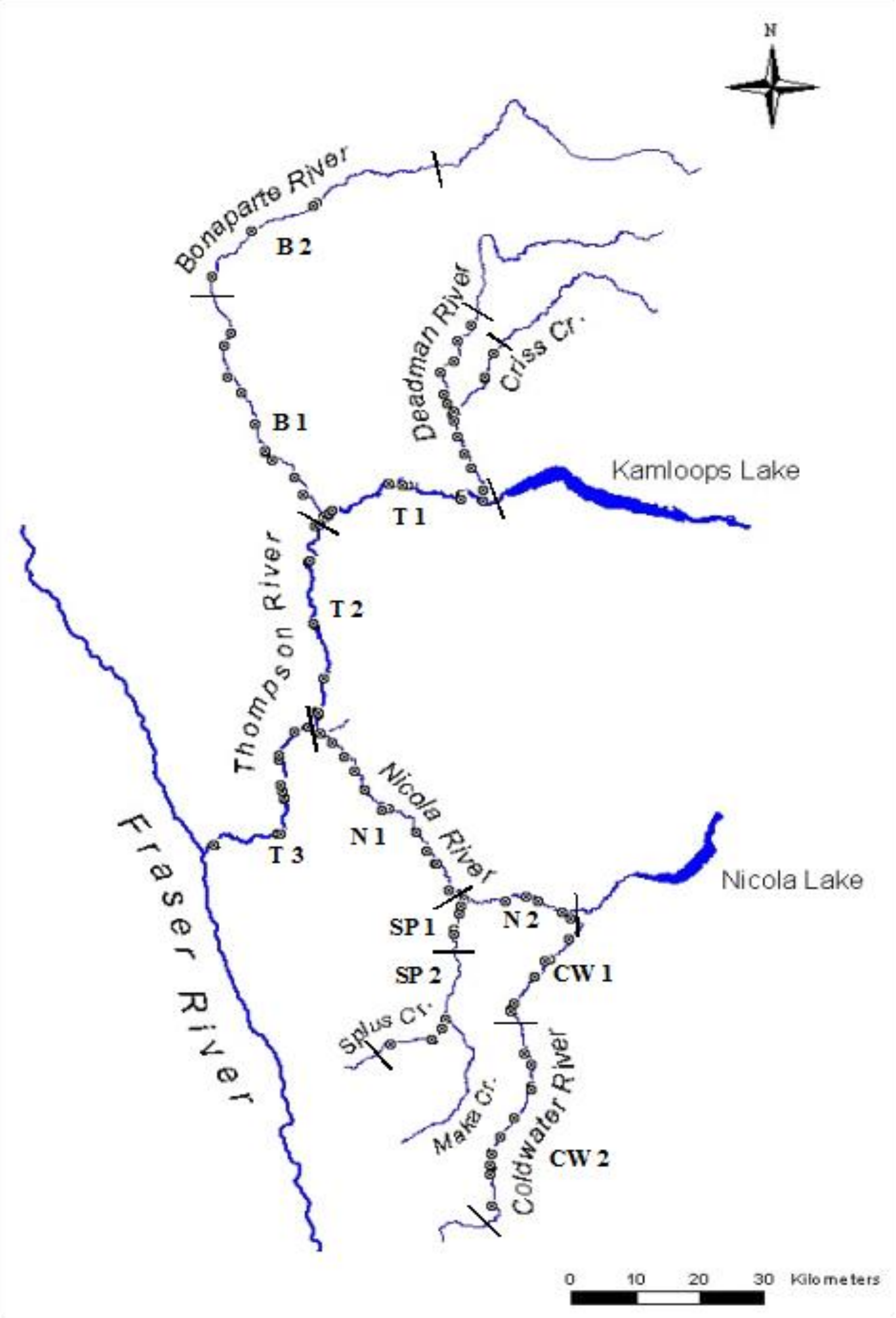

Figure 1. Map of the lower Thompson River basin showing all mainstem and tributary reaches included in the study area. Reach names are given in bold for streams with more than one reach. Reach breaks are indicated by solid slashes and juvenile sampling sites are indicated by dotted circles (Decker et al. 2015)

