# Evaluation of the 2010 Predictions of Run-Timing and Survival of Wild Migrant Yearling Chinook and Steelhead on the Columbia and Snake Rivers

Technical Report

Postseason Analysis
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## Executive Summary


Columbia Basin Research uses the COMPASS model on a daily basis during the outmigration of Snake River Chinook and steelhead smolts to predict downstream passage and survival. Fish arrival predictions and observations from program RealTime along with predicted and observed environmental conditions are used to make in-season predictions of arrival and survival to various dams in the Columbia and Snake rivers. For 2010, calibrations of travel and survival parameters for two stocks of fish—Snake River yearling PIT-tagged wild Chinook salmon (chin1pit) and Snake River PIT-tagged steelhead (lgrStlhd)—were used to model travel and survival of steelhead and Chinook stocks from Lower Granite Dam (LWG) or McNary Dam (MCN) to Bonneville Dam (BON). This report summarizes the success of the COMPASS/RealTime process to model these migrations as they occur.

We compared model results on timing and survival to data from two sources: stock specific counts at dams and end-of-season control survival estimates (Jim Faulkner, NOAA, pers. comm. January 12, 2011). The difference between the predicted and observed day of median passage and the Mean Absolute Deviation (MAD) between predicted and observed arrival cumulative distributions are measures of timing accuracy. MAD is essentially the average percentage error over the season. The difference between the predicted (model) and observed (control-release data) survivals is a measure of survival accuracy.

MAD values for Chinook (chin1pit) were low (4.0% ) from LWG to BON but for steelhead (lgrStlhd) were higher (14.7%).

This year for Chinook, the model and the survival data are in agreement. The modeled survivals (LWG-MCN, 0.77 and MCN-BON 0.72) match the control-release survivals (0.75 and 0.64). Surprisingly, the modeled survivals were very similar to 2009.The Steelhead were more difficult to reconcile. The modeled survivals (LWG-MCN, 0.53 and MCN-BON 0.50) are much lower than the corresponding control-release survivals (0.80 and 0.79 ). It is not obvious why the steelhead model and data results are so different.

As in previous years, there are problems in reconciling the three types of measures on the river: COMPASS model output, the control-release study data and the observations of PIT-tagged fish at the dams.

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## *Introduction*

During the 1996 migration season, Columbia Basin Research launched a prototype, run-timing system, named CRiSP/RealTime for its two principal components. Program RealTime was developed to take advantage of historical data to predict the proportion of a particular population that had arrived at an index site in real-time and to forecast the elapsed time to some future percentile in a migration at the site. The CRiSP program (Columbia River Salmon Passage model) predicted downstream migration and survival of individual stocks of wild and hatchery spawned juvenile fish from the tributaries and dams of the Columbia and Snake rivers to the estuary. The model described in detail fish movement, survival, and the effects of various river operations on these factors. Beginning in 2007, the downstream modeling program CRiSP was replaced with COMPASS; a regionally accepted data set and model of juvenile passage and survival developed by collaborators at CBR, NOAA/NMFS, BPA and other regional agencies and tribes.

The CRiSP/RealTime project was originally launched in an effort to provide real-time in-season projections of juvenile salmon migration to managers of the Columbia-Snake River hydrosystem to assist the managers in decisions about mitigation efforts such as flow augmentation, spill scheduling and fish transportation. In COMPASS, fish migration and survival is a function of river conditions, dam configurations and reservoir operations which are modeled from flow and spill forecasts, historical data, and year-to-date data.

At the beginning of 2007, two stocks had available travel-time and survival calibrations for use in the new COMPASS model: steelhead and yearling Chinook of both wild and hatchery origin from Lower Granite Dam to McNary Dam and then from McNary Dam to Bonneville Dam. Although the RealTime portion of the model continued to generate predictions for numerous Chinook stocks, their movements below Lower Granite Dam were modeled with common migration and survival parameters. For 2008 and 2009, an acceptable calibration of Chinook and steelhead using only data of wild fish was available.

This report is the postseason analysis of the utility and accuracy of the COMPASS portion of the 2010 predictions of survival and passage that uses available calibrations along with in-season river conditions (flow, spill, TDG and temperature) that are initially predicted (in early season) and eventually observed. The effectiveness of these modeling efforts are compared to observations of passage and survival that are now available since the season is complete. The analyses and graphic presentations herein document the year's passage of select stocks of juvenile salmon and steelhead and demonstrate changes in accuracy of the model predictions as the season progressed.

## *Methods*

The COMPASS and RealTime models have their own calibrations and documentation separate from this postseason analysis of their joint performance. The general algorithm for their interaction is depicted in Figure 1. COMPASS is described in more detail in Zabel et al. (2008). See also: http://www.springerlink.com/content/hu614372k277/?sortorder=asc&p_o=20 . For further details on the RealTime forecaster, see http://www.cbr.washington.edu/rt/rt.html.

In 2007, the COMPASS model had two calibrations complete for Columbia/Snake River hydrosystem: Yearling Chinook and steelhead from the Snake River between Lower Granite Dam and Bonneville Dam, but these included both hatchery and wild fish. Since 2008, calibrations were available for wild fish only of both species. These are coded “chin1pit” and “lgrStlhd”. Other stocks were also modeled with these calibrations even though the specific parameters were not calibrated separately for the individual stocks.

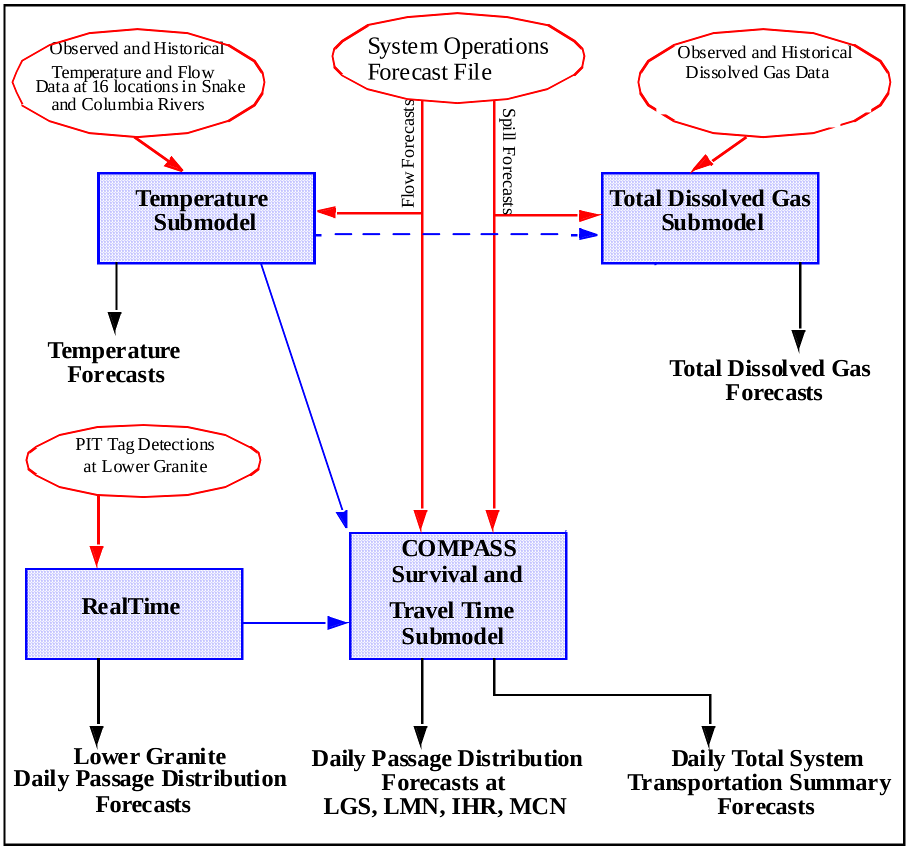



Figure 1 Simplified schematic of RealTime and COMPASS complex.

COMPASS predictions are made daily and are a function of 1) expected and/or known distribution of fish, 2) calibrated migration and survival parameters, and 3) expected and/or known environmental conditions. The output of a daily run includes details on fish passage for the entire year and therefore is predictive. The predictions are then compared with observations at the end of the year. Observations are counts of individually identified PIT-tagged fish that belong to one of six groups: the calibrated stocks: “chin1pit”, “lgrStlhd”, and additional groupings including: “real”, a select group of Chinook from Snake River watersheds; “mcnChin1S”, Snake River Spring/Summer Chinook ESU passing MCN; “mcnStlhdC”, Upper Columbia River Steelhead ESU passing MCN; and “mcnStlhdS”, Snake River ESU Steelhead passing MCN. The groups of fish, their RealTime name and applicable calibration are identified in Table 1.

Table 1 Observation/Prediction matrix and travel-time and survival calibrations for COMPASS predictions (see www.cbr.washington.edu/crisprt ).

| Sp[1]. | Field Name | RealTime Name | Release Site | COMPASS Sites | Calibr’n |
|---|---|---|---|---|---|
| Y | Selected PIT-tagged fish | real | LWG | LGS to BON | Chin1 |

| | | | | | |
|---|---|---|---|---|---|
| Y | PIT-tagged Wild Run-At-Large | chin1pit* | LWG | LGS to BON | Chin1 |
| S | Snake River Wild Migrant | lgrStlhd* | LWG | LGS to BON | Stlhd |
| Y | Snake River ESU Spring/Summer | mcnChin1S | MCN | JDA to BON | Chin1 |
| S | Snake River ESU | mcnStlhdS | MCN | JDA to BON | Stlhd |
| S | Upper Columbia River ESU | mcnStlhdC | MCN | JDA to BON | Stlhd |

[1] Species: (Y= Yearling Chinook; S=Steelhead)
[*] NOAA/NMFS calibrated stock.

*Summaries*

Numerous summaries can be derived from the detailed COMPASS outputs that include fish routing and environmental conditions on a day-by-day and dam-by-dam basis, but encompassing measures such as overall passage and survival are the most revealing of the larger processes at work. Predicted and observed median passage day and arrival distributions as well as survival of stocks at various locations are compared. Observations that are available for comparison to model output are limited to detections of PIT-tagged fish in the bypass system. The real-time efficiency of the dam in routing these fish into the bypass system is unknown and therefore the observation is an index of passage only. Bypass efficiency (BE) varies in time at a dam and between dams.

The formula expressing BE considers these independent diversions and accounts for the fact that fish may be attracted to spill flow in preference to turbine flow. A formula for BE during a time step is:

$$BE = FGE \cdot (1 - SLE) \cdot (1 - F \cdot SE) \cdot 100 \quad (1)$$

- *F* = fraction of daily flow that passes in spill.
- *SE* = Spill Efficiency, the fraction of fish that pass in spill relative to the fraction of flow passing in spill. This is often > 1.
- *SLE* = Sluiceway Efficiency or Surface Bypass Collector Efficiency, in COMPASS, these are equivalent.
- *FGE* = Fish Guidance Efficiency, the fraction of fish passing into turbine intake that are bypassed.

BE is also equal to the ratio of counts at the blue dot to the count at the red dot (Figure 2). The counts at the blue dot position are the available observations. Improvements to the index using estimates of FGE, SLE, and SE are possible, and required for getting the actual count of arrivals correct. This is an integral part of the RealTime process for assessing the number of fish and their distribution at the first dam (LWG or MCN depending on the stock).

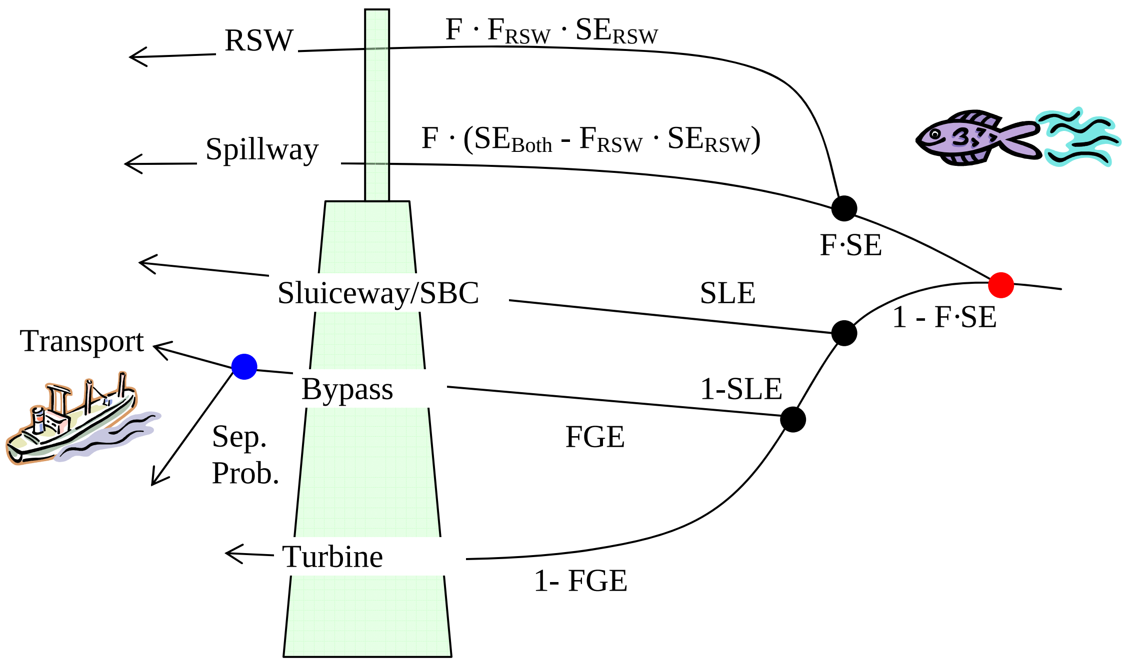



Figure 2 Possible routings of fish at a dam. The dots represent bifurcations of the population where there are only two possible routes. In the case of the RSW and Spillway routes, these do NOT necessarily sum to one. F = fraction of daily flow that passes in spill. $SE_{Both}$ = Spill Efficiency for both normal spillway and RSW, the fraction of fish that pass in spill relative to the fraction of flow passing in spill. This is often > 1. SLE = Sluiceway Efficiency or Surface Bypass Collector Efficiency, in COMPASS, these are equivalent. FGE = Fish Guidance Efficiency, the fraction of fish passing into turbine intake that are routed to the bypass system.

*MAD*

Travel prediction accuracy is measured in two ways: 1) with the difference between the day of a predicted percentile and its observed day (at the end of the season) or 2) with mean absolute deviation (MAD) between cumulative arrival percentages and corresponding predictions over the entire season. When the season ends, the cumulative percent passage of each stock, on each day, at each site are known. For every day during the season that a prediction was made, the absolute difference between the predicted and observed cumulative passage is computed and these are summed over all prediction days:

$$MAD = \frac{1}{N}\sum_{i}^{N}\left|F_i - \hat{F}_i\right| \times 100 \qquad (2)$$

where $F_i$ = cumulative passage percentage on day *i* computed from observations, $\hat{F}_i$ = predicted cumulative passage percentage *for day* i *made on day* i. This is a single indicator of the average discrepancy between the model and the data. However, the results are easy to skew downward by including more of the tails of the cumulative distributions because prior to (or after) the run it is easy to predict and observe that the run is at 0% (100%) which adds another zero to the sum in eq(2). We compute MAD when both the predicted and observed passage is between 0.5 and 99.5 percentiles. We found that summing over the 0 – 100 percentiles of the observations was not revealing due to extraneous outliers in stocks with very low numbers which in turn drops the MAD values to artificially low values because the peak of the run is a small part of the time period. MAD is also used to assess the utility of the calibration in modeling similar stocks.

A "snapshot" measure called the OneDay-MAD evaluates any COMPASS run against the final observed fish passage:

$$OneDayMAD = \frac{1}{N}\sum_{i}^{N}\left|F_i - \hat{F}_{ij}\right| \times 100 \qquad (3)$$

where $\hat{F}_{ij}$ = predicted cumulative passage percentage *for day* i *made on any day* j. There are three OneDayMAD computations of interest: "Post-MAD" for a COMPASS run when environmental conditions and LWG arrival distribution is known; "First-MAD" which evaluates an early run when both environmental and arrival are predicted; and "Pre-Post-MAD" which evaluates a special COMPASS run that uses the predicted environmental conditions with the final (known) arrival observations.

Fish Guidance Efficiency and Spill conditions during fish passage are also collected since they could affect interpretation of passage numbers. Spill, flow and other river conditions data is available from DART (http://www.cbr.washington.edu/dart/river.html). FGE is not directly measured but is computed as a function of environmental conditions and also was extracted from COMPASS input and output files for a seasonal, stock-specific average.

*Survival*

The chin1pit and lgrStlhd stocks correspond to wild yearling Chinook and steelhead controls of Snake River origin fish released at either Lower Granite Dam or McNary Dam. For the control data, weekly releases were separately analyzed for their survival to downstream locations (Faulkner, NOAA, pers comm. January 12, 2011.) These data-control survivals are compared to the COMPASS- generated survival. They *are* different measures. NOAA generated survivals are for each cohort and vary across the season. A single measure of survival is taken to be the count-weighted average of the weekly cohort survival across the season. COMPASS generates a prediction of the aggregated survival for the entire season every day it is run and these values tend to converge and stabilize over the season such that changes in the predicted survival become smaller from day to day as the season progresses.

Reach by reach survival are compared where possible and overall survival to BON or MCN are compared to the COMPASS model outputs.

## *Results*

The chin1pit and lgrStlhd COMPASS stocks were modeled on corresponding wild fish originating in the Snake River. The chin1pit calibration was also applied to the movement and survival of the "real" and "mcnChin1S" stocks in COMPASS. The lgrStlhd calibration was also applied to "mcnStlhdC" and "mcnStlhdS" stocks. The calibrated stocks "chin1pit" and "lgrStlhd" are the emphasis of the analysis and are identified in appropriate tables by shading.

*Summaries*

The counts of stocks observed at various locations are shown in Table 2. These are recorded counts in the bypass system, not necessarily the total number passing the dam. The declared median passage day which is the in-season day when COMPASS predicts "this day is the median passage day" is shown in Table 3. The observed day-of-year of median passage is shown in Table 4. They are all confined to a 6 day window at LWG, 15 days at MCN, and 6 days at BON. The differences between the declared and observed median passage days are in Table 5. These are uncertain for chin1pit (predictions near mid-season are not available). They are negative for lgrStlhd (they arrived earlier than predicted) in the Snake river and positive in the Columbia River. Details on passage are available from the web at the archive of Inseason Forecast predictions web page (http://www.cbr.washington.edu/crisprt/archive.html).

Details of the cumulative passage distribution of the individual stocks are shown in "Appendix 1: Observed Cumulative Counts" and illustrate the lack of symmetry in arrival detections across the season (time) and along the river (space). It is not possible for there to be more fish at a lower dam compared to an upper dam. If survival is perfect, the counts would be the same. All other mechanisms produce an increase in mortality and therefore steadily dropping counts as the cohorts move downstream. Model results are difficult to evaluate in light of observation errors such as these.

*Prediction accuracy: MAD*

The MAD values depict the average daily error in predicted percentage for the season and are shown in Table 6 (an alternative in Table 7). When MAD is very low, there is good correspondence between the prediction and the observations. MAD values over the 0.5-99.5% percentile range for chin1pit and lgrStlhd at MCN were 3.3% and 5.0% respectively. At BON, 4.4% and 14.7% respectively.

Final Day MAD (Post-MAD) uses the hindsight of the true release distribution and known flows and spill as shown in Table 8. At MCN, MAD values over the 0.5-99.5% range for chin1pit and lgrStlhd were 13% and 14% respectively. At BON, 16% and 24% respectively. Post-MAD compared to MAD at BON is increased at MCN and BON for both chin1pit and lgrStlhd.

Pre-Post-MAD, uses the hindsight of the true release distribution, but uses pre-season predictions of flow and spill, and is shown in Table 9. Pre-Post-MAD values over the 0.5-99.5% range for chin1pit and lgrStlhd at MCN were 1.6% and 10.1% respectively. At BON, 15.2% and 20.1% respectively.

There is no obvious explanation for why the Final Day MAD (theoretically best possible timing prediction) is worse than the Pre-Post MAD.

*Spill and Fish Guidance*

Spill conditions during passage influence passage routing and the number of detections at a dam. When spill is relatively uniform over the passage period, it is less likely to bias the passage distribution. Higher spill often means greater un-detected passage. Spill conditions and observed passage timing are illustrated in Figure 3. They are stable with conditions similar to 2009. This is a direct result of NMFS-BiOP stipulated spill levels which are targeted at specific flows or percentages (NMFS 2008). Spill at LWG was between 25% - 40% during most of the passage period but climbed to over 50% at the tail end of the passage. At BON, spill was above 40% during passage. LGS, JDA, and MCN had very stable spills throughout the season.

Fish have various routes through the dam (e.g. the spillway, surface collector, or turbine). Related to spill passage is the efficiency of the dam at routing non-spilled fish into the bypass system. Bypass fraction is based on fish guidance efficiency (FGE) and other measures. The ratio of all arriving fish that end up in the bypass system is the bypass fraction. Bypass fraction computed by COMPASS is shown in Table 10. For comparison, modeled FGE is shown as well. The bypassed fraction is always lower or equal to FGE (see Figure 2), and is sensitive to spill. BON still has very low values (comparable with 2008 and 2009) but some other dams are much more significant.

