Evaluation of the 2008 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 2008, 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. Dec. 16, 2008). 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 and observed survivals is a measure of survival accuracy.

Model results and timing data were in good agreement from LWG to John Day Dam (JDA). Predictions of median passage days for the chin1pit and lgrStlhd stocks were 0 and 2 days (respectively) later than observed. MAD for chin1pit and lgrStlhd stocks at JDA were 2.3% and 5.9% (respectively). Between JDA and BON modeling and timing data were not as well matched. At BON, median passage predictions were 6 and 10 days later than observed and MAD values were 7.8% and 16.0% respectively.

Model results and survival data were in good agreement from LWG to MCN. COMPASS predicted survivals of 0.77 and 0.69 for chin1pit and lgrStlhd, while the data control's survivals were 0.79 and 0.68. The differences are 0.02 and 0.01 (respectively), nearly identical. However, from MCN to BON, COMPASS predicted survivals of 0.74 and 0.69 while the data controls survivals were 0.47 and 0.53 respectively. Differences of 0.27 and 0.16.

In summary: Travel and survival of chin1pit and lgrStlhd stocks were well modeled in the upper reaches. Fish in the lower reaches down through BON suffered unmodeled mortality, and/or passed BON undetected. A drop in bypass fraction and unmodeled mortality during the run could produce such patterns by shifting the observed median passage day to appear artificially early.

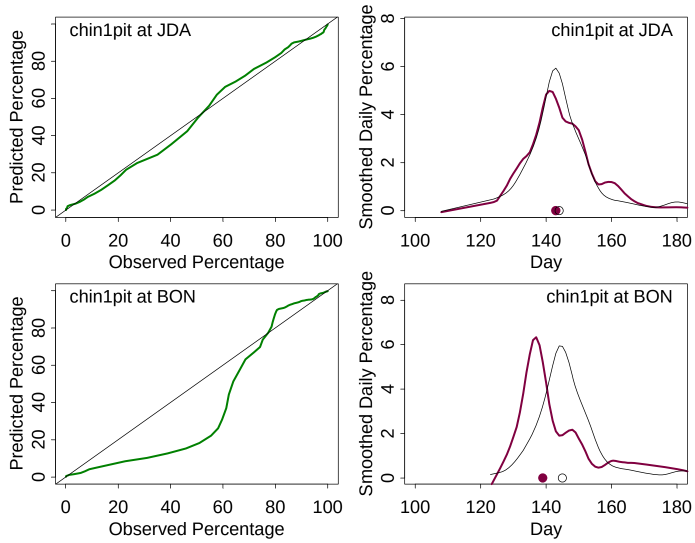

Figure 1 Illustration of passage detection bias at BON. Left panels compare the percentiles of observed and the final prediction. The 1:1 line is shown. The right panels show the daily observed percentages in a darker red line and the predicted values in a thinner black line. The median day is marked with a point. JDA is well modeled. BON observations are biased early.

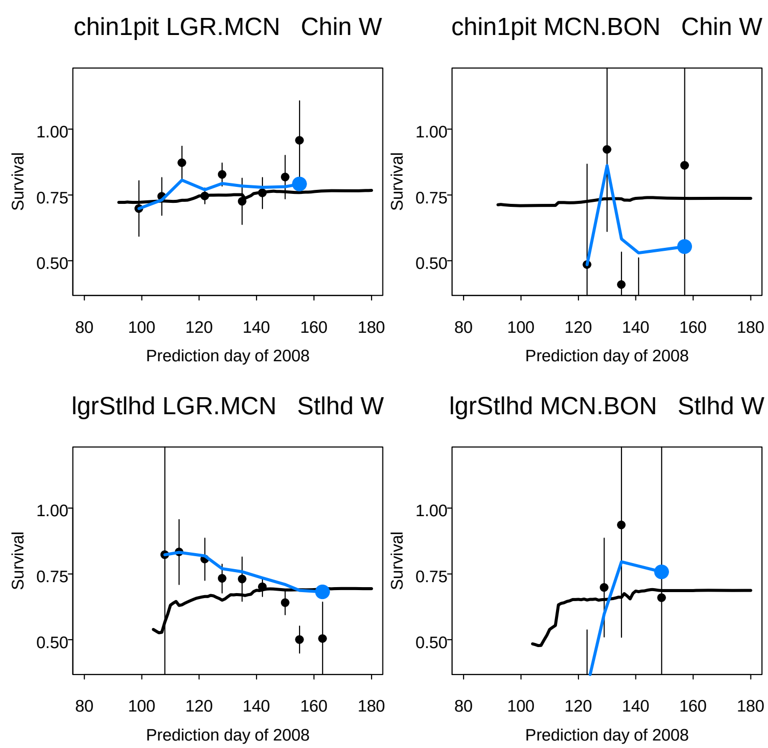

Figure 2 Illustration of COMPASS generated survival across the season (quasi-horizontal black lines of the overall survival prediction made each day) and data-control estimates of survival (point estimates of weekly survival with whiskers depicting standard error). The blue line depicts the weighted average survival of the weekly cohorts with the blue dot at the final estimate. Survival modeling to MCN is in good agreement with the data, though there was a trend across the season affecting the lgrStlhd. Between MCN and BON survivals fluctuated widely for both stocks.

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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 project was originally launched in an effort to provide real-time inseason 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, 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 2008 predictions of survival and passage that uses available calibrations along with in-season river conditions that are initially predicted and eventually observed (flow, spill, TDG and temperature). 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 3. 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. For 2008, calibrations were available for wild fish only of both species. These are coded “chin1pit” and “lgrStlhd”. In 2008, other stocks are also modeled with these calibrations even though the specific parameters were not calibrated separately for the individual stocks.

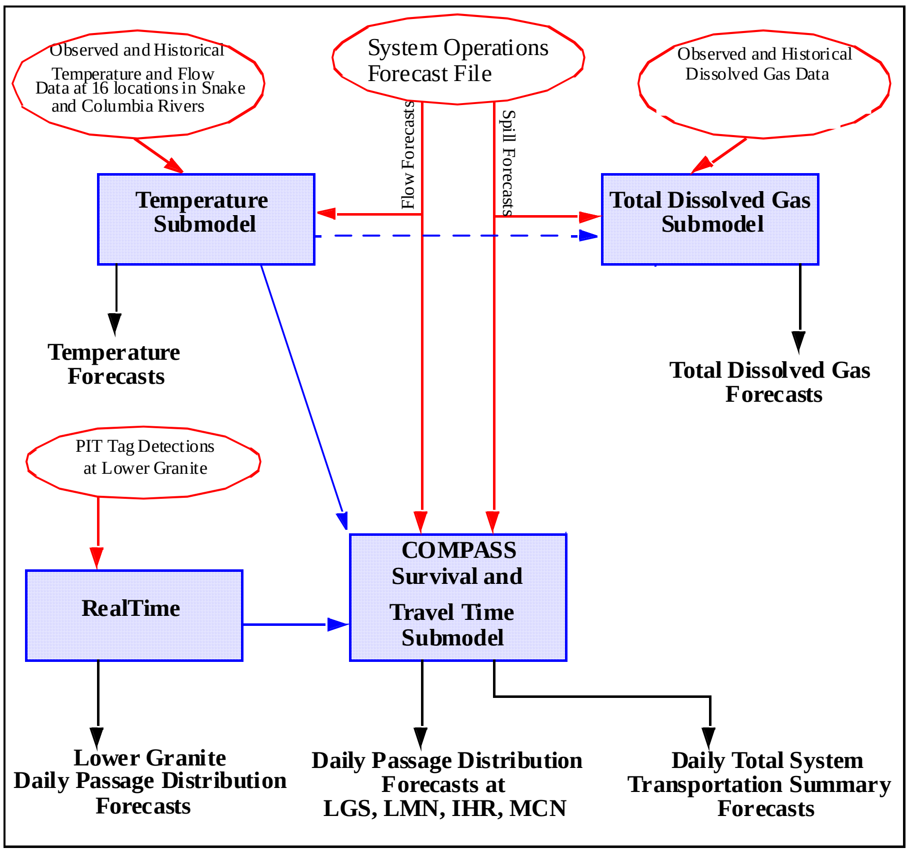


Figure 3 Simplified schematic of RealTime and COMPASS complex.

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 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	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 realtime 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 over flows into the turbine. A formula for BE during a time step is:

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

- 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 4). 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).

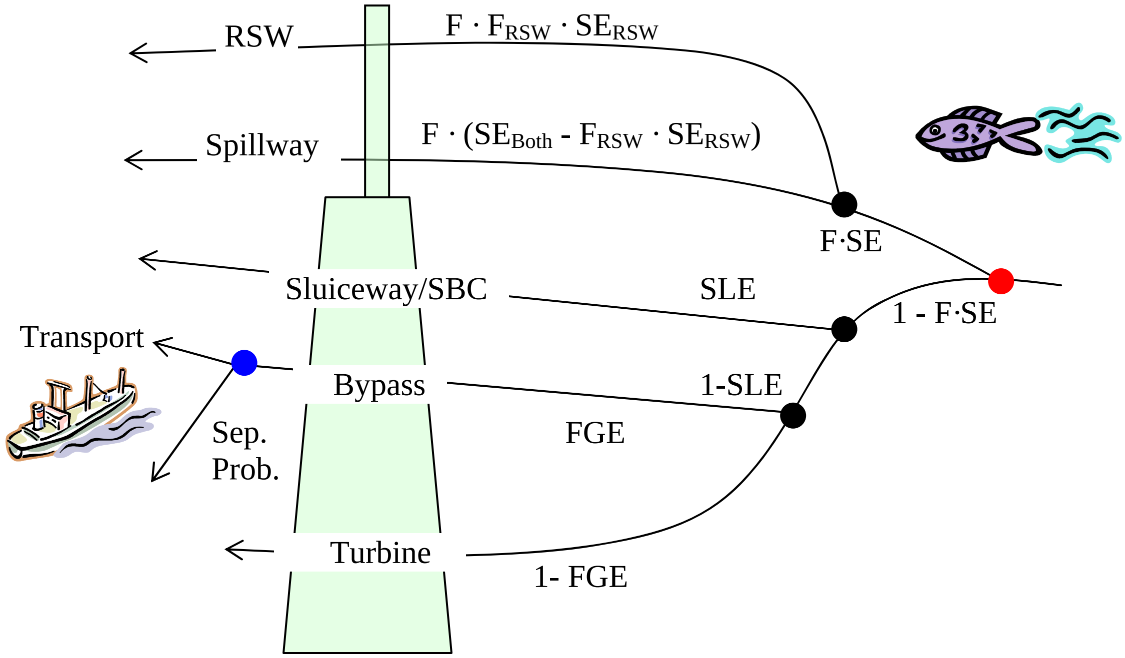


Figure 4 Possible routings of fish at a dam. The dots represent bifurcations of the population where there are only two possible routes. In the case of the RSW and Spillway routes, these do NOT necessarily sum to one. F = fraction of daily flow that passes in spill. SE_{Both} = Spill Efficiency for both 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:

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

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(1). 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:

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

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 affect interpretation of passage numbers. Spill 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.

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 Dec. 16, 2008.) 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.

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 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”. This is shown in Table 3. The observed day-of-year of median passage is shown in Table 4. They are all confined to a 3 day window at LWG, a 5 day window at JDA and a 5 day window at BON. The differences between the declared and observed days are in Table 5. These are minimal at JDA (2 and 3 days for the chin1pit and lgrStlhd respectively). There is a much bigger discrepancy at BON (8 and

10 days respectively). 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 illustrates the lack of symmetry in arrival detections across the season (time) and along the river (space).

Prediction accuracy: MAD

The MAD values depict the average daily error in predicted percentage for the season and are shown in Table 6. When MAD is very low, there is good correspondence between the prediction and the observations. At JDA, MAD values for chin1pit and lgrStlhd were 2.3% and 5.9% respectively. At BON, 7.8% and 16.1% respectively.

Post-MAD uses the hindsight of the true release distribution and known flows and spill as shown in Table 7. Post-MAD improves for upstream sites but not so for the distributions at BON where the Post-MAD was equal or worse to the season MAD.