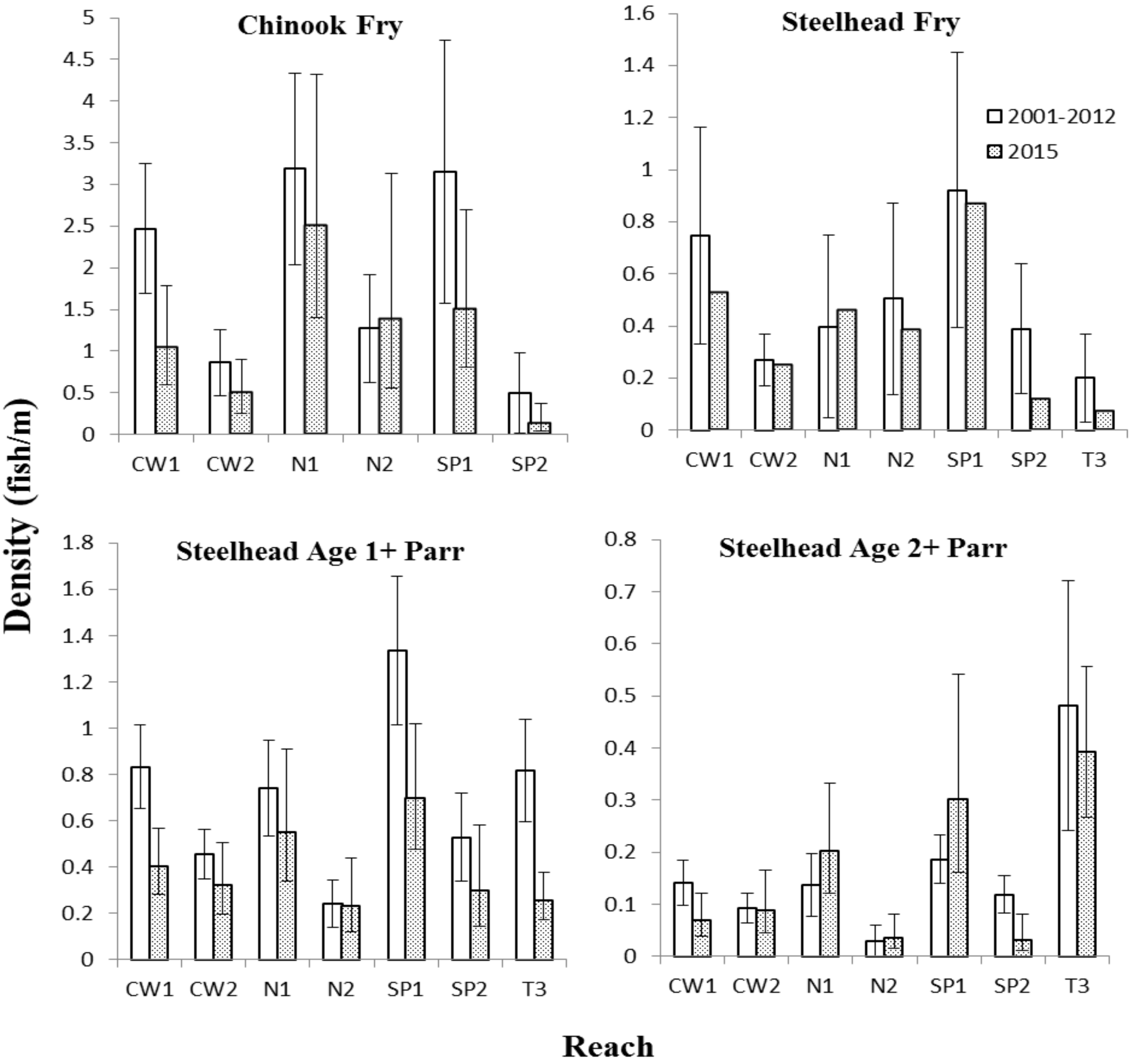

Figure 2. Mean density 2001-2012 and density in 2015 of Chinook fry, Steelhead fry, and age-1+ and age-2+ Steelhead parr in run habitat in six reaches in the Nicola River basin and one reach in the lower Thompson River. Error bars indicate 95% confidence limits of the mean 2001-2012 and 95% credible limits of density in 2015.