In a dam, the bypass system is where PIT-tagged fish are observed. Thus, high spill and low FGE both result in fewer observations. Depending on spill and the availability of other possible passage routes (Figure 2), the bypassed fraction may be a small fraction of the overall total (e.g. BON =0.11 for chin1pit, see Table 10). Since only bypassed fish are counted as "observed" this is the most important explanation for seemingly paradoxical results, e.g. relatively high observations at a downstream dam compared to an upstream dam (Appendix 1: Observed Cumulative Counts), and certainly means that observations in the bypass system alone can not be used for computing survival.

*Survival*

Modeled survival generally converges to a stable value as the season progresses as evidenced by the time series of the survival predictions (see Appendix 4: Survival Predictions with Data Controls). Time series of survival predictions made through the season are depicted in stages from LWG to MCN and MCN to BON. Final COMPASS-modeled survivals from LWG to BON in 2010 for chin1pit and lgrStlhd are 0.55 and 0.27 respectively. A summary of COMPASS generated survivals between dams is shown in Table 11 and Table 13 for the respective stocks (e.g. see http://www.cbr.washington.edu/crt/get?FishType:Stock:Year=chin1:real:&Forecast=1&Config=survival&DataSource=pit&River=snake&Input=crisp). The Chinook survivals are remarkably similar to 2009. The steelhead are distinctly lower (LWG to BON survival in 2009 was 0.41 for lgrStlhd).

COMPASS generated survivals can be compared in a limited way to control-data survival estimates (Table 12 and Table 14, respectively), but these are slightly different measures. Some of these model-data comparisons are shown in Figure 5. The controlled-release survivals were computed separately over the two sections of river (J. Faulkner, pers. comm., January 12, 2011) and are further aggregated as release count-weighted average of the survivals. From LWG to MCN, COMPASS predicted survivals of 0.77 and 0.53 for chin1pit and lgrStlhd respectively, corresponding data controls survivals were 0.75 and 0.80. Differences of 0.02 and 0.27. From MCN to BON, COMPASS predicted survivals of 0.72 and 0.50 while the data controls survivals were 0.64 and 0.79 respectively. Differences of 0.08 and 0.25.

Modeled steelhead survival appears to be anomalously low.

### *Results: Tables and Figures*

Table 2 Counts of yearling stocks used in this analysis passing PIT-tag detectors at six prediction sites for 2010. These are a subset of all PIT-tagged fish passing the sites.

| | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 4526 | 3725 | 1078 | 4328 | 949 | 2189 |
| chin1pit | 11982 | 10163 | 3389 | 10450 | 2680 | 5207 |
| lgrStlhd | 5753 | 8563 | 2148 | 3497 | 1648 | 5266 |
| mcnChin1S | - | - | - | 15583 | 3514 | 7633 |
| mcnStlhdC | - | - | - | 379 | 257 | 848 |
| mcnStlhdS | - | - | - | 3497 | 1648 | 5266 |

Table 3 Declared median passage day-of-year. This is the in-season day on which COMPASS identifies "this is the median arrival day". Note: Day 135 = May 15. Stock "chin1pit" has a gap in predictions overlapping their median passage at all dams

| Stock | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 122 | 130 | 133 | 138 | 143 | 145 |

| | | | | | | |
|---|---|---|---|---|---|---|
| chin1pit | NA | NA | NA | NA | NA | NA |
| lgrStlhd | 131 | 138 | 140 | 145 | 152 | 155 |
| mcnChin1S | - | - | - | 137 | 145 | 147 |
| mcnStlhdC | - | - | - | 133 | 141 | 143 |
| mcnStlhdS | - | - | - | 137 | 143 | 146 |

Table 4 Observed median passage day-of-year. Note: Day 135 = May 15.

| Stock | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 129 | 138 | 144 | 134 | 142 | 136 |
| chin1pit | 134 | 140 | 156 | 138 | 147 | 140 |
| lgrStlhd | 132 | 138 | 141 | 137 | 141 | 138 |
| mcnChin1S | - | - | - | 135 | 141 | 138 |
| mcnStlhdC | - | - | - | 131 | 131 | 135 |
| mcnStlhdS | - | - | - | 137 | 141 | 138 |

Table 5 Difference between Declared and Observed median arrival day-of-year. (Table 3 - Table 4) Positive (negative) values mean the prediction was late (early). Note: chin1pit predictions were *not* available on median passage prediction day.

| Stock | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 1 | -5 | -9 | 5 | 2 | 10 |
| chin1pit | - | - | - | - | - | - |
| lgrStlhd | -8 | -8 | -10 | 0 | 4 | 9 |
| mcnChin1S | - | - | - | -4 | 3 | 8 |
| mcnStlhdC | - | - | - | -1 | 4 | 2 |
| mcnStlhdS | - | - | - | -7 | -6 | -1 |

Table 6 Mean Absolute Deviation (MAD) between predicted and observed passage distributions for selected sites and each stock using (0.5 -99.5%). They are computed over longer “tails” of the arrival distribution and are always less than MAD computed as in Table 7

| | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 2.0 | 5.2 | 16.0 | 7.5 | 6.6 | 12.4 |
| chin1pit | 2.6 | 1.6 | 2.3 | 3.3 | 1.0 | 4.0 |
| lgrStlhd | 10.4 | 9.0 | 16.7 | 5.0 | 7.3 | 14.7 |
| mcnChin1S | | | | 3.6 | 3.0 | 9.2 |
| mcnStlhdC | | | | 9.6 | 7.3 | 3.4 |
| mcnStlhdS | | | | 8.4 | 8.8 | 4.2 |

Table 7 Alternative Mean Absolute Deviation (MAD) between predicted and observed passage distributions for selected sites and each stock using (1 -99%). They are computed over the shorter “tails” of the arrival distribution and are always greater than MAD computed as in Table 6 because it uses a more central portion of the run.

| | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 2.2 | 5.7 | 17.2 | 8.6 | 7.2 | 13.6 |
| chin1pit | 3.1 | 2.0 | 2.7 | 3.9 | 1.0 | 4.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| lgrStlhd | 12.1 | 10.0 | 17.8 | 5.4 | 8.0 | 15.6 |
| mcnChin1S | | | | 4.2 | 3.3 | 9.9 |
| mcnStlhdC | | | | 9.8 | 7.3 | 3.4 |
| mcnStlhdS | | | | 9.4 | 9.4 | 4.5 |

Table 8 Final Day (Post) MAD. Allows for full knowledge of release distributions and best environmental information. Note that all Chinook stocks use the "chin1pit" calibration and all steelhead stocks use the "lgrStlhd" calibration.

| | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| real | 6.1 | 6.2 | 18.0 | 7.4 | 6.8 | 13.7 |
| chin1pit | 1.7 | 3.3 | 11.8 | 12.8 | 5.4 | 15.9 |
| lgrStlhd | 1.7 | 3.1 | 6.9 | 14.0 | 15.6 | 24.1 |
| mcnChin1S | | | | 2.0 | 5.7 | 11.5 |
| mcnStlhdC | | | | 2.5 | 9.1 | 13.8 |
| mcnStlhdS | | | | 1.5 | 7.4 | 13.4 |

Table 9 Pre-Post-MAD. Compares year-end observations with a COMPASS run that used early-season's anticipated environmental information (March 15) combined with full knowledge of release distributions (observations).

| Stock | LWG | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|---|
| chin1pit | 1.3 | 3.5 | 13.1 | 1.6 | 5.4 | 15.2 |
| lgrStlhd | 1.1 | 2.8 | 9.5 | 10.1 | 11.7 | 20.1 |

Table 10 Modeled bypass fraction in 2010. Fish released at LWG or MCN have theoretical bypass fractions = 1 because the observed counts are spill-adjusted prior to creating a release. Downstream, only fish entering the bypass system are enumerated and counted as observed. Some 2008 and 2009 values are shown for comparison.

| COMPASS effective Bypass Fraction | LGS | LMN | MCN | JDA | BON |
|---|---|---|---|---|---|
| real | .25 | .09 | .35 | .19 | .12 |
| chin1pit | .25 | .12 | .33 | .19 | .11 |
| lgrStlhd | .24 | .14 | .15 | .14 | .07 |
| mcnChin1S | - | - | - | .19 | .12 |
| mcnStlhdC | - | - | - | .11 | .08 |
| mcnStlhdS | - | - | - | .12 | .08 |
| 2009 chin1pit | .31 | .22 | .36 | .25 | .11 |
| 2009 lgrStlhd | .37 | .32 | .15 | .15 | .08 |
| 2008 chin1pit | .24 | .21 | .31 | .29 | .09 |
| 2008 lgrStlhd | .24 | .37 | .18 | .25 | .06 |

Table 11 COMPASS generated survivals for chin1pit in 2010. Shaded cells indicate there is no corresponding data-based estimate of survival

| | LGS | LMN | IHR | MCN | JDA | TDA | BON |
|---|---|---|---|---|---|---|---|
| LWG | 0.91 | 0.87 | 0.84 | 0.77 | 0.65 | 0.58 | 0.55 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LGS | | 0.96 | 0.92 | 0.85 | 0.72 | 0.64 | 0.61 |
| LMN | | | 0.96 | 0.89 | 0.75 | 0.67 | 0.64 |
| IHR | | | | 0.92 | 0.78 | 0.69 | 0.66 |
| MCN | | | | | 0.84 | 0.75 | 0.72 |
| JDA | | | | | | 0.89 | 0.85 |
| TDA | | | | | | | 0.95 |

Table 12 Weighted-average survival for control-release data on Snake River Wild Chinook in 2010 (Faulkner pers comm. January 12, 2011). Shaded cells indicate there is no data.

| | LGS | LMN | IHR | MCN | JDA | TDA | BON |
|---|---|---|---|---|---|---|---|
| LWG | 0.96 | 0.87 | | 0.75 | | | |
| LGS | | 0.91 | | | | | |
| LMN | | | | 0.87 | | | |
| IHR | | | | | | | |
| MCN | | | | | 0.94 | | 0.64 |
| JDA | | | | | | | 0.68 |
| TDA | | | | | | | |

Table 13 COMPASS generated survivals for lgrStlhd in 2010. Shaded cells indicate there is *only* a COMPASS estimate of survival (no corresponding control-release data estimates of survival)

| | LGS | LMN | IHR | MCN | JDA | TDA | BON |
|---|---|---|---|---|---|---|---|
| LWG | 0.86 | 0.74 | 0.65 | 0.53 | 0.37 | 0.30 | 0.27 |
| LGS | | 0.85 | 0.75 | 0.62 | 0.43 | 0.35 | 0.31 |
| LMN | | | 0.88 | 0.72 | 0.50 | 0.40 | 0.36 |
| IHR | | | | 0.82 | 0.57 | 0.46 | 0.41 |
| MCN | | | | | 0.69 | 0.56 | 0.50 |
| JDA | | | | | | 0.81 | 0.72 |
| TDA | | | | | | | 0.90 |

Table 14 Weighted-average survival for control-release data on Snake River Steelhead in 2010 (Faulkner pers comm. January 12, 2011). Shaded cells indicate no data.

| | LGS | LMN | IHR | MCN | JDA | TDA | BON |
|---|---|---|---|---|---|---|---|
| LWG | 1.01 | 0.86 | | 0.80 | | | |
| LGS | | 0.86 | | | | | |
| LMN | | | | 0.94 | | | |
| IHR | | | | | | | |
| MCN | | | | | 0.82 | | 0.79 |
| JDA | | | | | | | 0.98 |
| TDA | | | | | | | |

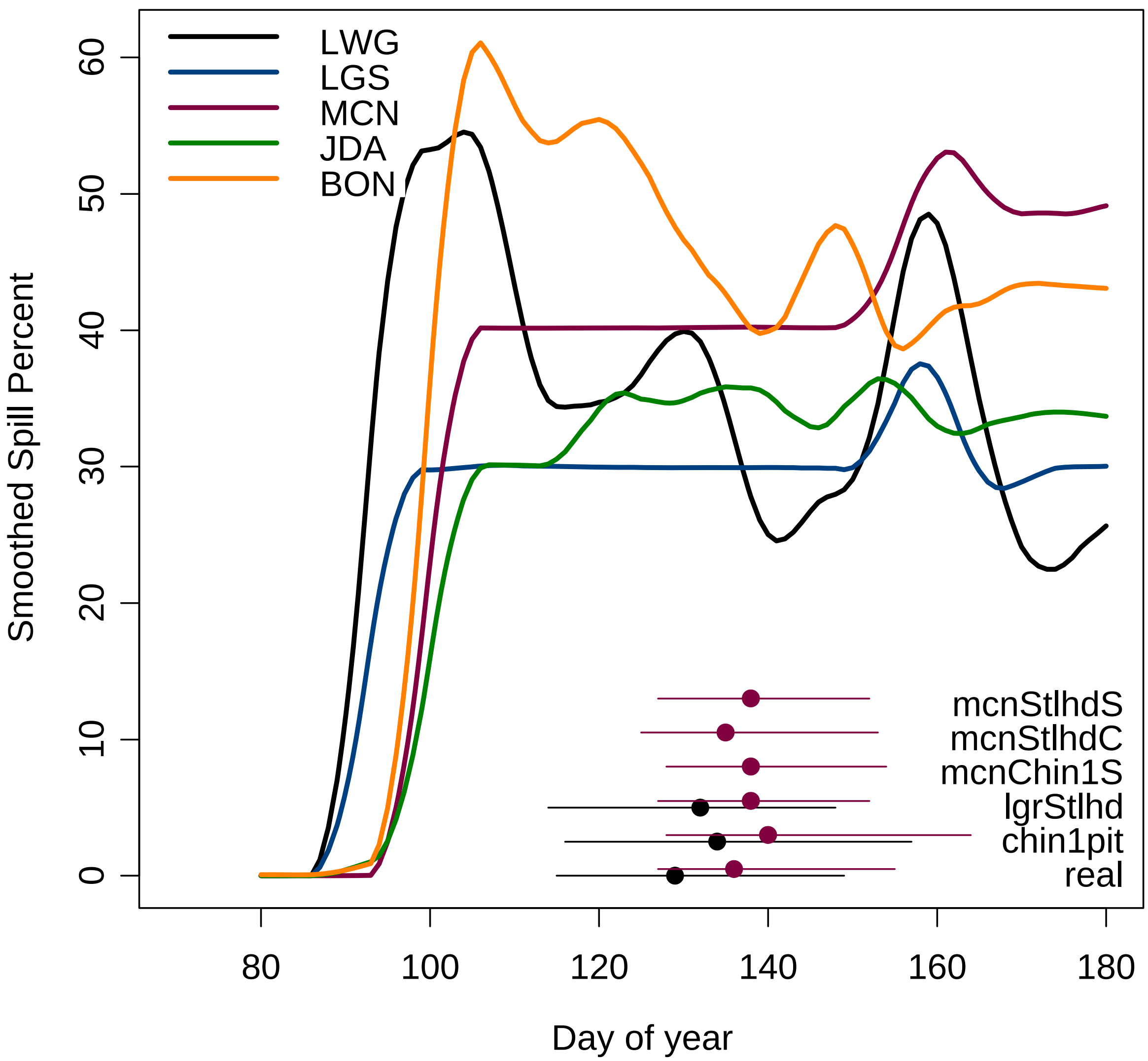



Figure 3 Spill percent (smoothed) at dams during passage in 2010. Stock abbreviations and whiskers of the middle 80% of the observed fish and median day (point) passage at LWG (black) and BON (red) at the bottom. We infer that the passage at intermediate dams as being between the first (LWG) and last (BON).

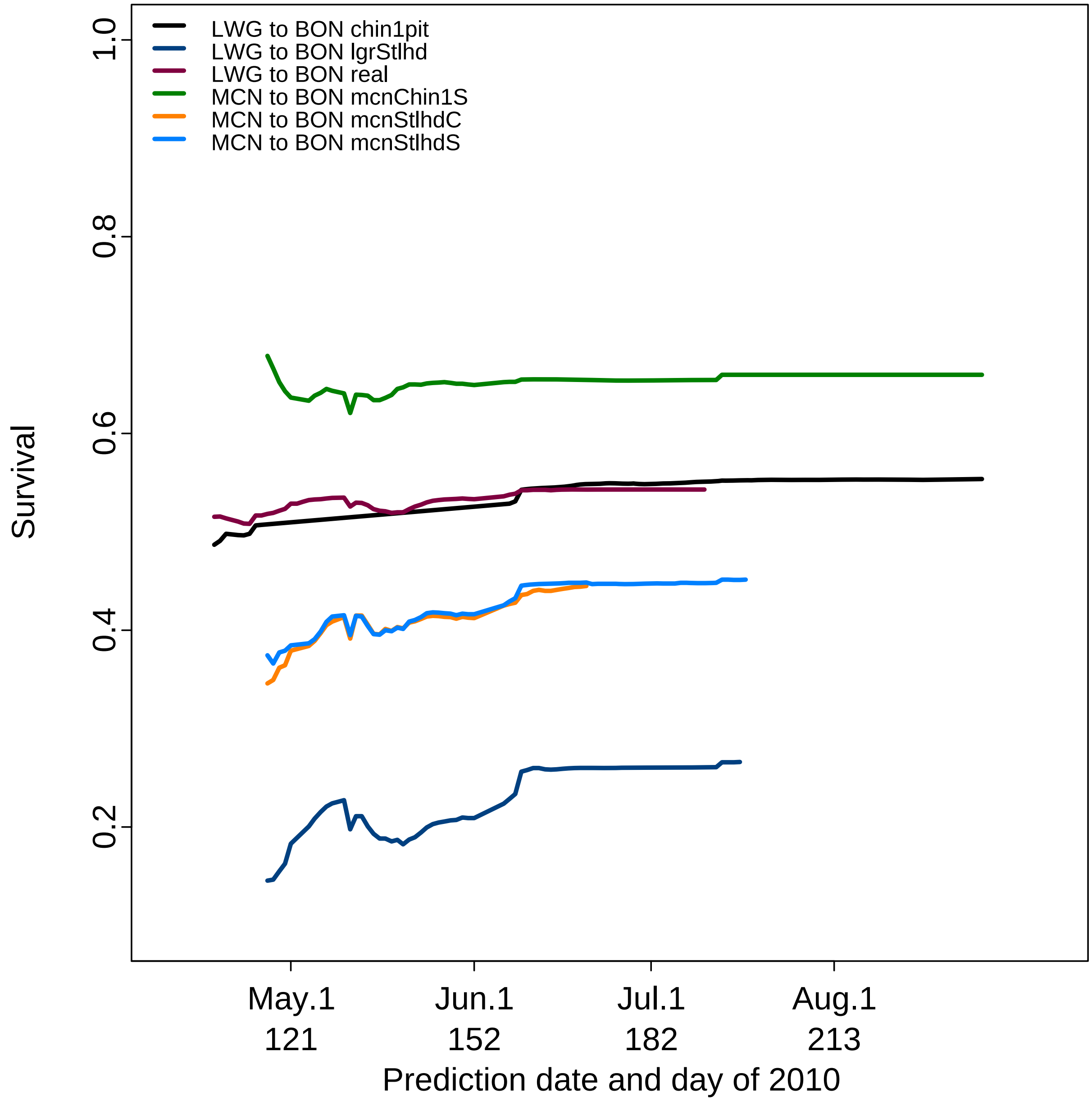



Figure 4 Predicted survivals to BON for each stock as the season progressed.

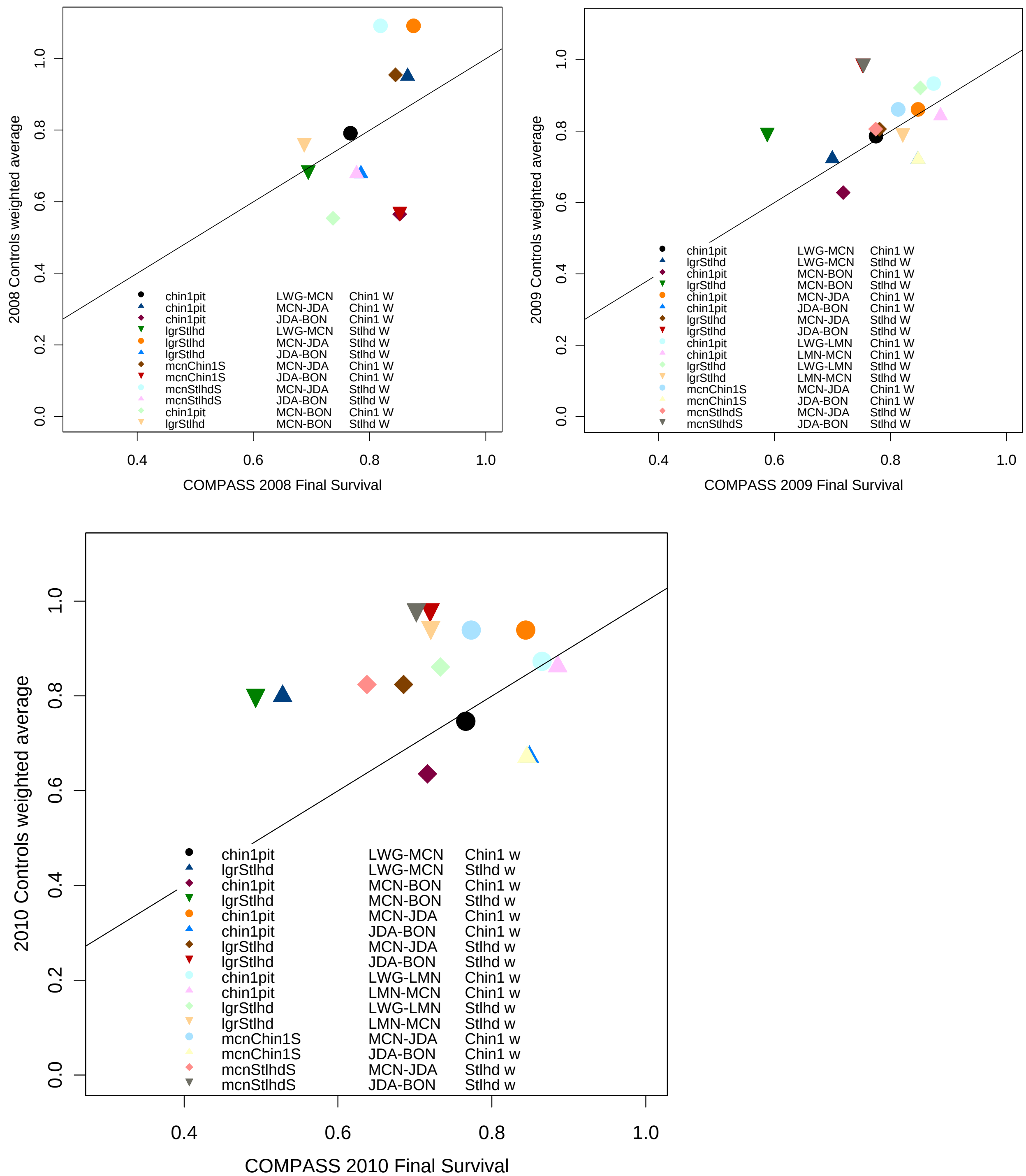



Figure 5 Comparison of control survival data against COMPASS-generated survivals. The 1:1 line is shown. There are four calibrations available to COMPASS: Steelhead and Chinook in either the lower Snake River or the mainstem Columbia River. Years 2008 and 2009 are above the current year.