Pre-Post-MAD, uses the hindsight of the true release distribution, but uses preseason predictions of flow, and is shown in Table 8. As expected, these MADs are not as good as the corresponding Post-MAD values in Table 7. To see the consistency or discrepancy in more detail, they are depicted in plots of observed and predicted cumulative arrivals for each stock/site in Appendix 2: Observations and Predictions.

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 **Error! Reference source not found.**. Spill at LWG was ~30% during most of the passage period but climbed to over 50% at the tail end of the passage, while at LGS ~40% spill at the beginning of the run dropped to about 30% and rose back up. At BON, during passage, spill was just below 40% and rose by ~10% during passage. JDA had very stable spills throughout the season, near 35% during passage. BON has the greatest discrepancy in observations but some of the least variability in spill fraction. Therefore, it seems unlikely that spill level can explain the passage effects.

Related to this 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. Fish have other routes through the dam (e.g. the spillway, surface collector, or turbine). Bypass fraction computed by COMPASS is shown in Table 9. For comparison, modeled FGE is shown as well. The bypassed fraction is always lower or equal to FGE (see Figure 4), and is sensitive to spill.

In a dam, the bypass system is where PIT-tagged fish are observed so high spill and low FGE both result in fewer observations. Depending on spill (**Error! Reference source not found.**) and the availability of other possible passage routes (Figure 4), the bypassed fraction may be a small fraction of the overall total (e.g. BON =0.09 for chin1pit see Table 9). 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, and certainly means that observations in the bypass system can not be used for computing survival.

Survival

Modeled survival changes across the season and generally converges to a stable value as the season progresses as evidenced by the time series of the survival predictions. Final COMPASS modeled survivals from LWG to BON for chin1pit and lgrStlhd are 0.57 and 0.48. Time series of survival predictions made through the season are depicted in stages from LWG to MCN (Figure 6), and MCN to BON (Figure 7). COMPASS generated survivals can be compared to some limited control data survivals. These are slightly different measures. Some of these model-data comparisons are shown in Figure 8. From LWG to MCN, the COMPASS prediction and the data controls have excellent correspondence. Between MCN and JDA the data depicts the survival as being higher than COMPASS and between JDA and BON it is lower. (Appendix 4: Survival Predictions with Data Controls.) Considering the controls and the COMPASS runs, both chin1pit and lgrStlhd are well modeled from LWG to MCN and to a certain extent from MCN to JDA. The reach from JDA to BON was poorly modeled.

The control data survivals were computed separately over the two sections of river (Faulkner, 2008 pers. comm., Dec. 16, 2008) and are based on the count-weighted average of the survivals of the fish released on one week intervals. From LWG to MCN, COMPASS predicted survivals of 0.77 and 0.69 for chin1pit and lgrStlhd, while the data controls survivals were 0.79 and 0.68. Differences of 0.02 and 0.01. From MCN to BON, COMPASS predicted survivals of 0.74 and 0.69 while the data controls survivals were 0.47 and 0.53 respectively. Differences of 0.27 and 0.16.

Results: Tables and Figures

Table 2 Counts of yearling stocks used in this analysis passing PIT-tag detectors at six prediction sites.

	LWG	LGS	LMN	MCN	JDA	BON
real	5702	4827	3166	2702	1861	874
chin1pit	11101	9049	5799	4845	3419	1713
lgrStlhd	6139	8600	3497	2777	2861	2098
mcnChin1S	-	-	-	7864	5879	2744
mcnStlhdC	-	-	-	690	820	438
mcnStlhdS	-	-	-	3822	4384	2548

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	LWG	LGS	LMN	MCN	JDA	BON
real	130	136	137	141	144	145
chin1pit	134	138	141	143	145	147
lgrStlhd	133	136	137	142	145	146
mcnChin1S	-	-	-	140	143	145
mcnStlhdC	-	-	-	143	148	149
mcnStlhdS	-	-	-	139	141	143

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

Stock	LWG	LGS	LMN	MCN	JDA	BON
real	127	133	140	135	143	138
chin1pit	128	135	140	135	143	139
lgrStlhd	129	133	141	134	142	136
mcnChin1S	-	-	-	136	144	140
mcnStlhdC	-	-	-	138	143	139
mcnStlhdS	-	-	-	138	146	138

Table 5 Difference between Declared and Observed median arrival day-of-year. (Table 3 - Table 4) Positive values are late, negative values are early.

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

Table 6 Mean Absolute Deviation (MAD) between predicted and observed passage distributions for selected sites and each stock.

	LWG	LGS	LMN	MCN	JDA	BON
real	5.94	1.32	3.22	6.45	1.85	9.0
chin1pit	11.66	4.83	4.54	8.10	2.33	7.8
lgrStlhd	7.02	3.85	4.63	9.8	5.88	16.1
mcnChin1S	-	-	-	5.20	2.93	4.8
mcnStlhdC	-	-	-	8.55	5.34	12.9
mcnStlhdS	-	-	-	6.94	9.66	8.5

Table 7 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	1.4	2.5	5.5	4.6	2.4	8.2
chin1pit	2.2	2.2	3.2	4.7	1.8	7.8
lgrStlhd	3.1	2.5	3.5	10.3	6.7	16.7
mcnChin1S	-	-	-	3.2	2.1	5.7
mcnStlhdC	-	-	-	4.1	3.5	11.6
mcnStlhdS	-	-	-	4.5	3.1	15.2

Table 8 Pre-Post-MAD. Compares year-end observations with a COMPASS run that used early-season's anticipated environmental information combined with full knowledge of release distributions.

Flow prediction	Stock	LWG	LGS	LMN	MCN	JDA	BON
Mar 23	chin1pit	1.3	3.2	4.6	4.0	1.7	6.2
Mar 23	lgrStlhd	1.6	1.9	6.4	6.9	3.3	13.6
Apr 23	chin1pit	1.3	2.3	3.3	4.9	1.5	8.1
Apr 23	lgrStlhd	1.6	2.1	3.8	10.2	6.7	16.6

Table 9 Modeled passage fraction through the bypass system (bypass fraction). This is related to the spill efficiency and the fish guidance efficiency (see Figure 4). For RealTime/COMPASS runs, the fish that are released at LWG or MCN have 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.

COMPASS effective Bypass Fraction	LGS	LMN	MCN	JDA	BON
real	.24	.20	.33	.28	.09
chin1pit	.24	.21	.31	.29	.09
lgrStlhd	.24	.37	.18	.25	.06
mcnChin1S	-	-	-	.28	.09
mcnStlhdC	-	-	-	.25	.06
mcnStlhdS	-	-	-	.24	.06

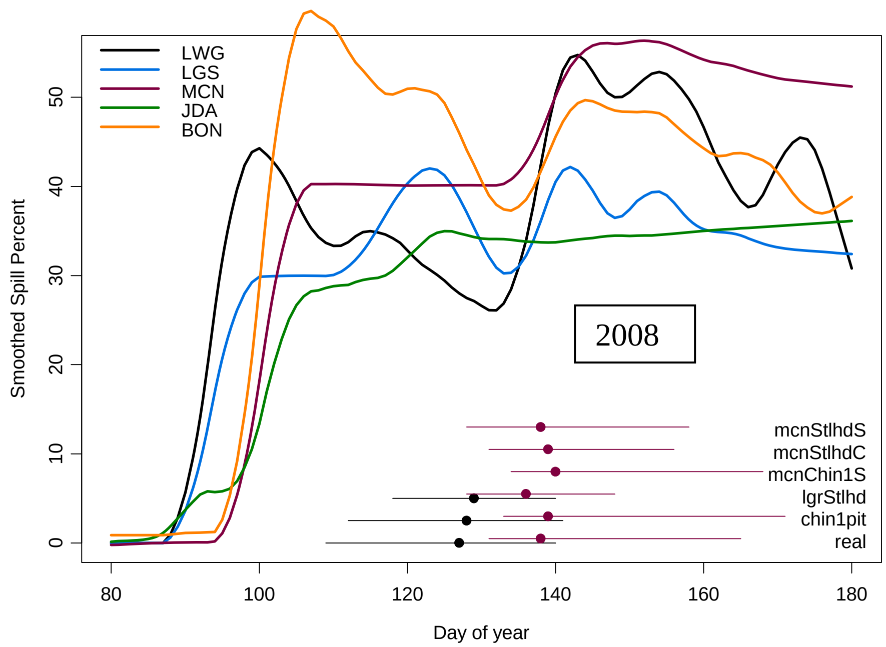


Figure 5 Spill percent (smoothed) at dams during passage in 2008. Stock abbreviations and whiskers of the middle 80% of the observed fish and median day (point) passage at LWG (black) and BON (red). We infer that the passage at intermediate dams as being between the first (LWG) and last (BON).

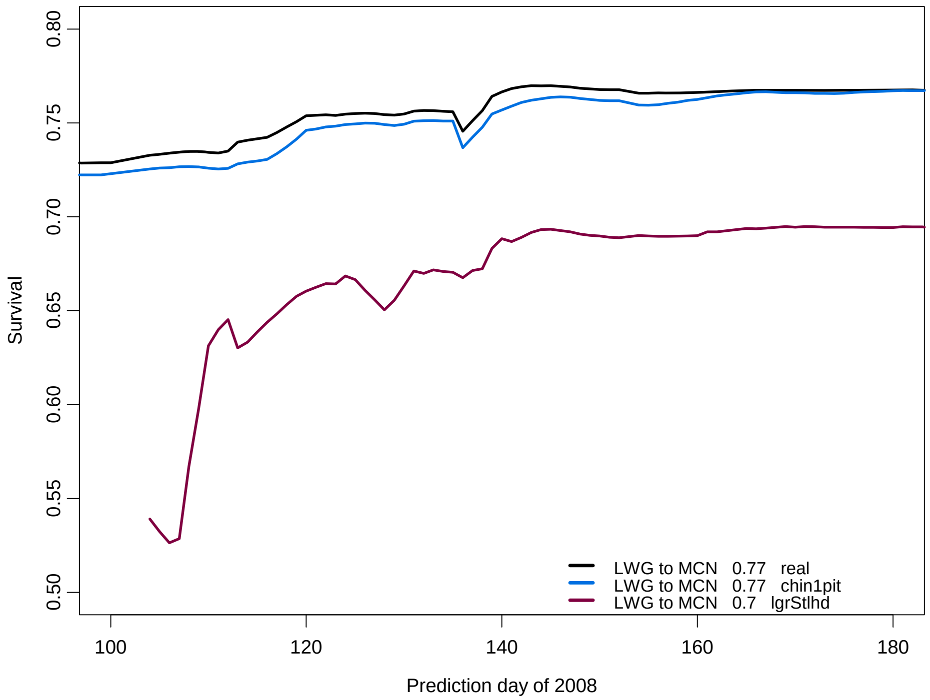


Figure 6 Survival predictions over the 2008 season from LWG to MCN. Written survival is the final prediction of the survival made by COMPASS, the latest survival prediction in the time series.

