Predicted Fall Chinook Survival and Passage Timing Under BiOp and Alternative Summer Spill Programs Using University of Washington's Columbia River Salmon Passage Model

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The NWPPC 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 high (1974), medium (1960), and low (1977) flow years using the Columbia River Salmon Passage Model (CRiSP). The two summer spill programs consisted of BiOp 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 www.cbr.washington.edu/crisp/crisp.html .

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

- Water temperature
- Daily flow
- Hourly planned spill and spill percent
- Water elevation
- Headwater dissolved gas
- Transport operation
- 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 Council 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 with the exception of using 2001's water temperatures and full transport at Snake River projects in the low flow scenarios to more closely model warm conditions and low flow transport operations.

A range of potential impacts on Snake and Upper Columbia fall chinook stocks was examined by using yearly variations in release profiles. Snake River fall chinook were released at Lower Granite Dam with a release timing modeled after the smolt index at the dam for each year from 1995-2002. Upper Columbia fall chinook were released in the Rock Island tailrace with a release timing modeled after the smolt index at RIS for each year from 1995-2002. The 2003 smolt indices were modeled by taking the actual smolt index through July 1 2003 and appending the 8 year average for the remainder of the season. The annual total indices are provided in table 1. Hanford Reach fall Chinook were released at river kilometer 593 with a single release profile modeled after the cumulative "1 3 W" pittag 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.

Table 1. Cumulative subyearling smolt indices at LGR and RIS. *Estimate using YTD smolt index with in-season forecasts.

Year	LGR	RIS
1995	31230	14193
1996	18533	15308
1997	98550	19109
1998	89120	17209
1999	310989	28345
2000	747839	13693
2001	740554	22651
2002	753596	26325
2003*	1543304	59528

The results of the *Average flow Bi-Op scenarios* relative the *no spill options* are presented in Table 1. The range of results is based on the annual variations in smolt indices. For Hanford Reach fall chinook, the model projects an additional 0.21% morality under no August spills and an additional 1.99% under no summer spills. For Snake River fall chinook, CRiSP projects up to 0.13% additional morality under no August spills and up to 0.61% morality under no summer spills. For Upper Columbia fall chinook, the model projects up to 0.18% additional morality under no August spills and up to 0.33% additional morality under no summer spills.

Table 2. Average survival and transport percents for Bi-Op conditions with the range of losses for the alternative spill scenarios under a historical range of release profiles.

Average Survival and Transport under Bi-Op conditions								2003 Smolt Migrant Lost due to	
Wild Fall Chinook Stock	Release Site	2003 Modeled Population Estimate	In-river Survival	Total System Survival	Percent Transport	Total BON Passage	Median MCN Arrival Date	No August Spill	No Summer Spill
Hanford Reach	Hanford Reach	2500000*	42.2%	49.5%	20.0%	123875	26-Jun	5250 (0.2%)	49750 (2%)
Snake River	Lower Granite	1543304**	38.1%	77.0%	78.4%	118788	27-Jul	401 (0.03%) to 2084 (0.14%)	2624 (0.17%) to 9430 (0.61%)
Upper Columbia	Rock Island	59528**	7.5%	17.3%	21.1%	10310	15-Jul	32 (0.05%) to 79 (0.13%)	109 (0.18%) to 198 (0.33%)

* Assumes Hanford reach smolt 'release' of 2,500,000
**2003 Population estimate from FPC smolt indices and Columbia Basin Research's In-season Forecast as of July 13 (see http://www.cbr.washington.edu/crisprt/index.html).

The limited impact of the alternative 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 26th. The in-river migrants from the Snake River suffer up to 4.32% 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 stocks, a combination of early migration 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.

Table 3. Survival and passage results for Under Bi-Op spill scenario.