### *Summary and Discussion*

There are several significant considerations that make prediction of travel and survival challenging. Broadly, these challenges relate to environmental conditions, stock-specific calibrations and bias in observations. Unfortunately, they cannot always be clearly distinguished. For 2010, steelhead survival is modeled very low while Chinook survival is nearly identical as modeled in 2009.

*River Conditions: Flow and Spill*

In order to model the movements and survival of fish in the river, COMPASS requires environmental conditions for each day of the year, principally flow, spill and temperature. Egregious errors in flow prediction could make a meaningful difference in passage and survival predictions. Preseason predictions of water must be used with relevant updates made as the season progresses. These are obtained from flow forecasts provided by the Bonneville Power Administration, with observations updated daily from DART (http://www.cbr.washington.edu/dart/river.html). In 2010, flow conditions at both LWG and BON during the main part of the migration (~April 10 to May 30 at LWG) were below the 10 year average compared to 2009 when flows were higher than the average (Figure 6). Figure 7 shows available early flow forecasts from April 18 and May 15 (days 108 and 135), and the final observations at LWG and BON dams. The predictions of flow were very close to the observed flow this year. Spills are stipulated very explicitly and have little variation between years. Since river elevations are also very close to 2009 levels (see http://www.cbr.washington.edu/dart/river.html) the reduced flows of 2010 compared to 2009 therefore imply a reduction in overall water velocity and therefore increased travel time and decreased survival a mechanism that COMPASS incorporates explicitly. However, modeled survivals to BON are remarkably stable for chin1pit between 2009 and 2010 despite these differences, while lrgStlhd modeled survivals were lower than in 2009. The lower survivals for steelhead (compared to 2009) is at least consistent with this.

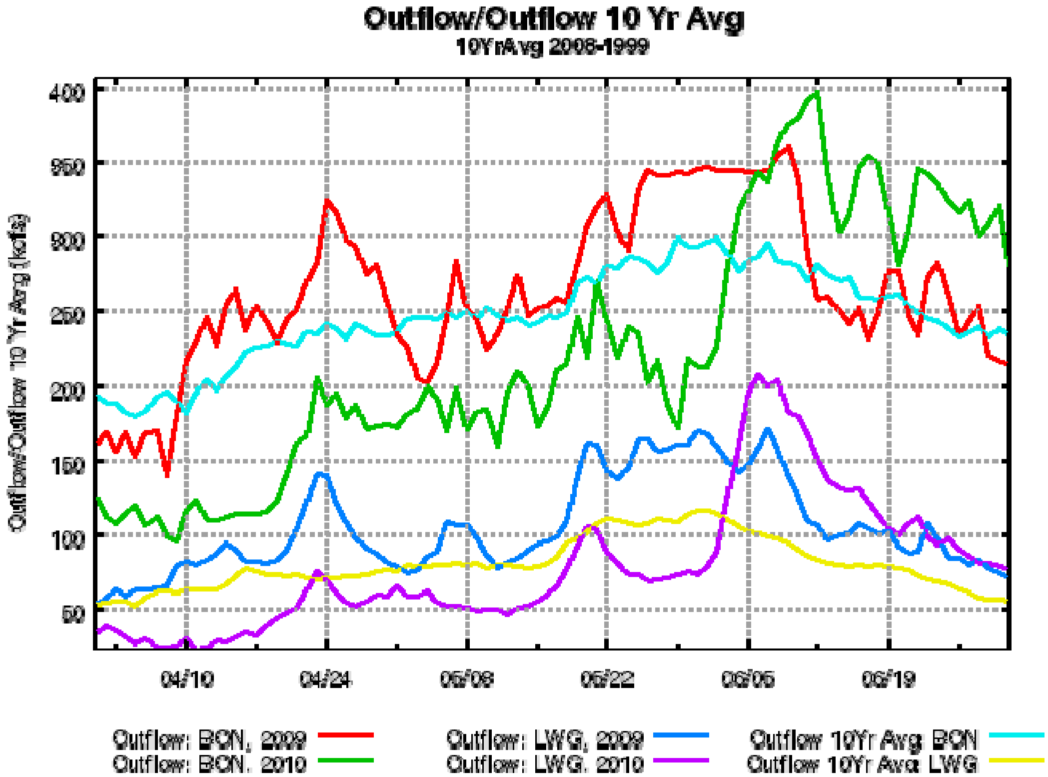



Figure 6 Comparisons of flows at LWG and BON in 2010 and 2009 during the outmigration relative to the previous 10 year average. Flows in 2010 (2009) were below (above) average.

Using the earliest available (10 March) flow predictions and hindsight knowledge of the exact arrivals at Lower Granite Dam, we ran the model to specifically address the importance of the pre-season flow predictions. MAD was computed with eq(3). The differences in timing and/or survival are not judged against each other but are compared to the final passage observations and survival controls. These special model runs called Pre-Post Runs are compared to the Post (or Final) Run when all known fish passage and environmental data can be used for a retrospective of the year. Differences between these two runs show the importance of the pre-season flow predictions.

There is a very large gap (i.e. MAD, see Figure 9) between the post/pre-post predictions and the final observations at BON. However, the flow component of the travel time model should result in the fish arriving quickly because the 2010 flows were greater than the 10 year average from 1999-2008 (see Figure 6) yet the predictions as a group are paradoxically late. Passage at certain upstream dams (e.g. LMN) may be better predicted, but a lack of consistency is a much greater concern. In general, the sensitivity of the travel time component of the model is verified in the plots of daily survival and travel time (Figure 18 - Figure 20) where there is a sudden drop in travel time of chin1pit and lgrStlhd for releases in the first week of June corresponding to the large jump in flows and spills shown in Figure 7and Figure 8. The model appears to be correctly sensitive and therefore imperfect flow predictions are not responsible for anomalous modeling.

A dramatic change in the spill pattern during the run can easily bias the timing observations by allowing more fish to pass the dam undetected. At BON, the level of spill may not be as important as the fact that the bypass fraction is quite low and therefore sensitive to low passage numbers, and variation in bypass or spill flow. The spill volumes were quite steady (Figure 8), but the fractions varied at LWG and BON and dropped over the season  (Figure 3) except near the end of the runs in early June when they jumped along with the flows. Assuming that higher spill percentage results in higher un-detected passage then we should observe a disproportionate fraction of the run near the beginning instead of the end of the run as the spill levels increase. In fact, the observations precede the model (Appendix 2: Timing Observations and Predictions and Figure 9) which is consistent this interpretation, but the runs are very close to their ends and the number of fish affected is a small fraction of the total run so the magnitude of the problem is still unexplained.

*Observations*

Errors in model-to-data timing comparisons are often related to problems in detecting fish as they pass the dam. This has been a problem for years (Beer et al. 2007) and continues to be so. Spill variability is related to observation variability because it creates a bias over time in the proportion of fish passing the detectors, and skews the passage distributions. When cumulative passage curves at adjacent dams touch or cross in time series plots, it is an indicator of detection bias (see Appendix 1: Observed Cumulative Counts). A *change during the run* in spill efficiency, fish guidance efficiency or any other influence on dam passage routes can create this.

Second, when downstream detectors count more fish than those upstream of it then fish are getting through the upper dam(s) without detection (see Table 2 and Appendix 1: Observed Cumulative Counts). This could happened due to variable configuration of the dams, differential spill percentage encountered by the cohort as it passes downstream, or variability in the efficiency of moving fish into the bypass system. In Figure 13, for example, the chin1pit passage at LWG is distinctly trimodal. It continues to be modeled and observed as trimodal through the next Snake River dam (LGS) but becomes bi-modal at LMN. Apparently, the first "wave" is not observed at LMN but shows up again at MCN and JDA. We expect the trimodal distribution to move downstream in a fairly consistent pattern. Having it lose one of these modes at an in-between dam and then have it observed again downstream suggests that the detectors have not found the fish and not that the survival or travel time is disrupted for these fish. The data-control survivals of hatchery Chinook to LMN are >1, and then from LMN to MCN are anomalously low both of which suggest an observation problem.

*RealTime inputs*

The inputs from program RealTime are based on observations and extrapolated forward in time so that a complete release prediction is available for COMPASS. There is not yet any way to precisely anticipate the fish arrivals, so RealTime's pattern matching algorithm uses all to-date observations of fish in the bypass system at LWG and compares the available information to historical patterns. In addition, the observations of counts of fish in the bypass system are modified daily according to an estimate of the site's bypass efficiency. This is one reason the prediction and the observation do not match exactly at the release dams (MCN and LWG) and there may be differences in median passage day with MAD > 0%. The input distribution on any given day is the best available but may be significantly different from the actual distribution which is not known until the end of the season. In 2008, the chin1pit group of fish was unimodal, in 2009 bi-modal and in 2010, tri-modal. Steelhead were bi-modal in 2010.

In the early season, however predictions of the run distribution are basically unimodal. Since the distribution is recomputed daily as fish arrive, the median arrival day is not known exactly and therefore MAD at the release site can be significant, although it is generally lower than at downstream locations. In fact, MADs for chin1pit and lgrStlhd at LWG are 2.6 and 10.4, respectively, improved for chin1pit and worse for lgrStlhd compared to 2009. In Figure 10 it is apparent that the prediction of passage is pushed later three successive times for the Chinook which corresponds to the three modes of the chin1pit distribution. (Note where the red line moves horizontally or dips down in the Chinook plot). The steelhead fish are similar at mid-May. Skewed predictions are biased inputs to COMPASS that propagate downstream. Since COMPASS predictions at downstream locations are compared to the observations, input errors are propagated through model results. Multi-modal distributions at release tend to be smoother at downstream locations due to spreading of the population controlled by specific parameters in the input file.

*Travel-time Calibrations*

In principle, the Post predictions of travel time and survival should be the best possible. Although it is a hindcast of the passage, it is also a measure of the effectiveness of the calibration in terms of a validation. As a timing assessment, it has the best possible inputs: observations of all conditions in the system and the correct distribution of fish at the uppermost dam. Using the final run as the prediction of each day's percentiles and computing MAD gives our best possible measure of the model's ability to anticipate the timing of the fish: Final-Day MAD (see Table 8). This does not always improve and the reasons for that are not necessarily consistent, for example a survival bias and an observation bias could reinforce or compensate for each other.

If any travel calibrations are incorrect, it would appear as a consistent or increasing bias in travel time estimation (see Appendix 2: Timing Observations and Predictions). If the discrepancy gets worse, then the travel-time modeling may be suspect. Having the prediction curves lie to one side of the corresponding observations and steadily increasing may suggest a systematic error such as the calibration. Final-MAD for the lgrStlhd increases steadily downstream of LWG. Another source of timing errors could be that the fish have different rates in the different reservoirs. There are in fact two migration rate equations used distinctly for the upper and lower portions of the river, but further discrimination may not be possible ever with the available data. In the early season, poor timing predictions are at least in part due to the assumed input distribution of fish at LWG which are then propagated through the system, but at the end of the season, the distribution of fish are well known.

*Survival Calibrations*

Survival modeling is compared to the control-release data. Our discussion focuses on the wild fish but hatchery fish are also illustrated in Appendix 4: Survival Predictions with Data Controls. Modeled survival through MCN is very comparable to the data for chin1pit. COMPASS reported 0.77 and the data-controls weighted average was 0.75. A difference of 0.02. The lgrStlhd COMPASS survival to MCN was 0.53 and the control was 0.80. A much larger 0.27 difference. From MCN to BON, COMPASS reported 0.72 and 0.50 for chin1pit and lgrStlhd, and the data-controls were 0.64 and 0.79, respectively. Differences of 0.08 and 0.29. Again, the steelhead with a large discrepancy. The control-release survival data for lgrStlhd are consistently above the modeled results. In years past, the section of river between JDA and BON seemed to be the most variable in the system but this year differences seem more systematic. It is not clear what is the fundamental reason for the low modeled survivals, but understanding survival-sensitive processes is essential to meaningful calibrations for COMPASS and beginning to reconcile the differences between the two methods of evaluating survival: control-release studies and COMPASS modeling.

### *Summary and Discussion Tables and Figures*

Table 15 Comparison of passage and survival to BON showing the relative importance of the environmental predictions. MAD values in this table use the OneDay-MAD computation (eq(3)). The early in-season run is when both arrival and environment are predicted (April 18, April 27). The post-season run is when both the arrival and environment are known. The Pre-Post run used predicted environmental conditions and known LWG arrival distributions.

| | Runs | Env. | LWG Passage | COMPASS median passage (BON) | COMPASS Survival to BON | MAD |
|---|---|---|---|---|---|---|
| Chin1 | Early (Apr 18) | Predicted | Predicted | 158 | 55 % | 19.7 |
| | Post | Known | Known | 151 | 56% | 14.8 |
| | Pre-Post* | Predicted | Known | 151 | 55 % | 15.2 |
| Stlhd | Early (Apr 27) | Predicted | Predicted | 145 | 41 % | 15.3 |
| | Post | Known | Known | 153 | 41% | 22.7 |
| | Pre-Post* | Predicted | Known | 150 | 41 % | 20.1 |

*March 15 water prediction & observed (final) fish arrival at LWG

Table 16 Difference in days between *final* predicted 10, 50 and 90 percentiles and the corresponding observed percentiles. Compare to Table 5.

| Difference between Predicted 10% and Observed 10% | | | | | | |
|---|---|---|---|---|---|---|
| | LWG | LGS | LMN | MCN | JDA | BON |
| real | 0 | 2 | -13 | 5 | 7 | 10 |
| chin1pit | 1 | 4 | -12 | 8 | 8 | 11 |
| lgrStlhd | 1 | 1 | 3 | 6 | 10 | 11 |
| mcnChin1S | | | | 1 | 6 | 9 |
| mcnStlhdC | | | | 2 | 3 | 4 |
| mcnStlhdS | | | | 1 | 4 | 4 |
| **Difference between Predicted 50% and Observed 50%** | | | | | | |
| | LWG | LGS | LMN | MCN | JDA | BON |
| real | -7 | -8 | -11 | 4 | 1 | 9 |
| chin1pit | -1 | 0 | -14 | 8 | 4 | 13 |
| lgrStlhd | -1 | 0 | -1 | 8 | 11 | 17 |
| mcnChin1S | | | | 2 | 4 | 9 |
| mcnStlhdC | | | | 2 | 10 | 8 |
| mcnStlhdS | | | | 0 | 2 | 8 |
| **Difference between Predicted 90% and Observed 90%** | | | | | | |
| | LWG | LGS | LMN | MCN | JDA | BON |
| real | -5 | -7 | -9 | 5 | -6 | 6 |
| chin1pit | 1 | 0 | -2 | 6 | 0 | 5 |
| lgrStlhd | 2 | 1 | -5 | 7 | 3 | 14 |
| mcnChin1S | | | | 2 | -5 | 5 |
| mcnStlhdC | | | | 4 | -1 | 12 |
| mcnStlhdS | | | | 0 | -2 | 9 |

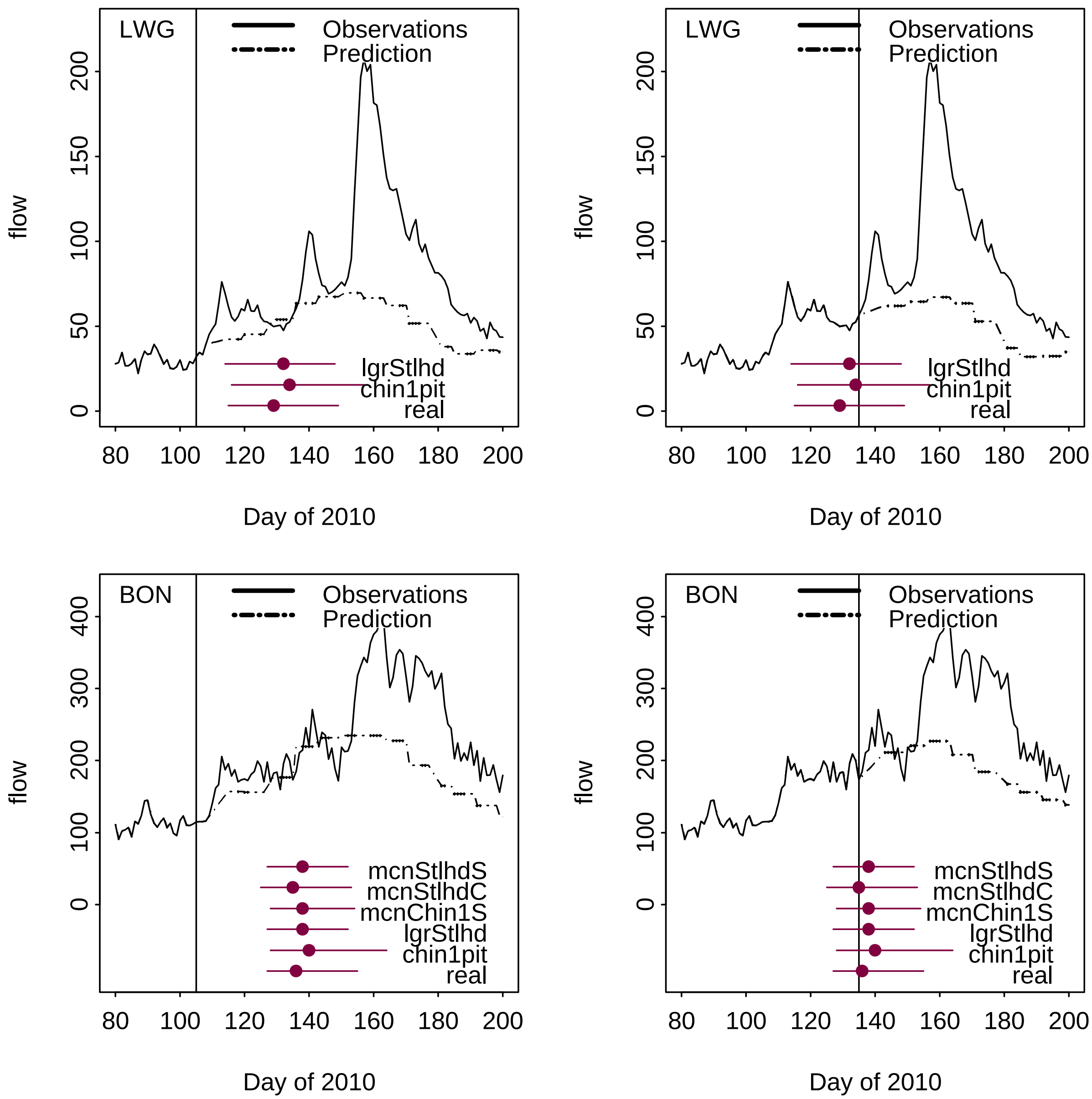



Figure 7 Predicted flow for 2010 made on April 18 and May 15 (day 108 and 135) and final observed flow at LWG and BON. Vertical lines show the prediction day. Passage metrics are at LWG and BON showing median day and 10% to 90% passage whiskers. The flows were well predicted for most of the migration season. There was a large unanticipated spike in flow near the very end of passage.