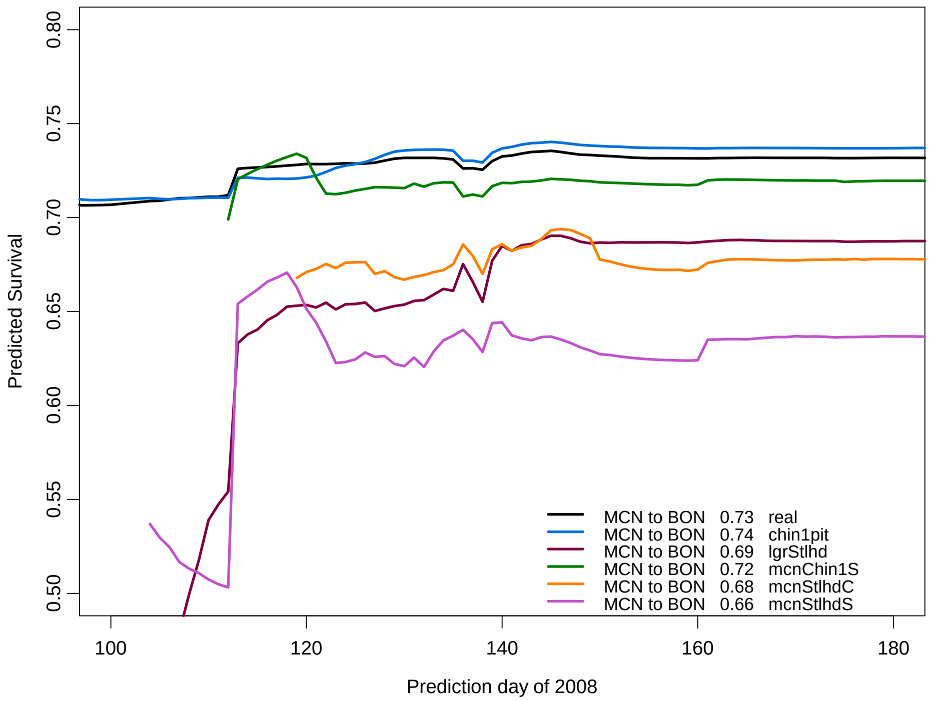


Figure 7 Survival predictions over the 2008 season from MCN to BON. Written survival is the last value, the final prediction of survival made by COMPASS

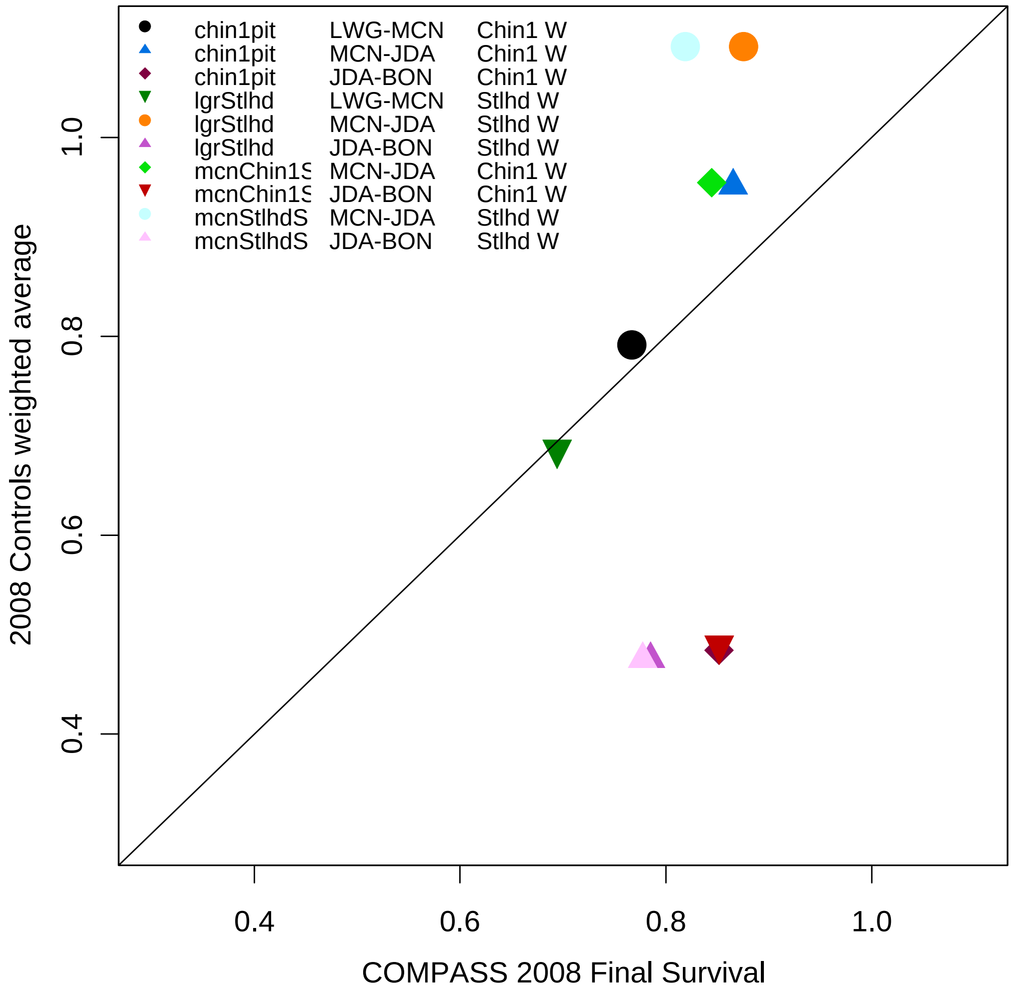


Figure 8 Comparison of 2008 control survival data against COMPASS-generated survivals in 2008. The 1:1 line is shown. There are four calibrations available to COMPASS: Steelhead and Chinook in either the lower Snake River or the mainstem Columbia River. The chin1pit and lgrStlhd COMPASS stocks from LWG-MCN have excellent agreement with the survival control data. It also shows how similar the other stocks are to the calibrated stocks

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 observations.

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 and spill, and relies on preseason predictions of water and relevant updates that are made as the season progresses. These are obtained from flow forecasts provided by the Bonneville Power Administration and observations updated daily from DART (http://www.cbr.washington.edu/dart/river.html). Egregious errors in flow prediction could make a meaningful difference in passage and survival predictions, but for 2008 flow conditions during the main part of the migration (at LWG between day ~110 to ~140, April 20 to May 20) were close to the predictions available near the beginning of the run. Figure 9 shows available early flow forecasts from March 23 and April 23 (days 82 and 113), and the final observations at LWG and BON dams.

Using the March 23 or April 23 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(2). 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 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.

Post-MAD values at upstream sites were better than the inseason MAD although there was no improvement for BON arrivals. Although we expect the Pre-Post-MAD values to be between the Early and Post MAD values, it is not true for the chin1pit stock. The reason is that the Pre-Post COMPASS run for chin1pit reached 100% much sooner that the first COMPASS run did. Because MAD is computed based on percentages, the longer-tailed prediction results in MAD averages over many small discrepancies. This is visible in Figure 10. Since travel-time is dependent on flow, it is consistent with the fact that the early season predictions for mid-summer flows were greater than what actually occurred (see Figure 9). The model is sensitive to flow inputs, and for 2008 there were only moderate differences between the early prediction and the resulting flows. Ironically, the earlier flow forecast of March 23 resulted in more accurate runs (as measured by MAD) than the April 23 flow forecast. One explanation is that with lower flows, fish would be moved more slowly in the model and therefore appear to have timing downstream that is closer to the observations which are ahead of the model predictions. The anomalous results in MAD are probably not related to flow or the manner in which COMPASS uses this information.

A dramatic change in the spill pattern during the run could bias the timing observations, however, the most anomalous observations were made at BON and there, spill fraction was quite stable compared to other sites. This suggests that it was not a source of error in determining timing metrics, either.

Observations

Error in model-data timing comparisons is often related to problems in detecting fish as they pass the dam. This has been a problem in the past (Beer et al. 2007) and continues to be so. Spill variability is related to observation variability because a bias over time in the proportion of fish passing the detectors 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. 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). COMPASS specifically models the bypass fraction as being higher at JDA than at MCN for lgrStlhd and it is reflected in the observations of lgrStlhd fish. More were detected at JDA than MCN. This is likely to continue into future years as long as the spill efficiency stays the same at the two locations.

Third, a change in the survival while the stock is passing will alter the apparent distribution of the run significantly. This may have been what happened to the lgrStlhd this year. Weekly cohort survivals of lgrStlhd dropped through the season as shown in Figure 17.

Two of the above issues seem to be apparent at BON for 2008. In Figure 11, the June 14 prediction of chin1pit shows very good correspondence to the observations at JDA, a sign that inputs and calibration are very good; however, the observations at BON have strayed far from the prediction and the median arrival of the observed fish is very advanced and precedes the median arrival at JDA, upstream. Jim Faulkner, NOAA (pers. comm Dec. 16, 2008) noted that the bypass screens at BON powerhouse 2 were removed from May 23 to June 19 and that gull predation on smolts in the tailrace of JDA and TDA was more extensive than in the past. Figure 12 shows a similar result for the lgrStlhd. Although observations were ahead of the prediction at JDA, they become quite extreme at BON.

RealTime inputs

The inputs from program RealTime are based on observations but extrapolated forward in time so that a complete release prediction is available for COMPASS. There is not yet any way to 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 site and there may be differences in median passage day and 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 fact, MADs for chin1pit and lgrStlhd at LWG are 11.7 and 7.0, respectively. In Figure 13 it is apparent that the prediction of median passage kept being pushed back later for several days for both the Chinook and steelhead. Early, skewed predictions result in inputs to COMPASS with the same bias that propagates downstream. Since COMPASS predictions at downstream locations are compared to the observations, input errors end up being propagated in model results.

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 far as timing is concerned, it should have 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 7). This does not always improve and the reasons for that are not necessarily consistent, for example a survival bias and an observation bias could look the same or compensate for each other.

In general, the current calibrations are better than in 2007 when modeled fish all appeared to move too slowly. When prediction curves lie to the right of the corresponding observations (i.e., the fish really arrived at the location in advance of the prediction) as seen in Figure 10 for the lgrStlhd at BON, it suggests a systematic error such as the calibration but there are other reasons for such a discrepancy (see Observations above).

The propagation of timing error results in increases in MAD from upstream to downstream and consistent discrepancies between predicted and observed percentiles. When a predicted percentile is later than the observed percentile, the timing error (days) is positive. Table 11 shows differences in days for the predicted minus observed 10, 50 and 90 percentiles. The numbers are all very low except for BON and there are good reasons for believing that the observations there are uniquely bad as described above.

Survival Calibrations

Survival modeling through JDA seems to be very accurate in COMPASS compared to the control release studies (see Figure 8 and Appendix 4: Survival Predictions with Data Controls). Different control release groups had quite variable survivals over the season, whereas COMPASS predictions tended to stabilize as the season progressed. COMPASS input data varies less and less with each passing day as it adds observations to the inputs. As time passes, the known distribution of the fish arriving at LWG becomes a greater proportion of the modeled passage distribution and the environmental conditions encountered are known, and not forecast. The survival predictions stabilize along with the environmental inputs.

Summary and Discussion Tables and Figures

Table 10 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(2)). The early in-season run is when both arrival and environment are predicted. April 4 and 13 are the early prediction days for the Chinook and Steelhead respectively. 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	MAD
Chin1	Early (Apr 4)	Predicted	Predicted	143	0.515	3.8
	Post	Known	Known	143	0.568	7
	Pre-Post (Mar 23)	Predicted	Known	144	0.528	6.2
	Pre-Post (Apr 23)	Predicted	Known	145	0.545	8.1
Stlhd	Early (Apr 13)	Predicted	Predicted	149	0.261	21.2
	Post	Known	Known	144	0.478	15
	Pre-Post (Mar 23)	Predicted	Known	145	0.290	13.6
	Pre-Post (Apr 23)	Predicted	Known	146	0.440	16.6

Table 11 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	0	-3	-1	1	3
chin1pit	1	1	-3	0	1	3
lgrStlhd	2	2	-4	7	7	12
mcnChin1S	-	-	-	2	2	4
mcnStlhdC	-	-	-	2	2	9
mcnStlhdS	-	-	-	2	3	9
Difference between Predicted 50% and Observed 50%						
	LWG	LGS	LMN	MCN	JDA	BON
real	1	0	-5	4	-1	6
chin1pit	1	-1	-3	6	0	6
lgrStlhd	2	2	-4	7	2	10
mcnChin1S	-	-	-	2	-1	4
mcnStlhdC	-	-	-	2	1	7
mcnStlhdS	-	-	-	4	0	10
Difference between Predicted 90% and Observed 90%						
	LWG	LGS	LMN	MCN	JDA	BON
real	1	-6	-8	-2	-5	-11
chin1pit	3	-6	-6	-4	-4	-15
lgrStlhd	2	0	-3	2	0	5
mcnChin1S	-	-	-	3	2	-4
mcnStlhdC	-	-	-	3	2	0
mcnStlhdS	-	-	-	3	4	5