Flow Regime	Release Start (Julian)	Survival	Total System Survival	Percent of Release Transported	Total Passage to below BON	Median Arrival Date at MCN
Average	152	42.22%	49.55%	19.98%	UNK	26-Jun
High	152	45.19%	52.10%	20.77%	UNK	26-Jun
Low	152	41.44%	55.25%	35.09%	UNK	26-Jun
Average	161	36.42%	80.09%	83.09%	24448	25-Aug
Average	159	37.55%	79.58%	82.25%	13968	8-Aug
Average	146	37.68%	78.87%	81.09%	67759	30-Jul
Average	156	39.69%	76.87%	77.46%	237038	22-Jul
Average	151	39.12%	78.12%	79.57%	580316	21-Jul
Average	153	39.58%	77.24%	78.08%	568247	13-Jul
Average	148	34.86%	71.53%	73.53%	536584	28-Jul
Average	148	40.15%	73.43%	72.04%	836686	4-Jul
High	161	39.28%	80.20%	82.48%	24481	21-Aug
High	159	42.14%	79.62%	80.63%	13974	30-Jul
High	146	42.89%	79.10%	79.37%	67956	21-Jul
High	156	47.23%	75.14%	69.39%	231685	12-Jul
High	151	45.85%	77.30%	74.56%	574190	11-Jul
High	153	47.24%	76.06%	71.11%	559583	4-Jul
High	148	41.81%	74.01%	73.39%	555184	17-Jul
High	148	49.19%	70.76%	58.91%	806421	28-Jun
Low	161	32.47%	79.38%	83.03%	24227	31-Aug
Low	159	32.49%	79.07%	82.90%	13876	18-Aug
Low	146	32.32%	78.76%	82.71%	67650	11-Aug
Low	156	30.76%	77.83%	81.82%	239871	7-Aug
Low	151	31.79%	78.39%	82.32%	582197	2-Aug
Low	153	31.10%	77.82%	81.83%	572345	28-Jul
Low	148	28.46%	68.27%	71.62%	512044	6-Aug
Low	148	28.73%	76.05%	80.35%	865831	18-Jul
Average	91	8.29%	18.76%	22.07%	2663	11-Jul
Average	91	6.03%	16.61%	22.34%	2543	22-Jul
Average	91	11.82%	21.04%	20.91%	3621	2-Jul
Average	91	7.23%	17.29%	21.46%	4879	16-Jul
Average	91	8.80%	17.21%	19.11%	2356	12-Jul
Average	91	4.59%	14.40%	20.60%	3262	23-Jul

Average	91	5.30%	15.88%	21.91%	4043	23-Jul
Average	91	7.98%	17.40%	20.36%	4162	11-Jul
High	91	10.98%	17.85%	16.63%	2533	10-Jul
High	91	8.02%	15.44%	17.08%	2363	21-Jul
High	91	14.73%	20.39%	15.09%	3509	1-Jul
High	91	9.85%	17.08%	16.93%	4821	15-Jul
High	91	11.37%	17.79%	15.81%	2436	11-Jul
High	91	6.24%	13.44%	16.04%	3044	22-Jul
High	91	7.27%	14.99%	17.30%	3817	22-Jul
High	91	11.14%	17.83%	16.36%	4265	10-Jul
Low	91	5.92%	21.37%	29.59%	3034	12-Jul
Low	91	4.43%	18.35%	27.68%	2809	23-Jul
Low	91	9.03%	24.20%	30.20%	4164	2-Jul
Low	91	5.14%	19.35%	27.81%	5460	17-Jul
Low	91	6.63%	19.62%	26.50%	2686	13-Jul
Low	91	3.19%	16.34%	25.93%	3702	24-Jul
Low	91	3.79%	17.56%	27.00%	4472	24-Jul
Low	91	5.59%	20.06%	28.03%	4798	12-Jul

Table 4. Survival and passage results under No August spill scenario with comparisons to the BiOp.

Release Profile	Fall Chinook Stock	Flow Regime	In-River Survival	Total System Survival	Percent of Release Transported	Modeled impact of No August Spill vs. BIOP		
						In-River Survival	System Survival	Total Losses to BON Tailrace
Average	Hanford	Average	41.93%	49.33%	19.98%	-0.29%	-0.21%	UNK
Average	Hanford	High	44.97%	51.94%	20.77%	-0.22%	-0.16%	UNK
Average	Hanford	Low	41.04%	55.03%	35.09%	-0.41%	-0.23%	UNK
1995	Snake	Average	34.03%	79.96%	83.09%	-2.38%	-0.13%	-40
1996	Snake	Average	35.37%	79.45%	82.25%	-2.18%	-0.13%	-24
1998	Snake	Average	36.15%	78.76%	81.09%	-1.54%	-0.11%	-93
1999	Snake	Average	38.81%	76.78%	77.46%	-0.88%	-0.09%	-275
2000	Snake	Average	38.40%	78.06%	79.57%	-0.72%	-0.06%	-443
2001	Snake	Average	39.02%	77.19%	78.08%	-0.56%	-0.05%	-388
2002	Snake	Average	33.20%	71.42%	73.53%	-1.65%	-0.11%	-860
2003	Snake	Average	39.97%	73.40%	72.04%	-0.18%	-0.03%	-292
1995	Snake	High	37.31%	80.07%	82.48%	-1.96%	-0.13%	-41
1996	Snake	High	40.86%	79.50%	80.63%	-1.28%	-0.12%	-20
1998	Snake	High	42.14%	79.02%	79.37%	-0.75%	-0.08%	-67
1999	Snake	High	46.82%	75.05%	69.39%	-0.41%	-0.09%	-263
2000	Snake	High	45.62%	77.27%	74.56%	-0.22%	-0.03%	-258
2001	Snake	High	47.09%	76.03%	71.11%	-0.15%	-0.03%	-216
2002	Snake	High	41.07%	73.92%	73.39%	-0.74%	-0.09%	-671
2003	Snake	High	49.16%	70.75%	58.91%	-0.03%	-0.01%	-110
1995	Snake	Low	30.03%	79.27%	83.02%	-2.43%	-0.11%	-34
1996	Snake	Low	29.53%	78.94%	82.89%	-2.96%	-0.13%	-23
1998	Snake	Low	29.31%	78.63%	82.71%	-3.01%	-0.13%	-112