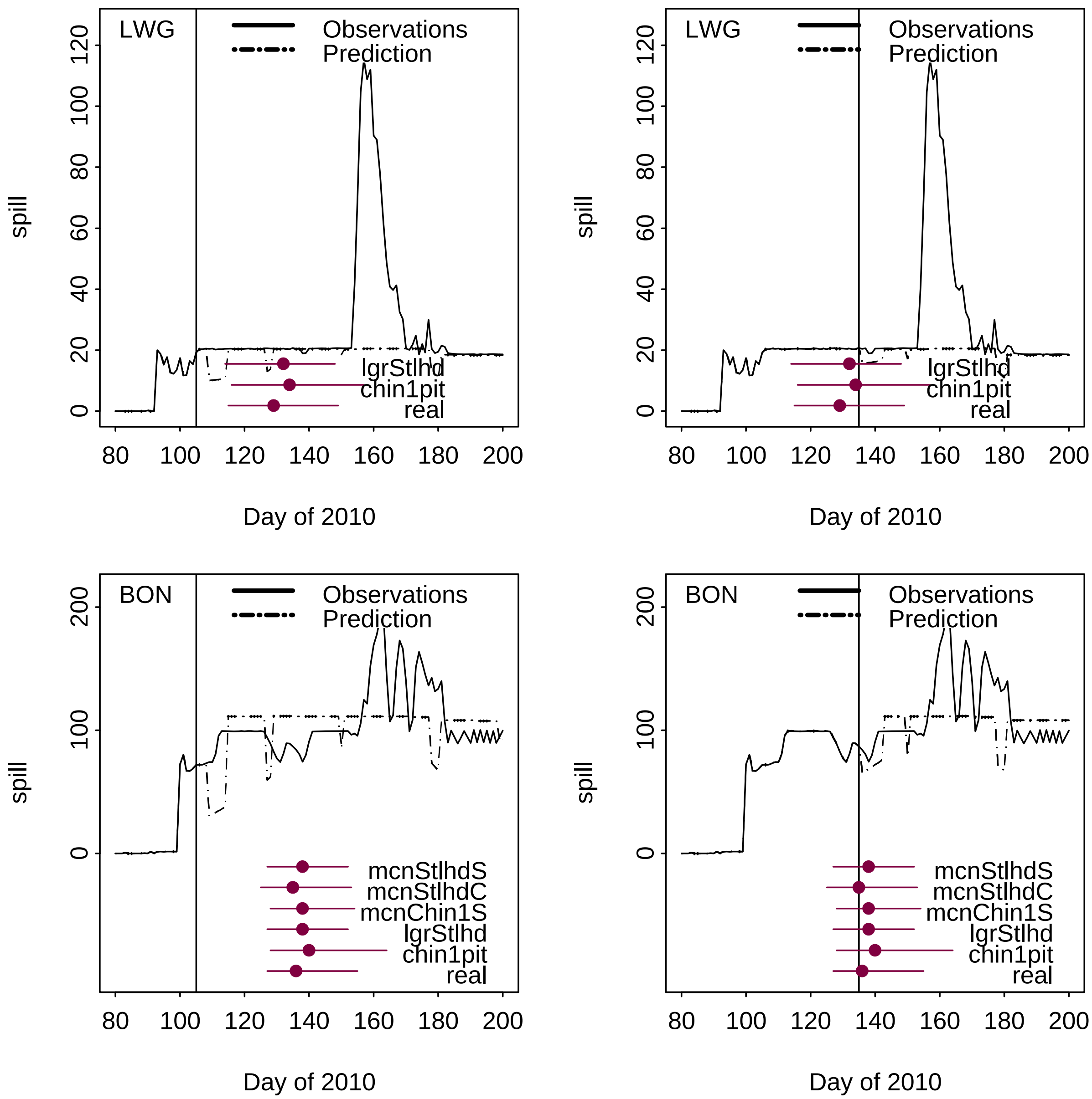



Figure 8 Predicted spill for 2010 made on April 18 and May 15 (day 108 and 135) and final observed spill at LWG and BON. Vertical lines show the prediction day. Spill volumes are explicitly stipulated at these two sites. Passage metrics are at LWG and BON showing median day and 10% to 90% passage whiskers. The spikes in spill correspond to anomalously large flows near the end of the passage season.

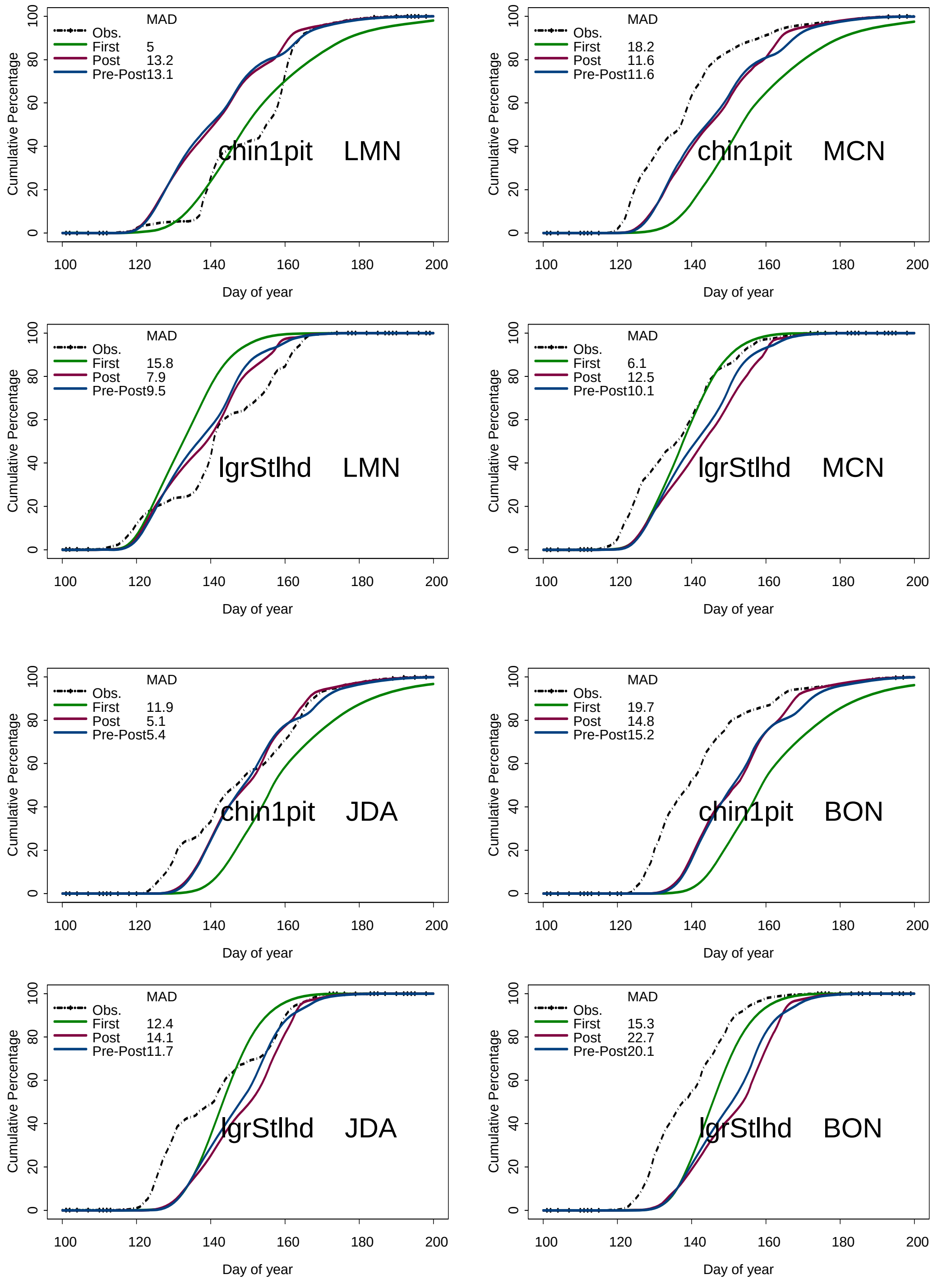
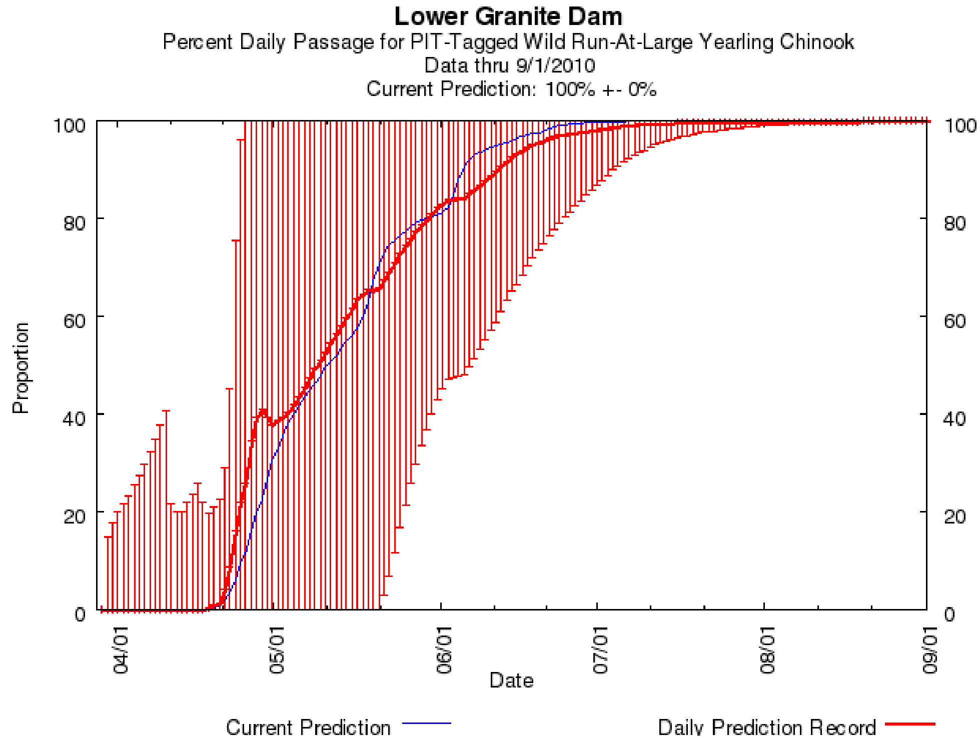



Figure 9 Comparison of LMN, MCN, JDA, and BON passage using three distinct COMPASS runs for chin1pit and lgrStlhd. “First” is the April 15 prediction based on anticipated arrivals and anticipated environmental conditions. “Post” uses all observations. “Pre-Post” uses the record of observed arrivals and the preseason environmental predictions from April 15. Note: May 1 = Day 121.



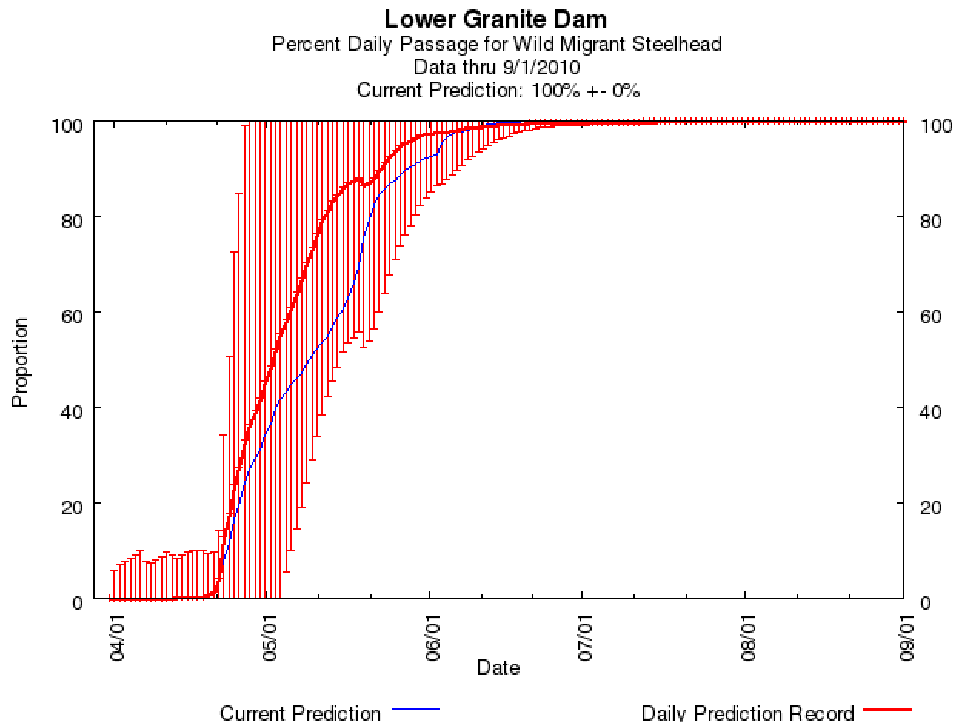




Figure 10 RealTime predictions and observations of Chinook and steelhead passing LWG in 2010 (see also http://www.cbr.washington.edu/crisprt/index_snake_pit.html). Vertical bars show the 95% confidence interval. The current prediction is the redistribution of the passage based on hindsight. Note: May 1 = Day 121.

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NMFS. (2008). "Remand of 2004 Biological Opinion on the Federal Columbia River Power System (FCRPS) including 19 Bureau of Reclamation Projects in the Columbia Basin (Revised pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon)." Retrieved August 18, 2010, from https://pcts.nmfs.noaa.gov/pls/pcts-pub/pcts_upload.summary_list_biop?p_id=27149.

Zabel, R.W. and 11 other authors. 2008. Comprehensive passage (COMPASS) model: a model of downstream migration and survival of juvenile salmonids through a hydropower system. Hydrobiologia. 609:289-300.

## Appendix 1: Observed Cumulative Counts

First, the totals of each stock observed at the six dams in 2010 are shown (Figure 11). Then, the cumulative observations of stocks at counting dams are shown (Figure 12) separated by stock. Ordinate (y axis) scales vary. The lines span the entire range of the run from first detection to last.

Accurate profiles are expected to be sequenced with more fish upstream and generally decreasing downstream due to mortality or accidental transport. However, each location is more or less effective at detecting tagged fish in addition to variations in dam passage routing. Increases in counts from upstream to downstream are a clear indication that observation errors are significant — true for all six of these stocks. JDA and LMN are particularly suspect.

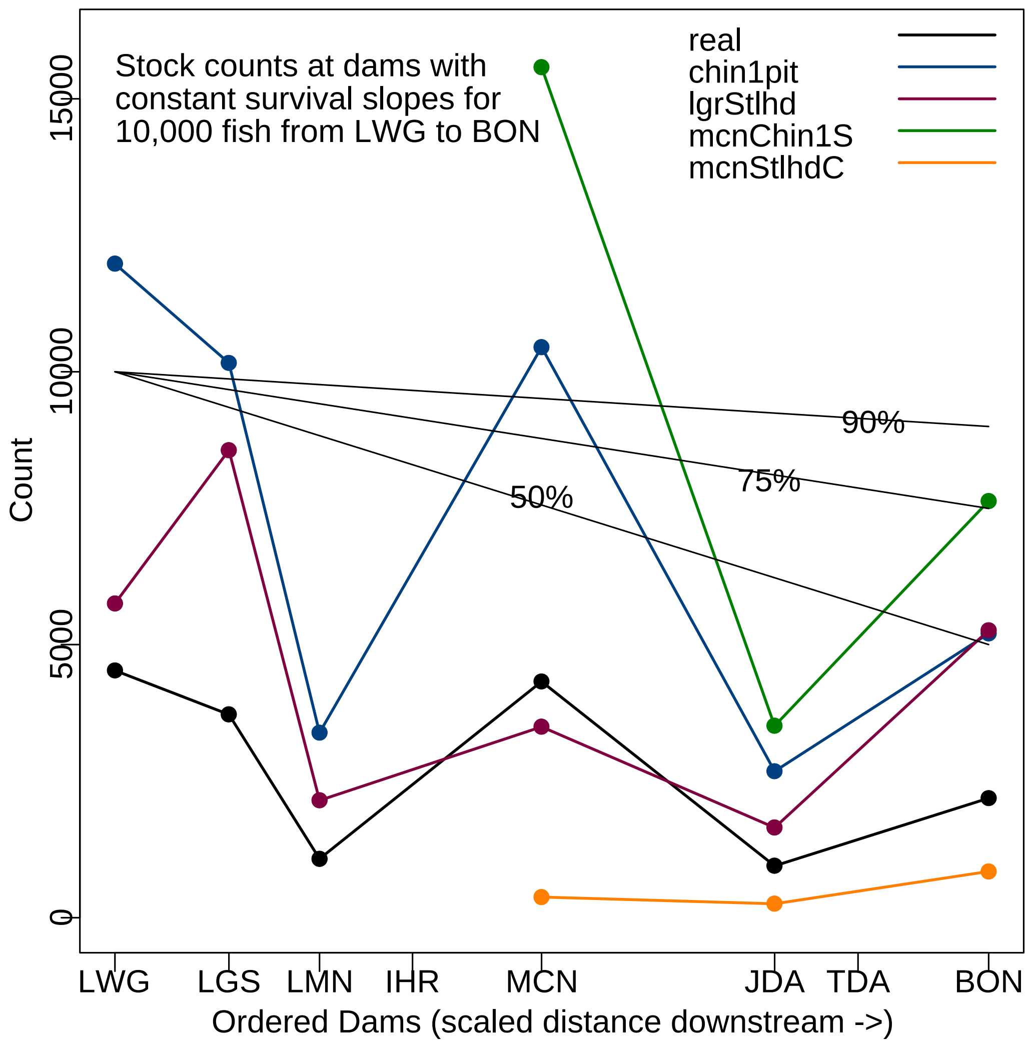
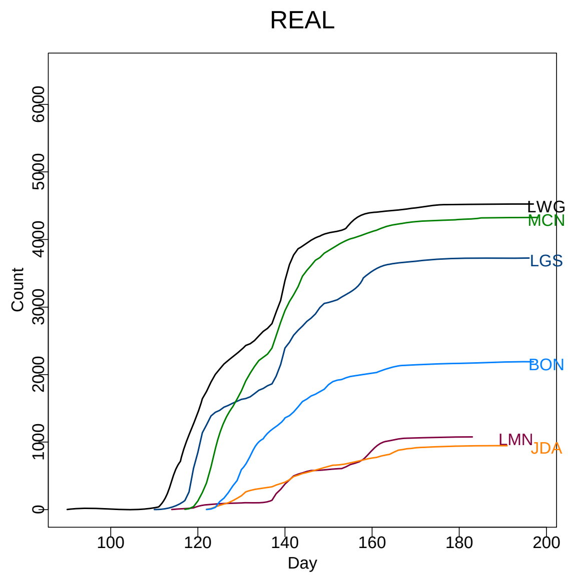
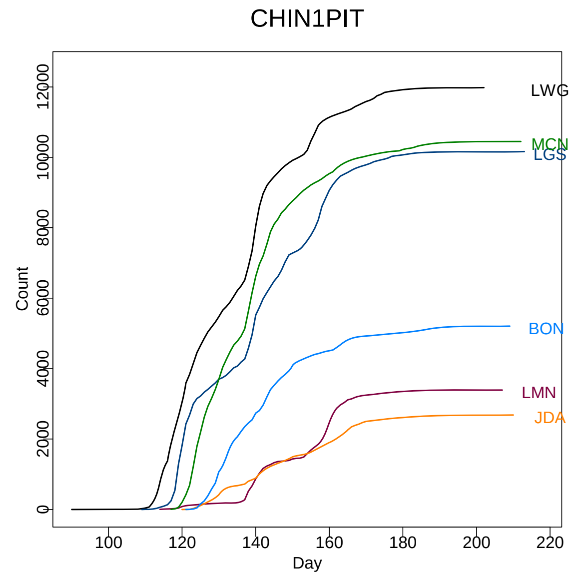
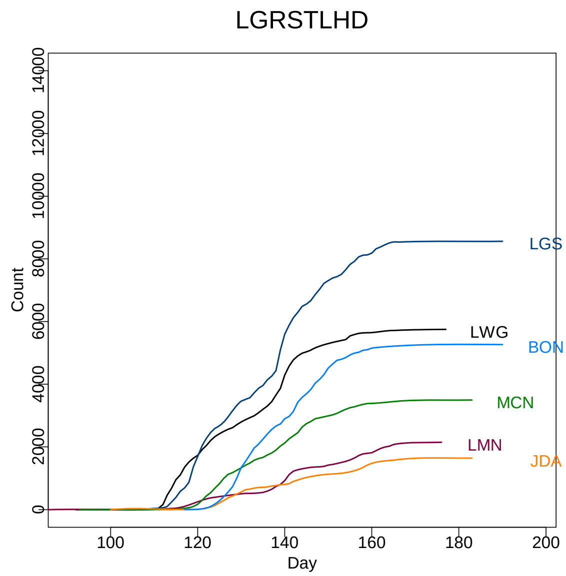
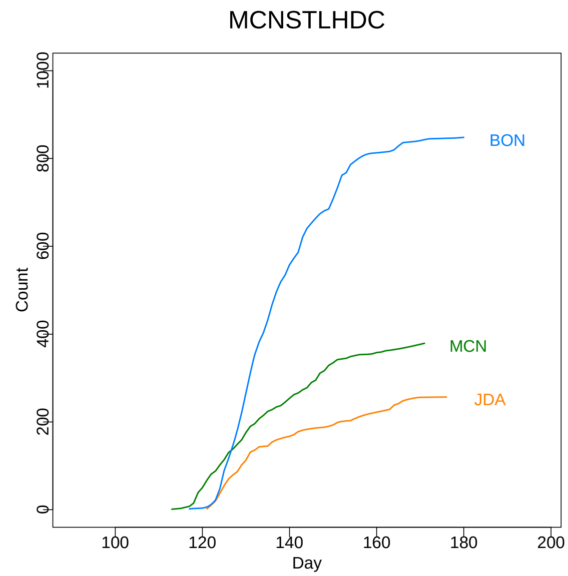



Figure 11 Stock counts at dams. Mortality between dams lowers the numbers from one dam to the next. Observation errors can make the numbers appear to increase or decrease from upstream to downstream. Below MCN, lgrStlhd are equivalent to mcnStlhdS.