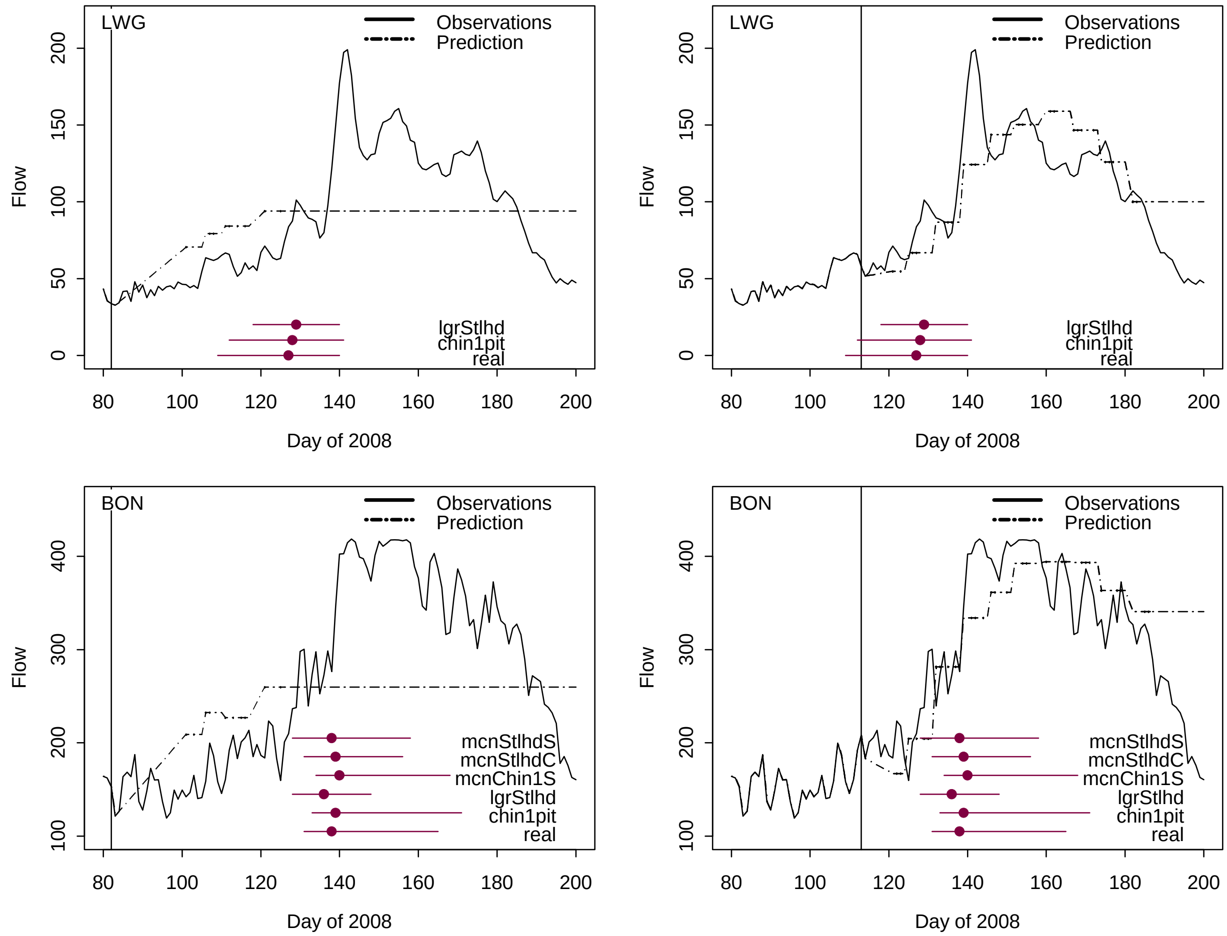


Figure 9 Predicted flow for the season made on March 23 and April 23 (day 82 and 113) and final observed flow at LWG and BON. Vertical lines show the prediction day. Passage metrics are at LWG and BON showing median day and 20% and 80% whiskers.

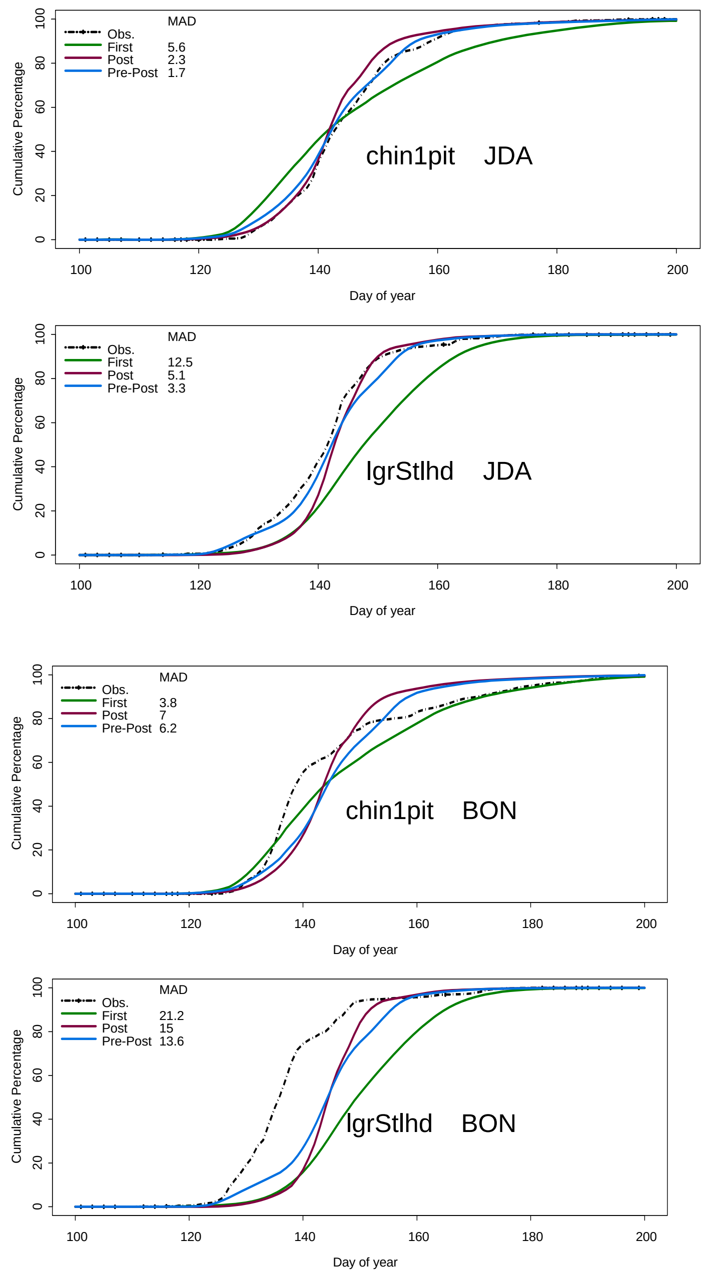


Figure 10 Comparison of Bonneville passage using three distinct COMPASS runs for chin1pit and lgrStlhd. “First” is the April (1 or 13 respectively) prediction based on anticipated arrivals and anticipated environmental conditions. “Post” uses all observations. “Pre-Post” uses the record of observed arrivals and the preseason environmental predictions from March 23 (April 23 not shown). We expect the Pre-Post run to be between the others. For 2008, skewed observations distorted arrival distributions at BON such that pre-season low flow predictions actually better simulated the final distribution and resulted in very good MAD for the “First” run.

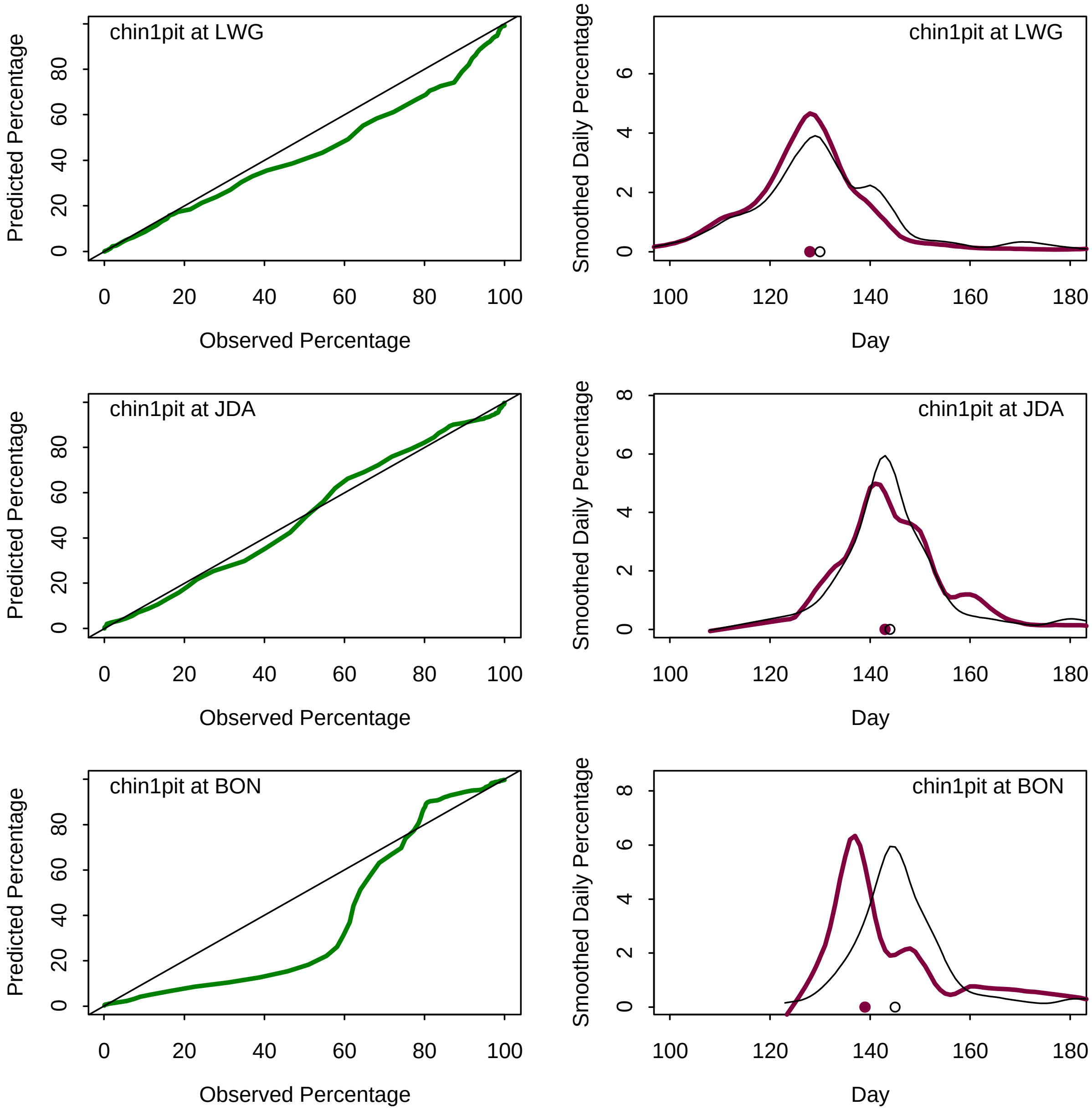


Figure 11 Assessment of bias in observations for chin1pit compared to the June 14 prediction. In left-side panels, the Predicted percentage on June 14 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations and predictions. Observations are nicely modeled at MCN and this pattern continues to JDA. The shift to left-skew for BON is apparent from the advance of the median day relative to the predicted day and ahead of the upstream dam JDA.