1999	Snake	Low	28.63%	77.74%	81.81%	-2.13%	-0.09%	-288
2000	Snake	Low	29.42%	78.29%	82.32%	-2.36%	-0.10%	-749
2001	Snake	Low	28.86%	77.72%	81.83%	-2.25%	-0.10%	-713
2002	Snake	Low	25.47%	68.14%	71.62%	-2.99%	-0.13%	-957
2003	Snake	Low	27.40%	75.99%	80.35%	-1.34%	-0.06%	-693
1995	RIS	Average	8.17%	18.71%	22.07%	-0.13%	-0.06%	-8
1996	RIS	Average	5.76%	16.50%	22.34%	-0.28%	-0.12%	-18
1998	RIS	Average	11.70%	20.99%	20.91%	-0.12%	-0.05%	-9
1999	RIS	Average	6.95%	17.16%	21.46%	-0.28%	-0.13%	-36
2000	RIS	Average	8.52%	17.07%	19.11%	-0.28%	-0.13%	-18
2001	RIS	Average	4.28%	14.28%	20.60%	-0.30%	-0.13%	-28
2002	RIS	Average	5.02%	15.76%	21.91%	-0.29%	-0.12%	-31
2003	RIS	Average	7.79%	17.31%	20.36%	-0.19%	-0.09%	-21
1995	RIS	High	10.87%	17.79%	16.63%	-0.11%	-0.06%	-8
1996	RIS	High	7.79%	15.32%	17.08%	-0.24%	-0.12%	-19
1998	RIS	High	14.63%	20.33%	15.09%	-0.10%	-0.06%	-10
1999	RIS	High	9.59%	16.94%	16.93%	-0.26%	-0.14%	-39
2000	RIS	High	11.11%	17.65%	15.81%	-0.27%	-0.14%	-19
2001	RIS	High	5.95%	13.29%	16.04%	-0.29%	-0.15%	-33
2002	RIS	High	7.02%	14.86%	17.30%	-0.25%	-0.13%	-33
2003	RIS	High	10.96%	17.73%	16.36%	-0.18%	-0.09%	-23
1995	RIS	Low	5.75%	21.32%	29.59%	-0.17%	-0.05%	-8
1996	RIS	Low	4.10%	18.25%	27.68%	-0.33%	-0.10%	-15
1998	RIS	Low	8.87%	24.15%	30.20%	-0.15%	-0.05%	-8
1999	RIS	Low	4.82%	19.24%	27.81%	-0.32%	-0.10%	-29
2000	RIS	Low	6.34%	19.52%	26.50%	-0.29%	-0.10%	-14
2001	RIS	Low	2.85%	16.24%	25.93%	-0.33%	-0.10%	-23
2002	RIS	Low	3.47%	17.46%	27.00%	-0.32%	-0.10%	-26
2003	RIS	Low	5.36%	19.98%	28.03%	-0.23%	-0.08%	-18

Table 5. Survival and passage results under No Summer Spill scenario with comparisons to the BiOp.

Release Profile	Fall Chinook Stock	Flow Regime	In-River Survival	Total System Survival	Percent of Release Transported	Modeled impact of No Summer Spill program vs. BIOP		
						In-River Survival	System Survival	Total Losses to BON Tailrace
Average	Hanford	Average	39.52%	47.56%	19.98%	-2.69%	-1.99%	UNK
Average	Hanford	High	43.48%	50.86%	20.77%	-1.71%	-1.25%	UNK
Average	Hanford	Low	37.32%	52.96%	35.09%	-4.12%	-2.30%	UNK
1995	Snake	Average	33.25%	79.92%	83.09%	-3.16%	-0.17%	-53
1996	Snake	Average	33.69%	79.35%	82.25%	-3.86%	-0.23%	-42
1998	Snake	Average	33.96%	78.61%	81.09%	-3.73%	-0.26%	-225
1999	Snake	Average	35.56%	76.45%	77.46%	-4.12%	-0.42%	-1307
2000	Snake	Average	34.95%	77.78%	79.57%	-4.17%	-0.35%	-2564
2001	Snake	Average	35.26%	76.83%	78.08%	-4.32%	-0.41%	-3044
2002	Snake	Average	31.01%	71.27%	73.53%	-3.85%	-0.26%	-1982
2003	Snake	Average	35.93%	72.82%	72.04%	-4.22%	-0.61%	-6956
1995	Snake	High	36.46%	80.01%	82.48%	-2.82%	-0.19%	-59