REAL
Count
Day
LWG
MCN
LGS
BON
LMN
JDA


CHIN1PIT
Count
Day
LWG
MCN
LGS
BON
LMN
JDA


LGRSTLHD
Count
Day
LGS
LWG
BON
MCN
LMN
JDA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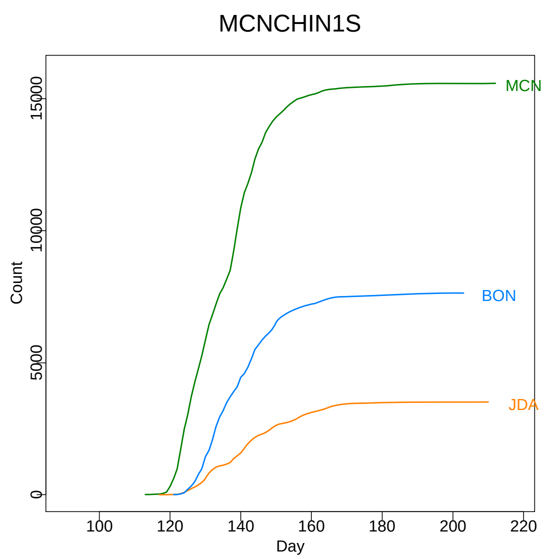
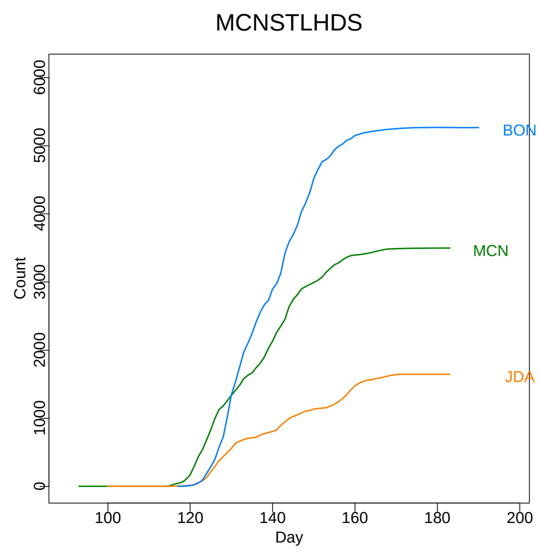
Count
Day
BON
MCN
JDA


MCNCHIN1S
Count
Day
MCN
BON
JDA


MCNSTLHDS
Count
Day
BON
MCN
JDA

## Appendix 2: Timing Observations and Predictions

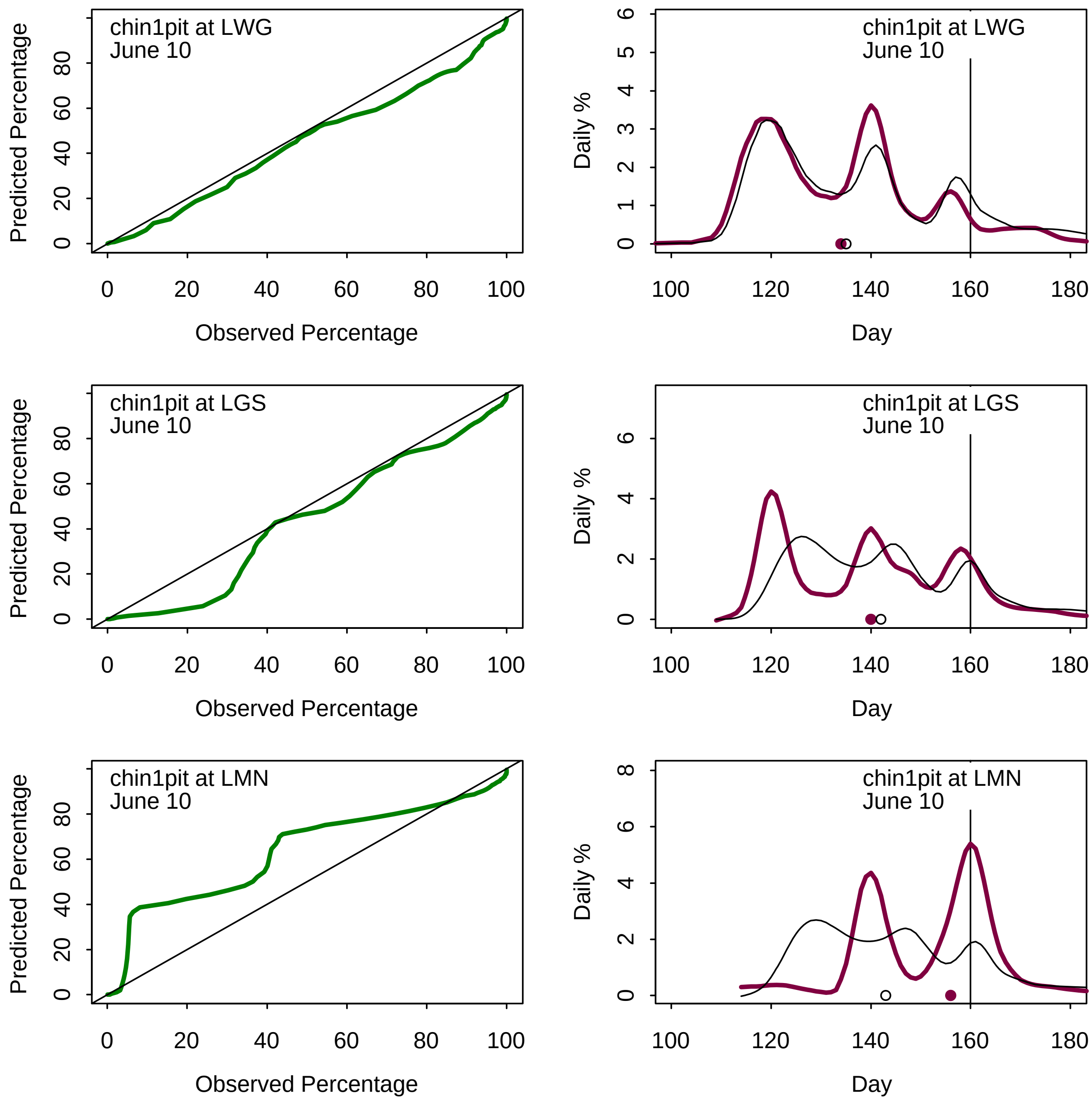



Figure 12 Assessment (at LWG, LGS, and LMN) of bias in observations for chin1pit compared to the June 10 prediction in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

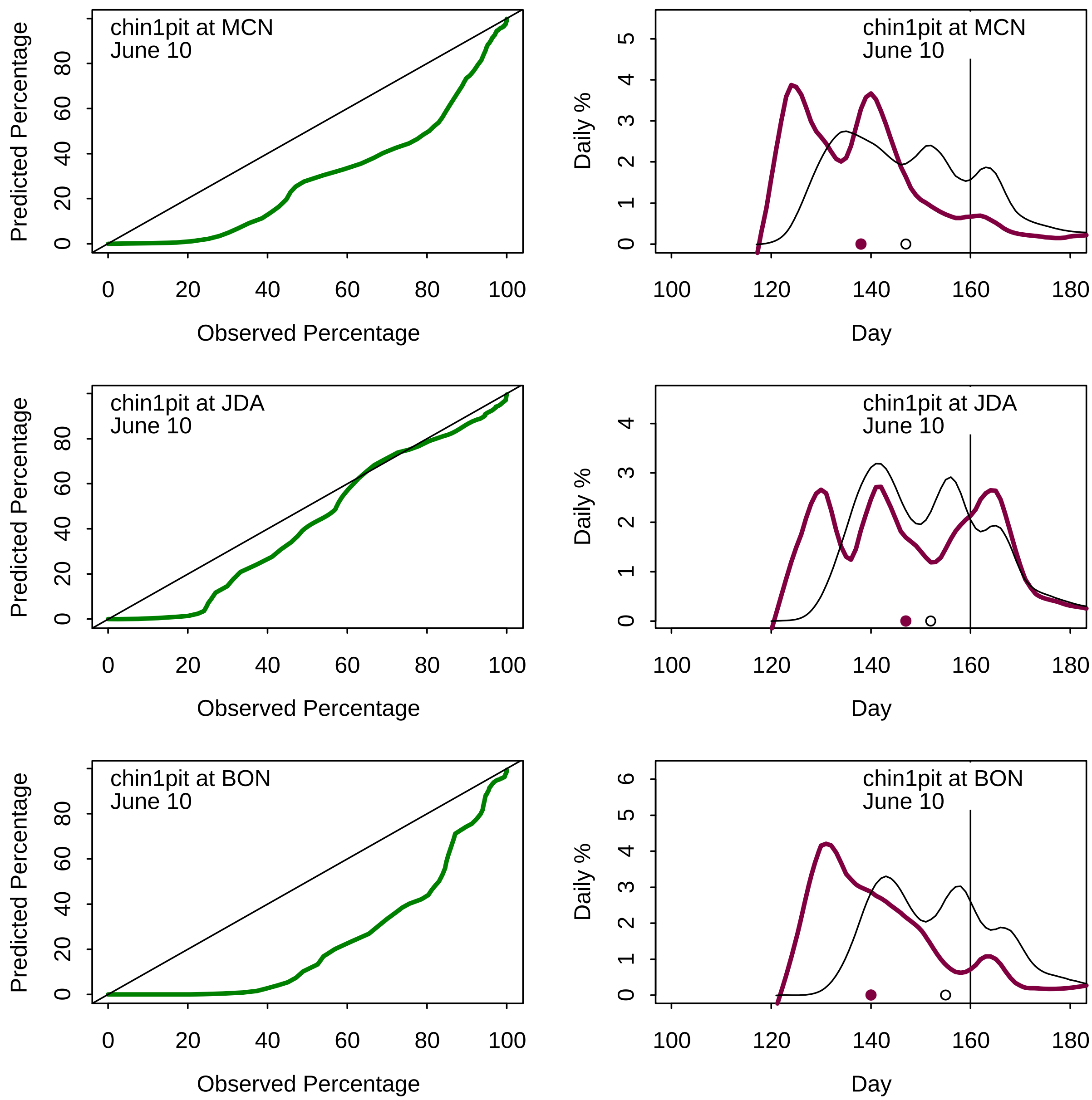



Figure 13 Assessment (at MCN, JDA, and BON) of bias in observations for chin1pit compared to the June 10 prediction in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

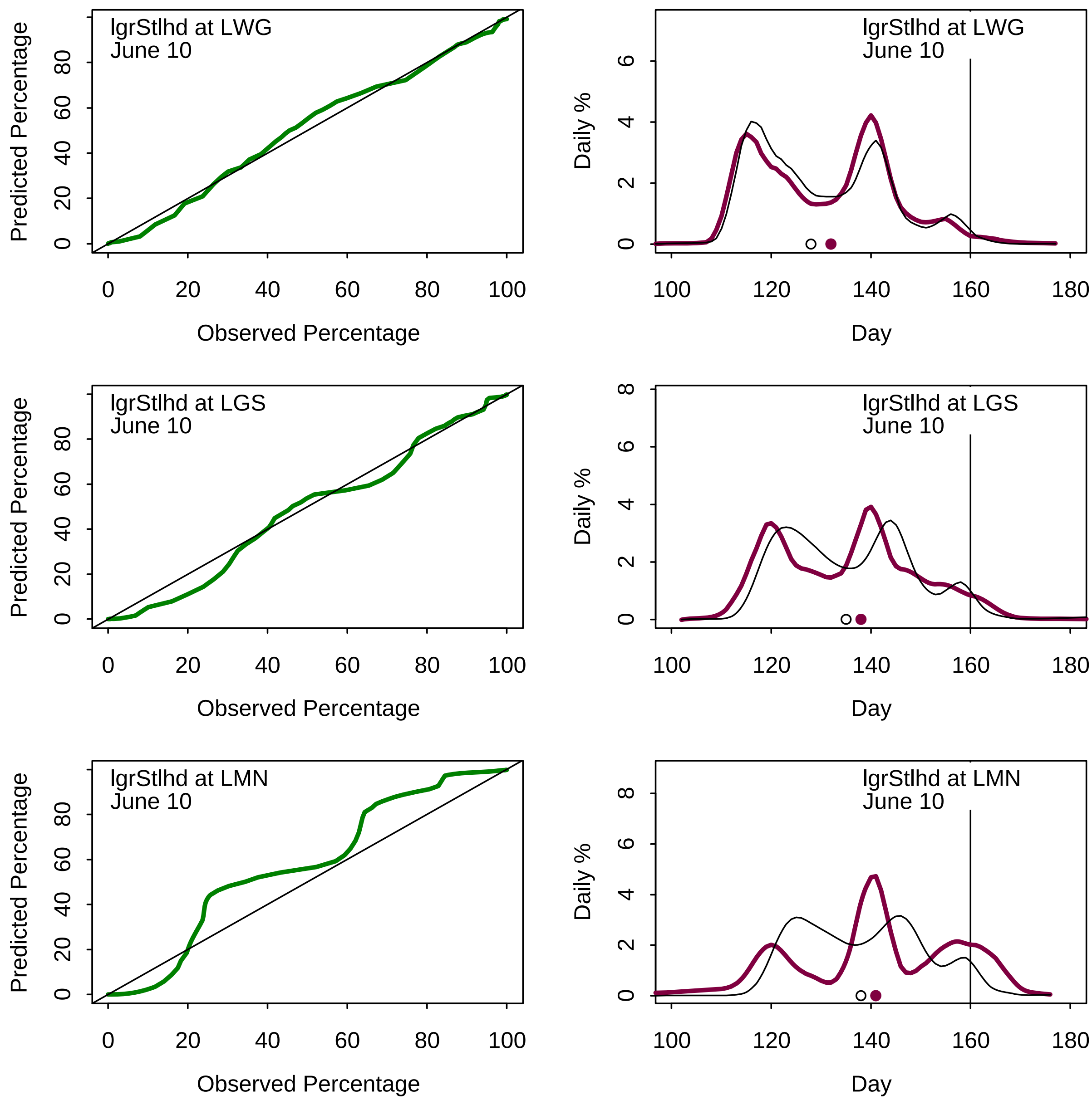



Figure 14 Assessment (at LWG, LGS, and LMN) of bias in observations for lgrStlhd compared to the June 10 prediction in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

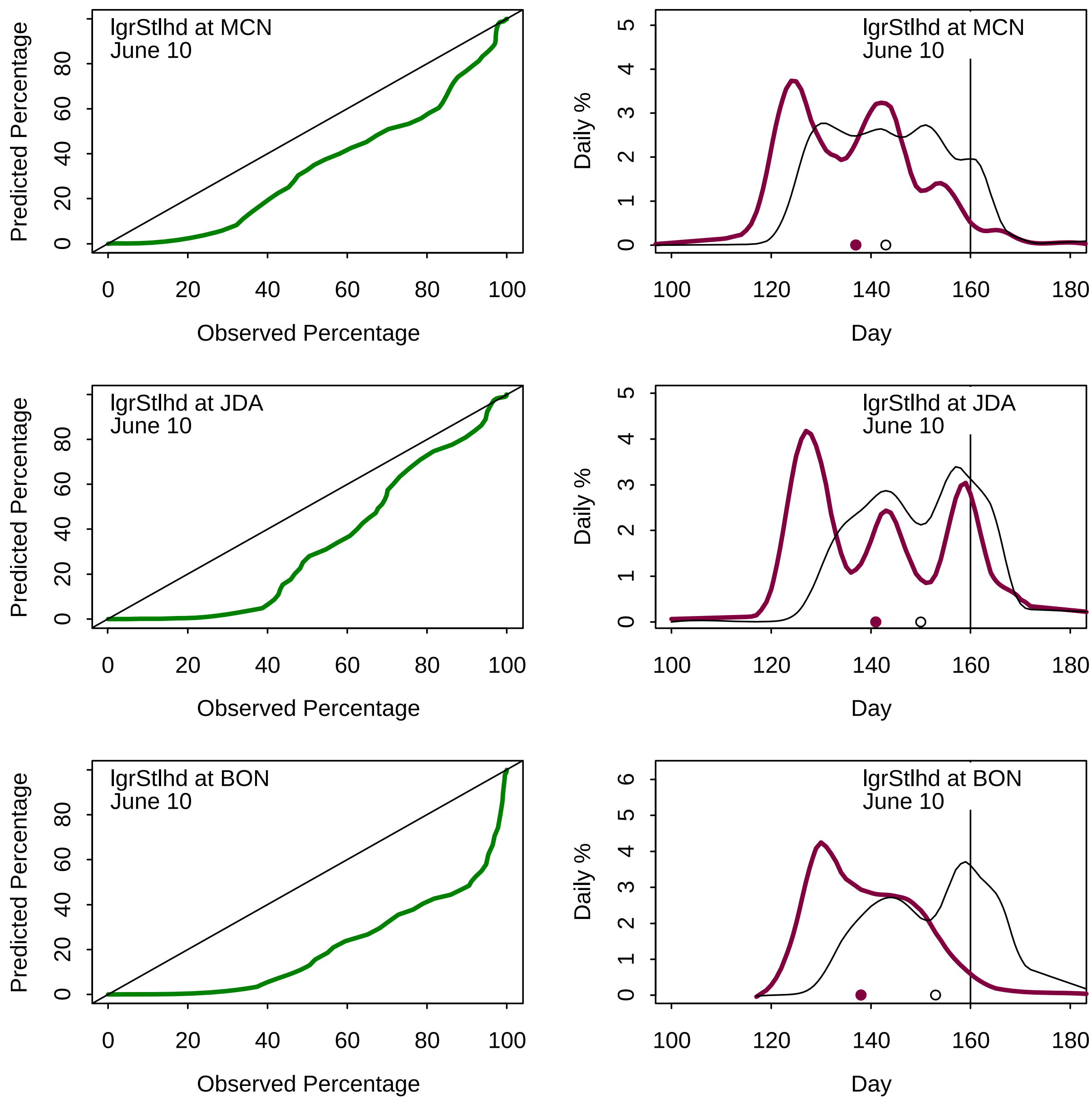



Figure 15 Assessment (at MCN, JDA, and BON) of bias in observations for lgrStlhd compared to the June 10 prediction in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

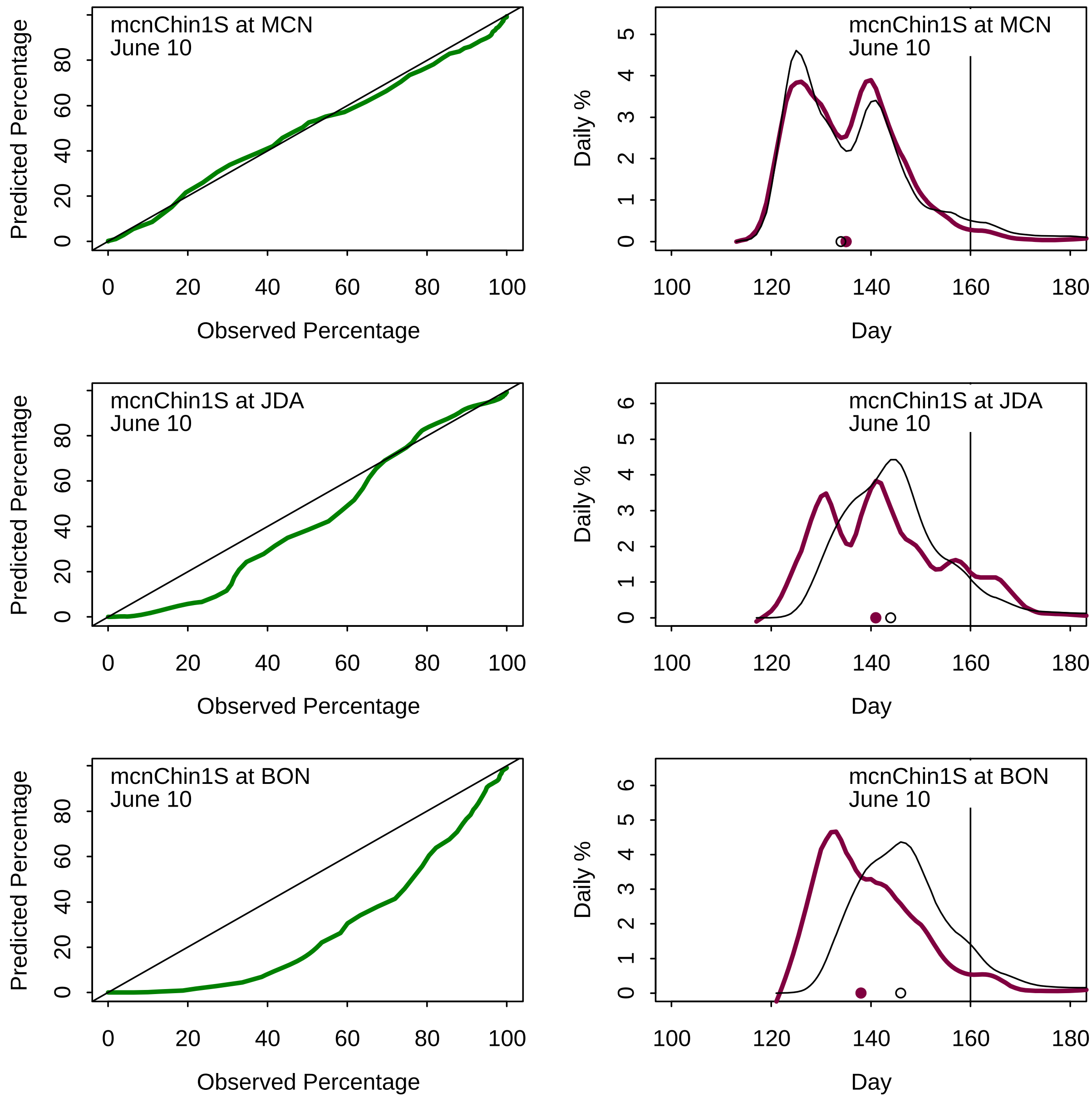



Figure 16 Assessment of bias in observations for mcnChin1S in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

