Predicted Fall Chinook Survival and Passage Timing Under BiOp and Alternative Summer Spill Programs Using the Columbia River Salmon Passage Model

Chris Van Holmes and James Anderson
Columbia Basin Research
University of Washington

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The BPA requested Columbia Basin Research to perform a comparison of Columbia Basin salmon fall chinook stock survivals under the Bi-Op and two alternative summer spill programs for medium (1960) flow years using the Columbia River Salmon Passage Model (CRiSP). The two summer spill programs consisted of Bi-Op conditions with no August spill and Bi-Op conditions with no July and August spill. CRiSP models salmonid passage and survival through the Columbia River, its tributaries, and estuary. A brief description of the model is presented at the end of this report and complete details are available at http://www.cbr.washington.edu/crisp/crisp.html .

CRiSP takes river parameters as inputs for each pool and project:

- Daily Water temperature
- Daily flow
- Hourly planned spill and spill percent
- Daily Water elevation
- Daily Headwater dissolved gas
- Daily transport operation
- Daily Fish release schedules

CRiSP is most effective as an analysis tool when few parameters are changed from scenario to scenario. Monthly and semi-monthly project flows and spills were provided by the NPPC for the BiOp scenario. Taking into account operation limits, spill percents were then reduced to their minimums for the two alternative spill scenarios. All scenarios were run with the same stock release schedules, headwater dissolved gas levels, water temperatures and transport schedules.

The potential impacts on Snake and Upper Columbia fall chinook stocks were examined by using the average smolt index profile at RIS and LGR. Snake River fall chinook were released at Lower Granite Dam with a release timing modeled after the average smolt index at the dam from 1995-2003. Upper Columbia fall chinook were released in the Rock Island tailrace with a release timing modeled after the average smolt index at RIS from 1995-2003. Hanford Reach fall Chinook were released at river kilometer 593 with a single release profile modeled after the cumulative “1 3 W” PIT-tag releases in the Hanford Reach. All stocks were modeled through the Bonneville tailrace. The CRiSP travel time and survival parameters used in these scenarios were calibrated using PIT-tag survival estimates and observed travel times for each stock. The population size for each stock was scaled to equal the population estimate used in the SIMPAS results presented at the February 4th, 2004 TMT meeting shown in Table 1.

Table 1. Smolt Population estimates used in SIMPAS modeling for the Summer Spill Alternatives

Stock	Population Estimate
HR Fall Chinook	25,000,000
Snake R Fall Chinook	1,052,000
Upper Columbia Fall Chinook	2,574,000

The results of the *Average flow Bi-Op scenarios* relative the *no spill options* are presented in Table 2. For Hanford Reach fall chinook, the model projects an additional 0.4% morality with no August spill and an additional 4.0% with no summer spill. For Snake River fall chinook, CRiSP projects 0.1% additional morality with no August spill and 0.5% morality with no summer spill. For Upper Columbia Summer chinook, the model projects 0.5% additional morality with no August spill and 1.6% additional morality with no summer spill.

Table 2. Wild fall chinook average survival and transport percents for Bi-Op conditions with the modeled losses for the alternative spill scenarios.

CRiSP Modeled Average Survival and Transport under Bi-Op conditions								2004 Smolt Lost due to	
Wild Fall Chinook Stocks	Release Site	2004 Modeled Population Estimate	In-river Survival to BON Tailrace	Total System Survival to BON Tailrace	Percent Transport	Total Passage to BON Tailrace	Median MCN Arrival Date	No August Spill	No Summer Spill
Hanford Reach	Hanford Reach	25,000,000	42.2%	49.6%	20.0%	12387000	20-Jun	-53500 (-0.4%)	-496750 (-4.0%)
Snake River	Lower Granite	1,051,615	9.4%	34.72%	35.21%	365254	12-Jul	-668 (-0.1%)	-4621 (-0.5%)
Upper Columbia	Rock Island	2,573,832	7.7%	17.6%	16.78%	452973	12-Jul	-2214 (-0.5%)	-7378 (-1.6%)

The limited impact of the no August spill scenarios on the Hanford Reach fall chinook is due mainly to the earlier migration of these fish. The median arrival day of the modeled Hanford Reach stock at McNary Dam is June 20th. The No Summer Spill scenario has a significant impact on these migrants as they encounter only one transport project. The in-river migrants from the Snake River experience up to 4.1% more mortality under the No Summer Spill scenario relative to the Bi-Op spill. But because the majority of this stock is transported before encountering altered spills at the John Day, Dalles and Bonneville dams the final impact on system survival is below 1%. For the Rock Island stock, a combination of transport at McNary, and the limited number of remaining in-river migrants affected by spill changes at the last three projects limits the effects of the spill alternatives.

CRiSP vs. SIMPAS Results

SIMPAS and CRiSP are two models commonly used to examine various hydrosystem scenario impacts on salmonid migration and survivals in the Columbia Basin. A major difference between the two is that SIMPAS uses a single annual time step to calculate results. CRiSP uses a daily time step to pass migrants through river segments, encountering daily hydro-system and transport conditions along the migration route. Every effort has been made to match CRiSP parameters such as FGEs, spill efficiencies, and project routing mortalities to the estimates used in SIMPAS. CRiSP also contains pool predation mortalities and migration equations calibrated to observed migration and survival data. Both models indicate a negative impact of reduced summer spill and summer migrants as can be seen in Table 3.