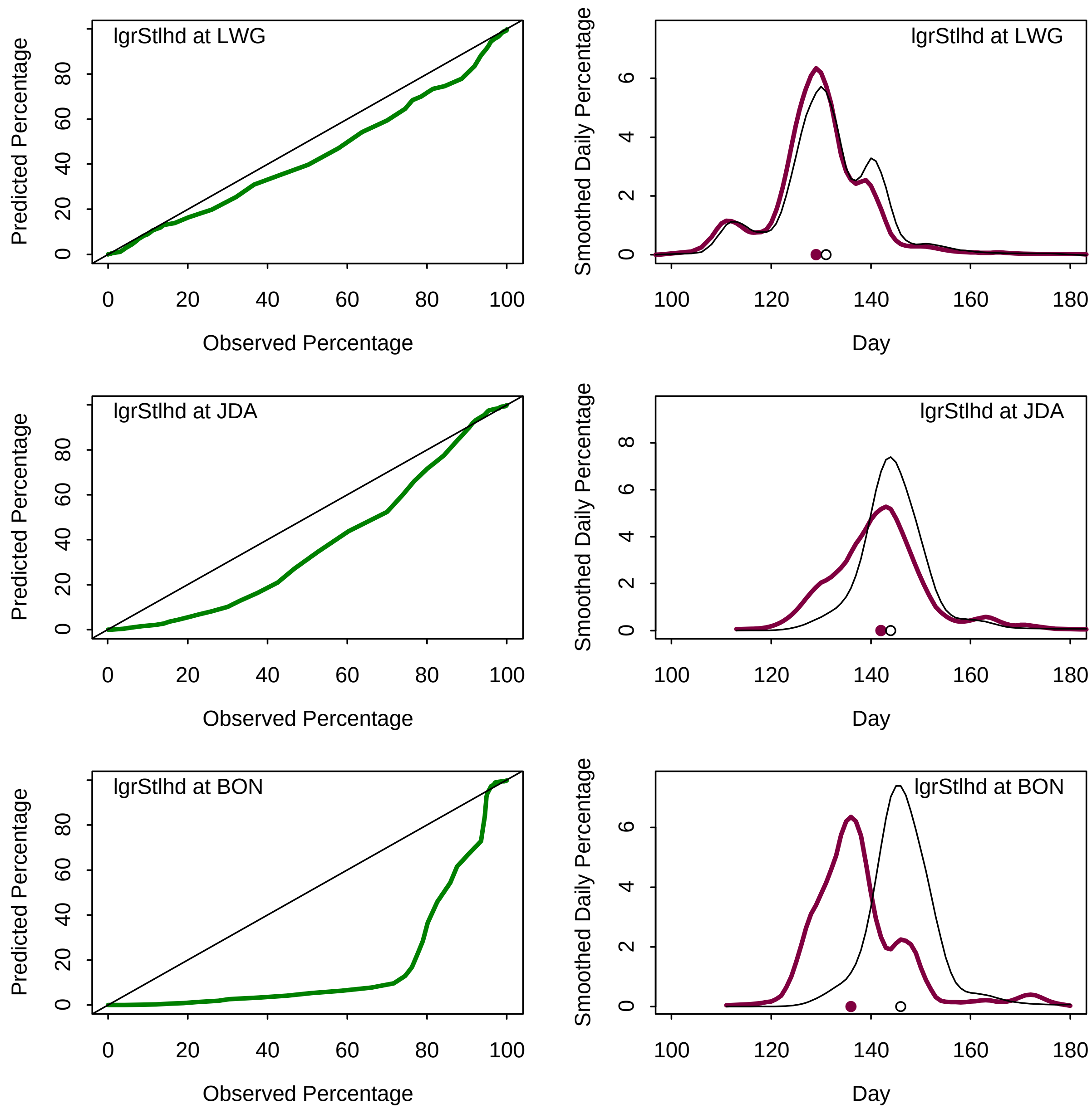


Figure 12 Assessment of bias in observations for lgrStlhd compared to the June 14 prediction. In left-side panels, the Predicted percentage on June 14 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations and predictions. Observations are slightly left-skewed at MCN and this pattern continues to JDA. The dramatic left-skew at BON is apparent from the advance of the median day relative to the predicted day and earlier than the upstream dam JDA.

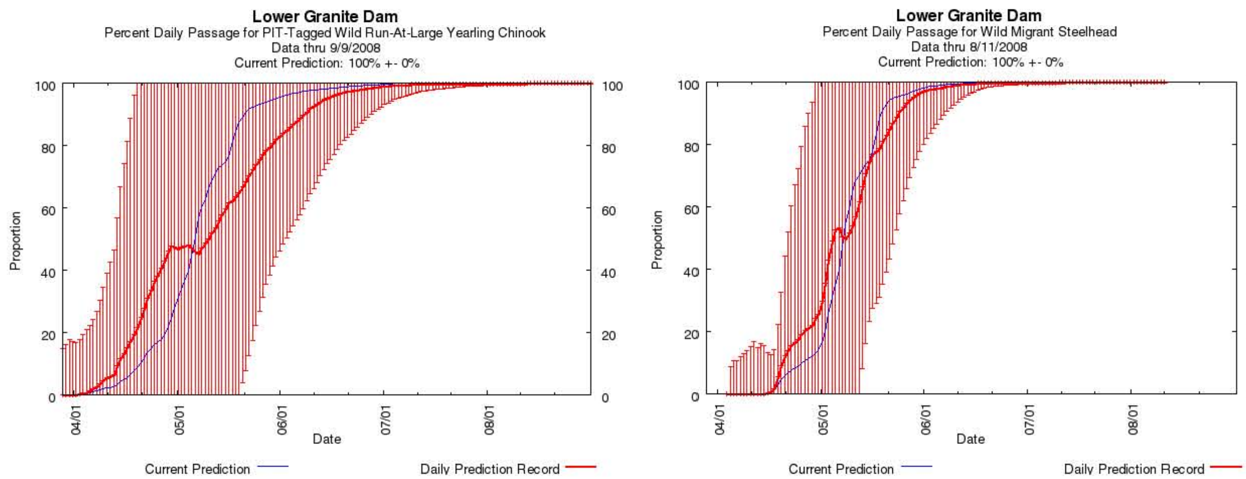


Figure 13 RealTime predictions and observations of Chinook and steelhead passing LWG (see also http://www.cbr.washington.edu/crisprt/index_snake_pit.html). Both the Chinook and steelhead passage predictions had to be shifted later during the run. Vertical bars show the 95% confidence interval. The current prediction is the redistribution of the passage based on hindsight.

References

Beer, W.N., Iltis, S.I., Anderson, J.J. 2007. Evaluation of the 2006 Predictions of the Run-Timing of Wild Migrant Yearling Chinook, Subyearling Chinook and Steelhead and Water Quality at Multiple Locations on the Snake and Columbia Rivers using CRiSP/RealTime. Technical Report 2006. BPA Project Number 1989-108-00. Contract Number 00028556.

Faulkner, J. 2008 pers. comm. NOAA/NMFS Control Release survival estimates for 2008.

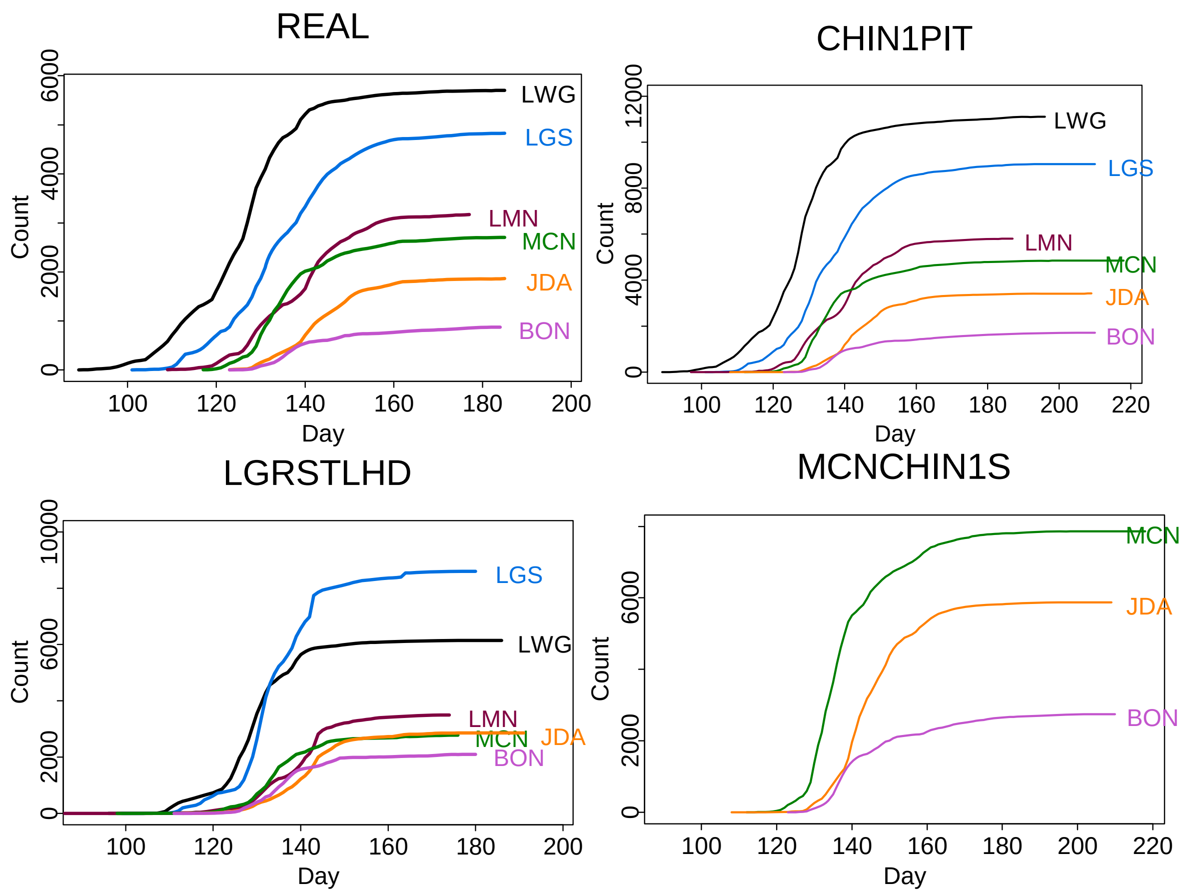
Zabel, R.W. and 11 other authors. 2008. Comprehensive passage (COMPASS) model: a model of downstream migration and survival of juvenile salmonids through a hydropower system. Hydrobiologia. 609:289-300.

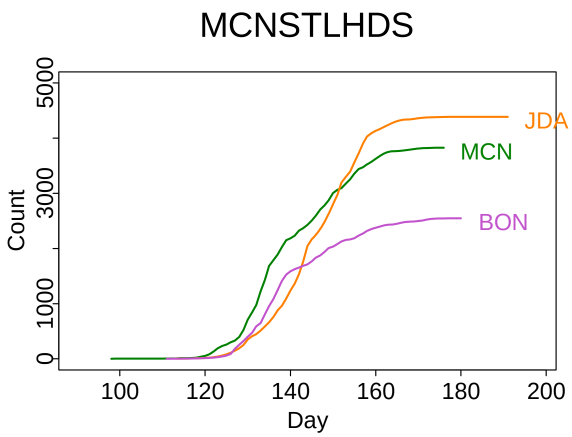
Appendix 1: Observed Cumulative Counts

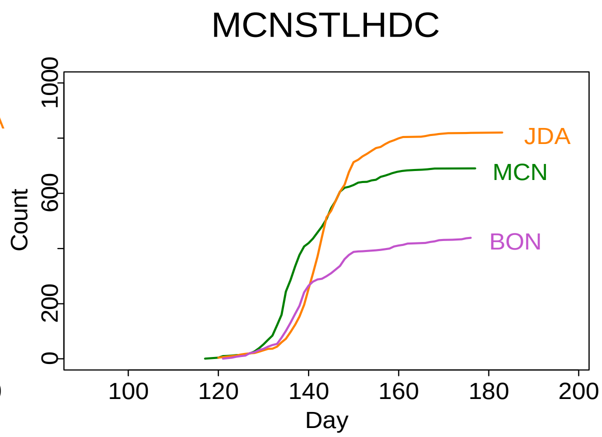
The cumulative counts (observed) of stocks at counting dams are shown in the following plots, organized by stock. Ordinate (y axis) scales vary. The lines span the entire range of the run from first detection to last.

The profiles could be expected to be sequenced from upstream to downstream and generally decreasing due to mortality or transport. However, some downstream locations are more or less effective at detecting tagged fish and there are variations in routing during dam passage.

For example in the “LGRSTLHD” plot, LGS counts exceed LWG and JDA counts exceed MCN.




MCNSTLHDS
Count
Day
0
1000
3000
5000
100
120
140
160
180
200
JDA
MCN
BON


MCNSTLHDC
Count
Day
0
200
600
1000
100
120
140
160
180
200
JDA
MCN
BON

Appendix 2: Observations and Predictions

See also Figure 11 and Figure 12 for chin1pit and lgrStlhd stocks.