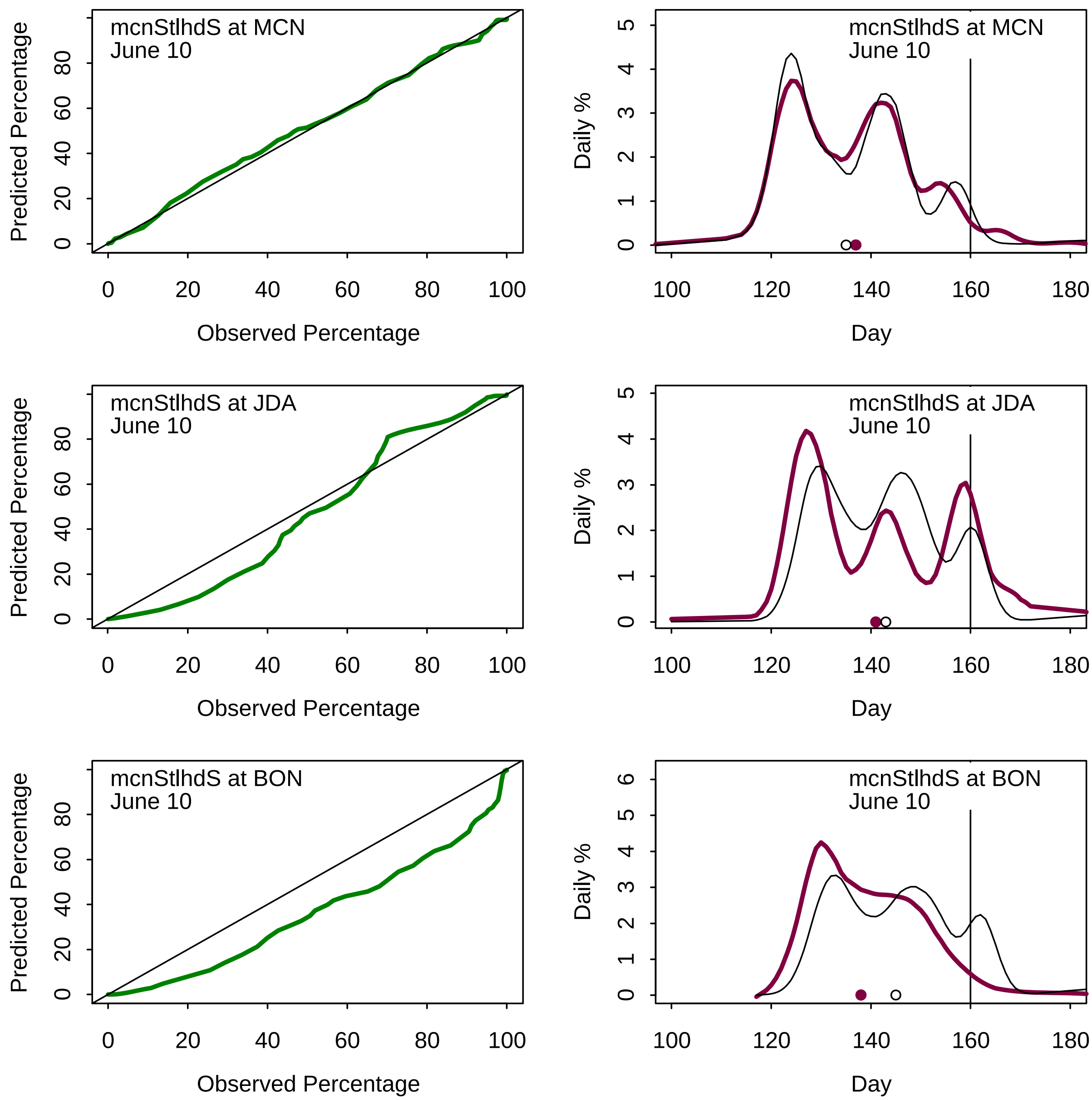


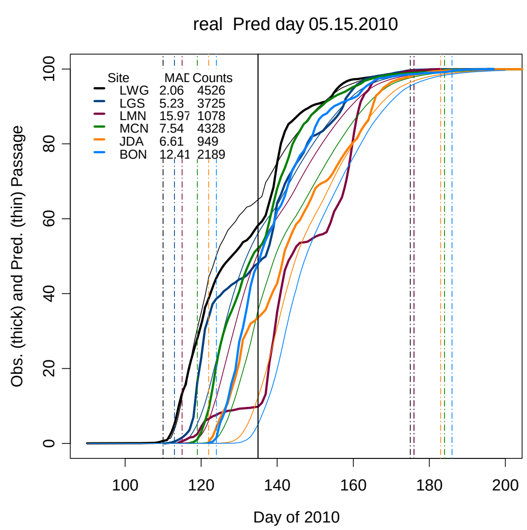

Figure 17 Assessment of bias in observations for mcnStlhdS in 2010. In left-side panels, the Predicted percentage on June 10 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations (filled) and predictions (open).

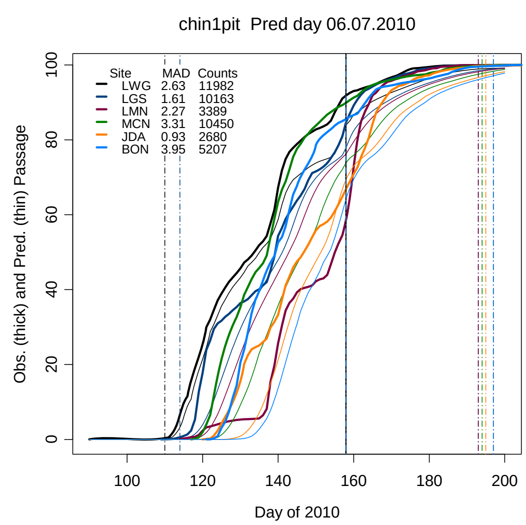
## Appendix 3: Observations, Predictions and MAD

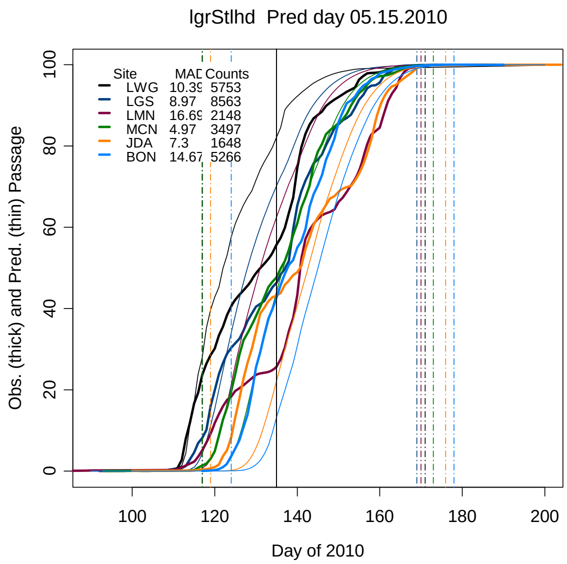
MAD day range calculations are made between 0.5 to 99.5 percentiles on both prediction and observation when possible. The graphs in this appendix depict all of the data used to compute MADs.

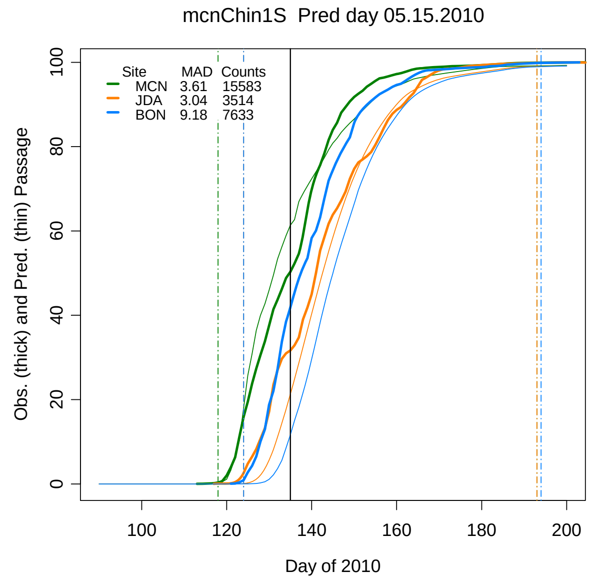
- All graphs have the same abscissa and ordinate ranges.
- Line color varies for different dams, each of which has a three letter code, followed by the MAD value (mean absolute deviation between observed and prediction passage percentage).
- Observations (Predictions) have the thicker (thinner) lines.
- Date ranges of the passage profiles depict the beginning and end days for the MAD calculations, i.e. between the 0.5 and 99.5 percentiles.

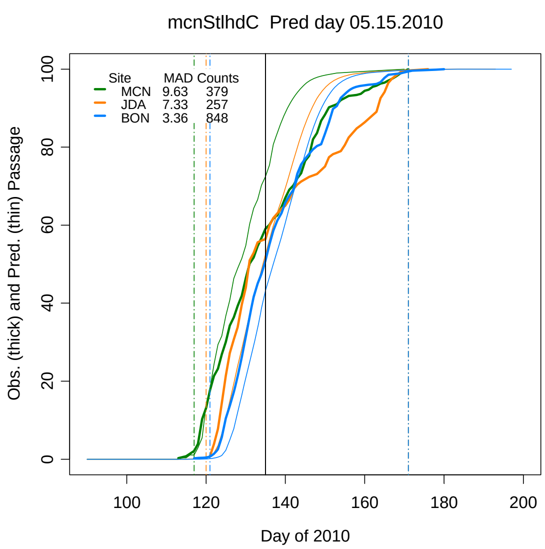
Prediction curve is the sequence of point predictions for the run and therefore can vary up or down from one day to the next. The dam LMN had the highest MAD values in 2010. The uppermost dam arrivals are predicted by RealTime and COMPASS extrapolates that prediction downstream according to a migration model with movements controlled through calibrated parameters.

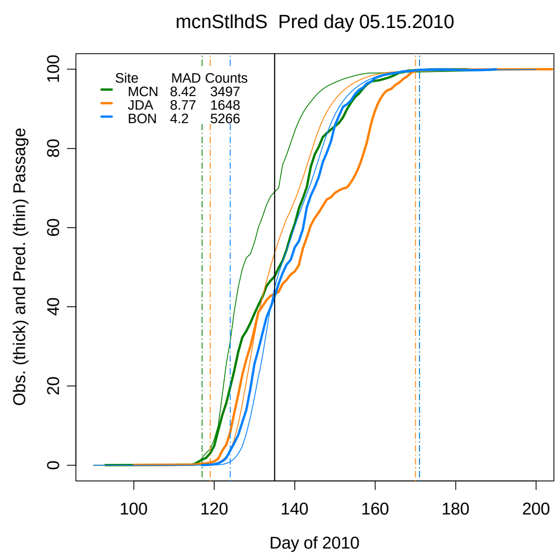



lgrStlhd Pred day 05.15.2010
Site MAD Counts
LWG 10.39 5753
LGS 8.97 8563
LMN 16.69 2148
MCN 4.97 3497
JDA 7.3 1648
BON 14.67 5266
Obs. (thick) and Pred. (thin) Passage
Day of 2010


mcnChin1S Pred day 05.15.2010
Site MAD Counts
MCN 3.61 15583
JDA 3.04 3514
BON 9.18 7633
Obs. (thick) and Pred. (thin) Passage
Day of 2010


mcnStlhdC Pred day 05.15.2010
Site MAD Counts
MCN 9.63 379
JDA 7.33 257
BON 3.36 848
Obs. (thick) and Pred. (thin) Passage
Day of 2010


mcnStlhdS Pred day 05.15.2010
Site MAD Counts
MCN 8.42 3497
JDA 8.77 1648
BON 4.2 5266
Obs. (thick) and Pred. (thin) Passage
Day of 2010

## Appendix 4: Survival Predictions with Data Controls

There are two types of graphics that follow
Type 1: COMPASS/RealTime output (CBR 2011)

- Predicted survival for fish released on that day is shown in green.
- Mean predicted travel time plus or minus one standard deviation in red.
- Median travel time (blue asterisk)
- Title indicates the overall survival for the cohort since it accounts for the number of fish on each day (not shown in this display).

Type 2: Summary of controlled release studies (Faulkner pers. comm January 12, 2011).

- Title has: “COMPASS Name” “Release and Recovery sites” “Controls-Species” “Controls - Rearing Type”. The Rearing types for the controls are chosen to match the observation stock.
- Black line is the time series of COMPASS prediction of the survival for the entire run made on each day (as opposed to daily survivals in the other plots).
- Control group Mean Survival (black circles) and Standard Errors (whiskers) are depicted for each release. The size of the circle is proportional to the number of fish released.
- Blue line shows the cumulative weighted average of the (data) survival estimates.
- The point estimates of survival are plotted at the *release day*, whereas the COMPASS line is referenced to the *prediction day*.
- “LGR” indicates Lower Granite Dam (a.k.a. LWG).

Other notes: Control release survival estimates are not available between all possible sites.
The time spans across the two types of graphs are very similar.

Day 80 = March 21
Day 130 = May 10
Day 180 = June 29

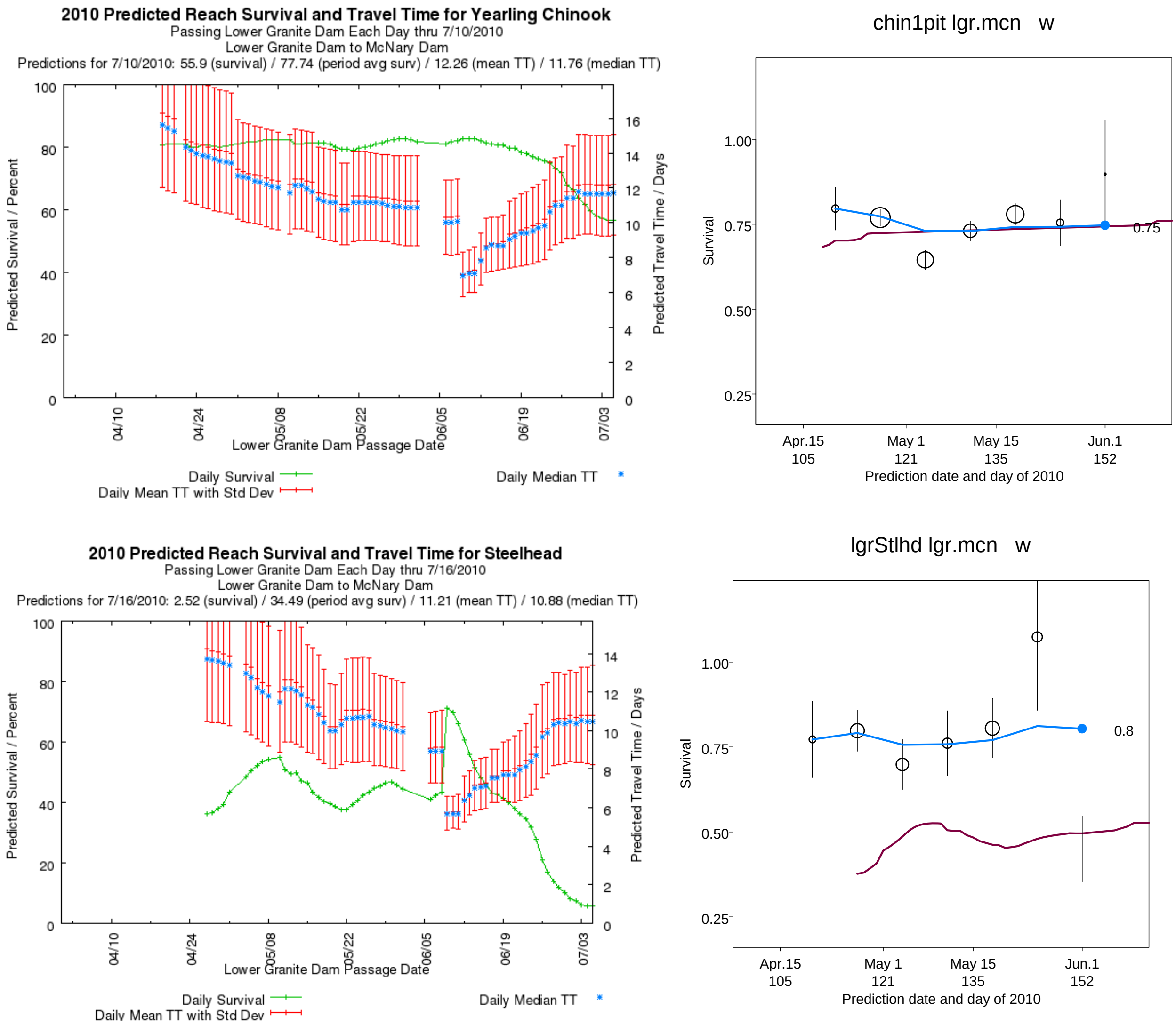



Figure 18 Daily survivals of chin1pit (above) and lgrStlhd (below) using COMPASS (left side) and corresponding data controls (right side) over the migration season in stages from LGR (LWG) to MCN.

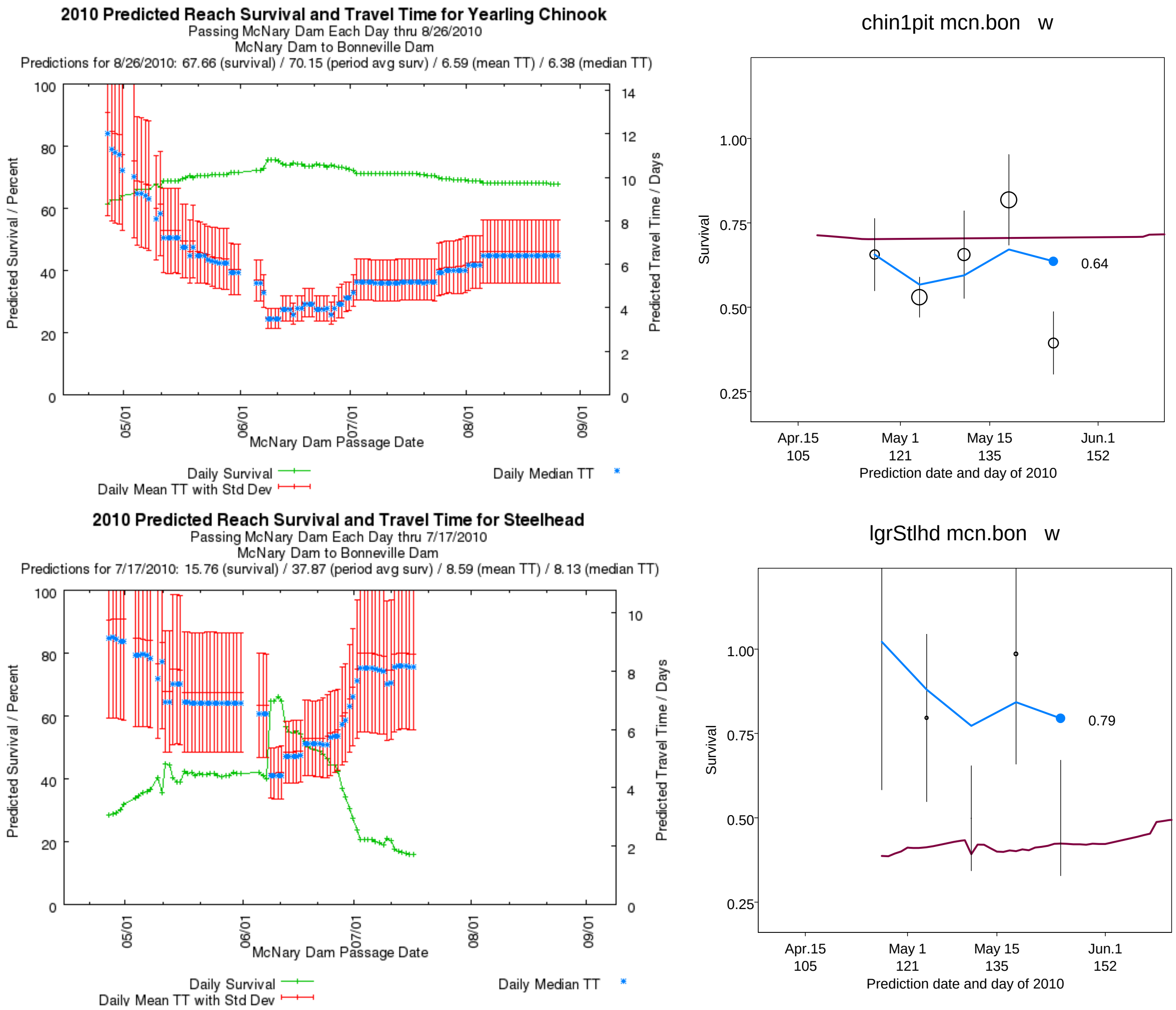
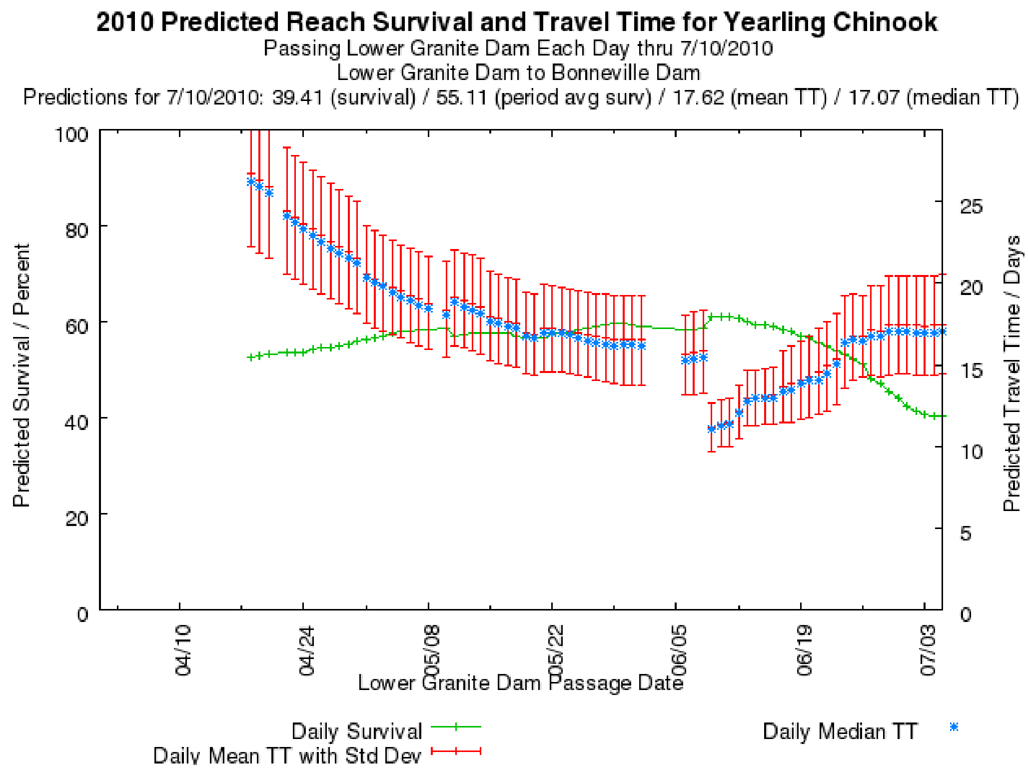



Figure 19 Daily survivals of chin1pit (above) and lgrStlhd (below) using COMPASS (left side) and corresponding data controls (right side) over the migration season in stages from MCN to BON.