TABLE 3. A comparison of SIMPAS and CRiSP results for summer spill alternatives

Modeled 2004 Smolt Migrants Losses				
Stock	No August Spill		No Summer Spill	
	SIMPAS	CRiSP	SIMPAS	CRiSP
Hanford Reach	-162600 (-1.6%)	-53500 (-0.4%)	-524,102 (-5.1%)	-496,750 (-4.0%)
Snake River	-363 (0.3%)	-668 (-0.1%)	1,204 (-0.8%)	-4,621 (-0.5%)
Upper Columbia	16,741 (-1.5%)	-2214 (-0.5%)	53959 (-5.1%)	-7,378 (-1.6%)

For Hanford Reach fall chinook, both models indicate a loss of approximately 500,000 smolts under the no summer spill scenario given an initial population of 25,000,000 juveniles. SIMPAS indicates a larger impact of the no August spill scenario on these smolts primarily due to the difference in migration timing between the two models. CRiSP indicates the median passage of these Hanford reach smolts at McNary dam is on June 20th. SIMPAS models 66% of this population passing in July and August. The Snake fall chinook results for the two models are very similar. For the Upper Columbia fall chinook, CRiSP models a much lower overall survival rate (20.16%) than SIMPAS

(41.11%). CRiSP models these releases from the tailrace of Rock Island Dam, providing a longer migration path and increased mortality before reaching the FCRPS.

Modeling Mitigation Efforts in CRiSP

The CRiSP model has the potential to explore the impacts of mitigation efforts as well. Complex transportation scenarios are possible using Army Corp transport rules. Modeled predation is controlled in part by predator densities that could be are affected by predator control programs. CRiSP can also model the effects of temperature variations resulting from flow augmentation scenarios.

Model Description

CRiSP.1 models passage and survival of multiple salmon stocks through the Snake and Columbia rivers, their tributaries, and the Columbia River Estuary. The model recognizes and accounts for several aspects of the life-cycle of migratory fish--fish survival, migration, and passage--and their interaction with the river system in which they live.

Fish survival through reservoirs depends on:
- Predator density and activity
- Total dissolved gas (TDG) super saturation levels dependent on spill
- Travel time through a reservoir.

Fish migration rate depends on:
- Fish behavior and age
- Water velocity which depends on flow, cross-sectional area of a reach, and Reservoir elevation.

Fish passage through dams depends on:
- Water spilled at the dam
- Bypass screens at turbine entrances and fish guidance sluiceways
- Fish delay at dams
- Turbine operations

CRiSP.1 computes daily fish passage on a release-specific basis for all river segments and dams. Passage and survival of fish through a reservoir is expressed in terms of the fish travel time through the reservoir, the predation rate in the reservoir, and a mortality rate resulting from fish exposure to total dissolved gas supersaturation, an effect called gas bubble disease (GBD). Fish enter the forebay of a dam from the reservoir and may experience predation during delays due to diel and flow related processes. They leave the forebay and pass the dam mainly at night through spill, bypass or turbine routes, or the fish are diverted to barges or trucks for transportation. Once they leave the forebay, each route has an associated mortality rate and fish returning to the river are exposed to predators in the dam tailrace before they enter the next reservoir.

CRiSP.1 integrates a number of submodels that describe interactions of isolated components. Together they represent the complete model.

Travel Time — The smolt migration submodel, which moves and spreads releases of fish down river, incorporates flow, river geometry, fish age and date of release. The arrival of fish at a given point in the river is expressed through a probability distribution.

The underlying fish migration theory was developed from ecological principles. Each fish stock travels at an intrinsic velocity as well as a particular velocity relative to the water velocity. The velocities can be set to vary with fish age. In addition, within a single release, fish spread as they move down the river.

PIT-tagged data over the past 10 years was used to calibrate the travel time parameters are calibrated for spring and fall chinook and steelhead from the Snake River Basin and the Upper Columbia River Basin. Travel time parameters are derived from calibrations to PIT tag data collected over the years 1992 through 2003.

Dam Passage —Timing of fish passage at dams is developed in terms of a species dependent distribution factor and the distribution of fish in the forebay. The model uses the current best estimates of fish guidance efficiency (FGE) and spill efficiency compliant with the SIMPAS model to route fish though various passage options.

Predation Rate — The predation rate submodel distinguishes mortality in the reservoir, the forebay, and the tailrace of dams. The rate of predation depends on temperature, smolt age, predator density, and reservoir elevation.

The predation rate parameters are calibrated using laboratory studies of the response of predators to temperature and field studies of smolt migration survival. The model is calibrated for spring and fall chinook and steelhead from the Snake River Basin and the Upper Columbia River Basin using NMFS published survival data and in-house survival estimates based on SURPH an mark recapture estimation model. The survival parameters are derived from calibrations to PIT tag data collected over the years 1992 through 2003.

Gas Bubble Disease — A separate component of the mortality submodel is mortality from gas bubble disease produced by total dissolved gas (TDG) supersaturation. The mortality rate is species specific, and it is adjusted to reflect the relationship of fish length and population depth distribution to TDG supersaturation experienced by the fish. The gas bubble disease rate is calibrated from laboratory studies.

Total Dissolved Gas Super saturation —Total dissolved gas (TDG) supersaturation are described by mechanistic models which include information on geometry of the spill bay and physics of gas entrainment.

The TDG generation equations used for gas production include the newest developments by U.S. Army Corps of Engineers, Waterways Experiment Station (WES) as well as additional work done by Columbia Basin Research. The gas calibration has been verified for 13 dams for the years 1995 through 2001.

Flow ─In these scenarios, flow is specified at dams using results of system hydro regulation models and historical flows as provided by the NWPPC.

Water Velocity ─Water velocity is used in CRiSP.1 as one of the elements defining fish migration. Velocity is determined from flow, reservoir geometry and reservoir elevation. *Transportation Passage* ─Transportation of fish at collection dams is in accordance with the methods implemented by the U.S. Army Corps of Engineers. Low flow years employ full transport at Snake River projects.