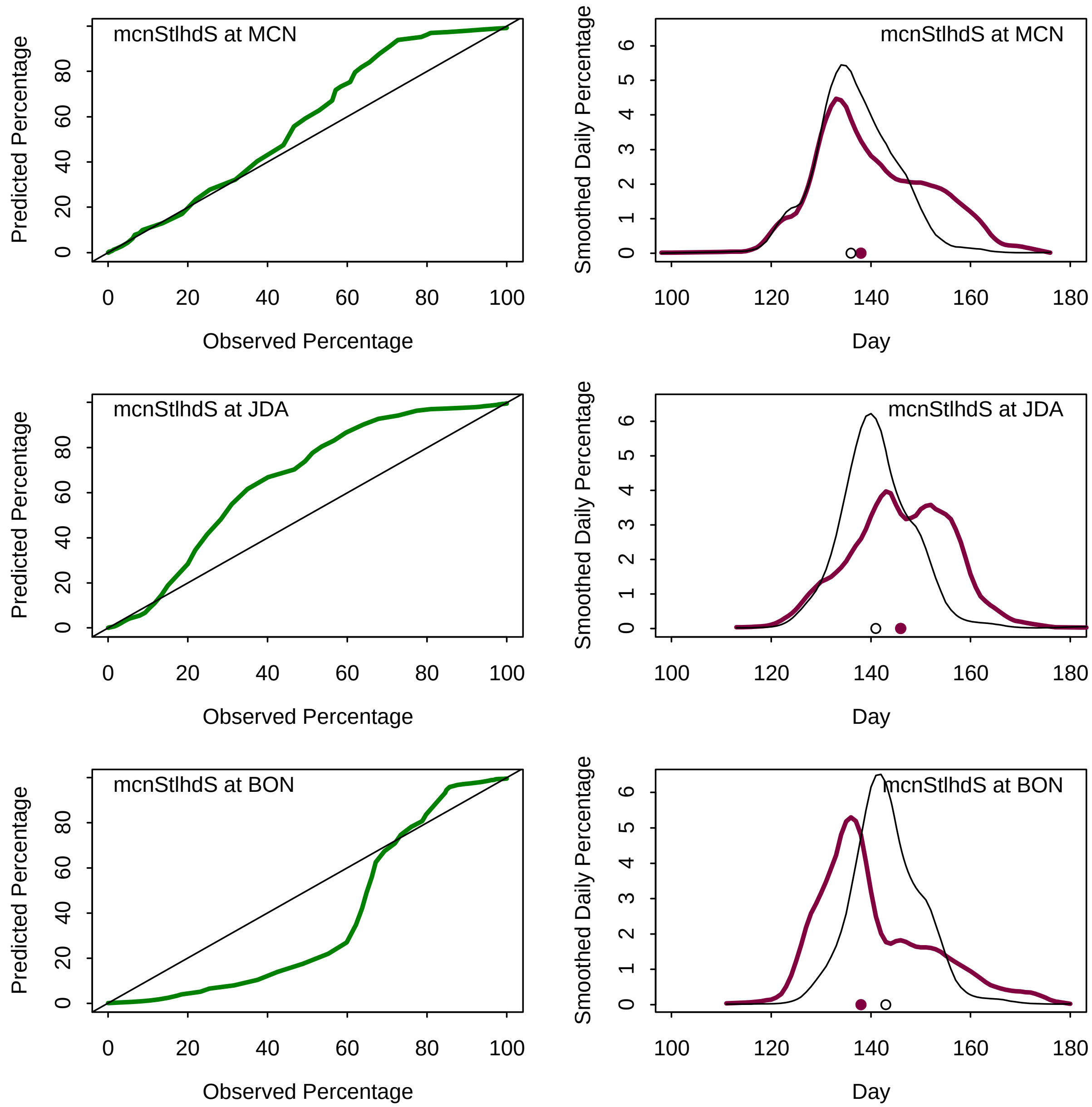


Figure 14 Assessment of bias in observations for mcnStlhdS. In left-side panels, the Predicted percentage on June 14 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations and predictions. Observations begin right-skewed at MCN and this pattern continues to JDA. The shift to left-skew for BON is apparent from the advance of the median day relative to the predicted day.

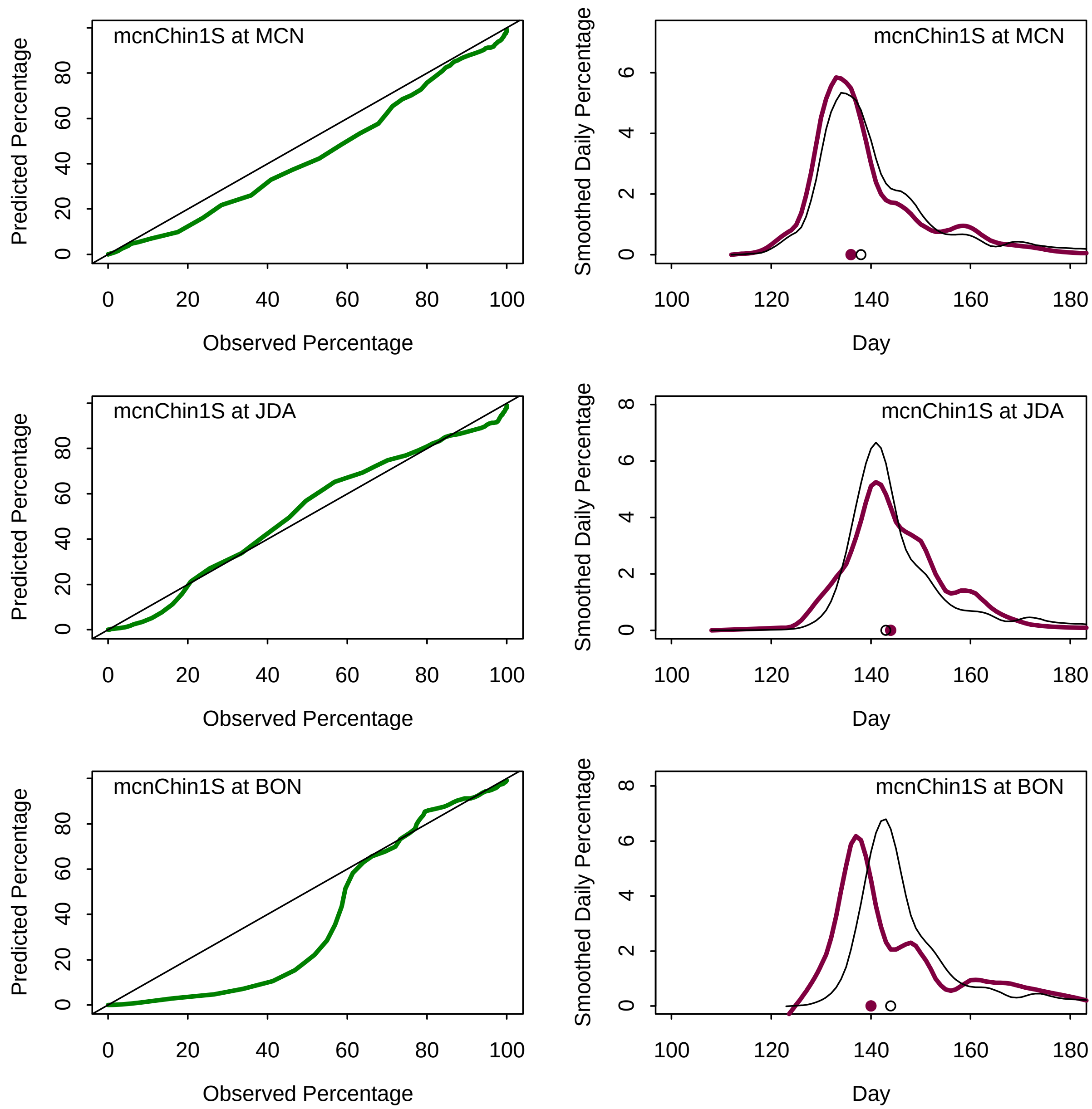


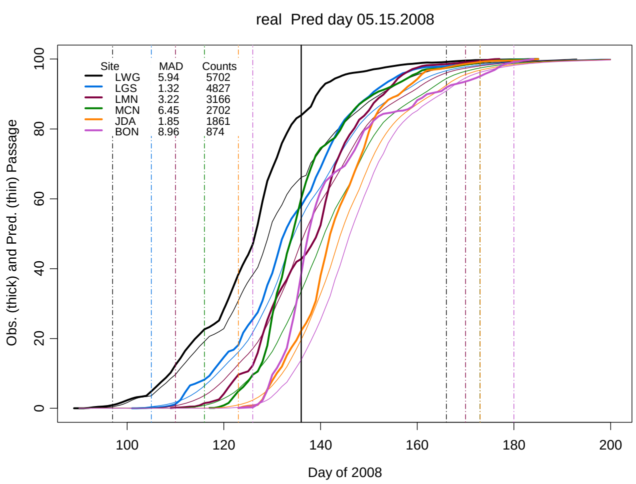
Figure 15 Assessment of bias in observations for mcnChin1S. In left-side panels, the Predicted percentage on June 14 is plotted against the final observed percentage. In right-side panels, smoothed daily percentages for the observations (thick, red line) and the predictions are overlaid. The dots depicts the median day for the observations and predictions. Observations match the predictions nicely at MCN and this pattern continues to JDA. The shift to left-skew for BON is apparent from the advance of the median day relative to the predicted day.

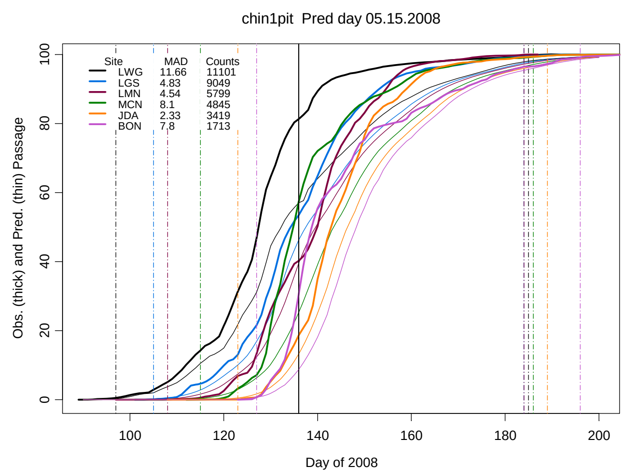
Appendix 3: Observations, Predictions and MAD

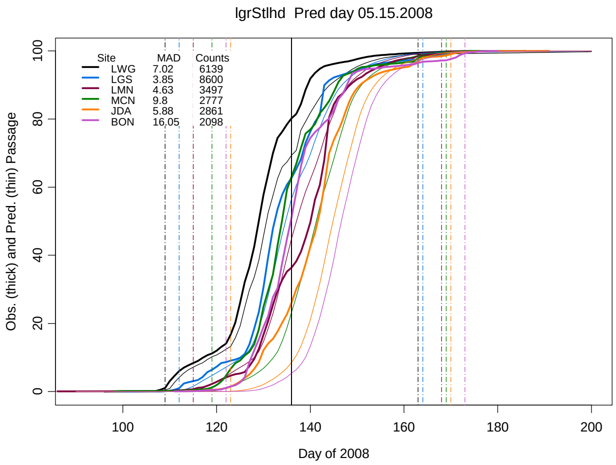
MAD day range calculations are made between 1 to 99 percentiles on both prediction and observation when possible. The graphs in this appendix depict all of the data used to compute MADs.