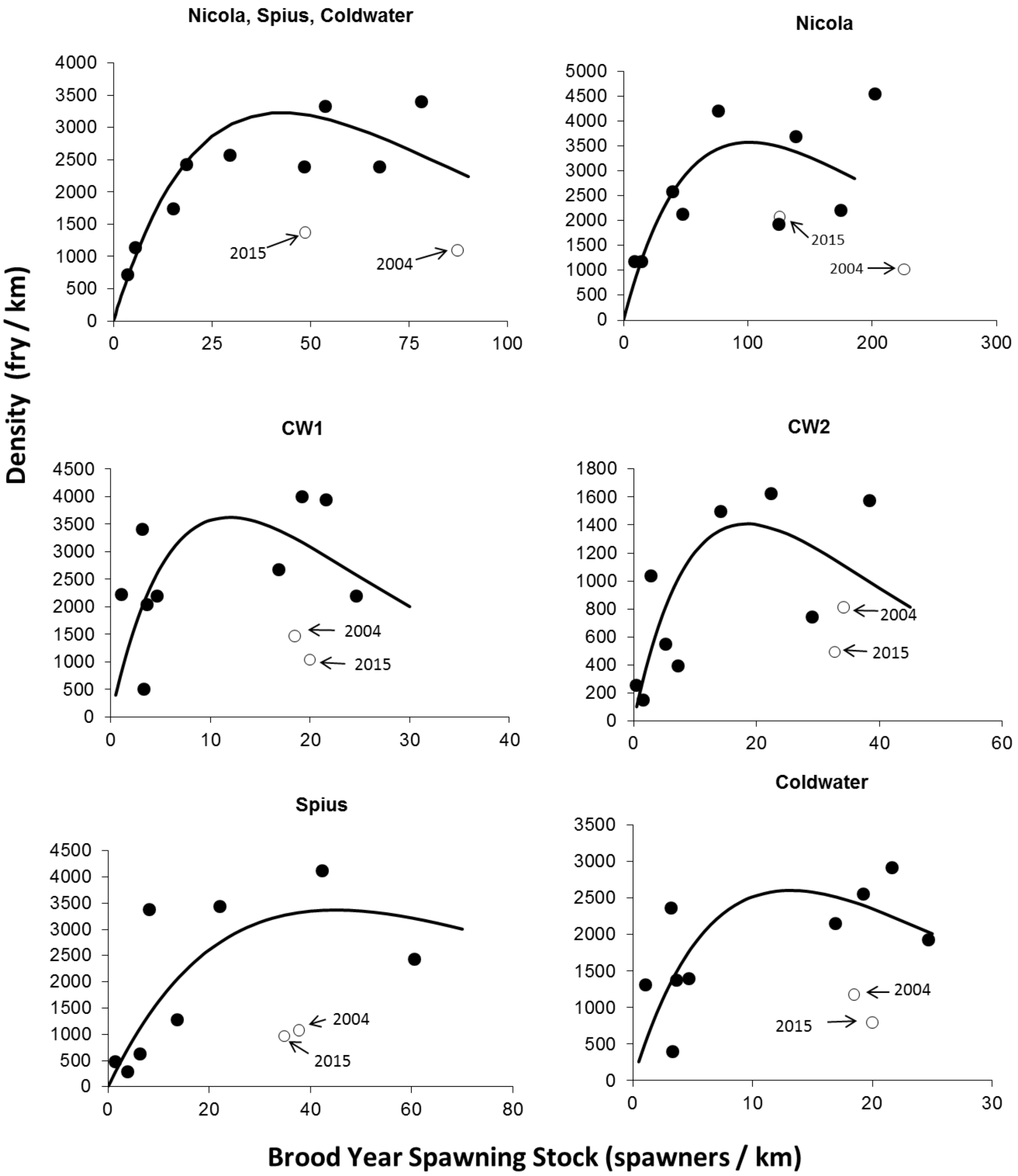

Figure 3. Ricker stock-recruitment curves fitted to brood spawner escapement and Chinook fry abundance in run habitat for the Coldwater, Spius and Nicola Rivers combined and for subsections with river or reach specific spawner escapement estimates. Solid dots represent those used to fit Ricker curve while open dots were not.

