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

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. Since 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 2016 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. 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.

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	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. In addition, varying efficiencies between dams negates the possibility of using these observations directly to estimate reach-by-reach survival.

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:

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

- 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.
- $PIT\text{-}PH_{dam}$ = Proportion of fish that pass through the bypass or turbine routes. These fractions are aggregated in order to compute the total exposure of the stock to powerhouses.

BE is also equal to the ratio of counts at the blue dot to the count at the red dot (Figure 1). 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).

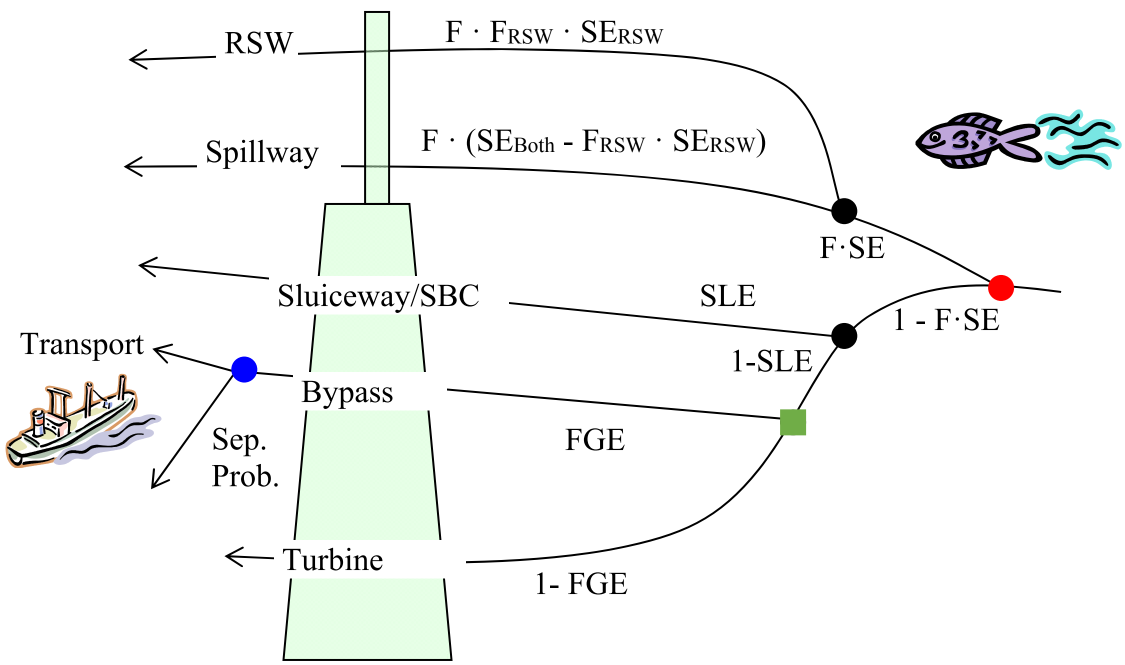

Figure 1 Possible routings of fish at a dam. The dots represent bifurcations of the population where there are only two possible routes. In the case of the RSW and Spillway routes, these do NOT necessarily sum to one. F = fraction of daily flow that passes in spill. SE_{Both} = Spill Efficiency for both 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. $PIT\text{-}PH_{dam}$ = Proportion of fish that pass the dam via the bypass system *or* turbine.

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:

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

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:

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

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 and Traveltime

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. Summaries of these experiments are obtained from NOAA/NMFS each year. For the control data, weekly releases are separately analyzed for their survival to downstream locations. These data-control survivals are compared to the COMPASS- generated survival. They *are* different measures. Control-release 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.

Traveltime assessments are based on the difference (in days) between the median release day at LWG and the median recovery day at BON. This is done for the control-release data, the modelled fish, and the the water travel rate of the water passing LWG when the modelled fish are released. These all result in a single measure (days) for each stock and each of the three travle times.