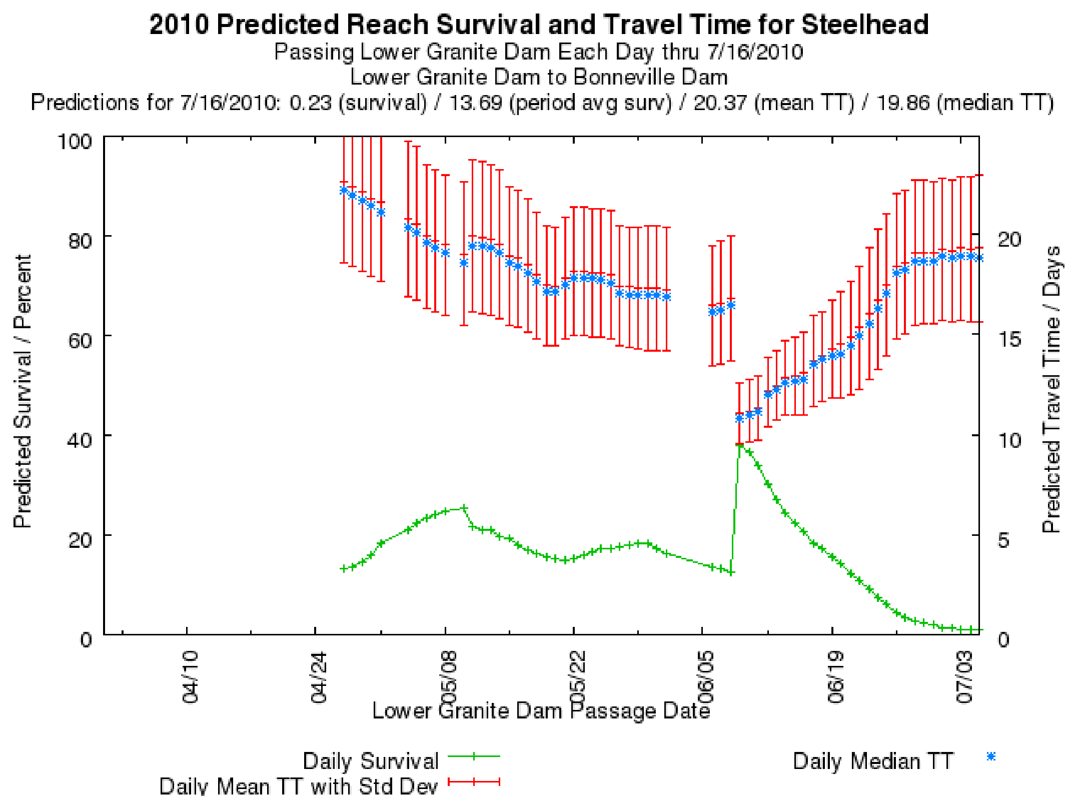




Figure 20 Daily survivals of chin1pit (above) and lgrStlhd (below) using COMPASS over the migration season in stages from LWG to BON.

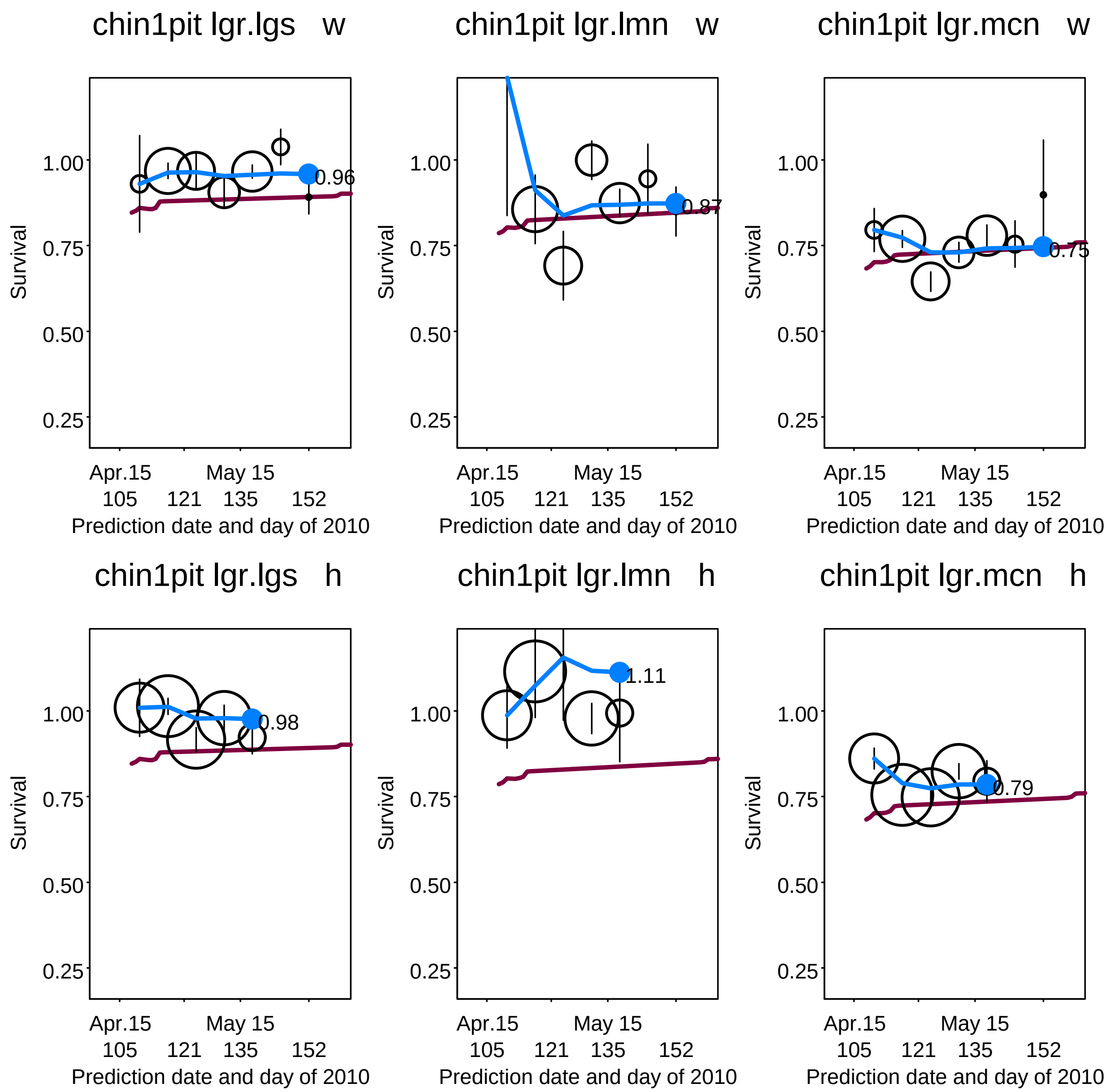



Figure 21 Part 1. All Chin1pit COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Chinook (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

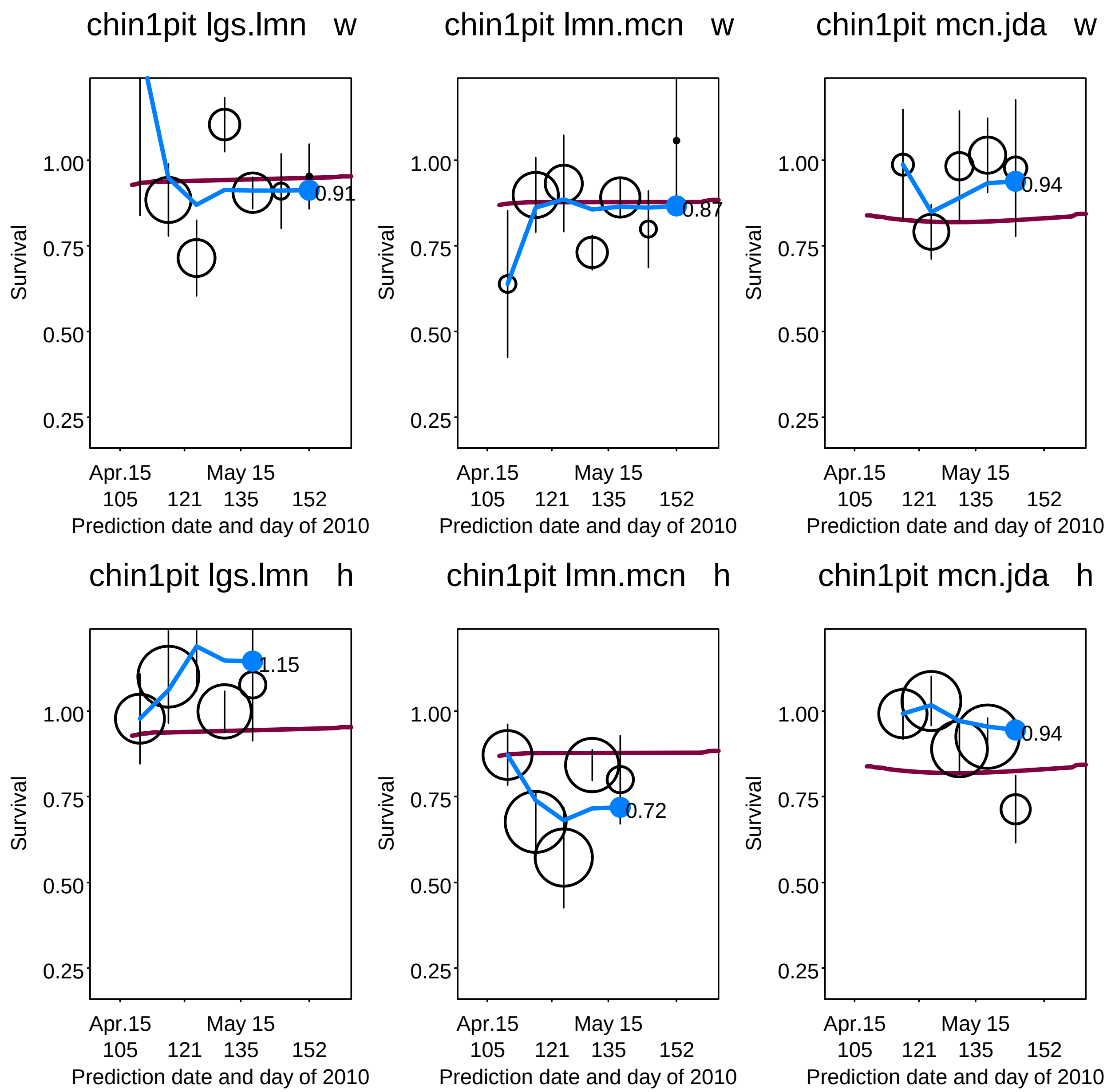



Figure 22 Part 2. All Chin1pit COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Chinook (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

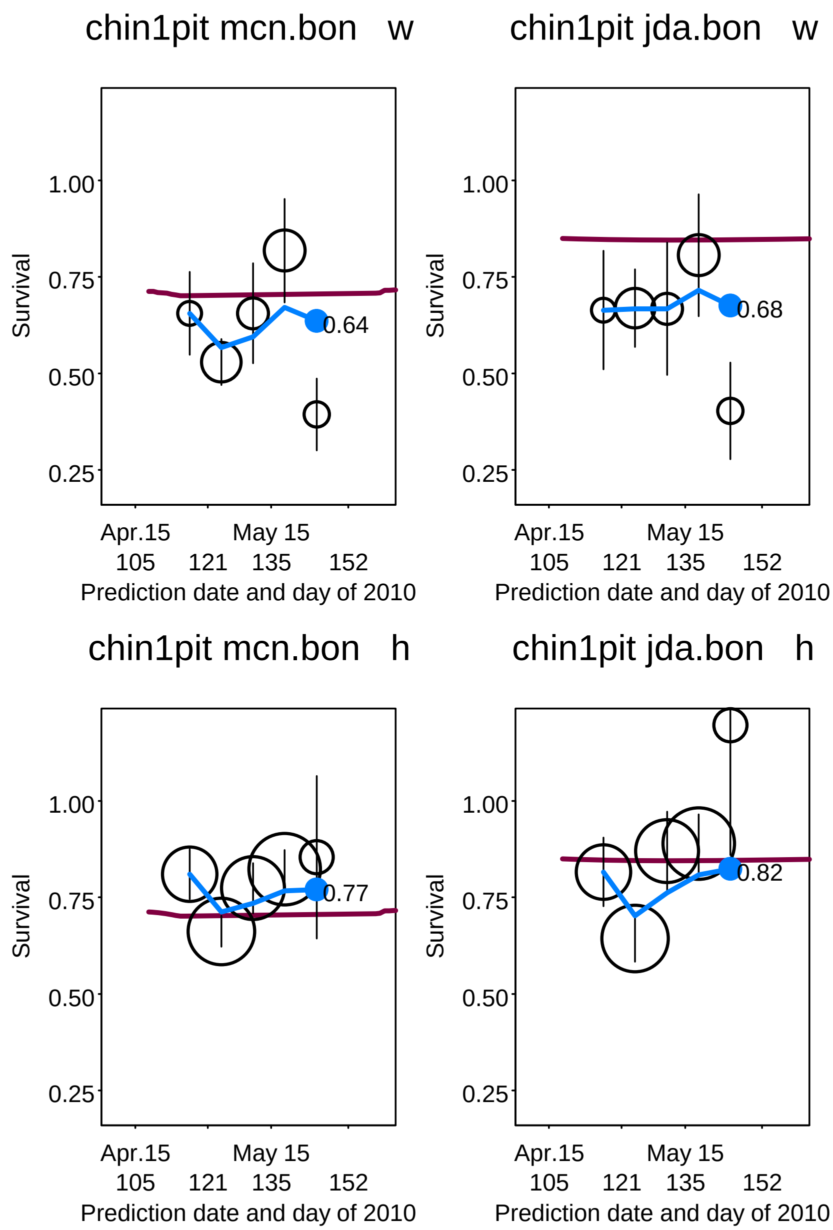



Figure 23 Part 3. All Chin1pit COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Chinook (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

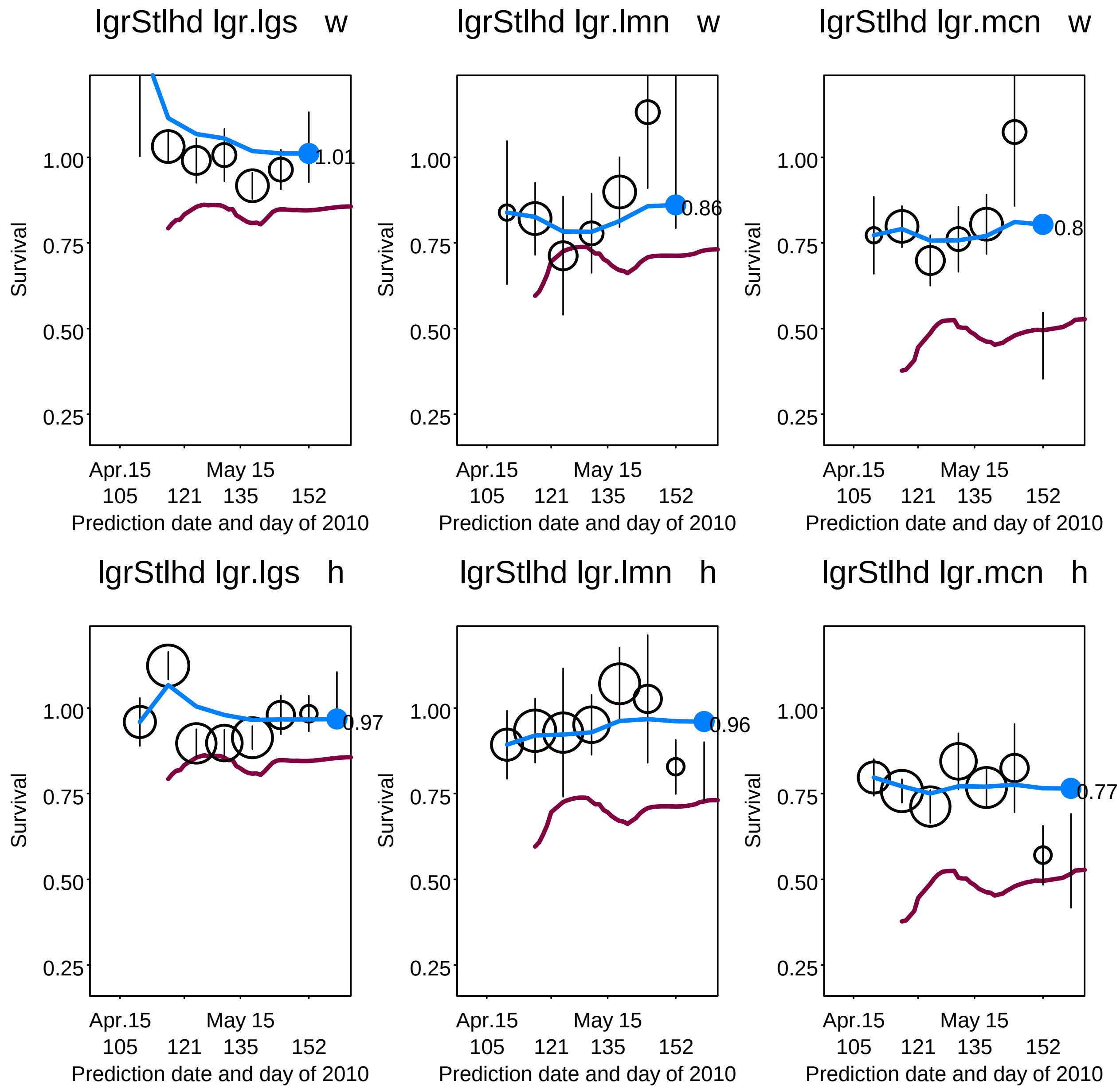



Figure 24 Part 1. All lgrStlhd COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Steelhead (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