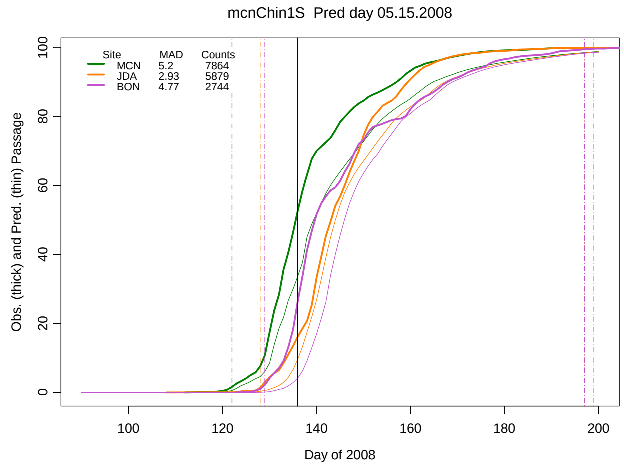
- All graphs have the same abscissa and ordinate ranges.
- Line color varies for different dams, each of which has a three letter code, followed by the MAD value: mean absolute deviation in prediction passage percentage.
- Observations (Predictions) have the thicker (thinner) lines.
- Date ranges of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

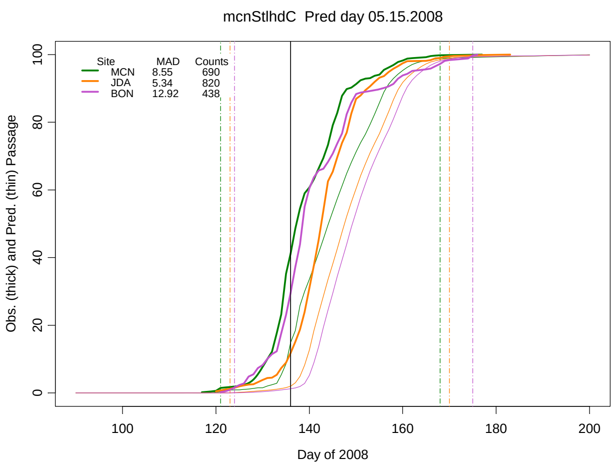
Prediction curve is the sequence of point predictions for the run and therefore can vary up or down from one day to the next. Predictions that began/ended after/before the first/last observations for a stock have their beginning/ending days and observations depicted for a narrower range than 1 - 99 percentiles. For example, the first prediction for snakeChin1 was on day 123 (May 3) at all six locations, long after the fish had begun to migrate. The mcnStlhdC run was very poorly modeled for most of the season as shown by the gap between the observation and prediction curves as well as the high MAD values. The uppermost dam arrivals are predicted by RealTime and COMPASS extrapolates that prediction downstream according to a migration model.

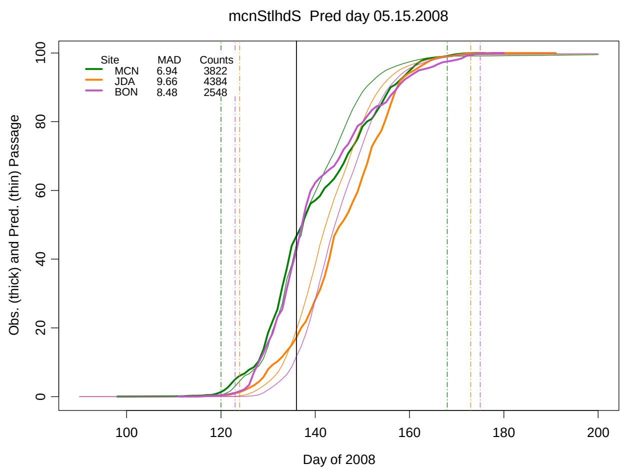





lgrStlhd Pred day 05.15.2008
Site MAD Counts
LWG 7.02 6139
LGS 3.85 8600
LMN 4.63 3497
MCN 9.8 2777
JDA 5.88 2861
BON 16.05 2098
Obs. (thick) and Pred. (thin) Passage
Day of 2008


mcnChin1S Pred day 05.15.2008
Site MAD Counts
MCN 5.2 7864
JDA 2.93 5879
BON 4.77 2744
Obs. (thick) and Pred. (thin) Passage
Day of 2008


mcnStlhdC Pred day 05.15.2008
Site MAD Counts
MCN 8.55 690
JDA 5.34 820
BON 12.92 438
Obs. (thick) and Pred. (thin) Passage
Day of 2008


mcnStlhdS Pred day 05.15.2008
Site MAD Counts
MCN 6.94 3822
JDA 9.66 4384
BON 8.48 2548
Obs. (thick) and Pred. (thin) Passage
Day of 2008

Appendix 4: Survival Predictions with Data Controls

The graphics that follow depict COMPASS output and controlled survival studies of fish groups.

Guide to the graphics that follow:

- 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.
- Control survivals (black points) and Standard Errors (whiskers) are depicted for each release.
- Colored line shows the cumulative weighted average of the survival estimates.
- The point estimates of survival are plotted at the *release day*, whereas the COMPASS line is referenced to the *prediction day*.
- All abscissa and ordinate ranges are identical.
- "LGR" indicates Lower Granite Dam (a.k.a. LWG).

Good correspondence between data controls and modeling is shown with the "chin1pit LGR.MCN Chin W" plot. COMPASS predicted survival consistently over the season (the relatively flat prediction time series line) and the data confirmed this with narrow confidence regions for all release groups and a weighted average survival for the entire group over the whole season of 0.77.

Interesting interpretations of the survival controls data are:

1) very low survival from JDA to BON in mid-run for all groups
2) survivals >1 between MCN and JDA for all groups, most conspicuous for steelhead
3) a steady drop in survival over the season for lgrStlhd from LWG to MCN.

There seem to be significant unmodeled effects in the river between JDA and BON this year. The confidence intervals on the survival data are quite narrow around the very low survival measures.

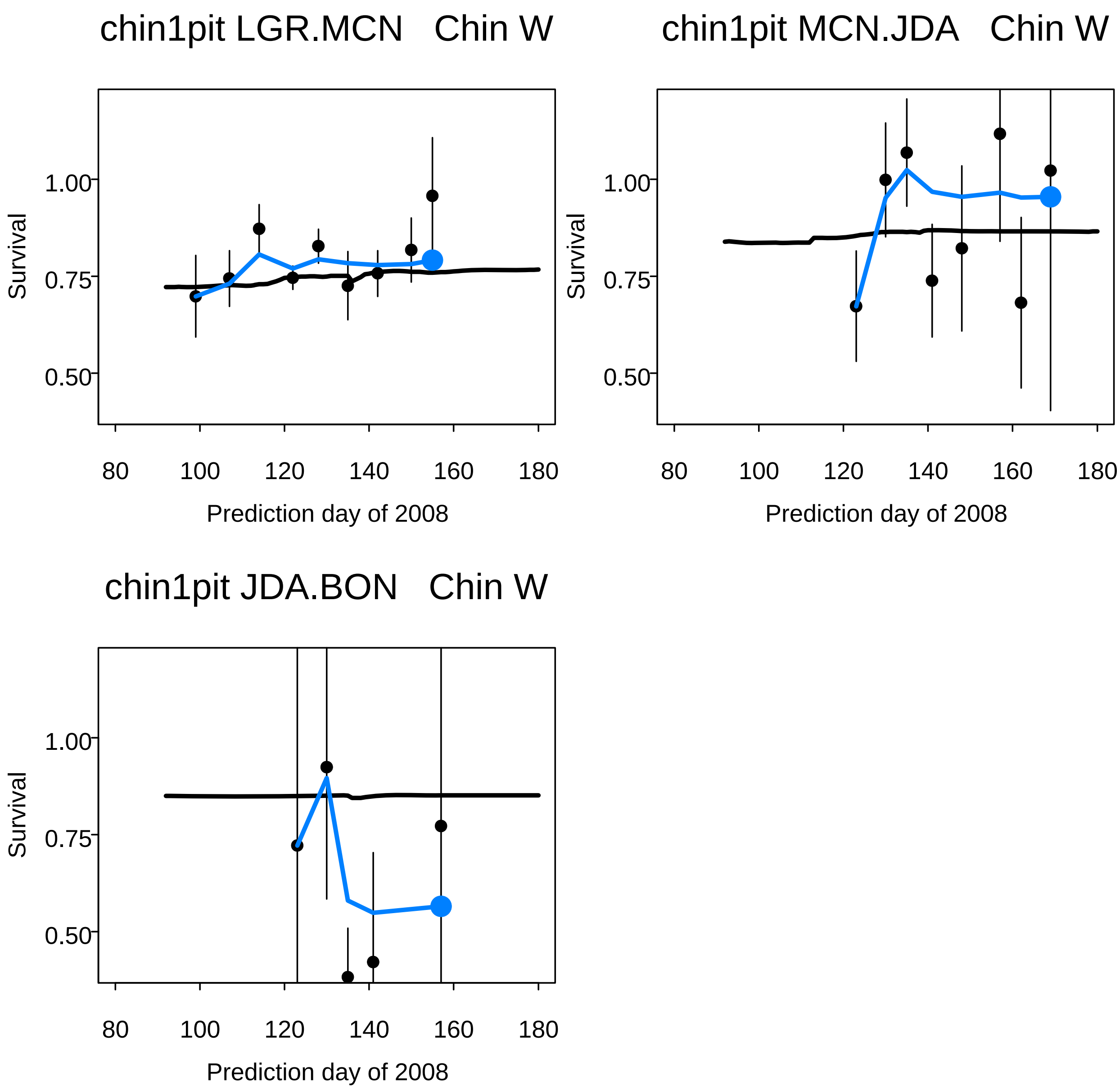


Figure 16 Survival of chin1pit COMPASS and data controls survivals over the migration season in stages from LGR (LWG) to MCN, MCN to JDA, and JDA to BON.

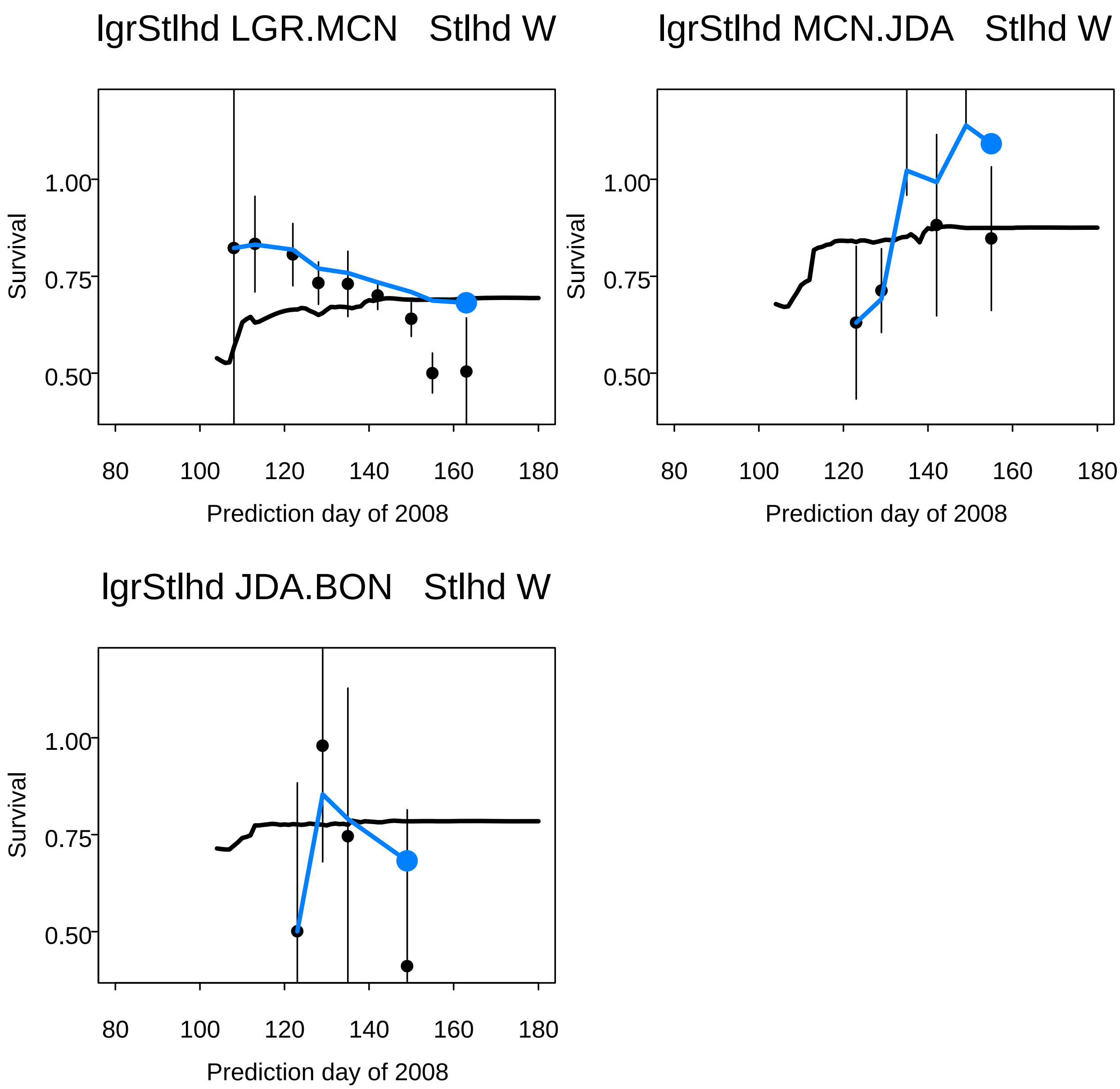


Figure 17 Survival of lgrStlhd COMPASS and data controls survivals over the migration season in stages from LGR (LWG) to MCN, MCN to JDA, and JDA to BON.