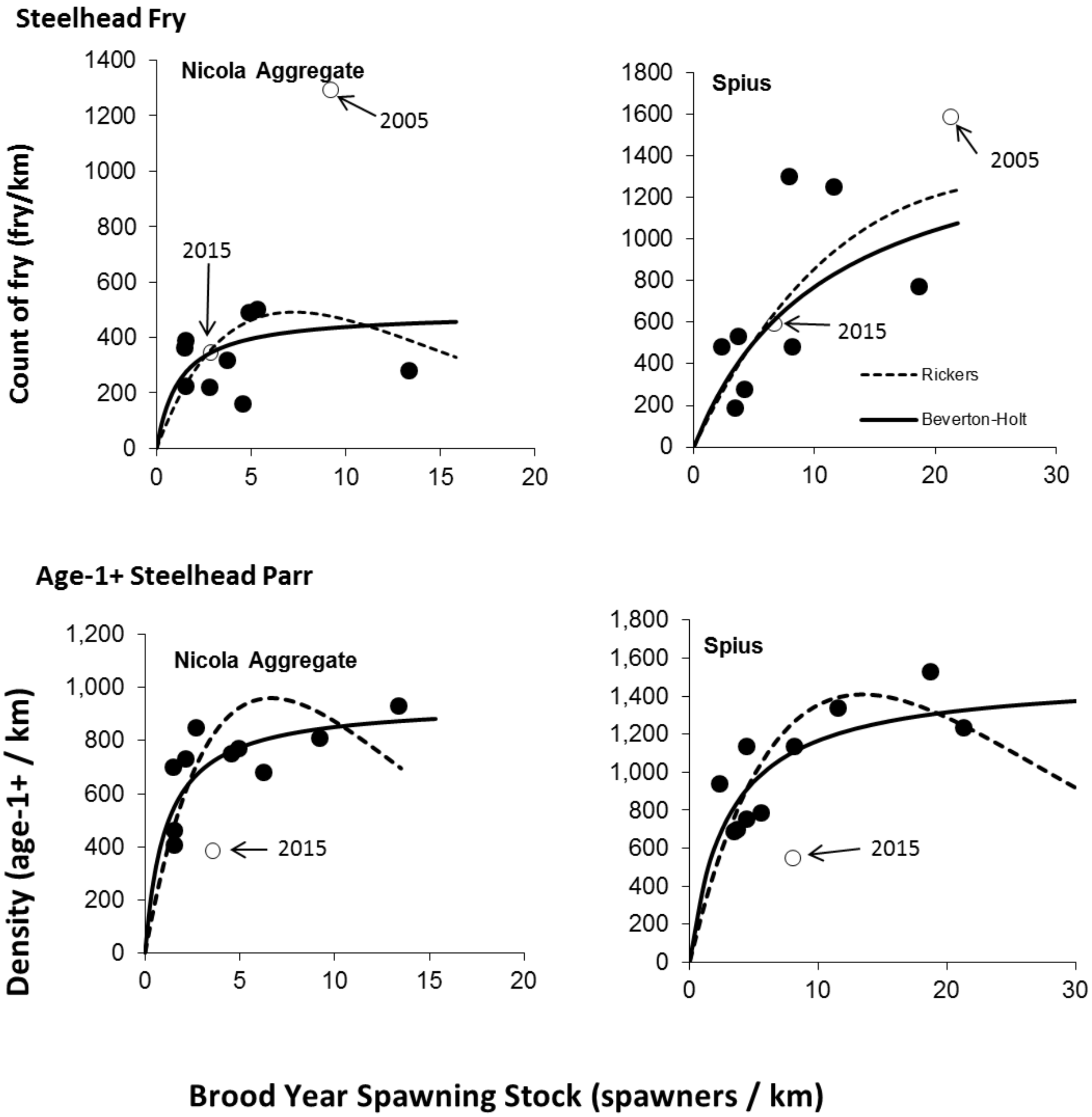

Figure 4. Beverton Holt and Ricker stock-recruitment curves fitted to brood spawner escapement and Steelhead fry and age-1+ parr density in the aggregates of run habitat in Nicola Aggregate and Spius Creek. Fry density based on snorkel survey count data unadjusted by detection probability (see Section 3.2.1). Solid dots represent