1996	Snake	High	39.35%	79.37%	80.63%	-2.79%	-0.26%	-45
1998	Snake	High	40.52%	78.85%	79.37%	-2.37%	-0.25%	-213
1999	Snake	High	44.97%	74.67%	69.39%	-2.26%	-0.47%	-1461
2000	Snake	High	43.35%	76.91%	74.56%	-2.49%	-0.39%	-2890
2001	Snake	High	44.96%	75.62%	71.11%	-2.28%	-0.44%	-3260
2002	Snake	High	39.24%	73.70%	73.39%	-2.57%	-0.31%	-2311
2003	Snake	High	47.17%	70.13%	58.91%	-2.02%	-0.63%	-7204
1995	Snake	Low	29.76%	79.26%	83.02%	-2.71%	-0.12%	-37
1996	Snake	Low	28.90%	78.91%	82.88%	-3.59%	-0.16%	-28
1998	Snake	Low	28.30%	78.58%	82.70%	-4.02%	-0.18%	-151
1999	Snake	Low	26.90%	77.66%	81.81%	-3.86%	-0.17%	-530
2000	Snake	Low	27.51%	78.20%	82.31%	-4.28%	-0.19%	-1395
2001	Snake	Low	26.68%	77.62%	81.82%	-4.42%	-0.20%	-1443
2002	Snake	Low	24.51%	68.10%	71.61%	-3.95%	-0.17%	-1274
2003	Snake	Low	24.38%	75.84%	80.34%	-4.36%	-0.20%	-2324
1995	RIS	Average	7.63%	18.45%	22.07%	-0.66%	-0.31%	-44
1996	RIS	Average	5.49%	16.38%	22.34%	-0.55%	-0.23%	-36
1998	RIS	Average	11.17%	20.71%	20.91%	-0.65%	-0.33%	-57
1999	RIS	Average	6.74%	17.06%	21.46%	-0.50%	-0.23%	-65
2000	RIS	Average	8.41%	17.02%	19.11%	-0.38%	-0.19%	-25
2001	RIS	Average	4.16%	14.22%	20.60%	-0.43%	-0.18%	-41
2002	RIS	Average	4.81%	15.67%	21.91%	-0.49%	-0.21%	-54
2003	RIS	Average	7.45%	17.13%	20.36%	-0.53%	-0.26%	-63
1995	RIS	High	10.48%	17.56%	16.63%	-0.51%	-0.28%	-40
1996	RIS	High	7.54%	15.18%	17.08%	-0.49%	-0.26%	-39
1998	RIS	High	14.22%	20.09%	15.09%	-0.51%	-0.30%	-53
1999	RIS	High	9.37%	16.82%	16.93%	-0.48%	-0.26%	-74
2000	RIS	High	10.98%	17.58%	15.81%	-0.39%	-0.21%	-29
2001	RIS	High	5.80%	13.21%	16.04%	-0.44%	-0.23%	-51
2002	RIS	High	6.81%	14.75%	17.30%	-0.46%	-0.24%	-61
2003	RIS	High	10.69%	17.58%	16.36%	-0.45%	-0.25%	-60
1995	RIS	Low	5.24%	21.15%	29.59%	-0.68%	-0.23%	-33
1996	RIS	Low	3.92%	18.19%	27.68%	-0.51%	-0.16%	-24
1998	RIS	Low	8.34%	23.96%	30.20%	-0.68%	-0.24%	-42
1999	RIS	Low	4.67%	19.19%	27.81%	-0.47%	-0.16%	-43
2000	RIS	Low	6.28%	19.49%	26.50%	-0.36%	-0.12%	-17
2001	RIS	Low	2.79%	16.22%	25.93%	-0.40%	-0.12%	-27
2002	RIS	Low	3.35%	17.42%	27.01%	-0.44%	-0.14%	-36
2003	RIS	Low	5.05%	19.87%	28.03%	-0.54%	-0.19%	-44

Because numerous input possibilities can alter the CRiSP results it is important to compare model runs that vary as few parameters as possible for meaningful results. For example, it would not be reasonable to compare high flow results with low flow results as the temperature profile for the low flow years would be significantly warmer. And so it would become difficult to determine whether changes in survival were due to temperature or to flow alterations.

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 in turn depends on flow, cross-sectional area of a reach, and Reservoir elevation.

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

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 super saturation, 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

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.

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

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 found in the SimPass model to route fish though various passage options.

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.

Total Dissolved Gas Super saturation ─Total dissolved gas (TDG) super saturation 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.