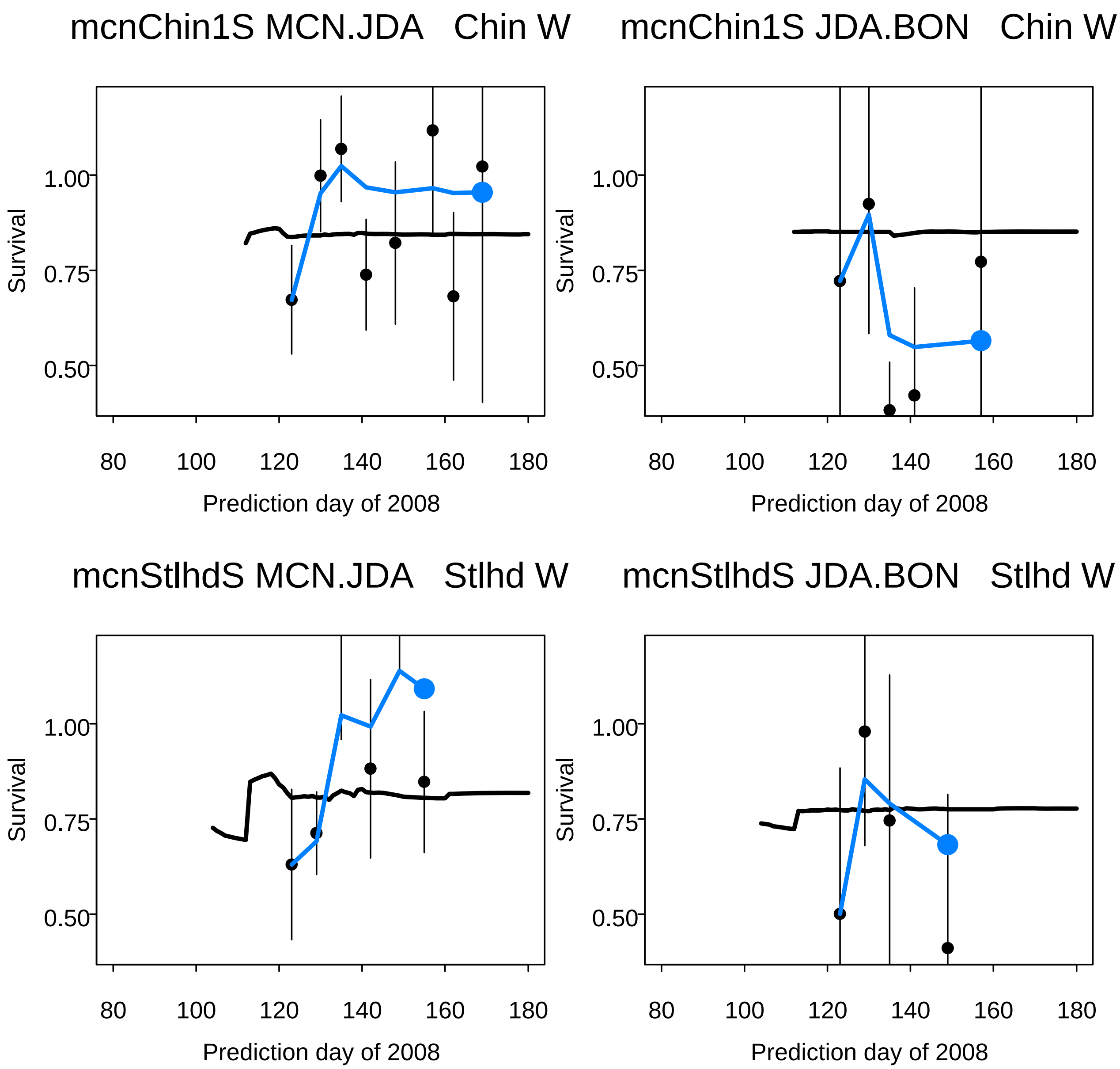


Figure 18 Survival of MCN releases: mcnChin1S and mcnStlhdS in COMPASS and data control survivals of Chinook and Steelhead over the migration season in stages from MCN to JDA, and JDA to BON.

Appendix 5: Modeled FGE and FPE during migration season

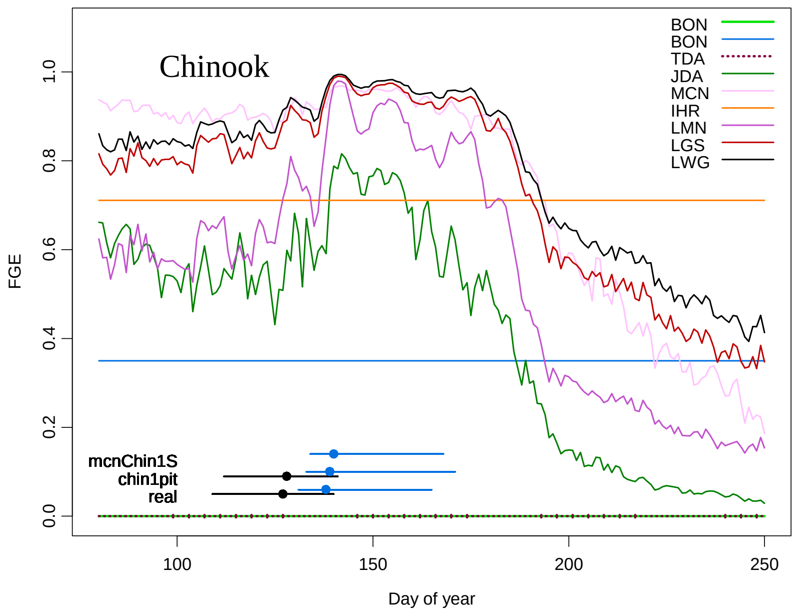


Figure 19 Computed FGE and passage of Chinook. Notes: Bonneville has 2 powerhouses (PH). FGE = 0 at BON (#1 PH) and TDA.

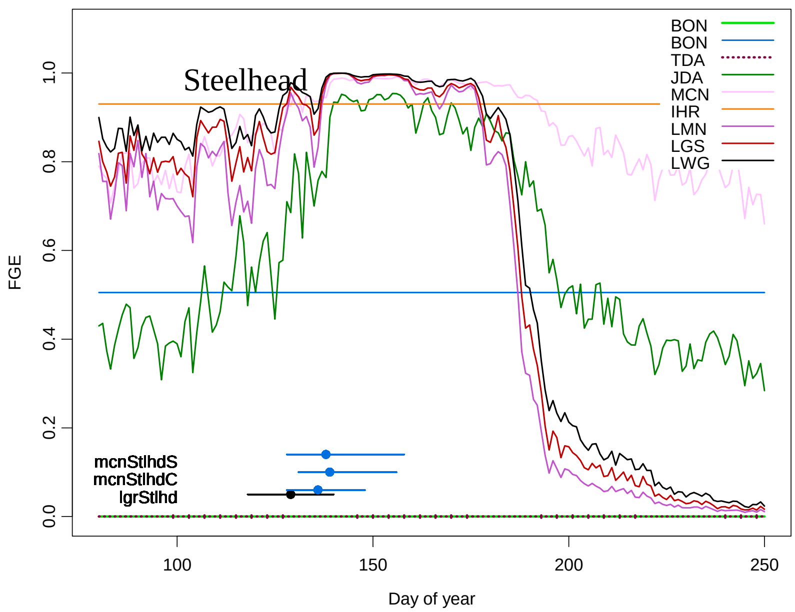


Figure 20 Computed FGE and Passage of Steelhead. Notes: Bonneville has 2 powerhouses (PH). FGE = 0 at BON (#1 PH) and TDA.

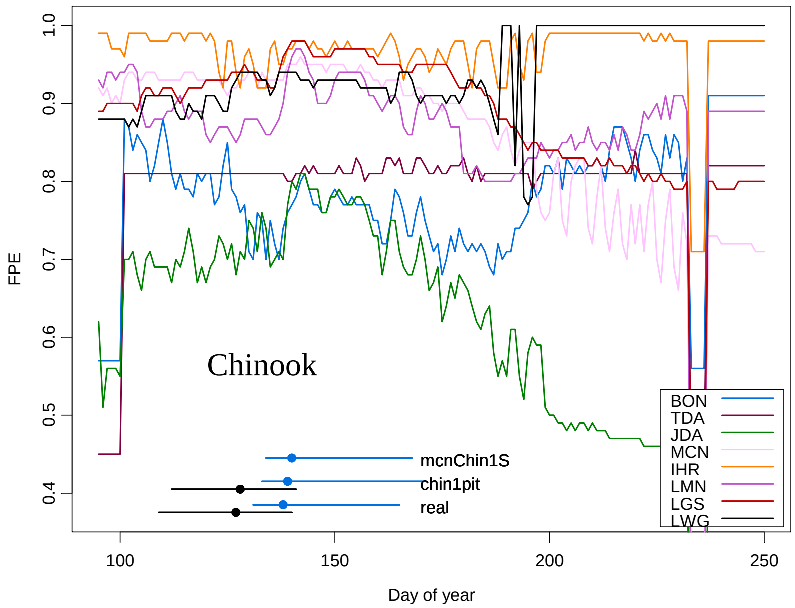


Figure 21 Computed FPE for Chinook based on flow, spill, spill efficiency, and FGE in COMPASS runs.

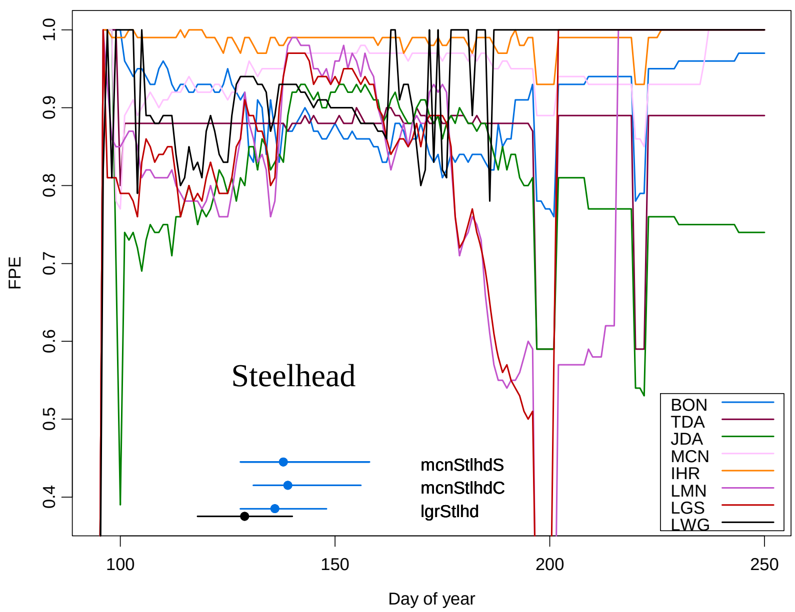


Figure 22 Computed FPE for Steelhead based on flow, spill, spill efficiency, and FGE in COMPASS runs