those used to fit stock-recruitment curves while open dots were not.

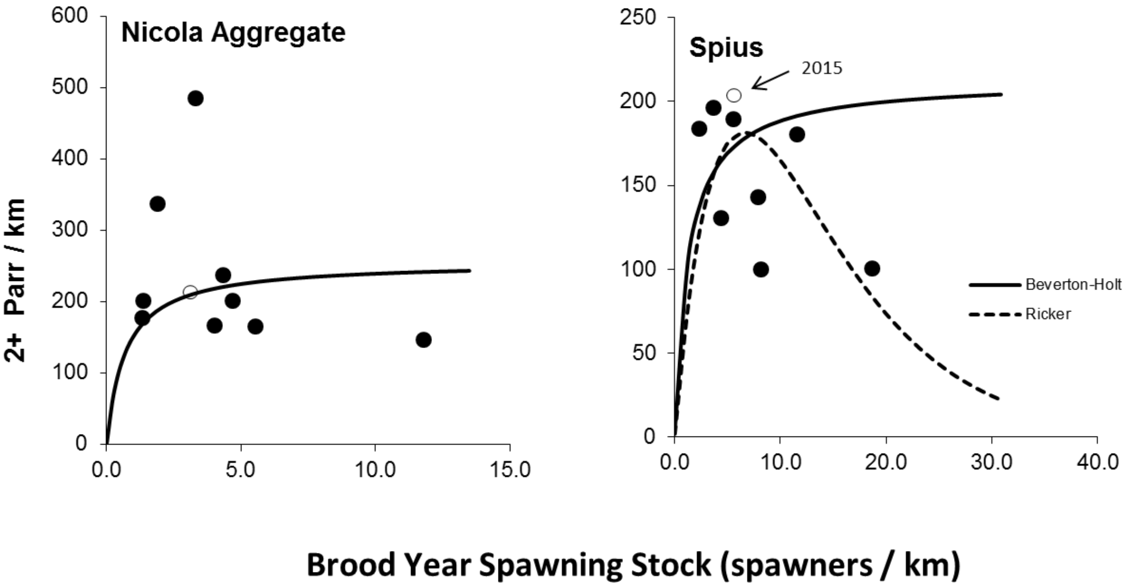

Figure 5. Beverton Holt and Ricker stock-recruitment curves fitted to brood spawner escapement and age-2+ parr density in the Nicola Aggregate and in run habitat for Spius Creek. Solid dots represent those used to fit stock-recruitment curves while open dots were not.