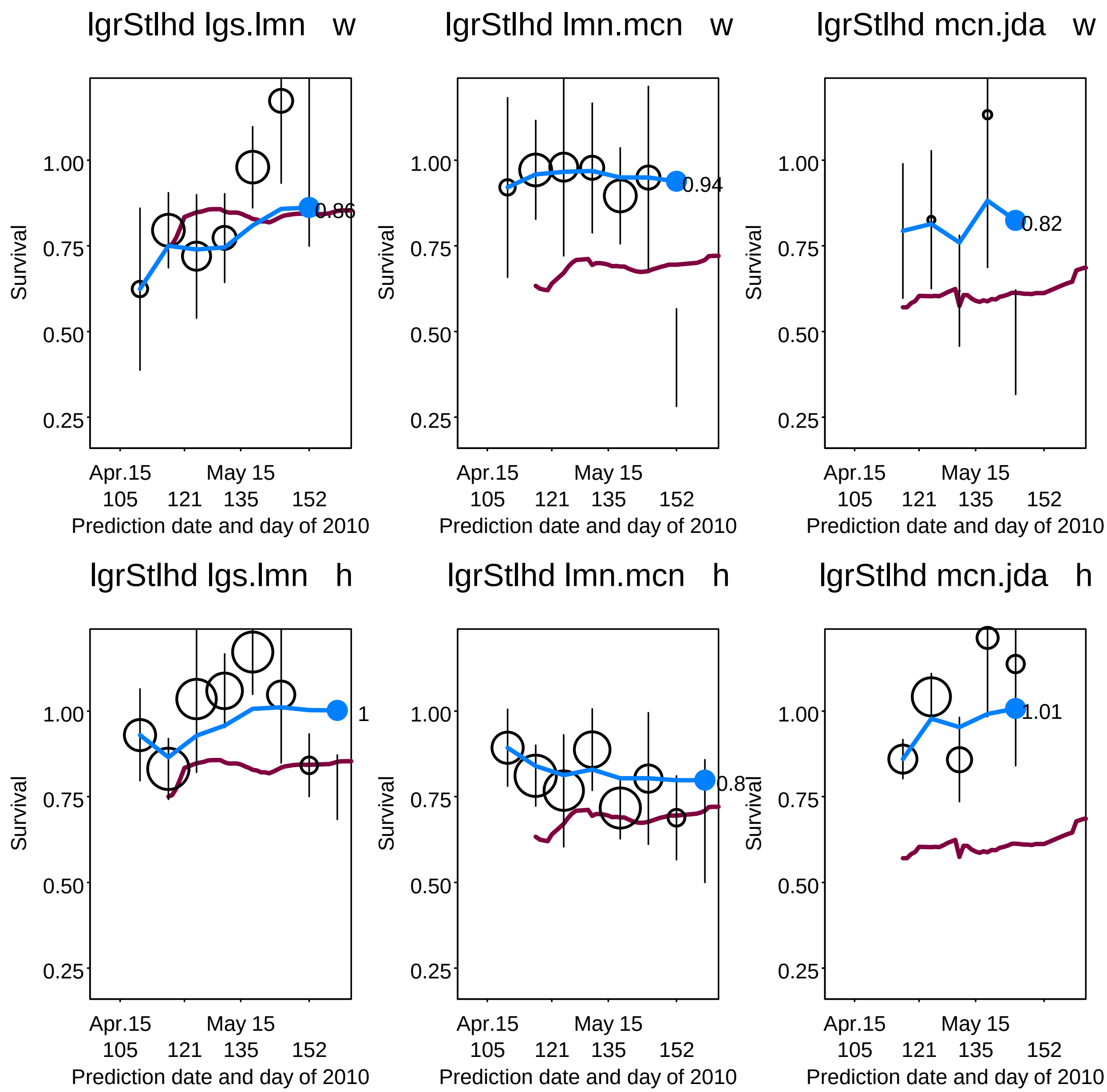



Figure 25 Part 2. All lgrStlhd COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Steelehad (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

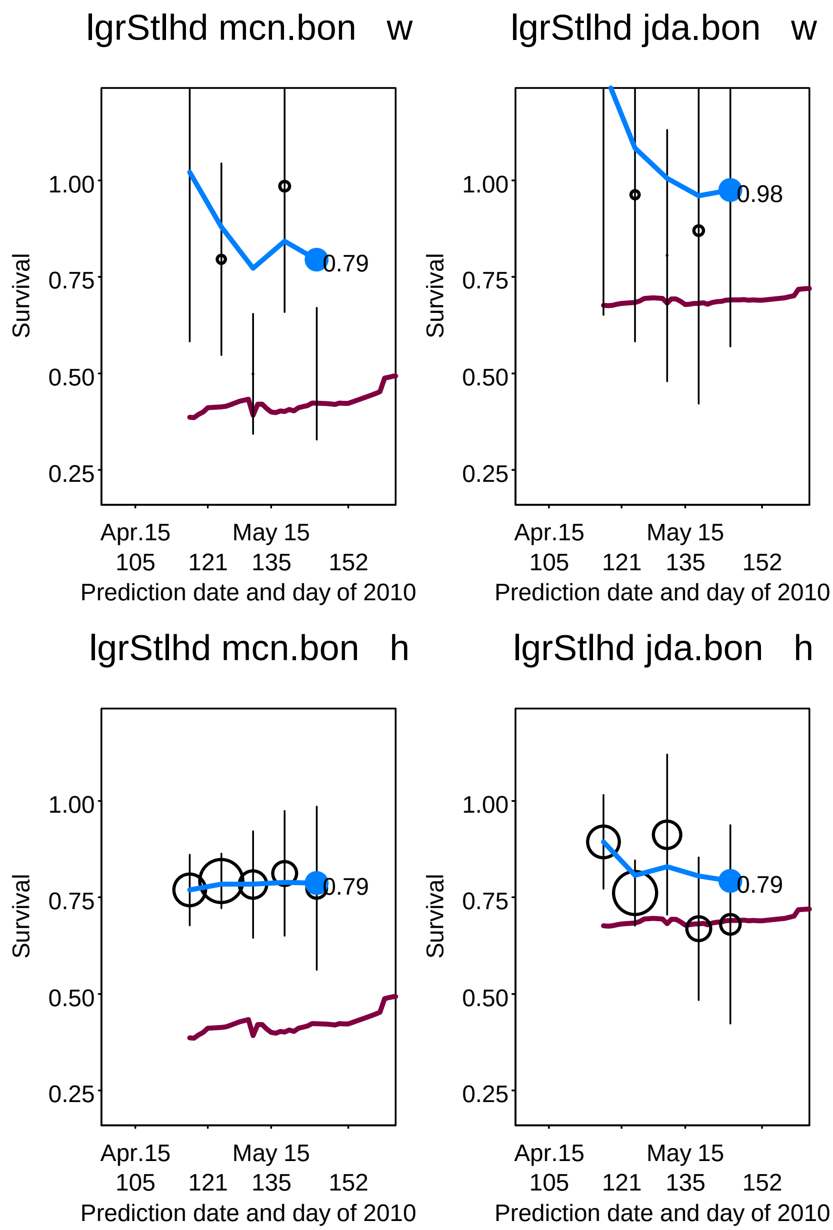



Figure 26 Part 3. All lgrStlhd COMPASS-modeled survivals (heavy line) and Control-release data survival estimates for wild (above) and hatchery (below) Steelehad (circles scaled by release size and centered on release day, whiskers show standard error) blue line shows weighted (by release number) survival to date. Final count-weighted average survival written out as well.

## Appendix 5: Modeled FGE and FPE during migration season

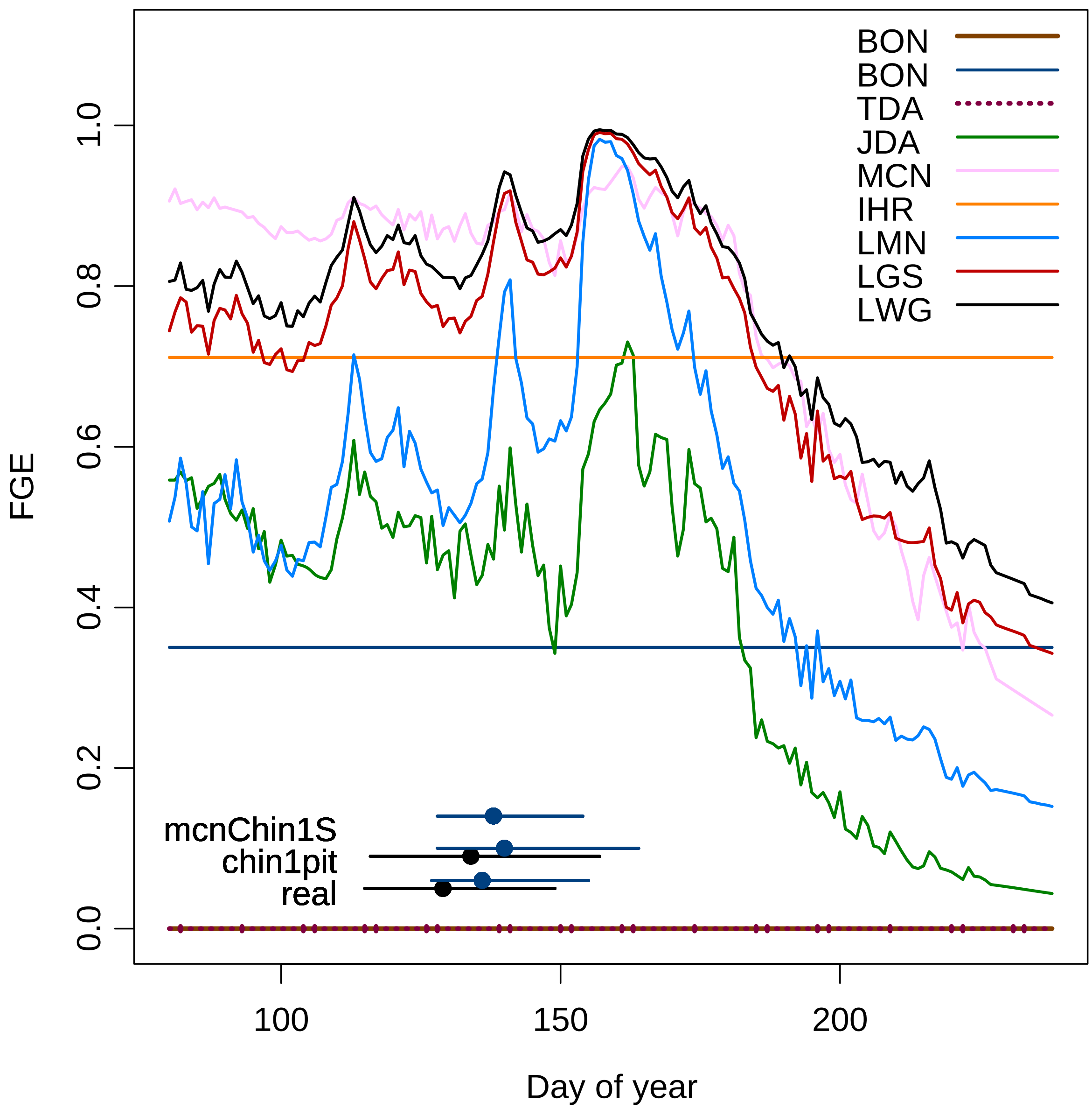



Figure 27 Computed FGE and passage of Chinook in 2010. Notes: Bonneville has 2 powerhouses (PH). FGE = 0 at BON (#1 PH) and TDA.

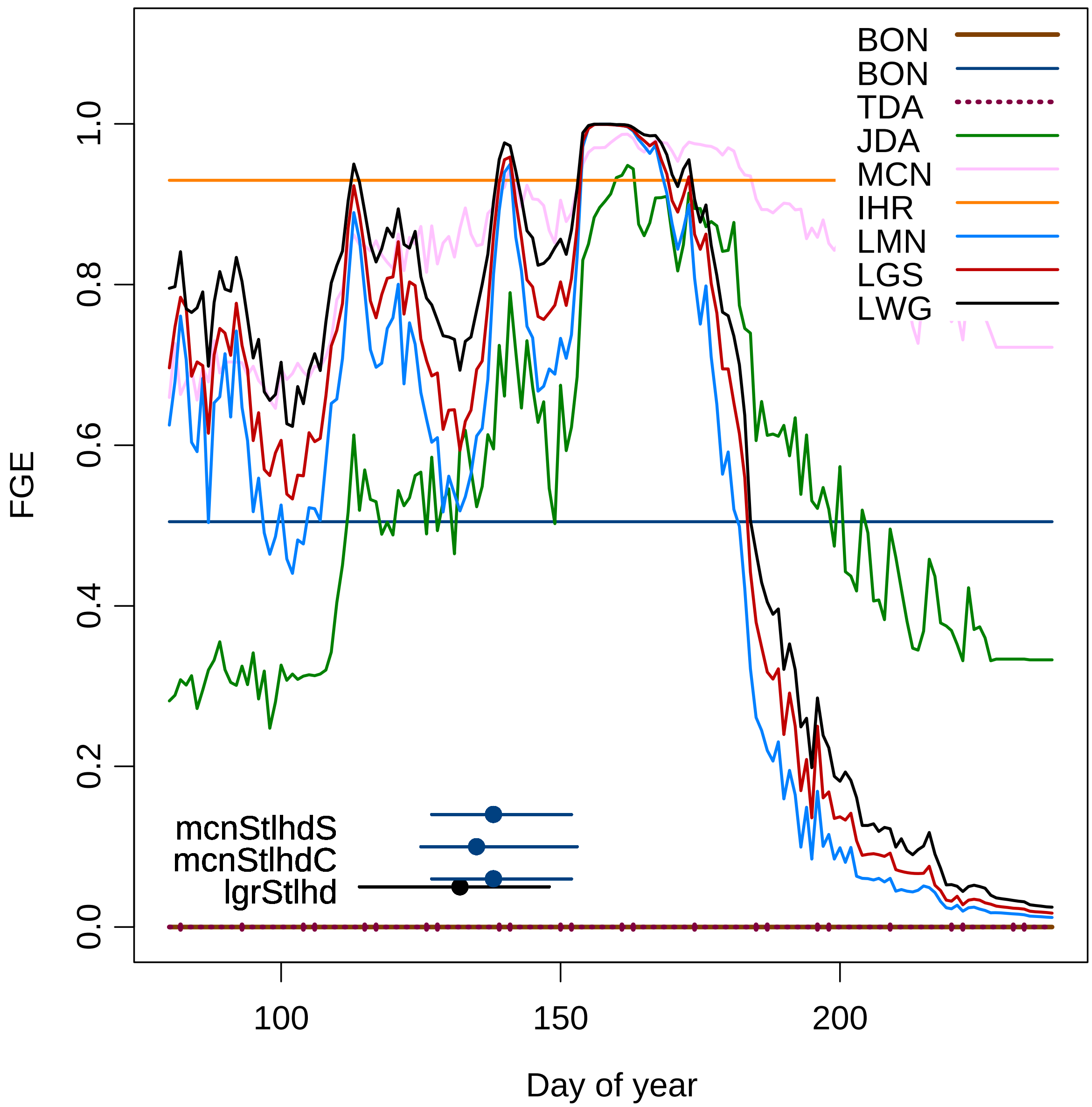



Figure 28 Computed FGE and Passage of Steelhead in 2010. Notes: Bonneville has 2 powerhouses (PH). FGE = 0 at BON (#1 PH) and TDA.

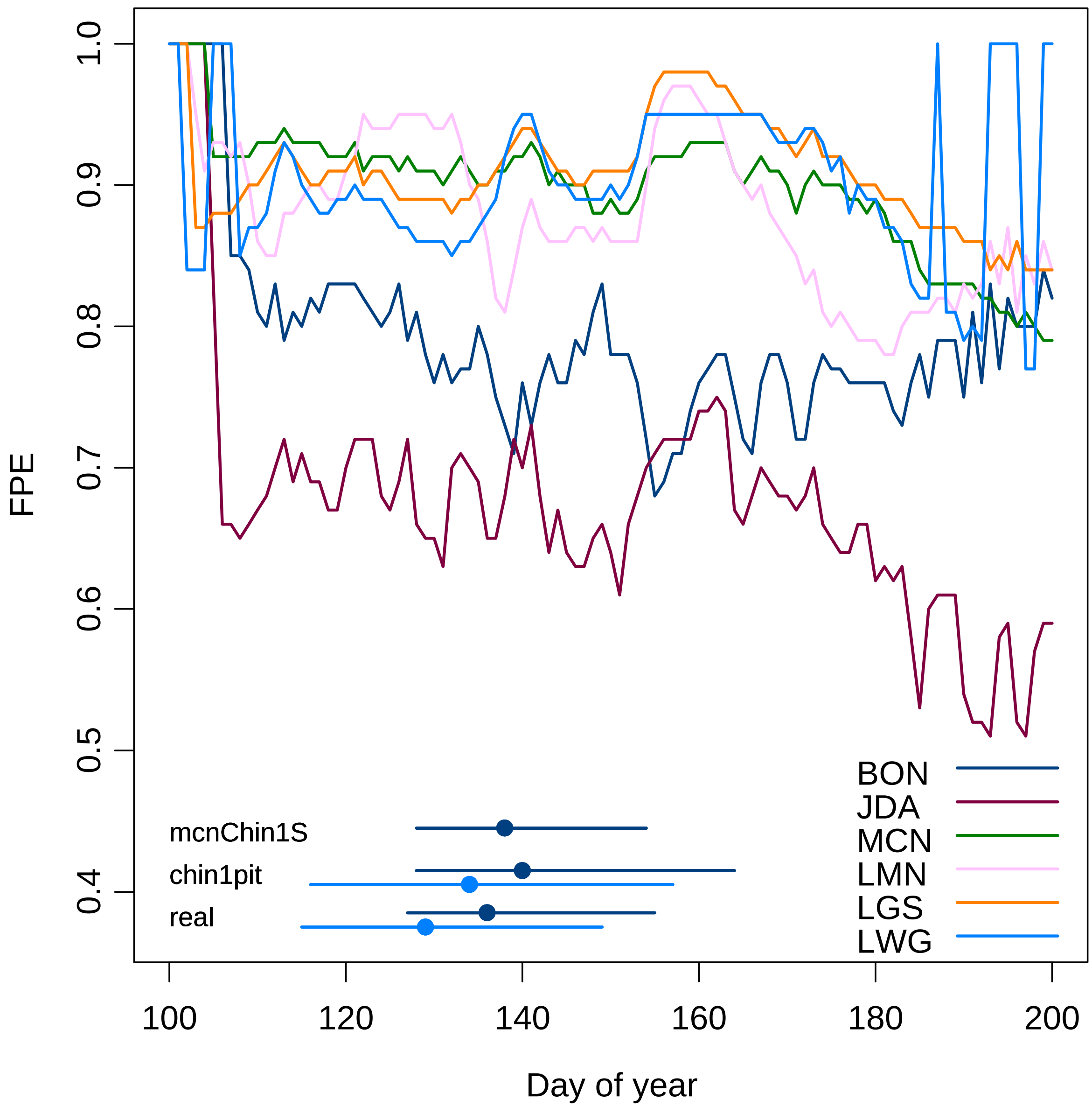



Figure 29 Computed FPE for Chinook in 2010 based on flow, spill, spill efficiency, and FGE in COMPASS runs.

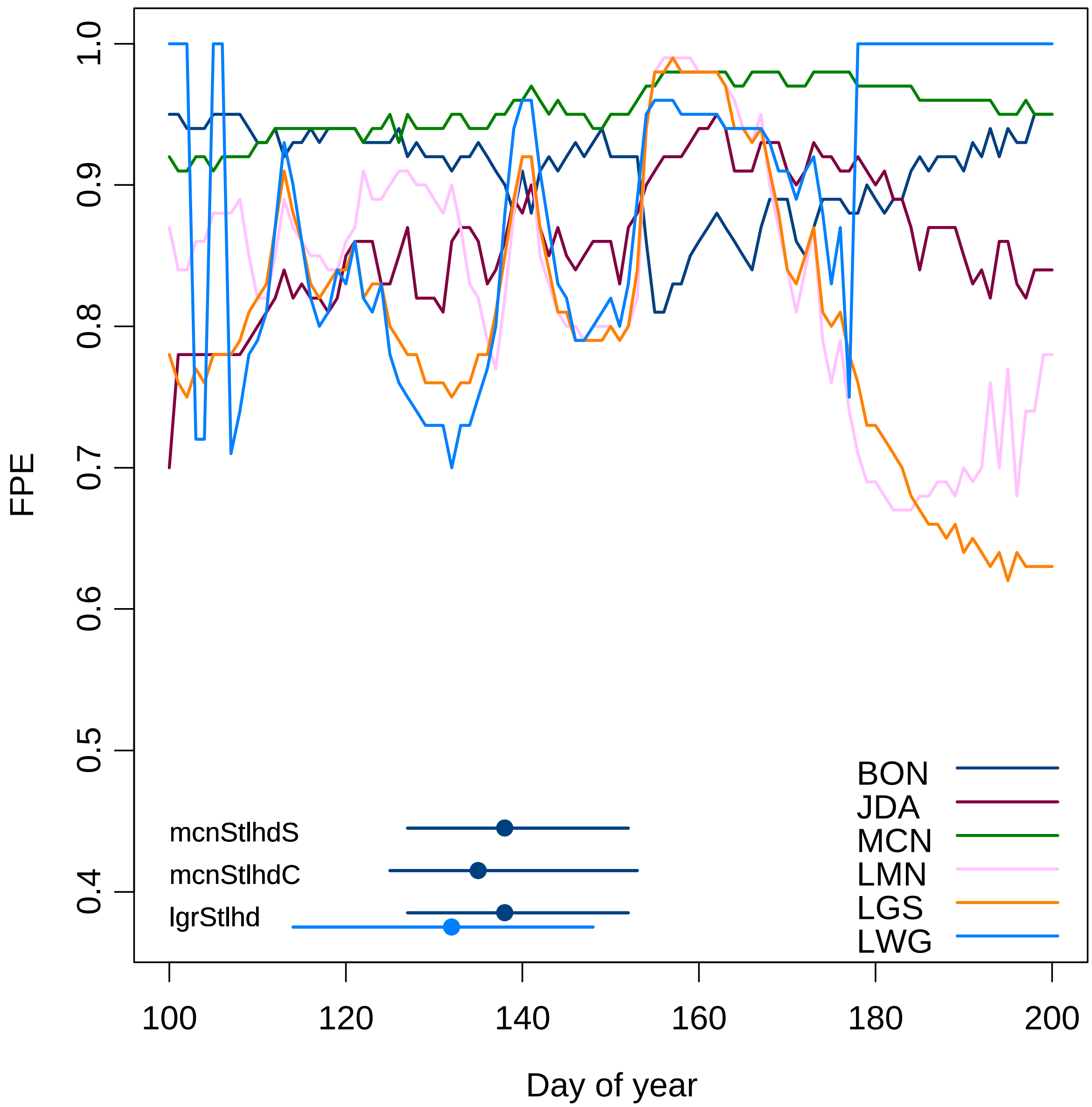



Figure 30 Computed FPE in 2010 for Steelhead based on flow, spill, spill efficiency, and FGE in COMPASS runs